Optimal location of FACTS device for power system security improvement using Hybrid GA-ACO

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Abstract - *Power System security is a important issue specially in heavily loaded condition. In the method of reformation, voltage stability issue becomes even more serious in power system security. To solve the problem, we incorporate reactive power compensation concept by Static Synchronous Compensator (STATCOM). This paper shows the application of Ant Colony Optimization (ACO) plus Genetic Algorithms (GA) for optimal location and capacity of a STATCOM in a power system. Lastly model shows the optimal location and ability of STATCOM to enhance power system voltage stability by using GA-ACO. This process demonstrates the enhancement of voltage stability margin and so to improve the power system security.*

Key Words: **Genetic Algorithms, Ant Colony Optimization, power system security, voltage Stability, Static Synchronous Compensator (STATCOM), etc.**

1. INTRODUCTION

Power systems components mainly consist of generators, transmission lines, transformers, switches, active or passive compensators and loads. A compound system that is nonlinear, non-stationary, and level to instability and faults is the Power system networks. Back up of a power system can be accomplished by improving the voltage profile, increasing the transmission capacity and others. To address some of those problems Flexible AC Transmission System (FACTS) devices are an alternate solution [2]. The FACTS devices have three types, such as series controllers, shunt controllers and combined series-shunt controllers. In standard, the series controllers insert voltage in series with the line and the shunt controllers insert current into the system at the point of connection. The combined series-shunt controllers insert current into the system with the shunt part of the controllers and voltage in series in the line with the series part of the controllers.

In the case of voltage support, shunt FACTS devices, such as STATCOM and SVC are typically used. This study is paying attention on the steady state performance of multiple STATCOM devices in the power system. Mostly, it is desired to get out their optimal location and capacity. Varied integer linear and non-linear programming's are the traditional optimization method has been investigated to address this problem; however due to multiple local minima and great computational effort difficulties occur. To overcome these problems, Evolutionary estimation Techniques have been used to solve the optimal location of FACTS devices. This study, which uses the Genetic algorithms (GA), has been tested for finding the optimal location and capacity, with promising results [1].

This paper applied the ability of the GA operated after can promote the Ant Colony Optimization (ACO) efficiency. The objective of GA is to improve the searching feature of ants by optimizing themselves to create a better result, because the ants produced arbitrarily by pheromone method are not necessary better. This process can not only search the optimum solution rapidly to advance convergence, but also enhance the locality search. The load flow analysis (commonly called load flow or power flow) is the basic tool for investigating power system state variables, and it is very important part of the system supervisory, planning and optimal operation. The unbalance three-phase load flows based on the Equivalent-Current-Inject (ECI) were applied successfully to the distribution system. Because of the voltage – controlled buses (PV Bus) it is not capable to apply the ECI model to the high voltage transmission systems. In this a power flow moves toward based on ECI model is presented. PV Bus model were developed, and according to the network characteristics, the decoupled models were also proposed. This paper introduces the application of GA-ACO for optimal location and capacity of a STATCOM in the power system for enhancement of the power system security.

2. BASIC CONCEPT: STATCOM

STATCOM is a second generation FACTS device used for shunt reactive power compensation. The principle of STATCOM is the reactive power compensation where the reactive power and voltage magnitude of the system can be adjusted such as shown in Fig. 1. It consists of three paths: shunt (coupling) transformer, voltage source converter (VSC), and capacitor. The reactive power is distributed in the power system by the converter control.

The SATCOM active P and reactive power Q are shown in (1) and (2).

$$P=((V_s*V_i)/X_s)\cos\delta \qquad (1)$$

$$Q=(V_s^2/X_s)-((V_s*V_i)/X_s)\cos\delta \qquad (2)$$

Where Xs: is coupling transformer equivalent reactance

$$\delta : \theta s - \theta i$$

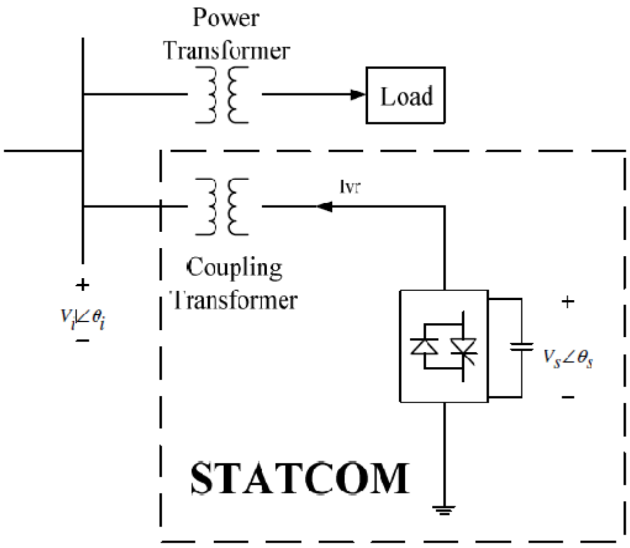

Fig -1: STATCOM connected to power system

The combination of a voltage source converter, an inductive reactance of the power system is STATCOM. The convert supply leading current to the AC system if the converter output voltage V_i is made to lead the related AC system voltage V_S. Then it supplies reactive power to the AC system by capacitive operation. On the other hand, the converter absorb lagging current from the AC system; if the converter output voltage V_i is made to lag the AC system voltage V_S then it absorb reactive power toward the AC system by inductive operation. If the output voltage is equal to the AC system voltage, the reactive power exchanges.

3. HYBRID OF GENETIC ALGORITHM AND ANT COLONY OPTIMIZATION (GA-ACO)

The vast literature on heuristics tells us that a promising approach to obtaining high-quality solutions is to couple a local search algorithm with a mechanism to generate initial solutions. In fact, in most search procedures, the better the solutions quality returned, the higher the computation time required. Such a coupling of solution construction of ant colony system with local search of GA is a promising approach for unit commitment problems. GA has been successfully applied to a wide range of applications, mainly in solving combination optimization problems. GA improves a solution constructed by an ant. In the following, we study how the performance of the ACO algorithms improved when coupled with GA.

A common form of hybrid algorithm is the combination of the local search and global search. ACO is good at global search but slow to converge; GA is good at fine tuning but often falls into local optima. In this paper, the hybrid approach complements the properties of ACO and GA search heuristic methods. Ant colony optimization is used to perform global search to escape from local optima; Genetic algorithms are used to conduct fine tuning.

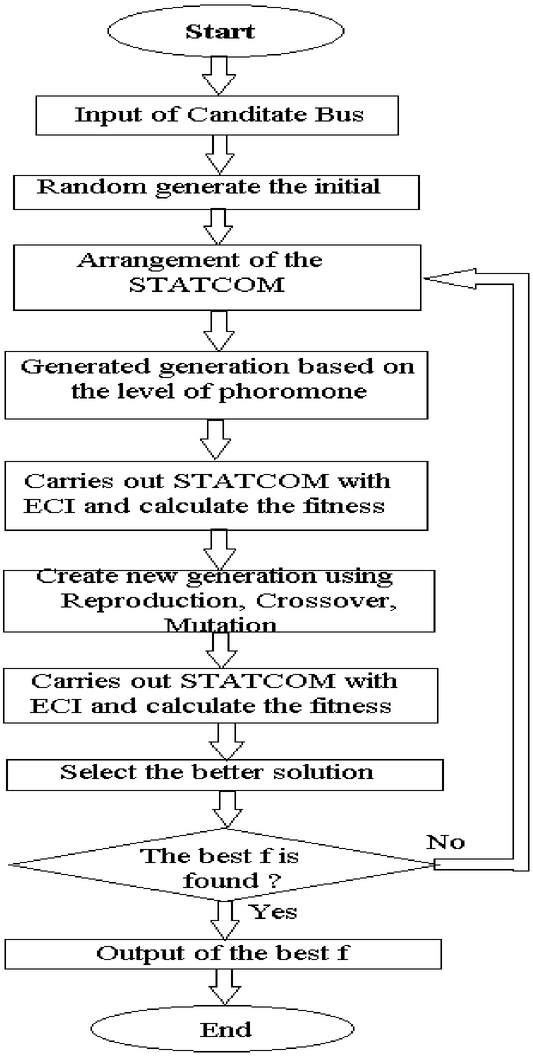

Fig -2: Flowchart of GA-ACO Optimization

The procedure of GA-ACO is as follow:

Procedure: ACO plus GA

1. Input test data;
2. Set the parameters of GA-ACO;
3. Generated solutions based on the level of pheromone;
4. Fitness evaluation;
5. Calculate selection probability to select a pair of ant to be parents;
6. Apply a crossover and mutation to generate offspring;
7. Evaluate offspring;
8. Select the better solution from parents and offspring;
9. Update the pheromone;
10. If a pre-specified stopping condition is satisfied, stop the run; otherwise, return to step 3.

4. OBJECTIVE FUNCTION

In such a power network, it is desirable to keep the voltage deviations between ±5% to avoid voltage collapses during faulty conditions. In general, if the load requirements increase, the voltages at the corresponding buses may drop below 0.95p.u. and consequently an additional voltage support is needed at that particular bus. In this study, the voltage support will be provided by a STATCOM, and its optimal location and capacity will be determined by using GA-ACO.

For instance, the IEEE 30-Bus system in Fig. 4 has 5 generators buses where voltage is regulated by the generator AVRs. These generator buses do not need a STATCOM and are omitted from the GA-ACO search process. Also considering the topology of the system, the bus numbers are limited to the range from 1 to 30.

STATCOM selection to install the location principle

1. Because STATCOM are expensive, therefore the minimum device installed is searched for economic efficiency reasons.

2. Generator buses where voltages are regulated by the generator do not need STATCOM installation.

3. Each bus is limited to the installation of one device. Installing more does not represent a significant effect.

4. If the bus voltage is above 0.95 p. u., then STATCOM is not installed.

According to the above discussion, candidates Bus are shown in Table 1.

Table -1: Candidate Bus

Bus No.	15	18	19	20	21	22	23
Bus No.	24	5	26	27	28	29	30

5. SIMULATION RESULTS

A 30-Bus test system is used for this paper. The test system consists of 5 generators and 24 PQ bus (or load bus). The problem to be addressed consists of finding the optimal location (bus number) and power rating (MVA) of STATCOM. In this case the GA is able to find different options for both location and capacity of the STATCOM. The solution found by GA-ACO, in terms of bus location and for each STATCOM unit, is shown in Table 2.

Table -2: Solution Found By GA-ACO

STATCOM Unit	Location (Bus Number)
1	26
2	29

The best solution is found by inserting STATCOM at bus 26 and bus 29. The power flow results, the bus voltage with STATCOM for 30% load is show in Fig. 3. The voltage comparison with and without STATCOM is shown in table. 3 The system not including the STATCOM has 17 buses with voltage below 0.95 p. u. Once the STATCOM units are connected to buses 26 and 29 the voltage is enhanced.

Table -3: Bus Voltage from Power Flow Result

Bus No.	p. u. voltage with STATCOM	p. u. voltage without STATCOM
1	1.060	1.060
2	1.043	1.043
3	1.024	1.026
4	1.015	1.018
5	1.010	1.010
6	1.017	1.013
7	1.006	1.004
8	1.020	1.010
9	1.045	1.025
10	1.029	1.002
11	1.082	1.082
12	1.054	1.027
13	1.071	1.071
14	1.037	1.010
15	1.031	1.003
16	1.036	1.009
17	1.026	0.999
18	1.018	0.990
19	1.014	0.986
20	1.017	0.989
21	1.017	0.988
22	1.023	0.991
23	1.017	0.988
24	1.014	0.977
25	1.033	0.978
26	1.000	0.959
27	1.061	0.987
28	1.020	1.011
29	1.090	0.967
30	1.059	0.955

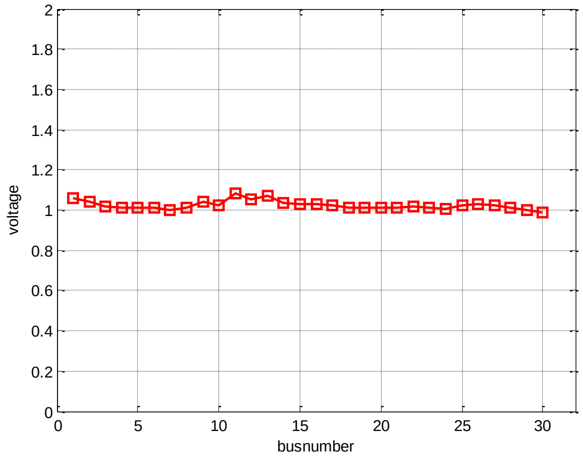

Fig. 3: Bus voltage with STATCOM for 30 % load

Additionally, In order to study the effect of the load conditions in the optimal solution found by the GA-ACO, simulations are carried out by changing the load in each load center in a range from 60% to 90%. The Fig. 4 and Fig. 5 are the with STATCOM bus voltage for different load. In Fig. 4 and Fig. 5 is registered again a voltage improvement.

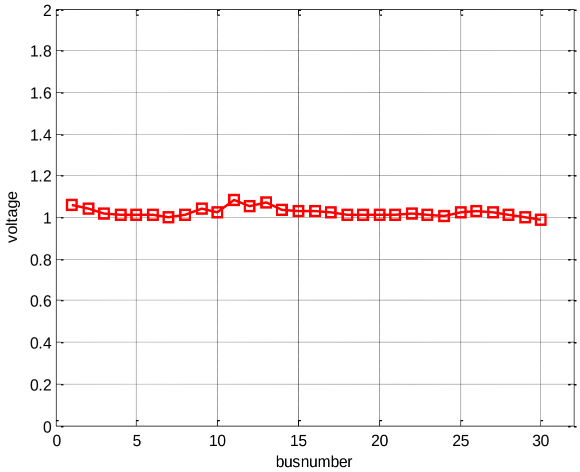

Fig. 4: Bus voltage with STATCOM for 60 % load

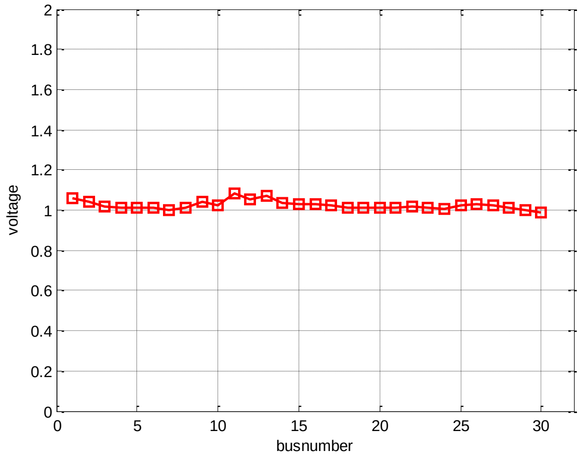

Fig. 5: Bus voltage with STATCOM for 90 % load

The results obtained by the different load conditions for STATCOM capacity are shown in Table 3 and Table 4. Fig. 6 and Fig. 7 illustrate the relationship between the capacity of STATCOM and different load conditions. From Table 3 and Table 4, the capacity of the STATCOM does change under different load condition.

Table -4: Location and Capacity of First STATCOM for Different Load Conditions

Load (%)	Location (Bus)	Capacity (MVA)
30	26	$3.173*10^4$
60	26	$3.217*10^4$
90	26	$3.263*10^4$

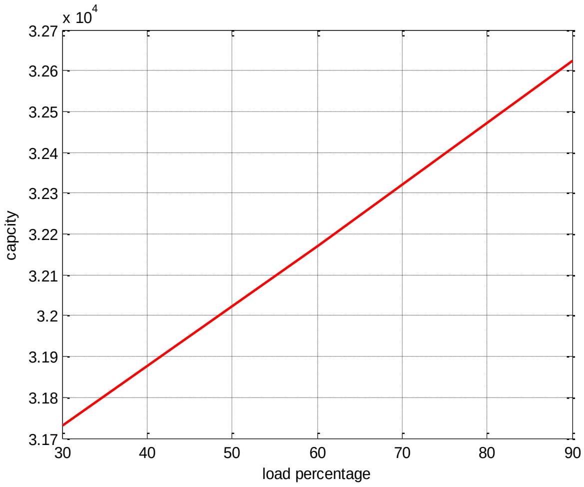

Fig. 6: STATCOM capacity for different load condition

Table -5: Location and Capacity of Second STATCOM for Different Load Conditions

Load (%)	Location (Bus)	Capacity (MVA)
30	29	$3.156*10^4$
60	29	$3.175*10^4$
90	29	$3.228*10^4$

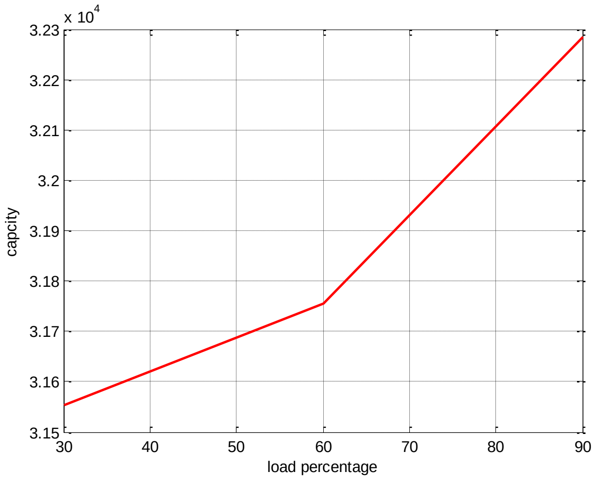

Fig. 7: STATCOM capacity for different load condition

6. CONCLUSIONS

The paper has demonstrated the application of GA-ACO for location and capacity of STATCOM in a power system considering at each bus the voltage constraints. The study is carried out for the aim of power system security margin enhancement. Simulation results through an IEEE 30bus validate the efficiency of the optimal location and capacity of STATCOM. The result shows the significantly voltage stability enhancement and hence power system security enhancement.

REFERENCES

[1] Y. D. Valle, J. C. Hernandez, G. K. Venayagamoorthy, R.G. Harley, “Multiple STATCOM Allocation and Sizing Using Particle Swarm Optimization” Power Systems Conference and Exposition, Oct. 2006, pp. 1884-1891.

[2] Y. del Valle, J.C. Hernandez, G.K. Venayagamoorthy, and R.G. Harley, “Optimal STATCOM Sizing and Placement Using Particle Swarm Optimization”, Transmission & Distribution Conference, Latin America, September 2006, pp.1-6.

[3] Reza SIRJANI, Azah MOHAMED, Hussain SHAREEF, “Optimal Placement and Sizing of Shunt FACTS Devices in Power Systems Using Heuristic Optimization Techniques: a Comprehensive Survey”, University Kebangsaan Malaysia, 2012, pp. 335-341.

[4] Subramaniam Nachimuthu DEEPA, John Basha RIZWANA,“Imperialist Competitive Algorithm for Minimization of Losses by Optimally Locating Facts Controllers in Power System”, IU-JEEE Vol. 15(1), 2015, pp. 1889-1896.

[5] Mohd Rozely Kalil, Ismail Musirin, Muhammad Murtadha Othman, “Ant Colony Based Optimization Technique for Voltage Stability Control”, International Conference on Power Systems, September 2006, pp.149-154.

[6] Marco Dorigo, Thomas Stutzle, “Ant Colony Optimization”, the MIT Press Cambridge, Massachusetts London, England.

[7] Akhilesh Tiwari, Satya Prakash Dubey, Alok Kumar Dubey, “Performance Analysis And Review Of Ant Colony Optimization Based Hybrid Active Power Filter For Three Phase Four Wire System”, International Journal of Advanced Engineering Research and Studies, Jan.-March,2015, pp.300-304.

[8] Prakash Burade, Jagdish Helonde, “Optimal Location of FACTS Device on Enhancing System Security”, International Journal of Scientific & Engineering Research Volume 3, Issue 5, May-2012, pp.1-7.

[9] Y. V. Balarama Krishna Rao, R. Srinivasa Rao & V. V. K. Reddy, “ABC Algorithm Based Comparative Analysis Of Optimal SVC And TCSC Placement To Maximize Loadability”, International Journal of Electrical and Electronics Engineering Research, Vol. 4, Issue 6, Dec 2014, 53-64.

[10] G. Ramana, B. V. Sanker Ram, “Power System Stability Improvement Using FACTS With Expert Systems”, International Journal of Advances in Engineering & Technology, Sept 2011, Vol. 1, Issue 4, pp. 395-404.

[11] E. Nanda Kumar, R. Dhanasekaran and R. Mani, “Optimal Location and Improvement of Voltage Stability by UPFC using Genetic Algorithm (GA)”, Indian Journal of Science and Technology, Vol 8(11), June 2015, pp. 1-6.