Chapter 1

Introduction

1.1. Introduction

The emergence of powerful practical numerical optimization methods for power system engineering and operation have ensured that the best electrical and financial performance can be attained. The value contributed by optimizations used in power system is considerable not only in terms of operational reliability but also security. Systems run with optimization based monitoring and control react better to both expected patterns in power demand and sudden equipment failure.

Optimization concepts and algorithms were first introduced to power system dispatching, resource allocation and planning in the mid of sixties in order to mathematically formalize decision-making with regard to the myriad of objectives subject to technical and non-technical constraints. There is a phenomenal increase in research activities aimed at an implementing dispatch, resource allocation problem and at planning optimally [MOM 08].

In power system operation and planning, there are many optimization problems. In this regard, problem is classified either as operational or planning depending upon time frame. In the operations scheduling problem, studies are extended up to twenty-four hours while, planning problems are solved to the time frame of the years. The hourly commitment of units, the decision whether a unit is on or off at a given hour, is referred as unit commitment.

Economic load dispatch is fundamental consideration for power system. The main objective of economic load dispatch problem is to minimize the total fuel cost while meeting all the load demands with all the system constraints. The optimal power flow is known as extended version of conventional economic load dispatch problem.
The Economic Load Dispatch (ELD) of power generation unit has always been an important issue in the electric power utility industry. Here, the total required generation is distributed among the generator units is operated by cost minimization. Economic load dispatch problem is basically a non-smooth optimization problem with various equality and inequality constraints. To address such a problem, several methods have been developed i.e. Evolutionary Programming, Genetic Algorithm, Tabu Search, Artificial Neural Network and Particle Swarm Optimization (PSO). The robust convergence characteristic of the PSO algorithm plays a promising role in the solving ELD problems.

The increasing demand for an Optimal Power Flow (OPF) tool for analyzing different states and control strategies for various studies has become imperative since late 60’s. Here the main objective is to determine the optimal operating state of the power system. This is achieved by optimizing the objective function while satisfying certain specified constraints. The main purpose is to minimize the fuel cost subjected to network and generator operation constraints.

Several mathematical techniques e.g. non-linear programming, linear programming, dynamic programming [YUA 91], [YU 92], Newton-Raphson method, Lagrange relaxation technique [ROU 85], [SHA 05], Bender’s decomposition algorithm and interior point methods have been applied to analyze the OPF problem. These classical methods are limited in handling algebraic functions and unable to consider the dynamic characteristics.

Use of PSO techniques in solving OPF problem significantly relieves the assumption imposed on the optimized objective functions. This approach proves to be very useful for analyzing different standard IEEE test bus systems viz. modified IEEE 30-bus system, IEEE 57-bus system and IEEE 118-bus system with different objectives those reflect final cost minimization, voltage profile improvement and voltage stability enhancement. Keeping in view the today’s requirements, the work must focus on OPF robustness, accuracy and scalability. In consideration with the changing scenario, OPF is market oriented application, thereby making the research in a direction to have the integration of new formulations and algorithms attending OPF issues.
Also, with the incorporation of FACTS devices and deregulation of a power sector, intelligent techniques have been emerged to further simplify highly complex OPF problems.

Finally, in the same realm is optimal power flow (OPF), which holds the promise of extending economic dispatch including the optimal setting of under load tap-changers, generator real and reactive powers and phase-shifter taps. The optimal power flow has been expanded as how problems arise to include new objective functions and constrains. Other application extending the work to optimization of the network includes VAr planning, network expansion and availability transfer capability.

In recent years, the advancement of computer engineering and the increased complexity of the power system optimization problems have led to greater need for and application of specialized programming techniques for large scale problems. These include dynamic programming, Lagrange multiplier methods, and evolutionary computation methods such as genetic algorithm. These techniques are often hybridized with many other techniques of intelligent systems, including Artificial Neural Network (ANN), Expert systems (ES), Tabu Search algorithm and Fuzzy Logic [BAL 04], [SRI 05], [GEO 07].

Nature has always been a source of inspiration for innovating new concepts, techniques and computational applications in diverse fields. Many soft computing methods, extensively used in the various fields of engineering and computer science, are also biologically inspired and are based on nature's problem solving strategies. Nature inspired optimization algorithm are techniques which imitate some natural phenomenon to find an optimum solution of a problem.

Nature-Inspired Algorithms have been gaining much popularity in recent years due to the fact that many real-world optimization problems have become increasingly large, complex and dynamic. The size and complexity of the problems nowadays require the development of methods and solutions whose efficiency is measured by their ability to find acceptable results within a reasonable amount of time, rather than an ability to guarantee the optimal solution.
There are many Nature Inspired Tools for optimization and some of them which are important and commonly used for optimization are given below:

1. Genetic algorithm
2. Ant colony optimization
3. Particle swarm optimization

A Genetic Algorithm (GA) is a search technique used in computing to find exact or approximate solutions to optimization and search problems. Genetic Algorithms are categorized as global search heuristics. Genetic algorithms are a particular class of evolutionary algorithms (EA) that use techniques inspired by evolutionary biology such as inheritance, mutation, selection and crossover.

Swarm intelligence is a relatively new approach for problem solving that takes inspiration from the social behaviors of insects and of other animals. It is relatively a new nature inspired algorithm that may be used to find optimal solutions to numerical and qualitative problems. The concept of Particle Swarm Optimization (PSO) consists of, at each time step, changing the velocity of each particle towards its pbest and gbest location. PSO has been successfully applied in many research and application areas and it gets better results in a faster, cheaper way in comparison to its counter parts. In particular, ants have inspired a number of methods and techniques among which the most studied and the most successful is the general purpose optimization technique known as ant colony optimization. Ant Colony Optimization (ACO) is a new natural computation algorithm which mimics the behaviors of ants’ colony. It was proposed by Italian scholar M. Dorigo in 1990’s. It is a very effective combination optimization method.

1.2. Proposed Work

1.2.1. Problem Description

Optimization has now become an important part in of most of the domains of engineering and hence in present scenario, there is a strong need of optimization. In past different types of nature inspired optimization tools have been developed such as Genetic Algorithm, Particle Swarm Optimization, Ant Colony Optimization, etc. as per suitability
and requirement of a particular problem to be dealt with. Most of the times, these problems happen to be quite complicated due to the actual and practical nature of the objective function or the model constraints. Most of the optimization problems are constraint based and constraint may be specific or fuzzy, deterministic or stochastic in nature.

Here, the purpose is to develop optimization techniques which are robust and effective in handling many classes of optimization problems. These optimization techniques can encounter difficulties, such as getting trapped in local minima, increased computational complexity and not being applicable to certain objective functions. This led to the need of developing a new class of solution methods that can overcome these shortcomings.

1.2.2. Proposed steps

The Evolutionary and swarm intelligent optimization techniques will be developed in this work and used for selected power system applications like Economic Load Dispatch and Optimal Power Flow.

The basic outline of the proposed work is as follows:

1. Study and literature survey of optimization techniques for economic load dispatch and optimal power flow problems.
2. Develop the integrated tool for optimization problem (Synergism of fuzzy system with genetic algorithm and particle swarm optimization techniques).
3. Validating and verifying the above developed tool using Benchmark Testing.
4. Finally, apply it to power system optimization problems like ELD, OPF.

1.3. Thesis Organization

The thesis has been broadly organized into three sections. The first section (Chapter 2) includes literature review of economic load dispatch (ELD) and optimal power flow (OPF). The objective is to introduce basic ideas of optimizing techniques for optimization
of output power of generators in order to reduce the generation costs. This part also describe the conventional techniques, artificial intelligence, fuzzy systems, genetic algorithm, particle swarm optimization techniques and other hybrid techniques for optimization of power system problems.

The second section (Chapter 3) deals with development of optimization tools. Different components of soft computing techniques i.e. neural networks, fuzzy systems, evolutionary algorithm, swarm intelligent techniques and their integration have been discussed in details. The developed tools are validated with six benchmark problems and results are compared.

The last section (Chapter 4), different soft computing techniques and their synergism have been applied to system optimization of electrical power plants to achieve certain predefined objectives as mentioned in the proposed work. The results obtained with these techniques have been compared.

The chapter wise description of the thesis is given below.

**Chapter 1** gives the brief introduction about the optimization techniques and their application applied in electrical power system problem like economic load dispatch, optimal power flow. This introduction is followed by the problem statement and the proposed work of this research.

**Chapter 2** starts with electrical power system optimization problem. The exhaustive literature survey of economic load dispatch and optimal power flow has been done in this chapter. The conventional, genetic algorithm, swarm intelligence and hybrid technique applied to ELD problem has been reviewed in first section and OPF problem has been reviewed in second section. Finally, the chapter gives the conclusions therein.

**Chapter 3** starts with development of genetic algorithm (GA) and particle swarm optimization (PSO) tools. The synergism of fuzzy system with genetic algorithm and particle swarm optimization has been developed. These tools are validated with six well-known benchmark problems. The details about genetic algorithm, fuzzy system and
particle swarm optimization are also given in this chapter. Discussion on results comparison and validation under different condition has been worked out in order to emphasize the successful application of these synergetic approaches.
Chapter 4 deals with system optimization of economic load dispatch and optimal power flow problems. The synergism of fuzzy system with GA and PSO is applied for optimizing the fuel cost of different generating unit systems and the results obtained using these methods are compared.

Finally, Chapter 5 gives the detailed conclusions of the entire work and the scope of future studies. Chapter-wise flow of thesis is shown in Figure 1.1.

1.4. Conclusions

With the recent developments in the restructuring of power systems and active introduction of competition in the power sector, it has become necessary to maintain the quality and continuity of power supply. Any unprecedented failure of system component may cause a huge financial loss to the utilities. Therefore every component of the power system needs to be monitored continuously and to be optimized and take an appropriate step at an appropriate time.

******