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Internet of Things in Power Industry

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ABSTRACT

The electric power industry is a critical part of modern society. The industry is constantly evolving and innovating. As technology advances, so does the industry. The Internet of things (IoT) is key to most problem areas in this industry. IoT is a network of physical devices or things just as the Internet is a network of computers. It refers to physical devices that use electronics, sensors, and software to connect and exchange data with other devices over the Internet. In an IoT network, various devices, such as your car, toaster, coffee maker, etc., can communicate and exchange data. IoT has the potential to drastically change the electric power sector. IoT can help electric power companies become more productive by lowering operational costs, eliminating unplanned downtime, and improving asset reliability. This paper delves into the profound impact of IoT on the electric power industry.

KEYWORDS: *Internet of things, IoT, industrial Internet of things, IIoT, power, power industry, power systems, utility companies*

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INTRODUCTION

The electric power industry is an ever changing and essential part of modern life. It is responsible for the generation, transmission, and distribution of electricity to homes and businesses. Power systems provide the required energy in all sectors, making them the backbone of modern living. The systems are responsible for supplying energy to all types of loads—from household appliances to industrial machinery—by forming a network of components that transfer, supply, and deploy electric power. The entire network of power systems can be divided into three components for generation, transmission, and distribution [1].

In the power industry, we are experiencing a global energy crisis and the demand for energy is undergoing a transformative shift. As we confront the challenges posed by the current global energy crisis, it is evident that the power and utilities sector stands at the precipice of transformative change. In spite of the situation, demand for power and utilities surges. Amid heightened demand and evolving environmental consciousness, Internet of things (IoT) integration emerges as a beacon of innovation for the power and utilities sector. The power industry is rapidly changing due to the introduction of IoT technology. In the power industry, IoT technology is being used to create smarter and more efficient grids. The application of IoT-powered solutions in power systems significantly improves their efficiency.

OVERVIEW ON INTERNET OF THINGS

The concept of the Internet of things (IoT) has been around since the late 1990s, but it gained momentum in the 2000s with the rise of Internet-connected devices. The Internet began with some military computers in the Pentagon called Arpanet in 1969. It expanded throughout the 1980s as a set of four parallel military networks, each at a different security level. The core technology which gives the Internet its particular characteristics is called Transmission Control Protocol/Internet Protocol (TCP/IP), which is essentially a set of rules for communication [2]. Figure 1 shows the components of IoT platform [3].

Internet of Things (IoT) is a worldwide network that connects devices to the Internet and to each other using wireless technology. IoT is expanding rapidly and it has been estimated that 50 billion devices will be connected to the Internet by 2020. These include smart phones, tablets, desktop computers, autonomous vehicles, refrigerators, toasters, thermostats, cameras, alarm systems, home appliances, insulin pumps, industrial machines, intelligent wheelchairs, wireless sensors, mobile robots, etc. Figure 2 illustrates various applications of the Internet of things [4].

There are four main technologies that enable IoT [5]: (1) Radio-frequency identification (RFID) and near-field communication, (2) Optical tags and quick response codes: This is used for low cost tagging, (3) Bluetooth low energy (BLE), (4) Wireless sensor network: They are usually connected as wireless sensor networks to monitor physical properties in specific environments. Communications technologies in Internet of things are portrayed in Figure 3 [6].

IoT technology enables people and objects to interact with each other. It is employed in many areas such as smart transportation, smart cities, smart energy, emergency services, healthcare, data security, industrial control, logistics, retails, structural health, traffic congestion, manufacturing, and waste management. The Internet of things is extensively developed world-wide with a focus on civilian applications such as electric power distribution, intelligent transportation, healthcare, industrial control, precision agriculture, environmental monitoring, etc.

INDUSTRIAL INTERNET OF THINGS

The growth of the internet of things (IoT) is drastically making impact on home and industry. While the IoT affects among others transportation, healthcare, or smart homes, the Industrial Internet of Things (IIoT) refers in particular to industrial environments. IIoT is a new industrial ecosystem that combines intelligent and autonomous machines, advanced predictive analytics, and machine-human collaboration to improve productivity, efficiency and reliability. It is bringing about a world where smart, connected embedded systems and products operate as part of larger systems [7].

The industrial Internet of things (IIoT) refers to the application of the Internet of things (IoT) across several industries such as manufacturing, logistics, oil and gas, transportation, energy/utilities, chemical, aviation and other industrial sectors. A typical industrial Internet of things is shown in Figure 4 [8].

IIoT is often used in the context of Industry 4.0, the Industrial Internet and related initiatives across the globe. Industry 4.0 describes a new industrial revolution with a focus on automation, innovation, data, cyber-physical systems, processes, and people [9]. With Industry 4.0, the fourth industrial revolution is set on merging automation and information domains into the industrial Internet of things, services, and people. The communication infrastructure of Industry 4.0 allows devices to be accessible in barrier-free manner in the industrial Internet of things, without sacrificing the integrity of safety and security [10]. Figure 5 shows a typical representation of IoT [11].

IOT IN POWER SYSTEMS

In addition to providing electricity to homes and businesses, the electric power industry also provides a variety of other services such as electric vehicle charging stations, energy storage solutions, and grid modernization. The power industry is the groundwork of the industrial world, supplying commercial, industrial, manufacturing, and residential customers with essential energy. The integration of the Internet of things (IoT) into electrical systems has emerged as a transformative force, reshaping the way we interact with and manage power.

The Internet things (IoT) has revolutionized the electric power industry and has enabled efficient, secure, and cost effective processes. It is a key tool for enabling the smart coupling of the power and heat sectors. It will help to distribute electricity without loss. In power industry, the Internet of things (IoT) refers to the integration of various connected sensors and devices across the electricity grid, allowing for real-time monitoring, data collection, and analysis. It is a network of connected devices, like sensors and smart meters, deployed across the power grid to collect real-time data on energy generation, distribution, and consumption, allowing for optimized grid management. IoT includes three core elements that make this technology so prominent: asset digitalization, asset data collection, and computational algorithms to manage the network created by interconnected assets. All these components can enhance the efficiency and performance of the electric power grid.

The electric power industry can be broken down into three main categories: generation, transmission, and distribution, as illustrated in Figure 6 [12]. IoT is becoming increasingly important in the power generation industry. IoT technology enables the efficient and secure transfer of data from power plants to the grid, allowing for more efficient operations and improved reliability. IoT in power transmission is being used in a variety of ways. For example, it is being used to monitor and control the flow of electricity in the grid, as well as the temperature and pressure of the system. This is helping to reduce power losses due to fluctuating conditions. In addition, IoT is being used to detect and diagnose faults in the system, which can then be quickly addressed. Figure 7 shows IoT in power transmission system [1]. IoT is also playing a major role in the advancement of the power distribution industry. With the help of IoT, power distribution networks can now be monitored and controlled remotely. This has allowed the industry to improve efficiency by avoiding downtime and reducing manual intervention [13].

APPLICATIONS OF IOT IN POWER SYSTEMS

In power systems, IoT plays important roles. IoT is a versatile technology and it can be applied in several situations in the power systems. The application of IoT technology has also enabled the emergence of a "smart grid", which is an intelligent and highly automated energy distribution network. Common areas of applications include the following [14]:

- *Smart Grid:* Traditional power grids are designed to transmit electricity from a large, centralized power station to a wide network of homes and businesses in the area. Smart grids are electrical grids that involve the same transmission lines, transformers, and substations as a traditional power grid. A smart grid facilitates the bi-directional transmission of data and electricity. The five components of a smart grid include advanced metering infrastructure (AMI), distribution automation, demand response, energy storage systems, and smart sensors and devices. Enabled by IoT technology, the grid ecosystems integrate data, electrical flow, and digital communications, providing transparent communication between electrical flow and data. These smarter variants of electrical grids can help optimize electrical usage and reduce bills for consumers with innovative networking capabilities. Smart grids have many applications and can supply power to consumers using digital communication that enables the monitoring and analysis of the electrical supply. They are designed with energy efficiency and sustainability in mind. Figure 8 shows the old grid versus the smart grid [15], while Figure 9 shows the smart grid [16].
- *Smart Metering:* A good illustration of using IoT in the energy industry is smart metering. Smart meters are IoT devices installed at individual homes and businesses. They are used to measure and record monitor electricity consumption in real-time, providing detailed usage data to both consumers and utility companies for better billing practices. Smart meters enable two-way communication between the utility company and the consumer. They track utility energy consumption through IoT technology. The most significant advantages of smart meter integration are their remote monitoring capabilities and that smart meters provide businesses with a means of tracking, monitoring, and adjusting their utilities usage. Figure 10 shows smart metering [12].
- *Smart Homes:* IoT makes our homes "smart", letting homeowners manage lighting, air conditioning, security systems, and home appliances with just one touch. Smart homes, equipped with IoT-enabled devices, represent a paradigm shift in residential living. From smart thermostats and lighting systems to intelligent appliances, homeowners can now create an interconnected ecosystem that adapts to their preferences and lifestyle. The integration of IoT in home security systems has brought about a revolution in safety. Smart cameras, doorbells, and sensors enable real-time monitoring, with alerts sent directly to homeowners' smartphones. Automated door locks and surveillance systems can be remotely controlled, providing an unprecedented level of security and convenience. IoT for smart homes is shown in Figure 11 [17].
- *Smart Cities:* The staggering rate of urbanization as well as overpopulation has brought many global concerns, such as air and water pollution, energy access, and environmental concerns. In this line, one of the main challenges is to provide the cities with clean, affordable, and reliable energy sources. The recent developments in digital technologies have provided a driving force to apply smart, IoT based solutions for the existing problems in a smart city context. Smart factories, smart homes, power plants, and farms in a city can be connected. In a smart city, different processes, i.e., information transmission and communication, intelligent identification, location determination, tracing, monitoring, pollution control, and identity management can be managed perfectly by the aid of IoT technology. IoT for a smart city is shown in Figure 12 [17].
- *Industrial Automation:* In the industrial sector, IoT plays a pivotal role in automation, offering unparalleled benefits in terms of efficiency and productivity. Connected sensors and devices facilitate real-time monitoring of machinery, allowing for predictive maintenance and minimizing downtime. This connectivity also enables seamless communication between different components of a manufacturing process, optimizing workflow and reducing operational costs. One of the primary benefits of IoT in

industrial environments lies in the copious amount of data produced by interconnected devices. This data provides valuable insights into performance metrics, energy consumption, and overall equipment effectiveness.

- *Automation of Energy Usage:* IoT-based home automation and smart metering technologies make this possible. A prime example is an IoT energy management solution Vakoms has been working on energy usage. The software is aimed at automating energy consumption intelligently helping households avoid excessive energy usage during high demand. Consuming electricity during high demand is bad. The software works perfectly with smart meters, allowing users to forget about manual transferring of the metering data. The plugin can communicate directly with the electricity provider, collecting and sending the meter readings at any moment when required.
- *Workplace Safety:* Connecting smart devices over the workplace can offer automated control over the operation management process. According to Microsoft, 37% of power and utilities organizations adopt IoT for its workplace safety benefits. For example, connected systems can be implemented in workplace equipment for increased safety. For utility workers, this might surround including proximity sensors in cherry pickers to let workers know when they are too close to live power lines or similar hazards. Automated scheduling maintenance of various equipment can help reduce workplace injuries and boost compliance ratings of the company. Smart devices reduce the chances of human error in critical operations that further boost workplace safety.
- *Employee Safety:* In addition to workplace safety, IoT integration can provide an essential means of increased employee safety. For example, IoT components can ensure that equipment is only run by authorized users.
- *Demand Response:* IoT allows utilities to communicate with large energy consumers, adjusting their power usage based on grid conditions, such as during peak demand periods, to balance load. Demand response systems include smart thermostats, smart appliances, and energy management systems, which enable demand response programs where consumers can adjust their electricity usage based on grid conditions or price signals. By analyzing data from smart meters, utilities can incentivize customers to reduce their electricity usage during peak demand periods. Smart grids can help consumers reduce their electricity bills by advising them to use devices with a lower priority when the electrical rates are lower. This also helps in the real-time analysis of electrical usage and charges.
- *Electric Vehicle Charging:* The burgeoning adoption of electric vehicles opens up new business opportunities in the power and utilities sector. To pave the way for the full-scale adoption of electric vehicles (EVs) in America, the nation must address the infrastructure needs for large-scale operation. This includes the essential requirement for a robust vehicle-to-grid infrastructure. IoT technology emerges as the key solution, playing a pivotal role in supporting the infrastructure necessary for the widespread operation of EVs.
- *Predictive Maintenance:* By analyzing sensor data, potential equipment failures can be predicted, allowing for preventative maintenance to be scheduled, minimizing downtime and improving grid reliability. Predictive maintenance and optimized grid operations can lead to significant cost savings.
- *Remote Infrastructure Maintenance*: While smart grids provide comprehensive asset maintenance, IoT also provides thorough remote monitoring of infrastructure for utility companies in general. IoT sensors and components can instantly notify headquarters of remote infrastructure updates.

BENEFITS

There is no denying that the increasing utilization of IoT devices in the power systems brings numerous benefits, including improved efficiency, reliability, and sustainability. IoT provides a platform to collect, analyze, and share data from various sources and to enable better decision-making. The implementation of IoT solutions has made it possible to detect potential faults and failures faster, ensuring a reliable and safe energy delivery. Other benefits of IoT in power systems include the following [18,19]:

- *Automation:* IoT technology can be used to automate the electricity grid. Smart grids allow utilities to automatically adjust the electricity supply and demand to maintain a reliable power supply. This reduces the need for manual intervention and improves the reliability of the electricity grid.
- *Renewable Energy Integration:* IoT devices play a crucial role in the integration of renewable energy sources like solar and wind power. IoT sensors can optimize the integration of variable renewable sources like solar and wind power into

the grid by providing real-time data on generation fluctuations. IoT facilitates seamless integration of variable renewable energy sources into the grid by monitoring their output and adjusting power flow accordingly.

- *Better Use of Resources:* IoT can also help automate resource usage and thereby reduce the power and water consumption of a business. This is an inexpensive system which can be deployed with simple motion detection devices that detect and measure resource usage and compare it with the presence of employees.
- *Improved Efficiency*: Real-time data analysis allows for optimized power flow management, reducing energy losses, and improving grid performance. IoT technology is being used to make the electric power industry more efficient. Smart meters, for example, monitor electricity usage and send data to utilities in near real-time. This allows utilities to better manage their electricity supply and demand, leading to improved energy efficiency.
- *Improved Customer Service*: IoT technology is being used to improve customer service in the electric power industry. Smart meters, for example, can be used to provide customers with detailed information about their energy usage, allowing them to better manage their energy consumption.
- *Cost Reduction:* IoT technology can be used to reduce costs in the electric power industry. IoT helps reduce downtime periods by automatically scheduling maintenance whenever the equipment shows signs of wear. By optimizing grid operations and enabling preventative maintenance, IoT can lead to significant cost savings for utilities.
- *Customer Engagement:* Access to detailed energy usage data empowers consumers to make informed decisions about their electricity consumption and potentially reduce their bills.
- *Asset Monitoring:* Sensors on power generation equipment like turbines and transformers collect data on their health and performance, enabling predictive maintenance to prevent outages.
- *Intelligent Monitoring Systems:* They are equipped with sensors and communication capabilities and are deployed throughout the power grid infrastructure to monitor various parameters, including voltage, current, temperature, and line conditions. This data is used for predictive maintenance, fault detection, and performance optimization.
- *Sustainability:* The smart grid system in IoT benefits the environment by optimizing energy distribution, reducing energy waste, integrating renewable energy sources efficiently, and enabling real-time monitoring. This leads to a more sustainable and eco-friendly energy infrastructure.
- *Load Balancing*: Electrical load balancing refers to how power stations can store excess power during downtimes to allocate as demand increases. IoT technology can not only assist utilities organizations with load balancing as well as how they generate power through increased insights and data.
- *Emissions Monitoring:* Through the deployment of advanced sensors, IoT devices are game changers for organizations looking to not only monitor but actively and effectively minimize emissions.
- *Predictive Load Forecasting:* Similar to load balancing, the increased data that IoT equipment offers utilities organizations can analyzed to provide predictive actionable insights that can be used to forecast when demand is at its highest.

CHALLENGES

While the principles of IoT are similar no matter what industry, the precise application may be obscure in different sectors. In addition to dealing with rising energy demand, the electric power industry has to contend with challenges like stringent emission regulations, rising reliability standards, ageing infrastructure, the spread of distributed energy resources (DER), workforce retirement, and a high frequency of accidents. Other challenges of IoT in power systems include the following [1,12,18]:

- *Increasing Demand:* The electricity demand has been rising steadily for decades. This has put immense pressure on the industry to increase production and meet the demands of consumers. This has increased the cost of electricity, as well as an increase in the complexity of the industry's operations.
- *Ageing Infrastructure:* Many of the power plants, transmission lines, and other infrastructure used by the electric power industry are ageing and in need of replacement or repair. This can be a costly process and can lead to disruption of service in some areas. Integrating IoT devices may necessitate upgrades to existing power grid infrastructure. With the growing power

requirement across the globe, we need to find smarter solutions for generating, storing, and delivering electricity. Today, the best way to accomplish this is for governments to replace traditional power grids with smart grids.

- *Climate Change:* As the world becomes increasingly aware of the impact of climate change, the industry is feeling the pressure to reduce its emissions. To do this, many electric power companies are investing heavily in renewable energy sources such as wind and solar. Integration of renewable energy and optimization of energy use are key enablers of sustainable energy transitions and mitigating climate change.
- *Data Management*: IoT devices generate massive amounts of data continuously. Handling the data generated requires robust data analysis and storage systems. It is not enough to store the data securely; it must be processed, analyzed, and presented understandably to be useful. Constant real-time data collection is practically impossible with human labor. Yet, IoT can make it so simple. Integrating IoT solutions and sensors in the smart grid distribution lines and the power substations will enable companies to collect real-time consumer consumption data.
- *Lack of Standards:* Many IoT devices lack a centralized and standardized security framework. Lack of standardized communication protocols can complicate integration of various IoT devices from different manufacturers. The absence of unified regulations and standards for IoT security leaves manufacturers with discretion over the security measures they incorporate into their devices. Because smart devices lack standardization, some organizations are making efforts to increase security awareness across various industries that rely on IoT technology.
- *Security Concerns:* Security is a huge concern for energy producers. IoT devices are facing security challenges due to the fast-paced nature of IoT development, the wide range of devices and industries involved, resource constraints, and the absence of unified security frameworks. IoT devices in the energy sector can be targeted by cyber attacks, including hacking, malware, and DDoS attacks. Protecting sensitive grid data from cyber threats is crucial. To mitigate risks, it is imperative to implement robust security measures throughout the grid infrastructure. Regular vulnerability assessments and security audits should also be conducted to identify and address any weaknesses in the grid's smart devices.
- *Cybersecurity:* One major vulnerability is weak authentication and encryption. The electric power industry is increasingly being targeted by hackers. As IoT devices become more integrated into the power grid, the risk of cyberattacks increases. A coordinated attack could manipulate energy flows, cause cascading failures, disrupt power to critical infrastructure, and damage the grid infrastructure. This highlights the need for increased security measures to ensure the safety and stability of the power grid. A strong cybersecurity culture begins with leaders who take cybersecurity seriously and create rules to make sure it is implemented. It is a shared responsibility among stakeholders, including utility companies, manufacturers, regulators, and individuals, to work collaboratively in safeguarding the power grid against evolving threats.
- *Regulation:* The electric power industry is highly regulated by both state and federal governments. These regulations ensure that the industry is safe and reliable. But this can make it difficult for companies to adjust to changing regulations. Regulatory bodies often set standards for grid reliability and performance. Internet of things and energy systems must ensure compliance with these standards to maintain grid stability and avoid penalties.
- *Cost:* Solutions to all the challenges and issues are coupled with huge investments. If we are talking about the modernization of the existing power systems, every step from hardware sensors to software updates has to be paid for. Large-scale implementation of an IoT solution requires a large financial investment, as it involves devices, networks, support, and applications.
- *Connectivity:* Connectivity is a critical element in any IoT system, as the connectivity scheme is the conduit through which all of the system devices are interconnected and are able to communicate with the cloud. Reliable connectivity is a concern in power system design, particularly for systems that will be deployed in geographically remote areas with spotty coverage. For power system operation in remote areas, satellite connectivity will be the best option, whereas in locations with adequate provider network coverage, cellular or Wi-Fi can be used.
- *Power Management:* IoT devices perform a range of functions in a given power system and hence require a constant energy supply in order to keep up with the demand from the various system elements. Effective power management is

essential if the IoT system is to perform efficiently. The most common way to save power is by putting the system into sleep modes (modem, light or deep sleep) when appropriate.

- *Complexity:* The exponential growth of IoT or any other technology is bound to drive up its complexity. As each company working on IoT solutions has pursued its own methods for developing such complex solutions, the number of protocols has spiraled.
- *Lack in Skill Set*: IoT remains a fairly new concept that is slowly working its way into the major technological sectors. Deploying IoT into existing systems requires the engineer to have the necessary skill set and to have a proper understanding of the existing power system into which IoT technology is being integrated. Maintaining these complex, costly systems will also require skilled professionals.

CONCLUSION

IoT is a scalable and flexible technology that can be useful for any company looking for digitization, automation, or optimization of its processes. It is helping to improve the efficiency, safety, and reliability of the energy grid. It is also helping to reduce energy wastage and costs. IoT is drastically transforming the electric power industry. It is allowing utilities to monitor energy consumption and provide a more reliable and efficient power grid. It is all about the connection of assets, data, and technology personalization. IoT offers new opportunities for consumers to engage with the power sector. As the technology evolves, it is expected that more sophisticated applications of IoT will be seen in the power industry, leading to further improvements in energy production, distribution, and consumption. More information about Internet of things in the power industry can be found in the books in [20-24] and the following related journals:

- *IEEE Internet of Things Journal.*
- *IEEE Smart Grid*
- *Energies*

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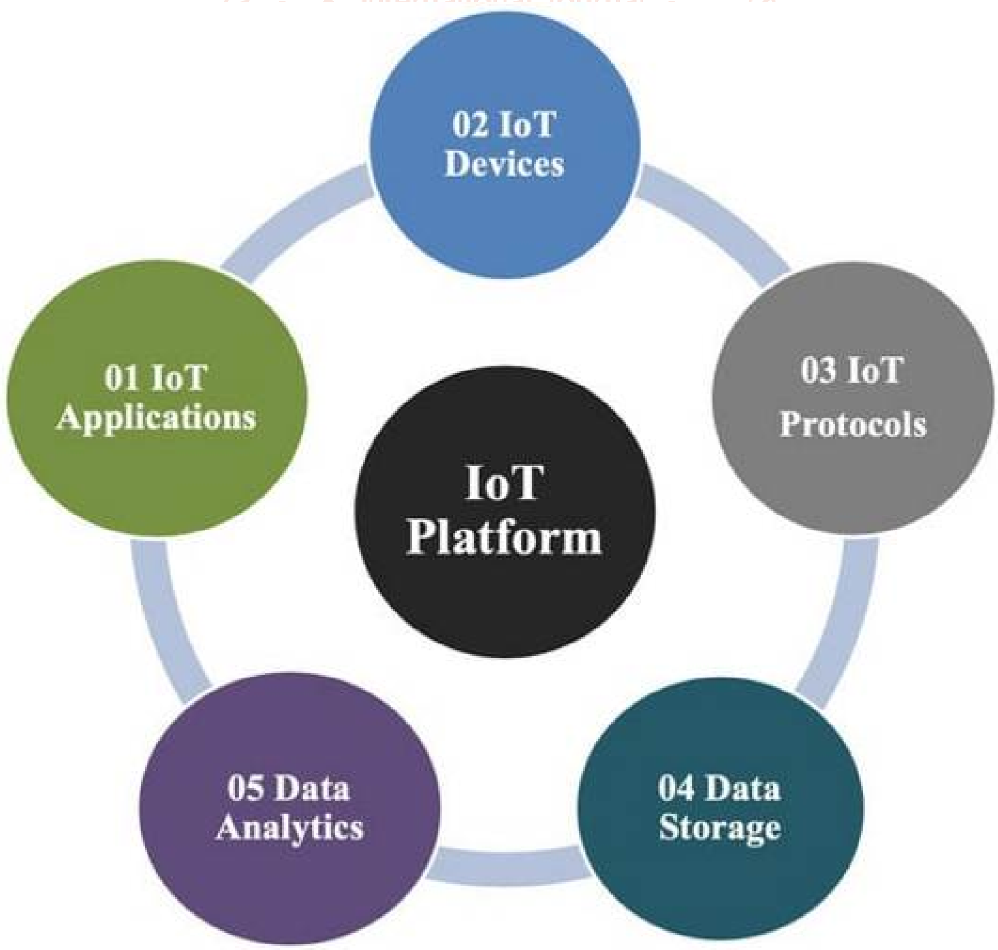

Figure 1 Components of IoT platform [3].

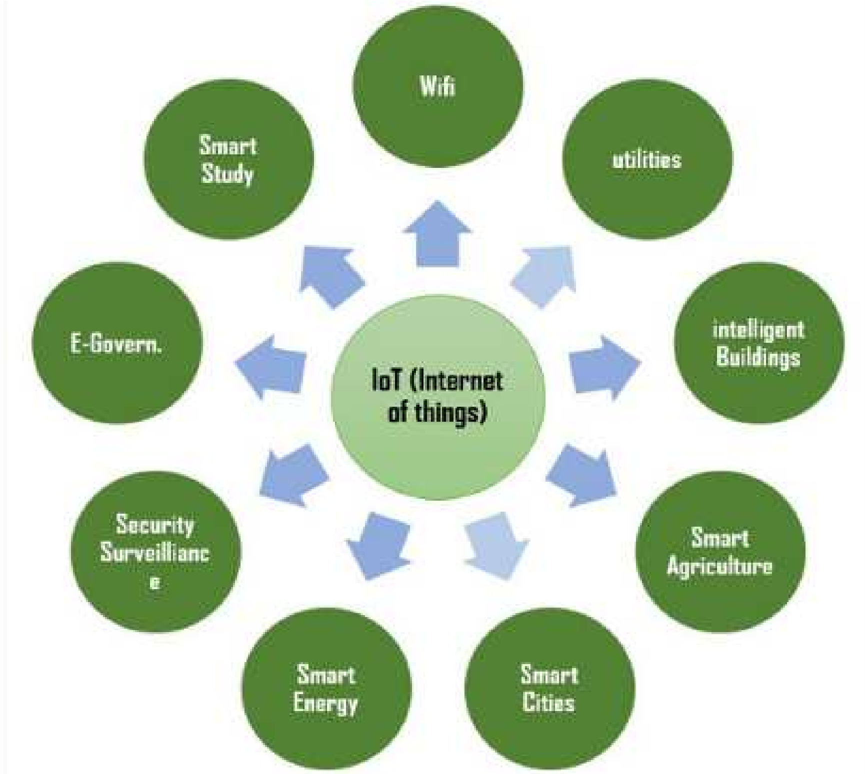

Figure 2 Applications of the Internet of things [5].

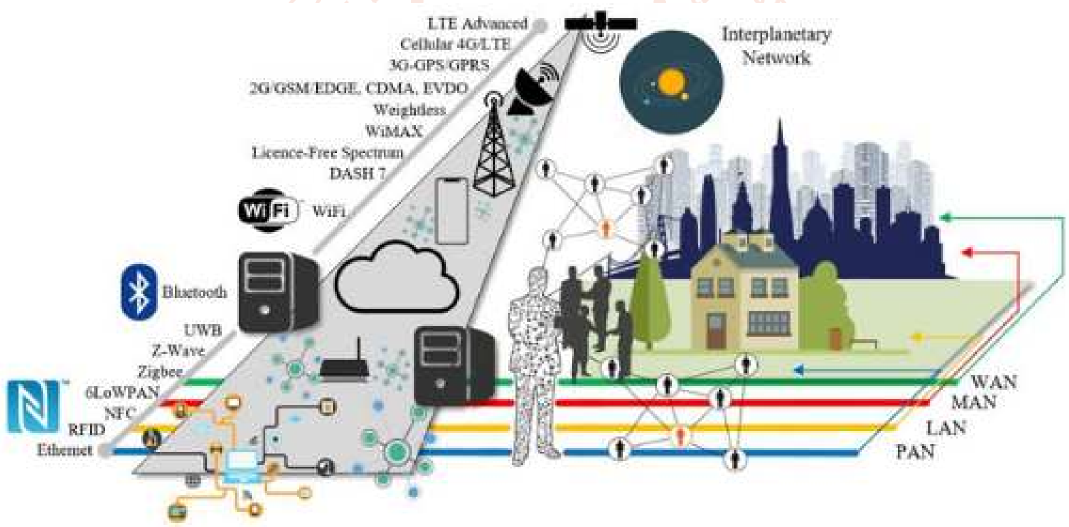

Figure 3 Communications technologies in Internet of things [6].

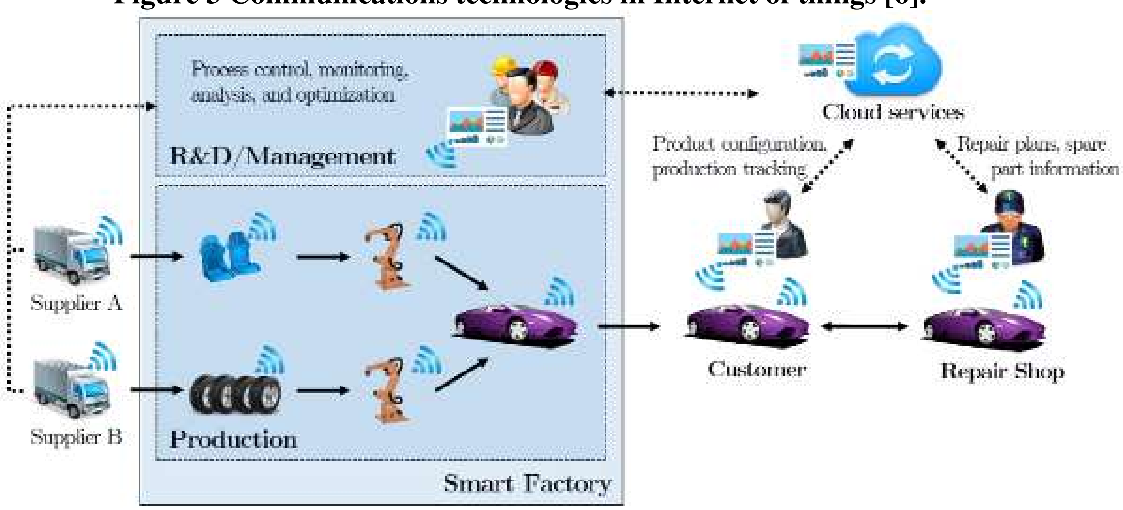

Figure 4 A typical industrial Internet of things [8].

Figure 5 A typical representation of IoT [11].

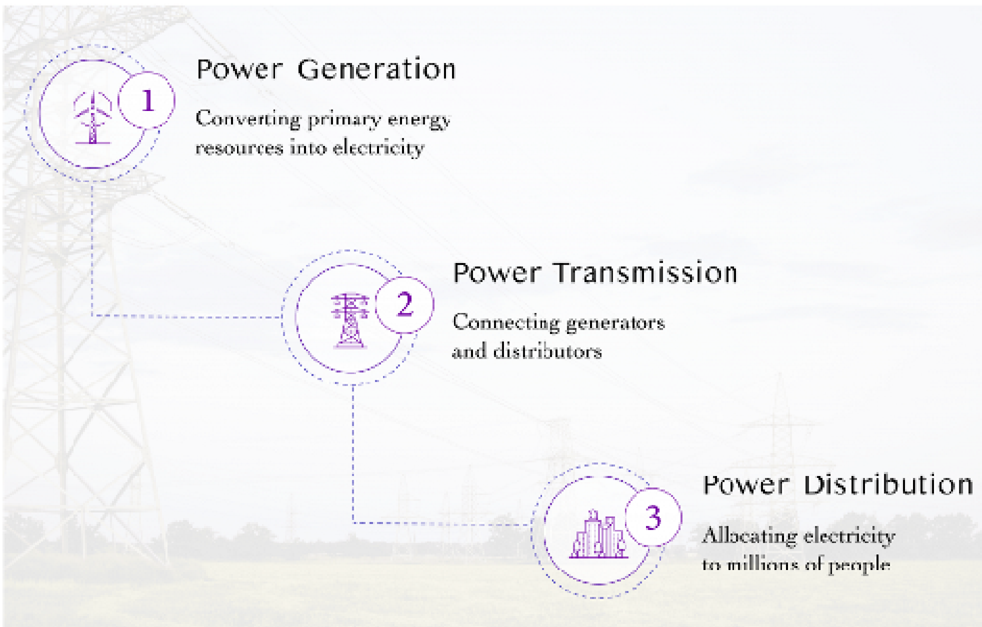

Figure 6 Three components of a power system [12].

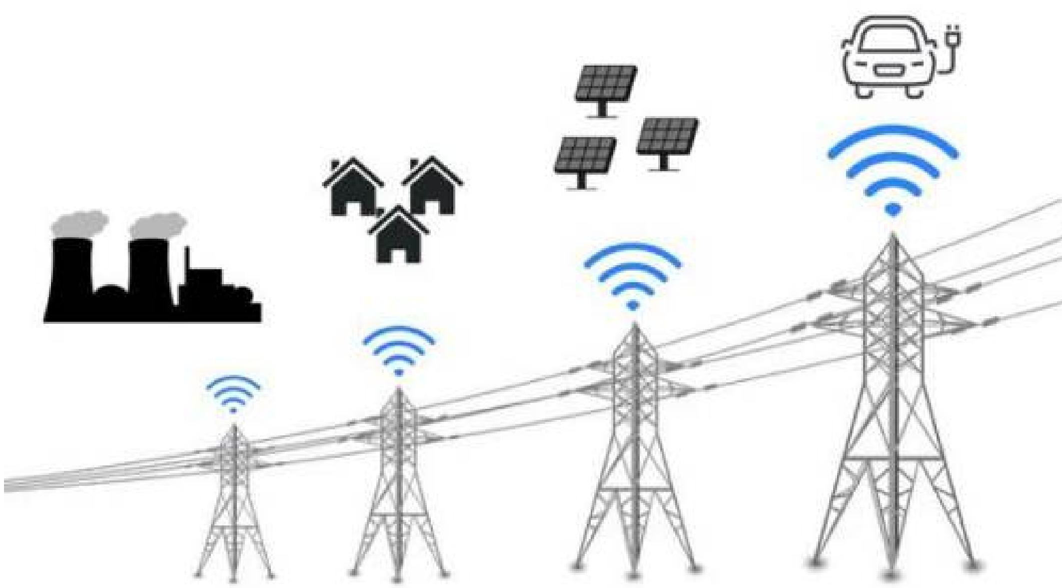

Figure 7 IoT in power transmission system [1].

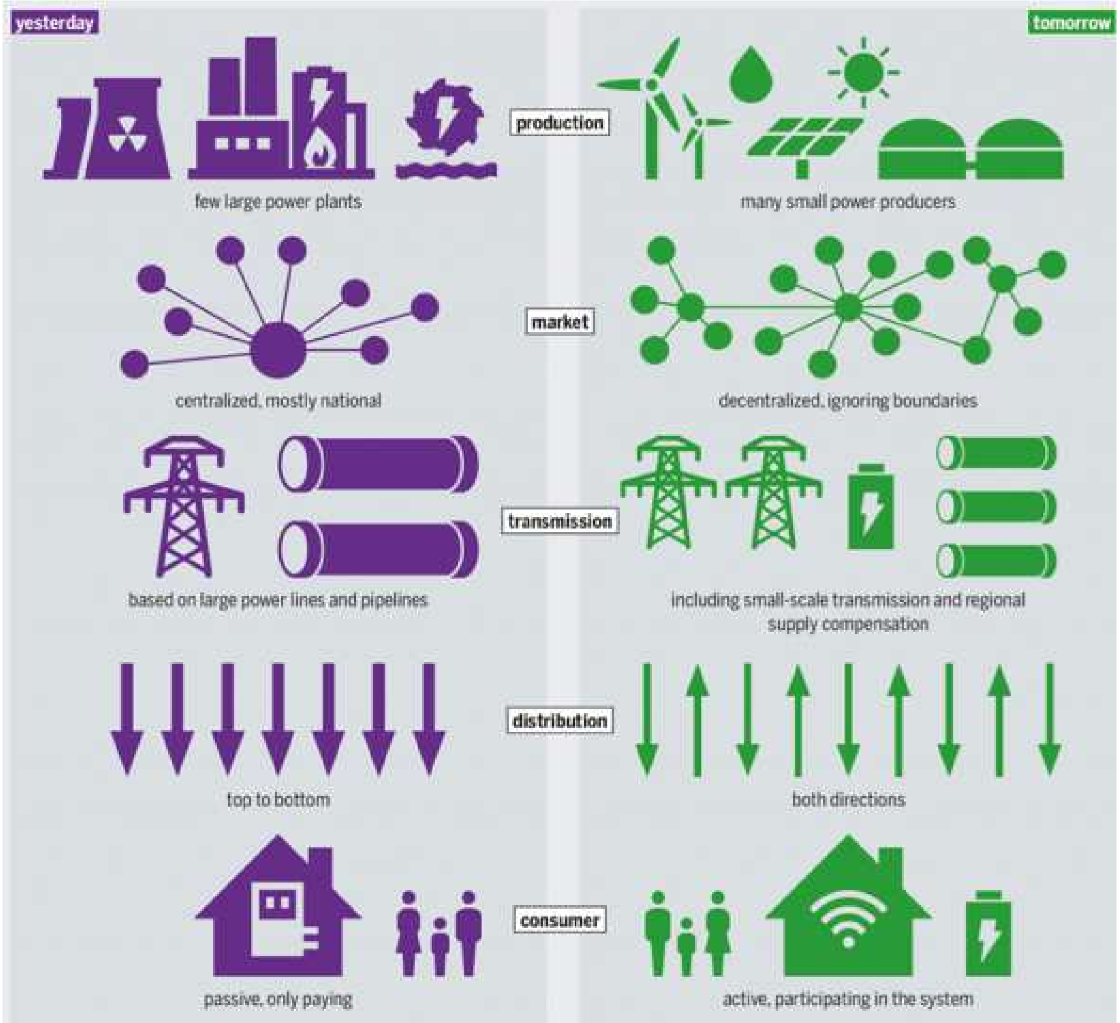

Figure 8 The old grid versus the smart grid [15].

Figure 9 Smart grid [16].

Figure 10 Smart metering [12].

Figure 11 IoT for smart homes [17].

Figure 12 IoT for a smart city [17].