

the leading electrical & electronics monthly (English)

# ieema journal

VOL 17 • ISSUE NO. 10 • JUNE 2026

PGS. 92

ISSN 0970-2946 • ₹100/-

# ENERGY METERS

## USD 2 BILLION DOMESTIC DEMAND OPPORTUNITY BY 2034



### OTHER STORIES:

- **INSIGHTS:** Energy Companion Smart Meter; Renewable Integration Challenges and its Metering Perspective
- **SPECIAL REPORTS:** India meets Highest Peak Power Demand; Rajasthan's First Semiconductor Plant
- **FOCUS:** Smart Meters – Driving Sustainable Energy Transition; Electrical Design for Net-Zero Buildings

# Renewable Integration Challenges and its Metering Perspective

This paper by Sushil Kumar Jangir and Shafik Ahmad of Secure Meters Ltd highlights the need for ongoing technical innovation to enhance the reliability and flexibility of power systems with high renewable energy penetration.

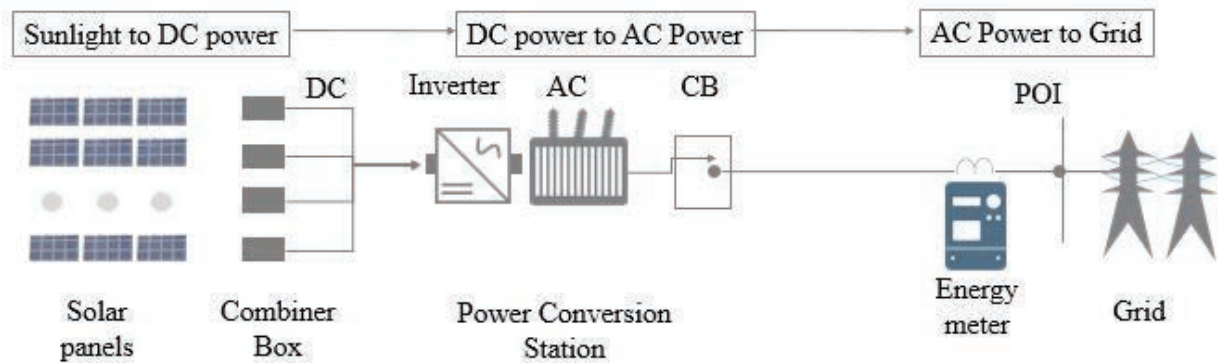


The increasing penetration of renewable energy (RE), particularly inverter-based resources (IBRs) such as solar photovoltaic (PV) and wind power plants, has introduced new challenges to power system stability and reliability. Unlike conventional synchronous generators, RE plants interface with the grid through power electronic inverters, whose behaviour during grid disturbances significantly influences overall system performance.

One of the most critical challenges associated with high RE penetration is the ability of inverters to remain connected and support the grid during fault conditions, commonly referred to as fault ride-through (FRT).

FRT capability is defined as the ability of a grid-connected device, such as an inverter, to stay connected and operate within specified limits during voltage disturbances, including voltage sag and swell caused by grid faults. Historically, many inverters were designed to disconnect rapidly during such events to protect internal components. However, large-scale and simultaneous disconnection of PV plants during grid disturbances can lead to severe consequences, such as frequency instability, voltage collapse, and cascading outages. Consequently, modern grid codes mandate that inverters must remain connected and actively support the grid during faults by providing dynamic reactive power

Figure 1: Typical Configuration of a Utility-Scale Solar PV Power Plant



and controlled active power response. The rapid expansion of RE capacity has amplified challenges related to grid stability, power quality, voltage control, and regulatory compliance.

In the Indian power system context, Grid-India plays a crucial role in managing system operations during grid events, ensuring reliability and availability, driving regulatory compliance to meet national renewable targets, maintaining accountability to the Ministry of Power (MoP), and approving first-time charging and integration of renewable plants. Key technical challenges associated with inverter-based RE integration include harmonics and power quality (PQ) issues, voltage flicker, grid stability concerns, voltage and reactive power control, weak grid conditions, and compliance with stringent FRT requirements.

Figure 1 illustrates a typical layout of a utility-scale solar PV power plant up to the point of interconnection (POI), comprising solar PV arrays,

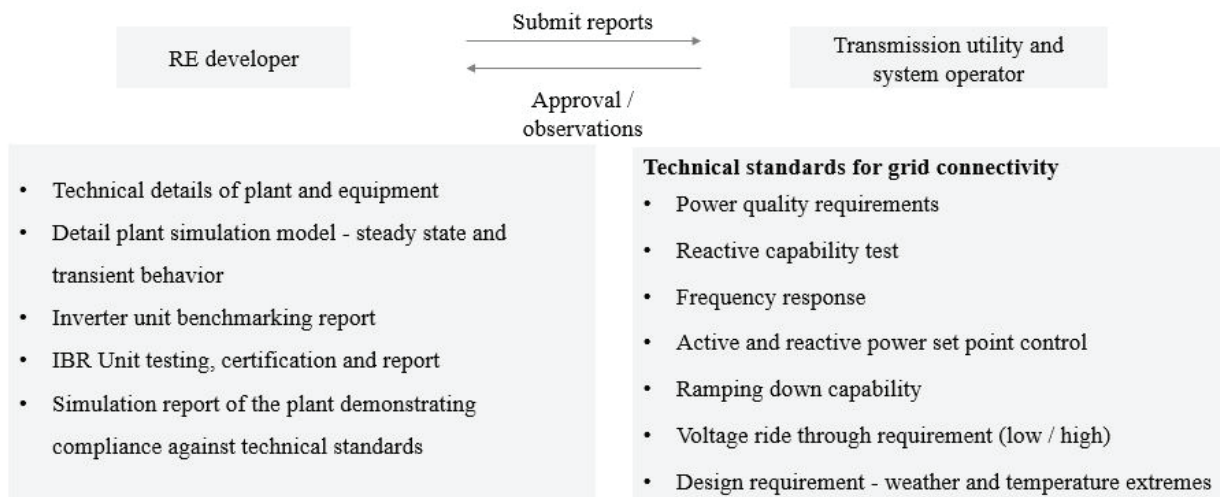
direct current (DC) combiner boxes, grid-tied inverters, step-up transformers, substations, and centralised monitoring and control systems such as supervisory control and data acquisition (SCADA).

These components collectively enable efficient power conversion, protection, grid synchronisation, and remote operation. Emphasis is placed on first-time RE integration approval processes and compliance verification, as seen in Figure 2.

After RE integration, operational common issues observed include unexpected inverter tripping during real-time grid events that are not accurately reflected in simulation models. This discrepancy often arises due to unmodeled inverter protection settings, excessive active power reduction during minor voltage dips, non-compliance with high voltage ride-through (HVRT) requirements, and inadequate coordination between protection and control systems.

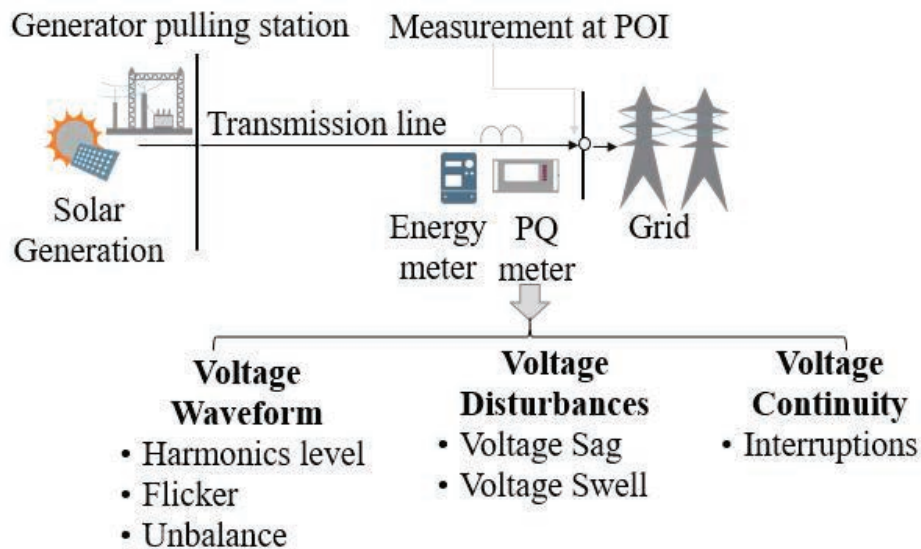
From a regulatory perspective, evolving grid

Figure 2: First Time RE Integration – Approval Process



Source: CIGRE-India Study Committee C2 Webinar Series presented by A Janardhan, Pradeep Kumar Sanodiya, dated: 1st Dec-23[1]

**Figure 3: Power Quality Measurement and Monitoring at POI**



codes demand advanced inverter functionalities, accurate PQ measurements, harmonic mitigation, and dynamic reactive compensation solutions such as static synchronous compensator (STATCOMs), leading to increased project costs and implementation complexity.

This paper outlines key grid connectivity regulations at the POI and its monitoring, including:

- Continuous PQ monitoring using IEC 61000-4-30 Class A meters.
- Harmonic emission limits as per IEEE 519.
- Monitoring of voltage sag, swell, and interruptions, power factor requirements within  $\pm 0.95$ .
- Operation within the frequency band of 49.5 Hz to 50.5 Hz, mandatory FRT testing, and the provision of dynamic reactive power support by RE generators.

### Applications

Continuous measurement and monitoring at the POI are required as per the Central Electricity Authority (CEA) Technical Standards for Connectivity to the Grid[2] and the Indian Electricity Grid Code (IEGC) Regulations[3]. These standards specify that solar and wind power plants must ensure compliance at grid connection points through continuous harmonic measurements using permanently installed meters that conform to IEC 61000-4-30 Class 'A'. Harmonic measurements are conducted to verify that voltage harmonics remain within prescribed limits on the utility side, and current harmonics remain within prescribed limits for each user. Accordingly, the meter or software solution should be capable of detecting the direction of harmonics.

Compliance with these codes is mandatory for

the connection and continued operations of the renewable plant. Regular monitoring ensures that the plant stays within these limits, ensuring grid stability.

Figure 3 illustrates installation of a revenue meter and PQ meter installation at POI.

### Findings

#### Finding through PQ meter

Normally, energy meters are installed at interconnection points. Due to the low processing capability of energy meters, the disturbance at POI cannot be found.

We installed revenue and PQ meter at interconnection points of two solar power plants in Maharashtra. We observed instantaneous data, waveform streaming, events trends, and PQ compliance according to EN50160 and IEEE 519.

Findings are below (also refer to Table 1):

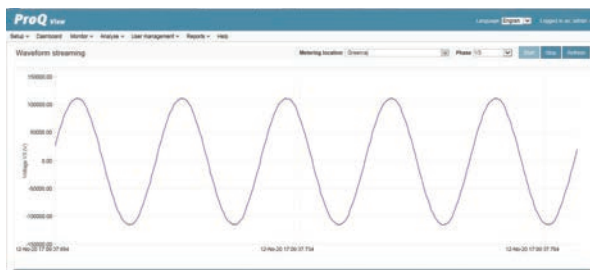
- Harmonic distortion observed voltage THD: 1 percent and current THD: 1 percent to 29 percent (at lower generation).
- Dominating current harmonics is 3rd order.
- Harmonic flow is source to load.
- IEEE 519-2014 compliance observed 'Failed'.
- Voltage quality (EN50160) compliance also failed.
- Frequent voltage sag/dip events observed at POI.
- Most of the sag events are downstream.
- Rapid voltage change events recorded.
- Distorted current waveform.
- High reactive power flow in under load line during nights.

**Table 1: Findings through the PQ meter data**

Measurement and Observation (One month data)	50 MW 132kV/110 V, 500A/1A	5 MW 11 kV/110V 300A/5A
Average current during 7:00 - 17:30	~94 A	~145 A
Max current flow	~142A	~287A
Voltage THD	1%	1%
Current THD	1% to 7%	1% to 29%
Dominating current harmonics	5 <sup>th</sup> and 7 <sup>th</sup>	3 <sup>rd</sup>
Harmonic flow direction	Source to load	Source to load
IEEE 519 compliance	Failed for TDD	Pass
Voltage quality (EN50160) compliance	Pass	Failed
Frequent events	Sag (downstream)	Sag (downstream)

**Figure 4: Sinusoidal Waveform Captured at Interconnection Point (Large Solar Plant)**

**(a) Voltage Waveform Streaming**



**(b) Current Waveform Streaming**



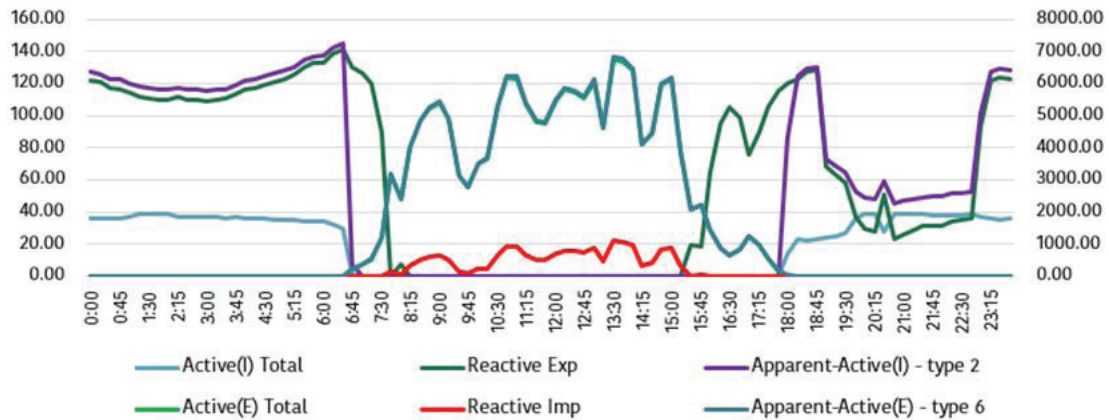
Also captured is the Sinusoidal waveform at interconnection point (large solar plant; refer to Figure 4). Captured are real-time voltage and current waveform streaming to analysis distortion in sinusoidal waveform at interconnection point. We observed high current THD, due this current waveform distorted. It means harmonic affects the pure sinusoidal waveform.

Additionally, we observed the generation, load, and THD behaviour (Refer to Figure 5).

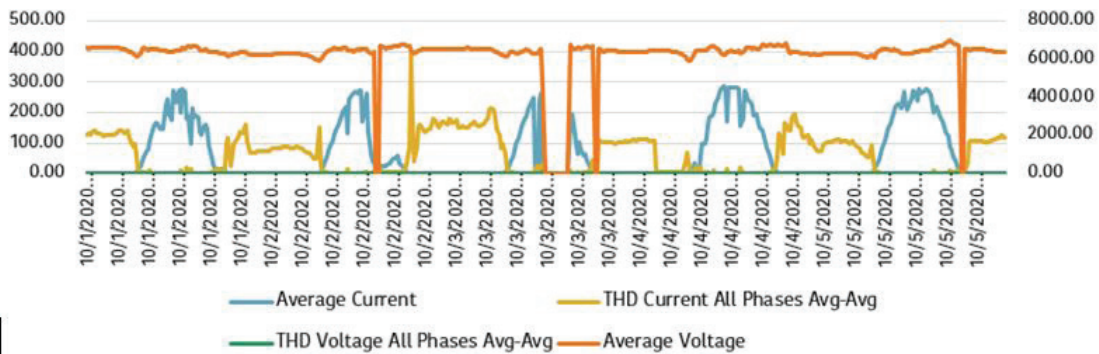
Using logger data, we observed the behaviour of load and generation for 24 hours. During the night, solar generation plant drew the load from high voltage transmission utility. Figure 6 shows the low active power (~40 kW), where high reactive power (~120 kVAr) was recorded. Due to this, higher maximum apparent demand (~130 kVA) was logged, which led to unnecessary penalty to the generator. During the night, with low loaded line capacitance, the reactive power generates high.

Additionally, it was observed that harmonic distortion is higher at lower current and lower at higher current, as shown in Figure 6.

**Figure 5: Generation, Load, and THD Behaviour in Day and Night Time**



**Figure 6: Harmonic Distortion Behaviour at Lower and Higher Current**



**An Integrated Single-Meter Solution That Combines Revenue Metering & Power Quality**

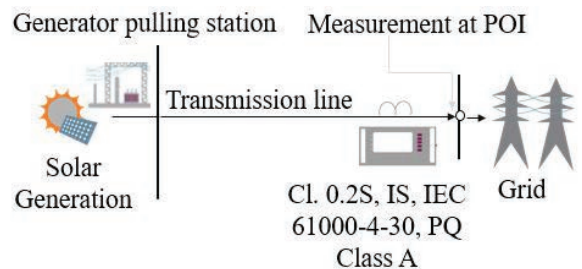
Considering the emerging need of precision metering for revenue and PQ compliance monitoring at POI, an integrated single-meter solution that combines revenue metering and PQ measurement provides a cost-effective and optimised approach for grid-connected installations. In contrast to deploying separate revenue and PQ meters – which requires additional metering panels, voltage and current transformers (VTs and CTs), extensive wiring, and independent data acquisition systems – the integrated solution significantly reduces both capital expenditure and operational costs. Furthermore, the use of multiple independent metering systems introduces challenges related to data synchronisation, consistency, and authenticity, which are effectively addressed through a unified (Revenue and PQ) metering architecture.

Figure 7 illustrates installation of a single meter that combines revenue metering and PQ monitoring.

The above solution supports multiple communication protocols, enabling seamless

interoperability within heterogeneous substation environments. Precision energy meters are often required to communicate using diverse protocols such as Modbus, IEC 61850, and Ethernet/IP to interface with various equipment and control systems. Multi-protocol capability allows simultaneous integration with legacy infrastructure and modern digital platforms without the need for external protocol converters, thereby simplifying system design and enhancing reliability.

**Figure 7: Integrated Single Box Solution for Both Revenue Settlement and Power Quality Compliance Monitoring**



In addition, the availability of multiple communication ports enables simultaneous data access by multiple stakeholders. Grid operators, maintenance personnel, and third-party monitoring services can securely access metering data in parallel without operational interference. Dedicated communication channels support real-time grid monitoring for operators, while parallel data streams can be provided to SCADA systems or remote monitoring platforms for supervisory and analytical purposes.

This architectural flexibility ensures efficient data exchange across systems with varying protocol and data format requirements, supporting advanced grid operations and improved system reliability.

Furthermore, the availability of reliable PQ measurements enables the potential adoption of PQ-based tariff mechanisms in the future, supporting penalisation or incentive schemes. The proposed solution also provides a complete turnkey offering, encompassing hardware, communication infrastructure, servers, software platforms, and long-term maintenance, thus ensuring scalability, reliability, and regulatory compliance.

### Technical Contributions

This paper presents significant technical contributions that enhance grid visibility, control, and compliance for renewable energy (RE) integration. The proposed approach extends real-time visibility of grid parameters and performance beyond the POI, enabling a deeper understanding of network behaviour.

Localised control mechanisms reduce dependency on communication latency between the POI and IBRs, thus improving operational reliability. Continuous local feedback loops simplify ramp-up and ramp-down processes, ensuring smoother grid interaction.

The solution facilitates verification of grid code and grid connectivity compliance at the POI, including continuous power quality monitoring using permanent metering. It enables data-driven actions for system improvement by RE developers as well as central transmission utilities (CTU) and state transmission utilities (STU) operators.

Integrated dashboards and visualisation tools support preventive actions and power quality assessment. Furthermore, the proposed integrated single-meter solution offers a cost-effective means to detect, measure, and evaluate supply voltage quality alongside revenue and trade energy parameters. Overall, the work highlights the need for ongoing technical innovation to enhance the reliability and flexibility of power systems with high RE penetration.

### Conclusion

Verification of grid code and grid connectivity compliance at the POI, including continuous PQ monitoring using permanent PQ meter. It enables data-driven actions for system improvement by RE developers as well as CTU/STU operators.

Overall, the work highlights the need for power quality measurement along with revenue metering at POI to enhance the reliability and flexibility of power systems with high RE penetration.

### Bibliography

- [1] CIGRE-India Study Committee C2 Webinar Series presented by A Janardhan, Pradeep Kumar Sanodiya, dated: 1st Dec-23
- [2] [https://cea.nic.in/wp-content/uploads/2020/02/notified\\_regulations.pdf](https://cea.nic.in/wp-content/uploads/2020/02/notified_regulations.pdf)
- [3] <https://cercind.gov.in/Regulations/180-Regulations.pdf>

### ABOUT THE AUTHORS



**Sushil Kumar Jangir** is the leading **technical specialist** and **Deputy General Manager** at **Secure Meters Ltd.** Having served the company for almost two decades, he mainly contributes to product development and application engineering; he is dedicated to

addressing power quality, summation, Grid metering, and Network monitoring & analytics solutions.

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.



**Shafik Ahmad** is **General Manager** and **Vice Dean of Secure Academy** at **Secure Meters Ltd.** Having served the company for almost three decades, he is dedicated to addressing strategic training needs of employees while nurturing growth of new joiners.

Ahmad holds degrees of BE Honors in Electrical Engineering and MBA. He has taken on several critical roles throughout his career, including embedded software development, head of product validation, head of quality assurance, senior project manager in R&D, and head of product management in marketing. He was also part of the team that developed India's first 'Frequency-Based ABT Metering Solution' – an innovation that earned the Government of India's Best R&D Award.

