CHAPTER 1

INTRODUCTION

1.1 Statement and significant of the problem

Demands for electrical utilities are growing every year, building new power plants or expanding new transmission networks may help to meet these ongoing requirements. However, several problems concerning these constructions include the environmental management and the pollution control of nearby power plant's areas, the high cost of power plants installation and operation, and also the land acquisition for constructions.

Moreover, the process to permit, site, and construct new transmission lines has become extremely difficult, expensive, and time-consuming. Therefore, regarding to achieve more optimal and profitable operation of the power system than new power plants construction, improvement of utilization and control of the existing power system is required.

Flexible AC Transmission System (FACTS) controller is one of the advanced applications of current power system control technology. FACTS controllers' parameters can also be adjusted to provide adaptability for the transmission networks planning in the future. Therefore, FACTS provides advanced alternative solutions as cost-effective purpose [1].

Examples of FACTS controllers used for enhancing power system control are Unified Power Flow Controller (UPFC), Thyristor Controlled Series Capacitor (TCSC), Thyristor Controlled Phase Shifter (TCPS), and Static Var Compensator (SVC). It has been proved that these FACTS controllers can be used to increase power transfer capability and enhance system controllability resulting in minimizing power losses in transmission network [2-3].

1.2 Problem statement

The maximum performance of using FACTS controllers to increase total transfer capability (TTC) and minimize systemic energy loss could be obtained by choosing the suitable types and locations, and settings appropriated parameters capable for each transmission system. Optimal allocations of FACTS controllers are very complicated to determine for optimal solutions.

Conventional methods such as neural network (NN) as well as several modern heuristic methods including evolutionary programming (EP) [4], Genetic Algorithm (GA), and Particle Swarm Optimization (PSO) are used to optimize these parameters [5-9]. For examples, in [10], EP is used to determine the optimal allocation of four types of FACTS controllers. Test results indicated that optimally placed OPF with FACTS controllers by EP can enhance the TTC more than OPF without FACTS controllers.

However, these methods have general disadvantageous characteristics, for examples, NN as well as EP and GA are time-consuming, especially for weight training and for convergence to find the optimal answer values, respectively. On the other hand, EP, GA and PSO give the local answer values, which are not the global optimal ones.

In addition, among these modern heuristic methods, PSO showed more advantageous performance than that of EP, and GA. It has been indicated that PSO seems to arrive at its final parameter values in fewer generations with less time-consuming than and GA [11]. Also, PSO gives a better balanced mechanism and more capable of adaptation to the global and local exploration abilities. These advantages of PSO are simple and easy to achieve without many parameters need to be adjusted. This might be due to the fact that EP and GA involve more random parameters, caused of crossover and mutation, while PSO involves less random behavior. PSO can also be applied to solve various optimization problems in electrical power system such as power system stability enhancement [12] and capacitor placement problem [13]. Since the most cost-effective purpose is the key to improve power system capability for responding the ongoing energy demand, hybrid form of these methods is therefore interesting and advantage to provide optimal and profitable solving operations of the power system. Moreover, the hybrid form has never been developed in any previous studies.

As mention above for more advantageous performance of PSO, in this study, PSO will be selected as the main form to combine with other methods, for examples, EP or GA. The developed hybrid form of PSO will be investigated as well as the objective function will be formulated. Multi-objective functions of maximization or minimization setting properties will also be investigated.

1.3 Literatures review

Yuryevich and Wong [14], developed an efficient and reliable evolutionary programming algorithm for solving the optimal power flow (OPF) problem on the IEEE 30 bus test system. EP has accurately and reliably converged to the global optimum solution.

Abdelaziz *et al*. [15] proposed the suitable location and sizing of FACTS controller in electrical power system aim to solving the optimal distribution system reconfiguration problem for power loss minimization. Their proposed PSO gives an optimal or a near optimal solution and finding a feasible solution to the 32-node system and the 69-node system.

Bhasaputra and Ongsakul proposed the hybrid of Tabu Search (TS) and Simulated Annealing (SA) in [16]. This approach has been proposed to find the optimal placement of multi-types FACTS devices to minimize the total generator fuel cost of all loading levels. The considered FACTS devices included TCSC, TCPS, UPFC, and SVC. Test result on the IEEE 6-bus test system showed that the hybrid TS/SA can obtain better solutions than the sensitivity index approach.

Ongsakul and Jirapong proposed the hybrid of EP and SA which is named the improvement evolutionary algorithm (IEP) in [17]. This IEP simultaneously searches for types, locations, and parameters of four types FACTS devices, real power generations except slack bus in source area, real power loads in sink area, and generation bus voltages. The four types of FACTS devices are included: TCSC, TCPS, UPFC, and SVC.Test results on IEEE 30-bus test system and Thailand 58-bus system indicate that optimally placed optimal power flow with FACTS devices by IEP could enhance the TTC value more than the original evolutionary programming.

Jirapong and Ongsakul proposed the hybrid of EP, TS, and SA which is named hybrid evolutionary programming (HEA) in [18]. This HEA approach simultaneously searches for real power generations except slack bus in a source area, real power loads in a sink area, and generation bus voltages to solve the OPF-based ATC problem. Test results on the modified IEEE 24-bus reliability test system (RTS) indicate that ATC determination by the HEA could enhance ATC far more than those from EP, TS, hybrid TS/SA, and improved EP (IEP) algorithms.

In [19], Ting *et al*. presented the hybrid PSO (HPSO), which is merged binary PSO (BPSO) and real coded PSO (RCPSO) for solving unit commitment problem (UC). The HPSO is compared with EP, GA, unit characteristic classification GA (UCC-GA), dynamic programming (DP), lagrangian relaxation (LR), lagrangian relaxation genetic algorithm (LRGA), and HPSO. The problem formulation of unit commitment (UC) take into consideration the minimum up and down time constraints, start-up cost, and spinning reserve and is defined as the minimization of the total objective function. Test results showed that HPSO is competent in solving this UC problem in comparison to other existing methods.

In [20], Qi *et al*. proposed a multi-objective evolutionary algorithm based on the parallel evolution of multiple single-objective formulation and pareto archive formulation. For each single-objective formulation, evolutionary algorithm is applied to optimize separately each of multi-objective functions, where individuals generated by tournament selection from the union of single-objective and pareto archive formulation form the single-objective formulation of next generation. Simulations manifest that the proposed method can realize the search from multiple directions to obtain the non-dominated solutions scattered more uniformly over the Pareto frontier with better convergence metric compared to well-known non-dominated sorted GA - II algorithm (NSGA-II).

Abido proposed the multi-objective evaluation algorithm (MOEA) for solving the IEEE 30-bus test system with multi-objective nonlinear optimization problem [21]. The results of MOEA have been compared with NSGA, niched pareto GA (NPGA), and strength pareto EA (SPEA). Test results confirm the potential and effectiveness of MOEA compared to the traditional multi-objective optimization techniques.

Radu and Besanger presented their research in [22]. MOGA is used to characterize the pareto optimal frontier (non-dominates solutions). The objective functions are maximization of the system security and minimization of investment cost of FACTS devices. The optimization process is focused on three parameters, which are the location of FACTS devices, type of FACTS devices, and sizes of FACTS devices. Test results showed that MOGA is successfully tested on IEEE 14-bus test system for several numbers of FACTS devices.

Benabid *et al*. proposed the methodology which is based on a variant PSO specialized in multi-objective optimization problem known as non-dominated sorting particle swarm optimization (NSPSO) in [23]. NSPSO is used to find the optimal location and setting of two types of FACTS devise, TCSC and SVC that maximize static voltage stability margin (SVSM), reduce real power losses (RPL), and load voltage deviation (LVD). The optimization is carried out on two and three objective functions for various FACTS combinations. The proposed method is validated on IEEE 30-bus and realistic Algerian 114-bus power system. The simulation results are compared with those obtained by PSO and NSGA-II. The comparisons show the effectiveness of the proposed NSPSO to solve the multi-objective optimization problem and capture pareto optimal solutions with satisfactory diversity characteristics.

1.4 Thesis Objectives

The main objectives of this thesis are as follows:

1) To develop a new hybrid particle swarm optimization (PSO) method based on general PSO, evolutionary programming (EP), and tabu search (TS) to determine the optimal allocation of Flexible Alternating Current Transmission System (FACTS) controllers in electrical transmission systems.

2) To develop a new method for solving multi-objective functions of FACTS controllers allocation based on Pareto optimality concept.

1.5 Scope of Thesis

1) The new hybrid method is developed from general PSO, EP, and TS.
2) The optimal allocation of FACTS controllers includes determining number, type, parameter setting and location of static var compensator (SVC), thyristor controlled series compensator (TCSC), thyristor controlled phase shifter (TCPS), and unified power flow controller (UPFC).
3) The multi-objective functions are designed to maximize total transfer capability (TTC), minimize power loss and total cost of FACTS controllers.
4) The proposed method is tested on the practical 230-500 kV Electricity Generating Authority of Thailand (EGAT) transmission systems and test results are compared with those from other modern heuristic methods.

1.6 Research location

The research is conducted at the High Voltage Building, Department of Electrical Engineering, Faculty of Engineering, Chiang Mai University, Thailand.

1.7 Outline of the thesis

This thesis is organized into six chapters as follows:

Chapter 1 presents an introduction and background of this research. This chapter also reviews the state of the art of the overview of FACTS controller and literature review of the using of heuristic methods. After that, the objectives of the thesis are presented and the related state of the art is studied.

Chapter 2 presents the basic structure and principles of FACT controllers, Unified Power Flow Controller (UPFC), Thyristor Controlled Series Capacitor (TCSC), Thyristor Controlled Phase Shifter (TCPS), and Static Var Compensator (SVC) which are used in this research. And the concepts of optimal power flow (OPF) with FACTS controller are presented in this chapter, too.

Chapter 3 presents the heuristic methods PSO (Particle Swarm Optimization), EP (Evolutionary Programming) and TS (Tabu Search) which are used in this thesis. Following by the characteristics of hybrid method which is developed in this thesis.

Chapter 4 presents the multi-objective function. This includes a discussion of fuzzy C-mean with selection technique which is used in this thesis.

Chapter 5 investigates a performance of improvement method.

Finally, Chapter 6 presents the conclusions and suggestions for future research.