FEASIBILITY OF SMART GRID IN BANGLADESH: AN OVERVIEW AND IMPLEMENTATION

A Project and Thesis submitted in partial fulfillment of the requirements for the Award of Degree of Bachelor of Science in Electrical and Electronic Engineering

Submitted by

Md. Al-Amin Mridha
ID: 151-33-2313
Farid Uddin Masud
ID: 151-33-2413

Supervised by

Dr. AKM Alamgir
Associate Professor
Department of EEE

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING
FACULTY OF ENGINEERING
DAFFODIL INTERNATIONAL UNIVERSITY

November,2018

Certification

This is to certify that thesis entitled "**Feasibility of smart grid in Bangladesh: An overview and implementation**" is done by the following students under my direct supervision and this work has been carried out by them in the laboratories of the Department of Electrical and Electronic Engineering under the Faculty of Engineering of Daffodil International University in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering. The presentation of the work was held on 20 December 2018.

Signature of the candidates

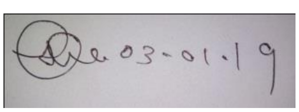
____

Md. Al-Amin Mridha
ID:151-33-2313

____

Farid Uddin Masud
ID:151-33-2413

Supervised by



____

Dr. AKM Alamgir
Associate Professor
Department of EEE
Daffodil International University

The project and thesis entitled **“Feasibility of smart grid in Bangladesh: An overview and implementation”** submitted by **Md. Al-Amin Mridha**, ID No: 151-33-2313, **Farid Uddin Masud.**ID:151-33-2413 Session: Fall 2018 has been accepted as satisfactory in partial fulfillment of the requirements for the degree of **Bachelor of Science in Electrical and Electronic Engineering** on 22 December 2018.

BOARD OF EXAMINERS

____

Dr. Engr. … Chairman
Professor
Department of EEE, DIU

____

Dr. Engr. --- External Member
Professor
Department of EEE, DIU

____

Dr. Engr. --- Internal Member
Professor
Department of EEE, DIU

Dedicated to

Our Parents

CONTENTS

LIST OF FIGURES

LIST OF TABLES

List of Abbreviations

ATO	Advanced Transmission Operations
AMI	Advanced Metering Infrastructure
ADO	Advanced Distribution Operations
AAM	Advanced Asset Management
AC	Alternating current
AMM	Automatic Meter Management
AMR	Advance Meter Reading
ADR	Automatic Demand Response
AGC	Automatic Generation Control
APSCL	Ashuganj Power Station Co. Ltd
BPDB	Bangladesh Power Development Board
RMS	Root Mean Square
CB	Circuit Breaker
CR	Cluster Router
UV	Ultraviolet
CIS	Customer Information System
CCTV	Closed Circuit Television

DESCO	Dhaka Electric Supply Co. Ltd.
DPDC	Dhaka Power Distribution Co. Ltd.
DSE	Distribution State Estimation
DCC	Data and Control Center
DMS	Distribution Management System
DER	Distributed Energy Resources
DR	Demand Response
DG	Distributed Generation
DA	Distribution Automation
DoE	U.S Department of Energy
EISA	Energy Independence and Security Act
EMS	Energy Management System
EGCB	Electricity Generation Company of Bangladesh Ltd.
FAN	Flexible AC Transmission System
FACTS	Customer Information System
GHG	Greenhouse Gas
GTO	Gate Turn-Off thyristor
HAN	Home Area Network.
ISO	Independent System Operator
IP	Internet Protocol
PGCB	Power Grid Company of Bangladesh Ltd.

LIST OF SYMBOLS

λ	Wavelength
λ_B	Bragg wavelength
n_{eff}	Effective index
Z	Position along the grating
N	Mode index
F	Fundamental Frequency
ω	Angular frequency
M	Modulation Index
T	Fundamental Time Period

ACKNOWLEDGEMENT

First of all, we give thanks to Allah or God. Then we would like to take this opportunity to express our appreciation and gratitude to our project and thesis supervisor **Dr. AKM Alamgir , Associate Professor** of **Department of EEE** for being dedicated in supporting, motivating and guiding us through this project. This project can't be done without his useful advice and helps. Also thank you very much for giving us opportunity to choose this project.

We also want to convey our thankfulness to **Professor Dr.Md. Shahid Ullah, Head** of the **Department of EEE** and **Professor Dr. M. Shamsul Alam Dean** of the **Department of EEE** for his help, support and constant encouragement.

Apart from that, we would like to thank our entire friends for sharing knowledge; information and helping us in making this project a success. Also thanks for lending us some tools and equipment.

To our beloved family, we want to give them our deepest love and gratitude for being very supportive and also for their inspiration and encouragement during our studies in this University.

ABSTRACT

The old electricity network infrastructure has proven to be inadequate, with respect to modern challenges such as alternative energy sources, electricity demand and energy saving policies. Moreover, Information and Communication Technologies (ICT) seem to have reached an adequate level of reliability and flexibility in order to support a new concept of electricity network—the smart grid. In this work, we will analyze the state-of-the-art of smart grids, in their technical management, security, and optimization aspects. We will also provide a brief overview of the regulatory aspects involved in the development of a smart grid, mainly from the viewpoint of the Bangladesh. To increase the Generation, Transmission and Distribution efficiency and increase the system reliability smart grid plays an important rule. The smart grid vision generally describes a power system that is more intelligent ,more decentralized and resilient ,more controllable and better protected than todays grid.

Keywords: smart grids; energy; renewable; grid intelligence; energy efficiency; energy storage, Substation Automation.

CHAPTER 1

INTRODUCTION

1.1 Introduction

Over the past 50 years, electricity networks evolved from the “local grid” networks in the beginning of the century to interconnected electric grids, based on generating stations of notable scale (1000–3000 MW) distributing power to major load centres that divided energy to a large number of individual consumers. The generating stations, or power plants, were built in order to provide massive amounts of energy, due to the nature of power generation technologies in use (hydroelectric, coal, oil, and gas). By the end of the 20th century, however, this model proved to be unreliable and inadequate. First of all, the demand forecast techniques and the data processing technologies could not efficiently provide the desired energy at the desired time, thus power distribution was based upon rough average classifications.

Moreover, the emerging environmental issues and the geopolitical interdependence of power sources limited the development of economies of scale. The main challenges that a modern electricity network has to face are:

- Privacy issues between energy suppliers and customers;
- Security threats from cyber attack
  National goals to employ alternative power generation sources;
- Significantly more complexity in maintaining stable power with intermittent supply;
- Conservation goals that seek to lessen peak demand surges during the day so that less energy is wasted in order to ensure adequate reserves;
- High demand for an electricity supply that is uninterrupted;

- Digitally controlled devices that can alter the nature of the electrical load and result in electricity demand that is incompatible with a power system that was built to serve an "analog economy".

These challenges require the development of an intelligent, self-balancing, integrated electric network that makes use of the modern ICT techniques to manipulate and share data. The smart grid technology tries to answer these needs. In this survey, we propose an overview of the main aspects of smart grids development and implementation.

1.2 Historical Improvement Of Electricity Grid

The first alternating current power grid system was installed in 1886 in Great Barrington, Massachusetts. In those days, the actual grid had been the centralized unidirectional program associated with energy tranny, electrical power submission, as well as demand-driven manage.

In the 20th century local grids grew over time, as well as had been ultimately interconnected with regard to economic and reliability reasons. Through the sixties, the electric grids of developed countries had become very large, older as well as extremely interconnected, along with a large number of 'central' generation power stations providing capacity to main fill centers by way of higher capability energy outlines that have been after that branched as well as split to supply capacity to scaled-down commercial as well as household customers within the whole provide region. The actual topology from the sixties grid had been a direct result the actual powerful financial systems associated with size: big coal-, gas- as well as oil-fired power stations within the 1 GW (1000 MW) in order to 3 GW size continue to be discovered to become cost-effective, because of efficiency-boosting functions that may be economical only if the actual channels turn out to be large.

Power stations were located strategically to be close to fossil fuel reserves (either the actual mines or even water wells on their own, otherwise near to train, street or even interface provide lines). Siting associated with hydro-electric dams within hill places additionally highly affected the actual framework from the rising grid. Nuclear energy vegetation had been sited with regard to accessibility to air conditioning drinking water. Lastly, fossil fuel-fired power stations had been at first really polluting as well as had been sited so far as financially feasible through populace centers as soon as electrical power submission systems allowed this. Through the past due sixties, the actual electrical power grid arrived at the actual mind-boggling most of the populace associated with created nations, along with just outlying local places leftover 'off-grid'.

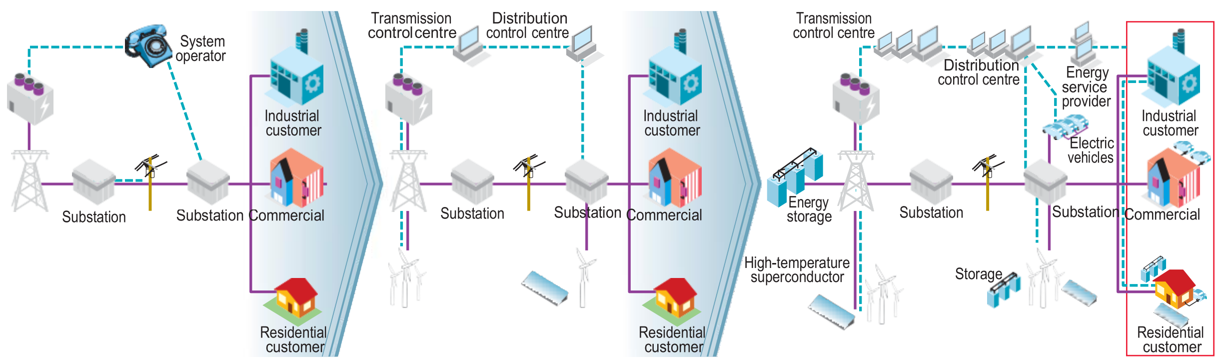
Metering of electricity consumption was necessary on a per-user basis in order to allow appropriate billing according to the (highly variable) level of consumption of different users. Due to restricted information selection as well as digesting capacity throughout growth of the grid, fixed-tariff plans had been generally set up, in addition to dual-tariff plans exactly where night-time energy had been billed in a reduce price compared to day time energy. The actual inspiration with regard to dual-tariff plans had been the low night-time need. Twin charges permitted using low-cost night-time electrical power within programs like the sustaining associated with 'heat banks' that offered in order to 'smooth out' the actual every day need, as well as decrease the amount of turbines which must be switched off immediately, therefore enhancing the actual utilisation as well as success from the generation and transmission facilities. The actual metering abilities from the 1960s grid meant technological restrictions about the level in order to that cost indicators might be spread with the program.

With the 1970s towards the 1990s, developing need resulted in more and more power stations. In certain places, way to obtain electrical power, particularly from maximum occasions, couldn't maintain this particular need, leading to bad energy high quality such as power shutdowns, energy slashes, as well as brownouts. Progressively, electrical power had been relied upon with regard to business, heating system, conversation, illumination, as well as amusement, as well as customers required actually greater amounts of dependability.

For the finish from the twentieth hundred years, electrical power need designs had been set up: household heating system as well as air-conditioning resulted in every day highs sought after which were fulfilled through a range of 'peaking energy generators' that could just end up being switched on with regard to brief intervals every day. The actual fairly reduced utilisation of those peaking machines (commonly, gasoline turbines had been utilized because of their fairly reduce funds price as well as quicker start-up times), with the required redundancy within the electrical power grid, led to higher expenses towards the electrical power businesses, that have been offered as elevated charges. Within the 21st hundred years, a few building nations such as The far east, Indian, as well as South america_had been viewed as innovators associated with wise grid deployment.

1.3 Definition of Smart Grid

There are several definitions for Smart Grid from different organizations such as European Technology Platform on Smart Grid (SmartGrids ETP), International Electrotechnical Commission (IEC), US Department of Energy (DOE), etc. DNV in Norway has a definition inspired by IEC and SmartGrids ETP:



Past Present Future

Electrical infrastructure
Communications

Figure 1.1. Evolutionary process of smartening the electricity grid

"A Smart Grid is an electric power network that utilizes two-way communication and control-technologies to cost efficiently integrate the behavior and actions of all users connected to it – in order to ensure an economically efficient and sustainable power system with low losses and high levels of quality, security of supply and safety". Smart Grid is enhanced version of today's electricity grids and as a result doesn't look significantly different from what we have today that is made from copper and iron lines or cables . What it actually does is adding intelligence to the traditional power grid in an evolutionary process. Figure 1.1. shows this evolution. There are some misconceptions for Smart Grid as well. The main one is considering smart meters as Smart Grid. Even though smart metering enables some features and functionalities of Smart Grid, Smart Grid encompass a much wider area of technologies and solutions and is by no means restricted or strictly delimited by the introduction of smart metering. The other mistake is considering Smart Grid as a revolution in power electricity grids. As mentioned earlier, Smart Grid will be an evolution.

1. 4 Significant of smart Grid/ Study

Because regarding 2005, there's been growing interest in the Smart Grid. The recognition that ICT offers significant opportunities in order to modernise the actual procedure associated with the electrical networks has coincided with an understanding that the power sector may just end up being de-carbonised in a practical price if it's supervised as well as managed successfully. Additionally, numerous much more factors have coincided in order to promote interest in the Smart Grid. In several areas of the planet (for instance, the united states and many nations within European countries such as Bangladesh), the actual power system broadened quickly in the 1950s as well as the transmission and distribution gear which was set up after that has become past it's style existence as well as looking for alternative. The need to refurbish the transmission and distribution circuits is an obvious opportunity in order to innovate along with brand new styles as well as operating practices. Consequently a few of the existing power transmission and distribution lines are operating near their capacity and some renewable generation can't be linked. This particular requires much more smart ways of growing the power transfer capacity of circuits dynamically and rerouting the power flows via much less loaded circuits. Any kind of power system operates within prescribed voltage and frequency limitations. When the voltage exceeds it's top restrict, the actual padding associated with aspects of the power system and consumer equipment may be damaged, resulting in short-circuit problems. As well reduced the voltage might cause malfunctions of customer equipment as well as result in excess current and tripping of some lines and machines. Modern society requires an increasingly reliable electricity supply because much more as well as more critical loads are connected. conventional method of enhancing dependability had been to set up extra repetitive circuits, through substantial capital price as well as environment effect. The Smart Grid strategy is by using smart post-fault reconfiguration to ensure following a (inevitable) difficulties within the power system, the particular materials in order to clients tend to be taken care associated with nevertheless to avoid the price connected with several circuits which may be just partially packed regarding a lot of their very own existence. Much less repetitive circuits result in far better using home nevertheless higher electrical losses.

1.5 Scope of Smart Grid

Power lack is really a globally issue. At present, more than 40 countries show power system instability as well as load-shedding due to electricity shortage. United states as well as Western businesses tend to be at present focusing on creating 'smart electric grid' systems in order to enhance energy circulation utilizing electronic radios with regard to better electrical grid manage as well as energy conservation. The requirement to construct Smart Grid systems is actually increasing globally as well as Bangladesh may become the leader in this region associated with technologies improvement. Because energy need is actually growing each year within Bangladesh, it's not feasible to construct energy channels quickly. Smart Grid system can minimize this problem. In case of load-shedding, brought on by electric energy lack within the country, the actual Smart Grid may instantly recalculate as well as deliver electrical power The basic needs to implement Smart Grid are digital radios, circuit breakers and so on. Each electronic radios as well as circuit breakers have to update the actual procedure associated with country's electrical grid, which may be created as well as manufactured in Bangladesh in large scale. With the help of expatriate Bangladeshi engineers, Bangladesh can start designing and manufacturing the electrical parts required to up-grade the electricity grid in Bangladesh to ensure that, Bangladesh can be an early developer and adopter of the Smart Grid technology.

1.6Methodology

The study was conducted mainly based on the data collected from the different secondary sources like Bangladesh power development board, power division, and power cell, U.S Department of Energy (DoE), Smart Grids European Technology Platform etc.Different statistical reports, relevant research papers, books and many national and international journals have also been reviewed for this study.

CHAPTER 2

RESEARCH MOTIVATION

Research motivation

The actual global power insufficiency offers straight foiled the actual economics, culture, improvement from the countries, as well as conditions via green house gas (GHGs) as well as through attaining co2 credit. The actual developing demand of power around the world has been envisaged as well as logged to become rapid. Insufficient resource along with out-of-date system national infrastructure, environment alter, increasing energy expenses, offers lead ineffective as well as progressively unpredictable electric program. With this particular, the actual global issue offers elevated particular crucial factors where the actual energy revolution for any eco-friendly as well as environmentally friendly long term tend to be assured as well as ensued.

2.1Fossil fuel deadlock

Increasing energy demand is actually banging stress upon fossil energy provide and today essential oil pursuit in the direction of "unconventional" essential oil assets. Altering via fossil energy sources to be able to renewables offers considerable advantages for example self-reliance through globe marketplace fossil energy costs and also the development associated with an incredible quantity of completely new eco-friendly function. Furthermore, it might provide energy towards the 2 million individuals presently without having use of energy services. The actual closer to think about the actions essential to phase-out gas faster in order to save the particular Arctic via gas goal, avoid dangerous large sea drilling duties and to go away gas shale inside the ground are usually well- thought-out. The particular relocate the actual fossil-driven reliant energy resources for the renewable energy resources (RES) may be undertaken worldwide depending on considerable requirements. The particular powerful features in the RESs which is creating reasonably environmentally friendly method to produce energy together with a smaller amount environment problems, is really amongst it is main.

2.2Climatic change threat

The threat of climate change, caused by rising global temperatures, is the most significant environmental challenge being encountered by the world since the beginning of the 21st century. It has major implications for the world's social and economic stability, its natural resources and in particular, the way we produce our energy. In order to avoid the most catastrophic impacts of climatic change, the global temperature increase must be kept as far below 2°C as possible. The main greenhouse gas is carbon dioxide (CO_2) produced by using fossil fuels for energy and transport. Keeping the global temperature until 2°C is often referred to as a 'safe level' of warming; beyond which unacceptable risks to the world's key natural and human systems might occur. Even with a 1.5°C warming, increase in drought, heat waves and floods, along with other adverse impacts such as increased water stress for up to
1.7 billion people, wildfire frequency and flood risks, are projected in many regions. Partial de-glaciation of the Greenland ice sheet, and possibly the West Antarctic ice sheet, could even occur from additional warming within a range of 0.8 – 3.8°C above current levels. If rising temperatures are to be kept within acceptable limits then we need to significantly reduce our GHG emissions.

2.3Global negotiation

Inside 1961 to be able to market financial improvement in addition to globe industry, the actual community forum related to countries dedicated to democracy and also the industry economic climate, supplying the machine to be able to assess strategy runs into, search for options to be able to standard issues for example globally heating system, in addition to figure out excellent techniques in addition to co-ordinate home in addition to globally recommendations related to it is individuals, for example fortification related to green power. This specific lead to the particular improvement in the Business with regard to Monetary Co-operation in addition to Enhancement (OECD), as well as the associate nations are usually greater income monetary techniques using a higher Individual Enhancement List (HDI) and for that reason can be produced countries. Furthermore, recognizing the particular worldwide risks associated with environment alter, the particular signatories for the 1992 UNITED NATIONS Construction Conference upon Environment Alter (UNFCCC) decided to the actual Kyoto Process within

1997. The particular Procedure became a member of into stress inside previously 2005 which is 193 individuals satisfy continuously to be able to exercise extra digesting in addition to enhancement in the agreement. This past year, the particular UNFCCC have been not able to supply a fresh atmosphere adjust agreement toward powered in addition to sensible emission cuts. In the 2012 Meeting, there's agreement to attain a fresh agreement via 2015 and to adhere to an additional commitment period of time in the conclusion associated with 2012. The particular advised minimization guarantees publish via governing bodies will most likely enable globally heating system to be able to no less than 2. 5 to be able to 5 amounts warmth enhance more than pre-industrial quantities.

2.4Climate change and security of supply

Use of every supplies in addition to financial stability is becoming near the top of the particular energy policy agenda. Rapidly fluctuating oil prices are usually protected to be able to a mixture of several events, nonetheless 1 cause of these kinds of price diversities is really that supplies associated with verified property related to fossil energy sources have grown to be infrequent plus much more pricey to produce. Several ‘non-conventional’ property for instance shale gas are becoming financial, together with harmful final results for your local environment. Uranium, the fuel for nuclear power, may also be the actual restricted supply. In comparison, the particular materials related to renewable energy that are technically accessible worldwide are usually large adequate to provide greater than 40 events a lot more energy when compared with planet at present utilizes, completely, in line with the newest IPCC Special Report Renewables (SRREN). Cost cuts in just the past couple of years have changed the particular economics of renewables fundamentally, especiallywind flow in addition to solar solar (PV) combined with the typical functions such as, emission related to minimum GHG and so are the actual virtually inexhaustible fuel. A few technologies happen to be aggressive; the actual solar as well as the wind flow industry have looked after twin quantity improvement costs a lot more than 10 years at this time, leading to faster technology deployment worldwide.

2.5 Nuclear issues

To each climate protection and energy security, nevertheless their own statements aren't backed through information. The newest Energy Technology Perspectives report published by the International Energy Agency (IEA) includes a Blue Map scenario such as the quadrupling associated with nuclear capability in between present many years as well as 2050. To do this, the actual statement states which normally thirty-two big reactors (1, 000 MW each) would need to end up being constructed each year through right now till 2050. According to the IEA's own situation, this kind of substantial nuclear growth might reduce co2 emissions through under 5%. Much more practical information evaluation exhibits yesteryear improvement background associated with nuclear power and the global production capacity help to make this kind of growth very unviable. Having a character of its catastrophic aftermath and its indispensable biohazard activities, in the past circumstances and also the long term values, numerous reactors may be ended as well as slowdown in a variety of expanses over the world. Japan's main nuclear incident from Fukushima within 03 2011 carrying out a tsunami arrived twenty five many years following the damaging surge within the Chernobyl Nuclear Power Plant, showing the actual natural risks of nuclear energy. Nuclear energy is merely hazardous, costly, offers ongoing waste materials fingertips difficulties as well as can't decrease emissions with a big sufficient quantity. In comparison, renewable energy is also a viable solution for replacing the world's exlusive, hazardous and intolerably costly nuclear energy.

2.6Energy efficiency

The most cost competitive way to reform the energy sector. There's huge possibility of decreasing the use of power, whilst supplying exactly the same degree of energy services. New business models to implement energy efficiency must be developed and must get more political support. The process forward will need a cutting-edge energy program structures including each brand new systems as well as brand new methods for controlling the actual system to make sure the stability in between variances within energy demand and supply. The important thing aspects of this particular brand new energy program structures tend to be mini grids, wise grids as well as an efficient large scale super grid, that could perform the powerful part within redesigning the actual global energy situation along with elements such as guidelines, legislation, as well as efficiency of market along with expenses, advantages as well as providers that additionally normalizes the actual power and energy market using the decrease associated with co2 foot prints as well as foot- pulling the actual GHG emissions.

2.7Modernization opportunities

Since the early 21st century, opportunities to take advantage of improvements in electronic communication technology to resolve the limitations and costs of the electrical grid have become apparent. Technological limitations on metering no longer force peak power prices to be averaged out and passed on to all consumers equally. In parallel, growing concerns over environmental damage from fossil-fired power stations has led to a desire to use large amounts of renewable energy. Dominant forms such as wind power and solar power are highly variable, and so the need for more sophisticated control systems became apparent, to facilitate the connection of sources to the otherwise highly controllable grid. Power from photovoltaic cells (and to a lesser extent wind turbines) has also, significantly, called into question the imperative for large, centralized power stations. The rapidly falling costs point to a major change from the centralized grid topology to one that is highly distributed, with power being both generated *and* consumed right at the limits of the grid. Finally, growing concern over terrorist attack in some countries has led to calls for a more robust energy grid that is less dependent on centralized power stations that were perceived to be potential attack targets.

CHAPTER 3

CONETIONAL POWER GRID VS SMART GRID

A good electric grid is a complete interconnected network with regard to delivering electric power through electric collection also called transmission line from generation station to finish customer. Electric grid also consists of transformer (step-up, step-down, energy transformer, present transformer etc), blend, signal breaker, exchange and so on. Within electrical grid, you will find 3 primary components specifically the actual era train station, the actual transmission line and also the submission program. A distribution system connects all of the clients in order to transmission line. The transmission lines are the connecting link between the generation stations to distribution system. Within the transmission line, 2 transformers are utilized to voltage up and down. Because of a few specialized issue, difficult in order to higher voltage to decrease tranny deficits voltage is actually elevated the feasible degree through step-up transformer. Lastly, final stage associated with transmission line, voltage is actually downed the feasible degree through step down transformer and is supplied to distribution system is actually organized through feeder, the actual submission sub-station, submission transformer, illumination arrestor, and it is bidirectional as well as guide information selection program. Right now you want to expose up-to-date electric grid where all system tend to be managed through instantly through main through digital program referred to as "The Wise Grid Technology". The smart grid technology is actually development associated with conventional electric grid system. With this program mainsupport collection and so on. With this grid system, there's small automation program exactly where just about all security products tend to be electro- mechanised that safeguard the actual grid outlines as well as gear throughout unwanted situation, alter is going to be within accumulating information that feeling instantly by utilizing smart meter and communication technology is actually put into the grid to collect and analysis the data from smart meter and imposed sensor numerous stage in most grid system. The primary perform associated with the smart grid technology is actually just about all information associated with finish make use of as well as all grid system provides even any fault condition in order to middle stage through instantly which program is ready prevent the fault. With this section all of us demonstrated fundamental intro as well as features associated with traditional grid as well as wise grid, assessment in between wise grid as well as traditional grid. Additionally all of us demonstrated the reason why wise grid is essential.

3.1Definition of conventional electric power grid

An **electrical grid** is an interconnected network for delivering electricity from producers to consumers. It consists of

- Generating stations that produce electrical power
- high voltage transmission lines that carry power from distant sources to demand centers
- Distribution lines that connect individual customers. Power stations may be located near a fuel source, at a dam site (to take advantage of renewable energy sources), and are often located away from heavily populated areas. The electric power which is generated is stepped up to a higher voltage at which it connects to the electric power transmission net.

The bulk power transmission network will move the power long distances, sometimes across international boundaries, until it reaches its wholesale customer (usually the company that owns the local electric power distribution network).

On arrival at a substation, the power will be stepped down from a transmission level voltage to a distribution level voltage. As it exits the substation, it enters the distribution wiring. Finally, upon arrival at the service location, the power is stepped down again from the distribution voltage to the required service voltage(s).

Electrical grids vary in size from covering a single building through *national grids* which cover whole countries, to *transnational grids* which can cross continents.

3.2 Introduction of Conventional electric power grids

The power grid system is the Electrical utility distribution system which provides power to the consumer (end-user.) Beginning at the Power Generation Plant continuing on through the transmission lines to the substation and local distribution network, finally to the individual consumer. Power grids are smaller distinct sections of this system which together make up the entire distribution network Operationally the conventional electrical grid starts at power generating systems such as power stations that generate 3 phase alternating current (AC) electricity. The 3 phase AC current is passed through a transmission substation that uses transformers to step up (increase) the voltage from thousands of volts to hundreds of thousands of volts. Increasing the voltage allows for efficient transmission of electricity over long distances. After being converted to high voltage, the 3 phase electricity is sent overlong-distance tranny outlines via 3 outlines, 1 for every stage. Prior to it may be distributed to finish customers, the electricity must pass through a power substation that steps down (decreases) the actual voltage along with transformers in order that it could be distributed in order to towns as well as utilized in houses as well as companies in the proper voltage.

The 3 stage present can be used simply because electrical power is actually produced inside a sine influx which has highs as well as troughs, and therefore power power for any solitary stage vary in between less strong as well as more powerful times. Through producing three phases as well as offsetting all of them through 120 levels, as soon as associated with peak power is actually equally distributed between your three phases, permitting much more constant peak power output. Getting constant peak power output is essential primarily with regard to commercial reasons, at the. grams., commercial 3 stage engines. Alternating current can be used since it is simpler to alter voltages by using it compared to along with DC, along with a very high voltage is actually basic in order to long-distance electrical transmission since it decreases energy loss through decreasing opposition within the cables. Today's electrical national infrastructure is actually made up of the complicated program associated with power era, tranny techniques, as well as submission techniques

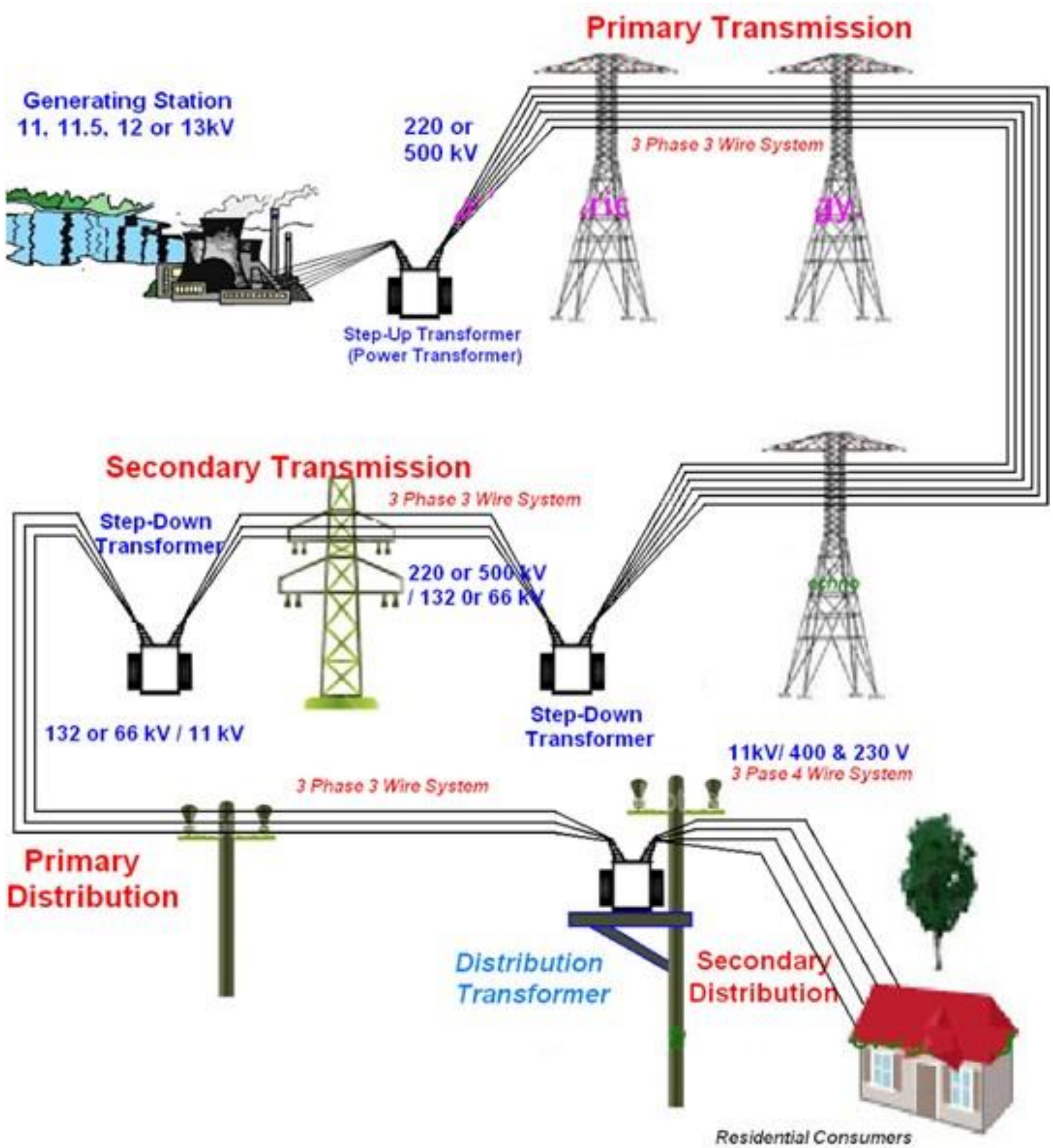


Figure3.1 : Conventional electric grid

. The actual main aspects of this technique consist of.

Power generation plants, which are facilities designed to produce electric energy. Typical power generation plants are fueled by coal, natural gas, hydroelectric, or nuclear.

A substation, is a high-voltage electric system facility. It is used to switch generators, equipment, and circuits or lines in and out of a system. Some substations are small with little more than a transformer and associated switches. Others are very large with several transformers and dozens of switches and other equipment.

Transmission lines, which can be hung overhead or underground, carry electric energy from one point to another in an electric power system. The main characteristics that distinguish transmission lines from distribution lines are that they are operated at relatively high voltages, they transmit large quantities of power, and they transmit the power over large distances

A distribution system originates at a distribution substation and includes the lines, poles, transformers and other equipment needed to deliver electric power to the customer at the required voltages.

3.3The Grid Challenges Faced in Running

- Gap in generation & demand during summer peak.
- Less diversification in generation and high dependency on limited natural gas (small hydro generation).
- No automatic frequency control mechanism (Primary & Secondary Control, (frequency varies from 49-51 Hz).
- Fragile distribution system (absence of distribution SCADA)

- Inadequate NLDC's SCADA/EMS control over Power Plants.
- Many small generating units (IC engine & costy oil based) connected with transmission network (hampers reliability)
- Large fluctuating loads (arc furnaces) connected to grid
- The Electricity Grid Code is not followed & practiced by all users
- Insufficient R&D and Manpower Development.

3.4 Initiatives to be undertaken to face the challenge

i. More base loaded plants (running on coal/LNG/NUKE) under implementation & planning stages.
ii. More interconnected systems (cross boarder electricity) with neighboring countries under progress and planning stages.
iii. Primary & Secondary Frequency control mechanism has to be established to stabilize system frequency
iv. Rectification of (qualitative) distribution network, especially in urban area (more control & visibility)
v. Connection of distributed generators (small units) & large fluctuating loads in proper manner.
vi. Introducing new technologies i.e WAMS, FACTs, PMU, SVC, ESS etc
vii. Improvements in rules & regulations.
viii. More R&D facilities developments of Test Bed for Smart Grid & New & renewable Energy growth.
ix. Manpower development for power industry

3.5Concept of Smart grid

Smart Grid is developed by the European Technology Platform for 7th Frame Work Program. Since Smart Grid is still in research stage, there is no coincidence with the accurate definition for it, what features should it have, what goal should it achieve, what is the important point for develop it. Moreover considering the varying situations in different countries-economic development, developing strategies and policies, it is hard to obtain a unified definition.

A modernization of the Nation electricity transmission and distribution system is to maintain a reliable and secure electricity infrastructure that can meet future demand growth.
The smart grid technology has:

- Advanced metering infrastructure (AMI)
- Flexible AC transmission system (FACTS)
- Distribution automation (DA)
- Distributed generation (DG)
- Substation automation (SA)
- Demand response (DR)

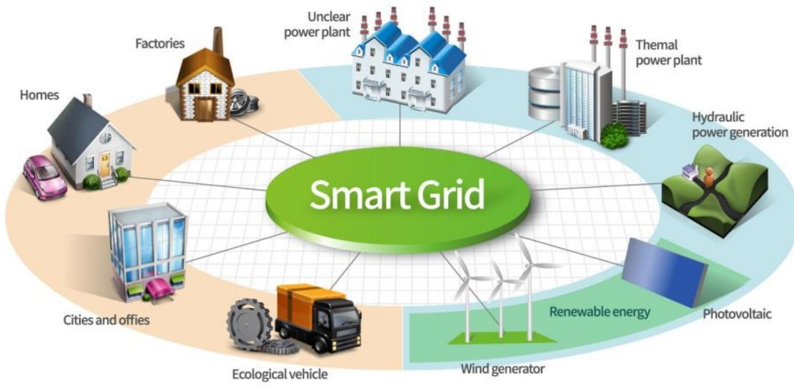


Fig:3.2Schematic diagram of smart grid

3.6Smart Grid challenges

Technical challenges

The smart grid is at a nascent stage of development. As such there are numerous technical challenges to be overcome.

1. Merging planning and real-time analysis
2. Very large system models
3. Handling a large amount of AMI data
4. AMI-based decision making
5. Time series simulation
6. DG integration and protection
7. Cheap energy storage technology

In addition to the over, with regard to efficient interoperability of smart grid devices, strong requirements have to be created. In addition, with an increase of opportunities within the smart grid sector, numerous wise grid systems happen to be becoming put in place within the energy grid. Within the lack of common requirements, these types of systems encounter the risk to become too early outdated or even encounter it's protection becoming jeopardized. Elevated reliance on dispersed era, need aspect assets as well as submission program programs considerably boost the systems' contact with cyber susceptability. The whole protection structures could be constructed upon current conversation as well astechnologies infrastructures, additional joining this using the electrical grid make it possible for the actual Wise Grid execution from numerous amounts within the electric power system. In addition, the strong construction with regard to conformity screening as well as accreditation of smart grid devices as well as techniques have to be set up to make sure interoperability as well as cyber protection.

Business & Financial challenges

The company situation for any wise grid must be set up with regard to effectively implementing the smart grid plans within real life. Within it's the majority of common conditions, a company situation offers the fundamental reason with regard to expense within tasks with regard to company alter. Within the wise grid industry, the actual organizations considering creating company instances tend to be mainly system providers and perhaps electrical power merchants as well as recently rising gamers for example era as well as need aggregators. The initial capital cost of a full-fledged smart grid deployment will be considerably higher as well as justifying this along with site-proven advantages may be the greatest company problem dealing with the actual power business. In addition, ındividuals are suspicious concerning the price advantages of this expense since the price benefits appear to be small when compared to expense created. Additionally, in the macro plan degree, the ability business must satisfy the needs associated with resource-saving as well as environment-friendly culture, adjust to environment alter as well as verify along with environmentally friendly atmosphere. Additional, discussing the price of typical national infrastructure over the advantages based on numerous programs will give you a far more practical price or advantage percentage for every software within an incorporated program with regard to complete move away past the actual initial phase. Along with a lot opportunities put in the actual wise grid situation, it is necessary for that resources to recuperate their own expense expenses. Mostly smart grid is associated along with expenses cost savings in the customer finish, however it's also essential to notice which on the wider viewpoint wise grids can result in possible cost savings through growing the actual dependability from the energy grid. For instance, using the execution associated with wide-area dimension systems (WAMS) as well as phasor dimension models (PMUs), the actual 2003 excellent northeast blackout might have been prevented preserving the actual Ough. Utes. a good around $10 Million within financial damage. Finally, there's a have to tackle customer issues concerning plug-in crossbreed electrical automobiles (PHEVs) in terms associated with prices, expenses advantages, specialized specs as well as dependability. The actual connect within crossbreed automobiles that will perform an essential part within long term wise grid systems are very expensive and considered as a luxury rather than method to cut costs as well as decrease co2 emissions. At the moment, the price of transforming the crossbreed automobile to some connect within crossbreed electrical automobile is actually higher as well as there's hardly any national infrastructure as getting national infrastructure to aid this particular brand new technologies. Additionally, PHEV's possess nevertheless not really acquired common popularity like a factor in order to decreased green house gasoline emissions, because the fossil energy bottom fill vegetation would be the types running these types of automobiles. All these issues in the PHEV sector need to become solved to attain common popularity associated with it's technology and thus economic as well as environment advantages.

Regulation challenges

Along with opportunities with regard to smart grid deployment as sophisticated metering national infrastructure believed to become close to $27 Million, and also the Brattle Group's evaluation associated with close to$1. 5 Trillion in order to revise the actual grid through 2030 (Chupka et ing. 2008) it's apparent how the price element and also the legislation allowing the actual recuperation associated with this kind of opportunities would be the greatest problems the actual smart grid motion encounters. Although the Smart grid is actually seen as an assortment of systems which allow a completely brand new method of working power systems, the actual resources as well as government bodies frequently notice because an accumulation of brand new types of transmission and distribution investments, every containing not familiar services as well as support channels. The actual resources, government bodies, along with other stakeholders will need to assess these types of opportunities through calculating their own worth in order to clients, their own effect on power prices, as well as exactly how clients as well as machines that make use of the brand new abilities tend to be billed for his or her make use of. These days, with an increase of anticipation in the smart grid, regulating companies encounter the amazing job of creating certain the actual investements produced in this particular field don't show useless. Having a restricted expertise swimming pool with this field as well as growing requirement of recruiting, the actual government bodies have to occupy this particular problem along with dedication as well as determination in order to change the present grid right into a smart grid. Smart grid indicates "computerizing" the electric utility grid which include including two-method digital communication technology in order to products linked to the grid. Every gadget utilized on the actual system could be provided devices to collect information (power yards, voltage devices, problem sensors, and so on.), in addition two-way digital communication between your gadget within the area (e. grams., consumer, substation, tranny, distribution) and also the utility's system procedures middle. A vital function from the smart grid is actually automation technologies which allows the actual power change as well as manage every individual gadget or even an incredible number of products from the main area. Because described through the primary features, OE has a vision of a smart grid that uses electronic technologies to enhance dependability, resiliency, versatility, as well as effectiveness (both financial as well as energy) from the electrical shipping program. Smart grid technologies is definitely an development associated with following 10 years energy program not really trend therefore current electrical grid may nevertheless as well however, many sophisticated technologies, elements is actually put into this as well as shamelessly include just about allfeasible energy source. With this section all of us demonstrated obvious idea regarding "Smart Grid Technology" through determining smart grid, conceptual type of smart grid technologies, technologies utilized, perform associated with smart grid technologies.

Though a clear and concise definition of the Smart Grid is still evolving, there are several characteristics that remain common to many smart grid architectures. These characteristics clearly define the Smart Grid's potential benefits to the overall electric power system. They are:

- Anticipates and responds to system disturbances in a self-healing manner
- Incorporates information and communication technologies into every aspect of electrical generation, delivery and consumption in order to
    - Minimize environmental impacts
    - Enhance markets
    - Improve reliability and service
    - Reduce costs and improve efficiency

Comparison between Smart grid and Conventional Grid

Table: 3.1 Comparison between conventional grid and smart grid

Method	Generation	power Generation
Self-heals	Responds to prevent further damage.	Automatically detects and responds to actual and emerging transmission and distribution Problems
Operation and Management	Artificial device calibration	Remote Monitoring
System topology	Radial structure	Network structure
Control system	Regional	Pan-regional
Motivates & includes the consumer	Consumers are uninformed and no participative with the power system	Informed, involved and active consumers.

Provides power quality for 21st century needs	Focused on outages rather than power quality problems.	Quality of power meets industry standards and consumer needs.
Accommodates all generation	Relatively small number of large generating plants.	Very large numbers of diverse distributed generation and plants. Storage devices deployed to complement the large generating
Enables markets	Limited wholesale markets still working to find the best operating models.	Mature wholesale market operations in place

- The smart grid further employs digital information, distribution automation and various control strategies to facilitate deployment and integration of
  - Distributed Energy Resources
  - Renewable energy generation
  - Automated systems
  - Energy Storage systems
  - Peak shaving technologies
- Accommodates all types of generation techniques and energy storage options
- Provides higher power quality required for the 21st century digital economy
- Operates effectively and optimizes the utilization of existing and new assets.
  Operates resiliently and effectively against attacks and natural disasters etc.

CHAPTER 4

The Smart Grid Technology

4.1 Definition of the Smart Grid Technology

When we are discussing about smart grid technology a question is what Smart Grid is?
Shortly we can say; Smart Grid = IT + Electric Grid
That means smart grid is nothing but the conventional grid with IT in order to achieve better reliability, flexibility, efficiency, resiliency and to give better service to end users.

The concept of Smart Grids was developed in 2006 by the European Technology Platform and they defined "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. A smart grid employs innovative products and services together with intelligent monitoring, control, communication, and self-healing technologies in order to:

1. Better facilitate the connection and operation of generators of all sizes and technologies;
2. Allow consumers to play a part in optimizing the operation of the system;
3. Provide consumers with greater information and options for choice of supply;
4. Significantly reduce the environmental impact of the whole electricity supply system;
5. Maintain or even improve the existing high levels of system reliability, quality and security of supply;
6. Maintain and improve the existing services efficiently;
7. Foster market integration towards an European integrated market.

According to the U.S Department of Energy (DoE):

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

According to U.S Department of Energy (DoE) the Functional Characteristics of smart grid are:

1. Self-healing from power disturbance events.
2. Enabling active participation by consumers in demand response.
3. Operating resiliently against physical and cyber attack.
4. Providing power quality for 21st century needs.
5. Accommodating all generation and storage options.
6. Enabling new products, services, and markets.
7. Optimizing assets and operating efficiently.

4.2 Working Principle of Smart Grid Technology

Along with traditional utility technology, whenever a sapling arm or leg drops on the power line as well as produces a good outage or perhaps a fault occurs upon distribution line or customer aspect that's the reason why produces a good outage, for instance, the actual power discovers only if the customer calls to complain. Having a smart grid system, products across the system may instantly inform the actual power precisely whenever as well as exactly where a good outage happened, close the circuit from which area, in order to "island" the fault, re-route power around unsuccessful gear as well as produce a comprehensive "trouble ticket" for any restore team. Typically, electric utilities estimation that the particular kind of gear will probably need replacing following a lot of many years and therefore replaces each and every bit of which technology inside that lots of many years -- actually products which have a lot more useful life remaining inside them. The smart grid system may place faltering grid devices prior to they provide away, allowing the actual power make use of an infinitely more cost effective replacement strategy. Whenever clients receive use of information regarding their very own energy make use of, they are able to alter their own routines to become much more efficient and save money. Clients may ultimately have the ability to observe how the buying price of electrical power modifications with respect to the time it's utilized, plus they can change their own utilization of the merchandise in order to occasions when it's less expensive.

The largest financial savings within utilizing smart grid might be present in enhanced effectiveness associated with electricity-delivery operations. For instance, when the voltage is famous as well as up-to-date often throughout the utility's grid, the actual power can function a lot more effectively. Instead of delivering additional voltage to the grid to pay for feasible dips someplace upon which grid, voltage drops could be recognized as well as tackled remotely. This type of immediatereaction allows the actual power give you the minimal quantity of voltage required for smooth operations. Resources screening this particular advantage within real life tend to be confirming large financial savings nearly instantly.

4.3 Why Implement the Smart Grid now?

The actual electrical power techniques throughout globe in addition to Bangladesh encounter numerous problems such as aging national infrastructure, ongoing development sought after, the actual integration associated with more and more adjustable green power resources as well as electrical automobiles, the requirement to enhance the protection associated with provide as well as the requirement to reduce co2 emissions.

Smart grid systems provide methods not only to satisfy these types of problems but additionally to build up the solution power provide that's much more power effective, less expensive and much more environmentally friendly.

The actual smart grid ought to be put in place to attain subsequent duties as well as benefits: Growing dependability, effectiveness as well as security from the energy grid. Allowing decentralized energy era therefore houses could be each a power customer as well as provider

Versatility associated with energy usage in the client’s aspect to permit provider choice (distributed era, photo voltaic, blowing wind, as well as biomass) Improve GROSS DOMESTIC PRODUCT through making much more brand new, eco-friendly training collar power work associated with green power business production, Allowing plug-in electrical automobiles, cell, as well as wind generator era, power preservation as well as building.

Provide higher amounts of home elevators electrical power prices as well as usage in order to customers, that will provide them with higher manage more than their own usage as well as assist all of them decrease their own expenses.

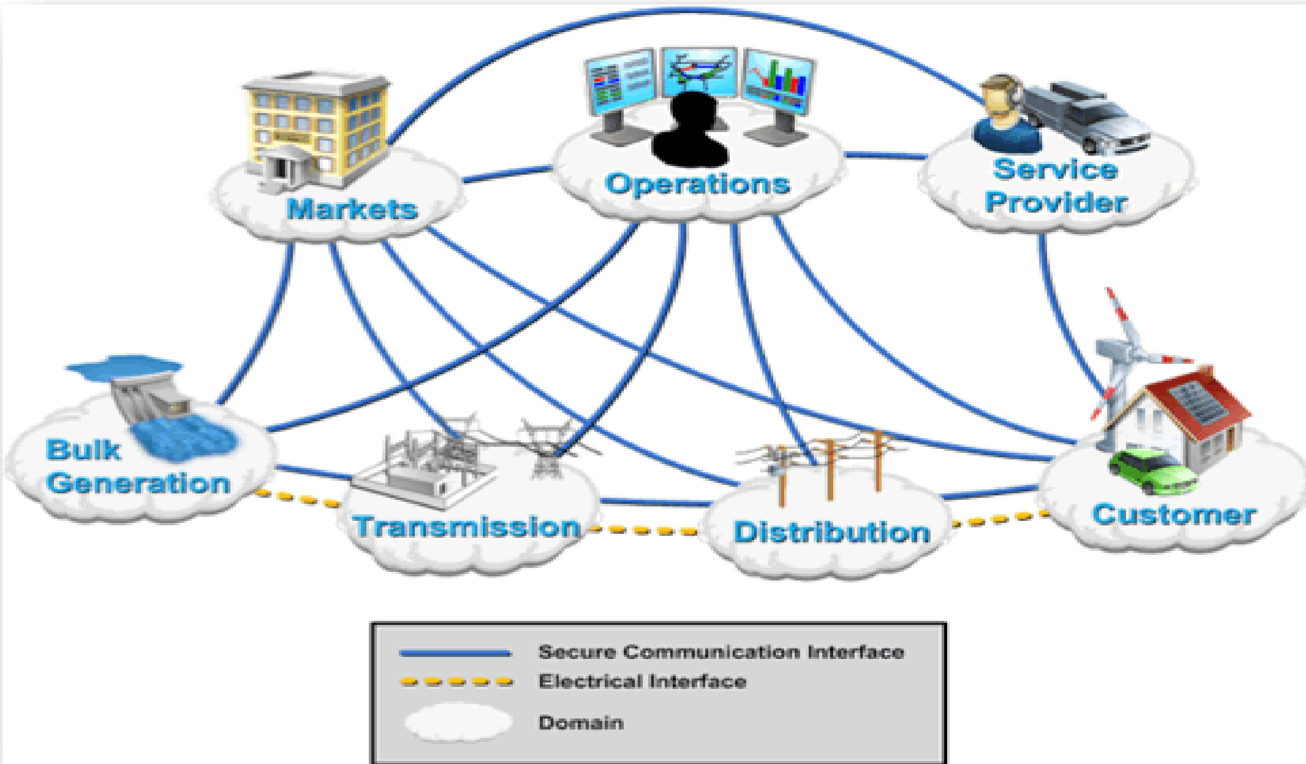


Figure: 4.1 Conceptual model of Smart Grid Technology in NIST

4.4 Smart Grid Conceptual model

Under the Energy Independence and Security Act (EISA) of 2007, the National Institute of Standards and Technology (NIST) create framework using a systems approach to be flexible, uniform and technology-neutral, because no single technology developed will be able to satisfy all requirements for the smart grid. By building a framework based on possible application scenarios a robust model develops, the first release, a high-level conceptual reference model for the Smart Grid.

The NIST Conceptual Reference Model is descriptive, and is intended to be high level. The NIST conceptual Model can serve as a tool for identifying actors and possible communication paths in the Smart Grid. The figure below provides a high level grouping of what NIST has deemed as the smart grid domain. The seven Domains in the Smart Grid Conceptual Model include:

- Bulk generation
- Transmission
- Distribution
- Customers
- Markets
- Service providers and
- Operations

It shows all the communications and energy/electricity flows connecting each domain and how they are interrelated. Each individual domain is itself comprised of important smart grid elements that are connected to each other through two-way communications and energy/electricity paths. These connections are the basis of the future, intelligent and dynamic power electricity grid.

The NIST Smart Grid Conceptual Model helps us to understand the building blocks of an end-to-end smart grid system, from Generation to (and from) Customers, and explores the interrelation between these smart grid segments.

At IEEE, the smart grid is seen as a large "System of Systems," where each NIST smart grid domain is expanded into three smart grid foundational layers: (i) the Power and Energy Layer, (ii) the Communication Layer and (iii) the IT/Computer Layer. Layers (ii) and (iii) are enabling infrastructure platforms of the Power and Energy Layer that makes the grid "smarter."

Bulk Generation:

Applications in the Bulk Generation domain are typically the first process in the delivery of electricity to customers. Electricity generation is the process of creating electricity from other forms of energy, which may vary from chemical combustion to nuclear fission, flowing water, wind, solar radiation and geothermal heat.

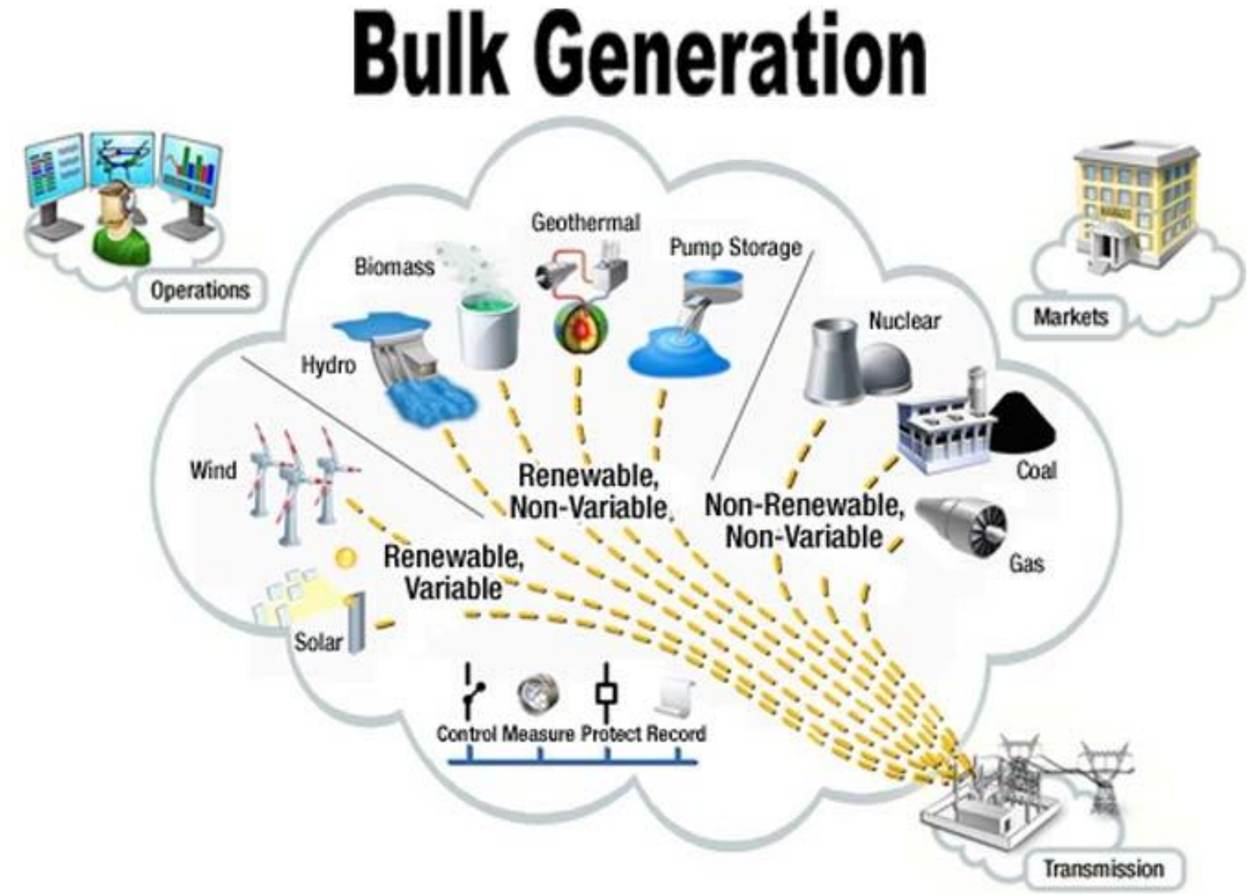


Figure: 4.2 Bulk Generation Domain (Conceptual Model of Smart Grid Technology)

The Bulk Generation domain of the smart grid generates electricity from renewable and non-renewable energy sources in bulk quantities. These sources can also be classified as renewable, variable sources, such as solar and wind; renewable, non- variable, such as hydro, biomass, geothermal and pump storage; or non-renewable, non-variable, such as nuclear, coal and gas. Energy that is stored for later distribution may also be included in this domain.

Table 4.1 Typical Applications in the Bulk Generation Domain

Application Category	Description

Control	Performed by actors that permit the Operations domain to manage the flow of power and reliability of the system. An example is the use of phase angle regulators within a substation to control power flow between two adjacent power systems
Measure	Performed by actors that provide visibility into the flow of
	power and the condition of the systems in the field. In the future, measurement might be found built into meters, transformers, feeders, switches and other devices in the grid. An example is the digital and analog measurements collected through the SCADA system from a remote terminal unit (RTU) and provide to a grid control center in the Operations domain.
Protect	Performed by Actors that react rapidly to faults and other events in the system that might cause power outages, brownouts, or the destruction of equipment. Performed to maintain high levels of reliability and power quality. May work locally or on a wide scale.
Record	Performed by actors that permit other domains to review what has happened on the grid for financial, engineering, operational, and forecasting purposes.
Asset Management	Management performed by actors that work together to determine when equipment should have maintenance, calculate the life expectancy of the device, and record its history of operations and maintenance so it can be reviewed in the future for operational and engineering decisions.

The Bulk Generation domain is electrically connected to the Transmission domains as well as communicating with the Operations and the Markets domain. Some benefits to the Bulk Generation domain from the deployment of the smart grid are the ability to automatically reroute power flow from other parts of the grid when generators fail.

Transmission:

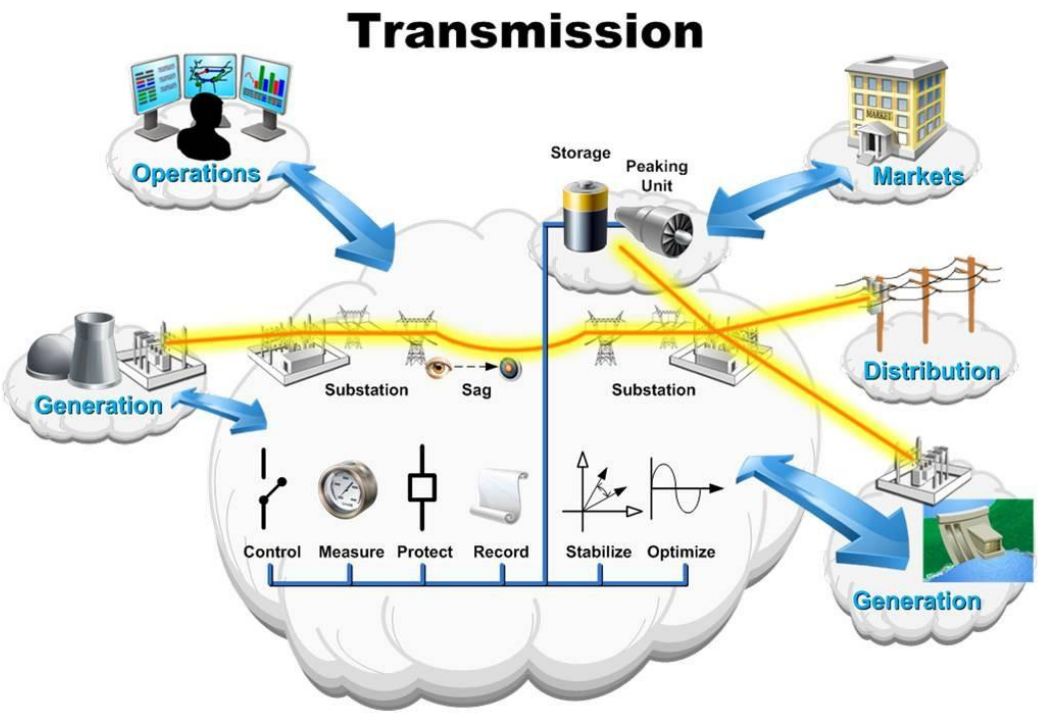


Figure: 4.3 Transmission Domains (Conceptual Model)

Transmission may be the mass move associated with electrical energy through era resources in order to submission via several substations. The actual Transmission domain is actually electrically attached to the majority Era as well as Distribution domains, in addition to interacting using the Procedures, as well as Markets domain names. The transmission network is usually run with a Local Transmission Operator or even Impartial Program Operator (RTO/ISO) in whose primary responsibility would be to preserve balance about the electric grid through managing generation (supply) with load (demand) over the transmission network. The actual Transmission domain might include distributed energy assets for example electric storage space or even peaking generation units. Energy and supporting supplementary providers (capacity that may be sent whenever needed) tend to be acquired with the Markets site as well as planned as well as run in the Operations domain. They're after that shipped with the Transmission domain towards the utility-controlled submission program last but not least in order to customers. Stars within the transmission domain can sometimes include remote control fatal models, substation meters, protection relays, power quality monitors, phasor measurement units, sag screens, fault recorders, as well as substation person interfaces.

Table 4.2 Typical application of Transmission domain

Application Category	Description
Substation	The systems within a substation.
Storage	A system that controls the charging and discharging of an energy storage unit
Measurement &	Includes all types of measurement and control systems to

Distribution:

The actual Distribution domain is electrically connected between your Transmission domain and the Customer domain in the metering factors with regard to consumption. The actual Distribution domain additionally communicates using the Operations and Markets domains. The actual Distribution domain distributes the electricity in order to as well as in the finish customers in the smart grid. The actual distribution network links the actual smart meters as well as just about all smart area products, controlling as well as managing all of them via a two-way cellular or even wireline communications network. Stars within the transmission domain can sometimes include remote control fatal models, substation meters, protection relays, power quality monitors, phasor measurement units, sag monitors, fault recorders, as well as substation person interfaces.

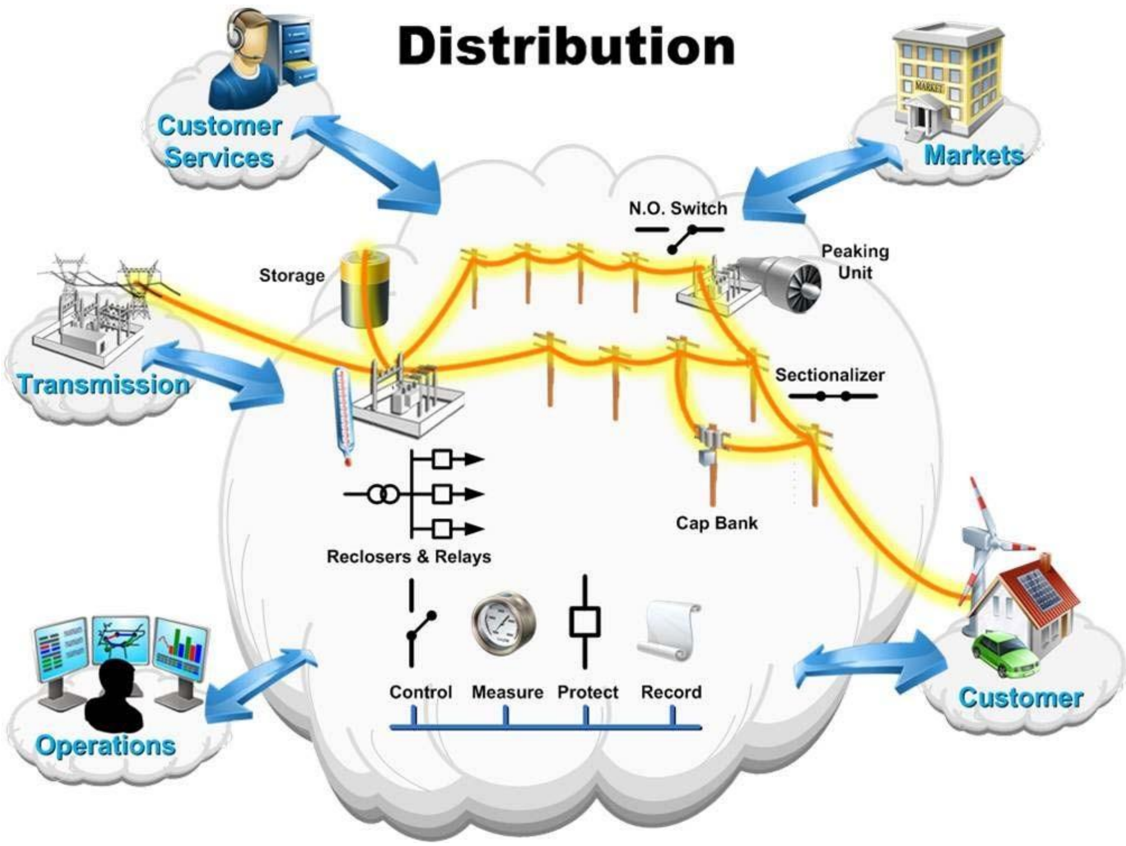


Figure: 4.4 Distribution Domain (Conceptual Model)

The Distribution domain is electrically connected between the Transmission domain and the Customer domain at the metering points for consumption.

The Distribution domain also communicates with the Operations and Markets domains. The Distribution domain distributes the electricity to and from the end customers in the smart grid. The distribution network connects the smart meters and all intelligent field devices, managing and controlling them through a two-way wireless or wire line communications network.

Table 4.3 Typical Applications within the Distribution Domain

Application Category	Description
Substation	The control and monitoring systems within a substation.
Storage	A system that controls a charging and discharging of an energy storage unit
Distributed Generation	A power source located on the distribution side of the grid.
Measurement & Control	Includes all types of measurement and control systems to measure, record, and control with the intent of protecting and optimizing grid operation.

Customer:

The actual Customer domain is actually electrically connected towards the Distribution domain. This communicates using the Distribution, Operations, Markets, as well as Service Provider domains. the Distribution, Operations, Markets, as well as Service Provider domains. Stars within the Customer domain usually allow customers to handle their own energy usage and generation. These types of stars offer manage as well as info circulation between your Customer and also the additional domain names.

The actual limitations from the Customer domain are usually regarded as the actual utility meter and/or one more communication entrance towards the power in the office space. The actual Customer domain from the smart grid is actually in which the end-users associated with electricity tend to be attached to the actual electric distribution network with the smart meters.

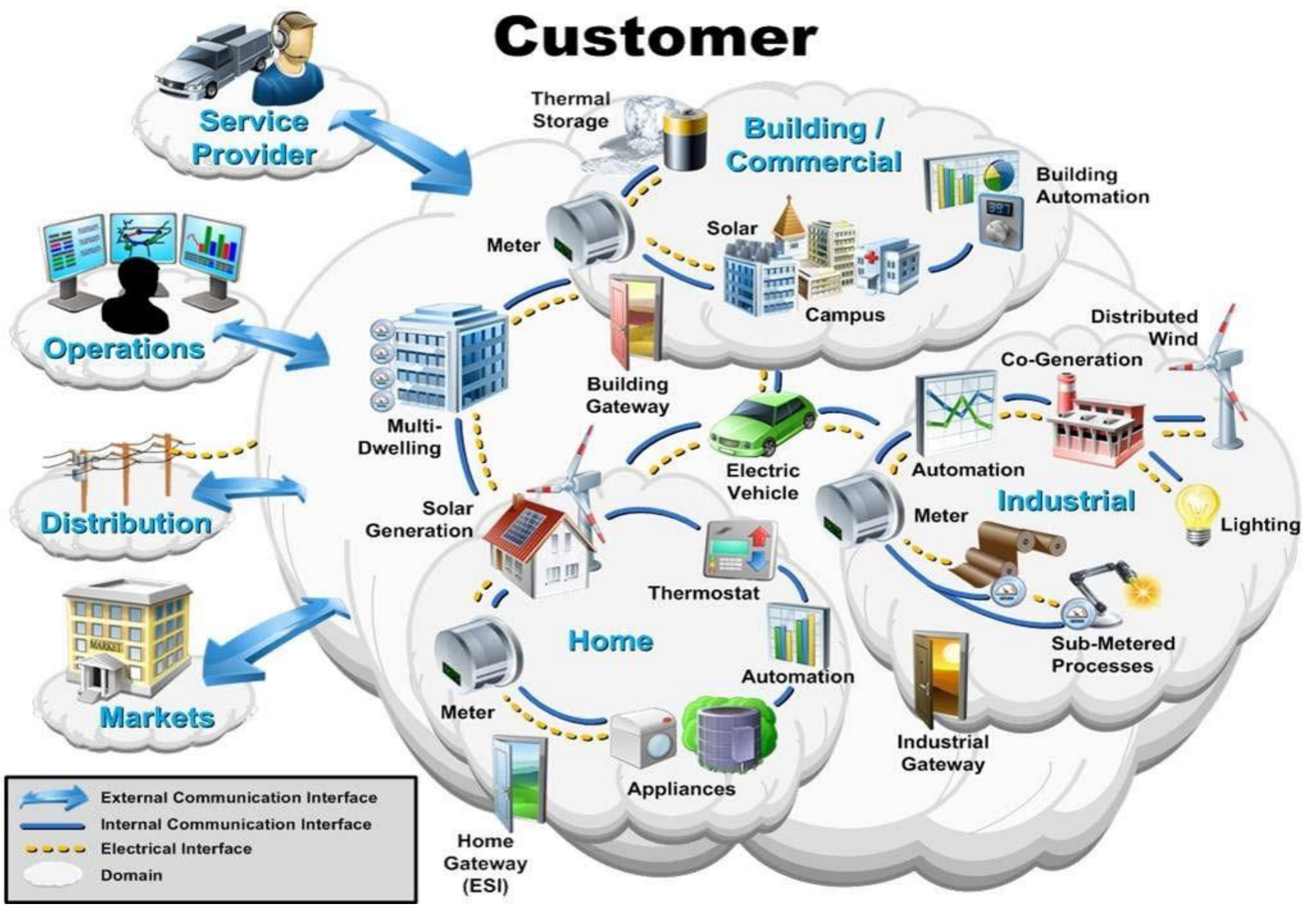


Figure: 4.5 Customer (Conceptual Model of Smart Grid Technology)

The actual smart meters manage as well as handle the actual circulation associated with electricity Stars within the Customer domain usually allow customers to handle their own energy usage and generation. These types of stars offer manage as well as info circulation between your Customer and also the additional domain names. The actual limitations from the Customer domain are usually regarded as the actual utility meter and/or one more communication entrance towards the power in the office space. The actual Customer domain from the smart grid is actually in which the end-users associated with electricity tend to be attached to the actual electric distribution network with the smart meters. The actual smart meters manage as well as handle the actual circulation associated with electricity.The limits of these domains are typically set at less than 20kW of demand for Home, 20-200kW for Commercial/Building, and over

200kW for Industrial. The electric vehicle is an example of an actor that interfaces with all three domains.

All three domains (industrial, commercial and residential) have a meter actor and a gateway that may reside in the meter or may be an independent actor. The gateway is the primary communications interface to the Customer domains. It may communicate with other domains via Advanced Metering Interface (AMI) or another method such as the Internet. It typically communicates to devices within the customer premises using a home area network or other local area network. The gateway enables applications such as remote load control, monitoring and control of distributed generation, in-home display of customer usage, reading of non-energy meters, and integration with building management systems. It may also provide auditing/logging for security purposes.

Table 4.4 Typical Application Categories in the Customer Domain

Application Category	Description
Building or Home Automation	A system that is capable of controlling various functions within a building such as lighting and temperature control.
Industrial Automation	A system that controls industrial processes such as manufacturing or warehousing. These systems have very different requirements compared to home and building systems.
Micro-generation	Includes all types of distributed generation including; Solar, Wind, and Hydro generators. Generation harnesses energy for electricity at a customer location. May be monitored, dispatched, or controlled via communications.

Operation:

Stars within the Operations domain carry out the actual continuing administration features essential for the actual sleek procedure from the power system. Whilst nearly all these types of features are usually the duty of the controlled power, most of them might be outsourced in order to service providers plus some might develop with time. For example, it's quite common with regard to some customer support features in order to participate the actual Company site or even Markets domains.

The normal programs carried out inside the Operations domain can sometimes include: network operation, network operation monitoring, network control, fault management, operation feedback analysis, functional data as well as confirming, real-time network calculation, dispatcher instruction.

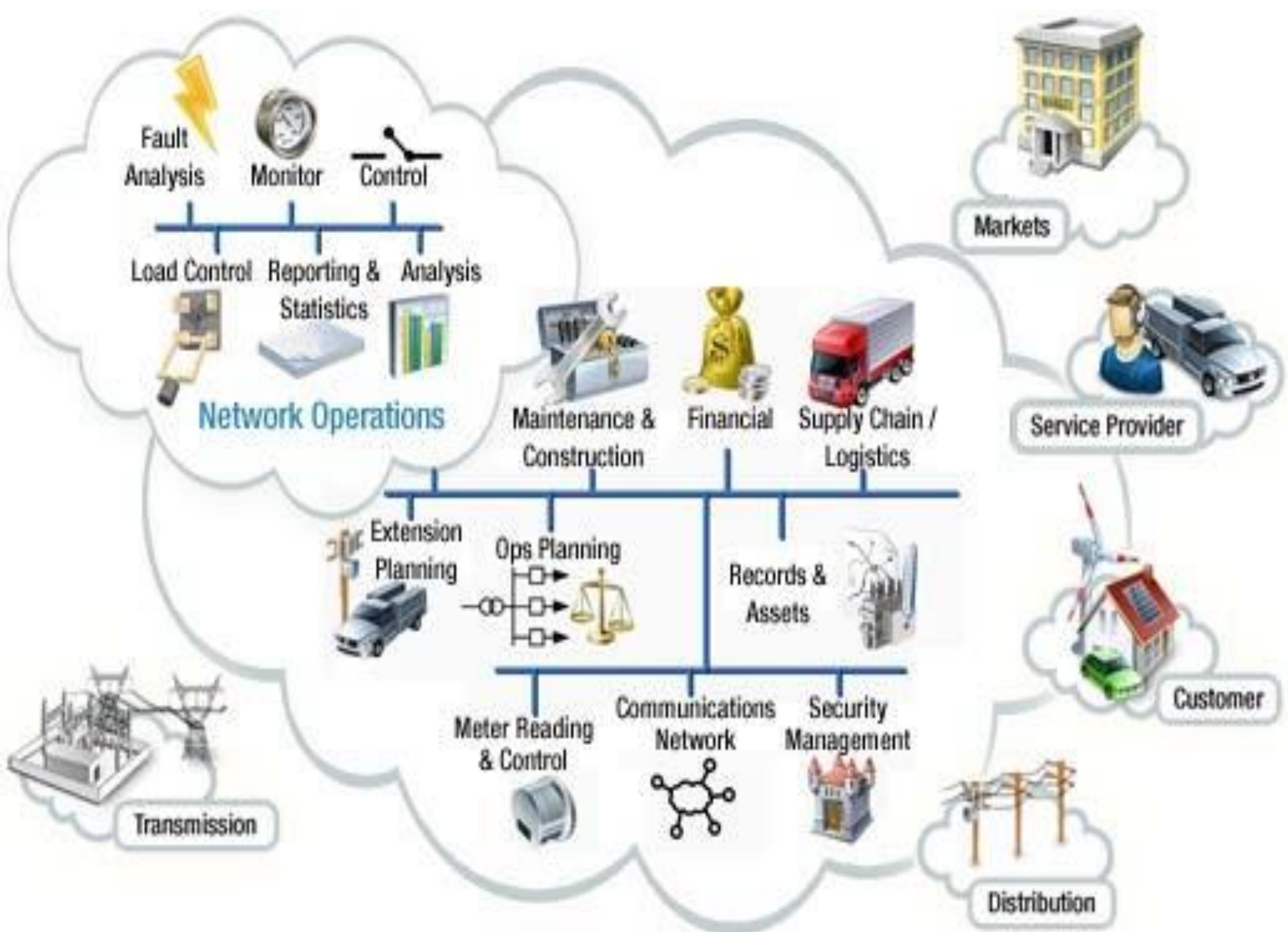


Figure: 4.6 Operation (Conceptual Model of Smart Grid Technology)

Table 4.5 Typical Applications in the Operations Domain.

Application Category	Description
Monitoring	Network Operation Monitoring actors supervise network topology, connectivity and loading conditions, including breaker and switch states, and control equipment status. They locate customer telephone complaints and field crews.
Control	Network control is coordinated by actors in this domain, although they may only supervise wide area, substation, and local automatic or manual control.
Fault Management	Fault Management actors enhance the speed at which faults can be located, identified, and sectionalized and service can be restored. They provide information for customers, coordinate with workforce dispatch and compile information for statistics.
Analysis	Operation Feedback Analysis actors compare records taken from real-time operation related with information on network incidents, connectivity and loading to optimize periodic maintenance.
Reporting an Statistics	Operational Statistics and Reporting actors archive on-line data and perform feedback analysis about system efficiency and reliability.
Calculations	Real-time Network Calculations actors (not shown) provide system operators with the ability to assess the reliability and security of the power system.

Training	Dispatcher Training actors provide facilities for dispatchers that simulate the actual system they will be using (not shown in Figure 9-5).
Records and Assets	The Records and Asset Management actors track and report on the substation and network equipment inventory, provide geospatial data and geographic displays, maintain records on non-electrical assets, and perform asset investment planning.
Operation Planning	Operational Planning and Optimization actors perform simulation of network operations, schedule switching actions, dispatch repair crews, inform affected customers, and schedule the importing of power. They keep the cost of imported power low through peak generation, switching, load shedding or demand response.
Maintenance and Construction	Maintenance and Construction actors coordinate inspection, cleaning and adjustment of equipment, organize construction and design, dispatch and schedule maintenance and construction work, and capture records gathered by field to view necessary information to perform their tasks.
Extension Planning	Network Extension planning actors develop long term plans for power system reliability, monitor the cost, performance and schedule of construction, and define projects to extend the network such as new lines, feeders or switchgear.

Customer Support	Customer Support actors help customers to purchase, provision, install and troubleshoot power system services, and relay and record customer trouble reports.

Market:

Actors in the Markets domain typically perform pricing or balance supply and demand within the power system. The boundaries of the Markets domain are typically considered to be at the edge of the Operations domain where control happens, and at the domains containing physical assets (e.g. generation, transmission, etc).

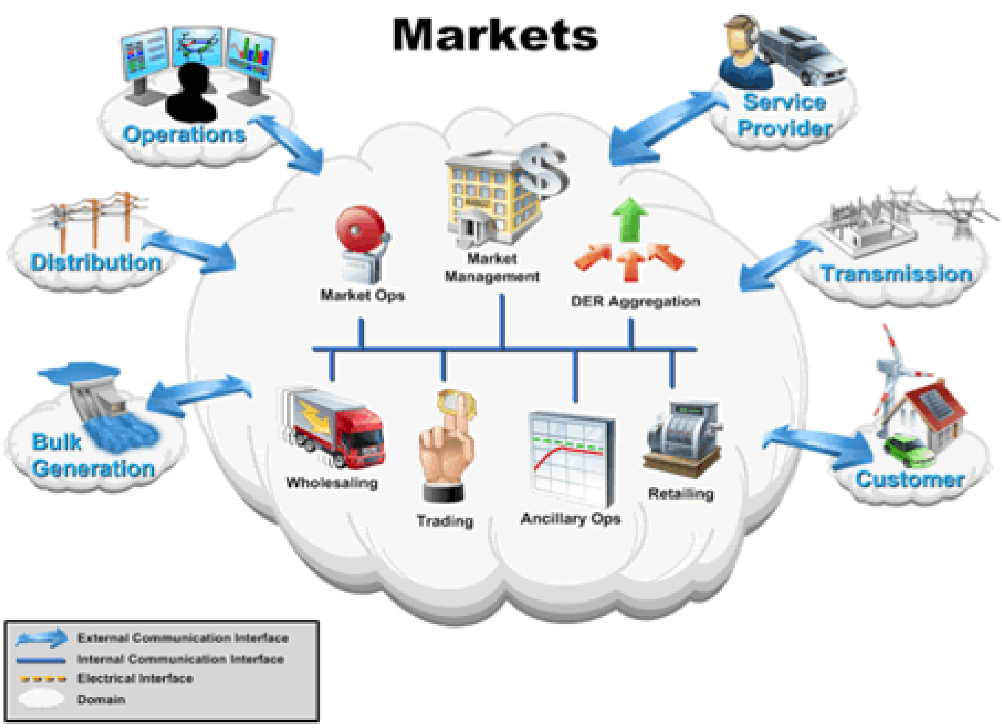


Figure: 4.7 Market (Conceptual Model of Smart grid Technology)

The interfaces between the Markets domain and those domains containing generation are most critical because efficient matching of production with consumption relies on markets. Besides the Bulk Generation domain, electricity generation also takes place in the Transmission, Distribution, and Customer domains and is known as distributed energy resources (DER). NERC CIPs consider suppliers of more than 300 megawatts to be Bulk

Generation; most DER is smaller and is typically served through aggregators. DERs participate in markets to some extent today, and will participate to a greater extent as the smart grid becomes more interactive.

Table 4.6 Typical Applications in the Market Domain.

Application Category	Description
Market Management	Market managers include ISOs for wholesale markets or NYMEX/CME for forward markets in many ISO/RTO regions. There are transmission and services and demand response markets as well. Some DER Curtailment resources are treated today as dispatchable generation.
Retailing	Retailers sell power to end customers and may in the future aggregate or broker DER between customers or into the market. Most are connected to a trading organization to allow participation in the wholesale market.
DER Aggregation	Aggregators combine smaller participants (as providers or customers or curtailment) to enable distributed resources to play in the larger markets.
Trading	Traders are participants in markets, which include aggregators for provision and consumption and curtailment, and other qualified entities. There are a number of companies whose primary business is the buying and selling of energy.
Market Operations	Make a particular market function smoothly. Functions include financial and goods sold clearing, price quotation streams, audit, balancing, and more.
Ancillary Operations	Provide a market to provide frequency support, voltage support, spinning reserve and other ancillary services as defined by FERC, NERC and the various ISOs. These markets function on a regional or ISO basis normally.

Service Provider:

Actors in the Service Provider domain include the organizations providing services to electrical customers and utilities. That is, the actors in this domain typically perform a variety of functions that support the business processes of power system producers, distributors and customers. These business processes range from traditional core services such as billing and customer account management to enhanced customer services such as home energy generation and management. It is expected that service providers will create new and innovative services (and products) in response to market needs and requirements as the smart grid evolves. These emerging services represent an area of significant economic growth. Services may be performed by the electric service provider, by a third party on their behalf, or in support of new services outside of the current business models.

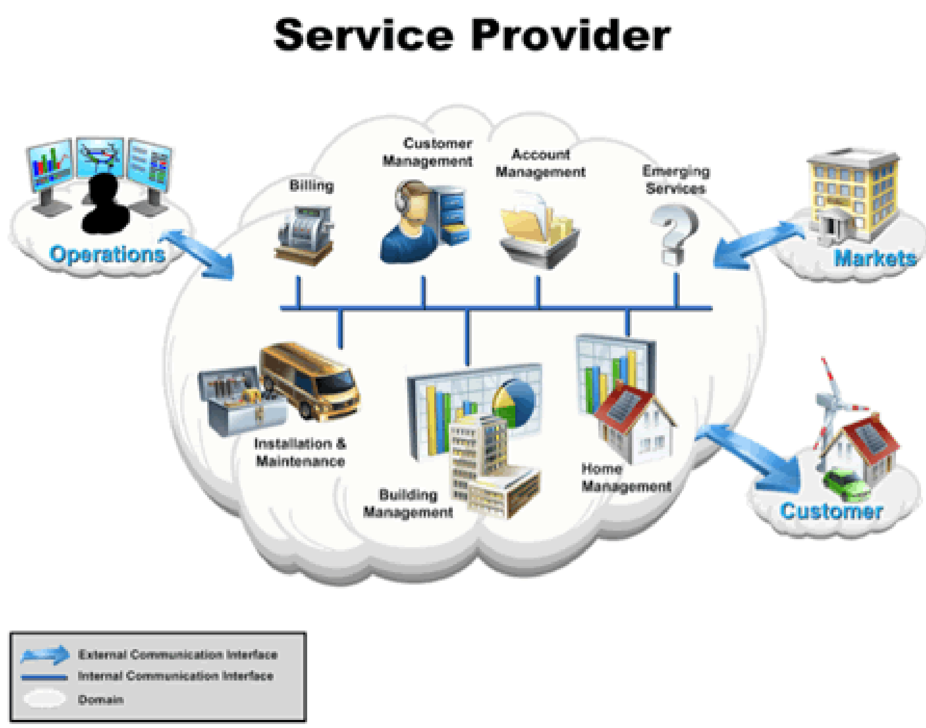


Figure: 4.8 Service Provider (Conceptual Model of Smart grid Technology)

The boundaries of the Service Provider domain are typically considered to be the power transmission and distribution network controlled by the Operations domain. Services provided must not compromise the security, reliability, stability, integrity and safety of the electrical power network.The Service Provider domain is typically electrically connected at the Customer domain. It communicates with the Markets, Operations and Customer domains. Of these, the interfaces to the Operations domain are critical for system control and situational awareness but the interfaces to the Markets and Customer domains are critical for enabling economic growth through the development of "smart" services. The Service Provider domain may, as an example, provide the "front-end" connection between the customer and the market(s).

Table 4.7 Typical Applications in the Service Provider Domain.

Application Category	Description
Customer Management	Managing customer relationships by providing point-of-contact and resolution for customer issues and problems.
Installation & Management	Installing and maintaining premises equipment that interacts with the Smart Grid.
Building Management	Monitoring and controlling building energy and responding to Smart Grid signals while minimizing impact on building occupants.
Home Management	Monitoring and controlling home energy and responding to Smart Grid signals while minimizing impact on home occupants.
Billing	Managing customer billing information, including sending billing statements and processing payments.
Account Management	Managing the supplier and customer business accounts.
Emerging Services	All of the services and innovations that have yet to be created. These will be instrumental in defining the Smart Grid of the future.

4.5Function of the Smart Grid Technology:

In leading a national transformation to a smarter grid, OE's first step was to define not only a vision for the future electric delivery system but also the functional characteristics. Beginning in 2005, OE convened seven regional workshops across the country, involving regulators, utilities, vendors, legislators, research institutions universities, and other stakeholders to forge a common vision and scope for the smart grid. This two-year effort resulted in identification of the principal smart grid functional characteristics that comprise the foundation of OE's smart grid program.

- Self-healing from power disturbance events
- Enabling active participation by consumers in demand response
- Operating resiliently against physical and cyber attack
- Providing power quality for 21st century needs
- Accommodating all generation and storage options
- Enabling new products, services, and markets
- Optimizing assets and operating efficiently

The smart grid uses technological advancements to achieve its principal goals, which are summarized below.

4.5.1Self-healing from power disturbance events:

A smart grid performs continuous self-assessments to detect and analyze issues, takes corrective actions to mitigate them and rapidly restores grid components or network sections as necessary. These digital technologies can also handle problems that are too large or quick for human intervention.

4.5.2 Enabling active participation by consumers in demand response:

Customers are a key part of the electric power system. They have access to new information about electricity usage, pricing and incentives that in turn better motivates purchasing patterns in behavior. This leads to a more efficient and reliable operation of the overall grid.

4.5.3Operating resiliently against physical and cyber attack:

A smart grid protects against outside forces by incorporating a system-wide solution that reduces physical and cyber vulnerabilities and enables fast recovery from disruptions.

4.5.4Providing power quality for 21st century needs:

A smart grid provides power quality for the digital economy by helping to monitor,diagnose, and respond to power quality deficiencies. This dramatically reduces customers' losses due to poor power quality.

4.5.5Accommodating all generation and storage options:

A smart grid enables power generation and distribution from multiple and widely dispersed distributed sources such as solar power system and wind turbines which create more efficient integration of renewable energy resources and other new technologies. Storage technologies can also be integrated into the electric power system to flexibly store electric power for later use in batteries, flywheels, super capacitors, and any other emerging storage technologies.

4.5.6Enabling new products, services, and markets:

A smart grid enables new products, services, and markets by linking buyers and sellers together - from the consumer to the Regional Transmission Organization. It braces the creation of new electricity markets, from the energy management system at home to technologies that allow consumers and third parties to bid their energy resources into the electricity market.

4.5.7Optimizing assets and operating efficiently:

A smart grid optimizes asset utilization and enables efficient operation by improving load factors, lowering system losses, and managing outages or faults in an enhanced manner.

4.6Smart Grid Application:

4.6.1Distributed Generation

Distributed Generation (DG) refers to power generation resources at consumer locations or stand-alone Distributed Generation (DG) plants, which are connected into the utility distribution system. DG sources deployed solely to support the energy demands of their owner and not connected into the grid are excluded from the discussion, since there is no connectivity of these DG sources to the Smart Grid network. Also excluded from discussion here are bulk energy generation sources connected directly into the transmission systems.Many types of DG sources which impact on greenhouse gas reduction; large-scale deployment of DG is perhaps the most important component of the Smart Grid evolution. Distributed generation source may be including the following:

1. Solar power
2. Wind power
3. Geothermal
4. Small hydro
5. Biomass and Biogas
6. Fuel cell
7. Combined heat and power

4.6.2Distributed Storage

Electric energy storage has many advantages in utility operations. Many power plant technologies (bulk as well as DG) cannot easily or cost-effectively match generation and demand in real time. Energy drawn from electric energy storage can be used to compensate for variation in demand. Storage of large amounts of electric energy, however, is a challenging task. This task is particularly difficult when the energy must be stored over long periods of time (minutes, hours).The term distributed storage (DS) is used to refer to an electric energy storage device connected to the grid that is able to store electric energy received from the grid (charging) and deliver the stored energy to the grid (discharging) when necessary. In DS, Discharge time should be as large as possible. Examples of DS technologies include the following:

1. Battery
2. Flywheel
3. Super-capacitors
4. Pumped-hydro

Distributed generation and distributed storages are collectively called Distributed Utility. The communication networking requirements associated with managing the grid connection for storage are similar to those associated with managing DG.

4.6.3 Electric Vehicles (EVs)

Use of electric vehicles can potentially reduce Green House Gas (GHG) emissions, provided the GHG emissions associated with electric power generation are lower than the emissions associated with internal combustion engines. Vehicles running on an electric motor are more efficient than internal combustion engines .While all electric vehicles contribute directly or indirectly to GHG emissions, we limit our discussion to EVs that use power from the grid. These so-called *plug-in* vehicles may use gasoline, diesel, or fuel cells as additional fuel stored in the vehicle in that case, the EVs are called plug-in *hybrid vehicles*. Thus, EVs that operate only from power supplied by fossil fuels or fuel cells in the vehicles (including many non- plugged-in hybrid cars) are excluded from this discussion. Also excluded are EVs that receive electric power from the grid or special-purpose power lines from a power plant but do not use batteries in the vehicle for storing the electric energy to run its motors (such as electric trains and some mass transit road vehicles).EVs can also be considered distributed storage systems in their own right, provided the charged batteries in the vehicle are used to supply power to the grid. Therefore, when plugged into the grid (through power sockets at homes, businesses, or special- purpose *EV charging stations* such as at a parking lot), the EV batteries can be charged from the power supplied by the grid (Grid-Vehicle), and, based on agreement with the utility, the batteries can be discharged into the grid (Vehicle- Grid) as a DS source. EV owners may charge vehicle batteries when the energy rates are lower (if lower rates are offered by the utility during its nonpeak hours). The unused energy.

4.6.4Teleportation

There are occasions when a fault in the transmission line (including at a transmission substation) requires the power supply to be disconnected by tripping a circuit breaker in either or both substations connected by the transmission line. Inter-substation communication between the (distance) relays for responding to a fault is called teleportation.

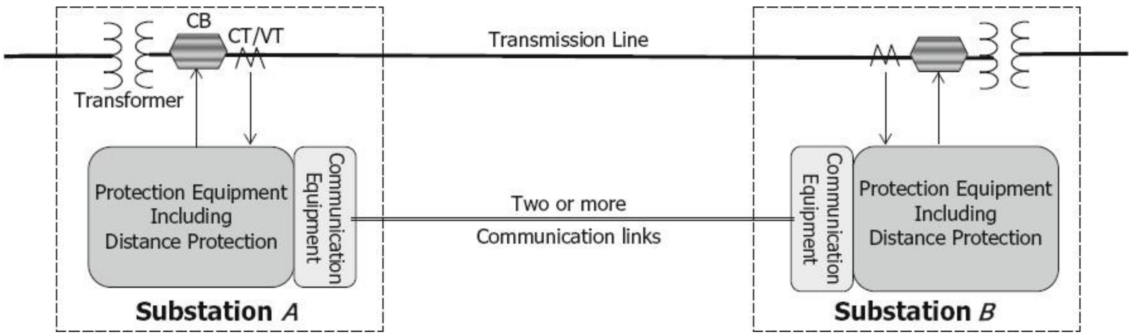


Figure 4.9 Teleprotection configuration

There are many teleprotection scenarios each requiring communication between substations. Consider an example scenario where there is a fault on the transmission line between substation A and B in figure. Based on the measurements received from the instrumentation connected to CT/VT at substation A, the distance relay at A determines that there is a fault and sends that information (permissive signal) to the relay in substation B through the communication line between the substations. If the relay at substation A also received the indication of that fault from substation B (based on the measurements by the protection relay at substation B), the relay at substation A sends the trip signal to the circuit breaker at substation A and the transmission line circuit is tripped at substation A. A variation of this scenario requires that the relay in substation A send the trip signal to the circuit breaker, if it does not receive the fault signal from B within a preconfigured time.

4.6.5CCTV:

Physical security of assets and buildings is extremely important for utilities, particularly at substations, DCCs, and other strategic locations. Equipment used to support physical security includes Closed Circuit Television (CCTV) cameras. Typical deployment of CCTV in a substation is illustrated in Fig. 4.10. While some refer to CCTV systems as including only analog cameras, we include IP cameras with direct IP-based video output in CCTV systems. The number of cameras and their locations in the substation depend on the size of the substation yard, camera range, and camera capabilities such as focus and coverage. A Digital Video Recorder (DVR) deployed at the substation is used to locally record video streams from the cameras. Live video streams from cameras as well as recorded videos are transmitted to the DCC over a communication networ

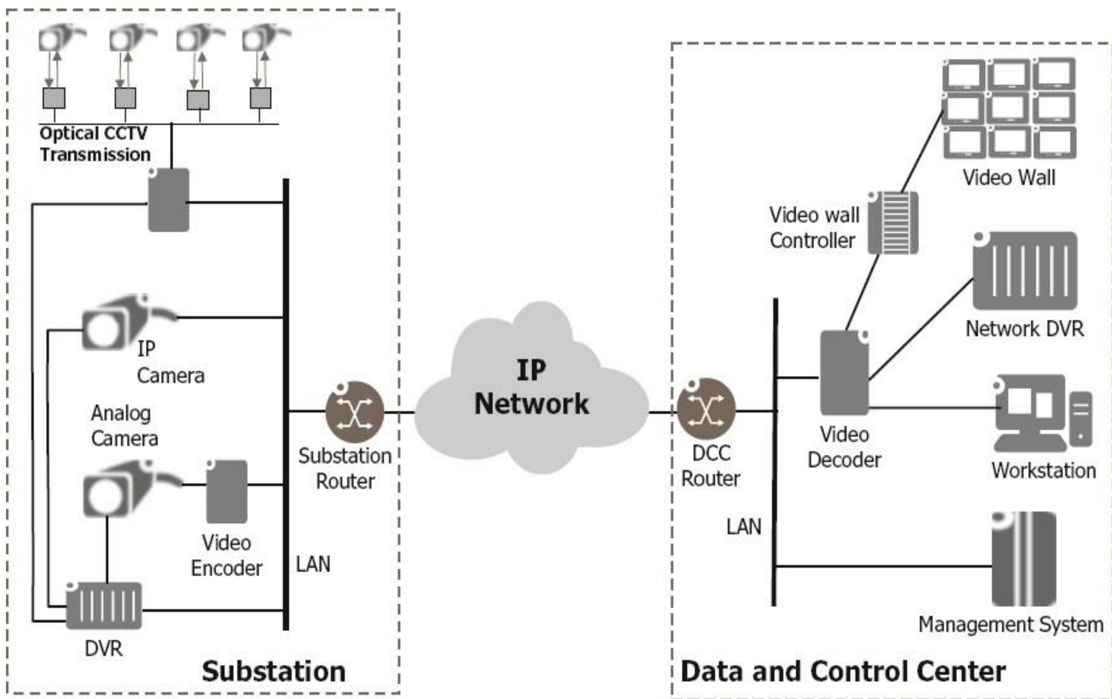


Figure 4.10 Components of a CCTV system

The video management system at the DCC determines the live video and the DVR video streams that need to be transmitted from the substation at a given time. A received video stream at the DCC may be fed into a collection of video monitors (video wall) that are monitored by DCC security staff. The security staff can control the video feeds displayed at the video wall at any time and may also control the video streams received from the cameras (in multiple substations) as well as their resolution. Optionally, the video streams can be stored by the network DVR.The cameras as well as the video management system may use sophisticated video analytics to automatically control the camera movement and zooming to capture “interesting” images as well as for processing the received images to derive security-related inferences from video streams.

4.7Technology uses in the Smart Grid:

Various technologies that enable smart grid operation can be grouped into five key technology areas.

1. Integrated communication Technology
2. Sensing and Measurement Technologies
3. Advanced Components
4. Advanced control methods
5. Improved interfaces and Decision support

4.7.1Integrated Communications Technology:

Of these five key technology areas, the implementation of integrated communications is "a foundational need, required by the other key technologies and essential to the modern power grid. Integrated communications will create a dynamic, interactive mega infrastructure for real-time information and power exchange, allowing users to interact with various intelligent electronic devices in an integrated system sensitive to the various speed requirements (including near real-time) of the interconnected applications."

- Broadband Cable
- Power Line Communications (PLC)
- Broadband Power Line (BPL)
- Radio Frequency Identification Devices (RFID)
- Cellular (3G)
- Spread Spectrum (SS) Radio Systems
- Cellular (CDMA and TDMA)
- Three GPP (3GPP) Long Term Evolutions (LTE)
- Digital Subscriber Line (DSL)
- Fiber-to-the-Home (FTTH)
- Integrated Digital Enhanced Network (IDEN)

- Wi-Fi
- Internet Protocol (IPv4 and IPv6)
- WiFiber
- IPv6 over Low power WPAN (6lowpan)
- Wireless Interoperability for Microwave Access (WiMAX)
- Leased Lines & Dial-up
- Z-Wave, Zigbee for Home Automation
- Multiple Address (MAS) Radio

4.7.2Sensing and Measurement Technologies:

Sensing and Measurement "is an essential component of a fully modern power grid. Advanced sensing and measurement technologies will acquire and transform data into information and enhance multiple aspects of power system management. These technologies will evaluate equipment health and the integrity of the grid. They will support frequent meter readings, eliminate billing estimations, and prevent energy theft. They will also help relieve congestion and reduce emissions by enabling consumer choice and demand response and by supporting new control strategies."

- Advanced Metering Infrastructure (AMI)
- Cable Monitoring System
- Circuit Breaker Monitoring System
- Current Sensor
- Fiber Optic Sensor
- Instrument Transformer
- Outage Management System
- Power Quality Monitoring System
- Sag Profile and VAR Monitoring System
- Temperature Monitoring System
- Transformer Monitoring System
- Wide Area Measurement System (WAMS)
- Wireless Condition Monitoring

4.7.3Advanced Components:

Advanced components "Advanced components play an active role in determining the electrical behavior of the grid. They can be applied in either standalone applications or connected together to create complex systems such as microgrids. These components are based on fundamental research and development (R&D) gains in power electronics, superconductivity, materials, chemistry, and microelectronics

- Narrow-band PLC Solutions
- Advanced On-load Tap-changer (OLTC)
- One Cycle Control Controller
- Advanced Protective Relays
- Programmable Communication Thermostats
- Controllable Network Transformer (CNT)
- Real-Time Demand Response and DER Control Device
- Short Circuit Current Limiter (SCCL)
- Current Limiting Conductor (CLiC)
- Smart Meter
- FACTS
- Solid State Transfer Switch (SSTS)
- Flow Control using HTS Cable
- Static Shunt Compensator (STATCOM)
- Static Synchronous Series Compensator (SSSC)
- Load Control Receiver
- Static Var Compensators
- Thyristor Controlled Series Compensators
- Unified Power Flow Controller (UPFC)
- Meter Data Management

4.7.4Advanced control methods:

Advanced Control Method technologies are "the devices and algorithms that will analyze, diagnose, and predict conditions in the modern grid and determine and take appropriate corrective actions to eliminate, mitigate, and prevnt outages and power quality disturbances. These methods will provide control at the transmission, distribution, and consumer levels and will manage both real and reactive power across state boundaries."

- Advanced Feeder Automation
- Advanced Substation Gateway
- Distributed Intelligent Control Systems
- Distribution Automation (DA)
- Energy Management System (EMS)
- Fault Locator for Distribution Systems
- Grid Friendly Appliance Controller
- SCADA
- Substation Automation (SA)

4.7.5Improved interfaces and decision support:

Improved Interfaces and Decision Support are "essential technologies that must be implemented if grid operators and managers are to have the tools and training they will need to operate a modern grid. Improved Interface and Decision Support technologies will convert complex power-system data into information that can be understood by human operators at a glance. Animation, color contouring, virtual reality, and other data display techniques will prevent data overload and help operators identify, analyze, and act on emerging problems."

- Consumer Gateway and Portal
- Distributed Energy Resources Controller
- Grid Friendly Appliance Controller
- Micro grid Control Software
- Power Distribution Analysis Software
- Power Transmission Analysis Software

- Real Time Digital Simulator (RTDS)
- Smart Appliance Interface (SAI) Unit
- System Visualization Software
- Universal Power Interface

CHAPTER 5

CYBER SECURITY

5.1Network Security:

The Smart Grid network should form a separate security zone from other networks and should support all security measures typical for any enterprise environment such as protection from external networks, including extranet connections to networks of utility partners and the Internet. Although technology exists today to help utilities meet the enterprise-level security challenges, the complexity and the large number of smart devices required to connect seamlessly and provide the intelligence that makes the grid smarter also make the grid more vulnerable to attacks. According to Lockheed Martin, by 2015, the Smart Grid will offer up to 440 million potential points of attack also known as "attack surfaces". Additionally, depending on the utility, the Smart Grid network may carry utility business traffic, or there may be a separate utility business data network that must be connected to the Smart Grid network at one or more points to support data transfer between them. Smart Grid applications have very stringent requirements for security, since vulnerabilities can be exploited to destabilize the grid, potentially leading to outages across entire cities or regions. Thus, a security breach can negatively impact the critical requirement of electric service providers, namely, service reliability. Utilities and regulators are acutely aware that grid modernization cannot move forward without a comprehensive and effective approach to security. The main objectives for grid security are to (1) minimize the attack surface, (2) increase the effort/time required to compromise the network, and (3) decrease the amount of time required to detect and respond a compromise. The focus of this chapter is the development of a network security architecture. The architecture partitions the Smart Grid network into security zones. Network security elements within each security zone maintain the security requirements specific to individual zones

5.2Importance of Smart Grid Security

Energy security is a national security issue. Potential attacks may be launched by hostile foreign entities or individuals and the introduction of malware. With the use of communication networks to enable a more efficient transmission and distribution grid, there are growing concerns that the network (and therefore the grid) is becoming more susceptible to cyber attacks. For example, the number of cyber attacks against critical US infrastructure has grown dramatically in the recent years [59]. To address this need, the Smart Grid cyber security market is expected to exhibit huge growth before the end of the decade, climbing from a global value of $7.8 billion in 2011 to $79 billion in 2020 .Examples of Cyber security Attacks on the Grid Critical infrastructure companies, more specifically utilities, are subject of frequent and increasingly aggressive denial- of-service attacks. These attacks are currently focused on the utilities' Internet interfaces. Advanced persistent threat attacks can also be launched by bypassing these Internet interface protections via phishing, etc. For example, Stuxnet bypassed the Internet interfaces. In addition, future cyber attacks could potentially be directed at application interfaces or internal systems using attack vectors such as smart meters, mobile workforce devices (mobile data terminals), or points within wireless FANs. As the Smart Grid rollout continues, there will be a growing number of utilities communicating in complex ways over a mix of public and private networks. Smart Grid evolution is extending communication networks to many DG locations including homes and businesses. With such a large number of FANs, supporting the growing number of endpoints, Smart Grid network protection will be infeasible without wide deployment of security infrastructure.Talent, Canada provider of SCADA software systems to utilities in many countriesrecently warned its customers of a breach of its company network that allowed a hacker to bypass its internal firewall, installing malicious software and stealing files related to SCADA control software. In 2007, researchers at the Idaho National Laboratory showed how to access a power plant's control system through the Internet. Running an emulator, the researchers simulated the destruction of a 27-ton power generator by power cycling the generator at very short intervals. Many majorcyber security events have already taken place, including Stuxnet, Aurora, RuggedCom, and smart meter hacks [62]. In 2009, there were news reports that the power grid had been penetrated by espionage agents who are suspected of having inserted rogue code in their target. Forty percent of critical infrastructure companies that responded to a McAfee survey reported finding Stuxnet in their systems, with the number increasing to 47 % in the electric sector. An illustrative example of the evolving threat landscape and the need for defense in depth is the Stuxnet attack: in 2010, the Stuxnet worm targeted SCADA systems used to monitor and control industrial processes. One of the ways the Stuxnet virus spread was by infecting project files in a grid control system made by Siemens. The Stuxnet malware is a graphic illustration of the potential risk of impairment of operations and even of physical destruction of equipment.Breach of privacy is another major concern in utility networks since they manage customer-related information and other information that may be subject to privacy regulations. This information, if disclosed, could result in punitive penalties or at least damage to the utility's corporate image. Confidentiality controls for privacyrelevant information are crucial and should apply to information in situ as well as in transit. A detailed consideration of these issues can be found in.

5.3Smart Grid Security Architecture

An overarching principle for designing grid security is the separation of the operational grid network from the general business network in terms of both data sharing and network access. Whether the utility business network is integrated with Smart Grid network or they are two separate networks, separation of business application traffic and grid operations and control application traffic is an important principle. Even within the Smart Grid operations and control network, requirements for security may differ between applications, systems, and/or locations. Further, it may be necessary to isolate traffic subject to one set of security requirements from the traffic with a different set of requirements.Therefore, the Smart Grid security architecture is divided into multiple security zones. We illustrate this concept with an example including five security zones: Enterprise Zone, Transmission Zone, Distribution SCADA Zone, Distribution Non-SCADA Zone, and the Interconnect Zone. Different levels of protection are required in each of these zones based on the criticality of application data for grid operations.Since security requirements are based on the criticality of applications, it is generally the case that the security requirements apply across different physical networks and operational domains. (Depending on the utility and its security processes, a different classification is possible.)

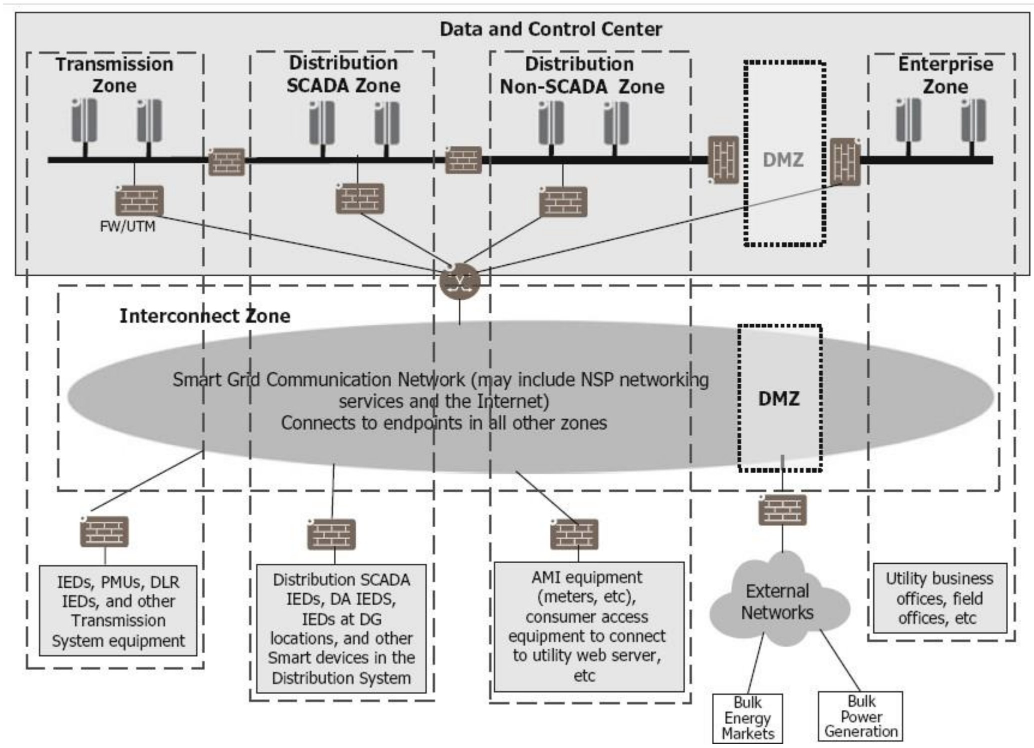


Figure 5.1 Security zones in Smart Grid communication network (an example)

Enterprise Zone The Enterprise Zone is comprised of the business systems, their users, traffic between these systems, and traffic between the systems and users. These business systems include servers and clients used for functions such as human resources, finance, information technology, customer service, billing, internal product development, and procurement. In the case of the integrated Smart Grid network that supports business traffic, the Enterprise Zone includes business traffic. Each businessfunction should have its own security perimeter implemented via appropriate access controls for systems and assets. This security perimeter provides better visibility and accountability to information being transmitted on the enterprise network. It is possible that the business systems need to access operational data. Therefore, the Enterprise Zone is isolated from all of the other operational zones through the use of Demilitarized Zones (DMZs). The DMZ includes systems such as proxy servers to provide access to operational data without the need of directly accessing the operational zones themselves.There are many different ways to design a network with a DMZ. For the Enterprise Zone, a dual-firewall DMZ is a security best practice. This approach employs two firewalls to create a DMZ: the first firewall is configured to all traffic destined to the DMZ only, and the second firewall allows only the traffic from the DMZ to the internal network. In this setup, two sets of firewalls need to be compromised in a successful security attack.

Transmission Zone IEDs, PMU, and other transmission substation elements, IEDs deployed at transmission lines (such as DLR IEDs), the TMS systems at the DCC, and communication between all these entities are included in the Transmission Zone. Additionally, communication between the DCC systems and the bulk power generation, energy markets, and other external systems are also a part of the Transmission Zone. Traffic over these external systems must also be afforded the same security implementation as communication between the transmission elements within the utility. Note that extranet communication with bulk generation and markets, and even a utility's internal communication for some Smart Grid networks,may be carried over NSP networks and/or the Internet.

Distribution SCADA Zone SCADA IEDs in distribution substations, IEDs deployed at the feeders for distribution automation (DA), DMS systems at the DCC, and communication between these entities for SCADA and DA are included in Distribution SCADA Zone. Additionally, connections to other smart devices are also included. These smart devices include IEDs at DG locations (including at microgrids and other consumer locations). Increasingly, the Distribution SCADA Zone will be required to support communication for direct load control of consumer appliancessuch as air conditioners and electric water heaters. As with the Transmission Zone, communication between entities within the Distribution SCADA Zone may be carried over NSP networks and the Internet. For example, use of the Internet may be the only viable option for connecting the smart devices at residential locations to the utility communication network.

Distribution Non-SCADA Zone Distribution Non-SCADA Zone covers the communication aspects of the distribution system that are not critical to grid control. Such communication includes providing customers with data about electricity usage through the AMI infrastructure. Thus, the Distribution Non-SCADA Zone includes AMI devices such as meters, data concentrators, head ends, and the MDMS. A utility may provide web access to its customers for their individual energy management. Such web access (often over the Internet) is also a part of the Distribution Non- SCADA Zone. In addition to network security, user privacy is important to avoid revealing sensitive information, such as whether and when customers are at home, which could be inferred from energy utilization information.

Interconnect Zone The Interconnect Zone includes the interconnecting networks between the entities of different zones. These networks include the Smart Grid network, business network if separate from the Smart Grid network, and connections to external entities. With Smart Grid communication increasingly reaching a large number of devices deployed outside of substations and at consumer locations, the interconnecting communication network must support the necessary security mechanisms that will separate critical and noncritical data. Additionally, the Interconnect Zone also includes mobile workforce communication that needs interconnection with all other zones.Although we can segment the interconnection network itself into these neatly defined security zones, in a practical implementation, such implementation will not be cost- effective. Many network links, network elements, and even the local area network (such as at the DCC) will need to carry traffic for more than one of these security zones. Fig. 6.1 for an illustration of the security zones defined above and secure separation between these zones. Note that the individual zone boundaries are logical and do not interconnect with each other. All connections carrying traffic betweenentities of different zones go through the Smart Grid network or the external networks shown, and through the security apparatus necessary for separation between the zones. For completeness, the separation (for security) of utility operations and business data traffic is shown, whether the business network is integrated with the Smart Grid network or it is itself a separate network.Note that the DMZ may need to be implemented at different locations in the network. Some of the examples of DMZ placement are as follows:

I. ADMZ is placed between the DCC LANs connecting servers supporting the utility operations and control systems such as the TMS, DMS, and MDMS systems and the LAN connecting the data center systems.

i. At the WAN router (WR) locations collocated at the business locations, a DMZ is placed between the WR and the cluster router (CR) at that location.

ii. ADMZ is used to separate the Internet connection (usually at the DCC) from the LAN(s) at that location.

II. Before describing the network security architecture for each of these security zones, we make some basic assumptions about the existence of security safeguards at the device, system, and organizational levels:

1. **Device-level protection:** Due to the large number of devices deployed in the Smart Grid network, isolation and protection between components (such as circuit boards) of these devices are necessary to prevent a failure or compromise in one component from affecting another. We also assume that in the event of an attack, the time and space separation of functions prevent the spread of malware among different systems. If one of the applications is compromised by an intrusion, the others will continue to perform unaffected. The affected partition can be disinfected and rebooted, while other virtual boards continue to run.
2. **System-level protection:** Physical security for grid elements including barriers, locks, access control, and CCTV must be provided.
3. **Organizational level protection:** In addition, for any security solution to be effective, it is critical that policies and mechanisms are enforced at the organization level. For example, the necessary access controls, firewalls, intrusion detection and prevention, cryptography, and anti-malware applications should be actively used, monitored, and managed. Further, personnel-related security considerations andprocedural policies are required, including screening, security awareness, and training.
4. **Incident management:** While risk management and vulnerability management can help reduce the frequency and impact of actual incidents, it is essential that there are procedures in place for managing security incidents when they do occur. Incident management includes detection, analysis, communication, correction, recovery, and retrospective assessment. Roles and responsibilities must be clearly defined and documented. Ideally, there should be an automated system to support incident management including the categorization, classification, communication, and escalation

of incidents. In the extreme, an incident may require disaster recovery activities such as migration to a backup site. It is important to test incident management procedures with realistic scenarios.

5.4 Security Zones

5.4.1 Transmission Zone

Transmission substations are a key element of the Transmission Zone. While regulatory standards such as NERC CIP standards address only certain transmission substations (typically above 100 kV), bulk power plants, and DCC(s) supporting these locations, for simplicity and consistency, all substation security implementation should follow the regulatory standards even if formal compliance is not required.Figure 6.2 illustrates the security architecture for the Transmission Zone as it is applied to the transmission substations and at the DCC location housing TMS servers.All IEDs, PMUs, and other substation assets requiring communication are included in an ESP at the substations. The utility may choose to implement more than one ESP at a substation for operational purposes and for ease of compliance with regulatory standards. Note that there may be other substation equipment that is not included in an ESP. For example, CCTV cameras in the substation need not reside in an ESP, even if one or more cameras are used for regulatory compliance of the ESP security.Unified Threat Management (UTM) appliances (also known as next-generation firewalls) combine multiple network security functions (e.g., firewall, DPI, IDS/IPS,encrypted IPSec VPN) into one integrated device, thereby simplifying network operations and management. The UTM manager function (in a security operations server) operates and manages firewall/UTM appliances that are deployed throughout the Transmission SCADA network. The UTM manager is responsible for updating security policies and signatures used by UTM appliances to detect threats to the Transmission SCADA systems as well as manage encrypted (IPSec) VPNs. UTM functions may be implemented in routers; otherwise, separate security appliances with UTM function must be deployed as shown. The (security) monitor is present to facilitate continuous monitoring to detect intrusions or traffic anomalies. The static nature of a SCADA network with its well-defined network flows can be leveraged by the

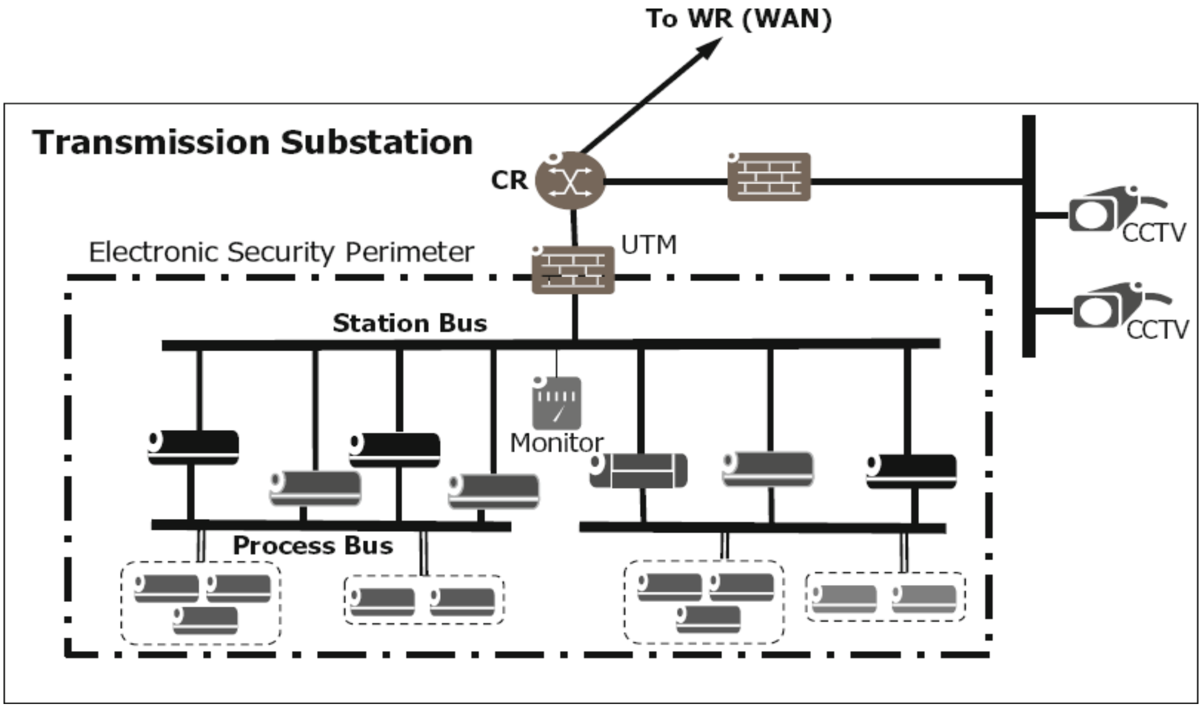


Figure 5.2 Transmission Zone security architecture (in substations) and DCC

monitor to provide situational awareness by monitoring LAN traffic for anomalous network flows in a nonintrusive manner. In addition to threat managementand surveillance functions, the DCC includes one or more servers providing other security functions such as authentication.(Note that we have used the term DCC to denote utility location(s) that houses utility grid management and control functions. Thus, the DCC includes the security operations function, even though the utility may deploy the security and operation servers at a DCC location that is separate from the DCC location housing the TMS function.) Among these security management functions are maintenance of network and system logs (Syslog), UTM, and key management (used in authentication and encryption). Another required function is Next-Generation Security Information and Event Management (NextGen SIEM) to manage security monitors and to report and log any anomalous network flows observed by these monitors. The NextGen SIEM system provides real-time analysis and correlation of security alerts generated by Transmission SCADA devices and security appliances in order to reduce false positives and to allow security operations personnel to focus on highpriority threats. The NextGen SIEM system employs long-term storage of historical data to facilitate its analysis of data over time and to provide retention of correlation data for regulatory (such as NERC CIP) compliance. The NextGen SIEM can also be used to automatically generate reports required for regulatory compliance. This system also provides two capabilities that are useful for monitoring the security of the Transmission SCADA network. The first capability is the ability to correlate and analyze network flow information along with traditional Syslog information to manage threats. NextGen SIEM systems also include analytics engines that provide network-wide security intelligence to support multiple activities (e.g., threat detection, forensics, compliance) and to provide customized views of data to different people in an organization, depending on their roles.

5.4.2Distribution SCADA Zone

Distribution management has extended beyond monitoring and controlling substation IEDs to the deployment of the DA IEDs and IEDs used for monitoring and controlling the DG connected to the distribution system. Similarly, in addition to the SCADA master control, DMS functions may include one or more of the functions.While the trend is to use standards-based protocols such as DNP3 over IP networks, there may be distribution system functions that use proprietary protocols over purpose-built networks. The use of isolated networks eliminates many potential threats: however, it also limits the utility's access to their own information, increases the total cost of ownership, and brings additional data management overhead. Proprietary protocols also are not typically designed for comprehensive secure operations. Further, the distribution system functions may need to share data with applications and authorized users across the utility enterprise. This additional exposure to the enterprise network significantly increases the threat and vulnerabilities to the critical security controls of the distribution system. Some of these vulnerabilities can be effectively addressed via the DMZ between the operational zones and the enterprise zone.Figure 6.3 shows the schematic of the security architecture for a Distribution SCADA Zone that includes substation and DA IEDs and the DCC with DMS systems.Note that all DA IED traffic should be encrypted using, for example, IPSec VPNs. While DA traffic is concentrated using a substation-based DA concentrator as shown in Fig. 6.3, DA IEDs may be connected to the DA SCADA master directly over individual wire line or wireless FANs.While regulatory agencies may not require an ESP at a distribution substation, enclosing the substation IEDs and other equipment in an ESP is recommended.

Such an approach ESP will allow secure updates to the SCADA system without threatening the system's operational capacity. There should also be monitoring of transferred data to ensure that security enforcements are being implemented and to limit access only to authorized entities in the operational environment. All SCADA and DA data transfers should support encryption to preserve data integrity and confidentiality of

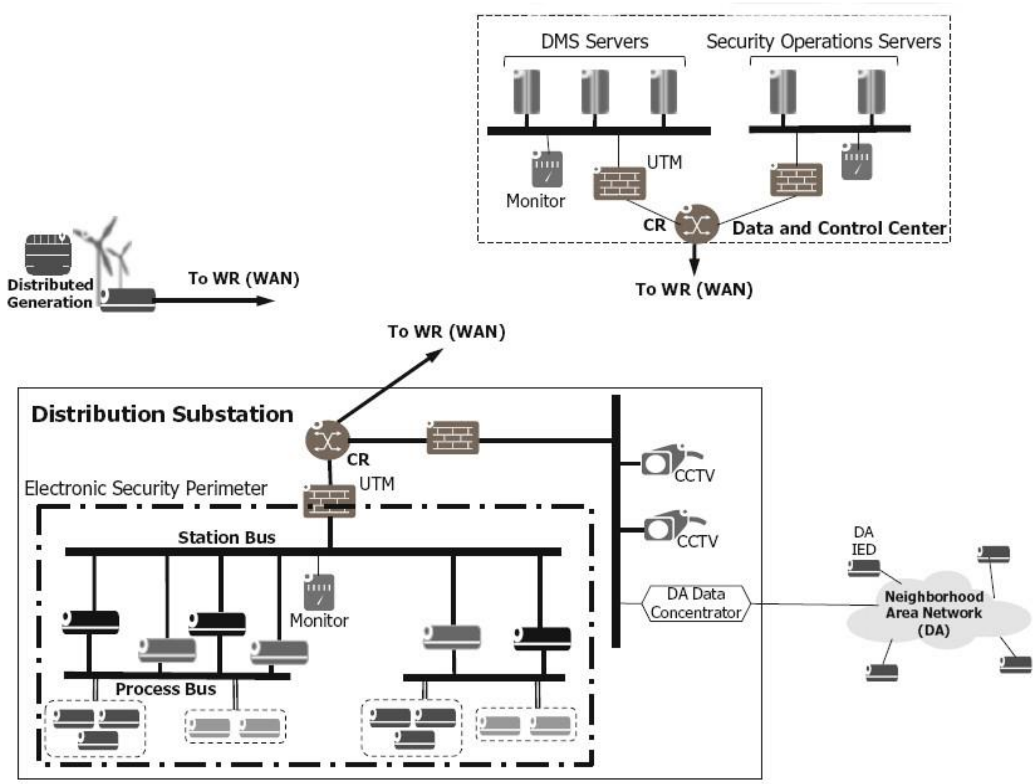


Figure 5.3 Distribution SCADA Zone (Distribution substation, DA, and DCC)

communications between servers and workstations without needing to alter operational procedures. IPSec encryption supports this requirement. Use of Transport Layer Security (TLS) is another option. In addition, the routers and UTM must be configured to screen critical communication ports on servers from external access. To limit the scope of SCADA security requirements, all applications not required for successful operation of the SCADA system should be external to the ESP. Thus, there may be entities (in addition to CCTV) that are outside of the ESP.DG deployment including microgrids, particularly if connected to the MV distribution system, is also increasingly becoming a key element of the Distribution

SCADA Zone. DG sources play a critical role since they can be managed as dispatchable generation sources. Note that IEDs deployed at the DG communicate with corresponding IEDs at the distribution substation, particularly for tele protection.Since the Distribution SCADA Zone is still in the early phase of deployment, it is crucial that security solutions are scalable and extensible. For example, the systemshould readily support state-of-the-art antivirus packages and evolving authentication technologies, such as biometrics, persistent smartcards, and access tokens, allowing security administrators to use the most advanced tools available to combat potential new threats.The security network architecture for this zone, with the use of the UTM functions and (security) monitors, is similar to that of the Transmission SCADA Zone in Fig.6.2. The DCC function for security management (such as inclusion of NextGen SIEM and the UTM manager) is similar to the one for the Transmission SCADA Zone.

5.4.3 Distribution Non-SCADA Zone

The dominant non-SCADA application in the distribution network is AMI. In this section, we present AMI as a typical non-SCADA application; general requirements apply to many other distribution applications such as EV charging and retail energy markets.Threats to AMI range in severity from power theft by a few consumers to network intrusion by foreign entities. Insider security attacks by individuals for financial gain are also not uncommon. Power theft is a relatively low-level threat. If unaddressed, however, power theft could leave the system vulnerable to attacks with greater impact on the grid. The primary vector for this type of an attack is physical access to the meters themselves. It may also involve using the network to modify meter firmware. Although AMI is not itself considered critical infrastructure, the data obtained from the AMI network may be used to control load. Thus, a cyber attack that tampers with AMI data could potentially impact grid operation. A more thorough threat analysis for the AMI network can be found in .Drawing on parallels with AMI, the security vulnerabilities on the Distribution Non- SCADA Zone maybe classified based on the attack vector:

Device attack vector: Smart meters are physically accessible to many and therefore susceptible to several attacks that tamper with the device or the data theygenerate. It is also possible to launch configuration attacks through communication interfaces to the customer's appliance control equipment. One potential example is the reverse engineering attack on meters. A potential impact of this attack could be that AMI meters at consumer locations would underreport electric usage. Other impacts could include underreporting of ancillary services such as natural gas usage (if gas meters report through the electric smart meters) or failure to report correct status or outage information.

Network attack vector: Vulnerabilities in the AMI network could be used to launch denial-of-service attacks whereby the attacker could flood communications within the AMI network. The resulting bandwidth shortage would affect any utility communications using the same media. In particular, meters could have difficulty communicating status and usage information as well as receiving pricing information. The AMI network, along with the trust relationships between the various systems involved, and the commodity hardware and software that these systems use could also be leveraged to launch large-scale attacks on the grid itself. This could impact the entire power grid since the overall AMI system may provide connectivity from the balancing authority or regulating agencies (such as the ISO/RTU in the United States and Canada) all the way to individual meters at residential and small business customer locations.

Insider attack vector: Insiders with physical access to the systems involved or administrator access to either systems or networks such as the AMI headend system, the EMS, or the network infrastructure supporting these systems could perform attacks at either the computer or network level. The insider could potentially modify software or settings on any systems such that critical information is changed as it flows through that system.We now present a security solution in the Distribution Non-SCADA Zone that implements the following security features:

1. In most cases, real-time monitoring of consumption can quickly detect many low-level attacks on meters. AMI solution vendors and utilities can mount an effective defense against rogue AMI devices by using a data transmission standard for AMI data and investigating abnormal usage patterns. This willrequire encouraging AMI vendors to move from proprietary systems to an industry standards such as Open AMI and to

incorporate security requirements to the standard. One mitigation strategy for the consumer attack vector is to detect and investigate anomalies in power use. Such investigation involves checking configuration and firmware of the meters of suspected consumers. This can be automated at minimal expense to the utility while maximizing the likelihood that unauthorized modifications are detected. Cross-check mechanisms can also be implemented to detect and correct corrupted information before grid operations are impacted. Further, correlation of AMI data with SCADA meter data will allow for the detection of meter-level attacks that tamper with monitored data.

2. To address the insider threat, utilities need to exercise due diligence to show that insiders are not cooperating with other players in the energy sector. In addition, all communications from the head end to the customer endpoint should be treated as control traffic. As such, authentication of commands should be put in place. Good authentication processes will prevent person-in- the-middle and spoofing attacks by insiders with access to the AMI network. While head end systems are clearly not critical cyber assets in the sense of regulatory standards, the utility may want to treat them as such and implement personnel and system security management. Measures such as background checks and auditing will deter insiders who attack through physical access to AMI or related systems. Host-based intrusion detection with software integrity checking of the head end systems will detect changes to these systems by insiders. Utilities should conduct frequent, irregular audits of head end output. All user commands and actions in the head end systems should be repudiable, which will require logging and strong user authentication.
3. System maintenance tasks such as the application of system patches to address newly disclosed vulnerabilities must be completed in a timely manner. Standard exploits to well-known vulnerabilities will be openly available, making it easy for even unsophisticated hackers to exploit them. In addition, sophisticated adversaries may be able to exploit vulnerabilities that are not yet disclosed and for which no patch exists – so-called zero-day exploits. Toaddress zero-day exploits, it is important to have robust incident recovery mechanisms.
4. Since the AMI communication network will frequently share some or all communication links with other utility communication networks, there is a potential for attacks that take advantage of poor separation of communication channels. Bypassing such separation

could impact the ability of TMS systems to communicate with bulk generation, resulting in possible attacks on the bulk electric grid. This attack depends on AMI connectivity. There are several AMI solution technologies, and vulnerability of an AMI network depends heavily upon the vulnerabilities in the communication technologies used.

5. Terrorist and nation-state threats are mitigated by all of the above measures because they make the target more difficult to compromise. Additional effective approaches to protecting against this threat are router access lists, firewalls, protected communication between the AMI network and other networks, strong communication authentication, and detection and halting of rapid market fluctuations.

5.4.4 Interconnect Zone

The Interconnect Zone that carries traffic for different operational functions must be logically separated based on the most stringent security requirements for the particular application. This logical separation can be achieved with MPLS services. Logical separation is more cost-efficient than physical separation, because it streamlines capital costs by avoiding multiple instances of physical devices and reduces associated operational costs. Using MPLS services at L1, L2, and IP layer (VPRNs), secure traffic isolation can be achieved, preventing attacks between MPLS services or from an MPLS service to the MPLS control plane. Networking products with MPLS services support will generally also provide device security (physical and logical access control) including security at administration and management interfaces. Note that MPLS services do not provide native data encryption. Therefore, it is necessary that the traffic be encrypted at higher layers (e.g., using IP or TLS).

5.4.5 Additional Security-Related Operations

Despite implementation of security architectures and security measures, it is inevitable that information and communication systems will have vulnerabilities. Often these are unknown (i.e., “zero-day”) vulnerabilities that have not yet been identified by vendors or utilities but that may have been discovered by malicious agents and may be actively used in zero-day attacks. Often vulnerabilities are known but have not yet been remediated. For example, patches may not be available or not yet deployed due to operational reasons (downtime, cost, risk of failure, etc.). The risks associated could be addressed via secure development and procurement of software and hardware and hardened configurations of systems, applications, and services. This includes disabling all unused components, ports, and services. It also can include enabling any optional security-pertinent features (e.g., encryption, logging) and configuring restricted access controls. Assets should be subjected to periodic vulnerability scanning using vulnerability scanning tools (e.g., Nessus). Vulnerability scanning has been known to cause operational systems to crash; therefore, scanning must be performed during a maintenance window. Log analysis and the security monitors mentioned previously can passively fingerprint OS versions, patch levels, and the extent of hardening performed on the system. Tools specific to functionality or protocols (e.g., SCADA) can also be used where appropriate. Often security vulnerability can be removed by a software patch, when the correction becomes available. However, patching of operational systems can be complex and risky. It is important to have a thorough inventory of systems to be patched, along with up-to-date versioning information. Patches must be tested before deployment. Patches must be deployed quickly and consistently and with a minimum downtime (ideally no downtime). Crucially, it must be possible to reverse a patch and return a system to the previous operational version should a problem arise. A patch management system can help with the complexity of this management task.

5.5 Cyber security standards

There are several standards which apply to the security of substation equipment and many are under development. For overall security assessment, the standard ISO 27001 is widely used and specifies the assessment of risks for a system of any sort and the strategy for developing the security system to mitigate those riseFurthermore, ISO 28000 specifies security management specifically for a supply chain system.

5,5,1IEEE 1686: IEEE Standard for substation intelligent electronic devices (IEDs) cyber security capabilities

This standard originated from an IED security effort of the NERC CIP (North America Electric Reliability Corporation – Critical Infrastructure Protection). The standard is applicable to any IED where the user requires “security, accountability, and auditability in the configuration and maintenance of the IED".The standard proposes different mechanisms to protect IEDs. The IED shall:

- be protected by unique user ID and password combinations. The password should be a minimum of 8 characters with at least one upper and lower cases, one number and one alpha-numeric character.
- not have any means to defeat or circumvent the user created ID/password. The mechanisms such as "embedded master password, chip-embedded diagnostic routines that automatically run in the event of hardware or software failures, hardware bypass of passwords such as jumpers and switch settings" shall not be present.
- support different level of utilization of IED functions and features based on individual user-created ID/password combinations.
- "have a time-out feature that automatically logs out a user.
- record in a sequential circular buffer (first in, first out) an audit trail listing events in the order in which they occur.
- monitor security-related activity and make the information available through a real-time communication protocol for transmission to SCADA."

5,5,2 IEC 62351: Power systems management and associated information exchange – data and communications security

IEC 62351 is a series of documents which specifies the types of security measures for communication networks and systems including profiles such as TCP/IP, Manufacturing Message Specification (MMS) and IEC 61850. Some security measures included in the standard are: authentication to minimize the threat of attacks, some types of bypassing control, carelessness and disgruntled employee actions; authentication of entities through digital signatures; confidentiality of authentication keys and messages via encryption; tamper detection; prevention of playback and spoofing; monitoring of the communications infrastructure itself

CHAPTER 6

Implementation of Smart Grid in Bangladesh

The actual expression 'Digital Bangladesh' implies government's commitment in order to quickly set up pc as well as It (IT) throughout Bangladesh to enhance efficiency from the support supplying government bodies. This particular idea could be prolonged to incorporate utilization of digital technologies in order to change the current dilapidated electricity distribution network of Bangladesh right into a 'smart electrical grid'. Smart grid may avoid electricity black outs as well as 'black-outs' which happen many times each day, leading to function disruptions as well as economic losses to the nation. Wise electronically rc grid allows step-by- action steady fill add-on as well as elimination. Below automated remote control electronic stereo as well as computer control, absolutely no portion of the actual network can get full and obtain guarded through electrical harm through stopping extreme current flow. This kind of network operation automation via utilization of electronic stereo manage from the Bangladesh electric grid may make sure steady power provide countrywide."Smart Grid" is really a contemporary idea that describes the actual transformation from the popular or even standard electric power grid to some contemporary power grid. This particular brand new transformation is really a not far off means to fix the actual power system difficulties from the contemporary hundred years. Rejuvenation from the present electric power distribution program is definitely an essential action in order to put into action the actual Smart Grid technology. Therefore, distribution system engineers ought to be familiar with the data associated with Smart Distribution System. Additionally the shoppers ought to recognize the advantages that they'll end up being taking pleasure in out of this up-to-date power system. This particular document provides short fine detail associated with Smart Grid. The actual concentrate of the document would be to acquaint along with Smart Grid viewpoint in order to Bangladesh in which the power system is extremely comprehensive, complicated as well as very older. The actual distribution system loss is high and also the clients encounter every day prepared fill losing. To deal with the actual power turmoil along with other difficulties, the traditional distribution program ought to be updated in order to wise distribution program. which is a part of Smart Grid. Though it is a very new and expensive concept, yet Bangladesh Government has showed positive approach. The main objective of this paper is to discuss the Smart Power Generation, Transmission and Distribution System, its importance in Bangladesh power system and the progress & prospects. On the other hand, the scarcity of energy in Bangladesh is anticipated to endure for the next 50 years; as electricity demand is increasing every year surpassing generation capacity and distribution capabilities.

6.1 Present structure of power sector

1 Apex Institution

Power Division, Ministry of Power, Energy & Mineral Resources (MPEMR)

2. Generation

1 Bangladesh Power Development Board (BPDB)
2 Ashuganj Power Station Company Ltd. (APSCL)
3 Electricity Generation Company of Bangladesh (EGCB)
4 North West Power Generation Company Ltd. (NWPGCL)
5 Coal Power Generation Company Bangladesh Ltd. (CPGCBL)
6 Independent Power Producers (IPPs)

2 Transmission

1. Power Grid Company of Bangladesh Ltd (PGCB)

3 Distribution

1. Bangladesh Power Development Board (BPDB)
2. Dhaka Power Distribution Company (DPDC)
3. Dhaka Electric Supply Company Ltd (DESCO)
4. West Zone Power Distribution Company (WZPDC)

5. North-West Zone Power Distribution Company (NWZPDC)

6. Rural Electrification Board (REB) through Rural Co-operatives Transmission Sub-Sector.

6.2Present scenario of power sector of Bangladesh

Table7.1 Power sector scenario of Bangladesh

Electricity Growth	2017
Installed Capacity (MW)	9.00%
Maximum Generation (MW)	16,193 MW (2018)
Total Consumers (in Million)	2 Crore 99 lakh
Transmission Lines (ckt km)	11,122 Circuit KM (June 2017)
Distribution Lines (km)	4,55,000 KM (June 2017)
Per Capita Generation	464KWh (June 2017)

Transmission Operator

Power Grid Company of Bangladesh (PGCB)

Transmission Line

400 kV : 165 Circuit km

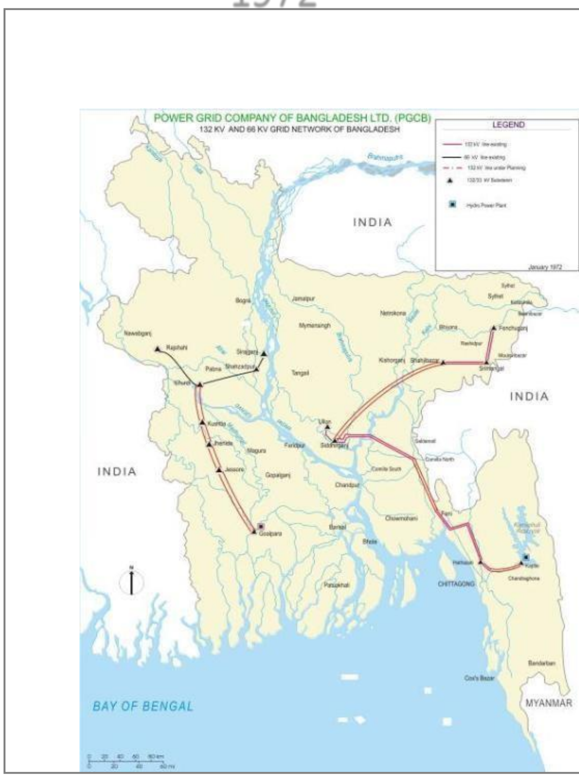
230 kV : 3,172 Circuit km

132 kV : 6,359 Circuit km

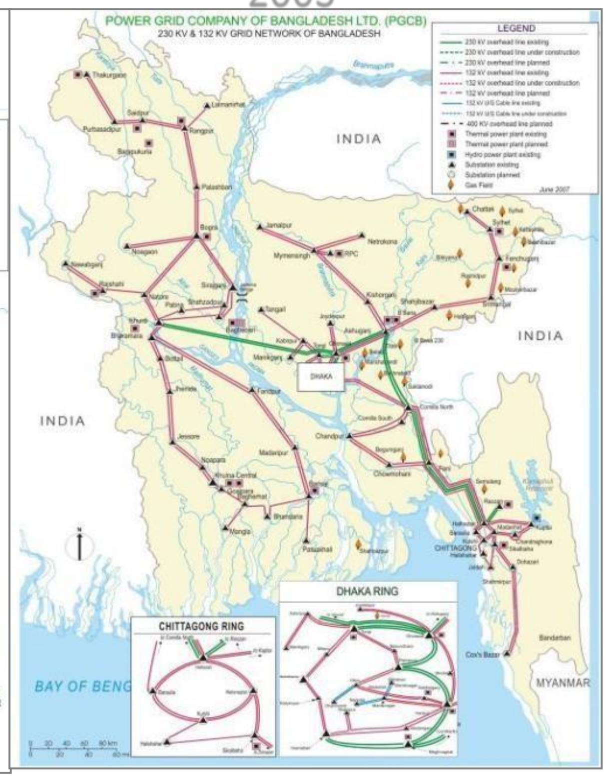
Total : 9,695 Circuit km

ChronologicalDevelopmentofTransmissionNetwork

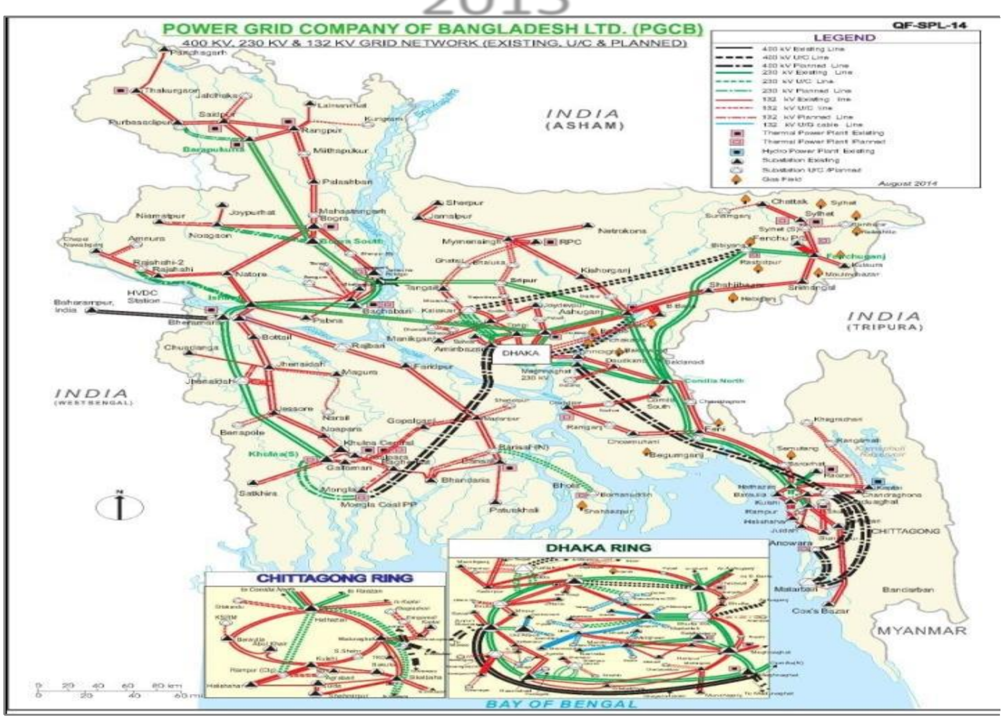
1972



2003

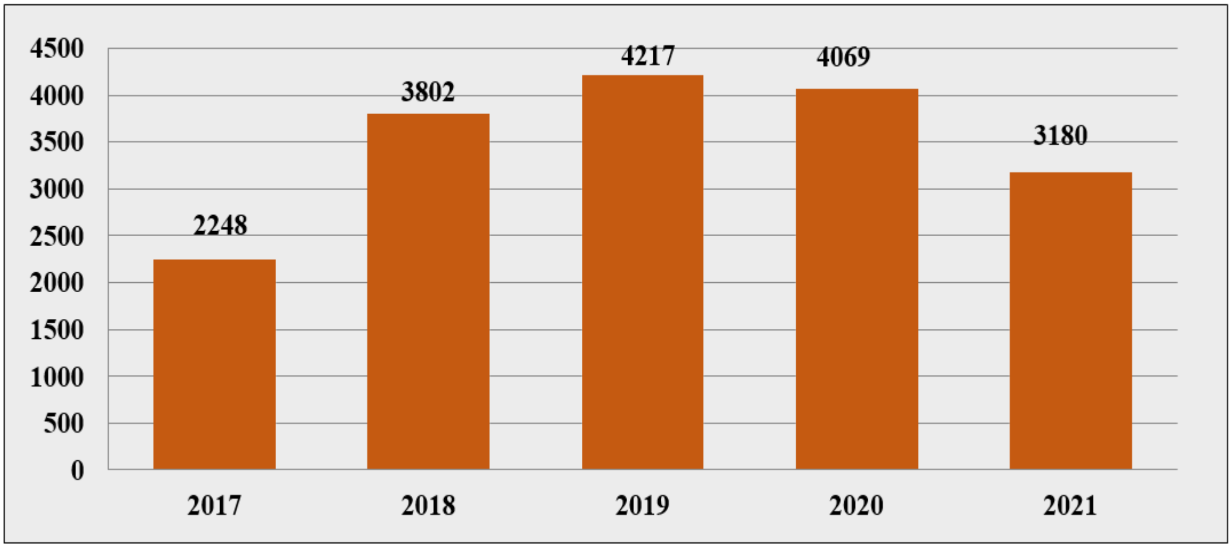


2015



Mid Term Plan for 2017 - 2021

Calendar Year Wise Projects Completion (From 2017 to 2021)



- Energy Conservation and Solar Power issues in the National Building Code
- Include Energy Conservation and Alternative Energy issues in the text book curriculum
- Installation of Solar Panel in the Govt., Semi Government and autonomous organizations within next 3 years
- Use of CFL bulb in all ministries and public sector entities.
- About 10.5 million CFL distributed in first phase and 17.5 million will be distributed soon
- Conventional street lights will be replaced by LED and solar subsequently
- Public awareness for energy conservation
- Discontinuation of incandescent bulb and electric heater subsequently
- Limited use of Air Conditioners keeping temp at 25 degree C
- Encouraging the business community for using solar energy
- Introduction of Energy Star Rating system in the electric appliances through BSTI
- Discouraging use of neon sign in the markets/ shopping malls at night
- Closing of markets and shopping malls within 8 p.m.
- Introduction of quality pre-paid and smart meters all over the country

6.3 Challenges to implement smart grid

Changing in order to smart grid through conventional grid isn't always easy. Although power usage development is actually higher, era is actually faltering to satisfy need price. A worldwide statistics on energy usage is actually provided beneath:Challenges necessary to satisfy the execution associated with smart grid could be split in to 2 different kinds; security challenges and integration challenges.

. **Security Challenges**

1. Network security of distributed systems across meters, substations and in- home devices including authentication, detection, and monitoring.
2. Identity & access management for managing customer information.
3. Messaging and application security communications including data, network communications, and transactions.
4. Security policy management and implementing web services security standards.
5.

Integration Challenges

i. Adoption of SOA architecture.
ii. Web service enablement of legacy apps.
iii. Format bridging, transformation and routing.
iv. Handling wide variety of non-XML data formats.
v. Interfacing with partners and customers.

6.4Prospect of Smart Grid in Bangladesh

Energy lack is really a globally issue. At present, a lot more than forty nations display power system lack of stability as well as load-shedding because of electricity shortage. Northern

United states as well as Western businesses tend to be at present focusing on creating 'smart electrical grid' technologies in order to enhance energy circulation utilizing digital radios with regard to better electrical grid manage as well as energy conservation. The requirement to construct Smart Grid technologies is actually increasing globally as well as Bangladesh may become the leader in this region associated with technology development. Because energy demand is actually growing each year within Bangladesh, it's not feasible to construct power stations quickly. Smart Grid program may reduce this issue. In case of load-shedding, brought on by electrical energy lack in the United Kingdom, the actual Smart Grid may instantly recalculate as well as deliver electricity to any or all customers pretty The fundamental must put into action Smart Grid tend to be digital radios, circuit breakers and so on. Each digital radios as well as circuit breakers have to update the actual procedure associated with country's electrical grid, which may be created as well as stated in Bangladesh within big size. By using expatriate Bangladeshi engineers, Bangladesh can begin creating as well as production the actual electrical parts necessary to up-grade the actual electricity grid in Bangladesh to ensure that, Bangladesh is definitely an earlier creator as well as adopter from the Smart Grid technology.

Integration of Renewable Energy

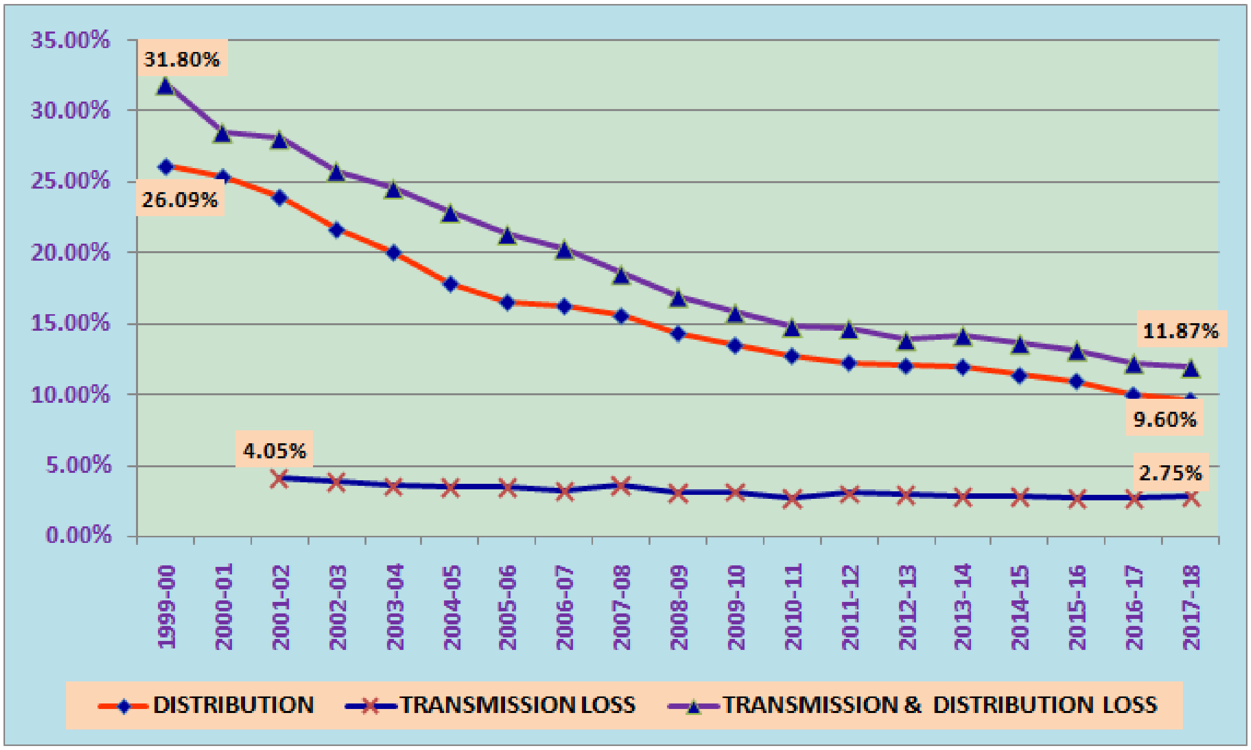
Because transmission amounts of renewable energy will probably carry on growing the re-think from the current energy managing paradigm might be needed. Luckily, a good functional smart grid has got the possible in order to offset a few of the issues which are presented through higher amounts of renewable energy generation. The smart grid requires benefit of possible enhancements that may be designed to conventional operation by using communications and information. Present power system is not able to forecast as well as identify this kind of variability and for that reason can't assistance or even manage this particular. Apart from results about the grid differs along with various transmission amounts of blowing wind as well as solar energy. Therefore dependability is really a main issue right now. Therefore, the delicate manage program is needed that will are made up effective tranny, need reaction as well as smart energy storage space quite simply the smart grid could be modified.A good energy storage system is needed to put into action renewable energy resources. Whilst renewable energy can-not always end up being run inside a traditional method, it'sconduct could be forecasted and also the predict info is precisely the type of info that the smart grid should make use of in order to improve system efficiency. Therefore, merely we are able to observe that renewable energy is definitely an additional benefit in order to Smart Grid.

6.5 Preparing a roadmap for implementation of smart grid

In the short explanation over, it might be noticed which smart grid is a transformation or even trip in the existing condition from the grid in the direction of including some wiser systems/applications inside a phased method as well as based on the company focal points of every power. To be able to handle as well as accomplish this transformation effectively, comprehensive preparing as well as improvement of the execution technique, strategy as well as recommendations are needed, addressing procedures, choice of technologies as well as requirements, source needs as well as capability creating applications with regard to resources, government bodies, execution companies as well as technology companies. The clear as well as thorough strategy as well as roadmap for that execution associated with smart grids might assist technology development, capability creating as well as expense preparing. Therefore to begin with require a affective roadmap associated with smart grid, which might put together through advisory as well as execution panel or even any kind of specialized group employed through federal government. In most roadmap, there's period variety by which period objective associated with task is going to be accomplished. However all of us, within our research, recommend a few conceptual style without having period variety that'll be additional inside a last roadmap.

6.6 Reduce Transmission & Distribution Loss in Bangladesh Day by Day by Using Smart Grid Components

FY	DISTRIBUTION	TRANSMISSION LOSS	TRANSMISSION & DISTRIBUTION LOSS
1999-00	26.09%		31.80%
2000-01	25.34%		28.43%
2001-02	23.92%	4.05%	27.97%
2002-03	21.64%	3.79%	25.69%
2003-04	20.04%	3.48%	24.49%
2004-05	17.83%	3.42%	22.79%
2005-06	16.53%	3.44%	21.25%
2006-07	16.26%	3.15%	20.25%
2007-08	15.56%	3.51%	18.45%
2008-09	14.33%	3.06%	16.85%
2009-10	13.49%	3.08%	15.73%
2010-11	12.75%	2.66%	14.73%
2011-12	12.26%	2.96%	14.61%
2012-13	12.03%	2.94%	13.79%
2013-14	11.96%	2.74%	14.13%
2014-15	11.36%	2.76%	13.55%
2015-16	10.96%	2.63%	13.10%
2016-17	9.98%	2.67%	12.19%
2017-18	9.60%	2.75%	11.87%



6.7 DPDC to install smart grids for the first time in Bangladesh

Dhaka Power Distribution Company (DPDC) will be installing smart grids for the first time in Bangladesh in the capital's Dhanmondi, Azimpur, Green Road, Lalmatia and Asad Gate areas. New substations will accompany the smart grids in these five areas. Related sources said: "Power lines are spread all over the streets and underground in an entangled mess and it is difficult to determine one from the other in times of power connection issues. "Sometimes other organizations snip power transmission lines out of the blue while working underground, but the severed line cannot be recovered afterwards. "With the help of smart grids, we can instantly address issues such as power outage in an area or house as they will use sensors and automatic response mechanism to deliver immediate responses." They also said: "Smart grid will prevent loss of power in nearby areas due to power mishaps in some other area as all its functions will be computer-regulated." Regarding smart grid, DPDC Executive Director Engineer Md Ramiz Uddin Sarker said: "With the help of this technology one can monitor one's power consumption. Similarly, it is possible to use technology to ensure a smooth and flawless transmission of electric power. "Usually a lot of time is wasted on locating transmission failures. But now, using modern technology, we can locate and fix the issue instantly." DPDC also said that it will be possible for consumers to choose power "plans" most suitable to them just like internet package plans for mobile phones. There will be a card in the electric meter boxes of households and organizations, much like a SIM card, which will transmit information on how much electricity has been consumed to a modern central management ward every 15 minutes. With the installation of these smart grids all over the city, "peak" and "off-peak" cost of electricity can also be determined separately. Consumers can then decide how much to consume based on those prices. Donor organization France Development Agency (FDA) has agreed to spend $12 million on this venture. Managing Director of DPDC Bikash Dewan said: "FDA is already providing funds for a tech-smart transmission project. They have also agreed to invest $12 million on the smart grid venture. "We will begin by setting up the grids in five areas but we aim to do so all over the city eventually. But to do so, we require huge amounts of investment," he added. An AFD team had arrived in Dhaka last month and examined DPDC's substations and their transmission in various areas. At the same time, DPDC had a discussion with the AFD team about smart grids. Bikash said: "AFD will present the proposal of the smart grid investment in their board meeting and then finalize it by signing with Bangladesh Economic Relations Department (ERD). "The planning commission has advised for a prompt course of action regarding the matter. So we envision carrying out the plan by the end of this year," he added.

CHAPTER 7

Conclusion and Recommendation

7.1 Conclusion

Emission coupled with source as well as national infrastructure restrictions tend to be dampers. Existing installed power capacity might have to end up being bending through the finish of the 10 years to satisfy energy need of its growing population and expectations of a high GDP growth economy. A summary of Bangladesh Power Market along with brief analysis about the power system units is actually referred to. Power market in Bangladesh is usually seen as a poor people need aspect administration as well as reaction with regard to insufficient correct national infrastructure as well as attention.Smart Grid Technology can intuitively overcome these issues. Likewise, it may recognize decrease in collection deficits in order to conquer existing power shortages, improve the actual dependability associated with provide, power quality improvement and it is administration, guarding income, stopping thievery and so on.. Integration of RES is expected to play significant influence about the procedure from the power system with regard to environmentally friendly energy in future. Grid rules tend to be setup in order to stipulate the actual appropriate needs with regard to effective as well as safe procedure associated with power system for those network customers as well as these types of specs need to be fulfilled to be able to incorporate wind generator to the grid. Several technical as well as functional difficulties with elevated power penetration offers talked about with regard to rising Bangladesh power system.Additionally, Microgrids tend to be making brand new smart grid technology needs within the regions of automation, administration as well as manage associated with alternative energy sources along with energy storage products. The actual statement might manual long term guidelines that in order to guide Bangladesh power system to consider a number of actions in order to put into action Smart grid with RES integration.

The thesis presents a discussion on Bangladesh Power Strategy along with its pitfalls in various technical and non-technical themes, by having an structured method of develop the actual conceptualization associated with Smart Grid. Design used through the government and several personal physiques, tend to be offered within the thesis. Additional, numerous potential customers associated with environmentally friendly energy as well as off-grid options, Rural Electrification (RE) as well as development associated with Micro Grid together with numerous guidelines as well as regulatory affairs of Bangladesh can also be offered right here.

7.2 Recommendation

This study clearly indicates that there is potential for reduction of peak load and reduction of overall electricity consumption through demand response. Both types of reduction seem to depend a lot on consumer engagement. So participations with grid will be increased actively of consumer. Also, few more work related to micro grids and hybrid energy with energy storage systems are premeditated to complete by near future. Upon the finalizing of the entire study, the further research perspective would deliberately act as an advocate to discover the rank and strategy of nation’s development in power and energy with respect to current and future energy demand.The business case for smart grids is more obvious for society than it is for utilities alone. This implies that regulators should be forward-looking and play an important role in driving the development of the smart grid. Regulators can influence the development not only through technology mandates or financial incentives, but also through the promotion and communication of social norms and objectives.From this thesis’ review of consumer engagement theories and practical demand response studies, the following recommendations for regulators can be formulated:

1. Clearly communicate societal goals and regulatory targets, and provide incentives and education to end consumers. This will contribute toward individual consumers’ alignment with these goals and will increase consumer engagement.
2. Design policies that align utility goals with societal and consumer goals, i.e. focus on service quality rather than quantity, giving incentives for electricity savings, rather than electricity sales.

3. Rather than focusing on the mandatory installation of smart meters, make it mandatory for utilities to provide consumers with frequent, accurate, timely consumption data (real-time and disaggregated, if possible) and historic comparisons.
4. Allow or mandate utilities to use “opt-out” schemes for dynamic pricing rather than “opt-in” schemes.
5. Ensure clear, stable and supportive regulatory conditions
6. Accelerate R&D and support evaluation efforts and sharing of results to ensure systematic learning and knowledge capitalization in this new area.

REFERENCES

[1] http://www.answers.com/Q/What_is_power_grid_system

[2] http://www.energygroove.net/technologies/electrical-grid/

[3] http://www.enernoc.com/our-resources/term-pages/more-about-power- generation-transmission-and-distribution

[4] V.K. Mehta & Rohit Mehta. Principle of power system. New Delhi: S.Chand, 1982

[5] X. S. Zhou, L. Q. Cui and Y. J. Ma, "*Research on Smart Grid Technology,"* 2010 IEEE International Conference on Computer Application and System Modeling (IC-CASM-2010*)*, Vol. 3, 2010, pp. 599-603.

[6] *Position Paper on Smart Grids, "An ERGEG Conclusions Paper,"* European Regulator Group for Electricity & Gas (ERGEG), 10 June 2010.

[7] Smart Grid Information ClearingHouse. http://www.sgiclearinghouse.org /learnmore.

[8] The Smart Grids European Technology Platform. http://www.smartgrids .eu/ETPSmartGrids.

[9] Smart Grid Information ClearingHouse. http://www.sgiclearinghouse.org /learnmore.

[10] Smart grid conceptual model. http://smartgrid.ieee.org/ieee-smart-grid/smart- grid-conceptual-model .

[11] *"The Smart Grid: An Introduction"*-the nature, challenges, opportunities and necessity of Smart Grid implementation. 2009. http://energy. gov/oe/services/technology-development/smart-grid.

[12] Smart Grid Concept and Characteristics. http://electrical-engineering- portal.com/smart-grid-concept-and-characteristics

[13] IEC: Communication Networks and Systems in Substations Parts 1–10, IEC Technical Report IEC/TS 61850-1 to IEC/TS 61850-10, 2002–2005

[14] Electric Power Research Institute (EPRI): Environmental Assessment of Plug- In Hybrid Electric Vehicles. Nati/onwide Greenhouse Gas Emissions, vol. 1, Final Report. Electric Power Research Institute, Palo Alto, July 2007

[15] Kim, H., Thottan, M.: A two-stage market model for microgrid power transaction via aggregators. Bell Labs Tech. J. special issue on Vertical Markets. **16**(3), 101–107 (Dec 2011)

[16] IEC: Communication Networks and Systems for Power Utility Automation, Part 90-1: Use of IEC 61850 for the communication between substations, Technical Report, IEC/TR 61850-90-1, 2010

[17] U. S. Department of Energy: Benefits of Demand Response in Electricity Markets and Recommendations for Achieving Them. DoE Report to the U. S. Congress Pursuant to Section 1252 of the Energy policy Act of 2005, Feb 2006.

[18] Kim, H., Thottan, M.: A two-stage market model for microgrid power transaction via aggregators. Bell Labs Tech. J. special issue on Vertical Markets. **16**(3), 101–107 (Dec 2011)

[19] Ekanayake, Janaka.. [et al.]. Smart Grid Technology and Application. New Jersey; *A John Wiley &*

Sons, Ltd., 2012.

[20] ZigBee Alliance: ZigBee Specification Overview. http://www.zigbee.org/ Specifications/ZigBee/Overview.aspx (2012)

[21] HomePlug Alliance: HomePlug Technology Application: Smart Grid/Smart Energy.http://www.homeplug.org/tech/app_smart_energy (2012)

[22] Hossain, Ekram. Smart Grid Communication and Networking. New York; Cambridge University Press, 2012.

[23] IEEE (2011) *IEEE 802 LAN/MAN Standards Committee*, IEEE, March 2011, http://www.ieee802.org/minutes/2011-March/802%20workshop/index.shtml

[24] IEEE Power & Energy Society (2010) *IEEE Std 1815TM-2010: IEEE Standard for Electric Power Systems Communications-Distributed Network Protocol (DNP3)*, June.

[25] Deering, S. and Hinden, R. *Internet Protocol, Version 6, (IPv6) Specification*, http://www.rfc-editor.org/rfc/rfc2460.txt (accessed on 4 August 2011).

[26] Budka, K., Deshpande, J., Doumi, T., Madden, M., Mew, T.: Communication network architecture and design principles for Smart Grids. Bell Labs Tech. J. special issue on Eco-Sustainability and Green Information and Communications Technology, Vol 15., No. 2, pp 205–227, Sept 2010.

[27] Hossain, Ekram. Smart Grid Communication and Networking. New York; Cambridge University Press, 2012.

[28] Budka, K., Deshpande, J., Thottan, M.: Communication network transformation for Smart Grid evolution, UTC J. Utilities Telecom Council,
Washington, DC, May 2012

[29] Budka, K., Deshpande, J., Thottan, M.: Communication network transformation for Smart Grid evolution, UTC J. Utilities Telecom Council,
Washington, DC, May 2012

[30] Kreith, F. and Goswami, D.Y. (2007) *Handbook of Energy Efficiency and Renewable Energy*, CRC Press, New York.

[31] Krzysztof Iniewski. Smart Grid Infrastructure & Networking. New York:
McGraw Hill Professional, Aug 21, 2012

[32] Kezunovic, M., Ghavami, M., Guo, C., Guan, Y., Kardy, G., Dam, L.: The 21st Century Substation Design, Final Project Report, Power Systems Engineering Research Center, PSERC Publication 10-15, 2010

[33] IEC: Communication Networks and Systems in Substations Parts 1–10, IEC Technical Report IEC/TS 61850-1 to IEC/TS 61850-10, 2002–2005

[34] Lakervi, E. and Holmes, E.J. (1996) *Electrical Distribution Network Design*, IEEPower Engineering Series 21.

[35] *IEA Demand Side Management Programme*, http://www.ieadsm.org/

[36] Gellings, C.W. (2009) *The Smart Grid: Enabling Energy Efficiency and Demand Response*, The Fairmont Press, Lilburn.

[37] Grigsby, L.L. (ed.): Electric Power Engineering Handbook, Electric Power Generation, Transmission, and Distribution, 3rd edn. CRC Press, Boca Raton, 2012.

[38] *IEEE C37.118: Standard for Synchrophasors for Power Systems*, IEEE, 2005.

[39] Paolone, M., Borghetti, A., Nucci, C.A.: A synchrophasor estimation algorithm for the monitoring of active distribution networks in steady state and transient conditions. In: 17th Power Systems Computation Conference, Stockholm, Sweden, 22–26, Power System Computation Conference, Zurich,
Aug 2011

[40] Dy Liacco, T.E. (1967) The adaptive reliability control system, *IEEE Transactions on Power Apparatus and Systems*, **PAS-**86 (5), 517–531.

[41] Ota, H., Kitayama, Y., Ito, H. *et al.* (1996) Development of transient stability control system (TSC system) based on on-line stability calculation. *IEEE Transactions on Power Systems*, **11**(3), 1463–1472

[42] Staszesky, D.M., Craig, D. and Befus, C. (2005) Advanced feeder automation is here. *IEEE Power Engineering Magazine*, **3**(5), 56–63.

[43] Storm, D.: 440 Million New Hackable Smart Grid Points. COMPUTERWORLD BLOG, Oct 2010. http://smartgrid.ieee.org/newsieee- smart-grid-news/1663-440-millionnew-hackable-smart-grid-points

[44] Markey E.J., Waxman, H.A.: Electric Grid Vulnerability: Industrial Responses Reveal Security Gaps, U.S. Congressional Report, May 2013

[45] Global Smart Grid Cyber security Systems Market Value (2012–2020). http://www.researchandmarkets.com/research/lzbwmq/global_smart_grid.
May 2013

[46] CNN: Sources: Staged Cyber Attack Reveals Vulnerability in Power Grid. CNN, 26 Sept 2007.

http://articles.cnn.com/2007-09-26/us/power.at.risk_1_generatorcyberattack- lectric-infrastructure?_s=PM:US

[47] Termineter: An Open-Source Tool Designed to Assess the Security of Smart Meters. SecureState.com, Aug 2012. http://www.securestate.com/ResearchandInnovation/ Pages/Tools_test.aspx

[48] Baker, S., Filipiak, N., Timlin, K.: In The Dark: Crucial Industries Confront Cyber attack. Center for Strategic and International Studies, McAfee.com Report, 2011

[49] Herold, R., Hertzog, C. (eds.): Data Privacy for the Smart Grid. Auerbach Publications, Boca Raton, July 2014

[50] present power Scenario of Bangladesh http://greeninfrabangla.com/593/

[51] Power division http://www.powerdivision.gov.bd/user/brec/42/80

[52] Position Paper on Smart Grids, "An ERGEG Conclusions Paper," European Regulator Group for Electricity & Gas (ERGEG), 10 June 2010.

[53] Vision and Strategy for Europe's Electricity Networks of the Future, European Smart Grids Technology Platform, Directorate-General for Research Sustainable Energy Systems, EUR 22040.

[54] X. S. Zhou, L. Q. Cui and Y. J. Ma, "Research on Smart Grid Technology," *2010 IEEE International Conference on Computer Application and System Modeling (IC-CASM-2010),* Vol. 3, 2010, pp. 599-

[55] https://www.dhakatribune.com/business/2018/05/05/dpdc-install-smart-grids-first-time-bangladesh/

[56] Ministry of Power, Energy and Mineral Resources (MPEMR); https://www.mpemr.gov.bd/