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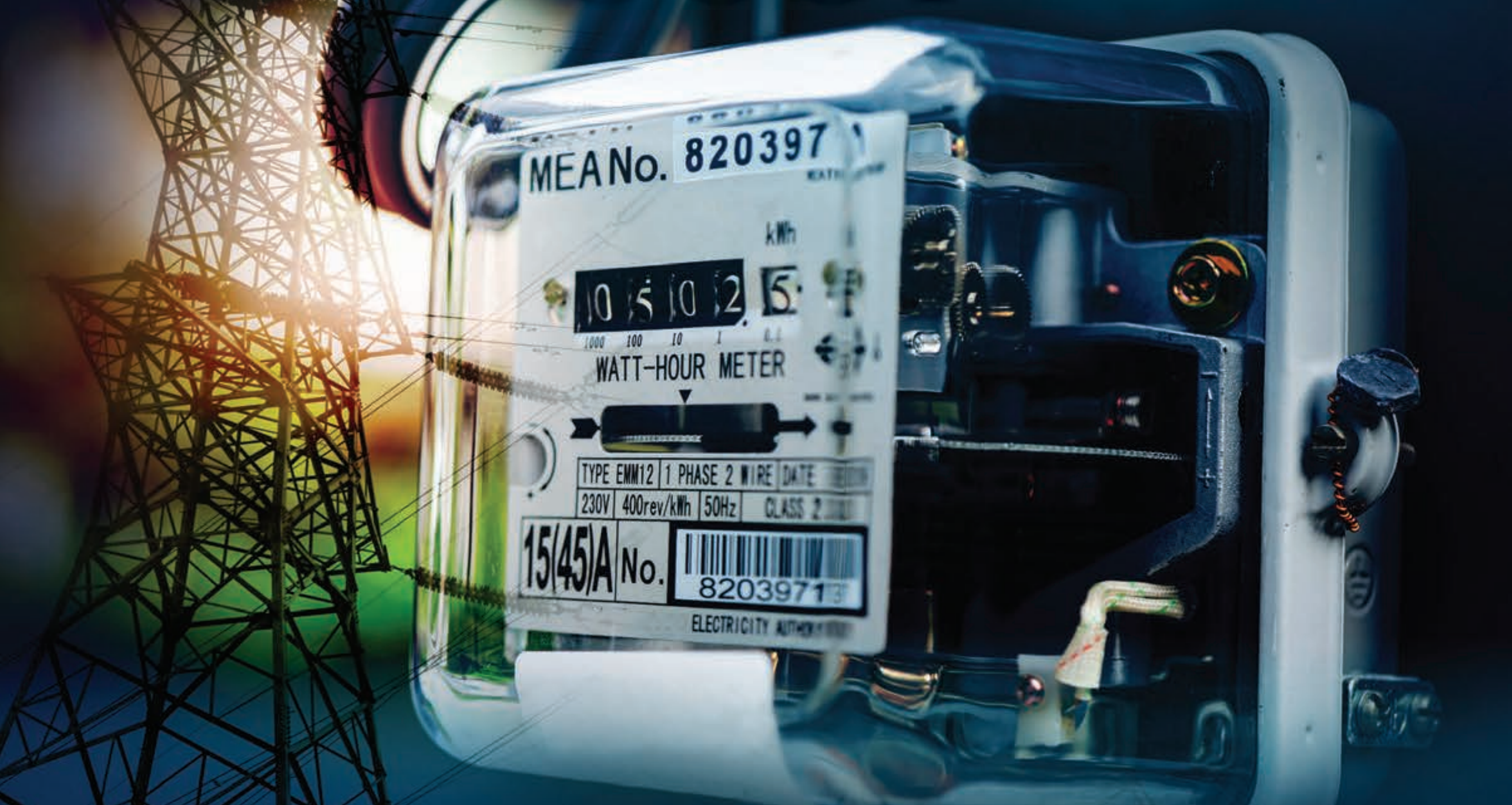
# INTELLIGENT METERS: SAVING ENERGY AND COST

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- **SPECIAL REPORT:** World's First and Largest GW-scale Integrated RE Project
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Fire Safety Conclave
16 MAY 2025

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# FROM THE PRESIDENT'S DESK

***Dear Readers,***

I am very happy that IEEMA JOURNAL is coming out with a special issue on metering, an area that is becoming very important to support energy transition.

The rollout of smart meters, particularly smart prepayment meters, is ushering in a transformative era for India's power sector. This is the largest rollout of smart metering in India. More than 250 million meters will be installed by distribution utilities. This transition is more than just a technological upgrade – it represents a fundamental shift in how electricity is consumed, paid for, and managed. At the heart of this revolution is consumer empowerment.

Prepaid smart metering allows consumers to pay for electricity as per their convenience, much like recharging a mobile phone. This flexibility has brought about a significant behavioural change. In one of the distribution companies in India, many consumers are now purchasing electricity three times a month, tailoring their usage to their needs and budget. This granular control was unimaginable in the legacy billing system.

For utilities, smart metering is equally transformative. The availability of real-time consumption data provides a rich foundation for distribution system monitoring. Utilities can now detect outages faster, reduce losses, and plan maintenance more efficiently.

Moreover, as India ramps up its renewable energy capacity, smart metering will be essential for managing variable generation. With accurate, near real-time data, utilities can better integrate solar and wind energy into the grid, ensuring stability while enabling cleaner energy.

Smart metering also opens doors to advanced load forecasting – a critical capability as our cities grow and demand patterns evolve. This will help utilities optimise procurement, reduce costs, and ensure reliable supply.

Perhaps one of the most consumer-friendly benefits is the simplification of new connections. With digital identity linkage and remote provisioning, the time-consuming paperwork and physical visits can become a thing of the past.

As IEEMA, we are proud to support this smart metering journey through innovation, collaboration, and advocacy. The roadmap ahead is ambitious, but the benefits – for consumers, utilities, and the environment – are profound. It is now time for all smart metering providers and utilities to come together and ensure smart metering is used beyond revenue improvement.

Let us continue to work together to make this vision a reality. The future of electricity is smart, inclusive, and empowering.

**SUNIL SINGHVI**

***Dear Readers,***

India's power sector is undergoing rapid transformation by modernising its distribution grid with the country-wide adoption of smart metering solutions under the Revamped Distribution Sector Scheme (RDSS). The scheme aims at deploying 250 million smart meters by 2027.

Hon'ble Union Power Minister Shri Manohar Lal has also directed states to install prepaid smart meters in all government establishments, including colonies, with an aim to improve energy efficiency and timely payment of dues. The Union Minister has also asked states to complete installation of smart meters for commercial and industrial consumers and high load consumers by November 2025. Several other policy actions are also being taken up to scale implementation.

By leveraging metering data with advanced analytics and machine learning (ML), utilities can unlock transformative applications.

In this special edition on smart meters, we delve into how metering data can help drive reform in the distribution sector, enable network resilience, and support India's sustainable energy goals.

Quality, safety, and reliability are among the key focus areas for IEEMA, and we have been promoting these across the spectrum in the industry.

In May, IEEMA launched a series of training for promoting electrical safety for ITI graduates and linesman along with its implementation partner – the National Power Training Institute (NPTI). A total of 240 participants across Delhi, Hisar, Varanasi, and Kota will undergo this training during the year, building a safer and more skilled workforce for the power sector.

IEEMA also organised the Delhi edition of the Electrical Fire Safety Conclave in May to discuss electrical safety, reinforcing the urgency of collective action and awareness to build a more resilient and secure electrical ecosystem. We will soon be hosting similar conclaves in Bengaluru and Kolkata.

Also watch out for some of our flagship events – the first ever North-East Power Conclave in Guwahati on June 17-18, 2025; the MEP Consultants Meet in Kochi from June 12-14, 2025; an IEEMA-ADB Workshop on Regional Co-operation for Building Resilient Supply Chains in SASTEC on July 24, 2025; and the T&D Conclave in Delhi on July 25, 2025.

**CHARU MATHUR**

COVER STORY

# METERING DATA:
# The Key Enabler for Distribution Utility Reform and Energy Transition

This article elucidates how metering data can be utilised to drive reform in the distribution sector, enable network resilience and support India's sustainable energy goals, by enhancing utility operations, thus establish that data-driven insights and decisions optimise distribution networks and investments to finally empower the consumer.

In India, the power sector is undergoing rapid transformation with the increasing penetration of distributed energy resources at the distribution level and the nation-wide adoption of smart metering solutions under the Revamped Distribution Sector Scheme (RDSS) that aims to deploy 250 million smart meters by 2027 (revised target).

Driven by the unique model of Advanced Metering Infrastructure Service Provider (AMISP), this initiative is transforming the nation's power distribution network by improving billing accuracy, improving the financial health of utilities, and reducing AT&C losses. While these are the immediate and well-recognised benefits—a more strategic opportunity and true potential lies in the intelligent use of metering data beyond the revenue or billing purposes.

### Abbreviations

- AMISP: Advanced Metering Infrastructure Service Provider
- AT&C: Aggregated Technical and Commercial
- CT: Current Transformer
- DER: Distributed Energy Resources
- DLMS: Device Language Message Specification
- DT: Distribution Transformer
- LT: Low Tension voltage
- ML: Machine Learning
- RDSS: Revamped Distribution Sector Scheme
- SMNP: Smart Meter National Program
- TOU: Time of Use
- VT: Voltage Transformer

## Introduction

India's electricity power distribution network is at the crossroads of rising energy demand, the integration of distributed energy resources (DERs) like solar panels and electric vehicles (EVs), which have led to increasing consumer expectations, while utilities face unprecedented challenges. By replacing traditional meters with smart meters, India is modernising its distribution grid and unlocking a treasure trove of data that can drive smarter energy decisions.

Smart meters have the following categories:

a. Direct connected single phase meter for consumers.
b. Direct connected three phase meter for consumers.
c. LT CT operated meters for bulk consumer and DT.
d. CT/VT operated import-export meter for bulk consumer, feeders and DT.

These meters record numerous data points, including:

- Daily and billing energy data
- TOU and maximum demand
- Load profile
- Events data.

While utilities currently use this data primarily for billing, its potential extends far beyond such as network analytics, quicker new connection feasibility, consumer indexing, quick outages detection and restoration, optimising network investments, managing peak loads, and aligning consumer demand with grid capacity—all driven by metering data coupled with network asset information.

## Smart Metering in Brief

The key benefits of this smart metering initiative:

- Eliminates manual meter reading and human errors that ensure **accurate and timely bills,** ensuring transparency.
- Helps utilities to improve cash flows through prepayment.
- Empowering consumers with **prepayment,** which helps them track monetary energy consumption and effectively do financial budgeting.
- Enables **remote disconnection** or **reconnection** for defaulters, improving collection efficiency.
- Outage management and faster restoration,
- Encourages energy-saving behaviour through data visibility.

However, the real benefit is in harnessing the data collected from smart meters, using which, utilities can transform from being reactive to being proactive, addressing both today's challenges and tomorrow's opportunities.

## Emerging Network Challenges

The integration of DERs such as rooftop solar, electric vehicles (EVs), battery storage, non-linear loads, etc., is adding new and diverse variability into the power distribution network.

In addition, continuous economic enhancements and subsequently, rising energy demand are increasing the complexity in the network.

Unlike the predictable, one-way flow of traditional grids, modern networks face bidirectional power flows, as shown in Figure 1.

The increasing penetration of DERs could lead to a less predictable and reverse flow of power in the system, which affects the traditional planning and operation of distribution and transmission networks along with network unbalance, voltage regulation and unscheduled network interruptions.

**The absence of or the limited power flow visibility, especially in low voltage (LV) networks, can cause problems for distribution utilities.** Monitoring, timely and efficient upgrading of the system is now a priority for distribution companies to **ensure network capacity utilisation, reliability and resilience.**

Apart from non-technical loss dominance, the **contribution of technical loss percentage in the distribution network is also high.** The trail-end LV distribution system coupled with DER penetration has many challenges:

All of these introduce **complexities in the ecosystem,** such as:

- **Unpredictable loads:** Wide variations in network and transformer loading.
- **Voltage issues:** Fluctuation and phase imbalances.
- **Overloaded assets:** Inadequate capacity of transformer and lines.
- **Energy losses:** Energy loss assessment in a dynamic network.
- **Planning gaps:** Traditional methods lack dynamic demand and DER growth mapping.
- **Supply-demand issues:** Simultaneous high demand or high generation scenarios.
- **New connection delays:** Elongated time required in conducting new connection requests' feasibility and issuing the connection.

Overall, **these challenges strain network stability, reliability,** and **scalability.** Utilities also face immense pressure to reduce operational costs, improve customer service, and process connection requests efficiently.

## Unlocking the Power of Metering Data

The energy meter's ability to store granular data carries the potential of providing load forecasting insight on diverse and new categories of consumption patterns. Besides this, they also provide an opportunity to study the stress a network will experience in the future with DERs penetration and identify weak links in the network.

In addition, data simulation and visualisation can help network planners with incredible insights for network augmentation and preventive maintenance, thus minimising stress and subsequent network asset failure.

Therefore, by leveraging the metering data with advanced analytics and machine learning (ML), utilities can unlock transformative applications. Highlighting some of the key applications:

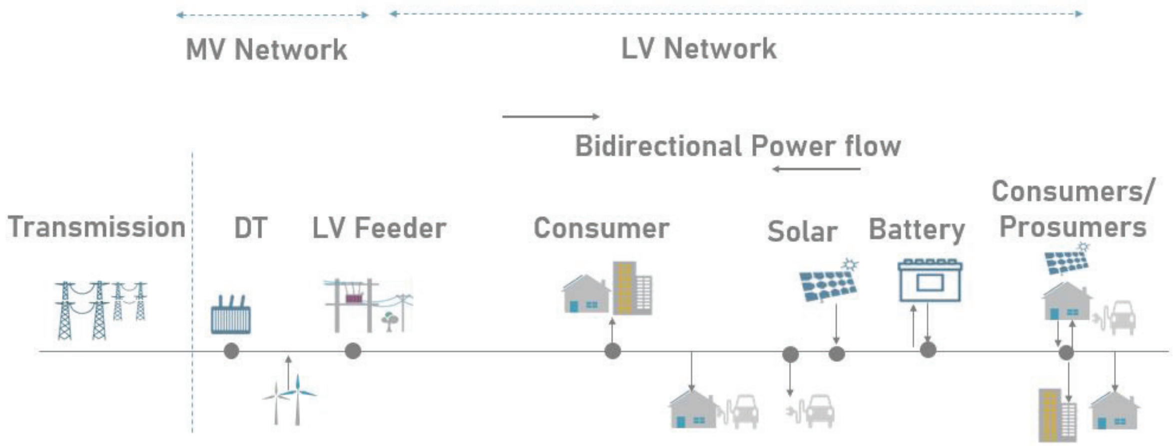
(a) Distribution network analytics
(b) Consumer indexing
(c) Enhanced energy accounting
(d) Data-driven connection feasibility assessment
(e) Dynamic tariff design
(f) Load curtailment and demand alignment
(g) Consumer data analytics
(h) Theft identification

### (a) Distribution network analytics

Effective use of metering data for data-driven network analytics such as power flow, stressed areas in the network, hosting capacity, voltage violation and N-1 contingency in meshed type networks.

**Hosting capacity analysis** has undergone a

**Figure 1: Bidirectional power flow in network**



significant transformation. The ability of distribution networks to accommodate additional load or generation is influenced by multiple factors, including voltage deviations, voltage fluctuations, thermal stability, and short-circuit currents. It also depends on the existing equipment on the circuit at any given time, which may change as utilities make future investments. Moreover, the utility's distribution planning practices—particularly how they assess the need for upgrades or other mitigation measures—play a critical role in determining hosting capacity.

**A power flow study** with time series (load profile) data allows continuous information about limit violations, voltages, line and transformer loading, bus voltage magnitudes calculation, power loss evaluation and transfer capability estimation.

**Time-series** data usage with load flow analysis environments enables accurate simulations of network upgrade needs—such as conductor replacements or transformer augmentations. This analysis allows utilities to assess the impact on hosting capacity for rooftop solar installations, electric vehicle (EV) loads, and new prosumer connections. Such predictive capabilities support the prioritisation of capital expenditures while ensuring grid stability and scalability. The metering time series data update can be done weekly, daily or even in shorter time. On a dashboard, the source and result data are displayed in different views. This allows continuous information about limit violations (voltages, line and transformer loading) in the grid.

**Case Study: Network Hosting Capacity Evaluation**

In one of the urban cities of Rajasthan, we performed network analytics using metering data.

Figure 2 illustrates the amount of additional load or generation that can be safely integrated into the grid. Under the given load conditions, the hosting capacity at each pole was determined to be 0 kW. Load flow analysis revealed that the connected conductor's ampacity was insufficient, which significantly limited the network's overall hosting capacity and led to increased energy losses.

**Simulation of Stress Condition in Network**

Meter data-driven simulations help to identify vulnerabilities and weaknesses in the system, allowing utilities to proactively address potential issues and improve the reliability and resilience of the grid.

Such analysis is especially useful for optimal targeting of future grid investments. Additionally, it provides insights into dynamic grid behaviour based on meter data. Network stress analysis serves various purposes like transmission planning, tariff determination, market studies, stability analysis, contingency screening, and corrective action planning.

**Simulate Stress in Network by Adding EV Chargers**

Simulation results are illustrated in Figure 3, where 14 nos. voltage violations were observed by adding 100% percent of the quantity of EV chargers (50 EV chargers) and no voltage violation at 50%

EVs (25 nos. EV chargers). Such simulation helps for proactive action planning and targeted investment in the network.

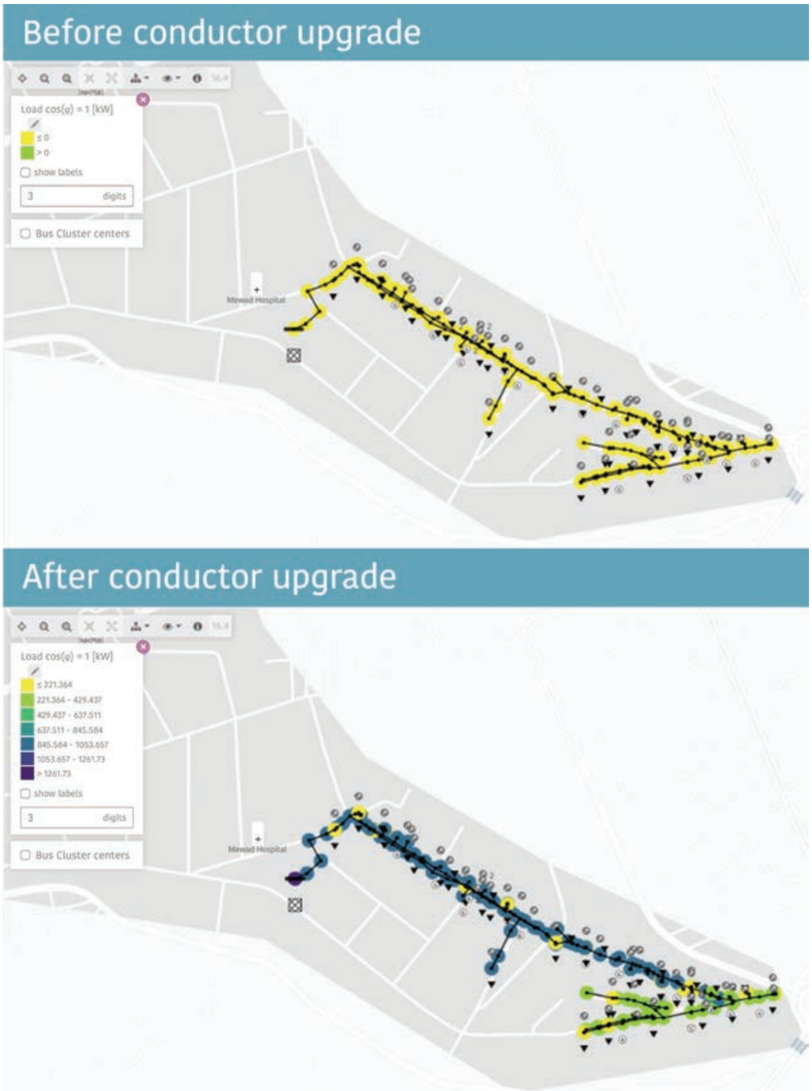
**N-1 Contingency Analysis**

In high-reliability urban networks meshed underground systems, software tools with N-1 contingency analysis have proven especially valuable. By simulating the failure of individual network elements one at a time, utilities could identify which circuits would be most impacted by outages. This enabled them to plan reinforcements and switching strategies that maintain continuity of supply even during faults, ultimately enhancing network reliability and regulatory performance.

**Maximising Network Capacity Utilisation**

DT and feeder meter data help utilities analyse real-time feeder loading and uncover imbalances or inefficiencies in asset utilisation. This supports better phase balancing at transformer levels and can inform non-wire alternatives to traditional network augmentation. By fully utilising existing DT and feeder meter data helps utilities analyse real-time feeder loading and uncover imbalances or inefficiencies in asset utilisation. This supports better phase balancing at transformer-level assets before investing in new infrastructure. Distribution utilities can significantly reduce capital expenditure and lower system losses.

**Figure 2 Hosting Capacity Evaluation**




**Asset Monitoring**

Distribution transformers, switchgear, and cables are often stressed due to overloading, poor power quality, or delayed maintenance. Traditionally, these issues were identified only after failures occurred, leading to unplanned outages and costly emergency repairs.

The above insights are very useful for the network enhancement and augmentation plan that are prepared under various schemes which are more scientific, accurate and methodological and serve the basic purpose of delivering reliable power without any constraints.

**Case study: Voltage Analytics Using Metering Data in an Urban City of Rajasthan (Suspected Transformer Condition)**

In one of Rajasthan's urban cities, network analytics was conducted using advanced metering data to identify voltage mismatches. The analysis focused on comparing actual voltages recorded by meters with those derived from load flow analysis at various network buses—demonstrating a highly effective use of metering data for grid validation. Figure 4 illustrates voltage variation suspecting transformer condition on site by matching load flow analysis and actual meter data.

The load flow analysis was conducted on an 11 kV feeder comprising these 13 transformers, with the following results:

- 11 nos. of transformers had voltage error margins below 1%.

Figure 3 Stress simulation by adding EV load in the network

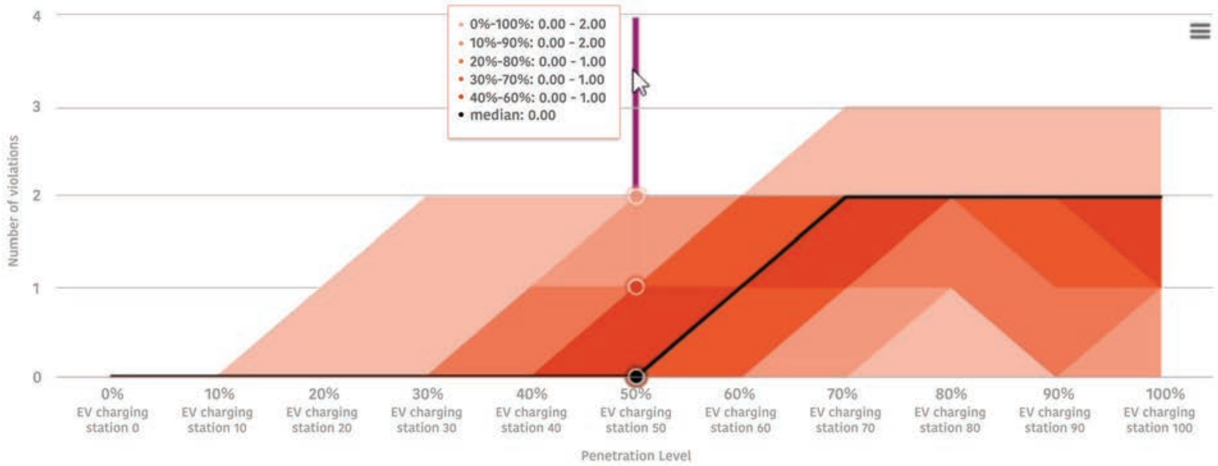



Figure 4 Comparing meter's data vs derived voltage through load flow analysis

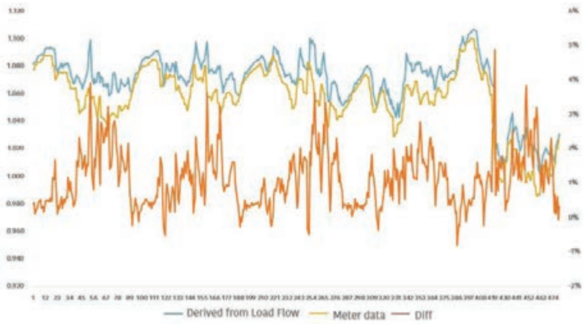



Figure 5 Repaired Transformer

- 1 no. transformer showed an error exceeding 2%, attributed to age and prior repairs. Illustrated in Figure 5
- 1 no. transformer exhibited an error greater than 40%, due to a missing potential transformer (PT).

A site visit confirmed that the high-error transformer had been previously repaired and was originally manufactured in 2015.

### (b) Consumer Indexing

It is essential to map each electricity consumer to the correct transformer, feeder, and distribution network in a structured, geo-tagged, and digital format.

Accurate tagging of consumers using machine learning-based classification can significantly improve distribution transformer (DT) load balancing and enhance the accuracy of energy accounting.

Presently, in many distribution utilities, consumers are not correctly tagged to their actual power sources. For example, a consumer may physically receive power from the R-phase of a distribution transformer but may be incorrectly tagged to the Y-phase in system records. This misalignment hinders effective load flow analysis and prevents corrective planning.

However, smart meter time-series data (15 or 30-minute interval data), combined with ML (machine learning)-based algorithms, may ensure right tagging and reduce AT&C losses.

### (c) Enhanced Energy Accounting

A fully integrated metering data system across feeders, DTs, and consumers enables granular and accurate energy accounting. In addition, it provides proactive visibility into asset health and areas for improvement within the distribution network.

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By leveraging metering data, utilities can:

- **Track & monitor losses:**
  - o Feeder-wise and DT-wise energy accounting.
  - o Identify unmetered nodes and tagging gaps.
- **Detect pilferage:** Alerts for pilferage detection and reduction.
- **Generate insights:** Data insights supporting informed decision-making.
- **Monitor effectively:** Monitor feeder/DT health, peak demand, and phase imbalances – through various reports and dashboards.

**Case Study:**

In the two Rajasthan cities, meter data-driven energy audits reduced losses by identifying unmetered nodes and network gaps **(Figures 6 & 7).** MIS reports highlighted overloaded transformers and phase imbalances, enabling swift corrective actions.

**Figure 6. Energy loss reduction using meter data in City 1**

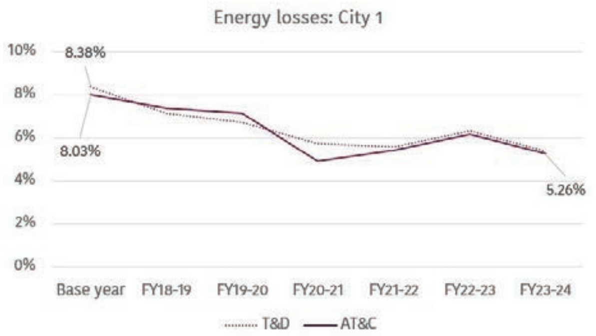
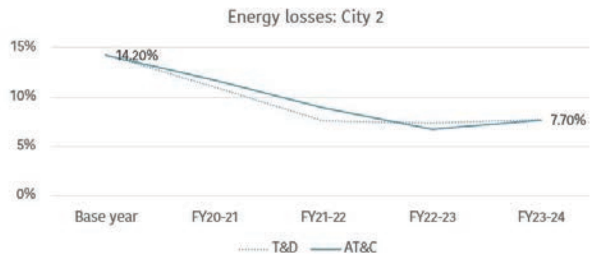



**Figure7 Energy loss reduction using meter data in City 2**




❖ ***Feeder and DT Meter Health MIS report***
- Peak demand of the DT and feeder
- Relative unbalance among phases of DT
- Maximum current and minimum voltage
- Voltage variations

❖ ***T&D and AT&C Loss Analysis***
- Monthly T&D and AT&C Report
- Billing and collection efficiency for each feeder and DT

### (d) Data-driven Connection Feasibility

Traditionally, new connection requests often require time-consuming site inspections with the following broad stages:

i. Verification of sanctioned load based on square footage
ii. Legal compliance check and classification as urban or rural
iii. Assessment of nearby line routes and site conditions
iv. Identification of nearby poles for service line extension
v. Line and network capacity assessment for new connection or addition of PV/EV on the network

By leveraging the metering data in combination with data-driven models, such as:

- **Simulating Load Impact:** Assess the infrastructure capacity without physical visits.
- **Creating Digital Twins:** Virtually model the network to locate new connections.

Utilities can achieve quicker turnaround times, improved operational efficiency, and enhanced customer experience.

**Case study:**

In one of the urban cities of Rajasthan, the traditional process of evaluating technical feasibility for new connections, previously taking several hours to days, was significantly reduced to just a few minutes to hours.

This improvement was made possible through data-driven load flow simulations, leveraging profile data from smart meters.

Using this approach, the following technical feasibility steps were performed:

i. Creation of a digital twin to accurately locate the proposed new connection
ii. Identification of nearby poles suitable for assigning the connection
iii. Calculation of the distance from poles to the customer connection point

As a result, technical feasibility assessments were completed within 5 minutes. Refer to Figure 8 for illustration.

**Figure 8. Technical feasibility is completed in less than 5 minutes.**

| Consumer | Connection details | Technical feasibility manual ( Utility) | Technical feasibility using data driven application |
|---|---|---|---|
| 110211035167 | 8 kW I3 Phase I Residence | 3 Hour 56 Minutes | < 5 Min |
| 110211035165 | 1 kW I1 Phase I Residence | 5 Hour 31 Minutes | < 5 Min |
| 110211035032 | 5 kW I3 Phase I Residence | - | < 5 Min |
| 110211035170 | 5 kW I1 Phase I Shop | 2 Days 6 Hour 3 Minutes | < 5 Min |
| 110211035177 | 2 kW I1 Phase I Shop | 12 Days 4 Hour 13 Minutes | < 5 Min |
| 110211035150 | 5 kW I 1 phase ISolar | 0 Hour 2 Minutes | < 5 Min |
| 110211035159 | 1 kW I 1 phase INormal | 4 Hour 20 Minutes | < 5 Min |

In a nutshell, this saved resources and money and improved overall customer experience.

### (e) Dynamic and Equitable Tariff Design

Granular metering data **supports responsive tariff structures,** such as ToU pricing, that align with grid needs and consumer behaviour.

Regulators can leverage this data to **simulate the impact of time-of-use (ToU) pricing,** evaluate demand elasticity across different consumer categories, and design tariffs that promote energy conservation without disproportionately affecting vulnerable populations. With accurate load profiling, tariffs can be better aligned with the true cost reflective of service—supporting both grid efficiency and consumer equity.

Advanced analytics on metering data also **facilitates the implementation of dynamic pricing structures at the local grid level.** These structures help balance supply and demand, optimise grid capacity, and encourage consumer participation in modern energy practices such as:

- **Energy trading:** Peer-to-peer energy trading.
- **Promoting sustainability:** Incentivise rooftop solar, EV charging, and energy-efficient appliances.
- **Supply-demand balancing:** Encourage usage during off-peak hours.

### (f) Consumer Data Analytics:

Machine learning-driven algorithms and analytics help consumers understand their usage patterns and optimise consumption. For example, detecting major contributor seasonal loads (e.g., ACs or heaters) enables targeted energy-saving recommendations and demand side participation. This proactive insight helps consumers to make informed decisions to reduce overall consumption linked to electricity tariffs and grid constraints scenarios.

### (g) Theft Identification:

Electricity theft remains a major source of commercial losses for Indian distribution utilities (DISCOMs), especially in high-loss zones and unmetered areas. Smart metering, combined with advanced analytics, provides a powerful solution for detecting and curbing theft.

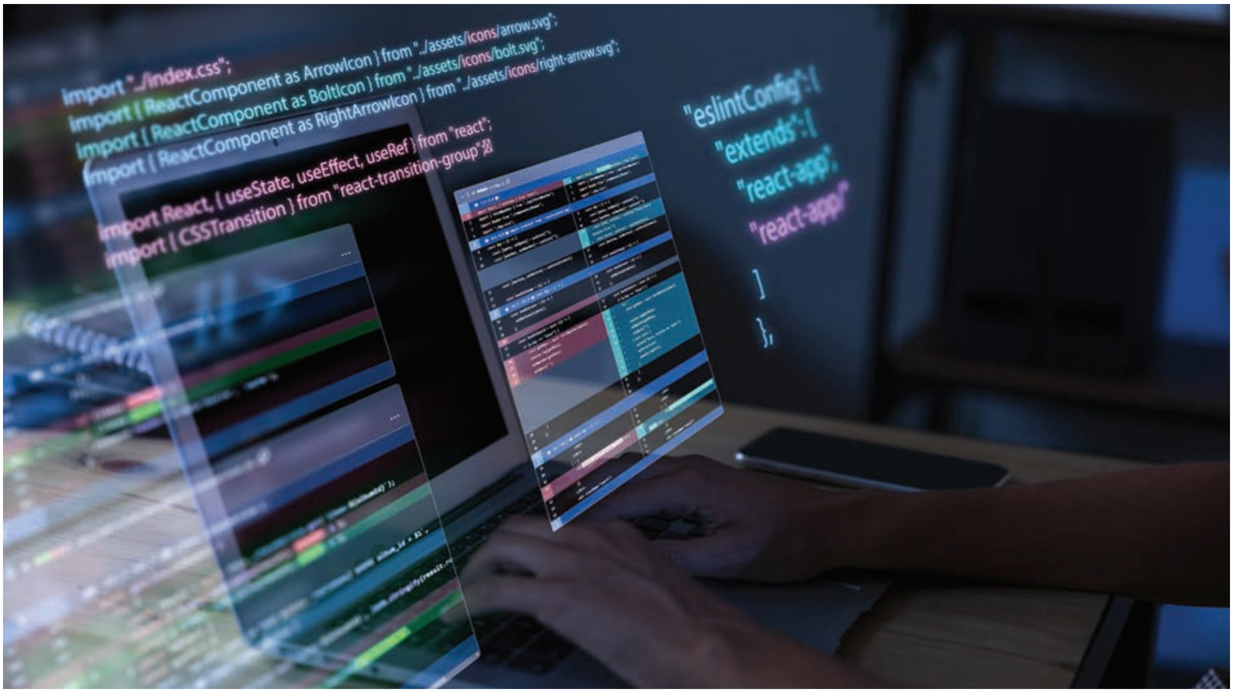
By continuously monitoring usage patterns and comparing energy inflows (at transformers/ feeders) with outflows (at consumer meters), utilities can conduct real-time energy audits to spot anomalies. Sudden drops in recorded consumption, tamper alerts, or irregular load curves can indicate bypassing (either partial or full) or meter tampering.

In addition, AI-based analytics can identify suspicious patterns — such as a load suddenly dropping after peak hours or consistent zero consumption in otherwise high-usage areas.

### (h) Load and Demand Alignment:

Smart meters can play a pivotal role in managing grid stress and optimising demand:

- **Load Curtailment:**
  During grid emergencies or overloaded situations, smart meters enable utilities to implement



targeted load reduction. Real-time data identifies high-consumption areas, allowing remote curtailment by setting the load limits to lower values, minimising disruptions while maintaining grid stability and consumer convenience.

- **Bridging Gap Between Contracted and Recorded Demand:**
  Many consumers often face penalties when their recorded demand exceeds their sanctioned (contract) demand, or utilities over-allocate capacity, leading to inefficiencies.
  Smart meter data provides accurate demand profiles, enabling utilities to adjust contract demand to match actual usage. This minimises penalties for consumers and optimises asset utilisation for utilities.

## Conclusion

**Metering data is the backbone of India's energy transformation.** By moving beyond billing and employing advanced tools and technologies, utilities can harness this digital asset to **enhance grid reliability, optimise investments, manage peak loads, and empower consumers.**

Besides this, the metering data provides an **opportunity to study the stress a network would experience in the future** with DERs penetration and **identify areas (weak links)** in the network.

In addition, **data simulation and visualisation** can help network planners with incredible **insights for network augmentation and preventive maintenance,** thus **minimising stress and subsequent network asset failure.** In a nutshell, **the applications are vast and diverse – metering data will drive the digital edge for utilities, ensuring a resilient, sustainable, and equitable energy future.**

## ABOUT THE AUTHORS


**Sushil Kumar Jangir** is the leading technical specialist and as a Senior Manager at Secure Meters he contributes mainly to product development and application engineering. Having served the company for almost two decades, Jangir is a graduate in electrical engineering and holds an advance certification in power distribution management. He has served the power sector in both divisions of utilities and industries for over a quarter of a century.

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# Advanced Metering Infrastructure Deployment Challenges

**AASHISH GAUR** of **Genus Power Infrastructure Limited** explores key challenges faced by AMISPs in India and provides recommendations for overcoming them to ensure successful AMI deployment across the country.

Availability of quality of power is the basic and mandatory need of every citizen of India. Deployment of smart metering systems will provide empowerment to end-consumers (monitor and control the usage), provide benefits to society (to build transparency and trust), build nations (to use the resources with best capacity), and lastly, help utilities develop processes and systems for moving operations to the next level.

With this context, in July 2021, the Government of India (GoI) initiated the world's largest advanced metering infrastructure (AMI) programme under the Revamped Distribution Sector Scheme (RDSS) to replace 250 million electricity meters with smart prepaid meters. This programme, applicable to all state-owned electricity distribution companies (discoms), aims at modernizing the power distribution sector. However, several challenges hinder the full-scale deployment of AMI systems in India, ranging from technological barriers to regulatory hurdles. This whitepaper explores the key challenges faced by AMI service providers (AMISPs) in India and provides recommendations for overcoming them to ensure successful AMI deployment across the country.

## Introduction

AMI refers to a system that measures, collects, and analyses energy usage data, and communicates this data between customers and utilities. AMI typically includes smart meters, communication networks, and data management systems.

An AMISP is responsible for deploying, operating, and maintaining the infrastructure necessary for the successful implementation of AMI. This includes installation of smart meters, establishment of communication networks, and integration with the utility's backend systems. AMISPs play a critical role in enabling utilities to manage energy usage more efficiently and facilitate smarter energy consumption.

Through the RDSS, the GoI will contribute 15 percent of the project cost as a grant to discoms, which will be passed on to AMISPs. Power Finance Corporation Ltd (PFC) and Rural Electrification Corporation Ltd (REC) are the designated nodal agencies for RDSS, managing different groups of discoms. REC has also issued a standard bidding document (SBD) for the appointment of AMISPs, which all discoms should follow to access the grant. The AMI system must be maintained by the AMISP for approximately 93 months post commissioning.

As of September 2024, contracts for 117 million meters have been awarded by state discoms following the SBD contract terms and conditions.

The deployment proposed in AMI refers to a network of smart meters deployed in various locations such as residential and non-residential. These smart meters are designed to facilitate two-way communication with the head end system (HES) and meter data management system (MDMS). The HES is tasked with managing the smart meters, overseeing the communication network, and gathering data and is integrated into the meter data management (MDM). The role of the MDM is to process, validate, and analyse the vast amount of data collected for various utility functions. These include billing, customer service, grid operations, and planning for demand versus supply management.

In India, smart meters are required to operate in prepaid mode and come with integrated relays that allow for remote connection and disconnection of services based on the consumer balance. On one hand, it enables the utility to control the electricity supply at end-consumer premises while on the other hand, it adds complexity and places greater reliance on the communication network, making timely responses critical.

The integration of millions of hardware devices, communication networks, HES, MDM, mobile apps for utility and consumers makes AMI a complex system to implement and manage. Key challenges include achieving seamless integration, ensuring reliability, preventing obsolescence, managing ongoing maintenance, training utility staff, and educating consumers about the system.

## Deployment Challenges & Solutions

As of 2024, only 11.5 percent of the target (of awarded contracts) has been achieved, with many AMISPs and discoms facing significant challenges in deployment of the AMI system. A combination of financial, technical, and policy-related issues has contributed to slow progress. While there are success stories in a few states, widespread AMI deployment remains a challenge due to India's unique socio-economic and infrastructural landscape. We can categorise key challenges as below:

- SAT process and its approvals.
- New requirements and implementation.
- Execution challenges.
- Communication challenges.
- Skill development and social challenges.

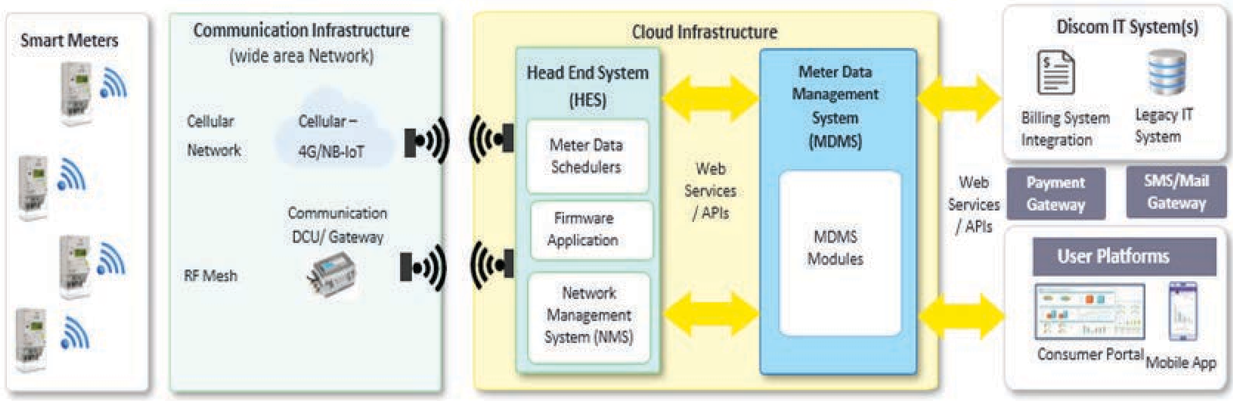
Let us have a detailed discussion on the above key challenges.

### SAT Process and its Approvals

The payment cycle for AMISP is directly connected to the successful completion of system acceptance tests (SAT) by the utility and strict adherence to service level agreements (SLAs). However, a few challenges can impact both SAT and SLA compliance:

- Frequent power outages, disconnected, permanent disconnected, FIR registered by utility officials, and many other reasons impact SLA compliance for AMISP systems. To address this, these cases need to be exempted from the AMISP scope. However, achieving this exemption requires a common understanding and approval from utilities.
- Obtaining approval for the proposed SAT from the utility is a critical challenge. The SAT must

**Fig 1: Advanced Metering Infrastructure and Interfaces**



be completed according to the project's defined milestones to ensure timely progress. For AMISP, adhering to this schedule is crucial to maintaining their revenue cycle throughout the remainder of the project implementation.

- Delay in the SAT significantly increases the number of meters to be tested, creating challenges in verifying the system's ability to handle the larger volume of meters and data transactions. Ensuring the system maintains performance and stability under this increased load becomes a major challenge in such situations.
- Some test cases outlined in the SAT are particularly challenging to execute within the given timeframe due to the large volume of meters involved.
- A detailed representation of changes is proposed to MOP/REC in different forums for due updates of the processes with a pragmatic approach.

## New Requirements and Implementation

There is a list of other issues, including the inclusion of new requirements, policy and regulatory requirements, that impacts overall product and systems availability. It also impacts installation progress on a regular basis and creates challenges during the installation process.

### Regulatory and policy level requirements

There are requirements around common pluggable module initiative, dual sim/e-sim/muti-profile sim in communication module, different tamper logics, display parameters requirements and its implementation. Seal requirements are posing multiple challenges around interpretation, implementation, and product changes over time. It impacts the product and systems availability for mass production and deployments.

A set of new requirements during the execution phase impacts multiple changes in meter firmware, software deployment (WFM/MDMS/HES), and field processes. It impacts the pace and maintenance of systems on a regular basis. The requirement changes are important but should be governed through change control board with due change analysis and impacts.

Along with the above, implementing prepayment systems must adhere to various regulatory requirements, tariff standards, and supportive policies and incentives. In some regions, unclear or frequently changing policies can lead to frequent adjustments in the prepayment system, increasing complexity and making implementation more challenging.

### Business process implementation

Prepayment process is the key component of AMISP. Implementing a prepayment process in AMISP systems in India involves several challenges. Prepayment systems require users to pay for their electricity usage in advance, which necessitates integration with smart metering, billing, and data management systems. Here are some key challenges faced during the implementation of prepayment processes:

Integrating prepayment functionality with existing AMI systems, billing software, and customer management systems requires seamless coordination. Any discrepancies or integration issues can lead to errors in billing and customer accounts.

## Execution Challenges

The installation of AMI in India presents several challenges due to the unique geographic, social, infrastructural landscape, dependency of multiple stakeholders. Here are some key execution challenges specific to field installations in India:

### Shut down availability for DT/feeders

Proper shutdowns are crucial for safely installing or upgrading metering infrastructure at the distribution transformers (DTs) or feeders. However, obtaining timely shutdowns from the discom can be difficult. Due to the critical nature of electricity supply, many regions or areas face restrictions on when and how long power can be turned off, particularly in densely populated or industrial areas.

This non-availability of proper shutdowns hampers the overall progress of system metering, leading to project delays and increased operational costs.

### Lack of feeder information for underground 11 kV cables

Many feeders in India use underground 11 kV cables, and often there is a lack of proper mapping, marking, or pole painting that shows detailed feeder information. Without this information, it becomes difficult for the AMISP team to identify and map the correct feeders.

The AMISP team is then forced to rely heavily on existing discom staff to provide accurate information. This leads to delays, errors, and dependency on discom personnel, which can slow down the system metering process and reduce overall project efficiency.

### Outdated network diagrams and unavailability of unique names or codes

In many cases, the network diagrams or drawings provided by discoms are either outdated or inaccurate. This makes it difficult for AMISP teams to locate the exact DTs or feeders, further complicating the system metering process.

In addition to the above, the unique names or codes for the DTs or feeders are often inconsistently generated or ambiguous, causing significant challenges for the AMISP in integrating these feeders or DTs into their system.

**Controlled area allocation by utilities**

The utility often provides specific areas (binder/MRU) for meter installations in a controlled manner. This structured approach, while ensuring oversight, causes process bottlenecks that hinder the AMISP team's ability to scale operations and ramp up installations efficiently. This slows down the overall project timeline.

Additionally, during the monthly billing activities of discoms, there is often non-availability or shifting of designated installation areas. This process typically takes five to seven days for each subdivision office, leading to disruptions in installation planning, team relocations, and further delays in the overall project timeline.

**Mismatch in consumer database**

There are significant discrepancies in the consumer database maintained by a discom's billing system, leading to multiple challenges during the installation process:

- **Meters not present on site:** In many cases, meters are listed in the billing database but do not physically exist at the installation site. This creates confusion and delays during fieldwork.
- **Incomplete or inaccurate data:** Key information such as meter numbers, consumer phase details, and other essential data are often missing or incorrect in the database. This lack of accurate records hampers the installation process, as field teams must verify and correct information on-site, causing further delays.

**Geographical diversity**

India's vast and diverse geography presents significant challenges for the deployment of Advanced Metering Infrastructure (AMI) in the country.

- **Rural and urban disparities:** The vast geographical diversity of India poses significant challenges in deploying AMI infrastructure. In urban areas, dense population centres can complicate installation logistics while in rural regions, the lack of basic infrastructure and reliable connectivity requires additional effort and investment to ensure smooth installation and functionality.
- **Weather and terrain issues:** Many parts of India experience extreme weather conditions, such as monsoons, heatwaves, and flooding, which can delay or disrupt the installation of smart meters. Additionally, difficult terrains like mountainous or forested regions increase the complexity of both, the installation and ongoing maintenance of AMI systems.

## Communication Challenges

India's diverse and often underdeveloped infrastructure poses challenges for establishing reliable communication networks, especially in rural areas. Communication-related are critical since the success of the system depends heavily on reliable data transmission between smart meters, the utility, and the service provider. Here are key communication challenges:

**Network reliability**

Network reliability is a critical factor in the success of AMISP systems. There are several challenges in ensuring network reliability and these can impact the overall performance of the AMISP system.

- **Unstable connectivity in remote areas:** In rural or hard-to-reach locations, the availability of reliable communication networks (cellular, radio frequency) can be limited, leading to intermittent or failed data transmission.
- **Network downtime:** AMI systems require consistent, real-time data transmission, and any network downtime or disruptions can affect billing accuracy, load management, and customer services.

**Bandwidth limitations**

As AMI systems scale up to include thousands or millions of meters, communication networks need to accommodate this massive scale. Ensuring that all devices can reliably send and receive data without bottlenecks is a significant challenge.

Smart meters generate large amounts of data continuously. If the communication network is not designed to handle this volume, there may be delays in data transmission, leading to inaccuracies in real-time monitoring.

**Frequent power outage or poor power quality**

Frequent power outages and poor power quality can significantly disrupt the operation and effectiveness of RF mesh networks used in AMI systems.

When a power outage occurs, devices within the RF mesh network, including smart meters and communication nodes, may reboot or lose power temporarily. This can lead to interruptions in data transmission and communication between nodes.

Mesh networks rely on a stable and consistent network topology to efficiently route data. Frequent power interruptions can cause devices to disconnect and reconnect, leading to frequent changes in the network configuration. This can disrupt the routing paths and increase the time required to reestablish communication between nodes.

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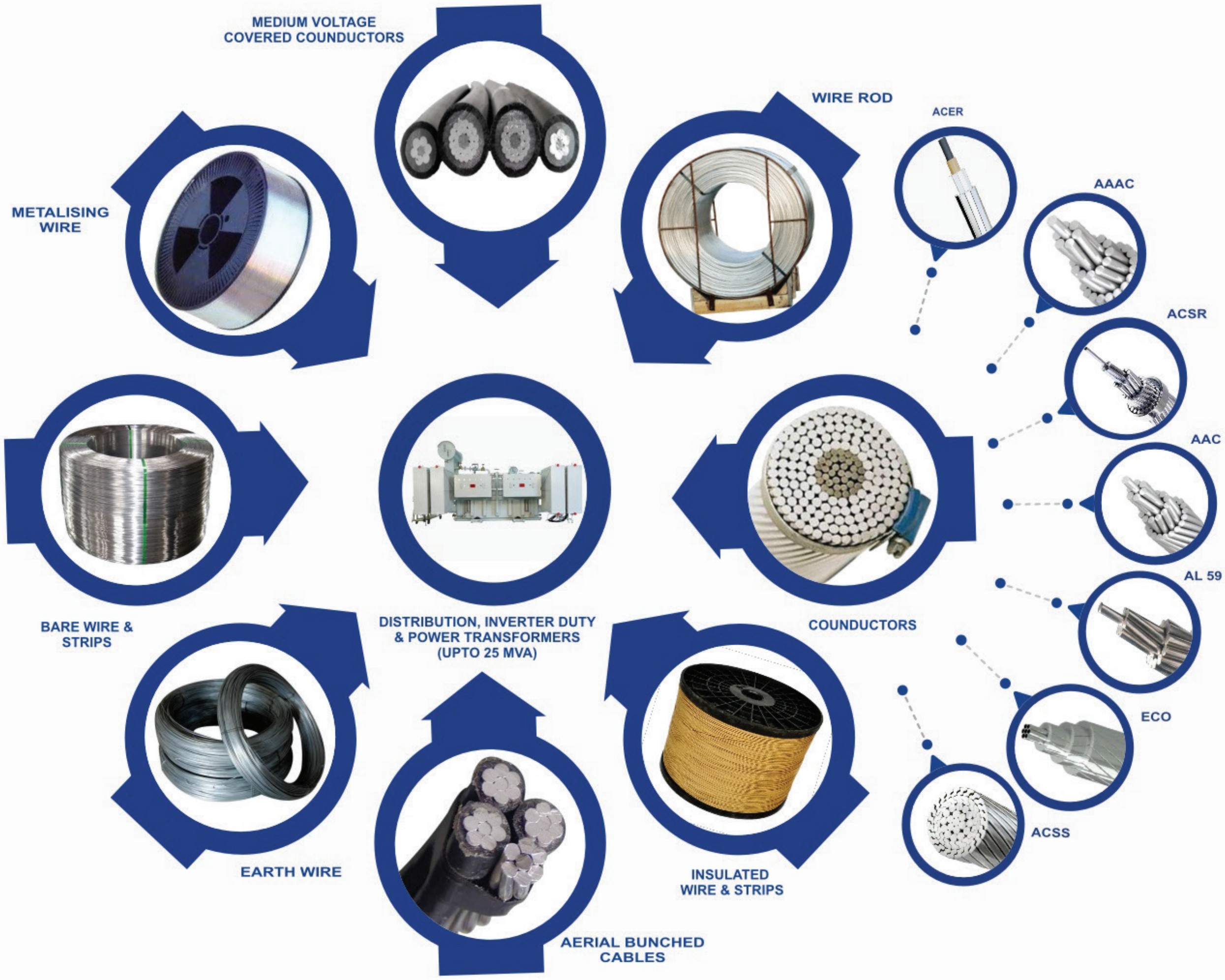


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Some feasible solutions to attend e or mitigate the above challenges are hybrid communication modules having a combination of RF and cellular, narrow band internet of things (NBIoT), and a Bluetooth local port in smart meters.

## Skill Development & Social Challenges

Utility metering is a complex field, where expertise is gained through years of hands-on problem solving and project execution. AMI implementation has made it more complex.

Deploying a skilled workforce and trained discom staff for AMISP projects in India presents several challenges. AMISP deployment is hampered by various technical, operational, and human resource-related challenges.

### Skilled workforce shortage

One of the biggest challenges is the lack of a sufficiently skilled workforce to manage the technical and operational demands of AMISP projects.

AMISP projects require personnel with expertise in smart meter installation, communication networks, data analytics, and cybersecurity. The workforce must have proficiency in handling Internet of Things (IoT) technologies, data acquisition systems, and other IT infrastructure related to smart metering. The scarcity of professionals with these niche skills is a significant bottleneck.

India's vast and diverse geography, with challenging terrains in rural areas, makes it difficult to deploy a trained workforce.

Moreover, the workforce involved in traditional metering and power distribution systems often lacks the technical knowledge required for AMISP deployments. Upskilling to handle smart metering technology is necessary but time-consuming and costly.

Skilled professionals with expertise in smart technologies are in high demand across various sectors such as telecom, information technology (IT), and manufacturing. This leads to high attrition rates for trained personnel.

### Social challenges

Deploying AMISP systems in India involves navigating several social challenges. These challenges can affect the overall success and efficiency of AMISP projects. Here's a detailed look at these challenges:

### Consumer resistance

Consumers may lack awareness or understanding of the benefits and operations of AMI systems, leading to resistance or reluctance to adopt new technologies. Concerns about data privacy and the accuracy of smart meters can result in resistance to new systems.

In certain regions, there is a risk of vandalism to installed meters, particularly if local consumers feel that the new systems are unfair or unnecessary. Additionally, meters and related equipment may be targetted for theft, especially in remote areas.

### Socio-economic challenges

India's diverse socioeconomic landscape means that different consumer segments may have varying levels of readiness and capability to adapt to prepayment systems. Addressing the needs of economically weaker sections can be challenging.

In lower-income areas, consumers may struggle with upfront costs or the concept of prepaying for electricity, leading to potential implementation hurdles and vandalism of installed smart meters.

## Case Study: Ongoing Successful Implementation of AMI System

- **Discom:** South Bihar Power Distribution Company Limited (SBPDCL)
- **Area:** Bhagalpur, Jamui, Shekhpura, Banka
- **Total scope:** 1 million smart meters
- **Total installation:** 0.67 million smart meters

### Key achievements in SBPDCL project implementation

- Successfully installed 670,000 smart meters with prepaid functionality, operational from day one of installation.
- Hybrid communication modules having a combination of RF and cellular have been deployed to mitigate the communication challenges.
- Achieved 94 percent daily communication success rate and over 98 percent success in daily auto-reconnection and recharge processes.
- Seamlessly integrated the AMISP system with key utility systems, including billing, NFMS, and Sampurna systems.
- Conducted comprehensive consumer awareness programmes to address resistance and enhance understanding of smart meters among consumers.

### Utility initiatives for smooth project implementation

- Conducted in-depth discussions and brainstorming sessions on all processes and integration parameters with AMISP at the project initiation stage, ensuring alignment with the utility's vision and preventing unnecessary confusion.
- Strengthened IT infrastructure to efficiently handle the daily bulk data exchange between AMISP and the utility's billing system.
- Ensured secure exchange of consumer master data strictly via API to prevent any leakage of confidential consumer information.


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- Generated and shared 100 percent unique codes with AMISP to ensure seamless mapping between network components.
- Conducted timely training sessions for utility staff to improve their ability to manage, monitor, and maintain the new infrastructure.
- Enabled instant correction of consumer information by AMISP and utility staff in case of discrepancies and provided on-demand consumer data request option for urgent situations where a consumer, area, or MRU is not assigned to a field officer, ensuring uninterrupted installation activities.

## Conclusion

The deployment of smart meters in India marks a significant step toward enhancing energy efficiency and improving the operational effectiveness of utilities. However, the large-scale implementation within a short timeframe presents numerous challenges. By staying informed and utilising both proven and innovative solutions, these challenges can be effectively addressed, leading to substantial savings in time, effort, and costs. By adopting a coordinated approach that includes policy support, financial incentives, and consumer education, India can overcome these challenges and realise the full benefits of AMI.

## ABOUT THE AUTHOR

Aashish Gaur has 19+ years of experience across product management, project management and business development for smart grid solutions development and AMI deployment across different power distribution utilities. He has managed client accounts, generated sales pitches, and developed business solutions to deliver top and bottom-line growth. Gaur is an expert in handling large-scale projects with focus on customer requirements, operational excellence and the right use of technology. He is currently working as AGM-Project Engineering and handling solutions and its deployment for AMISP projects across different utilities in India. Gaur is also working in multiple national committees in BIS and CEA for formulating standards and regulatory guidelines while working with stakeholders and policymakers in India.

# Auto Regulated Grid Links In Inter Connected Power Systems

## Dynamics of the National Power Grid

India is spread almost 1,822 miles apart from the east to the west and approximately 1,997 miles from the north to the south. Thus, the actual daytime varies by two hours between the eastern and western zones of India affecting the power requirements which concur to the local day-night periods. This diversity in the demand is favourable to managing local peak and off-peak demands.

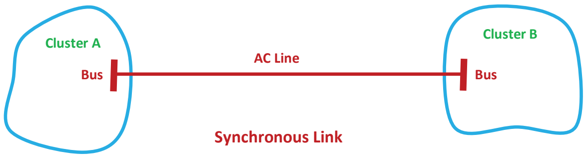
Similarly, climatic variations, particularly in temperature from northern to southern areas, are favourable to managing local seasonal demand. A higher heating load is recorded in winter but no cooling load in summer is noted in the northern area. Contrarily, in the southern area, there is no heating load in winter but a higher cooling load in summer.

Maximum hydropower is available during monsoons from run-off river projects, though available at the fag-end of the monsoon, when the dam overflows to aid irrigation and similar projects; however, it is available at the onset of summer in the northern area due to the melting of the ice.

Thermal generation is hampered during the monsoon due to lumpy coal/lignite feeding. Thermal generation drop due to higher ambient temperature in summer causes insufficient condenser cooling and low vacuum. Gas turbine generation drops due to low-density air. The effect is predominant where there are more such plants.

Also, holidays fall on different days in different regions of India as per the local races and religions affecting power dynamics. The extent, duration, and time of power demand for lift irrigation too varies in different regions depending upon the crop pattern and irrigation requirements.

In addition to these periodic variations, there may be stray incidences causing variations in supply or demand of power. Generation is likely to be affected due to forced outages of generators, faults on evacuating lines, disturbances in fuel supply chain caused due to accidents or agitation in transport or fuel sources. Power demand is also affected by natural calamities like cyclones, droughts, floods, earthquakes, etc. Power demand can be also affected by agitations like bandhs, rasta-rokos, strikes, etc.




Variations in power supply and demand can lead to surplus power in some areas while leaving other areas to face power shortages. Providing power support to starving areas is easy in a wider grid system. The cost of power from various sources differs depending on the price of fuel, transportation cost, operating cost, resource availability, taxes, etc. The national grid facilitates optimal overall economic grid operation in addition to equitable utilization of available resources.

### Grid Development

Original power systems were direct current (DC) standalone systems that only catered to local loads. Parallel operation of generators was only possible at the local bus of power plants. Load catering to long distances was not sensible due to high losses and large voltage drops. So, it has no scope for grid consideration. But this constraint is solved with the development of the device for transformation of voltage level.

Henceforth, power transfer over long distances transformed to a higher voltage with a lower current– most losses and voltage drops are controlled due to a low current. Feasibility of power transport to long distances and parallel operation of generators at varied locations made a way to the grid system. But voltage transformation was possible in the alternating current (AC) system only. Hence, existing standalone DC power plants were converted to an AC system and interconnected. The power system expanded with many power plants operating in synchronism and catering to loads in a wide area.

Expansion continued to form a state grid of single ownership. Letters on central sector power plants came up as pooled sources having allotted shares for various power systems. State grids were extended to draw power share from these power plants. Ultimately, a regional grid was established by indirect and direct links with other power systems. Efforts were made for inter-region connections. But trial operations were not fruitful at this stage. Thereafter, regional grids were interconnected with high voltage direct current (HVDC) links to start with national grid benefits. This regional asynchronous interconnection continued for a few years. Finally, synchronous connections amongst regions were established in steps, forming the present synchronous national grid.

## Pros and Cons of a Synchronous Link

**Pros**

- Synchronous interconnection is straightforward by transmission line with no need for specific equipment or setup.
- Power assistance is instantly automatic in case of exigency in any part of the grid.
- Frequency excursions are narrow and slow due to increased stiffness of a wider grid system having a larger bias and higher inertia.

**Cons**

- An increase in the fault level may require higher-capacity equipment at some locations.
- System control is difficult with multiple partners.
- There is a probability of disturbance spreading from one to another region.
- Power flow in the transmission network is automatically governed by system parameters, available networks, and injections and extraction of active reactive power at various locations. The task is intricate to relieve critically loaded elements to avoid untoward incidents.
- The frequency remains common for all in the grid. Abnormal frequency operation is detrimental to equipment at power plants and consumers. Regions capable of operating systems at a comfortable frequency level are dragged for risky operation.

## HVDC Link

HVDC links were established between regions in the past when synchronous operation was not practicable at the time. Such asynchronous links were operative for a few years till synchronous links were established.

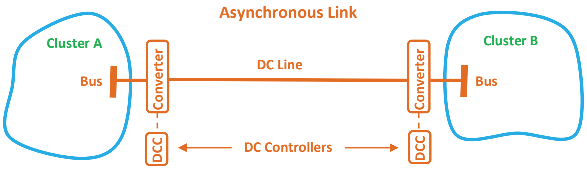
## Pros and Cons of Asynchronous Link

**Pros**

- Power transfer on this link is controlled and regulated as desired.
- The region's system frequency is independent of other regions.
- There is no scope of spreading disturbance in one region to another due to isolation.
- The region can be operated at the desired frequency.
- The system operation is better coordinated with limited partners.

**Cons**

- Require specific setup, equipment, and operation expertise.
- The system is slow because of manual operation. Time is spent on formalities and implementation.

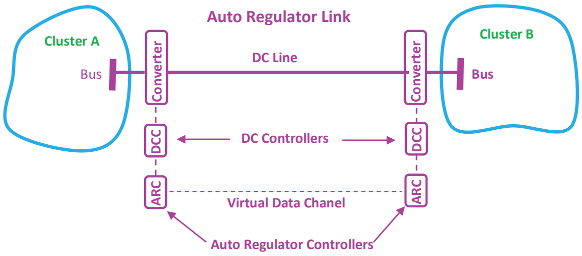



This implies that neither of the two options is right for the purpose; both the alternatives have favorable and unfavorable characteristics. The only option now is to modify either of the links to overcome constraints; one option is the auto regulated DC link.

## Auto Regulator DC Link

The present Indian power system is a synchronous national grid. Inter-region HVDC links established earlier are already available and operated in hybrid mode to manually regulate power flow on inter-region AC links.

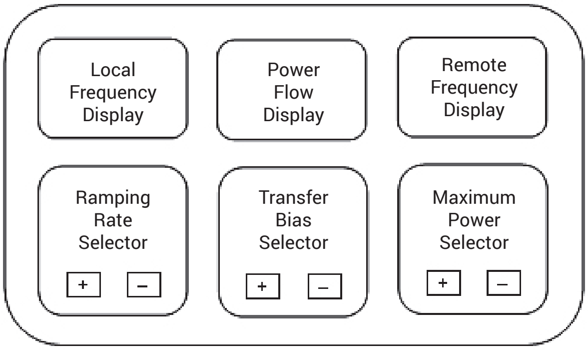
The operating characteristic of the high-voltage long transmission line was unfavorable at loads apart from surge impedance loading. However, it could be made flexible for operation at any loading by integrating with the flexible AC transmission system (FACTS) devices. A similar HVDC link can be made versatile for operation as an auto regulator link. The basic requirement is the following.




- Fast scanning frequency transducers installed at one of the ends, transmitting data to the control unit;
- Fast scanning frequency transducers installed at the other end to transmit data to the control unit via the data channel;
- Actual power flow signal from the HVDC controller.

<u>The control unit developed with the following basic features:</u>

- Three displays for local frequency, remote frequency and actual power flow;
- Three control settings for transfer bias, maximum power and ramping rate;
- Data links with the local and remote frequency sensor and HVDC controller.
- Usual modems, power supply, etc.




**Functioning:** Controller programmes evaluate Expected Power Transfer.
Expected Power Transfer X = Transfer Bias × (Local Frequency – Remote Frequency)
X is restricted to maximum power setting.
Deviation D = Required Power Transfer X – Actual Power Flow P i.e. D = X – P
Signal pass to HVDC controller to raise export as per ramping.
Actual power flow P increases from high frequency region to low frequency region.
Frequency drops in high frequency region due to export;
Frequency rises in low frequency region due to import;
Expected Power Transfer X reduces due to reduction of frequency difference.
Deviation D reduces the Expected Power Transfer 'X' decrease and Actual Power Flow 'P' increases.
Repeated after each doze, till deviation 'D' is less than allowed tolerance.

Power transfer at this level continues till changes in load or generation in either region.
Power transfer increases when 'D' is positive due to following changes.

- Power injection increase in exporting region
- Load decrease in exporting region
- Power injection reduces in importing region
- Load increase in importing region.

Power transfer decreases when 'D' is negative due to following changes.

- Power injection decrease in exporting region
- Load increase in exporting region
- Power injection increase in importing region
- Load decrease in importing region.

**Fiscal Impact:** Frequency in the exporting region is always higher than in the importing region. The unscheduled interchange rate of the exporting region is lower than that of importing region. Power sent at export point and received at import point differs due to line loss. UI charges payable to export region is less than receivable from import region. The balance of two is transfer gain for the link.

**Analytical Equation:** Consider HVDCAR link between regions S operating at higher frequency and region R operating at lower frequency.
System bias is Bs MW/Hz and Br MW/Hz respectively.
Frequency in isolation is Fsn Hz and FrnHz respectively.
Transfer Bias setting is Bt MW/Hz.


After close of the link power P flows in the link.

| | | |
|---|---|---|
| System Bias MW/Hz | Bs | Br |
| Frequency (Open Link)Hz | Fsn | Frn |
| Frequency(Close Link)Hz | Fsc | Frc |
| Transmission Bias MW/Hz | Bt | |

Let power transfer is X MW from region S to region R;
Frequency drop from Fsn to Fsc in region S due to loss of X MW transferred to Region R;
X = Bs (*Fsn-Fsc*)
Frequency rise from Frn to Frc in region R due to gain of X MW received from Region S;

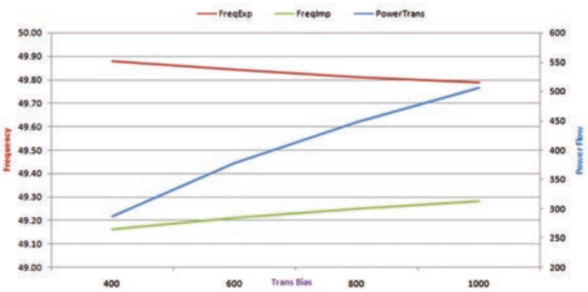

PESU

X = Br (*Frc-Frn*)
Power transfer X is the proportional difference of frequency between regions.
X = Bt (*Fsc-Frc*)
Solving these three simultaneous equations for X, Fsc and Frc in term of Bs, Rs, Bt, Fsn and Frn.
We get:
X =*(Fsn-Frn)BtBsBr/BsBr +BtBs +BtBr*
Fsc = Fsn – X/Bs
Frc = Frn + X/Br.

**Calculation:** Consider isolated operating regions as under.
Region S has bias 2400 MW/Hz operating at 50.00 Hz.
Region R has bias 1800 MW/Hz operating at 49.00 Hz.
Transfer bias of link is set at 1000 MW/Hz
Power transfer and frequencies when HVDCAR link closed.
Actual Power transfer P = 507 MW
Region S Frequency Fsc = 49.789 Hz
Region R Frequency Frc = 49.282 Hz
Changes in power transfer and frequencies when load / generation changes in any region.
Consider 600 MW generation drop in region S.
Expected isolated frequency drop in region S = 600/2400 = 0.25Hz
Expected isolated frequency of region S = 50.00--00.25 = 49.75 Hz.
Revised power transfer and frequencies recalculate is as under as
Actual Power transfer P = 380.3 MW
Region S Frequency Fsc = 49.592 Hz
Region R Frequency Frc = 49.211Hz
In this way revised power transfer and frequencies can be calculated when changes in any region.

## Performance

Transfer bias setting establishes solidarity of connection. Low bias allows less power transfer and wide frequency difference, whereas a higher setting allows more power transfer and a narrow frequency difference. Maximum power selection is useful to set a limit for power export based on spare resources and internal network loading conditions.




## Conclusion

The proposed link has all the benefits of an HVDC connection plus the flexibility for automatic power transfer with limits to regions in deficit. Regional grids are rigid enough to tolerate the most probable disturbances. Acute disturbance could not be prevented even in a strong synchronous grid but may have wide repercussions. The proposed link provides optimum balance between system rigidity and complexity. A synchronous connection is like a partnership company with unlimited liability, whereas an HVDCAR connection is like a limited company having limited liability. The comfortable region automatically assists one in need, but with a safeguard of its own system. Crisis in other regions does not jeopardize helping regions as exporter frequency is always higher than importer regions, and there is limit setting for export. This works as sure islanding, contrary to tentative success in planned islanding in synchronous interconnection.

Existing available HVAC links are useful with back-to-back interconnections or useful for redial assistance to regions in need.

## Future Scope

Design and development of hardware and software for controller units.

## ABOUT THE AUTHORS

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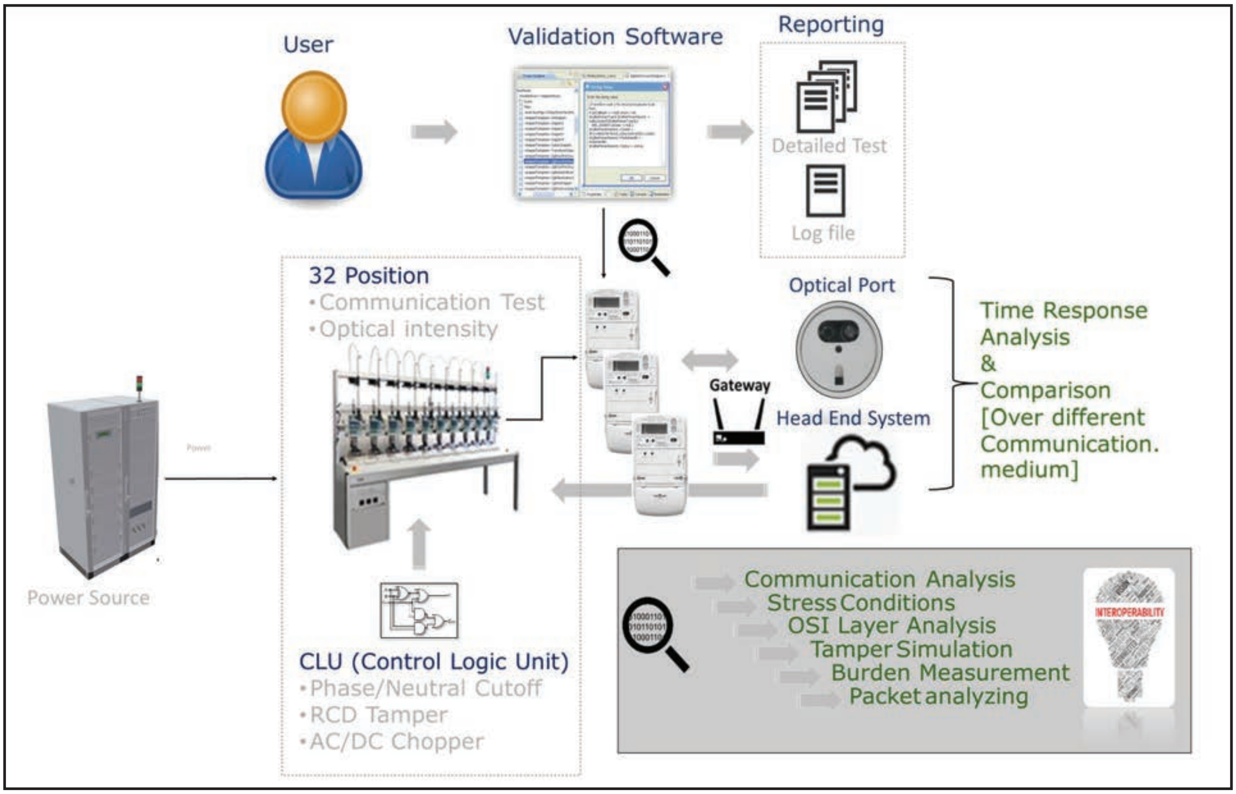
# Essential Role of Integrated System Testing in Factory Acceptance Testing (FAT) for Smart Metering Systems

This technical paper provides an insight into the importance of the role of advanced metering infrastructure system providers, by defining their function. The paper further elaborates on the significance of integrated system testing during factory acceptance test to show its indispensability for ensuring the success of smart metering systems.

In the evolving world of energy management, **smart metering systems** have become a cornerstone for utilities looking to optimize operations, enhance service delivery, and better manage energy consumption. These systems, involving a combination of **smart meters, communication networks, data management platforms,** and **analytics systems,** offer far-reaching benefits, but they are also complex, requiring rigorous validation before deployment. For an **Advanced Metering Infrastructure Systems Provider (AMISP),** ensuring the system's readiness through a thorough **Factory Acceptance Testing (FAT)** process is essential. Among the most critical phases of FAT is **Integrated System Testing (IST)**, which evaluates how the entire smart metering ecosystem functions as a unified system, not just as isolated components.

This article delves into why Integrated System



Testing is indispensable during FAT for smart metering systems, specifically for AMISPs, and how it ensures that the system meets all performance, functional, and security expectations before it is deployed in the field.

## 1. The Role of AMISP in Smart Metering Systems

AMISPs play a central role in the design, development, and deployment of smart metering systems. They are responsible for delivering an integrated solution that includes:

- **Smart Meters:** Devices that measure energy usage in real-time, and communicate data to central systems.
- **Communication Infrastructure:** Networks that facilitate data transfer between meters, data collection systems, and control centres.
- **Data Management and Analytics:** Systems that aggregate, process, and analyse the data collected from meters to enable accurate billing, reporting, and predictive analytics.
- **User Interfaces:** Dashboards and reporting tools for utility operators, field technicians, and customers.

AMISPs must ensure that all these components work together in harmony, providing an efficient, scalable, and secure system. Also misbehave of one of the component of integrated system may affect the functional performance of other component as well. To achieve this, **Integrated System Testing (IST)** during **Factory Acceptance Testing (FAT)** is crucial.

## 2. What is Integrated System Testing (IST)?

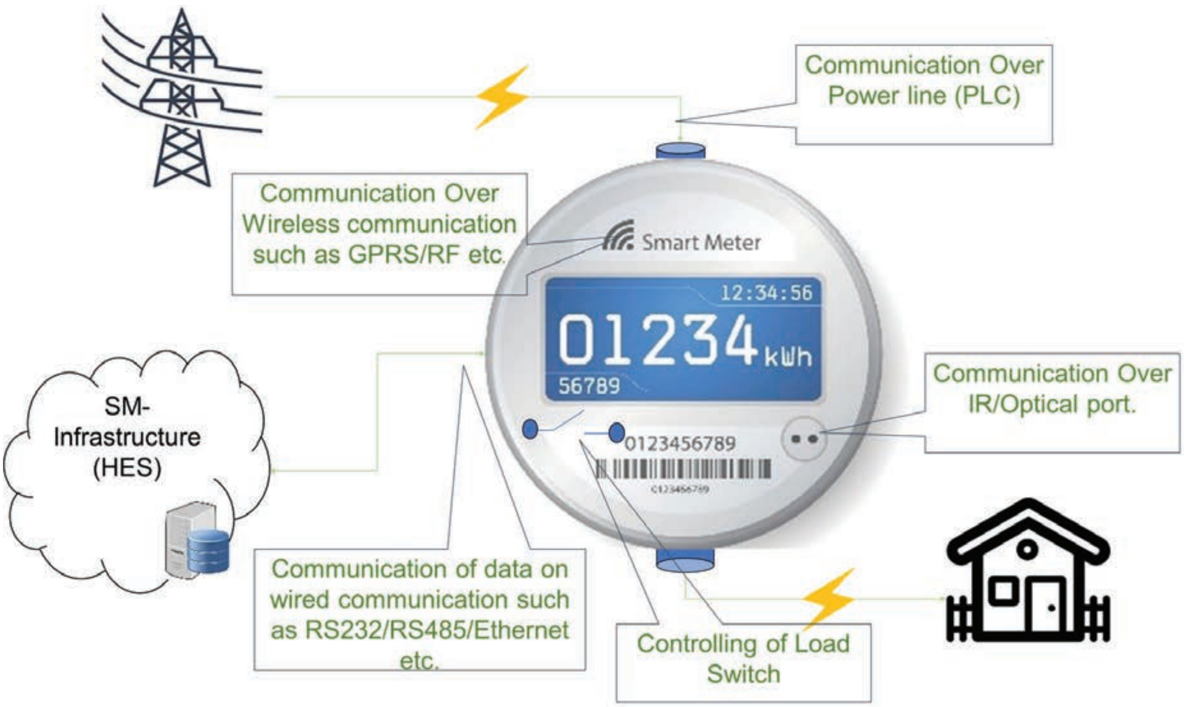
Integrated System Testing is the phase of FAT that goes beyond individual component testing (hardware, software, etc.) and focuses on how these components work together as a whole system. This testing involves verifying that:

- **Data Integrity:** Data flows seamlessly from the smart meters through the communication network to the central data systems without corruption.
- **End-to-End Functionality:** The system's components are fully integrated, ensuring that each part of the system—smart meters, network, backend infrastructure, and user interfaces—works together to deliver expected outcomes.
- **System Behaviour under Real-World Conditions:** The system is tested to evaluate its performance under varying load conditions, including high traffic, communication failures, and other potential challenges encountered during real-world operations.
- **Interoperability:** The smart metering system must interact smoothly with third-party systems, such as billing software, customer information systems (CIS), and demand-side management platforms.

In short, IST ensures that the complete system operates effectively in a real-world environment, before it is deployed in the field.

## 3. Why Integrated System Testing is Crucial during FAT for Smart Metering Systems

While each individual component of a smart



metering system may function as expected during initial unit tests, it is only through integrated testing that you can identify issues that might arise when all components work together. Below are the primary reasons why IST is crucial during FAT for smart metering systems:

### 3.1. Seamless Integration of Components

A smart metering system is a multi-faceted ecosystem, including smart meters, communication modules, data aggregation platforms, analytics tools, and user-facing interfaces. Even if each component performs well independently, there's always a risk that the system as a whole may not integrate seamlessly. For instance, the communication between smart meters and central systems might be affected by network congestion, signal loss, or interoperability issues. Integrated System Testing ensures that all components communicate as expected, and the entire infrastructure works together without disruptions.

### 3.2. End-to-End Validation of Data Flow

Smart metering systems are fundamentally data-driven. Data is generated by the meters, transmitted via communication networks, processed by central systems, and finally used for billing or analytics purposes. A breakdown in any part of this flow can cause significant issues, such as delayed readings, inaccurate billing, or even system failures. IST ensures that:

- Meter readings are accurately collected.
- Data is correctly transmitted to the central platform.
- The data is properly processed and stored for reporting and billing.
- The system can handle high-frequency data points, typical of modern smart metering systems.

### 3.3. Mitigation of Deployment Risks

Deploying a smart metering system without sufficient integrated testing can expose AMISPs to significant risks, including:

- **Data discrepancies:** Errors in how data is processed or communicated could result in inaccurate billing, customer dissatisfaction, and regulatory non-compliance.
- **Operational disruptions:** Failure to integrate different system components can lead to operational bottlenecks, system downtimes, or reduced functionality.
- **Security vulnerabilities:** Without IST, there is a risk of overlooking security loopholes in data transmission, storage, or access.

Through IST, these risks are mitigated by identifying and resolving issues before the system is deployed in the field.

### 3.4. Ensuring Scalability and Performance

Smart metering systems must often scale to support millions of devices across large geographical areas. Performance testing during IST evaluates how the system will handle high data volumes, varying network loads, and high-frequency meter reads. For instance, how will the system perform if thousands of meters transmit data simultaneously? Can the network handle such a load? These scalability tests are critical for ensuring that the system can grow with the utility's needs and remain functional even under peak demand.

### 3.5. Validating System Interoperability

Smart metering systems do not operate in isolation. They often need to interface with third-party systems such as customer information systems (CIS), billing platforms, grid management systems, and demand response systems. These interfaces need to function correctly for the overall system to deliver value. Integrated System Testing verifies that the smart metering system can seamlessly integrate and exchange data with external systems, ensuring that all systems function together without errors.

## 4. Key Aspects of Integrated System Testing for Smart Metering Systems

Several critical areas must be thoroughly tested during IST to ensure a successful outcome for FAT:

### 4.1. Meter-Data Communication Validation

Testing the communication between the smart meters and the communication network is a central aspect of IST. This includes validating:

- **Signal strength** and **network reliability.**
- **Data accuracy,** ensuring that the data sent by the meter reaches the backend system without errors.
- **Communication protocols,** verifying that the network can support the transmission of data using the required protocols (e.g., **Wi-Fi, LoRaWAN, PLC, NB-IoT,** etc.).

### 4.2. Data Accuracy and Integrity Checks

Smart metering systems are highly sensitive to data integrity. Any discrepancies in the data can lead to serious issues in billing, reporting, or system operation. IST ensures that data:

- Is transmitted accurately from the meter to the central system.
- Can be correctly processed by the backend software without errors.
- Is stored and retrieved consistently during reporting or analysis processes.

### 4.3. Security Testing

Security is a paramount concern in smart metering systems. Integrated testing ensures that:

- **Encryption** protocols are used for data transmission to prevent data breaches.
- **Access controls** are in place to ensure that only authorized personnel can access sensitive data.
- The entire communication system is secure against potential cyberattacks.

### 4.4. Load and Stress Testing

Smart metering systems need to be capable of handling high loads. Testing the system under stress conditions, such as heavy data traffic or simultaneous meter read requests, ensures that the system performs reliably during peak demand periods. This might involve testing:

- The ability to handle spikes in data requests from meters.
- Network congestion scenarios.
- The response time of the system under heavy loads.

## 5. Test system for Integrated System Testing during FAT.

The test system for integrated system testing must be capable to address the prime requirement to interface with HES through cloud or test server. The test system must create different simulation of field (real world) conditions. Whereas the end to end test will be performed in several simulated field conditions.

The architecture of a smart metering validation system typically consists of multiple layers of testing to ensure the metering system operates as expected in real-world conditions.

### 5.1. Communication Testing:

- Ensures that the communication protocols used between devices (e.g., meters, DCUs, HES) comply with the required standards.
- This includes testing for the correct encoding/ decoding of messages, handling of errors, and the reliability of the communication under different conditions.

### 5.2. Optical Port Intensity:

- Optical ports are used for data exchange, and testing ensures the optical interface functions correctly under various light intensity conditions.

### 5.3. Simulation of Boundary Conditions:

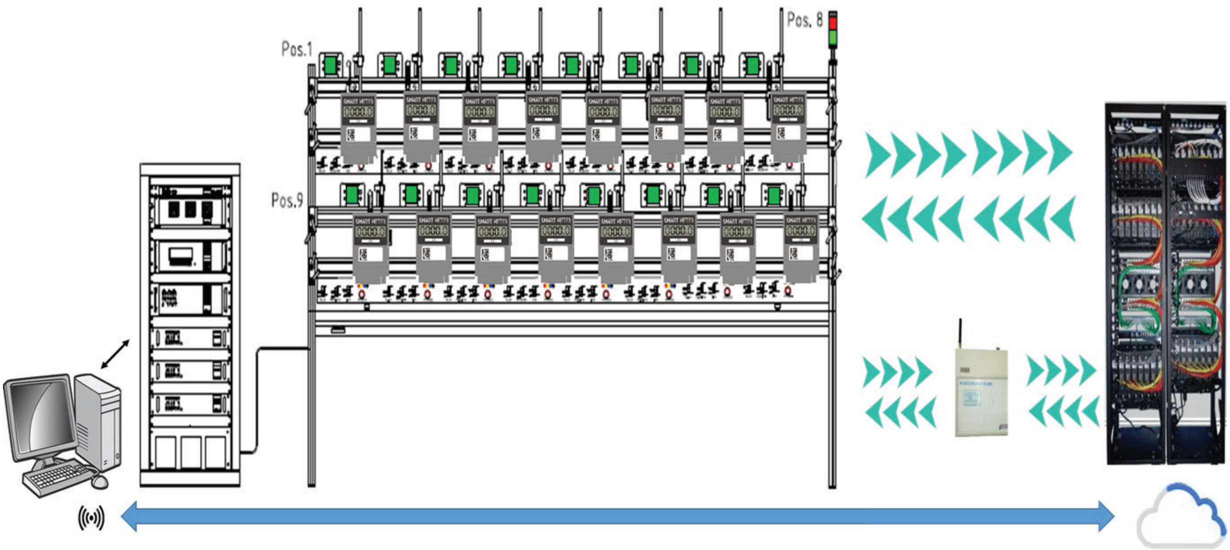
- This involves simulating extreme or boundary conditions like low signal strength, high temperature, or network failure to see how the system responds.

### 5.4. Magnetic Influence & Load Switch Alerts:

- Magnetic fields can interfere with meter readings, so testing is done to check if the system can detect such anomalies.
- Load switch alerts are triggered when the meter's load-switching functionality (for disconnecting/ reconnecting power) needs to be verified.

### 5.5. Instantaneous Parameters Testing:

- Measures key operational metrics like current and load in real-time to ensure they match expected parameters.
- Alerts related to abnormal behaviour (e.g., high current) are also tested to ensure proper responses.



**5.6. End-to-End Verification:**

- Ensures the entire system functions from the metering device to the Head-End System (HES). This involves simulating data transmission, validation of received data, and ensuring timely communication under various conditions.

**5.7. Signal Strength Testing:**

- Testing at varying signal strengths (e.g., 50%, 75%) ensures reliable bi-directional communication under different network conditions.
- Testing low signal strength is critical for systems where reliable communication is a priority, especially in remote areas.

**5.8. Firmware Over-The-Air (FOTA) Updates:**

- FOTA testing ensures that both meters and DCUs can successfully receive firmware updates over the air, without issues like data corruption or failed installations.

**5.9. Failover Testing:**

- Verifies the system's resilience by testing failover scenarios where the DCU or the meter's mesh network faces disruptions.
- Failover tests ensure that the system can continue functioning or switch to a backup communication path when a primary path fails.

**5.10. RTC Drift Testing:**

- Verifies the accuracy of the Real-Time Clock (RTC) in meters and DCUs, especially under harsh environmental conditions (like high temperatures).Ensures that the clock drift does not impact system functionality or data logging.

**5.11. Logging and API Testing:**

- Logs data for system monitoring and testing access via APIs, ensuring accurate data reporting (e.g., temperature at 70°C) and seamless integration with backend systems using protocols like IPV6.

**5.12. Component Failure Simulations:**

- Simulates failures in critical components (e.g., communication modules, load switches) to test the system's response and recovery, ensuring system stability in real-world scenarios.

This comprehensive validation approach helps guarantee that a smart metering system is reliable, resilient, and compliant with operational standards. Each test addresses a specific part of the system, ensuring that the whole architecture can function under varying and challenging conditions. As per Model SBD of REC, the integrated testing for 100 hours as part of FAT is mentioned, it will be more fruitful to conduct this test under different simulated real world conditions.

## 6. Inference towards the subject

Integrated System Testing during Factory Acceptance Testing (FAT) is indispensable for ensuring the success of smart metering systems deployed by Advanced Metering Infrastructure Systems Providers (AMISP). By rigorously testing the complete system as an integrated whole, IST mitigates risks, ensures that all components work seamlessly together, and confirms that the system will function reliably in the field. For AMISPs, the benefits of IST far outweigh the challenges, ensuring that they can deliver a robust, scalable, and secure solution that meets the growing needs of utilities and their customer.

## ABOUT THE AUTHORS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# World's First and Largest Gigawatt-scale Integrated Renewable Energy Project

This pioneering project by Greenko includes 4,000 MW of solar, 1,000 MW of wind, and 1,680 MW of pumped hydropower generation.

The Pinnapuram Integrated Renewable Energy Project is the world's first and largest gigawatt-scale integrated project with solar, wind, and pumped storage components that can supply schedulable power on demand (SPOD) which is dispatchable and schedulable renewable energy for the first time to consumers across India.

This pioneering, world-first and largest gigawatt (GW)-scale integrated renewable energy project by Greenko includes 4,000 MW of solar, 1,000 MW of wind, and 1,680 MW of pumped hydropower generation. With a storage capacity of 10,080 MWh per day in a single cycle, the dispatchable, carbon-free energy generated from the project will support

industries such as green steel, green aluminium, and green hydrogen production.

**Hon'ble Union Minister of New and Renewable Energy & Consumer Affairs, Food & Public Distribution, Shri Pralhad Joshi,** recently visited Greenko's integrated renewable energy project at Pinnapuram, Andhra Pradesh, and applauded its scale and rapid progress. The Union Minister took an aerial tour of the facility and visited various components of the mega integrated renewable energy project.

Said **Union Minister Shri Pralhad Joshi,** "Witnessing an integrated renewable energy storage project at Pinnapuram in action – the world's first and largest of its kind, right here in our country – is a matter of pride and a shining example of India's green energy potential," in a press statement released by Greenko.

Explaining technical aspects of the project, **Anil Chalamalasetty, Group CEO & Managing Director, Greenko,** said the groundbreaking initiative – which combines solar, wind, and pumped storage power – will make a vital contribution to global efforts to decarbonise hard-to-abate industries. "Once completed, this rapidly progressing project will drive economic growth in the region, foster the development of ancillary industries, and create employment opportunities," he said.

Notably, the project is expected to assist in avoiding 3.3 million tonne of $CO_2$ emissions annually. Designed for clean energy generation, storage, and on-demand supply, it will play a pivotal role in enhancing India's energy security and accelerating its transition to greener sources.

"Greenko is leading the energy transition with its innovative storage solutions, developing several pumped hydro storage projects across India to establish a cloud storage platform with a capacity of over 100 GWh," adds Chalamalasetty.

Greenko's Intelligent RE Cloud Storage Platform, combined with India's One Nation, One Grid policy, is facilitating the production of the world's lowest-cost green molecules and driving the acceleration of decarbonisation of global economies.

## Project Details

The Pinnapuram Integrated Renewable Energy Project has been conceived as the world's first and largest gigawatt-scale integrated project with solar, wind, and pumped storage components that can supply schedulable power on demand (SPOD) which is dispatchable and schedulable renewable energy for the first time to consumers across India.

The Government of Andhra Pradesh (GoAP) approved the project with 1,000 MW solar, 550 MW wind, and 1,200 MW of standalone pumped storage capacities to be developed in Phase-I with the possibility to enhance capacities in subsequent stages to 3,000 MW solar, 2,000 MW wind, and 2,400 MW standalone pumped storage depending on technical feasibility, site suitability and associated requirements, and demand from various state discoms, STUs and other consumers.

The Pinnapuram project is being developed with a total investment of US$ 4.2 billion – comprising US$ 1.2 billion for the pumped storage component and US$ 3 billion for the solar and wind generation infrastructure.

This pioneering initiative marks a significant milestone in India's transition to sustainable energy.

# NEW ENERGIES POWERING INDIA

With nearly 86 percent of the 33 GW power capacity added in FY25 coming from renewable sources, India is committed to achieving 500 GW of non-fossil fuel capacity by 2030 as it overtakes Germany to become the world's third-largest generator of electricity from wind and solar, IEEMA JOURNAL reports.

India's total installed power capacity has reached 472 GW as on April 30, 2025, according to a report by the Central Electricity Authority (CEA). A large part of this contribution was driven by renewable energy (RE), reflecting the country's continued shift towards clean energy.

India's clean energy sector demonstrated robust growth in FY2024-25, reinforcing its commitment to achieving 500 GW of non-fossil fuel capacity by 2030. Specifically, the country added 29.5 GW of renewable capacity during the year, led by a record 23.8 GW of solar installations and 4.15 GW of wind capacity, pushing the cumulative solar and wind capacities beyond 105 GW and 50 GW, respectively. According to the Global Electricity Review, India has overtaken Germany to become the world's third-largest generator of electricity from wind and solar.

This is the result of effective government policy implementation, such as the launch of the Pradhan Mantri Surya Ghar Muft Bijli Yojana, which catalysed the rooftop solar segment. Additionally, the timely issuance of wind guidelines further strengthened the policy landscape.

"The electrical and electronics manufacturing industry will be key in scaling clean energy, advancing grid modernisation, and strengthening transmission networks," said **Shri Manohar Lal, Hon'ble Union Minister of Power and Minister of Housing and Urban Affairs, Government of India,** at the grand inauguration of ELECRAMA 2025 – the world's largest electrical show. "Expanding EV infrastructure and vehicle-to-grid (V2G) technology will further accelerate the shift towards e-mobility," added the hon'ble minister. "By 2030, India aims

**Renewable Energy Installed Capacity (in MW)* (as on March 31, 2025)**

| RE Source | Achievements FY2024-25 (Apr 2024 to Mar 2025) | Cumulative Achievements (as on March 31, 2025) | Share (%) |
|---|---|---|---|
| Wind power | 4,151.31 | 50,037.82 | 22.73% |
| Solar power | 23,832.87 | 105,646.49 | 48.0% |
| Small hydro power | 97.30 | 5,100.55 | 2.32% |
| Large hydro power | 760.00 | 47,728.17 | 21.69% |
| Biomass (bagasse) cogeneration | 387.76 | 9,821.32 | 5.26% |
| Biomass (non-bagasse) cogeneration | 0.00 | 921.79 | |
| Waste-to-power | 59.60 | 309.34 | |
| Waste-to-energy (off-grid) | 194.81 | 530.87 | |
| **Total** | **29,483.65** | **220,096.35** | |

**Source: MNRE Physical Progress Report as on March 31, 2025.*

to achieve 800 GW of generation capacity, with 50 percent from renewables, reinforcing its role as a global clean energy leader."

## Key Achievements: FY2024-25

India made significant strides in renewable energy and clean technology during FY2024-25, advancing its goal of achieving 500 GW of non-fossil fuel capacity by 2030. Here's an overview of key achievements across sectors:

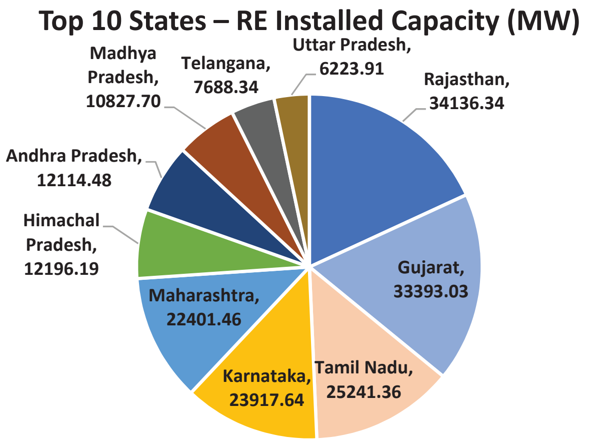
### SOLAR ENERGY

**Record installations:** India added approximately 23.83 GW of new solar capacity in FY2024-25, surpassing the 100 GW milestone and reaching a cumulative solar capacity of 105.65 GW.

**Rooftop solar expansion:** The *Pradhan Mantri Surya Ghar Muft Bijli Yojana* has achieved a historic milestone with 10 lakh solar-powered homes as of 10th March 2025. The initiative has already disbursed Rs4,770 crore in subsidies to 6.13 lakh beneficiaries, making solar energy more accessible.

Says **Vineet Mittal, Director, Co-Founder, Navitas Solar,** "India is undergoing a transformative energy shift, with solar power at the forefront of its clean energy ambitions. As of 2025, India stands as the third-largest solar power generator globally, having surpassed Japan with over 113 billion units (BU) of annual solar electricity production. This aligns with the government's vision to meet 50 percent of its

**Top 10 States Contribute 85.5% of India's Total RE Installed Capacity *(as on March 31, 2025)***




electricity needs from renewable sources by 2030 and achieve net-zero emissions by 2070."

He shares that solar capacity in India has grown exponentially – from just 2.8 GW in 2014 to more than 100 GW today. "This momentum is backed by supportive policies like the production-linked incentive (PLI) scheme, rising energy demand, and a push for domestic manufacturing. The country's total renewable energy capacity now exceeds 125 GW, with solar as the dominant force. With peak electricity demand projected to surpass 365 GW by 2030, solar energy will be vital for ensuring energy security and sustainability," Mittal avers.

Amid this rapid evolution, Navitas Solar is proud to be a key enabler of India's green energy mission, says Mittal. The company currently operates a 3-GW solar module manufacturing facility, delivering high-efficiency, quality-certified modules to domestic and international markets. Looking ahead, Navitas is setting up a 2.5-GW solar cell manufacturing plant by 2026, with plans to scale this up to 6 GW by 2027, creating a fully integrated solar manufacturing ecosystem.

## WIND ENERGY

**Steady growth:** Wind power capacity increased by 4.15 GW in FY 2024–25, bringing the total installed wind capacity to over 50 GW.

## ENERGY STORAGE

India's energy storage initiatives gained momentum as key battery energy storage projects were commissioned and tenders were floated, supported by clarity from the Central Electricity Authority (CEA) regarding storage mandates.

**Energy storage system (ESS):** As per the CEA, as of December 31, 2024, India's installed ESS capacity stands at 4.86 GW, comprising 4.75 GW of pumped storage plants (PSPs) and 0.11 GW of battery energy storage systems (BESSs).

**Pumped storage projects:** The CEA has approved a record number of detailed project reports (DPRs) of six hydro-pumped storage of about 7.5 GW in record time during FY2024-25 in states including Odisha, Karnataka, Maharashtra, Madhya Pradesh, and Andhra Pradesh. It plans to concur a minimum of 13 PSPs of about 22 GW during FY2025-26.

The Ministry of Power has also directed all states and implementing agencies to award all BESS contracts by June 2025 to enable the Viability Gap Funding programme to be completed by May 2027.

Says **Hitesh Kumar, CEO, Fluence India,** "India's renewable energy ambitions will be achieved on the foundation of safe and reliable energy storage. While cost pressures dominate discussions, it is imperative that we build solutions that last. We must focus on deploying storage solutions that don't just meet price expectations but are reliable, free from cybersecurity vulnerabilities and meet or exceed performance expectations over life of the asset – ensuring every megawatt stored is a megawatt delivered, safely and efficiently."

Interestingly, a research team led by Nagaland University has developed a patented, cost-effective method for producing high-performance electrode material – functionalised graphene – for next-generation energy storage devices. The technology will make way for cheaper and more scalable supercapacitors with improved energy density and retention. It holds potential for electric mobility, defence systems, and critical infrastructure applications.

## ELECTRIC VEHICLES (EVS) AND CHARGING INFRASTRUCTURE

The electric mobility ecosystem expanded rapidly, with electric vehicle (EV) sales exceeding 2.5 million units, bolstered by continued FAME-II incentives and the upcoming FAME-III framework. Over 14,000 public EV chargers were installed, with states and urban bodies leading the charge on infrastructure rollouts.

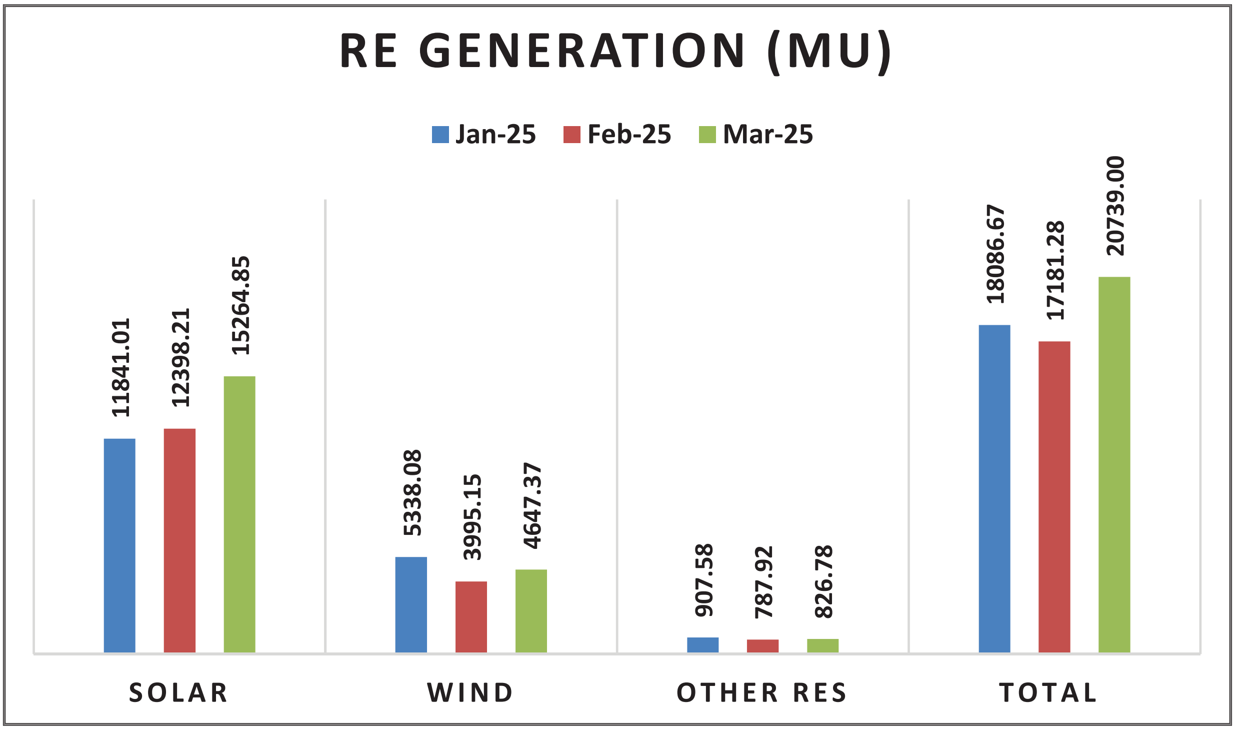
**EV penetration:** EV sales exceeded 2.5 million units, led by two-wheelers and three-wheelers in FY2024-25.

**FAME II and III:** FAME-II subsidies continued; FAME-III draft introduced in Q4FY25 with more focus on buses and charging infra.

**Domestic manufacturing:** Battery and EV component production was picked up under the PLI-Auto and ACC Battery Storage scheme.

**Public chargers installed:** Over 14,000 new public chargers were added in FY25.

The Union Government is planning to expand EV charging facilities across major public infrastructure




*Other RES includes biomass, bagasse, small hydro, and others.*

including at airports, highways, and for the first time at ports. The charging facilities are likely to have battery-swapping facilities.

Furthermore, a recent report indicates that India will have 123 million EVs on road by 2032 under the best case scenario. Adopting EVs can bolster the country's economy while supporting the ambitious target set for 2030-EV penetration of 30 percent.

## GREEN HYDROGEN

The green hydrogen sector experienced strategic investments with NTPC, IOCL, and ACME Energy spearheading pilot projects, while ports and Indian Railways progressed in deploying use cases. The government issued tenders for over 412,000 tonne of hydrogen production and 1.5 GW of electrolyser manufacturing in FY2024-25.

**National Green Hydrogen Mission:** India targets the production of 5 million tonnes of green hydrogen annually by 2030, requiring 125 GW of renewable energy capacity.

**Mission rollout:** National Green Hydrogen Mission implementation began; MNRE launched tenders for 412,000 tonne of green hydrogen production and 1.5 GW of electrolyser manufacturing capacity during FY 2024-25.

**First movers:** NTPC, IOCL, and ACME Energy commenced pilot-scale hydrogen projects.

**Ports and Railways:** Cases of the use of green hydrogen were initiated at Kandla Port and Indian Railways.

Says **HydrogenWala Shardul Kulkarni, Managing Director & CEO, Deesha Power Solutions Pvt Ltd,** "India witnessed a crash of ~85 percent in solar prices and installations crossing 70 GW. This happened in two decades. Similarly, India's hydrogen story is likely to witness the same pricing trajectory and exponential growth, albeit in half the time viz just one decade. For an energy importing country like India, it is a great boon and opportunity to become energy independent." He adds that like solar started in a distributed manner in kilowatts, green hydrogen has also started in India through small H2 or near consumer premises. "In a matter of time, it will get transgressed to big H2 forging pathways for India's net-zero."

These developments are testament to India's commitment to a sustainable energy future, with significant progress in solar and wind energy, innovative projects in hybrid and floating solar, expansion of EV infrastructure, and ambitious plans for green hydrogen production. They reflect a significant shift in India's energy landscape, with robust, strong regulatory support and industry momentum driving innovation, investment, and growth. Integrating solar, wind, storage, hydrogen, and e-mobility solutions enhances energy security and positions India as a global leader in clean technology. Continued collaboration between government, industry, and innovators will be key to sustaining this trajectory and unlocking new opportunities for green growth.

# SUPERCAPACITORS: Building Next-Gen Energy Storage Devices

Nagaland University-led research team has developed a cost-effective method for building next-generation energy storage devices that can reportedly store large amounts of energy and charge quickly.

There is a pressing need for advanced energy storage solutions. Energy storage devices enable efficient storage of energy from renewable sources, such as sunlight, wind, ensuring its availability for future use. Despite variations in their methods of storing and delivering energy, most energy storage devices share a common purpose: to store charge. Among these, supercapacitors stand out for their ability to rapidly store and discharge energy.

In light of this, a team of researchers at Nagaland University has developed a novel and environment-friendly method for producing bromo-graphene – a modified form of grapheme – for eco-friendly chemical processes in industrial applications.

The research team that undertook this study includes Suraj Kumar, a DST-INSPIRE Fellow, Nagaland University, working under the joint supervision of Prof. Dipak Sinha, Chemistry Department, Nagaland University and Prof. Dinesh Rangappa from the Applied Sciences (Nanotechnology) Department at Visvesvaraya Technological University, Karnataka.

## The Magic Method

This new method uses a safer brominating agent called tetrabutylammonium tribromide to convert reduced graphene oxide into bromographene. This process is completed in an hour – the fastest time reported so far. Moreover, it also avoids the need for harsh conditions, making it safer and environment friendly.

The new approach also has one of the highest reported bromine contents, making it useful for further chemical modifications that can lead to new advancements in electronics, composites, and other high-tech materials.

Graphene – a two-dimensional wonder material that gained global fame in 2010 – is celebrated for its potential to transform industries such as electronics, drug delivery, touch screens, paints, energy storage, and water purification.

While it is known for its exceptional strength and outstanding electrical and thermal conductivity, its practical use is often hampered by its poor solubility in common solvents. Bromographene – a modified form of grapheme – helps overcome this

restriction by enhancing its chemical reactivity and versatility.

The research team behind this has introduced a new method for preparing bromographene, with their work already earning them a German utility model IPR. The energy density of these tested supercapacitors is comparable to that of Nickel-Cadmium (Ni-Cd) batteries.

## What's Different!

A critical part of a supercapacitor's performance is the materials used for its electrodes, the high cost of which has been a barrier. With this cost-effective method introduced, completing the entire procedure is much faster than the traditional processes.

While also simplifying the manufacturing process, the material delivers significantly enhanced performance, enabling a supercapacitor with a wide 2.2 V electrochemical window, an energy density exceeding 50 Wh/kg, and 98 percent energy retention after 10,000 cycles. Notably, it achieves a fivefold increase in gravimetric energy density compared to its non-aminated counterpart, demonstrating both scientific novelty and commercial potential.

What's more, unlike traditional methods that are time-consuming and resource-intensive, this new approach operates under moderate temperature and pressure conditions. This makes it energy-efficient, faster, and more suitable for large-scale production.

Conventional methods demand high temperatures, elevated pressures, and lengthy processing times, and typically involve converting bulk graphite into graphene oxide, followed by a series of steps to reduce and functionalise it. In contrast, this newly developed process directly transforms bulk graphite into aminated graphene, thus not only reducing time and resource usage but also operating under moderate temperature and pressure. Scalable and energy-efficient, it stands out as one of the quickest methods available for producing this material.

## Here's how!

This approach avoids the use of high temperatures, pressures, and toxic chemicals. It also achieves a high degree of amination ( 6%), with the nitrogen content controllable by adjusting the pH of the reaction mixture (RM). The success of this method has been confirmed through X-ray photoelectron spectroscopy (XPS), Fourier transform infrared (FTIR), and energy dispersive spectroscopy (EDS). The surface morphology of the NH2–rGO was analysed using scanning electron microscopy (SEM). Furthermore, the incorporation of amine groups enhances the wettability of rGO, making it an excellent electrochemical material. The effect of this functionalisation has been systematically studied to evaluate the potential of NH2–rGO as supercapacitor electrodes. Variants of NH2–rGO – namely A-5, A-7, A-9, and A-12 show significant improvements compared to unfunctionalised rGO.

The symmetric supercapacitor fabricated with this as-synthesised material demonstrated (1) a significantly higher specific capacitance compared to rGO and similar materials, (2) exceptional charge-discharge cycling stability, with around 98 percent capacitance retention after 10,000 cycles of continuous operation, and (3) remarkable improvements in both gravimetric and volumetric energy and power densities, surpassing those of rGO by many folds and even outperforming some binary composites. Additionally, the use of the ionic liquid 1-ethyl-3-methylimidazolium tetrafluoroborate (EMIMBF4) in acetonitrile allowed to overcome the limited electrochemical window of water-based electrolytes, expanding the operating voltage window to 2.2 V, thus enhancing the potential for practical applications.

Indeed, such devices are an answer to the growing demand for more efficient and sustainable energy storage systems.

# POWERful Women Leading the Front

The **Women in Power Conclave at ELECRAMA 2025** brought together industry-leading women under a single platform to celebrate their incredible progress while also setting a platform for connecting, learning, and leading.

The **Women in Power Conclave at ELECRAMA 2025** is an IEEMA initiative that has grown into a platform where women can connect, learn and lead.

## Inaugural Session

The inaugural session of the conclave set the stage for thought-provoking conversations about challenges faced by women while also celebrating the incredible progress made by women entrepreneurs.

At the inaugural session of the Women in Power Conclave, **Aaryaa Satyanarayana, Chairperson, Women in Power, IEEMA**, delivered a heartfelt speech, commending attendees for their commitment to women's empowerment in the power sector. She traced the journey of the Women in Power (WIP) Chapter, launched under the leadership of Anil Saboo, Past President, IEEMA, and celebrated its growth – from five members to a vibrant network of over 100 women. Addressing doubts about the relevance of such initiatives, she emphasised the ongoing need


Inaugural Session

Ruchika Drall, Deputy Secretary, Ministry of Environment, Forest and Climate Change, Govt of India

Aaryaa Satyanarayana, Chairperson, Women in Power, IEEMA

Mahua Acharya, Founder CEO, INTENT

for support systems that bridge access gaps for women in the industry. Drawing from her personal experiences, Satyanarayana encouraged women to step up, travel, attend expos, and take on leadership roles. She highlighted inspiring stories – like Telangana's first female line worker and the Pink Substation team – as proof of progress. Concluding with a warm invitation, she urged women to engage with the WIP Chapter, attend events, and visit the WIP stall at ELECRAMA 2025.

**Charu Mathur, Director General, IEEMA,** set the context for discussion with a heartfelt reflection of her journey with the WIP initiative at IEEMA. She acknowledged the progress made while reinforcing the need for continued efforts to eliminate deeply ingrained workplace biases.

Key takeaways from her address:

- Inclusion should become a default, not a special effort.
- Unconscious bias and exclusion still exist.
- Create awareness and promote equitable environments.
- Make gender representation a systemic norm.

**Ruchika Drall, Deputy Secretary, Ministry of Environment, Forest and Climate Change, Government of India,** highlighted the critical economic need for gender parity. She underscored that gender equality is not just a moral cause, but a strategic economic imperative.

Key takeaways from her address:

- Women contribute only 18 percent to India's GDP despite being 48 percent of the population.
- Educational, financial, and institutional limitations.
- Empowering through government schemes like Beti Bachao Beti Padhao, Mudra Yojana, Stand Up India.
- Women to take up a strong role in renewable energy and environmental innovation.
- Chalk out the way of progress through skill development, mentoring and financial access.

**Mahua Acharya, Founder CEO, INTENT,** shared powerful anecdotes from her global career, emphasising the importance of resilience, support structures, and inclusive goals in the workforce.

Key takeaways from her address:

- Persistence of stereotypes: Subconscious bias remains a major hurdle.

Simrit Powar, Chief Manager (I/C), Power Grid Corporation of India Ltd – Chandigarh

Anil Saboo, Past President, IEEMA

Poonam Pande, AVP & Head-International Marketing, IndoAsian

Vibha Gupta, Business Segment Head-Electrification & Automation, Siemens

Vera Silva, CSO/CTO, GE Vernova's Electrification Systems

Ruchi Kukreja, AVP, Hindalco Industries Ltd

- Ambitious inclusion targets: The electric bus programme driven by her aimed for 25 percent female drivers; landed at 6 percent – but goals must be set high.
- Retention is as important as recruitment: Women often leave the workforce at key life stages.
- Work-life balance: Shared domestic responsibilities are essential.
- Breaking norms: Encourage women to stay in, grow, and lead in their careers.

**Simrit Powar, Chief Manager (I/C), Power Grid Corporation of India Ltd – Chandigarh,** introduced India's first Pink Substation, led and operated entirely by women, as a symbol of technological excellence and gender inclusion.

Key takeaways from her address:

- Pink Substation: First-of-its-kind, digitally automated, and solar-powered.
- Women-led innovation: Her team manages maintenance, emergencies, and green initiatives.
- Workplace wellness: Powergrid offers childcare, fitness, and mental health facilities.
- Overcoming gender stereotypes: Women proving technical capability and leadership in field roles.
- By participating in conferences, community work and crisis responses, they have been able to create a niche for themselves.

In his address, **Anil Saboo, Past President, IEEMA,** began by expressing his admiration for the commitment and dedication of women in the power sector, highlighting their perseverance and resilience.

Key takeaways from his address:

- He highlighted the need for more women in the sector, noting India's goal to grow its economy and power sector significantly.
- He also shared how the WIP initiative began in 2020 as a space to learn, grow, and support one another.
- He emphasised how sharing personal journeys fuels collective confidence and invites more women to join the movement.
- By reinforcing belief that women will transform the power sector and thanked everyone for being part of the inspiring session.

**Babburi Shirisha, ILM/MRT/Medchal, Southern Power Distribution of Telangana Ltd,** recounted her trailblasing journey as Telangana's first female lineworker, breaking gender norms in one of the most male-dominated roles in the sector.

Key takeaways from her address:

- Defied social norms: Being only daughter, supported by her family to pursue a technical career.
- Job designation challenges: "Linewoman" didn't exist officially – she pioneered it.
- Rigorous selection: She has passed demanding physical and technical tests.
- Representation matters: She inspired the sector to consider renaming the role to "lineperson."

Doris U Gacho, Executive Director, POCB, Philippines

Chris Leong, Global Chief Sustainability Officer, Schneider Electric


Babburi Shirisha, ILM/MRT/Medchal, Southern Power Distribution of Telangana Ltd

- She embodies resilience and has inspired policy and mindset shifts for generations to come.

Concluding the session, **Poonam Pande, AVP & Head-International Marketing, IndoAsian,** delivered a heartfelt vote of thanks, expressing deep gratitude to everyone who made the event meaningful. She specially acknowledged the esteemed speakers for their insightful contributions. She thanked Charu Mathur for her unwavering energy and support and Aaryaa Satyanarayana for her inspiring leadership and for constantly motivating the team to aim higher. She also extended appreciation to Sunil Singhvi, President, IEEMA, and Vikram Gandotra, President-Elect, IEEMA and Chair, ELECRAMA 2025, for their continued encouragement and presence.

## Panel Discussion

The Women in Power Conclave also hosted a thought-provoking panel discussion featuring influential women leaders from the global energy, construction, and sustainability sectors. The discussion delved into the realities of breaking barriers in male-dominated industries, the evolving definition of leadership, and the policies needed to create a truly inclusive workforce. The panellists shared personal experiences, highlighting the importance of self-advocacy, networking, and corporate accountability in driving gender diversity. From career advancement challenges to work-life balance solutions, this report captures the key takeaways and powerful insights that made the session a defining moment in the movement towards greater representation of women in the power sector.

The session was moderated by **Vibha Gupta, Business Segment Head-Electrification & Automation, Siemens.** The panel featured distinguished women leaders across the globe: **Chris Leong, Global Chief Sustainability Officer, Schneider Electric; Vera Silva, CSO/CTO, GE Vernova's Electrification Systems; Doris U Gacho, Executive Director, POCB, Philippines; Ruchi Kukreja, AVP, Hindalco Industries Ltd; Aaryaa Satyanarayana, Chairperson, Women in Power, IEEMA.**

The discussion revolved around breaking barriers in male-dominated industries, strategies for career advancement, and promoting inclusive workplaces.

**Points of discussion:**

- **Women's ambitions and challenges:** The biggest hurdle for women is often their own self-limiting beliefs. Panellists emphasised the need for women to push boundaries, take risks, and actively seek leadership roles.


Panel Discussion

- **Evolving leadership:** While industries have made strides in gender diversity, true inclusivity requires continuous effort. Companies must ensure that women are not just hired but also promoted to decision-making roles.
- **Sustainable workforce policies:** Organisations should implement mentorship programmes, flexible work arrangements, and parental leave policies that support women's career growth without forcing them to choose between work and family.
- **Work-life balance:** Many panellists shared personal experiences on managing careers while raising families. They highlighted progressive company policies – like mandatory parental leave, flexible working hours for working mothers – as crucial in supporting women professionals.
- **The power of networking:** Building strong professional networks and advocating for oneself were cited as essential for career progression. Women must proactively seek opportunities, ask for what they deserve, and embrace lifelong learning.

The session concluded with a rapid-fire question-and-answer round. The discussion concluded with the note that while challenges remain, the momentum for change is strong. With the right support systems and a shift in mindset more women can step into leadership roles and drive the future of the power sector.

## Fireside Chat Session

The Fireside Chat Session at ELECRAMA 2025 was a vibrant gathering that celebrated leadership, innovation, and inclusivity in the power sector. Moderated by **Dr. Shivani Sharma** from Hitachi Energy Ltd, the session featured distinguished panellists who shared their unique journeys and insights, inspiring the audience with their experiences. Set in a warm and engaging environment, the fireside chat featured distinguished guests who have shattered barriers and led by example in their respective fields.

Panellists included **Laxmi Singh, Commissioner of Police, Uttar Pradesh Police; Bani Varma, Board Member, Director (Industrial Systems & Products) & Director (E, R&D)-Additional Charge, Bharat Heavy**

Laxmi Singh and Bani Varma


Fireside Chat Session

**Electricals Ltd; Siddharth Bhutoria, Vice President, IEEMA and Vice Chairman, ELECRAMA 2025; Charu Mathur, Director General, IEEMA; Aaryaa Satyanarayana, Chairperson, Women in Power Chapter, IEEMA.**

Dr. Shivani Sharma and Charu Mathur

**Power-Packed Conversations**

**Charu Mathur** set the stage for an afternoon of engaging dialogue. She discussed the importance of the 'Women in Power' chapter within IEEMA, which aimed at connecting career-oriented women in power and energy sectors and women leaders to discuss workplace challenges and inspire more women to choose the electrical and electronics industry as a potential career path.

**Laxmi Singh,** being a spearhead in law enforcement, shared her insights on leading in high-stakes environments, leveraging technology in policing, and fostering community trust. She passionately spoke about the importance of resilience, adaptability and mentorship, stating, "Leadership isn't about having all the answers – it's about asking the right questions and empowering those around you."

Aaryaa Satyanarayana and Siddharth Bhutoria

**Bani Varma,** a seasoned leader in the power sector, took the audience through her journey of navigating leadership, integrating sustainability in business strategies, and breaking the glass ceiling. She emphasised the critical role of diverse leadership in driving innovation and how mentorship has been pivotal in shaping the next generation of women leaders.

Adding a vital perspective on allyship, **Siddharth Bhutoria** discussed the role of male allies in fostering gender diversity. He challenged industry leaders to move beyond policies and actively advocate for inclusive workplaces. His key takeaway: "Real change happens when inclusion is not just a mandate, but a mindset."

As the session concluded, the panellists shared their advice for future leaders. From embracing change to challenging unconscious biases, the conversation reinforced that leadership knows no gender – it thrives on vision, courage, and collaboration.

**Aaryaa Satyanarayana's** passion for empowering women in the power sector was evident as she spoke about the transformative role of the Women in Power chapter at IEEMA. With a steadfast commitment to breaking barriers, she highlighted the importance of mentorship, networking and policy-driven change in fostering a more inclusive industry. Under her leadership, the Women in Power chapter has become a thriving platform for women professionals to share experiences, access growth opportunities, and drive meaningful change. Her vision for the future is clear – creating a landscape where women don't just participate but lead with confidence, innovation and impact.

The session ended with networking lunch, where conversations continued over shared aspirations and new connections.

# ‘Health & Electrical Safety’ for Linemen and ITI Students

IEEMA, under its CSR initiative, conducted a special training programme on ‘Health & Electrical Safety’ for linemen and ITI students, in partnership with the National Power Training Institute (NPTI).

IEEMA, under its corporate social responsibility (CSR) initiative, has launched a specialised training programme on ‘Health & Electrical Safety’ for linemen and ITI students, along with its implementing partner National Power Training Institute (NPTI).

A total of 240 participants across Delhi, Hisar, Varanasi, and Kota will undergo this vital training during the year under this programme, building a safer and more skilled workforce for the power sector. The first batch of 50 trainees began in Hisar, Haryana, on May 5, 2025.

The session in Delhi at NPTI Badarpur trained 50 participants through safety kit demos and hands-on learning. IEEMA leadership was also present to engage with the trainees.



**Training programme on ‘Health & Electrical Safety’ for linemen and ITI students in Hisar, Haryana.**

**Training programme on ‘Health & Electrical Safety’ for linemen and ITI students at NPTI Badarpur, Delhi.**

# Electrical Fire Safety Conclave, Delhi

IEEMA's Electrical Fire Safety Conclave at Delhi brought together key stakeholders from industry, regulatory bodies, and policy think tanks to address the critical issue of electrical fire hazards.


IEEMA's Electrical Fire Safety Conclave at the India Habitat Centre, New Delhi, on May 16, 2025, aimed at bringing together key stakeholders from industry, regulatory bodies, and policy think tanks to address the critical issue of electrical fire hazards. This was the second leg of IEEMA's national initiative after Mumbai, with upcoming sessions in Bengaluru and Kolkata.

The session was graced by dignitaries including Chief Guest **Shri Vivek Srivastava, IPS, Director General, Fire Services, Civil Defence & Home Guards, Ministry of Home Affairs,** and Guest of Honour **Shri Sanjay Kulshrestha, Chairman and Managing Director, HUDCO.**

**Vikram Gandotra, President-Elect, IEEMA,** urged for certified BIS-compliant components, regular fire drills, and the elimination of counterfeit products. He stressed, "Safety is not an option, it is a necessity."


**Vivek Srivastava, IPS, Director General, Fire Services, Civil Defence & Home Guards, Ministry of Home Affairs**


**Sanjay Kulshrestha, Chairman and Managing Director, HUDCO**

Vikram Gandotra, President-Elect, IEEMA

Charu Mathu, Director General, IEEMA

Dr Rajesh Arora

Shashi Amin, NEC Member, IEEMA

**Charu Mathu, Director General, IEEMA,** highlighted alarming statistics – more than 25,000 annual fire incidents from electrical causes – and announced IEEMA's new training programme with NPTI for linemen and ITI students. In her welcome address, she reaffirmed IEEMA's role as an industry mobiliser and policy partner, aiming to ensure that *"Bijli ki raftaar ho tez, par suraksha ho har mod par saath."*

**Shashi Amin, NEC Member, IEEMA,** in his presentation, cited several tragic fire accidents like the Uphaar Cinema and AMRI Hospital cases to underscore the urgency of reform in installation and fire audit systems.

Chief Guest **Shri Vivek Srivastava, IPS, Director General, Fire Services, Civil Defence & Home Guards, Ministry of Home Affairs,** in his keynote address, emphasised how BIS-certified equipment play a crucial role in preventing fire accidents and its importance in creating awareness about its long-term benefits among consumers. "Choosing certified products over poor quality wires and electrical components not only enhances safety but also proves to be cost-effective in the long run," he highlighted. He observed that IEEMA's awareness campaign on safety and quality will go a long way in preventing hazards and addressing critical electrical fire safety concerns.

The vote of thanks delivered by Shashi Amin emphasised the need for collaboration and awareness to build fire-safe infrastructure.

## Technical Sessions Overview

**Session 1 – Regulatory Framework: Provisions, Challenges and Opportunities**

**Moderator:** Vimal Chopra, Director, Ashkali Engineering & Management Services Pvt Ltd

**Panellists:** PR Lonkar, Fire Advisor, Fire Services, Civil Defence & Home Guards, Ministry of Home Affairs, Government of India; Rishika Sharan, Chief Engineer, Central Electricity Authority (CEA); Dr US Chillar, Director General, Institution of Fire Engineers (India); Arun Kumar S, Head (Civil Engineering Dept), Bureau of Indian Standards (BIS).

**Session 2 – Electrical Fire Safety in Today's Buildings & Construction**

**Moderator:** Shruti Goel, Director, Protech Consulting and Proion Consultants Private Limited

**Panellists:** Anil Jauhri, Former CEO of the National Accreditation Board for Certification Bodies (NABCB); LKS Rathore, IES, Director, Central Electricity Authority; Sanu Mathew, Co-Founder & Managing Director, SEED Engineering Consultant, Dubai; Vinay Singh, Director, Ralys Consultants; Debajyoti Mukherjee, Vice President-Technical, Polycab India Ltd.


Session 1 – Regulatory Framework Provisions, Challenges and Opportunities


Session 2 – Electrical Fire Safety in Today's Buildings & Construction


Session 3 – Electrical Fire Safety in IT Parks and Data Centres


Session 4 – Best Practices and Technologies of Electrical Fire Safety

**Session 3 – Electrical Fire Safety in IT Parks and Data Centres**

**Moderator:** Rajnish Aggarwal, Partner, PDA Consultants

**Panellists:** Sajan Khanna, Partner & Principal Consultant, GSP Design Consultant; Sheetal Tuteja, Managing Partner, AEON Design & Development LLP; Anil Kaushik, DGM-SCM, MEP Sourcing, Bharti Airtel Ltd, (Nxtra Data Center); NK Singh, Founder & CEO, Data Center Guru.

**Session 4 – Best Practices and Technologies of Electrical Fire Safety**

**Moderator:** Abrar Ahmad, Director, ABN Consultant

**Panellists:** Harish Sharma, Electrical Consultant, BDS Consultants; Deepak Tikle, Executive Director, V-Marc India Limited; AK Rajput, Former Member (Power System), Central Electricity Authority; Krishan Goswami, Electrical Safety Officer, BSES Rajdhani Power Ltd.

## Knowledge Sharing and Case Study

The knowledge **sharing session and case study by Dr Rajesh Arora** offered real-world perspectives on proactive safety practices and architectural design strategies to mitigate fire risks.

More than 150 participants attended the conclave, including electrical consultants and engineers, fire safety professionals, builders and architects, government officials, and policymakers such as Central Electricity Authority (CEA), BIS, key government officials, safety auditors and facility managers.

## Conclusion

The conclave concluded with a renewed call for:

- Policy reinforcement and enforcement
- Training and capacity building
- Use of quality-certified electrical products
- Pan-India collaboration on safety standards.

IEEMA extends heartfelt gratitude to all speakers, delegates, sponsors, and partners for making the event a resounding success.

The event was sponsored by Title Sponsor – **Polycab India Ltd** and Platinum Sponsors – **Apar Industries Ltd and V-Marc India Ltd.**

# Training Programme on Transformer Technology & Performance Testing

IEEMA conducted a one-day training programme on the subject with an aim to enhance participants' understanding of transformer design, manufacturing, quality control, performance evaluation, and testing procedures.

The Indian Electrical & Electronics Manufacturers' Association (IEEMA), Western Region, successfully conducted a one-day training programme on **Transformer Technology & Performance Testing Requirements** on May 16, 2025, at Sayaji Hotel, Vadodara, Gujarat.

This comprehensive training programme aimed at enhancing participants' understanding of transformer design, manufacturing, quality control, performance evaluation, and testing procedures in line with both Indian and international standards. It also highlighted good maintenance practices and emerging trends such as the application of Internet of Things (IoT) and Artificial Intelligence (AI) in transformer systems.

## Welcome Address

**Keyur Shah, Convener, Gujarat State Chapter, IEEMA,** inaugurated the session by welcoming the faculty and participants. He emphasised on the importance of such knowledge-sharing platforms and encouraged participants to actively interact to gain the most from these expert-led discussions.

The training programme was conducted by **J Santhosh, Former Additional Director and Unit Head, Central Power Research Institute (CPRI), Bhopal.**

### Programme Highlights & Key Takeaways

- Refresher on fundamental transformer theory and key concepts.

- Critical aspects of design and manufacturing processes.
- Technological advancements in core materials, winding materials, loss reduction, and improved cooling systems.
- Significance of various routine, type, and special tests in accordance with standards.
- Hands-on understanding of transformer testing laboratories and practices.
- Methods for evaluation and interpretation of test results.
- Discussion on futuristic trends and industry challenges.

## Concluding Remarks

The programme concluded with **YV Joshi, former head of engineering, Gujarat Energy Transmission Corporation Limited (GETCO),** delivering the closing remarks. He extended his heartfelt thanks to Santhosh for his detailed and engaging presentations and appreciated the participants for their active involvement, which made the training programme both interactive and insightful.

## Participation and Outcomes

The training programme saw an enthusiastic participation of more than 65 delegates from across the country, representing a wide range of utilities and organisations such as Adani, Transformer & Rectifier, L&T, Doble Engineering Company, ERDA, Siemens, Andritz India Pvt Ltd and Shilchar Technologies Ltd, among others. The training programme was sponsored by The MOTWANE Manufacturing Company.

QNA

# Practical On-the-Field Technical Queries On Transformer *(Part-34)*

This section features queries about the abnormal conditions of transformers, sent by readers working in field units and most of those addressed by transformer industry expert **Er P. K. Pattanaik,** and a few by transformer expert **Er. P. Ramachandran.**

Technical issues and practical problems which arise in the field with solutions are published regularly in the QNA Section for the benefit of our readers, including other field engineers and practitioners facing similar circumstances. We urge readers to share more queries, suggestions and feedback on *editor.ieemajournal@ieema.org*.

**QUERY**

What are the indications to of acetylene presence during Dissolved Gas Analysis (DGA)?

**REPLY**

Acetylene in DGA indicates an internal arc with a temperature release of more than 700 degrees centigrade. This may be due to internal sparking at the metallic point. Sometimes with the generation of acetylene gas, the transformer may not trip if such sparks are on the non-current carrying path. Some non-current carrying metallic parts, like the core, score frame, stacks, etc., result in the heating caused by the ionization on the body for an unequal electromagnetic path distribution. So, to ensure the cause of acetylene release, close monitoring and internal inspection are needed. The general practice is that if the system does not trip due to an electrical relay and acetylene is traced, then the rising trend of this gas needs to be monitored to ensure its effects;

if it is an increasing trend, then internal inspection is needed to confirm the cause, followed by a rectifying action.

## QUERY

What is the formula for the calculation of Total Dissolved Gas Content (TDG%) and the Total Dissolved Combustible Gas Content (TDCG%) in percentage?

1. Explain the difference.
2. Which one is generally referred to for charging of transformers?
3. What is the practical implication for charging new transformers with these gases?
4. Which standard gives more information about this?

## REPLY

Total dissolved gas and total dissolved combustible gas content are not the same.

Total dissolved gas includes nine gases which have $N_2$ and $O_2$ as well.

Total dissolved combustible gas does not include $CO_2$, $N_2$ and $O_2$. The reference standard for the total dissolved gas is IEEE C57.152.2013.

Total dissolved combustible gas limit is IEEE C57.104, even the IEC 60059:2015, may be referred.

A. Total Dissolved Combustible gas = $\{H_2 + CO + CH_4 + C_2H_2 + C_2H_4 + C_2H_6\}$ in ppm.

B. Total Dissolved Gas Content = $\{\text{all above} + N_2 + O_2 + CO_2\}$ in ppm.

But how to calculate the same in percentage (%)? Is it like (TDCG in ppm/1 million) × 100 = value in percentage (%)? **The author has asked to delete this line!!**

## QUERY

We have a 31.5 MVA PTR that failed in 2015. In 2018 it was sent to the repair bay. At that time its oil was drained and kept in barrels at the substation. Its furan analysis indicates 0.98 (moderate deterioration of paper insulation). Its properties were also tested (except DGA); they indicate satisfactory results. Now can we use this oil for any other transformers after filtration?

## REPLY

Oil acidity, IFT, Tan delta, flash point and resistivity are the deciding factor for the use of the oil. Yes, this oil can be re-used if the oil gets re-conditioned and obtains the required allowable value.

## QUERY

What is the best practice for using back-up protection relays for transformer protection?

## REPLY

1. Usually a directional element is used with an IDMT feature, looking in the direction towards the transformer on the incoming of the transformer (LV side of an estimated 132/33 kV system) along with a non-directional highest element with an IDMT feature to cause an outage of the system in case of a severe fault in the outgoing feeders or, in the case of a non-actuation of the outgoing feeders.
2. But a maximum of 33 kV outgoing feeders use a non-directional element with an IDMT feature and also a high-set element with instant tripping. This is because these feeders are generally radial load connected feeders.
3. But for interconnected feeders between two stations, a directional element could be better to define the directions towards the line only.

## QUERY

Why does the transformer trip on changing the tap position to the extreme point sometimes?

## REPLY

Perform the testing of the differential relay while the transformer is in service. Change the tap and measure the operating currents on the differential relay.

Check whether the magnitude of the current is within the setting limit or beyond. If it is beyond the setting limit, then the bias setting should be changed to at least 20% instead of 15%.

Recommendation: In general, the bias setting of the differential relay should be set at 20% to accommodate the residual current due to the CT mismatch, the tap position voltage mismatch, the measurement tolerance, the setting criteria, etc.

## QUERY

When a Bucholz tripped twice at a site, a suspicion about a defect in the ratio link plate led to the open inspection of a new 110/33 kV, 16 MVA transformer. After a rectification, the transformer was put into service. After charging the transformer, a rise in temperature from 52 degrees in winding to 72 degrees with a load of 20% was noted within five hours. Since all tests are found within limits and normal, what is the reason for the rise in the temperature?

## REPLY

The abnormal rise in temperature is due to the following reasons:

1. Sometimes air gets trapped in the oil circulation path, stopping its circulation with the rise in temperature.
2. If the radiator valves are closed, it may cause a rise in the temperature.
3. The thermospocket where the probe is fitted sometimes results in no oil; if so, the temperature may also rise.
4. During parallel operation, if taps remain unequal, then circulation current and abnormal sharing of reactive current may cause the temperature to rise.
5. The WTI CT as calibrated may be used with different ratios, causing a rise in the temperature.
6. Faulty temperature indicators could also be one of the reasons.
7. As observed during the first loading under cold conditions sufficient thermal head is required to kick-start the convective oil current in the cooling circuit. Before this happens, the transformer temperature may rise in a short time and normalize in a few hours.

Please note: For any reason, if the same happens due to an internal spark or an arch, then at least the Bucholtz relay needs to be initiated. If it happens to be any internal fault, then the protection relays like differential/REF need to be initiated. So please do not be worried; rather, check this rise in temperature with all indicators like HV WTI, LV WTI and OTI.

## QUERY

What is the difference between a generator transformer and a power transformer?

## REPLY

(1) A generator transformer is a power transformer and a step-up transformer. It depends upon the generating voltage and the voltage to which it is required to be stepped up. The vector group of such transformers is YNd1. For instance, a generator of 210 MW that generates a voltage of 15.75kV (delta) and is required to be stepped up to 220kV; that's when the generator step-up transformer rating should be 250 MVA.

(2) All transformers which have primary and secondary volts in kV are known as power transformers. Generally, these transformers in the transmission area are star-star connected.

## QUERY

What is the evolution of the use of inhibited oils in transformers?

## REPLY

1) The process of adding chemical inhibitors in oil to improve oxidation stability was started in the US around 1950, after which, in both the US and Europe, using inhibited oil developed into standard practice. The most used inhibitor was Di Tertiary Butyle Para Cresol (DPBC – a white powder of about 0.4% in weight). But in the UK, it was looked at with reservation as it was feared that people would sell old, used oil as new oil after adding inhibitors. So, in India also, customers asked for uninhibited virgin oil.
2) But a big change came about in oil manufacturing in India during 1990s. Indian oil suppliers started to import oil and supply it instead of making oil here by the acid washing method. This imported iso-paraffinic oil was cheaper, highly purified by hydro-cracking with a colour that was almost like water and a density of 0.82 instead of 0.89 of oil that was used till then. These oils had one problem the purification process would remove all natural oxidation inhibitors. Thus, in this oil, inhibitors needed to be added to gain stability. To overcome the stigma for inhibited oil from users, oil manufacturers added a note in a small print noting that IS 335 revision oil with 0.05% inhibitor must be considered as uninhibited oil. They added a small quantity of inhibitors to the uninhibited oil. Since everybody was happy, and with these new paraffinic oils, IR values of transformers went up to the giga range instead of the usual mega range acquired till then, only because of the high resistivity of oil.
3) So today only fully inhibited oil is purchased, as all good quality oils are highly purified oil with 0.3 to 0.4% DPBC added to it.
4) The latest International Electrotechnical Commission codes (IEC) on oil give parity for reclaimed oil (inhibitors added after reclamation) with new oil.

## QUERY

We have some transformers in our solar plants in which we are facing Buchholtz issues every day. Daily we are releasing gases and the next day the same issues arise. On DGA all parameters we found to be normal within limits.

## REPLY

The transformer, when under observation, notes problems in the valve placed towards the conservator. This valve can be either fully closed or partly closed, or it might have a flexi metallic bellow that disturbs the oil flow and causes the gap of air in the flow path. Also, upon checking, it was found with a flexi corrugated bellow and fitted to an angle that didn't allow proper oil flow during the extension of oil.

Solar linked transformer loads are of fluctuated nature, due to flexible climatic condition. So, oil flow to the conservator becomes irregular in nature. Now due to the placement of a metal below and improper oil flow through this resulted in an air gap and the accumulation of the same results in the operation of the Buchholtz relay. Rectification of the same helped for non-actuation of further.

## QUERY

We have noted severe oil leakage at the lower load from the HT bushing of a 220/33 KV transformer. What is the reason and how can it be controlled?

## REPLY

The bushing used might be of OIP type, so oil leakage at even a lesser load indicates improper mounting of the bushing or tension on the connection inside the tank. Dismantle the OIP bushing and check its installation properly.

## QUERY

Are the results of a magnetic balance test of a YNyn0 three-phase power transformer and those of a Yy0 auto-transformer, the same? If not, then what will be the trend?

## REPLY

The result pattern is the same for both the magnetic balance test for auto and the two-winding transformer. Sometimes the following deviations are seen:

1. If a higher voltage rating and test are conducted for the HV part with a low-voltage application, then the flux linking on the core won't be effective, resulting in an anomaly in values.
2. If the balance test is done after the DC winding resistance, then the resultant anomalies may come due to the residual DC component in the winding.
3. If the geometry of the magnetic path is different, then also an abnormal value may be read.

## QUERY

On inquiry after the failure of the 220/132 KV transformer, it was observed that the tertiary winding earthing and neutral earthing are interconnected and grounded to a common point. So, could we justify that both should be separated and finally connected to the earth mat?

## REPLY

If the neutral is a conductor, then the potential of the transformer neutral will be close to zero held by the earth mass. If the flow of the current is largely through the earth mass back to the transformer neutral, the potential of the earth mass around the transformer will rise.

Here the concern is on the earthing practice of power transformer (PTR) and its auxiliaries.

1. If the tertiary is not loaded, then one of the terminals needs to be solid earth on a separate pit or a tripod pit (three interconnected earth pits being separated by a 6-meter space in between), and finally, the tripod must be connected to the earth mat.
2. If the tertiary is loaded, but the winding is not loaded, then this too needs solid grounding or to be connected with a suitable (lightning arrester) LA, but the basic insulation level of the insulation used must be high.
3. Winding neutral also must be solidly grounded, just like a tripod on point 1, and again to be connected to the mat.
4. The body earthing needs to be connected to a separate pit and again connected to the mat.
5. Earthing is to be taken to separate pits as mentioned above, but finally all connected to the mat. The reasons for tertiary failure could be varied.

## QUERY

What is the safest limit of loading for any power transformer?

## REPLY

The optimum loading on the transformer is not more than 80% of its capacity. Efficient loading is up to 50% of its capacity. Under any circumstance, the temperature of the winding and the oil is to be within the guaranteed values. At the same time, oil temperature shall not exceed 100 degrees centigrade even for short durations. The flash point of the oil in the new PTR as received is 120 degrees centigrade, while in an in-service power transformer, it will be lower due to the deterioration of oil. When our atmospheric temperature is 50 degrees at full load on the power transformer, the oil temperature may touch 100 degrees centigrade.

We take LV side values as loading. When LV side current is rated full load current and we are operating the PTR at the highest tap due to low voltages of the system, the HV side current will be 25% more than rated full load current on HV. Taking all these into account, the optimum loading on the power transformer will not be more than 80% of its capacity. However, time-to-time temperature rise is to be taken into account. We have to delete the terms "overloading" and "overvoltage operation" of both power and distribution transformers from the dictionary of transformers.

*Er. P.K. Pattanaik is Director (Operation) at Odisha Power Transmission Corporation Ltd., Odisha.*

## Union Minister Shri Pralhad Joshi inaugurates solar PV testing facility at NISE

Marking a major advancement in India's renewable energy capabilities, Union Minister for New and Renewable Energy Shri Pralhad Joshi inaugurated the PV module testing and calibration lab at the National Institute of Solar Energy (NISE) at Gwal Pahari in Haryana. Speaking at the occasion, the minister stated that the new lab will set global benchmarks in solar research and development (R&D), testing, training, and policy support while marking a bold step towards self-reliance, innovation, and global excellence.

Shri Joshi also said that NISE is now equipped to offer comprehensive testing, calibration, and certification services, particularly for PV modules and technologies, where no established standards currently exist. He termed the lab a pioneering facility for India and further highlighted that as Indian companies scale up the production of large modules, this lab will ensure that products meet the highest quality standards.

The lab aligns with BIS standards and will provide a major boost to the production-linked incentive (PLI) scheme and support India's aspiration to become a global manufacturing hub. With the new facility, NISE will significantly improve its efficiency, quality, and research in accordance with global benchmarks.

Union Minister Shri Pralhad Joshi also advised NISE to build partnerships, develop talent, and push boundaries so that its work resonates across laboratories, manufacturing units, and solar farms worldwide. He also acknowledged that NISE is already working on advanced technologies like perovskite solar cells and bifacial panels.

## DPIIT extends timeline for implementation of QCO on Safety of Household, Commercial and Similar Electrical Appliances

The Department for Promotion of Industry and Internal Trade (DPIIT), Ministry of Commerce & Industry, has extended the implementation timeline for the Safety of Household, Commercial and Similar Electrical Appliances (Quality Control) Order, 2025. The decision follows stakeholder consultations chaired by Union Minister of Commerce and Industry Shri Piyush Goyal on May 15, 2025.

Taking cognisance of industry concerns regarding implementation challenges and legacy stock, the DPIIT has notified the revised Quality Control Order on May 19, 2025. To enable ease of doing business, the QCO will now come into force from March 19, 2026, for domestic large and medium enterprises as well as for foreign manufacturers.

The QCO applies to all electrical appliances intended for household, commercial, or similar applications with rated voltage not exceeding 250V for single-phase appliances and 480V for others, including DC-supplied and battery-operated appliances. Appliances already covered under separate QCOs or existing mandatory BIS certification requirements are excluded from its ambit.

Furthermore, the QCO incorporates several key relaxations and exemptions:

- Additional time for micro and small enterprises (MSEs): Six-month extension for micro enterprises and three-month extension for small enterprises.
- Exemption for imports by domestic manufacturers for producing export-oriented products.
- Exemption for import of up to 200 units for R&D purposes.
- Provision for clearance of legacy stock (manufactured or imported before implementation) within six months from the effective date.

The QCO is a critical step in restricting the import of sub-standard products and ensuring consumer safety, while also enhancing competitiveness of Indian industry. It reflects a strategic push to raise product standards in India, enabling Indian manufacturers to thrive in both domestic and international markets.

## Union Minister Shri Manohar Lal visits Nepal to strengthen India-Nepal energy cooperation

Union Minister of Power and Housing & Urban Affairs, Shri Manohar Lal, recently visited Nepal, marking a new chapter in India-Nepal energy cooperation. Accompanied by Nepal's Minister of Energy, Water Resources & Irrigation,

Shri Dipak Khadka, and senior officials from both nations, the Union Minister reviewed key bilateral energy initiatives aimed at enhancing regional connectivity and sustainable power development.

During his visit, Shri Manohar Lal reviewed the progress of the landmark 900-MW Arun-3 Hydroelectric Project in Nepal's Sankhuwasabha district being developed by SJVN Limited. The Arun-3 project stands as a symbol of robust India-Nepal partnership in the hydropower sector. Shri Manohar Lal also inaugurated the commencement of electromechanical works at the powerhouse site, a critical milestone towards the project's timely completion.

A memorandum of understanding (MoU) was also signed between POWERGRID, a Maharatna Central Public Sector Enterprise (CPSE) of India, and the Nepal Electricity Authority (NEA) in the presence of Shri Manohar Lal and Shri Dipak Khadka. This MoU paves the way for the incorporation of two joint venture companies (JVCs) – one in India and one in Nepal – to implement high-capacity cross-border transmission infrastructure.

The proposed projects include the development of the 400-kV Inaruwa (Nepal) – New Purnea (India) and 400 kV Dododhara (Nepal) – Bareilly (India) double-circuit transmission systems. These critical transmission links will significantly boost power exchange capabilities between the two countries, fostering energy security, grid stability, and economic growth across the region.

## MNRE Minister Pralhad Joshi launches Green Hydrogen Certification scheme

The Ministry of New and Renewable Energy (MNRE) recently organised a national workshop on opportunities for 'Micro, Small & Medium Enterprises (MSMEs) in the Green Hydrogen Supply Chain' in New Delhi.

Shri Pralhad Venkatesh Joshi, Hon'ble Union Minister of New and Renewable Energy, highlighted the government's commitment to fostering innovation-led growth and emphasised that MSMEs will serve as the backbone of India's energy transition through their innovative capabilities and localised solutions. He highlighted the critical role MSMEs will play in realising the mission's objectives of building a self-reliant green hydrogen ecosystem by 2030.

The minister also launched the Green Hydrogen Certification Scheme of India (GHCI), a foundational step towards creating a robust framework for certifying green hydrogen production and ensuring transparency, traceability, and market credibility.

Shri Santosh Kumar Sarangi, Secretary, MNRE highlighted some key achievements in the implementation of National Green Hydrogen Mission. He stressed upon the importance of building capacities, facilitating finance, and strengthening technology linkages to empower MSMEs to meaningfully participate in this new industrial landscape. He reiterated the ministry's commitment to building institutional and infrastructural support for green hydrogen, with MSMEs playing a critical role.

The Government of India is implementing the National Green Hydrogen Mission with an objective to make India a global hub of production, usage and export of green hhydrogen and its derivatives.

## Union Minister of State for Power and New & Renewable Energy Shri Shripad Naik chairs meeting for addressing issues on viability of distribution utilities in the country

The Union Minister of State for Power and New & Renewable Energy, Shri Shripad Naik, recently chaired the 4th meeting of group of ministers constituted for addressing issues related to viability of electricity distribution utilities in Vijayawada.

Shri AK Sharma, Energy Minister, Uttar Pradesh, Shri Gottipati Ravi Kumar, Energy Minister, Andhra Pradesh, Shri Hiralal Nagar, Minster of State for Energy, Rajasthan and Smt. Meghana Sakore Bordikar, Minister of State for Energy, Maharashtra as members of the Group attended the meeting. The meeting was also attended by senior representatives from All India DISCOM Association (AIDA), senior officials from Central Government, State Governments, State Power Utilities of Member States and Power Finance Corporation (PFC) Ltd.

The Union Minister of State highlighted about deliberations held during the first three meetings of GoM regarding challenges being faced by distribution utilities and stressed upon the need for regulatory reforms. He also mentioned about the key actionable items identified by GoM till the last held meeting including the steps that needs to be taken by the Central and the state governments for improving efficiency of utilities.

Discussions revolved around the need for having a comprehensive review of the tariff policy that is in sync with the present requirements and challenges of the utilities and its consumers. A presentation also highlighted the action plan proposed to reduce the outstanding debts and losses of the distribution utilities.

key points of discussions included the role that state governments may play for ensuring cost reflective tariff, in ensuring timely payment of subsidies and government department dues, expediting works ongoing under the Revamped Distribution Sector Scheme, including smart metering works, increasing the use of artificial intelligence and data analytics to improve power purchase optimisation and demand forecasting, among others. The states also requested GoI for support in reforming its distribution sector through measures like distribution franchisee, privatisation, introduction of parallel licensee, among others.

The group of ministers reiterated their commitment and expressed resolve to take necessary measures for improving the financial viability of distribution utilities.

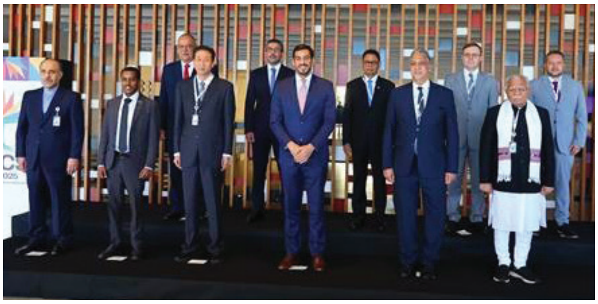
## India and Denmark renew MoU that will support India's ambitious target of achieving net-zero emissions by 2070

India and Denmark have reinforced their long-standing energy cooperation by recently signing a renewed Memorandum of Understanding (MoU). The MoU was signed by Shri Pankaj Agarwal, Secretary, Ministry of Power, Government of India, and H.E. Mr. Rasmus Abildgaard Kristensen, Ambassador of Denmark to India, in the presence of Shri Manohar Lal, Hon'ble Minister of Power and Housing & Urban Affairs. This agreement reflects the continued commitment of both countries to accelerating clean energy transitions.

The renewed MoU supports India's ambitious target of achieving net-zero emissions by 2070. It aims at fostering knowledge exchange and technological collaboration between the two countries, particularly around clean and sustainable energy solutions. The renewed agreement broadens the partnership to cover advanced areas such as power system modelling, integration of variable renewable energy, cross-border electricity trading, and development of EV charging infrastructure. It also emphasises increased knowledge exchange through expert interactions, joint training sessions, and study tours. Shri Manohar Lal, Hon'ble Minister of Power and Housing & Urban Affairs, in a PIB release, said that the renewed energy cooperation expresses the mutual commitment of India and Denmark to foster sustainable development.

## India leads call for inclusive energy governance at BRICS Energy Ministers' Meet in Brazil

Shri Manohar Lal, Union Minister for Power and Housing and Urban Affairs, led the Indian delegation for the BRICS Energy Ministers' Meeting hosted in Brasília on May 19, 2025, under Brazil's Presidency. The Union Minister highlighted energy security as one of the most pressing current challenges and emphasised the need to strengthen BRICS cooperation to ensure economic stability and sustainability, as well as to promote equitable access to energy resources globally.



He reaffirmed India's unwavering commitment to building a sustainable and inclusive energy future and lauded Brazil's leadership under the theme, 'Strengthening Global South Cooperation for More Inclusive and Sustainable Governance'. He further emphasised the critical role of energy security, access, and affordability in advancing global development goals.

The Union Minister also showcased India's rapid progress in clean energy, highlighting some of the key achievements. He also emphasised the role of the Global Biofuels Alliance in advancing cooperation in the biofuels sector and underscored India's commitment to energy efficiency through innovative programmes such as the Energy Conservation Sustainable Buildings Code, rooftop solar initiatives, and efficient appliance standards.

The BRICS Energy Ministers reaffirmed their commitment to strengthening energy security and advancing UN Sustainable Development Goal 7 (SDG 7), focusing on universal electricity access, clean cooking, and tackling energy poverty. They emphasised the need for just, inclusive, and balanced energy transitions in response to climate change.

The Ministers called for stronger partnerships, supported open, fair, and non-discriminatory international energy markets, and encouraged the use of local currencies in energy trade.

Underscoring energy security as vital for socio-economic development, they highlighted the importance of market stability, resilient infrastructure, diversified energy sources, and critical minerals for clean technologies.

They reaffirmed the goal to double energy efficiency by 2030 and emphasised enhanced cooperation and knowledge sharing among BRICS nations. Lastly, they committed to elevating BRICS' global energy role and advancing shared priorities under India's Chairship in 2026.

## Karnataka Government seeks electric buses under PM E-Drive

The Ministry of Heavy Industries (MHI) has received a formal proposal from the Government of Karnataka seeking allocation of electric buses under the centrally sponsored PM E-Drive initiative. Karnataka Transport Minister Shri Ramalinga Reddy submitted the state's request, citing need for enhanced urban public transport systems in key cities.

Responding positively, Union Minister for Heavy Industries and Steel Shri HD Kumaraswamy held deliberations with senior officials of the Ministry and assured the Karnataka Government of complete support from the Centre. The Union Minister confirmed that the process of allocation is already underway, and that the state will receive electric buses in a phased and prioritised manner.

Notably, 14,000 electric buses are to be allocated to nine major cities under the PM E-Drive initiative. Discussions between the Union and state governments have also covered associated infrastructure, including charging stations, bus depots, and vehicle maintenance systems. Officials from both sides explored implementation models to ensure rapid rollout across identified urban clusters.

The PM E-Drive initiative aims at augmenting city bus operations with 14,028 electric buses. The scheme has an outlay of Rs10,900 crore over two years from April 01, 2024, to March 31, 2026.

## Brainstorming session held on pumped storage projects to power India's renewable future

A high-level brainstorming session on 'Pumped Storage Projects: Powering India's Renewable Future' was recently organised by THDC India Ltd


and Central Electricity Authority (CEA) in association with NTPC, with the support of CBIP & INCOLD, in New Delhi. The event focused on the growing role of pumped storage projects (PSPs) in supporting India's renewable energy transition and achieving the national target of net-zero emissions by 2070.

Shri Pankaj Agarwal, IAS, Secretary, Ministry of Power, GoI, during his address, reportedly emphasised that ensuring grid stability is a matter of urgent national priority and every state must actively contribute to this effort. He further underlined the need for sub-regions within states to become self-sufficient from a grid management perspective, with a strong focus on flexible generation and load shifting.

Shri Akash Tripathi, (IAS), Additional Secretary (Hydro), Ministry of Power, GoI, in his address, highlighted that the genesis of this workshop lies in the need to bring together relevant stakeholders to collaborate on accelerating the development of PSPs.

Shri MG Gokhale, Member (Hydro), CEA, highlighted the vast potential of PSPs in India, emphasising their critical role in achieving the country's net-zero targets through reliable energy storage. He noted that about 3 GW of PSP capacity is expected to be added in 2025-26, including the commissioning of the 1,000-MW Tehri PSP in the coming months.

Shri Gurdeep Singh, CMD, NTPC, stressed the urgent need for large-scale deployment of PSPs, stating that the energy transition cannot succeed without robust storage solutions. Given the intermittent nature of renewables, he emphasised the need of storage capabilities for a stable shift to renewable energy and reliable grid management.

Shri RK Vishnoi, CMD, THDCIL, noted that the focus will be on identifying roadblocks and exploring ways to ensure faster and more efficient execution of projects on the ground.

Shri AK Dhinkar, Secretary, CBIP, highlighted the importance of accelerating the development of PSPs as a key player in building a resilient and sustainable future.

## NATIONAL

### CEA notifies draft CEA (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations, 2025

The Central Electricity Authority (CEA) has notified the draft CEA (Technical Standards for Construction of Electrical Plants and Electric Lines) (1st Amendment) Regulations, 2025. A key revision, as per the draft amendment, includes the updated right of way (RoW) requirements for various voltage levels ranging from 66 kV to 1,200 kV and high voltage direct current (HVDC) systems up to ±800 kV. The amendment provides separate RoW norms for different terrains using conventional and high-

performance conductors. The amendment also mandates compliance with the CEA (Measures Relating to Safety and Electric Supply) Regulations, 2023 and the guidelines for rationalised use of high-performance conductors.

### SJVN subsidiary commences commercial operations of 78.23 MW capacity in Rajasthan

SJVN Green Energy Limited (SGEL), a wholly owned subsidiary of SJVN Limited, has reportedly commenced commercial operations of 78.23 MW capacity under Phase-II of the 1,000 MW grid connected solar photovoltaic power project (CPSU Tranche-III) in Bikaner, Rajasthan. The 1,000-MW solar power project is being developed by Tata Power Solar Systems Limited at Rs54.92 billion on EPC basis.

### SAEL to invest Rs50 billion in 5 GW solar cell manufacturing facility

SAEL Limited is reportedly planning to invest Rs50 billion to set up a 5 GW solar cell manufacturing

facility in Greater Noida, Uttar Pradesh. This is in line with the government's approved list of models and manufacturers policy, which will mandate local sourcing of solar cells from June 2026. As reported, the company is also exploring the manufacturing of wafers and ingots, depending on policy direction and market conditions.

### NTPC to raise Rs40 billion via NCDs

NTPC Limited is reportedly planning to raise Rs40 billion through the issuance of unsecured, non-convertible debentures (NCDs). The issuance will be done via private placement at a coupon rate of 6.84 percent per annum for a tenure of 10 years with maturity on May 9, 2035, as reported. The raised funds will be used to meet capex requirements, refinance existing loans, and for other general corporate purposes. The debentures are proposed to be listed on the Bombay Stock Exchange (BSE).

### MNRE issues clarifications on inclusion of solar cells in ALMM

The Ministry of New and Renewable Energy (MNRE) has issued clarifications regarding the inclusion of solar cells in the Approved List of Models and Manufacturers (ALMM). As reported, the ministry clarified that solar cells with potential induced degradation (PID) and non-PID characteristics will be considered different product families and enlisted separately. Furthermore, cell data such as efficiency and wattage will be collected during ALMM inspection and used to calculate and enlist average efficiency.

### OTPC and Assam Power Development Corporation to develop 250 MW BESS

A subsidiary of Oil and Natural Gas Corporation – ONGC Tripura Power Company Limited (OTPC) – and Assam Power Development Corporation Limited have announced a joint venture to develop a 250-MW battery energy storage system (BESS) in Assam.

The project aims at storing solar power in the battery system during the day and distributing it through power substations during peak hours or at night, when solar generation is unavailable. The first such initiative in the northeastern region, the project is expected to enhance solar power utilisation and grid reliability in the region.

## NHPC raises Rs19.45 billion via NCT

NHPC Limited has reportedly raised Rs19.45 billion through the issuance of unsecured, redeemable, non-convertible, non-cumulative and taxable (NCT) 6.86 percent AF series bonds 2040 on a private placement basis. The 15-years tenure bonds have a maturity date of May 6, 2040. The issue is proposed to be listed on the wholesale debt market segment of the BSE and the NSE.

## NHPC and RRVUNL sign MoU for developing two 1,000 MW PSPs in Rajasthan

NHPC Limited and Rajasthan Rajya Vidyut Utpadan Nigam Limited (RRVUNL) have signed a memorandum of understanding (MoU) for developing two 1,000 MW pumped storage projects (PSPs). These projects, to be developed in Rajasthan, will be implemented by the joint venture company formed.

## Uttar Pradesh approves PPA to procure 1,500 MW thermal power for 25 years

The Uttar Pradesh cabinet has approved the signing of a power purchase agreement (PPA) between Uttar Pradesh Power Corporation Limited (UPPCL) and a private developer for procuring 1,500 MW of thermal power at a tariff of Rs5.38 per unit.

The contract has been awarded through competitive bidding and is expected to commence supply from 2030-31, spanning over 25 years. The project aims to meet the state's rising power demand at lower costs as compared to existing and upcoming thermal projects.

## Assam approves Rs77.3 billion thermal power policy initiatives

With an aim to strengthen the state's thermal power infrastructure, the Assam Government has approved the Assam Thermal Power Generation

Product Promotion Policy 2025 with investment proposals worth Rs77.3 billion. Key provisions include free land allocation, water and road infrastructure support, and power offtake through tenders. The government is targetting a power demand of 5,000 MW by 2032 and aims at making Assam a regional hub for thermal power.

## RVNL to set up 300 MW hybrid renewable energy project for Indian Railways

Rail Vikas Nigam Limited (RVNL) is reportedly planning to develop a 300-MW hybrid renewable energy project in collaboration with the Ministry of Railways. The hybrid project is expected to be in Bihar, Jharkhand, or Karnataka. The project, estimated at Rs15 billion, is expected to include solar, wind, and energy storage components and will also incorporate energy storage to ensure firm power supply during peak hours. RVNL is expected to lead the infrastructure development for the project.

## Odisha Government approves Rs11.91 billion renewable energy projects

With an aim to enhance the state's sustainable energy infrastructure, the Odisha Government has granted in principle approval to seven renewable energy projects worth Rs11.91 billion. These include two wind power projects of 95.7 MW, four ground-based solar projects totalling 53.97 MW, and Odisha's first battery storage project with a 0.6 MWh capacity.

# INTERNATIONAL

## India and Saudi Arabia sign agreement on energy cooperation

India and the Kingdom of Saudi Arabia have reportedly signed an agreement to enhance cooperation in the energy sector, aiming at ensuring security of supply for all energy sources. Both sides have agreed to collaborate on balancing global energy market dynamics and strengthening supply chain resilience. The agreement also includes cooperation support for India's strategic reserve programme, collaboration in electricity and renewable energy, including the completion of a detailed joint study on electrical interconnection between the two countries. As reported, India and Saudi Arabia will also exchange expertise in grid automation, connectivity, security, and resilience, alongside cooperation in renewable energy and energy storage technologies. Both countries have also committed to jointly advance the development of green and clean hydrogen.

## Adani Group signs MoU with Bhutan's DGPC to jointly develop 5,000 MW hydropower projects

Adani Group has signed an MoU with Bhutan's Druk Green Power Corporation (DGPC) to jointly develop 5,000 MW of hydropower projects in Bhutan. This is further to the ongoing partnership between the two entities for the 570/900-MW Wangchhu hydropower project. DGPC holds a 51 percent stake in the project with Adani holding the balance 49 percent. The broader 5,000-MW initiative will include additional hydropower and PSPs to be identified, planned, and implemented in phases.

## ADB commits US$ 10 billion for ASEAN transnational power grid

The Asian Development Bank (ADB) is planning on allocating up to US$ 10 billion towards the Association of SouthEast Asian Nations (ASEAN) power grid (APG) initiative to expedite cross-border connections and national grid projects. To boost energy security, enable power trade, and drive sustainable development across the region, the bank has also programmed another US$ 27 billion in financing to support the region's energy transition and clean energy investments over three years. This ambitious project aims at creating a unified regional energy network across 10 southeast Asian countries, facilitating cross-border electricity trade, reducing costs, improving energy supply resilience, and accelerating the shift to clean energy sources.

## Reliance Power signs PPA with GDL for 500 MW solar project in Bhutan

Reliance Power Limited has signed a commercial term sheet for a long-term PPA with Green Digital Private Limited (GDL), a company owned by Druk Holding and Investments Limited (DHI), the investment arm of the Royal Government of Bhutan. Reliance Power and DHI will jointly develop Bhutan's largest solar power project through a 50:50 joint venture, as reported. The 500-MW project represents the largest foreign direct investment in Bhutan's solar energy sector to date with an estimated capital outlay of up to Rs20 billion. The project will be developed in phases in 24 months on a build-own-operate model.

# CORPORATE

## Hindalco Industries acquires complete stake in EMMRL

Hindalco Industries Limited has completed the acquisition of 100 percent equity stake in EMIL Mines and Mineral Resources Limited (EMMRL), a wholly owned subsidiary of Essel Mining and Industries Limited (EMIL). Through this acquisition, Hindalco will now get control of the Bandha coal block, which holds an estimated 197 million tonne of reserves with a mine life of about 45 years. The coal block is located about 20 km from Hindalco's Mahan plant. It is expected to support Hindalco's aluminium smelters by securing raw material supply and enabling a sustainable coal logistics chain across rail, road, and conveyor systems.

## GE Vernova to invest Rs1.4 billion for expansion of grid equipment manufacturing in India

GE Vernova is reportedly planning to invest about Rs1.4 billion to expand its electrification manufacturing and engineering footprint in India. The investment will be undertaken by GE Vernova T&D India Limited. With this investment, the company plans on developing a new manufacturing line at its existing facility in Pallavaram, Chennai, and establishing a new facility in Noida. With this expansion, the company aims at boosting its capacity of manufacturing and testing next-generation transmission system equipment.

## ReNew Power to develop clean energy project in Andhra Pradesh at Rs220 billion

ReNew Power is planning an investment of Rs 220 billion to develop a renewable energy project in Anantapur, Andhra Pradesh. The project includes an 1,800-MW solar power plant, a 1,000-MW wind power project, and a 2-GWh battery energy storage system (BESS) and will be executed in two phases. In the first phase, the company will install a 587-MW solar power plant, a 250.8-MW wind power project, and a 415-MWh BESS, with the rest of the capacity to be developed in subsequent phases. The company is also planning to construct a 100-km extra-high voltage transmission line to deliver the generated power efficiently. Once completed, the project is expected to be India's largest renewable energy complex.

## ACME Solar commissions 52.5 MW Phase-I of 300 MW solar project in Rajasthan

ACME Solar Holdings Limited has commissioned Phase-I of 52.5 MW of its 300-MW solar power project in Bikaner, Rajasthan. The project, financed by Power Finance Corporation Limited, is connected to the Bikaner-II grid via a dedicated 220-kV transmission line. Once completed, it is projected to generate about 780 million units of clean electricity annually. The generated power will be sold on power exchanges on a merchant basis.

## Cleantech Solar commissions 80 MWp captive solar projects in Tamil Nadu

Cleantech Solar has commissioned 80 MWp of open-access solar photovoltaic (PV) projects for industrial consumers at its 275 MWp solar park in Tamil Nadu. The firm will supply power from the captive projects to support manufacturing operations of its corporate clients. As reported, key offtakers include First Solar in the US, DCW in India, and Murugappa Morgan thermal ceramics. Notably, this is the company's fifth renewable energy park in the Tamil Nadu.

## JSW Neo Energy signs 1,500 MW pumped hydro storage PPA with UPPCL

JSW Energy's wholly owned subsidiary – JSW Neo Energy Limited – has signed a PPA with Uttar Pradesh Power Corporation Limited (UPPCL) for supplying 1,500 MW (12,000 MWh) of pumped hydro energy storage capacity. As per the PPA, which will be valid for 40 years, JSW Neo Energy will be entitled

to receive a fixed capacity charge of Rs7.72 million per megawatt per annum. The project will allow for a scheduled energy discharge of 8 hours per day, including a maximum continuous discharge of six hours. The project will be developed in the Sonbhadra district and is expected to be commissioned in next six years.

## Avaada Energy to raise Rs40 billion through IPO

Avaada Energy is reportedly planning to raise Rs40-50 billion for expansion through an initial public offering (IPO). A large part of the funds is expected to be allocated for developing a 5-GW integrated solar module and cell manufacturing facility in Greater Noida, Uttar Pradesh. The IPO is currently in early stages of planning.

## Adani Power plans Rs1.2 trillion investment for capacity expansion to 30.67 GW by 2030

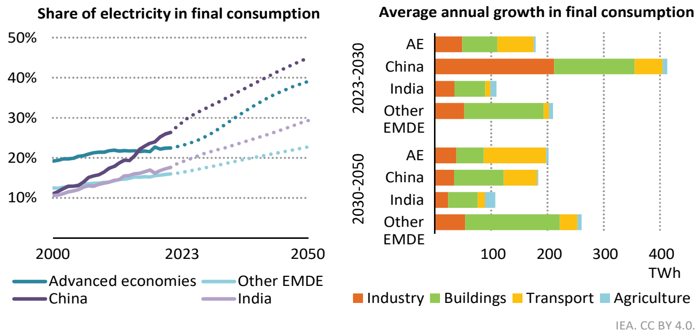
Adani Power Limited is planning a capex of Rs1.2 trillion over six years for expanding its power generation capacity from 17.55 GW to 30.67 GW by 2030. Notably, this marks the largest planned capacity expansion by a private sector power company in India. Adani Power has already placed advanced orders for 11.2 GW of ultra-supercritical boilers, turbines, and generators to ensure timely execution and secure its equipment supply chain, reports indicate.

## Waaree Energies acquires Kamath Transformers and Green New Delhi Forever Energy

Waaree Energies Limited has acquired 100 percent equity stake in Kamath Transformers Private Limited for about Rs 2.93 billion as part of its business expansion into the transformer manufacturing segment. Furthermore, Waaree Forever Energies Private Limited – a wholly owned subsidiary of Waaree Energies – has acquired 100 percent equity in Green New Delhi Forever Energy Private Limited, a newly incorporated non-operating entity. This acquisition aims at facilitating and holding specific power projects under the independent power producer framework.

# Global Scenario

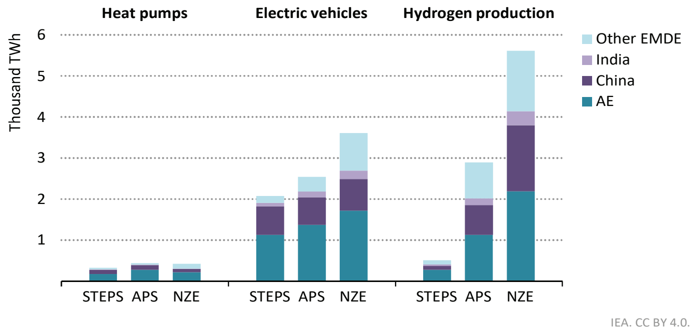
## Electricity in total final consumption and demand growth in the STEPS to 2050




*Emerging market and developing economies, especially China, dominate the growth story in all sectors, while advanced economies see demand increase as transport electrifies*

Notes: TWh = terawatt-hours; AE = advanced economies; Other EMDE = emerging market and developing economies other than China and India.

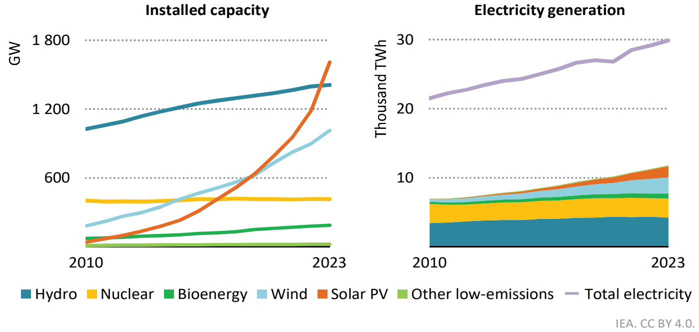
## Electricity demand growth from selected clean energy technologies by region and scenario, 2023-2035




*Electrification of road transport and electrolytic hydrogen production to tackle emissions in hard-to-abate sectors significantly boosts electricity demand in transition scenarios*

Notes: AE = advanced economies; Other EMDE= emerging market and developing economies other than China and India. Electricity demand for heat pumps represents space heating in buildings. Electricity demand for hydrogen production includes onsite production for industry and refineries.

## Global installed clean power capacity and electricity generation, 2010-2023




*Since 2010, installed capacity of solar PV expanded 40-fold, wind 6-fold, bioenergy 2.5-fold and hydro 1.4-fold, but electricity demand increased faster than clean power generation*

Note: Other low-emissions includes geothermal, concentrated solar power, marine, fossil fuels with carbon capture and low-emissions hydrogen and ammonia.

*Source: World Energy Outlook – Clean Energy*

# Indian Scenario

## Smart Metering in India

| Smart Consumer Metering | | | DT Metering | | | Feeder Metering | | |
|---|---|---|---|---|---|---|---|---|
| Sanctioned | Installed | Balance | Sanctioned | Installed | Balance | Sanctioned | Installed | Balance |
| 22,23,54,490 | 2,77,30,675 | 19,46,23,815 | 52,99,097 | 5,73,993 | 47,25,104 | 2,05,647 | 1,03,426 | 1,02,221 |

### Smart Consumer Metering (Nos) as on Apr 25

| Scheme | Sanctioned | Installed | Scheme | Sanctioned | Installed |
|---|---|---|---|---|---|
| DDUGJY | 38,400 | 38,400 | PMDP-Phase-I | 1,27,050 | 1,25,822 |
| IPDS | 6,90,616 | 6,90,616 | PMDP-Phase-II | 6,00,000 | 5,23,650 |
| IPDS (SG Pilots) | 32,642 | 32,642 | RDSS | 19,48,60,030 | 1,40,29,731 |
| IPDS ST&D | 1,19,641 | 1,19,641 | SDP | 58,930 | 55,580 |
| Non-RDSS to RDSS | 29,70,100 | 24,76,873 | Utility Owned | 2,26,78,559 | 94,68,163 |
| NSGM | 1,78,522 | 1,69,557 | | | |

| Agency | EESL | NSGM | PFC | REC | Utility |
|---|---|---|---|---|---|
| Sanctioned | 65,000 | 2,11,164 | 8,95,10,895 | 13,22,97,331 | 2,70,100 |
| Installed | 65,000 | 2,02,199 | 1,02,49,357 | 1,69,44,019 | 2,70,100 |

### DT Metering as on Apr 25

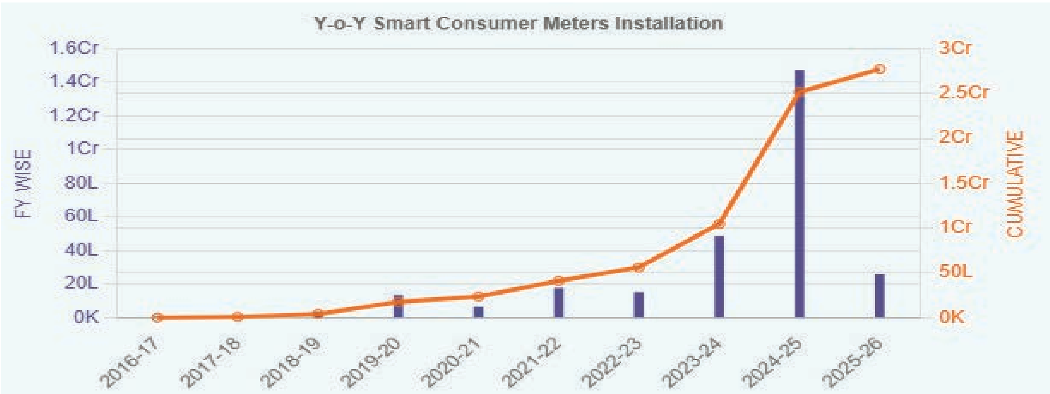
| Scheme | Sanctioned | Installed |
|---|---|---|
| Non-RDSS to RDSS | 52,000 | 31,410 |
| PMDP | 20,794 | 13,400 |
| RDSS | 52,00,692 | 5,10,508 |
| SDP | 1,931 | 1,804 |
| Utility Owned | 23,680 | 16,871 |

| Agency | Sanctioned | Installed |
|---|---|---|
| PFC | 18,22,654 | 2,57,478 |
| REC | 34,76,443 | 3,16,515 |

### Feeder Metering as on Apr 25

| Scheme | Sanctioned | Installed |
|---|---|---|
| Non-RDSS to RDSS | 455 | 627 |
| RDSS | 2,05,020 | 1,02,602 |
| SDP | 54 | 79 |
| Utility Owned | 118 | 118 |

| Agency | Sanctioned | Installed |
|---|---|---|
| PFC | 1,03,582 | 48,906 |
| REC | 1,02,065 | 54,520 |

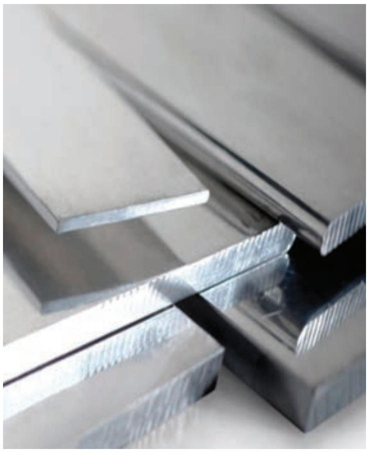


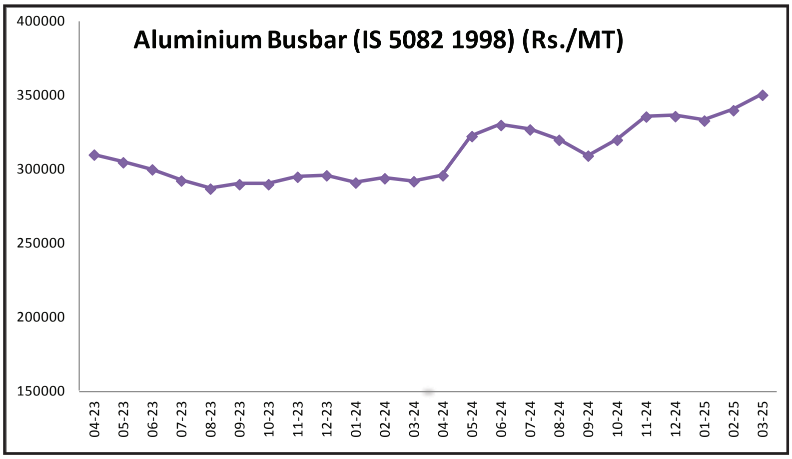

*Source: NSGM*


# Basic Prices and Indices

| | as on March 1, 2025 |
|---|---|
| **IRON, STEEL & STEEL PRODUCTS** | |
| BLOOMS (SBLR) 150mmX150mm | 44313.00 |
| BILLETS (SBIR) 100MM | 47368.00 |
| CRNGO Electrical Steel Sheets M-45,C-6 (Ex-Rsp) | 112.23 |
| **CRGO Electrical Steel Lamination** | 666381.00 |
| **NON-FERROUS METALS** | |
| Electrolytic High Grade Zinc | 290600.00 |
| Lead (99.97%) | 206600.00 |
| Copper Wire Bars | 893782.00 |
| Copper Wire Rods | 914057.00 |
| Aluminium Ingots - EC Grade (IS 4026-1987) | 284122.00 |
| Aluminuium Properzi Rods - EC Grade (IS5484 1978) | 289872.00 |
| Aluminium Busbar (IS 5082 1998) | 350410.00 |
| **OTHER RAW MATERIALS** | |
| Epoxy Resin CT - 5900 | 766.00 |

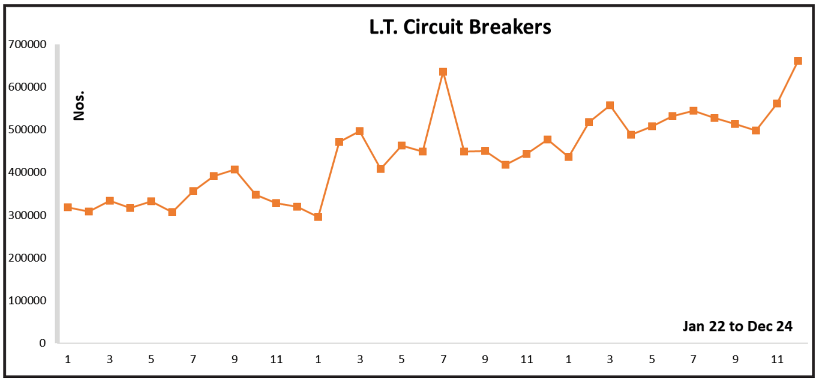
| | |
|---|---|
| Phenolic Moulding Powder | 110.00 |
| PVC Compound - Grade CW- 22 | 158325.00 |
| PVC Compound Grade HR - 11 | 159325.00 |
| Transformer Oil Base Stock (TOBS) | 96467.00 |
| | |
| **OTHER IEEMA INDEX NUMBERS** | |
| IN-BUSDUCTS (BASE August 2000=100) FOR THE MONTH January 2025 | 376.21 |
| IN - WT (BASE JUNE 2000=100) | 398.26 |
| Wholesale price index number for 'Insulators' (Base 2011-12 = 100) for the month January 2025 | 130.40 |
| Wholesale price index number for 'Manufacture of Basic Metals (Base 2011-12 = 100) for the month January 2025 | 137.20 |
| Wholesale price index number for' Fuel & Power (Base 2011-12 = 100) for the month January 2025 | 152.00 |
| ALL INDIA AVERAGE CONSUMER PRICE INDEX NUMBER FOR INDUSTRIAL WORKERS (BASE 2016=100) January 2025 | 143.20 |
| # Estimated, NA: Not available | |






*Source: IEEMA*

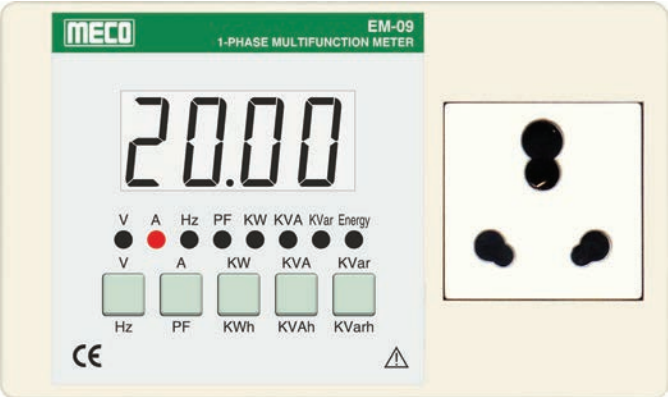
# Production Statistics




| Name of Product | ACC Unit | Production | | Highest Annual Production |
|---|---|---|---|---|
| | | For the Month December-24 | From Jan 24 to December 24 | |
| Electric Motors | | | | |
| AC Motors - LT | 000' KW | 1,802.00 | 20,074.00 | 19,195.00 |
| AC Motors - HT | 000' KW | 526.00 | 5,099.00 | 5,273.00 |
| DC Motors | 000' KW | 27.00 | 439.00 | 618.00 |
| | | | | |
| Switchgears * | | | | |
| Contactors | 000' Nos. | 1,704.00 | 18,303.00 | 16,503.00 |
| Motor Starters | 000' Nos. | 198.00 | 2,573.00 | 2,427.00 |
| SDF | 000' Nos. | 68.00 | 673.00 | 752.00 |
| Circuit Breakers DIN Rail Mounted | 000' Poles | 22,640.00 | 238,598.00 | 221,179.00 |
| Circuit Breakers - LT | Nos. | 660,715.00 | 6,433,768.00 | 5,703,052.00 |
| Circuit Breakers - HT | Nos. | 7,879.00 | 106,939.00 | 119,282.00 |
| Custom Built Product | Rs. Lakhs | 30,499.00 | 304,244.00 | 452,536.00 |
| HRC Fuses & Overload Relays | 000' Nos. | 1,215.00 | 15,848.00 | 17,246.00 |
| | | | | |
| Power Cables * | KM | 87,734.00 | 1,095,563.00 | 1,052,205.00 |
| | | | | |
| Power Capacitors - LT & HT | 000' KVAR | 6,167.00 | 64,156.00 | 65,385.00 |
| | | | | |
| Transformers * | | | | |
| Distribution Transformers | 000' KVA | 5,537.00 | 57,971.00 | 58,341.00 |
| Power Transformers | 000' KVA | 27,264.00 | 240,940.00 | 234,922.00 |
| | | | | |
| Instrument Transformers | | | | |
| Current Transformers | 000' Nos. | 656.00 | 5,086.00 | 1,390.00 |
| Voltage Transformers | Nos. | 17,668.00 | 210,316.00 | 217,752.00 |
| | | | | |
| Energy Meters | 000' Nos. | 2,868.00 | 32,194.00 | 28,579.00 |
| | | | | |
| Transmission Line Towers * | 000' MT | 107.00 | 1,130.00 | 1,250.00 |

** Weighted Production*

# Single Phase Multifunction Appliance Metre




**MECO Single Phase Multifunction Appliance Meter Model – EM-09** – is a **microcontroller based portable metre,** light weighted and simple to use. The single-phase measurement indicates TRMS value with 10 parameters like RMS voltage (V), RMS Current (mA), active power (kW), apparent power (kVA), reactive power (kVAr), power factor (PF), line frequency, active energy (kWh), apparent energy (kVAh) and reactive energy (kVArh). Model EM-09 is available with a measurement range of 1A or 5A or 20A AC with smart socket and power cord. It is also available (optional) with RS-485 port and power master software for MS report.

It displays 10 pages on a large LCD display (20 mm) and is equipped with five keys to program and view all parameters. It has auto or manual scroll display (user selectable), green and white backlight display, ABS casing suitable for desktop mounting, and is portable – these are key features of MECO EM-09.

Model EM-09 has various applications such as appliance testing, AC, refrigerator, washing machine, LED light testing, energy audit, studying energy efficiency of electrical equipment, building and power management system, product quality system, R&D department for designing energy efficiency products, among others.

# AD INDEX

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# SHOCKS and SPARKS

## FAMOUS FEASTS

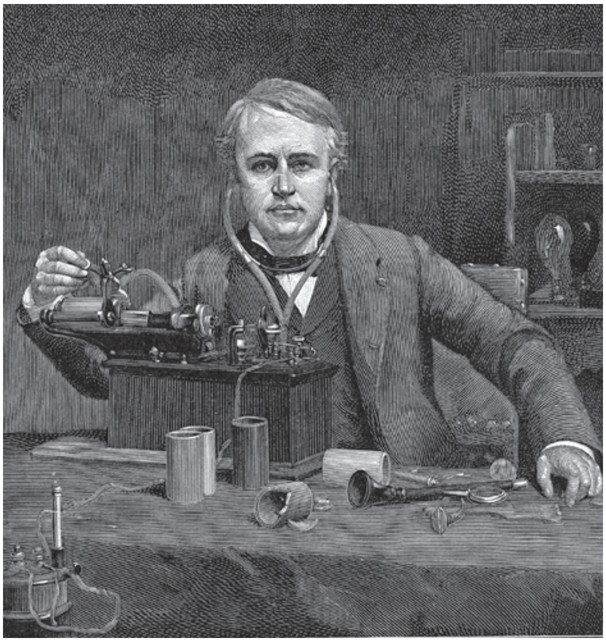
Edison who claimed that he was an Inventor and not a Scientist was quite a character. He approached theoretical and mathematical aspects of science with the same practical instincts and natural ability that characterised every other phase of his work. He often beat scientists and mathematicians in reaching the correct solution.

He often said, "these scientists and mathematicians make me tired. You ask them to solve a problem and they take a piece of paper, cover it with rows of a's and b's and x's and y's, decorate them with lots of numbers, scatter a mass of fly-specks around them and then give you an answer which most probably is all wrong."

Edison's school of scientific experimentation was essentially empirical. Once he was seeking a solvent for hard rubber. He gave this problem to several scientists, but no result seemed to be forthcoming. Ultimately Edison took the matter in his own hands. He ordered samples of chemicals available in the towns and emersed a small fragment of hard rubber in a vial of each one of the many chemicals. It was an enormous number, but Edison found his solvent.

Before succeeding to develop a new storage battery, he conducted some 50,000 unsuccessful experiments. One eminent scientist, not knowing the hard work behind the invention, admired the simplicity of the process and remarked, "Thomas you are a born genius. How quickly you get your results."

"Results?" replied Edison, "Why man, I have gotten a lot of results. I know fifty thousand things that won't work."



A step which seems obvious after it has been taken is frequently obscure before it has been pointed out. No matter how close to it, we may have been led by the slow and painful process of learning and experimentation. One such step was taken by Edison in one of the processes of subdividing an electric current. Subsequently a patent row arose over the matter, in which the famous English Physicist Tyndall was called upon to testify.

He mentioned that he had followed the same course taken by Edison and had hesitated before the final step, which now seemed so childishly clear. One of the attorney's demanded of him, "When the next step was so obvious why did you not take it?"

"Because" replied Tyndall, "I was not Thomas A. Edison."

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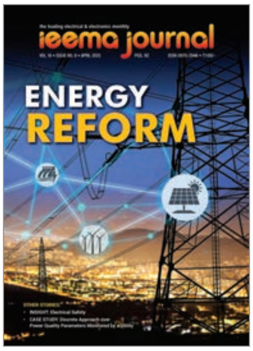

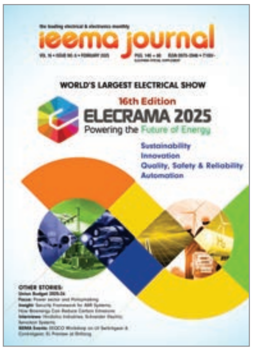

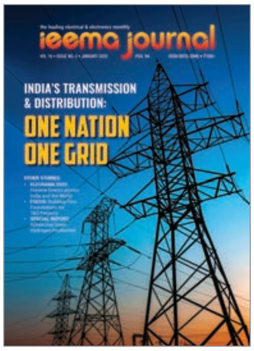


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