CHAPTER 2
REVIEW OF LITERATURE ON MANAGEMENT OF AUTOMATION IN ENERGY SYSTEMS

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Generation, transmission and distribution systems together constitute an energy system. These three sub-systems have different techno-managerial issues to be managed for their reliable and efficient operations. Supervisory control, automation and real time data acquisition is a must for complex systems/networks for reliable and safe day-to-day operation of such systems. Relevant literature (covering a period of more than 15 years) on generation, transmission, distribution, supervisory controls, data acquisition and automation is cited here for ready reference. Special focus is maintained on critical concepts on SCADA techniques used by various researchers/investigators, including the author.

Generation of electrical power is accomplished through various conventional and well-known energy sources like; Atomic / Thermal (including Gas)/ Hydro and the Renewable energy sources like Solar and Wind. Almost all commercial electrical generation is achieved by using electromagnetic induction, whereas mechanical prime mover is employed to rotate a generator. Various sources of electrical power have different economics and breakeven capacities, the capital investment and running cost of each generation method varies with location and size. Mechanical energy is developed using different energy conversion concepts like: heat engines,
water head, wind velocity, tidal waves etc. Power generation is discussed in detail in the following text.

2.1 POWER GENERATION

Conventional energy sources on earth include fossil fuels in the form of coal and petroleum products (Liquid, Gas). Energy in the form of potential or kinetic energy of water is also available. Process of Atomic fusion and fission have also been recognized and used to harness nuclear energy. For Thermal and nuclear power plants, an intermediate medium is essential for conversion of thermal energy contained in fuels to mechanical energy. In other cases of potential/kinetic energies from water or wind the medium itself is generally utilized as conversion medium.

Thermal power plants utilize steam as a medium where thermal energy from fuel is used to produce steam at requisite pressure. The steam so produced drives a steam turbine coupled to an alternator/ generator. Identically in a full-size nuclear power plant, the heat of a nuclear reaction is used to produce steam which drives a steam turbine and consequently a generator. In gas turbine based thermal power plants (single or combined cycle) the turbines are driven directly by high temperature and pressure gases produced by the combustion of natural biogas, gas or the petroleum based fuels.

![Fig.2.1 Schematic of an Ultra super critical thermal power plant](image-url)
In a combined cycle thermal power plants both steam turbine and gas turbines are used efficiently to generate power by natural coal gas in a gas turbine and use high temperature exhaust (residual heat) to super heat steam, generating additional power through the steam turbine. The combined cycle power plants offer efficiencies of close to 60%. The steam turbines are most common prime movers and currently support about 80% of the generation capacity in the world.

Fig. 2.2 Gas Turbine based Power Plant.

Fig. 2.3 Large Hydro Power Plant
The potential and kinetic energy of water stored in a dam has been a conventional as well the renewable source of energy. Matching to the storage head parameters low, medium and high head water turbines are installed at hydro power plants to utilize this energy source and harness electrical energy. Kaplan, Francis and Palton turbine are commonly used at hydro power plants. Large dams such as Hoover Dam, Three Gorges Dam (China), Fig. 2.3 provide large amounts of hydroelectric power, up to 22.5 GW.

Apart from conventional energy sources, the solar, wind, tidal, geothermal and many more forms of energy are available as Renewable energy sources. In solar thermal power plants the steam generated by direct or focused (concentrated) solar radiations in collectors/ heat exchangers. A solar thermal power plant based on parabolic trough is shown in Fig.2.4. Geothermal power and ocean thermal energy conversion (OTEC) are also available to mankind to harness energy.

![Solar Thermal Power Plant](Image)

**Fig. 2.4 Solar Thermal Power Plant**

Wind speeds in the range of 5-12 m/s are potential sources of energy in coastal areas. Most of the wind turbines generate electricity from naturally occurring wind. Solar updraft tower use wind that is artificially produced inside a chimney by heating the inlet air with sunlight and venting it through the chimney creating an artificial draft is seen as a form of solar thermal energy.
Biogas is often combusted where it is produced, such as a landfill or wastewater treatment plant, with a reciprocating engine or a micro gas turbine. Chemical reactions (oxidation and reduction) are used in fuel cells to generate electric energy. It is worth noting that combined cycle thermal power plants have reported highest efficiencies (close to 60%) followed by Ultra super-critical thermal power plants. Both of these technologies are still under concept stage, field trials. Super critical thermal power plants with 42-44% efficiency are a practical reality. Solar photo voltaic and solar thermal power plant does not require any fuel and hence are claimed to be lean on operational costs.

2.2 TRANSMISSION OF GENERATED POWER
The electrical power once generated is transmitted to the consumer located at various sites. Domestic and commercial establishments act as a load or consumers of the generated electric power. The function of transmission line is to carry or transfer the electric power to its destination through power substations. HVAC (High Voltage Alternating Current) transmission lines are used for medium distances while HVDC (High Voltage Direct Current) lines are preferred for transmission along long distances. The transmission lines have natural characteristics which cause loss of power during transmission, HVDC is preferred due to less loss of power but the equipment used for HVDC lines are costly therefore it is only applied for long line transmission. HVAC is preferred for short and medium length transmission lines. The economics and efficiency is thus managed using appropriate mix of HVAC and HVDC lines.

Transmission, moving large amounts of power, over very long distances is different from distribution, which refers to the process of delivering electric energy to consumers at their specific locations such as industries, colleges, hospitals, a residential area and street or a commercial park. Distribution is usually from the substations and feeder lines that take power from the high voltage grid and progressively step down the voltage eventually to 230V level at which power is domestically utilized.
The transmission and distribution or “T&D” system includes everything between a generation plant and an end-user site. Along the way, some of the energy supplied by the generator is lost due to the resistance of the wires and equipment that the electricity passes through. Most of this energy is converted to heat. Just how much energy is taken up as losses in the T&D system depends greatly on the physical characteristics of the system in question as well as how it is operated. Generally speaking, T&D losses between 6% and 8% are considered normal. After receiving the electrical power from the generating station through transmission line to substation, the distribution takes place. The substations are located near domestic or commercial consumers, hence the substation have a very complex network of power distribution. The distribution point that is a substation has the entire details of what kind and characters of ‘load type’ of consumers are on their network.

Electrical loads are constituted or defined by three parameters; a Resistance, an Inductive Reactance and a Capacitive Reactance. The Reactance denoted as XI and Xc are frequency dependent and their amplitude vary in direct and inverse proportion to the frequency. As the system is constituted by elements every element and the load in a system has its effect on the entire network. The generator, the transmission line and the equipment in distribution network being parts of the network, individually influence the overall performance of the network in other words any kind of disturbance caused. In any part of power network system would cause disturbance to the entire network.

Most of the transmission lines that make up the transmission grid today are high-voltage AC lines. Long HVDC transmission are considered advantageous over HVAC transmission for considerably lower line losses per MW (~25% lower )and for higher load carrying capacities (two to five times the capacity of an AC line). HVDC lines are flexible and able to precisely manage and control flow of power. However, the relatively high cost of HVDC terminal stations relegated the technology to being used only in long-haul applications.
Power Semiconductor Devices based in power transmission equipment known as Flexible AC Transmission Systems (UPFC) provides a variety of benefits and supports higher transmission efficiency. It allows existing AC lines to be loaded to its capacity without increasing the risk of disturbances on the system. A UPFC device can enhance transmission capacity by 20 to 40% and stabilize the line voltage. UPFC devices present a fine example of how efficiency and reliability improvements often go hand in hand. Unlike shifting and constructing a new transmission line, UPFC devices can be implemented quickly (less than a year from purchase to completion in some cases). On implementation they immediately boost the transmission capacity of the given line while also providing voltage support and bolstering the local grid’s ability to withstand disturbances.

2.3 SCADA AUTOMATION AND ARCHITECTURE
Supervisory Control and Data Acquisition (SCADA) Automation is essential to introduce efficiency in control of power flow and related operations of an equipment or a system. This introduction is aimed at eliminating wastage of power and to support achieving the goal of increased efficiencies and economy of operation. It also provides security to the power network and helps in maintaining reliable, uninterrupted supply by intelligent algorithms. A broad review here describes various aspects of SCADA concepts, components, equipment and applications.

Multi-function Meter (MFM) are devices that record and store system data. The data/information so available is processed in analyzers as per set-rules/logics and displayed/relayed as control signals. In a network, numerous MFMs and associated hardware are used to accomplish desired data acquisition. Layout of a single-phase network power system with Multi-Function Meters is shown in Figure 2.5 (A) and 2.5 (B) outlines the SCADA architecture for a power system featuring 4 generators, 4 transmission lines, 5 loads, PLCs, wireless unit and computer system. A Computer Interface is used for the purpose of data transfer and provision of data acquisition (Logging) through a RS485 port.
Fig. 2.5 (A) layout of data acquisition system in a power system model.

Fig. 2.5 (B) Front end design of software
The above figures detail a Master Data Acquisition System featuring a RS485 port, a Modbus and USB connections. The figures also display data acquisition from various MFM on computer software. The software shown in Figure 2.5 (A) displays layout of Power System MFM’s marked G1 to G4 for generators, TL1 to TL4 for transmission lines, L1 to L5 for loads and for UPFC device as UPFC 1 & UPFC 2

Modbus Master Data Acquisition System is based on the paper by Khare Ramleela et.al title, “SCADA Automation in Energy Management Systems” [103]. The architecture of the figure 2.5 has been designed and used by the author in the construction of his Dynamic Monitor reference title, “SCADA Automation in Energy Management System” [103].

2.4 REVIEW OF THE LITERATURE

Lindeberg Charles T.’ and Wayne R. (1993) [1] in their study, “Project Planning For EMS & SCADA Systems Block” have described a typical supervisory control and data acquisition (SCADA) system for Energy Management system (EMS) stipulated an installed life of only 15 years. System requirements and the underlying technology are rapidly changing, they analyzed, system obsolesce is imminent in a short span of time. The study stated that the asset takes 5 years or more to implement a new EMS or SCADA system therefore, the utility engineers be trained and shall be familiar with the process of managing EMS or SCADA Hardware. The authors of this paper concluded that implementing a new EMS SCADA is a challenge and is addressed effectively by using state-of-the-art project management tools.

Leslie D.’, A. Hlushko’, S. Abughazaleh And Frank Garza (1994) [2] in their study, “Tailoring SCADA Systems for Standby Power Applications” have analyzed in their paper that SCADA systems used in manufacturing and process industries in addition to electric power utilities for energy management, for including economic dispatch and managing pricing of energy. However, the use of SCADA in smaller
power generation systems is not quite popular. The authors of this paper have concluded how a SCADA system was custom developed for a standalone power generation system installed in a sky scraper meets standby power requirements due to failure of utility power. The standby power in response to the system also contained rising loses and was designed to distribute power into the building’s electrical infrastructure through existing vertical bus ducts.

Askounis Dimitris And Emmanuel Kalfaoglou (2000) [3] in their study, “Greek Ems-SCADA: From the Contractor to the User” have indicated that the national electric utility of Greece has a modern Energy Management System (EMS).

This paper has analyzed the field experience with Supervisory Control and Data Acquisition (SCADA) system during its two years of commercial operation. It elaborates the improvements implemented during this period in three areas telecommunications, man-machine interface and core SCADA functions. The authors of this paper concluded that all computer based information systems cannot be fault free. Information system faults can be related to hardware or software design which skipped testing. Such faults are identified during commercial operation of the systems and are attended during service by the user / manufacturer.

Thomas Mini S., Parmod Kumar, and Vinay K. Chandna (2004) [4] in their study, “Design, Development, And Commissioning of a Supervisory Control and Data Acquisition (SCADA) Laboratory for Research and Training” have indicated that their paper reports a state-of-the-art Supervisory Control and Data Acquisition (SCADA) for Laboratory facility for power systems at Jamia Millia Islamia, New Delhi, India. It had been designed to function as a research and training center. The authors of this paper have analyzed the design, commissioning, and functioning of the SCADA/EMS laboratory facility, based on distributed-processing technology.
Choi Donghyun, Hakman Kim, Dongho Won, and Seungjoo Kim, (2009) [5] in their study, “Advanced Management Architecture for Secure SCADA Communications” have indicated the security requirements for SCADA systems. The authors of this paper investigated whether the existing key-management protocols for the SCADA systems satisfy these requirements. They have proposed advanced key-management architecture for secure SCADA communications. The contribution of their work supported both message broadcasting and secure communication.

Ahin Savas¸ S¸, Mehmet Ölmez, and Yalçın Isler, (2010) [6] in their study, “Micro-controller-Based Experimental Setup & Experiments for SCADA Education“ have described that in the field of automation technology, research and development SCADA for industrial applications has increased rapidly in recent years. This paper gives a detailed description of some laboratory experiments in virtual-instrument aided supervisory control and data acquisition (SCADA) systems.

Coates M, Kenneth M. Hopkinson, Scott R. Graham, and Stuart H. Kurkowski, (2010) [7] in their study, “A Trust System Architecture for SCADA Network Security” have indicated the use of a communications network security device, called a trust system, to enhance security of supervisory control and data-acquisition (SCADA). The major goal of the trust system is to increase security with minimal impact on utility communication systems. 1) The paper has summarized major threats against SCADA systems; 2) Has discussed new trust system implementations, which allowed the trust system to be used with a wider array of network-enabled equipment; 3) Has discusses key SCADA security issues and shows how the trust system responds to such issues; 4) this paper has analyzed the impact of the trust system when widely prevalent TCP/IP network communication is used; and 5) The paper discussed a new hypothetical scenario to illustrate the protection that a trust system provides against insider threats. The authors concluded that the proposed Trust system will comply with the strict
requirements of the SCADA network while providing a secure environment. The trust system is flexible and can be implemented and best fits the needs of SCADA networks.

The objective of their research was to establish a secured network, using a trust system, for the power grid. SCADA systems may be of interest to hackers and unauthorized users. Administrators should take precautions including closing unnecessary ports, keeping system patches up to date, and should keep themselves up to date on current computer security practices.

Choi Donghyun, Sungjin Lee, Dongho Won, and Seungjoo Kim, (2010) [8] in their paper, “Efficient Secure Group Communications for SCADA” the authors have analyzed the efficient scheme that decreases the computational cost for multicast communication. Reduces the number of keys to be stored in a remote terminal unit and provides multicast and broadcast communications.

They proposed advanced key-management architecture for the secure SCADA communications and redefined security requirements for a SCADA system.

Coletta Carcano A., M. Guglielmi, M. Masera, I. Nai Fovino, and A. Trombetta (2011) [9] in their paper, “A Multidimensional Critical State Analysis for Detecting Intrusions in SCADA Systems” have indicated an innovative approach to Intrusion Detection in SCADA systems based on the concept of Critical State Analysis and State Proximity. The theoretical framework was supported by tests conducted with an “Intrusion Detection System prototype”, implementing the proposed detection approach. The key elements of their technique were the concept of Critical State, and the assumption that an attacker, will need to modify the state of the system from safe to critical. The critical state validation, normally finds its natural application in the industrial control field, where the critical states are generally well-known and limited in number.

Queiroz Carlos, Abdun Mahmood, and Zahir Tari (2011) [10] in their paper, “Scadasim—A Framework for Building SCADA Simulations” have described
about attacks on SCADA systems, highlighted the need to analyze the security risks and develop appropriate security solutions to protect the systems. The authors have researched in problem area where there is lack of proper modeling tools to evaluate the security of SCADA systems. As widely accepted in academic and industrial communities, it is impractical to conduct security experiments on live systems. The authors in their paper have concluded a framework which was a novel solution to create realistic simulations of SCADA systems based on a combination of network simulation and real devices connectivity. It solves a number of logical and implementation problems in the simulation environment to allow real world devices (such as smart meters, RTUs, etc.) to be attached to the simulator. The simulation framework, SCADA, also allows user to study the effects of malicious attacks on the devices and on the simulated network.

Otani Tetsuo & Hiromu Kobayashi, (2013) [11] in their paper, “A SCADA System Using Mobile Agents for Next-Generation Distribution System” have analyzed distribution system capable of solving problems caused by the connection of numerous distributed generators. A supervisory-control-and-data-acquisition (SCADA) system for this distribution system should be economical, flexible, and reliable, and should execute a real-time process. In this paper, the authors studied a SCADA system using mobile agents for flexibility. In addition, they showed two types of communication protocols that ensured fault tolerance agent migration, and perform experiments where the SCADA system executes earth fault protection within the required time. From The results they have concluded that the SCADA system based on their proposed technology shall be capable to fulfill real-time processing requirement. Their research had proposed a SCADA system using mobile agents and a wide-area Ethernet.

Escudero J. I., J. Luque, and A. Carrasco (2004) [12] in their paper, “Experimental Study on The Transmission of Measurements by Tolerance in SCADA systems” have analyzed the relationship between a measurement error and the time elapsed since that measurement was taken in the field, to learn about its behavior in a
supervisory control and data acquisition (SCADA) system. This study has extended knowledge of electrical measurements, they quickly reached their maximum error value because of their age. Therefore, it was not necessary to send measurements to the control center at small intervals: it is possible to wait for a given time without having a higher associated error. After getting these results, they have done an experimental study about electrical measurements, in which these measurements were sent to the control center only if they exceed a given percentage of the former measurement, what can be called measurement tolerance.

Escudero J. I., J. A. Rodríguez, M. C. Romero, and S. Díaz (2005) [13] in their paper, “Deployment of Digital Video and Audio Over Electrical SCADA” have analyzed a special characteristics and propose solutions so multimedia integration with SCADA was possible in power systems communication. frequently, electric utilities are equipped with an underlying data network (usually one of optic fiber) whose bandwidth is suitable for video, audio and data transport. Also innovations on communications technologies like power-line communications and wireless networks are important factors to take into account for this integration. From a technical approach, this integration was feasible, such as they have described in this paper, and they are still working on the implementation of a specific system and about transmission of multimedia and tele control information. This integration extends functionality of SCADA system, and enriches existing tele control functions by adding new operation, maintenance support, and operators training functions.

Davidson Euan M., Stephen D. J. McArthur, James R. McDonald, Tom Cumming, and Ian Watt (2006) [14] in their paper, “Applying Multi-Agent System Technology In Practice: Automated Management And Analysis Of SCADA and digital fault recorder data” have analyzed the use of multi-agent system technology to automate management and analysis of SCADA and digital fault recorder (DFR) data. The multi-agent system, entitled “Protection Engineering Diagnostic Agents” (PEDA), integrates a legacy intelligent system that analyzes SCADA and DFR
data to provide data management and online diagnostic information to protection engineers. As the results presented in this paper demonstrate, PEDA supports protection engineers by providing access to interpreted power systems data via the corporate intranet within minutes of the data being received. The authors discuss methods of developing a multi-agent system that is robust for continual online use within the power industry.

Fovino Igor Nai, Alessio Coletta, Andrea Carcano, and Marcelo Masera (2012) [15] in their paper, “Critical State-Based Filtering System for Securing SCADA Network Protocols” have presented an innovative approach of a design of filtering systems based on the state analysis of the system being monitored. The aim was to detect attacks composed of a set of “SCADA” commands that, when considered in isolation on a single-packet basis, can disrupt the correct behavior of the system when executed in particular operating states. The proposed firewall detected these complex attacks. This paper presents a new network filtering approach for the detection and mitigation of a particular class of cyber attacks against industrial installations. This technique was based on monitoring the evolution of the state of the protected system and on the analysis of the command packets between master and slaves of SCADA architecture.

Amin Saurabh, Xavier Litrico, Shankar Sastry, and Alexandre M. Bayen (2013) [16] in their paper, “Cyber security of water SCADA systems—part i: analysis and experimentation of stealthy deception attacks”, have aimed to perform security threat assessment of networked control systems with regulatory and supervisory control layers. They have analyzed the performance of a proportional-integral controller (regulatory layer) and a model based diagnostic scheme (supervisory layer) under a class of deception attacks. They adopted a conservative approach by assuming that the attacker has knowledge of:

1) the system dynamics;
2) the parameters of the diagnostic scheme; and
3) the sensor-control signals.
Kirsch Jonathan, Stuart Goose, Yair Amir, Dong Wei, and Paul Skare, (2014) [17] in their paper, “survivable SCADA via intrusion-tolerant replication” have reported on the experience designing, architecting, and evaluating the first survivable SCADA system—one that is able to ensure correct behavior with minimal performance degradation even during cyber attacks that compromise part of the system. They have analyzed the challenges they faced when integrating modern intrusion-tolerant protocols with a conventional SCADA architecture and present the techniques they developed to overcome these challenges. The results illustrate that the survivable SCADA system not only functions correctly in the face of a cyber attack, but it also processes in excess of 20,000 messages per second with a latency of less than 30 ms, making it suitable for even large-scale deployments managing thousands of remote terminal units. In addition to the conventional challenges to availability, such as hardware crashes, power failures, and network partitions, SCADA providers must also anticipate the consequences of cyber attacks. As the compromise of the highest value asset, the SCADA Master, can have potentially disastrous consequences, their work has focused on protecting this entity via intrusion-tolerant replication.

Huang Shyh-Jier, and Chih-Chieh Lin (2002) [18] in their paper, “Application of ATM-Based Network for An Integrated Distribution SCADA-GIS System”, they have analyzed, an asynchronous transfer mode (ATM)-based network is applied as the communication backbone between geographical information system (GIS) and supervisory control and data acquisition (SCADA). Because the ATM network is a true multiservice network that provides broadband services and meets the different quality of service requirements, this technique is increasingly important in a modern communication system.

The paper begins with the event generator that brings different messages to the ATM network from various local area networks. A statistical evaluation is then employed to examine the amount of message flow and the quality of service, where the outcome is assessed based on traffic, capacity and performance of the
proposed method. Test results help solidify the effectiveness of the approach for power system communication applications. In this paper, an ATM based communication network was proposed to serve as the backbone between the GIS and SCADA system.

Medina Verónica, Isabel Gómez, Joaquín Luque, and Sergio Martín (2002) [19] in their paper, “Estelle: A Method to Analyze Automatically the Performance of Telecontrol Protocols in SCADA Systems”, have presented the use of ESTELLE, a formal description technique, as a method to calculate automatically the performance of telecontrol protocols in SCADA systems. Some specific primitives are added to the ESTELLE description language in order to achieve that goal. As an example, they analyze the performance of a telecontrol protocol. The results obtained from this method are compared to performance measurements obtained from analytical and simulated solutions.

Şahin Savaş and Yalçın İşler (2013) [20] in their paper, “Microcontroller-Based Robotics and SCADA Experiments”, they have described how Supervisory Control and Data Acquisition (SCADA) and robotics experiments in control and automation education can be conducted at reasonable cost. These setups consisted of a fluid tank, a Cartesian robot with a three-axis robot arm, and serial, parallel, USB, and TCP/IP communication ports.

Shrivastava Amit and Anand Khare (2014) [21] have presented Micro Grid model which simulates a power system and has the features of SCADA automation to study its advantages and to finally implement it in real power system. It also suggested some experiments which can be done on the proposed smart GRID Model.

Khare Ramleela and Filipe R E Melo (2014) [22] in their paper, “Automation of Water Distribution Plant” have discussed that automation provides optimized solution to problems of storage and distribution of water. The chapter highlights
low cost new equipment and new techniques for reliable and efficient management of this technology. The entire network including a standby generator has features of SCADA (Supervisory Control and Data Acquisition) automation to control and monitor water supply and in case of power failures to maintain continuity of power supply. The scheme of automation is such that the Manager of water project is able to implement it with full understanding of the project without being dependent on contractors and suppliers.

Khare Ramleela and Rodrigues E Melo Filipe [23] in their paper, “Economic and Efficient Management of Transmission and Control of Electrical Power – Design of A SCADA Power System Monitor” have discussed about the rapid increase in research and development in automation technology that has led to a gap between education and industry. Developing countries need to keep in touch with the latest developments; this poses some difficulties for education in industrial automation, such as cost, lack of student motivation, and insufficient laboratory infrastructure. Low-cost experimental setups may overcome many of these challenges described by the author. The author has developed the Power System Monitor described in details in chapter 4 which demonstrates the application of SCADA architecture for automation. Supervisory Control and Data Acquisition (SCADA) has been demonstrated on the Dynamic model of Power System Monitor constructed for the purpose. One can get clear understanding of how to implement SCADA automation in industry to improve economic and efficient management of all activities.

Khare Anand (1985) [24] in his book, “Reliability in Electrical Systems”, has described AC Network Analyzer model for use in practical fault analysis. This model worked on conjugate impedance principle that is capacitive reactance represented inductive reactance and it was used by electrical utility services.

Aaron St. Lager et.al. (2009) [25] in their paper, “A Analog Emulator for training in Power System” have developed software interfaces with the hardware to allow
for control of data acquisition and analysis. The equipment has limited capacity of 2 generators, metering is also limited. It does not have feature of Supervisory Control. It has limited utility.

Shrivastava Amit and Khare Anand (2013) [26] have discussed the Micro Grid model which simulates a power system and has the features of SCADA automation to study its advantages and to finally implement it in real power system. It suggests the approximate cost to build the model along with the SCADA Architecture. It also suggests experiments which can be done on this proposed smart GRID Model.

Khare Ramleela, Rodrigues E Melo Filipe (2013) [27] in their paper, “Economic And Efficient Management of Transmission And Control of Electrical Power – Design of A SCADA Power System Monitor” have described comprehensive equipment for practical study of power system networks; assembled on scaled down parameters to represent generator, transmission lines and distribution of power to simulate the real time generation and transmission of power in electrical industry. The SCADA architecture transmits the data to computer software and parameters of generation and transmission can be controlled by changing rotary switch positions manually on the model and through PLC and relays by wireless arrangement. Experiments were conducted for Power Flow through transmission line and Fault Analysis. The results were compared with and without UPFC – Unified Power Flow Controller. This will help to study the efficient and economic management of power generation and transmission.

Tara Kalyani and Tulasi Ram Das (2008) [28] in their paper, “Simulation of real and reactive power flow control with UPFC connected to a transmission line” have investigated the performance of Unified Power Flow Control devices through simulation by using MATLAB and PSCAD software to validate the performance of the UPFC and shown improvement in real and reactive power flow through transmission line with UPFC when compared to the system without UPFC. They have studied 230 kV transmissions Line of 500 km carrying 100 MVA Power.
Nashiren F. Mailahand, et al (2009) [29] in their paper, “Single Phase UPFC Simulation and construction”, have gone one step further by not only simulating through MATLAB and SIMULINK software but also constructing a lab scale model of UPFC and showed good performance of UPFC in controlling power flow and phase angle in their chosen power system study.

The output voltage of the series converter is added to the AC terminal voltage via the series connected coupling transformer. The injected voltage acts as an AC series voltage source, changing the effective sending-end voltage as seen from node $\delta$. The product of the transmission line current and the series voltage source determines the active and reactive power exchanged between the series converter and the AC system. The real power demanded by the series converter is supplied from the AC power system by the shunt converter via the common DC link. The shunt converter is able to generate or absorb controllable reactive power in both operating modes (i.e. rectifier and inverter).
Reference [2] interconnection of UPFC Devices with transmission line

PR Sharma, Ashok Kumar and Narender Kumar (2007) [30] in their paper, “Optimal Location for Shunt Connected UPFC Devices in Series Compensated Long transmission line” have analyzed optimal location for shunt connected UPFC Devices in series compensated long transmission line. They have conducted their study on the model of series compensated 345 kV, 450 km line and concluded that optimal location of UPFC Devices varies with the change in the level of series compensation to get the maximum benefit in terms of power transfer and stability of the system.

AS Kannan and R Kayalvizhi (2010) [31] in their paper, “Modeling and Implementation of D-Q Control System for UPFC” have made a study of fault in transmission line connected with UPFC and concluded that: UPFC is effective in damping the power swings in transient states. The performance of the UPFC was checked by applying various faults across a transmission line to which UPFC is connected by simulating on MATLAB and SIMULINK software. The transmission line parameters used for the study are line to line voltage 230 kV, transmission rating 100 MVA, DC link Capacitor 0.75 Farads (7,50,000 micro Farads), DC link voltage 38 kV, length of transmission line 300 km, line Resistance R 9.6 Ohms, Inductive Reactance XI 116.49 Ohms, Capacitive Reactance Xc 341.1 M-m. Their result showed that fault current of 14 kA without UPFC, voltage drop is very high during the fault, when the UPFC is placed in transmission line for the same fault, the fault current is reduced to 5kA as per the software simulation result. This study has enhanced the understanding of the fault phenomena so that measures can be taken in protecting expensive equipment from getting over stressed.
Hosny A Abbas and Ahmed M Mohamed (2011) [32] in their paper, “Review on the Design of web based SCADA System Based on OPC DA Protocol” have analyzed OPC / OLE i.e. Open Process Control / Object Linking and Embedding. This interface is supported by almost all SCADA Visualization & Process Control Systems. They have described research efforts to design and implement to access an OPC DA server through the internet. The OPC design would require technology like XML and web services, JAVA and AJAX. They have concluded that for real time SCADA application internet based software OPC need further development. This would provide Management of SCADA application for transmission and control of power and other automation applications.

Bhanu Chennapragada Venkata Krishna et al (2003) [33] in their paper, “Power System Operation and Control Using Fact Devices” have discussed that the Unified Power Flow Controller UPFC) is a second generation UPFC device, which enables independent control of active and reactive power besides improving reliability and quality of the supply. This paper has described the basic principle of operation of UPFC, its advantages and to compare its performance with the various UPFC equipment available. They have further stated that solid-state implementation of power-flow controllers will result in a significant reduction in equipment size and a progressive reduction in capital cost through the use of power semiconductor technology by allowing the use of standard, prefabricated power inverter modules in different applications. All these will hasten the application of the UPFC concepts and the achievement of goal—the higher utilization of electric power systems.

Sankar, Balaji, Arul (2010) [34] in their paper, “Simulation and Comparison of Various UPFC Devices in Power System” pointed out that the Power electronic based UPFC devices can be added to power transmission and distribution systems at strategic locations to improve the economic power transmission. The paper has dealt with the simulation of various UPFC Controllers using simulation program with Integrated Circuits Emphasis. The UPFC controllers control series impedance, shunt impedance, current, voltage and phase angle. They have described simple circuit
model of Thyristor Controlled Reactor, Thyristor Controlled voltage regulator and UPFC systems. The paper has described the control strategy for Real and Reactive powers of the transmission line using UPFC.

Seyedreza Aali, Daryoush Nazarpour (2010) [35] in their paper, “48 – Pulse GTO Center Node Unified Power Flow Controller” have presented the design of new topology combined from two SSSC and STATCOM. C_UPFC that can control active and reactive power flow in two sides of transmission line with injection of controllable voltage in the form of series in wide range and shunt inverter (STATCOM) in midpoint of transmission line, Compensates unbalance line current and it regulates the bus voltage and DC link voltage. The control strategies implement decoupled current control and auxiliary tracking control based on a pulse width modulation switching technique to ensure fast controllability, controlling algorithm based on d-q principal and 48-pulse multilevel inverter. The proposed system is modeled and analyzed using Matlab/Simulink and simulation results verified the proposed combination for C_UPFC which operates accurately.

Elkholy, F. H. Fahmy, A. A. Abou El-Ela (2010) [36] in their paper, “Power System Stability Enhancement using The Unified Power Flow Controllers” have proposed the functions of improving power quality and ensuring the continuity of electricity supply. The UPFC has been proposed to control simultaneously real and reactive power flows in the transmission line as well as to regulate the voltage bus using the UPFC. This device creates a tremendous impact on power system stability enhancement and loading of transmission lines close to their thermal limits. Thus, the device gives power system operators much needed flexibility to satisfy the demands that the deregulated power system imposes. Simulation results have shown that the UPFC is capable of controlling the line power flow and supporting the voltage level in extreme operating conditions and tracking the step changes in active and reactive power flow reference values.
Sidhartha Panda and Narayana Prasad Padhya (2007) [37] in their paper, “Power System with PSS and UPFC Controller: Modeling, Simulation and Simultaneous Tuning Employing Genetic Algorithm“ have presented a systematic procedure for modeling and simulation of a power system installed with a power system stabilizer (PSS) and a flexible ac transmission system (UPFC) - based controller. For the design purpose, the model of power system which is a single-machine infinite-bus power system installed with the proposed controllers is developed in MATLAB SIMULINK.

Larruskain D M and Zamora I. [38] in their paper, ‘Transmission and Distribution Networks: AC versus DC’ have discussed about the fast development in power electronics with new and powerful semiconductor devices like HVDC technology to transmit and distribute power in large and long networks. The technical and economical benefits of HVDC technology over AC systems for deregulation in the power industry, opening of the market for delivery of cheaper energy to customers and increasing the capacity of transmission and distribution of the existing lines are creating additional requirements for the operation of power system.

The transmission and distribution of electrical energy started with direct current (DC) in the late 19th century, but it was inefficient due to the power loss in conductors.
Alternating current (AC) offered better efficiency, since it could easily be transformed to higher voltages, with far less loss of power. AC technology was soon accepted as the only feasible technology for generation, transmission and distribution of electrical energy. However, high-voltage AC transmission has disadvantages and engineers were engaged in the development of a technology for DC transmissions as a supplement to the AC transmissions.

Ramesh M. & Jaya Laxmi A. [39] in their paper, ‘Enhancement of Power Transmission Capability of HVDC System Using UPFC Controllers’ have summarized the cost effective delivery of energy in the power market using power controllers such as HVDC and UPFC devices to transmit large amounts of power over long distances. The factors considered in their paper are cost, technical performance and reliability for controllability and increase in power transfer capability of the network. Also include: Reduced maintenance (b) Better availability (c) Greater reliability (d) Increased power (e) Reduced losses (f) Cost-effectiveness. It is economical to transfer power through HVDC transmission system as the power factor is near to unity that is the energy loss is very low at long distances.

Tomasz Drobik (2011) [40] in his paper, “High-Voltage direct current transmission lines” has discussed about the importance of HVDC technology and future scope of this technology. HVDC Transmission Lines in: Undersea connections, power transmission between two or more unsynchronized AC systems, connections of generating plants far from power grid, stabilizing AC grid.

Meah Kala (2008) [41] in his paper, “Comparative Evaluation of HVDC and HVAC Transmission Systems” has presented a comparative evaluation of HVDC and HVAC transmission systems. Current and voltage are the two important factors of the high voltage transmission line. The AC resistance of a conductor is higher than its DC resistance because of skin effect, and eventually loss is higher for AC transmission. HVDC transmission has less corona and radio interference than that of
HVAC transmission line. The long HVAC overhead lines produce and consume the reactive power losses in transmission line. Advantages of HVDC:

- Ground return hence each conductor can be operated as an independent circuit.
- No charging current and no Skin effect.
- Cables can be worked at a higher voltage gradient.
- Line power factor is always unity: line does not require reactive compensation.

Bulk power could be transferred using HVDC or HVAC transmission system from a remote generating station to the load center. Direct cost comparisons between AC and DC alternatives should be made. Long distances are technically unreachable by HVAC line. The break-even distances of overhead lines between AC and DC line ranges from 500 km (310 miles) to 800 km (497 miles). The HVDC has less effect on the human and the natural environment, which makes the HVDC friendlier to environment.

Bahrman M P [42] in his paper, “HVDC Transmission Overview” has given comparative evaluations, studies, and reviews of HVDC versus HVAC transmission systems, applications, different schemes of HVDC systems are also outlined. Power systems are having complex networks consisting of large number of interconnected subsystems. Overall reliability assessments of power network systems are performed to determine where and when new investments, maintenance planning, and operations are necessary. The cost of AC or DC transmission lines includes right-of-way (ROW) i.e. installations of towers, conductors, insulators, terminal equipment, and operational cost of losses in power during transmission. Feasibility and break-even distance studies have to be carried out before implementing a HVAC or HVDC system.

The author Danneels E. et al (2002) [43] in their paper, “The dynamics of product innovation and firm competences” have concluded that all creative ideas do not
become innovation until these are implemented and earn profits. He highlights here basic problems confronting the management:

1. Human problem of receiving attention from all the members of the company
2. The process in managing new ideas in to good returns
3. Institutional leadership

Innovations have always been essential for a firm’s long-term survival and growth.

Santos-Vijande and Álvarez- González (2007) [44] in their paper, “Innovativeness and organizational innovation in total quality oriented firms: The moderating role of market turbulence”, have concluded that “innovations play a role in the firms’ future and, further, by adapting to radical technological changes. The management of technological innovation is one of the most demanding challenges today.

Dodgson et. al. (2008) [45] in their paper, “The management of technological innovation: Strategy and practice” have proposed a model of technological innovation capabilities and investigate in detail the potential differential impact of a technological innovation. They contribute to the recent pool of knowledge, the theory about firms’ dynamic capabilities, and introduce technological innovation capability as one of the important dynamic capabilities that represents the dominant criteria of competitive advantage. They have presented combinations of capabilities and resources that can be developed, deployed and protected to sustain competitive advantage through technological innovations. The paper has outlined evidence from a case study that was conducted in 2012.

Literature review on dynamic capabilities Baretto, (2010) [46] in their paper, “Dynamic capabilities”, has reflected on a promising approach creates confusion that might hinder any more effective progress within the field.

management” have indicated the fine-grained case studies of firms and what is needed which have been able to sustain a competitive advantage over time in dynamic environments.

The dynamic capabilities view has emerged as an attempt to untangle the complex problem of sustainable competitive advantage in today’s dynamic environment, Eisenhardt & Martin (2000) [49] in his study, “Dynamic capabilities”. Teece et. al., (1997) [50] study, “Dynamic capabilities”. The underlying assumption is that firms which are able to sense and seize new opportunities, and further, reconfigure their resources in line with recognized opportunities and change can create and sustain competitive advantage. Teece (2009) [51] in his study, “Dynamic capabilities and strategic management: Organizing for innovation and growth”, Smith and Prieto (2008) [52] in their paper, “Dynamic capabilities and knowledge management” have argued that the premise of most dynamic capabilities research is that firms must use and renew their tangible and intangible resources and capabilities. Cepeda and Vera (2007) [53] in their paper, “Dynamic capabilities and operational capabilities” have considered that knowledge management processes lie behind the development and use of dynamic capabilities.

Lopez (2005) [54] in his paper, “Competitive advantage and strategy formulation” has commented that the knowledge-based view and the resource-based view as strategic management approaches are still essentially static in nature. Thus to sum up, knowledge equals a resource hence it should be transformed into a capability, Shih-Chia et. Al. (2007) [55] in his paper,” A conceptual frame work of the capabilities of knowledge application and innovation capabilities” said Dynamic capabilities arise from learning mechanisms of knowledge and experience accumulation processes. Zollo & Winter (2002) [56] his paper, “learning and the evolution of dynamic capabilities Organization Science” is in line with that, dynamic capabilities could be the real sources of sustained competitive advantage in competitive world.
Rothaermel and Hess (2007) [57] in their paper, “Building dynamic capabilities: Innovation driven by individual, firm, and network-level effects” have maintained that dynamic capabilities facilitate the ability of an organization to recognize a potential technological shift, and also its ability to adapt to change through innovation. Innovation requires a search for new information outside the existing knowledge in the areas unrelated to existing operations.

Since innovations play a key role in survival and growth of industry, developing an innovation is one of the important strategies that has been emphasized by Camison & Villar-Lopez (2012) [58] in their paper, “Organizational innovation as an enabler of technological innovation capabilities and firm performance” and Francis & Bessant (2005) [59] in their paper, “Targeting innovation and implications for capability development Technovation”.

Innovation studies have developed rapidly in recent years. The ability to continuously generate innovation capabilities in today’s business for good currency has been said by Elonnen et. Al. (2009) [60] in their paper, “Linking dynamic capability portfolios and innovation outcomes Technovation”, firms wanting to sustain their competitive position have to develop technology innovation. Firms need to upgrade innovation capability for developing and commercializing new technologies to sustain a competitive position. Wang et. al. (2008) [61] in their paper, “Evaluating firm technological innovation capability under uncertainty Technovation” and Burgelman et. al. (2004) [62] in their paper, “Strategic management of technology and innovation” have defined technological innovation capability (TIC) as comprehensive characteristics that facilitate and support an innovation strategy (Wang et al., 2008). An innovation strategy is the basis for the firm’s overall strategy (Dodgson et al. 2008). It further represents the link between customers’ needs satisfied by a firm’s products. Establishing such a link motivates technological innovation Pratali (2003) [63] in his study, “Strategic management of technological innovations in the small and medium enterprise” technological innovation capability, the resources of technology, inspiration and experiences and
Karagouni & Papadopoulos (2007) [64] in their paper, “The impact of technological innovation capabilities on the competitiveness of a mature industry” have discussed about generating technological innovation is one aspect in business success (Teece (1997) [50] title, “Dynamic’s capabilities and strategic management”), Indeed, only firms which are able to deploy their resources and capabilities upon the dynamic capabilities framework can create and sustain a competitive advantage, (Teece (2009) [51] in his paper, “Dynamic capabilities and strategic management: Organizing for innovation and growth”).

The earlier investigations presented here do not discuss the features of cable fault locator for the underground cables but only overhead lines. Hideyuki Takani, et al (2006) [65] in their paper, “Advanced Line Current Differential Relay with Distance Protection and Adaptive Fault Locator – Adaptive fault locator using line current differential telecom data and distance protection one-terminal data” had developed a fault locator which was incorporated in a line current differential protection relay and used positive sequence quantities. This paper presented an advanced fault location method and a new algorithm. Its use is limited to overhead lines.

Alexander, et al (2001) [66] in his study, “Power Transmission Line Fault Location Based On Current Traveling Waves”, have showed the calculations for fault location based on quantities from a single line terminal. A better estimate of the fault location can be made when current from other lines are used in the calculations. Its use is limited to overhead lines.

Abdelsalam Mohamed Elhaffar et al (2008) [67] in their paper, “Power Transmission Line Fault Location Based On Current Traveling Waves” have presented a fault locator based on the travelling waves initiated from the fault with the objective to propose an automatic technique based on travelling waves to locate the faults in the lines.
Radojević, et al (2009) [68] in their paper, “New Approach for Fault Location on Transmission Lines Not Requiring Line Parameters” have presented outline of new efficient settings, it does not require line parameters to determine the fault. The solution for the most common fault, the single line to ground fault, is presented and thoroughly tested for use in overhead lines.

Jan Izykowski, et al (2007) [69] in their paper, “A Fault-Location Method for Application With Current Differential Relays of Three-Terminal Lines” have described the new algorithm designed for locating faults on a three-terminal transmission line. The set of the fault-locator input signals was taken for developing the fault-location algorithm for applying current differential relays. They have shown that it can be accomplished using Phasor of three-phase current exchanged by the current differential relays.

Mohammad Abdul Baseer (2013) [70] in his paper, ‘Travelling waves for finding the fault location in transmission lines” has investigated the problems in fault localization using traveling wave voltage and current signals obtained at a single end of a transmission line. Fourier Transform is applied to traveling wave signals to obtain their frequency components in the fault signal.

Mahmoud S Awad (2012) [71] in his paper “On-line Determination of the Fault Location in a Transmission Line” has presented an on-line fault location algorithm for both single-ended and double-ended power lines. It has used the steady-state data of voltages and currents available by the measuring equipment and has calculated the fault location. Simulation studies have shown that the proposed algorithm yields quite accurate estimates.

Ai-hua Dong, et al (2013) [72] in their paper, “Overhead Line Fault Section Positioning System Based on Wireless Sensor Network” have introduced overhead line fault detection and location system as the core of industrial control computer. The software and hardware, the methods of current change and zero current detection
were used. Andrichak, et al (1991) [73] in their paper, “Distance Relay Fundamentals” have discussed the problems that are encountered in design and application.

Ouahdi D, et al (2009) [74] in their paper, “An approach in the Improvement of the Reliability of Impedance Relay” have presented an algorithm of impedance relay against short circuits and over voltages. This algorithm is based on theory of symmetrical components. To prevent the operation of the relay in overload mode a voltage drop check was introduced.

Warwick K., A.O. Ekwue and R. Aggarwal, (1997) [75] in their paper, “Artificial Intelligence Techniques in Power Systems” have discussed aging infrastructure of power industry, economics of aging coupled with well developed process of optimizing equipment life cycle. This paper discusses about maximizing life time of electricity network components through proper maintenance strategy and to minimize maintenance cost in the same time without decreasing the reliability of supply.

Bing Jiang, and Alexander Mamishev (2004) [76] in their paper, “Mobile Monitoring and Maintenance of Power Systems Sensors, Energy, and Automation Laboratory” have focused on one trend of power system monitoring, namely, mobile monitoring. The development in robotic maintenance for power systems has indicated significant potential of this technological approach.

Sensor technologies relevant to monitor the distribution system have been presented. They include acoustic sensing discrimination of energized cables, analysis of acoustic signatures of partial discharges, the fringing electric field sensing, acoustic sensing, and infrared sensing. The main purpose of this multi-sensor system was to monitor the aging status, water uptake, and incipient faults in electrical insulation. The framework of multi sensor signal processing challenges has been outlined as well.
REFERENCES


SCADA Systems IEEE Transactions on Industrial Informatics, VOL. 7, NO. 2, MAY 2011


[26] PhD thesis Communication with Amit Shrivastava and Dr. Anand Khare with reference to the PhD thesis submitted to Bhagwant University 2014


[37] Panda S and Padhya “Power System with PSS and UPFC Controller: Modeling, Simulation and Simultaneous Tuning Employing Genetic Algorithm“, *IJEEE1:1 2007*


[40] Drobik Tomasz ‘High-Voltage direct current transmission lines’, IEEE Conference Publishing


[72] Dong Ai-hua, Geng Xinlin, Yang Yi, Ying Su, Mengyao Li. (2013) ‘Overhead Line Fault Section Positioning System Based on Wireless Sensor Network’, PRZEGLĄD Elektrotechniczny, ISSN 0033-2097, r. 89 nr 3b


[87] Ziegler G (1999), Numerical Distance Protection, Siemens AG, Berlin &
Munich


[101] Siemens system manual ‘S7-1200 Programmable controller’