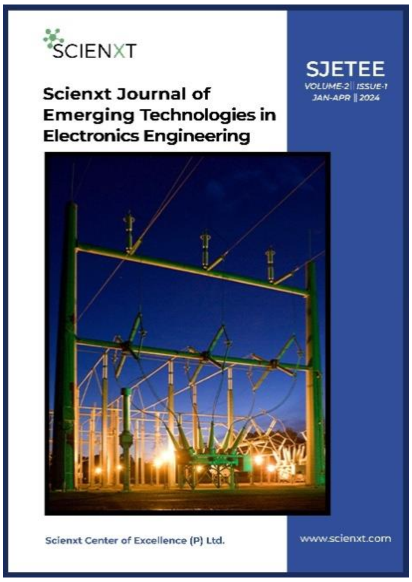

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A review paper on wireless communication technologies for smart grid systems

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Abstract:

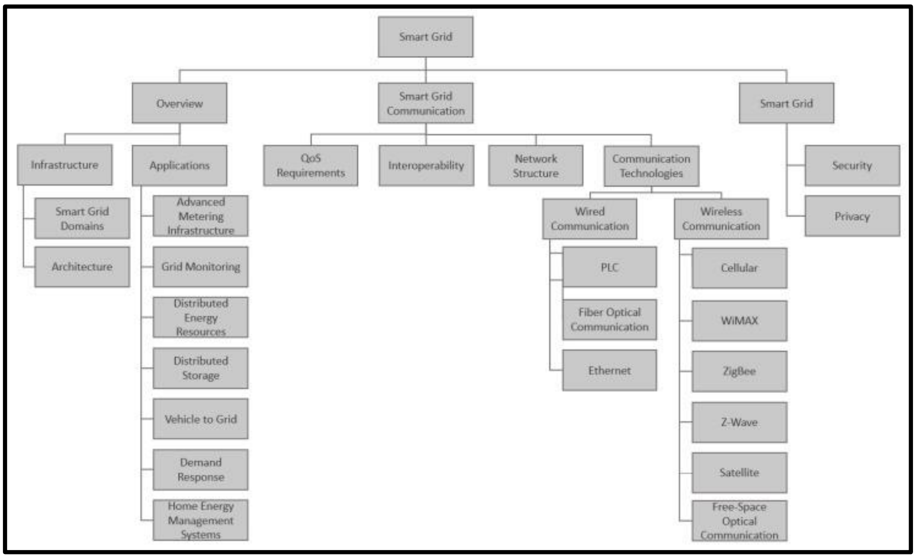
The smart grid is envisioned as the solution to meet 21st-century energy demands with a sophisticated, real-time approach by seamlessly integrating the latest digital communications and advanced control technologies into the existing power grid infrastructure. This innovative system aims to connect users worldwide through an energy-efficient and awareness-enhancing network. This paper offers a thorough examination of Wireless Communication Technologies (WCTs) for the implementation of the smart grid in a methodical manner. Various network attributes, such as Internet Protocol (IP) support, power consumption, and data rates, are taken into account to compare communication technologies within the smart grid context. Techniques suitable for Home Area Networks (HANs), such as ZigBee, Bluetooth, WI-Fi, 6LoWPAN, and Z-Wave, are discussed and evaluated based on consumer concerns and network attributes. Similarly, an analysis is conducted for wireless communication techniques for Neighborhood Area Networks (NANs), encompassing WiMAX and GSM-based cellular standards, from the perspective of utility concerns. Furthermore, this paper elaborates on smart grid applications,associated network issues, and challenges, providing a comprehensive overview of the subject matter.

Keywords:

Analysis, assessment, intelligent grid, technologies for intelligent grids, communication infrastructure for intelligent grids, wireless connectivity, wired connectivity, and security measures for intelligent grids

1. Introduction:

The current approach to generating and distributing electric power dates back to the last century and has remained largely unaltered since its inception. Traditional power grids are predominantly radial in structure, designed around centralized power generation. Reliability is maintained through the incorporation of excess capacity and a unidirectional flow of power from the power plant to the consumer, facilitated by high-voltage transmission lines spanning considerable distances. Consumers worldwide require a consistent and dependable energy supply that is both cost-effective and environmentally conscious. Power quality and environmental considerations are paramount. The general concerns of global consumers which may vary depending on regional circumstances and consumer requirements. The smart grid is envisioned to comprehensively tackle these concerns in a sophisticated and adaptable manner. The fundamental components of the smart grid encompass smart meters, sensors, monitoring systems, and data management systems, which orchestrate the exchange of information among diverse stakeholders, thus establishing a bidirectional communications network, also referred to as Advanced Metering Infrastructure (AMI). Additionally, smart grid applications encompass Energy Management Systems (EMS), Distributed Power Generation (DPG) and its seamless integration into the system, equipment diagnostics, control mechanisms, and overall optimized asset management. Plug-in Hybrid Electric Vehicles (PHEVs) and Electric Vehicles (EVs) significantly impact grid reliability, necessitating effective management within the smart grid framework, which warrants intensive research. These applications are heavily reliant on robust communications infrastructure. The Home Energy Management System (HEMS) requires a short-distance network known as the Home Area Network (HAN), while communication between users and utilities necessitates Neighborhood Area Networks (NAN) and potentially Wide Area Networks (WAN). Our objective is to investigate various short and long-range communications technologies applicable to key smart grid applications. we delve into the exploration and comparison of wireless communication options tailored for Home Area Networks (HANs), while focuses on the analysis of wireless communication alternatives for Neighborhood Area Networks (NANs). Section 4 provides a comprehensive examination of smart grid applications. Preceding the concluding remarks in Section 6, Section 5 addresses the challenges and issues pertinent to the realization of the smart grid .Gives an overview of Smart Grid infrastructure, domains, architecture, and applications



2. Overview of smart grid:

Communication plays a pivotal role in Smart Grids (SGs), distinguishing them significantly from traditional grids by facilitating two-way communication. Unlike traditional power grids that solely enable one-way communication between utilities and customers, SGs offer bidirectional communication. This bidirectional communication capability empowers the utilization of distributed smart sensors, distributed power generation, real-time measurements and metering infrastructure, as well as monitoring systems. Efficient information exchange is paramount for SGs to ensure reliable power generation and distribution. The following provides an overview of SG infrastructure, domains, network architecture, and SG applications.

2.1. Smart grid infrastructure:

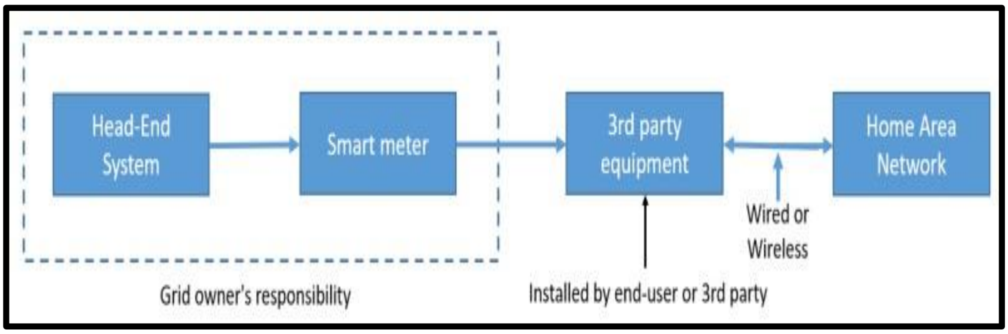
There is no universally accepted definition of a Smart Grid, but common to many definitions is the emphasis on communication for measurements, monitoring, management, and control. Communication plays a vital role in ensuring reliable, efficient, and secure power generation, transmission, and distribution. These communication systems facilitate the exchange of information between distributed sensing equipment, monitoring systems, and data management systems. Such solutions necessitate fast communication as generation, delivery, and consumption occur simultaneously. With the advent of distributed energy resources and energy storage systems, the importance of fast and reliable communication has increased. End-user expectations have also evolved, with demands for real-time information on electricity prices, customers contributing electricity to the grid, and electric vehicles serving as batteries within the grid. A primary goal of Smart Grids is to reduce costs and environmental impact while maximizing reliability, resilience, and stability. The smart meter serves as a cornerstone of Smart Grid infrastructure, forming a crucial part of the Advanced Metering Infrastructure (AMI). AMI is responsible for establishing reliable and secure high-speed two-way communication between smart meters at end-user locations and data control centers at utility companies for monitoring and control purposes. The full benefits of Smart Grid infrastructure are realized when smart meters, sensors, and measuring devices distributed throughout the power grid communicate effectively to ensure stability, detect, predict, and prevent faults, forecast load changes, and facilitate demand response .

2.2. Smart grid applications:

Advanced Information and Communication Technology (ICT) has transformed the world into a global village. It is foreseeable that the implementation of the smart grid will ultimately connect users worldwide through an energy-efficient and awareness-enhancing network. The smart grid encompasses numerous applications such as Advanced Metering Infrastructure (AMI), Distribution Automation (DA), Home Energy Management Systems (HEMS), Electric Vehicle (EV) management, and the integration of Distributed Generation (DG) from renewable energy resources in an efficient and reliable manner.

2.3. Advanced metering infrastructure (AMI):

Smart Grids (SGs) are recognized as one of the most extensive potential implementations of Internet of Things (IoT) networks, featuring smart meters and wireless sensors strategically positioned throughout the grid. Additionally, smart appliances communicate with each other to ensure the reliable and efficient generation and distribution of power. The advanced metering infrastructure (AMI) comprises physical and virtual components, including sensors, monitoring systems, smart meters, software, data management systems, and communication networks. AMI functions by collecting, analyzing, and storing metering data transmitted from sensors, monitoring systems, and smart meters located at end-user points to utility companies for billing, grid management, and forecasting purposes. Interactions within SGs are predicated on measured data and communication derived from sensor networks.



Smart metering architecture

2.4. Grid monitoring:

Monitoring the grid is imperative to uphold power quality standards across the entire power grid. Frequency, voltage, and waveform parameters must remain within specified thresholds, as deviations can lead to diminished lifespans for sensors, devices, and appliances connected to the power grid. Grid monitoring is executed through the deployment of smart sensors strategically positioned throughout the grid, along with Advanced Metering Infrastructure (AMI), and the integration of Supervisory Control and Data Acquisition (SCADA) systems. These monitoring systems for assessing the status of the SG infrastructure down to individual components aid in the rapid detection, prediction, and response to faults. This leads to enhanced management, more precise optimization of resources, swifter identification of grid faults, decreased troubleshooting time, and heightened reliability.

2.5. Vehicle to Grid (V2G):

The trend of vehicle electrification is evidently gaining momentum worldwide, indicating increased future interactions between the power grid and vehicles. Electric vehicles (EVs) and chargers, which link vehicles to the grid network, have the capacity to utilize energy stored in vehicle batteries and redistribute it to the grid as required. Within the power grid, EVs can play a crucial role in power balancing by offering rapid, high-power responses. Moreover, EVs have the potential to mitigate energy demand during peak load hours by consuming, storing, and subsequently returning energy when necessary.

3. Conclusions:

Realizing the vast potential of the smart grid for the betterment of humanity hinges on the swift advancement of sophisticated communications infrastructure and the optimization of network parameters. We have conducted separate reviews of Wireless Communication Technologies (WCTs) for Home Area Networks (HANs) and Neighborhood Area Networks (NANs), comparing them in terms of consumer preferences and utility needs. Wi-Fi provides high data rates and broader coverage (up to 100 meters indoors), whereas Bluetooth offers secure short-range communication (typically around 10 meters). However, ZigBee stands out for its low cost and low power consumption, making it a compelling choice for various smart grid applications. An overview of Smart Grid (SG) infrastructure, communication technologies, and their associated requirements, along with applications in premises network, neighborhood area network, and wide area network, has been provided. Additionally, cyber security challenges have been briefly outlined. We are currently witnessing the early stages of what promises to be a substantial transformation in the organization and management of electric power grids and generation. These changes are anticipated to be profound, with new opportunities emerging as technologies continue to advance. As new technologies are integrated into the grid, the volume of data and information exchange is rapidly escalating. Addressing security concerns is imperative to ensure the reliability of the power supply amidst these developments.

4. References:

(1) Zhou X., Ma Y., Gao Z., Wang H. Summary of smart metering and smart grid communication; Proceedings of the IEEE International Conference on Mechatronics and Automation (ICMA); Takamatsu, Japan. 6-9 August 2017; pp. 300-304.

(2) Priya P.P.S., Saminadan V. Performance analysis of WiMAX based smart grid communication traffic priority model; Proceedings of the International Conference on Communication and Signal Processing; Melmaruvathur, India. 3-5 April 2014; pp. 778-782.

(3) Farhangi H. The path of the smart grid. IEEE Power Energy Mag. 2009; 8:18-28. doi: 10.1109/MPE.2009.934876.

(4) Dileep G. A survey on smart grid technologies and applications. Renew. Energy. 2020; 146:2589-2625. doi: 10.1016/j.renene.2019.08.092.

(5) 5. Norwegian Smart Grid Research Centre Norwegian Smart Grid Research Strategy; Norwegian Smart Grid Research Centre. 2015. [(Accessed on 9 November 2021)]. Available online: https://smartgrids.no/wp-content/uploads/sites/4/2015/08/Norwegian-Smart_Grid__Research_Strategy_DRAFT_June10_WT_ks_hii.pdf

(6) Elhub Årsrapport 2020; Elhub 2021. [(Accessed on 9 November 2021)]. Available online: https://elhub.no/documents/2021/06/elhub-arsrapport-2020.pdf/

(7) European Commission Joint Research Centre Smart Electricity and Interoperability Smart Metering Deployment in the European Union. [(Accessed on 20 October 2020)]. Available online: https://ses.jrc.ec.europa.eu/smart-metering-deployment-european-union

(8) Global Smart Grid Federation. Smart Meter Security Survey. Global Smart Grid Federation; Washington, DC, USA: 2016.

(9) International Energy Agency Technology Roadmap. International Energy Agency. [(Accessed on 18 October 2020)]. Available online: https://www.iea.org/publications/freepublications/publication/smartgrids_roadmap.pdf

(10) Ghalib M., Ahmed A., Al-Shiab I., Bouida Z., Ibnkahla M. Implementation of a smart grid communication system compliant with IEEE 2030.5; Proceedings of the 2018 IEEE International Conference on Communications Workshops (ICC Workshops); Kansas City, MO, USA. 20-24 May 2018; pp. 1-6.