A COMPREHENSIVE STUDY ON SMART GRID DEVELOPMENT IN ‘OIC’ MEMBER STATES

By

MOHAMMAD HUSSAIN (142309)
MAAZ ABDULAZIZ (142316)

A Thesis Submitted to the Academic Faculty in Partial Fulfillment of the Requirements for the Degree of

HIGHER DIPLOMA IN ELECTRICAL AND ELECTRONIC ENGINEERING

Department of Electrical and Electronic Engineering
Islamic University of Technology (IUT)
Gazipur, Bangladesh

November 2017

A COMPREHENSIVE STUDY ON SMART GRID DEVELOPMENT IN ‘OIC’ MEMBER STATES

Approved by:

Dr.Khondokar Habibul Kabir

Supervisor and Assistant Professor,
Department of Electrical and Electronic
Engineering, Islamic University of Technology (IUT),
Boardbazar, Gazipur-1704.

Prof.Dr.Md.Ashraful Hoque

Head of department
Department of Electrical and Electronic Engineering,
Islamic University of Technology (IUT),
Boardbazar, Gazipur-1704.

Date: ……

Smart grid the new generation smart power grid "electricity with a brain"

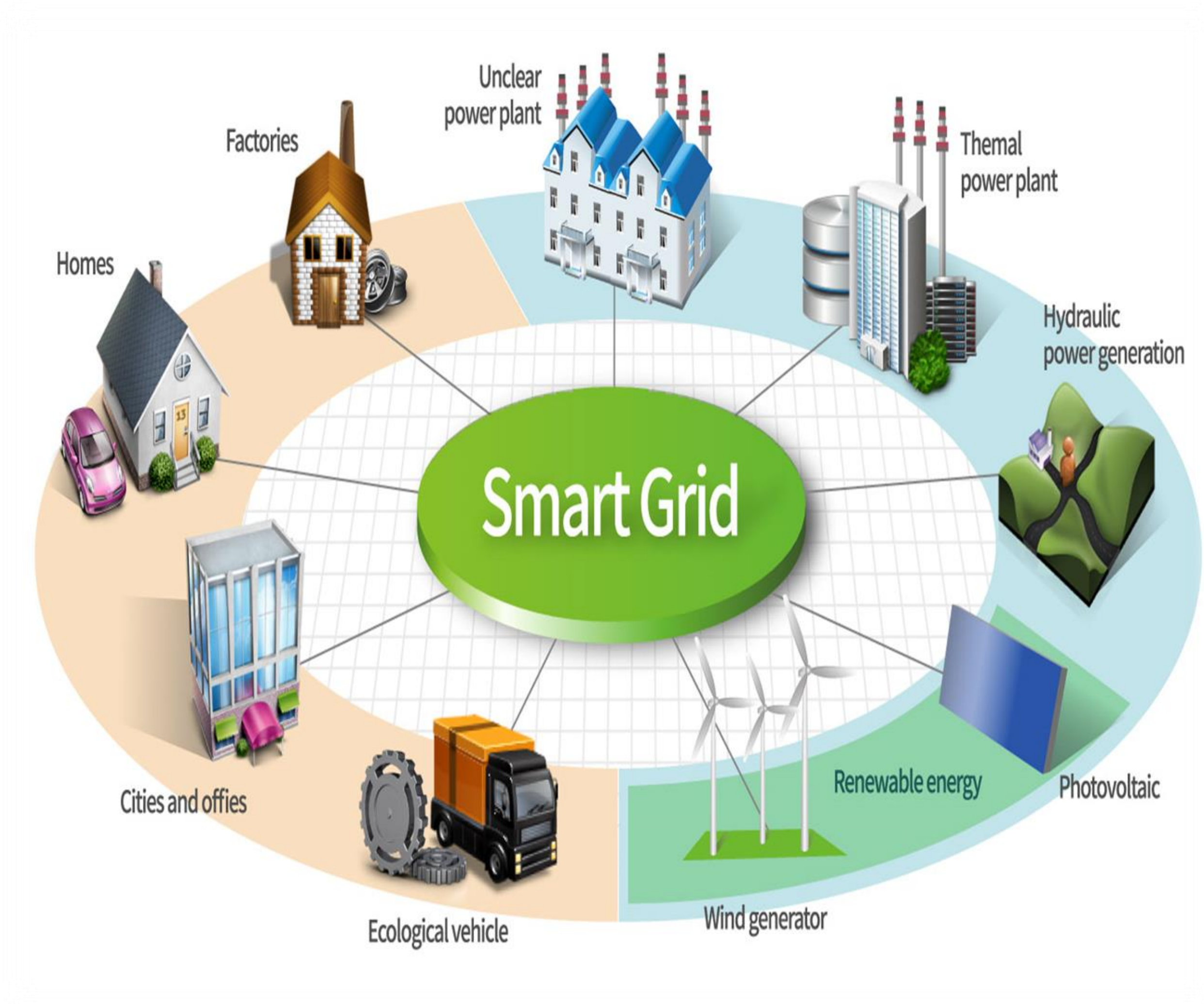


Table of Contents

List of figures

List of Tables

List of Acronyms

EISA07	Energy Independence and Security Act of 2007
DER	Distributed energy resources
U.S.	United state
DMS	Distribution management system
SG	Smart grid
DG	Distributed generation
PQ	Power quality
PV	Photovoltaic
LV	Low voltage
MV	Medium voltage
ADN	Active distribution network
SCADA	Supervisory control and data acquisition
SDG	Smart distribution grid
IOT	Internet of things
ICT	Information and Communication Technology
IEC TC 57	International Electrotechnical Commission Technical Committee 57
SIA	Seamless Integration Architecture
CIM	Common Information Model
DMZ	Demilitarized Zone
DR	Demand Response
IT	Information Technology
OIC	Organization of Islamic Cooperation
GDP	Gross Domestic Product
USD	U.S. Dollar
GWh	Giga watt-hour
KPI	Key Performance Indicators
GPRS	General Packet Radio Service
SASG	Saudi Arabia Smart Grid
IEA, 2011	International Energy Agency
EPC	Engineering, Procurement, and Construction
IEEO	Iran Energy Efficiency Organization
CEN	Comité Européen de Normalisation (French: European Committee for Standardization)

CENELEC	Comité Européen de Normalisation Électrotechnique (European Committee for Electrotechnical)
ETSI	European Telecommunications Standards Institute
ERGEG	European Regulators' Group for Electricity and Gas
SEGT2012	Conference on Smart Electrical Grids Technology 2012
EV	Electric Vehicle
V2G	Vehicle-To-Grid
TRY	Turkish New Lira (ISO currency code)
EMRA	Energy Market Regulatory Authorities
DISCO	Development of Information Services for Career Opportunities
R&D	Research and Development
RTU	Remote Terminal Unit
PLC	Programmable Logic Controller
AMI	Advanced metering infrastructure
GIS	Geographic Information System
ICSG	International Istanbul Smart Grid Congress and Exhibition
IEEE	Institute of Electrical and Electronics Engineers
UAE	United Arab Emirate
FREEDM	Future Renewable Electric Energy Delivery and Management
MPPT	Maximum Power Point Tracking

Acknowledgements

First of all we would like to express our sincere gratitude to our supervisor **Dr.Khondokar Habibul Kabir** for his kind guidance, encouragement and support. He has been an extraordinarily wonderful advisor, who has always inspired and motivated us by giving his thoughtful suggestions to overcome the challenges and successfully complete this work.

We are very thankful to our parents, brothers and sisters, they have done so much for us by encouraging, inspiring and helping us in the pursuit of knowledge, our parents have supported us from our very childhood until this point, they deserve the very best of our appreciation, without their support it would never be possible for us to come this far.

Above all, we would like to thank Almighty ALLAH for giving us the patience, knowledge and wisdom to carry out this work.

Abstract

Global warming, increasing amount of greenhouse gases and narrowness of Ozone layer are the biggest global challenges of 21st century therefore we need green and renewable energy and very efficient use of natural energy resources. Traditional electricity grid is passive, unreliable and inefficient. The generation system is centralized therefore there is very low efficient use of energy resources. Management system, control system and costumer consumption metering system are using very old technologies. Smart grid is a future grid that is equipped with integration of electrical, digital, information and communication technologies .It's automatic, distributed and intelligent features allow two-way flow of energy and information between power provider and consumers. It provides very efficient power transmission and distribution. In the generation system there is high rate of renewable energy penetration since it's capability of distributed generation and two-way flow of energy allows each consumer to be a producer as well.

Development of smart grid in some OIC (Organization of Islamic Cooperation) member states which have huge national resources such as oil reserves and natural gas and better level of economic development can help them to respond to many challenges, Ensuring the delivery of energy services in line with economic growth in a financially sustainable manner, and increasing access to energy services; Safeguarding the environment and its key natural resources by improving the efficiency of resource management, increasing energy efficiency, and the role of renewable energy. Smart grid makes it possible to integrate the grids of many of these countries into a single grid in order to share power and provide efficient power generation and distribution.

In this thesis smart grid concepts, architecture and technologies are demonstrated; the key challenges and opportunities in development of smart grid are discussed; Standardization recommendation from authentic international organization for standardization is given; a scenario of electricity generation and distribution strategies in each country is demonstrate; the current scope of smart grid development in some OIC member states with better development and economic level is studied ; the key challenges and problems that are faced in developing smart grid are discussed; and some recommendations to governments for developing smart grid are given .

Chapter 1

Introduction

1.1 Introduction

Many of our industrial, commercial and residential processes and appliances run on electricity. Electricity is generated these days from sources ranging from fossil fuels to solar radiation. As power generation grows with demand, the damage to the environment being caused by some of our traditional power generation methods is also increasing. Some modern renewable energy sources like the sun and wind are environment friendly, but their erratic nature makes them unreliable.
Traditionally the term grid is used for an electricity system that may support all or some of the following four operations: electricity generation, electricity transmission, electricity distribution, and electricity control but the traditional grid is passive, unreliable and inefficient. The generation system is centralized therefore there is very low efficient use of energy resources. Management system, control system and costumer consumption metering system is using very old technologies. A smart grid (SG), also called smart electrical/power grid, intelligent grid, intelligrid , futuregrid, intergrid, or intragrid, is an enhancement of the 20th century power grid. The traditional power grids are generally used to carry power from a few central generators to a large number of users or customers. In contrast, the SG uses two-way flows of electricity and information to create an automated and distributed advanced energy delivery network. By utilizing modern information technologies the SG is capable of delivering power in more efficient ways and responding to wide ranging conditions and events. Broadly stated, the SG could respond to events that occur anywhere in the grid, such as power generation, transmission, distribution, and consumption, and adopt the corresponding strategies. [1]

A smart grid network makes for the ideal bridge where the goals of modernization can meet those of a reliable public infrastructure. Smart grid is a computerized technology, based on remote control network, aiming to completely alter the existing electric infrastructure and modernize the national power grid. This is through empowering the demand response which alerts consumers to reduce energy use at peak times. Moreover, demand response prevents blackouts, increases energy efficiency measure and contributes to resource conservation and help consumers to save money on their energy bills. Smart grid technology represents an advanced system enabling two-way communications between energy provider and end users to reduce cost, save energy and increase efficiency and reliability. Utilities benefit from improving the grid's power quality and reliability through an integrated communication system with end users with more control over energy use. This is through decreasing services rates and eliminating any unnecessary energy loss in the network. Thus, all of these positive advantages will make smart grid technology a smart and efficient tool for utilities.

A smart grid uses sensing, measurement and control devices like smart meters which enable communication between power generation, transmission, distribution and consumption centers, thereby enabling the systems to respond according to the grid condition. Systems like Supervisory Control and Data Acquisition (SCADA), and Energy Management Systems provide real time communication between generation and consumption centers and help adjust power usage. Power usage at consumption centers can be regulated by turning connected devices on or off depending on factors like grid peak load demand, thereby reducing the strain on the grid. Smart grids also enable power suppliers to charge variable electricity rates for peak and off peak periods. This can also benefit the users who can schedule their high consumption equipment to run during off Peak periods, thereby reducing their power bills. [2]

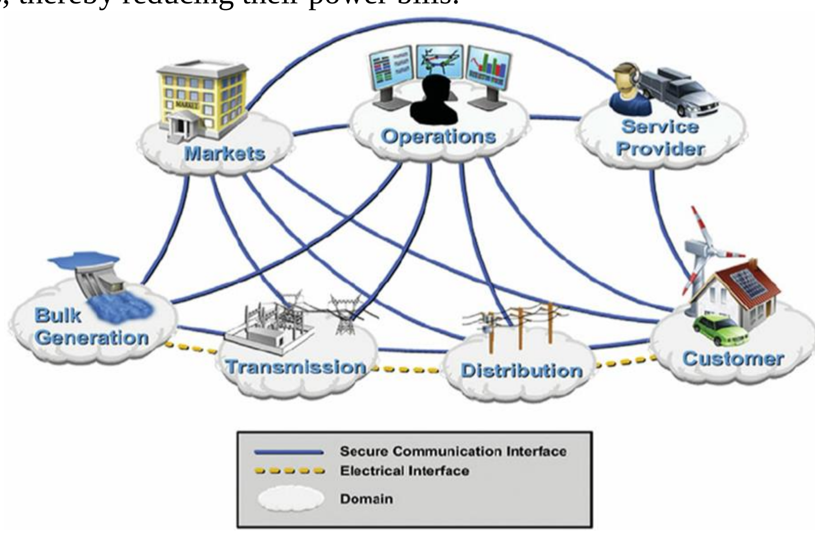


Figure1.1: NIST conceptual model of smart grid [1]

The U.S. Energy Independence and Security Act of 2007 directed the National Institute of Standards and Technology (NIST) to coordinate the research and development of a framework to achieve interoperability of SG systems and devices. According to the report from NIST the anticipated benefits and requirements of SG are the following:

1) Improving power reliability and quality.
2) Optimizing facility utilization and averting construction of back-up (peak load) power plants.
3) Enhancing capacity and efficiency of existing electric power networks.
4) Improving resilience to disruption.
5) Enabling predictive maintenance and self-healing responses to system disturbances.
6) Facilitating expanded deployment of renewable energy sources.
7) Accommodating distributed power sources.
8) Automating maintenance and operation.
9) Reducing greenhouse gas emissions by enabling electric vehicles and new power sources.
10) Reducing oil consumption by reducing the need for inefficient generation during peak usage periods.
11) Presenting opportunities to improve grid security.

12) Enabling transition to plug-in electric vehicles and new energy storage options.
13) Increasing consumer choice.
14) Enabling new products, services, and markets.

In order to realize this new grid paradigm, NIST provided a conceptual model (as shown in Fig.1.1), which can be used as a reference for the various parts of the electric system where SG standardization works are taking place. This conceptual model divides the SG into seven domains. Each domain encompasses one or more SG actors, including devices, systems, or programs that make decisions and exchange information necessary for performing applications. The brief descriptions of the domains and actors are given in Table1.1. Note that NIST proposed this model from the perspectives of the different roles involved in the SG.

Table 1.1: Domains and actors in the NIST SG conceptual model [1]

Domain	**Actors in the Domain**
Customers	The end user of electricity .may also generate, store and manage the use of energy.
Markets	The operators and participants in electricity markets
service providers	The organizations providing service to electrical customers and utilities.
Operations	The manager of the movement of electricity
Bulk generation	The generators of electricity in bulk quantities. May also store energy for later distribution
Transmission	The carrier of bulk electricity over long distance. May also store and generate electricity.
Distribution	The distributors of electricity to and from customers. May also store and generate electricity.

1.2 Difference between conventional grid and smart grid

1.2.1 Current Grid

Today, electric power distribution is made possible by the power distribution grid, a system of transmission mediums that allow electricity to be transferred at different voltages from the point of generation to our homes. (See figure 1.2)
Presently, the grid is facing a multitude of challenges that can be outlined in four categories. First there are infrastructural problems due to the fact that the system is outdated and unfit to deal with increasing demand. As a result, network congestions are occurring much more frequently because it does not have the ability to react to such issues in a timely fashion. Ultimately such imbalances can lead to blackouts which are extremely costly for utilities especially since they spread rapidly due to the lack of communication between the grid and its control centers.

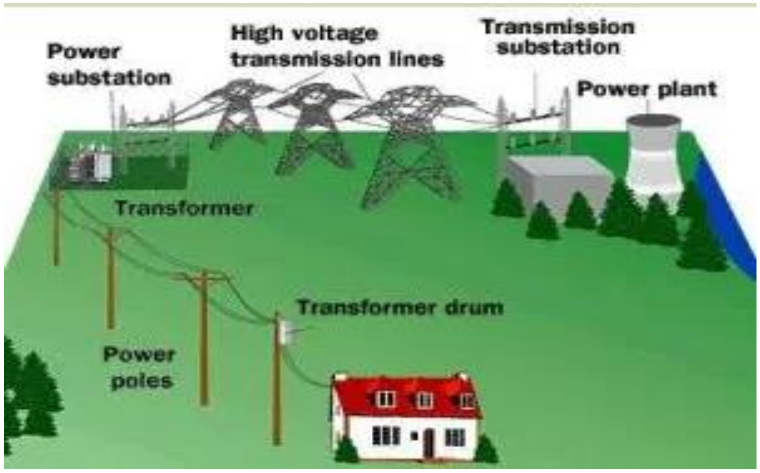


Figure 1.2: conventional grid [3]

A second flaw is the need for more information and transparency for customers to make optimal decisions relative to the market, so as to reduce their consumption during the most expensive peak hours. Finally, a third problem is the inflexibility of the current grid, which can't support the development of renewable energies or other forms of technologies that would make it more sustainable. In particular, the fact that renewable sources such as wind and solar are intermittent poses a significant problem for a grid that does not disseminate information to control centers rapidly. All of these problems are addressed by the smart grid through improved communications technology, with numerous benefits for both the supply and demand sides of the electricity market. (Li et al., 2010).

1.2.2 The Smart Grid

"A Smart Grid is an electricity network that can intelligently integrate the actions of all users connected to it – generators, consumers, and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies." (EU Report, 27)
Instead of completely replacing the current grid, the transition to a smart grid is simply a significant revamping of it with technologies such as meters, sensors and synchrophasors. When added to the existing infrastructure, these inventions will provide massive amounts of data about consumption, voltage, the health of infrastructure and many other aspects of the electricity supply to the control centers. More importantly, it is the rate of communication that is revolutionary, the synchrophasors report data up to 30 times a second, as opposed to the rate of once every two to four seconds with present day instruments. Table1.2 gives a brief comparison between the existing grid and the SG.

Table 1.2: Comparison between smart gird and conventional 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

With improved communications, the smart grid resolves many of the problems listed above, and provides benefits to consumers and suppliers. The analysis of here uses an economic supply and demand framework to understand the incentive structure for the smart grid, looking at the benefits to producers and consumers. (Economist, 2010) Figure 1.3 shows comparison between conventional grid and smart grid.

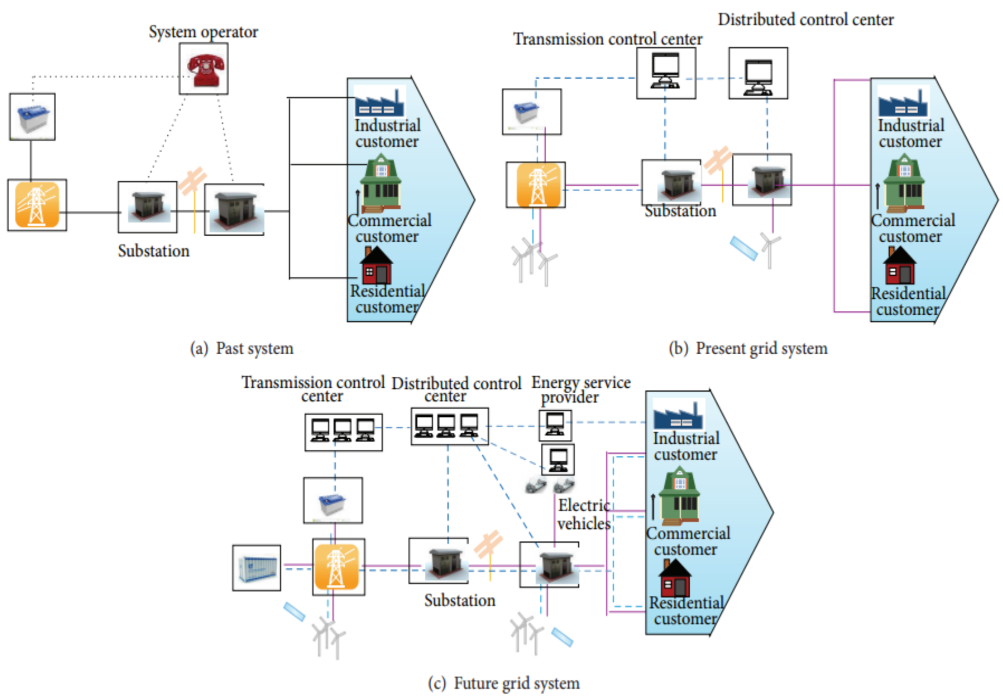


Figure 1.3 : comparison between conventional grid and smart grid [4]

1.3 Visions of smart grid

It is needed to bring some major improvement in the existing power grids and advances in key technology areas that will make these improvements possible. [5]
A vision for the Smart Grid is needed to set the foundation for a transition that focuses on achieving value in the following six areas:

1.3.1 Reliability

This term is used to show how efficient should the grid be to provides quality power to its consumers and be able to detect any problem and alerts it users. It should be capable of withstanding any heavy disturbance without failure. It also should try to solve any instability issues before affecting the consumers.

1.3.2 Security

In every system, security is the major concern. Without security, the system can suffer some physical and cyber-attacks. So as a matter of fact, our grid system need to be well protected to avoid the above mentioned problems. If it is not done as such, we may suffer from heavy blackout or may lead to high cost as such huge losses may occur and this will be uneconomical.

1.3.3 Efficiency

The system grid must be capable of using some techniques that will result to the transmission and distribution losses reduction, cost control, effective production of power and finally optimal utilization of assets. It should give the choice for the consumers to control the energy they use.

1.3.4 Environment-friendly

An excellent grid system should be void of any agent of environmental pollution. To achieve this, some new method of energy generation such as renewable energy resources should be used and also it should be more efficient.

1.3.5 Safety

Safety is one important aspect which needs to be considered. So the grid must be harmless to users in any sense and it the maintainers. Also, it should be sensitive for the patients whose lives solely depend on it for their survival. [6]

1.4 Characteristics of Smart Grid

1.4.1 Flexible

Like all other system, the smart grid needs to be flexible so that if there is any environmental disasters and any system change. By complying to this aspect of flexibility then shall we tag it to anything and considered as flexible solution. It should be safe for the infrastructures which is the vital kind of connections. **.** [7]

1.4.2 Clever and safe

A system can only be defined as being clever and safe if it can be used with simplicity and protected enough with security. Our power grid can be named as smart only if this conditions are being accomplished. This types of grid needs to be available in real time in order to be able to get access to any information they can be communicate

1.4.3 Efficient

Among the vital point of any kind of Smart Grid is the willingness of reducing the need of new infrastructures for the electrical grid. If we alter equipment into better gadgets, they will be sufficient to take control of the electrical delivery, guaranteeing the service and reducing the cost.

1.4.4 Open

Ability to incorporate some generation resources system safely is very important for our Smart grid. New generation distribution like renewable energy resources need to be integrated to the smart grid as they are the promising energy resources for the future to produce energy without having much impact on the natural environment. As such we can call our system as grid as smart. This this imply that we will have new market opportunities for the electrical field as a result of our grid smartness. Hence prospectus business opportunities.

1.4.5 Sustainable

Here come the crucial point, sustainability is a vital point of this kind of system to be in accordance with the natural environment, socially acceptable is essential

1.4.6 *Costumers activities and participation*

Consumers are key factors of a utility. They contributes in balancing between demand supplies and make sure of the reliability by altering the manner they utilize and buy electricity. Due to the different services offered by the utility to their customers, the ability of choosing the way they purchase. In such we can list this choices which includes:

- New technology
- New information about their electricity use
- New forms of electricity pricing and incentives**.**[8]

1.4.7 *Accommodation of all generation resources and storage devices*

As mention in the characteristics of smart grid above, the ability for it to incorporate or integrate new generations and storage facilities are very important for the future use and innovative world where we have a fast growing technology in the electrical field. So it should be designed in such a way that it satisfies both the vast, centralized power plants and the growing array of customer-sited distributed generation energy resources. These renewable distribution generations are as flows:

- Renewables
- Small-scale combined heat and power and
- Energy storage.

1.4.8 *Enabling new products, services and market*

Correctly designed and operated markets efficiently create an opportunity for consumers to choose among competing services. Some of the independent grid variables that must be explicitly managed are energy, capacity, location, time, degree by which it change and quality. Markets can play a major role in the management of these variables. Regulators, owners/operators and consumers need the flexibility to alter the regulations of business to be convenient in operating and market conditions.

1.4.9 *Providing power quality and cost management*

Not all commercial enterprises, and certainly not all residential customers, need the same quality of power. A smart grid supplies varying grades (and prices) of power. The cost of premium power-quality features can be included in the electrical service contract. Advanced control methods monitor essential components, enabling rapid diagnosis and solutions to events that impact the power quality, such as lightning, switching surges, line faults and harmonic sources.

1.4.10 Optimization of asset utilization and operating efficiency

A smart grid applies the latest technologies to optimize the use of its assets. For example, optimized capacity can be attainable with dynamic ratings, which allow assets to be used at greater loads by continuously sensing and rating their capacities. Maintenance efficiency can be optimized with condition-based maintenance, which signals the need for equipment maintenance at precisely the right time.
System control devices can be adjusted to reduce losses and eliminate congestion. Operating efficiency increases when selecting the least-cost energy-delivery system available through these types of system-control devices.

1.4.11 Provides resiliency to cyber-attacks and natural disasters

Resiliency refers to the ability of a system to react to unexpected events by isolating problematic elements while the rest of the system is restored to normal operation. These self-healing actions result in reduced interruption of service to consumers and help service providers better manage the delivery infrastructure. Figure1.4 shows the main features of smart grid.

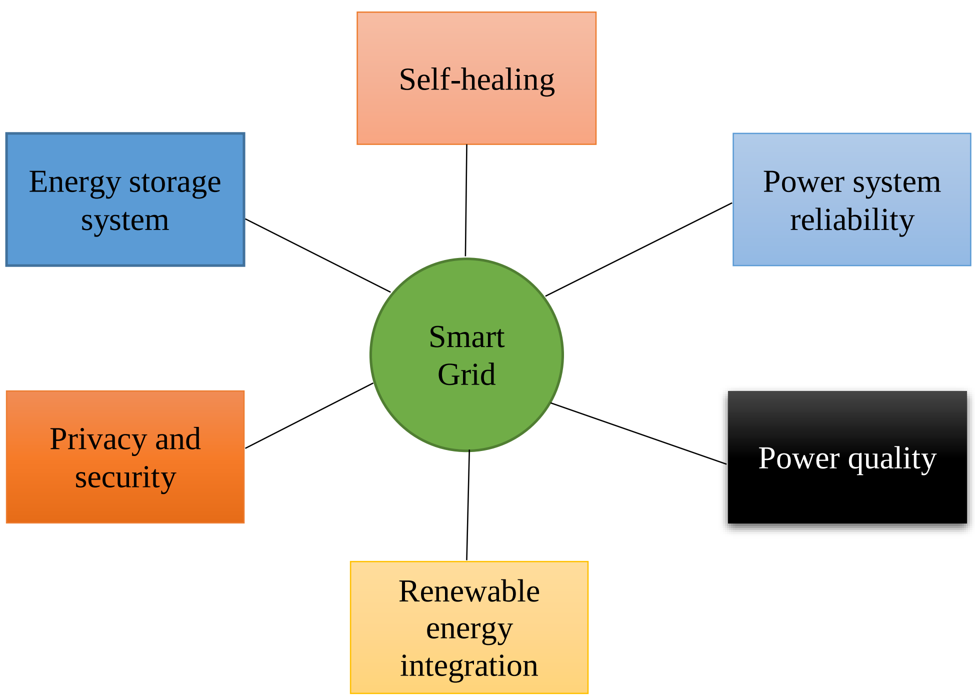


Figure 1.4: main features of smart grid

1.5 Technologies of Smart Grid

A smart grid is an electricity network that that makes use of digital and other advanced technologies to control and manage the transmission of electricity from all distributed energy generation sources to meet the varying electricity demands of users. One of the major function of a Smart grid is to organize all the needs and capabilities of generation distribution resources, the operators of the grid system, end-users and the market stakeholders of electricity to operate all the individual parts as one body in order for them to work to get and be more efficient as much as possible so that the running cost and environmental impacts can be minimized and hence maximizing system reliability, stability and finally resiliency. Figure 1.5 illustrates the difference between technologies of smart and conventional grid. [8]

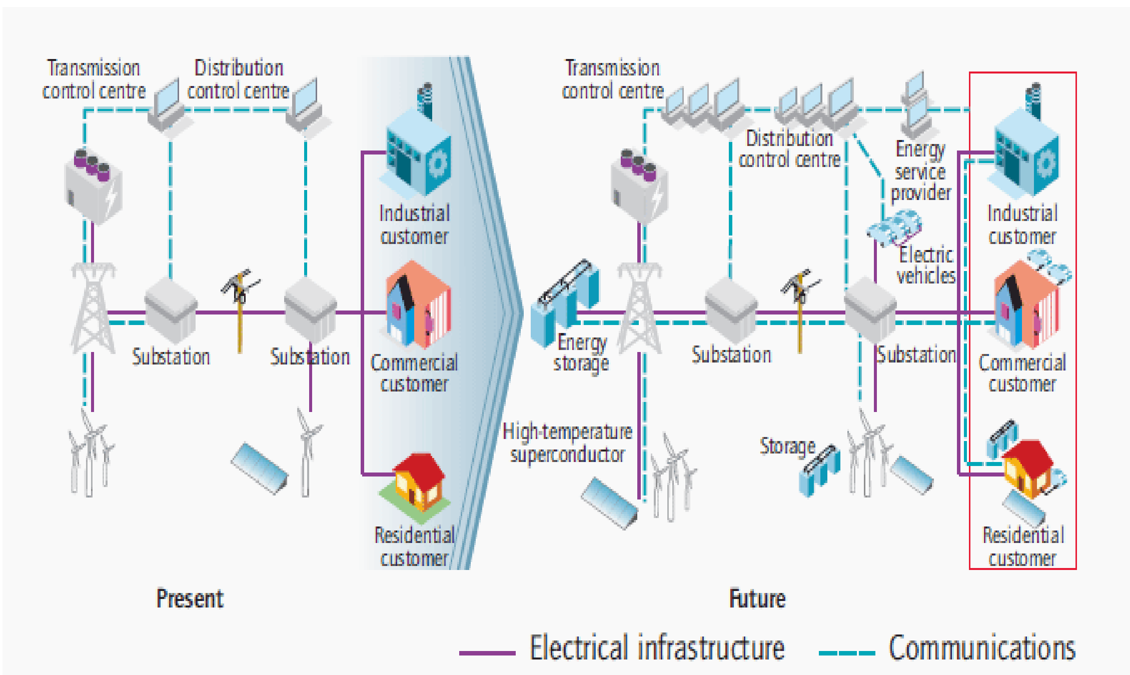


Figure 1.5: technologies of smart grid

One of the most important part which is made of advanced grid technologies is the electrical transmission of power. The leader and the market dominating enterprise in this domain of advanced technologies of smart grid is ABB. Others include the following.
FACTS which stands for Flexible Alternating Current transmission Systems devices enables existing transmission lines to deliver maximum power, and assists in stabilizing the grid with high precision of power control and High-Voltage direct current (HVDC) technology can deliver long distance power with minimal losses on land and under water, and connect asynchronous grids. Wide area monitoring system (WAMS) detects critical system parameters to in order to avoid the development of dangerous instability in the network. Supervisory Control And Data Acquisition systems (SCADA) analyses the real time conditions of the grid and provides data for rapid power adjustments.

Most of the changes are from the distribution network side and for end users. Specifically apply to the commercial and residential users. Below are some of the ABB's smart distribution network and buildings technologies are:

- Smart meters
- Building automation systems
- Electrical vehicle charging equipment
- Low voltage solar inverters
- High efficiency distribution transformers
- Substation and feeder automation. [8]

A complete overview of smart grid technology with interconnection between electrical and communication system is illustrated in figure1.6.
The smart grid can be defined as a smart electrical network that combines electrical network and smart digital communication technology. A smart grid has capability of providing electrical power from multiple and widely distributed sources, like from wind turbines, solar power systems, and perhaps even plug-in hybrid electric vehicles. [9]

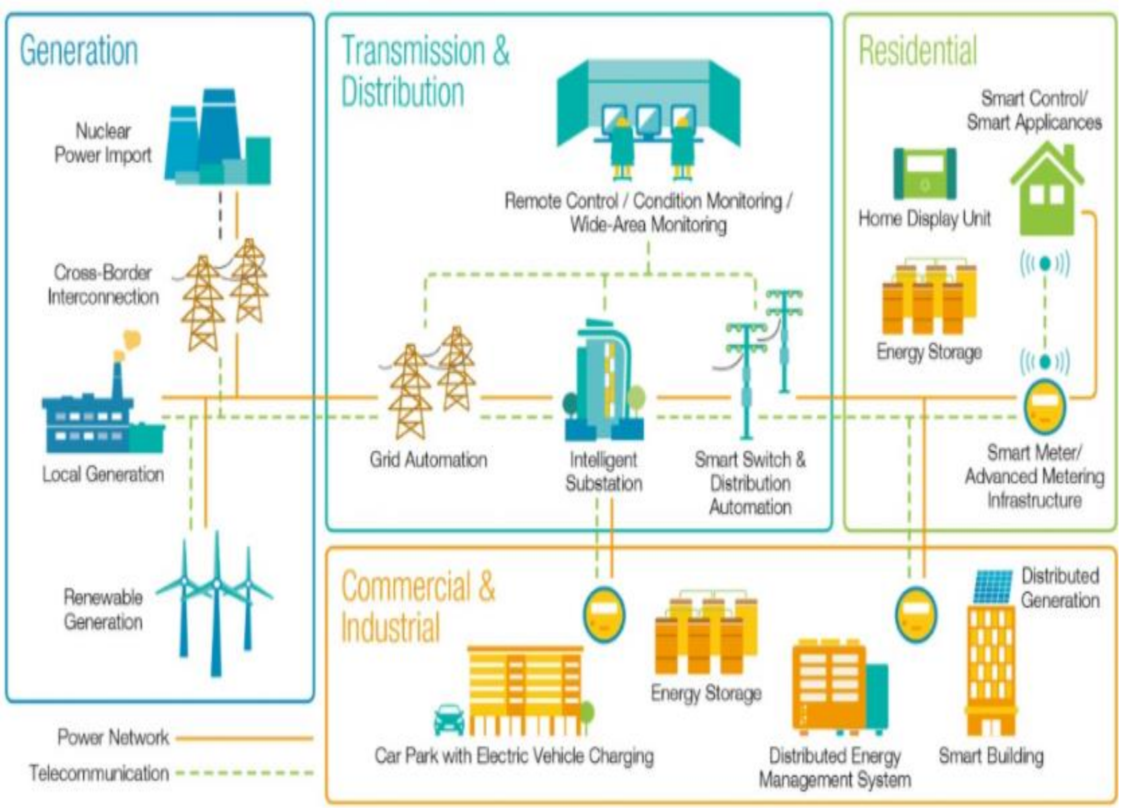


Figure 1.6: overview of SG technologies

1.5.1 *Integrated communications*

The key to a smart grid technology is integrated communications. It must be as fast as enough to real-time needs of the system. Depending upon the need, Many different technologies are used in smart grid communication like Programmable Logic Controller (PLC), wireless, cellular, SCADA (Supervisory Control and Data Acquisition), and BPL. Integrated communication uses sensors and measurement, advanced components and advanced control methods and decision support. (See figure 1.7).

Key features of Integrated Communication

a) Ease of deployment
b) Latency
c) Standards
d) Data carrying capacity
e) Secure
f) Network coverage and capacity capability

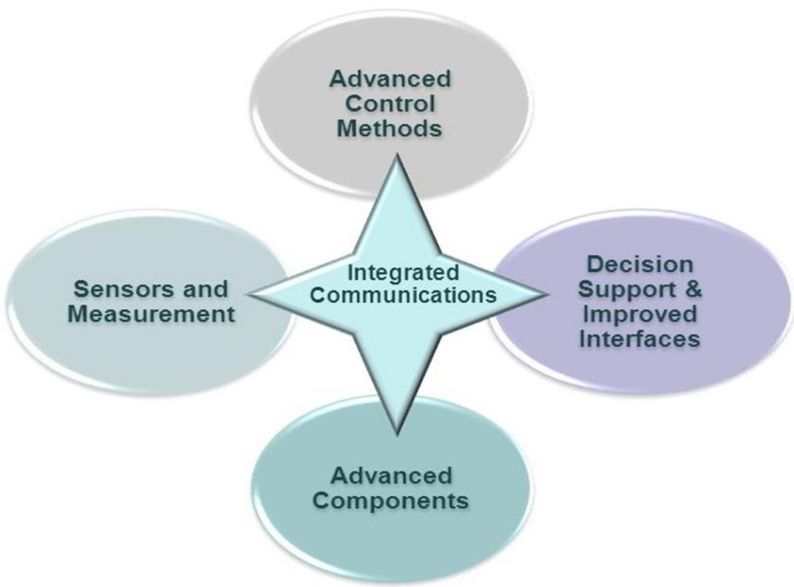


Figure 1.7: communication technologies of smart grid

The U.S Department of Energy has proposed four technologies that will help to change a conventional electrical grid into Smart Grid which are as follow:

1. Integrated and automated two way communication between all components of grid.
2. Automatic Control of distribution system and stability to fault.
3. Advance management panel, decision support software and mechanism.
4. Accurate sensing and measurement technologies

1.5.2 Smart meter

The upgraded technology of smart grids has well-coordinated automation equipment and control system, which respond accurately to meet the rapid increasing demand for electricity. During the era when these smart grids were not implemented all utilities companies were forced to send their respective workers to take meter reading and acquire data related to consumer. Smart meters use a secure communication network to automatically and wirelessly send your actual energy usage to your supplier. This means households will no longer rely on estimated energy bills or have to provide their own regular readings. An example of a smart meter based on open smart grid protocol (OSGP) in use in Europe that has the ability to reduce load and disconnect-reconnect remotely is shown in fig1.8.

Figure 1.8:smart meter

1.6 Application of Smart Grid

Smart grid plays an important role in modern smart technologies. Inclusion of digital technology into the smart grids ensures the reliability, efficiency and accessibility to the end-users about all the utilities which count towards the economic stability of the nation.[10]
Table 1.3 lists the most common applications of smart grid technology.
Right at the beginning of transition time it is disastrous to execute testing, to improve the technology by upgrading, developing and maintaining standards on a standard threshold and also application of these efficient grids serve all these problems. Basic uses of smart grids are as follows.

- They improve the adeptness of transmission lines
- Quick recovery after any sudden breakage/disturbance in lines and feeders
- Cost Reduction
- Reduction of peak demand

- They possess the ability to be integrated with renewable energy sources on a large level which leads to sharing of load and reduction of load on large scale

Table 1.3:most common applications of smart grid technology [9]

Future applications and services	**Real time Market**
Business and costumer care	Application data flow to/from end-user energy management systems
Smart charging of PHEVs and V2G	Application data flow for PHEVs
Distributed generation and storage	Monitoring of distributed assets
Grid optimization	Self-healing grid: Fault protection, Outage management, dynamic control of voltage, weather data integration, centralized capacitor bank control, distribution and substation automation, advanced sensing, automated feeder configuration.
Demand response	Advanced demand maintenance and demand response, load forecasting and shifting.
AMI (Advanced Metering Infrastructure)	Provide remote meter reading, theft detection, costumer prepay, mobile workforce management.

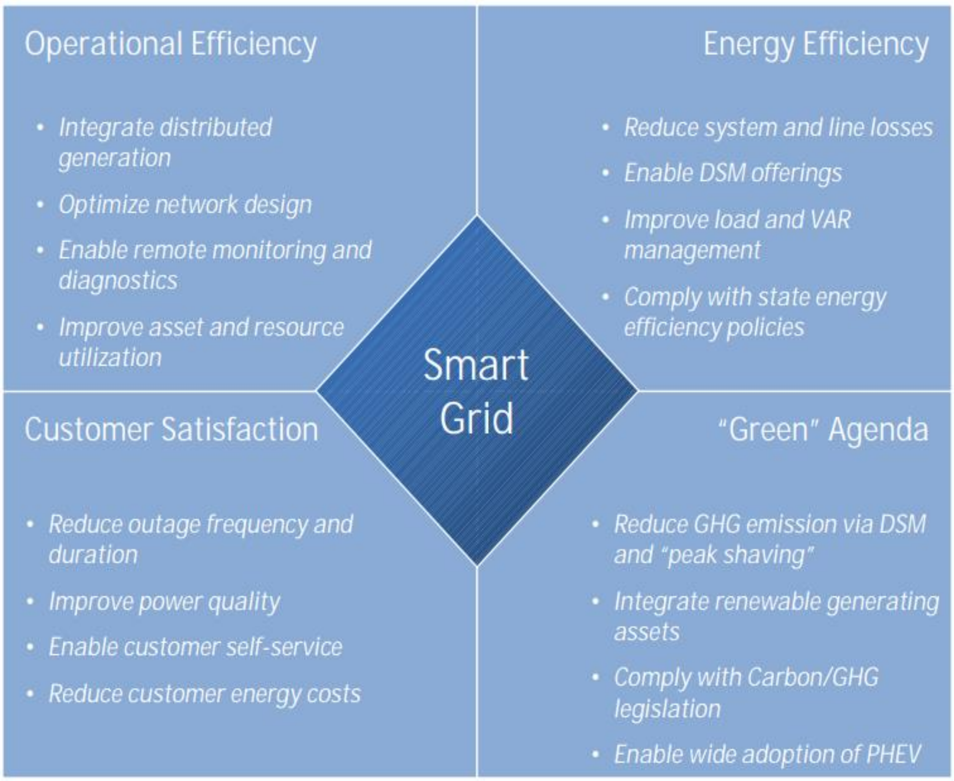
Applications of smart grid technologies on power distribution systems including integration of distributed energy resources, plug-in electric vehicles, distribution automation, and distribution system optimization makes it possible to achieve the objective of smart grid development.

1.7 Advantages of Smart Gird

- Integrate isolated technologies
- Enables better energy management.[9]
- Protective management of electrical network during emergency situation
- Better demand, supply/ demand response
- Better power quality
- Reduce carbon emissions
- Increased demand for energy: Requires more complex and critical solutions with better energy management
- Renewables Integration

The overall benefits of smart grid can be divided into four categories which are operational efficiency, energy efficiency, customer satisfaction and green agenda part which are explained in table 1.4.

Table 1.4: benefits of smart grid [11]



1.7.1 Utility benefits [12]

- ✓ Operational improvements
- ✓ Metering and billing
- ✓ Outage management
- ✓ Process improvement
- ✓ Work force management
- ✓ Reduced losses (energy)
- ✓ Asset utilization
- ✓ Asset Management improvements
- ✓ System planning
- ✓ Maintenance practices
- ✓ Engineering

These benefits are expected to improve customer satisfaction and reduce O&M and capital costs.

1.7.2 Consumer benefits

- ✓ Improved reliability.
- ✓ Improved overall level of service.
- ✓ Access to information.
- ✓ Ability to manage energy consumption.
- ✓ Option to participate in demand response.
- ✓ Convenient interconnection of distributed generation.
- ✓ Option to bid (sell) into electricity markets.
- ✓ Potential to dramatically reduce transportation costs (PHEV).

1.7.3 Societal benefits

- ✓ Downward pressure on electricity prices through
- ✓ Improved operating and market efficiencies, Consumer involvement
- ✓ Improved reliability leading to reduction in Consumer losses (~$135B)
- ✓ Increased grid robustness improving grid security
- ✓ Reduced emissions through integration of Renewable generation and reduced losses
- ✓ New jobs and growth in GDP
- ✓ Opportunity to revolutionize the transportation sector through integration of electric vehicles as generation and storage devices
- ✓ Societal benefits must be included in the value proposition

1.8 Disadvantages of Smart Grid

1.8.1 Security

The main concern in smart grid system is the security since smart grid make use of automated meters and advanced sensors and there is a two-way communication channel between costumer and power provider however some meters and communication channels can be hacked and the hacker get control of meters and increases or decreases the power demand information . [13]

Different part of grid can be hacked, however some are critical and need to be protected more seriously, in figure 1.9 we have shown a diagram which represents which part can be hacked easily and which one cannot.

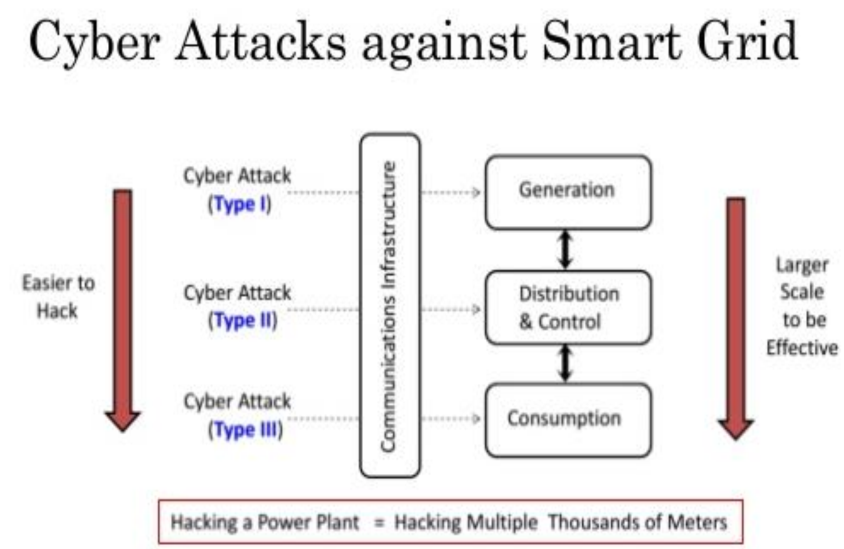


Figure 1.9: Cyber Attacks against smart grid

1.8.2 Complexity

Smart grid is an integration of various technology components like power system, communication system, data flow and analysis and network topologies and these makes it very complex thus the controlling and maintenance of grid is so challenging .

1.8.3 Expensive

As smart grid a complex system it is obviously expensive for both costumer and utility therefore it needs huge investment for development.

1.8.4 Grid Volatility

Smart Grid network has much intelligence at its edges; that is, at the entry point and at the end user's meter. But the grid has insufficient intelligence in the middle, governing the switching functions. This lack of integrated development makes the grid a volatile network. Engineering resources have been poured into power generation and consumer energy consumption, which are the edges of the network. However, if too many nodes are added to the network before developing the software intelligence to control it, the conditions will lead to a volatile smart grid.

1.9 Challenges of Smart Grid

1.9.1 Key Challenges

The Key Challenges for Smart Grids are: Strengthening the grid, Enhanced intelligence, Communications, Integrating intermittent generation, moving offshore, capturing the benefits of DG and storage and Preparing of plug- in hybrid vehicles. Let us peep in to each one separately. [14]

Strengthening the grid: It should be ensured that there is sufficient transmission capacity to interconnect energy resources, especially renewable resources. The electric power grid is over a century-old and is considered to be the largest and most complex interconnected physical system on earth. Due to its vastness, complexity and being inextricably linked to human development and involvement, it is termed to be an ecosystem in itself.

Enhanced Intelligence: Future Renewable Electric Energy Delivery and Management (FREEDM) system is proposed with the purpose of developing technology to revolutionize the nation's power grid, henceforth speeding renewable electric-energy technologies into every home and business. Since it contains many novel devices, the FREEDM system has features that are different from the traditional distribution system. The system diagram is shown in Figure 1.10 where it contains distributed energy storage device and distributed renewable energy resource has a loop configuration, which may allow a more flexible operation and improve the supply reliability; however, it becomes more challenging to protect the FREEDM system. In the FREEDM system, power electronics devices have been widely applied to gain intelligent energy management, improved power quality, and other advantages However, those that connect to the grid directly or through a transformer, can only allow about 2 pu current to flow during a fault; thus, the traditional fault detection methods, such as over current detection, is hindered because the current is not high enough. In addition, the load and supply of the FREEDM system may be significantly asymmetrical, resulting from the presence of distributed energy storage device and distributed renewable energy resource. The basic symmetrical components analysis therefore cannot be applied without modifications because the system is already asymmetrical under normal conditions. The conventional differential protection is not appropriate for a distribution such as the FREEDM system as well because the protection range of the system is the section, including not only the distribution lines, but the loads.

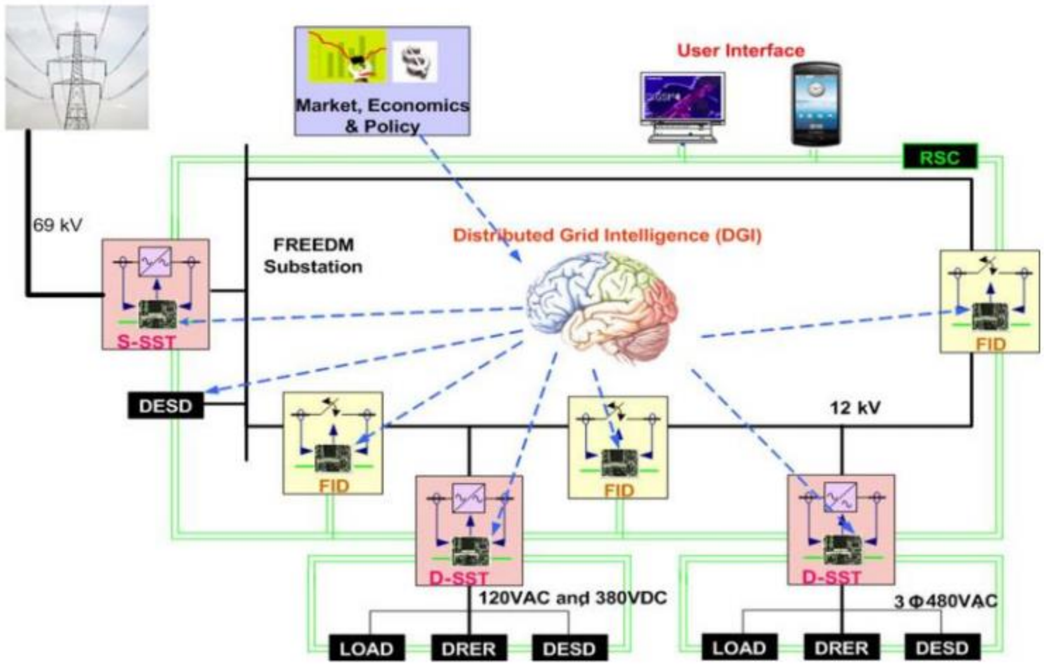


Figure 1.10: Electric grid diagrams conceptualizing

Communication: Smart Grid will integrate all the components of power system to enhance the performance of the grid. Much of the integration of components relates to communication systems, IT systems, and business processes. Efficient communication is needed for proper co-ordination of protective devices to adopt the new operating conditions. Distribution networks are designed to deliver power to customers within certain voltage tolerances without overloading equipment. For Smart grid, real time data and active grid management, requires fast and two-way digital communication with third party entities. Electric utilities use a wide variety of telecommunications including wired and wireless telephone, Voice and data dispatch radio, Fiber optics, Power line carrier communication, Satellite and internet.

A group-based protocol for improving the energy distribution in smart grids which is able to self organizes connections between smart nodes from different groups based on their available network connections and load. Advanced metering infrastructure (AMI) includes the both the physical smart meter (a digital electricity meter located at the end consumer that enables two-way communication) as well as the communications infrastructure to transport the data that is generated. The latter involves the development of an intelligent field area network that will facilitate the communications link back to the utility's operations and control center, but also to the network inside the home or building. One of the key outstanding questions in the AMI space is how smart meters will communicate with one another and with other devices on the grid. Here there are three main competing technologies: broadband over power lines, radio frequency mesh networks, and cellular networks. Smart Meters provide knowledge, increase awareness and change customers' behavior and attitudes in using renewable energy. In the future, renewable energy is the means to reduce carbon emissions and gas emissions during power generation. Although it may not be cheap in terms of the generation cost at the moment, customers can at least reduce the impact on climate change. Hence, if every household can use electricity and gas efficiently, there is a resulting need to minimize power generation as well.

Integrating intermittent generation: Economic dispatch deals with the minimum cost of power production in electrical power system analysis. More specifically, in solving this problem, one seeks to find the optimal allocation of the electrical power output from various available generators. Prior to the widespread use of alternate sources of energy, the problem involved only conventional thermal energy power generators, which use delectable resources such as fossil fuels. It has become apparent that there is a need for alternatives to thermal energy power generation. Finding the best ways of integrating intermittent generation including residential micro generation is a tough task. The main challenges of operating a power grid with a high proportion of generation based on renewable resources include that these resources: are less predictable than traditional fuel based power plants, may be far from load center's so power may have to flow through congested transmission paths, do not generally match the daily cycle of load variation, suffer from unusual operating constraints, such as, rapid variation or complicated weather dependence, and need to be tightly coupled to storage. It is widely accepted that renewable energy sources are the key to a sustainable energy supply infrastructure since they are both inexhaustible and non-polluting. A number of renewable energy technologies are now commercially available, the most notable being wind power, photovoltaic, solar thermal systems, biomass, and various forms of hydraulic power.

A method has to be proposed for optimally allocating different types of renewable distributed generation units in the distribution system so as to minimize annual energy loss. One associated term is MPPT - Maximum Power Point Tracking. Electricity in a PV system is generated by individual PV cells operating at low voltage and low current, dozens of individual cells are arranged in series-parallel configurations within a PV module, and tens to hundreds of modules are then arranged in series-parallel arrays to create high voltage and the desired power. But connecting cells in series forces the same current to flow in each cell, and connecting them in parallel enforces the same voltage .This is acceptable if each cell is perfectly identical and operates at the same temperature and insolation level. In practice, however, because the voltage-current characteristics of the PV cell are nonlinear, even small differences can result in substantial lost generation. Binning, the process of sorting cells based on tested performance by the module manufacturer adds cost to the system and can't compensate for differences that occur to statistical divergence as the cells age. Techniques for maximum power point tracking have therefore become standard practice.

Moving offshore: Developing the most efficient connections for offshore wind farms and for other marine technologies is a key issue. Potential benefits of the smart grid technology are that it's central control will now be able to control and operate many remote power plant, optimize the overall asset utilization and operational efficiently. In propose an innovative approach for the smart grid to handle uncertainties arising from condition monitoring and maintenance of power plant. Unlike traditional maintenance optimization methodologies that only consider the equipment lifetime distribution, an adaptive condition-based maintenance scheme is proposed in this paper. The key difference is that other operation related variations are also considered. This feature is particularly useful for offshore power systems because they are remotely located and difficult to access for data acquisition, inspection, and maintenance.

Capturing the benefits of DG and storage: Even if connected to the utility grid, renewable energy storages are usually coupled with other energy sources to improve robustness against intermittent outages. Hybrid energy systems are absolutely essential for remote off-grid installations. The popular approaches include the use of fossil fuel-driven generators (diesel), batteries, flywheels, super capacitors and compressed air systems. Their environmental impact is important, since the use of RESs is strictly related to providing a more sustainable energy processing. An adhoc hydrogen network in parallel to the electric grid may offer an effective storage system, leading to the use of renewable energy storages directly producing hydrogen and fuel cells as a transportable storage. This may eventually lead to the hydrogen era foreseen by some scientists. For new wind farms, the types of interconnection studies that are required at the distribution level can be summarized in terms of power quality and voltage impacts (short term and long term). For bulk systems, the typical concerns are more related to the impact on stability, voltage support, and ability to balance the intermittency using complementary generation, typically by allocating sufficient spinning reserves. Various studies have been completed in these areas. However, more work is still required in order to provide a generalized methodology, as existing methods are either not yet sufficient, or have not been made public. The main challenges with wind farm integration and energy storage can be listed as Intermittency, Ramp rates, Limiting wind farm power output.

Preparing of plug-in hybrid vehicles: Smart Grids must accommodate the needs of all consumers, electric vehicles are particularly emphasized due to their mobile and highly dispersed character and possible massive deployment in the next years, what would yield a major challenge for the future electricity networks. The emerging of plug-in hybrid vehicles results not only in the increase of electric vehicles as means of transportation, but also in the utilization of vehicle batteries for grid support, which is referred to as vehicle-to-grid (V2G). However, V2G is still at a conceptual stage, and the lack of practical and realistic frameworks to help moving from concept to implementation causes serious challenges to its adoption. In this context, proposes a practical model for the assessment of the contribution of V2G systems as a support to energy management within realistic configurations of small electric energy systems including renewable sources, such as Micro grids

Advanced power system monitoring, protection, and control:
Synchronized pharos measurements are becoming an important element of wide area measurement systems used in advanced power system monitoring, protection, and control applications. They are power system devices that provide synchronized measurements of real-time phases of voltages and currents. Synchronization is achieved by same-time sampling of voltage and current waveforms using timing signals from the Global Positioning System Satellite (GPS). Synchronized pharos measurements elevate the standards of power system monitoring, control, and protection to a new level.

1.9.2 Human Resource Challenges

Meeting the challenge will require a special set of engineering talents, including expertise in power system engineering electronics, including power electronics Engineering economics and finance System architecture and integration IT and software engineering Communications Project management Environmental engineering and more the engineering opportunities will be huge.

1.9.3 Design Challenges

Designing a Smart Grid is a challenging goal that imposes new approaches. Integrated system engineering is the process of architectural conception and complex control, safety and security systems designed a manner that also addresses the functioning in conditions of uncertainty or unfavorable context, in order to maximize his lifecycle. The concept of system architecture is the field of study and practice that ensures the transposition of user requests and their objectives in a development frame of primary functions, of structure and system behavior.
The architectural concept uses abstractions and oriented conceptual design methods, to limit ambiguities, to increase creativity and to manage the complexity of the process in preliminary stages of developing a system. To be able to manage uncertainty the system must be designed to be able to respond to operational, tactical and strategic issues. The main properties of the system are robustness and active flexibility. Table 1.5 shows the connection between those properties and uncertainty management.

Table 1.5: Uncertainty management of smart grid

Time scale and response mode	Uncertainty management	System modifications	
		Passive: Robustness	Active: Flexibility
Operational	Correcting a new source of variation highlighted by statistical analysis	Adapting process parameters with enlarged limits	Alternative strategies implementation
Tactical	Investment in new measurements	Robust design: selecting the processing times which cover variations	Organizing technological area as holon-cells capable to adapt
Strategic	Implementation of a system for working with clients and employees that would contribute to better quality, lower cost	Developing technology capable to meet the requirements of accuracy/quality over 10 years	Creating a network for competitive providers for continuous selection

Chapter 2

Literature review

2.1 Opportunity of smart grid

2.1.1 Supply Side Opportunities

The markets in this sector is primarily in working with TSO (Transmission Systems Operators) & DSOs (Distributor Systems Operators) or the larger Utility Companies. The main subsectors that are being researched / developed by Pilot Projects in are:

- Transmission Systems Conventional & Advanced
- Energy Storage
- Increased use of Photo Voltaic Technology
- Micro grids
- Smart Grids
- Network Optimization

2.1.2 Demand Side Opportunities

The markets in this sector is characterized by Pilot Projects and consumer adoption of Smart Technologies to control and reduce energy cost and usage. Projects that are being deployed in North West Europe include:

Development of Smart Energy Cities, Projects to Empower the Consumer, Smart Technologies for End User, Electric Vehicle Integration Projects and Metering Infrastructure. Figure2.1 shows a complete opportunities of pilot projects toward developing smart grid.

Figure 2.1: Smart grid opportunities [15]

2.2 Smart grid benefits for user

How does the smart grid save money? What is the smart grid? How does smart grid technology benefit our daily life as an energy user? For many people, these commonly asked questions are at the root of misunderstanding exactly how the smart grid benefits the average consumers daily. [16]

With smart grid technology we are able to save money, take control of your daily electric energy consumption more effectively and help protect the environment and we'll agree that there are many reasons why the smart grid is the beneficial to us in the following ways:

2.2.1 Saving money

Through advance metering, utilities are able to provide demand response programs, which are designed to assist energy users in cutting back on power usage during heat waves and cold spells by reducing peak-demand periods on the grid, saving you money.

2.2.2 *Managing energy consumption*

Digital metering is allowing individuals to moderate their household energy usage and reduce demand. It gives access to their electric consumption data, especially during high-energy usage peaks, which help energy users make better informed energy choices.

2.2.3 ***Energy reliability***

Digital meters are enabling utilities to provide more reliable energy service which decreases the amount of electric outages. Smart meters can electronically report the location of an outage before a person will ever have to call their utility, making restoration faster and status notification to individuals much easier.

2.2.4 Protecting the environment

The smart grid can cut air pollution from the electric utility sector as much as 30 percent by 2030, saving 34,000 deaths a year. Also, the smart grid ensures that renewable power sources like wind farms, solar plants and hydro stations can be integrated. Yearly energy savings from the smart grid could equal 70 million road trips around the world or driving an electric car 1.7 trillion miles.

2.2.5 The cost saving strategies

User implements cost saving strategies considering the available resources and infrastructure. In smart homes, visualization and prediction tools are used to provide estimates of energy supply, usage and energy prices. Scheduling the household loads and the energy sources according to the energy price is the main theme of cost optimization. The energy price depends on the utility and the locally available micro grid. The utility tries to indirectly control the loads in the user premises via a Demand Response (DR) program. The DR program primarily specifies energy price to balance the energy generation and energy demand. In a microgrid, the price signal fluctuates based on the energy generation from renewables and the energy demand of the participating households. The user may wish to earn a profit by trading the surplus energy in the energy market. The attainable profit depends on the nature of the market, market conditions and opponents' behavior. Figure 2.2 presents an overview of the methods used to minimize energy cost or maximize profit in smart homes. [17]

It is reported that the DR program has significant impact on cost reduction [Siano 2014]. Vardakas et al. classified the DR methods into three categories as shown in Figure 2.3 [Vardakas et al. 2015]. The first category is based on control mechanism, including centralized and distributed control. In the second category, DR methods are classified based on the motivating factors. The price based and the incentive based DR methods fall into this category. Finally, the third category is arranged based on the decision variables. Energy consumption can be controlled by scheduling a task operation and energy management i.e., reducing the power of a load operation. Recently, there has been reported an increased trend of optimization method development for DR program [Vardakas et al. 2015; Shariatzadeh et al. 2015].

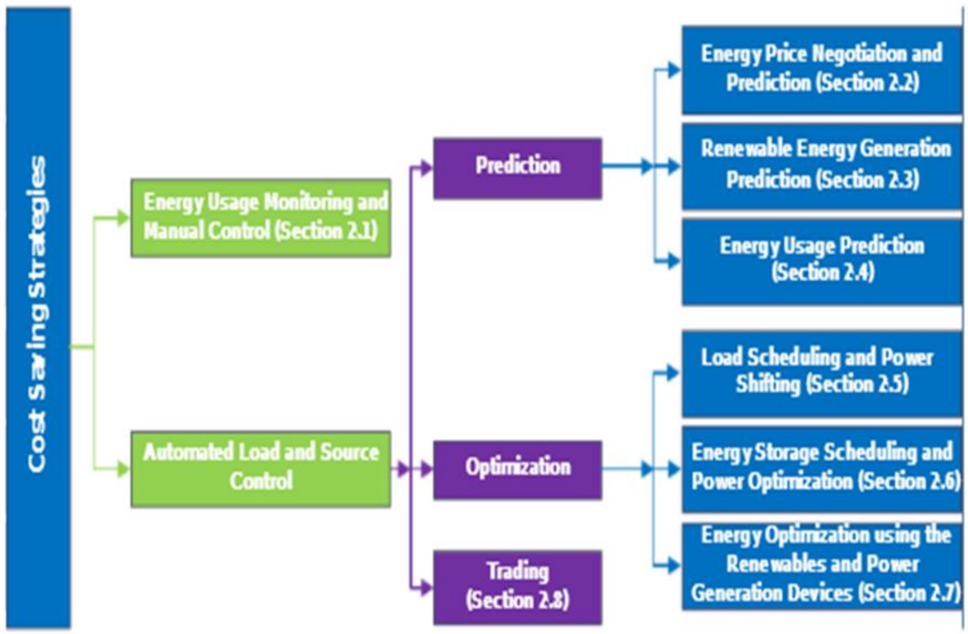


Figure 2.2: Overview of the cost saving strategies for smart homes

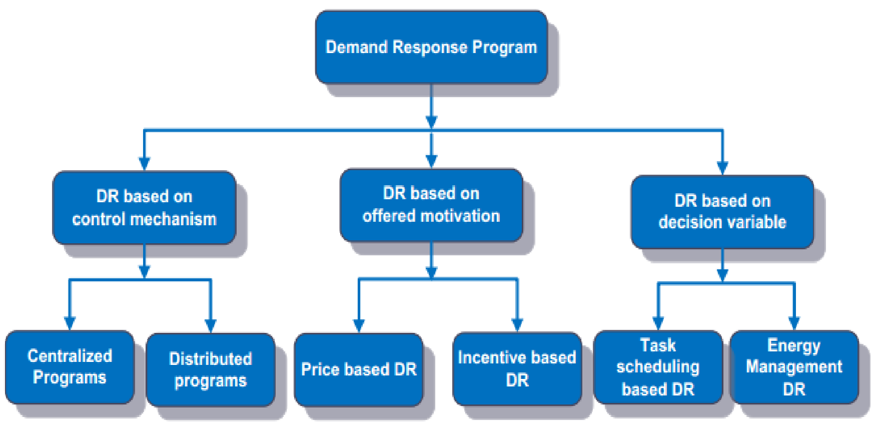


Figure 2.3: A classification of DR programs

2.3 Smart Grid in Future

The current mode of transmission and distribution of electricity has proven to be unreliable and inefficient. This is because the grid technology currently in use has changed very little since it was developed. Researchers are now experimenting with smart grid technologies to overcome the shortcomings of the traditional grid. [18]

A smart grid can help reduce greenhouse gas emissions by up to 211 million metric tons and is much more reliable than a traditional grid. This is what is driving investors to put their money in this new technology. By 2020, the industry is expected to have a valuation of over $400 billion.

2.3.1 Technologies for improving smart grid

The U.S. Department of Energy proposed an investment of $3.5 billion from the year 2016 to 2026 to promote innovation in the smart grid technology industry. Research will focus primarily on machine learning, plug and play technology, self-healing grid and total automation of the grid. Figure 2.4 shows the technologies that can help to solve smart grid development in the future.

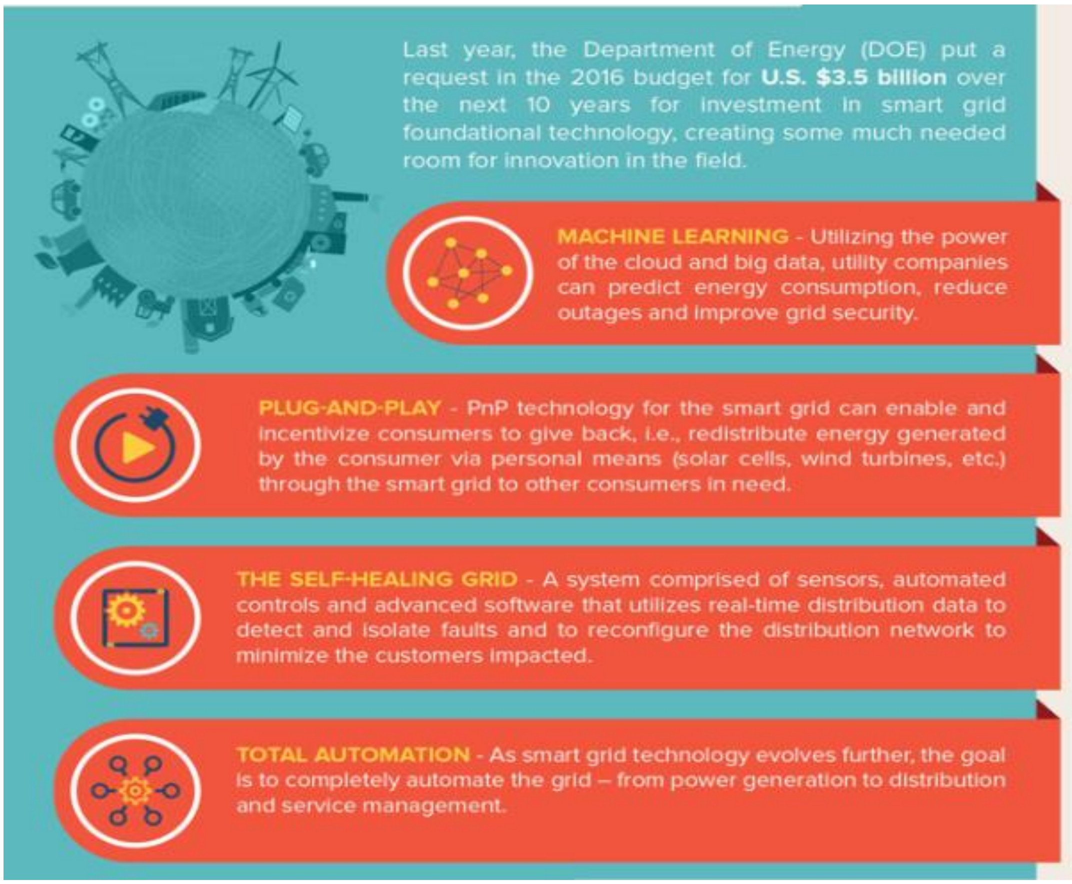


Figure 2.4: technologies that help future smart grid

2.3.2 Smart grid provides clean energy and cleans the environment

Smart grid is able to establish more focused and persistent customer participation, a smarter grid delivers end-use conservation and efficiency. In so doing, it also positively addresses world growing carbon footprint. [19]

Proving that timing is everything, a smarter grid can capture carbon savings from peak load shifting even if energy is not being saved. When peak load is reduced by means of demand response, many peaking plants and the carbon they emit are kept on the sidelines. From a behavioral perspective, there is measurable energy savings when consumers participate, approximately 6% in the residential sector. Awareness on the part of consumers to manage peak load by virtue of a feedback mechanism may incite greater attention to consumption patterns and results in savings. The full exploitation of renewable energy sources such as wind and solar is critical to managing the collective carbon footprint. However, when viewed against the limitations of the current grid, both technologies face barriers to full-scale deployment. A smarter grid enables grid operators to see further into the system and allows them the flexibility to better manage the intermittency of renewables. This in turn surmounts a significant barrier, enabling wind and solar to be deployed rapidly and in larger percentages. It has been estimated that the Smart Grid could reduce carbon dioxide emissions by up to 25%. The use of wind as 20% of the U.S. power supply could save 4 trillion gallons of water typically used in electricity generation between now and 2030, savings all the more significant due to increasing stress on water supply.

Figure 2.5: smart grid incorporation renewable energy resources in power system

We have discussed about smart grid definition, concepts, vision, benefits, and characteristics. However development and implementation of these concepts are so much challenging and needs lots research and study. The most important part of smart grid is the distribution system. The control strategies and costumer side management should be studied deeply. Standardization and type of communication system to be used and network topologies for protecting the grid against cyber-attack. In the following sections we are going to study all these things and also do a survey on existing methods and future proposed method by researcher and technical expertise.

2.4 A survey on smart grid concepts

Smart grid also called smart electrical/power grid, intelligent grid, intelligrid, futuregrid, intergrid, or intragrid is two way flow of electricity and information to create a widely distributed automated energy delivery network or it is an electric system that uses information, two-way, cyber-secure communication technologies, and computational intelligence in an integrated fashion across electricity generation, transmission, substations, distribution and consumption to achieve a system that is clean, safe, secure, reliable, resilient, efficient, and sustainable. [1]
It can revolutionize our daily lives. Following table shows a brief comparison between smart grid and existing grids. From a technical perspective the major systems of smart grid are divided into three systems as infrastructure system ,protection system , infrastructure system is divided into three subsystems as ,energy (advanced electricity generation delivery and consumption) , information (advanced information metering, monitoring and management)and communication (advanced communication management technologies, advance connectivity and information transmission , wired and wireless communication technologies) Smart management provides advanced and control and the objectives are like improving energy efficiency, profiling demand, reducing cost utility, and emission, based on the smart infrastructure by using optimization, machine learning, and game theory. Protection system: various failure protection mechanisms which improve the reliability security and privacy are studied. Advanced infrastructure used in SG on one hand empowers us to realize more powerful mechanisms to defend against attacks and handle failures, but on the other hand, opens up many new vulnerabilities. More thorough research on the smart protection system is desirable. Practical deployments and projects of SG should be well-analyzed before the initiative begins, these include customer's benefit and satisfaction.

SG is a complex system of systems, resulting in complicated interactions among energy, information, and communication subsystems. Utilities and organizations not having enough experience should be led by experienced people since the evolution of the SG infrastructure may ask for more experienced information and communication technology sectors to be involved. In addition to designing various management objectives and functionalities, the electric power industry needs to think about how to motivate customers to buy into these new ideas. Experience shows that only technologies leading to customer-oriented functionality will motivate customers to accept and use them. In order to reduce the cost electric utility may tend to neglect security and privacy issues and outsource the information management to a third party (e.g. a cloud provider) so the information confidentiality and integrity must be ensured .
When we introduce new technologies into SG, we should also assess the possible risk introduced therefore, we need to do a thorough assessment on the new technologies. It is likely to use unlicensed spectrum of frequencies in large scale SG. By using machine learning, game theory and optimization Smart management system provides many opportunities and flexibilities because it is based on the smart infrastructure system.

2.5 Survey on smart distribution system

It is essential to have a clear definition of "Smart Grid" from academia, industry and national lab perspective .especially in the distribution level.

EISA07 defined 10 following characteristics as goals toward development of smart grid**:** [20]

Use of digital information, Dynamic optimization ,integration of DER , demand response management , smart metering and automation , smart costumer appliances, Use of peak-shaving and advanced storage technologies ,Providing real time information for consumers, use of standard communication method and channel ,recognizing and reducing challenges and difficulties to adaptation of smart grid .

It is expected that smart grid will bring many social and economic and environmental benefits to the society, it will be automated and self-healed and hence will reduce outage time. The peak shaving function will increase overall efficiency by reducing losses. By smart metering user will get real time pricing and manage their energy usage based on price and convince them to reduce usage during peak demand time. In the distribution system many development need to be implemented. Title XIII OF EISA07 was used as ideal definition for the smart grid development. There are eight philosophies on smart grid distribution adapted from EISA07.Here, a survey is demonstrated which was distributed among respondents from different organizations in the U.S and it is hosted in the public by an internet service the respondent will be unidentified to each other.

The exhaustive survey was 67 questions and divided into eight sections. Some questions are as follows:

Identify which distribution voltage class is preferred for the integration of DER.

Since the wind and solar renewable energy sources are variable and non-dispatchable they require a series of technical considerations and it is important to know the expected percentage of their penetration in the grid distribution level.

Identify a preferred communication structure; identify preferred communication methods out of existing communication technologies that could be used; Identify the smart technologies that could be used for integration of DER; Rank the non-DER forms of peak-shaving strategies and identify how rapidly those strategies should be able to act; Identify the amount of control a utility should have over its consumers' demand response activities; Rank the functions of self-healing (preventative, corrective, emergency, and restorative) that should be implemented at the distribution level; Identify the sensors that may have increased usage in monitoring the distribution level; Identify preferred smart consumer devices technologies and their functionalities; Rank the order of importance product philosophies like standardized services, plug-and-play methodology and regulative accommodations could help the quick adjustment of smart technologies at the distribution level ;Identify a voltage level of islanding ability of DER; Identify the coveted functionalities of a smart distribution management system (DMS) and etc.

Survey was being circulated in 2009 among participants .The aim of this survey was to get an industry perspective definition and technical details of smart grid and identify the technologies that are preferred by industry.

2.6 Survey standardization studies

Researches on development and survey of smart grid are going on in different country with different focusing areas, in fact based on common requirements and ideas the term Smart Grid has gotten many definitions and every organization or research works are concentrating from different approach however all of them take the standardization as central them. [21]

Therefore and alignment between these approaches is essential in order to get them standardized, some core standard are to be identified and the best standard should be chosen. As a New-style ICT infrastructure of smart grid needs a high level of interoperability an established way to approach this challenge is the application of standards. In this paper several standardization recommendation roadmaps are described. An overview on the set of identified core standards are identified.

After summarizing all recommendation it is found that IEC TC 57 Seamless Integration Architecture SIA is a good basis and, most important, a general consensus for a smart grid standardization framework because several standards are already included.

Deferent region of the world have different focal topics all of them relay on the same standards. Vendors do not want to develop products for single markets, as this just rises costs and provides less Interoperability between products. There are several new focal topics coming up.

Future work on SIA : extension of three component .first add a new extensions and profiles of the CIM , The CIM already includes a large and rather complete data model, but it is not possible to model e.g. DER or multi-utility aspects in an appropriate way. Electro mobility should be part of the standardization framework. In detail, utility extensions.

2.7 Overview of smart distribution grid

1-The advantages of smart grid over conventional grids are like customer involvement to demand response, possibilities of introducing more renewable energy resources into grid, insuring power quality and economic pricing, optimizing assets and efficiency, self-healing, resiliency to attack and natural calamity. [22]

2-Micro grid is a small scale power grid system it has its own generation and load and provides power to local consumers. Currently researches in development of micro grid are widely spread in China Europe and US.

3-ADN (active distribution Network) which is another form of SDG ADN is a flexible network topology structure that can provides real time data, control and manage distribution system.

4-The difference between ADN and Micro grid :micro grid is a bottom-up system it can solve problems of the system operating in normal status and operating independently .while ADN is a public distribution system controlled by power company .micro grid scales and application are limited to local grids but ADN is a large scales of Grid .

5-The technologies exploited in smart grids must solve two problems of self-healing and DG Grid. Self-healing refers to ability of smart grid to monitor the system's state and eliminate any possible fault and prevent long power outages. The technologies like SCADA, Power Electronics, and Advanced metering infrastructures and advanced distribution Automation can overcome these challenges.
6-Problems that may be faced in constructing SDG: necessity of more flexible and reconfigurable network topology. Lake standard and protocol in communication since electric utilities are using various communication networks. Huge investment in infrastructure is needed. Process of huge data is a big challenges.
7-New technologies like IOT and Big Data will be able to overcome the above challenges

2.8 Power quality analysis of smart grid

Power quality issues are very critical for both grid and costumer they may result in plant shutdown, increase in overtime and products out of specification, losses and decrease in company´s profit. [23] Power quality in the smart grid is often affected by DGs like PV system connected to Grid, recloser and load since they causes voltage sag and negative operational impact. Therefore, it is very important to verify the use of high-tech equipment in distribution network and study their influences in terms of Power Quality (PQ). Use of computational tools for analysis of (PQ) is an excellent way to approach this challenge. In order to analyze power quality we should have some electrical circuit models for such components that will show their response and operation during different situations. That can be achieved by simulating them in some computational tools like MATLAB and simpowersystem.
To conclude, Recloser has relevance in PQ issues and small transient situations due to recloser opening in LV bus bar there are critical situations of voltage sag that can bring serious consequences for consumer.It would be better if other operational situations could be simulated, to verify other results on MV and LV, mainly with more DG connected at the distribution network.
Recommendations:
1-Have comprehension and necessary data from power system design.
2-Choose an appropriate computational model so the components from the distribution network can be adjusted on realistic way and the simulation result can be powerful.

2.9 Cyber security issues and monitoring

Since smart grid relay on communication in order to insure privacy and safety of information a specific cyber security must be developed otherwise the data and information can be missed or forged. In order to cope with these issues a cyber-architecture of smart grid with High adaptability for security monitoring is required

DMZ (Demilitarized Zone):

it is a physical or logical subnetwork that contains and exposes an organization's external-facing services to larger and untrusted network, usually the internet.[24] The purpose of a DMZ is to add an additional layer of security to an organization's local area network; an external network node only has direct access to servers and services in the DMZ, rather than any other part of the Network. An adaptable structure With Demilitarized Zone can provide higher security and reduce the investment. due to the guard of the DMZ, construction of special network for security monitoring is minimized because the monitoring system can share the same network when particular requirements are satisfied.

Security monitoring system for Smart Grid can be realized in two aspects. The first one is keeping the security of communication network, which is mainly based on the design of communication protocols. The second one is preserving the security of the whole grid, which is mainly based on analysis and management of smart grid information. Requirement of Cyber security: preserve user privacy, verify authenticity and integrity of all DR (Demand response), and protect DR bids and private information from untrusted entities. The employment of DMZ not only improves the security of the whole network, but also isolates the communicating load, which mitigates the influences caused by users' visits outside the DMZ.

Using DMZ the overall security will be improved.

Chapter 3

Smart grid in OIC member states

Organization of Islamic Cooperation (OIC) is an organization consist of majority Muslim countries from Asia, Africa and Europe. [25] Its member states are countries with different economic level and development statuses. Some countries (mostly Middle Eastern) have huge national resources such as oil reserves and natural gas therefore high rate of GDP. On the other hand some are having very low rate of development and industrial investment also the investment on electricity and basic infrastructure for electricity generation is very weak therefor they import electricity from neighboring countries. Despite that still there are many villages and regions that have not access the electricity. Many industries are complaining about insufficient electricity because they are running at a very low efficiency due to outage of power and use of personal generators.

In most countries where oil and gas resources are large, price distortions are considerable and cost recovery in electricity is low. In many countries this has led to inefficient use of supply, high energy intensity in energy use, increasing environmental problems, and a rapidly increasing burden on government finances. In countries which are net importers of fossil fuels, price distortions are generally less and cost recovery in the electricity sector has been somewhat better. However, the challenges they face is how to cope with high oil prices while financing the rapidly growing demand for energy in general, and electricity in particular. Some regions are highly susceptible to the risk of climate change impact due to water scarcity, concentration of economic activities in coastal areas and reliance on climate-sensitive agriculture. The high carbon emissions are predominantly from oil-producing countries. Another main problem in developing countries is the political issues and destructive war that is running for decades. War has worst impact on development and technology growth and energy production. There are some other problems to be noted:

- lack of man power and technical expertise
- Lack of qualities education and engineering schools.
- Corruption in governments and less concern on energy sectors.

To respond to the many regional challenges, Ensuring the delivery of energy services in line with economic growth in a financially sustainable manner, and increasing access to energy services; Safeguarding the environment and its key natural resources by improving the efficiency of resources management, and increasing energy efficiency, and the role of renewable energy. Smart grid is the best option for solving most of the energy related problems.

Here we have studied the current scope of smart grid development in some countries with better development level and economic level.

3.1 Qatar

3.1.1 Scenario of Electricity in Qatar

The International Monetary Fund ranked Qatar as having the fifth highest GDP per capita in 2016 with a 60,787 USD per capita nominal GDP over a population of 2.421 million inhabitants. In 2014, oil and natural gas production made up 51.1% of Qatar's nominal GDP. [26] Thus, Qatar has a worldwide high ranking of per capita GDP due to its significance production and exports in both crude oil and natural gas in proportion to its relatively small population. Qatar was the third top carbon dioxide emitter per capita in the world in 2009, (79.82 tonnes per capita). All emissions from building and cement production are local but some people may argue that some Qatar produced fuels and goods are consumed abroad.

The Electricity production from natural gas sources of Qatar is similar to that of Turkmenistan, Bahrain, Trinidad and Tobago, Brunei, Tunisia, United Arab Emirates, Belarus, Moldova, Algeria, Bangladesh with a respective Electricity production from natural gas sources of 100, 100, 100, 99, 99, 98, 98, 94, 94, 91 (% of total) and a global rank of 1, 3, 4, 5, 6, 7, 8, 9, 10, 11. The electricity production from natural gas sources of Qatar is 100 (% of total) with a global rank of two. (See Figure 3.1). [27]

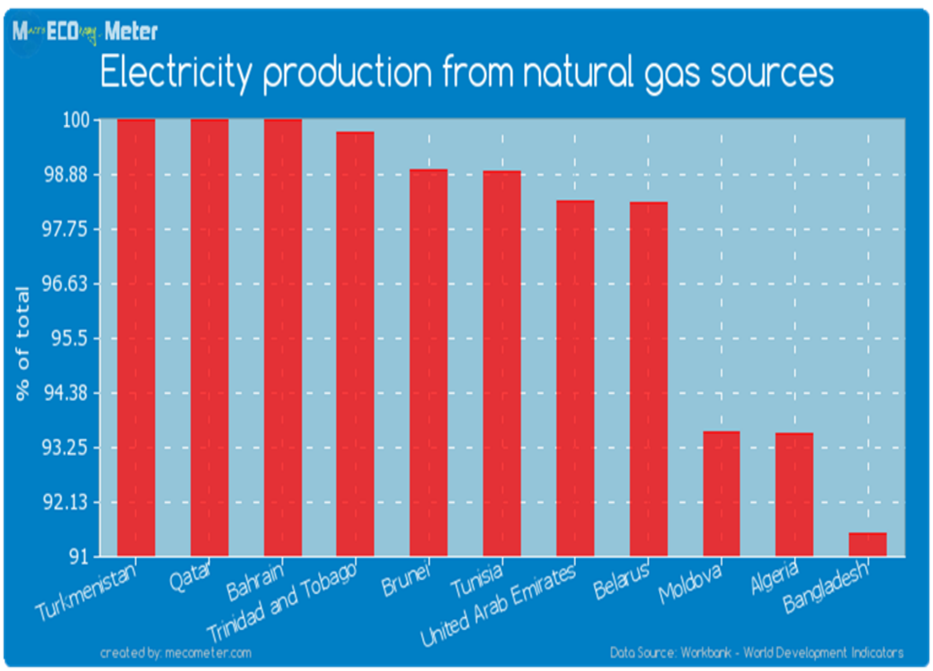


Figure 3.1: Electricity production from natural gas, Qatar compared to other Countries

The Electricity production from oil sources of Qatar is similar to that of Uzbekistan, Canada, Macedonia, Brunei, United Kingdom, Botswana, Colombia, Tanzania, Congo, Turkey with a respective Electricity production from oil sources of 1.04, 1.01, 1.00, 0.99, 0.99, 0.83, 0.82, 0.77, 0.70, 0.68 (% of total) and a global rank of 79, 80, 81, 82, 83, 85, 86, 87, 88, 89. The Electricity production from oil sources of Qatar is 0.87 (% of total) with a global rank of 84. (See figure 3.2).

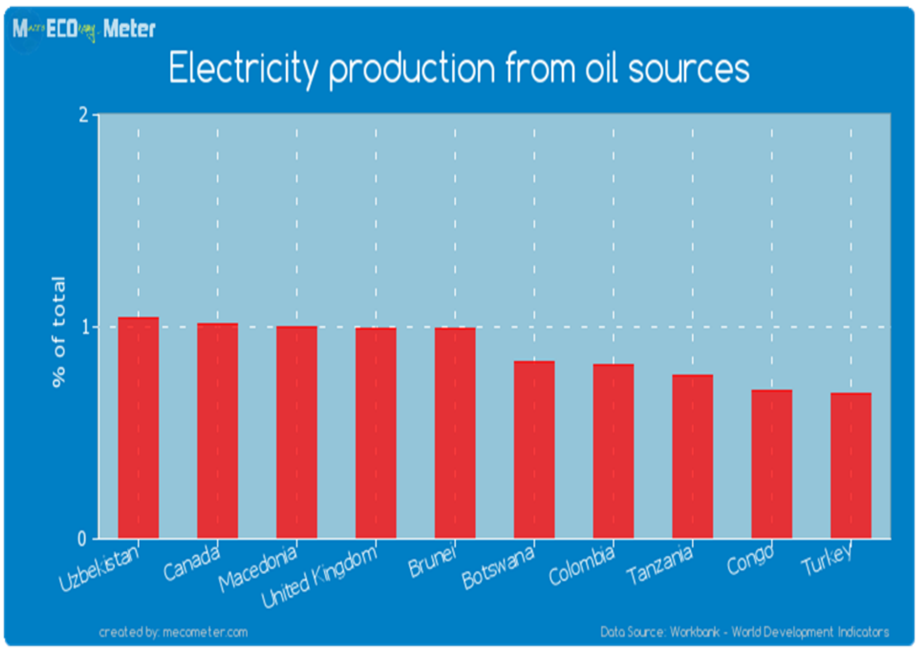


Figure 3.2: electricity production from oil sources, Qatar compared to other Countries

3.1.2 Kahramaa projects for renewable energy in Qatar

In August 2015, Kahramaa (Qatar General Electricity and Water Corporation) announced that it would begin construction of Umm al Houl Power, a desalination and power plant in the south of the country. The construction is estimated to cost around $2.75 billion and will have a capacity of 2520 MW and 136 million imperial gallons (620,000 m3) of potable water a day. [28]

Qatar's first major solar power plant was announced by Kahramaa in 2014, and is slated to begin operations by 2016. Its production capacity is expected to be 15 MW. In December 2015, Kahramaa stated that it had signed an agreement with Qatar Petroleum for cooperation in the development of solar power plants. Kahramaa would retain 60% ownership of the plants constructed under the agreement, while Qatar Petroleum would retain the remaining 40%. As of 2011, the electricity transmission networks consist of approximately 247 primary high voltage sub-stations. The network is coupled with 10500 low and medium voltage sub-stations (11 kV). Its voltage sub-stations are supported by a total 4000 km of overhead lines and 8,500 kilometres (5,300 mi) of underground cables running across the country. The National Control Center manages all network demand and data acquisition from generation plants and primary sub-stations.

The generation and generation capacity are as follows:

A. **Electricity generation**
   Generation of electrical energy in Qatar has increased over the past fifty years. the maximum load over the network during the period from 1988 to 2003 has risen from 941 MW to 2,312 MW. It reached 3,230 MW in 2006. By 2011, it had increased to 6,518 MW. The company was producing around 8,600 MW by 2014; a 2,000 MW surplus when compared to the 6,600 MW of demand.

B. **Electricity generation capacity**

   Kahramaa's electricity generation capacity was 28,144 GWh in 2010. This figure increased to 30,730 GWh in 2011 and 34,788 GWh in 2012 before dropping slightly, to 34,688 GWh in 2013. Another large expansion was recorded in 2014, when the electricity production capacity was raised to 38,963 GWh. Overall, from 2010 to 2014, Kahramaa's electricity generation capacity was increased at an average annual rate of around 10%.

3.1.3 Smart grid in Qatar

As we discussed in previous sections there are many opportunities and benefits of upgrading Qatar's power grid to smart grid and fortunately Qatar's government is already taking steps toward building smart grid .as per [29] Kahramaa and Belgian consultancy Elia Grid have signed an agreement to share knowledge experience around smart grid development. According to Trade Arabia, the agreement is aimed at encouraging the sharing of information, experiences and ideas to foster transmission development, network planning, KPIs (Key Performance Indicators) enhancement, better asset management exchanging technical information and joint co-operation.

The agreement was signed by Essa bin Hilal Al Kuwari, the president of Kahramaa, and Markus Berger, the chief executive of Elia Grid International, on the sidelines of the ongoing 'GCC Power 2016 Conference & Exhibition' at Doha. Changing the KPIs for the distribution of power, developing smart grid concept and renewable energy concept are the key objectives of this collaboration.

Implementation approaches

1. Replacement of all analogue meters in the Doha area by smart meter system using GPRS as its communication method by Kahramaa .
2. Installation of over 26 GW of solar capacity by 2024, led by Saudi Arabia, which will reduce the reliance on oil and gas power generation.
3. Deploy smart grid infrastructure that will help incorporate this solar power, enable better electricity demand management and improve reliability.

3.2 Saudi Arabia

3.2.1 Most productive region for renewable energy [30]

Saudi Arabia is the most potentially productive region for harvesting power from the sun. The increasing price of oil and its deficiency in future can attract many of the European countries to harvest solar energy for their nations from Saudi Arabia. Solar energy can be integrated to the power network by using smart grid technologies. The wind map of Saudi Arabia figure 3.3 indicates that the Kingdom is characterized by the existence of two vast windy regions along the Arabian Gulf and the Red Sea coastal areas. There are many regions with high speed wind.

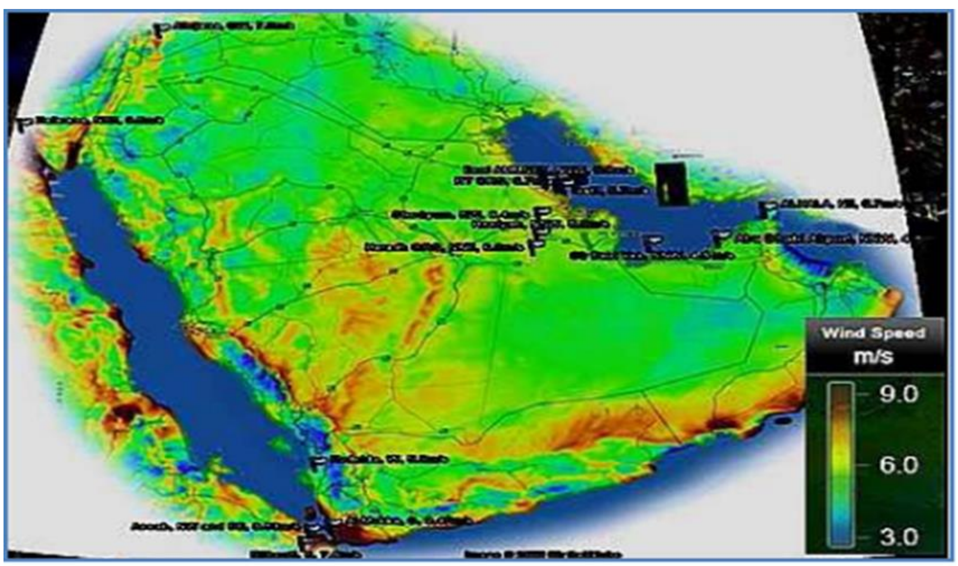


Figure 3.3: Wind map of Saudi Arabia

From Figure 3.4, it can be noted that the Arab states are the best areas to take advantage of solar energy. In Europe, most countries in North America, most Latin American countries, and the countries of Western Asia, the average annual rate of solar radiation is between 100 – 200 watt/m2, while in the Arab countries, including the Gulf countries, it reaches to about 250 watt/m2.

In 1980 Saudi Arabia started 'solar village' program to develop the use of the solar energy technology for application in remote regions. The Energy Research Institute, King Abdul Aziz City for Science and Technology conducted several solar energy research projects. These results show good potential for solar energy use in Saudi Arabia.

Another area where Saudi Arabia can benefit from the solar energy is desalination of water. According to Saudi Arabia’s national science agency, the Kingdom is now planning to build solar energy based desalination plants in order to save energy. A tremendous amount of oil is currently being used to provide power for the country's desalination plants; around 1.5 million barrels per day. This has caused the price of desalinated water to rise with the rise of oil price. Along with powering its desalination plants, the country also aims to use solar power to add generating capacity to its electricity grid. Solar energy can be integrated to the power network by using smart grid technologies.

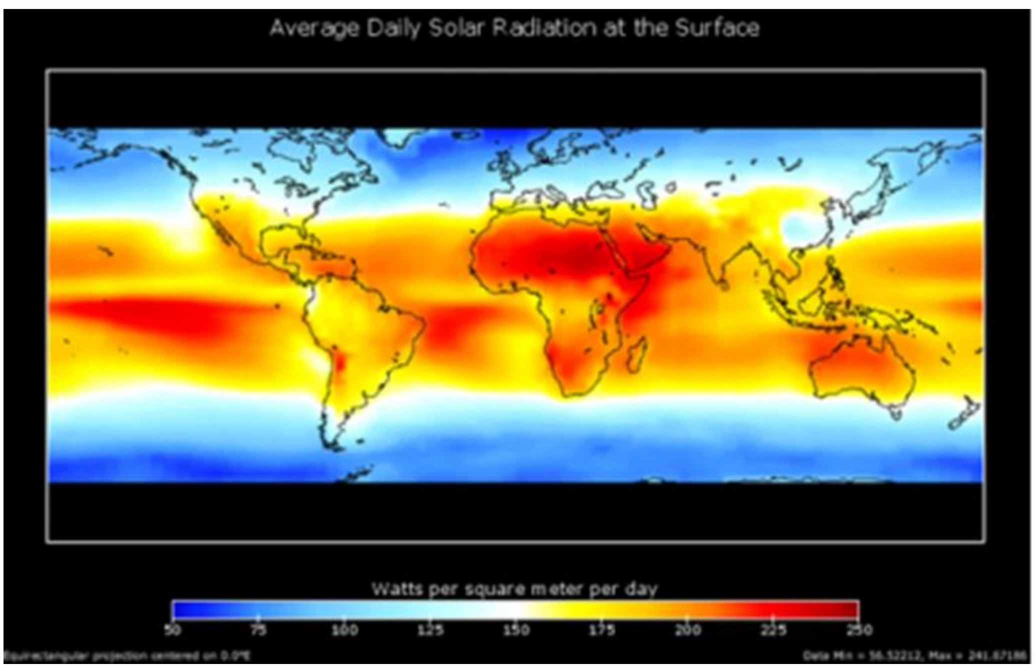


Figure 3.4: Distribution of solar radiation in Saudi

3.2.2 Role of smart grid in Saudi Arabia

Smart grid is the convergence of information and operational technologies applied to the electric power grid allowing sustainable options to customers and improved security, reliability and efficiency to utilities. Adapting smart grid technologies to utilize renewable energy sources for electric power generation will lead to conserve oil because conservation of petroleum products is essential to meet world's demand in the future. By enabling distributed energy resources like residential solar panels, small wind generators and hybrid vehicle, smart grid motivates small players like individual homes and small businesses to sell power to their neighbors or back to the grid. The renewable energy resources are for the most part intermittent in nature Smart grid technologies can enable the power systems to operate with large amount of such energy resources in such a manner that both suppliers and consumers are able to compensate for such irregularities. Developing smart grid technologies can help countries like Saudi Arabia, where this technology has huge potential, to meet at least part of world's growing energy demand with renewable energy sources. The variations in resource availability tend to limit any particular single renewable technology to specific locations and uses. The solution can be obtained by means of providing decentralized power with high reliability smart grid systems. These systems do not rely on a single energy source, but on diversified potential sources.

To conclude, it is clear that smart grid technologies can play an important role in integration of renewable technologies in the electric power network. As a result, it can help to conserve oil which is commonly being used for generation of electric power in the Kingdom of Saudi Arabia. The large-scale wind generation through smart grid reduces per-unit variability and increases predictability of wind generation. Lot of research work is essential to implement smart grid in the Kingdom. Successful efforts to implement such technologies will make Saudi Arabia a major megawatt exporter in the world and will lead to economic and environmental benefits.

3.2.3 Scope of development

The government of Saudi Arabia is already taking bold steps to adapt new energy efficiency standards as a national plan to reduce domestic energy consumption. For that, adapting and deploying smart grid will enable the kingdom to modernize the national grid.

In 2017 kingdom of Saudi Arabia organized a conference on smart grid and Renewable Energy (SASG-2017).The purpose of the conference was to bring together researchers, designers, developers and practitioners interested in the advances and applications in the field of Smart Grids, Green Information and Communication Technologies, Sustainability, Energy Aware Systems and Technologies.

Conference Topics: 1- Smart Grids 2- Renewable Energy and Grid Integrations 3- Energy Efficiency Measures and Methodologies 4- Smart Cities 5- Automation and Communication Technologies 6- Power System Planning, Operation and Maintenance 7- Regulatory Aspects and Market Operations 8- Standards for smart grid and grid codes.

3.3 Iran

3.3.1 Scenario of electricity and energy in Iran

Iran possesses third largest oil and second largest natural gas reserves in the world. Iran is in constant battle to use its energy resources more effectively in the face of subsidization and the need for technical advances in energy exploration and production. Iran recycles 28 percent of its used oil and gas whereas figures for certain countries stand at 60 percent. Iran is one of the most energy inefficient countries in the world, with the energy consumption three times higher than global average and 2.5 times than Middle East average (IEA, 2011). Energy consumption in Iran is 6.5 times than the global average. [31]

It is estimated that 18.5 percent of electricity generated in Iran wasted before it reaches consumers due to technical problems. Iran's domestic consumption and production have steadily grown together since 1984 and it is still heavily reliant on traditional thermal energy sources of electricity, with small fraction being produced by hydroelectric plants. Consumption has steadily risen and it is expected to rise about 6 percent per year for the coming decade (Taghizadeh, 2012).

Totally more than 98 percent of primary energy is derived from oil and gas and only less than 2 percent in form of hydro, coal and non-commercial energies (IEA, 2011).(see figure 3.5).all sources of renewable energy and nonrenewable energy can be incorporated by application of smart grid hence there is reduction in fossil fuel consumption .

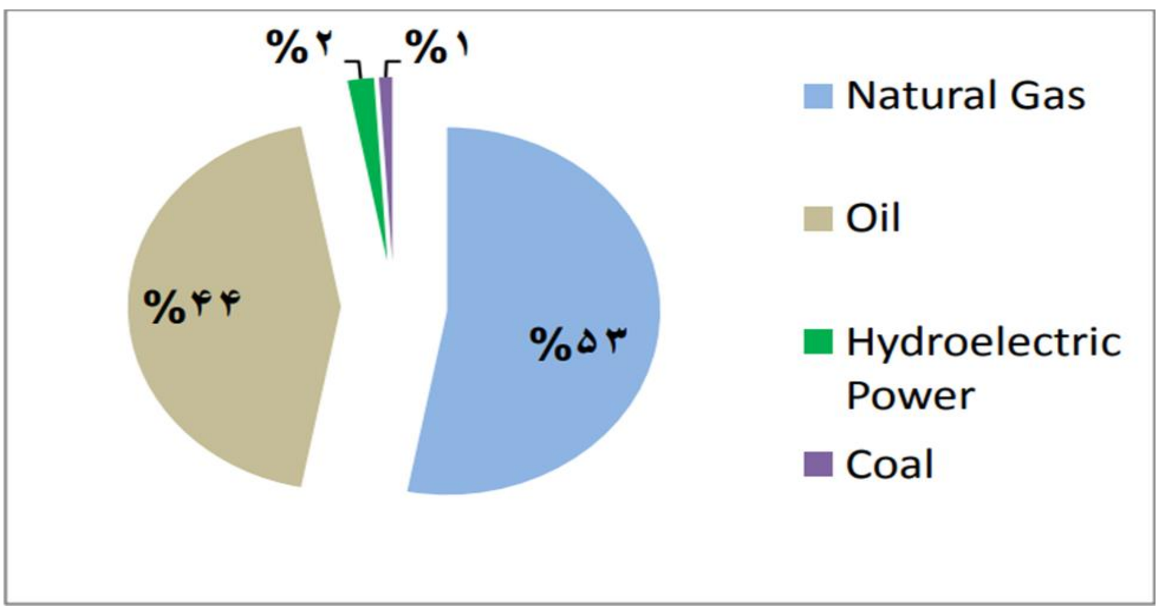


Figure 3.5: Iran Energy Consumption by Fuel Type

Major part of the electric energy supply in Iran is produced by steam, diesel and gas combined cycle plants. In addition this is increased seven times from 1979 to 1999 and was estimated to double between 2000 and 2010 as a developing country; Iran is likely to face larger electricity demand for industries in the not too distant future. Iran is characterized by significant electricity related challenges in terms of resources, infrastructure, cost and sustainability. We described the smart grid to aim these challenges. Technologies such as wind, solar PV, run of river hydro tidal where production of electricity is based on climatic conditions and therefore cannot be dispatched based on a need for additional power alone by applying the smart grid we can use all forms of these energy sources together. Demand response can be performed manually by the end-user or automatically based on predefined setting.

3.3.2 Scope of development of smart grid in Iran

A. "FAHAM" projects on smart metering [32]

Iran Energy Efficiency Organization, responsible for implementation and deployment of Smart Metering project (FAHAM) in Iran, started the first phase of smart metering project by selecting contractors through a tender that was executed successfully on 11 Dec 2011. The winners are thereby authorized for installing 1000000 smart meters in five separate distinct and predefined areas under the supervision of Tehran metropolitan, Alborz province, Zanjan province, Booshehr province, and Mashhad and Ahvaz Power distribution utilities. FAHAM is considered as the greatest ICT project in electric industry of Iran. The notable aspects of this project with various stakeholders and using successful projects experience of other countries, led them to employ EPC method to implement this project in Iran. In the next step, the authorities in Iran are working on development of an overall smart grid systems roadmap, in order to clarify the path for the next 10 years. During the realization of the FAHAM project, it was understood that there are many aspects of the work that had to be foreseen prior to further development and deployment of a smart grid system.

B. Business needs of FAHAM project

- Correcting customer's consumption pattern
- Preparing for complete elimination
- Applying energy management by the network operator in normal and critical conditions
- Improving meter readings and billing processes

- Reducing non-technical losses as well as monitoring technical losses in distribution network
- Improving the quality of service, reducing duration of power cuts and supervision on electric power quality
- Developing distributed generation and clean energy usage
- Possibility of electricity pre-sale and establishing electricity retail markets
- Optimizing operation and maintenance costs
- Providing appropriate management of water and gas meters

3.3.3 Smart metering implementation road map

1. **Standardization**

In order to cope with the challenges of an increasing deployment of innovative technologies and to foster the interconnectivity between these technologies, compilation features performance of smart metering system or standardization is an important step of smart metering implementation which has to be offered by responsible organization such as IEEO-SABA (Iran Energy Efficiency Organization).

The European Commission has mandated the European standardization organizations, i.e. CEN, CENELEC and ETSI, to adopt a set of standards for smart grids. Resulting from the mandate M/490, these standards will be a key step for the deployment of smart grids in Europe [CEN/ CENELEC/ ETSI, 2011]. A minimum common set of functionalities for smart metering has been put forward by the European Commission with the aim of enabling member states to identify common means of achieving cost efficiencies (and inefficiencies) in their rollout plans. The functionality set, developed jointly by the European Commission's directorates of Energy and Information Society and Media, comprises 10 functionalities. These were determined based on comments from member states in response to an initial list of 13 functionalities based on the ERGEG Guidelines of Good Practice on Regulatory Aspects of Smart Metering for Electricity and Gas. These ten functionalities area available on. [31]

2. **Short-term courses and seminars of smart metering systems**

The custodians this field such as FAHAM, universities, related associations and so on should make regular seminars to clear smart metering for experts, managers students and peoples. Fortunately, some short- term courses and Conference such as SEGT2012 have been started.

Topics of SEGT2012 conference are:

- Power and Energy System Applications (Generation, Transmission, Distribution, Markets, Operations, and Planning)
- Monitoring and Power Quality
- Distributed Generation, Energy Storages, and Micro grids

- Automation and Management of Electrical Energy Systems
- Reliability, Demand Response, Load Management and Forecasting
- Wide-area Metering, Monitoring, Control, and Protection
- Smart Grids Impacts on Fault Management (Protection Infrastructure, Emergency Response, and System Restoration)
- Electric Transportation and Vehicles
- Smart Grid Regulation and Standards
- Required Supporting Communications, Control and Information Systems
- Smart Sensors and Advanced Metering Infrastructure
- Information Technology, Database Management, and Cyber-Physical Systems Security

3. **Contractor support**

It is necessary to support smart grid's contractors on producing, importing, design and implementation. By this method, contactors work better and Department of Energy will get to its objects completely.

4. **Defining of smart metering equipment's specifications**

An electrical smart metering tool shall include Built-in or modular communication units to receive or send on-line commands using generic protocols for using in all regions of country.

To conclude, although there is a regulatory framework on implementation of Smart grid, but communication technology and electrical and physical environment is important. Therefore, it is necessary to localize generic smart metering implementation rules and implementation methods of smart grid in each province of Iran. In the following, practical steps are proposed.

a) Formation of committees such as restructuring, DG, micro-grid, IT and automation based on socio-economic studies.
b) Importance and aspects of smart grid such as fault following, loss reducing, reliability, supporting of renewable energy sources and asset management using AMI are defined in committees.
c) Division of project to practical phases such as:
    - Internet and library based research on electrical smart grid and advanced metering units
    - Possibility of distributed generation source in region
    - Research on current network and necessities of AMI implementation
    - Smart grid simulation, socio-economic analysis, study of results and proposals.

It seems the members of this project should have proficiency on reliability, smart metering and DG, power system programming. Furthermore, having power network software such as DIgSILENT and so on is necessary for this executive-research project. Therefore, target of this project will be

(a) Recognition of DG sources

(b) Recognition of appropriate to places advanced metering instruments,

(c) Recognition of technical and economic benefits of smart metering in region. Another result of using smart metering is making of a base for modification of consumption patterns and full implementation of targeted subsidies. Finally, considering the situation, synchronizing of benefit factors and Legal obligations are effective factors for implementation of smart grid.

3.4 Turkey

3.4.1 Growth of electricity demand in turkey

Turkey has 21 electricity distribution regions, run by 21 electricity distribution companies, including 13 private companies—Akedas, Aydem, Baskent, Camlibel, Coruh, Firat, Kayseri, Meram, Osmangazi, SEDAS, Trakya, Uludag, and Yesilirmak andeight state-owned companies, which are currently being privatised, namely AnadoluYakasi, Aras, Bogazici, Dicle, Gediz, Goksu, Toroslar and Van Golu Electricity Distribution Companies (DISCOs), as illustrated in Fig3.6. The privately-owned distribution companies serve 52–53% of Turkish customers, corresponding to 55% of electricity consumed, according to figures from the end of 2011.[33] The Turkish government earned approximately USD 6 billion in revenues from the privatisation of 13 regional companies. On average, 16% of electrical energy in Turkey is lost or stolen (the“loss and theft ratio”). Uludag DISCO has the lowest loss and theft ratio at approximately 7%. Dicle has the highest ratio at approximately 61%.

Turkey needs to introduce smart metering to reduce losses and thefts in distribution; to increase the quality of supply and efficiency; and to solve the problems encountered in operating day-ahead and balancing markets. All distribution companies have targets for dealing with technical and non-technical losses. These targets are set to create incentives to reduce the level of losses. If they can reduce the level of losses below the targets, distribution companies can earn higher profits than the regulated profit. In 2011, overall losses stood at 16%, of which technical losses were represented by 7–8% and non-technical losses were represented by 8–9%. The aim is to reduce overall losses to 10% by 2015.

3.4.2 Integration of the Turkish grid system with that of Europe

In order to provide a stable, low-cost, reliable, efficient, robust, sustainable and environmentally friendly electrical energy system to consumers, and a fully operational smart grid system needs to be established in Turkey. A smart grid system would provide the following advantages and accelerate the full integration of the Turkish grid system with that of Europe:

- Increase the quality and efficiency of supply.
- Solve problems encountered in running day-ahead and balancing markets.
- Enable frequency control by responding to spontaneous energy demand and holding energy in reserve.
- Reduce technical losses in the network and thefts.
- Enable more responsive load control of the energy transmission line.
- Allow power to be cut off and turned on remotely.
- Enable grid energy transmission capacity to be increased by reducing losses and controlling the active and reactive energy transmitted.
- Help policy makers, transmission system operators, and end users to prepare day-ahead plans.
- Improve the ease with which the grid can be overseen and controlled.
- Increase capacity to host distributed energy resources (DER).
- Increase the ratio of using renewable energy in the grid.
- Provide flexibility in demand and supply.
- Integrate electric vehicles (EV) into smart grids ensuring that the charging and communication infrastructure works properly rather than testing vehicle-to-grid (V2G) services.
- Enhance the use of storage systems as an additional source of grid.
- Improve collaboration between companies, universities and consumers.

If classical grids in Turkey were transformed into smart grids, not only would the above-mentioned benefits be achieved, but Turkey would be able to attract huge amount of investment and boost its economy. The Turkish grid system would then be a powerful player in the energy market in Europe. [33]

3.4.3 Scope of smart grid development

In line with the 2023 vision of the Turkish government, it has been stated that Turkey aims at replacing 35 million electricity meters with smart meters by 2023. By 2015, Turkey had invested altogether USD 5 billion in smart grids and is expected to increase its investments for the next decade. Between years 2016-2020, the distribution companies have an obligation to make new investments of TRY 18.5 billion (app. EUR 5 billion) in 5 years within the 3rd tariff period. These new investments will include both R&D projects as well as projects related to smart grids. [34]

Figure 3.6: Twenty one Electricity distribution regions in Turkey [33]

In accordance with the smart grid investment program imposed on the DISCOs by the Energy Market Regulatory Authorities (EMRA), the DISCOs were due to invest in their SCADA (supervisory control and data acquisition) systems and in their GIS (geographical information systems) by the end of 2012. The costs of these investments were covered by budgets approved by the EMRA However, some delays are expected to occur. EMRA's general approach to smart grid system investment is that it is an innovative sector; hence there is no need to restrict and direct the market development with strict regulations. EMRA sets the minimum criteria and allows the distribution companies to make the necessary adjustments for their own systems. It uses incentive-based regulation to deliver optimal solutions.

Turkey has two interconnection points with the East European Transmission Grid. The test period for synchronous parallel operation of the Turkish and European power systems started on 1 June 2011 and ended in September 2012. For the moment, trade is being limited to 400 MW from Bulgaria and Greece to Turkey and 300 MW from Turkey to Europe via these countries [34] .TEIAS currently has following actions regarding smart grid applications:

1. national control centre (Ankara);
2. emergency national control centre (Ankara);
3. 9 regional control centres;
4. Over 200 remote terminal units (RTUs); and
5. Approximately 12 remotely controlled substations

Automatic controls can help reduce the number of failures, increase the durability of the lines and cut the number of interruptions. Relaxing the system, enabling the system to reach a more stable state and balancing the peak hour demand are the benefits that could be obtained through bi-directional energy flow that would enable consumers to contribute as producers. In addition to offering many advantages to consumers, producers and all units associated with the energy problem would gain from increased market activity.

3.4.4 *Solutions for Turkey smart grid*

In general, the Turkish smart grid visions will require a wide range of solutions: [33]

- Implementing further Supervisory Control and Data Acquisition systems (SCADA)
- Different approaches to control smart meters (PLC, AMI, ACT)
- Collecting and processing big data from the smart grid systems
- Security solutions for cyber attacks
- Connectivity solutions for smart meters, including wireless communication systems
- Technology infrastructure (cloud services, 4G/5G services, sensor technologies)
- Energy storage solutions
- Renewable energy solutions
- Geographic Information System (GIS) solutions
- Energy and system auditing services

However, some of the above mentioned fields are already full of well-known global players. Thus, more specific niche areas could be the best option for Finnish companies. These include the likes of:

- Electricity storage
- Advanced metering seems to be a potential niche, but the level of competition is high especially with local providers. Still, Finnish companies can enter the advanced metering market. The best option may be to move forward together with a local partner. For instance, French and American companies use this method.
- In smart grids, consumer based solutions and services, such as ICT, mobile platforms and partnerships with telecom companies, will be among the most important issues in the future.

3.4.5 *Role of European companies*

Even though, the market recognition of Finnish companies in the Turkish smart grids sector might be limited, the general image of Finland in Turkey is very positive and always associated with high quality. One of the possible next steps is attending the ICSG (International Istanbul Smart Grid Congress and Exhibiton) in April 2017.

Chapter 4

Conclusion and future work

Smart grid brings many opportunities for both consumers and utility however in developing smart grid many challenges and problems can be faced .The issues such as cyber security, standardization and standard communication system is to be studied.

Nations should go for development of smart grid since smart grid can reduce dependency of electricity production from nonrenewable energy such as oil and natural gas and that will improve economy and it will have huge impact on climate change by reducing carbon emission. Smart grid enables to integrate renewable energy resources into grid which are available with a high potential in most of the countries, it is environment friendly and clean source of energy.

Fortunately most of OIC member states are going for smart grid development, there are many pilot project based on smart metering, running in countries like Turkey and Iran which is the first stage of smart grid but it is not much popular in some countries.

We have some recommendations for those countries which are not adopting smart grid that much, it may be because of poor economy or people wrong perception of smart meter radiation or lack of proper government strategy.

1. Since Smart buildings, homes and offices can encourage consumers for energy savings government can implement smart buildings with smart grid technology to get rid of extra economic and financial loss.
2. engineers can establish a smart grid consultant farm and create lots of employment for future engineers.
3. Since huge investment is needed for smart grid development government should run some Pilot joint projects with foreign investor.
4. Government energy authority should step forward to amend different sets of rules and policies in order to familiarize and educate the consumers about smart grid through media and newspaper.
5. Smart grid is a new concept and solution for power crisis, shortage and the way we are dealing with electric power, therefor it needs a lot of technical expertise and engineers and it is necessary that the smart grid technology should be included in the curriculum of universities.
6. The power companies should arrange seminars, training and classes to educate their employees about smart grid because they are already expert in conventional grid technologies and they can easily come up with a solution for a smart grid development challenge.
7. Lastly it is important to say that smart grid should not be considered as a dream but as a scope to improve power grid.

By applying these recommendations and methodologies smart will be a real phenomenon not a dream for all OIC countries including the ones with low economy.

In future we are going to do same studies on development of smart grid in other countries like UAE, Pakistan, Bangladesh, Egypt and etc. We will find smart grid solutions for countries with low economy which are not having enough electricity generation, proper management of electric power and give some more recommendation to governments to put a step forward toward development of smart grid so that we the Muslim Ummah will be less dependent on other countries and generate our own sustainable and clean energy and use it in very efficient and managed way for betterment of the of our society. And if possible we can integrate all our grids to one single grid that will be the best way we can help each other and become a united nation of Islam.

References

[1] Fang, Xi and Misra, Satyajayant and Xue, Guoliang and Yang, Dejun "Smart grid—The new and improved power grid: A survey", IEEE communications surveys & tutorials, 2012.

[2] Available:http://blog.mordorintelligence.com/development-of-the-smart-grid-network-in-iran/ [Accessed 2017]

[3] Available: https://smartgridtech.wordpress.com/smart-grid/ [Accessed 2017]

[4] M. A. Islam, M. Hasanuzzaman, N. A. Rahim, A. Nahar, and M. Hosenuzzaman, "Global renewable energy-based electricity generation and smart grid system for energy security", The Scientific World Journal, 2014.

[5] National Energy Technology Laboratory, "a vision for the smart grid", The Modern Grid Strategy, 2009.

[6] Available:http://www.ewh.ieee.org/r6/san_francisco/pes/pes_pdf/SmartGrid/SmartGridVision.pdf [Accessed 2017]

[7] Available:https://velatianetworks.com/2016/10/03/5-main-characteristics-for-any-smart-grid/ [Accessed 2017]

[8] Available:http://electrical-engineering-portal.com/smart-grid-concept-and-characteristics [Accessed 2017]

[9] https://www.elprocus.com/overview-smart-grid-technology-operation-application-existing-power-system/Available: [Accessed 2017]

[10] Available:https://www.electricaltechnology.org/2015/05/what-is-a-smart-grid.html[Accessed 2017]

[11] Available:http://www.ieeepesboston.org/files/2011/06/McDonaldSlides.pdf. [Accessed 2017]

[12] Available: https://www.netl.doe.gov/File%20Library/research/energy%20efficiency/smart%20grid/presentations/ACS-Conference_Miller_2009_04_APPROVED_2009_04_17.pdf [Accessed 2017]

[13] Available:http://researchonline.gcu.ac.uk/portal/files/24621175/SMART_GRID_MEPCON_2016.pdf [Accessed 2017]

[14] Joy, Jeena and Jasmin, Dr EA and John, Viju Rajan, “Challenges of smart grid”, International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, 2013.

[15] Available: https://www.naefrontiers.org/File.aspx?id=32042 [Accessed 2017]

[16] Available:http://www.whatissmartgrid.org/featured-article/4-ways-the-smart-grid-benefits-you[Accessed 2017]

[17] Alam Muhammad Raisul, St-Hilaire Marc, and Kunz Thomas, “Computational methods for residential energy cost optimization in smart grids: A survey”, ACM Computing Surveys (CSUR), 2016.

[18] Available:http://engineeringonline.ucr.edu/resources/infographic/future-of-smart-grid-technologies/ [Accessed 2017]

[19] Available:https://energy.gov/sites/prod/files/oeprod/DocumentsandMedia/Policymakers.pdf [Accessed 2017]

[20] Brown, HE and Suryanarayanan, S,“A survey seeking a definition of a smart distribution system”, North American Power Symposium (NAPS),2009.

[21] Sebastian Rohjans, Mathias Uslar, Robert Bleiker, Jose Gonz ´ alez ´ , Michael Specht, Thomas Suding and Tobias Weidelt “Survey of smart grid standardization studies and recommendations”, first IEEE international conference on Smart grid communications (SmartGridComm) ,2010.

[22] Ma, Youjie and Wang, Guidong and Zhou, Xuesong, “An overview on smart distribution grid”, IEEE International Conference on Mechatronics and Automation (ICMA), 2015.

[23] Motoki, {\'E}dison M and Perez, Filipe and Homero Filho, KR and de Souza, Paulo VG and de Carvalho Filho, Jos{\'e} Maria and Ribeiro, Paulo F , “Use of computational system for analysis of power quality in smart grid”, IEEE PES Innovative Smart Grid Technologies Latin America (ISGT LATAM), ,2015.

[24] Hu, Rui and Hu, Weihao and Chen, Zhe , “Research of smart grid cyber architecture and standards deployment with high adaptability for Security

Monitoring”, International Conference on Sustainable Mobility Applications, Renewables and Technology (SMART),2015.

[25] Available:https://en.wikipedia.org/wiki/Organisation_of_Islamic_Cooperation [Acces-sed 2016]

[26] Available: https://en.wikipedia.org/wiki/Energy_in_Qatar [Accessed 2017]

[27] Available:http://mecometer.com/whats/qatar/electricity-production-by-source/ [Accessed 2016]

[28] Available: https://en.wikipedia.org/wiki/Kahramaa [Accessed 2017]

[29] Available:https://www.metering.com/news/qatar-signs-agreement-belgian-firm-smart-grid/ [Accessed 2017]

[30] F.R. Pazheri, N.H. Malik, A.A. Al-Arainy, E.A. Al-Ammar and Imthias “A Smart Grid Can Make Saudi Arabia Megawatt Exporter”, Asia-Pacific Power and Energy Engineering Conference (APPEEC), 2011.

[31] Ashraf-Hesari, A and Hosseinian-Far A, “Smart grid applications in Iran”, 6thSASTech, 2012.

[32] Akoushideh, Alireza and Zobeiri, Mehrdad and Maybodi, Babak Mazloom-Nezhad, “A Survey on Implementation of Smart Grid in Iran”, International Journal of Modern Engineering Research (IJMER), 2013.

[33] Colak, Ilhami and Bayindir, Ramazan and Fulli, Gianluca and Tekin, Ibrahim and Demirtas, Kenan and Covrig, Catalin-Felix, “smart grid opportunities and applications in Turkey”, Renewable and Sustainable Energy Reviews, 2014.

[34] Available:http://www.cleantechfinland.com/-/opportunities-in-turkey-s-smart-grids-for-finnish-companies [Accessed 2017].