



Optimal parameter setting of UPFC and real power generation using Cuckoo Search Algorithm

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Abstract— In this piece of work, a new metaheuristic algorithm called Cuckoo Search Algorithm (CSA) has been implemented to solve the optimal power flow (OPF) problem for minimization of real power generation cost. A Unified Power Flow Controller (UPFC) has been integrated in the power system and henceforth the optimization of the generators has been performed to mitigate the generation cost. A UPFC is a combined shunt and series voltage converter type device used to reduce transmission line losses and to improve the voltage profile of the system. The CSA is one of the most efficient algorithms for solving single objective optimal power flow problems. The performance of the proposed method is tested on an IEEE 30 bus system and the results obtained have been compared to Genetic Algorithm (GA). CSA is found to give better results as compared to genetic algorithm (GA) in both without and with UPFC conditions.

Index Terms—Cuckoo Search algorithm, Optimal setting of FACTS device, Optimal Power Flow, UPFC

I. INTRODUCTION

Demand requirement of the consumer's is keep on changing so meet this changing demand, optimization of real power generation is required. The increasing demand in the power systems creates difficulties to the power system, and its secure and stable operation has become a challenging task. So for the purpose of supplying the power to consumers effectively power system network reconfiguration is required. In reconfiguration of the power system, Flexible AC transmission system (FACTS) devices play an important role. FACTS devices effectively control the power flow in the power system. Among FACTS devices, Unified Power Flow Controller (UPFC) is a multi-functional device which controls the voltage magnitude, phase angle and line reactance independently or jointly [1, 2]. But its performance is depending on the parameters of UPFC so the optimal setting of UPFC parameters is required.

In literature, this problem has been mentioned in various ways. For example, M. Saravanan et al. applied the PSO algorithm for finding size and location of FACTS devices considering the system loadability [3]. In Khai Phuc Nguyen et al [4] apply the cuckoo search

algorithm for optimal placement of static VAR compensator to improve the performance of the power system. The optimal solution given by Adaptive Differential Evolution algorithm is better than other evolutionary algorithm methods is explained by K.R.Vadivelu et.al [5]. Another research of optimal power flow using cuckoo search algorithm for improvement of voltage stability has been explained by M. A. Elhameed [6]. And the problem of real power generation reallocation is also solved using traditional optimization methods such as interior point, linear programming, nonlinear programming and quadratic programming. Drawbacks in these methods are the difficulty to obtain the global minimum due to many local minimums that exist in these problems. Heuristic optimization tools have been investigated such as evolutionary and genetic algorithm [7, 8], particle swarm optimization, ant colony [9], Bees algorithm, firefly algorithm [10, 11], bacterial foraging algorithm [12] and gravitational search and Tabu search to solve this problem. In this paper Cuckoo search is investigated and applied to IEEE 30 bus system for real power generation optimization and optimal setting of UPFC parameters to minimize the real power generation cost. Results obtained are compared with genetic algorithm, Cuckoo search gave better results.

The UPFC is an innovative FACTS device proficient of controlling of voltage magnitude, active and reactive power flows at the same time. The UPFC is created by the amalgamation of the static synchronous compensator (shunt device) and the static synchronous series compensator (series device). UPFC, connected in both series and parallel on a

transmission line of a power system, was invented by Gyugi in 1991.

In this work, CSA is implemented to explain the single objective function minimization of real power generation cost based on optimal generation reallocation and optimal parameter setting of the UPFC devices in electrical power system. It also gives a comparison between Cuckoo search algorithm and Genetic algorithm. To figure out the effect of the proposed method, an IEEE 30 bus system is

used. The real power generated and the voltage magnitudes at the PV bus are taken as limitations.

II. UNIFIED POWER FLOW CONTROLLER

UPFC conception has been projected by Gyugyi is used for control of power flow in ac transmission system. UPFC provides multifunctional control to solve reactive power compensation and voltage stability enhancement problems in the power system. The UPFC is capable of controlling multiple aspects of the power systems, viz., voltage magnitude, line impedance and phase angle either individually or in combination thus improving the performance of the systems. Hence the term ‘unified’ has been designated. [13].

The device is a amalgamation of a shunt connected Static Synchronous Compensator (STATCOM) and a series connected Static Synchronous Series Compensator (SSSC). The combination of above two devices is UPFC. Fig. 1 shows the simple model of UPFC. In UPFC exchange of real and reactive has been obtained through shared DC linkage. It is also capable of generation or absorption of controlled reactive power, thus providing autonomous shunt reactive compensation [14].

Fig. 1 A simple model of UPFC

Voltage source for UPFC is as given below:

$$V_{vR} (\cos \delta_{vR} + j \sin \delta_{vR}) \tag{1}$$

$$V_{cR} (\cos \delta_{cR} + j \sin \delta_{cR}) \tag{2}$$

V_{vR} and δ_{vR} are the voltage mag. and phase angle of the controllable shunt converter voltage source.

V_{cR} are the voltage mag. and phase angle of the controllable series converter voltage source.

It is assumed the impedance in the source has no resistance

[15]. The active and reactive power equations

are At bus k

$$P_k = [V_k V_m B_{km} \sin(\theta_k - \theta_m)] + [V_k V_{cR} B_{km} \sin(\theta_k - \delta_{cR})] + [V_k V_{vR} B_{vR} \sin(\theta_k - \delta_{vR})] \tag{3}$$

$$Q_k = -V_k^2 B_{kk} - [V_k V_m B_{km} \cos(\theta_k - \theta_m)] - [V_k V_{cR} B_{km} \cos(\theta_k - \delta_{cR})] - [V_k V_{vR} B_{vR} \cos(\theta_k - \delta_{vR})] \tag{4}$$

At bus m

$$P_m = [V_m V_k B_{mk} \sin(\theta_m - \theta_k)] + [V_m V_{cR} B_{mm} \sin(\theta_m - \delta_{cR})] \tag{5}$$

$$Q_m = -V_m^2 B_{mm} - [V_m V_k B_{mk} \cos(\theta_m - \theta_k)] - [V_m V_{cR} B_{mm} \cos(\theta_m - \delta_{cR})] \tag{6}$$

III. CUCKOO SEARCH ALGORITHM

CSA is a new optimization algorithm, based on the parasitism characteristic of the cuckoos, developed by Yang and Deb [16]. This method pretends the activities of the female Cuckoos to lay their eggs in the neighbour’s nest. This method contemplates the possibility that the host bird may discover and abandon the Cuckoo’s eggs. A recent study says that Cuckoo search algorithm is a more successful method in comparison to other metaheuristic methods.

The pseudo code of the CSA is accessible in [17] based on Initialization. In this a population of N_p host nests generated. This stage is corresponding to the phenomenon that cuckoo bird lays its eggs in nests of other species. In the new solution generation stage a new solutions is generated via Levy Flights corresponding to the case that host birds do not discover alien eggs in their nest and Cuckoo’s egg will be hatched and carried over to the next generation. The next stage aims to generate the second new solutions corresponding to the case that the host bird discovers the cuckoo eggs as the unfamiliar ones in her nest and host bird will throw Cuckoo eggs away the nest or forsake both Cuckoo eggs and their nest [18].

α is the step size, the product means entry wise multiplications. Levy flight provides a random walk whose random step length is drawn from Levy distribution:

$$\text{Levy} \neq t^{-\lambda}, (1 < \lambda < 3) \tag{8}$$

Objective function with this new set is also evaluated. If new objective function is better than old one, a portion P_a of new set is replaces an equivalent random set of the initial solution. The process is repeated until the maximum number of epochs is reached. Initial set of nests (n nests) may vary from 15 to 40 and P_a of 0.25 are suitable values for most optimization problems.

Overall Procedure

IV. FORMULATION OF THE OBJECTIVE

The problem is defined as follows:

Minimize $f(x)$

Subject to $g(x) = 0$, and

$h(x) < 0, x_l \leq x \leq x_u$

where $f(x)$ is a scalar function indicating the sum of the real power generation cost,

$g(x)$ are the power flow equations (equality constraint)

$h(x)$ the limits of the control variables (inequality constraint)

‘ x ’ is the state variable vector

x_l and x_u the lower and upper limits are.

The Minimization function can be represented as:

$$F = \min(\sum_{i=1}^{ng} a_i P_{Gi}^2 + b_i P_{Gi} + c_i)$$

Where $G_i=1, 2, 3, \dots, n_g$ and n_g = no. of. Generator buses

Reactive Power generation limits:

V_{vr} is the voltage magnitude (p.u) of the shunt converter

V_{cr} is the voltage magnitude (p.u) of the series converter

where P_L, P_{G_i}, P_{D_i} are the active power loss, generation and demand respectively of the system, N number of buses, n_g are the no of generators in the system respectively. The Voltage Magnitudes of the generator

PV bus NO	Generation limits		OPF with GA Without UPFC	OPF with GA and UPFC	OPF with CSA Without UPFC	OPF with CSA and UPFC
	Min	Max				
1	50	200	168.817	141.311	177.893	170.446
2	20	80	26.5423	52.8833	47.932	46.9049
5	15	50	35.7015	24.5714	21.9275	20.7027
8	10	35	25.8285	20.5254	21.632	31.3416
11	10	30	21.6473	13.3851	13.1864	10.4216
13	12	40	18.2117	39.8971	12.0027	12.0000

buses lies between 0.9p.u and 1.1pu.

V. RESULTS AND DISCUSSION

An IEEE 30 bus system is used for proving the effectiveness of the proposed technique. A MATLAB code is written for the considered system and the results are presented and analyzed. The parameters of CSA and GA used have been mentioned in Table I and Table II separately.

Table I Parameters of CSA

S.No	Variable	Value
1	Number of nests	20
2	Iterations Count	100
3	Discovery rate of alien eggs/solutions	0.25

Table II Parameters of GA

S.No	Variable	Value
1	Size of population	20
2	Max.No. of Generations	100
3	Crossover Fraction	0.8
4	Migration Fraction	0.2
5	Migration Interval	20

Table III Comparison of real power generation cost

without and with UPFC				
	Power Flow Solution	Total active power generation (MW)	Total Active power loss(MW)	Total active power generation cost (\$/hr)
GA-OPF	Without UPFC	296.7483	13.3483	832.7127
	With UPFC	292.5739	9.1739	828.4027
CSA-OPF	Without UPFC	294.5742	11.1741	808.2477
	With UPFC	291.8172	8.4172	801.5452

Table IV Comparison of UPFC parameters using Cuckoo Search algorithm and genetic algorithm

Parameters	CSA-OPF	GA-OPF
V_{CR} (p.u)	0.0400	0.0452
θ_{cr} (degree)	-87.1236	-88.2563
V_{VR} (p.u)	1.0062	1.0065
δ_{vr} (p.u.)	-15.4208	-16.0663

Table V Evaluation of the active power generated at various bus

The active power generation, power loss and real power generation cost for the IEEE 30 bus system without and with UPFC are shown in Table III. The active power generated is abridged to 291.8172 MW from 294.5742 MW and power loss are condensed to 8.4172 MW from 11.1741 MW due to UPFC in CSA based OPF. Table IV indicates the parameters of the UPFC device. Table V signifies the active power generated by the generator buses for GA method without and with UPFC and CSA based Optimal Power Flow without and with UPFC. By using CSA reallocation of generation has been accomplished resulting in less real power generation cost. Fig.2 and Fig.3 represents the convergence characteristics of fuel cost CSA without and with UPFC. From those figures it has been observed that by using UPFC in the system cost of the real power generation has been reduced. Fig. 4 indicates the voltage profile of 30 bus system using CSA based Optimal Power Flow without and with UPFC. It shows that the incorporation of an UPFC in the line coupled amid bus 29 and 30 in CSA based OPF voltage profile also improved. Fig. 5 represents the phase angles for 30 bus system using cuckoo search algorithm.

VI. CONCLUSIONS

In this paper, CSA has been applied to find the optimal values of the generating stations and optimal setting of the UPFC parameters based on minimization of the real power generation cost. The results obtained with cuckoo search algorithm are compared with genetic algorithm. The CSA is completely dominant and successful in the

determination optimal parameter setting of the UPFC device. Optimizing the parameters of UPFC devices along with optimization of real power generation cost is a complex problem which can be easily solved by using cuckoo search algorithm. The CSA always gives the better result with the advanced performance relative to with genetic algorithm. Comparison of the results in the absence and presence of UPFC shows the UPFC is highly recommended for the reduction of real power loss and generation cost of the power system.

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