# An Overview: Development Strategies of Smart Grid

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***Abstract—*** *A modern power grid infrastructure is required to deliver the energy to the consumer which is secure, efficient and reliable. With the passage of time demand of electricity at the consumer end is increasing compared to the rate of generation of electricity. Transmission losses and a poor distribution system which includes the power theft also account for the energy crisis faced by developing countries like Pakistan. This paper presents an advanced approach to overcome the flaws and drawbacks which are being faced by the present electric power network. The paper is distributed into two main sections; first section is about smart grids characteristics and its driving forces which is the motivation to incorporate the concept of smart grids. In the second section main functions of smart grids are discussed. Customers can be facilitated with advanced and enhanced services of smart transmission, smart protection, smart metering and smart control systems. At the end role of smart substation is discussed.*

***Key words:*** *component; Supervisory control and data acquisition SCADA; Circuit Breaker (CB); Solid state electronic meter (SSEM); Distribution system operators (DSO), information and communication technologies (ICT).*

## 1. Introduction

The restructuring of old generation and distribution power system is one of the ways to improve the performance and efficiency for the better utilization of energy. The asian development bank reports transmission and distribution losses of up to 24.3% (FY2003-2004) in Pakistan [1]. In order to overcome these problems and to transmit reliable and secure energy to the consumers, addition of distributed generation (DG) at the grid station is necessary which causes the complexity in the distribution network [2]. The addition of distributed generation makes the grid more intelligent and complex but they must be integrated sufficiently well with the power system. Renewable energy resources which include solar, wind and tidal energy are the focus of professionals and researchers to solve the current energy crisis. Pakistan is amongst those countries who receive a high level of solar radiations. Studies have shown that on average Pakistan receives 19MW per square meter of solar energy. The Government of Pakistan has set the 'Alternative Energy Development' board a target of generating around 9700MW by the end of 2030.The energy generated from renewable resources is installed into the national grid which causes many technical issues to face until and unless renewable generating sources are not properly integrated with the national grid [3].

Smart grids are an advanced approach of managing the power system especially at the distribution and consumer's end. This paper presents a vision of smart grids and its various features. Smart grid is analogous to Internet, therefore it may be called Energy Internet. As in Internet, data packets are sent to the receiver; likewise in case of smart grids energy is transmitted from the suppliers to the consumers. Smart grids are intelligent in sense of load management and sharing of information by using communication systems. In this paper future challenges and requirements of smart grids are summarized.

Smart grids are intelligent, flexible, offer resiliency, self healing and sustainability. Advanced power electronics devices e.g; FACTS family devices can be incorporated to improve the performance of transmission lines and make the power system more efficient. A more reliable control system which provides facilities of load management by forecasting the future loads of domestic, commercial and industrial consumers using mathematical prediction algorithms can be deployed.

## 2. Smart Grids and Its Driving Forces

The integration of communication systems technology and information or collected data with every part of electric power network to enhance market liberty, reduce cost, improve efficiency, reliability, services and minimizes environmental challenges is known as smart grid. Smart grids allows communication and data sharing between generating station, auxiliary equipments like transformers, circuit breakers, electric meters at consumer ends etc with the main control center where all the managements of data, billing, loads, operation and maintenance are performed [4].

The current transmission and distribution system is facing many critical challenges which are the driving forces to implement the smart generation, transmission, distribution, protection and utilization systems. Smart grids; a future vision is illustrated in Figure 1. The challenges faced by electric power systems are as outlined [5];

- The already installed infrastructure of electric power system is outdated and needs maintenance to overcome the present

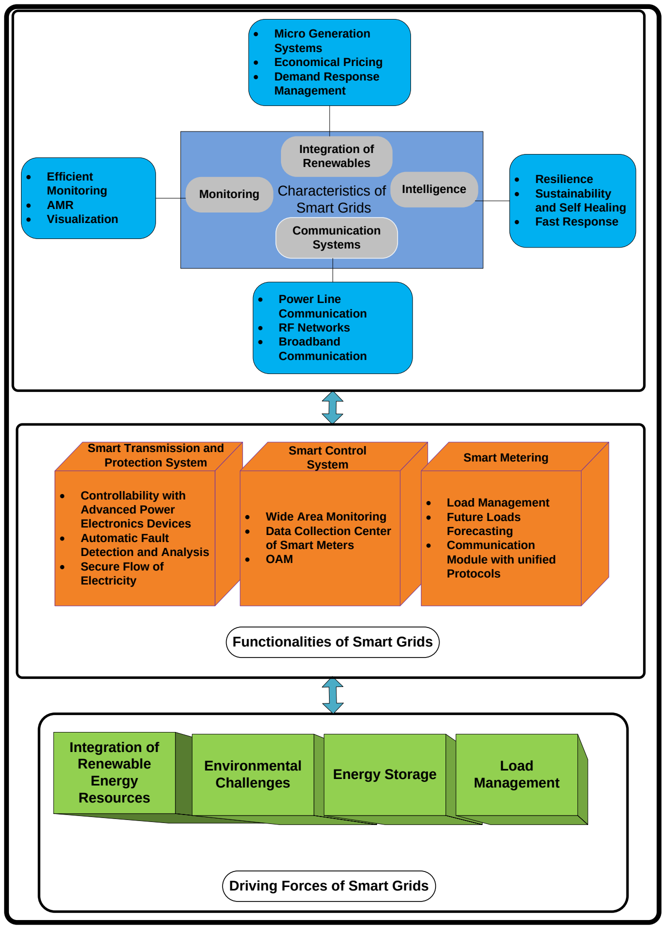


Fig. 1 Future vision of Smart Grids

consumer's requirements.

- With the time based development of countries which includes the increasing trend of industries and household electric appliances, the cost of fossil fuels is increasing and becoming unaffordable. Hence an alternate solution of this is the integration of renewable energy resources with the present electric power system.
- About 25 % of global greenhouse gas emissions are produced by electric power system, thereby causing an enormous deterioration in environment.
- Renewable energy systems can play a vital role in decreasing the production amount of greenhouse gases.
- Poor load management system causes huge line losses and power theft which can be managed by introducing the new load management system handled by advanced communication links and proper monitoring system.

By recognizing all these challenges the researchers and electric power community started to work on the concept of smart grid which may prove to be more reliable and efficient compare to the present electric power network.

## 3. Smart Transmission and Protection System

The current transmission system is using the supervisory control and data acquisition system (SCADA) which is slow. SCADA system provides the local protection; it protects only the limited parts of the grids or specific components and equipments. In order to add more intelligence to an electric power transmission system to make it more smart, independent agents which can be a processor have to install with each component or equipment, substation and power plant. The robust operation should be performed by these independent processors so that they can react immediately on the occurrence of any sort of abnormality in power transmission and protection system. The processors which are independent agents should have capability to communicate and interoperate with other processors [6]. By installing a processor with the electro-mechanical sensor that can assess the operation of sensor built into the CB will make it more intelligent by the use of communication system. Sensor values can be used for developing a more reliable protection system. Processor installed with an electro-mechanical sensor built into a CB is shown in Figure2 [7].

## 4. Smart Control Systems

The future vision of smart control systems is based on the existing control systems which can be made intelligent by providing extra facilities and functions to them.

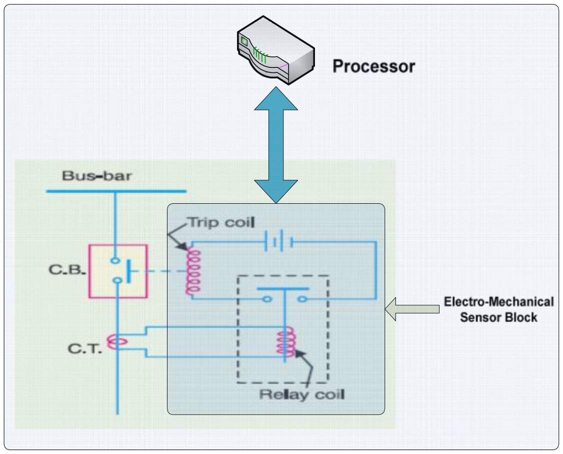


Fig. 2 Control of CB by an Electro-Mechanical Sensor

The new functions and facilities that can be provided and added into the smart control systems such as the use of advanced power electronics, FACTS (Flexible AC transmission system) family and HVDC (High voltage DC) devices, efficient monitoring system, automated metering system of electricity units, smart billing system, control systems for load management and controllability of the smart control systems for future reliability are discussed in this section [8].

### *A. Efficient Transmission of Electricity and Self Healing*

Smart transmission system will be able to monitor and analyze the operating conditions of transmission lines [9]. Advanced signal processing, wireless sensors, communication and analytical techniques which includes the FFT and Wavelet analysis of the signals can be performed in order to monitor the performances of transmission lines as well as high voltage and low voltage equipments like cables, circuit breakers and transformers etc. Sensors and processors along with communication links deployed besides the transformers will have the capability to monitor the transmission line performance under normal and abnormal conditions. When a transient or high voltage surge developed in the transmission line due to switching operation initiated by control center or due to lightning strokes which causes the insulation failure of transmission lines and transformers, especially the windings of the transformers get punctured. By the deployment of sensors and processors one can detect the abnormal condition of equipment, analyze it and isolate the faulty part of the system connected to the transmission line by tripping the circuit breaker and send the message to control room. An enhanced power transmission system, transmitting power from generation side to the end consumer is illustrated in Figure 3. Moreover transformer faults can be located and the severity of faults can be recognized with the help of FFT and wavelet analysis.

A sophisticated monitoring system for transformers (located at sub-stations and deployed in distribution system) can detect the healthy and faulty parts of the transformers; it can measure efficiently the magnitude of dissolved gases in the oil of the transformer.

Based on the performance of the transmission lines and auxiliary equipments with the help of operating conditions and parametric analysis; automatic fault detection and emergency response to the malfunctioning of equipments before the occurrence of fault that can interrupt the services, controller based protective relaying system can be introduced for the better protection of power system.

### *B. Application of Advanced Power Electronics Devices in smart grids*

FACTS family and HVDC devices have a capability to facilitate smart grids. FACTS devices are power electronic based system that is used to enhance the controllability and increase the capability to transfer power in more secure fashion. These devices also improve the dynamic stability and performance of the transmission lines. STATCOM (Static Synchronous Compensators) and SVC (Static VAR Compensators) belongs to the FACTS family of devices, which can be used to improve the voltage regulation, voltage stability and power factor of the electricity power network [4]. Utilization of FACTS family devices can make transmission system more flexible and efficient in order to improve the performance of transmission system. Furthermore with the increased trend of alternative energy and renewable energy resources, the integration of renewable energy resources with the current power system can become more reliable. The problems like inrush currents, fluctuations, Ferranti effects and other power system quality issues can be compensated in the future smart grids by installing advanced power electronic devices.

HVDC can provide a controllable and economical solution for the high voltage transmission lines of longer distances. They can be used to integrate the energy of large wind turbines. Current limiting conductors or fault current limiters which are based on power electronics can be installed to achieve the better utilization of transmission lines, system capacity, improved operating system under contingencies and increased reliability [10]. Traditional electromagnetic transformers can be replaced by advanced solid state transformers in order to obtain flexible transformation between various voltage levels. These solid state transformers have longer lifetimes, higher reliability and faster switching time which avoid the occurrence of faults and malfunctioning because these are free from switching bounces and arcing.

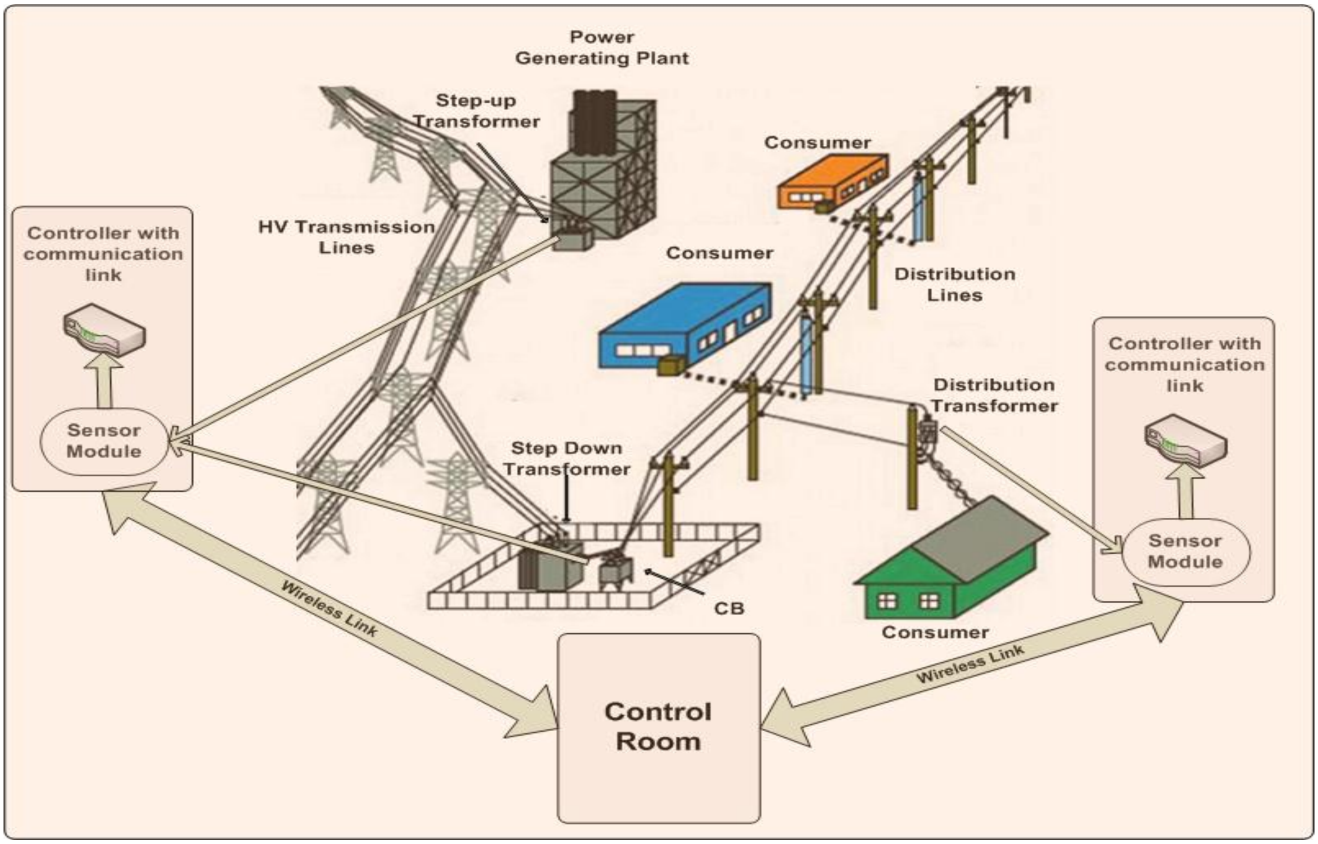


Fig. 3 Enhanced Power Transmission and Distribution Network

## 5. Load Management and Prediction for Future Needs of Electricity

The total load connected to the power grid can never remain constant and it will keep varying in different spans of 24 hours [11]. Daily and annual load curves are shown in Figures 4 and 5. Although the sum of various individual loads produces a total load but the overall load does not remain constant. It can be understand by the example of a popular TV program. When that popular program starts, millions of TV sets will turn on and a rapid power will be drawn by the overall load. This example highlights the daily load curve variations. Similarly for annual load variations the daily load curve variations of Pakistan's domestic customer in the summer season can be observed. Millions of air conditioners turned on in summer season after noon and nights and a rapid power is drawn by the load. In order to compensate these abrupt increases in power demand which cannot be handled by a single generator, multiple generators will be needed to put on standby mode. With the deployment of smart grids each individual customer can be warned in peak hours of that popular TV program or air conditioners to reduce the load in order to avoid any sort of discrepancy so that standby generators can turn on in this time.

Mathematical prediction algorithms can be used to predict the standby generators quantity in numbers [10]&[12].

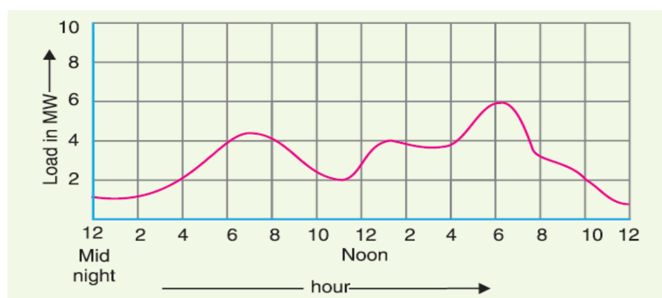


Fig. 4 Daily Load Curve [6]

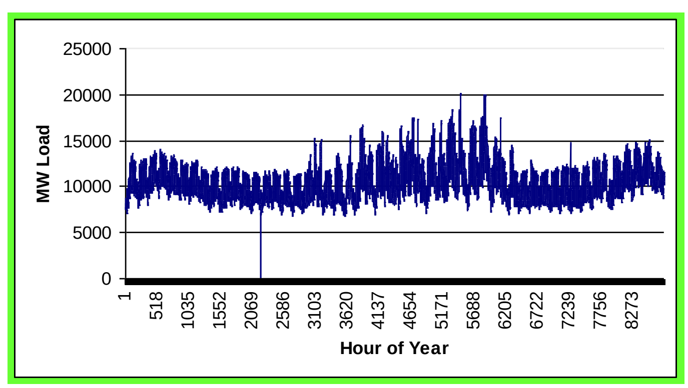


Fig. 5 Annual Load Variation Curve

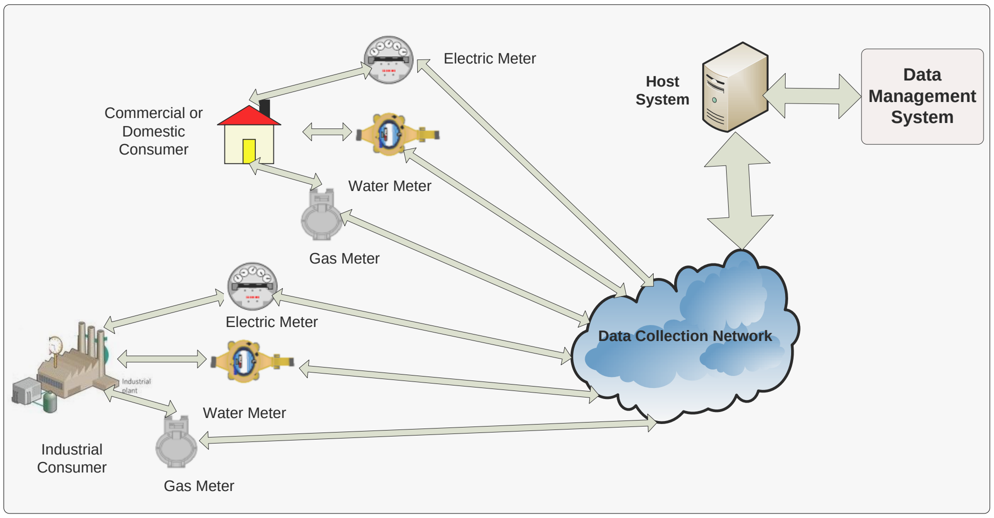


Fig. 6 Communications of Smart Meters

### A. *Smart Metering*

Electric meters are used to measure the electricity consumption by the customers [13]. The meters commonly used are electromechanical meters. Electromechanical design of meters remained very popular for last forty years and still considered to be the most reliable billing unit counting tool [12]. But in recent five to ten years transformation in metering technology converts the electromechanical meters to solid state electronic meter (SSEM). The strongest driving force for the SSEM is the feature of automatic meter reading due to which manual reading of meters will replaced with smart meter and physical presence of meter reader will become obsolete [15].

Today with the advancement in metering technology and communication systems the concept of advanced meters has emerged which can provide value added services to the utilities by improving the power quality monitoring, better load forecasting, reduced power theft, customer services enhancement and managing demand response [16]. Due to advanced metering one can take the meter readings on hourly basis or even more frequently that can make it possible to estimate the customer demand connected to the feeder line or transformer. If distributed system operators (DSO) take meter readings frequently then customers can be assisted by the customer services representatives about their peak loads and base loads starting and ending time and high bills complains can easily be handled. Furthermore peak loads and base loads of an area can also be estimated by smart metering system. By doing this proper sizing of equipments to handle the peak loads and base loads can be achieved which will increase the life and reliability of equipments and services while reducing cost. Frequent meter readings can also improve the load forecasting accuracy. Smart meters can help obtain the future load design and time based unit rates. These meters not only used for electric billing but can also be used for the billing of gas and water meters but the focus of this paper will remain on electric meter that is shown in above Figure 6.

### B. *Smart Metering Building Blocks*

Different types of components are used as a building block of smart metering system which includes data retrieval and collection network or control room where collected data can be sent and received, intelligent meters which can provide communication with the data collection network, each smart meter at the consumer end will be equipped so that it can have ability to communicate with a data collection network and a host database system. Collection of data will be performed without physical site visit where meter is deployed. The collected data is sent through data collection network to a database system host where data is analyzed and stored by proper management system. The main building blocks of smart meters are shown in Figure 6.

Today distribution system operators are looking for several types of communication systems for data collection. Information and Communication technologies are a fundamental element of the Smart Grid. Smart Grid cannot be practically implemented without a fully integrated communication system, through which its various entities may be able to communicate reliably within the grid [17]. Various media of communication are available as viable options, including the wireless, optical fiber, powerlines, etc, however powerlines hold an edge over all others, being the most pervasive network in the world, with the advantage of “No New Wires” solution. PLC technology has matured for low data rate communication in LV transmission lines, with applications in automatic meter reading (AMR), home-energy management and automation, etc [18]. Smart Grid necessitates communication between millions of users and the distribution grid, therefore significant consideration is given to the cost and reliability of the communication technology.

### C. *Smart Metering Useage*

According to a survey conducted by a US organization FERC (Federal Energy Regulatory Commission), the most demanding functions reported in United States regarding smart meters are as given in Table – I.

Table I. Survey Results of FERC [12]

| Entities | Customer's Response |
|---|---|
| Enhanced customer service | 74 % |
| Tamper detection | 52 % |
| Power quality monitoring | 42 % |
| Outage management | 39 % |
| Load forecasting | 33 % |
| Asset management, including transformer sizing | 25 % |
| Reduce line losses | 19 % |
| Premise device/load control interface or Capability | 18 % |
| Remotely change metering parameters | 17 % |
| Price responsive demand response | 16 % |
| Interface with water or gas meters | 6% |
| Pricing event notification capability | 2% |

The obtained results from the survey were below the expectations but it was due to the unawareness in the market consumers about smart metering system.

## 6. SMART SUBSTATIONS

The idea of smart substations is emerged when intelligence and reliability of substation is taken into account. The main problem with the present substations is the lack of information and data sharing with the main control room where data is collected and OAM actions are performed [4].

When faulty equipment is replaced with a new one in the substation, the status of the equipment is updated manually that is very prone to manual errors and if updating of equipment is forgotten to perform then database will show its old status which can cause major equipment handling problems. Smart substations incorporates the sensors based protective relaying system along with independent agents called processors which continuously keep on sensing the equipment performance and updating its new status via communication links automatically. The operation of this set up is much similar as a new hardware is installed in a computer; computer automatically reboots it and updates its new status. Smart about the performance of transmission lines and auxiliary substation can interact with other substations to provide the quality of services to the consumer. All distribution system fed by smart substation keeps updating the smart substation equipments i.e; transformers and circuit breakers. Any sort of abnormality in the performance of distribution system informs the smart substation remotely that is in interaction with the main control center from where management actions can be initiated. Nut shell of discussion is; smart substations have capability to reconfigure its status dynamically, rapid to faults response and natural disasters. The interaction of smart SS with transmission, distribution, local and main control centers is shown in Figure 7.

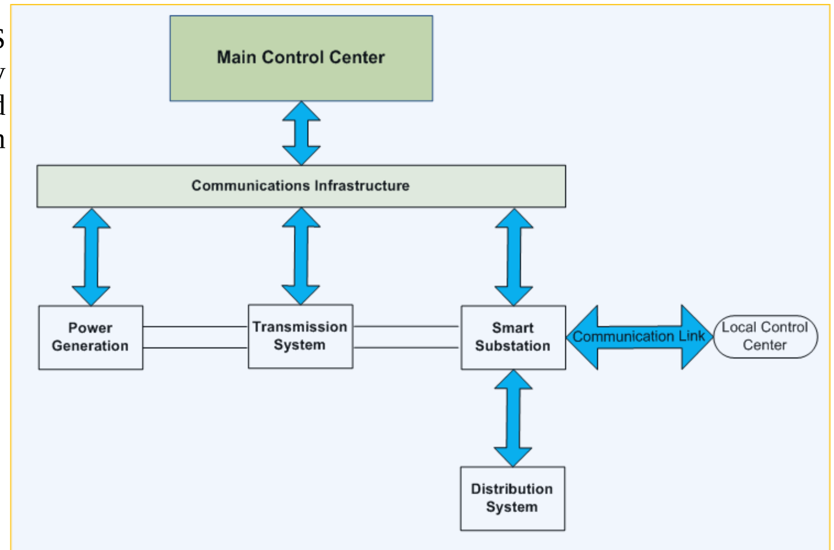


Figure 7 Interaction of Main Control Center with Power System

## 7. Conclusions and Recommendations

This paper has presented an overview of future smart grids so that delivery of electricity from generation to consumer side can make affordable by proper load management, reliable by using advanced power electronics devices like FACTS family and HVDC, resilience and self healing by using protective sensors along with processors facilitating the smart control system. In Pakistan the initiative of smart grid technologies can be taken from distribution load side where controllers with communication link can be incorporated at each transformer end for better performance of distribution lines. Smart meters can be added instead of old electro-mechanical meters or digital meters for better load management. The main features and characteristics of smart grids with an overall scenario of electric power system convergence to smart electric power network have been discussed. A lot of efforts, research and development are still invited to make the dream of smart grids come true.

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