SMART GRIDS:
A PROLOGUE & UNSCREW CHALLENGES THAT NEEDS TO BE ADDRESSED, A SHORT SURVEY ON HOW TO MAKE GRIDS SMARTER

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Received May 5, 2013, Revised June 17, 2013

ABSTRACT. A Smart Grid (SG) is an intellectual and logical electricity network that integrates the actions of all users connected to it and makes use of sophisticated and highly advanced information, control, and communications technologies to save energy, reduce expenditure and increase reliability and transparency. A smart grid can reduce energy cost; it makes energy usage efficient that result in a short term solution for the energy crisis. It also helps the distribution systems for better energy management and control. The field of Information & Communication Technology (ICT) and computer technology can play a major role in this hazardous situation all over the world. This paper presents current research issues and challenges that need to be addressed for reliable, efficient and flexible load distribution (LD) and management for smart grid design. The paper also presents some security & privacy issues that inform the grid station (GS) about consumer’s habits and personnel information. The article also tries to highlight major research issues in smart grid technology, which are helpful for the new researchers to find new research directions in this field & technology.

Keywords: Smart Grid, Information and Communication Technology, Grid Station, Load Distribution

1. INTRODUCTION & CONCEPTS: The electricity network consists of power plants, grid stations, transmission systems and distribution systems. Power plants are a major source of energy production. Grid stations are used for efficient load management, transmission systems transmits energy from production plants to grid stations. Distribution systems manage and provide the available energy to consumers. Simple analog meter are specific devices that are used to measure the energy consumption. Basic architecture for an energy system is shown in Fig 1.
The power produced at power stations are directed to the national grid, from where it is transmitted to the local grids for further distribution. This electricity system is still not reliable and is a mean for energy wastage and needs to be efficient to save energy. Similarly the problem of energy crisis and global warming is also needs to be explored for further enhancement and advancement. Modern computational & communication techniques can be applied for reliable energy transmission, distribution & load management. Such a field where ICT and computational methods are applied for achieving energy efficiency & can control the current situation of energy crisis is known as smart grid technology. The idea can also results in tracing the energy thieves using modern infrastructure. A smart grid is more reliable, more secure, stable, measurable, controllable, flexible, scalable, highly available to consumers, maintainable, sustainable and more optimized [1]. The technology not only enhances the energy system but also can control energy crisis, global warming and peak load efficient management. The basic components of smart grid architecture are smart meter, load management, local area network, internet and secure applications that can report the energy consumption correctly to the grid for billing purpose.

The rest of paper is summarized as. In section II, we gave an introduction to smart grid architecture. Section III highlights benefits & goals of smart technology. Section IV is dedicated to the new researchers to find out research directions in academia and research laboratories. Section V discusses the technology in brief, and finally we conclude and having some proper discussion on current energy crisis in Pakistan in following section i.e. Section VI.

2. **Smart Grids**: In Fig 2 the basic Smart Grid architecture is shown. Transmission system transmits the power produced at power plants. The smart grid distributes the power amongst the household and commercials. Smart meter calculate the energy consumed and send the information back to smart grid for an appropriate action. There is a need for energy management system to be installed on each smart grid. Also some appropriate and secure software system is needed for smart meter that can propagate the information of each household after a short interval of time.
A smart grid is a next generation power grid system where electricity distribution and management is upgraded through incorporating advanced two way communications i.e. ICT and pervasive computing capabilities to enhance power control, efficiency, reliability, cost, consumption and safety [6]. It tries to deliver electricity between suppliers and consumers using two way digital communication technologies and it controls smart and intelligent appliances at consumers to save energy, reduce cost and increase reliability, transparency and efficiency. In [4] the author proposed the basic Smart Grid secure architecture as shown in Fig 3. Each house is provided by a smart meter which can measure the electricity consumption and can communicate with the ESP for up to date data and monthly bill calculation. All smart meters are connected to a site current transformer which is further connected to the switchyard. The switchyard works as a proxy server between the household and ESP, where ESP is connected over an internet connection. The authors claimed that collector can prevent the household to be identified by ESP. TTP is trusted third party which is also connected over an internet connection. This architecture is more secure. A smart grid built on sensing technologies, communications, and control technologies tender a very talented opportunity for utilities and users.

3. BENIFITS & CHARACTERISTICS OF SMART TECHNOLOGY: A smart grid is to be more reliable, more secure, stable, measurable, controllable, flexible, scalable, highly available to consumers, maintainable, sustainable and more optimized. Expectations for the Smart Grid are great and will be realized through advances in each of the six value areas described below:

- **It must be more reliable.** A reliable grid provides power, when and where its users need it and of the quality they value.
- **It must be more secure.** A secure grid withstands physical and cyber-attacks without suffering massive blackouts or exorbitant recovery costs. It is also less vulnerable to natural disasters and recovers quickly.
- **It must be more economic.** An economic grid operates under the basic laws of supply and demand, resulting in fair prices and adequate supplies.
- **It must be more efficient.** An efficient grid employs strategies that lead to cost control, minimal transmission and distribution losses, efficient power production, and optimal asset utilization while providing consumers options for managing their energy usage.
- **It must be more environmentally friendly.** An environmentally friendly grid reduces environmental impacts thorough improvements in efficiency and by enabling the integration of a larger percentage of intermittent resources than could otherwise be reliably supported.
4. RESEARCH ISSUES: Some of the most challenging research issues in smart grid technology are security and privacy, smart meter, bill computation, cyber attacks, implementation and energy management. In [4] the authors have proposed a new secure smart grid architecture that can prevent personal information of a household to be identified by the electricity services provider i.e. ESP. electricity consumption control and bill computation are also given some importance in this paper but still the work needs to be improved.

An important aspect in a Smart Grid is Automatic Meter Reading (AMR). The digital device used for the same purpose is called Smart Meter. Different cyber attacks are to be studied and some secure smart meter is needed for secure communication and to prevent consumer's privacy. In [8] the authors have discussed and developed an integrated advanced AMR to tackle Distributed Management System with complete controlling and monitoring based on Geographic Information system (GIS).

The success of future smart grid depends heavily on the communication infrastructure, which is one the challenging research issue in smart grid technology [9]. A number of survey papers have discussed this issue and have placed a question mark for a secure, efficient and reliable communication infrastructure. Even though the roadmap of wide-reaching smart grid operation
is still not clear, it is almost assured that the prospect intellectual energy network empowered by advanced ICT technology will not only be as big as the in progress Internet technology, but also revolutionize folk’s lives in a fundamental way analogous to the Internet. As communication infrastructure is a groundwork technology for this huge smart grid progress, the authors in [9] predict that smart grids will be thrilling research vicinity for communication engineers in next years. Smart Grids requires real-time monitoring and analysis capacities not only to identify the early sign of breakdown and malfunction but also with the capabilities to take action to the occurred disturbances. For that reason broadband communication networks including cables, optical fibers, DSL and wireless communications will play an important role [21]. Binary Runtime Environment for Wireless (BREW) Technology can be used for connecting smart meters to the energy distribution centers efficiently and more secure as compared to other wireless communication technologies. Other communication technologies like wireless, WiFi, WiMax and satellite based communication are also of prime importance.

The control architecture is another key research issue. In conservative electric power systems, Supervisory Control and Data Acquisition (SCADA) systems are responsible for exchanging system status and control signals [2]. Presently, in smart technology there is a need to move toward the use of an automated agent technology, known as a multi-agent system. In [13] an agent-based technology was used to control generators in a micro-grid. Intelligent Distributed Autonomous Power Systems (IDAPS) [12] is one of the most recent papers that consider multi-agent systems.

Load forecasting in smart grid technology in another active research issue, as load forecast plays a momentous role in planning and operation of power systems. An intelligent system will make the energy distribution system more efficient and controllable [25]. Many ways such as Expert Systems (ES), Grey System Theory (GST), and Artificial Neural Networks (ANNs) are engaged for the purpose of load forecasting to simulate the smart grid technology. In smart grid technology, high exactness and correctness of the load forecasting is requisite to provide the accurate information about the power purchasing and generation in energy market, and to thus to prevent more energy from wasting and abusing that will help to maintain the energy cost in a reasonable range [26].

![Fig 4: An intelligent system](image)

In [25] the authors have focused on the behaviors of diverse training algorithms for load forecasting by back propagation algorithm in Neural Network, that are implemented in Neural Network Toolbox in MATLAB environment. After simulations they found trainer algorithm as one of the best choice for load forecasting. They claim that if more accurate results are needed, more neurons are needed in network architecture. In last they concluded and expected that if enough information were gathered and if the network was skilled more careful, then better results might be obtained. The intelligent system as shown in Fig. 4, its implementation in smart technology make the technology more reliable and well controlled and supervised. In prediction stage the energy consumption at each household and market is measured, afterward the intelligence system some specific supervisory action. Similarly during any transmission error the corresponding intelligence system will create alarm to activate proper supervisory action.
The integration of ICT makes the smart grid vulnerable to cyber attack. Security in smart grid is of major concern to the field researchers. Information security, information and communication technologies (ICT) infrastructure security, and application-level security are studied in the literature [27]. A range of communication networks are interconnected to the electric grid for the reason of sensing, defense, monitoring, and manage. These communication networks are associated with the SCADA systems for real-time control of the smart grid. The possibility of gigantic denial of service (DoS) attacks on the SCADA system has impacts on the overall performance and steadiness of the smart grid. Dealing with such cyber attacks on SCADA system is of utmost importance and needs researcher’s exploration. Protocol attacks, DoS attacks, intrusions, routing attacks, worms, spy-ware, and mal-ware are all possible attacks over smart grid either on AMI, Distribution Management System (DMS) and Energy Management System (EMS). In [27, 28] the authors have proposed a number of solutions like automatics load shedding, cooperative attack defense and trust management.

Security of such smart technology is of utmost importance and needs more focus. The background communication media i.e. BREW, WiFi, PAN and whatever else will play a major role in securing such systems. The technology will not to address the privacy of houses neither to help them in energy theft. Such issues will raise but they needs to be observed by the TTP. Surely a secure smart system will control the energy crisis and energy theft and will also never disclose the customer privacy.

5. SMART TECHNOLOGY AND RELATED WORK: The ambition of Smart Grid technology is to get better the protection and safety, reliability and economy i.e. financial system of power grid operations, as a consequence to diminish electricity costs, improve power utilization, efficiency and realize energy conservation and emission reduction i.e. GHG reduction.

It is not only the development of smart meter or home automation that we called it smart technology rather there is much more to be considered like operating the power plants using ICT, power electronics and storage technologies to balance the energy production and usage [5]. Table 1 summarizes the existing power grid technology and smart grid technology and compares both technologies [7].

<table>
<thead>
<tr>
<th></th>
<th>Existing Power Grid</th>
<th>Smart Grid</th>
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<tbody>
<tr>
<td>Technology</td>
<td>Mechanical</td>
<td>Digital</td>
</tr>
<tr>
<td>Communication</td>
<td>One Way</td>
<td>Two Way</td>
</tr>
<tr>
<td>Generation</td>
<td>Centralized</td>
<td>Distributed</td>
</tr>
<tr>
<td>Monitoring</td>
<td>Manual</td>
<td>Automatic</td>
</tr>
<tr>
<td>Restoration</td>
<td>Manual</td>
<td>Self</td>
</tr>
<tr>
<td>Failure</td>
<td>Maximum</td>
<td>Occasionally</td>
</tr>
<tr>
<td>Blackouts</td>
<td>Maximum</td>
<td>Minimum</td>
</tr>
<tr>
<td>Control</td>
<td>Limited</td>
<td>Pervasive</td>
</tr>
<tr>
<td>Customers Choices</td>
<td>Few</td>
<td>Many</td>
</tr>
<tr>
<td>Medium of Communication</td>
<td>Few Sensors</td>
<td>Sensors</td>
</tr>
<tr>
<td>Cost</td>
<td>Huge</td>
<td>Reduced</td>
</tr>
<tr>
<td>Reliability</td>
<td>Less</td>
<td>More</td>
</tr>
<tr>
<td>Security</td>
<td>Good</td>
<td>Less</td>
</tr>
<tr>
<td>Energy</td>
<td>Waste</td>
<td>Save</td>
</tr>
<tr>
<td>Meter</td>
<td>Analog</td>
<td>Digital</td>
</tr>
<tr>
<td>Performance</td>
<td>Less</td>
<td>Increased</td>
</tr>
<tr>
<td>Customer Satisfaction</td>
<td>Less</td>
<td>Increased</td>
</tr>
<tr>
<td>Strategic Planning</td>
<td>Not Available</td>
<td>Available</td>
</tr>
<tr>
<td>Maintenance Cost</td>
<td>Huge</td>
<td>Reduced</td>
</tr>
<tr>
<td>Transparency</td>
<td>Less</td>
<td>Increased</td>
</tr>
<tr>
<td>GHG Emission</td>
<td>Huge</td>
<td>Controlled</td>
</tr>
<tr>
<td>Power Loss in Power Grid</td>
<td>Maximum</td>
<td>Minimum</td>
</tr>
<tr>
<td>Grid Stability</td>
<td>Lesser</td>
<td>Higher</td>
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Modern Grid Initiative (MGI) [15] is a smart technology program recognized by United States Department of Energy (DOE) in 2005 through the Office of Electricity Delivery and Energy Reliability (OE) and the NETL i.e. National Energy
Technology Laboratory. Their focal point is on scalability issues and broad applicability of smart grids. Other project like GridWise [17], GridApps [18], GridWorks [19] and DV2010 [20] established by DOE, US also focuses on system delivery, smart technologies, smart grid machinery and sky-scraping speed communication correspondingly.

EPRI IntelliGrid [14] is a smart technology project recognized in 2001. Its duty is to permit the growth, integration and application of technologies to smooth the progress of the revolution of the electric infrastructure to cost-effectively provide sheltered, high-class, unfailing, trustworthy electricity goods and services. They are also paying attention in speedy simulation and modeling, communication in energy distribution system (EDS) and energy monitoring systems (EMS). They also spotlight on information and communication infrastructure that will turn out to be the underpinning of numerous smart grid applications together with security, QoS and availability.

EPRI Advanced Distribution Automation (ADA) [16] considers and focuses on steadfastness and power excellence; working costs; outage restoration time; integration of distributed generation and storage, customer service options; and integration of customer systems. GridWise [23] that is developed by DOE focus on change of an energy system to an intellectual, adaptive and self-healing system with capability of market-based structures to create income at all stages of the system development [22]. According to SG program, which was established by the European Technology Platform (ETP) in 2005 [24], the European Electricity Networks should be enough elastic to the needs and desires of power consumers, highly available to system users and renewable energy sources, protected and capable with high class of energy distribution.

6. CONCLUDING REMARKS: Pakistan is facing from energy crisis since last five years and no proper action has been taken by the government to overcome this major issue. If current situation exist, the problem will rise and will result in a black Pakistan. To bridge the energy supply-demand gap, government of Pakistan is evaluating different options including importing energy from the neighboring countries, as well as elevating domestic energy production using indigenous energy sources, such as, hydro, coal, nuclear, solar, and wind. Still these projects are long term solution. However in short term solution, there are numerous smarter ways that can eliminate need of importing energy or adding-on significant power generation infrastructure. The Smarter ways involve integration of Telecommunication Technologies, (including Sensors Networks, and Information Technologies) with existing Power System. Though marriage of Telecommunication Systems with Power System, has created a huge momentum for making the existing Power System Smarter all over the world, no attention has been given to the subject in Pakistan so far. The stipulate for electricity is greater than its supply nowadays. The smart grid enhances the functionality of the energy delivery system. This is not impossible since smart grid uses sensors, communications, computation, and control to make the system smart and by applying intelligence to it in the form of control through feedback. In [10], [11] the authors claimed that to utilize the available resources, customers also need to be changed, and they need to act smarter.

It is observed that only the production of energy is not sufficient to reduce the energy crisis. A number of other issues must be considered. For example the energy department will be an independent and autonomous body that will not be affected by any political party. Secondly commercialization of small turbines is the needed to solve the current energy crisis situations. Thirdly renewable energy sources (RES) like solar, wind, thermal and hydro must be considered as well. Fourthly efficient energy distribution systems (EEDS) are required to save energy and to limit the power waste.

In this article we discussed new research directions and have explored a number of challenges in the implementation phase of smart grid technology. A secure smart system will control the energy crisis and energy theft and will also never disclose the customer privacy.

ACKNOWLEDGMENT:
This work is fully supported by Abdul Wali Khan University, Mardan, Khyber Pakhtun Khwa (KPK), Pakistan. The author(s) of this article are greatly thankful to SAIMS i.e. Society for Advancement & Integration of Multiple Sciences for full guidance and major support. iFuture is also given a number of credits for arranging seminars on the subject matter. iFuture is a Research Group at the Department of Computer Science.

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