CHAPTER 1

INTRODUCTION

1.1 Need for the study

In this research, Optimal Power Flow is analysed for 30 bus system using various controllers. In an IEEE bus system, each bus has its specified voltage. But due to increase in load demand, in some cases voltage of bus is deviated from its rated value. Retaining of rated voltage of the bus even after load demand is stated as voltage stability in power system [Stevenson, W. D, 1982 & Ramana, N. V, 2010]. In this research OPF is proposed in IEEE bus system to maintain voltage stability in each bus. OPF is an important tool for power system operators both in planning and operation in the present day power systems. Optimal Power Flow is first discussed by Carpentier in 1962 [Sailaja Kumari, M. 2010 and James Daniel Weber, 1997].

The Optimal Power Flow (OPF) problem is defined as a static nonlinear optimization problem to determine all adjustable variables like real power generations, transformer tap positions, angle of the phase shifter, shunt capacitor capacity and or reactor etc., for minimizing the operating costs, transmission line losses or other appropriate objective functions [Pandya K. S. and Joshi, 2008]. While shunt capacitors and angle of the phase shifter transformer tap positions are discrete in nature, real power generation and bus voltages are continuous variables. Due to more number of variables and more number of boundary constraints it has to be solved using nonlinear programming techniques. The OPF solution gives the optimal active and reactive power dispatch for a static power system loading condition.

The increase in peak load demand and power transfer between
utilities have resulted in concerns about system voltage security. Voltage collapse has been deemed responsible for various significant disturbances, and significant research efforts are under way in an effort to further understand voltage phenomena. A major portion of this research is concentrated on the steady state aspects of voltage stability. Indeed, numerous authors have proposed voltage indices based upon some power flow analysis.

OPF is to locate stable state function point that reduces production expenditure and loss or increases load capacity in energy structure that enhances the structure functionality by fulfilling some restraints. Usually, diverse maximization techniques are employed in research papers to resolve OPF challenges. In certain study papers, the maximization procedure is carried out by taking into account entire fuel expenditure or the ecological pollution which happens at the time of energy production. According to other review papers, Flexible Alternating Current Transmission System (FACTS) controller devices are employed to enhance the energy flow not taking into account energy production expenditure [Hingorani, N. G. 1988 & 2000]. The various types of FACTS controller devices along with the different locations have varied advantages.

Unified Power Flow Controller (UPFC), Static Synchronous Series Compensators (SSSCs), Static Synchronous Compensators (STATCOMs), and Static Volt-Ampere- Reactive Compensators (SVCs) etc., line impedance, phase angle and bus voltages in the systems with power are regulated with flexibility and rapidity. Thus, the controls for power flow can be facilitated by FACTS, through which the capability of the power transfer will be enhanced, the generation cost will decrease, and the stability and the security of power systems shall be further improved. The FACTS controller devices are usually connected in a series concerning the transmission lines which increase the capability to transfer in the transmission system that effectively reduces the
reactance in transfer between buses which provides the connection between the lines.

Hence, the effectiveness of the concerned method was tested keeping the standards on IEEE system of 30 bus, and the comparison is effectively made on the performance with the FACTS controller device.

The OPF challenge could be defined as the best possible allotment of energy structure controls to gratify the precise purpose of fuel expenditure, energy loss, as well as bus voltage divergence. The control variables comprise of generator bus voltages, generator real powers; tap ratios of transformer in addition to the reactive energy productions of VAR sources.

The OPF solution, in contrast, includes an objective function that is optimized without violating the system operating constraints. These include the network equations, loading conditions, and physical limits on active and reactive power generation. The selection of the objective function depends on the operating philosophy of each power system. A common objective function concerns the active power generation cost. The economic dispatch problem is a particular case of the OPF problem [Wood A.J. 1984].

The important aspect of OPF is to determine the optimal settings of control variables for economic operation while satisfying various equality and inequality constraints [Vaisakha, K. 2013]. As a result, the OPF problem has been one of the most widely discussed subjects in the power system community since the 1960s. Over the years several research works have been published in this area, and several optimization techniques had been proposed. These methods vary in complexity, the speed of convergence and quality of solution achieved.
There are many conventional methods to calculate load flow problems such as Gauss Seidel Method, Newton-Raphson Method [Chen 1997], Fast De-Coupled Method, Linear Programming Method [Chung, T. S. 1996 & Lobato, E., 2001], Non-Linear Programming Method, Quadratic Programming Method [Dianov, E. et.al., & Momoh, J. A., 1989], Interior Point Method [Granville, S., 2006 & Monteiro, R. D. and Adler 1989], etc. All these methods have some drawbacks. The drawback of Gauss Seidel Method is that it takes too much iteration and time to solve Optimal Power Problem. In Newton-Raphson Method, the main drawback is its convergence characteristics which are dependent on initial conditions that sometimes fail to converge. Linear Programming Methods are fast and reliable, but the concerning problem is that they have some disadvantages associated with the piecewise linear cost approximation. The problem associated with Non-Linear Programming method is that the algorithms become complex and display insecure convergence. Quadratic Programming Method has a disadvantage with the piecewise quadratic cost approximation. Although Interior Point Methods are computationally efficient if the step size is not chosen properly, the sub-linear problem may have a solution that is infeasible in the original nonlinear domain.

The power system has to be reliable and within equilibrium because of reasons of economy as when anything wrong happens; its performance is adversely affected. This will lead to a loss or lack of power. Remedial measures have to be taken to begin its operation again and to bring it back to a condition of equilibrium. 

The stability limit describes the utmost power allowable to run through a specific part or a point of the system for the duration of which it is subjected to line disturbances or faulty flow of power.
The power system’s synchronous stability can be of various types based on the type of disturbance, and for the purpose of enhanced analysis it can be classified into the following three types as Steady state stability, Transient stability and Dynamic stability.

The electric power system is continuously growing and becomes larger in size and more complex. This continuous growth and complexity demands the need for on-line monitoring and control which necessitates the use of power flow analysis, economical load dispatch, optimal power flow, voltage stability and contingency analysis.

Particle Swarm Optimization (PSO) is an experimental maximization method on the basis of group maximization formatted by Eberhart & Kennedy in the year 1995 and motivated by communal activities of bird congregation or fish schooling. PSO optimizes a difficulty by comprising a group of candidate answers, referred to as simple numerical procedures over the particle's location and speed.

In this research various intelligent and optimization techniques are proposed to overcome drawbacks of PSO in OPF.

1.2 Problem statement

The Electrical systems have strict power quality measures. Hence, the reactive power and bus voltage values must be maintained within the specified limits and any deviations from this should be corrected. Automatic control of Secondary Voltage Control (SVC) is needed because of the fact that manual control will lead to the occurrence of emergency states. The SVCs can be used to correct the deviations from the limit. This analysis is about the control of bus voltage and reactive power without the use of SVC, but through the use of an intelligent algorithm as memory.
This research resolves the voltage instability problem and establishes voltage control through the use of Optimal Power Flow Algorithm. Voltage, real power and reactive power are controlled through equality and inequality constraints. Using the iterations from the Newton Raphson’s Method and optimizing voltage through the use of intelligent algorithms such as GA, PSO, and BAT Algorithm, this analysis has bettered the generator cost and Optimal Power Flow is established. With the help of the learning abilities of these intelligent algorithms, a fast and self-healing voltage control is realized and the performance of the system is improved over time. Improvement of performance of the power systems will take place simultaneously by the use of a sufficient and efficient memory learning process. Reduction in generator cost and improvement of the output voltage are the main objectives of this analysis.

1.3 Objectives of study

The main objectives of the study are as follows:

i. To develop the optimal power flow model for IEEE 30 bus system.

ii. To analyze the performance of PSO based optimal power on the IEEE 30 bus system with the objective of the minimum cost function to attain voltage stability. Voltage stability on each bus is analysed.

iii. To minimize the cost function and total loss BAT algorithm as proposed in the IEEE 30 bus system.

iv. To propose a genetic algorithm based optimum power flow to attain minimum cost, loss and to reduce the processing time.

v. To propose the UPFC in IEEE 30 bus system to enhance the voltage stability.
1.4 Methodology of the study

The Electrical systems have strict power quality measures. Hence, the reactive power and bus voltage values must be maintained within the specified limits and any deviations from this should be corrected. Automatic control of Secondary Voltage Control (SVC) is needed because of the fact that manual control will lead to the occurrence of emergency states. The SVCs can be used to correct the deviations from the limit. This analysis is about the control of bus voltage and reactive power without the use of SVC, but through the use of an intelligent algorithm as memory. An allowance of -5% and +5% are taken into consideration and there occurs an unstable state if these voltage constraints are exceeded. A proper control action should be taken in that case to protect the system.

1.5 Limitation of the study

Various optimisation algorithms are analysed in this research for optimum power flow. The main limitations in the optimisation algorithms are their processing time in real time implementation. Number of iterations decides the execution time, based on this execution time high speed controller such as DSP or FPGA has to be selected. This limits the application of low speed and low memory controllers in implementation.

1.6 Organization of the Thesis

This thesis is organized into six chapters including this chapter as follows.

Chapter 1: It provides the reader with a brief introduction of the work, objectives of the thesis and the outline of the thesis.
Chapter 2: It presents the detailed survey of Power Quality, Reactive Power Control, STATCOM, UPFC, Optimal Power Flow Solutions and Voltage stability in the power line.

Chapter 3: This chapter discusses the basics of optimum power flow and objective of power flow with the formulation in detail. It also includes the conventional Newton’s method with the details of IEEE 30 bus system.

Chapter 4: This chapter depicts general theory of particle swarm optimization, BAT algorithm and genetic algorithm and their contribution in optimal power flow for voltage stability. Comparison results are presented to validate the proposed system.

Chapter 5: This chapter presents the basic circuit, modeling and control strategy of UPFC. Enhancement of voltage regulation provided by the UPFC using simulated annealing method is discussed in detail with the comparison of the conventional PI controller.

Chapter 6: This chapter depicts the conclusion of the research work and suggestions for future work.