Transmission Plan for Envisaged Renewable Capacity

A Report

Vol-I

Power Grid Corporation of India Ltd.

July, 2012

Table of Contents

Table of Contents

Page

Table of Contents

Page

Table of Contents

List of Acronyms

ADB	Asian Development Bank
AGC	Automatic Generation Control
APTRANSCO	Andhra Pradesh Transmission Corporation Limited
AWS	Automatic Weather Station
CAES	Compressed Air Energy Storage
CAPEX	Capital Expenditure
CEA	Central Electricity Authority
CECRE	Control Centre of Renewable Energies
CPP	Captive Power Plants
CSP	Concentrating Solar Power
CTU	Central Transmission Utility
CUF	Capacity Utilization Factor
C-WET	Centre For Wind Energy Technology
DAS	Data acquisition System
DFIG	Double-Fed Induction Generator
DISCOM	Distribution Company
DPR	Detailed Project Report
DR	Demand Response
DSM	Demand Side Management
DVC	Damodar Valley Corporation
EMS	Energy Management System
EPS	Electric Power Survey
FACTS	Flexible AC Transmission System
FOR	Forum of Regulators
FRT	Fault Ride through
GCC	Generation Control Center
GETCO	Gujarat Energy Transmission Corporation Limited
GOI	Government of India
GPRS	General Packet Radio Service
GPS	Global Positioning System
HPTCL	Himachal Pradesh Power Transmission Corporation Limited
HWP	High Wind Penetration
IEGC	Indian Electricity Grid Code
ISO	Independent System Operator
ISTS	Inter State Transmission System
JNNSM	Jawaharlal Nehru National Solar Mission
LFC	Load Frequency control
LSWI	large scale wind integration
LVRT	Low Voltage Ride through
MEDA	Maharashtra Energy Development Agency
MNRE	Ministry of New & Renewable Energy
MSTECL	Maharashtra State Electricity Transmission Company Limited
NCAR	National Center for Atmospheric Research
NEP	National Electricity Policy

List of Acronyms

NLDC	National Load Dispatch Center
NREDCAP	New & Renewable Energy Development Corporation
NWP	Numerical Weather Prediction
OPGW	Optical Fibre Ground Wire
PCC	Point of Common Coupling
PV	Photovoltaic Cell
PMU	Phasor Measurement Unit
PPA	Power Purchas Agreement
PSMP	Power System Master Plan
RE	Renewable Energy
REC	Renewable Energy Certificate
REMC	Renewable Energy Management Centre
REMS	Renewable Energy Management System
RES	Renewable Energy Sources
RoR	Run of the River
RPO	Renewable Purchase Obligations
RRC	Renewable Regulatory Charge
RRF	Renewable Regulatory Fund
RRVPNL	Rajasthan Rajya Vidyut Prasaran Nigam Limited
SCADA	Supervisory Control & Data Acquisition
SCIG	Squirrel Cage Induction Generator
SERC	State Electricity Regulatory Commission
SHP	Small Hydro Power
SNA	State Nodal Agency
STATCOM	Static Compensator
STI	Space Time Insights
STU	State Transmission Utility
SVC	Static Var Compensator
TANTRANSCO	Tamil Nadu Transmission Corporation Limited
TEDA	Tamil Nadu Energy Development Agency
TES	Thermal Energy Storage
TSO	Transmission System Operator
UI	Unscheduled Interchange
ULDC	Unified Load Dispatch Center
UMPP	Ultra Mega Power Plants
UT	Union Territory
V2G	Vehicle to Grid
VSAT	Very-Small-Aperture Terminal
WAMS	Wide Area Monitoring System
WASS	Wide Area Special Protection Schemes
WECC	Western Electricity Coordinating Council
WLL	Wireless in Local Loop
WPF	Wind Power Forecasting

Executive Summary

Presently the total installed electricity generation capacity in India is about 200 GW (*as on 31.03.12*). Out of this about 12 % (24915 MW) is through renewable generation mainly wind (17353 MW) and balance is in the form of small hydro (3396 MW), Biomass (3225 MW) and solar (941 MW).

Various policies, regulatory and fiscal incentives have accelerated development of renewable energy (RE) generation. Due to such initiatives, large capacity addition though renewable generation is envisaged in the 12th Plan period. Recognizing the criticality of large scale development of RE capacity and its integration with grid, Ministry of New & Renewable Energy (MNRE) and Forum of Regulators (FOR)/CERC have entrusted POWERGRID to carry out studies to identify transmission infrastructure and other control requirements for RE capacity addition programme in 12th Plan and prepare a comprehensive report with estimation of capex requirement and financing strategy. Broad objectives of the studies include

i) Identification of transmission infrastructure for the likely capacity additions of RE based power (wind, solar and hydro) in Renewable rich states viz. Tamil Nadu, Karnataka, Andhra Pradesh, Gujarat, Maharashtra, Rajasthan, Himachal Pradesh and Jammu & Kashmir during the 12th Plan period.

ii) Estimation of capex requirement for the development of transmission infrastructure

iii) Providing strategy framework for development of a model for funding transmission infrastructure to facilitate speedy renewable power development

Respective State Nodal Agency(SNA)/STU have provided information regarding pocket/year wise wind/solar capacity addition programme in 12th Plan in the renewable potential rich states viz. Tamil Nadu, Karnataka, Andhra Pradesh, Maharashtra, Gujarat, Rajasthan, Jammu & Kashmir(J&K) and small hydro in Himachal Pradesh, J&K & Karnataka. Brief of capacity addition programme is shown in Table-1.1 & Table-1.2:

Table-1.1 : Wind / Solar Addition Plan in RE Rich States

State	Existing capacity (MW)		Addition in 12th Plan (MW)		Total capacity (MW)	
	Wind	*Solar*	*Wind*	*Solar*	*Wind*	*Solar*
Tamil Nadu	6370	7	6000	3000	12370	3007
Karnataka	1783	6	3223	160	5006	166
A.P	392	92	5048	285	5440	377
Gujarat	2600	600	5083	1400	7683	2000
Maharashtra	2460	17	9016	905	11476	922
Rajasthan	2100	200	2000	3700	4100	3900
Jammu & Kashmir	-	2	12	102	12	104
Total	***15705***	***924***	***30382***	***9552***	***46087***	***10476***

Table-1.2 : Small Hydro Addition Plan in RE Rich States

State	Existing capacity (MW)	Addition in 12th Plan (MW)	Total capacity (MW)
Karnataka	527	719	1246
Himachal	443	996	1439
J&K	118	362	480
Total	***1088***	***2077***	***3165***

Simulation for Study

Load flow studies were carried out for 2016-17 condition considering renewable capacity addition information along with demand projection in the 12th Plan as per draft 18th EPS, capacity addition programme from conventional generations and transmission corridors including High Capacity Corridors already planned in various regions.

Key Observations and Results

Observations

In **Tamil Nadu**, Solar Plants (3000 MW) are envisaged primarily in the districts of Vellore (175 MW), Erode (175 MW), Karur (175 MW),Pudukottai (175 MW) Madurai (175 MW), Coimbatore (175 MW) Dharampuri (175 MW), Tiruvannamalai (175 MW) & Cuddalore (175 MW) etc.. Wind capacity (12400 MW) are envisaged to be located mainly in the districts of Kayathar (2600 MW), Udumalpet (2400 MW), Tirunvelli (1400 MW), Vagarai (1100 MW), Tennampatty (1000 MW), Thappagundu (1000 MW), Rasapaliyam (900 MW), Anaikadavu (800 MW) and Kanarpatty (750 MW) etc.

In **Andhra Pradesh** Wind Farms (5300 MW) are env isaged in districts of Uravakonda (2600 MW), Kondapuram (1350 MW), Hindupur (700 MW) and Kurnool (400 MW). Solar Plants (380 MW) are envisaged in the districts of Kadapa (120 MW), Mahabubnagar (100 MW), Karimnagar (75 MW) & Ananthpur (75 MW) etc.

In **Karnataka** wind farms (5000MW) envisaged in districts of Belgaum (650MW), Koppal (500MW), Gadag (480MW), Davangere (640MW), Chitradurga (820MW) & Havery (530MW). Small Hydro (1250 MW) are envisaged in districts of Udupi (100 MW), Shimoga(90 MW), Dakshin & Uttar Kannad (250 MW), Mandya (200MW) as well as Chamrajnagar (80 MW).

In **Gujarat,** Solar Plants (2000 MW) are envisaged primarily in districts of Kutch (500 MW), Banaskantha (500 MW), Patan (550 MW) and some capacity in Surendranagar /Junagad & Ahmedabad. Wind Farms (7700 MW) are envisaged in districts of Kutch (2800 MW), Jamnagar (1000 MW), Rajkot (1800 MW), Surendranagr (950 MW), Banaskantha/Patan (800 MW), Amreli (350 MW) and other areas.

In **Maharashtra,** Solar Plants (900MW) are envisaged in districts of Osmanabad (360 MW), Yavatmal (150 MW), Nandurbar(150 MW) and Chandrapur (150 MW) etc. Wind Farms(11000 MW) are envisaged in districts of Sangli (2100 MW), Satara (1700 MW), Ahmadnagar (1450 MW), Kolhapur (1100 MW), Dhule/N'bar (1500 MW), Solapur (900 MW), Pune (650 MW) as well as some of the quantum in districts of Amravati, Nashik, Sindhudurg & Beed.

In **Rajasthan,** solar capacity (3900MW), plants are envisaged in districts of Jaisalmer (2000 MW), Jodhpur (1225 MW) and Bikaner (665 MW). Wind Farms (4100 MW) are envisaged in districts of Jaisalmer (3120 MW), Barmer (340 MW), Banswara (320 MW) as well as Pratapgarh (320 MW).

In **Himachal Pradesh,** Small Hydro Plants (SHP) (1400 MW) are envisaged in districts of Shimla (410 MW), Kullu (250 MW), Chamba (230 MW), Kangra (200MW), Kinnaur(120 MW) and Mandi (80 MW).

In **Jammu & Kashmir**, Small Hydro (480 MW) are envisaged primarily in the districts of Udhampur (111 MW), Baramula (51 MW), Jammu (48 MW), Srinagar (76MW), Leh (35 MW), Anantnag (33 MW) etc. Solar Plants (104MW) is envisaged to be located only in the district of Leh. Wind capacity (12.2 MW) is envisaged to be located in the districts of Udhampur (12 MW) and small capacity in Leh (0.2 MW).

The Renewable energy generating stations are connected with the grid normally at 33 kV, 66kV, 110kV & 132 kV level. The EHV transmission system beyond first connection point is either at 132kV, 220kV or 400kV depending on the quantum of power being pooled at EHV Substations. However large size generating stations are directly connected with the grid normally at 132 kV, 220kV level. Typical Schematic of various RE stations connectivity shown in Fig.1:

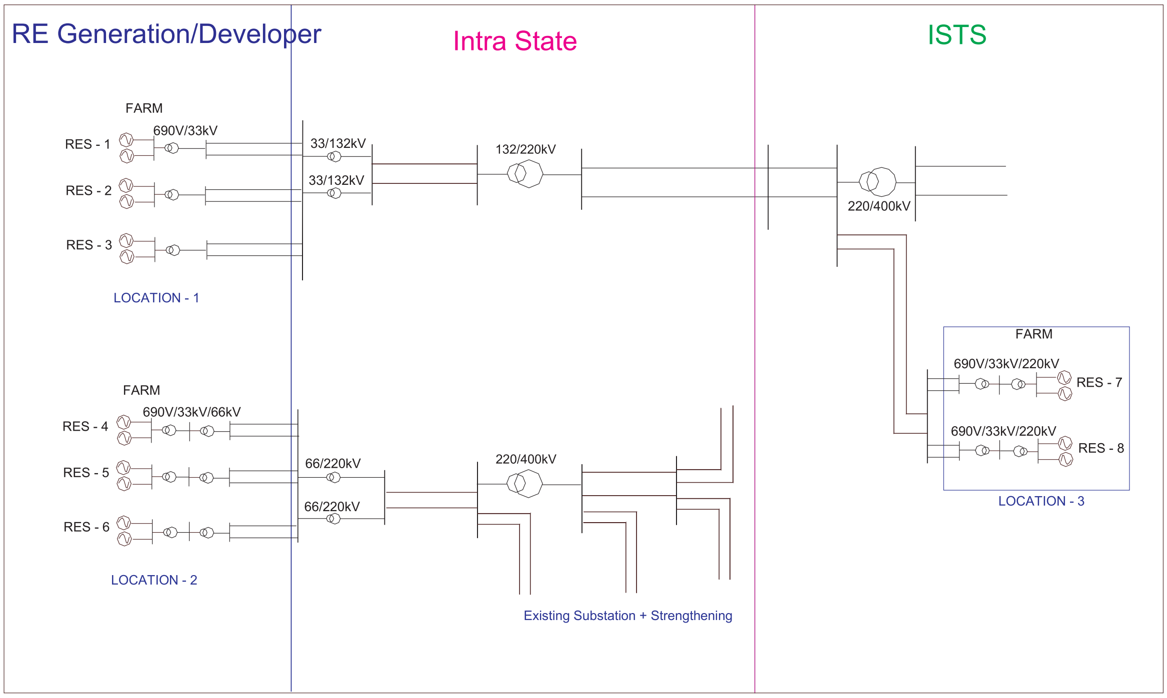

Figure 1: Typical Connection Arrangement of RE Generation Farm with Grid

From the past profile of renewable generation mainly wind and solar, it has been observed that the generation from the wind farms increases in other than peak demand period. Generally ramping of wind generation starts from 11:00 hour in most of the states except in Rajasthan which starts usually from 18:00 hour. Further maximum wind generation occurs in the monsoon season. Typical daily wind generation pattern for Tamil Nadu & Rajasthan is as shown in Fig-2&3.

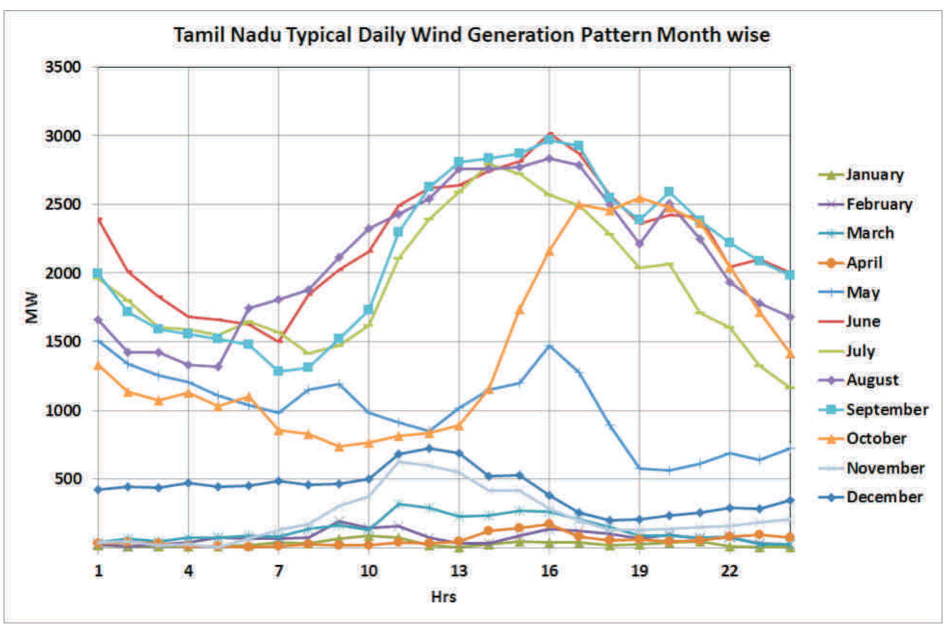

Figure 2 : Tamil Nadu typical daily Wind Generation Pattern Month wise (Source-TN SLDC)

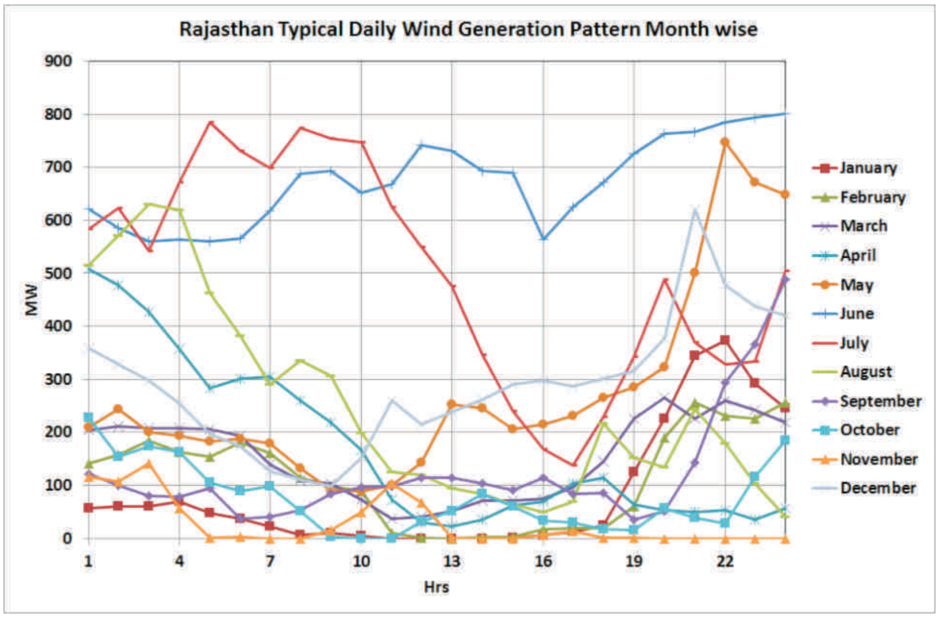

Figure 3: Rajasthan typical daily Wind Generation Pattern Month wise (Source-Raj SLDC)

Solar output is from 07.00 hour to 19.00 hour with peak ranging from 12.00 – 15.00 hour. In case of small hydro plants, there is not much daily variability in output, however, it varies seasonally. Accordingly studies have been carried out with maximum wind dispatch (70% of installed capacity) and solar dispatch (80%) during demand other than peak condition. However sensitivity analysis has been carried out with peak demand scenario with low wind dispatch (30%) and solar dispatch (10%).

It is envisaged that about 42 GW ofRE capacity may be added in the 12 th Plan period through Wind (30 GW), Solar (9.5 GW) and Small Hydro (2 GW), thus making total installed RE capacity to be about 67 GW by 2016-17. Further, envisaged RE capacity within RE rich States would be more than their proposed RPO target in 2016-17. Therefore, surplus RE generation would be transferred to other non-RE rich States.

Analysis of operation of Indian Grid reveals that operational challenges like High Ramp rate of load, particularly during the evening peak hours, Sharp change in load, particularly at the hour boundaries mainly due to agricultural load changes are being handled smoothly by grid operators on almost daily basis. Typical All India daily load curve is shown at Fig-4.

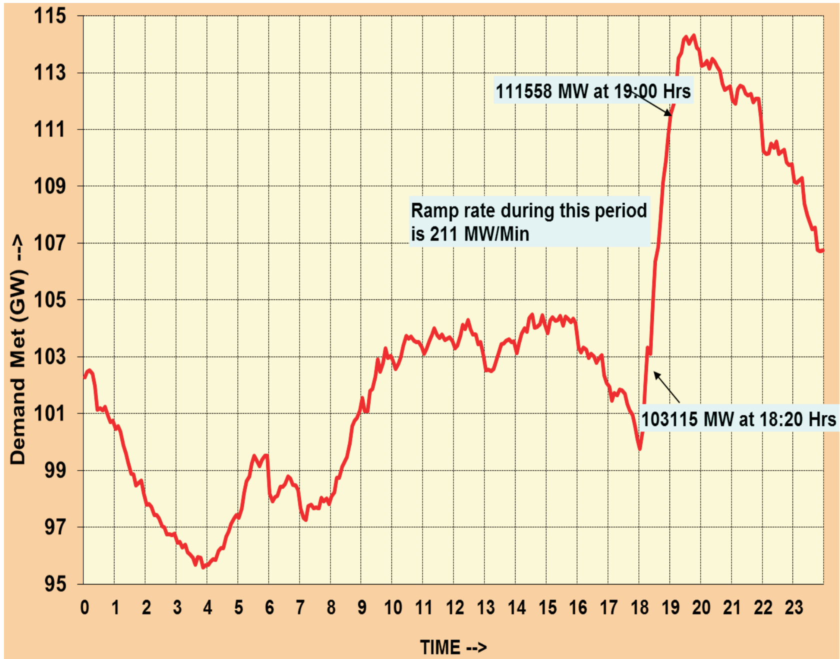

Figure 4: Typical All India daily load curve (Source-POSOCO)

Study of impact of variation of wind generation on the host state is also analyzed which reveals that the co-relation co-efficient between change in drawl of host state with respect to change in wind generation is actually closer to zero. This indicates that re-scheduling of conventional energy sources helps in mitigating whatever minimal effect that intermittency has on a state's imbalance and wind conclusively does not significantly add to the variability. Correlation between Wind Generation, Drawl & UI of Gujarat for one week period is shown at Figure-5 below.

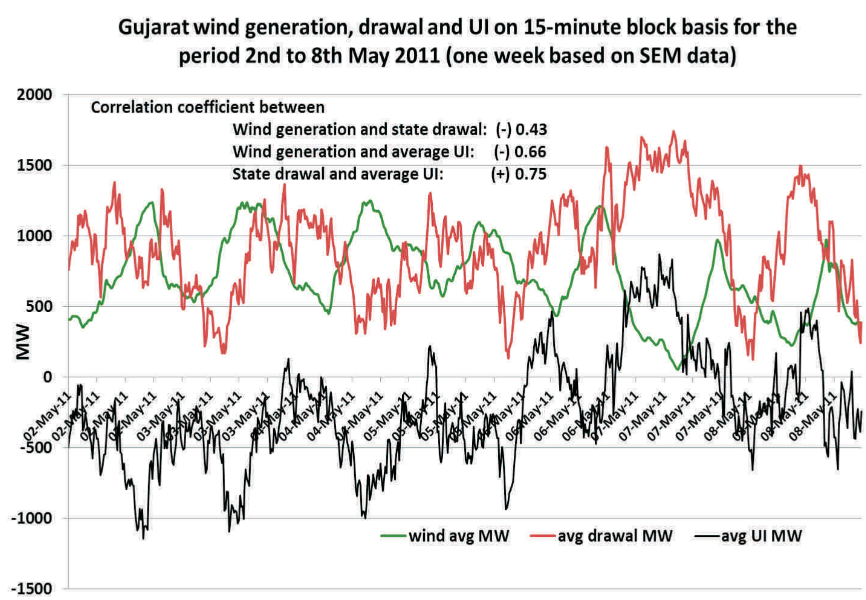

Figure 5: Correlation between Wind Generations, Drawl & UI of Gujarat (Source-POSOCO)

Above analysis indicates that intermittent generation can be handled, provided adequate transmission infrastructure is made available for transfer of power without congestion as well as balancing through conventional resources and/or other solutions are available.

Results

In order to facilitate transfer of RE power from the RE rich potential States to other States as well as absorption of RE power within the RE rich states (host state), transmission system strengthening both at intra state and inter state level have been identified. Intra State transmission system strengthening primarily comprises of pooling stations at 132kV, 220kV and 400kV level and associated transmission lines including other STU grid strengthening schemes. Major Inter State transmission strengthening (ISTS) mainly comprises of development of high capacity hybrid corridors as under:

- ± 500 kV, 2500 MW New Pugalur - Hyderabad HVDC Bipole
- 400kV Bachau (PG)- Solar Park-II (GETCO) – Udaipur- Kankroli(PG) D/c
- 400kV Kankroli- Ajmer(New) D/c
- 400kV Solar Park-II (GETCO)– Chittorgarh D/c
- 765kV Jodhpur(New) – Ajmer(New) D/c
- 765kV Ajmer – Suratgarh D/c
- 765kV Suratgarh – Moga D/c
- Suratgarh(existing)- Suratgarh (New) 400kV D/c
- Ajmer(existing)- Ajmer (New) 400kV D/c
- 400 kV Srisailam - Kurnool New D/c
- New Pugalur - Udumalpet 400kV D/c
- New Pugalur - Vagarai 400kV D/c (Quad)
- New Pugalur - Pugalur 400kV D/c (Quad)
- Hyderabad – Hyderabad(New) 400kV D/c (Quad)
- LILO of Tuticorin Pool-Salem 765kV line at New Pugalur (initially to be operated at 400kV)

- Augmentation of transformation capacity of 765/400kV & 400/220kV at Moga substation by 1x1500 MVA & 1x500 MVA respectively
- Establishment of 765/400kV, 2x1500 MVA S/s each at Jodhpur, Ajmer & Suratgarh
- Establishment of ±500kV, HVDC terminal stations(2500MW) each at New Pugalur & Hyderabad
- Establishment of 400 kV Substations at New Pugalur & Hyderabad
- Up gradation of 400kV Narendra & Kolhapur substations at 765kV level to facilitate charging of Narendra- Kolhapur D/c line at 765kV level

Summary of the proposed Intra State transmission strengthening including connectivity to STU network is also given as under:

Table 1.3 : Summary of Intra State Transmission System proposed by RE rich states (As per DPR excluding elements for conveyance to ISTS)

State	Transmission line	Sub Stations
Tamil Nadu	• 1440 ckms 400 kV line • 91 ckms 230 kV line • 45 ckms 110 kV line	• 1 no. of 400/230 kV S/s (830 MVA) • 1 no. of 230/110 kV S/s (300MVA)
Andhra Pradesh	• 460 ckms 400 kV line • 582 ckms 220 kV line	• 1 no. of 400/220 kV S/s (1260 MVA) • 5 no. of 220/132 kV S/s (1120MVA)
Gujarat	• 440 ckms 400 kV line • 1192 ckms 220 kV line • 40 ckms 132 kV line **For Solar Park –II** • 200 ckms 400 kV line	• 2 no. of 400/ 220 kV S/s (1260 MVA), • 3 no. of 220/132/66 kV S/s (500MVA) **For Solar Park –II** • 1 no. of 400/220/66 kV S/s (400/220 kV -630 MVA, 220/66 kV 500MVA)
Rajasthan	• 2010 ckms 400 kV line • 622 ckms 220 kV line • 1114 ckms 132 kV line	• 3 no. of 400/220 kV S/s (3945 MVA) • 9 no. of 220/132 kV S/s (1760 MVA) • 29 no. of 132/33 kV S/s (1025 MVA)
Himachal Pradesh	• 282 ckms 132 kV line • 134 ckms 66 kV line	• 4 no. new S/s (556 MVA)

Table 1.4 : Summary of proposed Connectivity System to STU network (Intra State)

State	Transmission line	Sub Stations
Tamil Nadu	• 1620 ckms of 230 kV line • 2840 ckms of 110 kV line	• 10 no. of 230/33 kV S/s (2900 MVA) • 22 no. of 110/33 kV S/s (4400 MVA)
Karnataka	• 630 ckms of 220 kV line • 1160 ckms of 132 kV line	• 4 no. of 220/33 kV S/s (1200 MVA) • 9 no. of 132/33 kV S/s (1750 MVA)
Andhra Pradesh	• 900 ckms of 220 kV line • 1600 ckms of 132 kV line	• 5 no. of 220/33 kV S/s (1600 MVA) • 12 no. of 132/33 kV S/s (2450 MVA)

State	Transmission line	Sub Stations
Gujarat	• 1080 ckms of 220 kV line • 2592 ckms of 66 kV line	• 12 no. of 220/66 kV S/s (4800 MVA)
Maharashtra	• 1800 ckms of 220 kV line • 3120 ckms of 132 kV line	• 11 no. of 220/33 kV S/s (3200 MVA) • 24 no. of 132/33 kV S/s (4850 MVA)
Rajasthan	• 990 ckms of 220 kV line • 1680 ckms of 132 kV line	• 6 no. of 220/33 kV S/s (1800 MVA) • 13 no. of 132/33 kV S/s (2650 MVA)
Himachal Pradesh	• 200 ckms of 132 kV line • 540 ckms of 33 kV line	• 6 no. of 132/33 kV S/s (550 MVA)
Jammu & Kashmir	• 90 ckms of 220 kV line • 80 ckms of 132 kV line • 260 ckms of 33 kV line	• 1 no. of 220/33 kV S/s (200 MVA) • 1 no. of 132/33 kV S/s (150 MVA)

In addition, summary of the proposed system strengthening within state for conveyance of ISTS transfer is also given as under:

Table 1.5 : Summary of system strengthening within state for conveyance of ISTS transfer (ISTS)

State	Transmission line	Sub Stations
Tamil Nadu	• 1240 ckms of 400kV line • 1500 ckms of 230kV line	• 6 no. of 400/230/110 kV S/s (6925 MVA) • 4 no. of 230/110 kV S/s (2650 MVA)
Karnataka	• 720 ckms of 220 kV line	
Andhra Pradesh	• 260 ckms of 400 kV line • 1178 ckms of 220 kV line	• 2 no. of 400/220 kV S/s (2205 MVA) • 4 no. of 220/132 kV S/s (600 MVA) • 400/220 kV S/s Augmentation (3465 MVA) • 220/132 kV S/s Augmentation (1450 MVA)
Gujarat	• 834 ckms of 220 kV line	• 400/230 kV S/s Augmentation (315 MVA)
Maharashtra	• 550 ckms of 220 kV line • 235 ckms of 132 kV line	• 220/132 kV S/s Augmentation (480 MVA)
Rajasthan	• 740 ckms of 400kV line • 480 ckms of 220 kV line	• 220/132 kV S/s Augmentation (2560 MVA)
Himachal Pradesh	• 20 ckms of 220 kV line • 310 ckms 132 kV line	• 1 no. of 33/220 kV S/s (126 MVA) • 220/132 kV S/s Augmentation (480 MVA)

Details of Intra state transmission strengthening and Inter State strengthening are given in ***Chapter 5***.

In order to maintain voltages in stipulated limits, reactive compensation in the form of switchable/controlled bus reactors as well as STATCOM/SVC as dynamic compensators, at strategic location has also been proposed.

Proposed measures to address intermittency and variability of generation

The output of the wind and solar based RE plants vary according to the available resources – the wind speed/ direction and the sun's insolation level. With high penetration level of RE capacity coupled with sudden drop in generation due to unexpected cloud cover or a lack of wind can impact grid stability. Therefore fast-ramping conventional energy sources, energy storage, demand side/demand response management must be carried out to meet demand. Measures to smooth out the intermittency and variability include enlarging the balancing area, load shifting, building in more flexibility in the generation portfolio etc.

Measures proposed to take care of intermittency and variability of grid connected RE generation is:

- Strong Grid interconnections
- Flexible generation, Ancillary Services, Reserves etc. for supply-balancing
- Demand Side management, Demand Response and Storage for load balancing
- Forecasting of Renewable generation
- Forecasting of Demand
- Establishment of Renewable Energy Management Centers (REMC) equipped with advanced forecasting tools along with reliable communication infrastructure
- Deployment of Synchrophasor technology i.e. PMUs/WAMS on pooling stations and interconnection with centralized control centre through Fiber Optic Communication for real time information, monitoring and control
- Capacity building at respective LDC/PCC/Conventional/Non-Conventional Generator regarding RE handling
- Institutional Arrangements with defined roles & responsibilities of various agencies/generation developer

- Technical Standard Requirements (Grid code, Connectivity standards, Real time monitoring etc.)
- Policy advocacy for development of power-balance market and pricing mechanism

Strong Grid interconnection

Strengthening/expansion of grid interconnection shall enlarge the power-balancing area. In a large interconnected system variation in frequency would be lesser for a given variation in generation/demand as well as it will help in reaping out the benefits of diversity in terms of spinning reserve and utilizing quick-start hydro/gas generation capacity in different parts of the grid for power-balancing.

Hydro potential in Northern-eastern region (NER), Sikkim and Bhutan may also be harnessed by development of high capacity transmission corridors between NER/Sikkim/Bhutan and load centers. Further, to take care of seasonal variation in generation from such hydro plants, the transmission corridors must be planned with hybrid HVDC and AC system so that grid parameters can be maintained.

Flexible generation

Spinning reserves (hot and cold), flexible high ramp rate generation would be required to handle variability and ramping associated with RE for power balancing. Spinning reserves through following type of generating units may be provided.

Hydropower Plant with Reservoir - It provides reserve capacity and expected to respond to grid frequency changes and inflow fluctuations. They also provide fast ramp up and ramp down (order of few seconds) capabilities.

Pumped Storage Hydropower Plant - Pumped storage plants due to their fast response and storage capacity have been proved to be excellent reserves. Presently, pumped storage Hydro capacity in operation is only about 1550 MW (Kadamparai – 400MW, Purulia-900MW, Ghatghar – 250 MW). This provides approximately 3000 MW variation between peak and off peak. Tehri PSP (1000MW) is also proposed to be added in 12th plan period. Revival of Srisailam LBPH (900 MW) and early commissioning of Tehri PSP (1000 MW) would provide a total of nearly 6500 MW regulation in the Indian grid.

Further several Pumped Storage Stations have been planned and developed in the Country which is not being operated in pumped mode due to commercial as well as technical issues. In addition there are many hydro plants which are feasible to be convertible into Pumped Storage Hydro Plant. Feasibility should be evolved to encourage participation of such Pumped storage plants for introducing more regulation into the grid with the increased Renewable penetration. In addition, some regulatory interventions/policy measures are required for encouragement of such projects through incentives so that such projects become financially viable and sustainable.

Combined cycle gas plants – These plants are efficient and can ramp up and down quickly but are expensive plants. Need judicious operation. .

Thermal plants: - Coal based plants are less flexible in response to load changes. Such plants can be used as reserve plants only if they are running at Technical Minimum. For this suitable market design is to be done through regulatory intervention.

Establishment of super-critical coal fired units is an important milestone in the Indian thermal plant scenario. Super-critical units are known for higher efficiency, but a lesser known aspect is more flexibility in terms of regulating generation. Typically, a supercritical unit can operate at the designed super-critical steam parameters between 80-100% of rated capacity. Thus, system can have about 20% variation in a flexible manner due to super critical technology. However this can be harnessed if the units are able to participate in the 'downward regulation' electricity market, which requires policy/regulatory measures.

Demand Side Management/Demand Response

Demand-Side Management (DSM) or Demand-response is one option to increase flexibility to accommodate variable renewable. It helps to reduce the operational costs of renewable integration through measures such as load shifting and peak shaving, which can reduce the need for a system operator to maintain costly ancillary services.

Smart grids would enable operators to better manage generation, transmission and storage in ways that more effectively respond to supply fluctuations and demand. Development of Smart Grid with DSM functionality and new storage mechanism may be expedited.

RE Generation Forecasting

Wind and Solar power forecast is the most important pre-requisite for their large scale integration in the grid. Significant amount of wind generation integration will largely depend on the accuracy of the wind power forecast. Decentralised forecasting with centralised control is the current best approach for reliable grid operation.

Forecasting shall be done from the micro level i.e. at the plant level and then shall be integrated/aggregated further at the SLDC and RLDC and then at the national level. For effective monitoring and control, forecasting tool must be integrated with the SCADA / EMS system

Energy Storage

Energy storage technologies offer a great solution to accommodate large scale Renewable penetration and address its inherent issues like variable and uncertain output. Energy Storage can handle the excess availability of renewable during off peak demand period and provide energy support during peak hours just like another hot /spinning generation reserve. Focus must be given to develop suitable energy storage solutions.

Establishment of Renewable Energy Management Centre (REMC)

A separate hierarchy of **Renewable Energy Management Centre** (REMC) is proposed which will work in tandem with SLDC / RLDC / NLDC for maximization of Renewable Energy generation and integration with main grid without compromising security and stability of power system. All Renewable Energy Management Centres (REMCs) at State and Regional level shall be co-located with respective Load dispatch centers (LDC). REMC shall coordinate with SLDC/RLDC for discharging various functionalities related to management of renewable energy generation. The typical data flow for various functionalities envisaged at the Renewable Energy Management Center is given in the Fig-6 below:

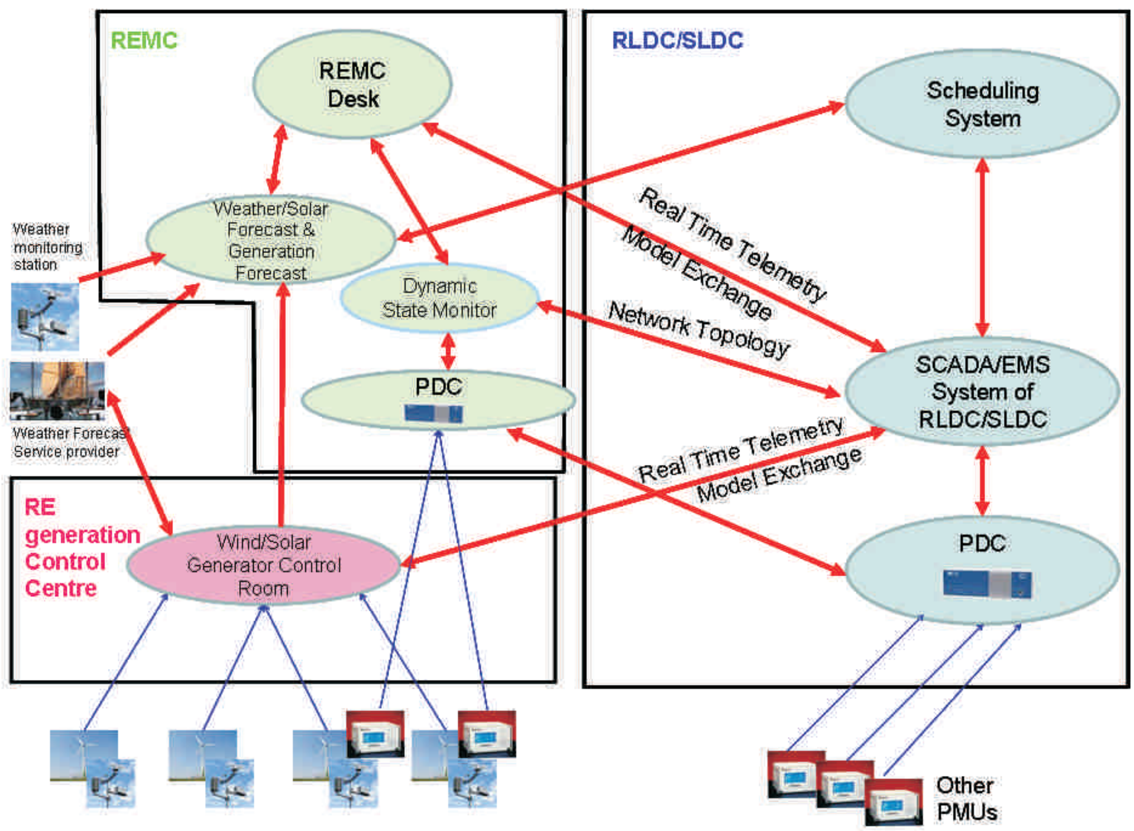

Figure 6: Typical Renewable Energy Data Flow

Market Design

Presently in Indian electricity market, Scheduling & dispatch, imbalances and congestion management is already implemented in India. Recent change that has been introduced in the Electricity Market for promotion of renewable is the introduction of 15-minute bidding in the Power Exchanges (instead of hourly bidding) with effect from 1st April 2012.

In addition to above, introduction of the following market mechanisms would further help in large scale integration of renewable sources of energy:

(a) **Flexible Generators:** A new product in the market may be developed where various generators with surplus capacity may submit their bid and based on their bid price during low frequency conditions they can be scheduled by the power system operator. Similarly the bid price shall be submitted by the generators which are ready to back down during high frequency condition and scheduled by operator during such high frequency scenarios. Regulator may define the bid-price band for the flexible generator. This will facilitate the optimization of generation and smooth integration of variable and intermittent renewable power.

(b) **Ancillary Market**: The Central Regulator is already in the process of introduction of Ancillary Services Market in the Country. This would help in harnessing services such as reactive power, Demand Response etc.

(c) **Evening Market**: More frequent operation of the Electricity Market through the Power Exchanges such as introduction of Evening Market as this would provide more opportunities to the market participants.

Real time monitoring system using Synchrophasor Technology

Wide area Special Protection Schemes (WASS) using Wide Area Monitoring System / Phasor Measurement Units at pooling stations and Phasor data concentrators at strategic locations integrated with REMC can help in predicting as well as can be used for controlling grid lines/ transformers being switched in and out. Installation of PMUs and PDCs at various locations along with optical fiber communication links integrated with REMC / LDCs are proposed for real time measurement and monitoring of system states.

Technological, Policy and Standard Requirements

To facilitate the high wind penetration, new regulations/connectivity standards are to introduced to ensure that their large scale integration don't affect the power system security & reliability. Such regulations/standards will also provide necessary guidelines to the developers forconnectivity with the grid as well as other technical requirements like fault ride through, reactive power support etc.

Institutional Arrangements required for integration of wind

Technology and markets can work smoothly only with proper institutional arrangements in place. Therefore, Role and Responsibilities of Developer/ DISCOM/STU/SLDC (in addition to statutory responsibilities already provided in Electricity Act 2003, Grid Codes) is proposed in **Chapter-7.**

Activities by Statutory Bodies/Authorities towards implementation of measures to address issues

In order to facilitate implementation of above discussed measures in addressing the issues associated with large scale integration of renewable, it is proposed that following actions may be taken up respectively by the Regulator, Statutory Authorities/MNRE, CTU/STU etc.:

S no.	Activities	Role
1	Strong Grid Interconnections (ISTS/Intra State) - Planning - Implementation	 CEA/CTU/STU STU/Tr. Licensee
2	Regulation for Flexible Generation, Ancillary Services and Generation Reserves - Market design	CERC/SERC CERC/SERC/POSOCO/CTU
3	Regulation for Demand Side Management / Demand Response including time-of-use tariff	CERC/SERC
4	Renewable Generation Forecasting - Policy formulation - Regulation - Implementation - Aggregation	 MNRE CERC/ SERC Developer SLDC/RLDC
5	Demand Forecasting	SLDC/State DISCOM

S no.	Activities	Role
6	Energy Storage Technology - selection, design & implementation	CTU/CEA/POSOCO
7	Establishment of Renewable Energy Management Centre - Policy formulation - Regulation - Implementation	 MNRE CERC/SERC POSOCO/SLDC
8	Approval/Deployment of Real time monitoring system using Synchrophasor Technology	CEA/CTU
9	Formulation of technical Standards for Renewable Generation	CEA/CTU
10	Capacity Building – Providing training	CTU/POSOCO/SLDC/STU
11	Institutional arrangement (Roles & Responsibilities of Developers /DISCOM/STU/SLDC etc.) – incorporation in EA 2003	MOP/CEA
12	➢ Assessment / Reassessment of onshore and offshore wind Energy Potential and update of Wind Atlas ➢ Assessment / Reassessment of Solar Energy Potential and update of Solar Atlas	C-WET/IMD

Need for RE Potential Reassessment

The scientific and research work carried out by various independent agencies have claimed that the potential for wind energy potential of the country is far in excess of Indian official estimates. Considering the importance of Renewable energy in Indian context, it is proposed that, MNRE, C-WET or Indian Meteorological Department (IMD) may take up Wind/Solar potential reassessment and re-develop Wind Power density as well as Solar Map of India.

Estimated Cost

i) Entire transmission system strengthening has been categorized into following two parts.

- Intra State Transmission strengthening including connectivity of RE farms to nearest point of common coupling(PCC) in STU network

- Inter State Transmission strengthening including connectivity of RE farms (=>50 MW) to nearest point of common coupling(PCC) in ISTS network

ii) Provision of Dynamic Reactive Compensation (STATCOM/SVC etc.) to provide dynamic voltage support

iii) To facilitate real time monitoring of the state of grid, installation of synchrophasor technology i.e. PMU/PDC and fibre optic communication links between PCC and control centres have been proposed.

iv) Provision of Energy Storage technology to provide instantaneous power balance

v) To facilitate forecasting of wind and solar generation, coordination with RE generator control centres, SLDC/RLDC/NLDC, control of RE generation etc., to begin with setting up of Renewable Energy Management Centre(REMC) at the Seven(7) Renewable (Wind/solar) rich States, three(3) RLDC [SR, WR & NR] and one(1) at NLDC is proposed.

Estimated cost of above proposed scheme and the same is as below:

• Intra State transmission system strengthening (for 7 States) incl. connectivity system	:	Rs. 20,603 Cr
• Inter State transmission system strengthening including connectivity system to ISTS	:	Rs. 18,848 Cr
• Dynamic Reactive Compensation	:	Rs 1204 Cr
• Real Time Monitoring System (PMU/PDC) including Fiber Optic Communication links)	:	Rs. 473 Cr.
• Energy Storage	:	Rs. 2,000 Cr.
• Establishment of Renewable Energy Management Centre	:	Rs. 234 Cr.
Total	***:***	***Rs. 43,362 Cr.***

Implementation Strategy

Gestation period for a Solar and Wind power project is about 6-12 months depending upon the capacity & location of the plant. To facilitate evacuation of the RE power, it is necessary to integrate the plant/RE Pooling station with grid network at PCC (Point of Common Coupling) through connectivity transmission system. However development of connectivity transmission system, establishment of RE Pooling station as well as transmission system strengthening in STU network for RE absorption, takes considerable time which is significantly more than the generation gestation period. In addition transmission system strengthening works at ISTS level, being developed through competitive tariff based bidding, also requires about 3-4 years time.

In view of the above, efforts should be made for faster implementation of the associated transmission works for RE, avoiding generation bottleneck. Transmission system for RE in particular can be classified into two (2) parts:

- **Intra State strengthening (STU)**- from Point of common coupling (PCC) to grid network for absorption of power within same area or host state including Connectivity Transmission system from RE Generation switchyard (beyond first step up voltage level) to Point of common coupling (PCC) in STU network

- **Inter state transmission system (ISTS)** - For transfer of power from RE rich state to other states, system strengthening within state for conveyance of ISTS transfer as well as Connectivity Transmission system from RE Generation switchyard (beyond first step up voltage level) to Point of common coupling (PCC) in ISTS network

Intra State transmission strengthening for absorption within state may be implemented by respective STUs. However, implementation needs to be carried out in a tight schedule so as to match with the progressive RE generation availability, to avoid any transmission congestion. For this, it is necessary to expedite the development of proposed Intra State Strengthening. In this direction, for faster implementation, support may be provided by some expert agency in form of consultancy with sound project management skill and technical expertise to STU.

Further, connectivity transmission system being the most critical element, hooks up the RE generation to the grid. As per the prevailing practice, wind generation developers have to develop connectivity interconnection. However, with the increasing renewable generation capacity, this may lead to sub optimal development of connectivity transmission system, as each developer shall tend to lay their own lines. Furthermore with the rising issue of ROW constraints, multiple lines in one common section may not be possible in future. Therefore, there is a need to adopt pocket wise, connectivity system development approach, which shall be a techno-economic optimal alternative. However for such approach, in which common connectivity system is proposed for development, STU having the expertise in transmission system development including obtaining statutory clearances should take the lead.

Development of connectivity transmission system also needs special emphasis for faster implementation, as otherwise it may lead to generation bottleneck. Therefore, above must be implemented in a tight schedule for which efficient project management skills are required.

Further, Pocket wise RE generation development should be prioritized in such a manner so that transmission infrastructure available in the pocket can be utilized optimally. Subsequently, other pockets may be developed along with commensurate transmission system.

Phasing for implementation of Intra state system strengthening scheme is discussed in ***Chapter-11***. However above proposed phasing may need to be reviewed in case of change in renewable capacity addition programme in certain pockets/complexes.

Inter State Transmission System includes Inter-state transmission strengthening across states to facilitate transfer of power beyond state boundaries. ISTS mainly comprises of ±500kV HVDC as well as 765kV/400kV AC transmission lines for Inter-state transmission of power.

In addition, identified system strengthening within the state for conveyance of ISTS transfer is also included in the ISTS. Phasing for implementation of System strengthening within state for conveyance of ISTS transfer is discussed in ***Chapter-11***.

High Capacity corridors, as a part of above ISTS, is proposed to be implemented in following three phases depending upon capacity addition as well as time required for implementation of the transmission system.

Phase-I (by 2014-15)

- 400kV Bachau (PG)- Solar Park-II (GETCO) – Udaipur - Kankroli D/c

Phase-II (2015-16)

- 400kV Solar Park-II (GETCO)– Chittorgarh D/c
- 765kV Jodhpur(New) – Ajmer(New) D/c
- 765kV Ajmer(New) – Suratgarh D/c
- 765kV Suratgarh – Moga D/c
- 400kV Kankroli- Ajmer(New) D/c
- Suratgarh(existing)- Suratgarh (New) 400kV D/c
- Ajmer(existing)- Ajmer (New) 400kV D/c
- New Pugalur - Udumalpet 400kV D/c
- New Pugalur - Vagarai 400kV D/c
- New Pugalur - Pugalur 400kV D/c (Quad)
- LILO of Tuticorin Pool-Salem 765kV line at New Pugalur (initially to be operated at 400kV)
- Augmentation of transformation capacity at 765/400kV & 400/220kV at Moga substation by 1x1500 MVA & 1x500 MVA respectively
- Establishment of 400 kV Substation at New Pugalur & Hyderabad
- Establishment of 765/400kV, 2x1500 MVA S/s each at Suratgarh, Jodhpur & Ajmer

Phase-III (2016-17)

- 400 kV Srisailam - Kurnool New D/c
- ± 500 kV, 2500 MW New Pugalur - Hyderabad HVDC Bipole
- New Hyderabad – Hyderabad 400kV D/c (Quad)
- Establishment of 400 kV Substation at New Hyderabad
- Establishment of ±500kV, HVDC terminal stations(2500MW) each at New Pugalur & Hyderabad
- Up gradation of 400kV Narendra & Kolhapur substations at 765kV level to facilitate charging of Narendra- Kolhapur D/c line at 765kV level

However above proposed phasing shall need to be reviewed in case of change in renewable capacity addition programme in certain pockets/complex of RE rich state. In addition, above phasing is proposed considering the implementation programme of Intra State Strengthening schemes, which otherwise can impact requirement of above proposed ISTS in different phases.

However, keeping in view the intricacies involved in implementation of ISTS scheme like ROW issues, forest clearances, high end technologies etc., implementation of ISTS, may be given to agency (ies) that have sufficient experience in development of EHV AC& HVDC System, technical expertise as well as strong project management skills.

Financing Strategy

In order to facilitate the development of transmission system as well as other infrastructure facilities as part of renewable capacity addition program in 12th plan, following financing strategy is proposed. The wind and solar generation is primarily an energy resource and not a capacity resource that can be relied upon to deliver energy on at the time of peak or on demand. The transmission required to deliver wind/solar/SHP energy is to be planned for state renewable policy compliance, economics and delivery of energy in different scenarios. Capacity Utilization factor for renewable generation is low. As per CERC Regulation there are no ISTS charges for Solar generation till 2014. Further each state has to fulfill their RPO target. In addition, Renewable generation is to be promoted for clean development. Keeping this in view, transmission charges for renewable generation need to be rationalized. Towards this, following financing strategy for development of Intra State & Inter State system strengthening is proposed.

- The intra state transmission strengthening scheme includes system strengthening within the state as well as transmission system from RE Generation switchyard (beyond first step up voltage level) to Point of common coupling (PCC) in STU network to facilitate absorption of power within the host state.

  The entire transmission strengthening involves three stretches i.e. Stretch-I : Transmission system from a particular generator to common connection point in STU grid: Stretch-II: System strengthening for common connection point to various points in the STU network; Stretch-III: Strengthening in ISTS network. Typical transmission connection arrangement for RE generation is shown in the Fig 1.

Generation from the Renewable sources like Wind & Solar generally have low utilization factor. Above aspect coupled with development of stretch-I for a specific Renewable generator would result into less utilization of the system in Stretch-I. However utilization of system under Stretch-II would be higher than Stretch-I due to increased no. of connectivity of various sources to state network. Further utilization factor of transmission system under Stretch-III would be relatively higher due to more no. of connection of various sources and interconnections.

Development of Stretch-I is under the purview of specific RE generation developer, whereas development of Stretch-II i.e. system strengthening within the state is to be carried out by respective states which has relatively lower utilization as compared to the inter-state system strengthening. In view of the above, there is a need to rationalize the transmission charges for the system strengthening within state (Intra state strengthening) to reduce the burden on the consumers.

Therefore, it is proposed that total capital expenditure requirement towards intra state strengthening i.e. about Rs.20,603 Cr, may considered through suitable funding arrangement. For this, it is proposed that at least 40-50% of the envisaged capex (Rs 20,603 Cr) may be provided through grant such as National Clean Energy Fund (NCEF) [20-25%] and Viability Gap funding (VGF) [20-25%] etc. so as to reduce the transmission charges on account of renewable capacity.

- ISTS strengthening has been evolved taking into account already planned high capacity transmission corridor(s) interconnecting various generation projects in different regions with load centers. This shall facilitate transfer of power from RE complex to load center in one scenario when RE generation is high and in other direction when RE is low, getting support from conventional generators. The evacuation as well as transfer of RE power from resource rich region to the load centers is also required in national interest in order to meet RPO targets of various states.

In addition, system strengthening within state for conveyance of ISTS transfer is estimated to be about Rs 7,052 Cr. Further, estimated cost towards connectivity of RE generation of more than 50 MW capacity to point of common coupling in ISTS network is estimated to be about Rs 1,581 Cr.

Thus Capital Expenditure for total Interstate transmission strengthening (Rs. 22,525 Cr) would include interstate transmission strengthening (Rs 10,215 Cr), System strengthening within state for conveyance of ISTS transfer (Rs 7052 Cr), Connectivity system to ISTS network (Rs 1581 Cr), Real time monitoring scheme (Rs 473 Cr), Dynamic reactive Compensation (Rs 1204 Cr) as well as Energy storage (Rs 2,000 Cr).

ISTS evolved for RE generation are of national in nature with total capital expenditure of about Rs. 22,525 Cr. It is proposed to be pooled in the national transmission pool account like other high capacity transmission corridors being implemented as a part of conventional generation. The transmission charges shall be shared by all the users (Designated ISTS users) in the pool as per point of connection transmission charges sharing norms.

In order to rationalize transmission charges, it is proposed that Debt component for ISTS capex (Rs 22,525 Cr) may be provided as grant/soft loan.

- For development of Renewable Energy management Centers (REMC), it is proposed that investment may be considered as Capital Expenditure of respective Regional Load Despatch Centres and charges recovered as per provision of Regulations specified by appropriate Commission.

  Estimated cost of above scheme is about Rs. 234 Cr.

Note: The above cost estimate is indicative only and has been made considering the line length, fibre optic length and based on the data available from various sources on different elements. Therefore, for carrying out realistic cost estimate, final survey is suggested regarding availability of Right of Way (ROW), space at substation, type of equipment etc.

Intentionally left Blank

Chapter-1

Background

1.1. Introduction

India has huge potential of Renewable Energy (RE) resources such as wind, solar, hydro etc. Most ofthe renewable capacity is in the renewable potential rich states of Tamil Nadu, Karnataka, Andhra Pradesh, Gujarat, Maharashtra, Rajasthan Himachal Pradesh and Jammu & Kashmir. These states contribute more than 80 to 90 % of total renewable capacity installations in the country. Various policy initiatives and fiscal incentives have created interest in developing renewable energy (RE) generation. Regulatory initiatives have also been taken to promote sale of RE power. Till recently, the quantum of RE power was small and it was presumed that connectivity with the nearest grid substation of State Transmission Utility (STU) would suffice for power evacuation and the RE power is consumed locally.

Now emphasis has been given to harness RE power on a large scale to bring economies of scale as soon as possible to supplement the capacity addition from conventional sources as well as for clean development. It is envisaged to add more than 42,000 MW renewable generation capacity during the 12th Plan period. The renewable energy (RE) resources are generally located in remote locations and confined in few states only. Grid infrastructure is needed to be sufficient to transport the renewable energy to the load centres. Further, distribution licensees in each state, Captive Power Plants (CPP) and Open Access Consumers must meet certain percent of their annual energy consumption through RE generation as part of their Renewable Purchase Obligations (RPO). In future scenarios, it is envisaged that home states would not be able to consume high cost RE power within the state beyond their RPO requirements and therefore RE power has to be transmitted to other states. Therefore, development of transmission system, both intra and inter-state transmission system to meet the needs of large scale renewable energy are extremely necessary. Without significant increase in transmission capacity all the renewable energy generated cannot be accommodated in the power system. Renewable energy is also characterized by the problem of intermittency and variability. Intermittent/variable supply from RE sources creates a complexity in the grid which is required to be addressed.

Recognizing the criticality of large scale development of RE capacity and its integration with grid, Ministry of New & Renewable Energy (MNRE) and Forum of Regulators (FOR) have entrusted POWERGRID to carry out studies to identify transmission infrastructure and other control requirements for RE capacity addition programme in 12th Plan and prepare a comprehensive report along with estimation of CAPEX requirement and financing strategy.

1.2. Objective of the study

The broad objectives of the comprehensive report include:

i) Identification of transmission infrastructure for the likely capacity additions of RE based power (wind, solar and hydro) in Renewable rich states viz. Tamil Nadu, Karnataka, Andhra Pradesh, Gujarat, Maharashtra, Rajasthan, Himachal Pradesh and Jammu & Kashmir during the 12th Plan period
ii) Estimation of CAPEX requirement for the development of transmission infrastructure
iii) Providing strategy framework for development of a model for funding transmission infrastructure to facilitate speedy renewable power development

1.3. Approach

On the advice of MNRE/Forum of regulators (FOR), POWERGRID visited the State Nodal Agencies (SNAs) and State transmission utilities (STUs) of renewable rich states for collection of information of envisaged renewable capacity addition by 2016-17. Based on the series of the discussions held between POWERGRID and SNA/STUs, SNA/STUs have provided pocket wise envisaged capacity addition by Renewable sources coming up in 12th plan. Some of the STUs also provided the details of transmission connectivity planned for evacuation of power from RE generation pockets planned in next 2-3 years. Information collected from respective SNA/STU is enclosed at Appendix-1. Data was informed to MNRE/FOR/CEA for their observation. CERC provided details of Renewable Purchase Obligation of states for 12th plan period. Further power demand for 12th plan period has been taken from available draft 18th Electric power survey (EPS) of CEA. Based on the above parameters, a study for evolution of transmission system for Renewable Generation has been carried out.

1.4. Organisation of the report

The report is organized in Twelve (12) different chapters. Key findings and results of the study as well as summary of the report is articulated in Executive Summary of the report. **Chapter-1** covers the background of the report and objectives of the study. An overview of the renewable generation scenario at present and future capacity addition programme in 12th plan is described in **Chapter-2**. **Chapter-3** includes operational trends of wind and solar generation in renewable potential rich states under various seasons. Study methodology and assumptions to evolve transmission requirement for evacuation of renewable power is highlighted in **Chapter-4**.

Studies and results including proposed transmission system strengthening are deliberated in **Chapter-5**. **Chapter-6** discusses need of reactive compensation for grid integration of renewables and includes proposal of switchable/controllable bus reactors as well as dynamic compensation. In **Chapter-7**, issues and mitigating measures in grid integration of large scale variable renewables are enumerated. **Chapter-8** describes need of Renewable Energy Management Center, its hierarchical structure & other related aspects. **Chapter-9** covers the international experiences of various utilities in addressing the grid integration issues of renewable.

Estimated cost (CAPEX) of establishment of above transmission and other control infrastructures is given in **Chapter-10. Chapter-11**, Strategy framework for financing as well as implementation strategy for proposed transmission system has been described. In the last chapter i.e. **Chapter-12**, Roadmap for Perspective Transmission Plan for RE Capacity by 2030 is proposed.

Report has been subdivided into two volumes. **Volume-I** comprises of above twelve (12) chapters including Executive Summary/Conclusion. **Volume-II** includes Annexure, Exhibits and Appendix referred in different chapters of Volume-I.

Chapter-2

Overview of Renewable Capacity

2.1 Existing Renewable Capacity

Presently the total installed capacity in India is about 200 GW (As on 31.03.2012). The capacity from conventional sources namely coal, gas, diesel, nuclear and large hydro amounts to about 88% share and non-conventional / renewable contribution isabout 12%. The mix of insta lled capacity of various types of generations (GW) on all India level is shown at Figure 2-1below:

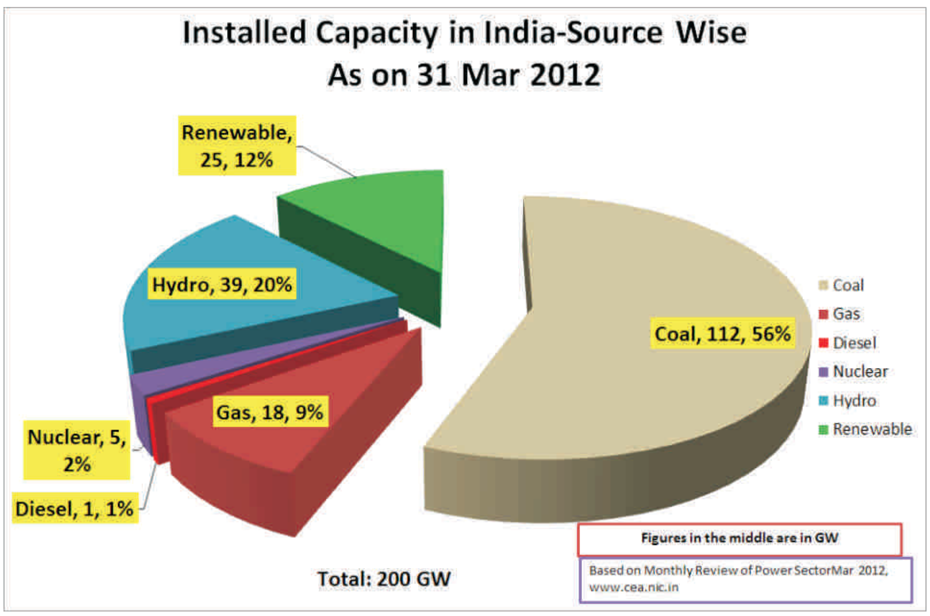

Figure 2-1 : Share of different types of generation capacity (Source- CEA monthly review of power sector, Mar'12)

Out of the various types of conventional generations, coal and based generation are generally considered as base load plants, whereas gas based generation as peaking units. In hydro plants, run off the river types are considered as base load plants whereas reservoir types as peak load plants.

2.2 Growth Trajectory of Renewable Capacity

India has been continuously progressing in conventional as well as renewable capacity addition. Since 9th Plan period, share of renewable capacity has increased from 2% to 12% as on today (about 6 fold increase). Electricity generation due to renewable has also increased to about 4% in overall electricity generation mix as on today. With such multifold growth, penetration of renewable power in Indian grid has increased. Presently, in our country about 25,000MW grid interactive as well as 700 MW off grid RE generation capacity is available. Out of this about 70% grid interactive capacity is contributed by the wind alone. Share of different RE resources in grid interactive installed capacity is given at Figure 2-2 as under:

Resources	***Grid-Interactive Capacity (MW)*** **up to 31.03.2012**
Wind Power	17353
Small Hydro Power	3396
Biomass Power / Bagasse Cogeneration	3225
Solar Power	*941*
Total	***24915***

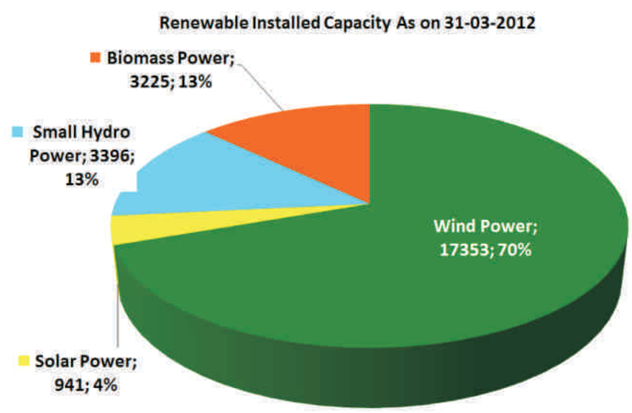

Figure 2-2 : Figure 8 : Renewable Installed Capacity (Source-MNRE)

Out of country's total installed capacity, coal based capacity has major share. However, in view of the challenges arising on coal availability as well as environmental concerns, now impetus has been given on harnessing of renewable energy sources like Wind, Solar, Small Hydro, Biomass / waste to energy etc. This shall also pave a new way to India's need for secure, affordable and sustainable energy for meeting its growing energy demand. Conducive policies, regulatory framework, financial Incentives etc. have also given a boost towards development of renewable capacity addition in past few years. Growth pattern of RE capacity addition in different five year plans is shown in Figure 2-3.

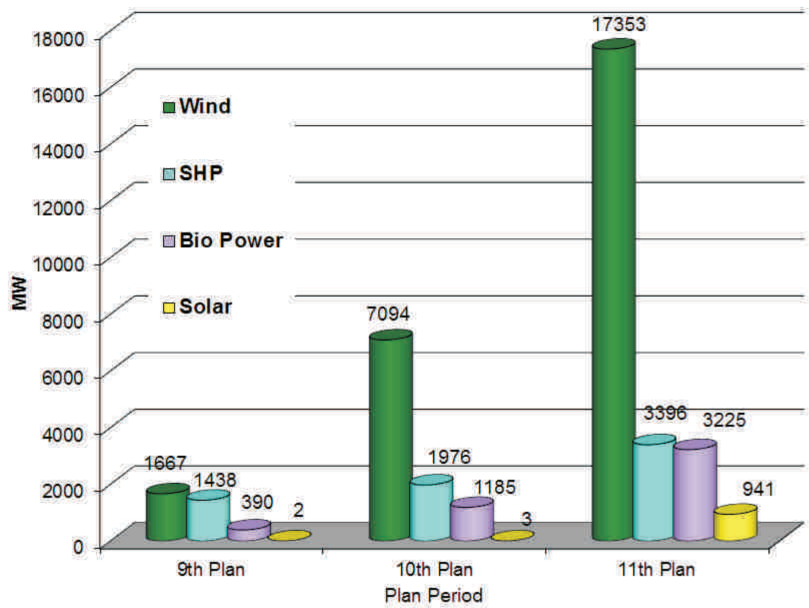

Figure 2-3 : Growth pattern of RE addition in different five year plans (Source- MNRE document on "Renewable Energy in India: Progress, Vision and Strategy")

2.3 Renewable Capacity Potential in India

India has been bestowed with abundant Renewable Energy potential. To harness the above potential, the Government of India (GOI) has been facilitating implementation of broad spectrum of conducive renewable energy programmes through an elaborate implementation mechanism.

Among various renewable energy resources, India possesses a very large solar and wind energy resource which is seen as having the large potential for the future. Solar Potential in India is about 20-30 MW/sq km (i.e.>100 GW). As per C-WET (Chennai), estimated wind potential is about 103 GW at 80 m hub height. The wind and solar map of India is depicted at **Exhibit A**. It is observed that wind and solar potentials are mainly confined in southern, western States viz. Tamil Nadu, Karnataka, Andhra Pradesh, Maharashtra, Gujarat, Rajasthan & Jammu & Kashmir.

It has been estimated that potential of Biomass/Bagasse power using agro-waste & agro-industrial residues is around 17000 MW and 5000 MW respectively. In addition, estimated potential of power generation from micro/mini/ small hydropower plants is about 15,000 MW from 5718 identified sites. Estimated potential of renewable generation capacity of various sources is shown at Figure 2-4

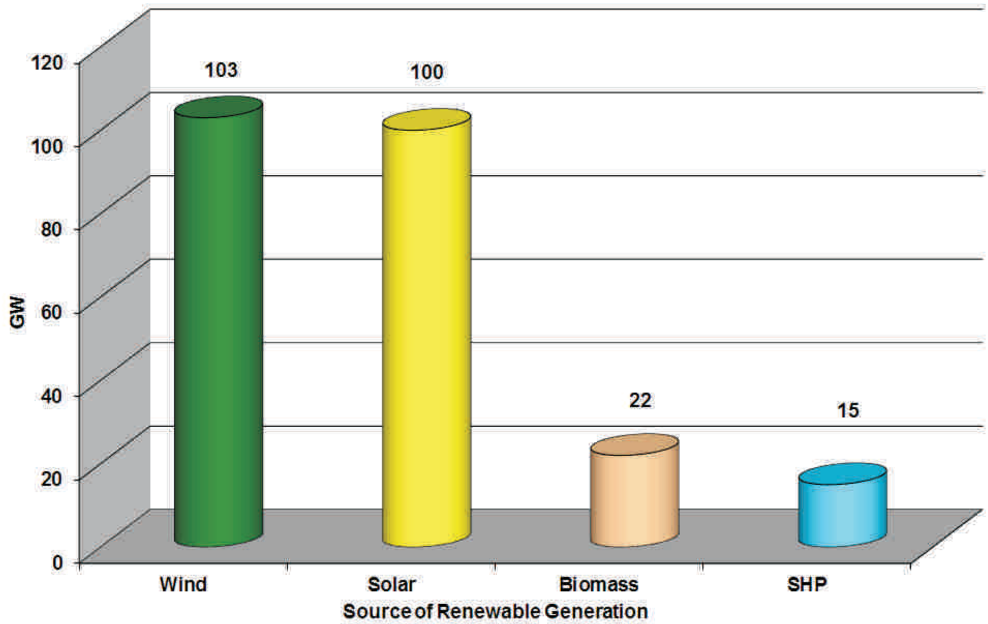

Figure 2-4 : Renewable Energy Potential (Source : C-WET & MNRE Vision document)

Earlier, MNRE has set ambitious targets for capacity addition for next five year plans. In its document on "Renewable Energy in India: Progress, Vision and Strategy", MNRE projected that RE capacities at the end of the 12th Plan i.e. FY 2017 & 13th Plan i.e. FY 2022 would be around 41,400 MW and 72,400 MW. Details of resource wise projected contribution of Grid Interactive Renewable Power are given at Table-2.1:

Table-2.1: Proposed Renewable capacity addition programme (MNRE)

Resource	12th Plan Projection for RE Addition	Total Projected Capacity by end of 12th Plan(2017)	13th Plan Projection for RE Addition	Total Projected Capacity by end of 13th Plan (2022)
Wind Power	11200	27300	11200	38500
Small Hydro Power	1600	5000	1600	6600
Biomass Bagasse Cogen Waste to Energy	500 1400 200	1525 3216 324	1000 700 500	2525 3916 824
Solar Power	3800	4000	16000	20000
Total	***18700***	***41400***	***31000***	***72400***

Source- MNRE document on "Renewable Energy in India: Progress, Vision and Strategy"

2.4 Renewable Capacity Addition Programme in 12th Plan

Major contribution in envisaged renewable capacity addition is through wind, solar and small hydro sources. Under the Jawaharlal Nehru national Solar Mission (JNNSM) launched in 2010, the government intends to commission 20,000 MW in grid-connected solar power by 2022. In the first phase, solar power generation capacity of around 1,100 MW will be created by 2013, which will be further increased to 10,000 MW by 2017 in the second phase of the programme.

As per MNRE's Working Group report on New and Renewable Energy for the 12th Plan, capacity addition envisaged through grid connected wind and small hydro generation is about 15,000MW and 2100MW respectively by 2017.

On the advice of MNRE and FOR, POWERGRID interacted with State Nodal Agency (SNA) / STU for collection of information on renewable capacity programme during 12th Plan in the Eight (8) renewable potential rich states viz. Tamil Nadu, Karnataka, Andhra Pradesh, Gujarat, Maharashtra, Rajasthan, Himachal Pradesh and Jammu & Kashmir. Information collected from respective SNA/STU is enclosed at Appendix-1. Based on the information, envisaged capacity addition through renewable in 12th Plan is about 42,000MW (30,400MW wind, 9,500MW solar and Small Hydro 2,100MW). State wise details of renewable capacity addition programme are given in Table 2.2(a) & (b).

Table 2.2(a) : Wind / Solar Addition Plan in RE Rich States

State	Existing capacity (MW)		Addition in 12th Plan (MW)		Total capacity (MW)	
	Wind	*Solar*	*Wind*	*Solar*	*Wind*	*Solar*
Tamil Nadu	6370	7	6000	3000	12370	3007
Karnataka	1783	6	3223	160	5006	166
A.P	392	92	5048	285	5440	377
Gujarat	2600	600	5083	1400	7683	2000
Maharashtra	2460	17	9016	905	11476	922
Rajasthan	2100	200	2000	3700	4100	3900
J & K	-	2	12	102	12	104
Total	***15705***	***924***	***30382***	***9552***	***46087***	***10476***

Table-2.2(b) : Small Hydro Addition Plan in RE Rich States

State	Existing capacity (MW)	Addition in 12th Plan (MW)	Total capacity (MW)
Karnataka	527	719	1246
Himachal Pradesh	443	996	1439
J&K	118	362	480
Total	*1088*	*2077*	*3165*

Year wise capacity addition programme during 12th plan in each of the above States as informed by them is given in Table 2.3 (a), (b) and (c).

Table-2.3(a): Wind based capacity addition programme

State	2012-13	2013-14	2014-15	2015-16	2016-17
Tamil Nadu	1200	1200	1200	1200	1200
Karnataka	620	600	700	780	523
A.P	1503	1435	257	1202	651
Gujarat	2633	300	1150	500	500
Maharashtra	1376	1570	2340	2250	1480
Rajasthan	400	400	400	400	400
Jammu & Kashmir	0	4	4	2	2
Total	*7732*	*5509*	*6051*	*6334*	*4756*

Table-2.3(b): Solar based capacity addition programme

State	2012-13	2013-14	2014-15	2015-16	2016-17
Tamil Nadu	200	500	600	800	900
Karnataka	40	40	40	40	0
A.P	15	0	120	100	50
Gujarat	350	350	300	300	100
Maharashtra	125	150	175	200	255
Rajasthan	500	1000	1000	900	300
Jammu & Kashmir	1	0	101	0	0
Total	*1231*	*2040*	*2336*	*2340*	*1605*

Table-2.3(c) : Small hydro based capacity addition programme

State	2012-13	2013-14	2014-15	2015-16	2016-17
Himachal Pradesh	105.45	219.65	165.15	307.45	198.02
Karnataka	161.21	108.5	152.8	150.8	145.3
J&K	26.5	35.95	39.0	108.0	152.35
Total	***293.16***	***364.1***	***356.95***	***566.25***	***495.67***

Pocket-wise total RE capacity addition in 12th Plan in each State is presented at ***Exhibit B1 to B8***.

Considering large scale RE Capacity addition through Wind/Solar generation, it is prudent that individual farm capacity may be of large size to bring economy of scale. Also, the generation plant may be equipped with suitable technology for grid integration as well as to ensure grid safety and security. A brief on various technologies available for renewable generation viz. Wind, Solar and Small Hydro is deliberated at **Appendix-II**.

2.5 Wind Penetration Scenario

In a power system, impact of renewable capacity specially wind power not only depends on its penetration level but also on the power system size (inertia), mix of generation capacities, robustness of interconnections, load variation patterns etc. Amongst various RE resources, wind being the major contributor as well as its virtue of variability and intermittency, it plays a dominant role in defining the renewable penetration level. In general following definitions are relevant in classifying penetration level:

Installed capacity penetration: It is the Installed wind capacity (MW) connected to an electrical system, normalized by the total installed capacity

Energy penetration: Electricity produced by the RE generation, normalized by the gross electricity consumption in the electrical system, usually on an annual basis.

Generally, low penetration means less than 5% energy penetration. Range of 5-10% energy penetration is termed as medium level of energy penetration. In India, present level of RE energy penetration is about 4% and capacity penetration is about 12%. Considering the 12th plan capacity addition programme for conventional generation of 79.62 GW, as per National Electricity Plan (Generation) [Jan'12], as well as envisaged RE capacity addition of 42 GW, it is expected that capacity penetration of RE by 2016-17 shall increase to about 21% [(42+24.9)/(79.62+200+42)] and energy penetration of about 14% [(66.9*0.32*8760*10^{-6})/(1349)].

As per the projections for 12th plan, wind shall again become major contributor (about 70%) to total RE capacity addition. Wind capacity penetration shall increase to about 15% from present 9% at all India Level. State like Tamil Nadu shall continue to have highest wind penetration capacity (about 40%) terms.

Details of present level of wind capacity penetration in renewable potential rich States is given at Table-2.4

Table-2.4: Renewable potential rich State wise wind penetration level

Sno	State	Total Installed Capacity(MW)*	Installed Wind capacity (MW) #	Wind cap Penetration (%)
1	Tamil Nadu	17602	6370	36%
2	Maharashtra	26142	2460	9%
3	Karnataka	13394	1783	13%
4	Rajasthan	10161	2100	21%
5	Gujarat	21972	2600	12%
6	A.P	16095	392	2%

** Source- CEA –Monthly review of power sector: 2012- Mar'12* *#- Information by SNA/STU*

As per the information received, energy penetration on daily and annual for wind rich states/region for year 2011-12 is given at Table-2.5

Table-2.5: Energy Penetration level

S no	State/Region	% Annual Energy penetration	% Max. daily Energy penetration
1	Tamil Nadu	10.3	26.4
2	Karnataka	6.0	23.1
	Southern region	***4.7***	***12.8***
3	Gujarat	5.0	18.4
4	Maharashtra	2.8	10.7
	Western region	***2.7***	***9.8***
5	Rajasthan	4.8	19.2
	Northern region	***0.9***	***3.7***
	All India	***2.4***	***6.7***

**** Source- POSOCO***

From the above it can be analyzed that % energy penetration on daily basis is much higher than annual basis. Therefore the system of respective states must be able to handle such a large penetration level on day to day basis. However such condition will emerge mainly during monsoon periods like June-July period.

As per the information provided by SNA/STU of RE Rich states, about 30 GW wind capacity shall be added in 12th Plan period. In addition, tentative capacity addition programme for conventional projects for 12th plan period is being considered. Considering above, wind Installed capacity penetration levels have been reassessed. Details of Wind capacity penetration level by 2016-17 time frame for RE rich states is given at Table-2.6.

Table-2.6: Renewable rich State-Expected wind penetration level

Sno	State	Total Capacity(MW)* (incl. conv /RE)	Wind capacity (future +existing) (MW)#	Wind cap Penetration (%)
1	Tamil Nadu	30947	12370	40%
2	Maharashtra	48739	11476	24%
3	Karnataka	17636	5006	28%
4	Rajasthan	19281	4100	21%
5	Gujarat	36957	7683	21%

Sno	State	Total Capacity(MW)* (incl. conv /RE)	Wind capacity (future +existing) (MW)#	Wind cap Penetration (%)
6	Andhra Pradesh	35274	5440	15%

** Tentative 12th Plan sector/mode wise capacity addition plan* *#- Information by SNA/STU*

2.6 Enabling Provisions of RE Generation

As per Electricity Act 2003 and the policies i.e, National Electricity Policy (NEP) and Tariff Policy, the responsibility of promoting generation of electricity from renewable sources of energy has been entrusted on the Appropriate Commission by:

- Providing suitable measures for connectivity to the grid
- Sale of electricity to any person
- Specifying, for purchase of electricity from such sources, a percentage of the total consumption of electricity in the areas of distribution licensee.

SERC have specified a Renewable Purchase Obligation (RPO) and have specified feed-in tariff (preferential tariff) and other terms and conditions to promote generation of electricity from renewable.

Besides certain fiscal incentives like tax holiday, generation based incentives, some of the key relevant policies and regulations to promote renewable capacity addition are as under:

a) Grant of Connectivity, Long term Access and MTOA of RE plant in ISTS

As per CERC (Grant of Connectivity, Long term Access and Medium term Open access in ISTS) regulation 2010, a generator or a group of generators using renewable source of energy including hydro with aggregate installed capacity of 50 MW can apply to the CTU for direct connectivity with inter state transmission system.

In case of renewable generator having capacity of 250 MW and above, it shall not be required to construct a dedicated transmission line to the point of connection and they shall be taken into account for coordinated transmission planning by the CTU and CEA.

b) Sharing of Transmission Charges

In case of Solar plants which are to be commissioned by 2014, as per CERC (Sharing of inter-state transmission charges and losses) Regulations 2010, ISTS charges/losses are exempted.

c) Renewable Energy Certificate

CERC has introduced Renewable Energy Certificate (REC) mechanism which is a market based instrument, to promote renewable sources of energy. This mechanism encourages setting up of large RE generation capacities at resource rich locations. Through this instrument, obligated entities; viz. DISCOM, Open Access Users and Captive Power Consumers can fulfill their renewable purchase obligation (RPO). The concept is based on 'un-bundling' the green power into two parts, one is 'electricity' another is 'green/environmental attribute' which gets converted to renewable energy certificate (REC). Normally, the premium attached with green power sources only gets converted as REC (One REC is equivalent to 1 MWh) and becomes tradable separately at Power exchanges which obligated entities can purchase from RE developers. However, RE generators who opt to sell electricity, at non preferential rates or APPC (Average Pooled Power Cost) is only eligible to earn REC upon registration. The mechanism is being operated by NLDC. Schematic of REC mechanism is shown at Fig 2-5.

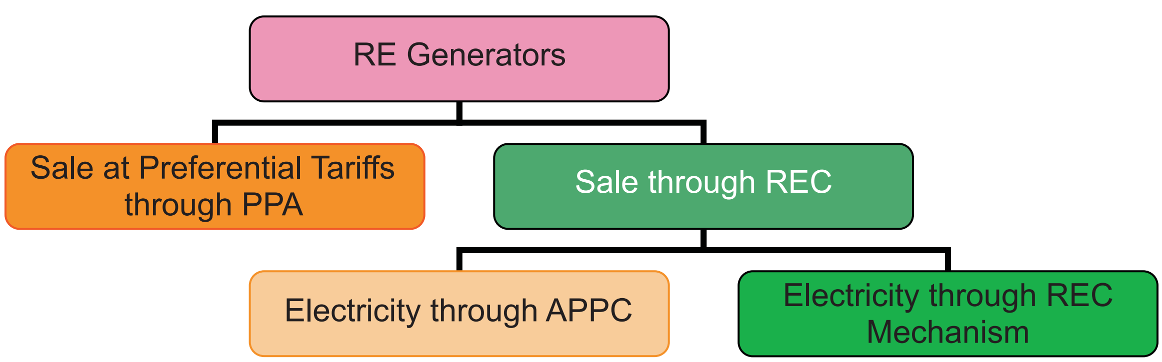

Figure 2-5: REC Mechanism

d) Development of Renewable Regulatory Fund

As per CERC (Indian Electricity Grid Code) Regulations, 2010, wind generators shall be responsible for forecasting their generation up to accuracy of 70%. For actual generation within ±30% of the schedule, no UI would be payable/receivable by Generator. UI charges for within this variation, i.e within ±30% would be applicable to the host state. In case of solar generation no UI shall be payable/receivable by Generator. The host State shall bear the UI charges for any deviation in actual generation from the schedule.

Implication of these UI charges to host State shall be shared among all the States/UT of the country/DVC in the ratio of their peak demand met in the previous month, in the form of a regulatory charge known as the Renewable Regulatory Charge (RRC) operated through the Renewable Regulatory Fund (RRF). Implementation of the RRF mechanismis applicable to wind farms with collective capacity of more than 10 MW and solar plants more than 5 MW connected at connection point of 33 KV or above level of State/ISTS and who have not signed any PPA with st ates/UT/DVC or others.

2.7 Projected Renewable Purchase Obligation (RPO)

In line with the Electricity Act 2003 and National Electricity Policy, SERC have specified a trajectory on Renewable Purchase Obligation (RPO) by each State in 12th Plan. As per the FOR report (Mar'12), State wise RPO target by 2016-17 is shown at Fig 2-6. The RPO target is 7-15% depending upon the availability of renewable capacity in the State, demand/energy consumption projection etc.

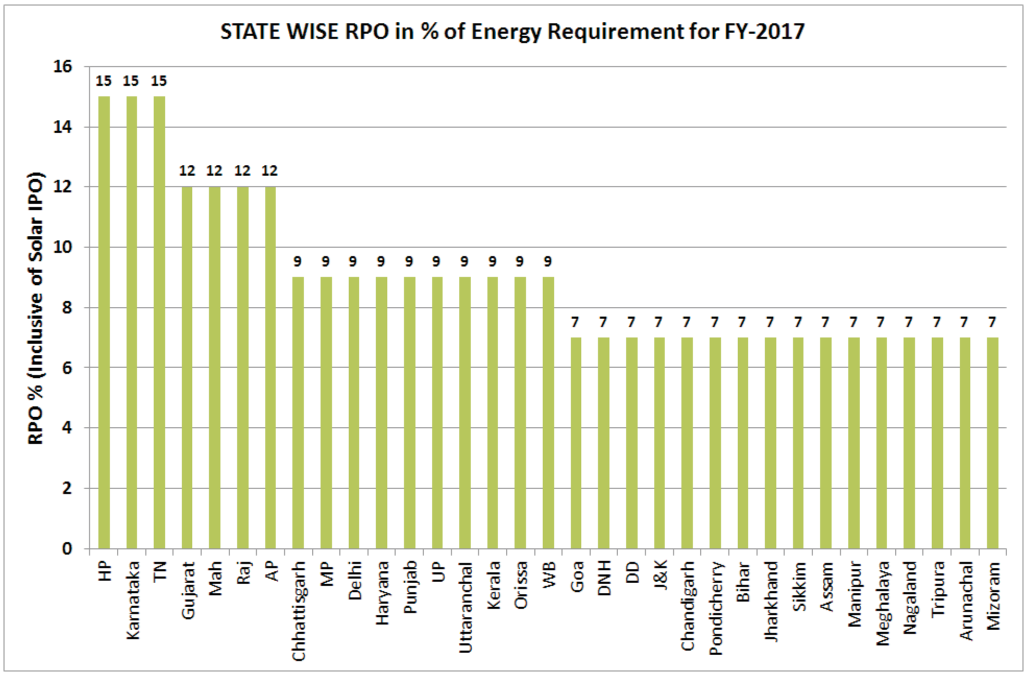

Figure 2-6 : Projected RPO target State wise for 2017 (Source – FOR report-Mar'12)

Wind / solar power generation and electricity demand pattern in the RE rich states / regions has been analyzed to identify transmission system strengthening for handling issues associated with large RE generation in the next chapter.

Intentionally left Blank

Chapter-3

Renewable Operational Trends

3.1 Seasonal/Daily wind generation pattern

Analysis of past wind data and electricity generation from wind in India indicates that wind generation maximizes during May to September (i.e, Pre monsoon & monsoon periods) mainly due to low-level jet/monsoonal flow as shown in Fig 3.1.

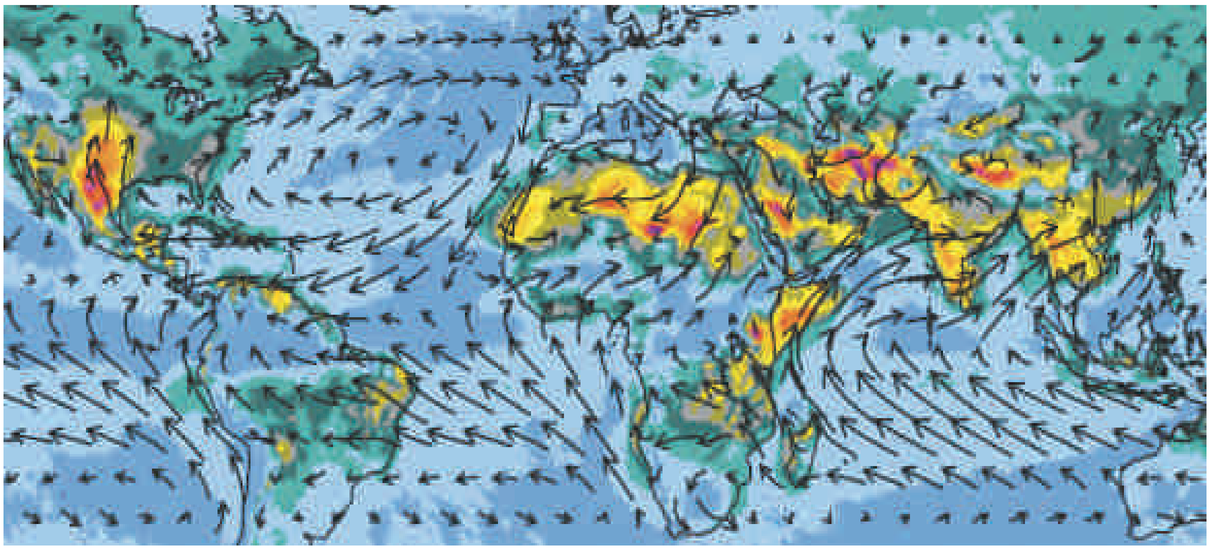

Figure 3-1 : Low level jet/Monsoonal wind flow in Indian Territory

It can be seen from the wind-map of India (Refer Exhibit A) that economically exploitable wind zones are mainly concentrated in Southern and Western part of country.

Based on the information shared by the respective SLDC of RE rich states regarding wind/solar generation, trends for wind pattern for different seasons / daily variation have been established and analyzed. The SCADA data available at SLDC / RLDC/ NLDC has been also analysed and presented in the following sections.

Annual profile of wind based electricity generation in RE potential rich regions has been shown at Fig 3.2.

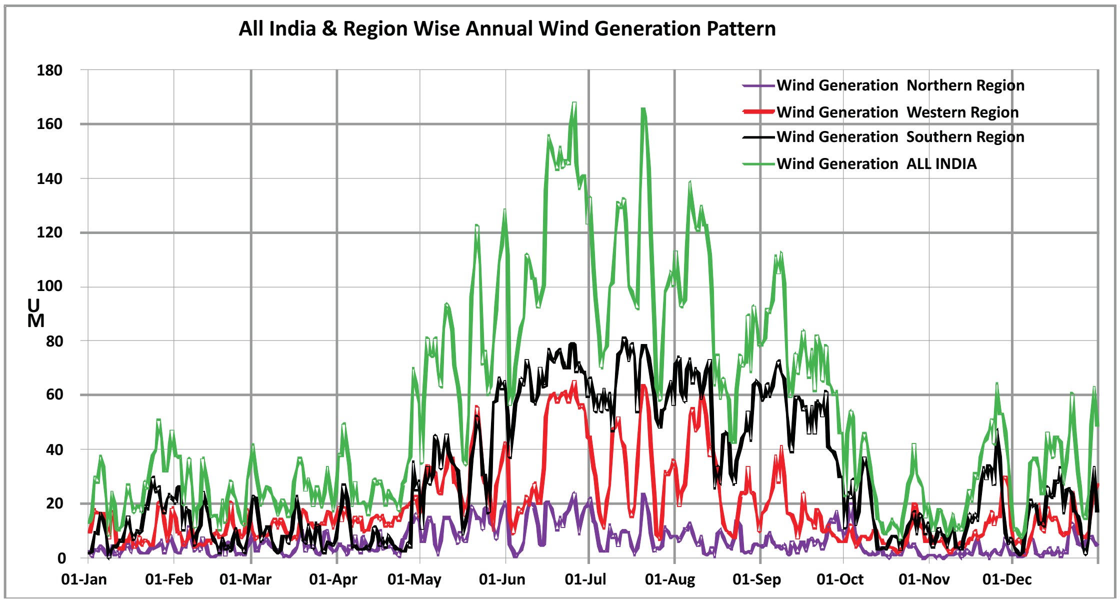

Figure 3-2 : Region wise annual wind generation pattern for RE Rich Regions during 2011 (Source-POSOCO)

Fig 3.3 indicates annual pattern of peak wind power generation for RE rich states. These plots indicates that wind based electricity generation is maximum during May to September.

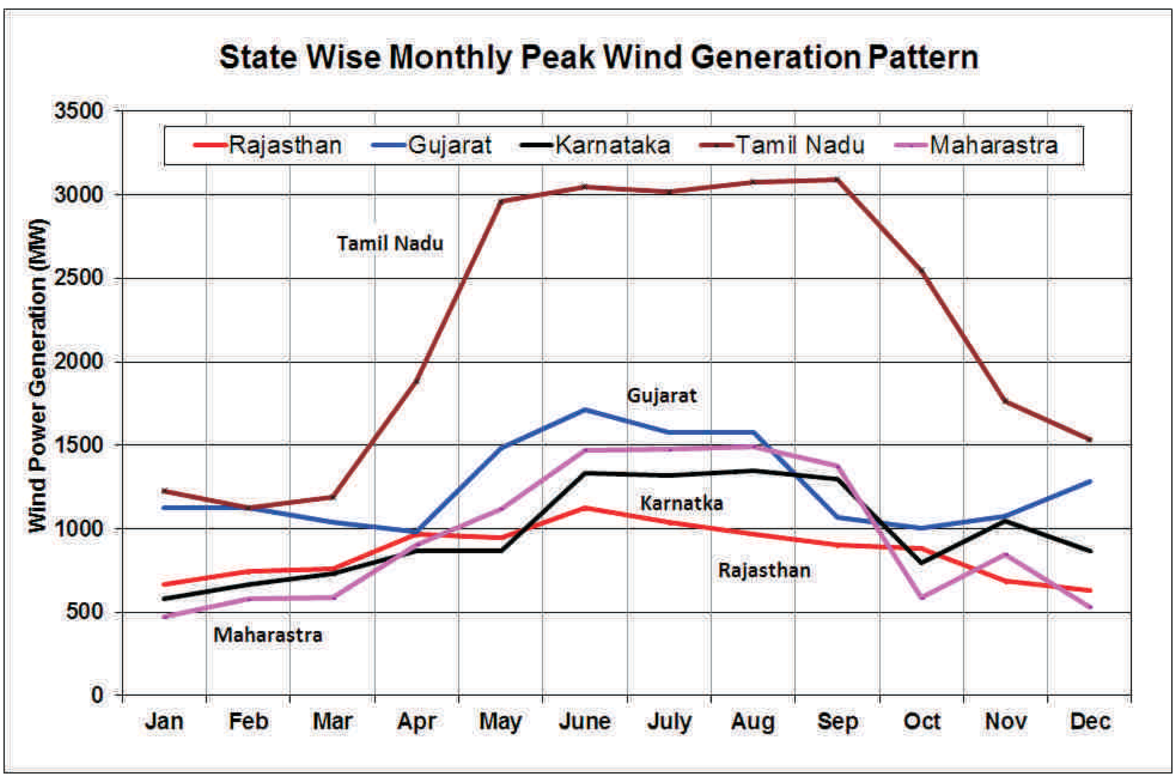

Figure 3-3 : State wise peak of annual wind generation pattern for RE rich States-2011(Source-Respective SLDC)

A typical day variation of wind generation pattern in each month of a year, for various RE rich states viz. Tamil Nadu, Karnataka, Gujarat, Maharashtra and Rajasthan are shown at Figure 3.4 to Figure 3.8

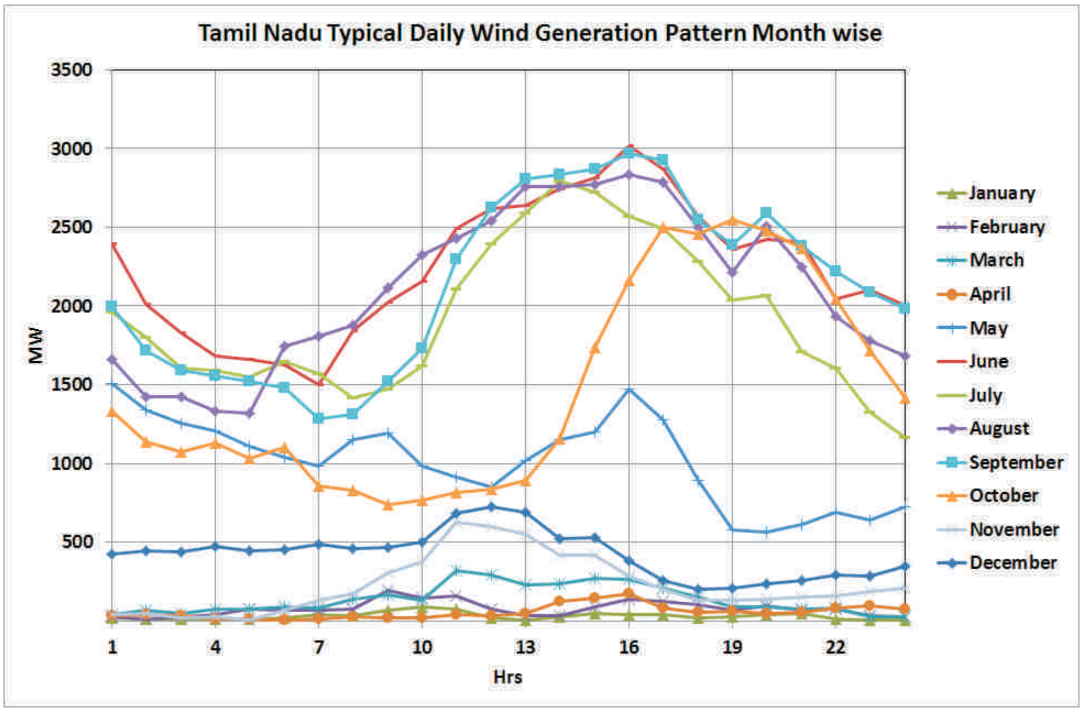

Figure 3-4 : Tamil Nadu typical daily Wind Generation Pattern Month wise (Source-TAN SLDC)

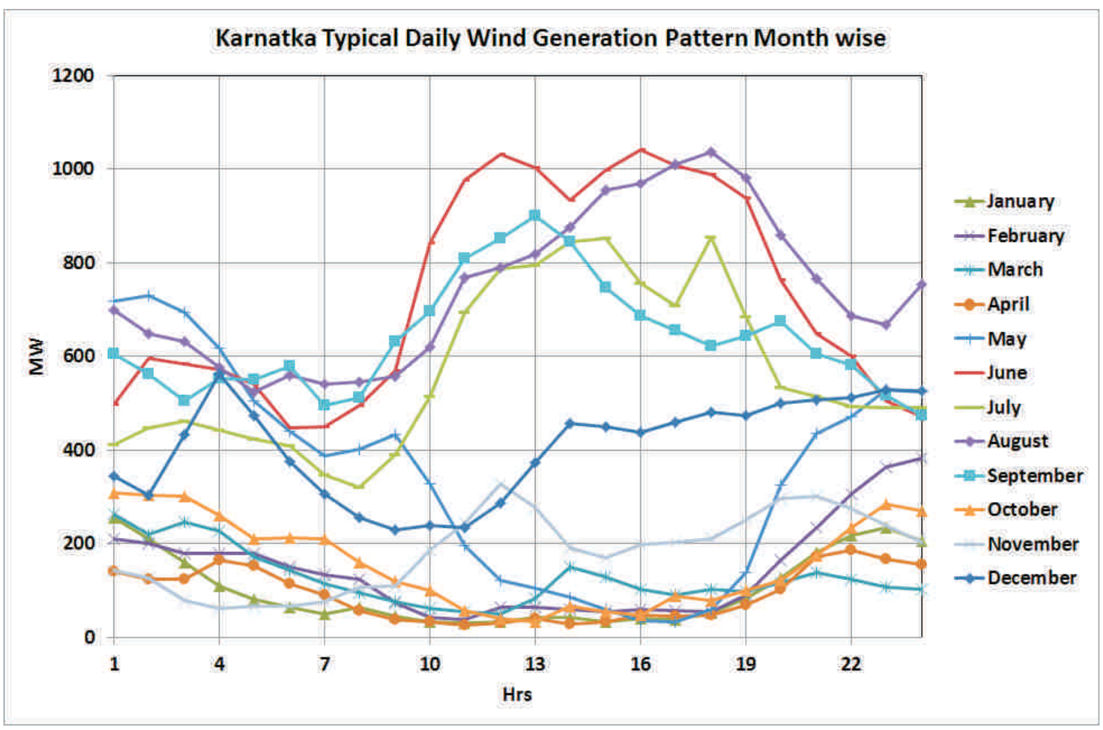

Figure 3-5 : Karnataka typical daily Wind Generation Pattern Month wise (Source-KN SLDC)

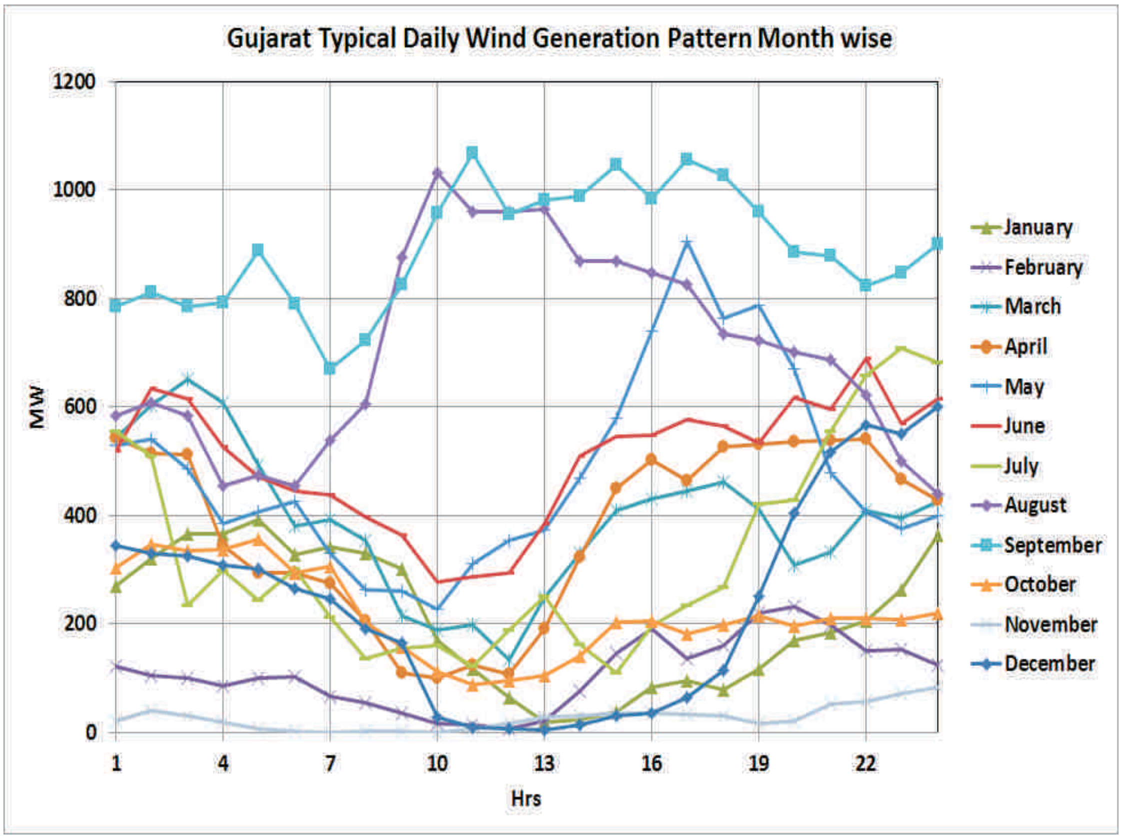

Figure 3-6: Gujarat typical daily Wind Generation Pattern Month wise (Source-GTECO/Guj SLDC)

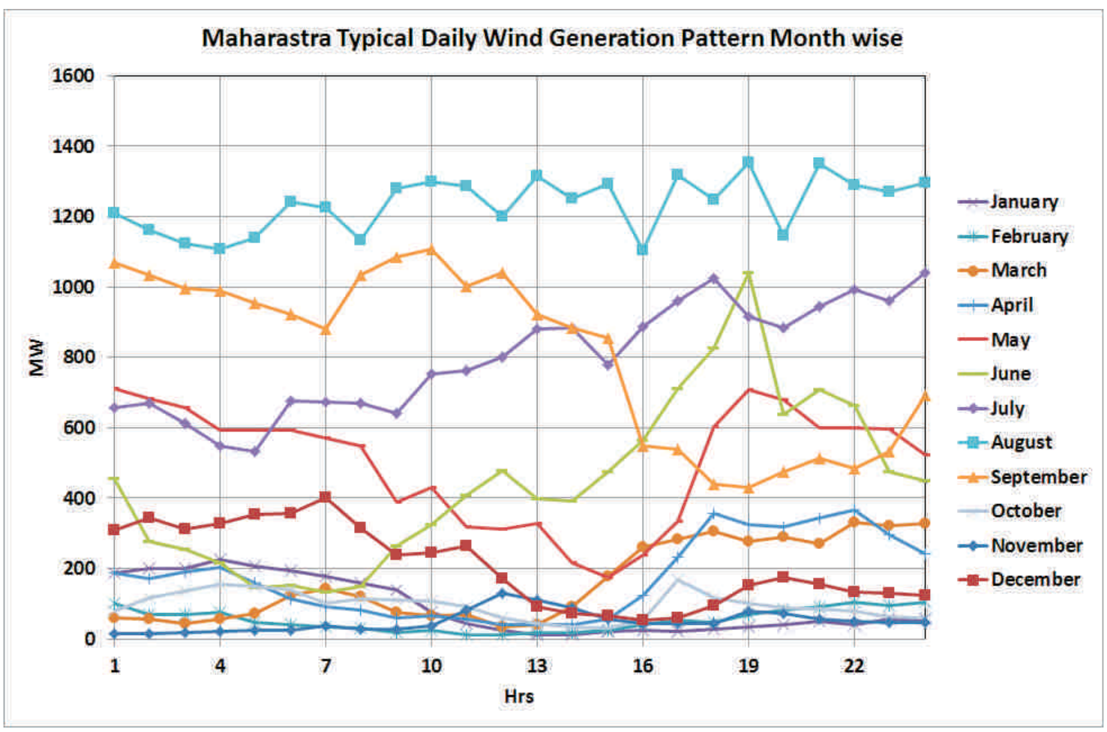

Figure 3-7: Maharashtra typical daily Wind Generation Pattern Month wise. (Source-Maha SLDC)

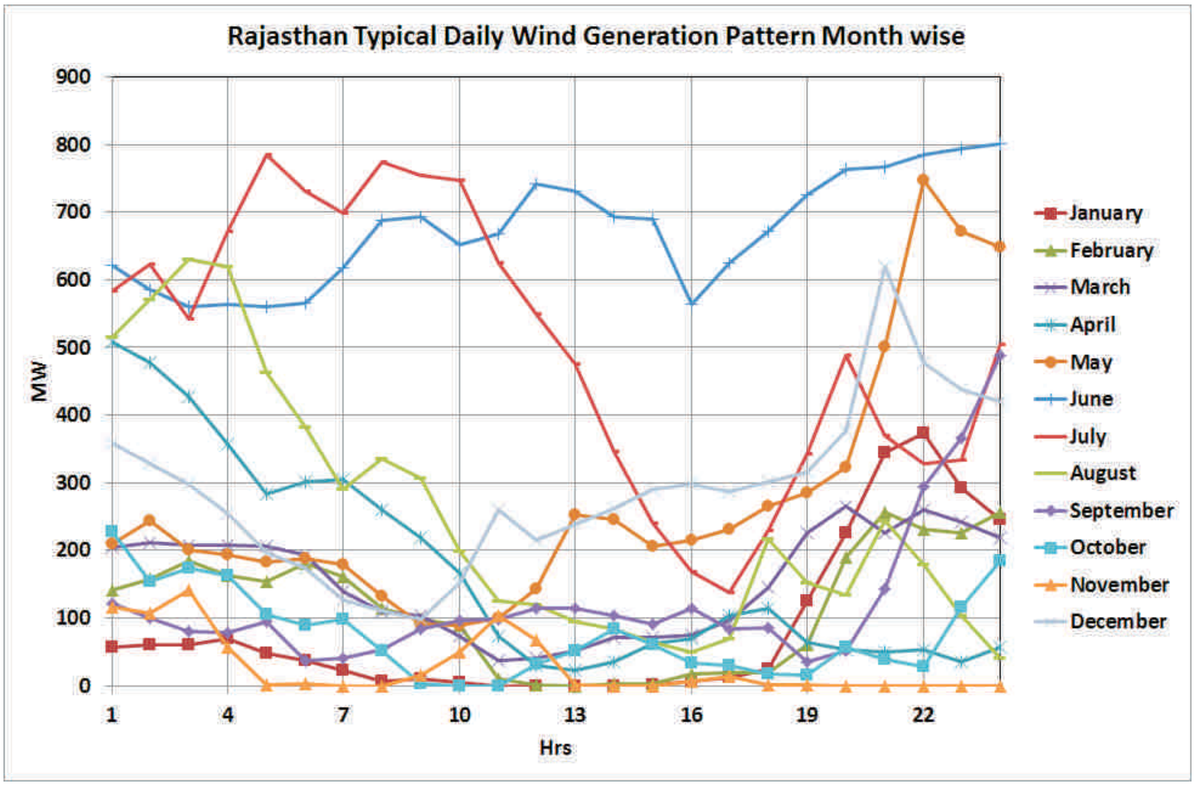

Figure 3-8 : Rajasthan typical daily Wind Generation Pattern Month wise (Source-Raj SLDC)

From these patterns it can be inferred that wind generation gradually achieves its peak from 11.00 to 16.00 hrs. Maharashtra has almost flat wind generation pattern throughout the day with some minor variation. However wind generation trend of Rajasthan is opposite to that of Tamil Nadu, Karnataka and Gujarat. In Rajasthan, wind generation peaks out in night staring from 18.00 hrs.

Annual profile of wind generation pattern indicates that maximum wind generation in these wind rich states occurs during the monsoon season from May to September.

3.2 Seasonal/Daily demand pattern

Based on the information shared by the RLDC and NLDC, annual pattern of electricity demand for different regions have been established and analyzed.

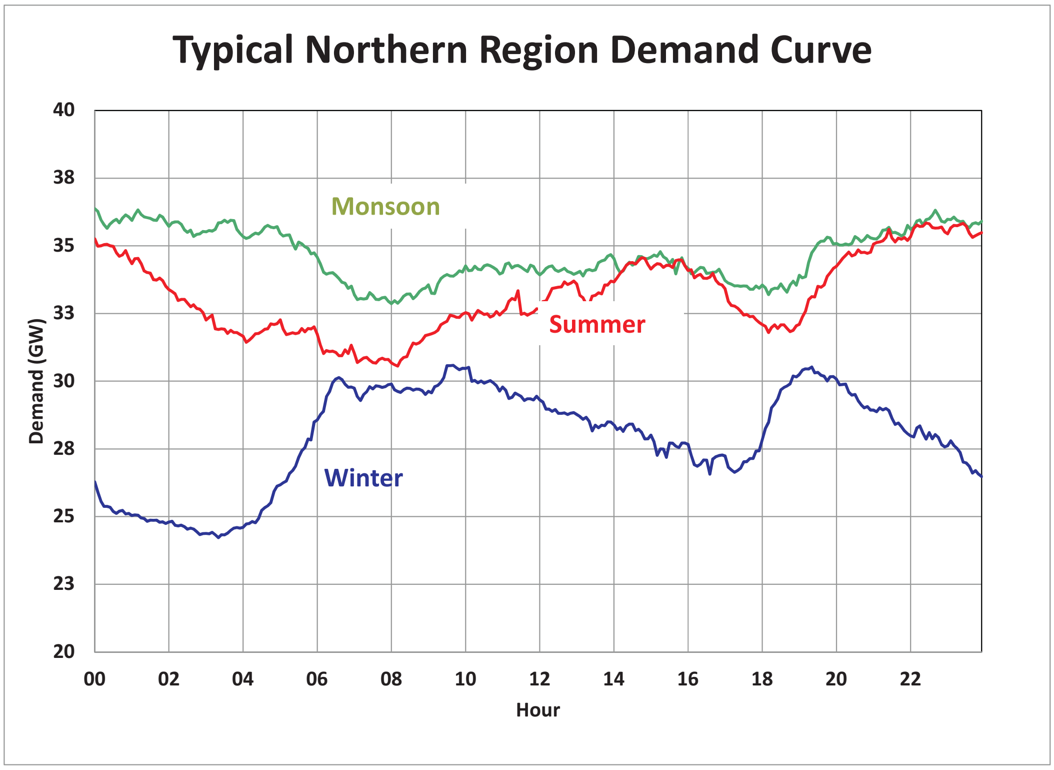

Figure 3-9: Typical daily demand curve of Northern Region (Source-POSOCO)

Annual pattern of electricity demand for different regions indicates that northern region witness maximum electricity demand during monsoon period i.e. from July to September. Refer Fig 3.9. High demand in northern region during monsoon/ summer period is mainly because of agricultural (Paddy season–season for sowing Kharif crop) and weather beating loads in the form of air-conditioner and cooler.

On the other hand, Southern and Western region witness maximum demand during January to March. Typical load curves for summer, winter and monsoon period for southern & western regions are shown in Fig-3.10 and Fig -3.11

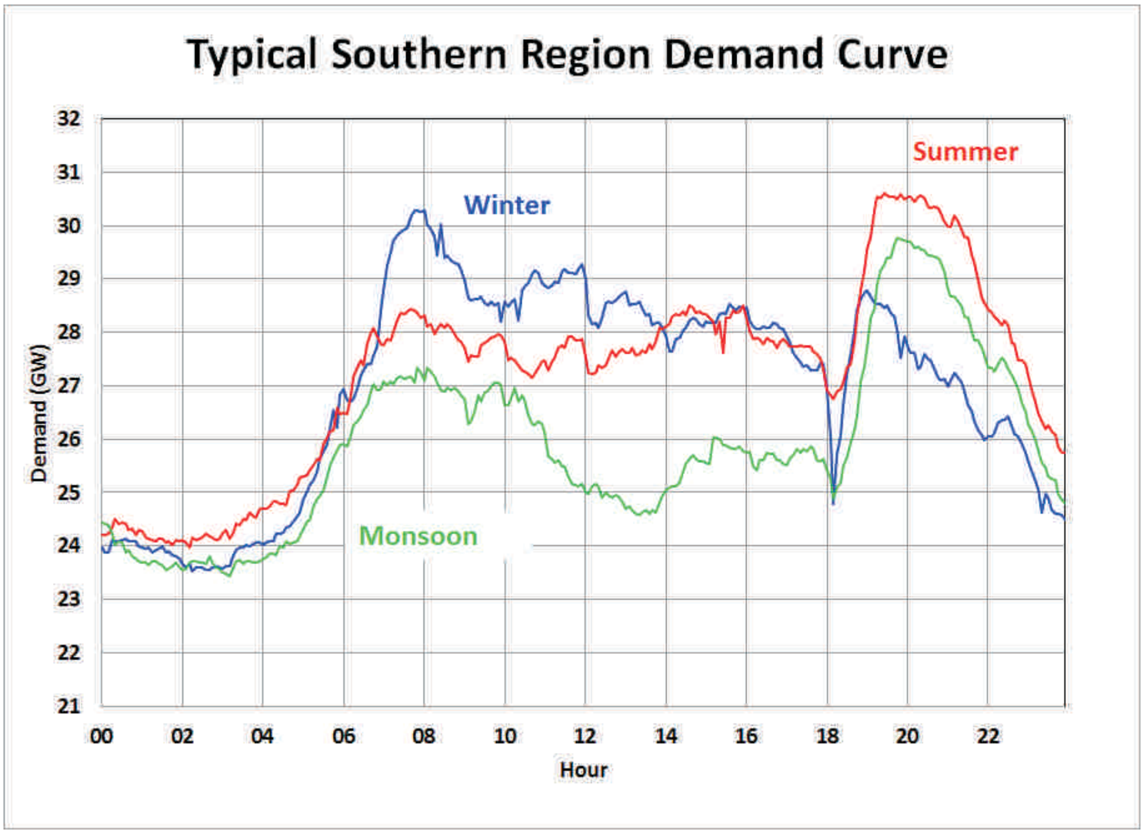

Figure 3-10: Typical daily demand curve of Southern region (Source-POSOCO)

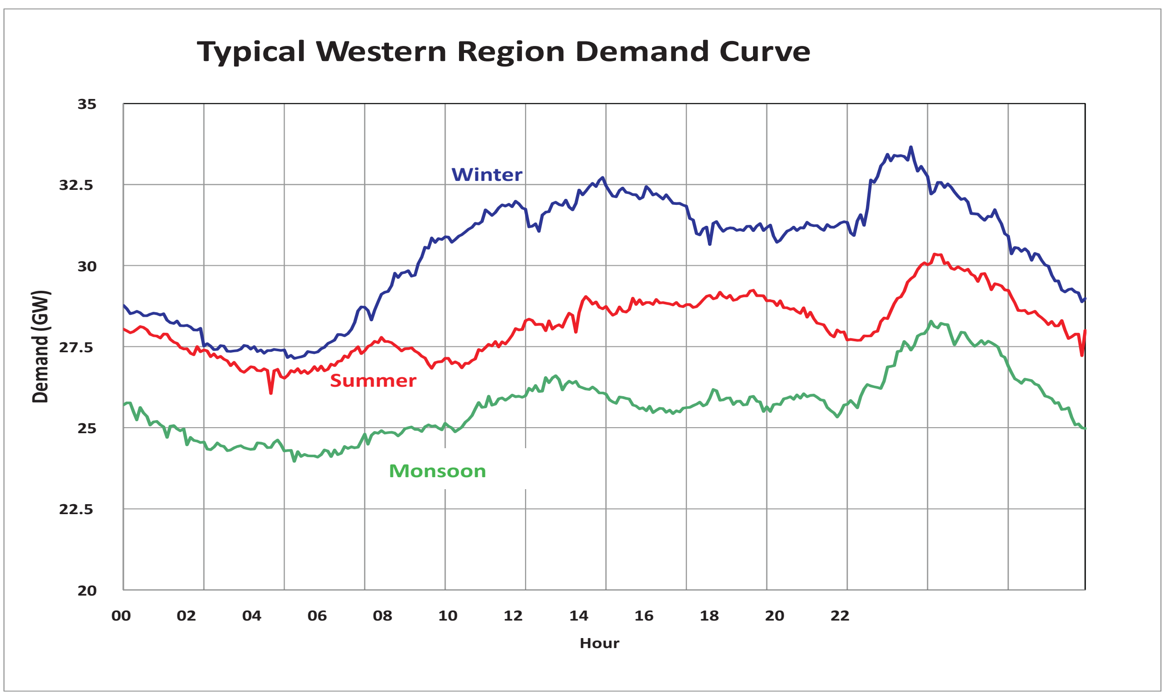

Figure 3-11: Typical daily demand curve of Western Region (Source-POSOCO)

Typical daily variation in demand in the wind rich states viz. Tamil Nadu, Karnataka, A.P, Gujarat, Maharashtra and Rajasthan during January, April, July and October are shown Fig-3.12 to Fig-3.17

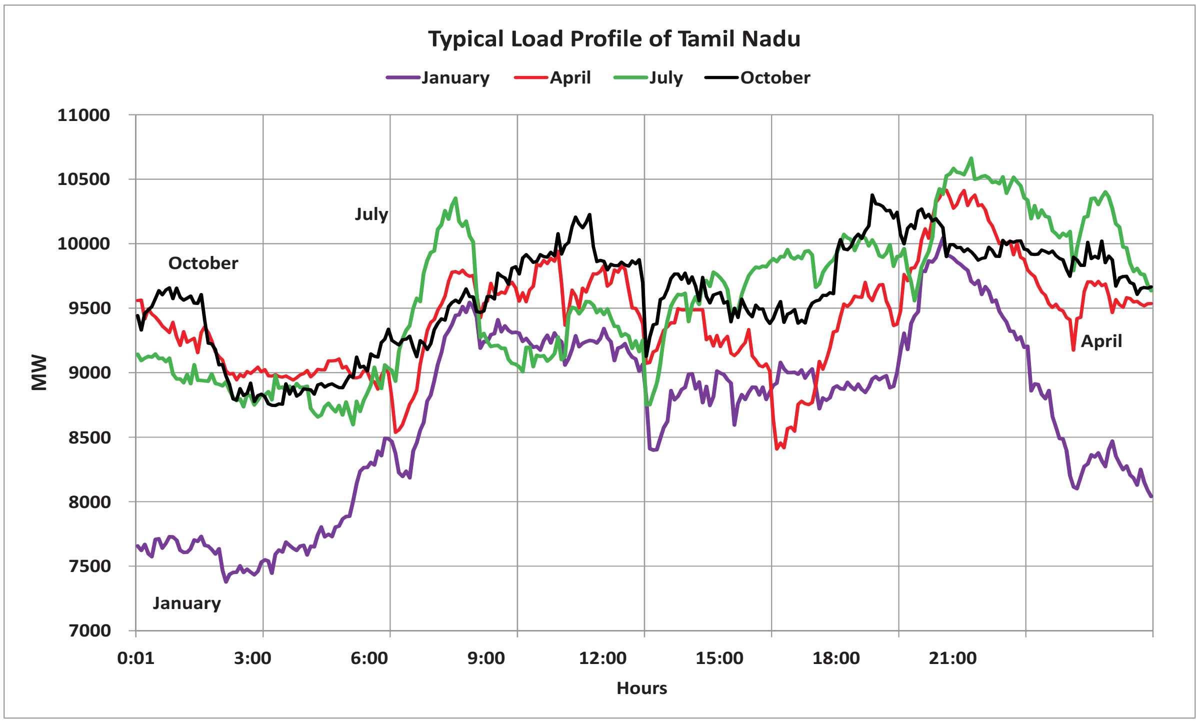

Figure 3-12: Typical daily demand curve of Tamil Nadu (Source-POSOCO)

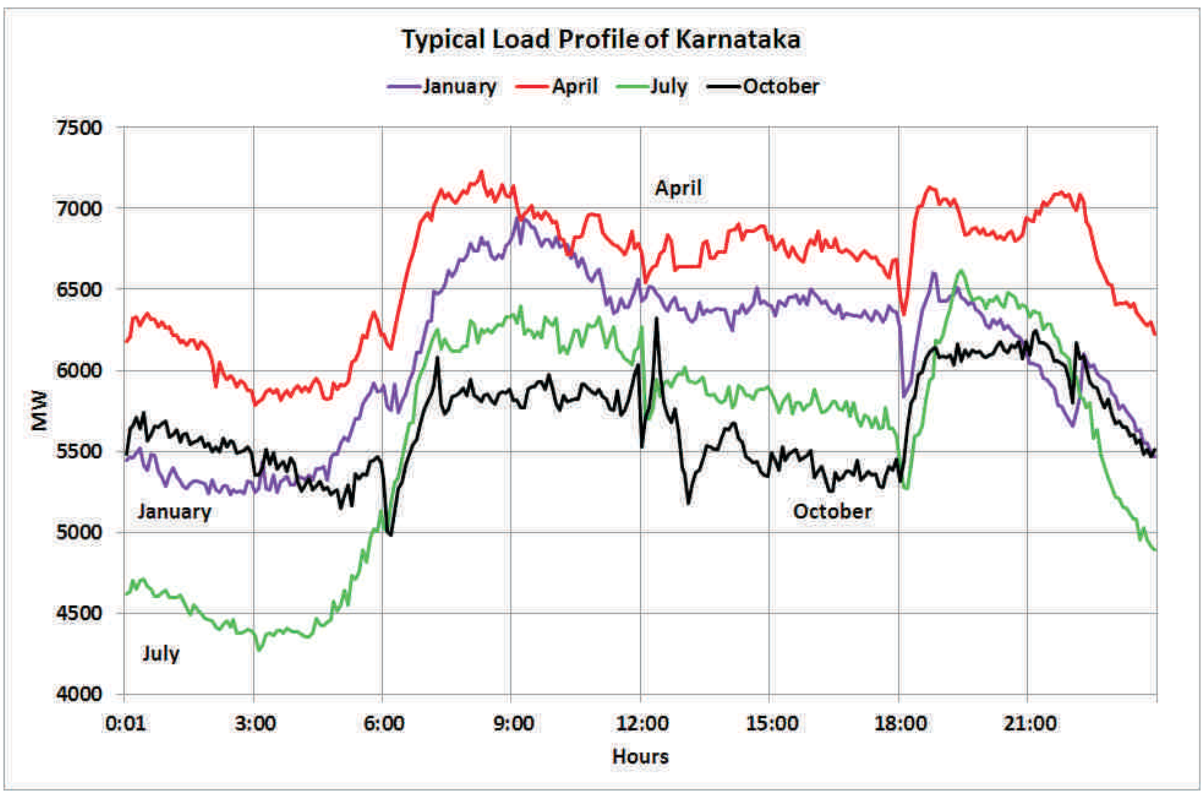

Figure 3-13: Typical daily demand curve of Karnataka (Source-POSOCO)

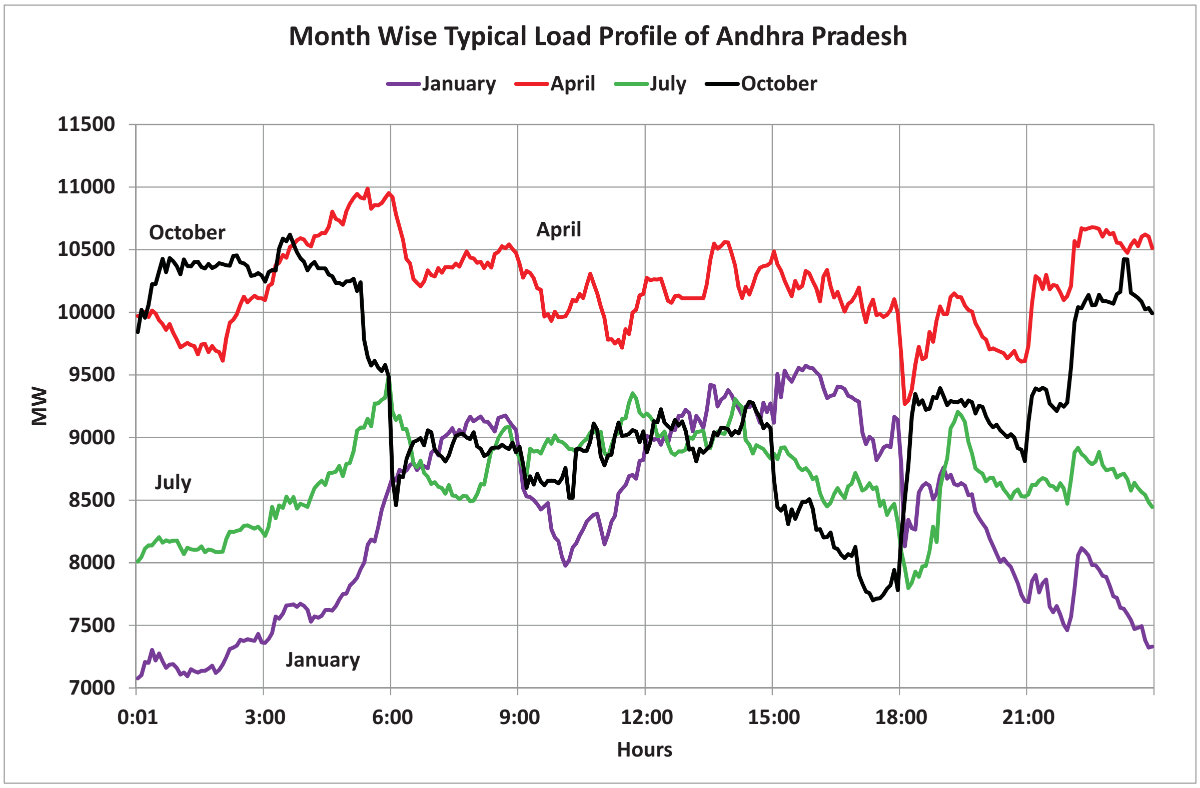

Figure 3-14: Typical daily demand curve of Andhra Pradesh (Source-POSOCO)

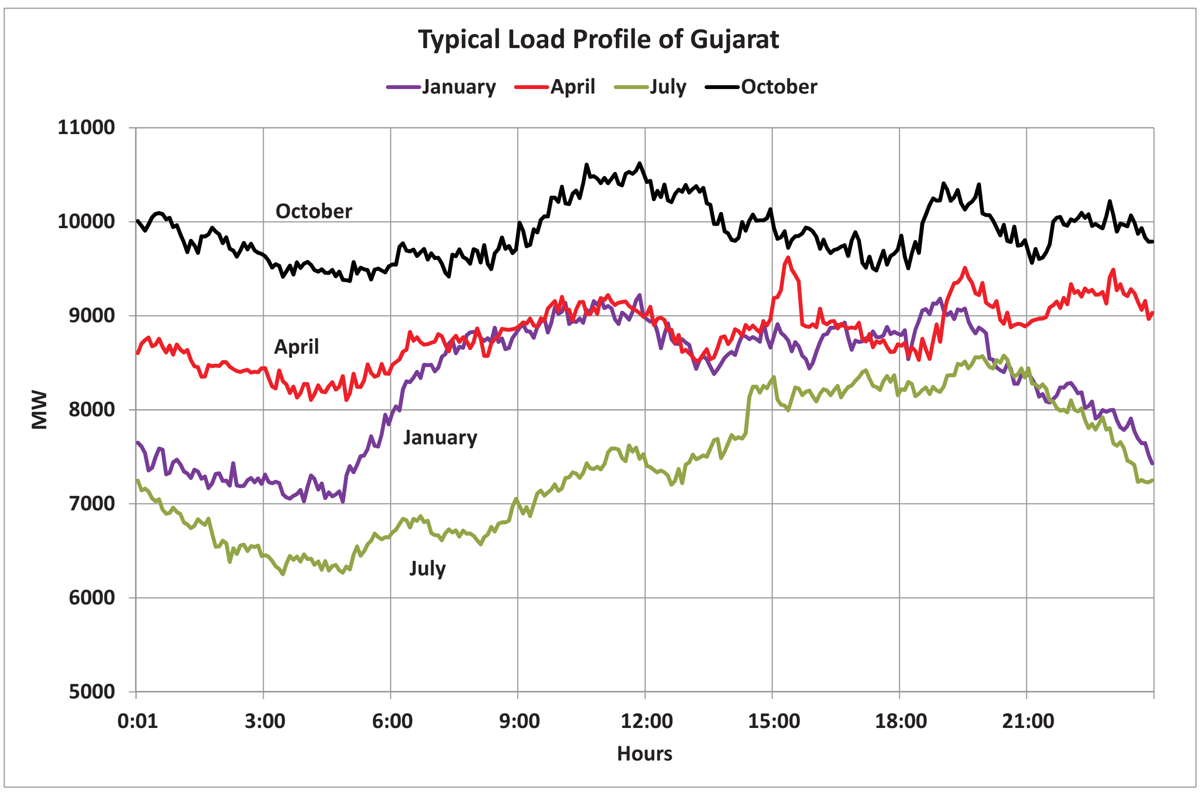

Figure 3-15: Typical daily demand curve of Gujarat (Source-POSOCO)

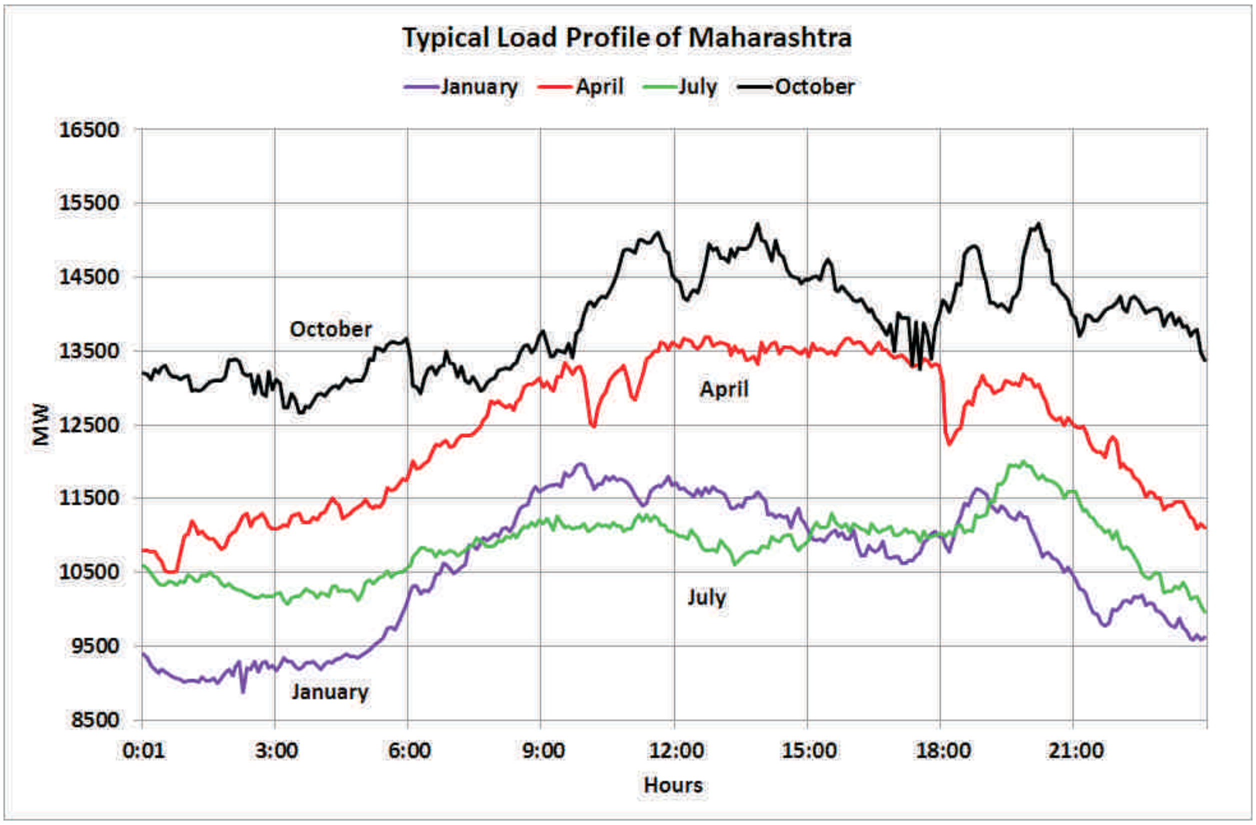

Figure 3-16 Typical daily demand curve of Maharashtra (Source-POSOCO)

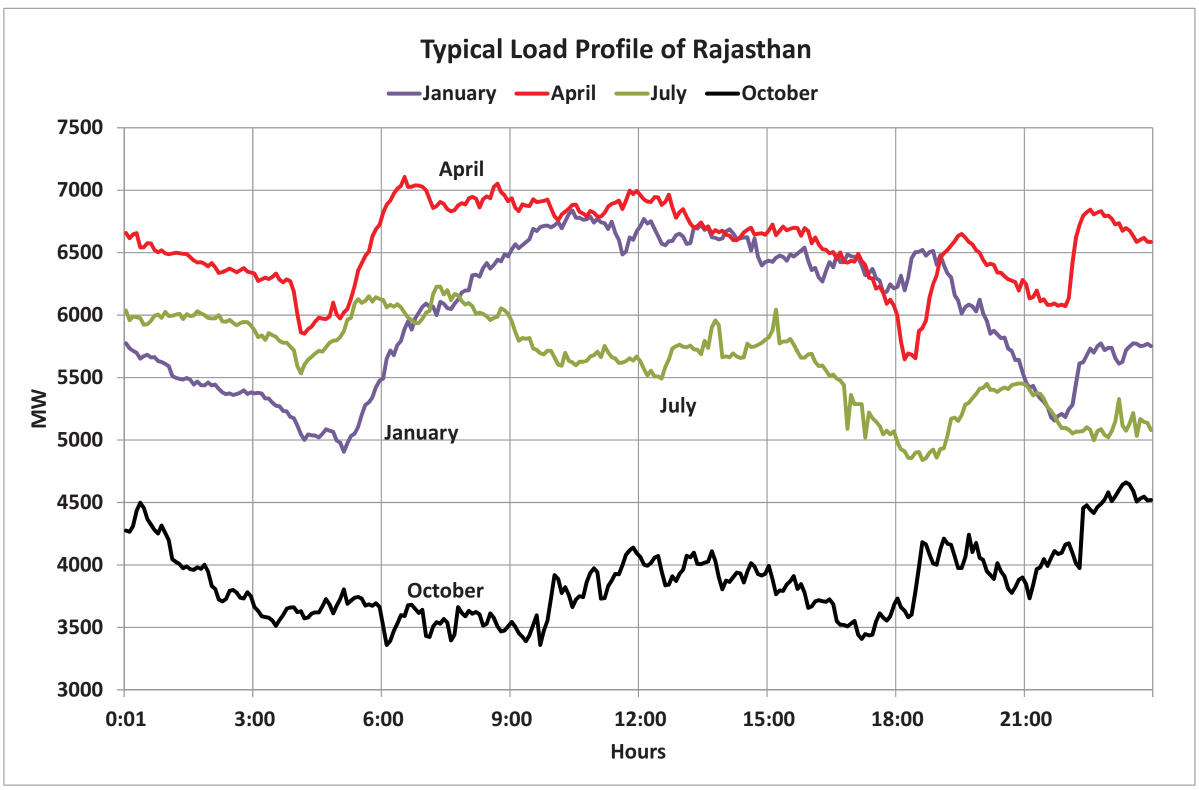

Figure 3-17: Typical daily demand curve of Rajasthan (Source-POSOCO)

Looking at the wind generation pattern and demand profiles of above mentioned wind rich states, it can be observed that during evening peak hours 19.00 hrs to 2000 hr when evening loads are picking up wind generation falls except for the Maharashtra where it remains almost flat and Rajasthan where wind starts to ramp up.

Overall reduction in wind generation during evening peak hours adds to the problem of peak load management that requires additional flexible generation to be added up for proper load generation balance. Such issues in wind generation add to the problem of reactive power management (voltage control) also. However wind being extremely variable in nature, scenario may change over any period of time.

3.3 Intermittency & Variability in Wind generation

Electricity generation from WTG depends on wind speed, direction etc. Due to variable / uncertain nature of above parameters, electricity generation from wind power plant also become uncertain i.e, intermittent and variable. Typical daily variation in wind power generation over a month (August'11) in Rajasthan has been shown at Fig 3.18 below

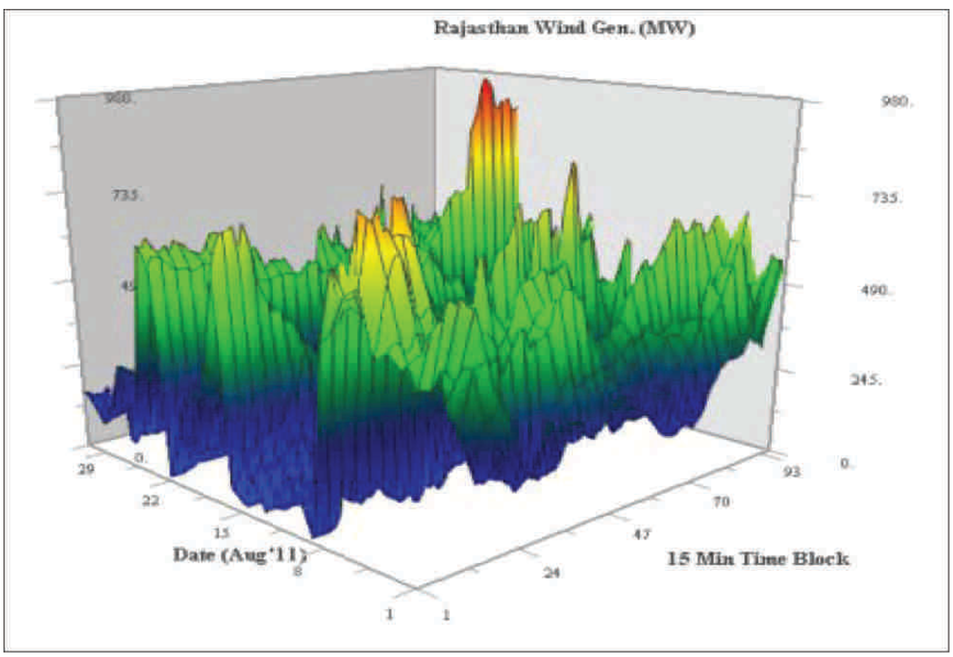

Figure 3-18: Daily Variation in Rajasthan Wind Generation (Source-Raj SLDC)

This shows that, output of WTG varies substantially in a day. However, the ramping up/down time of wind generation is generally 3 to 4 hours.

3.4 Present operational features to take care of sudden large variation in Load/generation

Analysis of operation of Indian Grid reveals that following challenges are already being experienced & handled by Grid operators:

- High Ramp rate of load, particularly during the evening peak hours
- Sharp change in load, particularly at the hour boundaries mainly due to agricultural load changes with consequent frequent spikes
- Frequency fluctuations in case of contingencies leading to generation or load loss; poor Frequency Response Characteristics (FRC) of individual sub-systems
- Impact of Wind Generation variability on Host state

Each of the above phenomenons is graphically illustrated in the subsequent sections for analysis.

(i) High Ramp rate of load

Fig 3.19 indicates the All India load curve for a typical day. It could be seen that the ramp rate during evening peak is of the order of 200 MW/minute for nearly sixty (60) to ninety (90) minutes which is catered to mainly by hydro generation. On festival days like Diwali, the ramp rate during evening peak is even higher as seen from Figure 3.20.

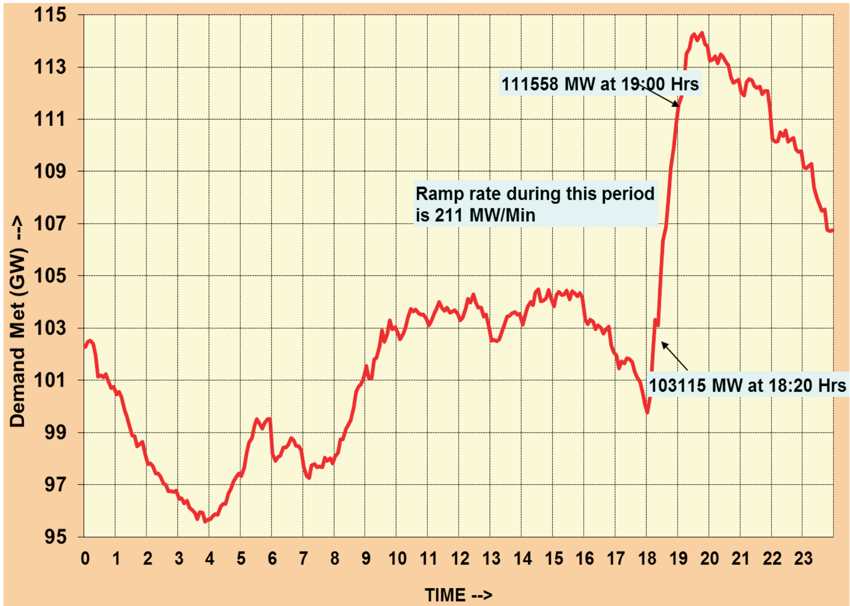

Figure 3-19: Typical All India daily load curve (Source-POSOCO)

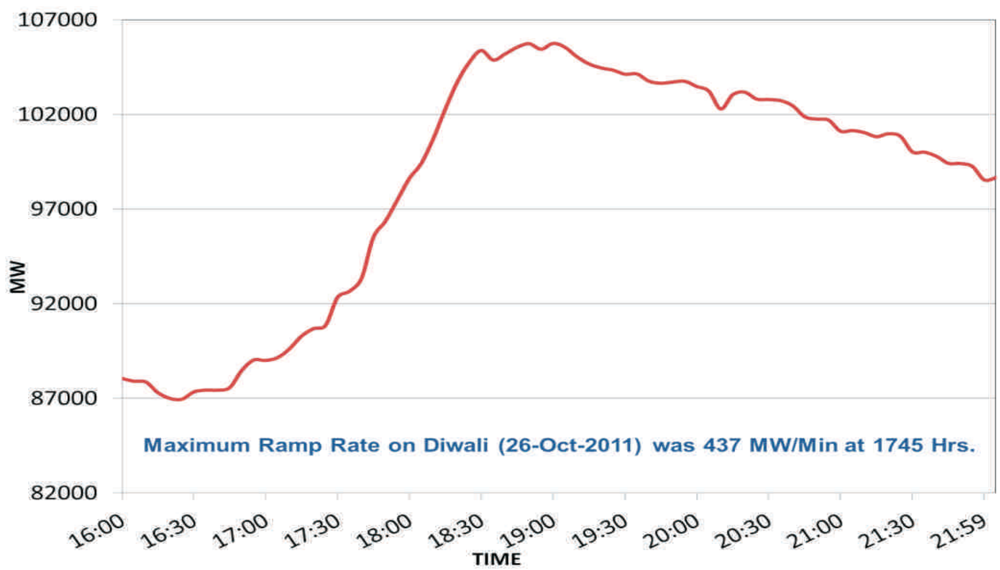

Figure 3-20: Evening peak ramping of All India load on the Diwali festival day (26th Nov 2011) (Source-POSOCO)

(ii) Sharp change in agricultural load

Agriculture loads in the country are provided staggered hours of supply ranging from six hours to fourteen hours per day. The loads are switched on/off zone-wise leading to step changes of 1000 MW or more mainly at the hour boundaries. Efforts at the regional level to stagger the same further spread over thirty minutes has yet to yield desired results as the problem is one of administration over a geographically vast area. Such large step changes in the absence of primary response leads to frequency fluctuation at the hour boundary. This is illustrated graphically in Fig 3.21 below.

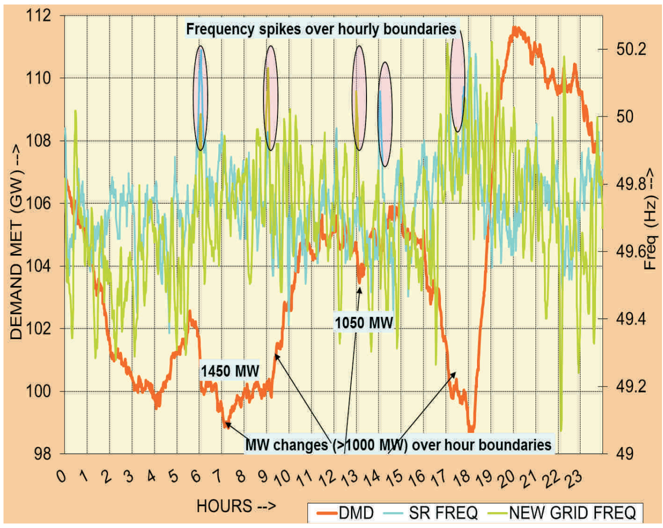

Figure 3-21: Hourly spikes at hour boundaries (Source-POSOCO)

(iii) Frequency Response Characteristics (FRC)

Apart from the above normal variations occurring almost on daily basis, there are situations when a step change in generation and/or load occurs due to contingencies. Under these conditions, the frequency fluctuates sharply and in the absence of primary response, the frequency fluctuations are fairly large. The Frequency Response Characteristics (FRC) of the system for different events in the year 2012 is evaluated as under:

Sno.	Event	NEW Grid FRC (MW/Hz)	SR Grid FRC (MW/Hz)	All India FRC (MW/Hz) when SR is synchronized
1	Talcher Kolar trip on 31.01.2012 @ 2149 hrs	2575	1597	4172
2	Talcher Kolar trip on 29.02.2012 @ 0310 hrs	2125	1373	3498
3	Bhadrawati HVDC Trip on 08.03.2012 @ 1622 hrs	1990	2042	4032
4	Bhadrawati HVDC Trip on 14.03.2012 @ 2122 hrs	1214	1177	2391
5	Talcher-Kolar Bipole Tripping on 22.04.2012 @ 14:32 hrs	2336	1071	3407
6	Talcher-Kolar pole-I Tripping on 01.052012 @ 17:17 hrs	3233	1729	4962

The above cases illustrate that the Indian electricity grids are already being subjected to large fluctuations in frequency on account of load changes as well as the impact of large contingencies. Since the Southern grid is expected to be synchronized with the NEW grid by 2013-14, the geographical diversity available for load and wind generation would help in minimizing the impact on the grid.

It would be observed that after the Southern grid is synchronized and if there is not much primary response from generators, the FRC of the All India grid would be of the order of 4000 MW/Hz. Considering the installation of 660 MW, 800 MW and 1000 MW generating units in the system and increasing penetration of renewable, RLDC have already prayed to the CERC for increased FRC so that frequency fluctuations in case of a large contingency and wind variability are minimal.

(iv) Impact of Wind Generation variation on Host state

An analysis has been carried out to study the impact of variation of wind generation on the host state. This is based on 15-minute average data for wind generation and state drawl for a one week period for the state of Gujarat based on data available at the SLDC website. If wind alone is responsible for a state's increase or decrease in net drawl from the grid then in case wind generation within a state were to go up by 100 MW then the state's drawlfrom the grid should come down by 100 MW if other things remain equal. This assumption would be true for smaller time periods of fifteen (15) minutes.

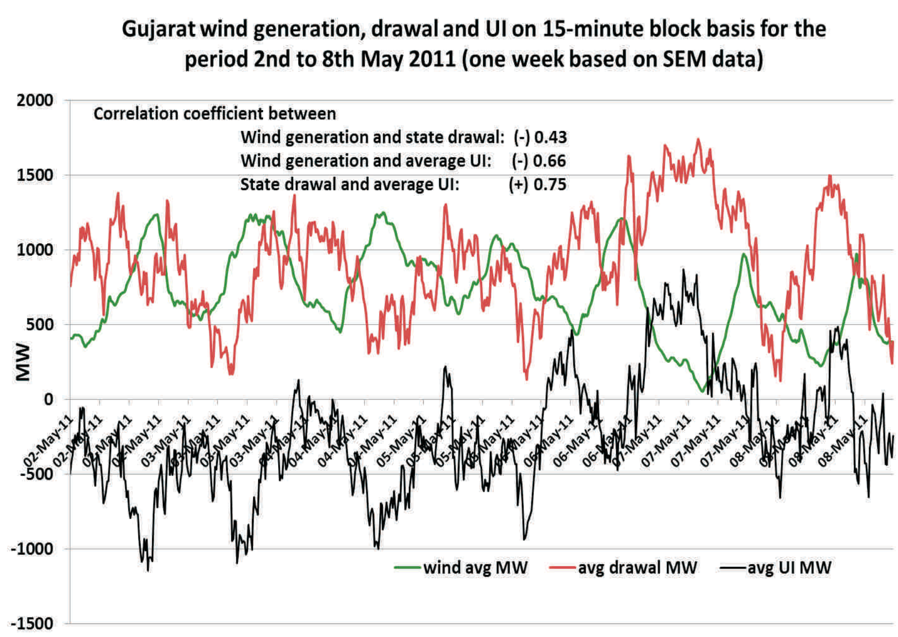

Figure 3-22: Correlation between Wind Generation, Drawl & UI of Gujarat (Source-POSOCO)

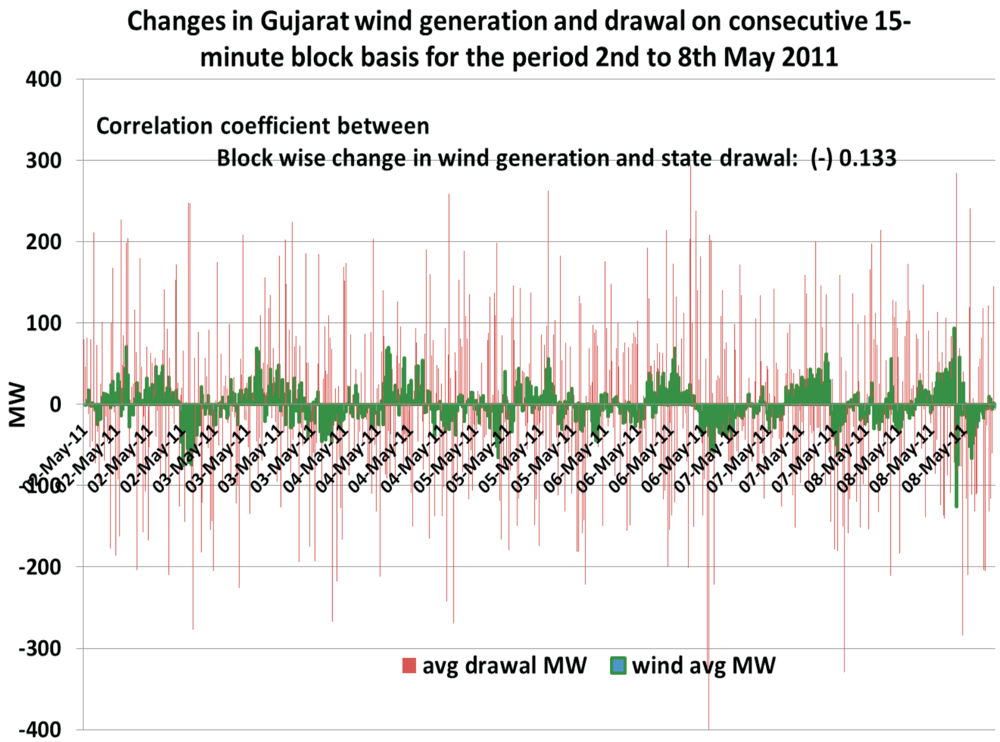

Figure 3-23: Correlation between Wind Generations, Drawl & UI of Gujarat (Source-POSOCO)

If wind alone was responsible for changes in the net drawl of states, then the co-relation co-efficient between change in drawl and change in wind generation between two consecutive time blocks over a large time horizon should be close to (-1). However, it is seen from the figure above that it is actually closer to zero when computed over a week (96 x 7 = 672 readings). Similar exercise could be done for a larger time period for different states. The month of May incidentally happens to be a high wind generation period and the variation of wind in the day was of the order of 800 MW. During the lean season, the effect would be much smaller.

For India as a whole, the penetration levels are of the order of less than 4 % in terms of energy which is expected to go up to say 12-13% over the next five years. All the above phenomena noted in real time grid operation indicates that intermittent generation can be handled, provided adequate transmission infrastructure is made available for transfer of power without congestion as well as balancing through conventional resources and/or other solutions are available.

3.5 Management of Intermittency & Variability in Wind generation

Presently, the variability and intermittency of wind energy generation is being addressed by the varying output of hydro plants whereas thermal plants are being operated as meeting the base load. Typical monsoon season daily demand and supply-mix in Southern region and all India scenarios in this regards are shown at Fig 3.24 and 3.25.

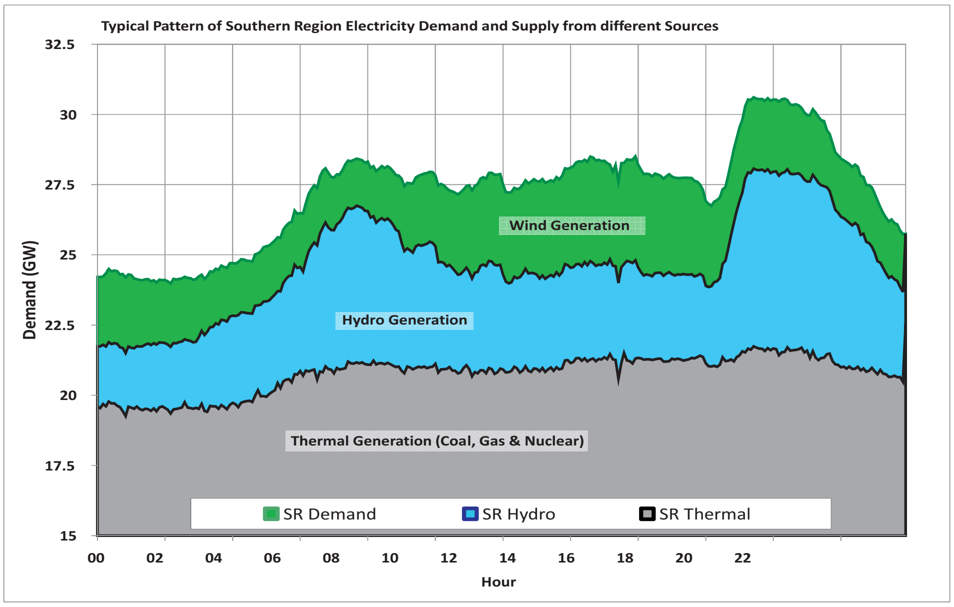

Figure 3-24: Typical demand profile and supply-mix in Southern region (July 2011)

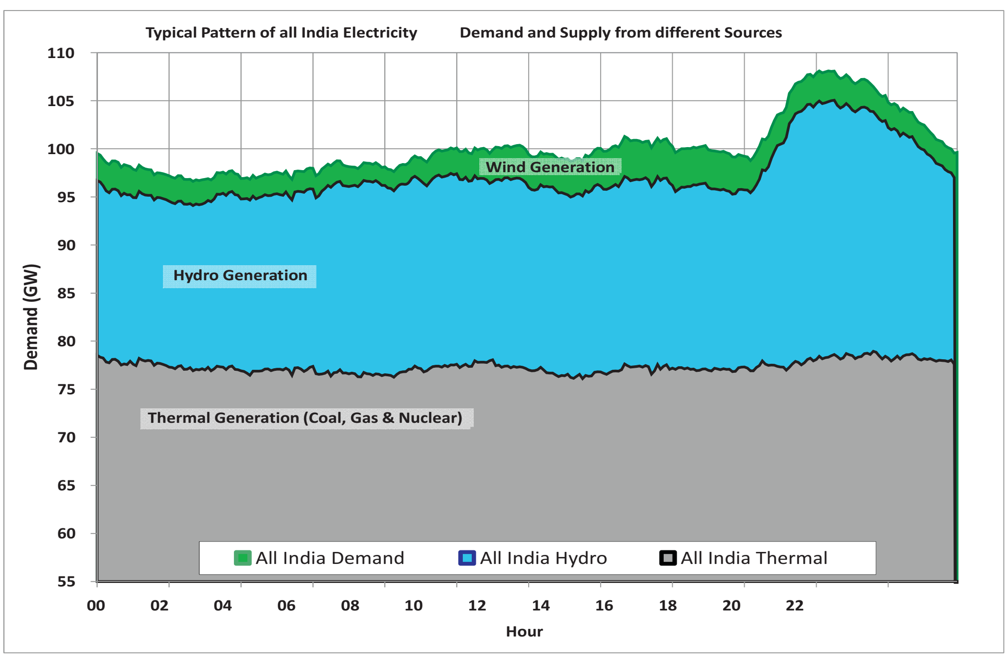

Figure 3-25: Typical demand profile and supply-mix on all India basis (July 2011)

From the all India load and generation pattern of monsoon season, it can be observed that during 2011 monsoon season, evening peak hour demand picks up at the rate of about 75 to 100 MW per minute and during this period, wind generation drops by 5 to 10 MW per minute. This additional demand in the system is mainly supplied through hydro plants.

From the all India Demand & Hydro generation pattern, hydro generation following the demand can be seen in the Fig 3-26 & 3-27.

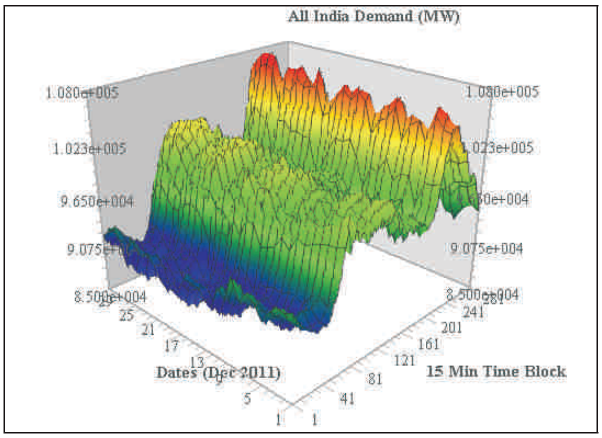

Figure 3-26

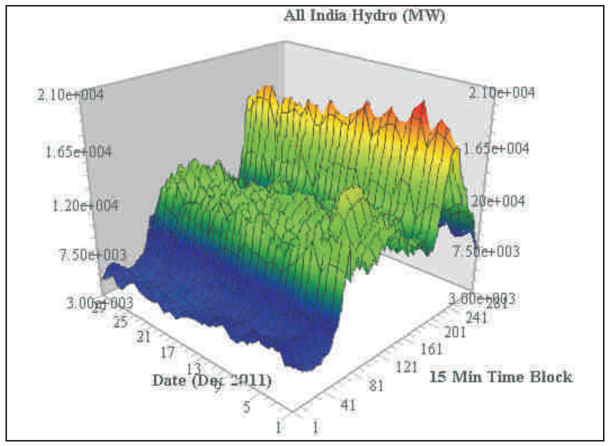

Figure 3-27

In the wind rich southern region, it has been observed that during other than peak period, to allow the dispatch of wind generation, base load thermal generations were also backed down (Refer Fig 3.24). With further increase in penetration level of RE generation, such problem of surplus generation is likely to aggravate during low demand period when wind generation is high.

3.6 Daily generation pattern from solar plants

At present, solar generation in India is dominated mainly in Gujarat. In the past one year, installed capacity of solar generation has grown substantially. A typical hourly Solar generation pattern in the month of Jan 2012 is shown at Fig 3.28. From the pattern it can be inferred that, solar generation follows, relatively a certain pattern with high generation during the day time and almost nil generation in the night, early morning and evening hours.

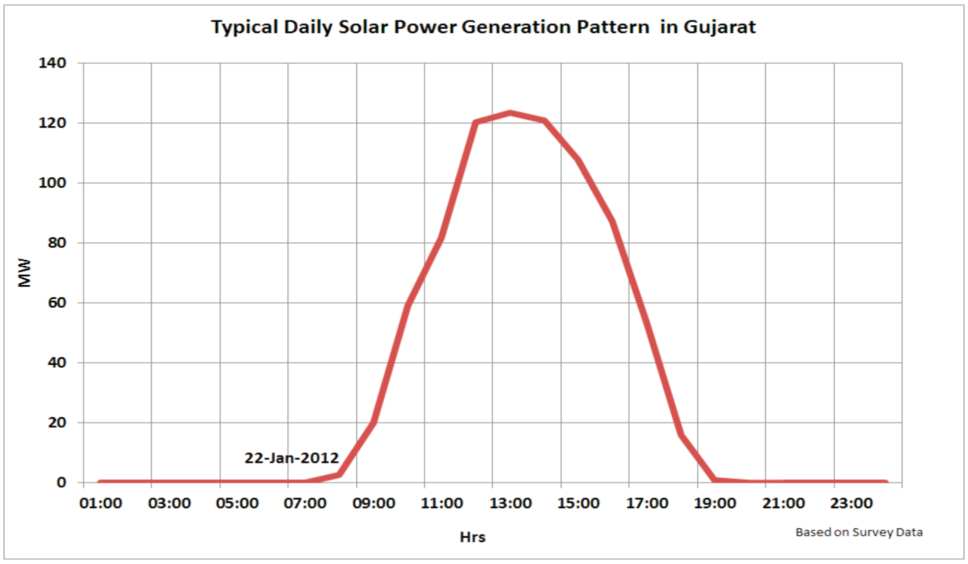

Figure 3-28: Typical daily solar generation pattern in Gujarat (Source-GETCO/Guj SLDC)

However, in the condition of cloud cover or rain, generation from solar plant also become intermittent & variable. A typical day plot of Charanka Solar generation in Gujarat with Cloud cover and Cloud Cover along with Rain is shown at Fig 3.29.

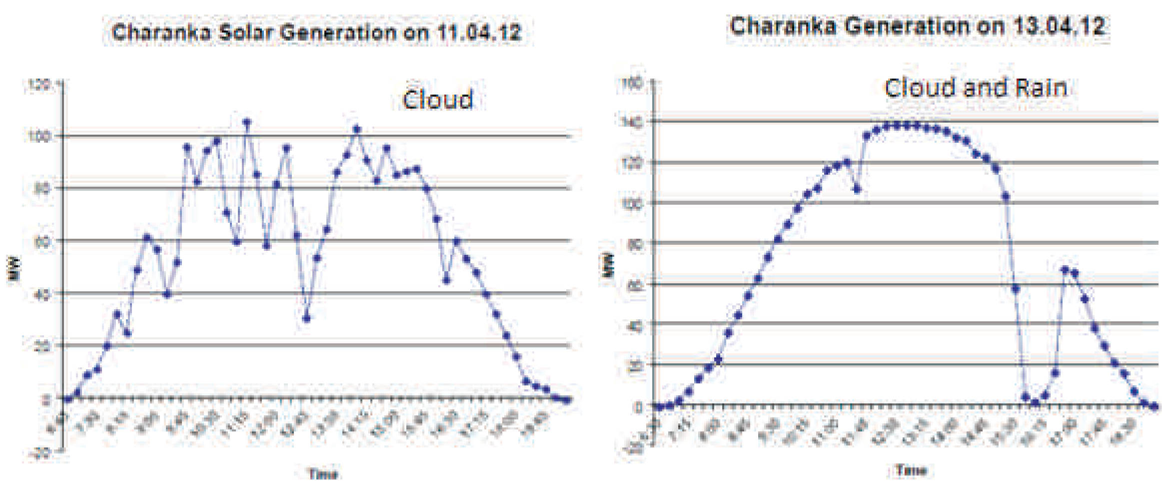

Figure 3-29: A Typical day solar generation pattern in Gujarat (Source-GETCO Presentation)

3.7 Wind and Solar Generation Pattern of a Day

Electricity generation from wind sources is intermittent and variable in nature. Maximum wind generation occurs in monsoon season. On daily basis, generally, maximum wind generation happens during 12.00 to 15.00 hrs in most of the wind potential rich States. In Rajasthan this occurs during night time after 18.00 hr. Further, maximum generation occurs during demand other than peak level.

Typical availability factor of wind generation during other than peak demand period (i.e. maximum RE generation) is in the range of 60-70% of capacity, whereas during peak demand period it is about 20-30%.

Generation from Solar plant is relatively certain and maximum output occurs during 12.00hr to 15.00 hr. with availability factor of about 70-80%. Output becomes zero during 19.00 hr to 06.00 hrA typical day variation of wind and solar generation in Gujarat is depicted at Fig. 3.30.

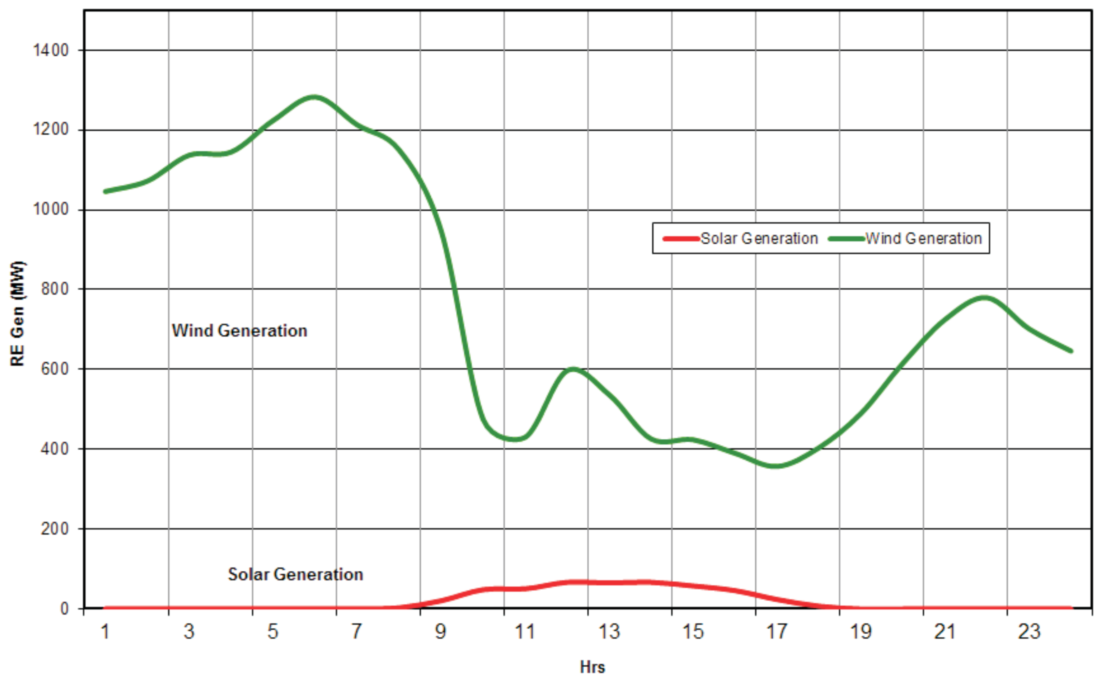

Figure 3-30: Typical daily wind and solar generation pattern in Gujarat-Dec'11 (Source-GETCO/Guj SLDC)

Scenarios considered for identification of transmission requirement has been described in the next chapter. All the assumptions and system study methodologies are also presented there.

Chapter-4

Study Methodology & Assumptions

4.1 Grid Integration of Renewable Energy sources

Some of the States have abundant renewable energy resources, while others are deficit. In case of large scale renewable generation, it is not possible to absorb the energy locally, particularly during other than peak hour condition. Transmission system is required to be planned for integrating renewable generation with the state grid as well as with the inter-state grid. Integrated planning approach would ensure that renewable generation does not have to be backed down during scenario other than peak demand period and local load centres are provided with uninterrupted supply even when renewable generation is not available.

The transmission system for Renewable Energy Sources (RES) are not stand alone schemes and require to be integrated with State grid and/or regional/national grid depending upon quantum of power to be transmitted. This integration provides reliability of transmission and power supply to the whole system. Owing to variable nature of RES energy, it requires support from the grid.

4.2 Approach of the Study

On advice of FOR/MNRE, POWERGRID visited the State Nodal Agencies (SNAs) and State transmission utilities (STUs) of renewable rich states for collection of information of envisaged renewable capacity addition by 2016-17. Based on the series of discussions held between POWERGRID and SNA/STUs, SNA/STUs have provided pocket wise envisaged capacity addition by Renewable sources coming up in 12th plan and existing RE capacity. Some of the STUs also provided the details of transmission connectivity planned for evacuation of power from RE generation pockets planned in next 2-3 years. Information collected from respective SNA/STU is enclosed at Appendix-1. Data was informed to MNRE/FOR/CEA for their observation. CERC provided details of Renewable Purchase Obligation of states for 12th plan period. Further power demand for 12th plan period has been taken from available draft 18th Electric Power Survey (EPS) of CEA. Based on the above parameters, studies for evolution of transmission system for Renewable Generation have been carried out.

4.3 Scenario and Dispatch of Renewable Generations

In order to identify transmission requirement for power transfer from Renewable energy sources mainly wind and solar, maximized renewable dispatch scenarios has been considered. It has been observed that generally high wind generation is encountered at the time of demand other than peak period. However, in Rajasthan wind generation pattern is complementary with reference to other wind rich States i.e; Rajasthan encounters maximum wind when others do not. However, wind being extremely variable this again cannot be concluded as a fact, however, this can be assumed as a general behavior.

Accordingly studies have been carried out for demand other than peak condition with high wind/solar generation scenario. However, sensitivity studies have been carried out for low wind/solar with peak demand scenario.

For study in other than peak demand scenarios, demand has been considered as 75% of the peak demand for various States except for the States of Northern region where it is considered as 90% of the peak demand(based on past demand profile). Load curve of Northern region reveals that in monsoon season, when the wind generation is maximum, the region has a typical flat load profile over the day due to its agricultural load. Further as per the past trends of maximum simultaneous injection at a particular time, dispatch generation in other than peak demand scenario for wind is considered as 70%, Solar as 80% and SHP as 70%. However, as Rajasthan has got complementary wind pattern with respect to other wind rich states, its wind dispatch is considered as 30% whereas solar at 80% in above scenario.

In peak demand & low RE generation scenario, dispatch for wind is considered as 30%, Solar as 10% and SHP as 70%. However, wind dispatch in Rajasthan is considered as 70% and solar as 10% during above scenario.

4.3.1 Load-Generation scenario along with RPO targets

From All India load generation Scenario, it has been observed that various states have different combination of renewable generation, Renewable Purchase Obligation (RPO) targets as well as their net surplus/deficit scenarios. Following strategy has been adopted while formulating the load-generation scenarios for study purpose. RE generation is considered as "must run" type and it is assumed that RPO targets shall be fulfilled by the respective States. A detailed exercise has been done to evaluate RE generation surplus/deficit situation based on proposed RPO requirement and RE capacity addition programme by 2016-17 as well as RE dispatch (wind & solar) in other than peak demand scenario. Details of above exercise are given at **Annexure-1**. Following cases have emerged:

Case-A: State overall surplus (conventional generation) as well as RPO Surplus

- It is assumed that RPO surplus capacity to be dispatched outside the surplus State. Surplus capacity from conventional sources may be exported to meet other state's deficits but it may be backed down (in case required) only up to the extent of net RPO surplus capacity.

Case-B1: State overall surplus but RE deficit and overall surplus >RPO deficit

Case-B2: State overall surplus but RE deficit and overall surplus <RPO deficit

- In the above two cases, state must import RE capacity atleast to the extent of its RPO targets fulfillment. However, being surplus in conventional generation, state must back down its conventional capacity up to the extent of RE import capacity.

Case-C: State overall deficit as well RPO deficit

- In this case, state must import RE capacity at least to the extent of its RPO targets fulfillment. In case of marginal overall deficit, state must import RE capacity at least to the extent of its RPO fulfillment by backing down conventional generation.

It is to mention that while establishing load generation scenarios for demand other than peak in 2016-17, it has been observed that various states may have overall surplus capacity after considering Renewable generation. Therefore, while finalizing load generation scenario for surplus condition, conventional generation backed down as per merit order dispatch wherein high cost gas based plants are being first to be backed down and then high cost State thermal plants. Secondly, reservoir based hydro plants are also considered to be not dispatched in such scenarios whereas Run-off-the-River plants are dispatched as maximum RE generation being monsoon season.

Further, to simulate worst case scenario, in case of high potential RE complexes, special area dispatches have been considered wherein generation from conventional resources in such pockets are kept at maximum dispatch.

4.3.2 Pooling of RE Generation

States have provided information about existing connectivity as well as connectivity granted at their STU network to future RE projects. For load flow simulation, such connectivity has been established depending upon the availability of network information (up to 220kV level) in load flow simulation cases. However, for future cases i.e. beyond 2014, wherein STU have not finalized the connectivity and STU/SNA provided the pockets of upcoming RE projects, assumptions have been made regarding pooling of such RE projects to nearest 220kV STU substations. In case of large capacity (more than 300-400 MW), pooling has been done at 400kV level also. Therefore, in case of revision in point of connectivity, transmission system shall have to be reviewed near the pooling stations.

4.4 Time Frame

On the advice of MNRE and FOR, study has been carried out for 12th plan period (2016-17). A comprehensive transmission scheme for RE resource rich states has been evolved for 2016-17 time frame. However, scheme can be implemented in phases depending upon the progress of RE capacity addition taking place in different time frames in 12th plan period.

4.5 Demand and Generation

Peak demand of various States of different regions has been considered as per the available draft 18th Electric Power Survey (EPS) Report corresponding to 2016-17 study time frame. In addition, motoring load of pumped-storage hydro plants in Tamil Nadu (400MW), West Bengal (900MW), Uttarakhand (1000MW) and Maharashtra (250 MW) are also considered as load in the respective States over and above the draft 18th EPS peak demand. In the motoring mode a pumped storage plant usually consumes 20 % more power than it produces during generator mode. Projected peak demand in each State by 2016-17 as per draft 18th EPS is given at ***Annexure-1***.

It is assumed that total demand of all the constituent States is being met through State's own generating stations, allocation of power from central sector generating stations, target allocationsfrom private sector generation projects located in that particular region and import from other regions. For the studied time frame, all new generation schemes likely to be commissioned by that time frame have been considered.

4.6 Transmission System

A number of transmission schemes are likely to be implemented by 2016-17 in various regional grids as a part of Inter-State Generating Stations/IPP/Grid strengthening schemes. Eleven (11) High Capacity Transmission Corridors in all the regions are under different stages of implementation. Above transmission schemes have been considered in the study. In addition, transmission system of different regions including STU networks (220kV level and above) which will be available during time frame of the study has been simulated based on the data available with POWERGRID. Some of the future network (400kV & 220kV level) has been considered from the details provided in regional maps of respective STUs.

4.7 Transmission Security Standards

As per CERC (Indian Electricity Grid Code) Regulations, 2010, as a general rule, the EHV grid system shall be capable of withstanding without necessitating load shedding or rescheduling of generation, the following contingencies:

- Outage of 220 kV D/c line or,
- Outage of 400 kV single circuit line or,
- Outage of 765 kV single circuit line or,
- Outage of one pole of HVDC Bi-polar line or
- Outage of an interconnecting transformer

Above security standards have been considered while evolving the transmission schemes for RE power transfer.

System studies results describing the required transmission infrastructure for evacuation of RE generation by the end of 12th five year plan has been presented in the next chapter.

Chapter-5

System Studies and Results

5.1. Studies for Evolution of Transmission system

As discussed earlier, wind/solar generation are available at remote geographical locations which are at a considerable distance from the demand centers. Moreover such distant wind/solar resources don't have sufficient nearby grid capacity for integration of large scale development with the transmission system. State Transmission Utilities (STU) has already planned to strengthen transmission system for integration of renewable capacity addition in next 2-3 years, which has been considered in the present studies. However, SNAs of the RE rich states have given future projection for RE capacity addition by 2016-17 for which pocket wise capacity addition was informed. Considering above, load flow studies have been carried out to evolve Intra-State as well as Inter-State transmission infrastructure for evacuation of Renewable power from eight (8) RE rich states i.e. Tamil Nadu, Karnataka, Andhra Pradesh, Maharashtra, Gujarat, Rajasthan, Himachal Pradesh and Jammu & Kashmir.

State wise details of study results and identified transmission system are elaborated in the following paragraphs.

5.2. RE capacity addition in Southern region

The following high capacity corridors have been planned in Southern Region:

a) High Capacity Corridor associated with ISGS Projects in Nagapattinam / Cuddalore Area of Tamil Nadu have been planned under Tariff based bidding:

- Nagapattinam Pooling Station - Salem - Madhugiri – Narendra – Kolhapur 765 kV Corridor

b) High Capacity Corridor associated with Krishnapatnam IPPs in Andhra Pradesh :

- Nellore Pooling station – Kurnool (New) – Raichur – Sholapur 765 kV Corridor

c) High Capacity Corridors associated with Vemagiri IPPs in Andhra Pradesh :

- Vemagiri Pooling Station – Khammam – Hyderabad – Wardha – Jabalpur 765 kV Corridor

d) High Capacity Corridor in Srikakulam area :

- Srikakulam – Angul – Jharsuguda – Dharam Jaigarh 765 kV Corridor

e) High Capcity Corridor in Tuticorin area :

- Tuticorin Pooling Station – Salem – Madhugiri 765 kV Corridor

Thus Southern Region is going to be synchronized with upper grid with the following links:

- Narendra – Kolhapur 765 kV D/c line
- Raichur – Sholapur 765 kV 2xS/c line
- Srikakulam- Angul 765 kV D/c line
- Hyderabad-Wardha 765 kV D/c line

The above High Capacity transmission Corridors have also been considered in the studies.

5.2.1. Study for Renewables in Tamil Nadu

As per the information submitted by the TEDA/TANTRANSCO, following renewable generation capacity addition in Wind & Solar is envisaged by 12th plan period.

Resource	Existing (as on Mar'12)	Future (by 16-17)	Total
Wind	6370	6000	12370
Solar	7	3000	3007
Total	*6377*	*9000*	*15377*

In **Tamil Nadu**, Solar Plants (3000 MW) are envisaged in the districts of Vellore (175 MW), Krishnagiri (125 MW), Villupuram (125 MW), Salem (125 MW), Erode (175 MW), Namakkal (125 MW), Cuddalore (175 MW), Tiruchirapalli (125 MW), Perambalur (106 MW), Ariyalur (106 MW), Madurai (175 MW), Coimbatore (175

MW), Dharampuri (175 MW), Karur (175 MW),Pudukottai (175 MW),Dindigul (106 MW),Sivganga (106 MW), Theni (125 MW), Virudhunagar (106 MW), Ramanathapuram (106 MW), Thoothukudi (125 MW),Tirunelveli (125 MW) & Tiruvannamalai (175 MW) and Wind capacity (12400 MW) are envisaged to be located mainly in the pockets of Kayathar (2600 MW), Udumalpet (2400 MW), Tirunvelli (1400 MW), Vagarai (1100 MW), Tennampatty (1000 MW), Thappagundu (1000 MW), Rasapaliyam (900 MW), Anaikadavu (800 MW) and Kanarpatty (750 MW.

Pocket wise renewable capacity envisaged by 2016-17 in various districts of TN State is enclosed at ***Exhibit B1.***

Based on the approach & assumption discussed in Chapter-4, for study purpose, following Load Generation Scenario is considered for Tamil Nadu by 2016-17:

Sno	**Parameters by 2016-17**	**Other than Peak/High RE (75% of EPS demand)**	**Peak demand/Low RE**
1	Draft 18th EPS Demand (MW)	14246	18994
2	Renewable Generation Dispatch (MW)	11064	4012
3	RPO (MW)	4720	4720
4	RE Surplus/ Deficit (MW) [2-3]	6344	-708
5	Allocation from Conventional generation (State+Central+IPP)	9312	12671

As per estimates, by 2016-17, capacity requirement to meet its projected RPO (15%), by TN, shall be about 4700 MW whereas RE maximum generation (12400 MWx 70% +3000 MWx80%) can be about 11000 MW in off peak hours. With this, TN is projected to be 6300 MW RE surplus which may be utilized in meeting RPO requirement of other RE Deficit States in off peak period.

For the study purpose, for the total existing renewable generation, connectivity of the RE projects has been considered at nearest available 220kV or 132 kV STU stations as indicated by the TANTRANSCO / TEDA. The future wind generation is fed radially to the future 400 kV substations from the 220 kV substations developed by developers of respective wind farms for which pocket wise RE quantum information has been furnished by TANTRANSCO. The connectivity has been considered at nearest 400kV substations/Pooling substations constructed dedicatedly for wind generation.

As indicated earlier, as per approach of the study, load flow has been carried out for two scenarios i.e. High wind/solar with low demand as well as Low wind/solar with high demand. In both the cases, requirement of transmission system arising out of RE injection has been assessed. Further, sensitivity analysis of the identified transmission system strengthening has been also carried out in other scenario. In the past, TANTRANSCO has also submitted proposal for strengthening of transmission network for Renewable energy projects in TN and the same was approved by CEA. Above transmission system has also been considered while carrying out for base case system studies. A detail of such transmission system is enclosed at ***Annexure 2-A***:

➢ **<u>Transmission System as per DPR (Phase – I Scheme approved by CEA)</u>**

- 400kV transmission line : 1500 ckt kms
- 230kV transmission line : 91 ckt kms
- 110kV transmission line : 45 ckt kms
- New 400/230kV S/s : 2 nos.
- New 230/110kV S/s : 1 no.
- 400/230kV Transformation cap. : 1775 MVA
- 230/110kV Transformation cap. : 300 MVA

Estimated Cost: Rs. 2752 Cr

With above approach, load flow results for High wind/solar with low demand as well as Low wind/solar with high demand is enclosed at following ***Annexures.***

Annexure	Details
9.1	Overall load Flow for SR other than Peak Without Strengthening

Annexure	Details
9.1-A	RE transmission study for other than Peak Demand Scenario without Strengthening-**Udumalpet** Area **Tamil Nadu**
9.1-B	RE transmission study for other than Peak Demand Scenario without Strengthening-**Salem** Area **Tamil Nadu**
9.1-C	RE transmission study for other than Peak Demand Scenario without Strengthening-**Thirunelveli** Area **Tamil Nadu**
9.2	Overall load Flow for SR Peak Without Strengthening
9.2-A	RE transmission study for Peak Demand Scenario without Strengthening-**Udumalpet** Area **Tamil Nadu**
9.2-B	RE transmission study for Peak Demand Scenario without Strengthening-**Salem** Area **Tamil Nadu**
9.2-C	RE transmission study for Peak Demand Scenario without Strengthening-**Thirunelveli** Area **Tamil Nadu**

However, in order to limit transmission system loading within stipulated limits in various transmission corridors in ISTS as well as Intra State transmission system, following strengthening's have been identified.

➢ **<u>Inter-State strengthening requirements</u>**

- 765kV transmission line : 60 ckt km
- 400kV transmission line : 370 ckt km
- HVDC transmission line :800 ckt km
- New HVDC S/s : 1 nos. (New Pugalur)
- HVDC Terminal capacity . : 2500 MW

Details of the above transmission scheme are enclosed at **Annexure 2-B**

➢ **<u>System Strengthening within state for conveyance of ISTS transfer</u>**

- 400kV transmission line : 1180 ckt km
- 230kV transmission line : 1500 ckt km
- New 400/230-110 kV S/s : 5 nos.
- 400/230kV Transformation cap. : 3780 MVA
- 400/110kV Transformation cap. : 2200 MVA
- New 230/110kV S/s : 4 nos.
- 230/110kV Transformation cap. : 2650 MVA

Estimated Cost: Rs. 2339 Cr

However, some of intra state strengthening elements which will be utilized for transfer of power outside the host state has been segregated from the Intra state strengthening proposed as a part of the DPR. Considering this, total strengthening requirement for transfer of power outside the host state including above evolved strengthening scheme (*Rs 2339 Cr*) is as under:

➢ **System Strengthening within state for conveyance of ISTS transfer**

- 400kV transmission line : 1240 ckt km
- 230kV transmission line : 1500 ckt km
- New 400/230-110 kV S/s : 6 nos.
- 400/230kV Transformation cap. : 4725 MVA
- 400/110kV Transformation cap. : 2200 MVA
- New 230/110kV S/s : 4 nos.
- 230/110kV Transformation cap. : 2650 MVA

Estimated Cost: Rs. 2498 Cr

Details of the above transmission scheme are enclosed at **Annexure 2-C**

Load flow results with above system strengthening for High wind/solar with low demand as well as Low wind/solar with high demand is enclosed at following ***Annexures***.

Annexure	Details
9.3	Overall load Flow for SR other than Peak With Strengthening
9.3-A	RE transmission study for other than Peak Demand Scenario with Strengthening-**Udumalpet** Area **Tamil Nadu**
9.3-B	RE transmission study for other than Peak Demand Scenario with Strengthening-**Salem** Area **Tamil Nadu**
9.3-C	RE transmission study for other than Peak Demand Scenario with Strengthening-**Thirunelveli** Area **Tamil Nadu**
9.3-D	RE transmission study for other than Peak Demand Scenario with Strengthening-**New Pugalur Pooling Stn** Area in **Tamil Nadu**
9.4	Overall load Flow for SR Peak With Strengthening
9.4-A	RE transmission study for Peak Demand Scenario with Strengthening-**Udumalpet** Area **Tamil Nadu**

Annexure	Details
9.4-B	RE transmission study for Peak Demand Scenario with Strengthening-**Salem** Area **Tamil Nadu**
9.4-C	RE transmission study for Peak Demand Scenario with Strengthening-**Thirunelveli** Area **Tamil Nadu**
9.4-D	RE transmission study for Peak Demand Scenario with Strengthening-**New Pugalur Pooling Stn** Area in **Tamil Nadu**

As informed by TEDA/TANTRANSCO about the pocket wise capacity being added by 12th plan period, a schematic has been enclosed at ***Exhibit-C1*** showing capacity of the pockets/complex as well as its grid interconnection with nearest 230kV or 400kV pooling substations points.

5.2.2. Study for Renewable in Andhra Pradesh

As per the information submitted by the APTRANSCO / NREDCAP, following renewable generation capacity additionin Wind & Solar is envisaged by 12 th plan period.

Resource	Existing (as on Mar'12)	Future (by 16-17)	Total
Wind	392	5048	5440
Solar	92	285	377
Total	*484*	*5333*	*5817*

Out of above renewable capacity, Wind Farms (5300 MW) are envisaged to be located mainly in districts of Ananthpur, Kadapa, Kurnool districts at the pockets of Uravakonda (2600 MW), Kondapuram (1350 MW), Hindupur (700 MW) and Kurnool (400 MW). Further, Solar Plants (380 MW) are envisaged to be primarily concentrated in the districts of Kadapa (120 MW), Mahabubnagar (100 MW), Karimnagar (75 MW) & Ananthpur (75 MW). The Pocket wise renewable capacity envisaged by 2016-17 in various districts of AP State is enclosed at ***Exhibit-B2.***

Based on the approach & assumption discussed in Chapter-4, for study purpose, following Load Generation Scenario is considered for Andhra Pradesh by 2016-17:

Sno	Parameters by 2016-17	Low demand/High RE (75% of EPS demand)	High demand/Low RE
1	Draft 18th EPS Demand	18902	25202
2	Renewable Generation Dispatch (MW)	4110	1670
3	RPO (MW)	5028	5028
4	RE Surplus/ Deficit (MW) [2-3]	-920	- 3358
5	Allocation from Conventional generation (State+Central+IPP)	13236	15694

As per estimates, by 2016-17, capacity requirement to meet its projected RPO (12%), by AP, shall be about 5000 MW whereas RE maximum generation (5400 MW x70% + 380 MWx80%) can be about 4100 MW in off peak hours. With this, AP is projected to be about 900 MW RE deficit.

For the study purpose, out of total renewable generation, connectivity of 3150 MW wind generation has been taken as per DPR of APTRANSCO. This quantum of wind generation is radially fed to the dedicated 400 kV substations of Kondapur, Hindupur and Uravakonda. For balance 2000 MW wind projects, the connectivity has been considered at the nearest available 400 kV or 220kV STU stations as indicated by NREDCAP/APTRANSCO.

As indicated earlier, as per approach of the study, load flow has been carried out for two scenarios i.e. High wind/solar with low demand as well as Low wind/solar with high demand. In both the cases, requirement of transmission system arising out of RE injection has been assessed. Further, sensitivity analysis of the identified transmission system strengthening has been also carried out in other scenario. In the past, APTRANSCO has submitted proposal for transmission network for Renewable energy projects in AP to MNRE. Subsequently, based on the discussions in the joint meeting of POWERGRID, APTRANSCO and CEA held on dtd.24.04.2012 & 25.04.2012, above proposed transmission system was reviewed. It was decided and agreed that Hindupur – Kondapur 400kV D/c and Uravakonda – Goothy 400 kV D/c lines could be del eted from earlier proposal and 400kV

Kondapur – Kurnool (AP), Kondapur – Uravakonda & Uravakonda - Mehaboobnagar D/c lines may be added in the scheme.

A detail of such transmission system is enclosed at ***Annexure 3-A*** as under:

- **Transmission System as per DPR**

  - 400kV transmission line : 720 ckt km
  - 220kV transmission line : 1024 ckt km
  - New 400/220kV S/s : 3 nos.
  - New 220/132kV S/s : 9 nos.
  - 400/220kV Transformation cap. : 3465 MVA
  - 220/132kV Transformation cap : 1720 MVA

Estimated Cost: Rs. 1761 Cr

Above transmission system has also been considered while carrying out for base case system studies. However adequacy or requirement of above proposal has also been assessed while performing studies.

With above approach, load flow results for High wind/solar with low demand as well as Low wind/solar with high demand is enclosed at following ***Annexures.***

Annexure	Details
9.1	Overall load Flow for SR other than Peak Without Strengthening
10.1-A	RE transmission study for other than Peak Demand Scenario without Strengthening-for Andhra Pradesh
9.2	Overall load Flow for SR Peak Without Strengthening
10.2-A	RE transmission study for Peak Demand Scenario without Strengthening-for Andhra Pradesh

However, in order to limit transmission system loading within stipulated limits in various transmission corridors in ISTS as well as Intra State transmission system, following strengthening's have been identified.

- **Inter-State strengthening requirements**

  - 400kV transmission line : 240 ckt km

- New HVDC S/s : 1 no. (Mailaram)
- 400/220kV Transformation cap. : 630 MVA
- HVDC Transmission Line : 800 ckt km
- HVDC Terminal Capacity : 2500 MW

Details of the above transmission scheme are enclosed at **Annexure 3-B**

➢ **System Strengthening within state for conveyance of ISTS transfer**

- 220kV transmission line :736 ckt km
- 400/220kV Transformation cap. : 2835 MVA
- 220/132kV Transformation cap. : 1450 MVA

Estimated Cost : Rs. 805 Cr

However, some of intra state strengthening elements which will be utilized for transfer of power outside the host state has been segregated from the Intra state strengthening proposed as a part of the DPR. Considering this, total strengthening requirement for transfer of power outside the host state including above evolved system strengthening scheme (*Rs 805 Cr*) is as under:

➢ **System Strengthening within state for conveyance of ISTS transfer**

- 400kV transmission line :260 ckt km
- 220kV transmission line :1178 ckt km
- New 400/220kV S/s : 2 nos.
- New 220/132kV S/s : 4 nos.
- 400/220kV Transformation cap. : 5760 MVA
- 220/132kV Transformation cap. : 2050 MVA

Estimated Cost : Rs. 1486 Cr

Details of the above transmission scheme are enclosed at **Annexure 3-C**

Load flow results with above system strengthening for High wind/solar with low demand as well as Low wind/solar with high demand is enclosed at following ***Annexures.***

Annexure	Details
9.3	Overall load Flow for SR other than Peak With Strengthening
10.3-A	RE transmission study for other than Peak Demand Scenario with Strengthening-for Andhra Pradesh
9.4	Overall load Flow for SR Peak With Strengthening
10.4-A	RE transmission study for Peak Demand Scenario with Strengthening-for Andhra Pradesh

As informed by APTRANSCO / NREDCAP about the pocket wise capacity being added by 12th plan period, a schematic has been enclosed at ***Exhibit-C2*** showing capacity of the pockets/complex as well as its existing grid interconnection with nearest 220kV or 400kV pooling substations points.

5.2.3.Study for Renewable in Karnataka

As per the information submitted by the KREDL, following renewable generation capacity addition in Wind & SHP is envisaged by 12th plan period.

Resource	Existing (as on Mar'12)	Future (by 16-17)	Total
Wind	1783	3223	5006
SHP	527	719	1246
Total	*2310*	*3942*	*6252*

Out of above 5000 MW wind capacity, plants are envisaged mainly in North & Middle part of Karnataka to be distributed among 15 district locations comprises of Belgaum (650MW), Koppal (500MW), Gadag (480MW), Davangere (640MW), Chitradurga (820MW) & Havery (530MW). Further, Small Hydro (1250 MW) are envisaged mainly in South-West part of Karnataka in districts of Udupi (100 MW), Shimoga(90 MW), Dakshin & Uttar Kannad (250 MW), Mandya (200MW) as well as Chamrajnagar (80 MW). Pocket wise renewable capacity envisaged by 2016-17 in various districts of Karnataka State is enclosed at ***Exhbit-B3.***

Based on the approach & assumption discussed in Chapter-4, for study purpose, following Load Generation Scenario is considered for Karnataka by 2016-17:

Sno	Parameters by 2016-17	Other than Peak demand/High RE (75% of EPS demand)	High demand/Low RE
1	Draft 18th EPS Demand	9577	12769
2	Renewable Generation Dispatch (MW)	4375	2375
3	RPO (MW)	3350	3350
4	RE Surplus/Deficit (MW) [2-3]	1025	(-) 975
5	Allocation from Conventional generation (State+Central+IPP)	6227	10394

As per estimates, by 2016-17, capacity requirement to meet its projected RPO by Karnataka, shall be about @15% i.e 3350 MW whereas RE generation (6200 MW x 70%) can be about 4300 MW in other than the peak demand scenario. With this, Karnataka is projected to be about 1000 MW RE Surplus which may be utilized in meeting RPO requirement of other RE Deficit States in off peak period.

For the study purpose, out of total renewable generation, connectivity of the RE projects has been considered at nearest available 220kV or 132 kV STU stations as indicated by the KREDL/KPTCL.

With above approach, load flow results for Low demand as well as high demand scenarios are enclosed at following ***Annexures***.

Annexure	Details
11.1-A	RE transmission study for other than Peak Demand Scenario without Strengthening-for Karnataka
11.2-A	RE transmission study for Peak Demand Scenario without Strengthening-for Karnataka

However, in order to limit transmission system loading within stipulated limits in various transmission corridors in ISTS as well as Intra State transmission system, following strengthening's have been identified.

➢ **System Strengthening within state for conveyance of ISTS transfer**

- 220kV Transmission line : 720 ckt km

Estimated Cost : Rs. 466 Cr

Details of the above transmission scheme are enclosed at **Annexure –4**.

Load flow results with above system strengthening for system Low demand *(Wind @70%, SHP @70%)* as well as System High demand *(Wind @30%, SHP @70%)* is enclosed at following ***Annexures***.

Annexure	Details
11.3-A	RE transmission study for other than Peak Demand Scenario with Strengthening-for Karnataka
11.4-A	RE transmission study for Peak Demand Scenario with Strengthening-for Karnataka

As informed by KREDL about the pocket wise capacity being added by 12th plan period, a schematic has been enclosed at ***Exhibit-C3*** showing capacity of the pockets/complex as well as its grid interconnection with nearest 220kV or 400kV pooling substations points.

5.3. RE capacity addition in Western region

The following high capacity transmission corridors have been planned in Western Region:

a) High Capacity Corridor associated with IPPs in Chhattisgarh :

- Raipur Pool- Wardha – Aurangabad 765kV 2xD/c
- Aurangabad- Padghe 765kV D/c
- Aurangabad- Dhule-Vadodra 765kV S/c
- $\pm$800kV,3000 MW Champa Pool – Kurushetra HVDC Bipole

b) Southern region System Strengthening – XVII

- Establishment of New 765kV substation each at Narendra (GIS) and Kolhapur (initially charged at 400kV)
- Narendra (GIS) – Kolhapur (new) 765kV D/C line (initially charged at 400kV) –

- LILO of both circuits of Kolhapur – Mapusa 400 kV D/C line at Kolhapur (new)
- Narendra (GIS) – Narendra (existing) 400 kV D/c Quad line

c) Common Transmission System Associated with ISGS Projects in Nagapattinam / Cuddalore Area of Tamil Nadu (WR Portion)

- Kolhapur – Padghe 765 kV D/c one circuit via Pune (initially to be op. at 400kV)

In addition to above, other high capacity corridors such as Indore-Vadodra 765kV line associated with IPP in MP & Chhattisgarh as well as 765kV Dharamjaygarh – Jabalpur Pool-Bhopal- Indore & 765kV Dharamjaygarh-Jabalpur Pool- Bina –Gwalior associated with IPP in Orrisa/Jharkhand are also considered.

All the above High Capacity transmission corridors have been considered in the studies.

5.3.1. Study for Renewable in Gujarat

As per the information submitted by the GETCO/GEDA, following renewable generation capacity addition in Wind & Solar is envisaged by 12th plan period.

Resource	Existing (as on Mar'12)	Future (by 16-17)	Total
Wind	2600	5083	7683
Solar	600	1400	2000
Total	*3200*	*6483*	*9683*

Out of above 9700 MW renewable capacity, 2000 MW Solar Plants are envisaged to be primarily concentrated to districts of Kutch (500 MW), Banaskantha (500 MW), Patan (550 MW) and some capacity in districts of Surendranagar /Junagad & Ahmedabad. Further, 7700 MW Wind Farms are envisaged to be located mainly in districts of Kutch (2800 MW), Jamnagar (1000 MW), Rajkot (1800 MW), Surendranagr (950 MW), Banaskantha/Patan (800 MW) as well as Amreli (350 MW). Pocket wise renewable capacity envisaged by 2016-17 in various districts of Gujarat State is enclosed at ***Exhibit-B4.***

Based on the approach & assumption discussed in Chapter-4, for study purpose, following Load Generation Scenario is considered for Gujarat by 2016-17:

Sno	Parameters by 2016-17	Other than Peak/High RE (75% of EPS demand)	High demand/Low RE
1	Draft 18th EPS Demand	13730	18305
2	Renewable Generation Dispatch (MW)	6978	2505
3	RPO (MW)	3600	3600
4	RE Surplus/Deficit (MW) [2-3]	3378	(-)1095
5	Allocation from Conventional generation (State+Central+IPP)	10130	15800

As per estimates, by 2016-17, capacity requirement to meet its projected RPO by Gujarat (12%), shall be about 3600 MW whereas RE maximum generation (7700 MW x70%+2000x80%) can be about 7000 MW in off peak hours. With this, Gujarat is projected to be 3400 MW RE Surplus which may be utilized in meeting RPO requirement of other RE deficit States in demand other than peak period.

For the study purpose, out of total renewable generation, connectivity of the RE projects has been considered at nearest available 220kV or 132 kV STU stations as indicated by the GETCO. For the balance quantum of RE injection, for which STU has not received the application or grant of connectivity is in process, however pocket wise RE quantum information has been furnished by GETCO/GEDA, connectivity has been considered at nearest 220kV or 400kV STU stations/Pooling substations. Some of the projects which have been granted connectivity by the CTU at 220kV level have also been taken into account.

As indicated earlier, as per approach of the study, load flow study has been carried out for two scenarios i.e. High Wind/Solar with low demand scenario and Low Wind/Solar with Peak demand scenario. In both the cases, requirement of transmission system arising out of RE injection has been assessed. Further, sensitivity analysis of the identified transmission system strengthening has been also carried out in other scenario. However, Special area dispatch for generation like

Mundra UMPP (4000 MW) as well as Adani Mundra (4620 MW) has been considered even in low demand scenario to assess the adequacy of transmission system as major portion of wind/solar generation is in this area. In past, GETCO has also submitted proposal for transmission network for Renewable energy projects in Gujarat to MNRE. Details of such transmission system are as under:

➢ **Intra State transmission Strengthening :**

- 400kV transmission line : 440 ckt km
- 220kV transmission line : 1574 ckt km
- 132kV transmission line : 40 ckt km
- New 400/220kV S/s : 2 nos.
- New 220/132kV & 220/66kV S/s : 3 nos.
- 400/220kV Transformation Cap : 1260 MVA
- 220/132& 220/66kV Transformation Cap : 500 MVA

Estimated Cost: Rs. 1680.41 Cr

Further, details of the above transmission scheme is enclosed at **Annexure 5-A**.

Additionally, GETCO vide letter dated 24.2.12 also informed tentative transmission scheme for integration of 500 MW Solar Power from Solar Park Phase-II (Distt. Banaskantha) with GETCO network. Details of transmission system is as under:

- 400kV transmission line : 200 ckt km
- 220kV transmission line : 40 ckt km
- New 400/220/66kV S/s : 1 no.
- 400/220kV Transformation Cap : 630 MVA
- 220/66kV Transformation Cap : 500 MVA

Further, details of the above transmission scheme is enclosed at **Annexure 5-B**.

Both the above transmission system(s) has been considered while carrying out for base case system studies. However adequacy or requirements of above proposal have also been assessed while performing studies. With above approach, load flow results for High wind/solar with low demand as well as Low wind/solar with high demand is enclosed at following ***Annexures.***

Annexure	Details
12.1	Overall load Flow for WR other than Peak Without Strengthening
12.1-A	RE transmission study for other than Peak Demand Scenario without Strengthening-**Gujarat**
12.2	Overall load Flow for WR Peak Without Strengthening
12.2-A	RE transmission study for Peak Demand Scenario without Strengthening-**Gujarat**

From the studies, it has been observed that there is a constraint in transfer of power from Gujarat to Northern region. Loadingon 400kV Zerda-Kankroli D/c line, a north-west interconnection, is observed to be critical and therefore necessitates strengthening of WR-NR transmission corridor emanating from Gujarat. However, it is to mention that Rajasthan being also RE as well as Off peak Surplus, would not need to absorb power but its high capacity transmission infrastructure shall be utilized to transfer power out of Rajasthan via 765kV Jaipur/Ajmer.

Therefore, in order to limit transmission system loading within stipulated limits in various transmission corridors in ISTS as well as Intra State transmission system, following strengthening have been identified.

- **Inter-State strengthening requirements**
  - 400kV transmission line : 1440 ckt km

Details of the above transmission scheme is enclosed at **Annexure 5-C**

- **System Strengthening within state for conveyance of ISTS transfer**
  - 220kV transmission line : 452 ckt km
  - 400/220kV Transformation cap : 315 MVA

Estimated Cost: Rs. 602 Cr

However, some of intra state strengthening elements which will be utilized for transfer of power outside the host state has been segregated from the Intra state strengthening proposed as a part of the DPR. Considering this, total strengthening requirement for transfer of power outside the host state including above evolved Strengthening scheme (*Rs 602 Cr*) is as under:

➢ **System Strengthening within state for conveyance of ISTS transfer**

220kV transmission line : 834 ckt km

400/220kV Transformation cap : 315 MVA

Estimated Cost: Rs. 782 Cr

Details of the above transmission scheme is enclosed at **Annexure 5-D**

Load flow results with above system strengthening for High wind/solar with low demand as well as Low wind/solar with high demand is enclosed at following ***Annexures***.

Annexure	Details
12.3	Overall load Flow for WR other than Peak With Strengthening
12.3-A	RE transmission study for other than Peak Demand Scenario with Strengthening-**Gujarat**
12.4	Overall load Flow for WR Peak With Strengthening
12.4-A	RE transmission study for Peak Demand Scenario with Strengthening-**Gujarat**

As informed by GETCO/GEDA about the pocket wise capacity being added by 12th plan period, a schematic has been enclosed at ***Exhibit-C4*** showing capacity of the pockets/complex as well as its grid interconnection with nearest 220kV or 400kV pooling substations points.

5.3.2.Study for Renewable in Maharashtra

As per the information submitted by the MEDA, following renewable generation capacity addition in Wind & Solar is envisaged by 12th plan period.

Resource	Existing (as on Mar'12)	Future (by 16-17)	Total
Wind	2460	9016	11476
Solar	17	905	922
Total	*2477*	*9921*	*12398*

Out of above renewable capacity, Solar Plants (900 MW) are envisaged to be primarily concentrated in districts of Osmanabad (360 MW), Yavatmal (150 MW), Nandurbar(150 MW) and Chandrapur (150 MW). Wind Farms are envisaged to be located mainly in districts of Sangli (2100 MW), Satara (1700 MW), Ahmadnagar (1450 MW), Kolhapur (1100 MW), Dhule/N'bar (1500 MW), Solapur (900 MW), Pune (650 MW) as well as some of the quantum indistricts of Amravati (200 MW), Nashik (400 MW), Sindhudurg (450 MW) & Beed (350 MW). Pocket wise renewable capacity envisaged by 2016-17 in various districts of Maharashtra State is enclosed at ***Exhibit –B5.***

Based on the approach & assumption discussed in Chapter-4, for study purpose, following Load Generation Scenario is considered for Maharashtra by 2016-17:

Sno	Parameters by 2016-17	Low demand/High RE(75% of EPS demand)	High demand/Low RE
1	Draft 18th EPS Demand	20962	27949
2	Renewable Generation Dispatch (MW)	8770	3535
3	RPO (MW)	5800	5800
4	RE Surplus/Deficit (MW) [2-3]	2970	(-)2265
5	Allocation from Conventional generation (State+Central+IPP)	15162	24414

As per estimates, by 2016-17, capacity requirement to meet its projected RPO by Maharashtra (12%) shall be about 5800 MW whereas RE maximum generation (considering wind/solar) (11500 MWx70%+900x80%) can be about 8800 MW in off peak hours. With this, Maharashtra is projected to be about 3000 MW RE Surplus which may be utilized in meeting RPO requirement of other RE Deficit States in off peak period.

For the study purpose, 8400 MW out of total renewable generation, connectivity of the RE projects has been considered at nearest available 220kV or 132 kV STU stations as indicated by the MSTECL. For the balance quantum of RE injection, for which STU has not received the application or grant of connectivity is in process, however pocket wise RE quantum information has been furnished by MEDA, connectivity has been considered at nearest 220kV or 400kV STU stations/Pooling substations on pro rata basis.

As indicated earlier, as per approach of the study, load flow has been carried out for two scenarios i.e. High wind/solar with low demand as well as Low wind/solar with high demand. In both the cases, requirement of transmission system arising out of RE injection has been assessed. Further, sensitivity analysis of the identified transmission system strengthening has been also carried out in other scenario.

With above approach, load flow results for High wind/solar with low demand as well as Low wind/solar with high demand is enclosed at following ***Annexures***.

Annexure	**Details**
12.1	Overall load Flow for WR other than Peak Without Strengthening
13.1-A	RE transmission study for other than Peak Demand Scenario without Strengthening-**Maharashtra**
12.2	Overall load Flow for WR Peak Without Strengthening
13.2-A	RE transmission study for Peak Demand Scenario without Strengthening- **Maharashtra**

It is to mention that major 765kV & 400kV high capacity transmission corridors, being implemented in Western region, are passing though Maharashtra which is considered in the studies. It is also being observed that in order to transfer surplus RE power from Southern region in other than the peak scenario, there is a critical loading of Narendra-Kolhapur line (operated at 400kV) in contingency conditions. Therefore to address above critical loading conditions, upgradation of the Narendra-Kolhapur transmission corridor at 765kV level is proposed.

Further, to limit transmission system loading within stipulated limits in various transmission corridors in ISTS as well as Intra State transmission system, following strengthening's have been identified.

➢ **Inter-State strengthening requirements**

- 765/400kV Transformation cap. : 3000 MVA

(Additional 3000 MVA transformation capacity at Narendra (SR) in above scheme)

Details of the above transmission scheme is enclosed at **Annexure 6-A**

➢ **System Strengthening within state for conveyance of ISTS transfer**

- 220kV transmission line : 550 ckt km
- 132kV transmission line : 235 ckt km
- 220/132kV Transformation Capacity : 480 MVA

Estimated Cost : Rs. 511 Cr

Details of the above transmission scheme is enclosed at **Annexure 6-B**

Load flow results with above system strengthening for High wind/solar with low demand as well as Low wind/solar with high demand is enclosed at following ***Annexures.***

Annexure	Details
12.3	Overall load Flow for WR other than Peak With Strengthening
13.3-A	RE transmission study for other than Peak Demand Scenario with Strengthening-**Maharashtra**
12.4	Overall load Flow for WR Peak Without Strengthening
13.4-A	RE transmission study for Peak Demand Scenario with Strengthening-**Maharashtra**

As informed by MEDA about the pocket wise capacity being added by 12th plan period, a schematic has been enclosed at ***Exhibit-C5*** showing capacity of the pockets/complex as well as its grid interconnection with nearest 220kV or 400kV pooling substations points.

5.4. RE capacity addition in Northern region

5.4.1. Study for Renewable in Rajasthan

As per the information submitted by the RRECL/RRVPNL, following renewable generation capacity addition in Wind & Solar is envisaged by 12th plan period.

Resource	Existing (as on Mar'12)	Future (by 16-17)	Total
Wind	2100	2000	4100
Solar	200	3700	3900
Total	*2300*	*5700*	*8000*

Out of above 3900 MW solar capacity, plants are envisaged in districts of Jaisalmer (2000 MW), Jodhpur (1225 MW) and Bikaner (665 MW). Wind Farms (4100 MW) are envisaged in districts of Jaisalmer (3120 MW), Barmer (340 MW), Banswara (320 MW) as well as Pratapgarh (320 MW). Pocket wise renewable capacity envisaged by 2016-17 in various districts of Rajasthan State is enclosed at ***Exhibit-B6.***

Based on the approach & assumption discussed in Chapter-4, for study purpose, following Load Generation Scenario is considered for Rajasthan by 2016-17:

Sno	Parameters by 2016-17	Other than Peak/High RE (90% of EPS demand)	Peak demand/Low RE
1	Draft 18th EPS Demand	11511	12790
2	Renewable Generation Dispatch (MW)	4350	3260
3	RPO (MW)	2560	2560
4	RE Surplus (MW) [2-3]	1790	700
5	Allocation from Conventional generation (State+Central+IPP)	8951	10230

As discussed in earlier sections, Rajasthan has got complementary wind pattern. Therefore in low demand scenario, wind is considered with 30% dispatch whereas Solar as 80%. Considering this, by 2016-17, capacity requirement to meet its projected RPO by Rajasthan, shall be about 12% (2560 MW) whereas RE generation (4100 MWx30%+3900 MWx80 %) can be about 4300 MW in off peak. With this, Rajasthan is projected to be 1800 MW RE Surplus which may be utilized in meeting RPO requirement of other RE Deficit States in Low demand scenario.

For the study purpose, out of total renewable generation, connectivity of the RE projects has been considered at nearest available 220kV or 132 kV STU stations as indicated by the RRVPNL. For the balance quantum of RE injection, for which STU has not received the application or grant of connectivity is in process, however pocket wise RE quantum information has been furnished by RRECL/RRVPNL, connectivity has been considered at nearest 220kV or 400kV STU stations/Pooling substations.

As indicated earlier, as per approach of the study, load flow has been carried out for two scenarios i.e. High wind/solar with low demand as well as Low wind/solar with high demand. In both the cases, requirement of transmission system arising out of RE injection has been assessed. Further, sensitivity analysis of the identified transmission system strengthening has been also carried out in other scenario. In past, RRVPNL has also submitted proposal for transmission scheme and supplementary transmission scheme for Renewable energy projects in to MNRE. Above transmission system has also been considered while carrying out for base case system studies. However adequacy or requirements of above proposal have also been assessed while performing studies. Details of such transmission system is as under

- **Intra State transmission system as per DPR** (*Main* + *Supplementary*)
  - 400kV transmission line : 2750 ckt km
  - 220kV transmission line : 622 ckt km
  - 132kV transmission line : 1114 ckt km
  - New 400/220kV S/s : 3 nos.
  - New 220/132kV S/s : 9 nos.
  - New 132/33kV S/s : 29 nos.
  - 400/220kV Transformation cap. : 3945 MVA
  - 220/132kV Transformation cap. : 1760 MVA
  - 132/33kV Transformation cap. : 1025 MVA

Estimated Cost : Rs 2935 Cr (Main tr.scheme)

Estimated Cost : Rs 1398 Cr (Supplementary tr.scheme)

Details of the above transmission scheme is enclosed at **Annexure 7-A**

With above approach, load flow results for Low demand & High demand scenarios are enclosed at following ***Annexures.***

Annexure	Details
14.1-A	RE transmission study for other than Peak Demand Scenario without Strengthening-**Rajasthan (765 kV & 400 kV)**
14.1-B	RE transmission study for other than Peak Demand Scenario without Strengthening-**Rajasthan (220 kV)**
14.2-A	RE transmission study for Peak Demand Scenario without Strengthening-**Rajasthan (765 kV & 400 kV)**
14.2-B	RE transmission study for Peak Demand Scenario without Strengthening-**Rajasthan (220 kV)**

From Load generation scenario, it is observed that Rajasthan being surplus in High demand as well as Low demand scenario, would not need to consume power in the state itself. In addition, RE surplus of Gujarat is also being injected in Rajasthan. From the studies, it has been observed that there is a constraint in transfer of power from Rajasthan to Northern region load centers. Considering this, a High Capacity 765kV Transmission Corridor right from Jodhpur to Moga via Ajmer and Suratgarh is being identified.

With above proposed strengthening near Jodhpur, loading on 400kV Jodhpur(N)-Merta line as well as 220kV lines loadings underlying 400/220kV Jodhpur (existing) substations shall be relieved. Further, this shall help is transferring RE power from Solar/Wind rich pockets in Rajasthan directly to other parts of Northern region.

Therefore, in order to limit transmission system loading within stipulated limits in various transmission corridors in ISTS as well as Intra State transmission system, following strengthening’s have been identified.

Load flow results with above system strengthening for Low demand & High demand scenarios is enclosed at following ***Annexures***.

Annexure	Details
14.3-A	RE transmission study for other than Peak Demand Scenario with Strengthening-**Rajasthan (765 kV & 400 kV)**

Annexure	Details
14.3-B	RE transmission study for other than Peak Demand Scenario with Strengthening-**Rajasthan (220 kV)**
14.4-A	RE transmission study for Peak Demand Scenario with Strengthening-**Rajasthan (765 kV & 400 kV)**
14.4-B	RE transmission study for Peak Demand Scenario with Strengthening-**Rajasthan (220 kV)**

- **Inter-State strengthening requirements**

  - 765kV transmission line : 1480 ckt km
  - 400kV transmission line : 580 ckt km
  - New 765/400kV S/s : 3 nos.
  - 765/400kV Transformation cap. : 10500 MVA
  - 400/220kV Transformation cap. : 500 MVA

Details of the above transmission scheme is enclosed at **Annexure 7-B**

- **System Strengthening within state for conveyance of ISTS transfer**

  - 220kV transmission line : 480 ckt km
  - 220/132kV transformation cap. : 2560 MVA

Estimated Cost : Rs. 563 Cr

However, some of intra state strengthening elements which will be utilized for transfer of power outside the host state has been segregated from the Intra state strengthening proposed as a part of the DPR. Considering this, total strengthening requirement for transfer of power outside the host state including above evolved strengthening scheme (*Rs 563 Cr*) is as under:

- **System Strengthening within state for conveyance of ISTS transfer**

  - 400kV transmission line : 740 ckt km
  - 220kV transmission line : 480 ckt km
  - 220/132kV transformation cap. : 2560 MVA

Estimated Cost : Rs. 1079 Cr

Details of the above transmission scheme is enclosed at **Annexure 7-C**

As informed by RRECL/RRVPNL about the pocket wise capacity being added by 12th plan period, a schematic has been enclosed at ***Exhibit-C6*** showing capacity of the pockets/complex as well as its grid interconnection with nearest 220kV or 400kV pooling substations points.

5.4.2. Study for Renewables in Himachal Pradesh

As per the information submitted by the HPTCL/HPERC, following renewable generation capacity addition in SHP is envisaged by 12th plan period.

Resource	Existing (as on Mar'12)	Future (by 16-17)	Total
SHP	443	996	1438

Small Hydro Plants (1400 MW) are envisaged to be primarily concentrated to districts of Shimla (410 MW), Kullu (250 MW), Chamba (230 MW), Kangra (200MW) Kinnaur(120 MW) and Mandi (80 MW). Pocket wise renewable capacity envisaged by 2016-17 in various districts of Himachal Pradesh State is enclosed at ***Exhibit-B7.***

Based on the approach & assumption discussed in Chapter-4, for study purpose, following Load Generation Scenario is considered for Himachal Pradesh by 2016-17:

Sno	Parameters by 2016-17	Other than Peak(90% of EPS demand)	Peak demand
1	Draft 18th EPS Demand	1599	1777
2	Renewable Generation Despatch (MW)	1008	1008
3	RPO (MW)	450	450
4	RE Surplus (MW) [2-3]	558	558
5	Allocation from Conventional / Hydro generation (State+Central+IPP)	1149	1327

As per estimates, by 2016-17, capacity requirement to meet its projected RPO by Himachal Pradesh, shall be about 15% i.e 450 MW whereas RE generation (1440 MW x @70%) can be about 1000 MW. With this, Himachal Pradesh is projected to be 550 MW RE Surplus which may be utilized in meeting RPO requirement of other RE Deficit States.

For the study purpose, out of total renewable generation, connectivity of the RE projects has been considered at nearest available 220kV or 132 kV STU stations as indicated by the HPTCL report has been prepared with technical assistance from ADB for 428 MW SHP projects. For the balance quantum of RE injection, for which HREDCL has furnished basin wise SHP quantum information, connectivity has been considered at nearest 132kV or 220kV STU stations/Pooling substations.

In order to evacuate potential in 5 river basins of the state, a Power System Master Plan (PSMP) report has been prepared by HPTCL with technical assistance from Asian Development Bank (ADB). On the basis of that a compressive scheme has been evolved by HPTCL for providing transmission infrastructure work for evacuation of 428 MW of power from Small hydroelectric projects in Himachal Pradesh Power. Details of the proposed transmission system are as under. Above transmission system has also been considered while carrying out for base case system studies. However adequacy or requirements of above proposal have also been assessed while performing studies. Details of such transmission system is as under :

- **Intra State Transmission System (DPR) proposed by HPTCL**
  - 220kV transmission line : 20 ckt km
  - 132kV transmission line : 282 ckt km
  - 66kV transmission line : 134 ckt km
  - New S/s : 5 nos.
  - Transformation capacity : 682 MVA

  Estimated Cost : Rs 456 Cr

Details of the above transmission scheme is enclosed at ***Annexure 8-A.***

With above approach, load flow results for Low demand & High demand scenarios is enclosed at following ***Annexures***.

Annexure	**Details**
15.1-A	RE transmission study for other than Peak Demand Scenario without Strengthening-**Himachal Pradesh**
15.2-A	RE transmission study for Peak Demand Scenario without Strengthening- **Himachal Pradesh**

From the studies, it has been observed that there is a constraint in transfer of power in few of 132kV transmission lines. In order to limit transmission system loading within stipulated limits, following strengthening have been identified.

➢ **System Strengthening within state for conveyance of ISTS transfer**

- 132kV transmission line : 310 Ckt km
- 220/132kV Transformation cap. : 480 MVA

Estimated Cost: Rs 150 Cr

However, some of intra state strengthening elements which will be utilized for transfer of power outside the host state has been segregated from the Intra state strengthening proposed as a part of the DPR. Considering this, total strengthening requirement for transfer of power outside the host state including above evolved strengthening scheme (*Rs 150 Cr*) is as under:

➢ **System Strengthening within state for conveyance of ISTS transfer**

- 220kV transmission line : 20 Ckt km
- 132kV transmission line : 310 Ckt km
- New 220/33kV S/s : 1 nos
- 220/132kV Transformation cap. : 480 MVA
- 220/33kV Transformation cap. : 126 MVA

Estimated Cost: Rs 230 Cr

Details of the above transmission scheme is enclosed at **Annexure 8-B.**

Load flow results with above system strengthening in system Low demand & High demand scenarios (SHP @70% in both scenarios) is enclosed at following ***Annexures***.

Annexure	Details
15.3-A	RE transmission study for other than Peak Demand Scenario with Strengthening-**Himachal Pradesh**
15.4-A	RE transmission study for Peak Demand Scenario with Strengthening- **Himachal Pradesh**

As informed by HPTCL/HPERC about the pocket wise capacity being added by 12th plan period, a schematic has been enclosed at ***Exhibit-C7*** showing capacity of the pockets/complex as well as its grid interconnection with nearest 220kV or 400kV pooling substations points.

5.4.3.Study for Renewables in Jammu & Kashmir

As per the information submitted by the JKPDD/JKEDA, following renewable generation capacity addition in Wind, Solar & SHP is envisaged by 12th plan period.

Resource	Existing	Future (by 16-17)	Total
Wind	0.06	12.2	12.26
SHP	118	362	480
Solar	2	102	104
Total	*120*	*476*	*596*

Out of above 596 MW renewable capacity, 480 MW Small Hydro are envisaged to be primarily concentrated in districts of Udhampur (111 MW), Baramula (51 MW), Jammu (48 MW), Srinagar (76MW), Leh (35 MW), Anantnag (33 MW) etc. Further, 104 MW Solar Plants are envisaged to be located in Leh region. Wind Farms are envisaged to be located mainly in district of Udhampur (12 MW). Pocket wise renewable capacity envisaged by 2016-17 in various districts of Jammu & Kashmir State is enclosed at ***Exhibit-B8.***

Based on the approach & assumption discussed in Chapter-4, for study purpose, following Load Generation Scenario is considered for Jammu & Kashmir by 2016-17:

Sno	Parameters by 2016-17	Other than Peak demand/High RE (90% of EPS demand)	High demand/Low RE
1	Draft 18th EPS Demand	2991	3323
2	Renewable Generation Dispatch (MW)	428	350
3	RPO (MW)	466	466
4	RE Surplus/Deficit (MW) [2-3]	(-) 38	(-) 116
5	Allocation from Conventional generation (State+Central+IPP)	1468	1721

As per estimates, by 2016-17, capacity requirement to meet its projected RPO by Jammu & Kashmir, shall be about @7% i.e 466 MW whereas RE generation (480 MW x 70%+104 MW x 80%+12 x 70%) shall be about 428 MW in other than the peak demand scenario. With this, Jammu & Kashmir is projected to be about 38 MW RE Deficit which may be met from other RE Surplus States in off peak period.

For the study purpose, out of total renewable generation, connectivity of the RE projects has been considered at nearest available 220kV or 132 kV STU stations as indicated by the J&KPDD. It is to mention that a no. of transmission system strengthening(s) at Intra State level (132kV/220kV) have already been planned for Jammu as well as Kashmir Valley, which are being implemented under PMRP scheme. In addition other strengthening schemes under Central Plan Assistance (CPA) e.g. 220kV Leh-Khalsti-Drass-Alusteng line have also been planned/being taken up.

Studies have been carried out considering all the above strengthening(s). It has been observed that Leh/Ladakh region, which has about 100 MW proposed Solar generation, has grid connectivity through 220kV line to Alusteng via Khalsti/Drass, which connects it to rest of the grid. Out of total 260 MW capacity envisaged in Leh/Khalsti/Kargil area [Solar(100 MW), SHP(70 MW), Nimoo Bazgoo(90 MW)] peak despatch shall be about 225 MW. Out of this, about 75 MW is expected to be consumed locally in the complex (Leh to Kargil), balance 150 MW is envisaged to be injected into the STU grid at Alusteng through above 220kV line, which is found to be adequate in normal condition.

Load flow results with above system strengthening for system Low demand *(Wind @70%, Solar @80% & SHP @70%)* as well as System High demand *(Wind @30%, Solar @10% & SHP @70%)* is enclosed at following ***Annexures***.

Annexure	Details
15.5-A	RE transmission study for other than Peak Demand Scenario for J&K
15.5-B	RE transmission study for Peak Demand Scenario for J&K

From the above results, it has been observed that along with the proposed strengthening(s) under various schemes like PMRP/CPA etc. for J&K at Intra State level, loading on the various transmission lines are found to be in order. Considering this, no further strengthening is envisaged, for the given RE capacity addition (Quantum & pocket wise) in the state of J&K. However implementation of the above strengthening(s), which have already been planned under PMRP/CPA etc., needs to be expedited for reliable evacuation and transfer of power. In addition, development of connectivity transmission system to interconnect various RE generation project to the nearest point of common coupling (PCC) in STU system should be given special emphasis for faster implementation. For this, connectivity transmission system is proposed as a part of Intra State strengthening system. Details of the scheme are given in ***Chapter-10***.

As informed by JKPDD/JKEDA about the pocket wise capacity being added by 12th plan period, a schematic has been enclosed at ***Exhibit-C8*** showing capacity of the pockets/complex as well as its grid interconnection with nearest 220kV or 400kV pooling substations points.

A Map showing High Capacity transmission corridors for envisaged Renewable generation in above RE rich states by 2016-17 is as under:

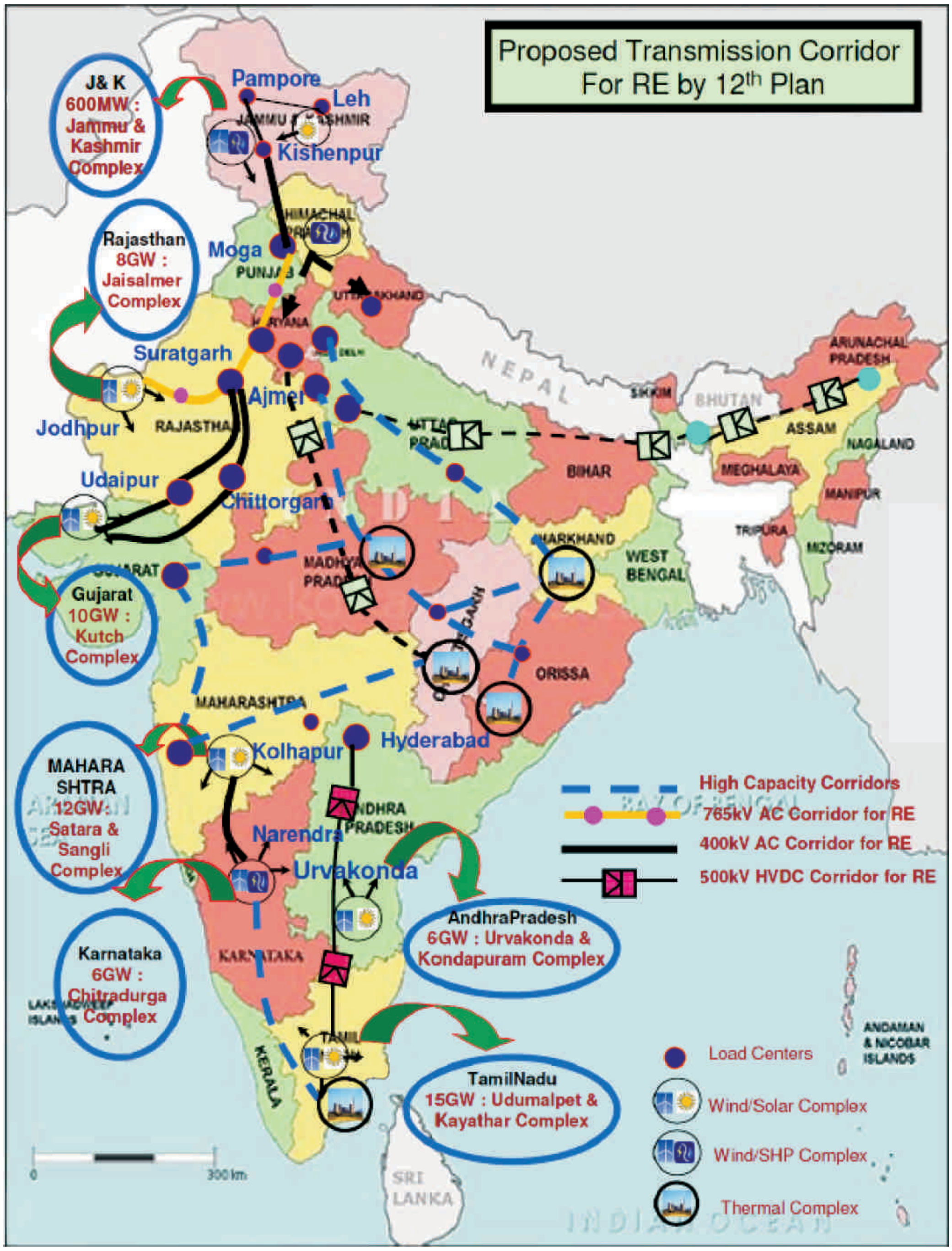

Figure 5-1: High Capacity transmission corridor for RE by 12th Plan

5.5. Other Observations

From the studies, it has been observed that due to demand growth, there is transmission strengthening requirement near the load centers in above RE rich states. However, this is not on account of injection from Renewables or displacement but due to increased load growth up to 2016-17 time frame. For this, studies may be carried out separately to identify optimal transmission system in Intra State considering the network strengthening plans of the respective STUs.

In case of space constraints for terminating new lines / transformers etc. at STU substations under proposed strengthening scheme as well as Right-of-Way constraints in proposed transmission links, the specific elements may be reviewed. STU may suggest any other suitable alternative/option in such situations.

Intentionally left Blank

Chapter-6

Reactive Compensation

6.1. Need of Reactive Compensation

At present, Induction machines are having majority stake in installed Wind generation technology in the country. Induction generators especially Fixed Speed (SCIG) machines are known for absorbing heavy reactive power during start up as well as some reactive power in normal operating conditions. Startup reactive consumption requirements of wind turbine generators are extremely high, sometimes equivalent to the power rating of the turbine. Due to Intermittent characteristics of Wind, generator start up can occur on numerous occasions during normal daily operation, necessitating huge quantum of reactive power requirement many a times in a day. In many conditions, such generation is also connected to the weak (low short circuit) network which can't sustain much reactive variation causing them to face voltage excursions.

To take care of above aspects, Static Reactive Compensation like shunt capacitors are generally provided by the developers at plant level in meeting the requirement of machine reactive power. However, inadequate shunt compensation along with transmission issues like weak interconnections etc. can put significant impact on the grid voltage stability.

Synchronous Generators have superior characteristics compared to Induction Generators also in terms of Reactive Injection/absorption. Double Fed Induction Generators are capable of generating a limited amount of reactive power and contributing in providing voltage support for the grid. Therefore with more such installations, reactive power issues could be handled to some extent.

Therefore in view of the variation of wind/solar power generation, generator characteristics and consequent impact of such aspects on grid voltages, reactive compensation requirement to control voltages within stipulated limits have also been analyzed.

6.2. Operational Experience of RE Rich States

Experience of various RE rich states like Gujarat, Maharashtra, Rajasthan & Tamil Nadu reveals some interesting facts about reactive compensation requirement at grid level during wind generation injection.

As a known fact, the Renewable generation (from wind/solar) is mostly available during other than peak demand period and connected to low grid voltage levels such as 33/66 kV or 132kV. Further, being connected to the low grid voltage level, during RE availability, local demand is met by distributed RE generation. Because of this, transformer loading on EHV level reduces to significant levels. This cause low loading conditions on EHV lines, aggravating the High voltage situation in the grid during other than peak demand hours. Most of the RE rich states have observed that High voltage grid conditions are aggravated in case of Renewable injections in other than the peak hours.

However, as informed, Tamil Nadu faces a Low voltage situation in case of heavy wind injection. This may be either on account of MVAR absorption by the Wind generators due to inadequate shunt compensation through Capacitor Banks at plant level or high level of loading on underlying network during wind generation injection or combinedly due to both the above reasons.

Considering the above situation, High Voltage Phenomenon due to Wind generation injection in low demand hours, is proposed to be addressed through Switchable/Controlled Reactor at 220kV & above voltage level. To address Low voltage situation, it is proposed that States should mandate RE developers especially wind (Induction generators) to keep adequate level of shunt compensation at plant level so as to meet their own reactive power requirement at the local level itself especially during start up.

Further, emphasis may be given on generators for “Fault Ride Through” (FRT) compliance so that RE generation is not lost during near grid fault situations. Generators may also adopt alternative solutions like installation of SVC or STATCOM to comply with FRT.

To take care of above aspects at the grid level, in the subsequent sections, several switchable/controlled reactors/STATCOMs are proposed as a part of dynamic compensation.

6.3 Approach for Reactive Power Compensation

In order to maintain the voltage in stipulated limits, at Point of Common Coupling (PCC), under different RE generation scenarios, Static as well as Dynamic reactive support is essential. For this, Reactive compensation is to be provided at strategic locations in the form of Switchable/Thyristor Controlled Reactors (TCR) as well as Dynamic VAR compensator such as STATCOM / SVC. As per CEA Manual on Transmission Planning criteria, limits for Steady State Voltage for different voltage levels must be as under:

Table-6.1: Stipulated limits for Steady State Voltage

Voltage (kVrms)		
Nominal	**Maximum**	**Minimum**
765	800	728
400	420	380
220	245	198
132	145	122

In order to address high voltage situations, Bus reactors at RE pooling stations are the solution. However at some places, in view of the variable reactive absorption requirement, Controlled Reactors (TCR) is found to be an appropriate solution.

In a grid with weak voltage support from remote generators, the problem of voltage fluctuation and fault recovery issues can be solved by using dynamic reactive power compensation. Capability of STATCOM to instantly absorb and deliver VARs makes it an excellent tool to prevent temporary voltage anomalies. Compared to Static Var Compensator (SVC), STATCOM offers faster operation because of voltage source converter (VSC) and no delay associated with thyristor firing. The main advantage of STATCOM over SVC is that the compensating current does not depend on the voltage level at the point of common coupling and compensating current is not lowered as the terminal voltage drops. Studies have shown that by placing a dynamic reactive power compensator at the point of common coupling of RE, transient and steady state stability can also be improved. A comparison of V-I characteristics of STATCOM & SVC is placed at Fig-6.1.

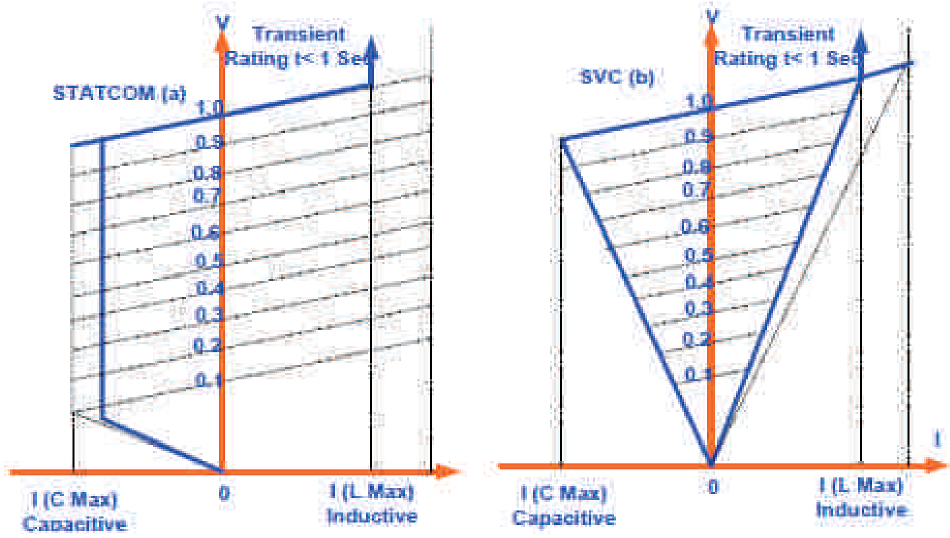

Fig-6.1: V-I Characteristics of STATCOM V/s SVC

Based on the operational experience of the respective RE States regarding either Low voltage profile of Point of common coupling (PCC) or low short circuit strength of RE Pooling stations, identification of location for placement of dynamic compensation is carried out. However exact location/sizing of above compensation shall be based upon the actual modeling related data pertaining to mechanical, electrical and other aspects of renewable generation like Wind/Solar.

In addition, intermittent/variable nature of RE sources may result in wide variations in quantum and direction of power flow on the Inter state high capacity transmission corridors. Therefore suitable dynamic reactive compensation at 400kV level is essential at strategic interfacing locations to introduce flexibility in handling of such variations. However, high short circuit strength of 400kV interfacing substations, calls for large dynamic compensation requirement for which Static Var Compensator (SVC) over STATCOM is found to be a suitable option.

6.4 Proposed Reactive Compensation

Requirement of following Bus reactors (Switchable/ Controlled reactor) are identified to deal with the High Voltage Situation in the Grid at 220kV & above voltage level. In addition, to provide dynamic voltage support, STATCOM are also proposed at strategic locations.
However, for the above analysis, it has been assumed that earlier agreed Reactive compensation in Respective Regional Standing Committees shall be in place.

(i) Addressing High Voltage Issues

To address high voltage issues during RE injection, following switchable Bus reactors (21 nos.) as well as Controlled Bus Reactors (12 nos.) are proposed:

Tamil Nadu

- Total 2 nos. 1x150 MVAR, 420kV Bus Reactors one each at substation Tappagundu & Rasipalayam-STU
- Total 2 nos. 1x125 MVAR, 420kV Bus Reactors one each at substation Salem & Hosur-ISTS

Andhra Pradesh

- Total 2 nos. 1x150 MVAR, 420kV Controlled Reactors one each at Kondapur, Hindupur -STU S/s
- 1x125 MVAR, 420kV Bus Reactors at Kurnool (New) -ISTS

Karnataka

- Total 2 nos. 1x150 MVAR, 420kV Controlled Bus reactor one each at Davangiri & Hiriyur-STU/ISTS
- 1x240 MVAR, 765kV Bus Reactors at Narendra S/s – ISTS S/s

Rajasthan

- Total 5 nos. 125 MVAR, 420kV Bus Reactors each at Jaipur, Merta, Ramgarh, Chittorgarh & Bhilwara (New) -STU S/s
- Total 4 nos. 1x150 MVAR, 420kV Controlled Reactors each at Bhadla, Akal, Bikaner, Jaisalmer -STU S/s

- Total 2 nos. 25/50 MVAR 220kV Bus Reactors each at Dechu, Pokran- STU S/s
- Total 3 nos. 240 MVAR, 765kV Bus Reactors each at Suratgarh, Jodhpur (New) & Ajmer (New) S/s – ISTS S/s

Maharashtra

- 1x50/25 MVAR, 220kV Bus Reactor at Dondaicha/Dhule - STU S/s
- 1x150 MVAR, 420kV Controlled Bus reactor(TCR) at Alkud (MSETCL) S/s- STU S/s
- 1x240 MVAR, 765kV Bus Reactor at Kolhapur S/s – ISTS S/s

Gujarat

- Total 5 nos. 1x25/1x50 MVAR, 220kV Bus Reactors, one each at 220kV Motipaneli, Bhatia, Bachau, Deodhar & Nakhtarna S/s- STU S/s
- 1x150 MVAR, 420kV Controlled Bus reactor(TCR) Bus Reactor at Solar Park-II - STU S/s

Estimated Cost of above reactive compensation is included in ISTS / system strengthening for conveyance of ISTS scheme as a part of Chapter-5.

(ii) Addressing Fault Ride Through(FRT) as well as Voltage Issues

To address Low/High voltage issues of RE rich states, during RE injection as well as to provide dynamic support during disturbances, dynamic VAr compensators like STATCOM, are proposed to be installed in pockets of group of RE farms at the following locations :

Tamil Nadu

(i) 220 kV Theni S/s : (+)100/(-)50 MVAR

(ii) 220 kV Kodikuruchi S/s : (+)100/(-)50 MVAR

(iii) 220 kV Udayathur S/s :(+)100/(-)50 MVAR

Andhra Pradesh

(i) 220kV Urvakonda S/s: (+)100 /(-)100 MVAR

Karnataka

(i) 220kV Chitradurga S/s: (+)50 /(-)100 MVAR

Gujarat

(i) 220 kV Radhanpur S/s : (+)50 /(-)100 MVAR

Maharashtra

(i) 220kV Vita/Pandharpur S/s: (+)50 /(-)100 MVAR

Rajasthan

(I) 220kV Tinwari S/s: (+)50 /(-)100 MVAR

J&K

(i) 220kV Budgam S/s: (+)125 /(-)25 MVAR

(ii) 220kV Udhampur S/s: (+)125 /(-)25 MVAR

Total Estimated Cost – Rs 704 Cr

(iii) Dynamic Compensation at 400kV level

Renewable Generation is characterized by virtues of intermittency and variability. 400kV High Capacity transmission Corridors integrated with such RE complexes, may encounter large variations in quantum and direction of power flow in different scenarios.

To address above aspects and maintaining grid stability, dynamic reactive compensation through Static Var Compensators (SVC) at following strategic interfacing locations is proposed.

(i) 400kV Kolhapur(PG) S/s: (+)400 /(-)300 MVAR

(ii) 400kV Udumalpet S/s: (+)400 /(-)300 MVAR

Estimated Cost– Rs 500 Cr

Note :
Above cost estimate is indicative only. In case of space constraints for terminating above bus reactors/dynamic compensators at STU Substations, the specific elements may be reviewed. STU may suggest any other suitable alternative/option in such situations.

However, exact location/sizing & type of the above proposed dynamic compensation shall be reviewed before actual implementation.

A Map showing location of proposed STATCOM of All India Map in above RE rich states by 2016-17 is placed at Fig-6-2:

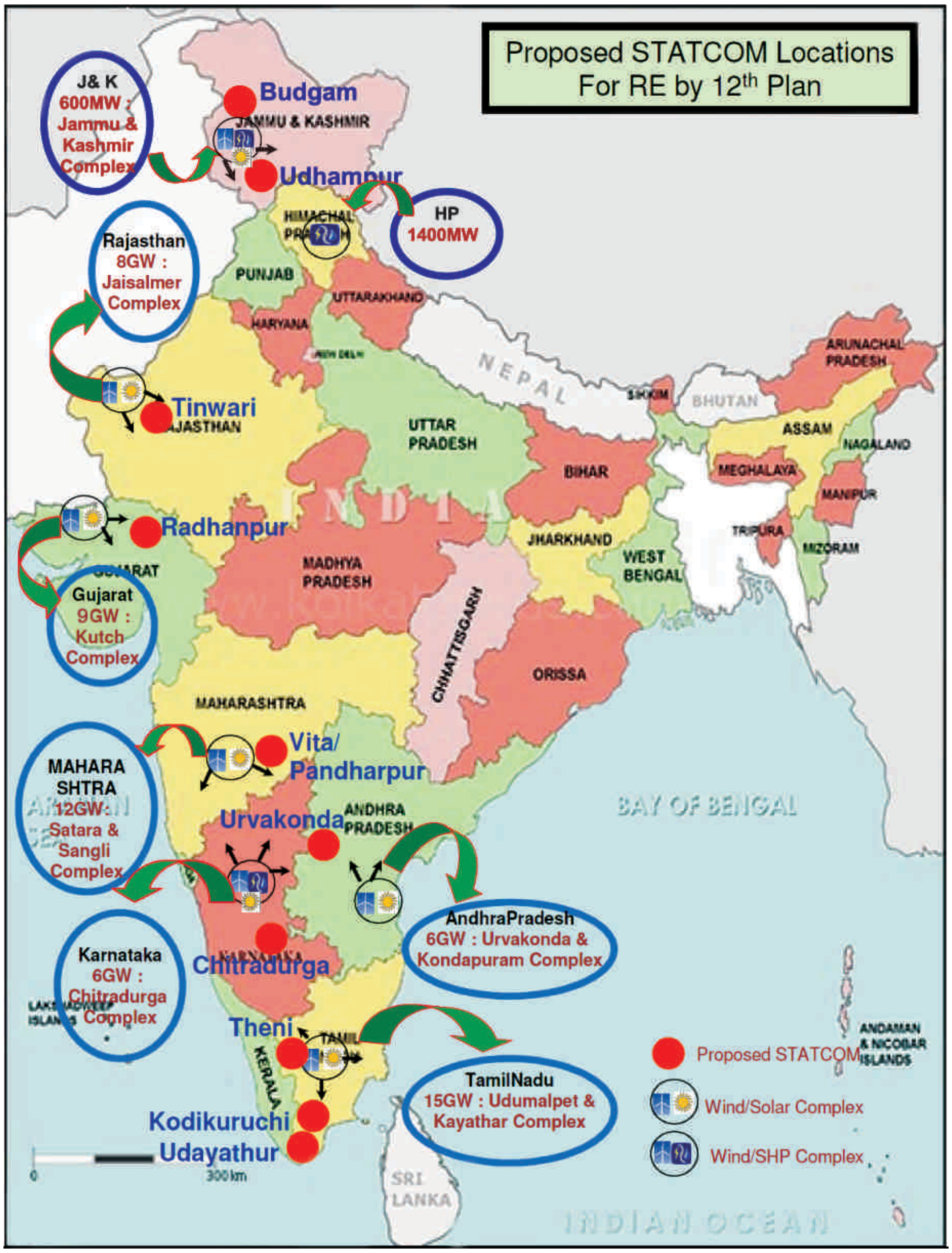

Figure 6-2: Proposed STATCOM Location

Chapter-7

Issues & Mitigating Measures in Renewable Integration

Amongst all Renewable energy resources, Wind Power is characterized by its intermittent & varying nature. Unlike the coal, nuclear and gas power plants on which the electric utilities have relied on for nearly a century, Wind farms and solar parks are not able to produce electricity on demand. Solar however as compared to Wind has relatively a certain pattern. Wind and solar power output fluctuate with weather conditions, creating two challenges for the electric system: added variability and uncertainty for grid operators and planners. Therefore with increased wind penetration, large variations in output may lead to influence in grid operation, stability & security as well as protection aspects.

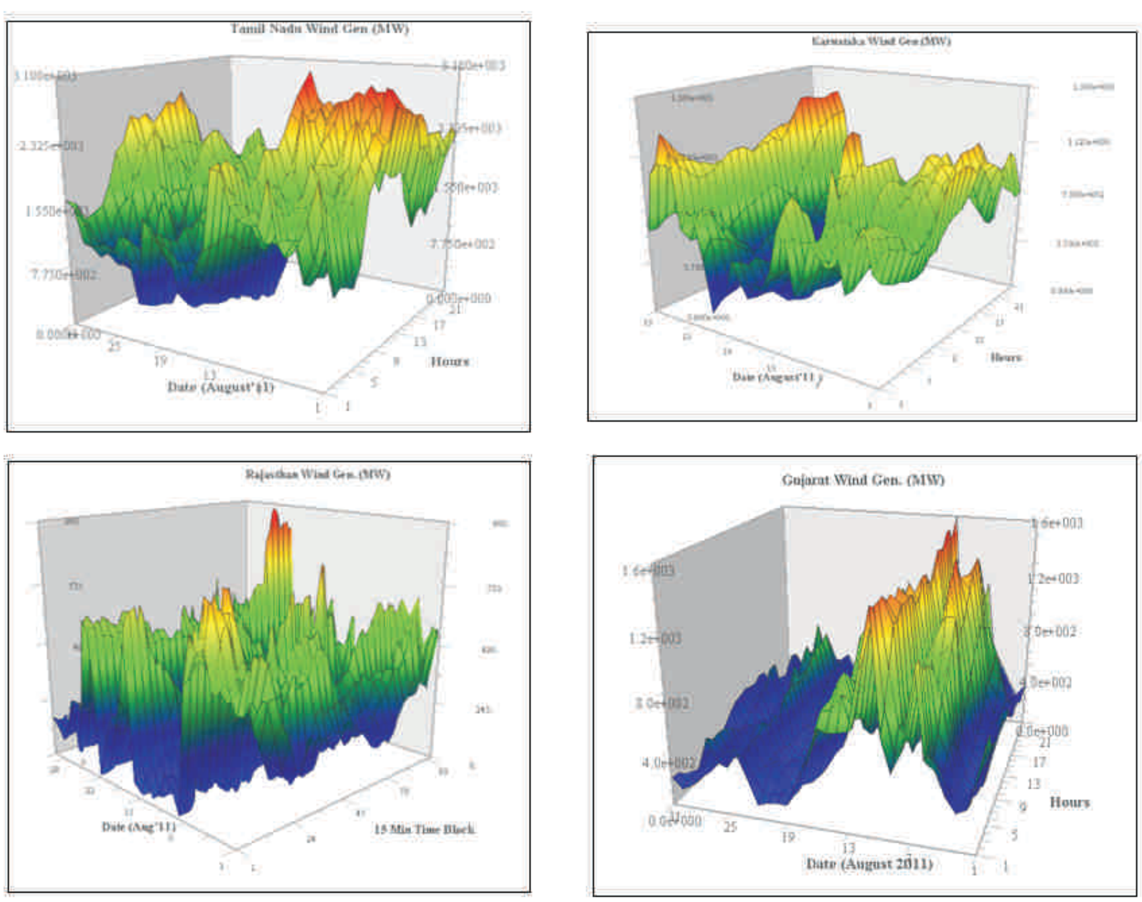

Figure 7-1: Variability of Wind Generation different States

Figure 7.1 shows the daily variability of a wind generation in Tamil Nadu, Rajasthan and Karnataka over the course of one month i.e. August 2011. (These plots are based on the daily wind generation data received from respective states.)

From a grid operator's perspective, the variability and uncertainty of wind and solar is analogous to customer demand, which also fluctuates throughout the day and over the course of the year. Variability arises because generation output changes according to the availability of the primary fuel (wind, sunlight), resulting in fluctuations in the electricity output.

Uncertainty occurs because the magnitude and timing of variable renewable output is not perfectly predictable, and the forecasts of this output may differ from actual conditions that occur in real time. Large sudden variations in wind generation can be observed from the wind generation plots which may create balancing challenges in grid operations.

The variability, in normal course, is addressed by scheduling the generation. Wind forecast have certain amount of uncertainty and are liable to deviate, to a large extent, from their predicted generation. These large deviations can cause congestion or supply side management issues in the areas where they are located. Large quantum of such sources feeding into grid poses new challenges because of higher unpredictability of net load variability and balancing such fluctuations.

Therefore large scale wind integration (LSWI) or High Wind Penetration (HWP) may lead to new requirements in the Power System to meet system security and reliability. Challenges due to LSWI/HWP are categorised into Grid Planning as well as Operation domains, for which details are given as under.

7.1. Challenges in Integration of Large Scale Renewables

7.1.1. Challenges in Grid Planning

- Large Scale Wind/Solar integration may introduce new patterns in the flow of power which may cause congestions in transmission & distribution networks in case of a conservative planning. Thus a balance has to be kept between the investment and system capacity to avoid congestion.

- Wind/Solar Plants have low gestation period than transmission strengthening, constraints may arise on account of large difference of gestations periods. Therefore, transmission system has to be undertaken well before the activities at such plants commence. Though it is not an issue in itself but if due to any reason, the plant fails to come up, the whole investment may go futile.

- Wind/Solar plants are generally located in remote/concentrated locations. The probability of such area not being a load centre is quite high. The power network is also weak in such area. Concentration of wind farms in one complex lack benefits of geographical diversity.

- Wind/Solar farms are known to be providing lesser grid support during system disturbances/exigencies than the conventional.

7.1.2. Challenges in Grid Operations

- Wind being variable & intermittent may cause severe stresses of the system and calls for suitable reserves/spinning capacities. With the lack of sufficient flexible support available from other conventional resources, it is very difficult to operate the system with large amounts of wind power.

- Concentration of such resources in one complex may cause supply management issues in case of sudden drop in wind generation.

- Wind plants generally are not capable to supply ancillary services like active power ramp up/down, reactive support to the system in a dispatchable, controllable manner like conventional generators.

- At present most of the wind plants are not capable to operate during severe voltage sags (Ride through capabilities) caused by system faults. In case this happens and large amount of wind generation trips in certain pocket, the system will be adversely affected magnifying the effect of fault.

- Some of the Wind turbines consume reactive power from the Systems, which can adversely impact the system during disturbances/high loadings unless suitable mitigating measures are taken.

- Due to lack of primary frequency response in the present Indian grid, system operators often find it difficult to maintain the system frequency within the permissible frequency band. The addition of large amount of wind (or solar photovoltaic solar) generation could potentially aggravate the problem. The concern is most acute during light load conditions with wind plants at high output, when fewer synchronous generators would be running, and overall grid inertial response will consequently be reduced.

- Harmonic voltage distortion at the connection point of Wind farms and solar parks are likely to increase due to the deployment of power electronic equipments for RE generation integration.

7.2. Mitigating measures in Integration of Large Scale Renewables

Large scale renewable integration calls for addressing numerous challenges. This imposes many technical/regulatory requirements and therefore need may arise for adoption of new technologies, equipment, control & protection, market mechanism, regulatory interventions as well as modifications in technical standards for connectivity.

Measures to address smooth integration of large scale renewables broadly includes forecasting of renewable generation, availability of flexible generation, robust transmission interconnection between various balancing areas, spinning reserves, demand Side Management / demand response, energy storage capacities and suitable market design for handling the reserve. Detailed operational, technical as well as regulatory requirements are described as under:

7.2.1. Operational/Technical Requirement of Large Scale Wind/Solar Integration

Successful operation of power system requires continuously achieving a balance between generation output and system load plus losses. This delicate balance must be maintained over periods ranging from instantaneous to years ahead. Such a wide boundary encompasses machine and system transient response, automatic governor action, Automatic Generation Control, and re dispatch, unit commitment, capacity procurement and infrastructure developments. The continuums is illustrated in the Figure 7.2.

High quality forecasting and confidence in the forecast are necessary to aid management of balancing energy from conventional plants. Availability of balancing plants in a range of sizes and time scales are critical resources. Use of markets and interconnections shall help to achieve energy balance.

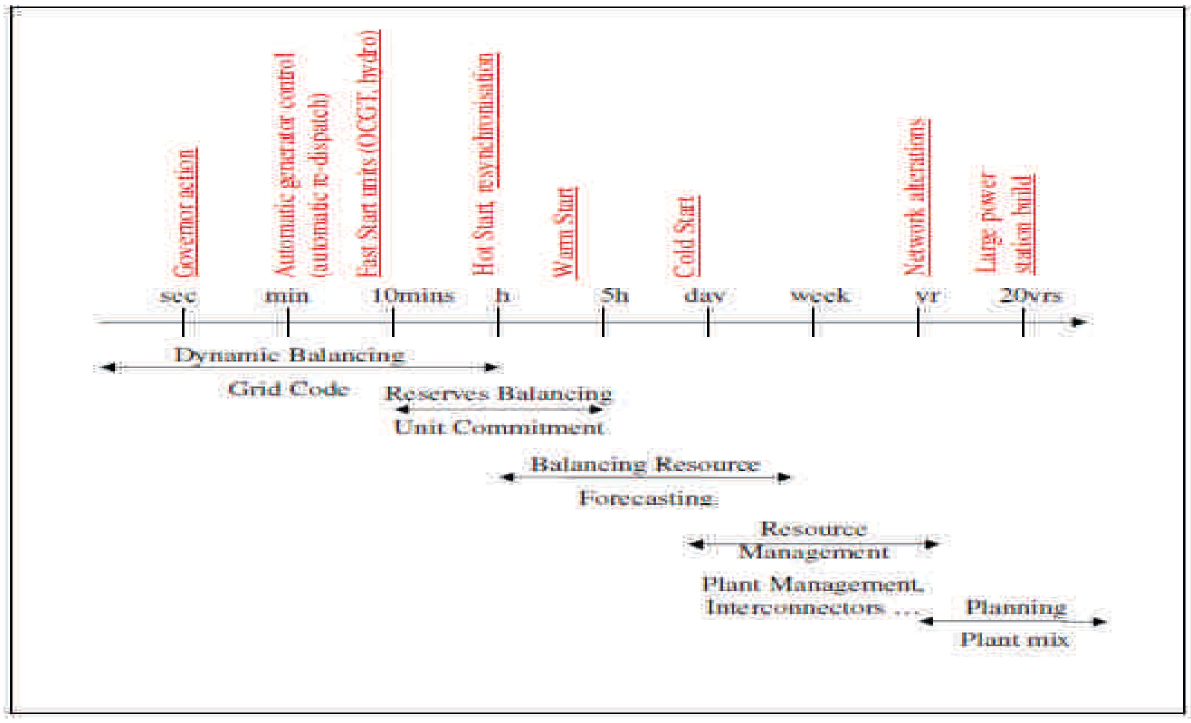

Figure 7-2: Boundary of various balancing resources

Balancing resources and other infrastructure include;

- Reserves like spinning/hot reserves, quick ramp up plants like pumped storage/gas turbines as well as frequency dependent loads in the system to address power-balance
- Flexible Generators which can respond to system requirement
- Demand Side Management & Demand Response
- Energy storage
- Strong transmission interconnections

- State-of-the-art in Centralized Forecasting centre and integration with SCADA through telemetry
- Suitable market design to handle reserves for power balancing
- Possibility must be explored to regulate or continuously control wind power through means like pitch control, wind farms SCADA etc.
- Deployment of synchrophasor technology i.e. PMUs/WAMS on pooling stations and interconnection with centralized control centre through Fiber optic communications for real time information, monitoring and control.
- FACTS devices such as STATCOM/SVC at strategic locations in the grid
- Relay Protection coordination

Figure 7.3 illustrates the impact that variability and uncertainty have on system control. Variability and uncertainty, including uncertainty caused by limited telemetry, grows with time and requires control of an increasing range of resources. The result is an expanding cone that must be filled with a sufficient quantity of flexible resources; otherwise power system reliability is jeopardized. As variability and uncertainty increase with increasing wind integration, the mouth of the cone widens, requiring additional system flexibility, either from existing resources or by addition of new resources.

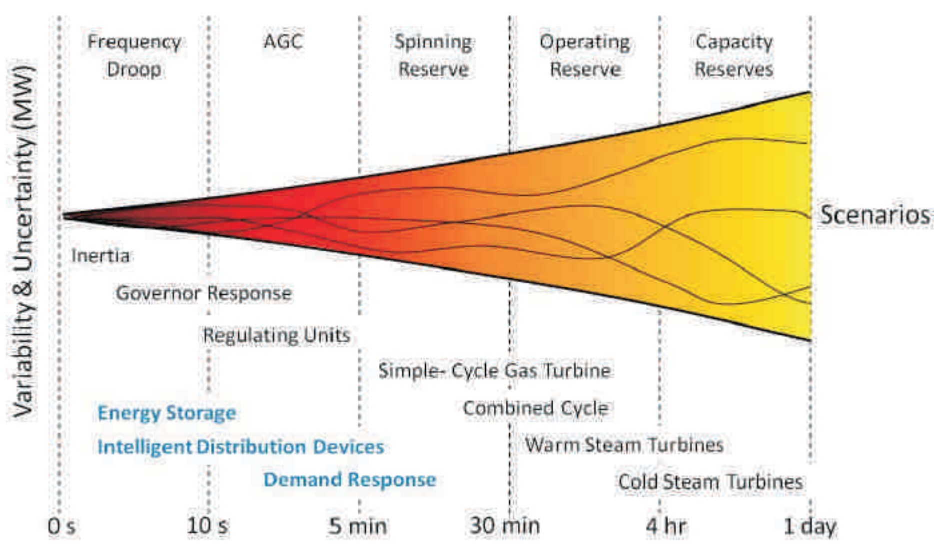

Figure 7-3: Growth of variability and uncertainty with time and associated resources and reserves available to maintain power-balance

While we are seeing an increase in wind integration, we are also seeing new technologies, such as FACTS devices, synchrophasors, energy storage, and demand response, which are accelerating the evolution of control systems. These technologies provide opportunities to improve visibility and control of the power grid, but also require new tools to manage and integrate a rapidly growing volume of data. At all times, the power grid must have a sufficient number of flexible and controllable resources to respond to variability. Though the magnitude of this variability decreases as we approach real-time operations, the number of flexible resources and their response capabilities (e.g., to support ramping) also decreases .

At present, flexible frequency band and availability based tariff (UI mechanism) plays a major role in balancing minute-to-minute variation in load and supply along with some reserve. These mechanisms also take care of unscheduled outages of a generator. In traditional practice, contingency reserve and operating reserve are used infrequently to provide replacement power. Variability of RE requires a reserve response that is both more frequent and bi-directional (i.e., requiring both curtailment and replacement power). With increasing integration of RE, we will see increasing variability of “net load” (load minus renewable generation), such as from the magnitude and duration of ramp events. Present practice of real time unbalance management may not be sufficient for handling large scale uncertainty in RE generation and may limit the integration of RE.

Details of the proposed key operational requirements are deliberated as under:

a. **Flexible Generation and Generation Reserves:**

To handle the intermittent & variable nature of renewable resources especially wind, fast response from flexible generation which can ramp up and down in response to supply variation is required. The mix of different type of generation with varying degree of response is desired so that at all point of time the generation of power could be matched with load. Since these power fluctuations vary from milli second to few hours or days, different types of generation reserves are used. System Reserves are primarily classified in three categories depending upon their activation time:-

Primary reserve/ Frequency response reserve: These are usually provided by units which are connected to the grid and can ramp up fast (within few seconds to a minute) in response of frequency fluctuations.

Secondary reserve or Spinning & non spinning reserves: Units which may or may not be on-line but provide ramp –up and ramp-down in 10-15 minutes.

Tertiary reserve: Units that are usually offline but require time varying from few hours to days for start-up or shut down.

These reserves are required to maintain the integrity of the system in case of imbalances between power consumption and power generation.

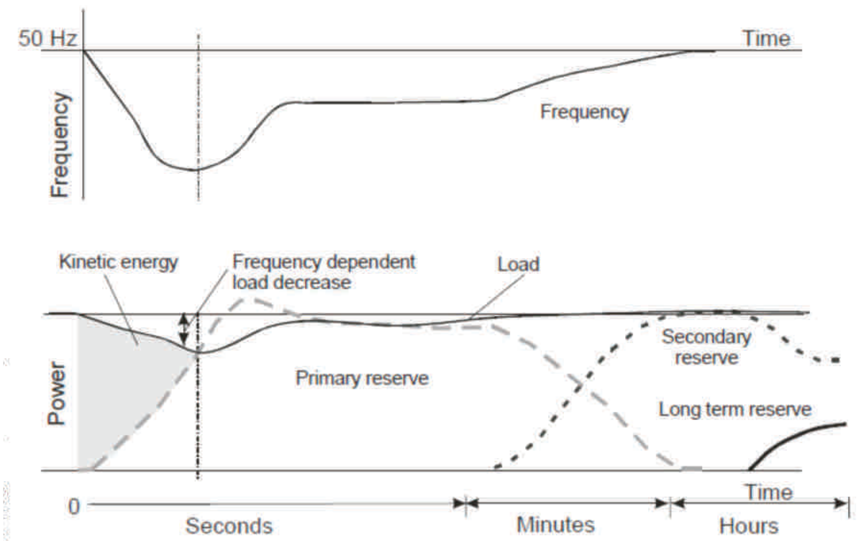

Figure 7-4: System Reserves

The experience of countries with higher penetration of renewable suggests requirement of long duration fast ramping spinning reserves. Such reserve comes from the plant like Hydro, Gas turbine or Thermal base load plant operating at part load. They are briefly discussed in terms of availability of their capacity into Indian Grid and meeting the reserve requirement of large scale renewable generation penetration:-

Hydropower Plant with Reservoir: - Hydro generating stations in India accounts for 20% of installed capacity. Hydropower plant with reservoir (storage hydropower), store water in a dam for use later during low water inflow condition. Therefore, power generation from these plants is more stable and less variable as compared to Run of the River (RoR) plants. They generate electricity when needed. They provide reserve capacity and can respond to load changes within seconds. In India, such power plants operate during peak hours to meet system peak demand.

Hydro Plants expected to respond to grid frequency changes and inflow fluctuations. They also provide fast ramp up and ramp down (order of few seconds) capabilities.

Pumped Storage Power Plant: **-** Pumped storage plants are not energy sources, instead they are storage devices. Water is pumped from a lower reservoir into an upper reservoir, during off-peak hours. The stored water is used to generate electricity during the peak load period or whenever there is demand. Because of their fast response and storage capacity, such stations proved to be an excellent reserve.

In India, pumped storage Hydro capacity in operation is only about 1550 MW (Kadamparai – 400MW, Purulia-900MW, Ghatghar – 250 MW). This provides approximately 3000 MW variation between peak and off peak. Another Pumped storage plant of capacity 1000 MW is under construction at Tehri. As a thumb rule a PSP need about 20% more power so as to operate at its rated capacity e.g. a 900 MW PSP would need about 1100 MW to pump up water into upper reservoir due to frictional and cavitations losses in the turbine, water conductor system and pump. Considering the large scale renewable integration, their requirement into Indian grid is much needed.

Hitherto considering their energy requirements and capital cost, it was felt that some regulatory interventions/policy measures are required for the financial encouragement of such projects, particularly regarding allocation of night power for pumping. The situation has undergone some change over the last few years with a vibrant Day Ahead Market (DAM) in electricity. Fig 7.5 and Fig 7.6 indicates the average minimum, maximum and average hourly Unconstrained Market Clearing Price (UMCP) in the India Energy Exchange (IEX) in the years 2010-11 and 2011-12. The DAM over the last two years has shown up a difference of the order of Rs.2 to Rs. 3 per unit between the night off peak hours and the evening peak hours.

Considering a Rs. 2 per kWh differential between the off peak hours and the peak, and assuming Rs. 2 per kWh night off peak rate, then

- Energy costs for 6 hours of pumping: 100 MW x 6 hours x Rs. 2/kWh =Rs. 1.2 million.
- Energy costs for 4 hours of generation: 100 MW x 4 hours x Rs. 4/kWh = Rs. 1.6 million.
- Net gain per day operationally: Rs. 0.4 million.

This works out to Rs. 10 crores per annum assuming 250 days per year of such operation on an average. This alone might not provide an adequate return to the pumped storage operator. The Regulator could come out with suitable guidelines for taking care of over-recovery or under-recovery through DAM. However, the important aspect here is that pumped storage is an alternative worth considering now.

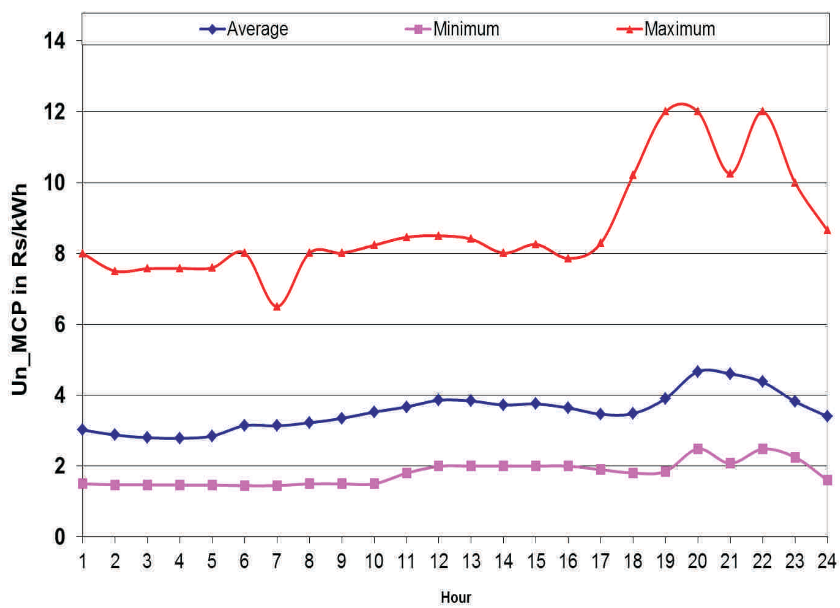

Figure 7-5: Unconstrained Market Clearing Price (UMCP) in IEX-2011-12

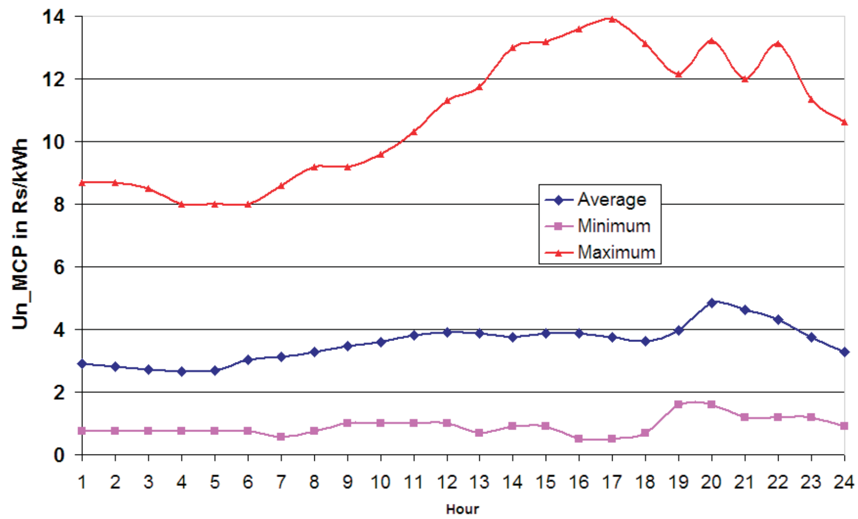

Figure 7-6: Unconstrained Market Clearing Price (UMCP) at IEX-2010-11

Revival of Srisailam LBPH(900 MW) and early commissi oning of Tehri PSP (1000 MW) would provide a total of nearly 6500 MW regulation in the Indian grid. Further several Pumped Storage Stations have been planned and developed in the Country which is not being operated in pumped mode due to commercial as well as technical issues. As per MSPGCL's petition bef ore MERC (94/2007), a list of such PSPs which are not being operated in Pumped mode as well as planned PSPs are enclosed at **Annexure-16** In addition there are many hydro plants which are feasible to be convertible into Pumped Storage Hydro Plant. Feasibility should be evolved to encourage participation of such Pumped storage plan for introducing more regulation into the grid with the increased Renewable penetration.

Combined cycle plants – Combined cycle plants which constitute 10% of the installed capacity in India presently are among the most flexible options to balance the variations. These plants are efficient and can ramp up and down quickly but they are expensive in terms of fuel/capital costs.

Thermal plants: - Coal plants accounts for 56% of total installed generation capacity. Since they have low variable cost and cannot be put on and off instantly (due to specific temperature and pressure requirement) they are made to run as base load plant. These plants are less flexible in response to load changes because of their longer startup (6 hrs when cold start-up & 4 hrs when hot startup) and shut down times. Their output has to be reduced gradually at 3 MW/min. Such plants can be used as reserve plants if they are running at or near Technical Minimum. However, in Indian context, the thermal generators are reluctant to operate at lower output because of reduce efficiency and no additional commercial benefit for reducing output.

One important change in the Indian thermal plant scenario is the establishment of super-critical coal fired units. In the 11th Plan, eight supercritical units have been synchronized (all in Western region) adding to a capacity of 5450 MW. In the 12 Plan, the coal fired capacity proposed to be added is 66,600 MW as per the draft National Electricity Plan out of which 42% or 27,900 MW would be super-critical units. In the 13th Plan, the coal fired capacity addition is expected to be 49,200 MW, all of which would be super-critical units. While the super-critical units are known for higher efficiency, a lesser known aspect is more flexibility in terms of regulating generation as compared to the natural circulation units having a boiler drum. Typically, a supercritical unit can operate at the designed super-critical steam parameters between 80-100% of rated capacity. Thus if we have about 70,000 MW capacity of super-critical units on bar at any point of time after the 13th Plan, 14,000 MW (20% of total available capacity) variation could be provided in flexible manner. This can be harnessed if the units are able to participate in the 'downward regulation' electricity market.

The utility of various types of generation, as reserves in Indian system to meet the demand, is depicted in Figure-7.6. It shows the behavior of different types of generation in the month of Dec'11 on all India basis.

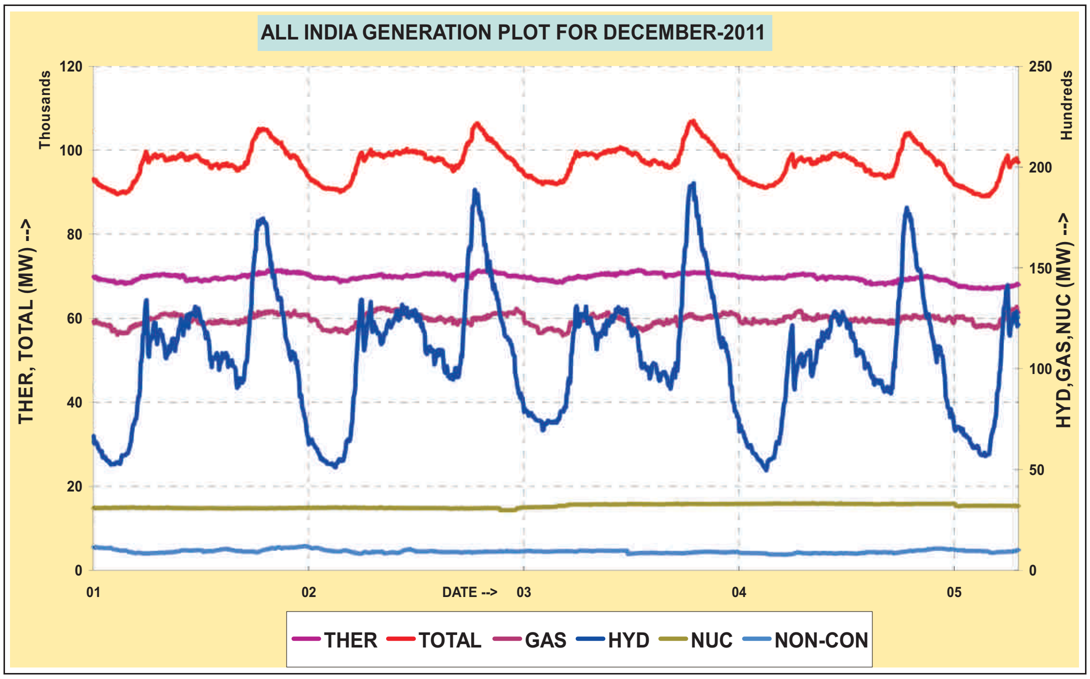

Figure 7-7: Participation of different resources in meeting demand

From the above figure 7.7, it may be noted that whenever the total generation (red color) dips, hydro plants (blue color) provides the support. Thermal plants (Magenta color) & gas plants (brown color) fail to provide immediate support whereas Nuclear plant (dark Green color) output does not respond to variation. Non-conventional i.e. wind in this case (Light blue color) has its own pattern which depend upon wind speed, direction etc.

It is observed that coal based plants act as base load generation source and hydro & gas provides peaking requirement. But due to high cost of gas, it is not a preferred reserve. Thus, pumped storage and reservoir type hydro plants remain the only viable reserve sources. With the expected large penetration of renewables, such reserves will also need to be encouraged & developed. Other option to maintain reserve is through thermal generating plants with suitable compensation mechanism.

Considering the importance of Hydro generation as a flexible reserve, it is proposed that adequate transmission infrastructure involving hybrid EHVAC /HVDC technology May be developed to harness Hydro Potential from the Hydro rich area such as north eastern region, Sikkim/ Bhutan. This shall facilitate in power balancing for grid support and smooth integration of large scale renewable. Implementation of ±800kV, 6000 MW Bishwanath Charyali (NER) – Agra (NR) HVDC transmission system for transfer of power from North Eastern as well as Sikkim / Bhutan to the load center is under progress. It is emphasized that more such green transmission highways between hydro rich pockets and major load centres are required to help large scale renewable integration.

a. Scheduling Philosophy

In India, decentralized control and operation have been adopted, which means that demand & generation is to be balanced at state level. The generation of each plant is scheduled on “day ahead basis” but they are permitted to dispatch as per the system conditions with the aim to bridge demand –supply gap. Indian Electricity Grid Code (IEGC) permits the frequency to fluctuate within a band of 49.5 Hz to 50.2Hz. The renewable generation presently constitutes about 12 % of total generation capacity in the country. The variations which are associated with such renewables do not affect the total generation in a substantial way. It is, therefore, easier to maintain frequency in the prescribed band through “frequency linked imbalances handling mechanism (UI)”. But as the penetration of renewables increases, the impact of their variability & intermittency may cause substantial variation in the total generation leading to wider load-generation gap. To handle these imbalances, forecasting and dispatching of renewable power will be an important aspect for their reliable & secure integration with the grid. Methodology for Wind Power forecasting is deliberated as under:

b. Wind power forecasting

Wind forecasting helps in optimization (Unit Commitment) and scheduling of conventional power plants (Economic Dispatch) & provides adequate caution or spinning reserve to balance out contingencies.

As per the Renewable Regulatory Fund (RRF) procedure of NLDC, forecasting should be an important requirement to avoid UI/RRC especially for wind. Since the wind generation has daily and seasonal pattern, the challenge before operator is its short term (upto few hours ahead) and next day forecast. Short term forecast helps in grid operations in managing reserve capacity dispatch in an optimal fashion, whereas the next day forecast will help in optimally scheduling the conventional generation.

Methodology of Wind Power Forecasting (WPF)

Advanced approaches for short-term wind power forecasting necessitate predictions of meteorological variables as an input using numerical weather prediction (NWP) models. Predictions of meteorological variables are converted to predictions of wind power production. Such advanced methods are traditionally divided into two groups. The first group, referred to as physical approach, focuses on the description of the wind flow around and inside the wind farm, and use the manufacturer's power curve, for proposing an estimation of the wind power output. In parallel the second group, referred to as statistical approach, concentrates on capturing the relation between meteorological predictions (and possibly historical measurements) and power output through statistical models whose parameters have to be estimated from data, without making any assumption on the physical phenomena

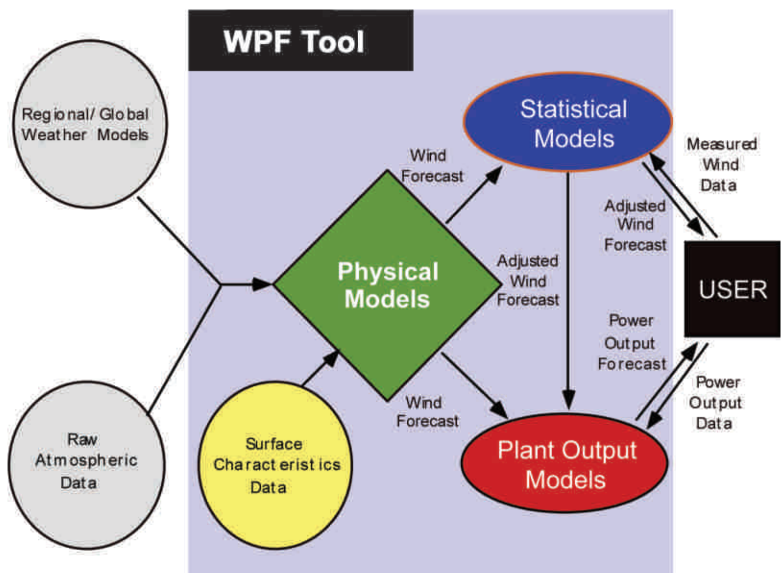

Figure 7-8: Methodology of Wind Power Forecasting

Around the world the wind power forecasting is done on three different time scales (1) very short-term (0-6 hrs); (2) short-term (6-72 hours), and (3) medium range (3-10 days). Forecast performance is expressed as a mean absolute error as a percentage of a wind plant capacity.

From the wind farm or solar power developer's perspective, forecast would greatly affect the revenue stream, particularly if the developer is made fully responsible for imbalance payments. Thus for the purpose of working out imbalances, the schedules should be based on the developer's forecast viz. a decentralized one. At the SLDC level many such decentralized forecast from different developers would be aggregated to work out the forecast for the state as a whole. The SLDC could run its independent algorithm to obtain the state level forecast. Such SLDC level forecasts are essentially for the purpose of system security viz. balancing actions, re-scheduling and network constraint mitigation. The RLDCs would aggregate state level forecasts while the NLDC would aggregate the regional level forecast.

Thus we need both decentralized and centralized forecasts, the former for commercial reasons and for which the developer is responsible while the latter is essentially for system security for which all the Load Despatch Centres (LDCs) are responsible.

In addition to above, with increasing solar penetration as well as intermittent/varying solar output in adverse weather conditions, Solar Forecasting is also very much essential.

a. Demand Side Management & Demand Response

Demand Side Management (DSM) or Demand Response (DR) through Smart Grid is another important option to increase the flexibility in accommodating the variable nature of large scale renewables. DSM/DR is designed to encourage consumers to modify patterns of electricity usage. In this way, DSM/DR helps to reduce the operational cost of renewable integration through measures such as load shifting and peak shaving thereby reducing the requirement of reserves. For this Smart Grid backbone system like advanced metering Infrastructure which includes provision for smart meters at the consumer premises, with two way (consumer and utility) communication and control features, time of use tariff mechanism to encourage consumers to shift their demand etc. need to be established.

b. Energy Storage

Energy storage technologies offer a great solution to accommodate large scale Renewable penetration and address its inherent issues like variable and uncertain output. Energy Storage can handle the excess availability of renewable during off demand period and energy support during peak hours just like another hot /spinning generation reserve.

Energy storage applications are classified into two broad categories: power applications and energy applications. Energy storage designed for power applications has the capacity to store small amounts of energy per kW of rated power output, and require high power output for relatively short periods of time (from several seconds to 10–15 minutes). Storage designed for energy applications has large energy capacity with discharge durations up to many hours.

There is a large variety of energy storage technologies either emerging or commercially available. Each technology has some inherent limitations or disadvantages that make each practical for a limited range of applications. The capability of each technology for high power and high energy applications is well defined and has been the subject of many studies. Utilities in several U.S. states have recently embraced new MW-scale energy storage technologies as part of their testing and demonstration projects to mitigate the effects of wind power variability.

There are multiple energy storage concepts employing various technologies that have wide ranges of capital and per-cycle costs, efficiencies, and energy densities (sizes and weights). List of such technologies are as under:

- Large Scale Batteries
- Flywheels
- Compressed Air Energy Storage (CAES)
- Thermal Storage (Molten Salt)
- Vehicle to Grid (V2G)
- Others like Super capacitors, superconducting Magnetic Storage, Hydrogen Energy Storage etc.

Comparison of above technologies with system ratings and grid support duration in terms of discharge time is depicted in Fig – 7.9 as under:

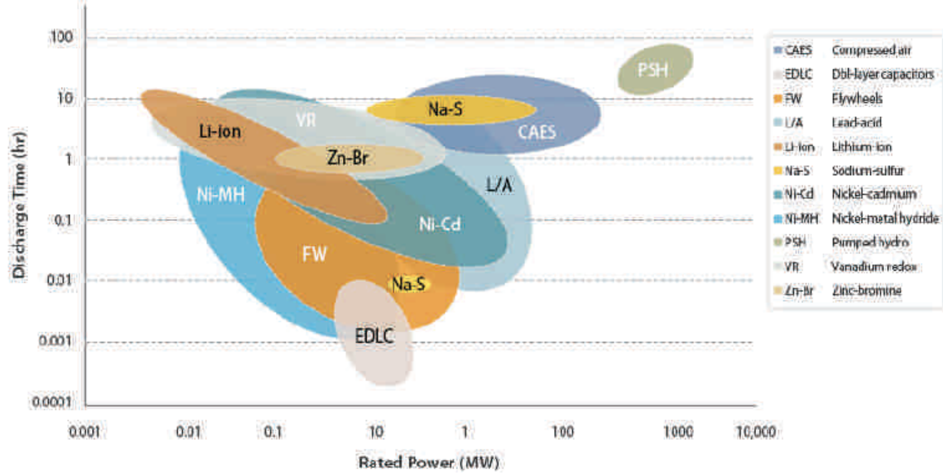

Figure 7-9: Comparison of Storage Technologies

A brief description on key Storage technologies is deliberated as under:

i. Large Scale Battery Storage

Several types of batteries are used for large-scale energy storage. Technologies that are used in field systems include lead acid, nickel/cadmium, sodium/sulfur, lithium-Ion, and vanadium-redox flow batteries.

Recently introduced Sodium-Sulfur (NaS) battery is the most mature high-temperature battery and has been demonstrated at over 190 sites in Japan totaling more than 270 MW with stored energy suitable for six hours daily peak shaving. The largest NaS installation is a 34 MW/245-MWh system for wind power stabilization in northern Japan (Fig-7.10). In the United States, several utilities have deployed NaS batteries for testing and demonstration purposes.

Figure 7-10: 34 MW NaS Battery Storage in Japan

ii. Compressed Air Energy Storage

Compressed air energy storage (CAES) technology is based on conventional gas turbines and stores energy by compressing air in an underground storage cavern. The CAES gas turbine uses 40% of the gas used in conventional gas turbines to produce the same amount of output power. This is achieved by combusting fuel after mixing it with stored air in the turbine

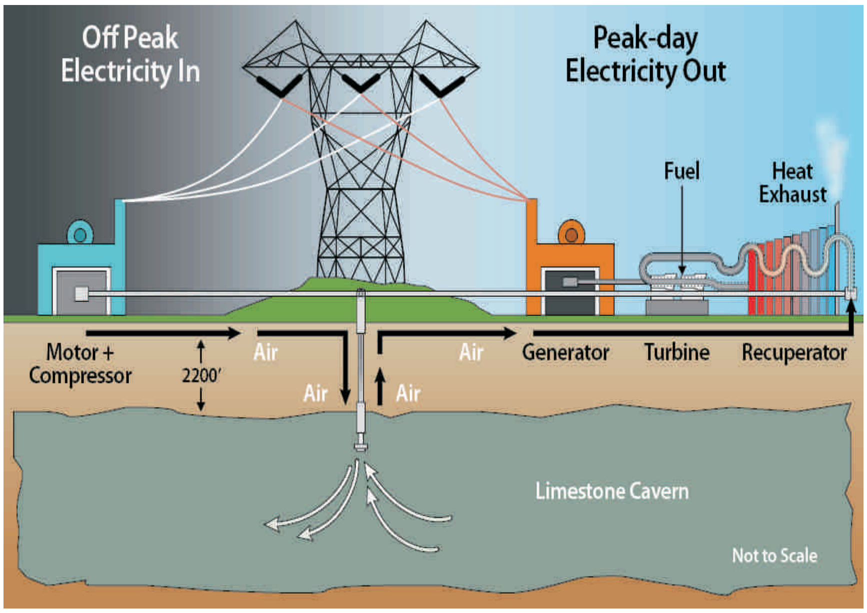

Figure 7-11: Compressed air energy storage (CAES) technology

Figure 7-12 : McIntosh 110 MW CAES, Alabama, US

The primary disadvantage of CAES is the need for an underground cavern created inside salt rock. It also relies on fossil fuels for operation. These factors may limit CAES applications in small island grids.

iii. Flywheel Storage

Flywheel energy storage consists of rotating massive rotor that is supported by magnetically levitated bearings and placed in a low vacuum environment to minimize friction losses. The rotor is connected to a motor/generator that interacts with the power grid via a power electronics converter. The flywheel system is a kinetic battery, spinning at very high speeds (up to 16,000 rpm) to store energy that is instantly available when needed. Some of the advantages of flywheels are low maintenance costs, long life (20+years or tens of thousands of deep cycles), and no environmental impacts. A layout of a 20 MW 5-minute flywheel storage plant by Beacon Power is depicted as below:

Figure 7-13: 20 MW (5 MWh), Stephentown, NY- Beacon Power Flywheels

iv. Thermal Energy Storage

Thermal energy storage (TES) is typically used for energy management applications like with Concentrating Solar Power (CSP) plants. In this application, thermal energy from the solar field is stored in some desired medium (steam or molten salt). This energy can be recovered at a later time of a day and used to generate electricity, turning this technology into a dispatchable source of energy.

It is to mention that economics of energy storage must be analyzed in comparison with a variety of competing technologies that also allow greater penetration of wind and solar, such as demand response, flexible generation, transmission optimization and improvements in operational practices of electrical utilities. In India, there is a need of application of such technology for smooth integration of large scale renewable penetration.

c. Market Design

Operating power system in a secure state is a prerequisite for power system operations. With the penetration of large wind generation the imbalances will go up which may require reserve generation to be put in and out on short notice. The imbalances handling mechanism (the frequency linked unscheduled interchange (UI)) is not adequate to handle such large imbalances as it does not encourage costly liquid generation like gas, LNG etc. based plants to participate during low frequency conditions and also no additional incentive is given to generator to reduce from schedule during high frequency condition.

Chapter 2 has already covered the Renewable Energy Certificate (REC) mechanism which provides an outlet to states to fulfill their RPO as well as enable treatment of 'green' electricity just like conventional electricity. Implementation of a pan India REC market is one of the major achievements of India in integrating renewable energy.

In the large scale renewable penetration scenario, requirement of balancing power, to take care of intermittency & variability of Renewable, by the end of 12th plan period, is assessed as under:

Resource	**Total RE Capacity by end of 12th plan (GW)**	**Availability (GW)**	
		Maximum Wind@70% Solar@80%	**Minimum Wind@25% Solar@0%**
Wind	46	32	11
Solar	10	8	0
Total	*56*	*40*	*11*

With this, it is estimated that there would be requirement for balancing of about 29 GW power by the end of 12th plan to take up RE ramp up/down phenomenon. Further in the peak hours, there would be additional demand of about 20 GW as compared to off peak hours by 2016-17. Considering both, there would be requirement of balancing of about 49 GW power. To cater to above requirements, availability of flexible generation like PSP (Hydro), Gas, Reservoir based Hydro by end of 12th plan is evaluated which shall help in meeting the balancing requirements to a certain extent.

Flexi generators	Installed * Capacity (GW) (by end of 12th plan)	Availability (GW)
Pump Storage Plant (Hy)	3.5	2
Gas Based Plant	19	11
Reservoir Based Hydro	28	17
Total	***50.4***	***30***

** Source- NEP(Generation)*

From above, it is estimated that flexible generation shall be contributing to about 30 GW balancing power. Therefore balancing power requirements for the remaining quantum i.e. about 20 GW, shall have to be catered through other flexible generation like super critical thermal generators & other thermal units as well as energy storage solutions. However, super critical & other thermal units to participate as flexible generation may need suitable commercial mechanism like downward regulation electricity market, ancillary service for peaking power etc. Emphasis must also be given to various Energy Storage Solutions by providing suitable commercial mechanism for its economic viability.

This section describes how strengthening various market mechanisms can help in integrating renewable energy generation into the grid in vast quantities.

The trading rules of electricity market design have four important features. These are scheduling & dispatch, imbalances, congestion management and ancillary services. Scheduling & dispatch, imbalances and congestion management is already implemented in India. Another change that has been introduced in the Electricity Market in the Country for promotion of renewable is the introduction of 15-minute bidding in the Power Exchanges (insteadof hourly bidding) with effect from 1st April 2012. It has already been mentioned that the generation from renewable energy sources is highly variable and more flexibility is needed on this account for the renewable energy sources. It is an established fact worldwide that smaller settlement period of 15-minute period helps in handling the variable generation from renewable sources.

In addition to above, introduction of the following market mechanisms would further help large scale integration of renewable sources of energy:

(a) **Flexible Generators:** A new product in the mark et may be developed where various generators with surplus capacity may submit their bid and based on their bid price during low frequency conditions they can be scheduled by the power system operator. Similarly the bid price shall be submitted by the generators which are ready to back down during high frequency condition and scheduled by operator during such high frequency scenarios. Regulator may define the bid-price band for the flexible generator. This will facilitate the optimization of generation and smooth integration of variable and intermittent renewable power.

(b) **Ancillary Market**: The Central Regulator is already in the process of introduction of Ancillary Services Market in the Country. This would help in harnessing services such as reactive power, Demand Response etc.

(c) **Evening markets**: More frequent operation of the Electricity Market through the Power Exchanges such as introduction of Evening Market as this would provide more opportunities to the market participants.

d. Automatic Generation Control (AGC)/Load Frequency Control (LFC)

For deciding upon requirement of Automatic Generation Control (AGC) towards renewable integration, calls for first understanding the present market mechanism adopted in India. India adopted the decentralized market mechanism considering its federal structure. Thus the state utilities have the entire freedom to dispatch their generation resources in whatever manner they deem fit. At the RLDC level, only the impact of such transactions on network loading is monitored and schedules revised accordingly. In addition to the decentralized market mechanism, India has also adopted a floating frequency approach (not insisting on 50 Hz constant frequency operation) and also not insisting on tight control viz. adhering to the drawl schedules. In case of AGC/LFC deployed in many systems worldwide, it would be seen that the objective of AGC is to minimize the Area Control Error (ACE) as well as bring frequency back to the normal values through corrective actions in the control area responsible for bringing about the frequency change. While attempt has been made in India to narrow the frequency band as well as restricting the volume of Unscheduled Interchange (UI) with a fair degree of success, constant frequency operation and tight control is still far away. Desirability of constant frequency and tight control is a matter of debate worldwide.

Against the above backdrop, AGC/LFC does not appear relevant in the Indian context. A frequency band of 49.8 Hz-50.2 Hz maintained through secondary and tertiary reserves tapped through the electricity market without a tight control is a more practical strategy which would also facilitate integration of renewable generation.

e. Real time monitoring system using Synchrophasor Technology

Renewable is expected to impact inter-grid power transfer capabilities to a large extent and significantly contribute in inter-area transfer capability. Due to its must run status, curtailment may be the last option for the system operator to control over-loadings. Wide area Special Protection Schemes (WASS) using Wide Area Monitoring System / Phasor Measurement Units at pooling stations and Phasor Data Concentrators at strategic locations integrated with control centers can help predict as well as can be used for controlling grid lines/ transformers being switched in and out. Installation of PMUs and PDCs at various locations along with optical fiber communication links integrated with REMC / LDCs are proposed for real time measurement and monitoring of system states.

7.3. Technological, Policy and Standard Requirements

I. Coordination of Wind Turbines (Repowering)

Due to technological advancements over the years, new generation of wind turbines are capable of grid support features like Fault Ride Through (FRT), handling frequency/voltage excursion, voltage control through reactive power control etc. Most of the existing WTGs don't offer such features. In future, both type of WTGs, which are quite different in technique and performance, shall co-exist.

For many wind turbine manufacturers, introduction of features like FRT and frequency capabilities in existing WTGs wind facilities is costly and challenging task. Therefore, incentives may be worked out to encourage modernization of existing WTGs. Such incentives are already being introduced in European countries to promote adoption of new technologies by old WTG owners so as to get the grid support during exigencies.

II. Regulatory/Connectivity Standard requirements

For connectivity of the renewable generation in ISTS network or to effect Inter-state transfer of power on long term basis, developer/utility shall have to apply to CTU as per CERC (Grant of Connectivity, Long-term Access and Medium-term Open Access in inter-State Transmission and related matters) Regulations, 2009. As per the Regulation, RE generator(s) having aggregate capacity of 50 MW can apply for connectivity in ISTS. However construction of dedicated transmission line to the point of connection shall be taken into account for coordinated transmission planning by CTU/CEA, for RE capacity of more than 250 MW. Considering the average capacity size of Renewable generation projects, the above regulation in particular may be reviewed so that more RE generation project can become part of coordinated transmission planning by CTU/CEA.

In addition, to facilitate the high wind penetration, regulations/connectivity standards are to be introduced to ensure that their large scale integration don't affect the power system security & reliability. Such regulations will also provide necessary guidelines to WTGs manufacturers regarding the features to be incorporated in their WTGs. Recently, CEA have come out with draft technical standard for grid connectivity which has included FRT feature requirements, frequency operating range, and reactive power support requirements by RE generators.

a) Voltage Fault Ride Through

In Induction wind turbines, disturbances and subsequent voltage dips (sags) near wind farm locations isolate them from the grid. At this moment, WTGs are very much required like any other generators to support the grid in terms of active/reactive power injection rather than isolate from the system.

Therefore, large increase in the grid connected wind capacity in power system necessitates that wind generation remains in operation in the event of network disturbances. For this reason and from the grid stability point of view, it is prudent that grid connected wind farms must withstand voltage dips to a certain percentage of the nominal voltage. Such requirements are known as Fault Ride through (FRT) or Low Voltage Ride through (LVRT) and they are described by a voltage vs. time characteristic denoting the minimum required immunity of the wind power station.

FRT requirements also include fast active and reactive power restoration to the pre-fault values, after the system voltage returns to normal operation levels. It may also require increased reactive power generation by the wind turbines during the disturbance, in order to provide voltage support, a requirement that resembles the behavior of conventional synchronous generators in over-excited operation. CEA draft technical standard for connectivity requires FRT compliance of generating station connected on or after 01.01.11. It stipulates that Wind generating stations connected at voltage level of 66 kV and above shall remain connected to the grid when voltage at the interconnection point on any or all phases dips up to the levels depicted by the thick lines in the following curve.

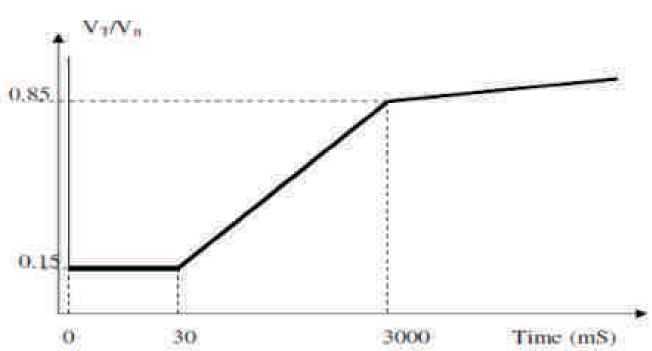

Figure 7-14: LVRT proposed under draft Standard for Connectivity

b) Voltage & Frequency Operating Range

In case of large scale wind penetration in India, it is required that suitable power frequency characteristics should be provided to each wind farm individually. Further, Wind farm should have a continuously acting voltage regulation system having characteristics like conventional AVRs or separate voltage, power factor/reactive power controller. Some of the aspects on above in draft connectivity standard requirement are as under:

(i)Frequency Control

The frequency of power system can be considered a measure of the balance or imbalance between generation and demand in the power system. Typically there is a dead band out of which generator is permissible to disconnect in the stipulated frequency range.

CEA draft technical standard for connectivity requires RE generator to be capable of operating in frequency range of 47.5 Hz to 52 Hz and shall be able to deliver rated output in the frequency range of 49.5 Hz to 50.5 Hz. Further, wind generating station connected at voltage level of 66 kV and above shall have facility to control active power injection in accordance with a set point, which shall be capable of being revised based on the directions of the appropriate Load Despatch Centre.

(ii) Voltage & Reactive Power control

Wind generator intermittency and reactive power requirement can lead to voltage fluctuation and grid disturbance. Voltage at the point of Grid connection depends upon the wind farm power station reactive power output, so wind farm are required to have reactive power compensation to be neutral at any operating point. Permissible system voltage variation +/- 5 % and frequency variation +3 % to -5%.

CEA draft technical standard for connectivity requires RE generator to be capable of supplying dynamically varying reactive power support so as to maintain power factor within the limits of 0.95 lagging to 0.95 leading and during voltage dips (under FRT capability), generators shall maximize supply of reactive current till voltage starts recovering.

Permissible Total Harmonic Distortion on voltage at point of common coupling is 5% with individual harmonic limited to 3%. In case of current harmonic total harmonic permissible is 8%.

III. Protection requirement

To integrate large scale distributed generation such as rooftop solar generation at consumer premise, net metering or separate export and import metering would be required. Traditionally, utility electric power systems were not designed to accommodate active generation and storage at the distribution level. A standard is required to define the technical requirement such as voltage regulation, synchronization, power quality (Limitation of DC injection, Limitation of flicker introduced, Harmonics), Islanding for interconnection distributed generation. Further, in order to facilitate net metering for Renewable generation, special protection arrangement is also required. Issues related to integration of distributed generation are as under:

- Reverse power flow – In the radial distribution network the overcurrent relays are usually unidirectional. When the renewable is connected, the power flows may be reversed which may require protection coordination.
- Synchronising Equipment to be installed at the consumers premises for smooth and successful synchronisation of consumer's generators with utility's grid. The customer system shall synchronise to the utility system while meeting the flicker requirements and without causing voltage variation.
- A line voltage relay to prevent the customer generator from being connected to a de-energised source. This relay is to disconnect the generator from a de-energized utility line and prevent its reconnection until the line is re-energized.
- Over current relays, under and over voltage relays and under and over frequency relays shall be installed. Lack of sustained fault current from the renewable sources may need special attention while coordinating the over current relays.
- The protection relay settings of utility system may need review in light of large amount of Net metered renewable power.

- Excessive Harmonic Protection : In accordance with IEEE 519, the total harmonic distortion (THD) voltage should not exceed 5.0% of the fundamental frequency or 3.0% of the fundamental frequency for any individual harmonic when measured at the PCC. The potential magnitude and frequency of the harmonics produced by a line commutated inverter could adversely affect other utility customers and, when numerous line - commutated inverters are installed, could adversely affect the utility's system. Therefore, a suitable excessive harmonic protection shall be installed.

  In order to address the protection issues suitable aspect may be introduced in CEA grid connectivity standard.

IV. Centralized Data Repository

Renewable capacity in the country is being added in a big way and in the years to come the growth is going to be still higher. Therefore, it is extremely important that a suitable institutional mechanism on the principles of a Registry is devised which may clearly contain the complete information about the renewable capacity, so that any techno-commercial mechanism involving a certain type/part of the capacity based on the date of commencing and/or any other suitable criteria can be implemented smoothly.

A central repository at Renewable Energy management center (REMC), which can work as a single source information repository & coordination point, is proposed to be established. All Renewable generators shall provide following data to the above repositories:

- RE Generation details like location (Latitude/Longitude), Voltage level/Step up transformer details & parameters, Machine type/details (reactance's)
- Shunt compensation details at plant level
- Dedicated connectivity line details/parameters
- Details/ size & Commissioning schedule of each renewable generation unit
- Details of metering arrangement
- Machine model related information for system studies (dynamic/steady state)

It is also proposed that central repository at REMC may also be connected with CEA/SLDC/RLDC for data exchange related to Renewable generators.

V. Implementation of connectivity transmission system for RE plants

In order to integrate large scale wind/ solar plants into grid, installation of matching transmission system between plants and nearest grid pooling stations (dedicated system) is essential.

Wind/Solar Plants generally have low gestation period as compared to implementation of such dedicated transmission system. Mismatch between development of generation project and its dedicated system shall affect power evacuation from RE plants. In view of the above suitable provisions may be made under the RE promotion policy to undertake development of the connectivity transmission system by a suitable agency. Considering this it is proposed that an integrated approach may be adopted to identify the location of various RE projects and their capacity so that development of dedicated system can be taken up well before the establishment of generation project.

In view of the above it is proposed that suitable provision may be made under the RE promotion policy to undertake development of connectivity transmission system for envisaged capacity addition by STU in consultation with an expert agency with technical expertise and sound project management skills.

7.4. Institutional Arrangements required for integration of wind

Technology and markets can work smoothly only with proper institutional arrangements in place. If we look at the developments in renewable energy development in India, private investment has been one of the major contributors to the progress in this sector. At present, wind Farm development is being undertaken mostly by Wind Turbine Manufacturers (*such as Suzlon, Enercon, Vestas etc.)* with the help of Investing firms and individual investors. These manufactures, on behalf of these Investors, also operate and maintain these wind farms in co-ordination with the concerned Distribution companies, STUs, SLDC and other agencies involved. Such manufacturers are generally called as 'Developers' in the Renewable Industry, the

Investing firms being called Investors. Though the Developers play a key role in developing the wind farms, their role is not formally defined in any policy document. As the wind industry is emerging as an alternative energy source in the power sector, there is a need to define the various terms like Developer, Investor and demarcate the roles and responsibilities of various agencies. Though the Developers play an important role in O&M of the Wind Farms, they are not a party to the PPAs, as PPAs are entered directly between Investor and Discom. As the Investors are large in number, fragmented and may not be technically equipped, it is difficult to implement any policy changes without the help of Developer. Therefore it is suggested that Forum of Regulators may formulate a Model PPA (tripartite) for the sale of RE power by the Investor and Discom involving the Developer.

Another change in the renewable landscape is the setting up of projects through the Independent Power Producers (IPP) route. With the IPP route, fragmentation of ownership is avoided and the plant can be treated just like any other conventional plant by the SLDC/RLDC for the purpose of scheduling, metering and accounting. The wind turbine manufacturer would in such cases be similar to an EPC contractor. Only issue that needs suitable treatment is that there could be dedicated lines set up by one IPP to the nearest interface point and later on more players might need the same corridor. In this case there is a need for a lead IPP who does co-ordination with the SLDC/RLDC for scheduling, metering, accounting and settlement on behalf of all the players connected to the dedicated system.

Further considering that grid parity in respect of renewable generation would be achieved in the coming years, intra state Availability Based Tariff (ABT) implementation is necessary so that forecasting, scheduling, metering, accounting and settlement system is well established and each agency discharges its role to perfection. In fact this aspect of institutional reform is very much essential for the integration of renewable energy resources.

Role and Responsibilities of Developer/ DISCOM/STU/SLDC (in addition to statutory responsibilities already provided in Electricity Act 2003, Grid Codes) is enclosed at ***Annexure-17.***

7.5. Activities by Statutory Bodies/Authorities towards implementation of measures to address issues

In order to facilitate implementation of above discussed measures for addressing the issues associated with large scale integration of renewable, it is proposed that following actions may be taken up respectively by the Regulator, Statutory Authorities/MNRE, CTU/STU etc.

S no.	Activities	Role
1	Strong Grid Interconnections (ISTS/Intra State) - Planning - Implementation	 CEA/CTU/STU STU/Tr. Licensee
2	Regulation for Flexible Generation, Ancillary Services and Generation Reserves - Market design	CERC/SERC CERC/SERC/POSOCO/CTU
3	Regulation for Demand Side Management / Demand Response including time-of-use tariff	CERC/SERC
4	Renewable Generation Forecasting - Policy formulation - Regulation - Implementation - Aggregation	 MNRE CERC/ SERC Developer SLDC/RLDC
5	Demand Forecasting	SLDC/State DISCOM
6	Energy Storage Technology - selection, design & implementation	CTU/CEA/POSOCO
7	Establishment of Renewable Energy Management Centre - Policy formulation - Regulation - Implementation	 MNRE CERC/SERC POSOCO/SLDC
8	Approval/Deployment of Real time monitoring system using Synchrophasor Technology	CEA/CTU
9	Formulation of technical Standards for Renewable Generation	CEA/CTU
10	Capacity Building – Providing training	CTU/POSOCO/SLDC/STU
11	Institutional arrangement (Roles & Responsibilities of Developers /DISCOM/STU/SLDC etc.) – incorporation in EA 2003	MOP/CEA
12	➢ Assessment / Reassessment of onshore and offshore wind Energy Potential and update of Wind Atlas ➢ Assessment / Reassessment of Solar Energy Potential and update of Solar Atlas	C-WET/IMD

Chapter-8

Renewable Energy Management Centre

8.1. Need for Renewable Energy Management Centre

To address the issues for grid integration of large scale renewable generation capacity, a planned approach is essential so as to ensure that power system safety, security and stability remains intact at all operating conditions. Therefore deployment of variable renewables viz. wind and solar power must be considered along with other key elements, such as RE forecasting tools, smart dispatching solutions, flexible generation with suitable market mechanism as well as robust transmission interconnections. Wind and solar, a variable, but predictable resources can be managed with careful day-ahead & hour-ahead scheduling. Load generation balance uncertainty introduces the need for additional reserves that supply the load in case of unpredictable reductions/increase in generation or increases/decrease in load. To deal with such variability and uncertainty in renewable generations, forecasts are crucial in the planning and operation process including resource or reserves management.

Prevailing practice on renewable dispatch in India is as under:

- Renewable Energy Generators are either predicting day-ahead energy schedule separately or not predicting at all. Further there is very little coordination between dispatcher and generators for such forecasting. System Operators are not getting the forecasted data in totality. At the most, total energy output during the day is being forecasted (in MUs) instead of power in MW with respect to time scale, which is not helping system operator in scheduling dispatch of renewable power in 15-minute time block.
- RE generators have gradually started equipping themselves with forecasting technologies. IEGC allows up to 30% deviation from schedules to wind generators without any implications on generators and Solar is not to be

penalized for any band of the deviations. Onus of deviation within 30% of schedule for wind is on host state/purchasing state or to be socialized through Renewable Regulatory Fund (RRF). As there is 30% deviation allowed in case of wind as well no such restriction on Solar, RE generators do not have any incentive for using advanced forecasting system. Definition of 'forecast errors' also vary. While most of the forecast service providers define 'forecast error' with reference to 'installed capacity' of wind farm, the commonly understood definition in India is with reference to the power output forecasts.

- Presently, most of the renewable generations are not telemetered to Load Dispatch Centre, resulting in day to day problem in managing load – generation balance. Availability of Real time RE generation data is essential for grid security.

Keeping in view the expected increase in renewable penetration into grid, there is a need to equip Power System Operators with additional tools along with real time data of renewable generators and associated components to mitigate the above issues. At present the SCADA/EMS system available at SLDCs and RLDCs is under up gradation, the up graded SCADA system shall have the capacity to accommodate the data of renewable generators as well as other related power system components. The following features in SCADA shall enable capturing the real time data of renewable generators:

- Data exchange of Real –time data of Renewable Generator Control Centre either on ICCP or IEC 60870-1-104 Protocol.
- CIM model exchange with Renewable Control centre for Transient applications and Dispatcher Training Simulator (DTS)

Considering the unique characteristics of Renewable especially Wind in terms of intermittency & variability, its geographical dispersion, connectivity at distribution as well as transmission voltage level, requires real time monitoring of generation as well as study of its dynamic impact on the system.

In view of the above a separate hierarchy of Renewable Energy Management Center (REMC) is proposed which will work in tandem with SLDC / RLDC / NLDC for maximization of Renewable Energy generation and integration with main grid without compromising security and stability of power system. Such centralized centers shall not only be cost effective but also help in developing necessary skills for Renewable Energy forecasting and dispatching in coordination with distributed RE Generators. States utilities should also take suitable measures for installation of the interface meters at the interconnecting points for the energy accounting.

All Renewable Energy Management Centers (REMCs) at State and Regional level are proposed to be co-located with re spective Load dispatch centers (LDC) integrated with real time measurement and information flow. All the REMCs shall coordinate as per the structure shown in Fig-8.1 for discharging various functionality related to management of renewable energy generation. The typical data flow for various functionalities envisaged at the Renewable Energy Management Center is given in the fig. 8.1 :

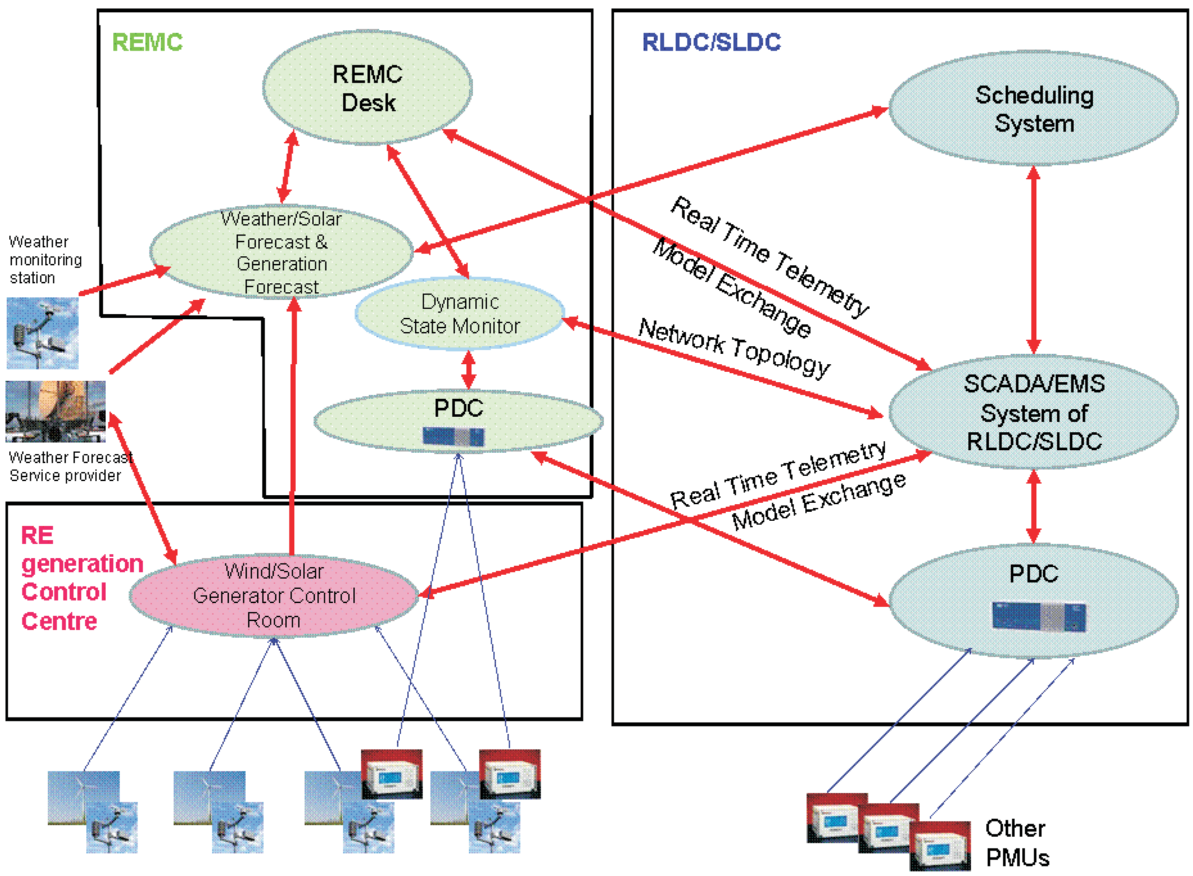

Figure 8-1: Typical Renewable Energy Data Flow

In case of large scale deployment of Renewables generators in the Grid on distribution system, the bidirectional flow of power would be required in the distribution network, therefore for power system modeling and metering suitable for bi-directional power flow would be required.

Since Renewable Energy management Centers are supposed to be co-located in the existing Control centre of Load Dispatch centre, these can be located in the existing control rooms with some modifications, wherever required. A separate desk shall be identified in the existing Control room of Load dispatch centers with a separate Video Display wall. Further Panel for servers for this REMC is proposed to be kept beside the SCADA/EMS servers. Under upgradation project of SCADA/EMS, Backup control centres are also being established. Since this is a replacement project additional space is being created at the control centre. Some of the SLDCs are also making new Control building setup under this project, the provision for additional space for URTDSM and REMC desk can be made in the design stage of the building itself. Further, a full-fledged control center may be required at national level which may be located in the existing NLDC building on a separate floor or adjacent to NRLDC building.

Major renewable capacity addition in the form of Solar & Wind during 12th Plan is envisaged in seven (7) renewable potential rich States viz. Tamil Nadu, Karnataka, Andhra Pradesh, Gujarat, Maharashtra, Rajasthan and Jammu & Kashmir. As discussed earlier, in some of the States proposed installed renewable capacity would be high and would results into penetration level about 30-40%, this may pose a great challenges to system operator for smooth integration of RE along with maintaining grid reliability and security. Therefore, to begin with it is proposed to setup REMC in above mentioned seven (7) states viz. Tamil Nadu, Karnataka, Andhra Pradesh, Gujarat, Maharashtra, Rajasthan and Jammu & Kashmir to be integrated with respective SLDCs. Further, REMC may be set up in the regions with high level of solar and wind generation at the three regional load dispatch centers namely, Northern, Western and Southern regions. At the national level REMC would also be provided. These REMC at SLDCs, RLDCs and NLDC has to be integrated with corresponding SCADA/EMS system for scheduling, load forecasting and other necessary functions required for load dispatching. All the REMCs and generating stations shall be time synchronized with GPS. Subsequently, with the increase in renewable penetration level in other States and Regions, more REMC may be established in the respective States. However similar Centre shall have to be provided in other SLDCs and RLDC progressively. Further these REMCs shall be equipped with load forecasting, scheduling and real time dynamic performance evaluation tools. However, the SCADA/EMS system needs to be supplemented by WAMS (Wide Area Measurement System) to capture the dynamic behavior of system due to integration of renewable in real time.

Renewable is expected to impact inter-grid power transfer capabilities to a large extent and significantly contribute in inter-area transfer capability. Due to its must run status, curtailment may be the last option for the system operator to control over-loadings. Wide area Special Protection Schemes (WASS) using Wide Area Monitoring System/Phasor Measurement Units can help predict as well as can be used for controlling grid lines/ transformers.

It is also proposed that the PMUs shall be installed at strategic locations, which shall provide the real time data to dynamic performance tools and supplements the functionality of EMS.

Under URTDSM (Unified Real Time Dynamic State Measurement) the PMU data acquisition system is being established which will provide the PMU data to the SLDC, RLDCs and NLDC. Provision to accommodate additional PMUs also required to capture the dynamic phenomenon due to renewable generators. These PMUs shall require Fiber Based communication which is also considered in the scheme.

8.2. Weather Monitoring Station (Mesonet)

Most of the existing Automatic Weather Stations (AWS) are too sparse and report too infrequently for mesoscale weather prediction. These stations are typically spaced 50 to 100 Km. apart and report only hourly on most occasions. “Mesoscale” weather phenomena occur on spatial scales of tens to hundreds of kilometers and temporal (time) scales of hours. Thus, an observing network with finer temporal and spatial scales is needed for mesoscale research. This need led to the development of the mesonet. For reference, a mesonet is a densely packed array of live weather observations placed around the area of interest that is used to monitor weather conditions prior to their arrival on site. A network of weather stations is typically placed in the direction of prevailing wind based on historical weather patterns, but it is often necessary to place instruments around an entire region of interest when weather patterns are not climatically unidirectional.

For the purpose of RE forecasting, in addition to existing weather stations of various agencies, deployment of specialized weather stations (mesonets) in wind producing / Solar park areas of India would be necessary. The sensors are mounted to 10 meter towers and existing hub height towers (50-100m). Some new towers may have to be built in some cases, as determined in future site surveys.

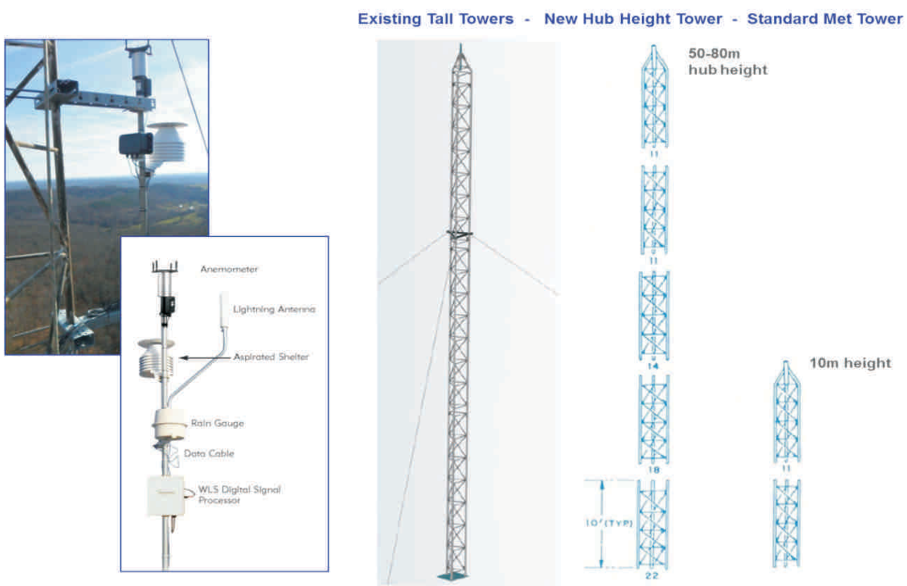

Figure 8-2: Weather Monitoring Station

The wind power forecasting models improve with every single observation point added to the network and there is no set scientific method that determines mesonet density in support of this operational process. However, industry best practices exist to help ensure successful outcomes.

The sensor includes the following sensor types and their respective specifications. The stations report data that provides certain weather parameters.

Wind Speed/Direction	**Res 0.1 m/s** 0-70 m/s 0.1 m/s (30 m/s) ± 3% (70 m/s)	➢ Wind speed ➢ Wind direction ➢ Outdoor temperature ➢ Auxiliary temperature ➢ High for the day ➢ Low for the day ➢ Outdoor temperature rate change ➢ Wind chill/Heat index ➢ Dew point ➢ Wet bulb ➢ Relative humidity ➢ Humidity change rate ➢ Min/max humidity ➢ Barometric pressure ➢ Barometric pressure rate ➢ Min/max barometric pressure ➢ Average wind speed ➢ Highest gust for the day ➢ Precipitation rate and type ➢ Daily, monthly, yearly rain ➢ Solar radiation ➢ Rain/hour rate ➢ Max rain rate/hour ➢ Light intensity ➢ Max light ➢ Last light ➢ Total (CG & IC) lightning (Option)
Temperature	-50 to +65 ˚ C ± (0,1 +0,05 t)	
Relative Humidity	0% - 100% ±3.5% 0.01%	
Atmospheric Pressure	500 - 1100 hPa 0.1 hPa ±0.3 hPa	
Precipitation Rate	Res 0.25 mm (+/-1% @ 25 mm/h)	
Solar Radiation (Option)	300-1100 (90%) to 1100 W/m^2	
Lightning Detection (Option)	Yes	

8.3. Deployment of Weather Stations in RE rich states

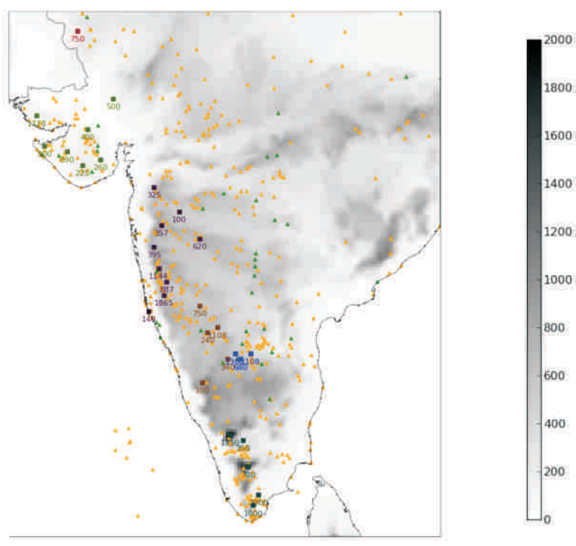

Figure 8-3: Current Wind Monitoring Stations operated by CWET

It is proposed that the weather stations must be deployed at the surface as well as at hub heights for wind monitoring. However for Solar, only surface weather stations are required. Therefore in case of wind & Solar parks in one complex, surface weather stations needed for wind shall be sufficient. However in case on only Solar projects in one complex, Surface weather stations shall be required.

All stations will be deployed in strategically selected areas so as to maximize the impact on the wind/solar power forecasting models. For planning purposes, the following is proposed.

- Guidelines for new weather station deployment for Wind farms:
  - Average Density of Surface AWS: 6km^2
  - Average Density of Hub Height AWS: 11km^2
- Assumptions made to estimate the number of stations for wind:
  - Average Production of 9 MW per km2
  - Average Wind Farm Capacity: 100 MW
- Therefore based on above assumptions following is required for Wind farms:
  - One Hub height AWS per Wind Farm
  - At least 2 Surface Weather Stations per Wind Farm

Further, one Surface weather stations per solar park (which is not in location of wind complex) is also considered. Details of AWS required for each complex is enclosed at ***Annexure 18***.

Table 8.1 : Estimation of Wind/solar Monitoring Stations

State	Surface AWS (nos)	AWS on Hub height Towers (nos)
Tamil Nadu	268	120
Andhra Pradesh	112	54
Gujarat	163	78
Maharashtra	226	111
Rajasthan	88	40
Karnataka	101	47
Jammu & Kashmir	1	1
Sub total	***959***	***451***
Total	***1410***	

8.4. Functionality of Renewable Energy Management Centre

It is proposed that REMC may have following responsibility areas:

- Forecasting of RE generation in jurisdiction area on day-ahead, hour-ahead, week-ahead, month-ahead basis.
- Real time tracking of generation from RE sources and its geo-spatial visualization.
- Close coordination with respective LDC for RE generation and control for smooth grid operation.
- Single source information repository and coordination point for RE penetration.

- On-line Dynamic security Assessment tool like Dynamic performance, Harmonic performance.

Functionalities for the key responsibility areas are deliberated as under:

8.4.1. Forecasting

Forecasting of Renewable generation is possible to a great degree of accuracy with proper tools. The tools shall have inputs from Meteorological agencies, Statistical probability techniques, historical inputs for localizing forecast, advanced modeling capabilities, real-time data assimilation and statistical post-processing technologies etc.

Local weather data is critical input for forecasting of RE generation output for the coming day/days. Wind Turbines are deployed with inbuilt wind measuring devices which continuously monitor wind speed, wind direction and ambient temperature. This information is fed to Wind Generator controller for adjusting pitch of blades and direction for optimum power generation. Generally the entire turbines in an area are connected with optical fibre network. Electrical and weather parameters of these wind turbines are brought to CMS (Central Monitoring Station) located in same area by the wind turbine manufacturer or developer. Many of the wind power developers are routing these data to their Main Control Centre via suitable communication medium like VSAT, fibre optic. This info rmation can also be brought to REMC via fiber optic link to act as input to Wind Energy forecasting module in Renewable Energy Management Centre. In addition, if weather stations are installed near wind farms, then data of same may also be routed to REMC via same communication link.

In Solar Power Plants also local weather monitoring sensors are to be installed. This would regularly monitor ambient temperature, luminosity, sun timings and humidity. This data can also be telemetered to REMC as input to Solar Energy forecasting module.

Presently forecasting tools are commercially available, which forecast power plant output with look-ahead periods ranging from minutes to days. Several commercial software are available. These software tools help in forecasting RE energy outputs by following ways:

- Take weather data both local and global as input. Based on historical weather input the wind flow pattern / solar irradiation is calculated for the RE location from hours to days with time resolution upto 15 minutes.
- Based on predicted weather and RE model renewable energy generation shall be forecasted with different confidence intervals.
- Ramp event is predicted in time, duration, amplitude and rate of increase/decrease
- Tools also take inputs from real time generation data for improvement in accuracy level of its statistical model tuning

8.4.2. Nowcasting

Nowcasting comprises the detailed description of the current weather along with forecasts obtained by extrapolation for a period of 0 to 6 hours ahead. In this time range it is possible to forecast specific weather events such as individual storms with reasonable accuracy. Forecasting tools using the latest weather data which are available through weather sensors/stations, meteorological department or any other agency shall be able to make prediction of the local events present in a small area such as a city and make a forecast for the immediate future hours. By this technique REMC may predict Solar / Wind energy output in short terms and SLDC can prepare for required ramping facilities.

8.4.3. RE Generation Control & Dispatch

Power System operators monitoring complete Power Grid may have urgency and priority to manage Grid in totality and therefore it will be suitable to have separate Control Centre desk for Renewable Energy generation which will not only keep track of generating parameters of each RE Generating plant in its area but also coordinate with Power System operators at State/Regional level for grid security and smooth operation of RE generators.

RE generators are generally connected to respective control centers of the developers (viz. generation control center) from where developers keep track of their RE farms by monitoring various parameters and issuing control actions, in case need arises. Therefore such generation control center (GCC) may act as interlocutors between RE generator and REMCs. GCC and REMC may be connected through reliable communication system like fiber optic so that necessary instructions issued by REMC to GCC for production regulation/curtailment or any other function for a particular RE generator may be adhered at the earliest.

8.4.4. On-line Dynamic Security Assessment

Online Dynamic Security Assessment tool (DSA) helps in assessing system stability in real-time system condition. Online DSA is essentially a technology that takes a snapshot of a power system condition, performs the desired security assessment (including determination of stability limits) in near real time, and provides the operators with warnings of abnormal situations as well as remedial measure recommendations, if applicable.

An online DSA system may consist of up tosix main functional modules, for which details are as under:

1) **Measurements**: This module obtains the real-time system condition. This function is also part of the Energy Management System (EMS). While measurements from traditional SCADA systems can generally meet online DSA input data requirements; the latest data collection technology-e.g. PMU-based-WAMs can provide much better and more accurate system conditions. This can greatly improve the quality of the online DSA application

2) **Modeling:** This critical module assembles a set of models suitable for DSA. Some functions in this module (such as the state estimator) are also part of the typical EMS, others may be functions specific to online DSA

- Creation of modified system conditions if forecast or study mode analysis is required
- External network equivalence
- Modeling of important equipment (such as wind turbines) and the associated control & protection systems, including reactive power compensation in addition to the conventional models required for offline planning studies
- Contingency definition that considers real-time node and breaker configuration

and special protection system arming status

- Corrections and enhancements to the system model from the state estimator, e.g., addition of missing system components (such as station service loads), merging or splitting generator units, correction of in-consistent data (such as generator reactive capabilities) and so on.

3) **Computation**: This module is the computation engine of DSA, which handles two types of problems associated with DSA:

- Steady state system performance, such as thermal, voltage deviation, and slow-voltage stability
- Electromechanical transient performance (from a few seconds up to 20 s, following a contingency) such As fast-voltage stability, transient stability, small signal stability, and frequency stability.

Three main analysis options are usually required to investigate these problems:

- Security assessment of the base-case conditions (for real time, forecast, study, and other purposes) determination of the stability limits
- Identification of applicable remedial actions to handle insecure contingencies and to increase the stability limits, if necessary.

In addition to the above analysis options, advanced computational techniques are often used to meet performance requirement, e.g., contingency screening techniques are used to quickly filter out noncritical contingencies from detailed analysis, and distributed computation techniques perform an analysis in multiple available CPUs to improve computation speeds.

4) **Reporting and visualization**: This module includes display and visualization of DSA results as well as reporting of the operational status of the DSA system. Considerable attention has been paid to the visualization of DSA results. This not only focuses on the information to be presented but also on how it is presented. Web-based and geographical display methods are becoming more and more popular.

5) **Control**: In this module, various controls(such as generator rejection) are used

as remedial actions to ensure system security. Online DSA can be integrated with such controls to provide settings calculated in real time and even to send the arming signals when the system condition requires such controls to react. This area is considered one of the main attractions of online DSA.

6) **Other functions**: This module collects functions to improve the reliability, usability, and applicability of the online DSA system. Some of these play important roles in the deployment of online DSA, including:

- System security, to be compliant with a specified set of cyber security standards
- Data archiving, to provide history Cases ready for use in study mode
- Integration with other analysis functions (such as oscillation monitoring based on PMU measurements) to extend online DSA functionality.

8.4.5. Performance Evaluation

REMC shall have Key Performance Indices measurement and reporting tools which will help in gradation of RE generators by evaluating their performance. Further they may be advised in timely manner to improve performance.

8.5. Proposed Information Flow System

RE generation is distributed in a very large area compared to conventional Generators. RE generation consist of multiple generators of small capacity ranging from few kW to few MW as opposed to conventional generation of 100's of MW of single unit.

The data acquisition system of RE generation is fairly well established and consists of multiple sensors interconnected through Wireless in Local Loop (WLL) / Low Power Radio (LPR) and communicating to Control Centre over one of many GPRS communication. However, these Control centers may require for additional features for exchange of real time data, Power system modeling, weather forecast, generation forecast etc as per the IEC standard IEC 61400-25. The implementation of the IEC 61400-25 series allows SCADA systems to communicate with wind turbines from multiple vendors. The application area of the IEC 61400-25 series covers components required for the operation of wind power plants, i.e. not only the wind turbine generator, but also the meteorological system, the electrical system, and the wind power plant management system.

It is proposed to use same Data acquisition System (DAS) with incremental modification to send data to REMC via reliable & robust communication links like that of fiber optic communication links. The additional parameters /sensors if required will be integrated with same. A robust communication system such as fiber optic cable, GPRS may be suitable for sending the data from distributed generation site to nearest pooling stations and further to REMCs at State and Regional / National level, where data shall be used for forecasting, control and dispatch of RE. Block diagram for information flow is shown in Fig 8.4.

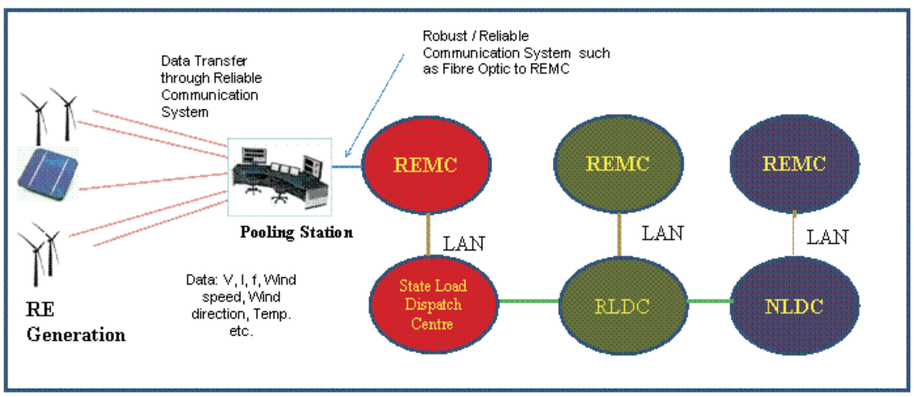

Figure 8-4: Block Diagram for Information Flow

Chapter-9

International Experience in Integration of Renewables

With 23 GW of installed Renewable generation capacity, India is in top five countries of the world in Renewable Installed Capacity. However countries like China, US as well as European countries like Spain, Germany and Denmark etc. have done lot of works in integrating large scale renewable integration. As compared to above countries, India still has to go miles on integrating large scale renewable.

Wind being the major contributor in Renewable generation, challenges, issues, costs and other factors associated with integrating wind generation are closely related to the penetration level of wind power in a given system. Higher penetration means more challenges for integration with grid. A list of transmission system operators that range from the highest wind generation penetration level to the lowest is shown at Figure 9.1

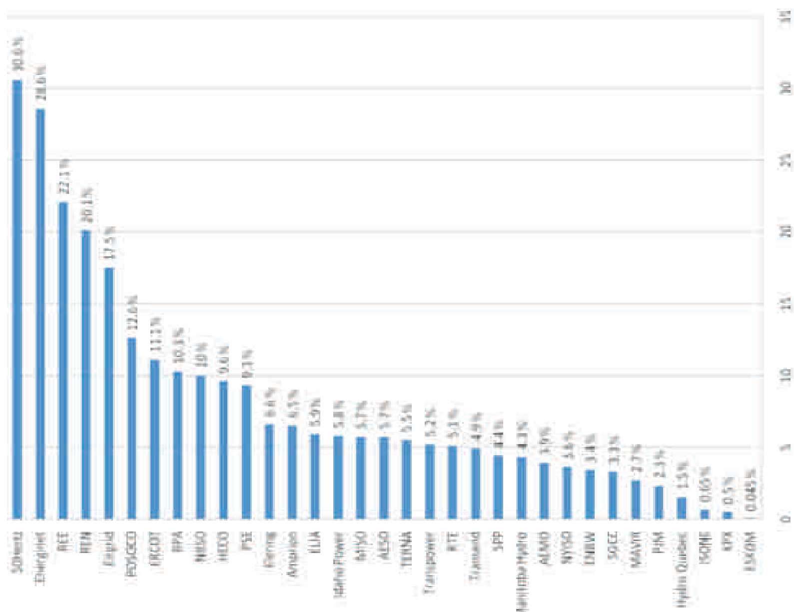

Figure 9-1: Wind Penetration level of TSOs

Experience of grid operators worldwide shows that besides several other factors, integrating a significant amount of wind largely depends on the accuracy of the wind power forecast. A broad agreement among operators exists today that, in order to effectively integrate wind energy into power system operations, centralized forecasting is the current best approach for reliably operating power grids with wind generation.

Experience of some of the world's leading RE/wind rich utilities with high level of penetration level based on literature survey and visit to some of the system operators has been given in the following sections.

9.1. Experience of REE (Spain)

Red Eléctrica de España, S.A.(REE) is dedicated to the transmission of electricity and the operation of electricity systems of Spain. Red Eléctrica, the Spainish TSO, started up a Control Centre of Renewable Energies (CECRE) in 2006, a worldwide pioneering initiative to monitor and control Renewable energy. CECRE allows the maximum amount of production from renewable energy sources, especially wind energy, to be integrated into the power system under secure conditions. CECRE is an operation unit integrated into the Power Control Centre (CECOEL). The generation of the renewable energy producers, which have been set up in Spain is managed and controlled by CECRE.

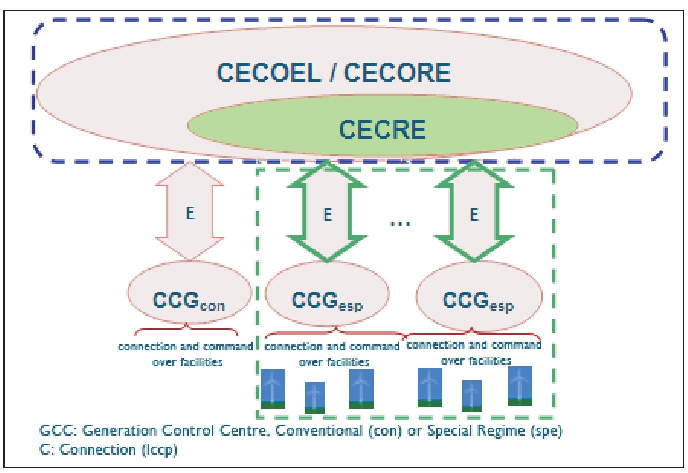

Figure 9-2: Hierarchy of CECRE in Spain

Under the above hierarchy, the generation control centre to which an electrical energy production facility is assigned, acts as its Generation Control Centre and interlocutor with Red Eléctrica. To this purpose, every generation control centre must be connected with the Red Eléctrica control centres and have been previously approved by Red Eléctrica. Red Eléctrica issues the corresponding qualification certificates of generation control centers.

After June 30th 2007, all wind production facilities with a total installed power greater than 10 MW must be controlled by a control center that is directly connected to the CECRE. These wind generation control centers must have enough control over the plants that they can execute CECRE's orders within 15 minutes at all times.

By means of 23 control centers of the generation companies, which act as interlocutors, CECRE receives, every 12 seconds, real time information about each facility regarding the status of the grid connection, production and voltage at the connection point. This data is used by a sophisticated tool which makes it possible to verify whether the total generation obtained from renewable energies can be integrated at any moment into the electricity system without affecting the security of supply.

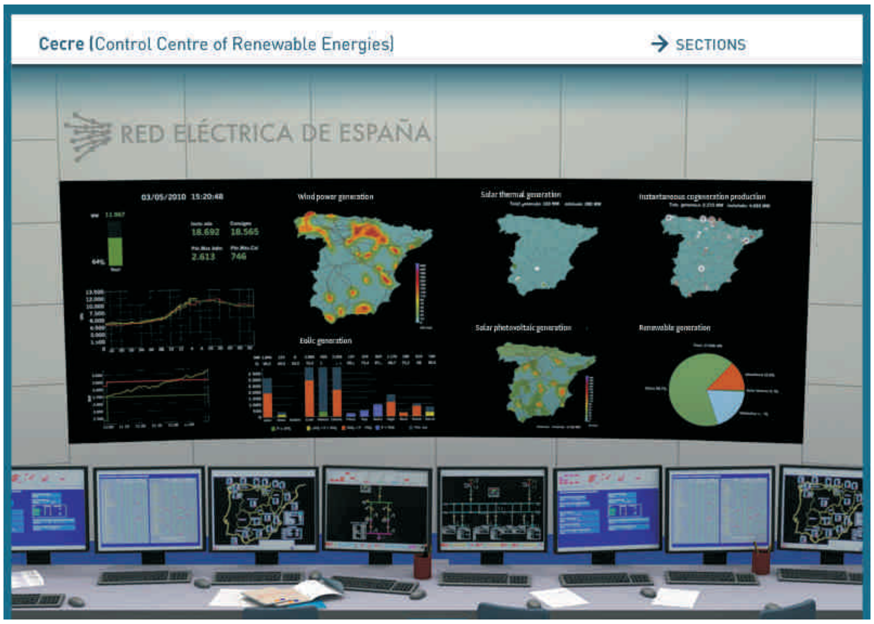

Figure 9-3: CECRE VPU-Spain

In order to anticipate possible incidences which may arise as a result of integrating renewable energies, CECRE constantly analyses the current scenario and predicts the operation measures which will be necessary so that the system remains in a secure state. In a system with as few electrical interconnections with neighbouring systems as the Spanish one, the Control Centre of Renewable Energies plays a determining role.

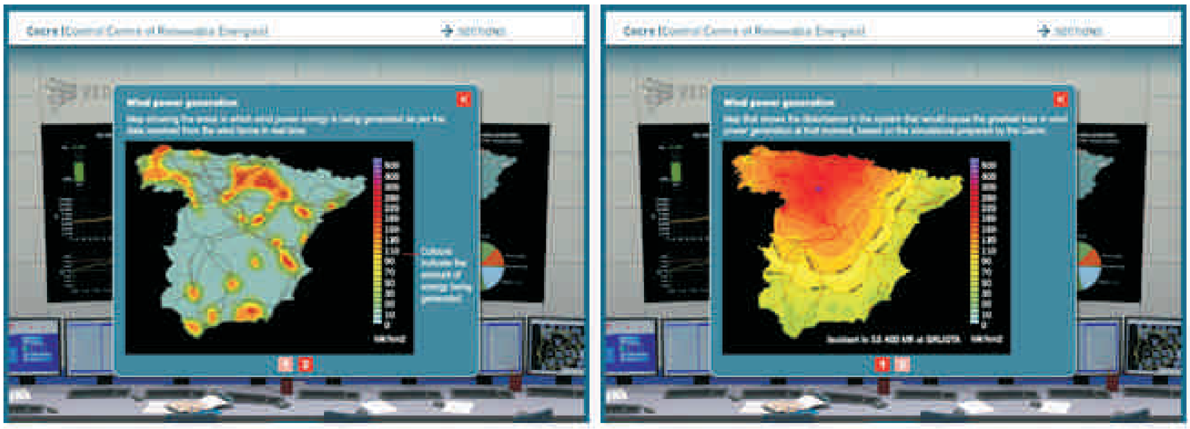

Figure 9-4: Real time Wind generation at VPU

It is to mention that on the occurrence of some of the following events, it is immensely challenging to integrate renewable production. CECRE constantly analyses the operational scenarios and takes the necessary measures so that system remains in secure state.

a. Disturbances in the system wherein some wind turbines (especially near the disturbance area) disconnects themselves (FRT incapable). This may result a sudden loss of wind power generation which may represent a risk to security of supply. This requires adequate spinning reserves or high ramp up generations.
b. Due to climate factors such as strong winds can lead to high generation of wind energy which may cause overloads or voltage excursions in the network. In such events, control center issues limiting production orders to RE generators and within 15 min of order issue, generators have to take necessary actions for compliance.
c. During off peak hours, Wind energy productions is usually high and it is not possible to further reduce the conventional generation as it may be needed in subsequent hours or at some particular time. In such state, control center issues limiting production orders to RE generators.

Wind Forecasting in Spanish System

The Spanish generation system depends strongly on wind power generation which is further going to increase in future as per Spanish Plans. On 06-Nov-2011, 60% of the demand was met by wind generation. This amount of contribution necessitates a proper forecasting tool for the Spanish power system. Although wind farms are declaring their forecasted generation, REE is also doing wind forecasting separately. SIPREOLICO is a wind prediction tool for the Spanish peninsular power system. It is a short-term wind power prediction tool (detailed hourly forecasts up to 48 Hrs in advance & aggregated hourly forecast up to 10 days in advance) developed by Universidad Carlos III de Madrid and Red Electrica. It is a highly flexible tool that can perform predictions according to the available data. If on line power production from a wind farm is not available, SIPREOLICO generates predictions based on past wind data and a wind farm power curve built from the technical characteristics of the farm. When on line measurements are available, a more accurate prediction is generated using an adaptive combination of a variety of statistical models.

For a given wind farm, SIPREOLICO uses following inputs viz. (a) the characteristics of the wind farm, (b) historical records of simultaneous incoming wind and output power, (c) on line measurements of power output, and (d) meteorological predictions. The algorithms that SIPREOLICO tilizat to generate the predictions depend on the types of the input available. Three different agents provide SIPREOLICO with wind power forecasts updated each hour: (i) AEOLIS: Up to 2.8 days horizon (ii) IIC: Up to 6.5 days horizon and (iii) METEOLOGICA: Up to 10 days horizon. The tool provides wind power forecasts with different confidence intervals: 10%, 15%, 50%, 85% and 90%. SIPREOLICO combines these forecasts with its own to produce a final prediction. Once the predictions are obtained for every farm, they are aggregated in zones and the final production prediction for the Spanish peninsular system is found. Reports are generated with desired aggregation level. The outputs of SIPREOLICO are the predictions, a set of confidence intervals of them, and a set of evaluation measures related with the precision of the predictions.

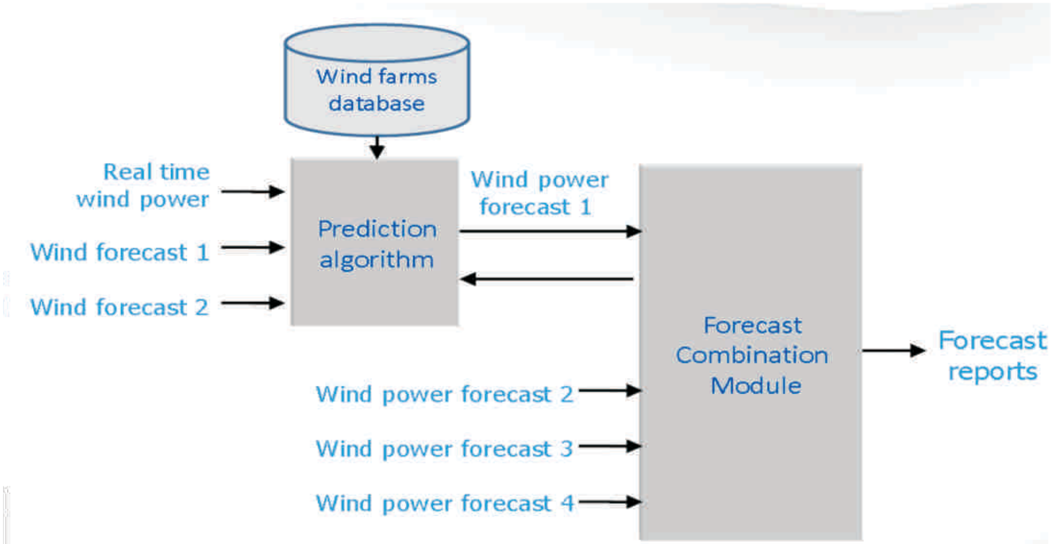

Figure 9-5: SIPREOLICO Algorithm

The evaluation of the predictions is also used by SIPREOLICO to modify the features of the prediction algorithms in order to adapt them to the last data received. The wind forecasts and real production graph of a typical day is as shown below:

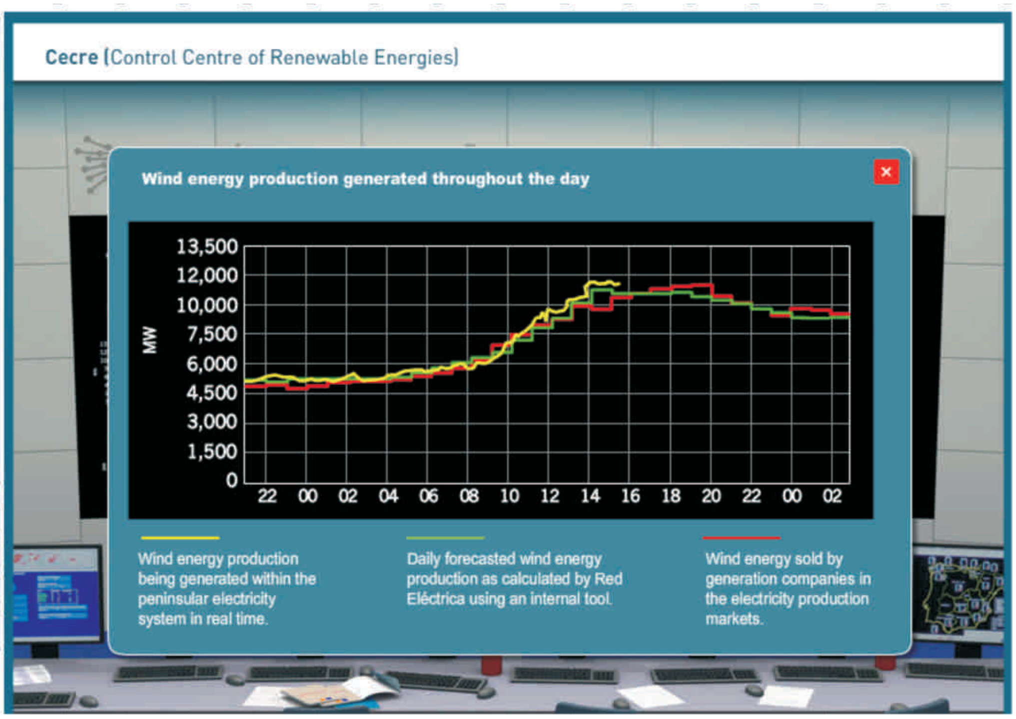

Figure 9-6: Wind Generation V/s Forecast

This wind forecast information is being passed on to the real time system operation department. This is being used for unit commitment and Automatic Generation Control. For taking care of variation of wind generation in the Spanish power system, a specific spinning reserve has to be kept available at the generation units. Mainly combined cycles power plants (I/C: 25,269 MW) are being used as a spinning reserve in the Spanish Power System.

9.2. Experience of 50 Hertz (Germany)

50 Hertz Transmission GmbH (50 Hertz) is a transmission grid operator and is 60 percent owned by the ELIA Group. The group also owns the Belgian TSO ELIA. As one of four TSOs in Germany, 50 Hertz operates in the northern and eastern parts of the country.

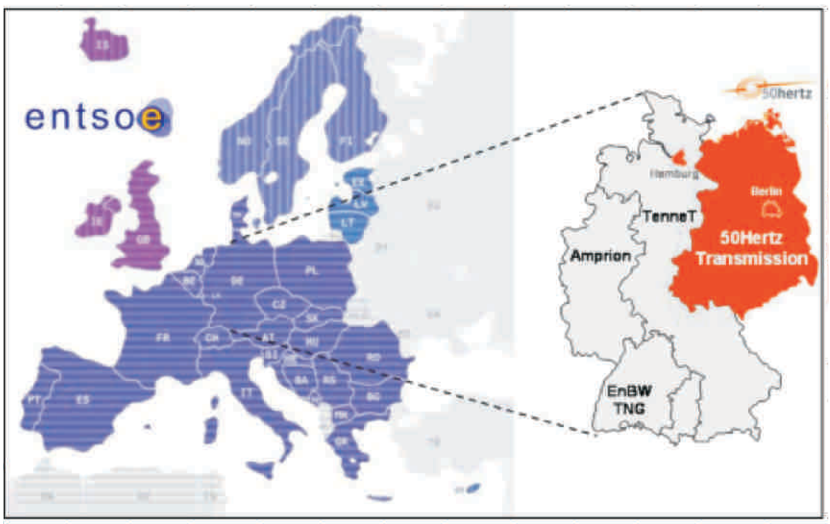

Figure 9-7: Map of synchronous network area belonging to ENTSO-E

50 Hertz has electrical interconnections to neighboring TSOs within Germany and externally with Denmark, Poland and the Czech Republic.

Figure 9-8: 50 Hertz Load Dispatch Center in Berlin

At the end of 2010, the installed wind power capacity in its grid was about 11.5 GW, which is about 42 % of the total wind capacity in Germany. 50Hertz has a generation mix and operational conditions, which make it very unique in the world wind power industry. At the end of 2010, the total installed generation in the 50 hertz control area (i.e. including the share connected to related distribution grids) was about 38,000 MW, of which about 30 % was wind. The peak load in 50Hertz control area is only about 17,600 MW. This makes 50 Hertz the only known power system in the world that has this level of wind power capacity, relative to both peak load and generation.

Over the years, 50 Hertz has proven to have successfully integrated wind energy management into their control room operations under a variety of challenging operating conditions, such as:

- Overload on control area internal power lines but also lines that interconnect 50 Hertz with the neighboring control areas (e.g., the polish TSO)
- Overloads of transformers linking the transmission level with the distribution level
- Problems with local voltage stability
- Problems with frequency stability/ system balance

This large constellation of RE generation has caused several operational challenges in 50Hertz control area, especially when the actual wind power infeed exceeded the demand such as during low load conditions. During these times, the excess wind capacity in 50 Hertz has to be transported to neighboring TSOs, where the electrical demand is much higher. This transport requires a very close coordination between 50 Hertz and neighboring TSOs in and outside of Germany. The recently developed ‘CORESO’ center is playing a vital role in coordination among TSOs in Europe.

Another important aspect of wind integration in 50Hertz is the fact that about 90% of all the wind generation is connected to the distribution system level, which is not operated by 50Hertz. 50Hertz operators, therefore, do not have access to all of the actual wind injections to the system in real-time.

Wind forecasting is currently being used in the 50Hertz control room. 50 Hertz uses three different forecast tools. It receives wind power forecast data from four different forecast service providers. Forecasts are provided for the entire 50Hertz area in Germany, and the regions within 50Hertz control’s area. The forecast horizon is 96 hrs and beyond that it's updated twice a day. The information is combined using a weighted sum. Dispatchers use the information to develop an operational forecast.

Congestions do occur temporarily in the 50Hertz grid as a result of varying wind patterns and other events. During periods of congestion in the grid, 50 Hertz redispatches power plants to manage overloads. European Commission Renewable Electricity Directive requires that wind generators are guaranteed priority dispatch, except for those conditions that affect the stability of the electricity grid. To ensure a reliable and secure electricity supply, the directive states that wind production can be curtailed if the grid is endangered. As part of the process, the curtailment orders are determined using information about generators that have the most impact on the congestion at the time.

As the majority of wind plants in 50 Hertz are connected at the distribution level, 50 Hertz has no direct control over this major wind share. However, this curtailment only occurs during heavy flow of power. As a last measure, 50 Hertz manually curtails winds by informing the respective distribution system operators about the required amount of power to be curtailed and for how long.

9.3. Experience of Elia (Belgium)

Belgium has about 16 GW total installed generation capacity, out of this wind energy is approximately 1 GW. The Belgian grid is interconnected with France, the Netherlands and the Luxemburg. Projects are also underway on direct interconnections with Great Britain and Germany. Belgium has set a national target to increase the renewable energy sector use so that by 2020, 13 % of the country's electrical consumption is met by renewables.

Belgium's central position in the European transmission systems means it has to cope with significant unscheduled physical flows (i.e. energy exchanges which are not governed by a commercial agreement between countries, but are simply due to the fact that energy moves freely through the grid without stopping at boarders).

Belgium's regional electrical submarket is controlled by the transmission system operator (TSO) Elia, along with a portion of Luxemburg. It manages a grid comprising of about 8,400 km of high voltage connections (ranging from 380 kV to 30 kV), composed of overhead lines and underground connections.

Phase shifting transformers are used by the Elia for control of power flow with France and the Netherland.

Elia is getting Renewable Energy generation forecast through external agency. Presently RE generation is managed by the existing TSO control centre. In future a separate control centre for RE generation management is proposed.

In the changed scenario of lager scale renewable generation in Belgium, many of the high voltage connections become overloaded and system has to be operated without fulfilling the N-1 criterion. In Europe it takes very long time (about 10 years) to build new transmission lines. To allow overloading of transmission lines with reliability and security, ELIA has started monitoring the sag of some of the selected critical transmission lines in real time by installing a special device called ‘AMPLION’.

Prior to establishment of CORESO center, that started operation in Feb 2009, there was no mechanism for co-ordination among different TSO of European grid. Absence of real time data exchange / coordination among TSOs resulted in threat to grid security, delayed restoration, poor situational awareness and sub-optimal utilization of transmission asset.

Elia along with 50 Hertz Transmission (Germany), RTE (France), Terna (Italy) and National Grid (UK) initiated co-ordination of electricity system operator (CORESO). It is first regional Technical center shared by several TSOs for ensuring a safe, reliable system that enables security of supply to many nations in Europe. For co-ordination among TSOs, a meeting is conducted every evening at 2100 hrs. through video/audio conferencing.

CORESO do forecasting for D-2, day ahead and intraday for the participating TSOs. It transfers significant information to TSOs for better situational awareness. It monitors real time data, Power exchanges on round the clock basis.

9.4. Experience of Cal ISO (USA)

The California ISO, a non-profit corporation, operates Western Interconnection made up of 14 states and portions of Canada and balances electricity supply and demand. It operates about 80% state's transmission grid (25,800 circuit miles). The ISO handles about 35% of the electricity flowing in the west and adheres to mandatory reliability standards set by the Western Electricity Coordinating Council (WECC). It keeps a pulse on an estimated 58,000 MW capacity from nearly 1400 power plant units that serve the electricity needs of 30 million customers in California with peak demand of about 27,000MW. It delivers about 289 million uninterrupted MWh per year.

One tool the ISO uses in managing the grid is the ancillary services market. Power suppliers offer special energy products that "stand by" and are ready to act in case of sudden loss of a power plant or transmission line.

It also forecast electricity supply and demand, paying close attention to transmission and generation requirements. Every five (5) minutes the ISO forecasts electrical demand, accounts for operating reserves and dispatches the lowest cost power plant unit to meet demand while ensuring enough transmission capacity is available to deliver the power. Assessments are also performed annually and predict the level of energy conservation that may be required of customers. It also coordinates planned and unplanned outages of transmission and generation facilities.

Renewable Energy Forecasting & Management System at Cal ISO:

The California ISO control centre is equipped with advanced geospatial maps and high-tech visualization tools which help to manage renewable integration. The control centre has dedicated renewable dispatch desk. Presently, the grid comprises of about 2700 MW wind generation capacity and 680MW solar capacity. Maximum dispatch from wind farm is about 1200MW while output from solar plant is almost at its full capacity. They carry out forecasting of wind generation through forecasting tools including weather stations for scheduling of dispatch. However, there is still wide variation in actual wind generation vis-a-vis forecasted output. Maximum wind generation occurs during off-peak period. Further, to keep pace with variable wind generation ramp-up and ramp-down characteristics, the balancing is being done with quick start hydro and gas power plants connected as hot spinning reserves. In addition, ISO maintains about 7% reserve generation capacity in the grid as well to cater to unforeseen situations.

There are four types of ancillary services products: regulation up, regulation down, spinning reserve and non-spinning reserve. Regulation energy is used to control system frequency that can vary as generators access the system and must be maintained very narrowly around 60 hertz. Units and system resources providing regulation are certified by the ISO and must respond to “automatic generation control” signals to increase or decrease their operating levels depending upon the service being provided, regulation up or regulation down.

Spinning reserve is the portion of unloaded capacity from units already connected or synchronized to the grid and that can deliver their energy in 10 minutes and run for at least two hours. Non-spinning reserve is capacity that can be synchronized and ramping to a specified load within 10 minutes.

Scheduling coordinators certified by the ISO as meeting the requirements of the ISO Tariff may participate in the ancillary services market.

With the above tools, market mechanism and advanced control centre, the ISO is now planning to integrate the largest portfolio of renewable energy in the world – 33% renewable resources by 2020.

There are weather stations that generate real-time weather data which is used by Cal ISO for hourly load forecast and wind generation possible abrupt/short term changes. Deployment of boundary layer network of radiometers is under progress to enhance forecasts.

The geo spatial visualization software provides solution for integration of large scale renewable generation into grid. It addresses the lack of uniform standards, unpredictable intermittency of renewable power, the complications of balancing conventional and renewable energy sources, up-gradation of data infrastructure etc. Its Renewable Intelligence solution delivers the ability to view and act on a portfolio of generation resources, both virtual and real, in the context of demand for stable and predictable operation of electric grid. The solution enables increased ability to manage renewables integration, optimaltilization of generation & transmission assets, improved reliability and capacity from renewable generation resources, greater predictability of grid operation using renewables etc.

9.5. International Connectivity Standard requirements for RE

Grid codes vary from country to country, since the power networks are of different size/characteristics, generation mix, operation procedures as well as wind penetration. Some of the requirements in international grid codes to accommodate large scale wind integration are discussed as under:

(a) <u>Voltage Ride Through (VRT) requirements under different grid codes</u>

VRT requirements cited in the different grid codes worldwide are presented below. Requirements depend on specific characteristics of each power system and the protection employed. They may deviate significantly from each other. Low Voltage Ride through (LVRT) requirements for Nordic, Danish, Belgian, Hydro-Quebec, Swedish and New Zealand grid codes appear to be more demanding. They stipulate that wind farms must remain connected during voltage dips down to 0%. The less severe requirement of the German code may be attributed to its strong interconnection to the UCTE system, as opposed to the weakly interconnected British system, where the need for active power restoration to the prefault values is more crucial for system stability. A com parison of different grid codes for LVRT regulation w.r.t Fault duration, Min. voltage level and recovery time is tabulated as under:

TSO/Country	Voltage Level (kV)	Threshold values	Fault Duration (s)	Min. Voltage Level	Recovery time
AEMC	100<V<250	----	0.12	0% Ur	----
AESO	TS	> 5 MW	0.625	15% Ur	90% after 3s
EIRGRID	110, 220	----	0.625 *	15% Ur	90% after 3s
Elkraft & Eltra	132, 150	Wind >100 kV	0.1	25% Ur	75% after 0.75s 100% after 10s

Energinet.dk (West Denmark/UCTE)	132, 150, 400	>1.5MW >100 kV	0.15	0% Ur	60% after 0.7s U_{LF} after 1.5s
Energinet.dk (East Denmark)	132, 150, 400	>1.5MW >100 kV	0.25	0% Ur	60% after 0.7s U_{LF} after 1.5s
E.ON	110, 220	Type 1	0.15	0% Ur	U_{LF} after 1.5s
E.ON	110, 220	Type 2 Limit 1	0.15	45% Ur	70% after 0.15s U_{LF} after 1.5s
E.ON	110, 220	Type 2 Limit 2	0.15	0% Ur	U_{LF} after 1.5s
FERC	115, 230, 345	> 20 MW	0.625 or 0.15	15% or 0% Ur**	90% after 3s
Hydro-Quebec	TS	----	0.15	0% Ur	90% after 3s
NGT	275, 400	----	0.14	15% Ur	90% after 3s
Nordel	132, 150 220, 400	Various ***	0.25 or 0.15	0% Ur	90% after 0.75s 25% after 0.25s
PSE	TS	----	0.625	15% Ur	80% after 3s
REE	TS	----	0.5	20% Ur	95% after 15s 80% after 1s
Scottish Power	132, 275	≥5MW	0.14 or 0.1	0% Ur	90% after 3mins 80% after 1.2s
Svk Sweden	220, 400	>100MW	0.25	0% Ur	90% after 0.75s 25% after 0.25s
Svk Sweden	220, 400	>1.5MW <100MW	0.25	25% Ur	90% after 0.25s
Transpower	110, 220	----	0.2 or 0.12	----	----
WECC	115, 230, 345	>10MVA >60 kV	0.15	0% Ur	90% after 1.75s

Grid Code requirements also need to take into account effect of system overvoltages for wind plants especially in DFIG machines. A comparison of different grid codes for High Voltage Ride Through (HVRT) regulation w.r.t overvoltage profile is tabulated as under:

TSO	Voltage Level (kV)	Overvoltage Profile
AEMC	100 – 250	0s < t ≤0.7s 130% 0.7s < t ≤0.9s non-linear decrease 0.9s < t 110%
AESO	TS	0s < t 110%
EIRGRID	110, 220	0s < t 113%
ELTRA & ELKRAFT (TOV Requirement)	132, 150	0s < t < 0.1s 130% 0.1s < t 120%
Energinet.dk	132, 150	0s < t < 0.2s 120% 0.2s < t 110%

E.ON	110, 220, 380	Not specified
FERC	115, 230, 345	Not specified
Hydro-Quebec	TS	Not specified
NGT	275, 400	Not specified
Nordel	132,150, 220, 400	Not specified
PSE	TS	Not specified
REE	TS	Not specified
Scottish Power	132, 275	T>0s 120% (132kV) T>0s 115% (275kV) T>15mins 110%
SvK	220, 400	Not specified
Transpower	110, 220	Not specified
WECC	115, 230, 345	T>0s 120% T>1s 117.5% T>2s 115% T>3s 110%

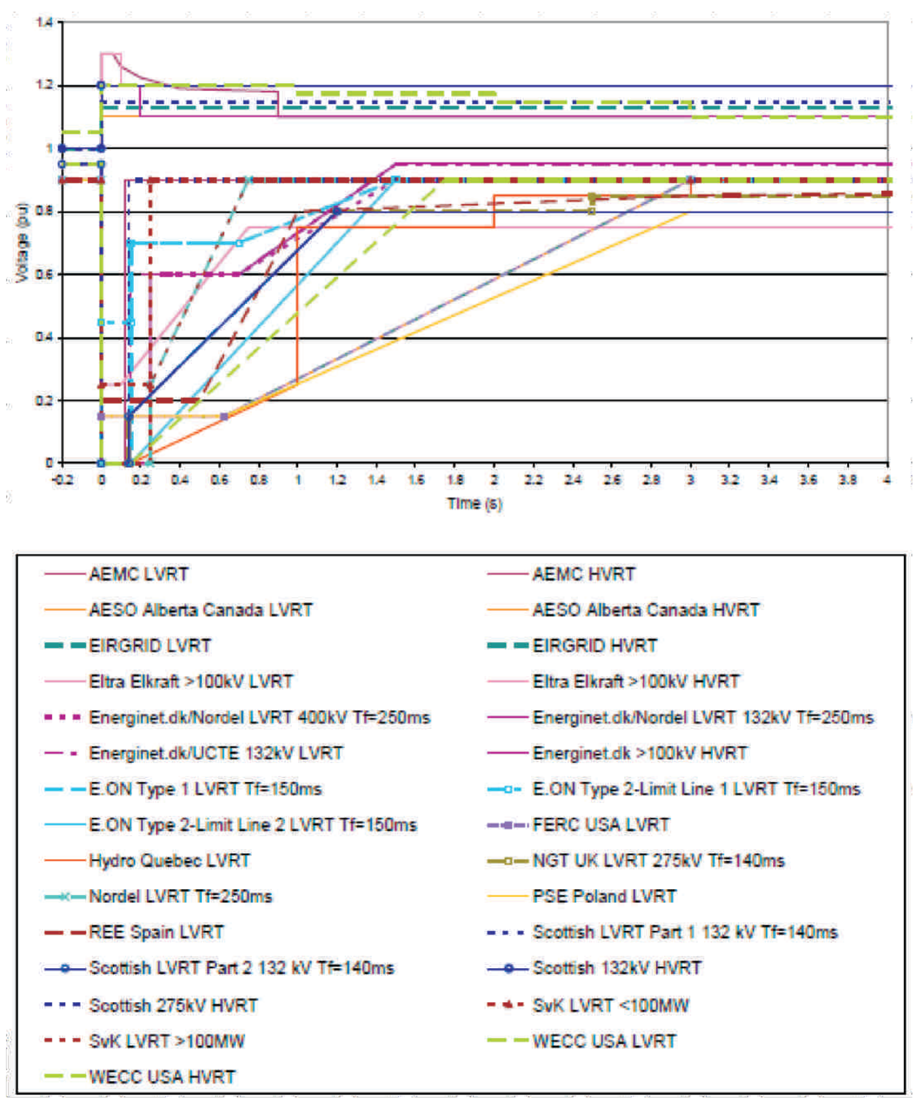

Figure 9-9-: LVRT/HVRT under different grid codes (Source)

(b) Voltage & Frequency Operating Range

Some of the regulations worldwide on Frequency operating range & Voltage/reactive control is deliberated as under:

I. Frequency Control

In different countries, operation range of frequency for wind plants is as under:

Spain & Germany – 47.5-51.5Hz

Denmark & UK – 47-52 Hz

Details of few practices used for frequency response in wind dominated countries are as under:

1) Limited frequency control- used in UK, Germany and Ireland where wind turbine reduces power output at 40% of nominal capacity/Hz at the event of higher grid frequency.
2) Linear frequency regulation – followed in Ireland & Spain, where on the high frequency scenario, output of wind generator decrease linearly with frequency at a rate fix by respective TSO till a limit where it is permissible to disconnect. In low frequency condition output of wind turbine increases is same way.
3) Frequency regulation with multi stage response –Danish grid code follow the configurable droop characteristics, where slope of power-frequency curve is adjustable and 4 droops are configured for four different frequency ranges

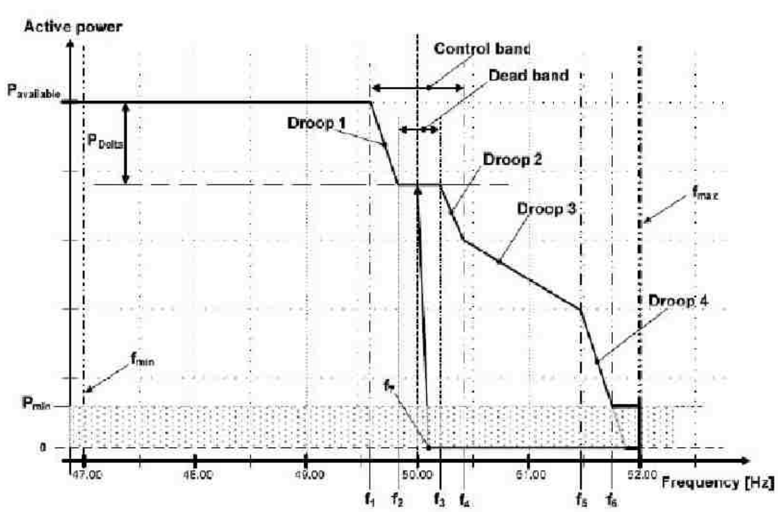

Figure 9-10: Danish grid code for wind generation droop

II. Voltage & Reactive Power control

In different countries, operation range of reactive power requirement for wind plants is as under:

Country	Reactive Power Range (p.u .of Full output)	Equivalent full load power factor
Denmark	-0.33-0.33	0.95-0.95
Germany	-0.228-0.48 -0.33-0.41 -0.41-0.33	0.95-0.95 0.05-0.925 0.925-0.95
Spain	-0.3-0.3	0.95-0.95
UK	-	0.95-0.95

Intentionally left Blank

Chapter-10

Estimated Cost

10.1. Estimated Cost

Cost of the proposed transmission system strengthening scheme, establishment of RE management center, fibre optic communication link & PMU/PDC for real time monitoring and control, dynamic reactive compensation as well as energy storage system have been estimated. Details are as under:

- **Intra State transmission strengthening scheme:** It comprises of transmission strengthening requirement within a particular State to facilitate integration of RE capacity into grid. This shall facilitate absorption of RE power by the host State to fulfill their RPO targets.

- **Inter State transmission strengthening scheme:** Envisaged capacity of Renewable in RE rich state is more than their RPO requirement, which shall necessitate transfer of power beyond host state boundary. Since, most of the RE plant capacity is comparatively low in the range of 30-100MW, same are being connected at lower voltage level like 66kV/132kV/220kV etc. in the STU grid. This shall require system strengthening within state for conveyance of ISTS transfer i.e. power transfer outside host State.

  In addition to above, transmission strengthening requirement across States to facilitate transfer of power from RE plants in a particular State to other States is also being identified as ISTS strengthening. The scheme mainly comprises of high capacity EHVAC and long distance HVDC transmission system.

- **Connectivity Transmission System:** It includes transmission interconnection of RE plants (beyond first step up level) to a common pooling station in the grid. These interconnecting links are generally at 66kV/132kV or 220kV level. Mostly, common pooling stations have transformation levels at 220/33kV or 66kV or 132/33 kV level. In order to facilitate interconnection of Wind/Solar/SHP plants with nearest grid pooling station, pocket wise capacity addition programme and requirement of transmission system strengthening have been identified. It is considered that first step-up capacity shall be at 33kV or 66kV level which shall be further stepped up at 132kV (60% of pocket capacity) and balance 40% capacity at 220kV level. Accordingly, the number of 33kV or 66kV/132kV and 33kV or 66kV/220kV substations and associated transmission lines has been identified.

Number of pooling station in each complex/pocket is identified based on the quantum of RE capacity envisaged in the future by STU/SNA. For interconnecting such pooling station with RE farms, it is being found that line length shall be of the order of 20-40 km, however in some of the complexes, distance may be even in the range of 5 km. Considering the above line lengths as well as transfer capacity for 220kV, 132kV and 66kV D/c lines, requirement of number of line bays as well as total line length is being derived at each level.

Ttransmission system for connectivity of RE generator beyond first step up voltage level (>33 or 66kV level) is as shown at Fig-10-1:

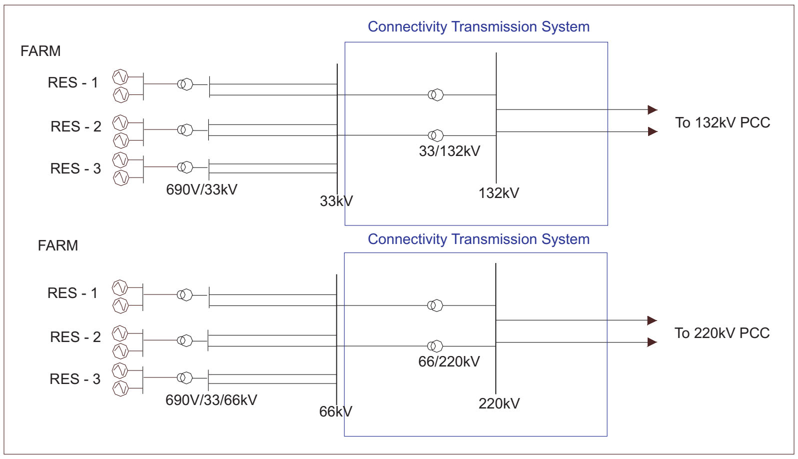

Figure 10-1: Connectivity transmission system for RE generator

Out of the total RE envisaged capacity, it is envisaged that some of the capacity shall be directly interconnected at nearest ISTS pooling/sub stations. Therefore, out of total identified connectivity system, majority of the system is being included in the Intra State transmission strengthening as it is being connected to STU grid at lower voltage level (33/66/132kV). Balance is proposed to be included in the ISTS strengthening which is envisaged to be interconnected at nearest ISTS pooling/sub stations.

Real time measurements/monitoring scheme: In order to measure system state at the point of common coupling on real time basis, it is proposed to provide installation of Phasor Measurement Units(PMU) at all the grid pooling stations/points of common coupling(PCC) and Phasor Data Concentrators(PDC) at strategic locations as part of Synchrophasor technology. To facilitate reliable communication between PCC and control centre, installation of fibre optic communication links are proposed.

Energy Storage: As part of power-balancing mechanism to address intermittency and variability of large scale wind/solar generation, provision of storage in various forms is proposed. This shall facilitate in maintaining grid stability to a certain extent.

Renewable Energy Management Centre: To deal with variability and uncertainty in renewable generations, forecasting of generation is essential. In addition, for power-balancing purpose, flexible type of generations in the form of spinning reserves, primary/secondary generation regulation etc. are required. Further, coordination with RE generators, State Load Despatch Centre(SLDC), Regional Load Despatch Centre(RLDC) and National Load Despatch Centre(NLDC) are required. This shall facilitate stable and secure operation of grid. To take care of above aspects, it is proposed to establish Renewable Energy Management Centre (REMC) at seven (7) renewable rich States to be integrated with the respective SLDCs, at regional level in Southern, Western and Northern region to be integrated with respective RLDCs and at National level integrated with NLDC.

10.2. Estimated cost of proposed transmission system strengthening

Five RE rich states have already identified intra state transmission system strengthening and submitted the DPR. The estimated cost as indicated in the DPRs are as under :

- Tamil Nadu : Rs. 2752 Cr
- Andhra Pradesh: Rs. 1761 Cr
- Gujarat: Rs. 1680 Cr

- Rajasthan: Rs. 4333 Cr
- Himachal Pradesh: Rs. 456 Cr

Total: Rs. 10,982 Cr

However out of the identified strengthening in DPR, some elements have been identified for the purpose of conveyance of ISTS transfer, cost of which has been excluded from above DPR cost. Considering this, balance cost for Intra State strengthening works for the five states are as under:

- Tamil Nadu : Rs. 2593 Cr
- Andhra Pradesh: Rs. 1080 Cr
- Gujarat: Rs. 1500 Cr
- Rajasthan: Rs. 3817 Cr
- Himachal Pradesh: Rs. 376 Cr

Total: Rs. 9,366 Cr

In addition above, system strengthening scheme within state for conveyance of ISTS transfer is also identified to facilitate transfer of power for onwards transmission of power to outside host State. Estimated cost of the proposed transmission system strengthening including elements from the proposed schemes in DPR, for Seven (7) RE Rich state is as under:

- Tamil Nadu : Rs. 2498 Cr
- Andhra Pradesh: Rs. 1486 Cr
- Karnataka: Rs. 466 Cr
- Gujarat: Rs. 782 Cr
- Maharashtra: Rs. 511 Cr
- Rajasthan: Rs. 1079 Cr
- Himachal Pradesh: Rs. 230 Cr

Total: Rs 7,052 Cr

In addition to above, estimated cost for connectivity transmission system (Intra State) i.e. transmission system between Wind & Solar farm and nearest **STU grid pooling** station/point of common coupling is tabulated in table 10.1:

Table -10.1 : Estimated cost of connectivity tran smission system for RE Plants (Intra State)

S.no	Particulars	Estimated Cost (Rs. Cr)
(i)	Tamil Nadu	2604
(ii)	Andhra Pradesh	1451
(iiii)	Karnataka	1046
(iv)	Gujarat	1295
(v)	Maharashtra	2871
(vi)	Rajasthan	1565
(vii)	Himachal Pradesh	268
(viii)	Jammu & Kashmir	137
	Total	***11,237***

Estimated cost of the proposed Inter-state transmission system is about **Rs 10,215** Cr. In addition, estimated cost for connectivity transmission system (ISTS) i.e. transmission system between Wind & Solar farm and **nearest ISTS** pooling station/point of common coupling is tabulated in table 10.2:

Table -10.2: Estimated cost of connectivity to ISTS

S.no	Particulars	Estimated Cost (Rs. Cr)
(i)	Tamil Nadu	247
(ii)	Andhra Pradesh	248
(iii)	Karnataka	252
(iv)	Gujarat	249
(v)	Maharashtra	273
(vi)	Rajasthan	256
(vii)	Himachal Pradesh	56
	Total	***1581***

Details of all above cost estimates are given at ***Annexure-19 to 27*** as described below***.***

Annexure	Details
19	Abstract Cost Estimate for ISTS
20	Abstract Cost Estimate for Tamil Nadu
21	Abstract Cost Estimate for Andhra Pradesh
22	Abstract Cost Estimate for Karnataka
23	Abstract Cost Estimate for Gujarat
24	Abstract Cost Estimate for Maharashtra

Annexure	Details
25	Abstract Cost Estimate for Rajasthan
26	Abstract Cost Estimate for Himachal Pradesh
27	Abstract Cost Estimate for J&K

Detailed breakup of cost estimates for connectivity transmission to ISTS points categorized as ISTS system is given at ***Annexure-28***.

10.3. Dynamic Reactive Power Compensation

Estimated Cost of ten (10) nos. Static Compensators (STATCOM) at various locations, to provide dynamic voltage support, is about Rs. 704 Cr.

Table -10.3: Estimated cost of Dynamic reactive compensation

S.no	Particulars	Estimated Cost (Rs. Cr)
1	Tamil Nadu – 03 nos.	173
2	Andhra Pradesh- 01 no.	77
3	Karnataka- 01 no.	58
4	Gujarat-01 no.	58
5	Maharashtra-01 no.	58
6	Rajasthan-01 no.	58
7	J&K-02 nos.	115
	Interest during construction & centages (18%)	***107***
	Total	***704***

In addition, estimated cost of two (2) nos. of Static Var Compensators (SVC) one each at 400 kV Kolhapur (PG) & 400 kV Udumalpet is about Rs 500 Cr. Further details of of above cost estimate is given at ***Annexure-29.***

10.4. Estimated Cost for setting up Renewable Energy Management Center with Forecasting tools

Cost for setting up of Renewable Energy Control Center equipped with Forecasting Tools etc. is estimated to be about Rs. 234 Cr. However, above estimates are tentative only which may be fine-tuned after taking inputs from various vendors.

Table -10.4: Estimated cost of REMC

S. No.	Items	Unit	Total no. of Units	Unit Rate (Rs.cr)	Total Estimated Cost (Rs. Cr)
1	Wind/Solar Power Forecasting System including Site Survey, Delivery, setup, installation, testing and tuning and Software license (One for each of the three RLDC + one for NLDC+ one for each of the seven RE rich States)	Nos	11	6.00	66.00
2	Computing Hardware including Compiler License, Servers (Historians) etc.	Nos	11	2.50	27.50
3	Services from Weather monitoring Agencies per annum (3 nos)	LS	3	3	9.00
4	Setting up Renewable Control Desk (2 nos. Operator Console for each, VPU cost, Interfacing cost etc.)	LS	22	0.03	0.66
5	Weather Monitoring Stations	Nos	1410		90.00
6	Miscellaneous including Contingencies	LS		5	5.00
				Sub Total	198.16
	IDC	@ 18 %		35.67	
				Total	**234**

10.5. Real time measurements/monitoring scheme

In order to facilitate real time dynamic state measurement of the grid pooling stations or point of common coupling, installation of PMU/PDC and associated Fibre Optic communication links are considered to be established in an unified manner. The estimated cost for each of the RE rich state towards real time dynamic state measurement scheme is given at table-10.5:

Table -10.5: Estimated cost of real time dynamic state measurement scheme

S.no	Particulars	Estimated Cost (Rs. Cr)
1	Tamil Nadu	83
2	Andhra Pradesh	53
3	Karnataka	55
4	Gujarat	55
5	Maharashtra	65
6	Rajasthan	47
7	Himachal Pradesh	21
8	J&K	22

9	Common (ISTS)	72
	Total	***473***

Cost of real time dynamic state measurement system through Phasor measurement units (PMU) at RE Pooling stations & Phasor Data concentrators (PDC) at REMC as well as communication system viz. fibre optic (OPGW) & terminal equipment is about Rs 473 Cr (*Details of break up of various components in the estimated cost for monitoring system & communication equipments for eight RE rich states is enclosed at* ***Annexure – 19-27***).

10.6. Summary of Cost Estimate

Summary of estimated cost of above schemes and other infrastructure is tabulated in Table-10.6:

Table -10.6: Summary of Estimated cost

S.no	Particulars	Estimated Cost (Rs. Cr)
1.	**Intra State Transmission System Strengthening**	**20,603**
1A.	For absorption of power within the state	9,366
(i)	Tamil Nadu	2593
(ii)	Andhra Pradesh	1080
(iiii)	Gujarat	1500
(iv)	Rajasthan	3817
(v)	Himachal Pradesh	376
1B.	Connectivity to STU network	11,237
2.	**Inter State Transmission System**	**18,848**
2A.	ISTS Strengthening	17,267
2B.	Connectivity to ISTS network	1581
3.	**Dynamic Reactive Compensation**	**1204**
4.	**Real Time Dynamic State Measurement Scheme as well as Communication Systems**	**473**
5.	**Energy Storage**	**2000**
6.	**Cost of Establishment of RE management Center** *(7 RE rich state, one each for NLDC / 3 RLDC)*	**234**
	Grand Total	***43,362***

Note: The above cost estimate is indicative only and has been made considering the line length, fibre optic length and based on the data available from various sources on different elements. Therefore, for carrying out realistic cost estimate, final survey is suggested regarding availability of Right of Way (ROW), space at substation, type of equipment etc.

Intentionally left Blank

Chapter-11

Strategy Framework for Transmission Development

11.1. Load factor of Renewable generations & impact of transmission tariff

Generally load factor of renewable generation is low; about 20-30% for wind and solar and about 40% for Small hydro. Whereas load factor of thermal generation is about 80% and that of hydro is about 40%. RE developer intending to sell electricity in the market requires grid connectivity and transmission access. Depending on its size, an RE project may be embedded in the local distribution network, connected to the STU grid or directly to the Inter State Transmission System (ISTS).

The renewable sources are confined in remote locations where there is insignificant local load. Therefore, long distance haulage of renewable energy is required to reach the load centres. For this, and considering the right of way issue, establishment of long distance high capacity transmission systems are required. As a result cost of transmission per unit of renewable energy becomes high. It is estimated that cost of transmission built for RES generation would be about double the cost of that built for a conventional hydro-thermal mix of generation.

As the transmission system is evolved for substantive amount of renewable power in 12th Plan, it would increase the overall transmission tariff of the State, which would have to be mostly borne by its consumers. This may discourage investment in transmission for renewablesFurther, the preferential ta riff for renewable energy particularly for solar energy is quite high; the consumers may not be burdened additionally with higher transmission tariff. Therefore there is a need to establish transmission system at the Intra State level, by providing grant, to lessen burden due to transmission investments/tariffs.

11.2. Implementation Strategy

Gestation period for a Solar and Wind power project is about 6-12 months depending upon the capacity & location of the plant. To facilitate evacuation of the RE power, it is necessary to integrate the plant/RE Pooling station with grid network at PCC (Point of Common Coupling) through connectivity transmission system. However development of connectivity transmission system, establishment of RE Pooling station as well as transmission system strengthening in STU network for RE absorption, takes considerable time which is significantly more than the generation gestation period. In addition transmission system strengthening works at ISTS level, being developed through competitive tariff based bidding, also requires about 3-4 years time.

In view of the above, efforts should be made for faster implementation of the associated transmission works for RE, avoiding generation bottleneck. Transmission system for RE in particular can be classified into two (2) parts:

- **Intra State strengthening (STU)**- from Point of common coupling (PCC) to grid network for absorption of power within same area or host state including Connectivity Transmission system from RE Generation switchyard (beyond first step up voltage level) to Point of common coupling (PCC) in STU network

- **Inter state transmission system (ISTS)** - For transfer of power from RE rich state to other states, system strengthening within state for conveyance of ISTS transfer as well as Connectivity Transmission system from RE Generation switchyard (beyond first step up voltage level) to Point of common coupling (PCC) in ISTS network

Intra State transmission strengthening, for absorption within state may be implemented by respective STUs. However, implementation needs to be carried out in a tight schedule so as to match with the progressive RE generation availability, to avoid any transmission congestion. For this, it is necessary to expedite the development of proposed Intra State Strengthening. In this direction, for faster implementation, support may be provided by some expert agency in form of consultancy with sound project management skill and technical expertise to STU.

Further, connectivity system being the most critical element, hooks up the RE generation to the grid. As per the prevailing practice, wind generation developers have to develop connectivity interconnection. However, with the increasing renewable generation, this may lead to sub optimal development of connectivity transmission system, as each developer shall tend to lay their own lines. Furthermore with the rising issue of ROW constraints, multiple lines in one common section may not be possible in future. Therefore, there is a need to adopt pocket wise connectivity system development approach which shall be a techno-economic optimal alternative. However for such approach in which common connectivity system is proposed for development, STU having the expertise in transmission system development including obtaining statutory clearances should take the lead.

Development of connectivity also needs special emphasis for faster implementation, as otherwise it may lead to generation bottleneck. Therefore, above must be implemented in a tight schedule for which efficient project management skills are required.

Further, Pocket wise RE generation development should be prioritized in such a manner so that transmission infrastructure available in the pocket can be utilized optimally. Subsequently, ot her pockets may be developed along with commensurate transmission system.

Phasing for implementation of Intra state system strengthening scheme is enclosed at ***Annexure-30***. However above proposed phasing may need to be reviewed in case of change in renewable capacity addition programme in certain pockets/complexes.

Inter State Transmission System includes Inter-state tansmission strengthening across states to facilitate transfer of power beyond state boundaries. ISTS mainly comprises of ±500kV HVDC as well as 765kV/400kV AC transmission lines for Inter-state transmission of power.

In addition, identified system strengthening within the state for conveyance of ISTS transfer is also included in the ISTS. Phasing for implementation of System strengthening within state for conveyance of ISTS transfer is enclosed at ***Annexure-31***.

High Capacity corridors, as a part of above ISTS, is proposed to be implemented in following three phases depending upon capacity addition as well as time required for implementation of the transmission system.

Phase-I (by 2014-15)

- 400kV Bachau (PG)- Solar Park-II (GETCO) – Udaipur - Kankroli D/c

Phase-II (2015-16)

- 400kV Solar Park-II (GETCO)– Chittorgarh D/c
- 765kV Jodhpur(New) – Ajmer(New) D/c
- 765kV Ajmer(New) – Suratgarh D/c
- 765kV Suratgarh – Moga D/c
- 400kV Kankroli- Ajmer(New) D/c
- Suratgarh(existing)- Suratgarh (New) 400kV D/c
- Ajmer(existing)- Ajmer (New) 400kV D/c
- New Pugalur - Udumalpet 400kV D/c
- New Pugalur - Vagarai 400kV D/c
- New Pugalur - Pugalur 400kV D/c (Quad)
- LILO of Tuticorin Pool-Salem 765kV line at New Pugalur (initially to be operated at 400kV)
- Augmentation of transformation capacity at 765/400kV & 400/220kV at Moga substation by 1x1500 MVA & 1x500 MVA respectively
- Establishment of 400 kV Substation at New Pugalur & Hyderabad
- Establishment of 765/400kV, 2x1500 MVA S/s each at Suratgarh, Jodhpur & Ajmer

Phase-III (2016-17)

- 400 kV Srisailam - Kurnool New D/c
- ± 500 kV, 2500 MW New Pugalur - Hyderabad HVDC Bipole
- New Hyderabad – Hyderabad 400kV D/c (Quad)
- Establishment of 400 kV Substation at New Hyderabad
- Establishment of ±500kV, HVDC terminal stations(2500MW) each at New Pugalur & Hyderabad
- Up gradation of 400kV Narendra & Kolhapur substations at 765kV level to facilitate charging of Narendra- Kolhapur D/c line at 765kV level

However above proposed phasing shall need to be reviewed in case of change in renewable capacity addition programme in certain pockets/complex of RE rich state. In addition, above phasing is proposed considering the implementation programme of Intra State Strengthening schemes, which otherwise can impact requirement of above proposed ISTS in different phases.

However, keeping in view the intricacies involved in implementation of ISTS scheme like ROW issues, forest clearances, high end technologies etc., implementation of ISTS, may be given to agency (ies) that have sufficient experience in development of EHV AC & HVDC System, technical expertise as well as strong project management skills.

11.3. Financing Strategy

In order to facilitate the development of transmission system as well as other infrastructure facilities as part of renewable capacity addition program in 12th plan, following financing strategy is proposed. The wind and solar generation is primarily an energy resource and not a capacity resource that can be relied upon to deliver energy on at the time of peak or on demand. The transmission required to deliver wind/solar/SHP energy is to be planned for state renewable policy compliance, economics and delivery of energy in different scenarios. Capacity Utilization factor for renewable generation is low. As per CERC Regulation there are no ISTS charges for Solar generation till 2014. Further each state has to fulfill their RPO target. In addition, Renewable generation is to be promoted for clean development. Keeping this in view, transmission charges for renewable generation need to be rationalized. Towards this, following financing strategy for development of Intra State & Inter State system strengthening is proposed.

- The intra state transmission strengthening scheme includes system strengthening within the state as well as transmission system from RE Generation switchyard (beyond first step up voltage level) to Point of common coupling (PCC) in STU network to facilitate absorption of power within the host state.

  The entire transmission strengthening involves three stretches i.e. Stretch-I : Transmission system from a particular generator to common connection point in STU grid: Stretch-II: System strengthening for common connection point to various points in the STU network; Stretch-III: Strengthening in ISTS network. Typical transmission connection arrangement for RE generation is shown in the Fig 11-1.

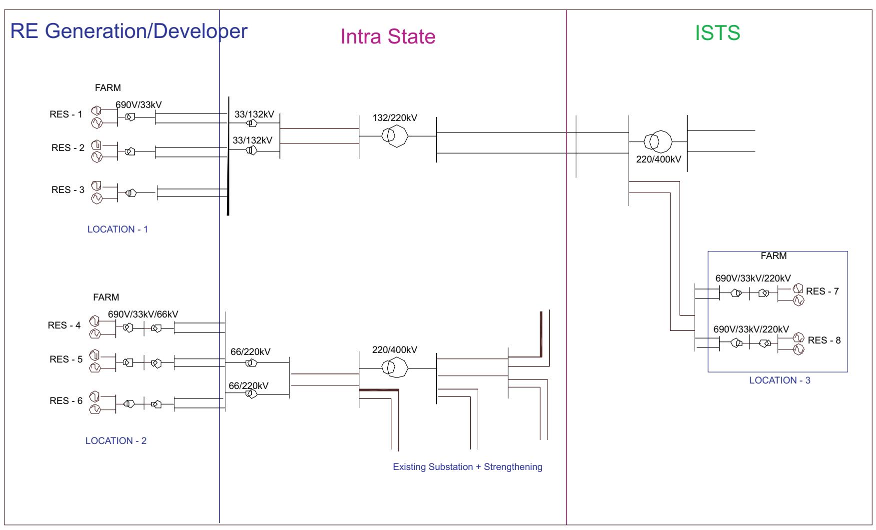

Figure 11-1: Typical Connection arrangement of RE Generation Farm with Grid

Generation from the Renewable sources like Wind & Solar generally have low utilization factor. Above aspect coupled with development of stretch-I for a specific Renewable generator would result into less utilization of the system in Stretch-I. However utilization of system under Stretch-II would be higher than Stretch-I due to increased no. of connectivity of various sources to state network. Further utilization factor of transmission system under Stretch-III would be relatively higher due to more no. of connection of various sources and interconnections.

Development of Stretch-I is under the purview of specific RE generation developer, whereas development of Stretch-II i.e. system strengthening within the state is to be carried out by respective states which has relatively lower utilization as compared to the inter-state system strengthening. In view of the above, there is a need to rationalize the transmission charges for the system strengthening within state (Intra state strengthening) to reduce the burden on the consumers.

Therefore, it is proposed that total capital expenditure requirement towards intra state strengthening i.e. about Rs.20,603 Cr, may considered through suitable funding arrangement. For this, it is proposed that at least 40-50% of the envisaged capex (Rs 20,603 Cr) may be provided through grant such as National Clean Energy Fund (NCEF) [20-25%] and Viability Gap funding (VGF) [20-25%] etc. so as to reduce the transmission charges on account of renewable capacity.

- ISTS strengthening has been evolved taking into account already planned high capacity transmission corridor(s) interconnecting various generation projects in different regions with load centers. This shall facilitate transfer of power from RE complex to load center in one scenario when RE generation is high and in other direction when RE is low, getting support from conventional generators. The evacuation as well as transfer of RE power from resource rich region to the load centers is also required in national interest in order to meet RPO targets of various states.

  In addition, system strengthening within state for conveyance of ISTS transfer is estimated to be about Rs 7,052 Cr. Further, estimated cost towards connectivity of RE generation of more than 50 MW capacity to point of common coupling in ISTS network is estimated to be about Rs 1,581 Cr.

  Thus Capital Expenditure for total Interstate transmission strengthening (Rs. 22,525 Cr) would include interstate transmission strengthening (Rs 10,215 Cr), System strengthening within state for conveyance of ISTS transfer (Rs 7052 Cr), Connectivity system to ISTS network (Rs 1581 Cr), Real time monitoring scheme (Rs 473 Cr), Dynamic reactive Compensation (Rs 1204 Cr) as well as Energy storage (Rs 2,000 Cr).

  ISTS evolved for RE generation are of national in nature with total capital expenditure of about Rs. 22,525 Cr. It is proposed to be pooled in the national transmission pool account like other high capacity transmission corridors being implemented as a part of conventional generation. The transmission charges shall be shared by all the users (Designated ISTS users) in the pool as per point of connection transmission charges sharing norms.

In order to rationalize transmission charges, it is proposed that Debt component for ISTS capex (Rs 22,525 Cr) may be provided as grant/soft loan.

- For development of Renewable Energy management Centers (REMC), it is proposed that investment may be considered as Capital Expenditure of respective Regional Load Despatch Centres and charges recovered as per provision of Regulations specified by appropriate Commission.

  Estimated cost of above scheme is about Rs. 234 Cr.

Note: The above cost estimate is indicative only and has been made considering the line length, fibre optic length and based on the data available from various sources on different elements. Therefore, for carrying out realistic cost estimate, final survey is suggested regarding availability of Right of Way (ROW), space at substation, type of equipment etc

Chapter-12

Perspective Transmission Plan For RE Capacity by 2030

12.1. Need of harnessing Renewable Energy resources

In developing countries like India, the energy demand always outpaces the supply. The energy needs of the country are growing at a very fast pace to meet high GDP growth. As per the "Draft Approach Paper for the Twelfth Five Year Plan 2012-2017 by Planning Commission":

Quote

For the GDP to grow at 9.0 per cent, commercial energy supplies will have to grow at a rate between 6.5 & 7.0 % per year. Since India's domestic energy supplies are limited, dependence upon imports will increase. Import dependence in the case of petroleum has always been high and is projected to be 80 per cent in the Twelfth Plan. Even in the case of coal, import dependence is projected to increase as the growth of thermal generation will require coal supplies which cannot be fully met from domestic mines.

Un quote

The energy demand in India is mainly met through electrical energy & Petroleum products. The production of energy by primary sources and their net import is given at Fig-12-1 & 12-2:

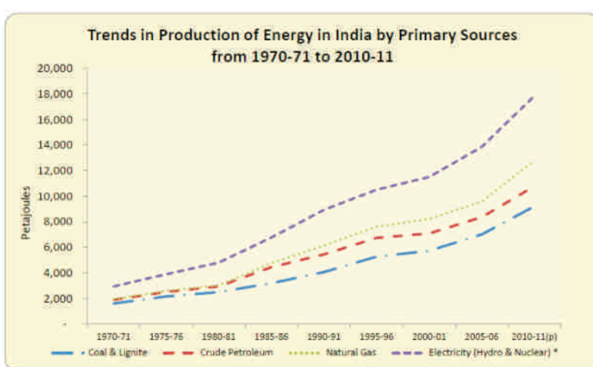

Figure 12-1: Production of energy by primary sources *(Source- MOSPI-ES2012)*

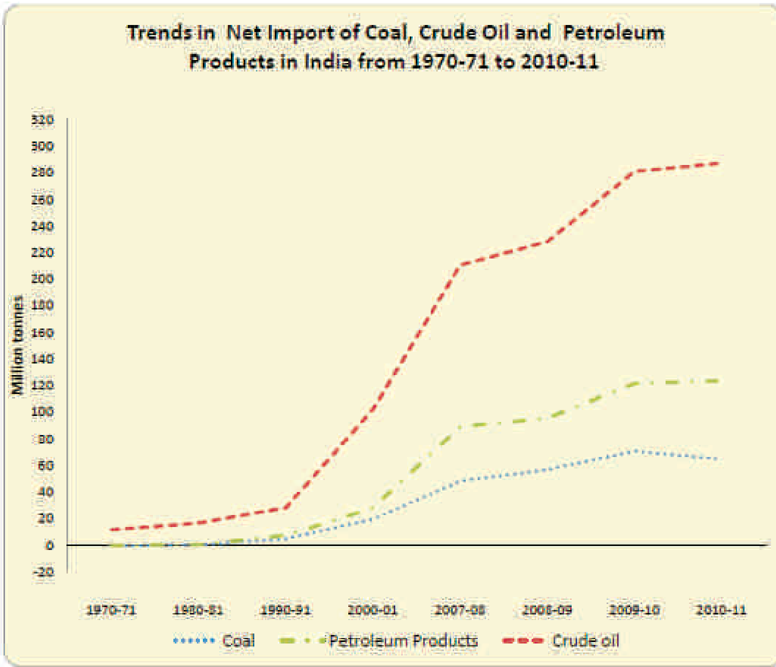

Figure 12-2: Net Import primary sources *(Source- MOSPI-ES2012)*

The electricity generation is hitherto primarily dependent on fossil fuels viz. Coal, Gas and Oil, and is also supplemented through hydro based generating stations and few nuclear generating stations. The petroleum products are primarily meant for meeting transportation requirement. Average Sectoral consumption pattern of petroleum products in India is shown at Fig-12-3.

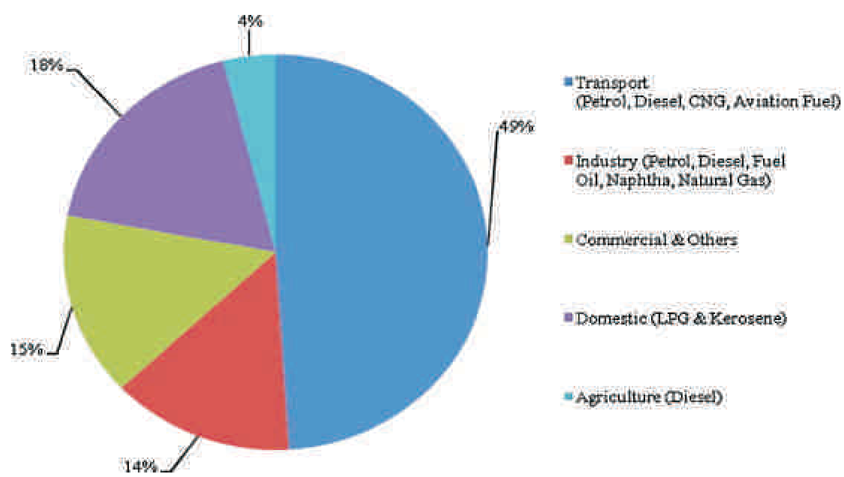

Figure 12-3: *Average sector-wise consumption pattern of petroleum products in India. (Source- Renewable and Sustainable Energy Reviews Volume 16, Issue 2, Feb'12)*

With regard to the availability of Coal in the recently held meeting (held in Feb'12) of the standing linkage committee (SLC) of Ministry of Coal, it was recorded that the total commitment of Coal India Ltd. for capacity addition is of the order of 423 million tones and the gap between the commitments made through LOA/FSA with Power Sector and other consumers vis a vis production projection works out to be more than 400 million tones. In other words, there is no scope for supply of Coal from domestic resources for generation capacity addition during 12th plan period.

Similarly with regard to the gas based generation projects based on the recommendation of the Ministry of Petroleum & Natural gas, Ministry of Power vide its order dated 14.03.12 have advised the generation developers not to plan generation addition uptill 2015-16.

To achieve a sustainable growth, energy security for our country is of paramount importance. Considering the depleting domestic fuel reserves in the country as well as increasing demand for energy consumption, India needs to harness alternative energy resources like Wind & Solar to achieve energy security.

Energy sustainability through alternative solutions such as harnessing ***Renewable energy***, which are naturally replenished, essentially unlimited and of low environmental impact, are being given impetus by the Govt. of India. This would not only help in reducing dependency on polluting and depleting fossil fuels but also in reducing CO2 emissions, to slow the rate of global warming. Renewable energy can be a potential source in meeting India's growing demand, to a certain extent, to keep up pace of GDP growth.

As per the estimates, total CO_2 emission from fossil fuel stations including thermal & gas fired shall be around 1164 MT per annum by 2016-17. In the 2016-17 scenario, energy demand shall also be met through RE Generation which shall in turn reduce the energy supplied through fossil fuel stations to some extent. This shall reduce the CO_2 emission in the country by 189 MT per annum which is about 16% reduction.

As per the National Electricity Plan (Generation), there would be requirement of about 842 MT coal for 178 GW thermal generation by the end of 2016-17. However considering the limited availability of domestic coal reserves, about 218 MT coal shall need to be imported to bridge the gap of fuel requirement. However with the availability of Renewable generation, about 20 GW (67 GW @30% CUF) shall make up for thermal generation to some extent. As per the thumb rule of requirement of 4.7 MT coal per 1 GW per annum, Renewable shall help in reducing the coal requirement by 94 MT per annum thus reducing the import requirement by 43% bringing in more energy security.

Further with the increased penetration of Electric Vehicles in the country, this would also help in reducing the dependence on import of petroleum product which is projected to be around 80% in the 12th plan period.

12.2. Energy from Fossil Fuel

As per the statistics available, India has only 0.6 % of world's Oil, 0.6 % of natural gas and 6 % of coal reserves. However these reserves are depleting very fast due to due to increase in demand for energy, not only at country level but also globally. Import of above primary energyresources to meet energy demand shall burden the economy with heavy outgo of foreign exchange as well it shall also be uneconomical in the long run. As per the statistics india's extractable fossil fuel reserve are as given in the table 12-1.

Table 12-1 : India's Extractable Fossil Fuel Reserve

Fuel	Production (2007)	Years of Supply at 2007 Production Rate
Coal	457 million tonne	169
Lignite	34 million tonne	36
Oil	34 million tonne	23
Gas+ Coal Bed Methane (CBM)	34 billion m^3	75

Coal

India's coal reserves are also declining at fast pace due to increased demand. While at the 2007 level of production coal will last for 160 years or more, at the rate at which coal consumption is currently growing it will not last for more than 40 years.

Oil & Gas

Considering the fast depleting oil reserves estimated at the current rate of production and consumption, it is expected that reserves shall last only up to 23 years.

Nuclear

India also has limited reserves of uranium, a nuclear fuel. Domestically available uranium supply can fuel only 10,000 MW of capacity for pressurized heavy water reactors (PHWRs). Further, India is extracting uranium from extremely low grade ores (as low as 0.1% uranium) compared with ores with up to 12–14% uranium in certain resources abroad. This makes Indian nuclear fuel 2-3 times costlier than international supplies. The country's substantial thorium reserves can be used, but that requires the fertile thorium to be converted into fissile material (uranium-233). In this context, a three-stage nuclear power program is envisaged. This program consists of setting up PHWRs in the first stage, fast breeder reactors (FBRs) in the second stage, and reactors based on the uranium-233–thorium-232 cycle in the third stage. The first-stage reactors produce plutonium as they generate electricity. This plutonium and the spent uranium from the first generation plants are then used in FBRs, which produce more plutonium than put in as they generate electricity. When fully recycled in this fashion, the domestic uranium can generate 500,000 MW of power. The catch is that an FBR takes eight to ten years before the plutonium inserted is doubled and a new FBR can be set up. Once there are enough FBRs, thorium will be used as blanket material to be converted into uranium-233 to fire the third stage. India's thorium reserves can provide millions of megawatts of power. It is also envisaged that in the first stage of the program, capacity addition will be supplemented by electricity generation from light water reactors (LWRs), initially through imports of technology but with the long-term objective of indigenization. Research and development into the utilization of thorium is also in progress. The pace of development of nuclear power is constrained by the rate at which plutonium can be bred and thorium converted to fissile material. Two possible scenarios, for development of nuclear power capacity with & without import of fuel technology is summarized in Table(12-2) below.

Table 12-2 : Possible development of India's nuclear power installed capacity, in MW. *Import* refers to the importing of power plants with fuel and the right to reprocess it. (Source: DAE)

Year	40,000 MW	8,000 MW	No Import
	Import by 2030	Import by 2020	
2030	1,10,000	63,000	48,000
2050	4,50,000	2,75,000	2,08,000

In order to achieve the above targets, there are hurdles to be crossed. The FBR technology must work well and reduce the doubling time for breeding plutonium, and popular reservations about the safety of nuclear plants have to be overcome.

12.3. Energy Security

In order to reflect our situation in terms of energy security, as per the Integrated Energy Policy document (Aug'06) of Planning commission, relevant para is as under:

Quote
We are secure when we can supply lifetime energy to all our citizens irrespective of their ability to pay it as well as meet their effective demand for safe and convenient energy to satisfy their various needs at competitive prices, at all times and with a prescribed confidence level considering shocks and disruptions that can be reasonably expected.
Unquote

Actions to improve energy security can be classified broadly into two groups, reducing risks and dealing with risks. The major policy options are:

a) Reducing Risks

- Reducing the requirement of energy by increasing efficiency in production and use of energy
- Reduce import dependence by substituting imported fuels by domestic fuels
- Diversify fuel choices and supply sources
- Expand domestic energy resource base

b) Dealing with Risks

- Increase ability to withstand supply shocks
- Increase ability to import energy and face market risk
- Increase redundancy to deal with technical risk

12.4. Impact of Renewables in Reducing Oil Imports

Import of petroleum productsform a major share of Indian import and place a high demand on foreign exchequer. As per the information available, transport sector alone consumes about 40-50%, which is a major chunk of petroleum consumption. The large consumption pattern for petroleum by transport sector may be attributed to factors like frequent braking actions, due to road conditions & Traffic volume, vehicle efficiency or less mileage etc.

The inherent characteristics of Renewable energy resources like wind & solar is that, it is available at the time when the traditional usage level of electricity is not high like off peak power demand hours. These characteristics can be gainfully utilized, if power available through such renewable resources is used by transport sector.

This can be achieved through electrification of transportation using electric vehicles (EV) or plug-in hybrid electric vehicles (PHEV). A brief of the Electric vehicle is described as below:

Electric Vehicles(EV)

Plug-in Hybrid Electric Vehicle (PHEV): It is a dual-fuel car (both the electric motor and the internal combustion engine can make the car run). It has a larger battery pack that is plugged into the electric grid for charging, increasing the share of electric power used by the car.

Battery Electric Vehicle (BEV): This is all electric vehicle, has no internal combustion engine and totally dependent on plugging into the electric power grid. Such Electric Vehicle can store electricity from renewable sources during other than the peak demand period when renewable generation is high so as to utilize energy available in that period and later use it for the purpose of transportation as well as feeding back into the grid, if required. This arrangement shall require periodic charging of the EVs for which charging stations shall have to be developed within reachable distances which in Indian context are not a concern due to widespread population thereby relatively smaller distances between adjacent towns & cities. However, a commercial mechanism through regulation needs to be devised to encourage market for such solutions.

EV Charging

The standard charging modes for EV are as under:

- **Mode 1** - slow charging from a regular electrical socket (1- or 3-phase)
- **Mode 2** - slow charging from a regular socket but which equipped with some EV specific protection arrangement (e.g., the Park & Charge systems)
- **Mode 3** - slow or fast charging using a specific EV multi-pin socket with control and protection functions

Charging of Electric Vehicle through Solar panels as well as through charging stations is as given in Fig-12-4 & 12-5:

Figure 12-4: Solar EV Charging

Figure 12-5: Plug in Charging

Battery technologies

A general comparison of the specific power and energy of the battery technologies in Figure 12-6 is as under. Although there is an inverse relationship between specific energy and specific power (i.e., an increase in specific energy correlates with a decrease in specific power), lithium-ion batteries have a clear edge over other electrochemical approaches when optimized for both energy and power density.

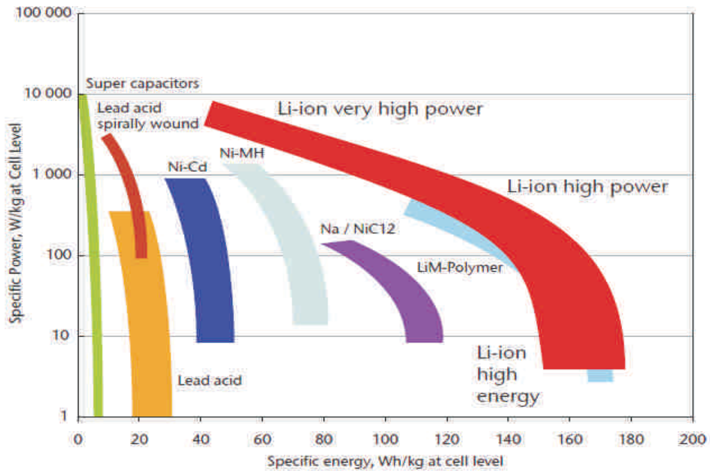

Figure 12-6: Different Battery technologies

In this manner, energy sustainability, through renewable, to some extent, may be achieved through two ways: by reducing dependence on thermal generation i.e. coal & oil imports as well as reduce dependence on oil for transportation through use of electric vehicles or energy storage technology.

12.5. Renewable Energy Potential

The development of Renewable energy sources for electricity generation like Wind & Solar is quite recent phenomenon. The technology involved in the electricity generation through these resources is evolving very fast. The per MW power available in a given area now is multiple of what it used to be about 3-4 years back. The scientific and research work carried out by various independent agencies have claimed that the wind energy potential of the country is far in excess of earlier official estimates by C-WET. Various agencies have estimated the Wind potential of the country, of which details are as under:

- **Centre for Wind Energy technology (C-WET)**

- *Wind potential in the country is 49 GW at 50 meter & 103 GW at 80 meter level taking into account 2% land availability figures*

- *In its new bulletin (issue-31), C-WET has also indicated that considering 6% land availability, estimated potential shall be about 300 GW in seven wind rich states*

- **Berkeley report (Sep'11) on "Reassessing Wind Potential Estimates for India: Economic and Policy Implications" in its report re-assessed the wind energy potential in India and concluded that**

- *The developable on-shore wind potential under the "no farmland included" scenario ranges from 748 GW to 976 GW (capacity factor greater than 22 percent).*

- *Under the "all farmland included" scenario, the potential ranges from 984 GW to 1549GW (capacity factor greater than 22 percent).*

- *The potential at high-quality wind energy sites alone (80m hub-height with a minimum capacity factor of 25 percent) ranges from 253 GW (no farmland included) to 306 GW (all farmland included) – more than five times larger than the current official estimate.*

- **Berkeley report (Rev-1:Mar'12) on "Reassessing Wind Potential Estimates for India: Economic and Policy Implications" in its report re-assessed the wind energy potential in India and concluded that**

- *The potential at high-quality wind energy sites alone (80m hub-height with a minimum capacity factor of 25 percent) is 543 GW, more than five times larger than the current official estimate*

- *The techno-economic on-shore wind potential ranges from 2,006 GW at 80m hub-height to 3,121 GW at 120m hub-height with a minimum capacity factor of 20 percent.*

- **Hossain J, et al., A GIS based assessment of potential for windfarms in India, Renewable Energy (2011), TERI univ.** ***(Apr'11)***

- *The potential of wind at 80m hub-height at Net PLF in the range of 15-45% would be around 4250 GW, while with Net PLF of 20-45%, wind potential estimated is around 2075GW*

- **Electricity from Wind: Global Perspective with Detailed Application to the US by Lu, Xi, Michael B. McElroy, and Juha Kiviluoma, Harvard University**

- *Annual Wind Energy Potential of India is estimated to be about 4000TWh [on shore (2900 TWh) and off shore (1100 TWh)]*

However such gigantic optimistic figures still needs a realistic review based on the scientific norms. Ministry has also launched a reassessment programme with 100 m anemometry to validate the potential at 100 m level in seven potential states including the land assessment.

Therefore, despite the facts that wind patterns are not varying, estimation of Wind potential is being revised on account of change in various reference parameters. Still, above estimates gives a very optimistic and encouraging projections.

However in order to harness full potential of Wind generation in the country, it would be prudent to develop offshore technology as well. India's 6,400 km-long coastal line offers enormous potential for off shore wind generation development. Off shore not only offers almost double, about 35-40% capacity utilisation factor, as compared to on shore wind generators but also provide solution of setting up of large scale generation projects at individual sites. Additionally, in some places concentration of such resources are close to load centers (few metros) which is again an added advantage.

Ministry for New and Renewable Energy (MNRE) has also constituted an Offshore Wing Energy Steering Committee (OWESC) under the chairmanship of Secretary, MNRE to steer the offshore wind power development in India in a directed and focused manner especially in Tamil Nadu, Maharashtra and Gujarat.

With a view to establish offshore wind farm in India, efforts have been taken by a working group consisting of expert members including from C-WET to study wind resource assessment on two locations viz. Rameshwaram and Kudankulam, high potential off-shore sites. However development & assessment of off-shore wind potential is yet to be achieved in a significant manner.

Solar Potential in India is also estimated to be about 20-30 MW/sq km which is about 5000 trillion units annually. However these estimates may also considered for a reassessment.

In view of the above, it is proposed that MNRE, CWET or Indian Meteorological Department (IMD) may take up Wind/Solar potential reassessment and re-develop Wind Power density as well as Solar Map of India.

12.6. The Push for Renewables and Energy Efficiency

To meet future energy demand, India will need to promote more renewables, develop smarter grids, and intensify energy R&D efforts. Some of the major advantages of renewable energy sources are as follows:

- Indigenous resources –Contributes to energy security
- Inexhaustible (such as solar, wind) or can be replenished (such as Biomass etc.)
- Good for the environment both locally and globally- clean energy
- Feasible for decentralised/distributed power generation.
- Lower cost of operation- free fuel in wind/solar generation
- Free from pollution and mitigates GHG emissions.
- Provides access to modern energy to all rural, isolated and low income populations

The government of India has recognized the large scope of solar energy and the country's inevitable eventual reliance on it. As a part of its national action plan to deal with climate change, it has launched eight national missions. These missions include a mission on energy efficiency and another on solar energy.

The National Solar Mission

The solar mission aims to make solar power cost-competitive with coal by 2020. To do so, it recognizes the need to promote the establishment of solar power plants to exploit economics of scale and stimulate innovations and cost reduction. It thus proposes to set up solar power plants with 20,000 MW of installed capacity by 2022. This will be supported through subsidies provided in the form of a feed-in-tariff (FIT). An innovative measure of reverse bidding for the feed-in-tariff has been introduced under which firms bid for the FIT. It is been seen that FIT has been reduced with a good margin in second round. Summary of comparison between CERC tariff and Average Bid Tariff is shown in figure 12-7 below:

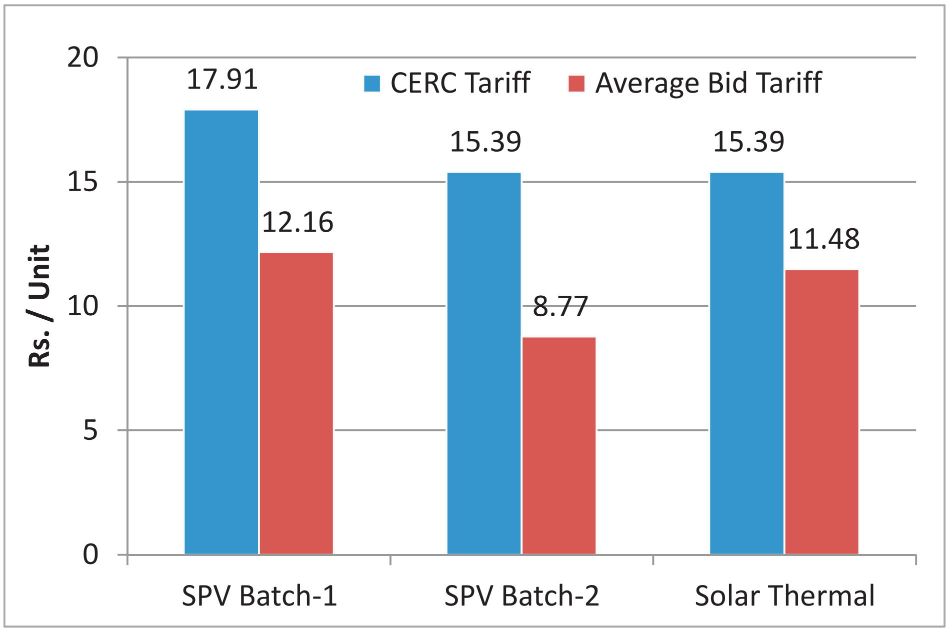

Figure 12-7: Comparison between CERC tariff and Average Bid Tariff (Source-MNRE presentation 4th ASEF, Apr'12)

Smart Grid

Solar power and wind power are not available on demand, however they need to be integrated into the grid. To do so effectively, application of smart grid technologies plays a prominent role. To use hydro power to complement solar and wind power, however, strengthening of national grid is crucial.

The rapidly growing demand will put pressure on existing transmission and distribution system. For inclusive and sustainable growth, electricity should be supplied to all people in all parts of the country at a affordable price. For this the grid should be equipped with intelligence through control & automation, communication, intelligence computing towards development of smart grid so that large scale integration of renewable is feasible.

With the technological development and increase in production volume, the cost of Solar PV module has been rapidly reducing. An estimate from International Renewable Energy Agency (IRNA) for trend in PV module selling Price with increase in production volume is shown in figure 12-8 below:

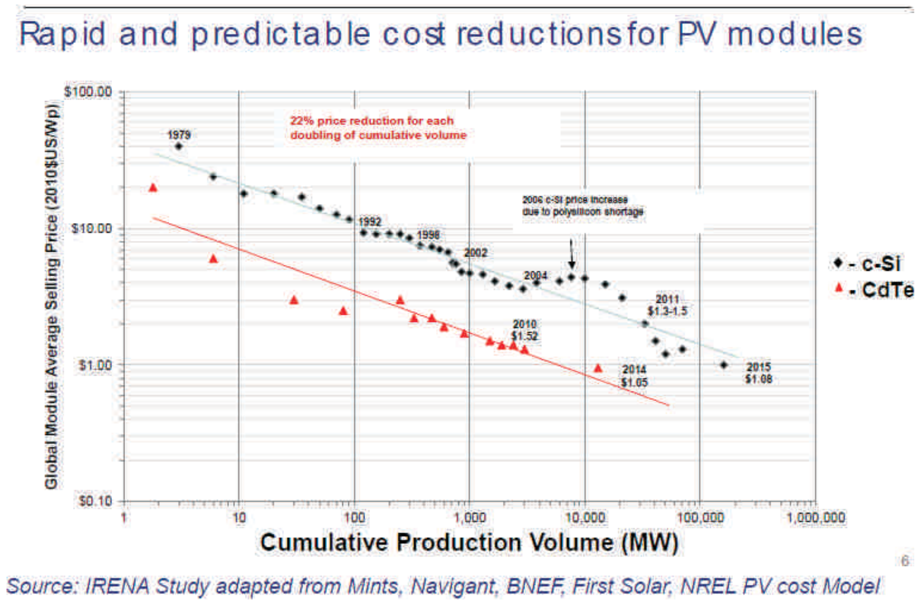

Figure 12-8: Cost of Solar PV module

Similar trend has also been observed in the levelised cost of solar energy by Lehmeyer International is as shown in figure 12-9 below:

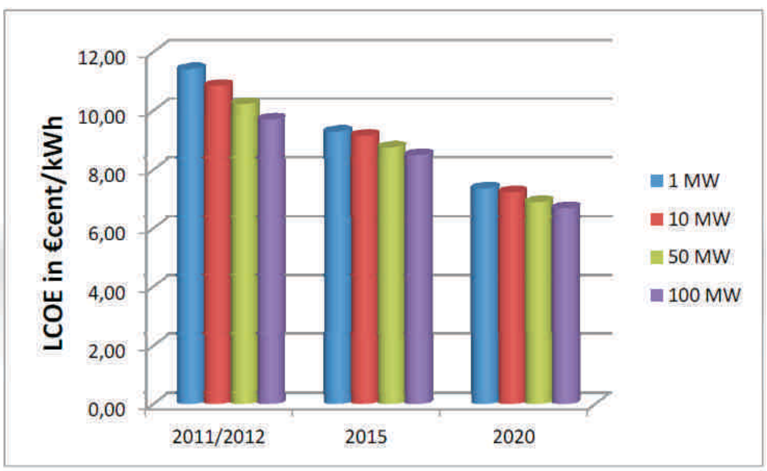

Figure 12-9: Levelised Cost of Solar PV module

12.7. Perspective Transmission Plan for Renewables

Considering above Wind/Solar potential estimates as well impetus given on development of Renewable generation, a perspective transmission plan for renewable, that serves as a road map has been chalked out for year 2030. However considering the challenges arising out of integration of renewable, broad contours of transmission plan has been prepared with following approach:

(1) Development of Hybrid EHV AC/ HVDC Transmission system for flexibility of controls

(2) Interconnection of RE rich regions as well as with major load centers as touch points

(3) Transmission corridors passing through conventional generation complexes like Andhra (Gas), Orrisa (Thermal), Jharkhand (thermal) etc. as well as new transmission corridors from hydro rich areas with NER/Bhutan to achieve supply balancing

An assessment has been carried out for RE contribution into power supply scenario for 2030. Estimation of Wind & Solar generation capacity is done based on the assumptions of the past growth trends in RE capacity addition. However, potential of above resources have been taken into account while doing an assessment.

The wind industry has experienced much higher growth rates in recent years. However, in future, the capacity growth shall not be able to maintain such an accelerated pace (176% for 2016-17). Therefore, it is likely that capacity addition shall achieve moderate growth rate beyond 2016-17 till 2030 (Growth rate assumed: 60% for 2021-22, 30% for 2026-27 & 15% till 2030 on reference growth of 2016-17). However even smaller growth rates shall translate into large figures in terms of annually installed megawatts making wind generation installed capacity to 164 GW by 2030, about 10 times of present capacity.

For Solar generation, it has been assumed that JNNSM envisaged solar capacity addition of 20 GW by 2022 (end of 13th plan) shall be in place and there shall be further (10 GW in 14th plan & 50% of last plan addition upto 2030) i.e.15 GW addition leading to 35 GW capacity by 2030.

Details of the envisaged Wind & Solar capacity addition by 2030 based on the above assumptions are as under:

Table -12.3 : Envisaged Wind & Solar Capacity

Resource	Present (GW)	2016-17 (12th plan) (GW)	2021-22 (13th Plan) (GW)	2026-27 (14th Plan) (GW)	2030 (mid 15th plan) (GW)
Wind	17	47	97	148	164
Solar	0.92	9.45	20	30	35

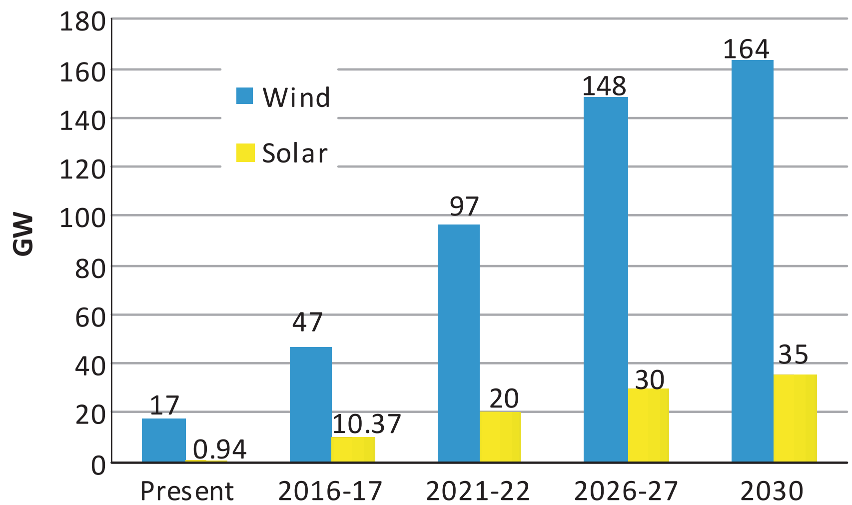

Figure 12-10: Envisaged Wind & Solar Capacity addition

In addition to above, it is assumed that Biomass Potential (22 GW) as well as Small Hydro potential (15 GW) shall be fully harnessed by 2030. Therefore total RE capacity availability by 2030 is envisaged to be about 236 GW (199 GW+37 GW).

Therefore keeping in view the pocket wise envisaged capacity addition by the end of 12th plan, Wind & Solar capacity of the different pockets in RE rich States has been estimated for 2030 on pro rata basis based on their contribution by the end of 2016-17.

Table -12.4 : State Wise Wind & Solar Capacity by 2030

State	Capacity (2016-17) # [GW]		Capacity (2030) [GW]	
	Wind	Solar	Wind	Solar
Tamil Nadu	12.37	3.01	44	10
Karnataka	5.01	0.17	18	1
AP	5.44	0.38	19	1
Gujarat	7.68	2.00	27	7

State	Capacity (2016-17) # [GW]		Capacity (2030) [GW]	
	Wind	Solar	Wind	Solar
Maharashtra	11.48	0.92	41	3
Rajasthan	4.10	3.90	15	13
J&K	0.012	0.104	0.04	0.35
Subtotal	***46.09***	***10.48***	***164***	***35***
Total	***56.57***		***199***	

 # As per SNA /STU information

From above estimates, it can be inferred that Tamil Nadu(44 GW) & Maharashtra (41 GW) shall continue to dominate the wind based capacity addition having almost 50% share of total capacity addition whereas Rajasthan (14 GW) & Tamil Nadu (10 GW) shall dominate in Solar based generation with almost 70% share of total capacity addition.

As per *"Integrated Energy Policy by Planning commission of India"* (IEP) *(Aug'06)* , Projected peak demand by 2031-32 is 592 GW and corresponding generation Capacity requirement shall be 778 GW. For year 2030, considering the growth rate as per IEP for 13th/14th & 15th plans, it can assumed that above statistics would be about 525 GW for peak demand, 680 GW as installed capacity requirement & energy requirement shall be about 3200 BUs. Considering that above envisaged generation capacity including RE shall be available by 2030, RE capacity penetration shall be 35% (199+37/680) whereas energy penetration shall be about 21% ([236*0.32*8760*10^-6]/3200).

As per the "Report on World energy scenario (2010) of Greenpeace International & European Renewable Energy Council", it is envisaged that renewable capacity by 2050 will grow to 775 GW (including 57 GW Hydro). Considering the above envisaged renewable capacity, it is expected that capacity penetration from renewable shall be more than 50% by 2050.

Keeping above in view, a perspective Transmission plan is prepared for 2030 which includes high capacity hybrid UHV/EHV AC & HVDC transmission system. This shall not only help in transfer of power from renewable rich state to other deficit states but also complement the parallel transmission system of conventional generation projects/grid strengthening scheme for transfer of power as well as to maintain grid parameters. Capacity of Transmission corridors from different complexes have been evolved based on the, assumptions that RE generation in other than the peak demand period shall be about 70%, however, some of the portion of that generation (about 20%) shall be used to meet RPO requirement of the state as well as available transmission infrastructure shall be utilized for transfers. Considering this, transmission capacity for Renewable by 2030, need to be established for 50% of the envisaged capacity addition.

Broad transmission infrastructure plan shall include following inter state high capacity transmission corridors emanating from RE rich states vis. Tamil nadu, Andhra Pradesh, Karnataka, Maharashtra, Gujarat & Rajasthan. However, it is to emphasize that apart from above proposed ISTS high capacity transmission highways, there would be requirement of intra state transmission system strengthening within STU transmission & distribution network of RE rich states.

Details of the proposed ultra-high capacity transmission highways are as under:

(a) SR-WR/ER- NR Transmission Corridors (TRC)

- 765kV Tamil Nadu (SR) RE complex- Maharashtra/Gujarat (WR)- Rajasthan-Haryana/Delhi (NR) D/c ***(TRC-1)***
- ±800kV, 6000 MW (Multi terminal) Tamil Nadu/Karnataka RE complex- Uttar Pradesh load centers HVDC Bipole ***(TRC-2)***
- 765kV Karnataka (SR) RE complex- Maharashtra/Madhya Pradesh (WR)- Uttar Pradesh/Uttaranchal- Punjab (NR) load centers D/c***(TRC-3)***
- ±500kV 2500 MW Tamil Nadu - Andhra Pradesh HVDC Bipole and 765kV Andhra Pradesh (SR)- Maharashtra(WR) load centers ***(TRC-4)***
- 765kV Tamil Nadu /AP (SR) RE complex – Orrisa (ER)– Jharkhand (ER)– Bihar (ER)– UP/Punjab (NR) Load centers D/c ***(TRC-5)***

(b) WR - NR & NR Transmission Corridors

- 765kV Gujarat RE complex – Rajasthan- Haryana/Delhi (NR) D/c ***(TRC-6)***
- ±800kV 6000 MW (Multi terminal) Gujarat - Rajasthan RE complex – Punjab load centers HVDC Bipole ***(TRC-7)***

- 765kV Rajasthan RE complex (Jaisalmer/Barmer)– Central Rajasthan – Punjab-J&K load centers D/c ***(TRC-8)***

(c) ER - NR Transmission Corridors

More transmission infrastructure involving HVDC technology may be developed to harness Hydro Potential of NER, Sikkim/ Bhutan to achieve supply balancing for smooth integration of large scale renewable:

- $\pm$ 800kV 6000 MW (Multi terminal) NER/Sikkim/Bhutan – Delhi/Haryana load centers HVDC Bipole ***(TRC-9)***

A schematic of above proposed 9 nos. (nine) ultra-high capacity transmission highways (***TRC-1 to TRC-9***) is shown at Fig 12-11 :

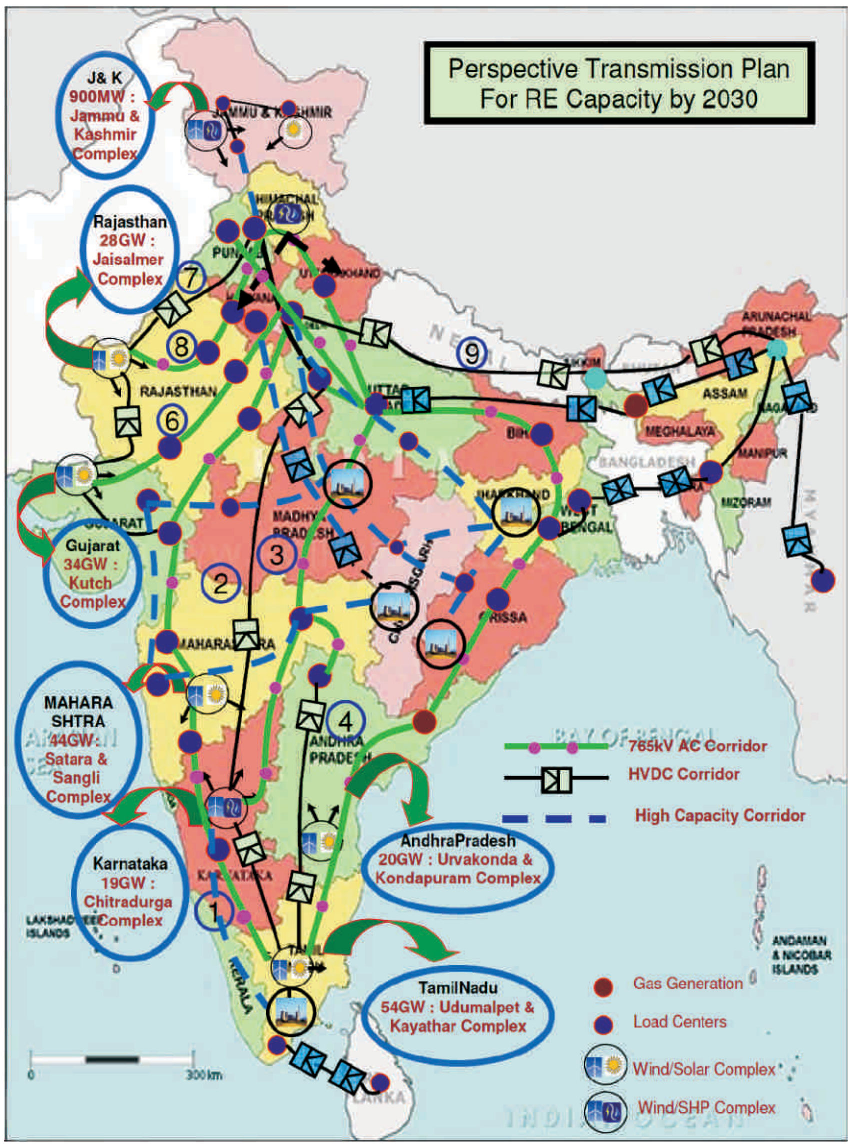

Figure 12-11: Proposed High Capacity transmission corridor for RE

12.8. Technological Trends

With its limited energy resources and large dependence on oil imports, India needs to adopt and develop emerging technologies to harness its renewable energy resources and their optimal utilisation. Some key initiatives which are necessary in present in this domain are:

- Development of Micro Grid for renewable
- Development of large size RE generators to achieve economies of scale
- Development of off-shore wind generation. Focus area on :
  - Installation of submarine DC cables for integration
  - VSC based HVDC technology
  - Reactive / dynamic compensation
- Deployment of roof-top solar and wall solar generation
- Development of Grid Scale Storage capacities
- Use of the latest control mechanism to handle the complexities associated with renewable generation

Bibliography:

Documents:

1. Government of India, “Electricity Act”, June 2003
2. Central Electricity Authority, Government of India, “Central Electricity Authority (Grid Standards) Regulations", 2010, June 26, 2010
3. Central Electricity Authority, Government of India, “Draft 18th Electric Power Survey (EPS) of India Report
4. Central Electricity Regulatory Commission, Government of India “Indian Electricity Grid Code (IEGC) -2010”, April 2010
5. Central Electricity Regulatory Commission, Government of India, “Terms and Conditions for recognition and issuance of Renewable Energy Certificate for Renewable Energy Generation”, January 2010
6. ABPS Infrastructure Advisory Private Limited, “Report on ‘Conceptual Framework for REC Mechanism in India” , June 2009
7. Central Electricity Authority, Government of India, “Manual on Transmission Planning Criteria”, June 1994
8. Philbrick, "Wind Integration and the Evolution of Power System Control," Power Engineering Society General Meeting, Minneapolis: IEEE, July 2010.
9. Philbrick, "Wind Integration and the Need for Advanced Support Tools”, Power Engineering Society General Meeting, Minneapolis: IEEE, July 2011.
10. International Energy Agency, “Harnessing Variable Renewables: A guide to the Balancing Challenge”, 2011
11. World Wind Energy Association, “Wind Energy International 2011/2012 yearbook” 2012
12. Safety in Numbers by IVAN M Dudurych, Alan Rogers, Robbie Aherne, Lei Wang, Fred Howell & Xi Lin in IEEE Power & Energy Magazine March/April 2012
13. 19 rules for transmission : lessons learned in wind generation by Dale obsorn: IEEE Power & Energy Magazine March/April 2012
14. CIGRE Technical Brouchere (Working Group 1.3), “Electric Power System Planning With The Uncertainty Of Wind Generation” , April 2006
15. Lawrence E. Jones, “Strategies and Decision Support Systems for Integrating Variable Energy Resources in Control Centers for Reliable Grid Operations : Global Best Practices, Examples of Excellence and Lessons Learned, Available at

    http://www1.eere.energy.gov/wind/pdfs/doe_wind_integration_report.pdf

Websites:

1. http://cea.nic.in/report.html
2. http://www.mnre.gov.in/
3. http://www.iea.org/
4. http://www.cwet.tn.nic.in/Default.htm
5. http://wwindea.org/home/index.php
6. http://www.cercind.gov.in/
7. http://nldc.in/REC.aspx
8. http://nldc.in/nldcmain.aspx
9. http://www.ree.es/ingles/home.asp
10. http://www.50hertz.com/en/index.htm
11. http://www.elia.be/
12. http://www.caiso.com/Pages/default.aspx