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Smart Grid's Methods for Real-Time Monitoring System: A Review

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ABSTRACT

This review paper discusses various techniques for real-time monitoring of power systems in smart grids. Real-time monitoring is essential for maintaining the stability, reliability, and security of the power grid. The paper covers several monitoring techniques such as phasor measurement units (PMUs), synchro phasors, advanced metering infrastructure and intelligent electronic devices. The working of techniques and their application of each technique are analyzed, along with their functions in different scenarios. The review also highlights the parameters of techniques based on real-time data in the directions for real-time monitoring in smart grids. The paper aims to provide insights into the current state-of-the-art techniques for real-time monitoring and the discussion on the efficiency based on the comparison of some parameters of techniques used in monitoring in smart grid.

Keywords: *Smart grid, real-time monitoring, synchro phasors, phasor measurement units, intelligent electronic devices*

INTRODUCTION

These days Smart Grid is a boon to the power system for monitoring the real-time data, we use different techniques in order to increase the effectiveness, dependability, and safety of power production, transport, and usage, an energy network known as a "smart grid" employs cutting-edge technologies, such as digital communication and control systems. A key component of smart grid technology is real-time monitoring, which allows grid managers to identify and react to power system disturbances instantly. The high-precision time-synchronized readings of voltage and current phasors provided by phasor measurement units (PMUs) allow for real-time study of power system dynamics. This technology is essential for real-time disturbance detection and response, grid security, and outage prevention.

PMUs known as synchronophasors offer extra details on the steadiness and oscillations of the power system. This technology is essential for real-time tracking and disruption response, lowering the possibility of outages and cascading failures. Electronic devices used to monitor and manage the components of an electricity system are known as intelligent electronic devices (IEDs). These gadgets give power system operations more efficiency and control because they can work independently or in accordance with a centralized control system.

Overall, the methods used in smart grids for real-time power system tracking are crucial for assuring a dependable, effective, and safe electricity network. Grid managers can identify and react to disruptions in real-time using state estimation, PMUs, synchro phasors, AMI,

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and IEDs, eventually enhancing the smart grid's overall performance and robustness.

SYNCHRO PHASORS

Synchro phasors are high-speed measurement technology that provides data at a rate of 30 times per second. They ah show a clear big picture of the electric grid. Synchro phasors are devices that measure the phase and magnitude of electrical waveforms typically in power systems. This technology typically uses sensors and communication networks to collect and transmit real-time data about the performance of the power grid. Synchro phasor data can help operators monitor and manage power system stability, identify and respond to disturbance and optimize power flow. It is an important tool for maintaining the reliability and efficiency of modern electrical grids.

Architecture, Applications

Depending on different practical and functional needs, synchronophasors may be independent devices with specific functions or they may be a part of a bigger system like the substations. Synchro phasors are used at distribution transformers and places of shared coupling to improve the spread of green energy sources and intelligent loads. Investigate harmonics and frequency disruptions. The device and network layers of the synchro phasor devices' design are outlined below.

PMU Device

Consists of current transformers (CTs) and potential transformers (PTs) that measure current and voltage magnitudes and convert them to digital data. Microprocessor module compiles these values, computes phasors, and synchronizes them with coordinated universal time (UTC), a standard reference used by global positioning system (GPS) receivers that acquire a time-lag based on the atomic clock of GPS satellites [21–24]. They can record individual phase voltage and current along with harmonics, negative and zero sequence values, and they can measure local frequency and its rate of change [25]. The data presents a dynamic picture of the grid at a particular moment. Measured data is transmitted as frames by PMUs and PDCs [26]. Data security is ensured by circular redundancy checking with 16 bits.

PMU Network

If a substation contains numerous PMUs, Local PDCs collect site-level data before sending it to a SuperPDC. PDCs run a number of data quality tests, set indicators based on problems found, record performance, verify, modify, scale, and normalize data, and translate between protocols [27]. The SCADA or energy control system of the utility usually has a direct interface with PDC.

PDCs can be set up as stand-alone units or combined with other grid system.

The FNET/Grid

Eye initiative has been overseen since 2004 by the Oak Ridge National Laboratory and the University of Tennessee Knoxville. Installed FDRs have been successful in capturing the grid's changing characteristics. Despite the fact that FDRs are basically PMUs, they are linked at 120 V and require less installation than conventional PMUs do [28]. While PMUs measure between 10 and 240 samples per second and use GPS receivers with 1ls precision for synchronization, FDRs measure nearly 1440 samples per second with a hardware accuracy of 0.5 MHz [29-31]. FDRs are primarily employed at renewable integration zones of the grid. It is outside the purview of this article because the author of [88, 89] has already discussed the architecture in great detail.

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FDR Network
FDRs can provide data on transients, load shedding, breaker reclosing, and the switching processes of capacitor banks and load tap changers [32]. They also use the internet to transmit data straight to the central computers for analytics. FDRs can be placed at buildings and workplaces, unlike PMUs.

Applications
Synchro phasors simplify power system security, dependability, and stability. Both online and offline forms are available [33]. PMUs can be used online to improve real-time SA, analyses defects and disruptions, find and evaluate oscillations and harmonics that affect power quality, and estimate states more precisely and quickly. Congestion management, offering efficient safety measures, benchmarking, system restoration, overload tracking and dynamic grading, verifying the SCADA network model, and enhancing total power quality are examples of offline applications [34-36]. Future frequency monitoring interface integration with command-and-control centers for power system health diagnosis to prevent cascading failures and event trigger module that detects and notifies the mismatch between generation and load caused by frequency variations are examples of real-time (online) applications of FDRs.

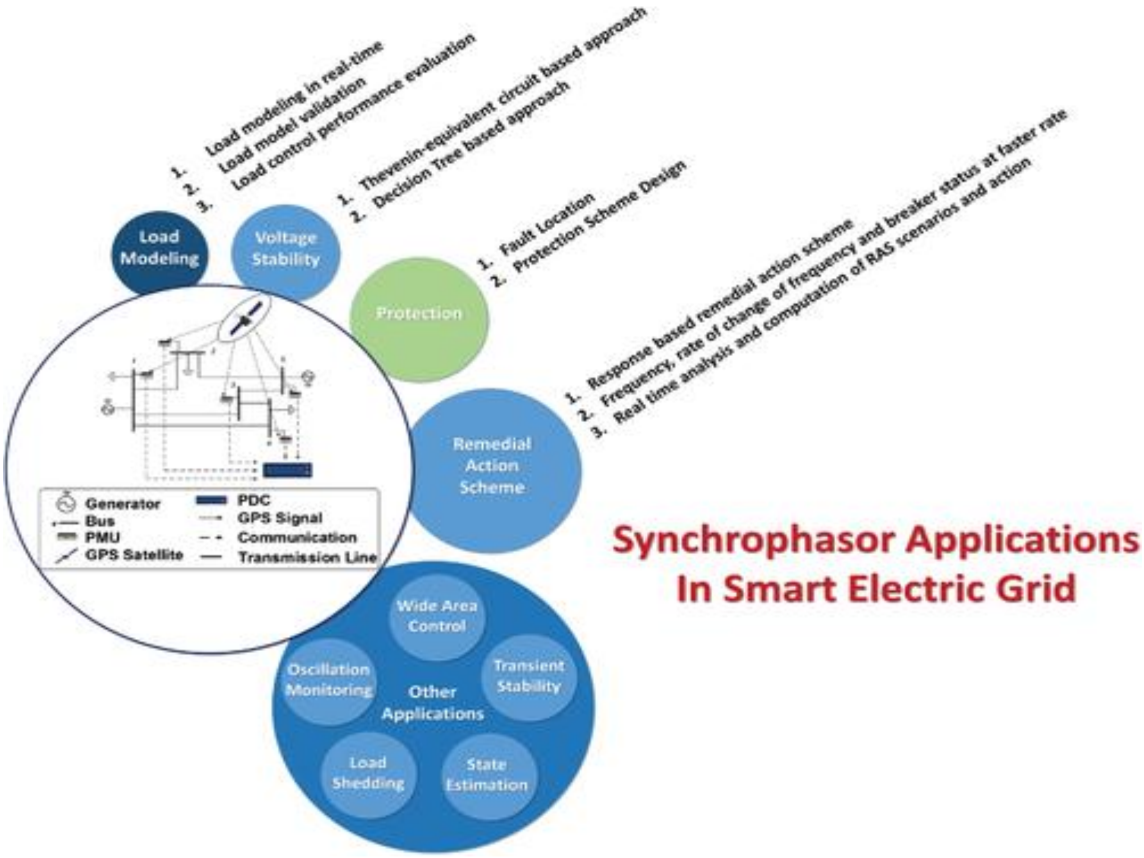

Fig. 1: *Showing the applications of synchro phasor technology in a smart grid.*

The advanced technology of synchronophasors gives real-time information on the condition of the electrical infrastructure. Synchronized voltage and current readings recorded at a particular time period are called phasor measurements, which the technology records and analyses. The electric power system needs synchronized phasor technology to be stable and reliable. The

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synchro phasor technology's main characteristics are as follows:

Accuracy
For synchro phasor measurements to be helpful for power system analysis and management, they must be extremely precise. Synchro phasor readings are usually within 0.01 to 0.05% of the nominal voltage or current in terms of precision.

Speed
Synchro phasors can be used to measure the frequency of an electrical pulse when it comes to speed. Because it reflects the number of cycles (or oscillations) per second, the frequency of an electrical wave is directly linked to its pace.

Maintaining a stable frequency in electricity networks is critical for assuring reliable and efficient functioning. Any departure from the system's standard frequency (usually 50 or 60 Hertz, based on area) can cause technology to malfunction or even fail, possibly resulting in outages or other interruptions. Power system operators can notice and react to changes in frequency more rapidly by using synchro phasors, which helps to keep system stability and avoid outages.

Scalability
Synchro phasors' scalability is made possible by the use of cutting-edge networking and communication technologies, which enable data to be sent quickly and effectively over great distances.

Operators can raise the general efficiency, dependability, and resilience of the grid by using synchro phasors to watch and manage power system operations at different scales. For instance, synchro phasors can be applied to maximize the use of renewable energy sources, improve the integration of dispersed energy resources, and find and pinpoint system faults. Synchro phasors will become more crucial as the power system develops and expands in order to maintain its secure and dependable functioning.

Reliability
When it comes to assuring the dependability of power networks, synchronophasors are indispensable. Synchro phasors provide instantaneous readings of the phase angle and magnitude of an electrical wave, allowing for the detection of changes in the frequency and voltage of the system that could be signs of possible issues. Power system managers can more quickly locate and separate system defects with the aid of synchro phasors, which enables quicker service restoration in the event of an outage. In order to maintain a steady and dependable supply of power, managers can modify the system by using synchro phasors to watch the output of these sources. In general, synchro phasors offer vital information that can aid power system managers in enhancing the grid's dependability and resilience and ensuring a steady supply of energy to customers.

Cost
Depending on the scale and complexity of the system, different power systems will cost different amounts to adopt synchro phasor technology. Synchro phasor’s fast ability to identify and pinpoint system faults can help minimize downtime and related expenses. This is one of their main advantages. Synchro phasors can also be used to improve the performance of the system's parts, extending their lifespan and lowering the need for expensive repairs. Overall, even though installing synchro phasors can be expensive initially, the long-term advantages of increased dependability, effectiveness, and

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incorporation of green energy can make it a sensible choice for power systems.

Compatibility
Generators, transformers, protective switches, and communication networks are just a few of the many power system technologies and components that synchro phasors are interoperable. Synchro phasors are able to easily combine with the infrastructure of the current power system thanks to the use of standardized protocols and communication interfaces.

Synchro phasors can also be combined with other smart grid technologies, like distributed energy resources (DERs) and advanced metering infrastructure (AMI), to give a more complete picture of the system and boost efficiency all around. All things considered, synchro phasors are a flexible and adaptable option for enhancing the dependability and efficacy of the power system due to their compatibility with the current architecture of the power system and other smart grid technologies.

User-Friendliness
Synchro phasors can be regarded as user-friendly because they give users concise, understandable data about the status of the power system in real time. Operators can obtain this information from any location at any moment using a variety of devices, including computer screens, cell phones, and tablets. Advanced analytics and visualization tools from Synchro phasors can also assist workers in spotting patterns and trends in data, making it simpler to spot possible issues and take preventative measures. Additionally, synchro phasors are made to function with current communication and power system technologies, making it simpler for system administrators to incorporate them into the system without interfering with regular operations.

Security
Voltage, frequency, and phase angle is just a few of the delicate data on power system circumstances that synchro phasors gather. Strong data security means should be in place in a safe synchro phasor system to guard against unauthorized entry, hacking, and other security risks. Synchro phasor devices are susceptible to cyberattacks because they are linked to the transmission networks of the power infrastructure. To guard against these kinds of assaults, a safe synchro phasor system should have strong cybersecurity means in place.

ADVANCED METERING INFRASTRUCTURE
The term "advanced metering infrastructure" (AMI) designates a category of technology used to electronically gather information from utility meters, such as those used to consumption of gas, water, and electricity. AMI systems generally involve the implementation of advanced digital meters that are capable of recording consumption data in much greater detail track than conventional mechanical meters.

A private communication network is then used to send this data to a central data management system, where it can be analyzed and used to create bills, track utilization trends, and spot possible utility network issues. AMI systems are intended to be more precise and efficient than conventional metering techniques, enabling utilities to handle their resources more effectively, cut down on waste, and provide better customer service. Additionally, they give consumers more thorough knowledge about their energy usage, enabling them to make wise choices regarding their consumption patterns and possibly reduce their bill payments.

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There are three main components of this infrastructure: -

- Site/field devices
- Communication network
- Utility control network

The heart of this technology is a smart meter. It will maintain an overall record of the power being supplied as well as the user's consumption.

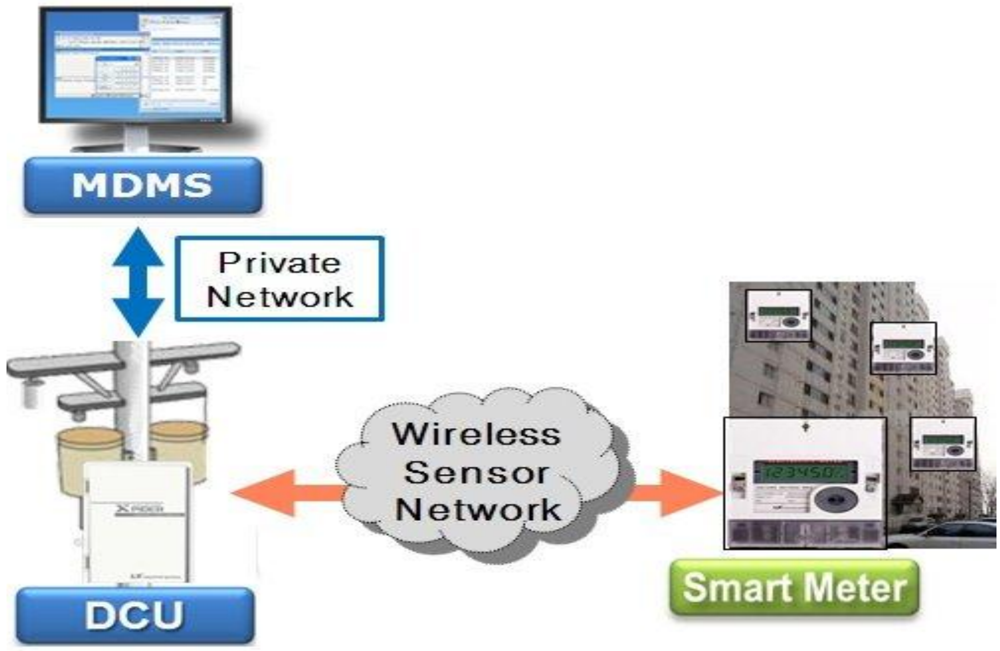

Fig. 2: *Show the three different components of advanced metering infrastructure.*

Here are some more details to help you comprehend AMI: -

Benefits
AMI provides a number of advantages, such as enhanced client happiness, quicker outage discovery and restoration, better administration of demand response programs, and more precise billing.

Technology
Advanced digital meters, transmission units, data collectors, and a centralized data administration system usually make up AMI technology. Data on usage is communicated from the meters to the data aggregators, who then send the information to the central system.

Data security and privacy are crucial because AMI systems communicate and gather sensitive customer data. To safeguard client data and stop illegal access, AMI systems are built with strong security features like encryption and authentication.

Installation of new digital meters and transmission infrastructure are part of the AMI implementation process. Although AMI deployment costs can be expensive, in the long run, the advantages frequently exceed the disadvantages.

Challenges
The implementation of AMI systems may be complicated by technological difficulties, policy and regulatory problems, and stakeholder management. To deploy AMI systems and profit from them, many utilities have effectively overcome these obstacles.

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THE ADVANCED METERING INFRASTRUCTURE MAIN CHARACTERISTICS ARE AS FOLLOWS

Accuracy

With the help of this technology, utilities can gather and fine-tune their data for analysis, making it easier for them to spot usage trends and patterns. The precision of AMI is a key component in ensuring that utilities can offer their clients dependable and effective service. AMI can measure energy usage more precisely by employing sophisticated metering technology, which is advantageous to both utilities and consumers.

Speed

In order for utilities to offer their clients dependable, effective, and fast service, AMI speed is a critical component. AMI allows utilities to increase business effectiveness, cut costs, and offer their clients improved services utilizing cutting-edge communication technologies and real-time data processing.

Scalability

Utilities can roll out the system gradually, beginning with a small trial programme and growing as necessary thanks to AMI's scalability. This makes it possible for companies to control costs and reduce the risks involved with simultaneously implementing a large-scale system. The utility can continue to offer dependable and effective service because the system can expand and adjust to new technologies and shifting consumer requirements.

Reliability

The amount of time that the AMI system is active and accessible to gather data is referred to as the system uptime. High system availability indicates that an AMI system is trustworthy because it is consistently accessible to gather data from users. For AMI to work correctly, accurate statistics are required. Accurate data on each customer's energy usage should be able to be collected and transmitted by an effective AMI system. This contains information on various factors, such as voltage, current, and power factor.

Cost

Automation of meter readings by utilities thanks to AMI can lower the price of human meter reading and data input. Meters can now be read online thanks to AMI, doing away with the need for meter readers to visit each client location. As a result, staffing costs are decreased, and by removing the need for meter readers to access potentially dangerous places, safety may also be improved. Utility companies can optimize their infrastructure and increase operational effectiveness by using AMI, which also gives them more precise data about usage trends. This can aid utilities in cutting down on energy waste and avoiding expensive building expenditures that are needless.

Compatibility

Meters, data networks, and back-end systems are just a few of the utility systems and equipment that AMI is made to operate with. As a result, utilities can easily and affordably incorporate AMI into their current systems. Cellular networks, powerline communication, and Wi-Fi are just a few of the connectivity systems that AMI is made to operate with. Utility companies can now choose the communication technology that best meets their requirements and offers the greatest coverage in their business region.

User Friendliness

AMI's user UI ought to be simple and straightforward to use. This covers the layout of any applications or websites that consumers might use to obtain information about their energy consumption as well as the hardware and software components. All clients should be able to use AMI,

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regardless of their level of technological knowledge or proficiency. For customers who might need help comprehending how to use the system, this includes offering guidance and instruction.

Security

AMI systems are susceptible to a number of security risks, such as illegal entry, physical tampering, and hacking. AMI systems are built with multiple levels of security, including encryption, identification, and access control, to counteract these dangers. Data is protected during transmission over communication networks by encryption. To guarantee that data is transferred safely between metros and utility back-end systems, AMI systems use encryption methods.

PHASOR MEASUREMENT UNITS (PMUS)

The PMU is described as a "device that generates time-synchronized voltage and/or current signals and synchronized phasor, frequency, and rate of change of frequency (ROCOF) values" [9]. The German-American electrical engineer and scientist Charles Proteus Steinmetz created the idea of phasor representation, which is what the PMU makes use of [37]. In particular, IEEE Std. C37.111-1991 [38], IEEE Standard Common Format for Transient Data Exchange (COMTRADE) for Power Systems (ANSI), for file storage, and IEC 61850 [39] have all been created to enable the power sector to keep or send time-tag data. Power company automation communication networks and devices, primarily for substation interactions.

Synchronization Phasor Measurement Units (PMUs) are sophisticated digital sensors that continuously monitor the electrical properties of an AC power supply. PMUs provide extremely accurate data on the amplitude, phase angle, and frequency of electrical impulses, and are used to monitor and manage the electrical power grid. Phasor measurements are used by PMUs to record the size and phase angle of a voltage or current waveform at a particular instant in time. In order to catch high-frequency transients and disturbances that may occur in the power system, they gather data at high sampling rates (often between 30 and 120 samples per cycle).

As the information gathered by PMUs is time-synchronized, measurements taken at various points throughout the electrical grid may be compared and examined to spot any problems or abnormalities. PMUs can offer operators real-time information about the health of the power grid, allowing them to make better-informed choices concerning the stability, security, and dependability of the system.

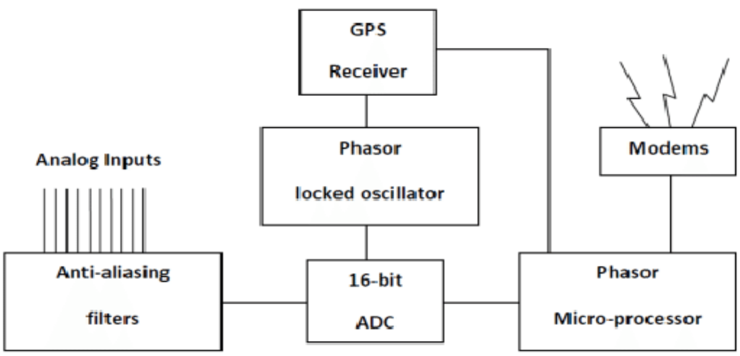

Fig. 3: *Block diagram of the Phasor Measurement Unit.*

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PMUS ARE UTILIZED IN MANY DIFFERENT APPLICATIONS, SUCH AS

Monitoring and Control of the Power System

PMUs can assist operators in locating and analyzing issues with the power grid, such as voltage variations, frequency instabilities, and oscillations. With the use of this information, power outages may be avoided and remedial measures can be taken.

Grid Optimization

PMUs can offer information on the functioning of the electric grid that can be utilized to enhance and increase the grid's efficiency. PMUs can be used, for instance, to locate grid segments with significant power losses and to spot transmission system congestion.

Power System Protection

PMUs can be used to identify power grid problems and initiate preventative actions, including turning on circuit breakers or tripping relays, to stop system damage.

Integration of renewable energy sources, such as wind and solar, into the power grid may be managed by operators with the use of PMUs.

THE MAIN CHARACTERISTICS OF PMU ARE AS FOLLOWS

Accuracy

PMUs need to be extremely accurate in their readings of both amplitude and phase angle. While the accuracy of phase angle measurements is usually stated in terms of the phase angle error, the accuracy of magnitude measurements is frequently expressed in terms of the measurement's percentage error. PMUs use sophisticated measurement methods and signal processing routines to remove sources of inaccuracy, such as noise and signal distortion, to achieve high precision. PMUs are also routinely adjusted to make sure their precision over time is maintained.

Speed

PMUs are able to detect shifts in the electrical system as frequently as every 16.7 milliseconds, or 1/60th of a second. Because it enables operators to rapidly discover and react to changes in the system, this quick measurement and reporting capacity is essential to keeping the stability and dependability of the electricity infrastructure. In general, a PMU's speed is crucial for the real-time tracking and management of the electricity infrastructure. PMUs can aid in the prevention of power outages and guarantee the effective and dependable supply of electricity by quickly and accurately giving data on the state of the power system.

Scalability

In order for a PMU to be utilized efficiently across a range of power system uses and setups, it must be scalable. PMUs can assist power grid operators in making knowledgeable choices about how to control the power system and guarantee an effective and dependable supply of energy by offering a flexible and scalable measurement option.

Reliability

To guarantee the stability and dependability of the electricity system, PMUs must be extremely reliable. PMUs are built with dependable hardware and software components and put through stringent testing and quality assurance processes in order to achieve high reliability. PMUs are also routinely adjusted to make sure they continue to be accurate and dependable over time. The readings from the PMU are compared to reference standards during this calibration

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procedure to make sure they fall within predetermined limits.

Cost
Depending on their characteristics, precision, and measurement powers, PMUs can range in price. Due to their sophisticated measurement features and real-time data transmission, PMUs are typically more costly than conventional power system measurement devices, such as electromechanical meters or digital fault recorders. However, thanks to technological advancements and efficiencies of scale, the price of PMUs has fallen over time. PMUs are now easier to use and cheaper utilities and power system managers as a result. Overall, the worth and advantages of a PMU to the electricity system must be weighed against its expense. The ability of PMUs to provide real-time data on power system conditions is crucial to preserving the security and dependability of the power infrastructure, even though they may be more costly than conventional monitoring devices.

Compatibility
Compatibility is crucial to ensuring that PMUs can be successfully incorporated into the electricity infrastructure and operate without a hitch with other gadgets and systems. Power grid operators can make educated choices about how to control the power system and guarantee an effective and dependable supply of energy by using the interoperable data that PMUs can provide on the state of the power system.

User Friendliness
To make sure that operators can use and understand the data given by the device, a PMU's usability is crucial. PMUs can assist power grid operators in making knowledgeable choices about how to control the power system and ensure an effective and dependable supply of energy by offering straightforward and simple-to-use interfaces and diagnostic features.

Security
The integrity and dependability of the electricity system depend on a PMU's protection. PMUs can assist power grid operators in making knowledgeable choices about how to control the power system and guarantee the efficient and dependable supply of electricity while defending against cyber threats by giving secure and trustworthy data on the state of the power system.

INTELLIGENT ELECTRONIC DEVICES (IEDS)
IEDs are deployed at numerous points throughout the power supply and are microprocessor-based devices. IEDs are employed to keep an eye on and manage the electrical system, sending real-time data to the control center. IEDs are able to recognize and react to power system faults and events, avoiding blackouts and cascade failures. IEDs may communicate with other components of the power system, enabling the power system to be controlled and managed in concert.

IEDs are utilized in power systems for a variety of purposes, including automation, control, monitoring, and protection. In order to avoid system damage and maintain system stability, they are used to identify abnormal operating situations in the power system, such as overcurrent or under/overvoltage. In reaction to shifting system circumstances, they may also be utilized to regulate the functioning of power system components including circuit breakers, transformers, and generators.

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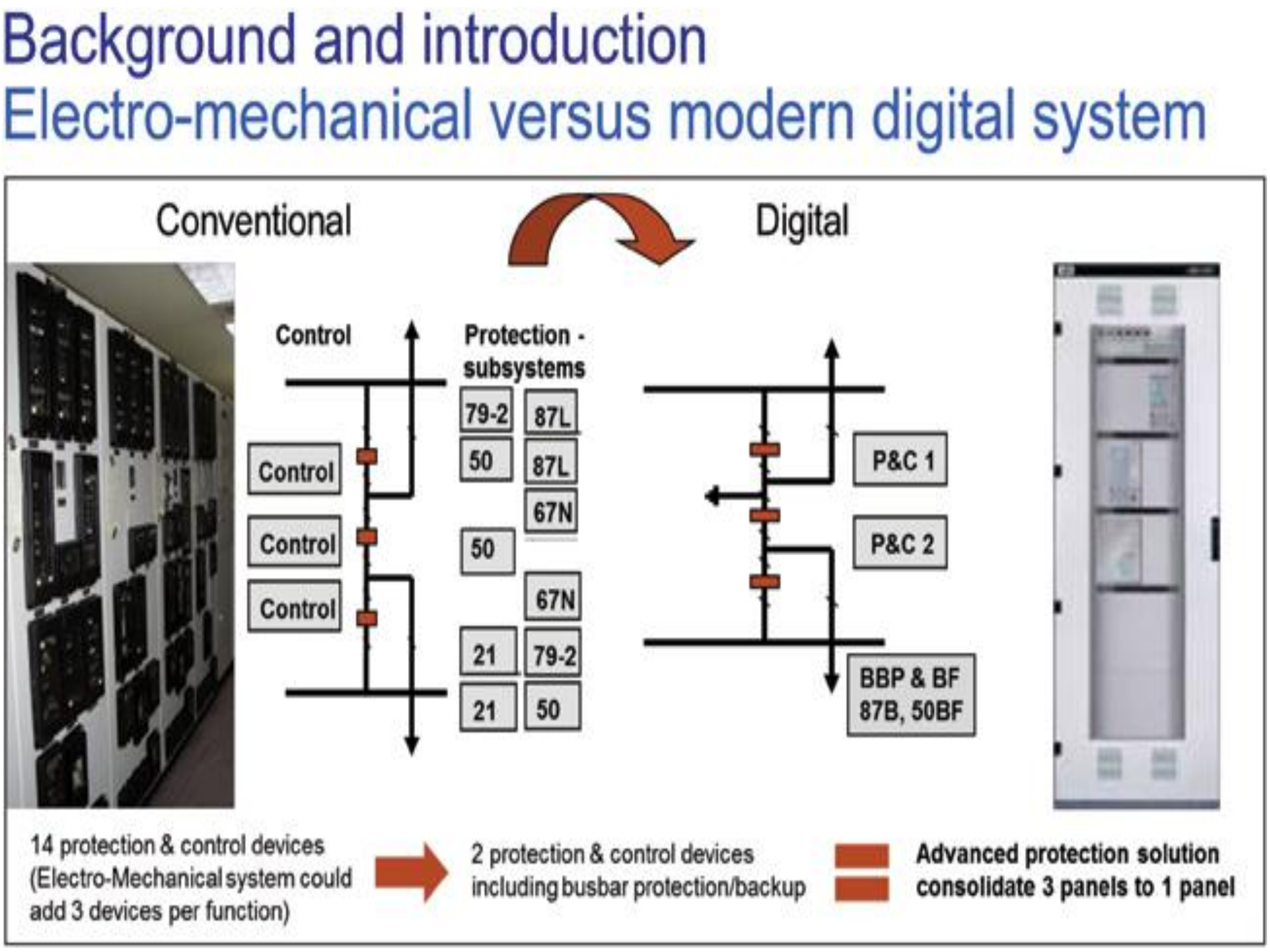

Fig. 4: *Modern protection system.*

MANY PREVALENT IED TYPES INCLUDE

Protection Relays

These tools are used to identify unusual power system operation situations and start the necessary preventive measures. They may be used to find abnormal circumstances like overcurrent, under/overvoltage, frequency aberrations, and others.

Power system failures are recorded and analyzed using digital fault recorders. They can offer useful data for fault investigation and problem-solving.

PMUs

These instruments are used to gauge the magnitude and phase angle of voltages and currents in the power system. They are utilized in monitoring and control applications including dynamic performance evaluation and power system stability.

Automated Voltage Regulators (AVRs)

These tools are used to control a power system's voltage. They can be utilized to keep a constant voltage level under a variety of system circumstances.

Digital Protective Relays

These tools are used to safeguard the components of the power system. They are capable of carrying out intricate protection tasks including differential and distance protection.

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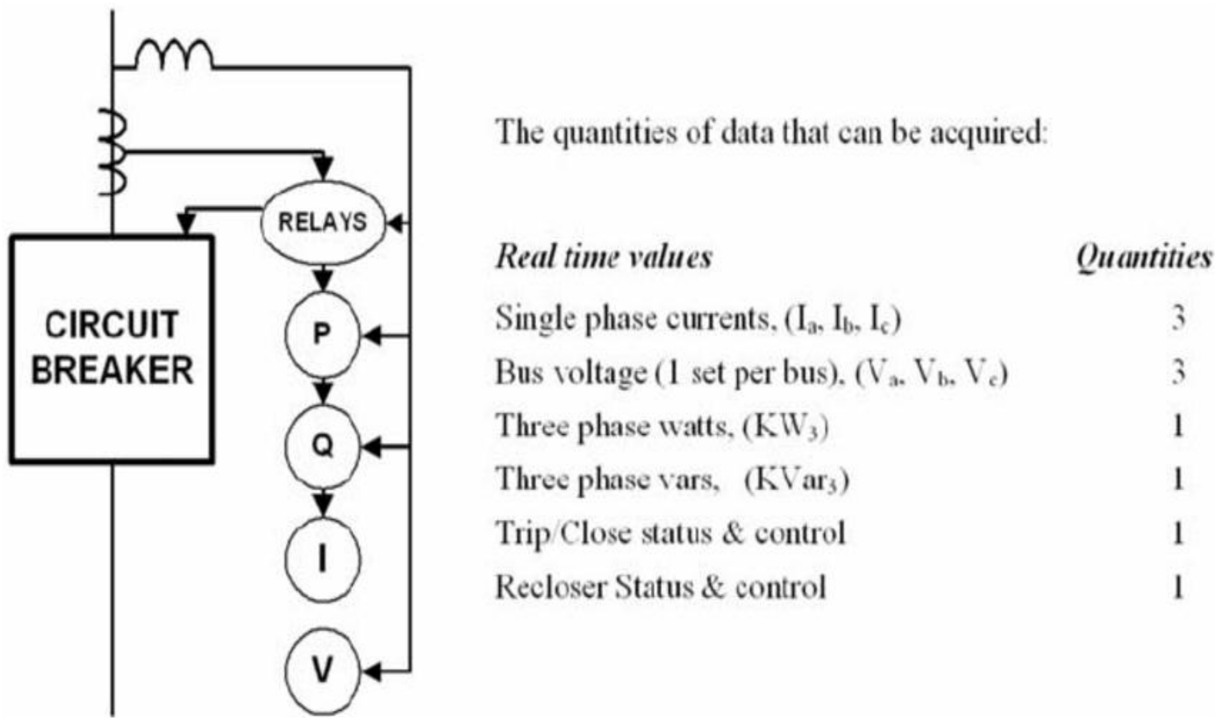

Fig. 5: *Conventional protection system.*

THE MAIN CHARACTERISTICS OF IED ARE AS FOLLOWS

Accuracy
IED precision is crucial for maintaining the safety and dependability of power systems, and highly accurate IEDs are required for the efficient operation of contemporary electrical networks.

Speed
IED speed is a key factor in determining the safety and dependability of power systems, and high-speed IEDs are necessary for the efficient operation of contemporary electrical networks.

Scalability
Highly scalable IEDs are necessary for the correct operation of contemporary electrical networks, and their scalability is crucial in assuring the flexibility and expandability of the protection system.

Reliability
IEDs' dependability is crucial for assuring the availability and uptime of the protection system, and contemporary electrical grids cannot operate properly without extremely dependable IEDs.

Cost
IEDs must be extremely cost-effective in order for contemporary electrical networks to be widely adopted and deployed, as the expense of IEDs has a significant impact on the affordability and fiscal viability of the protection system.

Compatibility
Highly compatible IEDs are crucial for the smooth operation of contemporary electrical networks because they ensure the interoperability and incorporation of the security system with other components of the power system.

User Friendliness
IEDs' usability is crucial in assuring the accessibility and usability of the protection system, and highly usable IEDs are necessary for the efficient operation of contemporary electrical networks.

Security

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Highly secure IEDs are crucial for the correct operation and defense of contemporary electrical grids, and the security of IEDs plays a critical part in assuring the safety of the protection system from cyber threats and attacks.

RESULT

Table 1: *Parameters of Intelligent Electronic Devices (IEDS).*

Parameters	**Synchrophasors**	**Phasor Measurement Units (PMUS)**	**Intelligent Electronic Devices (IEDS)**	**Advanced Metering Infrastructure**	**References**
Accuracy	High	High	High	Low	[1] North American SynchroPhasor Initiative (NASPI). (2022). Retrieved from https://www.naspi.org/ [2] Western Electricity Coordinating Council (WECC) Synchrophasor Program. (2022). Retrieved from https://www.wecc.org/synchrophasors
Speed	High	High	High	Low	Electric Reliability Council of Texas (ERCOT) Phasor Measurement Unit (PMU) System. (2021). Retrieved from https://www.ercot.com/services/comm/pmupmu [2] Western Electricity Coordinating Council (WECC) Synchrophasor Program. (2022). Retrieved from https://www.wecc.org/synchrophasors
Reliability	High	High	High	High	Z. Chen, P. Zhang, and L. K. Mestha, "Real-Time Estimation of Inter-Area Oscillation Modes Using Wide-Area PMU Measurements," IEEE Transactions on Power Systems, vol. 24, no. 1, pp. 34-44, Feb. 2009. doi: 10.1109/TPWRS.2008.2005006. C. Williams, "Smart Metering in the UK: A Review," Energy Policy, vol. 49, pp. 202-215, Oct. 2012. doi: 10.1016/j.enpol.2012.06.011.
Cost	High	High	Low	Low	Hernandez, J., & Ahmed, M. (2016). Smart grid communication infrastructures: Big challenges and research opportunities. IEEE Communications Surveys & Tutorials, 18(1), 7-27. Itron. (2019). How much does an AMI system cost? https://www.itron.com/na/resources/how-much-does-an-ami-system-cost
Compatibility	Yes	Yes	Yes	Yes	IEC 61850-6. (2013). Communication networks and systems for power utility automation - Part 6: Configuration description language for communication in electrical substations related to IEDs. International Electrotechnical Commission. National Institute of Standards and Technology. (2010). Guidelines for smart grid cyber security: Vol. 2, privacy and the smart grid. https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.1108r2.pdf
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CONCLUSION

Synchro phasors, intelligent electronic devices (IEDs), and advanced metering infrastructure (AMI). Each technology offers distinct powers that are required to guarantee an effective, safe, and dependable electric grid. PMUs offer time-synchronized, high-precision readings of voltage and current phasors, enabling real-time power system dynamics tracking. This technology is essential for real-time detection and response to disruptions, such as voltage changes and power outages, which enhance grid security and lower the risk of blackouts. Through two-way contact, AMI allows utilities to control the grid more effectively by giving them access to real-time statistics on energy usage from their customers.

A particular class of PMU called a synchro phasor offers more details on the stability and fluctuations of the power system. This technology lowers the possibility of outages and cascading failures by allowing grid managers to watch and react to changes in real-time.
Technologies like PMUs, AMI, IEDs, and Synchro phasors are essential for assuring an effective, dependable, and safe electric infrastructure. By giving managers the real-time data and insights, they need to make wise choices and act swiftly in the event of a problem; these technologies enhance the power system's overall performance and robustness.

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Gargi is a dedicated and ambitious B-Tech student specializing in Electrical and Electronics Engineering at Ajay Kumar Garg Engineering College. With a passion for learning and exploring new frontiers in her field, she has achieved remarkable milestones during her academic journey. With a keen interest in research and academic excellence, she showcased her expertise by publishing a paper in the Journal of Advancement in Electronics Design. Her paper showcases her ability to analyse complex issues within the realm of electrical and electronics engineering, highlighting her innovative thinking. In addition to her research achievements, Gargi's enthusiasm for technology and engineering has earned her recognition at Techfest, an esteemed technical festival held at the prestigious Indian Institute of Technology (IIT) Bombay. By participating in this renowned event, she had the opportunity to engage with fellow scholars, industry professionals, and technology enthusiasts, further enhancing her knowledge and network.

Gargi's dedication, hard work, and passion for her field are evident through her academic achievements and active involvement in various technical platforms. Her commitment to excellence, combined with her ability to adapt to emerging technologies and industry trends, positions her as a promising talent in the field of electrical and electronics engineering. With a strong foundation and a drive for continuous learning, Gargi is poised to make significant contributions to the field and pave her way to a successful career in the future.

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He is involved in many projects like Smart India Hackathon, KPIT Sparkle, University Innovation and R&D projects, etc. In addition, he actively participated in various technical and non-technical events at Zonal, University, National, and international levels. He was recently honored with **Young Researcher Award 2021** by INSC Bangalore for the no. of achievements, rewards, and publications at various national and international bodies.

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