Deciding Optimal Location of DPFC in Transmission Line Using Artificial Algae Algorithm

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Abstract—**In this paper, the application of artificial algae algorithm (AAA) in optimal placement distributed power flow controller (DPFC) with MCFC in transmission networks has been proposed The proposed method is tested on IEEE 14- bus system and the results are discussed. The biggest advantage of DPFC is that it can control the active and reactive power flow and bus voltages, simultaneously. In this paper, the optimal placement of one DPFC in IEEE-14 bus system and then optimal placement of two DPFCs in IEEE-14 bus system has been proposed. Optimal placement of DPFC in power system by AAA leads to increased stability and capacity of the power transmission in lines. The proposed model has been simulated in Matlab/Simulink and the performance results are tabulated.**

Keywords-artifical algae algorithm; DPFC; MCFC

I. INTRODUCTION

Increase in power demand has led modern power system networks to operate under stressed conditions. Load increase in the system is tolerable up to a particular limit but if it is increased further it may lead to voltage drop which may result to system instability and line overloading. FACTS devices help maintain system stability and maintain the system to normal condition. Many researchers proposed different methods to install FACTS devices in the system [1-5]. Optimal location of various FACTS devices in different test systems was done by multi-objective generalized approach [6], genetic algorithm and DE [7], PSO and harmony search algorithm [8] and several hybridized methods [9-12]. The major role of FACTS is to control the flow of real and reactive power by injecting a voltage in series with the transmission line. Real and reactive power flow control allow power flow in the specified routes. A new DPFC model with MCFC and ultra-capacitor is proposed in [13]. In this paper, AAA has been used to determine the optimal location of the DPFC proposed in [13].

II. ARTIFICIAL ALGAE ALGORITHM

It is a bio inspired meta-heuristic algorithm [14]. This algorithm has three main basic parts called evolutionary process, adaptation, and helical movement [15].

A. Evolutionary Process

In this process, the algae receive sufficient nutrients and enough sunlight to grow and reproduce. But if the circumstances are not supportive, for example if the sunlight is not enough, then the algae may die. This process can be mathematically expressed by:

$$G_j^{t+1} = \left(\frac{f_j(x)}{k + f_j(x)} \right) \times G_j^t \quad \text{for } j=1,2,3,\ldots.N \quad (1)$$

where, G is the size of the jth algal in time t and N is the colony in the system. Of all N colonies, the colonies that provide better solutions grow bigger because they get enough sunlight to grow. The colonies which do not give good solutions become smaller. The smallest colony dies. D is the problem dimension.

$$colony^{big} = \max(G_j^t) \quad \text{for } j=1,2,3,\ldots.N \quad (2)$$

$$colony^{small} = \min\left(G_j^t\right) \quad \text{for } j=1,2,3,\ldots.N \quad (3)$$

$$colony_m^{small} = colony_m^{big} \quad \text{for } m=1,2,3,\ldots.D \quad (4)$$

B. Adaptation

In this process the insufficiently grown algal colony tries to adapt to the environment. The insufficiently grown algal colony tries to resemble itself to the biggest algal colony:

$$starv^t = \max\left(A_j^t\right) \quad \text{for } j=1,2,3,\ldots.N \quad (5)$$

$$starv^{t+1} = starv^t + \left(colony^{big} - starv^t\right) \times rand \quad (6)$$

The initial starvation value is assumed to be zero for each algal and it is increased with time t. The starvation value of the jth algal colony in time t is A_j^t. The algal colony with the highest starvation value in time t is $starv^t$. Ap is a constant in the interval $[0,1]$ called adaptation constant which determines whether adaptation process will be applied or not in time t. If $rand > Ap$ then the adaptation will be applied.

C. Helical Movement

The algal cells generally swim helically to stay close to the water surface. Movement restriction due to gravity is displayed as 0 and viscous drag is displayed as shear force which is proportional to the size of the algal cell.

$$T(x_j) = 2\pi \left(\sqrt{\frac{3G_j}{4\pi}} \right)^{2/3} \quad (7)$$

$$x_{jm}^{t+1} = x_{jm}^t + \left(x_{im}^t - x_{jm}^t\right) \times \left(\Delta - T\left(x_J\right)\right) \times p \qquad (8)$$

$$x_{jk}^{t+1} = x_{jk}^t + \left(x_{ik}^t - x_{jk}^t\right) \times \left(\Delta - T\left(x_J\right)\right) \times \cos\alpha \qquad (9)$$

$$x_{jl}^{t+1} = x_{jl}^t + \left(x_{il}^t - x_{jl}^t\right) \times \left(\Delta - T\left(x_J\right)\right) \times \sin\beta \qquad (10)$$

III. Application of Artificial Algae Algorithm

The algorithmic steps of the application of AAA in optimal placement of DPFC with PEM are:

1. Randomly select DPFC parameters V_{se} and V_{sh}.
2. Perform load flow analysis of the system.
3. From the obtained result of step 2, calculate the value of the objective function.
4. Select the minimum value of the objective function as the best algae solution.
5. Update the algae colony using helical movement.
6. Perform the operation of reproduction and adaptation.
7. Repeat steps 2-4.
8. Compare the two outputs. If the stopping condition is achieved then stop, else repeat the same process again.

IV. Problem Formation

The proposed algorithm has been tested with standard IEEE 14 bus system. Numerical data and parameters were taken from [16]. In IEEE 14 bus system, load flow analysis is performed using the Newton Raphson method and the ranking is obtained from contingency analysis. The transformer ratio varies from its nominal value during the calculation process. First, the process assumes one DPFC is required to be placed in the system then the process is repeated for two DPFCs.

V. Simulation and Results

Ranking and performance parameter (PP) of the system based on contingency analysis is given in Table I. In Table I, only transmission lines whose PP is greater than or equal to 1 are shown. Table II, represents the optimized values of the transformer tap ratio. When one DPFC is considered, the application of AAA gives the location of DPFC between bus 4 and bus 10 as shown in Table III. When two DPFCs are considered, the application of AAA gives the location of DPFCs between bus 4 and bus 5 and between bus 6 and bus 9 as shown in Table IV. The final bus voltages after the simulation is over are given in Table V.

TABLE I.   RANKING

Line No.	From Bus	To Bus	No. of overload lines	No. of voltage violations	PP	Rank
1	1	2	5	7	12	1
3	2	3	4	5	9	2
2	1	5	2	6	8	3
10	5	6	1	5	6	4
4	2	4	2	3	5	5
14	7	8	0	3	3	6
15	7	9	1	2	3	7
13	6	13	1	2	3	8
5	2	5	0	1	1	9
7	5	4	0	1	1	10
9	4	9	0	1	1	11
20	13	14	0	1	1	12

TABLE II.   TRANSFORMER TAP RATIO

From	To	Ratio
3	4	1.064
4	6	1.062
6	8	1.042
9	11	1.081
12	13	1.109
14	15	1.084
16	17	1.038
18	19	1.074
10	21	1.052

TABLE III.   RESULT WITH ONLY ONE DPFC

Bus No.	Pi	Qi
4	-200	-150
10	-45	-20

TABLE IV.   RESULT WITH TWO DPFCS

Bus No.	Pi	Qi
4	-130	-100
5	-200	-145
6	-10	-3
9	-30	-90

TABLE V.   BUS VOLTAGES

Bus No.	Without DPFC	With 1 DPFC	With 2 DPFCs
1	1.05	1.05	1.05
2	1.05	1.05	1.05
3	1.03	1.01	1.01
4	0.98	1.02	1.00
5	1.00	1.03	1.01
6	1.05	1.05	1.06
7	0.05	0.98	1.00
8	1.05	1.05	1.06
9	0.90	1.05	1.06
10	0.88	0.97	0.80
11	0.95	1.00	1.00
12	0.94	1.01	0.90
13	0.95	1.00	1.00
14	0.84	0.98	0.90

VI. Conclusion

In this paper, optimal DPFC placement on an unstable power system because of contingency has been discussed. The optimal location of DPFC in IEEE 14 bus system using AAA has been tested. The proposed algorithm was executed for a maximum of 100 iterations and the results were tabulated. The case study of the IEEE 14-bus system confirmed that the developed algorithm is correct and effective. The losses are reduced and voltage profile is enhanced by placing DPFC(s) at optimal locations. The acquired solutions prove that the AAA has advanced specifications with accurate, balance characteristics, excellent quality of solution and best computation efficiency.

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