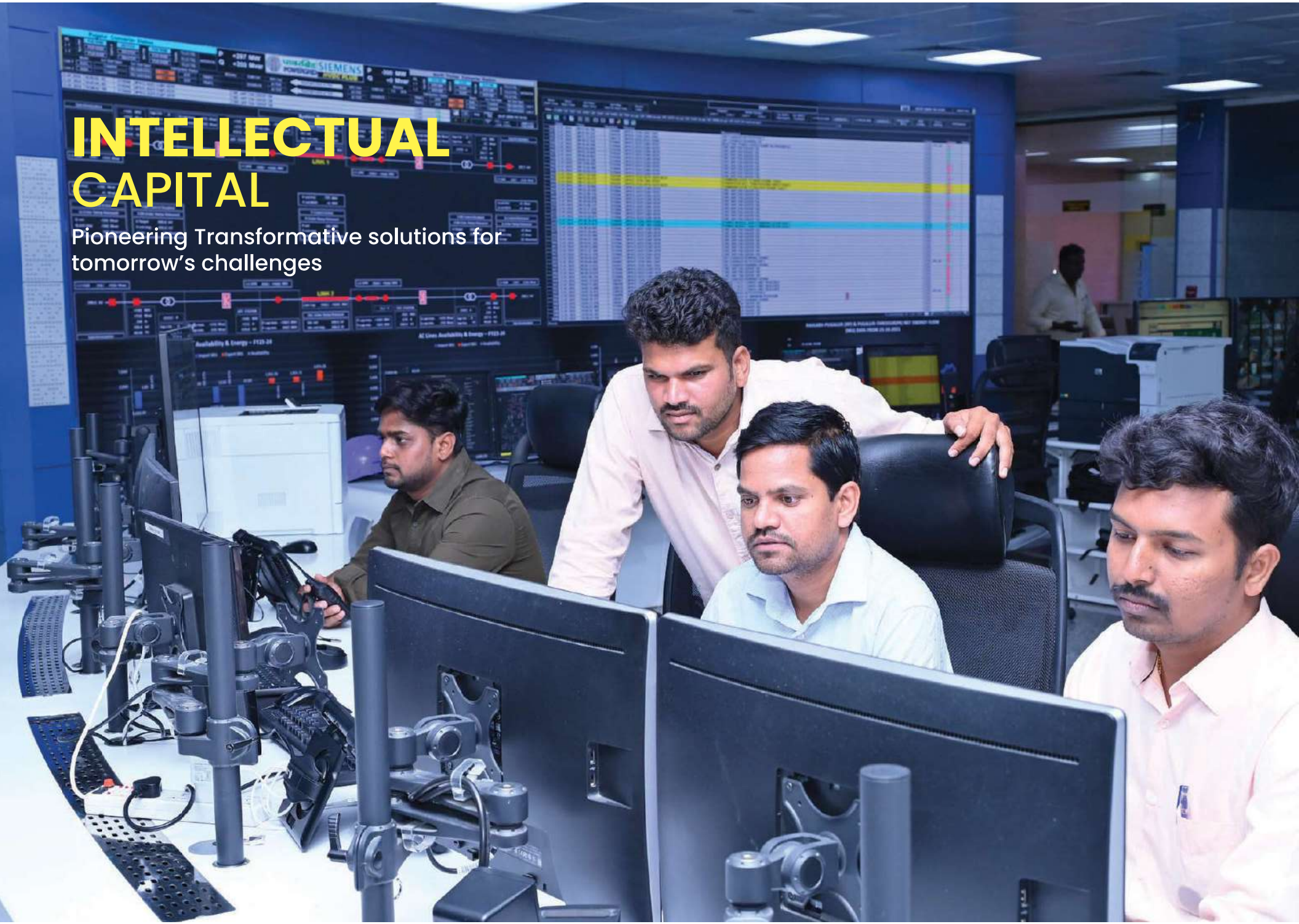

INTELLECTUAL CAPITAL

Pioneering Transformative solutions for tomorrow's challenges

RESEARCH AND DEVELOPMENT

Our collective knowledge, skills, and innovation are central to our success and adaptability in the dynamic energy sector. This section explores how we cultivate and leverage these critical intangible assets. Through strategic initiatives and investments, we foster a culture of continuous learning and knowledge sharing, empowering our workforce and improving operational efficiency. By harnessing our intellectual strengths, we maintain a competitive edge, advance technology, and ensure long-term value creation for stakeholders, facilitating reliable and efficient power delivery nationwide.

FOCUS AREAS

- **Research and Development**
- **Data Privacy and Cybersecurity**
- **Digital Transformation**

TECHNOLOGY ADOPTION AT POWERGRID

POWERGRID leads the way in adopting cutting-edge technologies in the transmission sector, marking significant milestones for India. Key advancements include:

- **1200kV UHVAC at Bina**
  The highest transmission voltage globally, showcasing India's engineering prowess.
- **High Voltage Direct Current (HVDC) Systems**
  - Asia's first multi-terminal ±800kV, 3000MW HVDC system, leveraging hydro resources from the North-East and Bhutan.
  - ±320kV, 2000MW VSC HVDC system connecting Tamil Nadu and Kerala.
- **Flexible AC Transmission Systems (FACTS)**
  Incorporating devices like STATCOM and SVCs to enhance grid stability.
- **High Temperature Low Sag Conductors**
  These increase the power-carrying capacity of transmission corridors.
- **Gas Insulated Switchgear (GIS) Substations**
  Operate at 400kV and 765kV, using only one-third of the land required for conventional Air Insulated Substations (AIS).
- **Nano-Coating for Insulators**
  Improves hydrophobicity, reducing failures and enhancing system reliability.
- **Resin Impregnated Paper Bushings at 765kV**
  Enhances equipment performance and ensures safety.

These technological innovations position POWERGRID at the forefront of modern infrastructure, driving India's energy sector towards greater efficiency and reliability.

POWERGRID and IIT Kanpur Collaborate on India's First Substation Inspection Robot

As India's power demands rise in the digital era, the need for smarter, safer, and more efficient infrastructure becomes paramount. In a pioneering effort, POWERGRID, in collaboration with the Indian Institute of Technology, Kanpur (IITK), has developed and tested a state-of-the-art Substation Inspection Robot. This initiative supports the national goals of Aatmanirbhar Bharat and Make in India.

This innovative robotic solution marks a significant advancement in automation, digitization, and predictive maintenance within India's power sector. Key benefits include:

- Reliable, error-free inspections under challenging conditions such as snow, rain, or low-light environments.
- Real-time alarm notifications and visual analytics for immediate response.
- Reduced inspection times and increased equipment availability.
- Data-driven predictive maintenance capabilities to minimize downtime.
- Enhanced safety by eliminating the need for human intervention in hazardous situations.

This first-of-its-kind technology positions India at the forefront of modern power infrastructure management.

Major Technological Initiatives during FY2024-25

Dynamic Voltage Stability

POWERGRID has installed 17 Static Synchronous Compensators (STATCOMs) and 3 SVCs within the 400 kV grid to boost voltage stability and facilitate renewable energy integration. These advanced devices quickly adjust reactive current to regulate voltage at grid connection points. Ten additional STATCOMs are currently being implemented.

High-Temperature Low-Sag (HTLS) Conductors

POWERGRID is upgrading its transmission network with HTLS conductors, which allow existing lines to carry higher currents without major structural changes. Operating at higher temperatures with minimal sag, these conductors enhance transmission capacity, system reliability, and renewable energy integration.

Patents-Innovation through Research

We have secured patents for several key innovations including System and method for health assessment of transformers / reactors, Thermal energy storage-based air conditioning system and a method to manufacture the same, FPGA based micro-grid control and monitoring system, Energy efficient all season roof screening and Smart socket and smart home energy manager.
For more information please refer to https://www.powergrid.in/en/technology-development-rd

Insulated Cross Arm for 400kV Lines

To reduce Right of Way (RoW) and improve ground clearance, POWERGRID is pioneering the use of Insulated Cross Arm technology for 400kV lines, a first in India.

Indigenous Emergency Restoration Systems (ERS)

To reduce reliance on imported ERS components, POWERGRID has developed modular ERS systems in collaboration with Indian partners. Capable of supporting transmission lines up to 400 kV, these locally manufactured systems enhance infrastructure resilience and have been deployed at test sites for training and evaluation.

3D PRINTER AND SCANNING TECHNOLOGY

POWERGRID is harnessing 3D printing and scanning technologies to drive innovation, sustainability, and efficiency in power transmission. These tools are revolutionizing maintenance, design, and component development by facilitating reverse engineering and rapid prototyping. Key applications include:

- Rapid Prototyping and Design Visualization
  These technologies accelerate product development cycles by allowing real-time visualization and testing of component designs before full-scale production or implementation.
- On-Site Component Fabrication
  Field teams can manufacture custom replacement parts directly on-site, addressing damage or obsolescence issues and reducing downtime by bypassing traditional supply chain delays.
- Advanced Power Systems Support
  The technologies aid in maintaining and replacing parts for complex systems like HVDC, GIS, and SVC, where component availability is often limited by vendor ecosystems.

COLLABORATION WITH IIT MADRAS ON OFFSHORE WIND POWER

POWERGRID is collaborating with IIT Madras to support India's goal of achieving 37 GW of offshore wind power capacity by 2030 in Gujarat and Tamil Nadu. With the initial phase involving the development of 5 GW Offshore Wind Energy project, POWERGRID is focusing on the design, engineering, construction, installation, testing, commissioning, and maintenance of:

- Offshore Pooling Substations
  These will include jackets, foundations, topsides, Gas Insulated Switchgears, transformers, reactors, and more.
- Undersea Export Power Cables
  This involves the installation of cables with transition joints at onshore locations.

The offshore wind energy evacuation system is a new frontier for both India and POWERGRID, presenting challenges related to the corrosive, salty, humid marine environment, cyclones, water currents, waves, and accessibility. The collaboration with IIT Madras aims to address these challenges by focusing on the design and engineering of offshore structures, equipment, and undersea power cables.

220 kV UNDERGROUND CABLE IN HILLY TERRAIN

POWERGRID was part of a strategic initiative to bolster grid reliability along the Srinagar–Leh Transmission System (SLTS), which faces extreme environmental challenges. This system, crucial for transferring power from the Northern Grid to remote areas like Srinagar and Leh, is often hindered by snow and avalanches, particularly in the Minamarg–Zojila section. This area experiences prolonged outages during winter months, compounded by road inaccessibility for 3–4 months each year, making maintenance difficult.

To address these issues, POWERGRID constructed an underground Extra High Voltage (EHV) cable system in the affected stretch. This technological advancement ensures:

- Redundancy & Rapid Restoration: The underground cable serves as a standby path, quickly activating when overhead lines fail due to environmental disruptions.
- Minimized Downtime: It provides rapid connectivity with existing infrastructure, reducing outage durations and facilitating quicker power restoration.
- Enhanced Reliability: An extra spare cable run is included, ready to integrate with the main phase conductors in case of faults, boosting system reliability and flexibility.

This project underscores POWERGRID's innovative approach to overcoming topographical and climatic obstacles, significantly enhancing power supply resilience to remote and strategically sensitive regions. By ensuring swift restoration and improved accessibility, it strengthens the northern grid infrastructure, setting a new benchmark for high-altitude transmission solutions.

POWERGRID has successfully patented an innovative **"System and Method for Health Assessment of Transformers and Reactors."** This breakthrough technology facilitates centralized monitoring and diagnostics for extensive fleets of transformers and reactors. It integrates a system and methodology for collecting design specifications, nameplate details, and routine test data from diverse sites and laboratories. The collected data is analyzed to assess asset health using selected parameters, and the results are visually represented through hybrid health indicators on a graphical user interface. This invention dramatically enhances proactive asset management and predictive maintenance capabilities.

DATA PRIVACY & CYBERSECURITY

At POWERGRID, safeguarding the integrity of our infrastructure is crucial, especially given our role in supporting critical government agencies and departments. Protecting sensitive information is central to our operations, encompassing data privacy and cybersecurity throughout our service lifecycle. We have fortified our defences with stringent policies and achieved ISO 27001 certification for Information Security Management Systems across all offices. Prioritizing employee training, we regularly engage in exercises conducted by organizations like the Computer Emergency Response Team (CERT-In) and the National Critical Information Infrastructure Protection Centre (NCIIPC).

POWERGRID Centre of Excellence in Cybersecurity

To address the evolving cybersecurity threats in the power sector, especially in substation automation and embedded systems, POWERGRID has established a Centre of Excellence in Cybersecurity at the Indian Institute of Science, Bangalore. This centre focuses on research in key areas such as Intelligent Electronic Devices (IED) analysis, risk and vulnerability assessments, and the development of protection systems against cyber-attacks. Currently, the centre is working on 15 projects aimed at anticipating future cybersecurity challenges and implementing effective mitigation strategies.

Computer Security Incident Response Team (CSIRT) – Power

In response to rising cybersecurity threats, the Central Electricity Authority (CEA) has formed CSIRT-Power, a specialized team to bolster the cybersecurity infrastructure of India's power sector. As an extension of CERT-In, CSIRT-Power focuses on enhancing cybersecurity resilience through advanced threat identification and mitigation tools. Its responsibilities include defining cybersecurity frameworks, analysing incidents, coordinating with CERT-In on cyber crisis management, and promoting cybersecurity research. CSIRT-Power acts as a central hub, bridging regulatory oversight with technical implementation to ensure a secure and resilient power sector.

- POWERGRID has set up the Integrated Indigenous Information Security Operation Centre (I3SOC) to monitor cybersecurity threats, staffed round-the-clock by expert professionals.
- Information Security Advisory Board consisting of eminent personalities in Cybersecurity was set up to advise on information security related matters. Information Security policy was updated as per the latest ISO 27001 standard.

DIGITAL TRANSFORMATION

POWERGRID has consistently been at the forefront of adopting cutting-edge technologies. A standout initiative in this area is the integration of machine learning-driven solutions into our operation and maintenance processes. This enables us to conduct comprehensive analyses and enhance asset health monitoring, allowing for rapid implementation of corrective or preventive measures to optimize asset management. As our asset portfolio expands, the adoption of advanced technology is proving crucial in achieving both operational excellence and cost efficiency simultaneously.

POWERGRID TRANSMISSION EXPERIENCE CENTRE

POWERGRID has introduced the Transmission Experience Centre to revolutionize engineer training in EHV transmission through immersive, hands-on learning. The facility features five specialized workshops:

- AIS Bay: Practical training in Air Insulated Substation equipment operation and maintenance.
- GIS Bay: Hands-on experience with Gas Insulated Substation assembly and testing.
- Substation Auxiliary Equipment: Focus on auxiliary systems like DCDBs and firefighting for maintenance and reliability.
- Transmission Line Workshop: Tactile exposure to EHV transmission line hardware.
- AR-VR Workshop: Use of Augmented and Virtual Reality for simulating transmission scenarios interactively

SPATIAL DECISION SUPPORT SYSTEM (SDSS) PROJECT

POWERGRID, in partnership with ISRO, is creating an SDSS to enhance transmission infrastructure management using geospatial technology. The project aims to:

- Identify transmission towers vulnerable to natural disasters.
- Monitor and manage vegetation growth near transmission lines in the Indian Himalayan Region.
- Train POWERGRID officials to use NRSC/ISRO-developed tools.
- Enable technology transfer and implementation.

OTHER INITIATIVES

- Drone Inspections: Programmable drones with AI/ML analytics improve substation inspection efficiency, accuracy, and safety.
- AR/VR Headgear: Augmented/Virtual Reality digital headgear aids maintenance with remote expert assistance, reducing downtime and enhancing safety and reliability.

GRIDCON-2025

GRIDCON-2025, organized by POWERGRID attracted over 10,000 participants from 32 countries, including policymakers and industry leaders. Focused on "Innovations in Grid Resilience," the conference highlighted reliability, sustainability, and adaptability in transmission systems. It showcased India's leadership in energy transition. With over 160 technical papers, a CEO forum, sessions on Women in Energy, and more than 150 global technology exhibits, the event fostered collaboration among utilities, academia, and global organizations.

DIGITALIZATION IN PROJECT EXECUTION

POWERGRID's Digital Leap: The IMPACT Story

POWERGRID launched the IMPACT platform in 2022 to digitally transform project execution and financial monitoring. This automated system manages over 30 million data records, reducing project timelines from 30–36 months to 18–24 months and cutting financial monitoring from one month to just one day. Despite challenges in digitizing legacy processes and resistance to change, focused training drove strong adoption, making IMPACT the second most-used tool in the organization. Looking forward, POWERGRID plans to enhance IMPACT with advanced AI features, including predictive delay models and Projects GPT, while ensuring robust security with ISO/IEC 27001:2022 alignment.

Project Monitoring Centre: Enhancing Real-Time Oversight

POWERGRID's Project Monitoring Centre at the Corporate Office marks a leap in real-time project monitoring. It enables live streaming of site activities from remote areas like Khavda-2 and Khavda-3 using IP cameras connected via PowerTel's secure network. This setup allows central teams to monitor progress and provide instant support to ground teams. Future upgrades will incorporate AI-driven video analytics and drone data to automate detection of construction progress, workforce activity, and safety compliance, thus promoting data-driven governance and efficient issue resolution.

PG Nirmaan: Digitalizing Construction Operations

PG Nirmaan, built on Microsoft Power Apps, is POWERGRID's custom digital solution for construction management. It replaces paper processes with real-time data capture, integrating with the IMPACT platform for centralized oversight. Initially, it digitizes field quality assurance forms for transmission lines, with future expansions to include substation construction and safety compliance. Additional tools, such as apps for progress updates and material tracking, enhance digital governance and efficiency in project execution, underscoring POWERGRID's commitment to operational excellence.