Power systems automation, communication, and information technologies for smart grid: A technical aspects review

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ABSTRACT

Smart grid (SG) introduced proven power system, based on modernized power delivery system with introduction of advanced data-information and communication technologies (ICT). SGs include improved quality of power transmission/distribution from power generation to end-users with optimized power flow and efficiency. In addition to above modern automation, two-way communications, advanced monitoring, and control to optimize power quality issues are the classic features of SGs. This ensures the efficiency and reliability of all its interconnected power system elements against potential threats and life time cycle. By integrating ICT into the power system SGs improved the working capabilities of the utility companies. Resultant of ICT with SG leads to better management of assets and ensure energy management for end users. This review article presents the different areas of communication and information technology areas involved in SG automation.

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1. INTRODUCTION

The present-day energy research focuses more on remedies for rapid growth of future energy demand at different utilization levels and holistic solutions for providing continuous and efficient energy-based systems [1]. The advancements in upcoming power systems introduce intelligent processes into the electrical power system to improve power quality and reliability [2]. To meet the power demand and decrease greenhouse gas discharges, renewable energy resources (RES) which are cleaner power sources can be considered as a positive solution [3]. However, RES possesses issues due to its intermittency nature [4]. The associated power fluctuations can be resolved by using efficient energy storage systems with RES [5]. The integration of different RES entities, the conventional grid operation, and control tasks is not simpler and convenient task. This is because the power system includes generation plants, transmission systems, distribution systems, market operators, and utility systems operators [6]. Efficient communication of data among the power system entities is essential for coordinating the smart grid (SG) [7]. The entire power system arrangement can be observed as a logical information network consisting of the electrical appliances considered as nodes (information sources) that transmit information to different sinks (data aggregators), which are interconnected through different levels of communication protocols. The information is transmitted from source nodes to sink (destination) nodes over information links bridged across different systems, i.e. utility organizations, customers, and communication protocols. To support optimal communication between these nodes, a set of interoperability standards is required [8]. The execution of the desired operations of the grid, requires well-established and reliable automation for effective monitoring and control using information and communication technologies (ICT) [9]. With the advancement in ICT, the legacy grid is transformed into SG. It is mainly organized in terms of integration of heterogeneous entities into the grid network. Power generation, transmission, and distribution are managed accordingly and intelligently based on the pro-active scheduling of loads by SG [10].

The most important advantage for utilities with SG is the availability of real-time data. This is because the data received on time make utilities more intelligent in terms of monitoring and controlling [11]. Utility servers receive huge amounts of data that can be assessed using intelligent and efficient data analytics. To reduce power costs, maintenance costs and outage costs, as well as to increase the life of power system assets, intelligent decisions must be taken at the system level [12]. Data decisions are combined with advanced control technologies and data communication technologies to decrease power disorders, segregate faults, and rapidly restore power outages. Table 1 introduces different advanced technologies of SG and their implementation details. SG must address the following four important challenges:

- SG must respond quickly to the changes in power demand that depends on consumer load usage. It should consider efficient energy technologies, for adopting the dynamic economic conditions. The effects of electric vehicles on SGs should also be taken into account [13].
- SG should accommodate hybrid generation options with all possibilities of RES and should save the ecosystem from carbon gases [14].
- SG should consider new technologies and techniques for addressing the problems raised due to variability and improbability from both demand and supply. This situation mostly occurs because of the intermittency of RES, and changing customer choices [15].
- SG should consider reliability and security of electric assets to ensure protection from different weather conditions, and cyber-attacks [16].

Table 1. Advanced technologies for implementing SG

Technology Area	Hardware	System and Software
Wide-ranging Area Monitoring [17]	Phasor Measurement Unit (PMU) [17]	SCADA, Wide Area Monitoring, Protection and Control (WAMPAC) [17]
ICT (Information & Communication technology) [6]	Communication equipment (Broadband wired and wireless access). [6]	CIS (Customer information system), ERP (Enterprise resources planning software). [6]
Renewable energy and distribution generation integration [18]	Battery storage, converter & inverter, Smart control systems, communication devices [18].	Distributed Automation and Management System (DAMS) [18].
Transmission Standardization [19]	Flexible AC Transmission Systems (FACTS), PMU, Synchro-phasors, connected with communication devices [18, 19].	Automated recovery systems [19].
Advanced Metering Infrastructure [20]	Smart meter, Sensors, Actuators, Smart displays, Home gateways [20]	Meter Data Management System (MDMS) [20]
Electric vehicle charging infrastructure [21]	Batteries Storage, Converters, Inverters, smart switches [21].	Smart Power billing, Grid to Vehicle (G2V, and V2G) methodologies [21].

The smartness of SG lies in the integration of an extensive range of physical power assets, and information resources for advanced monitoring and control. The SG makes distribution infrastructure more intelligent by employing multiple advanced technologies [22]. For scheduling generation and transmission systems SG enables exchange of real-time information exchange and allows power markets for power trade-off and generation scheduling [23]. Most suitable regulatory policies must be framed for the smooth unification of various technologies. Thus, the encouraging areas for SG services include anticipating RES generation, planning tariff, end-user complaint management, setting up and commissioning services, and financial management [24]. The SG architecture consists of three significant layers,

- Power system layer,
- Data communication layer and
- Information technology layer.

The power system layer consists of power generation, transmission and distribution systems, and end-user premises. The data communications layer is responsible for the communication of information on energy consumption based on latency requirements defined as per the policies of SG. Also, the communication layer allows the bi-directional flow of information from all the electrical components in the grid to utility centers and vice versa. The information technology layer is responsible for data collection, data analysis, and data management. It is mostly useful in making load scheduling decisions and energy management by utility companies [25]. The exchanged information between end-user and utility consists of the following two points [23-25], i) Energy consumption from the user side, and tariff from the utility side; and ii) Assessment of various situations of SG components allowing for their control, monitoring, and maintenance. Modern viable methodologies, tools, and advanced technologies in the areas of data analytics, control, and data communications allow power grids to self-regulate, leading to the strengthening of SG [26]. The following sections elaborate on various aspects that strengthen the performance of SG. Section 2 is about power system automation involved in SG. Section 3 explains SG data communications, section 4 deals with the aspects of information technology areas of SG, and section 5 concludes the paper.

2. SMART GRID – POWER SYSTEM AUTOMATION SCENARIO

The power system infrastructure is largely interconnected system with components like generator systems, transformers (step up/down type) and distribution feeders. They are distributed over a large area, leading to increased complexity in monitoring utility companies. The existing power system was planned as a centralized system with only unidirectional power supply, i.e, from power generating stations to end-user locations [27]. SG became an important resource for utilities because it provides better services for generation, transmission and distribution of power. It converts the above operations from a centralized system to the market-based operative system [28]. The integration of RES helps in decreasing carbon emissions but do not assure continuous supply. This problem can be addressed by adapting generation from RES, but this generation is unpredictable because of high penetration in environmental conditions. Hence, it is highly essential to pay attention to security mechanisms so as to ensure continuous supply and demand [29]. Figure 1 demonstrates the block diagram of an intelligent power system. The SG approach introduces complicated two-way communication (information flows) into electrical power systems.

The remote location of generation plant to the distribution area introduces high transmission and distribution losses. The advent of bidirectional communications in SG turns electrical components intelligent. Advanced computing in SG use information technologies and business approach to make it ready for modern time load dispatch, scheduling, and control [22, 26, 30]. The deployment of advanced information technologies like efficient data communication, intelligent electronics devices, and internet of things (IoT), increases the overall performance of power systems. Efficient planning of power systems plays a key role in the assessment of demand and supply. The advanced technologies oriented SG has a key place in future power systems. This is because SG not only introduces bi-directional communication between electrical components and utilities but also introduces advanced control and monitoring techniques for efficient energy management [31].

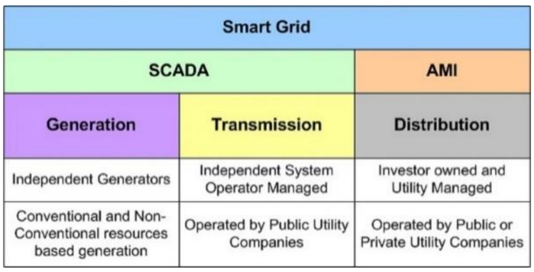

Figure 1. Block diagram of smart grid functions

2.1. SG for power systems scope towards generation side

Advanced research in power systems enables the electrical industry to act more intelligently. The interconnectivity among the different generation stations and mutual dependence have assured the greater reliability for power generation systems. The network associated with power systems has become more complex, and this has directed to the development of "intelligence" in systems that has gradually become highly developed over time. In contrast to the past system, the present power dispatch ensures added flexibility from the existing infrastructure [32].

There is a requirement for intelligent energy management techniques to meet power demand. adapted to systematic load scheduling between both conventional resources and RES. However, the continuous usage of conventional resources(coal and petroleum products) results in their depletion, although they assure constant power supply. In addition, the emission of greenhouse gases from conventional resources affects the ecology [33]. Hence, RES and sustainable energy resources are becoming an alternative and necessary factor in generating power, but there is a need to assure the quality of power. The intermittent nature of solar and wind energy resources leads to hasty fluctuations in power production [34]. Hence, there is a requirement for developing dynamic infrastructure and mechanisms for better management of power fluctuations. It requires adding a new form of intelligence [35]. The SG operates based on market scenarios and schedules the generation of power based on the current requirement. Thus, the power generation plants are scheduled based on real-time monitoring of load usage. Further, it aims to minimize the cost of operations and expects maximum revenues from various tariff systems [36, 37].

The SG accommodates the utility companies with a two-stage solution for generation management, firstly, at the generation plant level and secondly at the fleet level. The important facts considered in two stages are explained as follows:

2.1.1. For plant level, the key requirements as follows;

- Generation monitoring: The data is acquired in real-time from the metering resources. Based on the information obtained the generation is planned and the schedule is allocated to all energy sources accordingly. Also, the key performance indicators (KPIs) on the generation side are regularly monitored for increasing the reliability of the power. The KPIs include net-generation and gross generation with different trends [38].
- Merit order dispatch: The main goal for utilities will be to minimize the cost of generation. To minimize the cost, the load is optimally distributed across multiple units of generation. This is successfully scheduled by SG.
- Reporting function: With the introduction of SG the detailed report of plant and unit operations, scheduling of plants or units, plant load factor, and unscheduled interchanges are reported from utilities to the consumer and vice- versa [39].

2.1.2. The following are the important requirements for fleet management at utility control center

- Cost-effective generation: The generation of power is planned a day ahead in general. The introduction of SG enables the support for timely decisions based on installed capacity, location of consumer, equipment constraints and outages [39].
- Built-in plant level monitoring: The SG based utility control center is updated from all the generation plants regarding the generation capacity of each unit and aims for the generation of required demand [40].
- Optimization and revenue reconciliation: Revenue of a utility is based on the tariff structure called Availability Based Tariff. The tariff and its equivalent energy consumed can be validated against the details provided by load dispatch centers [41].
- Generation scheduling: This is the vanilla automation of the operations of a plant performed but the managers and operators therein. The solution is expected to calculate and provide for a generating capacity that would be optimal given all the constraints present in the system at that point of time[42].
- Tariff modeling: A dynamic solution should have the capacity to process changes in tariff models for any contingency based change in the regulations guiding the SG [43].

2.2. SG for power systems scope towards transmission side

Since the transmission system is the backbone of the entire power systems networks, its reliability factor has to be the maximum for a given growing demand for consumption of electricity. The growth of the energy sector could be curtailed in an instance when the transmission system remains stagnant. Some important building blocks of transmission system s are, PMU, phasor data collector (PDC), FACTS, advanced storage apart from the ever-increasing transmission in case of HVDC and HVAC, wide-area monitoring, and WAMPAC assures reliable transmission system [17-19, 33]. Although the capabilities of the transmission system can sustain the current load, SG implementation on a larger power system scale would have to upgrade the capacity of the transmission system prompting a considerable influx of capital [44].

In a basic power system scenario, the transmission system acts as a link between distantly located generation and consumption end of the power system [45]. This includes the aspect of interconnections in a power system which is a much-anticipated feature in SG scenario. A few important aspects can be enumerated such as: i) the facilitation of power transmission between two distinctly loaded locations, both spatially and temporally; resulting in reduced outages at both the said locations; and ii) utilization of distinct fuels to serve the end purpose of consumption of electricity. Thus, the sale of electricity in an SG scenario would only be prompted and promoted when there exists a robust transmission system. In this regard, synchro-phasors technology, is important for the operations of transmission systems particularly in improving the reliability [46]. Some important points of SG based transmission systems are explained in detail as follows:

2.2.1. Role of PMUs in advanced transmission systems

Synchrophasors can be understood as a representation of the magnitude and the phase angle of the sine waveform of the electric parameter which is synchronized with time hence, it is also time-synchronized. Synchro-phasors are measured by PMUs which are manifold faster than SCADA [47]. By virtue of their accuracy synchro-phasors have a higher amount of information regarding the power system's stability. This prompts the use of synchro-phasors in minimizing operation costs on the grid [48]. By virtue of their measurement capabilities, the use of PMUs affords subsequent solutions to problems faced in monitoring a vast network of the power system. Holistically observed, the use of PMUs can be imported to the broader schema of power system efficiency and reliability by incorporating the same in both model-based analysis and real-time solution and mitigation of power system imbalances. PMUs can be incorporated from model generation and analysis to the broader control scheme of the power system [49]. Although PMUs inherently provide a larger amount of data regarding the grid, the data could be further used, when implemented with SCADA to monitor the vast network [50].

2.2.2. Role of PDCs in advanced transmission systems

A network of PMUs utilizing the synchro-phasors system has its origins in a sub-station, which forms the ground level of the power system and develops by collecting real-time data from CT/PT (current transformer and potential transformer). The data from the PMUs is delivered to a PDC through a high-speed connection system [51]. Upon receipt of the data, the PDC would segregate bad data and time-stamp the rest into data sets. Further, this data is fed into a high-speed communication network to be analyzed or utilized by a higher capacity PDC.

2.2.3. Role of advanced transmission applications

The complex nature of the power system makes it further difficult to predict any system imbalances, faults, or such contingencies. In such conditions, any smaller interruptions in the power system would make the utilities more sensitive to the control systems and monitoring. The WAMPAC system is an advanced transmission protection system that works based on intelligent electronic devices (IEDs). IEDs are used to collect samples of input and output signals for high accuracy and communication quickly to PDC, and then to the control center. WAMPACs have ticked multiple check-boxes for implementation starting from the technical requirements of the power system to the economic viability and environmental requirements. Given these qualities of the WAMPACs, their use in the power system would only prompt a reliable and satisfying electric demand. To realize its technical aspects, the WAMPAC would require phasor and frequency information as acquired by a PMU based on sensors that would convey information of voltage, current phasor, and frequency [17-19, 52, 53].

2.3. Smart grid for power systems scope towards distribution systems

Distribution systems being geographically much more local and accessible have not seen much automation. Once the system is installed on the feeders and connected to the transmission system, it meant a completely local system for the utilities unlike the long transmission system or the generation end. It would only entail occasional changes [54]. Any reactive power arrangements that need to be made based on the load conditions through capacitor banks could be made automatically based on local signals and set parameters. Further, a fault condition would be dealt with only a given number of times automatically. Set lateral fuses would set off in an instance of current excess. The growing demand for consumption of electricity is leading to automation of the distribution systems as well. The smart grid policy requirements mention a higher need for distribution automation (DA) [55]. DA is to start from the user interfaces of power system spreading over the transmission system and interactions therewith leading to higher and interconnected distributed energy resources (DER) and any other aspect involving planning and engineering efforts to be put in [56].

2.3.1. Distribution automation functions

DA functions in isolation such as monitoring VARs on a feeder or identifying fault in the system. These functions are minuscule in their productivity when compared to the larger benefit of observing them in consonance with such other functions [57]. In any case, the DA functions rely on basic functions such as SCADA [58].

Key benefits of distribution automation

Based on the types of benefits that arise from the use of DA functions, they can be enumerated as five types as mentioned below. Further, the use case scenarios are assessed for these types of benefits:

- The use of DA systems entails explicit benefits such as lower implementation costs, costs avoided in operations and in the implementation, predictable and stable costs, and diverse choice of pricing for consumers [59].

– Reliability and quality benefits include benefits of reduction in the frequency and length of an outage, and providing a cleaner power and more reliable management of DG in conjunction with load management systems [60].
– Better positioning of the system format, a perspective of cybersecurity and cyber threat, better handling of insecure situations, increase in plant security and energy independence are possible through this raised quotient of reliability [61].
– The efficiency of the system in its handling of energy has its own benefits. It includes reduced energy use, reduced demand while the demand is expected to peak [59].
– The environmental impact of cleaner energy being generated will be positive in terms of reduced greenhouse gas production, other pollutants. This would mean further increase in greener energy through the increased use of a renewable source of energy [62].

3. SMART GRID – DATA COMMUNICATION SYSTEMS SCENARIO

The SG technologies have facilitated the availability of real-time data to benefit the utilities for making intelligent decisions during normal and hostile situations. With increased monitoring there shall be reduced failures, reduced maintenance, fewer outage costs and increased life of power system assets. The advanced control technologies integrated with the advanced data communication technologies will reduce power disorders segregate faults and result in rapid restoration of outages [63]. The communication set-up plays an important role in coordinating generation plants, transmission system, utility companies, distribution system and power market [64].

The employment of a data communication for transmission system can enhance monitoring in real-time and can protect the system from potential disturbances by reducing the losses and voltage variations thereby increasing the reliability and ensuring best utilization of the transmission system [65]. The DA and substation automation are important enablers for smart distribution systems. The increased usage of DERs is an option considered for forthcoming distribution systems. SG switches the peak loads by identifying and establishing different DERs from the available spinning reserve [66]. The employed communication infrastructure has an important role in interchanging information between the Distributed Automation and Management Systems and substations. In the smart distribution system, the exchange of information is expected between the end-user and the substation operator, for increasing stability [67]. Advanced data communication for advanced metering infrastructure (AMI) involves the bi-directional communication of data from end-user to utility and vice versa. For this purpose, networks like wireless communications, power line communications (PLC), fiber optic communications, public networks, or fixed radio frequency networks can be used [68]. The information collected by the smart meter can be communicated to the utility via the wired or wireless connection. It should also update the information to end-user or receive commands from utility and can only be possible through standard communication [69].

The smart meter is a sensitive and complex device that handles large data between home appliances and utility center without any disruptions. The smart meter data is most trustworthy, and the access is limited to a few people. The communication standards and strategies are framed to safeguard the data transfer within the network and should be protected [70]. Every smart meter is assigned with a unique identity and all the associated appliances are assigned with a similar identity to secure cryptographic encryption. The communication network should also support the smart meter even in the case of power outages happens. Communication technologies employed should be economic, should have better transmission ranges, with standard security features, and should provide the required bandwidth [71]. Based on the type of SG applications the data communication network systems are broadly classified into; home area networks (HAN), neighborhood area networks (NAN), and wide area networks (WAN).

The three networks are responsible for managing the entire appliances and applications from a centralized utility center [72]. Figure 2 shows a network model with different networks for SG. The end-user premises enabled by HAN mainly implements AMI and demand response. For coordinating smart meter for its monitoring purposes, HAN deploys various wireless technologies like Wi-Fi (IEEE 802.11) and ZigBee (IEEE 802.15.4) [73]. Wired solutions may include the use of Ethernet and PLC. However, wired communication supports good data rates, and security. Ethernet involves high cabling costs, and less flexibility compared to wireless. The usage of PLC for HAN is still in preliminary stages [74].

The NAN or Field area networks are mainly employed in between HAN and WAN. Two IEEE standards are carefully relatecd to NANs. The IEEE standard 802.15.4G mainly deals with an out-of-door environment with relatively low data rates (~ less than 100kbps) and is associated with a wireless smart metering utility network [74]. Secondly, IEEE 802.11s is closely related to network operations like node delivery and route selection of smart grid NANs. The privacy of data must be ensured from cyber-attacks for smart grid NANs [75].

WANs serves for SG between the NAN and utility center. WAN employs a high-bandwidth network for providing backhaul communication between different substations, distributed automation, and data aggregation points covering for thousands of kilometers apart. Safeguarding reliability and security of power systems are the most important aspects of WANs. Most of the utility operators like AT &T, Verizon, and Sprint make use of private WANs for increased security instead of depending on public networks [76, 77].

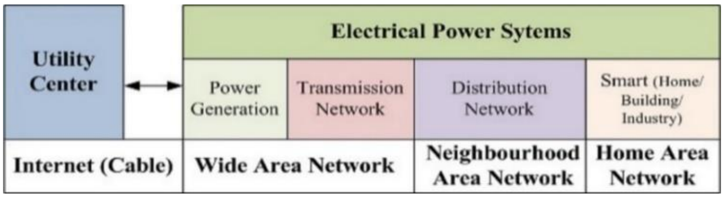

Figure 2. Network model with different networks for SG

4. ROLE OF INFORMATION TECHNOLOGY IN TERMS OF THE INTERNET OF THINGS AND ASSOCIATED SYSTEMS

4.1. Internet of things (IoT) for smart grid applications

The initial automation based improvements for the traditional grid were based on IoT concept. The early SG was originally known as intelligent utility network, or advanced distribution automation were the early version projects based on IoT concepts. This is not surprising, considering utilities have more "things" distributed over a wider area, as a vast, complex, interconnected machine, than almost any other industry. Intelligent things enable new use cases while the utility sector develops new energy-related services. Applying business analytics to data collected from smart meters and other devices in real-time to gain insights for better business decisions and automation is becoming paramount [78]. SG embodies a subset of IoT principles, and some of the more advanced projects made use of today's IoT concepts. Applying IoT to the changing world of distributed and renewable energy generation is one of the IoT business cases. Utilities often start with an IoT strategy in the context of their familiar smart grid projects. As they begin to encompass more of the aspects of IoT, such as analytics platforms, IoT cloud, sensor fusion, and data governance, they may use these principles in continuation of SG, either in different jurisdictions or for advanced functions such as distributed intelligence [79]. Figure 3 shows the IoT relative aspects for advanced energy management.

IoT can form a large-scale network and work autonomously. Restoration and maintenance of communication during failures and increased traffic are important points about IoT. Thus, it is considered as suitable for various communication media whether wired or wireless. IoT efficiently collects the data from a large number of different sensors. The important applications of IoT include monitoring of network configuration, communication quality, and device configuration. That are difficult to realize with conventional autonomous distribution networks [80].

One should also think of IoT by parsing the phrase. "Internet" is not necessarily the public Internet. For example, there is the more select Internet2 regional systems proposed for utilities such as the eastern interconnect data sharing network. "Things" include people; causing some to use the phrase "internet of everything". Technicians, vehicles, poles, consumers, and wind turbines, are 'things' in the broader view of IoT [81]. In short energy and utilities IoT 'to do' list: 1) focus on security [82], 2) implement cloud computing and big data and analytics pilot projects [83], 3) re-invent the end-user experience (customer or technician), 4) plan holistically and 5) pilot, learn, adapt. There exists research on employing IoT data for every analysis, with the innovative usage of new data discovery tools that can provide a high return on investment, as well as shorter paths to fault resolution and optimal operation.

4.2. Data management issues in smart grid

The SG systems generate huge amounts of data at different time intervals based on their type of application. The utilities need to address data management issues to make systematic utilization of data. This is obvious when one observes the frequency of data generations of these systems [84]. As observed, the generation of huge amounts of data in SG systems creates two-fold problems: primarily the storage and secondarily the consumption thereof as they lack appropriate infrastructure to make use of it completely. This data of consumers when appropriately utilized helps to save the problem of peak loads through price benefits. All of this is contingent on the knowledge of the consumers that their data could be used to help manage their energy consumption. This would start from the awareness of the consumers about the storage of data and data generation itself when they interact with the meters. The effective consumer behavior can thus be altered with an incentive to conserve energy and save money [85].

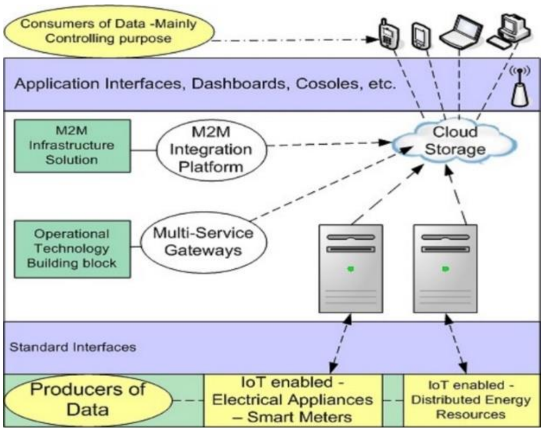

Figure 3. IoT relative aspects for advanced energy management

4.3. Cyber security challenges for SG

The reliability of the SG environment in computing capability to generate and manage such data is very clear. This reliability is also in part due to the interconnection of a multitude of such data generating electronic devices, thus, raising the issue of cybersecurity and prompting it to be treated as a high priority [86]. The nature of cybersecurity has been made specific and definitive to the domain of SG. Certain standards address this from the standpoint of an operator whereas others address it from the standpoint of implementation [87]. The series of incidents in December 2015 helps us understand the destructive capabilities of an SG environment not secure in terms of its cybersecurity aspects. In the said incident, the hackers-perpetrators had successfully acquired external control of the systems' human-machine interface leading to a 10 hours blackout and affecting the lives of about 225,000 people. The ex-post operations conducted by authorities from the US FBI to the Ukrainian authorities concluded that these attacks had targeted susceptible software on the system as the authorities had detected 'Black Energy' malware throughout the systems' internal networks leading to an attack on the control systems. The control over the system had to be regained by manual rebooting and resuming of operations of the system [88].

It is important to focus on the attacks on the information and communication networks of SG. Signal-based detection is carried at the PHY layer or MAC layer. where a DoS attacker can detect the presence of an attack based on the received signal strength indicator (RSSI) information. If the RSSI of several data packets is greater than threshold (that means the receiver node should properly receive them), the decoder at receiver end records errors in the received data. The attack detector can raise an alarm in the presence of an attacker. Some jamming resistant protocols include UFHSS, UDSSS and UFH-UDSS [89], DEEJAM [90] and timing-channel (TC) [91], and JADE [92]. Packet-based detection solutions can be implemented at any of the layers of SG networking and can compare packet delivery ratio at regular time intervals if significant packet transmission failures are detected then it serves as an alarm for attacks [93].

In light of the above considerations, a secure SG environment must have the following future goals: data confidentiality, message authentication, repetitive message detection, preserving privacy and aiding revocation of an action. The standard solutions designed to work distinctively with individual network applications would also have to make sure that the system as a whole is secure, thus, making cybersecurity a challenging research for the future for SG.

5. CONCLUSION

Modern technologies like ICT are being used to transform, the traditional grids to SG with advanced automation, becoming the hope for future energy needs. The most important factor for considering the SG is its efficient energy management with the introduction of DER. The demand response is handled logically, and peak loads can be shifted or postponed for other times. This way of managing the electricity shall not only increase the stability of the system but also decreases carbon emissions and protects the environment. The most important infrastructure for SG is establishing AMI technology for introducing the bidirectional communication to learn about the electric usage between the end-user and utilities. This introduced dynamic tariffs involve active participation at the end-user level. AMI includes technologies like WAN, NAN, and HAN for communication purposes. Different communication technologies serve different purposes based on the types of applications and work with various data rates. Interoperability issues among technologies like communication, information, and data management need to be still addressed critically. There is a need to find the gap between different technologies of SG and this has a large scope for future research. Maintenance of power quality is one of the major concerns addressed by SG. The smart meter at end-user premises and IED at distribution systems shall manage the voltage levels and power factor. The smart meters shall record the voltage levels delivered at end-user premises and informs the utility center about this information at regular time intervals. With this, data utility centers shall optimize the voltage levels, thereby, increasing the power quality of the system. With a better voltage, the appliances at the end-user premises work with higher efficiency. The power systems situation based operation or event-based operations are not sufficient for controlling and cannot guarantee system stability.

Remote monitoring is the prime advantage of SG technology. Remote monitoring devices include distribution transformers, capacitor banks, PMU, and smart meters. The concepts of remote monitoring and wide-area monitoring have generated technologies like WAMPAC that supports SG for enhanced management of power losses, faults, and disturbances. These monitoring technologies will lower power outages, increases power delivery, decreases operational costs and increases the end-user satisfaction. The increased use of RESs like the solar, and wind. shall benefit the customer in tackling real-time pricing for demand response billing.

Vehicle-to-Grid and Gird-to-Vehicle charging become the prime concern with better utilization of energy resources. Due to their high impact on power systems, large intensive research needs to be focused on this area by industry and academia. The main concerns pertaining to utilities like efficient data management, controlling, and communication of information need to be concerned with efficient SG operations. The privacy issues related to huge data integrity and confidentiality can be important future research of SG. The utilization of communication technologies increases the interconnections among various appliances of SG that introduces vulnerabilities because of cyber-security and related issues and need to be addressed by fine-grained technical approaches based on SG issues.

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