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Towards a Resilient Grid

Special Session with Naveen Srivastava, Director (Operations), POWERGRID

In this special session, Naveen Srivastava highlighted the scale and magnitude of POWERGRID's transmission network, which comprises over 280 substations with a total transformation capacity of over 550 GVA. Over the next five years, POWERGRID plans to commission high voltage direct current (HVDC) facilities and 800 kV substations. He also noted that POWERGRID was the first organisation to implement a 765 kV digital substation, located in Navsari.

Srivastava emphasised that asset management extends beyond routine operations and maintenance; it is a collaborative and multi-disciplinary function, which involves equipment upkeep, supply chain management, skill development, cybersecurity and continuous innovation. As wind zones expand and climatic events intensify, strengthening transmission towers and designing systems that can withstand cyclones and floods have become essential. He added that grid security remains a top priority, particularly in the current environment where supply chain constraints are widespread.

Srivastava explained that the challenges facing POWERGRID fall into four or five distinct categories. The first challenge stems from India's diverse geographical conditions, including hills, forests, cyclonic regions and flood-prone areas, which pose reliability concerns and make construction and maintenance difficult. The second major challenge is grid security, which becomes increasingly critical as the network expands and emissions increase.

The third challenge is the need for continuous innovation to keep pace with global technological developments and ensure the delivery of quality power to end consumers. The fourth challenge is linked to the ongoing energy transition, whereby the entire world, whether the logistics sector or the infrastructure sector, is undergoing rapid change. This has a direct impact on transmission operations.

Skill development is an equally critical area for POWERGRID. Srivastava stated that the organisation is incorporating artificial intelligence and machine learning into its training programmes and is exploring the recruitment of data scientists. With software now emerging as a core component of asset management, POWERGRID

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is building digital capabilities across its workforce and preparing teams for a more technology-driven operating environment.

Discussing the use of new technologies, Srivastava noted that digitalisation is central not only to operations but also to the management of remote substations. Centralised monitoring and maintenance require strong cyber resilience, continuous upgrades and advanced analytics. POWERGRID conducts transformer health indexing to determine criticality levels and uses drones for transmission line inspections. While drones have limitations, they remain valuable tools for rapid identification of defects. The company is now integrating asset performance management (APM) systems to support investment planning through data-driven insights.

Srivastava also highlighted that several pilots are underway. These include dynamic line rating projects, which are being implemented using sensor-based systems to assess real-time transmission capacity. Further, smart substations are being deployed and digital twin pilots have been initiated with five stations to simulate operational scenarios and optimise network behaviour. Cybersecurity is another major focus area, with a dedicated Centre of Excellence established at the Indian Institute of Science, Bengaluru.

On renewable energy integration, Srivastava stated that significant solar and wind generation is being injected into the grid, with offshore wind expected to be the next major contributor. Rajasthan and Gujarat are the primary regions where these challenges are most visible. He identified system inertia as a key technical issue and highlighted that POWERGRID has already commissioned 17 STATCOMs to enhance stability. As renewable energy is inherently intermittent, the deployment of battery energy storage systems will be fundamental to ensuring grid reliability. He added that performance in Rajasthan and Gujarat has improved significantly since the commissioning of STATCOMs, enhancing both power quality and energy security.

State Utilities

The session on "State Initiatives" featured remarks by P.C. Dhyani, Managing Director, Power Transmission Corporation of Uttarakhand Limited; Mayur Maheshwari, Managing Director, U.P. Power Transmission Corporation Limited (UPPTCL); Upendra Pande, Managing Director, Gujarat Energy Transmission Corporation Limited (GETCO); and D. Latha Vinod, Director (Projects), Transmission Corporation of Telangana Limited. The panellists discussed ongoing developments, key operational challenges and the major programmes being undertaken by state transmission utilities.

P.C. Dhyani noted that Uttarakhand's transmission segment has undergone a significant improvement in recent years, driven by stronger institutional coordination, rigorous project monitoring and a clear focus on resolving long-standing bottlenecks. He highlighted that, a few years ago, the state's transmission projects were grappling with persistent delays, weak contractor participation and unresolved staff-related challenges, prompting the utility to undertake a broad institutional reset. The focus shifted to internal restructuring, with HR-led grievance resolution, improved communication across field teams and efforts to rebuild a sense of ownership among employees.

In parallel, contractors were repositioned as development partners, with systematic interventions to address right-of-way (RoW) hurdles, forest clearances and payment-related issues through regular joint reviews. This collaborative approach has significantly compressed execution timelines, with recent Asian Bank Development-funded schemes progressing within 21 months compared to earlier norms that stretched to nearly three years. The utility has strengthened daily project monitoring through dedicated groups for each scheme, supported by active involvement from the chief secretary and the chief minister, whose emphasis on simplification and time-bound resolution has enhanced stakeholder responsiveness.

According to Mayur Maheshwari, over the past two to three years, UPPTCL has implemented a series of ambitious initiatives aimed at strengthening the state's transmission backbone and preparing its grid for rapidly evolving energy demands. He noted that Uttar Pradesh has added the largest transmission capacity in the country in recent years, alongside the addition of 4 GW of thermal generation capacity, driving growth across the value chain, from generation and transmission to distribution, supported by a strong digital and IT foundation.

A central pillar of recent reforms has been the shift from fragmented, contractor-driven execution to a project management-based approach anchored by IT systems. The corporation has implemented a comprehensive enterprise resource planning system through which vendor billing and payments are digitised and processed in real time. This has reduced administrative lag, improved transparency and enabled vendors to pre-position equipment and expedite project timelines. Maheshwari remarked that vendors have responded positively to this digital transition, which directly supports faster implementation of substations and transmission lines.

On the operations side, the transco has deployed drone-based patrolling, which has provided a valuable bird's-eye perspective for identifying equipment issues that cannot be detected from the ground level. This digital surveillance has helped address long-standing bottlenecks in maintenance.

Uttar Pradesh has also pursued extensive conductor upgradation, replacing over 1,000 km of transmission lines with high-temperature low-sag (HTLS) conductors. This in-situ replacement allows significant capacity enhancement without major RoW expansions, thereby increasing corridor efficiency while minimising delays. Looking ahead, the transco plans to explore projects outside the state transmission utility domain, signalling its intent to play a broader role in national transmission development.

With the ongoing expansion of programmes such as the Green Energy Corridor III, particularly for solar evacuation from Bundelkhand, UPPTCL is preparing to double its existing network. The integration of pumped storage and large-scale renewables is a critical part of future planning, particularly as India's solar capacity has grown from 3 GW in 2013-14 to 130 GW today, placing new demands on grid stability.

Quality and reliability have emerged as the next frontier. With growing demand from data centres, semiconductor industries and other critical facilities, Uttar Pradesh aims to provide error-free and highly reliable power. The state is in advanced stages of installing static synchronous compensators to support voltage stability and minimise losses. Integration with thermal and pumped storage systems remains essential, especially in districts such as Sonbhadra, which alone produces around 10,000 MW of power. Advanced artificial intelligence (AI) is being deployed for managing cooling interfaces in these systems.

Uttar Pradesh met a record peak demand of 32,000 MW, the highest in the country, and is planning an 8-10 per cent CAGR in demand towards 2030. This growth requires not only new substations and lines, but also the careful planning of load centres and industrial zones and the rapid expansion of rooftop solar.

Upendra Pande began his address by reflecting on GETCO's rapid growth in terms of both capacity and capability over the past few years. He noted that GETCO's training ecosystem, which handled around 2,200 personnel annually during the Covid-19 pandemic, has expanded significantly, scaling up to 3,500 participants the following year and 5,500 last year. In the current year, the number is expected to exceed 8,000, underscoring the corporation's continued focus on building skilled manpower to support the state's expanding transmission network.

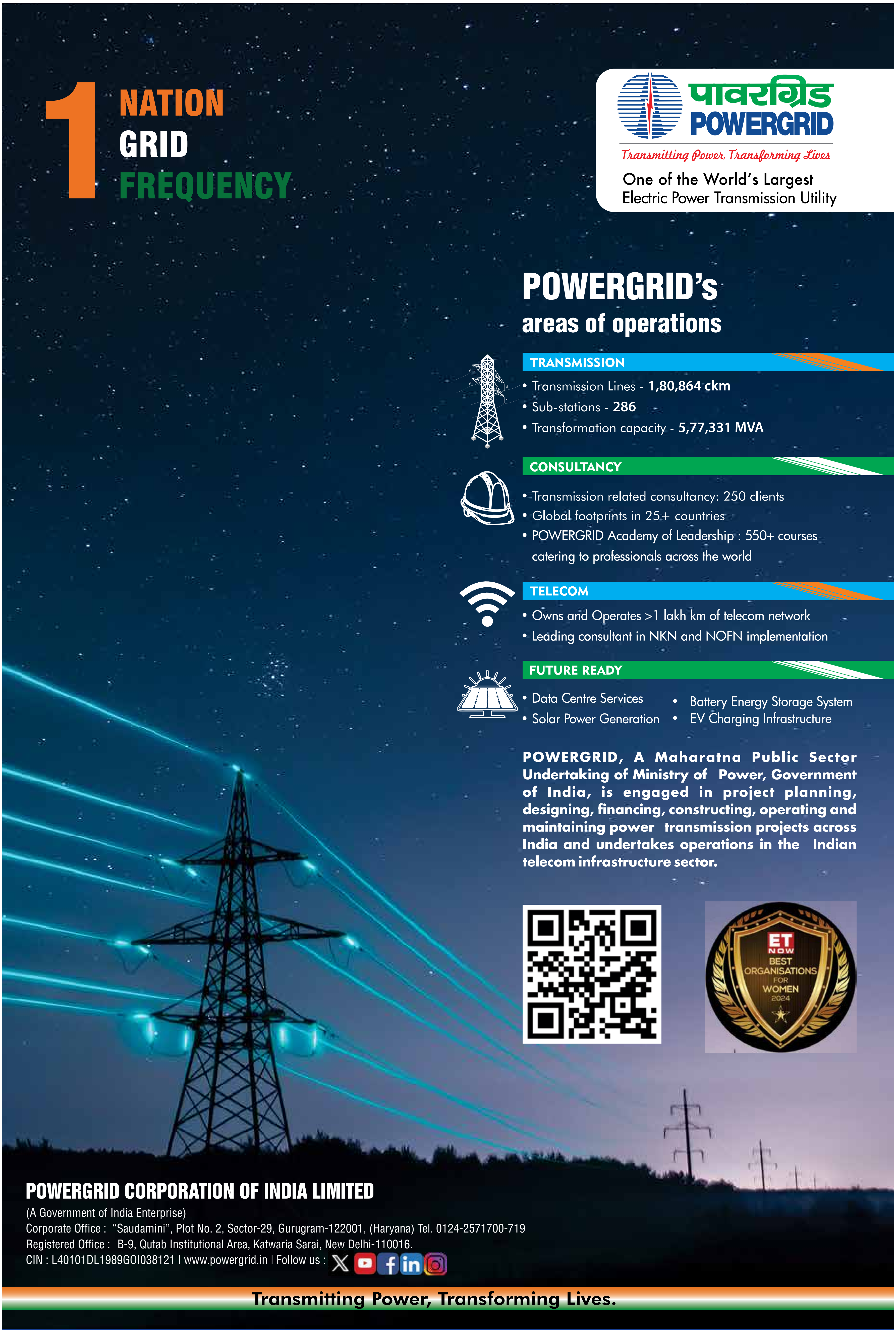
In parallel, GETCO's financial trajectory has strengthened. The corporation's turnover has grown from Rs 42 billion in 2020 to Rs 62 billion last year, and is now approaching Rs 70 billion. This growth, he noted, has been accompanied by extensive system augmentation, despite Gujarat's uniquely complex transmission architecture, including its characteristic 60-60 network configuration.

Pande highlighted several key technological interventions that have helped the state enhance its transmission efficiency. Over the past 18 months, GETCO has commissioned more than 50 transmission lines using HTLS conductors, all of which are operating successfully. The state has also accelerated the deployment of monopoles and narrow-based towers to optimise land utilisation, address RoW constraints and increase network flexibility. Further, GETCO has been transitioning its substations to integrated "stack-top" designs to better support high renewable energy penetration. One such integrated system has already been operating successfully for five years.

However, challenges persist, especially due to Gujarat's growing share of solar power, particularly rooftop solar, which has reshaped load patterns and created significant daytime surpluses. To address this, the state implemented a transformative initiative originally conceptualised under the Surya Gujarat Yojana. Instead of relying on storage, Gujarat created dedicated infrastructure to supply surplus daytime solar energy directly to agricultural feeders. This three-hour daytime supply has reduced subsidy requirements, eliminated the burden of night-time irrigation for farmers and successfully aligned the agricultural load curve with the solar generation curve.

Looking ahead, Pande outlined GETCO's roadmap for 2030, 2035 and 2047. The state's current peak demand of 26.9 GW is projected to reach 33 GW by 2030, 42 GW by 2035 and 63 GW by 2047. Renewable energy capacity is expected to rise to 100 GW by 2030, 185 GW by 2035 and significantly higher by 2047. To support this growth, GETCO plans to add new substations and associated transmission lines, which will require investments of Rs 800 billion-Rs 850 billion by 2030. By 2035, cumulative requirements are expected to exceed Rs 1,500 billion. These planned expansions, he concluded, will form the backbone of Gujarat's transmission system for the coming decades, enabling the state to meet its renewable energy targets while ensuring grid reliability and resilience.

According to Latha Vinod, Telangana's transmission sector is entering an exceptionally demanding expansion cycle as renewable energy, industrial growth and agriculture-driven consumption continue to surge. Moreover, the state is advancing a parallel strategy for urban and rural transmission reinforcement. Gas-insulated substations are increasingly being deployed within dense urban areas, while monopoles are planned between the outer ring road and the regional ring road. Beyond these zones, lattice or narrow-base towers remain the preferred solution, depending on local conditions. The utility is also undertaking large-scale reconductoring of existing lines using HTLS conductors, particularly where substation expansion space is limited. The adoption of pass modules, drone-based surveys and AI-enabled technologies is also underway to accelerate execution. Solar development is another critical driver.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However, challenges persist, especially in terms of material availability. Reportedly, delays in delivering breakers, filters, transformers and other critical equipment are affecting timelines, largely because transmission evacuation is being simultaneously expanded across the country.

Telangana's shifting load profile also adds to the existing challenges. With irrigation-driven agricultural demand doubling over the past decade and new loads emerging from data centres and industries, the state aims to increase transformation capacity substantially in the next five years. Additionally, the government continues to supply 24×7 free power to farmers and uninterrupted power across all categories, creating significant operational pressures.

Large-scale solar deployment, decentralised generation initiatives for households, and the roll-out of pumped storage schemes and battery energy storage system projects form a critical part of Telangana's grid balancing strategy. Meanwhile, static synchronous compensators, reactor installations and an enhanced capacitor-banking regime are being promoted to maintain system stability.

O&M Best Practices

The "O&M Best Practices" session featured a panel discussion among Dr Nilesh Kane, Chief Distribution, Tata Power; Sanil Namboodiripad, Chief Operating Officer, IndiGrid; Sandip Maity, Senior Vice President, Design and Engineering, Resonia; and Nihar Raj, Head – O&M, Adani Energy Solutions. The panellists discussed a wide range of topics, including key trends, challenges and emerging practices in transmission operations and maintenance (O&M).

Dr Nilesh Kane provided an overview of Tata Power's transmission operations, which span a large and expanding network, with a significant presence in Mumbai and ongoing expansion through multiple projects across Uttar Pradesh. The company is strengthening its transmission network while addressing operational challenges that arise in dense and heavily encroached urban environments.

Dr Kane highlighted that Mumbai's grid has evolved from 110 kV to 220 kV and is now moving towards 440 kV. It is also witnessing a major transition from overhead to underground networks, most of which are within tightly packed corridors.

He further observed that the close proximity of Mumbai's generation, transmission and distribution systems has led to a rapid increase in fault levels, significantly complicating system operations in some areas. Transient faults, widespread encroachments around tower locations and increasing clearance requirements due to multi-storey construction have intensified safety risks. He noted that network maintenance under these conditions requires solutions that enhance both safety and capacity, including reconductoring and expansion in line with the city's evolving load profile.

Further, undergrounding poses its own set of challenges, with reinstatement and permission costs accounting for a major share of project expenditure. Extensive construction activity and recurring faults also pose significant challenges. He emphasised that

right-of-way (RoW) constraints, asset theft, changing wind loads and evolving engineering assumptions during project execution are among the key bottlenecks faced by stakeholders.

To address these challenges, Tata Power has adopted several technology solutions, such as digital platforms and drones for commissioning and inspection. In addition, robotics are increasingly being used for breaker operations and asset condition tracking. The company has also introduced asset health cards to consolidate critical data, including dissolved gas analysis parameters, leakage current of lightning arresters and residual life calculations. A centralised platform integrates this information to support risk-based and opportunity-based zero breakdown maintenance. In addition, the company is undertaking dynamic load studies and numerical relay–based monitoring of feeders to optimise planning. Thermal cameras in air-insulated substations, ultrasound-based condition assessment and centralised data repositories further support proactive, opportunity-based maintenance strategies.

Looking ahead, Dr Kane identified advanced data analytics and artificial intelligence (AI)-enabled decision systems as the most promising technologies, which are currently under evaluation. These include dynamic load studies for future asset planning, digital devices on transmission lines to track real-time parameters such as temperature, humidity and sag, and centralised predictive systems for substations. He stated that safety-focused training through the company's training centre, supported by digitally captured site data, is expected to enhance installation and maintenance practices. Further, distributed batteries could reduce capital expenditure during transmission planning, especially as load and network data become more centrally processed.

Sanil Namboodiripad outlined IndiGrid's overall portfolio, noting that the company now operates across three major verticals: transmission, solar generation and a rapidly expanding storage business. IndiGrid has already commissioned its first battery energy storage system in Delhi and is developing four more projects. Transmission remains its core business, with a geographically diverse network stretching from the Northeast to Jammu & Kashmir and down to southern India.

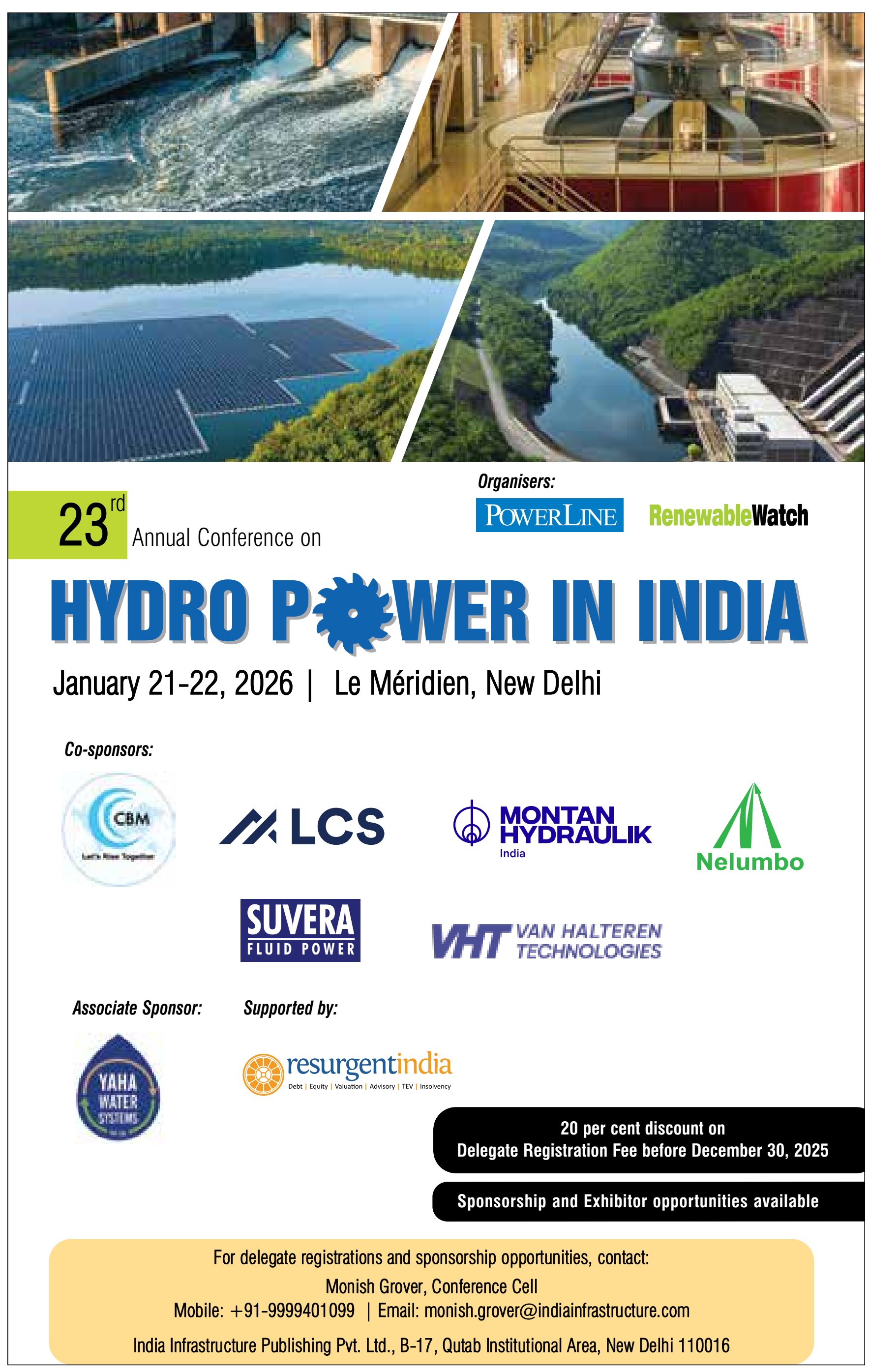
This wide footprint brings distinct operational challenges. In the Northeast, difficult terrain and river crossings affect tower foundations and long-term stability. In Jammu & Kashmir, harsh winters limit fieldwork for four to five months, requiring all preventive maintenance to be completed during the remaining period. To maintain high availability in such regions, IndiGrid deploys specialised snow vehicles and region-specific work methodologies.

IndiGrid also places strong emphasis on availability, reliability and climate resilience. Once a line is commissioned, the focus shifts to continuous risk assessment and resilience planning, especially as climate-related disruptions intensify. Floods in Punjab and the Northeast, as well as landslides in Himachal Pradesh, have posed significant challenges, potentially leading to conductor or tower failures. To mitigate these risks, IndiGrid conducts detailed resilience studies for each of its tower locations, mapping potential threats and formulating preventive action plans in advance.

Namboodiripad highlighted that data has emerged as a critical enabler across the company's operations. All test records, from transformer diagnostics to equipment assessments, are stored on IndiGrid's digital platform, improving health analysis and supporting predictive maintenance. Drone-based patrolling has further enhanced safety by reducing manual tower-top inspections. AI-based identification of defects has reached nearly 90 per cent accuracy. The team is now working to refine AI-based analysis to accurately distinguish between defects that impact availability and those that are non-critical, which is vital for efficient and targeted maintenance.

Looking ahead, Namboodiripad underscored that climate change is emerging as one of the biggest long-term challenges for transmission infrastructure. Strengthening grid resilience will require regulatory support and funding, especially for modifications based on geological and climate studies. Further, robust data and scientific assessments will be essential to ensure that necessary resilience measures are implemented and that the grid remains reliable in the coming years.

Sandip Maity highlighted a range of operational O&M challenges across the company's transmission assets in Gujarat, Maharashtra, Goa and the Northeast. Many of its assets are located in coastal belts or high-rainfall regions, where tower foundations are exposed to severe soil erosion, river meandering and accelerated wear. He stressed that polymer insulators in these geographies are becoming increasingly vulnerable and require systematic upgradation. These issues must be addressed to ensure asset availability.



He noted that grid compensation requirements have led to frequent switching instructions, placing additional stress on equipment originally designed for far fewer operations. Due to this, early signs of switching-related deterioration in equipment may emerge earlier than its expected 30-35 year life cycle. He also referred to the recent revision in seismic zoning norms, emphasising that assets located in newly reclassified high-risk zones must be reassessed and modernised to avoid long-term operational risks. Appropriate policy support from the government would facilitate this transition.

Maity noted that insulator failures remain a major concern. This issue was highlighted during the execution of the Mumbai Urja Marg Limited line elements, stretching from Patna to Navi Mumbai and further to Bhandup/Bikroli. Based on the anomalies observed, initial hotspot and thermal imaging diagnostics identified several insulators for replacement; however, the method lacked predictive strength. To strengthen reliability, Resonia has deployed the travelling wave fault locators method across its networks in Mumbai, Gujarat and the Northeast. This method, once calibrated, enables precise identification of fault locations, significant reduction of restoration time and improvement of asset performance.

Drone-based patrolling has also been introduced to address persistent challenges around RoW access and community disturbances that hamper manual inspections. Aerial data collected through drones is processed through an AI layer, offering deeper insights for condition-based diagnostics. This shift supports predictive maintenance rather than reactive interventions. He added that Resonia is exploring breaker monitoring solutions and smart sensor technologies to improve substation and transmission line behaviour forecasting. He has observed that in today's environment, the metric for O&M teams is no longer limited to ensuring availability; proactive, preventive maintenance has emerged as a key performance indicator.

Nihar Raj noted that India's power transmission sector is undergoing a significant transformation driven by climate change, accelerated grid expansion and rapid digitalisation. According to Raj, the traditional challenges associated with substation and transmission line maintenance have evolved significantly, demanding new strategies, technologies and organisational capabilities.

Many regions, such as Khavda in Gujarat, Rajasthan's desert corridors or the wind-intensive southern states, now present heightened risks of extreme winds, increased lightning incidences, and transient faults and fluctuations, among other concerns, underscoring the need for predictive maintenance practices and robust resilience frameworks.

A cornerstone of this transformation is digitalisation, which is increasingly redefining asset management across utilities. Raj emphasises that the success of any digital strategy depends on the workforce as it involves upskilling operational teams, redesigning workflows and promoting digital adoption at the ground level. As utilities shift towards remote operations and leaner on-site staffing, cybersecurity also becomes critical. Ensuring secure, high-availability connections between field assets and central network operations centres is now essential for real-time monitoring and reliable remote control. Parallelly, India's focus on self-sufficiency raises important questions about domestic manufacturing capabilities, vendor support structures and technology readiness for high-performance, 24×7 power systems.

Another emerging challenge is the growing complexity of grid operations due to rising renewable energy penetration. Large-scale solar and wind integration has resulted in localised voltage fluctuations, reactive power imbalances and rapid equipment ageing. Therefore, O&M strategies must be continuously refined to ensure a seamless interplay between green energy, grid stability and asset longevity.

To address these multidimensional challenges, Adani Energy Solutions Limited has adopted a multi-layered operational and technological strategy. A key initiative is the creation of an asset performance management group, leveraging the company's vast repository of equipment and system data. By combining historical asset records with real-time operational datasets, the utility has generated actionable intelligence to optimise maintenance schedules. This data-driven approach has already reduced maintenance efforts by 37 per cent, without compromising asset availability, underscoring the transformative potential of advanced analytics.

Climate-conscious risk management is another critical focus area. By analysing weather patterns and correlating them with fault occurrences, the company is identifying seasonal vulnerability windows for specific transmission lines. For instance, research on lightning performance and tower footing impedance revealed nuanced insights for the company. Such findings have guided targeted interventions, contributing to an over 87 per cent improvement in transmission line availability.

Digital tools are also enhancing field operations. Mobile applications enable real-time patrolling, digital dashboards support decentralised decision-making and IoT sensors provide continuous equipment condition data. For advanced technologies such as high-voltage direct current (HVDC) and flexible AC transmission systems, structured training programmes have been prioritised to build specialised O&M expertise. These initiatives have enabled the company to maintain HVDC availability above 99 per cent, surpassing normative requirements.

AI is emerging as a powerful catalyst for predictive O&M. AI use cases include automated defect identification across 43 types of transmission line anomalies, AI-enabled thermal imaging to predict polymer insulator failures, alarm analytics to forecast cascading events, and image analytics for substation fault prediction. Behavioural analytics using camera systems is being explored to enhance workforce safety. A new initiative involves predicting isokeraunic levels via satellite data to assess back-flashover risk, enabling proactive maintenance planning.

Collectively, these strategies reflect a sector where traditional O&M philosophies are giving way to data-centric, technology-driven and climate-resilient frameworks. As Raj notes, "What has brought us here will not take us to the next level," necessitating a fundamental reframing of O&M practices to meet the demands of India's future power systems. ■

Interview with Dr Praveer Sinha

"The sector stands at the crossroads of disruption and opportunity"

In a recent interview with *Power Line*, Dr Praveer Sinha, Chief Executive Officer and Managing Director, Tata Power Company Limited, shared his views on India's energy transition and the move towards 24x7 clean power. He spoke about the role of storage, digital technologies and smart grids; the impact of recent GST reforms; and the turnaround of the Odisha discoms. He also outlined the key steps needed to accelerate renewable energy growth and strengthen domestic manufacturing. Edited excerpts…

What are the key opportunities and strengths in the power sector, and what are some of the trends that you find most exciting today?

The most defining trend in the power sector is the energy transition. Earlier, this meant simply adding solar and wind capacity. Today, it is about delivering round-the-clock green energy by integrating solar, wind, hydro and storage.

The focus has shifted from just adding capacity to ensuring that the energy delivered is reliable, efficient and aligned with customer requirements. At the same time, grid management is becoming smarter with the adoption of digital technologies such as smart grids, forecasting tools, data analytics and artificial intelligence. These solutions are enabling more accurate demand-supply balancing and enhancing system resilience. Overall, the clean energy sector is undergoing transformative disruption, a trend that is set to accelerate as research, innovation and the adoption of advanced technologies continue to grow.

What have been the key achievements in the power distribution segment over the past year, and what kind of reforms are needed to accelerate the transformation?

The distribution segment has made remarkable progress in recent years. We are seeing widespread adoption of smart meters, SCADA systems, automation and enterprise planning platforms. States are at different stages of digital transformation, but across India, monitoring and management of both urban and rural networks have improved significantly. Importantly, consumer awareness has grown, and with it, expectations around the quality and reliability of supply. This is pushing utilities to raise their service standards.

Another notable development is distributed generation. Rooftop solar adoption is rising, and more consumers are becoming prosumers, feeding surplus energy back into the grid. Schemes such as the PM Surya Ghar Yojana (PMSGY) are also enabling localised generation, reducing dependence on long-distance supply and improving reliability.

Financially, discoms are showing better performance, though accumulated losses remain a challenge. With more operational discipline, performance will improve further.

At Tata Power, a major milestone has been the turnaround of the Odisha discoms. This was our first major distribution venture outside Delhi, and it demonstrated how a public-private partnership model can transform power distribution. Odisha posed a unique challenge with its vast geography of 154,000 sq. km and mix of urban and rural consumers, requiring solutions very different from a city like Delhi.

Over the past few years, we have achieved tangible improvements in power availability, customer service, billing efficiency and consumer satisfaction. The discoms are now financially healthier, and there is a clear sense of positivity among all stakeholders – consumers, government authorities and employees alike. While we still have some distance to go, we have achieved 75-80 per cent of our goals. Odisha has been a transformative journey, and it is a replicable model for other states.

What is your view on the recent announcement of GST reforms for the renewable energy sector, and how will it impact the sector?

The recent GST changes are highly significant, both for renewables and coal. For coal, the GST rate has been increased from 5 per cent to 18 per cent. However, the earlier cess of Rs 400 per tonne has been removed. For the grades commonly used in Indian thermal power plants (G9 to G13), this results in an 8-20 per cent reduction in costs. Since coal costs are a pass-through, this will lower tariffs for consumers. While higher-grade coal (G1 to G6) will see a cost increase, the overall impact is positive.

For renewables, the GST rate has been reduced from 12 per cent to 5 per cent. This will lower production costs and reduce the cost at which solar panels are supplied – whether for large utility-scale projects, rooftop solar, or schemes such as PM Surya Ghar. Although input credit is not available under the new framework, the lower tax rate will benefit developers and consumers alike. This is a very positive step by the government that will accelerate renewable adoption.

What are the key success factors to unlock the full potential of the renewable energy sector? How can project execution and development be accelerated?

India's transition to renewable energy is both ambitious and necessary, given the scale of its energy demand and the urgency of climate commitments. However, meeting these goals requires addressing multiple structural, technological and policy-related challenges. While significant progress has been made in expanding renewable capacity, certain bottlenecks continue to hinder the pace of deployment.

For large utility-scale renewable energy projects, one of the biggest challenges is land acquisition. Solar and wind projects, in particular, require extensive tracts of land, and securing these parcels can often be a slow and complex process. Beyond land, another significant hurdle lies in the evacuation of power.

> "We should transition from conventional to clean energy as quickly as possible. It may not be 100 per cent clean energy, but I see India reaching 80-90 per cent clean energy penetration in the coming decades."

While certain regions of the country have far greater potential for solar and wind generation, the crucial question remains how to transport this power efficiently to the demand centres. This requires not only robust transmission infrastructure but also shorter development timelines. Transmission projects typically take much longer to complete than renewable installations, making it vital to anticipate future requirements and plan transmission capacity well in advance.

Technology is another critical dimension of the energy transition. Storage solutions are becoming increasingly important, yet it is clear that reliance on lithium-ion batteries alone will not suffice. More diverse and efficient storage technologies must be explored to ensure stability and reliability. Self-sufficiency in manufacturing is equally essential. Although India has achieved reasonable module manufacturing capacity and is scaling up cell production, there is still heavy dependence on other countries for wafers. This gap requires urgent attention, and strengthening the production-linked incentive (PLI) scheme to provide stronger support will be key. In the long term, non-tariff barriers may also become necessary, given the difficulty Indian firms face in competing directly with global manufacturers.

On the supply side, the outlook varies across components. Module production has already reached a comfortable domestic level, and cell manufacturing is expected to achieve self-sufficiency in the next two years.

For ingots and wafers, the timeline extends further, with three to four years likely required before meaningful domestic capacity is in place. Many players remain cautious, adopting a wait-and-watch approach, as they still need technology partners, access to financial support and tariff subventions. The upcoming PLI scheme under consideration by the Ministry of New and Renewable Energy (MNRE) is expected to address these concerns and provide the necessary boost.

Encouragingly, many of these issues are already under discussion with the MNRE. There is a strong likelihood that new policy initiatives will be introduced in the coming months to strengthen domestic manufacturing and accelerate renewable energy deployment. With the right support mechanisms and forward planning, India has the opportunity to address these bottlenecks and move decisively toward its clean energy goals.

What is your vision for the future of the power sector, and how is Tata Power positioning itself to support the transformation?

India is moving in the right direction, but the pace must be faster. We should transition from conventional to clean energy as quickly as possible. While 100 per cent clean energy may not be realistic in the near future, I believe India can achieve 80-90 per cent clean energy penetration in the coming decades through a balanced mix of solar, wind, storage, pumped hydro, and eventually nuclear.

At Tata Power, we are positioning ourselves at the forefront of this journey. We have already commenced two pumped storage projects (PSPs) in Maharashtra: a 1,000 MW project at Bhivpuri and another 1,800 MW project that will soon begin at Shirawata. In Bhutan, we are building a 600 MW hydro project, with another 1,125 MW project expected to start by mid-next year. Over the next four to five years, our goal is to add around 5,000 MW of clean energy capacity.

We are also expanding our presence in transmission, having secured six projects in the past three years, all under construction. Some are expected to be commissioned this year, the rest next year. In the battery energy storage (BESS) segment, our 10 MW BESS project in New Delhi was South Asia's largest when commissioned in 2019, and we are now developing much larger integrated projects combining solar, wind, battery storage and pumped hydro.

By 2029, with our pumped hydro assets operational, Tata Power will be in a strong position to deliver clean, reliable, round-the-clock energy at scale. This is our vision, to play a pivotal role in India's clean energy future. ■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Green Energy Evacuation

Transmission infrastructure facilitating renewable integration

As India accelerates towards its ambitious targets of achieving 500 GW of renewable energy capacity by 2030 and attaining net-zero emissions by 2070, the development of a robust power transmission network will play a pivotal role in ensuring the efficient delivery of generated power. To support this, the government has taken significant steps to strengthen the transmission infrastructure and enable the seamless integration of renewable energy into the grid. Marking a major achievement, India has recently surpassed 500 GW of total installed power capacity, with non-fossil fuel sources accounting for more than half of it. This progress means that the country has reached one of its key COP26 Panchamrit commitments – achieving 50 per cent of its installed electric power capacity from non-fossil sources – five years ahead of schedule.

With the rapid expansion of clean energy capacity, the power transmission grid is encountering increasing challenges in maintaining reliability and stability. To facilitate the secure evacuation of renewable power, the government has placed a strong emphasis on developing energy storage systems to enhance the utilisation of existing transmission assets. At the same time, new inter- and intra-state transmission networks are being planned to match the pace of renewable energy growth. Efforts are also under way to strengthen grid interconnections, improve voltage and angular stability and minimise transmission losses.

Renewable energy evacuation

Green energy corridors help minimise curtailment, enhance grid stability and provide dedicated intra- and interstate transmission capacity supported by advanced control technologies and grid upgrades. Together, these measures ensure a cost-effective and reliable round-the-clock power supply.

- GEC-I: The Intra-State Transmission System Green Energy Corridor Phase I (InSTS GEC-I) scheme is being implemented by the state transmission utilities of eight renewable energy-rich states – Andhra Pradesh, Gujarat, Himachal Pradesh, Karnataka, Madhya Pradesh, Maharashtra, Rajasthan and Tamil Nadu – to establish 9,767 circuit (ckt) km of transmission lines and 22,689 MVA of substation capacity, facilitating the integration of 24 GW of clean energy. States such as Karnataka, Madhya Pradesh, Rajasthan and Tamil Nadu have completed their projects, while states such as Andhra Pradesh, Gujarat, Himachal Pradesh and Maharashtra received scheme extension till June 2025, with further extensions requested till December 2025. With respect to financial progress, as of July 2025, over Rs 28.39 billion has been released against the sanctioned grant of Rs 31.64 billion.
- GEC-II: The Green Energy Corridor-II (InSTS GEC Phase II) is being executed in Gujarat, Himachal Pradesh, Karnataka, Kerala, Rajasthan, Tamil Nadu and Uttar Pradesh to establish 7,919 ckt km of transmission lines and 24,488 MVA of substations to evacuate 20 GW of clean energy.
- GEC-III: The Indian government plans to advance the third phase of the GEC scheme to enhance InSTS renewable energy transmission capability. Under Union Budget 2025-26, the allocated fund for GEC-III is estimated at Rs 560 billion, of which the central government will contribute about Rs 224 billion or 40 per cent of the total budget. The remaining funds will come from state governments and stakeholders. Key states in this phase include Gujarat, Rajasthan, Maharashtra, Karnataka and Andhra Pradesh, with over Rs 290 billion projected from Gujarat.

Renewable energy zones

There is a strong emphasis on developing renewable energy zones and large-scale solar parks, including major projects at Bhadla, Khavda and Leh. Renewable energy potential zones are concentrated in a few states and that too far away from the load centres, necessitating the transfer of bulk power from the renewable energy potential zones to the load centres. For long-distance power transmission, generated power is stepped up to 220 kV and further to 400 kV and 765 kV, depending on the quantum of power and the associated distance. Thereafter, at load centres, it is again stepped down from 765 kV to 400 kV and further to 220 kV and lower voltages.

While several states have begun establishing these zones, gaps remain in the associated transmission connectivity. India's key renewable energy potential areas are concentrated in Rajasthan, Gujarat, Karnataka, Andhra Pradesh, Maharashtra, Tamil Nadu, Uttar Pradesh, Madhya Pradesh and the Leh region, where timely transmission development will be critical for harnessing their full potential. Transmission system has been planned for over 600 GW of renewable energy capacity/potential zones by the year 2031-32.

BESS

In October 2024, the Ministry of Power launched the National Electricity Plan (NEP) for transmission, with the aim to transmit 500 GW of renewable energy by 2030 and over 600 GW by 2032. With the rise of renewable energy, storage systems have become critical to absorb surplus clean energy and reduce curtailments. NEP-Transmission projects a BESS capacity of 8,680 MW by 2026-27 and 47,244 MW by 2031-32. To ensure the safe evacuation of renewable energy, the government has prioritised the establishment of energy storage facilities to optimise the use of transmission infrastructure.

BESS helps relieve transmission congestion by absorbing excess power during periods of high generation – particularly from renewable energy sources – and releasing it during peak demand. With renewables creating variability and intermittency, BESS provides rapid-response flexibility to maintain grid balance.

Other mega green energy evacuation projects under planning

Apart from the various ongoing intra-state projects, an important project sanctioned in 2024 under GEC-II was the establishment of an ISTS to support a 13 GW renewable energy project in Ladakh. Being implemented by POWERGRID, the project entails the construction of 713 km of transmission lines, covering 1,268 ckt km and the installation of two 5 GW high-voltage direct current (HVDC) terminals in Ladakh (Pang) and Kaithal (Haryana). The infrastructure will facilitate the transmission of electricity generated from the 13 GW renewable energy project, along with a 12 GWh BESS, in Ladakh. The cost of Phase II projects is about Rs 207.73 billion, and the central financial assistance will cover 40 per cent of the project cost, amounting to Rs 83.09 billion. POWERGRID will finance the remaining project costs through debt and equity. The project is scheduled for completion by 2029-30.

Meanwhile, projects for power evacuation from bulk consumers such as green hydrogen and ammonia plants of about 20 GW and others of about 18 GW are in the works. As per the Interim ISTS Rolling Plan 2029-30 by Central Transmission Utility of India Limited, almost 19,500 MW of ISTS schemes for various green hydrogen and ammonia plants are planned by FY 2030. Of these, five ISTS schemes, costing Rs 156.29 billion, will support green hydrogen projects in Gujarat, Tamil Nadu and Andhra Pradesh. Gujarat will benefit the most with 13,500 MW, while Andhra Pradesh and Tamil Nadu will receive 3,000 MW each. Three ISTS schemes (8,200 MW) for Gujarat and Tamil Nadu have been approved under tariff-based competitive bidding (TBCB).

In addition, mega transmission schemes are being planned for offshore wind transmission projects. Around 10 GW of offshore wind energy evacuation has been envisaged – 5 GW in Gujarat and 5 GW in Tamil Nadu.

FACTS and REMCs

The implementation of flexible AC transmission system (FACTS) devices, such as static synchronous compensators (STATCOMs) and static var compensators, is enhancing grid stability and voltage regulation. STATCOMs were considered for the first time in India with multivendor inverter-based resources at renewable energy pooling stations in the Rajasthan renewable energy complex. The presence of STATCOMs, at strategic locations with unique control features near solar power parks, improves power quality and facilitates the smooth integration of renewable energy sources into the existing power infrastructure.

Furthermore, renewable energy management centres (REMCs) established across India are strengthening real-time monitoring, forecasting and grid operations. Set up at both state and national levels and co-located with load despatch centres, these REMCs forecast solar and wind generation, manage imbalances and support power scheduling from renewable plants. By providing real-time situational awareness, they enable grid operators to make faster, more informed decisions, thereby improving the reliability of renewable energy integration.

Challenges and the way forward

While the shift towards clean energy continues to accelerate, several challenges persist. The cost of HVDC lines has increased nearly fourfold, raising concerns about the financial viability of expanding transmission networks and making affordability a critical issue. Although interstate transmission infrastructure has seen substantial progress, intra-state networks still lag behind.

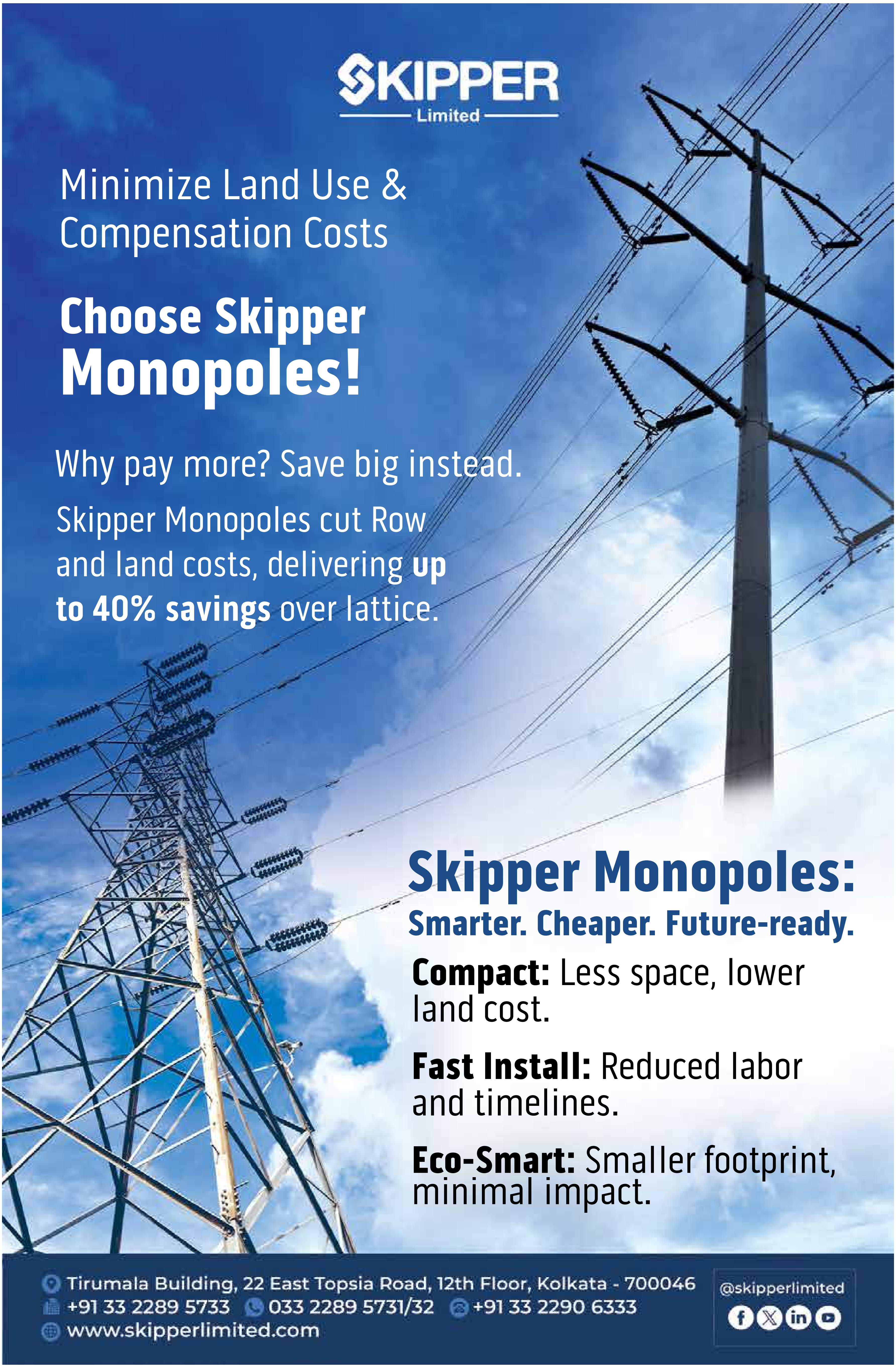
Over 50 GW of renewable energy capacity remains stranded across the country, leading to higher per-unit transmission costs, weakening project viability, and discouraging private investment. These constraints slow the addition of new capacity and hinder India's ability to integrate variable renewable energy at scale, increasing the risk of missing critical milestones in the nation's clean energy transition.

Building resilience against extreme weather events, particularly in cyclone-prone coastal regions and hilly terrains, has also become a key priority. Strengthening concession agreements with well-defined responsibilities and increasing cybersecurity frameworks are essential to secure the power sector. Further, the adoption of advanced technologies will be central to driving this transformation forward.

Over the 10-year period from 2022-23 to 2031-32, the NEP aims to add more than 191,000 ckt km of transmission lines and 1,270 GVA of transformation capacity at 220 kV and above. It also includes the addition of 33 GW of HVDC bi-pole links and plans to increase interregional transmission capacity from the current 119 GW to 143 GW by 2027 and 168 GW by 2032. The initiative presents a significant investment opportunity, estimating over Rs 9.15 trillion in the transmission sector by 2032.

Conclusion

The shift to clean energy demands extensive expansion and reinforcement of India's power transmission network. As the nation advances toward a sustainable energy future, the transmission system will act as the backbone of this transition, supporting continuous and reliable growth. Through optimisation of the existing grid and coordinated planning efforts, India is well-positioned to realise its ambitious clean energy goals. ■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Regional Ties

India strengthens its cross-border connections

Cross-border interconnections are becoming increasingly important as countries seek to strengthen energy security and integrate renewables into their grids. These links allow surplus power to flow across national boundaries and thus help balance seasonal and daily variations in demand and generation, thereby ensuring efficient use of regional resources. India, located at the centre of South Asia, plays a pivotal role in this process. Due to its geographical proximity to Nepal, Bhutan, Bangladesh, Myanmar and Sri Lanka, India has a natural advantage in coordinating power exchanges and enabling grid integration across the region.

Existing, under-construction and planned infrastructure

India's cross-border transmission network currently links the national grid with Nepal, Bhutan, Bangladesh and Myanmar through a mix of synchronous and asynchronous interconnections at the 11 kV, 33 kV, 132 kV and 400 kV levels. As per Central Transmission Utility of India Limited's (CTUIL) Interstate Transmission System (ISTS) Rolling Plan 2030-31 (Interim Report), at present, these interconnections have an installed transmission capacity of 10,323 MW, facilitating operational power transfer of about 5,414 MW. By 2027-28, the installed capacity is expected to increase by another 8,100 MW through interconnections under construction, enabling a rise in operational power transfer to 9,194 MW.

India-Bhutan

India's and Bhutan's cross-border transmission network has been developed primarily to facilitate hydropower imports from Bhutan. At present, the two countries are connected through synchronous interconnections with a total transfer capacity of about 7,560 MW. The network includes links such as the 132 kV Kurichu hydroelectric plant (HEP) (Bhutan)-Geylephu (Bhutan)-Salakati (India) single-circuit (S/C) line, the 132 kV Deothang/Motonga (Bhutan)-Rangia (India) S/C line, the 220 kV Chukha HEP (Bhutan)-Birpara (India) double-circuit (D/C) line, the 220 kV Malbase (Bhutan)-Birpara (India) S/C line, and the 400 kV Tala HEP (Bhutan)-Siliguri (India) two D/C lines. A major high-capacity corridor, namely, the 400 kV Mangdechhu HEP (Bhutan)-Jigmeling (Bhutan)-Punatsangchhu I and the II HEP (Bhutan)-Alipurduar (India) D/C line, serves as the main route for evacuating power from central Bhutan to India. Currently, power generation from the Punatsangchhu-I (1,200 MW) plant is delayed due to geological challenges. In November 2025, the Punatsangchhu-II (1,020 MW) plant was inaugurated by the Prime Minister of India and the King of Bhutan, following its full commissioning in August 2025.

Of the total transfer capacity, 2,651 MW of hydropower is currently being transferred from Bhutan's Tala, Chukha, Kurrichhu and Mangdechhu plants. The existing transmission network has also been designed to accommodate upcoming power from the Punatsangchhu-I project, which is expected to be fully commissioned by 2026-27. Once operational, the total power transfer between the two countries is projected to increase to around 4,531 MW.

India-Nepal

India and Nepal currently share a total transfer capacity of 1,600 MW through multiple low voltage links, as well as the 400 kV Dhalkebar (Nepal)-Muzaffarpur (India) D/C line, which is the first high-capacity interconnection between the two countries.

Several major power transmission projects are under construction to further expand this network. These include the 132 kV Kohalpur (Nepal)-Nanpara (India) D/C line, which is targeted for completion by December 2025. Further, the 400 kV Dhalkebar (Nepal)-Sitamarhi (India) D/C line, associated with Nepal's Arun-3 HEP, and the 400 kV New Butwal (Nepal)-Gorakhpur (India) D/C line are expected to be completed by March 2026 and May 2026, respectively.

Notably, in October 2025, Power Grid Corporation of India Limited (POWERGRID) and the Nepal Electricity Authority (NEA) signed joint venture (JV) and shareholder agreements to advance high-capacity cross-border transmission infrastructure between the two countries. As part of the agreement, one JV company will be incorporated in each country to implement the 400 kV Inaruwa (Nepal)–New Purnea (India) and 400 kV Lamki (Dododhara) (Nepal)–Bareilly (India) D/C lines. The agreements were formalised in November 2025. Under the ownership structure, in the Indian JV, POWERGRID will hold a 51 per cent stake and the NEA will hold 49 per cent, while the shareholding will be reversed in the Nepal JV. These projects are expected to significantly boost power exchange capabilities between the two countries, strengthening energy security and grid stability. With these additions, the total operational transfer capacity between the two countries is expected to more than double to around 3,500 MW in the coming years.

Recently, both countries agreed to develop three additional cross-border links: the 220 kV Chameliya (Nepal)-Jauljibi (India) D/C line, the 400 kV Nijgad/Harnaiya (Nepal)-Motihari (India) D/C line, and the 400 kV Lamahi (Nepal)-Lucknow (India) D/C line. For the Lamahi–Lucknow line, a joint study will first determine whether the Nepali termination point will be at Lamahi or Kohalpur, after which a detailed project report will be prepared.

India-Bangladesh

At present, Bangladesh imports around 1,160 MW of power from India through two interconnections. The first are the two 400 kV Baharampur (India)-Bheramara (Bangladesh) D/C lines, supported by two 500 MW HVDC back-to-back terminals at Bheramara. The second is the 400 kV Surjyamaninagar (India)-North Comilla (Bangladesh)-South Comilla (Bangladesh) D/C radial line, which operates at the 132 kV level. In addition, Adani Power has commissioned a 1,600 MW thermal power plant at Godda in Jharkhand to supply electricity to Bangladesh through a dedicated 400 kV D/C radial line that operates independently of India's main grid.

Looking ahead, a new 765 kV D/C line connecting Katihar (India), Parbotipur (Bangladesh) and Bornagar (India) is under planning. The project will enable an additional 1,000 MW of power transfer to Bangladesh. India will be undertaking the financing and construction of the entire project.

India-Myanmar

At present, power exchange between India and Myanmar is limited to about 2-3 MW, supplied from Moreh in Manipur to Tamu in Myanmar through an 11 kV radial line. Now, both countries are exploring options to scale up this capacity through multiple new interconnections, which together could enable the transfer of up to 504 MW of power from India to Myanmar. The proposed projects include a high-capacity Imphal (India)-Tamu (Myanmar) AC transmission line, supported by a 500 MW HVDC back-to-back system. Additionally, several low-capacity 11 kV radial links are being planned from Arunachal Pradesh, Manipur, Mizoram and Nagaland to supply electricity to border villages in Myanmar.

India-Sri Lanka

A 1,000 MW HVDC interconnection between Madurai, in India, and Mannar, in Sri Lanka, is at an advanced stage of discussion. The project will be implemented in two phases of 500 MW each, using voltage source converter technology. The transmission corridor will span about 285 km, including a 50 km submarine cable section across the Palk Strait.

Recently, in October 2025, the two countries held a virtual meeting to discuss implementation modalities and reaffirm their commitment to the project. Once operational, the interconnection is expected to enhance Sri Lanka's energy security by allowing it to import power during shortages and export surplus renewable energy.

India-Saudi Arabia and the UAE

Beyond South Asia, India is looking to expand its grid connectivity to the Gulf region. Plans are under way to establish subsea transmission links with Saudi Arabia and the United Arab Emirates (UAE), for which JVs have already been signed. The proposal involves constructing a 1,400 km line to Saudi Arabia and a 1,600 km line to the UAE, each with a capacity of 2 GW. Together, these projects are expected to entail an investment of around Rs 900 billion and will enable the export of clean electricity from India to both Saudi Arabia and the UAE.

Challenges and outlook

The expansion of cross-border transmission linkages remains constrained due to several challenges. Chief among these is the absence of a harmonised regional legal, regulatory and policy framework, which heightens investment risks for developers and financiers undertaking such projects. Additionally, technical coordination, covering grid codes, system security, scheduling, metering and despatch, are still managed bilaterally, making it challenging to ensure seamless and reliable operation of regional power networks.

Beyond these technical hurdles, the lack of regional institutions for joint planning, dispute resolution and regulatory coordination, coupled with political sensitivities and the absence of a multilateral electricity trading platform, continues to slow down the pace of deeper grid integration across South Asia.

Even so, momentum is building. Under the One Sun, One World, One Grid initiative, India is exploring transmission linkages beyond South Asia, particularly with the Gulf and Southeast Asian regions. Notably, a 2,000 MW transmission link connecting India's renewable energy sources to Singapore's grid is under active consideration.

The project is expected to advance both countries' decarbonisation efforts while strengthening regional energy security. Looking ahead, such collaborations could lay the groundwork for a broader ASEAN-India green energy corridor, potentially extending to Malaysia, Thailand and Indonesia.

Ultimately, the development of new cross-border interconnections will play a crucial role in enhancing energy security and optimising regional resources. India's leadership in driving these initiatives remains central to building a robust, resilient and interconnected power network that benefits the entire South Asian region. ■

Cross-border power transfer capacity by 2030-31 (MW)

Country	Existing	Under construction (by 2027-28)	Planned (by 2030-31)	Total
India-Bangladesh	1,160	0	1,000	2,160
India-Bhutan	7,560	0	0	7,560
India-Myanmar	3	0	504	507
India-Nepal	1,600	8,100	5,350	15,050
India-Sri Lanka	0	0	500	500
Total	**10,323**	**8,100**	**7,354**	**25,777**

Source: CTUIL's ISTS Rolling Plan 2030-31 (Interim Report)

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Global Best Practices

India aims to build a resilient offshore wind energy transmission network

The central government has set a 37 GW offshore wind target for 2030 and has approved Rs 7.45 billion viability gap funding package. Of this funding, roughly Rs 6.85 billion is dedicated to supporting the installation and commissioning of the initial 1 GW of capacity. With identified zones along the Gujarat and Tamil Nadu coasts showing high resource potential, there is a growing focus on preliminary assessments to build the required transmission infrastructure. The Central Electricity Authority has also proposed dedicated transmission corridors to integrate offshore wind power by the end of the decade.

Transmission design and configuration

The choice between HVAC and HVDC technologies is influenced by project distance from the shore, transmission capacity and overall efficiency. For sites within roughly 50 km of the coastline, HVAC networks are generally more economical due to simpler design and installation. For longer distances and higher capacities, HVDC systems provide lower transmission losses and are more suitable for bulk power evacuation.

In case of India, several offshore blocks, particularly along Tamil Nadu, are located relatively farther from the coastline and are, therefore, likely to require HVDC technology. Technical studies comparing HVAC and HVDC configurations are under way, with assessments considering seabed contours, sea depth, environmental conditions and long-term operational costs. Offshore substations will serve as the key nodes in this system, collecting power from turbine arrays, stepping up voltage and feeding export cables.

Evacuation framework

The Ministry of New and Renewable Energy has established a split-responsibility model for offshore wind evacuation. Developers will build and operate the internal project network up to the offshore pooling. This includes inter-array cables and connections to the offshore substation at voltage levels defined by the central transmission utility (CTU). Beyond this, the CTU will develop all export transmission assets, including submarine cables, offshore substations and onshore receiving infrastructure.

To support early commercial development, offshore wind projects commissioned by December 31, 2032, will be exempt from ISTS charges and additional surcharges, significantly reducing evacuation costs and enhancing financial viability.

Current progress

India's first major step toward offshore wind transmission development came with the government's July 2025 approval of a dedicated evacuation system for Gujarat's initial offshore wind project. POWERGRID will implement this system under the regulated tariff mechanism at an estimated cost of Rs 6.9 billion. The project is designed to evacuate 500 MW from the offshore wind zone and includes an offshore substation, 35 km of subsea cable, 10 km of underground cable and a 190 km 400 kV line from Mahuva to Vataman. Expected to be completed by March 2029, this will form the template for future offshore transmission networks and provide critical insights into subsea engineering, route surveys and coordination between multiple agencies.

India is preparing to launch its first offshore wind tender for Tamil Nadu by February 2026, backed by strong wind assessment results that indicate robust resource potential. Although Solar Energy Corporation of India's earlier offshore wind tenders were cancelled in August 2025 due to limited developer interest, the upcoming Tamil Nadu tender is expected to revive momentum in the sector.

The way forward

Global offshore wind leaders such as the UK, Germany and the Netherlands have demonstrated that strong, centralised transmission planning is essential for large-scale offshore deployment. India's centralised and phased approach is aligned with these global best practices and has been reinforced by collaborative efforts such as the India-UK Offshore Wind Taskforce, which focuses on supply chain development, financing and ecosystem building.

Going ahead, India's transmission strategy will need to remain flexible as technology evolves. A robust, timely and well-coordinated transmission system is essential to maintain investor confidence. Offshore transmission must also be planned to manage intermittency, which will require integration with storage solutions and grid-balancing mechanisms. Dedicated corridors and offshore pooling stations must be developed well ahead of wind farm construction to avoid bottlenecks.

With the current foundation of structured planning, public investment and regulatory clarity, India is positioned to build a resilient offshore transmission network that can support the next stage of its clean energy expansion. ■

Transmission Growth

Planned capacity additions till 2031-32

Projected transmission capacity additions up to 2032

Transmission system type/voltage class	At the end of 2021-22 (March 31, 2022)	Likely addition during 2022-27	Likely at the end of 2026-27 (March 31, 2027)	Likely addition during 2027-32	Likely at the end of 2031-32 (March 31, 2032)
Transmission lines (ckt km)					
HVDC ±320 kV/ 500 kV/800 kV bipole	19,375	80	19,455	15,432	34,887
765 kV	51,023	36,558	87,581	27,138	114,719
400 kV	1,93,978	34,618	228,596	20,989	249,585
230/220 kV	192,340	43,431	235,771	13,228	248,999
Total transmission lines	**456,716**	**114,687**	**571,403**	**76,787**	**648,190**
Substations (MVA)					
765 kV	257,200	343,500	600,700	319,500	920,200
400 kV	393,113	284,970	678,083	135,745	813,828
230/220 kV	420,637	147,860	568,497	42,610	611,107
Total substations	**1,070,950**	**776,330**	**1,847,280**	**497,855**	**2,345,135**
HVDC (MW)					
Bi-pole link capacity	30,500	1,000	31,500	32,250	63,750
Back-to-back capacity	3,000	-	3,000	-	3,000
Total HVDC	**33,500**	**1,000**	**34,500**	**32,250**	**66,750**

HVDC: High voltage direct current

Source: Central Electricity Authority

Transmission line and transformation capacity additions under ISTS and InSTS

		At the end of 2021-22 (March 31, 2022)	Planned addition during 2022-27	Likely at the end of 2026-27 (March 31, 2027)	Planned addition during 2027-32	Likely at the end of 2031-32 (March 31, 2032)	Total at the end of 2031-32 (March 31, 2032)
Transmission lines (ckt km)	ISTS	200,036	51,185	251,221	43,324	294,545	648,190
	InSTS	256,680	63,502	320,182	33,463	353,645	
Transformation capacity (MVA)	ISTS	460,965	472,225	933,190	348,165	1,281,355	2,411,885
	InSTS	643,485	305,105	948,590	181,940	1,130,530	

Source: Central Electricity Authority


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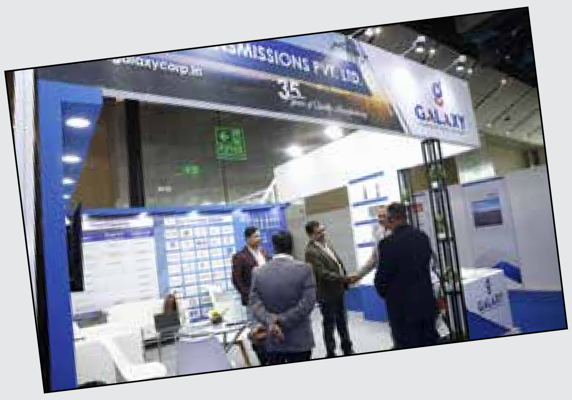
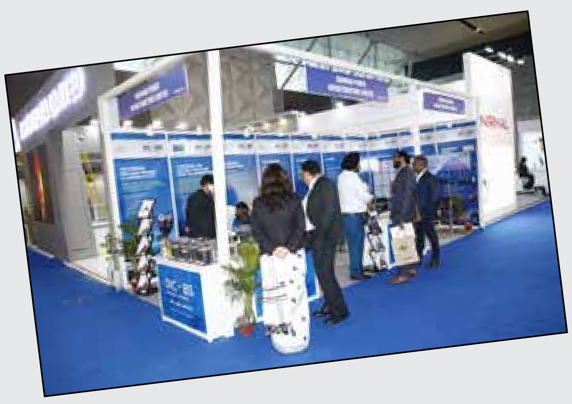
Snapshots from Day 2



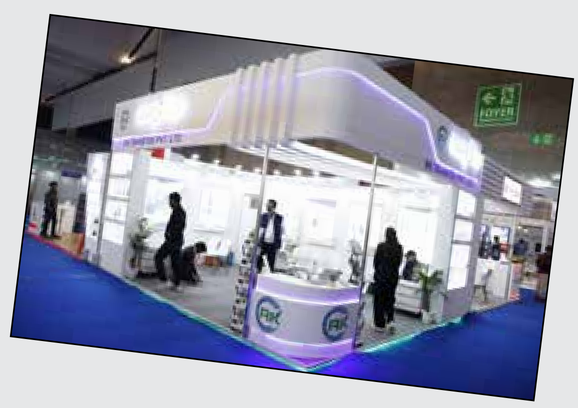



Snapshots from Day 2









TransTech India 2025

Agenda: Friday, December 12, 2025 (Day 3)

Time: 9:20 AM-9:30 AM Recap of Day 2

Recap by *Power Line*

Time: 9:30 AM-9:55 AM

Transmission Project Management Challenges and Best Practices

- Burra Vamsi Rama Mohan, Director (Projects), POWERGRID

Time: 9:55 AM-10:45 AM

Supply Chain and Procurement Challenges

- G.S. Budiyal, Director (Operations), Power Transmission Corporation of Uttarakhand
- K.K. Gupta, Executive Director, POWERGRID
- Rajan M.P., Chief Engineer, KSEB

Time: 10:45 AM-11:45 AM

Focus on Renewable Energy Evacuation

- Deepak Consul, Head – Grid & Connectivity, Gentari Renewables
- Manju Gupta, Executive Director, POWERGRID
- Deepak Khare, Senior Vice-President and Head of Projects, Blupine Energy
- Mahesh Vipradas, Vice-President, Sembcorp India

Time: 11:45 AM-12:20 PM

Cross-Border Transmission

- Kedar Silwal, Director, Nepal Electricity Authority
- V. Thiagarajan, Senior GM, POWERGRID

Time: 12:20 PM-12:45 PM

Exhibition Viewing, Tea/Cofee and Networking Break

Time: 12:45 PM-1:35 PM *(Parallel Tracks)*

Substations

- Dinesh K., Chief Engineer, KSEB
- M. Srinivasa Rao, Chief General Manager, POWERGRID
- Neeraj Yadav, Deputy President, Transrail Lighting

Time: 12:45 PM-1:35 PM *(Parallel Tracks)*

Drones

- Pradeep Singh Chauhan, Chief Manager, POWERGRID
- Kanav Kumar, Co-Founder and Director, Better Drones
- Representative from a leading EPC player

Time: 1:35 PM-2:25 PM

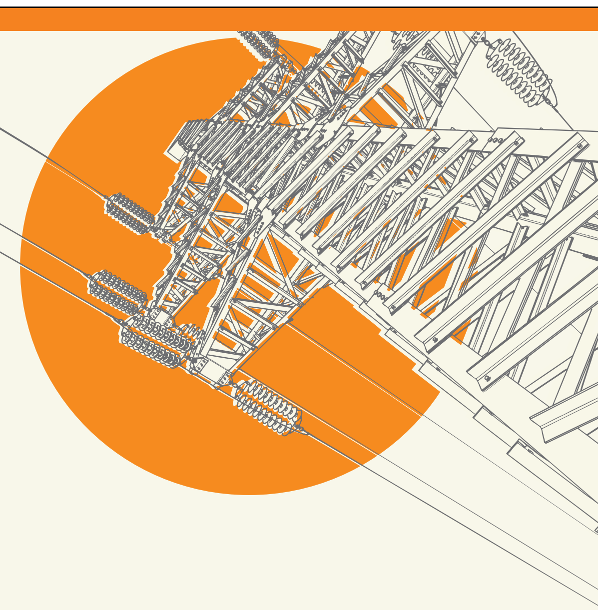
Special Valedictory Session: Skill Development for Transmission

- Dr Yatindra Dwivedi, Director Personnel, POWERGRID
- Srinivasan Ravi, Chief General Manager, HRD, TG Transco
- Dr V. K. Singh, Chief Executive Officer, Power Sector Skill Council

Conference Wrap-up and Closing Remarks, and Raffle Draw

Lunch, Exhibition Viewing and Networking

See You at



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