# An Overview of Performance Validation, Testing Protocols, and Standards for Smart Meters

**Vikram Kulkarni*[1], Bhisaji Surve[2]**

[1, 2]Assistant Professor (Senior), Dept. of Information Technology, Mukesh Patel School of Technology Management and Engineering, SVKM's NMIMS (Deemed to be University), Mumbai, Maharashtra, India.
Emails: vikram.kulkarni@nmims.edu ; bhisaji.surve@nmims.edu;

**Abstract**

This document provides a thorough overview of the testing protocols and standards for smart meters, which are essential parts of the contemporary smart grid. It emphasizes the switch from analog to digital smart meters, which provide two-way communication and real-time data on electricity consumption. In order to guarantee accuracy, dependability, conformity with international standards such as those from the IEC, NIST, and BIS, and the protection of customer data, the document highlights the significance of conducting thorough testing. In order to evaluate several performance factors including insulation, accuracy, and electromagnetic compatibility, it covers a variety of tests, such as metrology, load switch capability, data exchange protocols, and communicability. Smart meters must be thoroughly tested and validated in order for them to operate effectively, reliably, and safely. This will help utilities minimize revenue losses and encourage good energy management.

**Keywords:** Data analysis; Standards; Testing; Smart meters; Reliability; and Smart grid.

## 1. Introduction

For the header and the footer, just change the journal name and the abbreviation, then leave all other information for our production team at the ASPG editorial office to be updated after your paper acceptance.

This article gives linear model, which is the direct simplex method using neutrosophic logic, the logic that is the new vision of modelling and is designed to effectively address the uncertainties inherent in the real world founded by the Romanian mathematician Florentine Smarandache [1, 2]. In addition to that, Ahmed A. Salama presented the theory of neutrosophic classical categories as a generalization of the theory of classical categories [12,20], also, he developed, introduced, and formulated new concepts in the various disciplinary of mathematics, statistics, computer science by neutrosophic theory [17,18,19,22,28].

The smart grid, a cutting-edge electrical network that employs cutting-edge technology to improve the economy, dependability, and sustainability of the energy supply, is not possible without smart meters. Digital gadgets known as "smart meters" take the place of more conventional analog meters and provide real-time electricity consumption measurements. They may send information to the utility company and receive instructions from it thanks to their two-way communication capabilities [1].

In order to transmit data between meters and utilities, smart meters rely on a variety of technologies, including communication networks such as powerline communication, Wi-Fi, Zigbee, or cellular networks. They rely on Advanced Metering Infrastructure (AMI), which includes software programs, data management systems, and communication networks for remote meter management and real-time data interchange. Figure 1. The block diagram for testing and standards for smart meters. Data management systems use databases, storage, and analytics technologies to manage the massive volume of created data [2]. Advanced metering technology is used by smart meters to provide precise measurements, while security protocols protect system integrity and data privacy. User-friendly interfaces also let consumers obtain data on energy consumption and encourage energy saving. Examples of these interfaces include mobile apps and in-home displays. Smart meter and energy management system capabilities are further enhanced by ongoing technical breakthroughs [3].



Doi : https://doi.org/10.54216/JCHCI.070102
Received: August 02, 2023 Revised: October 19, 2023 Accepted: January 26, 2024

There are several reasons why testing smart meters is crucial. First of all, it guarantees the precision measurement of power consumption and guards against billing errors by ensuring the accuracy and dependability of the meters. Second, testing facilitates interoperability and compatibility between various deployments by ensuring adherence to industry standards and laws. Thirdly, it protects against tampering and illegal access by confirming the security and integrity of customer data. Furthermore, testing evaluates how well smart meters communicate with utility systems to guarantee efficient data transfer. Additionally, it validates the meters' features and performance, including demand response and time-of-use pricing. Additionally, testing verifies smart meters' resistance to various environmental conditions and assesses their long-term dependability and durability. In conclusion, it facilitates the display of regulatory adherence, guaranteeing responsibility and safeguarding customer interests. Thus, thorough testing is essential to guarantee smart meters that are accurate, dependable, safe, and compliant—a win-win situation for utility providers and customers alike [4].

The rest of the paper is structured as follows: in Section 2, we will examine in further depth the methods used for smart meter accuracy and reliability testing in an effort to give readers a better understanding of how these crucial factors are evaluated. Our study will provide insight into the standards and procedures used to assess the accuracy of smart meters' readings and their overall performance. We will continue to explore the complex realm of smart meter testing as we go through the ensuing parts. The security and integrity of customer data will be the main topics of Section 3, the particular test specifications for smart meters will be covered in Section 4, and the importance of thorough testing will be emphasized in Section 5. Together, these upcoming parts will provide a comprehensive understanding of the critical role that thorough testing plays in guaranteeing the dependability and security of smart meters in the context of contemporary smart grid technology. We will also cite a number of in-depth sources to support our analysis and conclusions.

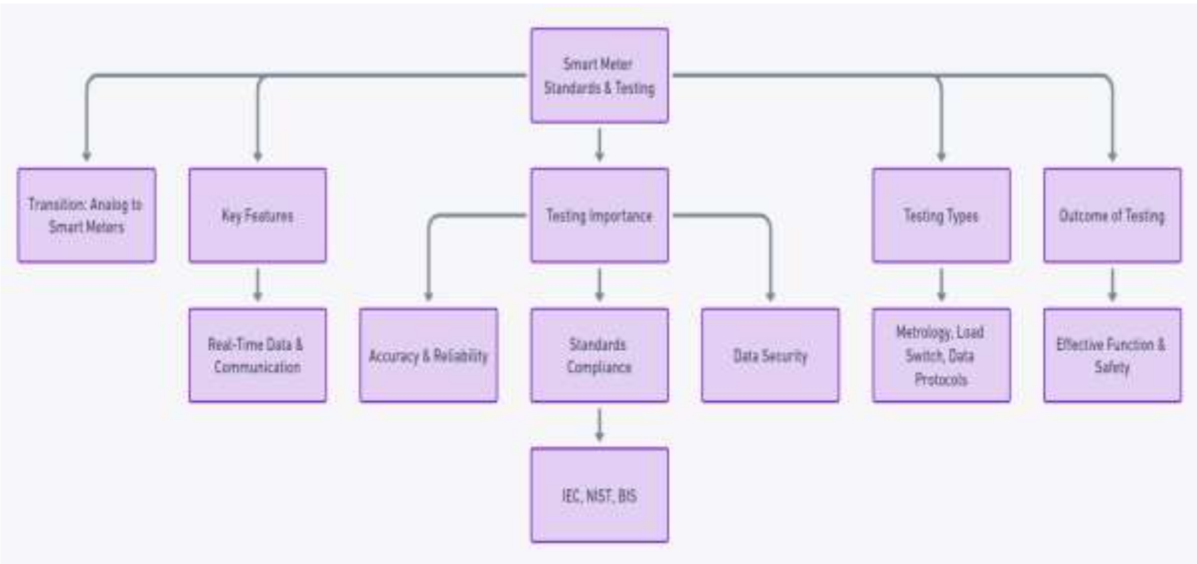


Figure 1: The block diagram for testing and standards for smart meters.

## 2. Verifying the meters' dependability and accuracy

It is important to guarantee the precision and dependability of smart meters for multiple rationales. First and foremost, since customers are only charged for the exact amount of electricity they use, accurate meters ensure billing equity. Customers are therefore encouraged to have faith and confidence in the metering system. Furthermore, accurate revenue collection from meters is essential for utility companies to prevent financial losses due to incorrect invoicing. Utilities can improve customer satisfaction, ensure equitable billing, and support their operational financial stability by keeping accurate and dependable meters [5].

Billing problems can be avoided in a number of ways. By verifying the readings on smart meters against established benchmarks and making any required corrections, routine calibration and maintenance help guarantee their accuracy. In order to confirm meter accuracy, utilities can put in place meter-testing programs. These can be carried out by complete testing conducted during installation and maintenance, or through sample testing. Utilities can take corrective action by utilizing data analytics and auditing approaches to identify



Doi : https://doi.org/10.54216/JCHCI.070102
Received: August 02, 2023 Revised: October 19, 2023 Accepted: January 26, 2024

anomalies in meter data that might point to billing problems. Customer education regarding smart meters, prompt correction of billing mistakes, and clear billing procedures enable customers to keep an eye on their usage and identify inconsistencies. Utilities can reduce billing errors, maintain precise and dependable smart metering systems, and encourage equitable billing practices by putting these strategies into effect [6].

Regulations and industry standards are essential for guaranteeing the precision, dependability, and compatibility of smart meters. An outline of some important guidelines and rules pertaining to smart meter testing is provided below:

**A. Standards of the International Electro-Technical Commission (IEC):**

Particularly for smart meters and other forms of power metering, the IEC has created a number of standards. IEC 62052, IEC 62053, and IEC 62056 are notable standards that address a variety of topics, including functionality, accuracy, communication protocols, and testing techniques. These standards are essential for guaranteeing the precision, dependability, and compatibility of smart meters and other power metering devices. They aid in the establishment of uniform procedures and system interoperability across various metering systems by offering specifications and recommendations for meter design, testing, and communication protocols. Adherence to these guidelines fosters clarity, precision, and dependability in the assessment and communication of energy information, which is advantageous for utility companies as well as customers [7]. The International Electrotechnical Commission (IEC) has established a number of significant standards related to electricity metering, including smart meters, including IEC 62052, IEC 62053, and IEC 62056. Below is a quick synopsis of every standard:

- IEC 62052: General requirements and test conditions for a.c. are provided by this standard, which is titled "Electricity metering equipment (a.c.) - General requirements, tests and test conditions - Part 1: General requirements and tests." electricity metering apparatus for alternating current. It addresses topics like mechanical design, electromagnetic compatibility, precision, dependability, environmental factors, and meter testing.
- The IEC 62053 standard, "Electricity metering equipment (a.c.) - Particular requirements - Part 21: Static meters for active energy (classes 1 and 2)," is dedicated to the measurement of active energy in a.c. with a particular focus on static meters. systems. It outlines the specifications for metrological requirements, performance attributes, accuracy classes, and testing procedures for static meters.
- IEC 62056: Referred to as "Electricity metering data exchange - The DLMS/COSEM suite - Part 1: Use of local area networks on twisted pair with carrier signalling," this standard outlines the data exchange protocol used for DLMS/COSEM (Device Language Message Specification/Companion Specification for Energy Metering) electricity metering systems. It offers a standardized communication protocol that enables utility systems, data concentrators, and smart meters to exchange data. The standard addresses topics including interoperability with various communication networks, security, message exchange protocols, and data formats.

**B. Standards from the National Institute of Standards and Technology (NIST):**

The Smart Grid Interoperability Standards, or SGS, are developed and maintained in the United States by the NIST. These standards address things like communication protocols, data sharing formats, meter accuracy, and interoperability testing methods. The accuracy, dependability, and interoperability of smart meters are guaranteed by a set of standards and criteria for testing created by the National Institute of Standards and Technology (NIST). When it comes to testing smart meters, utilities, manufacturers, and testing labs can all benefit greatly from these NIST standards and guidelines. They provide a framework for evaluating the security, interoperability, accuracy, and dependability of smart meters, which aids in guaranteeing the general caliber and functionality of these gadgets inside the smart grid ecosystem [8]. In order to contribute to a safe and effective smart grid infrastructure, stakeholders can analyze and validate the capabilities and compliance of smart meters by following these criteria. The following are some important NIST guidelines for evaluating smart meters:

Guidelines for testing the cybersecurity features of smart meters and the larger smart grid infrastructure are provided in,

- NISTIR 7823: Smart Grid Cybersecurity Testbed Capabilities. It describes different testbed capabilities and approaches to evaluate the dangers and security flaws related to smart meters.
- NISTIR 7823A: Smart Grid Use Cases: This paper provides an extensive collection of use cases for assessing and testing smart grid components, such as smart meters. These use cases, which address a



Doi : https://doi.org/10.54216/JCHCI.070102
Received: August 02, 2023 Revised: October 19, 2023 Accepted: January 26, 2024

range of scenarios and functionalities, aid in verifying the effectiveness, dependability, and compatibility of smart meters in diverse real-world contexts.

- NIST SP 1108: Testing Smart Grid Devices for Compliance with NIST Standards: This paper offers instructions for determining whether smart grid gadgets—such as smart meters—comply with NIST standards. It provides thorough testing protocols, scenarios, and approaches to confirm that smart meters meet the precise NIST criteria.
- NISTIR 7628: Guidelines for Smart Grid Cybersecurity: This paper addresses smart grid cybersecurity, including smart meter cybersecurity. It gives recommendations and best practices for safeguarding smart meter deployments and reducing potential cybersecurity concerns, but it does not include explicit testing methodologies.

### C. The Indian Standards Bureau (BIS)

In fact, the Bureau of Indian Standards (BIS) was a trailblazer in the establishment of smart meter conformance standards. The BIS published the smart meter standard IS 16444 (Part 1) in 2015, and IS 16444 (Part 2) in 2017. The smart metering market in India and others has benefited greatly from these internationally recognized standards [9].

The first section of IS 16444 addresses the overall specifications and testing methods for smart meters. It establishes standards for smart meter functioning, accuracy, and technical details. Data security, communication protocols, electrical safety, and metrological standards are only a few of the topics covered by the standard.

The functional specifications for smart meters are particularly covered in IS 16444 (Part 2). It outlines the several features and capabilities that smart meters ought to have, such as communication interfaces, load control, tamper detection, and time-of-use monitoring. By adhering to this standard, smart meters are guaranteed to fulfill precise performance standards and be able to facilitate enhanced energy management and invoicing features.

By encouraging openness, dependability, and compatibility amongst smart meter deployments in India and acting as a model for other nations creating their own smart metering standards, BIS's efforts to introduce these standards have had a major impact on the smart metering industry.

- **Cross-reference IS 16444: 2017 with Indian Standards**

The emphasis of IS 14697: 1999 (RA 2019) is on a.c. Watthour and VAR-hour meters that run on a static transformer. It outlines the specifications for the accuracy classes of Class 0.2S, 0.5S, and 1.0S. The precision, functionality, and testing protocols for these transformer-operated meters are outlined in the standard.

As previously indicated, IS 15959 (Part 1): 2011 (RA 2016) - This standard covers the data interchange for tariff, load control, and energy meter reading. The companion standard for static energy meters is the main topic of Part 1. It outlines the protocols, communication interfaces, and data interchange format needed for efficient load control and meter reading.

Another companion specification to IS 15959 is IS 15959 (Part 3):2017. It focuses on data interchange for tariff and load control for smart meters with transformer-operated kWh and kVARh, as well as electrical meter reading. It includes accuracy classes Class 0.2S, 0.5S, and 1.0S. For these transformer-operated smart meters to communicate and work together, the standard specifies the communication interfaces, formats, and data exchange protocols.

### D. Regulations at the national and regional levels:

Regulators frequently set strict guidelines for smart metering in order to guarantee system dependability, fair billing, and consumer safety. These specifications may differ from one nation or area to another. These could include testing techniques, data security, privacy protection, communication protocols, and meter accuracy standards. In order to guarantee the accuracy and dependability of their smart meter deployments, utility companies are usually required to adhere to certain requirements [11].

### E. Programs for Certification:

Programs to verify the precision and compliance of smart meters are provided by a number of organizations and certifying authorities. To make sure smart meters fulfill the necessary requirements, these programs put them through rigorous testing and compare their results to predefined criteria. Examples are the MID (Measuring



Doi : https://doi.org/10.54216/JCHCI.070102
Received: August 02, 2023 Revised: October 19, 2023 Accepted: January 26, 2024

Instruments Directive) certification in the European Union [13] and the Measurement Canada Certification for power meters in Canada [12].

### F. Standards for Interoperability:

An essential component of smart metering is interoperability, which enables easy integration and communication between meters made by various manufacturers and utility systems. Interoperability between smart meters and utility systems is made possible by standards like the Open Smart Grid Protocol (OSGP) [14], Common Information Model (CIM) [15], and DLMS/COSEM (Device Language Message Specification/Companion Specification for Energy Metering) [16], which specify data models and communication protocols. For the purpose of testing smart meters, adherence to various industry norms and laws is necessary. It guarantees that meters adhere to precision standards, communicate clearly, and protect user privacy and data security. Adherence to these guidelines and protocols bolsters the dependability and compatibility of intelligent metering platforms, fosters equitable invoicing procedures, and safeguards the concerns of both power providers and customers.

## 3. Verifying the accuracy and safety of customer information

The energy sector is seeing a rise in the use of smart meters, which makes it more important than ever to protect their security and integrity. Sensitive data is generated and transmitted by smart meters, leaving them open to manipulation and cyberattacks. Standards for evaluating the security and integrity of smart meters must so be developed and put into use.

- Standards for assessing the security of smart meters have been developed by the National Institute of Standards and Technology (NIST) and the International Electrotechnical Commission (IEC). These guidelines offer recommendations for testing procedures and best practices to guarantee the availability, confidentiality, and integrity of data from smart meters [17].
- A standard for protecting communication networks in the energy industry is IEC 62351. It contains instructions for evaluating the security of communication protocols, such as Home Area Networks (HAN) and Advanced Metering Infrastructure (AMI), that are utilized in smart meters. Thus, this enhances the resilience of the smart grid as a whole, the protection of consumer data, and the integrity of power system operations [18].
- Additionally, NIST has created a framework for evaluating smart meter security. The framework contains a number of recommendations for evaluating smart meter security, including threat modeling, penetration testing, and vulnerability assessments. Before smart meters are installed, the framework is intended to assist utilities and meter manufacturers in locating and fixing security flaws in them.
- A standard for communication between smart meters and other household appliances is called Smart Energy Profile, or SEP. Smart thermostats and energy management systems, among other devices, may communicate securely with smart meters thanks to security procedures included in the SEP 2.0 standard. Guidelines for evaluating the security of smart meter connectivity with other devices are included in the standard. The Zigbee Alliance is an international consortium of businesses dedicated to developing open, international standards for the Internet of Things (IoT). One of its standards is the Smart Energy Profile (SEP). For interoperability between smart meters, home energy management systems, and other gadgets in the smart grid ecosystem, SEP specifies a communication profile. The objectives of SEP are to enhance grid integration of renewable energy resources, enable demand response programs, and facilitate efficient energy management. It outlines the messaging formats, data models, and communication protocols that allow various systems and devices in the smart grid infrastructure to work together. The most popular versions of the standard, SEP 1.x and SEP 2.0, are defined in distinct ways. The most recent version, SEP 2.0, is built on a service-oriented design and has more features than its predecessor. It allows for versatile connectivity options for smart meters and other devices by supporting many communication protocols like Ethernet, Wi-Fi, and Zigbee. Smart meter readings, energy usage statistics, and pricing signals can all be sent between smart meters, utility systems, and consumer devices using the standardized framework that SEP offers. Customers can use it to get real-time data on energy use, make educated decisions about how much energy they use, and take part in demand response initiatives [20].

## 4. Smart Meter Test Requirements

The smart meter will be governed by:

- Metrology tests
- Test of the load switch's capability



Doi : https://doi.org/10.54216/JCHCI.070102
Received: August 02, 2023 Revised: October 19, 2023 Accepted: January 26, 2024

- Protocol for Data Exchange and
- Test for the communicability of smart meters (optional)

To verify the precision and dependability of smart meters, metrology testing include a variety of evaluations. Manufacturers, utilities, and regulatory agencies can evaluate the design, accuracy, and functionality of smart meters by carrying out these metrology tests. Throughout the meters' lifecycle, these tests assist verify that the meters will function properly, allow for correct billing and energy management, and assure compliance with safety and quality standards [19].

Three categories can be used to group these tests:

- **Type testing:** Type testing concentrate on assessing particular smart meter features and building requirements. The effectiveness of output devices, clearance and creepage distances for electrical safety, correct value display on the meter's interface, and suitable branding for compliance and identification are all evaluated by these tests.
- **Acceptance Tests:** Conducted during the first acceptance or installation of smart meters, acceptance tests are a subset of type testing. These tests confirm that the meters adhere to the established norms and specifications. They guarantee that the meters function properly, operate within reasonable accuracy bounds, and meet all applicable safety and construction requirements.
- **Routine Tests:** Throughout the course of a smart meter's operational lifetime, routine tests—a subset of acceptance tests—are carried out on a regular basis. To make sure the meters keep up with the necessary requirements, these tests are carried out on a regular basis. In order to guarantee the meters' continued functionality and compliance, routine testing concentrate on confirming the meters' continuous accuracy, dependability, and performance.

The standard procedure for assessing conformance is to have authorized laboratories perform tests, and then compare the test findings to the standards outlined in IS 16444 (Part 1). Adherence to these standards aids in guaranteeing that smart meters fulfill the necessary requirements and are capable of offering precise, dependable, and secure electricity consumption measurement and invoicing.

To make sure that smart meters are accurate, work well, and adhere to standards, their test requirements can be divided in several categories. These are the essential test prerequisites:

- **Properties of Insulation:**
  - Test for impulse voltage
  - Test for high voltage in AC
  - Test for Insulation Resistance

- **Accuracy Conditions:**
  - Examine the error bounds
  - Analysis of test findings
  - Meter continuous test
  - Examination of the initial state
  - Examination of the no-load state
  - Test of the impact of the surrounding temperature
  - Examine the error's repeatability
  - Quantity of influence test

- **Requirements for Electrical:**
  - Power usage test
  - Test of supply voltage influence
  - Examining the impact of short-term over currents
  - Evaluation of the impact of self-heating
  - Examination of the impact of heat
  - Test of immunity to earth fault influence

- **Electromagnetic Harmony:**



Doi : https://doi.org/10.54216/JCHCI.070102
Received: August 02, 2023 Revised: October 19, 2023 Accepted: January 26, 2024

- Measurement of radio interference
- Quick temporary burst test
- Immunity testing against electrostatic discharges
- Immunity test against radiofrequency fields
- Test for surge immunity

- **Climate-Related Effects:**
    - Test with dry heat
    - Chilled test
    - Cycle test for damp heat

The load switch test is only relevant in accordance with IS 16444 (Part 1). Only in accordance with IS 16444 (Part 1) for smart meters is the load switch test applicable. The purpose of this test is to assess the meters' capacity to switch loads. One feature of smart meters is the load switch, which enables remote control of electrical loads. For example, it can be used to connect or disconnect the power supply to a customer's property. Manufacturers of smart meters, utilities, and regulatory agencies can verify that the load switch feature works as intended by performing the load switch test. Utilities can use this capability to remotely control consumer power supply, carry out load shedding plans, and enhance grid efficiency in general.

This test's goal is to confirm that the load switch feature functions accurately and consistently. It entails evaluating how well the meter can manage the linked loads in response to commands from the utility or control center. Usually, the exam covers the following topics:

- **Functionality of the Load Switch:** The meter's ability to precisely and effectively carry out intended tasks, like load separation and reconnection, is assessed.
- **Remote Control:** The test evaluates how well the meter responds to load-switching remote commands. In order to regulate the power supply to the customer's premises, it determines whether the meter can efficiently receive and carry out directions from the utility or control center.
- **Correctness and Reliability:** The load switch test also looks at the meter's load control activities' correctness and dependability. It guarantees that the meter can precisely and reliably swap loads without any mistakes or problems.

## 5. Necessity of Testing

To guarantee smart meters' functionality, dependability, and safety, testing is essential. Verifying the insulating qualities, accuracy, dependability, electromagnetic compatibility, environmental durability, mechanical strength, and safety of smart meters is largely dependent on testing [24]. Smart meters can provide precise billing, dependable operation, and increased safety in the electrical grid system by going through extensive testing.

These are the justifications for the need for testing:

- **Insulation properties:** Smart meters are tested to ensure that they are capable of withstanding high voltages and maintaining appropriate insulation resistance. Insulation testing contributes to the safety of the meter and its users by preventing electrical leaks, malfunctions, and possible risks.
- **Accuracy:** To ensure that smart meters measure and record electricity use accurately, testing is necessary. Testing guarantees that meters give precise and dependable data for billing purposes, enabling fair and accurate assessment of energy use by comparing meter readings with reference values.
- **Reliability:** Testing aids in evaluating the functionality and dependability of smart meters in several scenarios. It guarantees low drift or deterioration and steady, precise meter operation throughout time. Accurate invoicing, improved customer satisfaction, and effective energy management are all made possible by reliable meters.
- **Electromagnetic compatibility (EMC) testing:** EMC testing verifies that smart meters are resistant to electromagnetic disturbances and do not interfere with other electronic systems or equipment. Testing verifies the meters' compatibility with the electromagnetic environment by evaluating radio interference, burst immunity, immunity to electrostatic discharges, and immunity to electromagnetic fields.



Doi : https://doi.org/10.54216/JCHCI.070102
Received: August 02, 2023 Revised: October 19, 2023 Accepted: January 26, 2024

- **Environmental Hardness:** The test looks at how well the smart meters can tolerate extremes in temperature, humidity, and speed at which the temperature varies. This guarantees that meters will function precisely and dependably in a variety of weather conditions.
- **Mechanical Robustness and Durability:** Smart meters undergo testing to assess its resilience to impacts, shocks, and vibrations. This makes it possible for meters to be transported, installed, and used often without losing accuracy or usefulness.
- **Safety:** To ensure adherence to safety guidelines and rules, testing involves safety evaluations. This entails testing for fire, heat, and dust resistance as well as water and dust intrusion prevention. Users and the electrical infrastructure are both protected when smart meters are safe.

## 6. Conclusion

Smart meters are essential components of the changing energy grid that are essential to the pursuit of a sustainable and efficient energy future. Their deployment, which is based on thorough testing and validation, is not just a technical formality but also a crucial step towards an intelligent and responsive energy system. These gadgets not only ensure precision, dependability, and security but also transform the relationship between the customer and the utility by providing insights into energy consumption in real time and enabling proactive energy management. It is crucial to install extensively tested and certified smart meters in the field because of their importance and necessity. This guarantees that they will operate dependably, carry out their intended tasks accurately, and keep people and equipment safe. Additionally, by guaranteeing accurate measurement and effective energy management, it assists utilities in minimizing revenue losses. The potential applications of smart meters, when combined with developments in AI and IoT, portend a new era of customized energy solutions and predictive grid analytics, extending their function much beyond simple measurement instruments. As such, they serve as a lighthouse on the path to a more connected, effective, and sustainable energy landscape, where accessibility and ongoing innovation are essential to achieving their full revolutionary potential.

**Funding:** “This research received no external funding”

**Conflicts of Interest:** “The authors declare no conflict of interest.”

## References

[1] P. William, A. Gupta, N. K. Darwante, S. S. Gondkar, A. Verma and V. Verma, Applications of Internet of Things in Smart Grid Intelligent Systems, 2022 International Conference on Augmented Intelligence and Sustainable Systems (ICAISS), Trichy, India, pp. 1175-1179, 2022.
[2] S.-Y. Hsieh, C.-W. Hsu, C.-H. Yeh, and G.-H. Zhang, Novel scheme for reducing communication data traffic in advanced metering infrastructure networks, *J. Supercomput.*, vol. 78, no. 6, pp. 8219–8246, Apr. 2022.
[3] M. U. Saleem, M. R. Usman, M. A. Usman, and C. Politis, Design, deployment and performance evaluation of an IoT based smart energy management system for demand side management in smart grid, IEEE Access, vol. 10, pp. 15261–15278, 2022.
[4] Ashok Kumar M ,Abirami A,Sindhu P,Ashok Kumar V D ,Rani V. "Modern Medical Innovation on the Preferred Information about the Medicine using AI Technique." Journal of Cognitive Human-Computer Interaction, Vol. 1, No. 1, 2021 ,PP. 8-17.
[5] C.-C. Sun, D. J. Sebastian Cardenas, A. Hahn, and C.-C. Liu, Intrusion detection for cybersecurity of smart meters, IEEE Trans. Smart Grid, vol. 12, no. 1, pp. 612–622, Jan. 2021.
[6] J. Ma, Z. Teng, Q. Tang, Z. Guo, L. Kang, and N. Li, Degradation trend evaluation for smart meters under high dry heat natural environments, Measurement, vol. 220, 2023.
[7] Ajay G,Abhishek Kumar,Venkatesan R. "Query-Based Image Retrieval using Support Vector Machine (SVM)." Journal of Cognitive Human-Computer Interaction, Vol. 1, No. 1, 2021 ,PP. 28-36
[8] G. Gosnell and D. McCoy, Market failures and willingness to accept smart meters: Experimental evidence from the UK," Journal of Environmental Economics and Management, vol. 118, 2023.
[9] M. Kochański, K. Korczak, and T. Skoczkowski,Technology Innovation System analysis of electricity smart metering in the European Union,” *Energies*, vol. 13, no. 4, p. 916, Feb. 2020.
[10] D. Cypher, “NIST smart grid interoperability panel priority action plan 2 : National Institute of Standards and Technology, Gaithersburg, MD, 2014.



Doi : https://doi.org/10.54216/JCHCI.070102
Received: August 02, 2023 Revised: October 19, 2023 Accepted: January 26, 2024

[11] Bureau of Indian Standards, IS 16444 (Part 1):2015 - Utility Meters - Smart Meters - Specification: Part 1 General Requirements and Tests, Bureau of Indian Standards, 2015. [Online]. Available: https://bis.gov.in/wp-content/uploads/2020/05/PM-IS-16444-1.pdf. [Accessed: Feb. 26, 2024].
[12] Sumithra.M,Vettri Chezhian. P,Raj Kumar. K,Nithish Kumar. S. "Automated Attendance System using Real Time Face Recognition and MySQL Database." Journal of Cognitive Human-Computer Interaction, Vol. 2, No. 1, 2022 ,PP. 15-18.
[13] Q. Sheng et al., Research and analysis on evaluation methods of electrical performance of smart energy meters, J. Phys. Conf. Ser., vol. 1802, no. 3, p. 032135, Mar. 2021.
[14] Vijay K. "Collaborating The Textual Reviews Of The Merchandise and Foretelling The Rating Supported Social Sentiment." Journal of Cognitive Human-Computer Interaction, Vol. 1, No. 2, 2021 ,PP. 63 - 72.
[15] UK Government, Smart Metering Implementation Programme: Regulatory and Commercial Framework, 2018. [Online]. Available: https://assets.publishing.service.gov.uk/media/5a79a29440f0b63d72fc7537/229-smart-metering-imp-regulatory-commercial.pdf. [Accessed: Feb. 26, 2024].
[16] https://ised-isde.canada.ca/site/measurement-canada/en/certification-requirements-and-recommended-practices. [Accessed: Feb. 26, 2024].
[17] https://single-market-economy.ec.europa.eu/single-market/european-standards/harmonised-standards/measuring-instruments-mid_en [Accessed: Feb. 26, 2024].
[18] https://www.osgp.org/en/technical [Accessed: Feb. 26, 2024].
[19] https://www.dmtf.org/standards/cim [Accessed: Feb. 26, 2024].
[20] Electricity metering data exchange – The DLMS/COSEM suite – Part 6-9: Mapping between the Common Information Model message profiles (IEC 61968-9) and DLMS/COSEM (IEC 62056) data models and protocols.
[21] D. Kohout, T. Lieskovan, and P. Mlynek, Smart Metering Cybersecurity—Requirements, Methodology, and Testing, Sensors 2023, 23(8), 4043, 2023
[22] https://syc-se.iec.ch/deliveries/cybersecurity-guidelines/security-standards-and-best-practices/iec-62351/ [Accessed: Feb. 26, 2024].
[23] https://standards.ieee.org/standard/2030.5-2013.html [[Accessed: Feb. 26, 2024].
[24] https://bis.gov.in/wp-content/uploads/2020/05/PM-IS-16444-1.pdf [Accessed: Feb. 26, 2024].
[25] https://bis.gov.in/wp-content/uploads/2020/05/PM-IS-16444-2.pdf [Accessed: Feb. 26, 2024].
[26] https://sarepenergy.net/wp-content/uploads/2023/07/Smart-Meter-Installer-Technician-Training-Module-.pdf [Accessed: Feb. 26, 2024].



Doi : https://doi.org/10.54216/JCHCI.070102
Received: August 02, 2023 Revised: October 19, 2023 Accepted: January 26, 2024