Controller Design of STATCOM for Power System Stability Improvement Using Honey Bee Mating Optimization

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ABSTRACT
Damping of low frequency electromechanical oscillations is very important for a safe system operation. The fast acting, of a static synchronous compensator (STATCOM) which is capable of improving both steady state and dynamic performance permits newer approaches to system stabilization. This paper presents a novel methodology for tuning STATCOM based damping controller in order to enhance the damping of system low frequency oscillations. The design of STATCOM parameters are considered an optimization problem according to the time domain-based objective function solved by a Honey Bee Mating Optimization (HBMO) algorithm that has a strong ability to find the most optimistic results. To validate the results accuracy, a comparison with Genetic Algorithm (GA) has been made. The effectiveness of the proposed controller is demonstrated through nonlinear time-domain simulation and some performance indices studies over a wide range of loading conditions. The simulation study shows that the designed controller by HBMO performs better than GA in finding the solution. Moreover, the system performance analysis under different operating conditions shows that the φ based controller is superior to the *C* based controller.

Keywords: STATCOM, honey bee mating optimization, power oscillation damping controller, low frequency oscillations.

Nomenclature

DC	Direct current
E'_q	Internal voltage behind transient reactance
E_{fd}	Equivalent excitation voltage
FACTS	Flexible alternating current transmission systems
FD	Figure of demerit
GA	Genetic algorithm
GTO	Gate turn off thyristor
HBMO	Honey bee mating optimization
ITAE	Integral of time multiplied absolute value of the error
K	Proportional gain of the controller
K_A	Regulator gain
M	Machine inertia coefficient
P_e	Electrical output power
PI	Proportional integral
P_m	Mechanical input power
PSO	Particle swarm optimization
SMIB	Single machine infinite bus
STATCOM	Static synchronous compensator
SVC	Static var compensator
TA	Regulator time constant
T'_{do}	Time constant of excitation circuit
T_e	Electric torque
T_s	Settling time of speed deviation
V_{dc}	Dc capacitor voltage
V	Terminal voltage
VSC	Voltage source converter
ω	Rotor speed
δ	Rotor angle
φ	Excitation phase angle
ΔP_e	Electrical power deviation
ΔV_{dc}	DC voltage deviation

1. Introduction

Leading in recent years, flexible alternative current transmission systems (FACTS) devices are one of the most effective ways to improve power system operation controllability and power transfer limits. Through the modulation of bus voltage, phase shift between buses, and transmission line reactance, the FACTS devices can cause a substantial increase in power transfer limits during steady state [1]. These devices are an addition to normally steady-state control of a power system but, due to their fast

response, the FACTS can also be used for power system stability enhancement through improved damping of power swings [2]. The real power flow with primary function of FACTS devices can be regulated to reduce the low frequency oscillation and enhance power system stability. Recently, several FACTS devices have been implemented and installed in practical power systems [3-5]. STATCOM is a member of the FACTS family that is connected in shunt with the system. From the viewpoint of the power system dynamic stability, the STATCOM provides better damping characteristics than the SVC. It is able to exchange transiently reactive power with the system, it can improve oscillation stability better than SVC [6, 7]. The STATCOM is based on the principle that a voltage source inverter generates a controllable AC voltage source behind a transformer-leakage reactance hence, that the voltage difference across the reactance can produce active and reactive power exchange between the STATCOM and the transmission network. Several trials have been reported in the literature of dynamic models of STATCOM in order to design suitable controllers for power flow, voltage and damping controls [8]. Wang [9] established the linearized Phillips–Heffron model of a power system installed with a STATCOM and demonstrated the application of the model in analyzing the damping effect of the STATCOM. Furthermore, seems that no efforts have been made to identify the most suitable STATCOM control parameter, in order to arrive at a robust damping controller. Intelligent controllers have the potential of overcoming the above mentioned problems. Fuzzy-logic-based controllers, for example, have been used for controlling a STATCOM [7, 10, 11]. The performance of such controllers can be improved by adaptively updating their parameters. Although using the robust control methods [12], the uncertainties are directly introduced to the synthesis. Due to the large model order of power systems, the order resulting controller will be very large in general which is not feasible because of the computational economical problems when implementing. Thus, one important issue, in this respect, is the tuning of the controller parameters of the STATCOM. For this reason, usually a linearized model of the system around a single operation is used for STATCOM controller design.

Many of the optimization techniques such as PSO [13, 14], GA and HBMO are used for optimization problems. The HBMO algorithm can be used to solve many of the same kind of problems as GA [15] and does not suffer from of GA's problems. Though GA methods have been employed successfully to solve complex optimization problems, a recent research has identified deficiencies on its performance [16, 17]. In order to overcome these drawbacks, the HBMO algorithm is proposed to optimal tune of controller parameters to improve power system stability in this paper. The HBMO algorithm is a very strong method for optimization and has emerged as a useful tool for engineering optimization. Hence, this method is efficient in handling large and complex search spaces [18, 19].

In this study, the problem of designing a robustly STATCOM based damping controller is considered as an optimization problem and both, HBMO and GA techniques are used for searching optimized parameters. The effectiveness and robustness of the proposed controller are demonstrated through nonlinear time-domain simulation and some performance indices studying the damp low frequency oscillations under different operating conditions. Evaluation results show that the HBMO based tuned damping controller achieved good performance for a wide range of operating conditions and is superior to the controller designed using GA technique.

2. Honey bee mating optimization

The honey bee is one of the social insects that only can survive as a member of a colony. The activity of honey bee suggests many characteristics such as; team work and communication. A honey bee colony is normally compossed by a single egg-laying queen whose life-span is longer than that of any other bee; and depending on the season, regularly lays around 60,000 workers . A colony may contain only one queen during its life-cycle. That is called monogynous. Only the queen is fed with "royal jelly." "Nurse bees" take care of this gland and feed the queen with it. The royal jelly allows the queen bee to become the biggest bee in the hive [20].

Several hundred drones live with the queen and its workers. Queen bee's life-span is about 5 or 6 years, whereas for the rest of the bees, specially