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LITERATURE SURVEY ON SMART GRID TECHNOLOGIES

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ABSTRACT
Electricity has staggering importance in our daily life and economic development. Efficient transmission and distribution of electricity is a fundamental requirement for every society. Smart grid technology is an essential to provide easy integration and reliable service to consumers. A smart grid system is a self-sufficient electricity network system based on digital automation technology for monitoring, control, and analysis within the supply chain. This paper discusses literature surveys of some researches and studies on Smart Grids technology. Smart Grid Technologies include integrated communications, sensing and measurement technologies, advanced components, advanced control methods, and improved interfaces and decision support. Smart Grid must have self-healing, consumer participation, resist attack, high-quality power, accommodate generation options, enable electricity market, optimize assets, enable high penetration of intermittent generation sources.

KEYWORDS:
Smart grid, Electric power grid, Energy sustainability, Efficiency, Reliability, Security and Economy

INTRODUCTION

Smart Grid is a concept for transforming the electric power grid by using advanced automatic control and communications techniques and other forms of information technology. It integrates innovative tools and technologies from generation, transmission and distribution all the way to consumer appliances and equipment and also integrates energy infrastructure, processes, devices, information and markets into a coordinated and collaborative process that allows energy to be generated, distributed and consumed more effectively and efficiently.

Smart Grids is a new concept for electricity networks. The initiative responds to the rising challenges and opportunities, bringing benefits to all users, stakeholders and companies. Smart Grid Technologies are already used in other applications such as manufacturing and telecommunications and are being used in grid operation.

Department of Energy (DOE) lists five fundamental technologies that will drive the Smart Grid:

1. Integrated communications, connecting electronic components to get information and control every part in real time, on the other hand, make every part of the Smart Grid both 'listen' and 'talk'.
2. Sensing and measurement technologies, to provide faster and more accurate response information of each important part of Smart Grid, such as remote monitoring, real time thermal rating, electromagnetic signature analysis, real-time pricing and demand-side management.
3. Advanced components, to apply the latest research in superconductivity, storage, power electronics and diagnostics. they include: flexible alternating current transmission system devices, high voltage direct current, first and second generation superconducting wire, high temperature superconducting cable, distributed energy generation and storage devices, composite conductors, and "intelligent" appliances.

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4. Advanced control methods, to monitor essential components, enabling rapid diagnosis and precise solutions appropriate to any event. There are three categories for advanced control methods: distributed intelligent agents, analytical tools, and operational application.
5. Improved interfaces and decision support, information systems reduce the complexity of Smart Grid to make both operator and manager use it more efficiently and easily, to amplify human decision-making.

New technologies bring new functions to Smart Grid, which make Smart Grid more competitive than the old power grid.

OVERVIEWS ON SMART GRID

A smart grid is an electrical grid which includes a variety of operation and energy measures including smart meters, smart appliances, renewable energy resources, and energy efficient resources. Electronic power conditioning and control of the production and distribution of electricity are important aspects of the smart grid. Smart grid policy is organized in Europe as Smart Grid European Technology Platform.

The smart grid is required for Increased use of digital information to improve reliability, security, and efficiency of the electric grid. Development and incorporation of demand response, demand-side resources, and energy-efficiency resources. Identification and lowering of unreasonable or unnecessary barriers to adoption of smart grid technology.

Structure of Smart Grid. "Smart grid" generally refers to a class of technologies that people are using to bring utility electricity delivery systems into the 21st century, using computer-based remote control and automation. These systems are made possible by two way digital communications technologies and computer processing that has been used for decades in other industries. They are beginning to be used on electricity networks, from the power plants and wind farms all the way to the consumers of electricity in homes and businesses. They offer many benefits to utilities and consumers mostly seen in big improvements in energy efficiency and reliability on the electricity grid and in energy users' homes and offices.

A smart grid is a holistic solution that employs a broad range of information technology resources, allowing existing and new gridlines to reduce electricity waste and energy costs. Plug-in hybrid electric cars will also require a smart grid to allow consumers to charge their vehicles when rates are low.

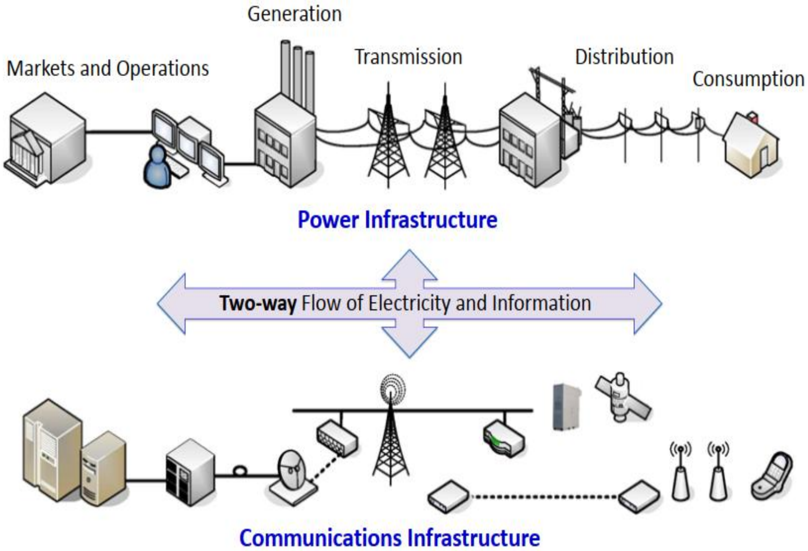

Fig 1 - Structure of Smart Grid

Applications of Smart Grid. The Following are the most common applications of smart grid technology.

- Fault protection,
- Outage management,
- Dynamic control of voltage,
- Weather data integration,

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- Centralized capacitor bank control,
- Distribution and substation automation,
- Advanced sensing,
- Automated feeder reconfiguration.
- Demand response.

Comparison of Existing Grid and Smart Grid. The existing utility grid is a centralized system where power flows in one direction, from generation resources through the transmission-distribution system to the customer. Table 1. shows the comparison of existing Grid and smart Grid. The Characteristics of a smart grid versus the traditional system as shown in Figure 2.

Table 1. Comparison of Existing Grid and Smart Grid

Existing Grid	Smart Grid
Electromechanical	Digital
One-way communication	Two-way communication
Centralized generation	Distributed generation
Few sensors	Sensors throughout
Manual monitoring	Self-monitoring
Manual restoration	Self-healing
Failures and blackouts	Adaptive and islanding
Limited control	Pervasive control
Few customer choices	Many customer choices

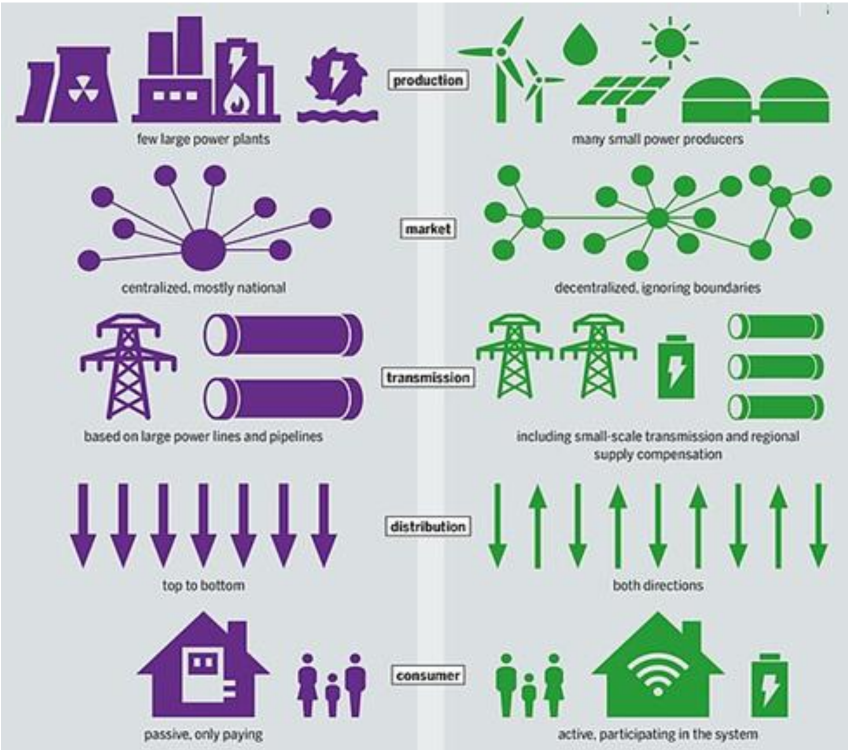

Fig 2 - Characteristics of a smart grid versus the traditional system

Smart Grid Benefits. According to the National Inst. of Standards and Technology (NIST) , the smart grid benefits are

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1. Improving Power Reliability and Quality for Better monitoring using sensor networks and communications and Better and faster balancing of supply and demand
2. Minimizing the Need to Construct Back-up (Peak Load) Power Plants for better demand side management and the use of advanced metering infrastructures
3. Enhancing the capacity and efficiency of existing electric grid for better monitoring using sensor networks and communications and Consequently, better control and resource management in real-time
4. Improving Resilience to Disruption and Being Self-Healing for better monitoring using sensor networks and communications and Distributed grid management and control
5. Expanding Deployment of Renewable and Distributed Energy Sources for better monitoring using sensor networks and communications, Consequently, better control and resource management in real-time, Better demand side Management, Better renewable energy forecasting models and Providing the infrastructure / incentives
6. Automating maintenance and operation for better monitoring using sensor networks and communications and Distributed grid management and control
7. Reducing greenhouse gas emissions for supporting / encouraging the use of electric vehicles and Renewable power generation with low carbon footprint
8. Enabling transition to plug-in electric vehicles
9. Increasing consumer choice for the use of advanced metering infrastructures, Home automation, Energy smart appliances and better demand side Management

Disadvantages of Smart Grid. The Disadvantages of Smart grid are

1. High cost due to replacement of analogue meters by more sophisticated electronic meters
2. Lack of regulatory norms for standards for technologies smart grid;
3. Lack of official technology documentation.
4. Installation is expensive

LITERATURE SURVEY AND CHALLENGES ON SMART GRID

Yasin Kabalci *et al.* [1] proposed a survey on smart metering and smart grid communication. In their review paper, it is aimed to disclose in a clear and clean way that what smart grid is and what kind of communication methods are used. All components of a smart grid are introduced in a logical way to facilitate the understanding, and communication methods are presented regarding to their improvements, advantages, and lacking feature. The developing generation, transmission, distribution and customer appliances are surveyed in terms of smart grid integration. The communication technologies are introduced as wire line and wireless classification where the key features are also tabulated. The security requirements of hardware and software in a smart grid are presented according to their cyber and physical structures.

Samaresh Bera *et al.* [2] presented a survey on cloud computing applications for smart grid. In their paper they discussed about that future smart grids are expected to have reliable, efficient, secured, and cost-effective power management with the implementation of distributed architecture. To focus on these requirements, they provide a comprehensive survey on different cloud computing applications for the smart grid architecture, in three different areas-energy management information management, and security. In these areas, the utility of cloud computing applications is discussed, while giving directions on future opportunities for the development of the smart grid.

Stefano Galli *et al.* [3] proposed a paper on role of power line communications in smart grid. In their paper they presented an overview of what PLC can deliver today by surveying its history and describing the most recent technological advances in the area. The application scenario of PLC within the Smart Grid is analysed in detail. Because a necessary ingredient of network planning is modelling, they also discuss two aspects of engineering modelling. The first aspect is modelling the PLC channel through fading models. The second aspect is the Smart Grid control and traffic modelling problem which allows us to achieve a better understanding of the communications requirements. Finally, this paper reports recent studies on the electrical and topological properties of a sample power distribution network.

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Richard E Brown *et al.* [4] presented a paper on impact of smart grid on distribution system design. Their discussion includes smart grid, distribution system of the future, and others. Functionally, a smart grid should be able to provide new abilities such as se f-healing, high reliability, energy management, and real-time pricing. From a design perspective, a smart grid will likely incorporate new technologies such as advanced metering, automation, communication, distributed generation, and distributed storage. Their paper discussed the potential impact that issues related to smart grid will have on distribution system design.

Vehbi C Gungor *et al.* [5] devised opportunities and challenges of wireless sensor networks in smart grid communications in smart-grid applications. Their paper starts with an overview of the application of WSNs for electric power systems along with their opportunities and challenges and opens up future work in many unexploited research areas in diverse smart-grid applications. Then, it presents a comprehensive experimental study on the statistical characterization of the wireless channel in different electric-power-system environments, including a 500-kV substation, an industrial power control room, and an underground network transformer vault.

Wenye Wang *et al.* [6] proposed a survey on cyber security in the smart grid structure. They presented a comprehensive survey of cyber security issues for the Smart Grid. Specifically, they focused on reviewing and discussing security requirements, network vulnerabilities, attack countermeasures, secure communication protocols and architectures in the Smart Grid. The aim to provide a deep understanding of security vulnerabilities and solutions in the Smart Grid and shed light on future research directions for Smart Grid security.

Mohit Khanna *et al.* [7] presented a survey on the communication architectures in smart grid. One important feature of the smart grid is the integration of high- speed, reliable and secure data communication networks to manage the complex power systems effectively and intelligently. They provided a comprehensive survey on the communication architectures in the power systems, including the communication network compositions, technologies, functions, requirements, and research challenges. As these communication networks are responsible for delivering power system related messages, they discussed specifically the network implementation considerations and challenges in the power system settings.

Francis M Wasilu *et al.* [8] presented a review on vehicle to grid and renewable energy sources integration.They presented a comprehensive review and assessment ofthe latest research and advancement of electric vehicles (EVs) interaction with smart grid portraying the future electric power system model in this paper. Their literature review on the integration of the renewable energy and the latest feasible solution using EVs with the insight of the promising research gap to be covered up are investigated. Furthermore, the feasibility of the smart V2G system is thoroughly discussed.

Patrick Mc Daniel *et al.* [9] proposed a paper on security and privacy challenges in smart grid.They discussed about the global electrical grids are verging on the largest technological transformation since the introduction of electricity into One home. The antiquated infrastructure that delivers power to our homes and businesses is being replaced with a collection of digital systems called the smart grid. This grid is the modernization of the existing electrical system that enhances customers' and utilities' ability to monitor, control, and predict energy use.

Anthony R. Metke *et al.* [10] presented a paper on security technology for smart grid networks. They have discussed about to upgrade the electric grid to increase overall system efficiency and reliability. Much of the technology currently in use by the grid is outdated and in many cases unreliable. There have been three major blackouts in the past ten years. The reliance on old technology cads to inefficient systems, costing unnecessary money to One utilities, consumers, and taxpayers. To upgrade the grid, and to operate an improved grid, will require significant dependence on distributed intelligence and broadband communication capabilities. The access and communications capabilities require the latest in security technology for extremely large, wide-area communications networks. They discussed about the key security technologies for a smart grid system, including public key infrastructures and trusted computing.

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Xi Fang *et al.* [11] proposed a survey on the new and improved power grid. In this article, they surveyed the literature till 2011 on the enabling technologies for the Smart Grid. They explored three major systems, namely the smart infrastructure system, the smart management system, and the smart protection system. Also proposed possible future directions in each system. Colorred (Specifically, for the smart infrastructure system, they explore the smart energy subsystem, the smart information subsystem, and the smart communication subsystem.) For the smart management system, they explored various management objectives, such as improving energy efficiency, profiling demand, maximizing utility, reducing cost, and controlling emission. For the smart protection system, they explored various failure protection mechanisms which improve the reliability of the Smart Grid, and explore the security and privacy issues in the Smart Grid.

Dilan Sahin *et al.* [12] presented a paper on smart grid technologies: communication technologies and standards. The smart grid can be considered as a modem electric power grid infrastructure for enhanced efficiency and reliability through automated control, high-power converters, modern communications infrastructure, sensing and metering technologies, and modern energy management techniques based on the optimization of demand, energy and network availability, and so on. They addressed critical issues on smart grid technologies primarily in terms of information and communication technology OCT issues and opportunities. They provided a contemporary look at the current state of the art in smart grid communications as well as they discuss the still-open research issues in this field.

Pravin P.Varaiya *et al.* [13] proposed a paper on smart operation of smart grid risk limiting dispatch. A smart grid is necessary to manage and control the increasingly complex future grid. Certain smart grid elements-renewables, storage, micro grid, consumer choice, and smart appliances-increase uncertainty in both supply and demand of electric power. Other smart gird elements-sensors, smart meters, demand response, and communications-provide more accurate information about the power system and more refined means of control. A new operating paradigm, called risk-limiting dispatch, is proposed. It treats generation as a heterogeneous commodity of intermittent or stochastic power and uses information and control to design hedging techniques to manage the risk of uncertainty.

Himanshu Khurana *et al.* [14] presented a paper on smart grid security issues. Their workgiven a broad brush description of issues related to smart-grid security. They have designed solutions in at this stage, before widespread deployment, would be beneficial.

Davood Mohammadi Souran *et al.* [15] proposed an article on Smart Grid Technology in Power Systems. In this article they surveyed of smart grid literature till 2011 on the enabling technologies for the smart grid. In this paper, three major systems are explored namely the smart infrastructure system, the smart management system, and the smart protection system. Possible future directions are also proposed in each system. For the smart infrastructure system, we specifically explore the smart energy subsystem, the smart information subsystem, and the smart communication subsystem. Various management objectives, such as improving energy efficiency, profiling demand, maximizing utility, reducing cost, and controlling emission are explored for the smart management system and for the smart protection system, various failure protection mechanisms which improve the reliability of the smart grid, and the security and privacy issues in the smart grid are explored.

Nikos Komninos *et al.* [16] proposed a survey in smart grid and smart home security –issues, challenges and countermeasures. They focused on issues related to the security of the smart grid and the smart home, which they present as an integral part of the smart grid. Based on several scenarios, they aimed to present some of the most representative threats to the smart home/smart grid environment The threats detected are categorized according to specific security goals set for the smart home/smart grid environment, and their impact on the overall system security is evaluated. A review of contemporary literature is also conducted with the aim of presenting promising security countermeasures with respect to the identified specific security goals.

Khosrow Moselhi *et al.* [17] presented a paper on reliability perspective of the smart grid. of necessary analytical capabilities. Their reviews about the reliability impacts of major smart grid resources such as

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renewables, demand response, and storage. They observe that an ideal mix of these resources leads to a flatter net demand that eventually accentuates reliability challenges further. A grid wide IT architectural framework is presented to meet these challenges while facilitating modern cyber security measures. This architecture supports a multitude of and temporally coordinated hierarchical monitoring and control actions over time scales from milliseconds and up.

Chen Shu-yong *et al.* [18] proposed a survey on smart grid technology. In this paper the connotation of smart grid is expounded. They analysed the conditions to develop smart grid in China, and points out the key technological problems to be solved for the development of smart grid in the fields of power network topology, communication system, metering infrastructure, demand side management, intelligent dispatching, power electronic equipment, distributed generation integration etc.

Hassan Farhangi *et al.* [19] presented a paper on the path of the smart grid. The electrical power industry is undergoing rapid change. The rising cost of energy, the mass electrification of everyday life, and climate change are the major drivers that will determine the speed at which such transformations will occur. They discussed about how quickly various utilities embrace smart grid concepts, technologies, and systems, they all agree onthe inevitability of this massive transformation.

S.Massound Amin *et al.* [20] presented an article on power delivery for 21st century. In this article, they presented the security, agility, and robustness/survivability of a scale power delivery infrastructure that faces new threats and unanticipated conditions. They explored a brief overview of the past work on the challenges faced in online parameter estimation and real-time adaptive control of a damaged F-15 aircraft. This work, in part, provided the inspiration and laid the foundation in One 1990s for the flight testing of a fast parameter estimation/modelling and reconfigurable aircraft control system that allowed the F-15 to become self-healing in the face of damaged equipment.

Ye Yan *et al.* [21] proposed a survey on cyber security on smart grid communications. A smart grid is a new form of electricity network with high fidelity power-flow control, self-healing, and energy reliability and energy security using digital communications and control. Top grade an existing power grid into a smart grid, it requires significant dependence on intelligent and secure communication infrastructures. It requires security frameworks for distributed communications, pervasive computing and sensing technologies in smart grid. In this paper, they summarize the cyber security requirements and the possible vulnerabilities in smart grid communications and surveyed the current solutions on cyber security for smart grid communications.

Yi Qian *et al.* [22] explored a survey on smart grid communication infrastructures –motivations, requirements and challenges construction and operation of a smart grid. In this paper, they presented the background and motivation of communication infrastructures in smart grid systems. They also summarized major requirements that smart grid communications must meet. Further they explored the challenges for a communication infrastructure as the part of a complex smart grid system. Since a smart grid system might have over millions of consumers and devices, the demand of its reliability and security is extremely critical. Through a communication infrastructure, a smart grid can improve power reliability and quality to eliminate electricity blackout.

V. Cagri Gungor *et al.* [23] proposed a survey on smart grid potential applications and communication requirements. A sophisticated, reliable and fast communication infrastructure is, in fact, necessary for the connection among the huge amount of distributed elements, such as generators, substations, energy storage systems and users, enabling a real time exchange of data and information necessary for the management of the system and for ensuring improvements in terms of efficiency, reliability, flexibility and investment return for all those involved in a smart grid: producers, operators and customers. This paper overviews the issues related to the smart grid architecture from the perspective of potential applications and the communications requirements needed for ensuring performance, flexible operation, reliability and economics.

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Costos Efthymiour *et al.* [24] presented a paper on smart grid privacy via anonymization of smart metering data. Their work described a method for securely anonymizing frequent (for example, every few minutes) electrical metering data sent by a smart meter. Although such frequent metering data may be required by a utility or electrical energy distribution network for operational reasons, this data may not necessarily need to be attributable to a specific smart meter or consumer. The method described in this paper provides a 3rd party escrow mechanism for authenticated anonymous meter readings which are difficult to associate with a particular smart meter or customer.

Roger N. Anderson *et al.* [25] proposed a paper on smart grid the future of the electric energy system. This paper presents a discussion of the future of the electric energy system, addressing the entire spectrum from power generation, through substations, to distribution and the customer, and the feedback loops along the way necessary to provide the computational intelligence necessary to make the “Smart Grid”. This paper introduces the Special Issue by presenting a broad definition for the Smart Grid. They discussed the necessary attributes for such a system-of-systems, review the need for change, and identify the technical challenges facing successful deployment.

DISCUSSION

Literature surveys of some researches and studies on Smart Grids technology are discussed in this paper. According to that the development and implementation of a smart grid for power supply is one of the pressing issues in the modern energy economy, given high national priority and massive investments, although the entire subject is still in its infancy stage. The smart grid delivers electricity from producers to consumers using two-way digital technology and allows control of appliances in the consumers' houses and of machines in factories to save energy while reducing costs and increasing reliability and transparency. Such a modern electricity network is promoted by many governments as a way of handling energy independence, global warming and security of supply.

A smart grid Technologies include integrated communications, sensing and measurement technologies, advanced components, advanced control methods, and improved interfaces and decision support. Smart Grid, an upgrade of the current system which is more reliable, efficient, affordable, secured, and environment friendly, is the solution of this growing concern. It is believed that Smart Grid will take us towards energy independence and environmentally sustainable economic growth.

In the future, Smart Grid will connect everyone to abundant, affordable, clean, efficient, and reliable electric power anytime, anywhere. It will offer the world the best and most secure electric services.

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