CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

The demand of electric power throughout the world has been dramatically increasing because of the economic growth and deregulation of power system. The needs of the optimal operation and the strategy for minimizing system cost due to electricity generation and losses in transmission lines become more crucial and play a significant role in modern power system operation. Optimal Power Flow (OPF) can be one strategy for meeting this requirement.

The main purpose of an OPF algorithm is to find the steady-state operation point of a generation-transmission system, which minimizes a pre-specified cost function and meets a set of operational and/or security constraints. The OPF problem is inherently a large-scale, nonlinear, non-convex, non-continuous optimization problem.

Generally, most of the conventional optimization techniques apply sensitivity analysis and gradient-based optimization algorithms to linearize the objective function and the system constraints around an operating point. Unfortunately, the problem of the OPF is highly a non-linear and a multimode optimization problem, i.e. there exists more than one local minimum. These conventional optimization techniques also suffer from drawbacks such as poor convergence, find only one solution in one computation run, are slow
and have limited capabilities for a large-scale system, weak in handling qualitative constraints, they can find only a single optimized solution in a single simulation run, they become too slow if the number of variables are large and they are computationally expensive for solution of a large system.

Hence, the local optimization techniques are not suitable for such a problem. Moreover, many mathematical assumptions such as convex, analytic and differential objective function have to be taken. However, the OPF problem is an optimization problem which is in general non-convex, non-smooth and non-differentiable objective functions. Therefore, conventional methods are not that efficient in solving OPF problem.

Recently, new evolutionary algorithms, namely Bacterial Foraging Optimization Algorithm (BFA) and Gravitational Search Algorithm (GSA), have been used for solving power system problems. These algorithms are versatile for handling various qualitative constraints, suitable for multi-objective optimal problems, and converge rapidly.

On the other hand, FACTS refers to Flexible AC Transmission Systems incorporating power electronic controlled devices, otherwise called as FACTS devices or controllers, which were used to enhance flexibility in power flow control. In a power system network, any sudden change could lead to instability; however the presence of FACTS devices improves the ability of power system to handle rapid changes in operating conditions. Power transfer capability of FACTS devices increases the security and stability of the system; thus enhancing the system’s performance in general. Different FACTS devices include TCSC, SVC, TCPS, UPFC, and UPQC. The power flow parameters such as bus voltages, line impedances, and phase angles can be easily controlled by incorporating FACTS devices.
The inclusion of FACTS devices in optimal power flow problem has the advantages of controlled power flow, increased transmission line capability to its thermal capability and improved transmission system security. The first paper on OPF with FACTS devices has been explained in Galiana et al. (1996), in which power flow control in electric power systems by use of controllable series capacitors and phase shifters were implemented.

Distributed generation (DG) technologies can provide energy solutions to customers that are more cost-effective, environmental friendly, provide higher power quality and reliability than conventional solutions. DG is nothing but a small scale electric power source - comprises of any form of renewable energy resources such as biomass, wind, solar, diesel generator, small hydro power, micro turbine etc. connected directly to the utility’s distribution network or on the customer site rather than connecting to the central generating station. DG provides multitude of services to the utilities and consumers that includes standby generation, peak shaving capability, base-load generation, or cogeneration. Further, for industries, DG can reduce peak demand charges, reduce overall energy use, ensure greater power quality and reliability, and reduce emissions. The capacity scale of DG ranges from several KW to 50MW. The aforementioned advantages have attracted the attention of researchers and motivated research on inclusion of DG in power system network.
1.2.1 Widening of OPF Solution Space

Solution space of conventional OPF is usually limited by the operation and control variable limits of the power system. This limitation usually prevents from attaining the expected improvements in the OPF objectives. Therefore, it became necessary to widen the operating margins and increase the controllability of the power system. FACTS devices, with its introduced flexibility and controllability of power flow, release some of the imposed constraints on the OPF and so help in widening the solution space.

On the other hand DG provides multitude of services to the utilities and consumers that includes standby generation, peak shaving capability, base-load generation, or cogeneration. Further, for industries, DG can reduce peak demand charges, reduce overall energy use, ensure greater power quality and reliability, and reduce emissions.

1.2.2 Assessment of FACTS Devices

Installing FACTS devices in any power system is an investment issue. It offers some flexibility to the power system at the expense of cost. Therefore, it is necessary for any new installation of FACTS to be very well justified. This justification needs an off-line simulation of the power system with the different candidate FACTS installations to assess the value added to the system. Among the different assessment tools used for this purpose, OPF
costs, voltage rise and fluctuations, reliability and stability problems. Therefore, it is necessary to place DG at appropriate location and required sizing. This optimal location and sizing can be formulated as an optimization task and solution can be achieved.

1.3 OBJECTIVES OF THE THESIS

The objectives of this thesis are as follow:

- To systematically analyze various problem formulations existing in solving OPF problem with and without FACTS and DG devices.

- To develop a model for finding the optimal type, location and rating FACTS devices in the OPF problem including FACTS devices using modern optimization techniques, such as Hybrid GSA, BFA and Enhanced BFA under variable loading condition.

- To develop a model for finding the optimal, location and rating of DG devices in the optimal power flow problem with DG devices using Modified Bacterial Foraging Algorithm considering system loadability.

- To compare the effectiveness of proposed algorithm with other algorithms in the literature.

- To investigate the effectiveness of proposed algorithm in term of minimizing the objective function and computation time of program.
1.4 SCOPE OF THE THESIS

The scope and limitations of this thesis are as follows:

- The OPF problem considers two types of FACTS device: Thyristor Controlled Series Capacitor (TCSC) and Static VAr Compensator (SVC) in solving OPF problem including FACTS devices for finding the optimal type, size and location.

- The objective of OPF with FACTS and DG devices is to minimize the total generator fuel cost, subject to power balance constraint, real and reactive power generation limit, voltage limit, transmission line limit, FACTS parameter limits and DG Limits.

- BFA, EBFA and Hybrid GSA Optimization technique are used to solve the OPF problem with FACTS and DG devices.

- MBFA optimization technique is used to find the optimal rating and location in solving the OPF problem including DG Devices.

- The problem of solving OPF with DG devices, Internal Combustion Engine (ICE) is considered due to its low cost compared to other DG devices. Also they can be integrated directly into the power grid as compared to renewable forms like wind and solar that need power converters for linkage purposes.

- The proposed algorithms are examined on the modified IEEE 14 bus and IEEE 30 bus test systems with FACTS device at the fixed location and validated with the existing evolutionary computational technique.
1.5 ORGANIZATION OF THESIS

The organization of this thesis is as follows:

**Chapter 1** provides an overview on OPF control considering FACTS and DG devices for minimizing the power loss and fuel cost. The need, scope and prime objectives of the present work and organization of the thesis are presented in this chapter.

**Chapter 2** gives extensive literature related to the performance improvement of power system using recent intelligence computational algorithms considering OPF with FACTS and DG devices that have been critically reviewed and presented.

In **Chapter 3**, different problem formulation of the OPF problem with the inclusion of FACTS and DG devices are presented. Mathematic modeling of FACTS devices is also included in this chapter.

In **Chapter 4**, an Enhanced Bacterial Foraging algorithm (EBFA) for the optimal size and location of FACTS devices have been presented. A comparison of this proposed algorithm with GA is made at the end of this chapter.

In **Chapter 5**, a hybrid GSA technique has been proposed for optimal Type, Location and Sizing of FACTS devices for solving optimal power flow considering FACTS devices.

In **Chapter 6**, Optimal sizing and location of DG using MBFA based OPF has been introduced to minimize losses and fuel cost function considering system loadability.
Chapter 7 concludes the thesis by emphasizing the major conjecture of the study. A summary of the research contribution and the scope for future studies are also incorporated in this chapter.