Optimal Location and Parameter Setting of Unified Power Flow Controller Using Ant Colony Optimization Technique

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OPTIMAL LOCATION AND PARAMETER SETTING OF UNIFIED POWER FLOW CONTROLLER USING ANT COLONY OPTIMIZATION TECHNIQUE

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***Abstract*-In this paper, Ant colony optimization is proposed for optimizing the power system losses and optimal setting of FACTS device. Flexible Alternating Current transmission System (FACTS) devices plays vital role in improving system performance and increasing transmission capacity without adding any new lines. Proposed system uses Ant Colony Optimization (ACO) technique for finding out the optimal number, the optimal locations, and the optimal parameter setting of UPFC (Unified Power Flow Controller) device to achieve maximum system load ability in the system with minimum installation cost. The voltage limits for the buses and lines thermal limits are taken as constraints during the optimization. For validate the proposed system IEEE 30 and 14-bus system is considered for finding the optimal location and size of UPFC device.**

***Keywords*- Optimal location; UPFC; Ant Colony Optimization (ACO); Cost function of UPFC**

I.INTRODUCTION

FACTS device introduces to increase the power transmission capacity of the system and reduce the reactive power loss in the system. Based upon the application types of FACTS device used. The installation of one FACTS device in the power system does not improve voltage stability and reduction in power system losses so multi-type FACTS devices are used to enhance both voltage stability margin and reduce losses in the system. As the load requirement increases, utilities are forward to maximize the consumption of their active transmission systems. While planning and operating of power system, power flow control in the transmission lines is a very important. Optimal power flow (OPF) is a nonlinear programming problem (NLP) which is used to minimize or maximize the desired objective function focus to certain system constraints by determining the optimal control parameter. An optimization technique is used to resolve the global optimum solution to a given power flow problem. Optimization means finding the best solution for the given non linear problem within the given constraints. Several predictable techniques like quadratic mixed integer programming, programming nonlinear programming (NLP), and Newton techniques are used to achieve the solution for most favourable power flow problems [20]-[23].

Many researchers developed different methods for finding the optimal location of UPFC and include cost function of UPFC [3]-[5]. The proposed method uses UPFC for system stability and improves the power flow in the transmission line. In this paper, factors to minimize to be consider for objective function is cost function and optimal allocation of the UPFC. Congestion management and immune algorithm was introduces to achieve optimal power flow. Genetic algorithm and particle swarm optimization techniques are used for finding the allocation of FACTS devices was proposed in [6]-[10]. The advantage of this method is that it can be easily implemented in existing power flow program and UPFC can be adjusted to work as series compensator, voltage regulator, or phase shifter.

II. PROBLEM FORMULATION

A. UPFC MODEL

UPFC consists of two voltage sourced Converters, as illustrated in Figure 1. These back-to-back converters, labelled "Converter 1" and "Converter 2" in the figure, are operated from a common dc link provided by a dc storage capacitor. As indicated before, this arrangement functions as an ideal ac-to-ac power converter in which the real power can freely flow in either direction between the ac terminals of the two converters, and each converter can independently generate (or absorb) reactive power at its own ac output terminal. Converter 2 provides the main function of the UPFC by injecting a voltage V with controllable magnitude and phase angle ρ in series with the line via an insertion transformer.

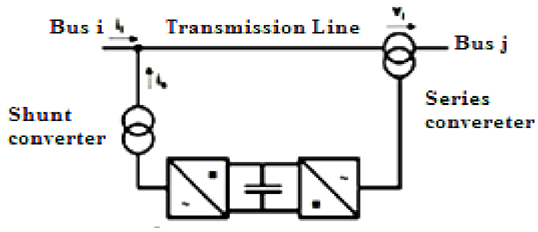

Figure 1. Operating principle of Unified Power Flow Controller

Shunt Converter: Converter 1(Shunt) provides local bus voltage control when it is operated by itself. It is operated together with converter 2(Series) has two main functions 1)To control bus voltage by reactive power injection to the transmission line 2) To supply active power to the series converter via DC link for series flow control[15]-[16].

Series Converter: It provides line power flow by injecting AC voltage with controllable magnitude and phase angle in series with the transmission line. This injected voltage provides series compensation for line voltage and angle regulation through transmission line current. This current flows through the voltage source resulting in real and reactive power exchange between the converter and AC system [1].

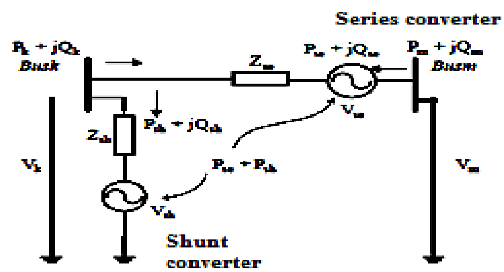

Figure 2. Equivalent circuit of UPFC

The steady state model can be derived by using equivalent circuit of UPFC shown in figure 2 [2]. The circuit consist of two ideal sources. The voltage source of the UPFC is:

$$V_{se} = V_{se}(\cos\theta_{se} + j\sin\theta_{se}) \quad (1)$$

$$V_{sh} = V_{sh}(\cos\theta_{sh} + j\sin\theta_{sh}) \quad (2)$$

Where 0≤ Θ_{sh} ≤2π V_{sh} and Θ_{sh} are the controllable magnitude and angle of voltage source indicating shunt converter $V_{sh\min} \le V_{sh} \le V_{sh\max}$ and similarly V_{se} and Θ_{se} are controllable magnitude and angle of voltage source indicating the series converter between the limits $V_{se\min} \le V_{se} \le V_{se\max}$ and 0≤ Θ_{se} ≤2 π correspondingly.

B. OBJECTIVE FUNCTION

In power system network it is desirable to keep the voltage deviation ±5% during faulty conditions. Same time real and reactive power losses in the network should be minimum. General, load requirement increase voltage drop may occur below 0.95p.u and subsequently additional voltage source is need for that particular bus. In this paper voltage and current support is provided by UPFC model, and optimal location determined by using Ant colony optimization technique.

The objective function is multi-criteria constrained because total losses and cost of installation of UPFC is considered into single optimization. The particular objective function gives compromise solution to power system problems:

$$F = \sum_{k=1}^{ntl} PQ_{loss} + \lambda \times 1000 \times C_{upfc} \times S \quad (3)$$

The cost function of UPFC in US $ / KVar

$$C_{UPFC} = 0.0003S^2 - 0.2691S_{FACTS} + 182.22 \quad (4)$$

Where, F is objective function; PQ_{kloss} is active and reactive power losses in the transmission line k; λ is a penalty factor; C_{upfc} is the cost of UPFC device in (US $/KVar), S operating range of the UPFC

III. IMPLEMENTATION OF ACO

A. OVERVIEW OF ACO

Ant colony optimization was developed by Dorigo et al in 1992. Ant finds the best and shortest path between the nest and food source. The ant deposits some quantity of aromatic substance on its path known as pheromone.

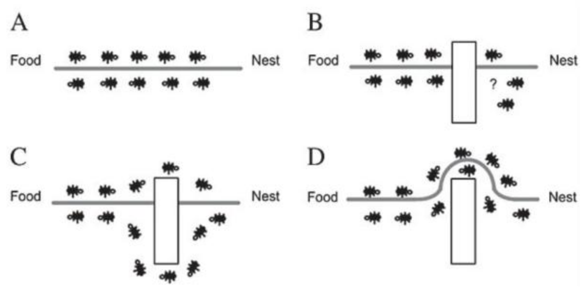

Figure 3. Ant movement in the nest

Pheromone quantity is always depends on the length of path and quality of the discovered food source. It is a combinatorial problem for solving the non linear system for finding the optimal solution. The optimal allocation of UPFC can be determined by Ant colony behaviour. Initially artificial ants moves randomly along on its path and deposit the pheromone. The other ants will follow the pheromone path for finding the food source. Higher intensity of pheromone motivates them to follow the path. With time, the pheromone trail is evaporating by the move of ants. Finally all ants choose the best and shortest path in their movement.

B. PROCEDURE FOR ACO ALGORITHM

STEP 1: INITIALIZE

Initialize the parameters and power flow data such as:

a. Number of iteration (iter)
b. Number of Ants (m)
c. Nodes (n)
d. Update coefficient (α)
e. Trace effect (β)
f. Initial pheromone level
g. Maximum limits of Voltage, angle, location
h. Dimension of search space
i. Penalty factor (λ) obtain

The maximum distance of every node can be calculated using this formula:

$$D_{\max} = \sum_{i=1}^{n-1} d_i \qquad (9)$$

d_i : denotes distance between two nodes. To obtain the d_{max} every node is set to be first node. If it is higher distance from the current node each ant will select the next node. This process will repeat until last node.

STEP 2: GENERATE FIRST NODE

Randomly generate the number for first node based on the uniform distribution, ranging from 1 to n.

STEP 3: STATE TRANSISTION RULE

This transitions rule decides which node ant visited next for its path. The ant positioned at current node and move to the next node by applying this rule is given by:

$$s=\begin{cases}\underset{u\in J_k(r)}{\arg\max}\left\{[\tau(r,u)]\cdot[\eta(r,u)]^{\beta}\right\} & \text{if } q\le q_0 \quad \text{(exploitation)}\\ S & \text{otherwise} \quad \text{(exploration)}\end{cases} \qquad (10)$$

New state transition rule is used to balance between exploration and exploitation.

$$p_{ij}^{k}(t)=\begin{cases}\dfrac{[\tau_{ij}(t)]\cdot[\eta_{ij}]^{\beta}}{\sum_{k\in allowed_k}[\tau_{ij}(t)]\cdot[\eta_{ij}]^{\beta}} & \text{if } k\in allowed_k\\ 0 & otherwise\end{cases} \qquad (11)$$

A high value for α means that trail is very important and therefore ants tend to choose edges chosen by other ants in the past. On the other hand, low values of α make the algorithm very similar to a stochastic multi greedy algorithm. Here q_0 is a constant parameter, q is a random variable, and S is the outcome of the probabilistic transition function.

STEP 4: LOCAL UPDATING RULE

The edge is updated by each iteration of an ant search using following equation:

$$\tau(r,s)\leftarrow(1-\rho)\cdot\tau(r,s)+\rho\cdot\Delta\tau(r,s) \qquad (12)$$

During the construction of solution, pheromone level is updated in the visited paths using above rule. Where $\Delta\tau(r,s)$ Initial pheromone trail and τ is Coefficient. Less visited path has lesser probability and the ant will not repeat that path again.

STEP 5: FITNESS EVALUATION

Fitness evaluation is performing after all ants have finished their tours. In this step, the control variable(*x*) is computed using the following equation:-

$$X=\frac{d}{d_{\max}}X_{\max} \qquad (13)$$

Where d denotes distance for every tour $d_{\max}$ denotes maximum distance for every tour (In this application bus is assumed as node).

STEP 6: GLOBAL UPDATING RULE

Pheromone produced by the ant is updated by global updating rule according to which the shortest route between the starting and ending point of tour is updated. Quantity of pheromone is updated only for one ant and its best fitness is determined. After all ants have completed their tours, the amount of pheromones is updated by using:

$$\tau(r,s)\leftarrow(1-\alpha)\cdot\tau(r,s)+\rho\cdot\Delta\tau(r,s) \qquad (14)$$

Fitness evaluation is performing after all ants have finished the path

$$\Delta\tau(r,s)=\begin{cases}(L_{gb}) & if\ (r,s)\in global-best-tour\\ 0 & otherwise\end{cases} \quad (15)$$

For the next iteration; the first node of globally best tour in the first iteration will be selected as first node by the each ant. Where L is length of the global best tour and b beginning of the tour: α pheromone parameter.

STEP 7: STOP CONDITION

Every path that was visited by ants should be evaluated. If a better path is discovered in the process, it will be kept for the next reference. The best path selected between all iterations engages the optimal placement of UPFC device. Where the convergence takes place in an identical path, which should be optimal one. Stop the process and make the best individual for optimal placement and minimize the cost of UPFC

IV SIMULATION RESULT AND DISCUSSION

The proposed algorithm is validated using IEEE-14 bus and 30 bus system. For simulation work, MATLAB programming code for Ant colony optimization and including the UPFC are developed together. Simulation is performed using MATLAB 2012. The parameter values for the proposed technique are given by:

Test System	Total Loss without UPFC
IEEE 14-Bus	13.38918
IEEE 30-Bus	3.469103

Table I: Initial parameters for ACO

Initial parameter values for Ant colony optimization	
Number of iteration(iter)	100
Number of ants(m)	50
Number of nodes(n)	50
Initial pheromone level (α)	0.05
Updating co-efficient(α_0)	1
Trace effect(β)	3
Penalty factor (λ)	0.001
Evaporation Co-efficient	0.1

Table II: Without UPFC Injection

There are no standard values for this type of optimization algorithm. Because it is stochastic population based algorithm. While using this technique in power system optimal location, dimension of the ant movement must be specified. The technique is performed with 100 trials for both the IEEE test system.

A. IEEE 14-BUS TEST SYSTEM

This test system consists of 5 generators, 20 transmission lines, 14 buses and 11 loads. The maximum limits of parameters or constraints needed to be considering for both test system. In this paper for IEEE 14-bus system $0 \le V_m \le 0.08$ and $0 \le \delta \le 3.14$ and 1 to 12 buses are considered. The results obtained for 100 trials and the optimal solution has been achieved. Allocation of UPFC by Ant Colony Optimization for this case is bus number from 7 to 9. In this case optimal location for fixing the UPFC is bus number 7 to 9 with minimum installation cost of 0.18826×10^6 US \$. This will reduce the real and reactive power losses and increase the power transmission capacity of the line.

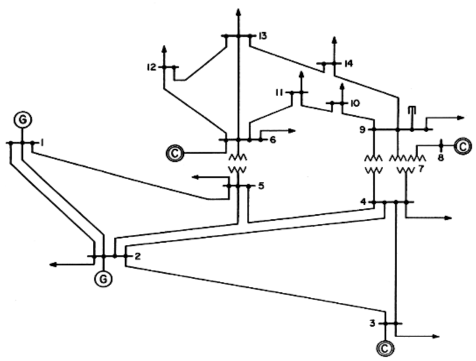

Figure 4. IEEE 14-Bus System.

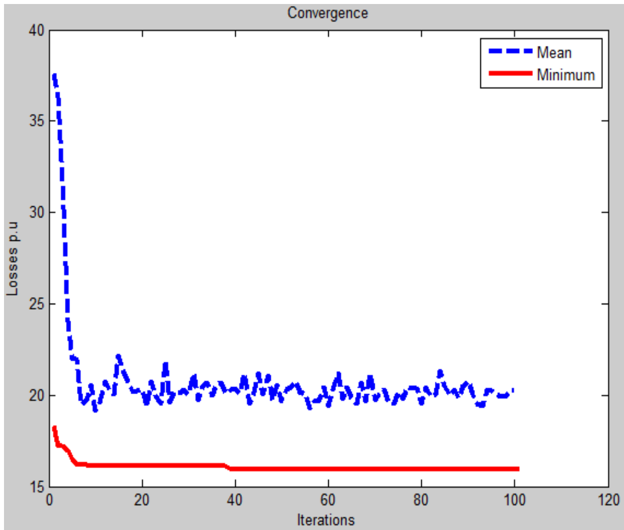

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Figure 5. Convergence characteristics for given objective function in IEEE 14-bus system

B. IEEE 30-BUS TEST SYSTEM

This test system consists of 6 generators, 41 transmission lines, 30 buses and 21 loads [25]. The results obtained for 100 trials and the optimal solution has been achieved. Similarly 30-bus system 1 to 26 buses included for optimal solution, remaining bus consists of transformers. UPFC Placement for this case, bus number 2 to 6.

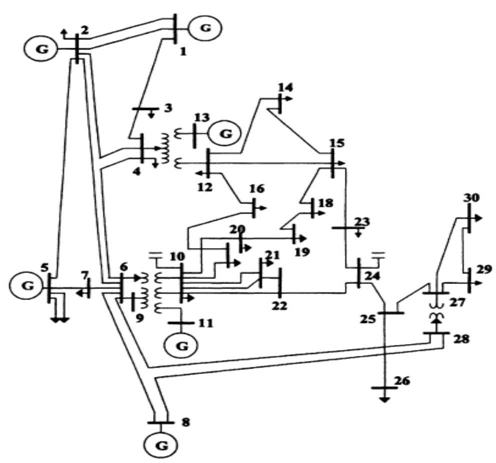

Figure 6. IEEE 30-Bus System.

In this case optimal location for fixing the UPFC is bus number 2 to 6 with minimum installation cost of 0.18819×10^6 US $. This will reduce the real and reactive power losses and increase the power transmission capacity of the line.

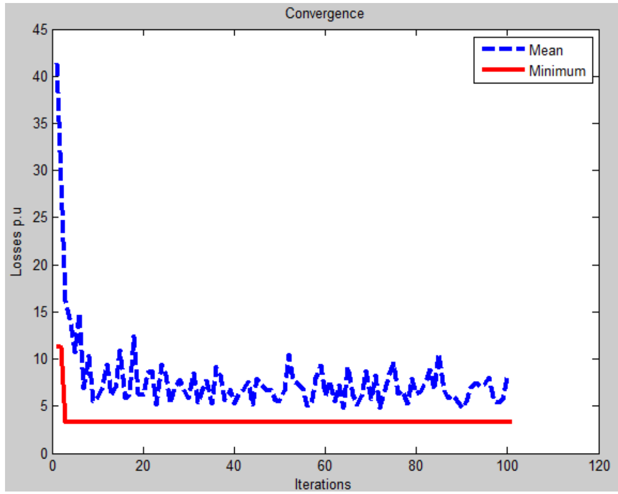

Figure 7. Convergence characteristics for given objective function in IEEE 30-bus system

This Paper mainly focuses on developing power flow solution of Power System networks with inclusion of UPFC model, as this device is capable of modifying the voltage, phase angle and then power flows in transmission lines.

Test System	Voltage in p.u	Angle	Total Loss	Cost of UPFC in $
IEEE 14-Bus	0.015874	3.140000	12.97151	188.21572
IEEE 30-Bus	0.080000	3.140000	1.779424	188.19847

Table II: Parameter setting of UPFC

V CONCLUSION

Ant colony optimization has been proposed for power system problem, solving optimal location of FACTS device. The proper placement of FACTS device, gives system instability. The comparison shows that ACO is versatile, robust and efficient. Further work is required to develop techniques for searching the neighbourhood, and present more efficacious sufficient conditions for convergence. This algorithm is well suited for path based system. The difficult of ACO in power system that converted into point based system for solving the problem. In future hybrid techniques have been implemented to minimize the transmission loss and cost reduction. Compared to conventional methods like sensitivity analysis, ACO gives better solution.

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