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OPPORTUNITY AND BENEFITS OF 5G ENABLED IOT IN THE FIELD OF SMART GRID SECURITY SYSTEM

A. Prasant Kumar Pani, B. Aruna Tripathy, C. Shuvendra Kumar Tripathy, D. Gopinath Palai,E. Mrunmayee Tripathy.

F. A. Author is a PhD candidate of Department of Electronics and Communication Engineering, REC, BPUT, Odisha(e-mail: prasantpani2011@gmail.com)

S.B. Author is a professor of Electronics and Instrumentation Engineering Department, OUTR (Formerly CET), Bhubaneswar, Odisha(e-mail: atripathy@outr.ac.in)

T.C. Author is an assistant professor of Electronics and Communication Engineering Department, TAT, BPUT, Odisha(e-mail: shuvendra12478@gmail.com)

F.D. Author is a professor of Electronics and Communication Engineering Department , GITA, BPUT, Odisha(e-mail: gpalai28@gmail.com)

F.E . Author is a Mtech candidate of Electronics and Instrumentation Engineering, Department OUTR (Formerly CET), Bhubaneswar, Odisha (e-mail: maaaurobinda@gmail.com)

Abstract

Smart grid precautions is a critical concern, and the utilize of 5G-enabled IoT and edge computing will help improve security in several ways. 5G networks will provide faster and more reliable communication between devices in the smart grid, enabling real-time monitoring and response to security threats. The stumpy latency along with high bandwidth of 5G networks make it possible to detect and respond to security breaches quickly, minimizing damage and disruption to the grid. IoT sensor devices will be used to supervise the grid and detect any deviation in the system. These devices will be placed at different points in the grid, collecting data on influence usage, temperature, power and other variables. After the analysis of the Sensor data, the concern person will identify potential security threats before leading a serious problem. Edge computing will be used to analyze, the process data in real-time, and finally that data to be sent to central servers. Because sensitive information is kept closer to the source and is less vulnerable to eavesdropping, this will reduce the probability of data breaches and cyber-attacks. Therefore, by enabling quicker, more reliable connectivity, real-time monitoring and reaction to security threats, and more effective data processing and analysis, 5G-enabled IoT and edge computing will advance smart grid security.

Index Terms— Smart Grid, 5G, IoT, Security System

I. INTRODUCTION

The development of technology has revolutionized various fields, as well as energy, with the smart grid emerging as a considerable development. The smart grid uses modern technologies

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like edge computing and 5G-based IoT to improve conventional power systems in grid. With 5G's high speed and very low delay, all the devices

can connect at the same time, which support power generation, demand response, and energy storage to the grid. IoT devices like sensors and smart meters collect information about energy use and environmental conditions. This will create valuable insights. Edge computing processes this data close to its source, which reduces delays, improves decision-making, and increases overall efficiency. Security is maintained through strong encryption. Due to the continuous monitoring, and quick threat detection it can reduce the risks of cyber-attacks. Together, these technologies make the smart grid more efficient, reliable, and secure while meeting growing energy needs.

II. INTERNET OF THINGS IN SMART GRID

The IoT is vital to the smart grid, connecting devices like sensors and smart meters that collect and exchange data to enhance the energy system's efficiency and reliability. These IoT devices gather data on energy consumption, voltage levels, and other critical parameters, which edge computing systems analyze to provide real-time insights into grid performance. This allows grid operators to optimize the system effectively. One key benefit is the provision of real-time energy consumption data, helping operators understand and manage usage better. The high speeds, low latency, and enhanced security of 5G facilitate this communication, improving grid security. Real-time monitoring and control enabled by 5G help detect and respond to security threats swiftly, enhancing the overall reliability of the smart grid. The overall wireless communication Technologies era is shown below.

Net work	Features						
	De-ploy-ment year	Data	Techno-logy	Fre-quency	speed	Advantage	disadvantage
1G	1980	Analog	AMPS, NMT TACS	800 MHz	2.4 kbps	Mobility	Spectral efficiency that is extremely low and bad han-doff
2G	1990	Digital nar-row band data	GSM, CDMA, IS-95	850-1900 MHz	64 kbps	protected, Mass Adoption long-term of battery	Data prices are extremely low, making it chal-lenging to meet demand.
3G	2001	Digital broadband packet data	WCDMA, UMTS, CDMA2000	800-2100 MHz	2Mbps	superior Internet practice	Internet failure problems
4G	2010	Digital Broadband packet data. Very high	Wi Max LTE Wi-Fi	2600 MHz	100 Mbps	High data rate,	Battery usage is higher, making it more costly.
5G	2020	Not yet defined	Had to be defined	3 to 90 GHz	10Gbps	Data coverage is better	

Table 1. Wireless communication technologies Features

The 1G network, introduced in 1980, was based on analog technology such as AMPS, NMT, and TACS. It operated at 800 MHz with a data speed of only 2.4 kbps. The main advantage

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of 1G was mobility, but it suffered from very low spectral efficiency and poor hand-off quality.

The 2G network, launched in 1990, moved to digital narrowband data using GSM, CDMA, and IS-95 technologies. It worked in the 850–1900 MHz range,

with a speed of 64 kbps. Its key strengths were better security, mass adoption, and longer battery life. However, the data rates were extremely low, making it difficult to meet rising demand.

In 2001, 3G was introduced as digital broadband packet data through technologies like WCDMA, UMTS, and CDMA2000. It used frequencies from 800 to 2100 MHz and provided speeds up to 2 Mbps. The advantage was a superior internet experience, but it often faced internet failure problems.

The 4G network, introduced in 2010, further improved digital broadband packet data using WiMAX, LTE, and Wi-Fi technologies. Operating at 2600 MHz, it offered speeds up to 100 Mbps. Its biggest strength was high data rates, but the drawback was high battery usage, which also increased cost.

Finally, 5G, introduced in 2020, operates at frequencies between 3 and 90 GHz, with speeds reaching 10 Gbps. Although its technology standards were initially not fully defined, it provides much better data coverage. The main disadvantages are not clearly mentioned, but challenges such as complexity and infrastructure costs are often associated with 5G

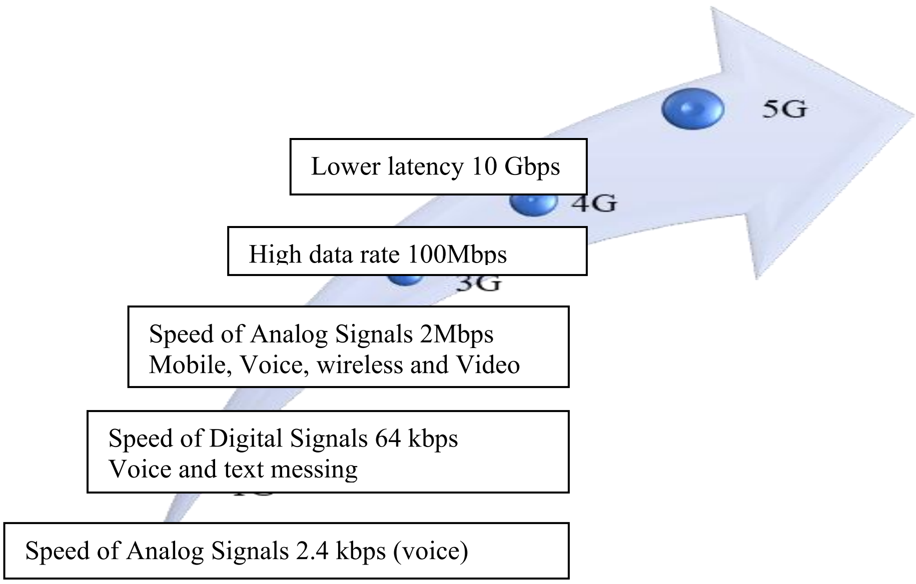

Fig.1. Evolution 1G to 5G communication network technologies considering speed of data Transmission

III. OPPORTUNITY OF IOT IN MANAGEMENT OF TSO, DSO AND REACTIVE POWER

Both Transmission System Operators (TSOs) and Distribution System Operators (DSOs) are essential to the efficient and dependable operation of a smart grid since they manage reactive power. Voltage control in the electrical system requires reactive power without it voltage

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levels can become unstable, leading to blackouts or brownouts. TSOs, responsible for the high-voltage transmission grid, manage reactive power using shunt capacitors, reactors, and synchronous condensers to maintain stable voltage levels. DSOs, responsible for the low-voltage distribution grid, use voltage regulators, capacitors, and other devices for the same purpose. Collaboration between TSOs and DSOs can optimize reactive power management; for instance, Reactive power management on both grids can be improved by DSOs giving TSOs real-time data on energy usage and voltage levels and vice versa. The effectiveness and efficiency of reactive power management are greatly increased by cutting-edge technologies like edge computing, IoT, and artificial intelligence. Real-time data on voltage levels and energy consumption is gathered using IoT sensors., which is processed and analyzed by edge computing systems to optimize reactive power management. AI algorithms analyze this data to identify patterns and predict when reactive power will be needed, allowing TSOs and DSOs to anticipate demand and take proactive measures.

Furthermore, demand response programs enabled by real-time data and advanced analytics help balance the grid load and manage reactive power effectively. Overall, leveraging advanced technologies allows TSOs and DSOs to improve reactive power management, ensuring stable voltage levels and the reliable and efficient operation of the smart grid.

IV. Benefits of 5G-enabled IoT computing can improve smart grid security:

Real-time monitoring and control enabled by 5G can quickly and effectively detect and respond to security threats. The overall classification of communication technologies varies in terms of technology, data rate, coverage, and frequency with respect to LAN, NAN, and WAN.

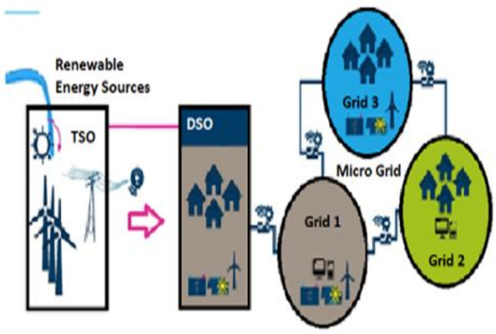

Fig.2 Distribution system of Renewable Energy

An AI-based micro smart grid system can be implemented in sectors such as smart homes, smart cities, smart buildings, and industries. Utilizing 5G networks, smart grids can deploy stronger authentication and encryption protocols to prevent unauthorized access. IoT devices combined with edge computing help secure data with strong encryption. Only authorized users can access the information. These devices improve visibility, allowing operators to monitor systems and control access. They can also detect unusual activity and block

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unauthorized changes. By tracking equipment health, IoT enables predictive maintenance. This reduces risks and prevents downtime. Edge computing spreads security functions across the grid, lowering the chance of a single point of failure. This makes the system more resilient. Machine learning and analytics process large amounts of data. They detect threats, study network traffic, analyze user behavior, and find anomalies. With 5G and edge computing, security responses become faster. Compromised systems can be shut down, affected areas isolated, and real-time patches deployed.These technologies also support scalability. New devices can be connected to the grid without affecting security. This makes the smart grid safer, more reliable, and better prepared for growing energy needs. User privacy is also protected. Data collection and transmission are kept to a minimum. Sensitive information is encrypted and secured. Together, 5G-enabled IoT and edge computing strengthen smart grid security. They provide threat detection, fast response, scalability, and privacy. The result is a secure, efficient, and dependable energy system for the future.

Application in SGs	LAN				NAN & WAN				
Technology	Wi-Fi	Zigbee	Z wave	Bluetooth	NB-IoT	Wi-SUN	Sigfox	LoRa WAN	LoRa modulation
Data rate	54 Mbps	250 kbps	40 kbps	721 kbps	14.4 kbps (2G) 100 Mbps (4G)	300 kbps	100 bps	50 kbps	0.3 - 37.5 kbps
Coverage	0-250 metre	0-100 metre	0-30 metre	0-100 metre	10-100 kilometre	500 metre - 5 km metre r	30-50 kilo metre (Rural) 3-10 kilometre (Urban)	10-15 kilo metre(Rural) 2-5 kilometre (Urban)	10-15 kilometre(Rural) 3-5 kilometre(Urban)
Frequency	2.4 and 5 GHz	2.4 GHz	900 MHz	2.4 GHz	824 MHz and 1900 MHz	900 GHz	868 MHz	900 MHz	900 MHz
Standard	IEEE 802.11b/g/n	IEEE 802.15.4	ITU-T G. 9959	IEEE 802.15.1	GSM/GPRS/EDGE, (2G), UMTS/HSPA (3G), LTE (4G)	IEEE 802.15.4g	Sigfox	LoRaWAN	LoRa modulation

Table .2. Categorization of the different application in Communication Technologies

V. Analysis

Taking into account the measurement sensors associated with state estimation, voltage control services may include actors such as

A. Load and Generation Forecasting Unit: These End Points are responsible for estimating the expected load and generation patterns in the power system. Load and generation forecasting units typically use historical data, weather data, and other relevant information to predict the future load and generation profiles. Accurate load and generation forecasting is crucial for effective voltage control services, as it helps in determining the optimal set-points for voltage control devices.

B. The Transmission System Operator (TSO) Optimal Power Flow (OPF): This mathematical optimization method is utilized to maximize the power system's performance. OPF determines the ideal settings for voltage control devices such transformers, capacitors,

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and reactors by taking into account a number of factors, such as generating outputs, line flows, and voltage magnitudes and angles. Because it aids in system-wide voltage level optimization, TSO OPF is essential to state estimation-related measurement sensors for voltage control services.

C. TSO SCADA/State: The Transmission System Operator (TSO) manages the grid in real time through the SCADA system. SCADA gathers data from sensors that measure voltage, current, and power flow. This information is used for state estimation to calculate values such as voltage magnitude and angle. Accurate state estimation supports reliable voltage control and better decision-making.

D. TSO OLTC: An On-Load Tap Changer (OLTC) is a transformer that allows tap changes while carrying load. By adjusting the tap position, it regulates voltage in the grid. The TSO monitors and controls OLTC devices to maintain proper voltage levels.

E. TSO FACTS: Flexible AC Transmission Systems (FACTS) manage power flow with the help of power electronics. Devices such as UPFCs, SVCs, and STATCOMs inject or absorb reactive power to control voltage. The TSO supervises these devices to ensure stable voltage regulation in the transmission system.

F. DSO OPF:The Distribution System Operator (DSO) uses Optimal Power Flow (OPF) methods for distribution networks. It considers distributed generation, loads, and grid limits to optimize voltage settings. Devices such as regulators, capacitor banks, and distributed generators are adjusted accordingly.

G. Power Compensation Units: Voltage is managed with devices like shunt capacitors, shunt reactors, and series capacitors. These inject or absorb reactive power to balance voltage levels. Both TSOs and DSOs use them in voltage management strategies.

H. Generator Controllers: Synchronous generators and renewable sources such as solar and wind have built-in controllers. These controllers regulate active and reactive power output. In this way, they help maintain system voltage and grid stability.

Conclusion

The Integration Of 5G And Iot Brings Major Advantages To Smart Grid Security. With 5G-Enabled Iot Devices, Smart Grids Can Gather Real-Time Data From Many Sensors And Systems. This Improves Monitoring And Control. The Data Also Helps In Quick Detection Of Cyber-Attacks Or Physical Intrusions.5G Offers High Bandwidth And Low Latency. This Ensures Fast Communication And Quick Response During Security Incidents. Strong Authentication And Encryption Secure Iot Devices Connected Through 5G. As A Result, Reliability Increases, Downtime Decreases, And Overall Grid Security Improves. These Benefits Help Operators Run The Grid More Efficiently, Cut Costs, And Serve Customers Better. However, New Challenges Also Arise. Greater Complexity And Potential Vulnerabilities Must Be Addressed. Careful System Design, Constant Monitoring, And Timely Updates Are Essential To Maintain Safety And Effectiveness.

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