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Optimal Placement of D-STATCOM Using Hybrid Genetic and Ant Colony Algorithm to Losses Reduction

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ABSTRACT

In this work, a modern algorithm by hybrid genetic algorithm and ant colony algorithm is designed to placement and then simulated to determine the amount of reactive power by D-STATCOM. Also this method will be able to minimize the power system losses that contain power loss in transmission lines. Furthermore, in this design a IEEE 30-bus model depicted and three D-STATCOM are located in this system according to Economic Considerations. The optimal placement of each D-STATCOM is computed by the ant colony algorithm. In order to optimize placement for each D-STATCOM, two groups of ant are selected, which respectively located in near nest and far from the nest. Moreover, for every output simulation of D-STATCOM that is used to produce or absorb of reactive power, a genetic algorithm to minimizing the total network losses is applied. Finally, the result of this simulation shows net losses reduction about 150% that it verifies the new algorithm performance.

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1. INTRODUCTION

Recently, Improving of power quality has been considered for power distribution companies and both low and medium voltage costumers [1]-[4]. There are many reasons for more attention to power quality of power distribution companies such as connect networks together to form larger networks because of fault element in the network, increasing harmonics in power systems, customers' increasing awareness of power quality issues, increased sensitivity of electrical devices against disturbances of distribution networks [5]-[7]. Because of the rise of unbalanced loading on each phase, biased faults always take place in the distribution system which beginnings unstable voltage and current with negative component [8]. The distribution sector as the main link between the people and the power industry role more evaluation and judgment than other power parts and that's why the increasing quality of the electricity distribution is essential. In addition, determine the optimum capacitor placement in the distribution system is used to minimize the energy losses with improving the voltage profile of the system and then enhancement of the power factors of a distribution system [9]-[13]. Many potential applications such as heuristics and linear non-linear optimization techniques have been explored to solve the power quality problem [14]-[17].

2. PRINCIPLE OF D-STATCOM

The D-STATCOM has been applied as a favourable device to provide an important role in the distribution system such as voltage sag mitigation, voltage stabilization, flicker suppression, power factor correction, and harmonic control [18]-[20]. It is notable that D-STATCOM is one of the important devices that are able to solve the power quality problems at the distribution network [21]-[22]. D-STATCOM has been used to solve the unbalanced faults in the system as a certain controller [22]. D-STATCOM is an unbiased three-phase voltage or current through an ability shunt device so that can control the magnitude and the phase angle [21]. Distribution Static synchronous compensator (D-STATCOM) includes a voltage source inverter like a controller, a DC energy storage and Gate Turn off (GTO) thristor which causes a balanced set of current or three phases sinusoidal voltage at the basic frequency. There is an efficient control of both active and reactive power which use as connecting device between the D-STATCOM and the AC system. Absorb or produce controllable active and reactive power can be applied by D-STATCOM construction [2].

Generally, the core of a D-STATCOM made of a three-phase inverter which on one side is connected to the network through the transformer and from the other side end to a capacitor which is its DC power. In addition, the input signals include voltage of bus (V), output current of convertor (I) and a reference voltage (dc). The real power is determined by reference voltage which is absorbed by the AC system to provide its internal losses.

3. BASIC CONCEPTS OF GENETIC ALGORITHM

In this paper Genetic Algorithm (GA) is used to Placement and determine the D-STATCOM as an optimal system [23]. Also, GA is an effective method in bulky and extended places that has coded variables so that led to the optimal solution [24]. The advantage of coded variables is that the code is the ability to transform a continuous space to a discrete space [25]. We use the GA method optimization in population or a set of points in a certain moment while the old method optimized has been applied for only point. This means that the large number of projects can be processed at a same time by GA and also it is notable that, GA method is based on directed randomness. In order to use of GA many concepts such as defined the objective function or cost function, definition and implementation of genetic space and definition and implementation of GA operators.

4. BASIC CONCEPTS OF ANT-COLONY OPTIMIZATION (ACA)

In recent years, extensive research on optimization methods has been used for solving dynamic problems in the field of engineering and business as well as numerous optimization methods have been considered [26]. The evolutionary methods that are well- known because their unique properties are more considered [26]-[27]. The ant colony optimization (ACA) is one of the optimization methods that have been investigated in evolutionary classification [26]-[28]. This optimization technique has been inspired by the behaviour of real ants for finding the meals by optimal performance as has the exceptional ability to solve the well-known optimization of engineering and business problems[26]. When an ant removed from its nest to reach food, leaves a trace in his path that is a chemical substance called pheromone [26],[29]. Consequently, the other ants guide to locate food with scent and follow the path marked out, so far the ants leaving pheromone in their path to add to its concentration [26].

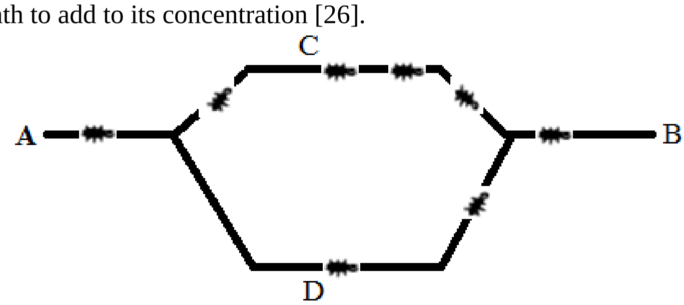

Fig.1. the test paths of ants

If exist several paths with dissimilar distances between the nest and the food of the ants, shortest path will be optimized because more pheromone of different ants remained behind the shortest path as shown in figure (1). In this schematic, at first, two paths that consist of ACB and ADB select by ants, After a number of ants in the shorter path ACB increased while the number of ants decreases in the prolonged path (ADB), accordingly, all the ants move in the shortest way.

5. POWER SYSTEM SIMULATION

Simulation results on a 30 bus of the IEEE are investigated that is one of the famous systems of power quality. After simulation of 30 bus of IEEE, Placement Optimizer of D-STATCOM is designed and then determine of D-STATCOM reactive power is calculated by using *a combination of* GA and ACA.

The used power system

One IEEE 30-bus model used so that 5 number of its bus have a generator as shown in figure (3).

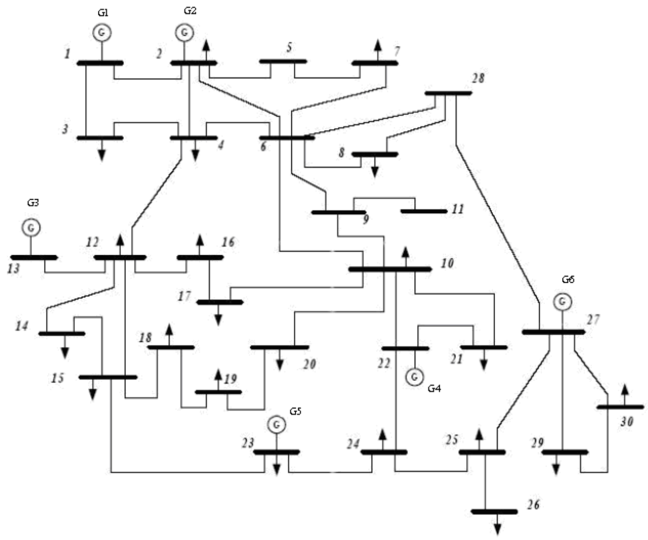

Fig. 3. IEEE 30-Bus Model

Data of transmission lines is one required information in system simulation; therefore, it should be reminded that this system has 41 transmission lines.

6. PLACEMENT OF D-STATCOM IN NETWORK

Determine the required number of D-STATCOM, placement and also the amount of reactive power generated or absorbed by the D-STATCOM is very significant stage to D-STATCOM designing. Due to economic considerations especially in power systems three similar D-STATCOM is installed. Because, the system has 30 buses, so, 30 choices are for the location of each D-STATCOM. Generally, one of bus uses to reference bus, and therefore, different modes for 3 D-STATCOM installed at 29 buses is as follows.

$$s = \frac{(n-1)!}{r!(n-1-r)!} \qquad (1)$$

Where (n) is total of bus and (r) is the number of D-STATCOM. Also, in order to obtain possible states(s) for three number of installed D-STATCOM in the system, we can write.

$$s = \frac{(30-1)!}{3!(30-1-3)!} = 3654 \qquad (2)$$

Thus, 3654 non-repetitive mode is available for the installation of D-STATCOM in the power system and also, finds an optimal point in all cases is focused by the combination of AG and GA.

7. GENETIC ALGORITHMS TO PLACEMENT AND DETERMINATION OF D-STATCOM

Due to important designing of active loads in each bus of D-STATCOM, the active and reactive power of each system is determined as follows.

p= [40.0000 -2.4000 -7.6000 -94.2000 0 -22.8000 -30.0000 0 -5.8000 0 -11.2000 40.0000 -6.2000 -8.2000 -3.5000 -9.0000 -3.2000]
-9.5000 -2.2000 -17.5000 40.0000 40.0000 -8.7000 0 -3.5000 40.0000 0 -2.4000 -10.6000] (MW)

Q= [5.3000 -1.2000 -1.6000 -19.0000 0 -10.9000 -30.0000 0 -2.0000 0 -7.5000 25.0000 -1.6000 -2.5000 -1.8000 -5.8000 -0.9000 -3.4000 -0.7000 -11.2000 15.0000 8.4000 -6.7000 0 -2.3000 30.0000 0 -0.9000 -1.9000] (MVAR)

As can be seen, the values of active and reactive power at the reference bus (bus 1) is unidentified so, these unidentified powers can be solved by the Newton –Raphson method.
There is not compensation by first bus in the range of 2 to 30, so, cost function can be defined as.

$$F_1 = 1000e^{(-1000[round(x(1)-x(2))])} + 1000e^{(-1000[round(x(1)-x(3)])} + 1000e^{(-1000[round(x(2)-x(3)]} \quad (3)$$

Where x (1), x (2) and x (3) are location of D-STATCOM respectively and also, If the selected location will be repeated, F_1=0.
The following equation is used to placement x (4) and x (6) in the range of 2 to 30.

$$F_2 = 1000e^{1000(X(1)-31)} + 1000e^{1000(X(2)-31)} + 1000e^{1000(X(3)-31)} + 1000e^{1000(1-x(1))} + 1000e^{1000(1-x(2))} + 1000e^{1000(1-x(3))} \quad (4)$$

Where x (4), x (5) and x (6), respectively, represent the reactive power generated or absorbed by each of the D-STATCOM. Also F_3 is applied in the range -50MW to +50MW to calculate the amount of reactive power generated or absorbed by each of the D-STATCOM as follows.

$$F_3 = e^{1000(X(1)-50)} + e^{1000(x(2)-50)} + e^{1000(x(3)-50)} + e^{1000(-50-x(1))} + e^{1000(-50-x(2))} + e^{1000(-50-x(3))} \quad (5)$$

After determining the amount and placement of each D-STATCOM in its bus by GA and then loss of the entire network is calculated by Newton- Rawson Method will be calculated, subsequently, cost function to minimize is defined by the genetic algorithm, so, we can write.

$$F_t = F_1 + F_2 + F_3$$

The following values are selected to minimize F_t by the GA.
Population size = 40, Mutation function = Gaussian, Mutation scale = 1and Mutation shrink = 1
The simulation results in is shown as below.

Table 1. Simulation results of the GA

	Number of bus	Reactive power output
D-STATCOM.1	4	25..3138
D-STATCOM.2	5	23.5348
D-STATCOM.3	10	32.4501

Total system losses with and without the D-STATCOM that is included the power losses in total transmission lines are shown in Table (2).

Table 2. system losses

Losses Without D- STATCOM	5.1685 (MW)
Losses with D-STATCOM	3.6441 (MW)

The voltage range of each bus in the system without D-STATCOM and with D-STATCOM is shown in figure (2) as:

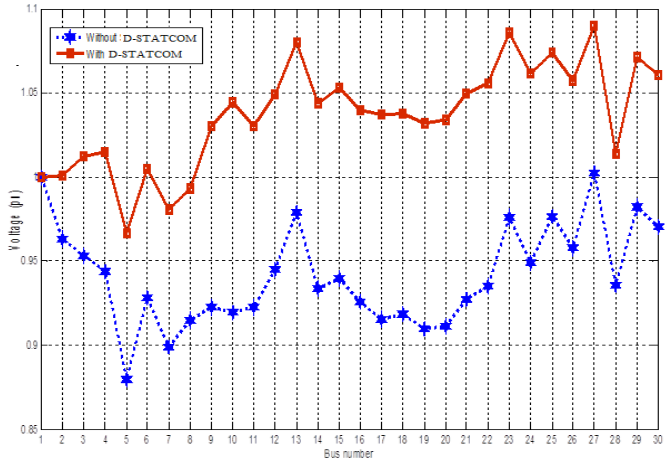

Fig.2. Profile voltage in 30-bus system with and without D-STATCOM

As shown in figure (2) existing of three D-STATCOM in the system not only reduces losses, but also improves the voltage profile and increasing the voltage of all bus in power system.

8. A HYBRID ALGORITHM WITH ACAF AND GA TO DETERMINE THE BOTH VALUE AND PLACEMENT OF D-STATCOM

So as to determine the Placement of three D-STATCOM in 30bus network, ACA is used and for determining the amount of reactive power generated or absorbed by each D-STATCOM, GA is utilized at all stages.

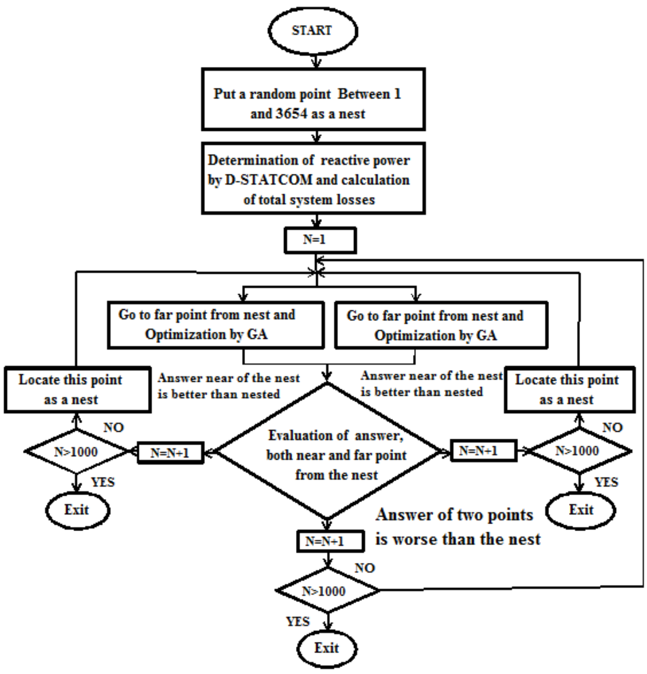

Fig.3. Flowchart of proposed method

As shown in the flowchart in Figure (3), first, a point is chosen randomly between 1 and 3654. This point is obtained of the equation (1) where this point is the non-recurring location of D-STATCOM at 3 installation bus between 2 to 30 of bus. The either optimum values of reactive power generated or absorbed of three D-STATCOM is calculated by GA By to reduce the total system losses. Optimization by GA is applied to the three variables as x (1), x (2) and x (3) which these variables represent each of the reactive power of D-STATCOM respectively. The GA will be stopped after 200 repetitions. Subsequent to this cycle (200 repetition), the lowest level of network losses will be stored as best answer.

In addition, a loop is formed that the number (N) of iterations is 1000. Subsequently, to reduce losses, ACA is employed by smart searching in the best point of the whole network to install three of D-STATCOM. Two random points near the nest and away the nest is selected to obtain Cost function as below.

$$F_T = Total\ Power\ Loss + F_3 \quad (3)$$

In all stages the algorithm will be stopped after 1000cycle and also exist 200 iterations of the genetic algorithm both near the nest and away the nest. As, 400,000 iterations are total reps to reach the optimal solution.

Simulation results of the proposed algorithm

Total losses of distribution lines are as two modes, one with three D-STATCOM with table (3) conditions,

Table. 3. The results of the proposed algorithm

		Number of bus	Reactive power production (MVA)
D-STATCOM	1	4	35.9828
D-STATCOM	2	10	45.7998
D-STATCOM	3	15	-16.8038

And the second, without D- STATCOM is given in table (4).

Table.4. Losses of system

Losses Without D-STATCOM	6.1685 (MW)
Losses Wit D-STATCOM According Table (3)	2.7934 (MW)

As shown in Table (4) the loss rate of a system with three D-STATCOM is dropped to 45.2849. Since the useful life of a power system is equal to 30 years, significantly reduce the cost will be prepared in production and transmission of power. System voltage profiles in two different modes, with and without the three D-STATCOM system is shown in figure (4).

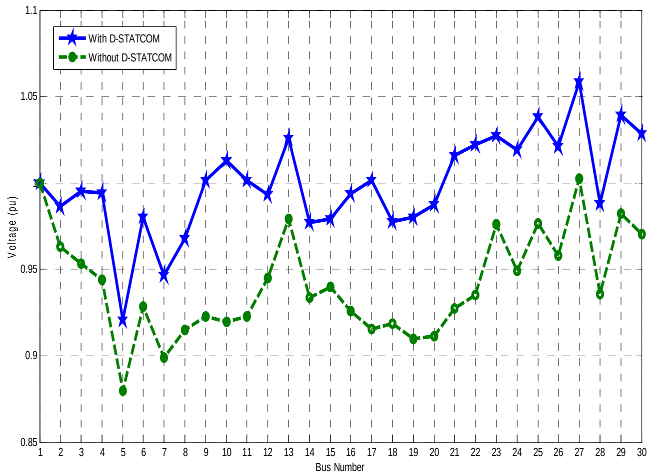

Fig.4. System voltage profiles, with and without the three D-STATCOM

As shown in figure (4), using D-STATCOM in the network not only reduces ohmic losses in the transmission system, but also significantly improves the voltage profiles.

Comparison of the results of the two methods provided (genetic algorithm and the proposed algorithm)

The comparison of the two methods is shown in table (5) briefly as:

Table 5. Comparison of the results of genetic algorithm and the proposed algorithm

	Placement D-STATCOM	Reactive power output(MVA)	total Losses of system	Time to reach the final answer	Total power generated by each the D-STATCOM (MVA)
Placement of D-STATCOM By proposed algorithm	4 10 15	35.9828 45.7998 -16.8038	2.7934	180 minutes	98.5864
Placement of D-STATCOM With Genetic Algorithms	4 5 10	25.3138 23.5348 32.4601	3.6441	5 minutes	81.3087
without D-STATCOM			6.1685		

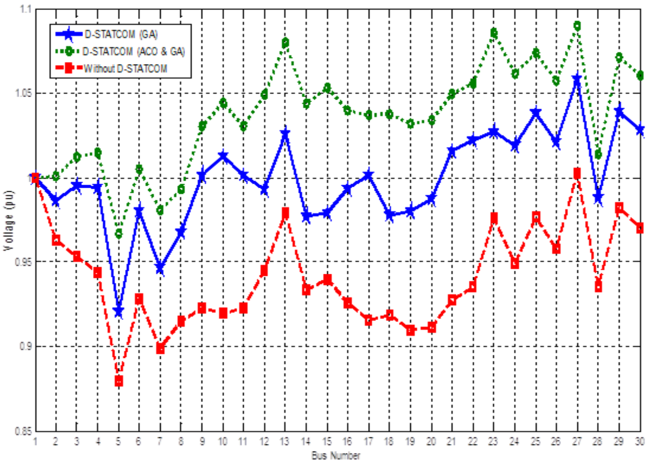

Fig.5.Voltage profiles at three different methods

As shown in figure (5)Voltage profiles in three different states is investigated as, without D-STATCOM, with D-STATCOM which its properties is calculated by the genetic algorithm and with D-STATCOM by proposed method.

9. CONCLUSION

Recently, improving of power quality has been considered for compensation of reactive power and harmonics because to solve the problem of optimum reconfiguration in distribution systems, an optimal manner has been needed. This paper presents a new approach for optimal manner of distribution systems which ACO is used to determine the placement of three of D-STATCOM in 30bus network and GA is utilized for determining the amount of reactive power generated or absorbed by each D-STATCOM. Installation and utilization of the D-STATCOM in distribution networks leads to especially significant for network qualities such as reducing of ohmic losses in transmission lines, improve voltage profiles and system efficiency. Finally, maintenance costs of the D-STATCOM in distribution networks and power systems are negligible so that the energy savings and economizing will be significant.

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