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The Impact and Application of Smart Grid on Global Energy Delivery

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Abstract: This paper presents a detailed survey of global energy delivery and smart grid approaches. Particularly in the sense that shows the impacts on the production of energy resources globally. How can energy losses be reduced, primarily by implementing smart grid approaches? Power transfers and reduction of energy sources can be made by smart grids with information technology (I.T) such as sensors digital meters and communication networks. Energy from photovoltaic and wind power are some of the energy delivery systems that have gained attention since they are cheap and environment-friendly and do not emit greenhouse gas. Presently available grid is insufficient to serve future systems. For this reason, an intelligent grid system is required to support future needs for society. This paper expounds on the impacts of the existing power delivery system and suggests a smart grid for global energy delivery on a better management system.

Keywords: GHG, T&D, BPL, ARE, AEDB, SERC, IOT.

Introduction

Energy delivery systems are in different forms, an energy source that is naturally regenerated over a short time scale and delivered directly or indirectly from the sun or natural movements, and the mechanism is referred to as renewable energy. While that derived from fossil fuels is referred to us non-renewable energy (Conti et al., 2014; Shen et al., 2012). Clean sources of energy are derived from renewable energies, which are from wind, solar, biomass, hydro, nuclear, tidal, and hydrogen. This kind has a much lower environmental impact than those from conventional technologies, i.e., from fossil fuels that emit greenhouse gas. Asia has become a significant player on the global scene in the last few decades. India and China are also developing at a rapid pace in the least of most people's expectations (Fadaeenejad et al., 2014).

Wind Power

Globally, most people do not realize the potential of wind power. Wind power first came about in Asia between 500 and 900 AD, and a vertical axis turbine was developed in Persia to grind grain and pump water. These wind turbines were made from wood. However, in recent years Europe and North

America have led in terms of installed wind capacity. The only wind energy source can collectively produce over 150,000MW of electricity in Pakistan. Average acceptable wind speed in most parts of the world lies from (6.2-6.9)m/s (good category) and (7.0-7.4)m/s (good category). India and China currently have the fourth and fifth most substantial number of wind turbines installed, respectively (Kar et al., 2016). It is interesting to note that India has 45,000MW of wind energy potential. Renewable energy potential:

Table 1. Renewable energy and it is electrical potential

Renewable Energy	Electricity Potential
Wind	0.346 Million MW
Solar	> 2 million M.W.
Biogas	1800 MW
Hydal	2000 M.W.
Geothermal	550 MW

Wind turbine takes less space on the ground other than an energy conversion system. Wind turbines, like windmills, are mounted on a tower to capture the most energy. At 100 feet (30 meters) or more aboveground, they can take advantage of the faster and less turbulent wind. Turbines catch the wind's energy with their propeller-like blades. Usually, two or three blades are mounted on a shaft to form a rotor (Kar et al., 2016; Zareen et al., 2012).

Solar Energy

Renewable energy mostly comes from either directly or indirectly from the sun. Approximately 174 pico-watts (P.W.) of energy are derived from solar radiation, which hit the atmosphere. One-third of the same is reflected into space. The atmosphere, clouds, ocean, and land absorbs the rest of 3,850,000 Energy-joules (E.J.) every year. The insolation of one hour is equivalent to more than the world's energy consumption for an entire year (Kumar et al., 2010). Solar energy is the largest so far in energy resources that are found on earth. Solar power is estimated at the potential at which its factors are taken into account. Globally, solar power is not feasible in many areas hence leading to low-cost competitiveness (Kar et al., 2016). The figure below illustrates an overview of how much area has to be covered in photovoltaic to cover the entire world's energy consumption.

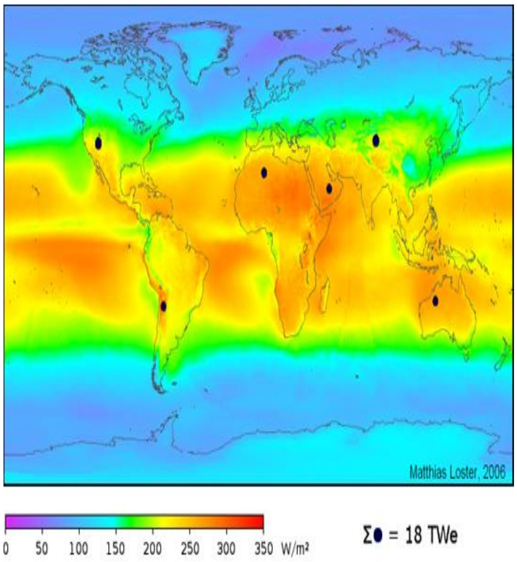

Figure 1. Image Credit, Wikimedia commons

In Cholistandesert (Bahawalpur, Punjab), Quaid-e-Azam solar park, with the capacity of 1000MW, has been established over the area of 5000 acres. Where 100MW of electricity has already been added to the Grid so far, once it will be completed, it will be the largest solar park in the world (Kar et al., 2016).

Hydroelectricity

Hydroelectric dams have been built around the world due to the presence of many rivers and lakes. Sixty-two thousand acres was the piece of land that one million people in China were relocated (Shen et al., 2012). This farmland was flooded. Tons of sewage is contained in the dam reservoirs.

Tidal Power

Tidal power has not been operational in many places, but shortly, it may play a key role in global energy systems. The coastlines are the best resources for dominant features that can harvest tidal energy. Tidal energy is estimated to stream supply of 150TW/h energy per annum. Pent land Firth is considered to be one of the world's best sites for tidal power. It is believed to provide half of Scotland's electricity. The other area with abundant tidal power resources in China, with more than 18.00 kilometers of mainland coastline and more than 14.000 kilometers of Island coastline. North America, Argentina, Russia, France, India, and South Korea are other territories with significant tidal power potential (Kumar et al., 2010).

Nuclear Energy

Nuclear power stations started operations in the 1950s, and this was considered as the first commercial nuclear stations. Nuclear energy provides about 11% of electricity to the world at present from about 450 power reactors. It is considered as the world's second source of low carbon power. Nuclear power plants are operational in 30 countries worldwide, and civil nuclear power can boost more than 17000 reactors years of experience (Kumar et al., 2010).

Fossil Fuels

Fossil fuels are energy that is acquired by the natural process of anaerobic decomposition of the buried dead organisms. It is not such an accessible resource in most countries, but still, it is usually tested several times in large scale and commercial zones. Biogas, which is generated from waste (dung) of cows, horses, and similar content in them, many gases. The fossil fuels are non-renewable hence draw finite resources that eventually become too expensive damaging the environment. It is contrary to renewable resources such as wind and solar, which are continually replenished and never run out. To achieve a 24/7 power supply, it is evident that renewable energy cannot manage as the sun goes down or the wind stops. For a constant supply, it is then to have a mix of solar, wind, and biogas (Kumar et al., 2010).

Coal Power

Electricity being generated from coal power has plateaued since 2014, leading to expansion fleet running fewer hours than ever. Coal power is getting competition from gas and renewables. Since 2000, there has been double coal-fired power in the world with a capacity of around 2,000 gigawatts (G.W.). It was after explosive growth in China and India. 236GW was further built, and 336GW is planned as a result of a wave of retirements across the E.U. and U.S. 186 GW is also set to retire by 2030, and 14 of the world's 78 Coal powered countries also plan for a total phase-out (Kumar et al., 2010).

Natural Oil & Gas

Natural energy is seen as an environmentally friendly option for coal. The world is growing on energy demands, and more mature technology from solar and wind are alternative energy resources. The world consumes and produces more than 100 trillion cubic feet of natural gas. Current projections suggest global consumption as a whole will rise to 156 trillion cubic feet by 2035. Much of the increases in consumption come from Asia, and increases in natural gas exports come from Middle East LNG (Kumar et al., 2010). Unlike oil, natural gas production is not dominated by the places with the most natural gas reserves. Iran and Qatar have the second and third largest reserves after Russia, but both provide only a small fraction of the world's total production. In 2009, both Qatar and Iran represented about 4 percent of global production, according to the U.S. Energy Information Administration (EIA). The United States is the world's largest producer but represents only a small fraction of global reserves.

Electrical Grid Stations

In 1886 the first A.C. Power grid system was installed in the Great Barrington, Massachusetts. The electrical grid is a centralized unidirectional system of electric power transmission, electricity distribution, and demand-driven control (Kaplan, 2009). The electric grid means a network that carries electricity from a plant where it is generated to the customers. This system includes wires, substations, transformers, switches, and much more. In the 1960s, an electrical grid in the developed countries had become an extensive, mature, and highly interconnected network with thousands of central power generating stations for delivering electricity from suppliers to customers.

The system consisted of generating stations, high voltage transmission lines to carry power to demand centers, and distribution lines that connected individual customers (Kaplan, 2009). Various grid elements are generation, distribution, and loads. Lack of investment for new installations combined with aged network components that are older than 40 has resulted in inefficient and increasingly unstable electric systems (Kaplan, 2009). The smart grid is a new paradigm to which the new electric grid is expected to evolve. It will be an enhancement of the 20thcentury electrical grid with an intelligent energy network (Kaplan, 2009).

The Smart Grid Technology

The smart grid is an electrical grid with smart meters, smart appliances, renewable energy resources, computer-based remote control and automation, control of production, and distribution of electricity (Fang et al., 2011). Traditionally electric grids used to carry power from few generators to a large number of users or customers.

The new smart grid uses a two-way flow system where electricity and information are created in an automated and distributed energy delivery network. It is beneficial to customers. China, India, and Brazil were seen as pioneers of the grid deployment in the 21st century (Fadaeenejad et al., 2014). Many countries have adopted smart grid development plans. The smart grid means computerizing the electric utility grid.

Features of a Smart Grid

The key features of a smart grid system include:

Outage Detection & Response

Technologies such as state estimations are used as technology in the smart grid [10], this improves the fault detection and allows self-healing of the network without the intervention of technicians. More reliable electricity supply is ensured and reduced vulnerability of natural disasters or attacks. The smart grid provides better outage detection and response by using distribution intelligence.

Two-Way Power Flow

It is the distributed energy resource and other assets such as rooftop solar panels, electric vehicles, and energy storage devices; however, classic grids are designed for one way flow of electricity (Amin, & Wollenberg, 2005).

Efficiency

Advanced metering infrastructure system and demand-side management, and the overall efficiency of the website have been improved. In contrast, the redundancy of transmission and distribution lines has been reduced, and the utilization of generators has been higher, resulting in lower electricity prices, improved power quality, and power Increased reliability. It saves consumers money and helps in the reduction of CO_2 emissions (Alagoz *et al.,* 2012).

Load Adjustment/ Balancing/Sharing

The load connected to the power grid can vary significantly over time. Traditionally, to respond to a rapid increase in power consumption, some spare generators are put on a standby mode, and the failure rate can only be reduced at the cost of more standby generators [10]. However, in smart grid technology, few of the customers may be warned to reduce the load temporarily or continuously, so load reduction by even a small portion of the clients may eliminate the problem of power failure or putting extra generators on standby mode. Depending upon the user's need, it may share load from the adjacent feeders as well (Fadaeenejad et al., 2014).

Peak Leveling and Time of Use Pricing

Reducing demand during the peak usage periods communication and metering technologies inform smart devices in the home and business when energy demand is high and track how much electricity is used and when it is used (Fang et al., 2011). It also gives the customers the ability to reduce consumption by communicating to devices directly to prevent system overloads (Gellings, 2009)

Market Enabling

The smart grid allows regular communication between suppliers and consumers and permits them to be more flexible and sophisticated in their operational strategies. Only critical loads will pay peak energy prices, and consumers will be more strategic when they use energy. At the domestic level, appliances with energy storage such as (refrigerator, heat banks, and heat pumps) will minimize energy costs (Kaplan, 2009).

Sustainability

The flexibility of the smart grid permits greater penetration of renewable energy resources such as solar and wind even without energy storage. The current infrastructure of the grid is not built to allow for many distributed feed-in points. However, smart grid technology provides the facility to accommodate many feed-in points both at the generational and transmission points (Popescu, 2015).

Demand Response Support/Demand-Side Management

It allows generators and loads to interact in an automated fashion in real-time, coordinating demand to flatten spikes with a two-way flow of information. It helps to eliminate the cost of adding reserve generators, cuts wear and tear, and helps to improve the life of the equipment. It also helps consumers to cut their energy bills by telling low priority devices to use energy only when it is cheapest. It helps to reduce power consumption at the consumer side during peak hours (Fang et al., 2011).

Smart Grid Technologies

The bulk of technologies being used in manufacturing and telecommunications are now adapted for use in grid operations.

Integrated / Data Communications Technology

It allows real-time control, information, and data exchange to optimize system reliability, asset utilization, and security (Amin, & Wollenberg, 2005). There would be vast benefits of data communication is made possible in grid system such as enhanced cybersecurity, handling sources of electricity like wind and solar power, and even integrating electric vehicles onto the grid.

Sensing & Measurement Technology

Grid stability, monitoring of equipment health, and energy theft prevention are possible by using smart meters (advanced microprocessor meters) and meter reading equipment, advanced switches and cables, backscatter radio technology, and digital protective relays.

Distributed Power Flow Control Technology

In this technology, power flow control devices are clamped onto existing transmission lines to control the flow of power within it. By doing this, transmission lines support greater use of renewable energy by providing more consistent, real-time control over how that energy is routed within the grid. This technology enables the grid to store energy more effectively from renewables for later use (Alagoz *et al.*, 2012).

Smart Power Generation Technology Using Advanced Components

Smart power generation is the concept of matching electricity generation with demand using multiple identical generators that can start, stop, and operate efficiently at the chosen load. Matching supply and demand is called load balancing, which is essential for a stable and reliable supply of electricity. Short term deviations in the balance lead to frequency variations, and prolonged mismatch results in a blackout. Load balancing task has become much more challenging as variable generators such as wind turbines and solar cells are added to the Grid (Gellings, 2009)

Power system automation Technology

It provides rapid diagnosis and provides precise solutions to specific grid disruption or outages. Power systems automation is done by

- Control systems (distributed intelligent agents)
- Analytical Tools (Software algorithms & high-speed computers)
- Operational applications (SCADA, substation automation, demand response)
- Programming Techniques (Artificial Intelligence)

Automation technology lets the utility adjust and control each device or millions of devices from a central location.

Application of IoT

IoT is everywhere, working hand in hand with technologies changing everything from the way we use machines and maintain machines and equipment. Application of IoT cuts across industries from utility management and transportation to education and agriculture to help businesses deliver more value to clients. The Internet of Things (IoT) can be used in the energy industry to transform the energy sector from energy generation to transmission, distribution, and consumption.

The system

The energy monitoring nodes use Peace fair PZEM-004t, low-cost energy meter using a non- invasive C.T. (current transformer) sensor. The SD3004 energy measurement chip and microcontroller for measuring the voltage, current, active power, and accumulative power consumption. Measured data is then submitted to the server via MQTT in JSON (JavaScript Object Notation) format. The Raspberry Pi 3 Model B as chose to run as a local server. Users can access information about their energy consumption via the web application or via the Internet.

Energy Monitoring Nodes

In monitoring the energy usage, the utilization of PZEM- 004T is considered. It is made by Peace fair Electronics. It operates on the principle of the current transformer and uses precision A.C. current transformer coil as a sensing part that has the output of 100A/100Ma. PZEM-004T provides voltage RMS current and calculates active power and total energy usage over time or accumulative power consumption. PZEM-004T uses SD3004 energy measurement Sochi from SDIC microelectronics. It has outstanding measurement accuracy. The figure below illustrates a simplified diagram of a developed IoT energy monitoring mode.

With sending the measured data from PZEM-004T via network or the Internet, the ESP8266 Wemos D1 mini communicates with VIA RS-232, and PZEM-004T (Cunjiang et al., 2012). The figure that follows is a prototype of the energy monitoring node in which PZEM-004T is connected WITH Wemos D1 mini via R.S.- 232 Port (Ejaz et al., 2017; Hall, & Foxon, 2014). The firmware for Wemos D1 mini was developed using the Arduino software environments.

The primary function of the Wemos D1 mini is used to collect energy data from the PZEM-004T and send received data to the server wirelessly through Wi-Fi. The data will be sent to the server approximately every 20 seconds. The JSON format is a lightweight data-interchange format and easy to understand. Therefore, JSON format is used for transmitting structured data over a network connection via MQTT.

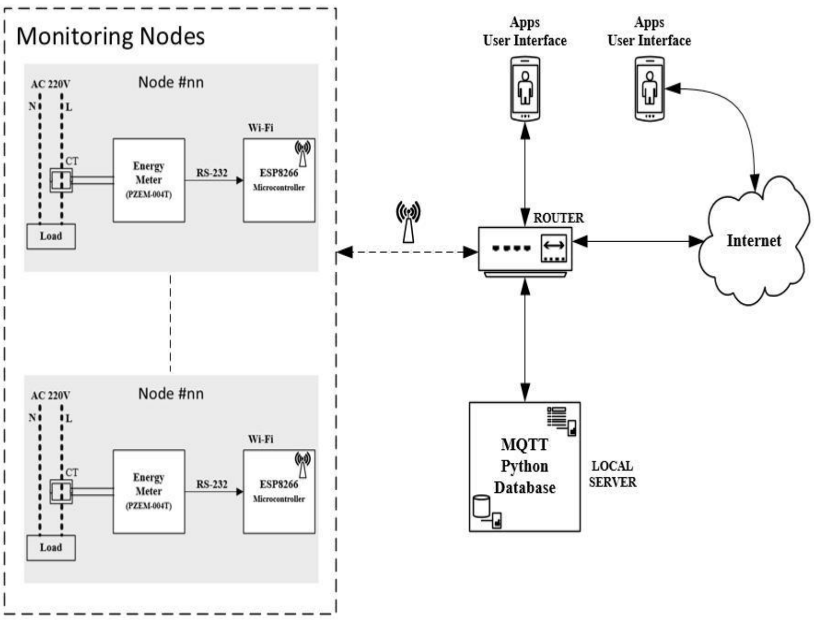

Figure 2. IOT energy system overview (Al-Ali et al., 2017)

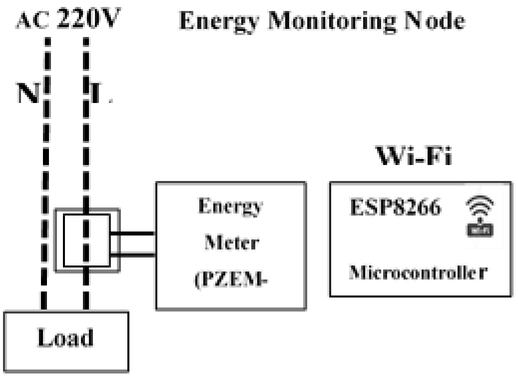

Figure 3. IoT Electric Energy Monitoring Module (Kaplan, S.M., 2009)

Figure 4. Prototype of an energy monitoring node

Energy Calculation

Energy consumed per day can be determined in (He, et al., 2016). The energy E in kilowatt-hours (kWh) per day is equal to the power P in watts (W) times' number of usage hours per day t divided by 1000 watts per kilowatt:

E(kWh day) = P(W) xt(h day) /1000(W kW) (Jenkins et al., 2015)

For example, if we use a desktop computer that requires power consumption of 300 watts and we use it for 8 hours per day. By following (He et al., 2016), thus this desktop computer will consume the electric energy per day at 2.4 kWh or 72 kWh per month. Hence, performing the calculation in (Jenkins et al., 2015), the energy consumptions are automatically stored and calculated in the database on the server.

Local Server

The Raspberry Pi, 3 model B, is responsible for running server software packages at a local network, the software includes MQTT broker, Python, database server using Influx D.B., and data visualization.

MQTT Communication Protocol

MQTT is a publish/subscribe protocol, which is straightforward and lightweight messaging designed for constrained devices and low-bandwidth, unreliable networks. It is the right solution for our design since it provides secure communication between the server and many IoT nodes (Popescu, G.H., 2015; Khan, J., & Arsalan, M. H., 2016). The central server is so-called a broker, and sensor nodes can subscribe to the topic, and the topics are created automatically. It can also publish the data to topics of any kind of data. The broker then distributes the data to any node that has subscribed to that topic. The publishing can be done at three quality of service levels (QoS). In our setup, we use the Eclipse Mosquito software that runs as a broker on our local server, the Raspberry Pi 3 (Zareen et al., 2012; Kwon et al., 2016).

Software

Since the sensor data are constructed data type as MQTT messages that will be published to a self-hosted MQTT broker [13, 22]. The python scripts to subscribe to those MQTT topics are use and then stores all messages in time series data in the Influx D.B. database (Stojkoska et al., 2017). The Influx D.B. is a time-series database. It is optimized for queries in the time domain. Influx D.B. has been used for storing sensor data as time series. The main reason for this is that it allows using the Grafana (Spencer et al., 2004) for analyzing the data. Grafana is a web-based data visualizing tool that can connect to Influx D.B. Using the Grafana, we can set up custom dashboards, alerts, and notifications from the data sets. Grafana has a very responsive web frontend.

Transforming Energy Generation with IoT

The power generation goal is to achieve affordable, available, and sustainable and reduced use of fossil emissions. Many organizations, like G.E., across the world, are increasingly leveraging on IoT to achieve these goals. There are three main areas where IoT can be very Impactful in Power generation (Kaplan, 2009; Yu, X., & Xue, 2016).

Remote Asset Monitoring/management system

Probably one of the most popular uses of IoT in industrial applications. Connected sensors are being used to measure wear, tear, vibration, temperature, and other parameters to determine the overall health of assets from turbines to transmission lines. Trends in the data obtained from sensors could be used to estimate the "time to failure" of critical infrastructures and plan maintenance, reducing downtime due to unscheduled maintenance and help avoid the economic consequences of such downtimes. Adopting IoT in power generations could also help identify safety issues like gas leakages before they cause harm to workers and equipment, generally helping stations attain new safety levels (Stojkoska, & Trivodaliev, 2017; Al-Ali et al., 2017)

Figure 5. An IoT power monitoring station (Kaplan, S.M., 2009)

Process Optimization

IoT can provide real-time information about the overall state of the entire generation station, and this is much-helping plant automation. Real-time data is being used to fine-tune the operations of plants, increasing energy conversion from fuels, and reducing the costs of maintenance (Werner et al., 2014).

Integration and Management of Renewable Energy Sources

A significant goal for power generation is the eradication of fossil fuels, but in the meantime, generating stations can cut down on emissions by combining energy generated through renewable means like Wind and Solar with the traditional coal or gas stations. IoT provides generating stations with information on-peak periods, which helps them plan alternation between renewable sources and fossils while also facilitating the Storage of excess energy and its use during peak demand periods (He et al., 2016).

The output and uptime of renewable sources can also be efficiently maximized using IoT based solutions as it helps to ascertain the production values and overall health of renewable sources irrespective of their location (Kwon et al., 2016).

Business Models and Decentralization

IoT is rapidly leading to energy decentralization. It is at the core of several new business models that are paving the way for the commercialization of small and medium scale renewable energy solutions (Al-Ali et al., 2017; Yu et al., 2015). From "pay as you use" off-grid solar system powering homes in developing countries like Nigeria, to large-scale, privately owned stations contributing energy to the grid in developed countries. It is also providing utilities with the information required to create flexible tariffs (e.g., higher tariffs during peak periods), giving consumers more options (Cunjiang et al., 2012).

Transforming Energy Transmission and Distribution with IoT

The problems during transmission and distribution, to some extent, are similar. They involve line failures, fault detection, losses on the lines, among others. Most of these problems could be solved with IoT.

Asset Management and Maintenance

Depending on the setup, assets involved with power transmission and distribution usually include substation equipment, transmission lines, amongst others. Each of these equipment develops faults and fails due to factors like overloading, vandalization, etc. With IoT, they can be monitored remotely with a range of sensors that monitor parameters like temperature, detect falling of utility poles before it causes safety hazards, and detects security breaches to prevent vandalism, which is rampant in developing countries. The ability of the sensors to identify failures and their sources, before they become critical, increases the productivity of repair teams and reduces downtime and other related losses. The overall spending on parts and repairs is reduced, making electricity more available and affordable.

Grid Balancing

IoT can provide the real-time information needed to manage congestion on T&D lines effectively. With IoT, the grid can ensure the connected generation stations have met the connection requirements from frequency to voltage control to prevent instability (Shrouf, & Miragliotta, 2015).

Figure 6. T&D Lines of Gridlines

Grid Contribution

One of the most significant future trends in electricity generation is the contribution of regular homes to the energy grid. Excess energy generated by solar panels at the rooftops in several homes is contributed/sold to the grid. One of the critical technologies that will drive this transformation is the IoT. The connection of renewable energy-based generation plants with varying production levels to the Grid will bring about variations in voltages at different nodes on the Grid, causing changes in power flow. However, all of these can be, managed using real-time data provided by IoT solutions, auto-adjusting the grid to maintain stability (Smid, & Nieboer, 2008).

Load Forecasting

Sensors installed at different substations and along distribution lines could provide real-time information on power consumption in different areas, which could help the utilities make automated and smart decisions around voltage control, network configuration, and load switching, among others. Trends in the data supplied could also be used as the basis for infrastructure upgrade and development (Druitt, & Früh, 2012)

Transforming Energy Consumption with IoT

Consumption is by far the section of the energy cycle where IoT has had the most impact. It started with AMR based (semi) smart meters and thermostats and has evolved to Smart electricity meters that predicts consumption pattern and with your permission control the supply of power to specific power-hungry equipment during peak time when power is expensive. Web-connected lightings that know when no one is home and automatically switches off the lights that were left working. Some of the essential opportunities IoT is enabling on the consumer side of energy are discussed below (Gellings, 2009; Yu, & Xue, 2016; Cunjiang et al., 2012).

Smart Decision Making

IoT is helping consumers save costs and make smart decisions about their power usage. Data from smart meters are sent to a mobile app through which consumers can access how much power has been consumed, how much more they can afford to consume based on their budget and take steps to tune consumptions accordingly. Consumers can turn off the supply of power to certain appliances and set conditions under which other appliances come on. With this, they can eradicate waste and optimize their consumption (Shen et al., 2012; Yu et al., 2015).

Access to Dynamic Billing and flexible Tariffs

As mentioned above, IoT has created a plethora of business models that have increased the availability and affordability of energy, and the biggest beneficiaries are the consumers who now have access to various plans and tariffs to subscribe to for constant and affordable power supply (Cunjiang et al., 2012).

New Power Solutions

Alongside new business models are new IoT based power solutions that facilitate monitoring, low scale generation, and Storage of power for consumers. We are gradually moving closer to a future where consumers can choose to buy power during periods when the tariffs are low and use during peak periods when tariffs are expected to be high (Hall, & Foxon, 2014).

Reduced Downtime

A new line of smart meters, enabled for two-way communication between the distribution station and consumer, are being deployed in developed countries. These meters send downtime notifications and other critical operation information to utility agencies. Utility agencies can act on this data and respond more quickly to outages due to faults and other factors. The meters also provide real-time data (Load forecasting) that helps the grid adjust power distribution as a result of variation in peak time across different areas (Druitt & Früh, 2012).

Sale of Power to the Grid

IoT is enabling technologies that could help small homes sell excess energy generated from sources like solar panels and wind plants to the grid. With technologies like "Vehicle to grid," even Electric cars could start contributing excess, unused energy to the grid (Kaplan, 2009).

Zero Net Energy Buildings

IoT is also powering consumer-driven concepts like the Zero Net Energy building. Zero Net energy means all the energy needs of that house is generated by the house mostly via the use of renewable energy sources. Each of the applications mentioned above represents opportunities for entrepreneurs and utilities to deliver additional value to customers, and the combination of all these applications will certainly help make energy cleaner, cheaper, more available and sustainable (Cunjiang et al., 2012; Hall, & Foxon, 2014).

Conclusion

IoT energy monitoring system, therefore, represents a low-cost design in energy use. The system helps in monitoring and tracking applications. Global energy demands are significantly rising, and employing real-time energy consumption monitoring and control systems is a necessity.

Comparing the impacts, this has created in the country, Sierra Leone has just started using a bit of internet of things application, especially in the metering section. Sierra Leone National Power Authority now being privatized, just automatic meter reading systems (AMR). It has urge customers to pay their electricity bills on time, thereby creating more money for the power authorities in terms of maintenance and payment of salaries to staff members. It has moved the country from 30% of the electricity supply to 80% as the present situation.

References

Conti, J.J., Holtberg, P.D., Beamon, J.A., Schaal, A.M., Ayoub, J.C., & Turnure, J.T., (2014). Annual energy outlook 2014. *US Energy Information Administration*, *2*.

Shen, Z. Y., Chen, L., Chen, T., & Di Baldassarre, G., (2012). Analysis of parameter uncertainty in hydrological and sediment modeling using GLUE method: a case study of SWAT model applied to Three Gorges Reservoir Region, China, *Hydrology & Earth System Sciences*, *16*(1) 121-132.

Fadaeenejad, M., Saberian, A. M., Fadaee, M., Radzi, M. A. M., Hizam, H., & AbKadir, M. Z. A. (2014). The present and future of smart power grid in developing countries. *Renewable and Sustainable Energy Reviews*, *29*, 828-834.

Kar, S. K., Sharma, A., & Roy, B. (2016). Solar energy market developments in India. *Renewable and sustainable energy reviews*, *62*, 121-133.

Zareen, N., Mustafa, M. W., Al Gizi, A. J., & Alsaedi, M. A. (2012). Worldwide technological revolutions and its challenges under smart grid paradigm: A comprehensive study. *Int. J. Sci. Eng. Res*, *3*(11).

Kumar, A., Kumar, K., Kaushik, N., Sharma, S., & Mishra, S. (2010). Renewable energy in India: current status and future potentials. *Renewable and sustainable energy reviews*, *14*(8), 2434-2442.

Kaplan, S. M. (2009). *Smart Grid: Modernizing electric power transmission and distribution; Energy independence, Storage and security; Energy independence and security act of 2007 (EISA); Improving electrical grid efficiency, communication, reliability, and resiliency; integrating new and renewable energy sources*. The Capitol Net Inc.

Kaplan, S. M. (2009, April). Electric power transmission: background and policy issues. Library of Congress, Congressional Research Service.

Fang, X., Misra, S., Xue, G., & Yang, D. (2011). Smart grid—The new and improved power grid: A survey. *IEEE communications surveys & tutorials*, *14*(4), 944-980.

Amin, S. M., & Wollenberg, B. F. (2005). Toward a smart grid: power delivery for the 21st century. *IEEE power and energy magazine*, *3*(5), 34-41.

Alagoz, B. B., Kaygusuz, A. S. İ. M., & Karabiber, A. (2012). A user-mode distributed energy management architecture for smart grid applications. *Energy*, *44*(1), 167-177.

Gellings, C. W. (2009). *The smart grid: enabling energy efficiency and demand response*. The Fairmont Press, Inc..

Popescu, G. H. (2015). Sustainable Development and the Implementation of Citizen-oriented Services. *Journal of Self-Governance and Management Economics*, *3*(4), 70-78.

Al-Ali, A. R., Zualkernan, I. A., Rashid, M., Gupta, R., & Alikarar, M. (2017). A smart home energy management system using IoT and big data analytics approach. *IEEE Transactions on Consumer Electronics*, *63*(4), 426-434.

Cunjiang, Y., Huaxun, Z., & Lei, Z. (2012). Architecture design for smart grid. *Energy Procedia*, *17*, 1524-1528.

Ejaz, W., Naeem, M., Shahid, A., Anpalagan, A., & Jo, M. (2017). Efficient energy management for the internet of things in smart cities. *IEEE Communications Magazine*, *55*(1), 84-91.

Hall, S., & Foxon, T. J. (2014). Values in the Smart Grid: The co-evolving political economy of smart distribution. *Energy Policy*, *74*, 600-609.

He, Y., Jenkins, N., & Wu, J. (2016). Smart metering for outage management of electric power distribution networks. *Energy Procedia*, *103*, 159-164.

Jenkins, N., Long, C., & Wu, J. (2015). An overview of the smart grid in Great Britain. *Engineering*, *1*(4), 413-421.

Khan, J., & Arsalan, M. H. (2016). Solar power technologies for sustainable electricity generation–A review. *Renewable and Sustainable Energy Reviews*, *55*, 414-425.

Kwon, D., Hodkiewicz, M. R., Fan, J., Shibutani, T., & Pecht, M. G. (2016). IoT-based prognostics and systems health management for industrial applications. *IEEE Access*, *4*, 3659-3670.

Werner, S., Wiltshire, R., Svendsen, S., Thorsen, J. E., Hvelplund, F., & Mathiesen, B. V. (2014). 4th Generation district heating (4GDH). *Energy*, *68*, 1-11.

Stojkoska, B. L. R., & Trivodaliev, K. V. (2017). A review of Internet of Things for smart home: Challenges and solutions. *Journal of Cleaner Production*, *140*, 1454-1464.

Spencer Jr, B. F., Ruiz-Sandoval, M. E., & Kurata, N. (2004). Smart sensing technology: opportunities and challenges. *Structural Control and Health Monitoring*, *11*(4), 349-368.

Yu, X., & Xue, Y. (2016). Smart grids: A cyber–physical systems perspective. *Proceedings of the IEEE*, *104*(5), 1058-1070.

Yu, Y., Liu, Y., & Qin, C. (2015). Basic ideas of the smart grid. *Engineering*, *1*(4), 405-408.

Shrouf, F., & Miragliotta, G. (2015). Energy management based on Internet of Things: practices and framework for adoption in production management. *Journal of Cleaner Production*, *100*, 235-246.

Smid, J. W., & Nieboer, N. (2008). Energy-efficient asset management for professional landlords. *International Journal of Strategic Property Management*, *12*(1), 19-34.

Druitt, J., & Früh, W. G. (2012). Simulation of demand management and grid balancing with electric vehicles. *Journal of Power Sources*, *216*, 104-116.

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