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Optimal Placement of SVC applying Queen-Bee-Assisted GA for voltage profile improvement

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Abstract: In power system transmission network, the problem of improvement in voltage profile is a task that must be evaluated in an ideal way. The paper presents a Queen- Bee -Assisted GA based optimization for improvement in voltage profile of power system transmission network. This algorithm has been used to evaluate power engineering optimization problems adopting desirable results than traditional techniques. This paper shows the application of Queen- bee -assisted- GA for ideal sizing and placement of SVC in a power system transmission network. The effectiveness of proposed algorithm is checked on IEEE-14 bus system. The result demonstrates that the Queen-Bee-Assisted GA is able to obtain the ideal solution with statistical significance and a large degree of convergence. The simulation results are presented to show a significant enhancement of the power system reliability and feasibility and potential of this new approach.

Keywords: FACTS, SVC, Heuristic optimization technique, Genetic Algorithm (GA), Voltage profile.

Introduction

Now a day, the larger demand has been employed on the transmission network in power system. Due to the increasing number of nonutility generators and heightened competition demand are rising day by day [1]. Power demand is increased with enhancement in population respectively needs the existing transmission networks to transmit large power. Therefore, controlling of power flow is required in the transmission network system, so planning and operation of power system is an important issue. On the other hand Voltage Instability and the problem of voltage collapse are the main reason for major blackout in the power system transmission network. However we have several conventional equipment such as transformer tap changers, phase shifters which are connected for enhancing Voltage Stability of the system. But, there are several drawbacks of such types of devices such as slow response, less reliability etc. [2]. Flexible AC Transmission Systems (FACTS) controller can be presented as a suitable device to remove such types of difficulties [3].

Basically FACTS are power electronics equipment which is very advantageous for enhancing transmission capacity and have capacity to control various parameters in power system. These types of devices can increase the stability of power system network and can support voltage with better controllability of their parameters such as impedance, current, phase angle and voltage. FACTS can improve dynamic behavior as well as it can maximize the reliability of power system networks and increase power flow control of the system [4-5-6].

There are various kinds to connect the FACTS devices such as in series, shunt, or a combination of both series and shunt. Shunt compensation increases the real power handling capacity of a line at a more economic cost than building other transmission line of the same as well as of advanced capability. Shunt FACTS devices offer easy control and reactive power support to the transmission network system. Basically Static VAR Compensator (SVC) and static synchronous compensator (STATCOM) are shunt connected FACTS devices. Due to economic factor, it is not imaginable that shunt controller are fixed in entire buses, so that to obtain the ideal placement and size of added compensator considering the analysis of steady state condition of system. In this paper SVC controller is used as a compensation device [4, 7].

For ideal location and sizing of SVC in the previous few years several global optimization algorithms have been proposed. These algorithms are generally inspired by nature analogy so these algorithms are also known as general purpose algorithm. These algorithms are applicable to a large range of problems. There are several optimization techniques such as [8] - Evolution strategies (ES)-1965, Genetic algorithm (GA)-1975, Simulated annealing (SA)-1983, Ant colony optimization (ACO)-1992, Particle swarm optimization (PSO)-1995, Harmony search algorithm (HSA)-2001, Bee colony optimization (BCO)-2004,Gravitational search algorithm(2009). In proposed paper, the problem of the ideal location of proposed FACT devices has been bounded as an optimization problem, and following optimization problem is solved applying a novel algorithm is known as Queen Bee Assisted Genetic Algorithm. This advanced optimization technique associates the growth of queen bee in a hive, using Genetic Algorithm [9]. Proposed technique has been employed to evaluate location and sizing of SVC devices. Effectiveness of proposed algorithm demonstrated on standard IEEE 14-bus test system. Voltage stability index is carried out to calculate the voltage stability at any given bus.

Problem Formulation

A. Modeling of SVC

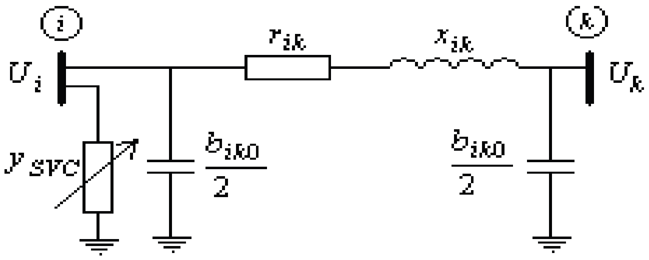

Fig 1: Equivalent circuit of an SVC connected to a bus terminal

Static Var compensator is a shunt connected FACT controller and is fitted in parallel with a bus. SVC generates or absorbs reactive power at the location where it is installed. Figure 1 shows the steady state model of the SVC. In this study, the SVC is modeled as a variable susceptance that can generate or absorb 50MVAr at nominal (1.0 p.u.) voltage at the selected bus.

B. Voltage stability index

Voltage stability is the ability of a system to preserve the value of voltage of the buses in the power system transmission network so that in the case of growth in nominal load, the active power delivered to the load by the system will maximize and both power and voltage are controllable. If system ability to sustain active power transfer and voltage value is lost, this condition is known as to be voltage unstable. A process where voltage instability leads to the voltage losses in a significant part of the system is known as voltage collapse. The power system is in higher risk at the time of voltage instability since the operators have no control over the system voltage and power flow. Reliable calculation of voltage stability in the power systems is essential for their operation and control [10].

In proposed techniques, the Voltage Stability Index is defined by L. in the proposed power system network, total number of buses is indicated by n, and the number of generator buses is indicated by g. In the case of a standard IEEE 14-bus test system, n=14 and g=6. Let V'm(i) indicates the voltage magnitude at the ith node. For IEEE-14 bus test system, i vary from 1 to 14. Here, in the proposed power system network L is defined as the net deviation of voltage magnitudes of every bus from unity. Thus, for a given system, the voltage stability index is defined as

$$L = \sum_{i=1}^{14} |1 - V'm(i)| \qquad \text{………….. (1)}$$

Under standard operating conditions V'm must be in between 0.95 to 1.1(p.u.). The aim of this process is to obtain the ideal locations for 3 SVCs to find an increased performance index. Mathematically, this can be enclosed as an optimization problem and is given below:

Minimize L ………………………………… . (2)

Subject to, 0.95≤V'm (p.u.) ≤1.1

C. Genetic algorithm

Genetic algorithm is a supreme and prevalent participant of evolutionary algorithm family. To be more appropriate, genetic algorithm buildup of a computing model for simulating natural and genetic selection which is associated to the biological evolution revealed in Darwin's theory. In this computing model, populace of kernel representation is known as chromosomes or genotype of the genome of aspirant solution (known as called individuals, creatures, or phenotypes) to an optimization could result in ideal solution, which are conservatively denoted in binary form as strings consist of 0 and 1s with assured length, but the encoding of different categories is possible which involve real values and order chromosomes. Operators which are used by GA are recognized as selection, recombination and mutation. Recombination is also famous as crossover (11-12).

D. Queen bee in a hive

The queen bee is an adult, mating female in a honey bee colony or hive. Her sole function is to serve as a reproducer. The queen which survives in a hive flies on a warm sunny day to a congregation area where hundreds or thousands of drones wait. The drones pursue the queen and several of them mate with her. At the end of mating, drones die very quickly when their abdomens burst. After mating with drones, the queen returns to the hive to lay eggs. The sperm deposited in the queen's body will be used to fertilize her eggs. The queens are developed from larvae selected by the worker bees and are kept in specially constructed queen cells which are larger than the other normal brood comb. The selected queens are specially fed in order to become sexually mature. When the young queens-also termed as virgin queens-are ready to emerge, they often begin to "pipe"- a shrill peeping, which is seen to be a challenge to other emerged or ready to emerge queens. It is believed that piping is a form of battle cry among competing virgin bees and is also a clear signal to worker bees which virgin queen is worthwhile to support. The emerged virgin queen finds and kills (by stinging) other virgin queens in the hive. Thus, the evolution of a queen bee can be visualized as survival of fittest mechanism.

In a honey bee colony or hive queen bee has an important place because of its adultness and mating female quality. Queen bee performs only single function that is works as a reproducer. Queen bee lives in a colony or hive flies on the summer days to a congregation zone where lots of drones wait. These drones mate with queen bees. At the end of mating, due to the abdomens burst drones die rapidly. After the process of mating queen back to her hive or colony and lay eggs. The sperm of the drones which dropped in the queen's body will be used as a fertilizer to lay her eggs. Larvae which are selected by worker bees developed the queens and are preserved in specially created queen cells which are greater than other general brood comb. The selected queens are fed in such a way that they become sexually mature. In this process young queens are called as virgin queens. When the virgin queens are prepare for emerge, they generally started with "pipe"-a sharp peeping, which is like a challenge for emerged queens or ready to emerge queens. It is considered that piping is a way of battle shout between challenging virgin bees. The emerged virgin bees obtains and kills (by stinging) other virgin queens in the colony or hive (10). Therefore, on the basis of Darwin's theory "survival of the fittest", evolution of queen bee can be imagined.

Procedure of algorithm

Step1: Generation of bees

The initial step, which is contained in generating bees in a possible solution range. Here, 1 bee refers to one comprehensive solution range for the problem that is many possible positions to locate the SVCs. Here bees can be represented by B1, B2, B3…..Bj…….Bn where bees population size is represented by n.

Step2: Queen bee, Bq

In whole of erratically generated bees, A bee which has ideal structure in decreasing equation (1) has been chosen as queen bee. In other words, we can say that the queen bee in the kth generation is located by the equation (1): at the moment the queen bee is separated and the other remaining (n-1) bees are presented as drones.

Step3: Mating Flight or reproduction

Mating flight produces by queen bee so the reproduction of next generation bees occur. Drones may not fly rapidly to touch or find the queen. This provides a facility for including a probability of recombination linked with each drone. Here recombination probability is denoted by Pr is fixed at an appropriate value between 0 and 1. The probability related with every drone is represented by Pj.

For Pj≥Pr, the drone allies with the queen creating 2 virgin queen bees. The recombination is developed just as crossover in standard GA.
For Pj< Pr, there are none any case of recombination and also no offspring takes place.

Step 4: Piping

All the virgin queen bees will contest each other and according to the theory of "survival of the fittest" one who won or fit will survive. Whole virgin queen incorporating with mother queen bee are once another time calculated, and the new queen bee is recognized; remaining bees are rejected.

Step5: Check for termination criteria

The program is completed and the new queen bee is considered as the ideal solution.

Step6: Formation of a new drone population for next mating flight
All the drones mating with the queen die and hence drones of population size (n-1) are now randomly generated once again for the next reproduction. The randomly generated drones and new queen bee form the population for the next generation. Now reaches to step3. After the mating the entire drones die, therefore population size (n-1) are erratically developed once another time for continuation the reproduction. Erratically developed drones and new queen bee generate the population for next another generation. After that process reach to step 3 that is mating flight or reproduction.

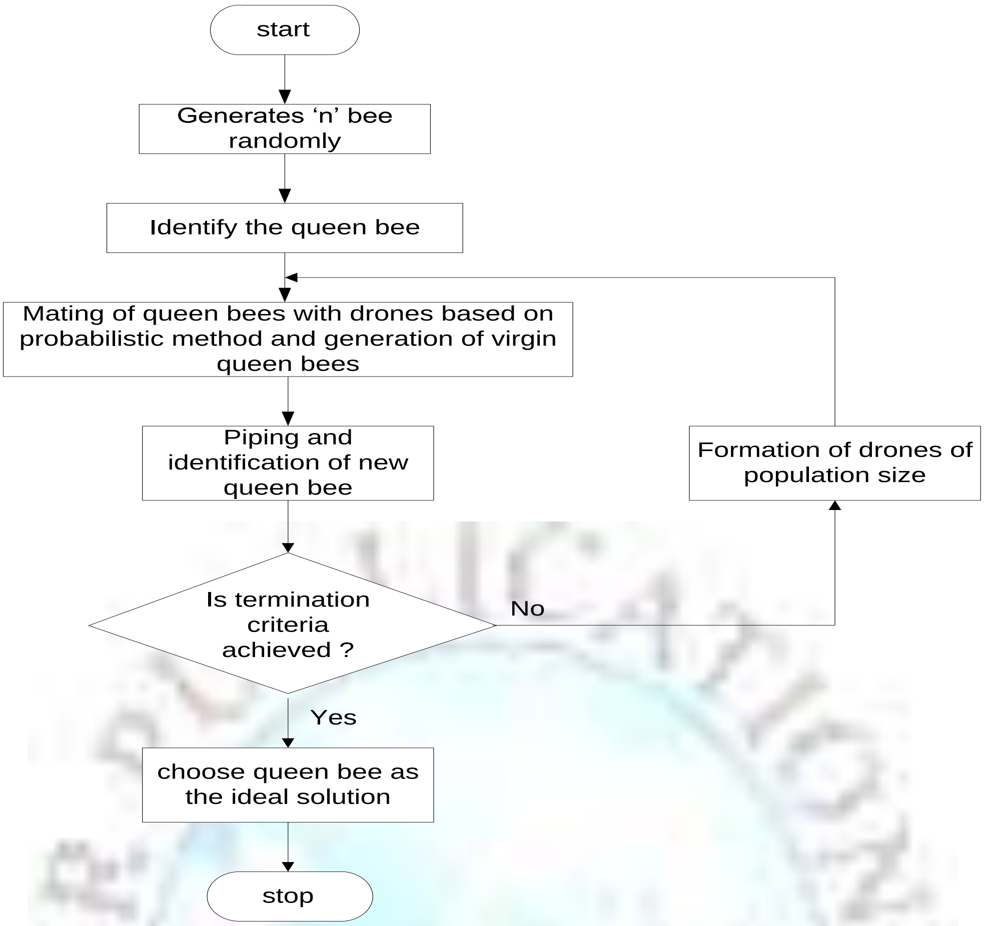

Fig. 2 Flow chart of Queen Bee Assisted GA

Result

For successful the operation of the proposed algorithm a simulation program is developed in MATLAB. We have considered 3 SVC to be allocated in the IEEE 14 bus system. Single line diagram of IEEE-14 bus test system is shown in figure 3.

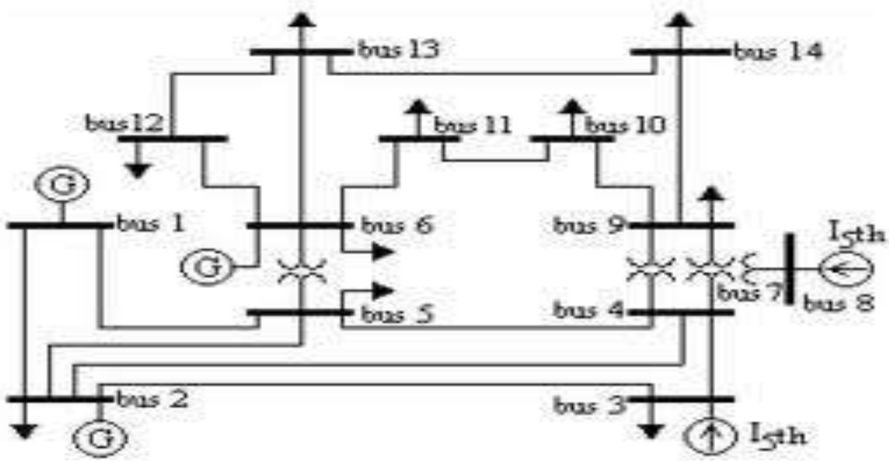

Fig.3: Single line diagram of IEEE 14- Bus system

The process of queen bee assisted GA is permitted for generations while an acceptable low value of objective function is not achieved. For comprehensive study, the result is also compared by standard GA. The convergence characteristics of Queen- Bee-Assisted GA are shown in Figure 4.

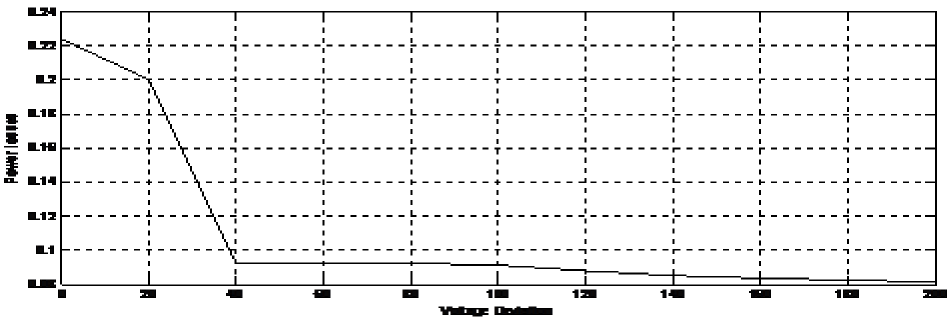

Fig.4 Convergence Characterstics

The graph clearly shows that the proposed algorithm converges at a faster speed. It is necessary to mention that in comparison, the initial values for both optimization algorithm are taken from similar population. It is essential to mention that the solution shown in Figure 3 is averaged over 20 trial runs. In both algorithms the population size is taken 10. In standard GA selection scheme is Combination of roulette wheel selection with elitism on the other hand in queen bee assisted GA, the best bee is queen. Standard GA contains Crossover probability which is 0.7 and queen bee assisted GA contains recombination probability that is also 0.7. Number of iteration for termination in both algorithms are 200.
At the end of 200 queen bee evolutions, the proposed optimization algorithm locates the optimal buses to be 5 and 9. With the SVCs located at these buses, the voltage profile of the IEEE 14 bus test system is calculated and is shown in Figure 5. The figure 5 clearly shows that queen bee assisted GA achieve optimal result.

Figure

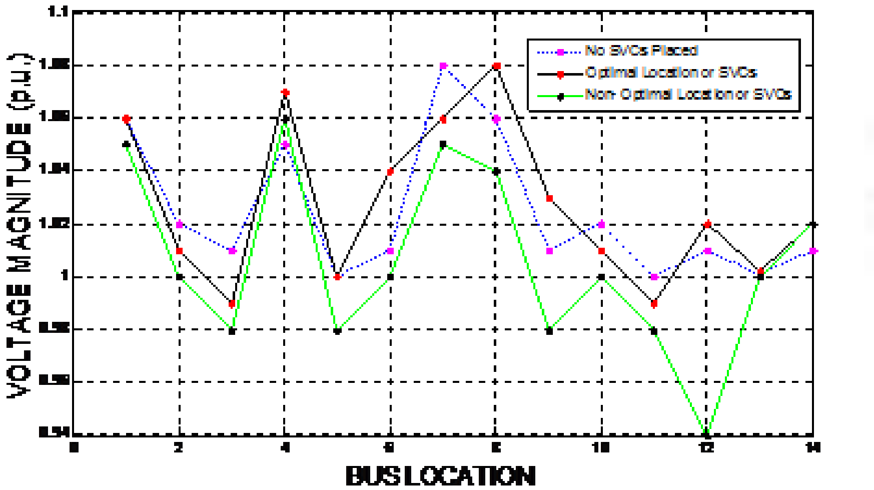

Fig.5 Voltage profile in IEEE 14 Bus system

Table.1. Voltage Profile

	No SVC	Non optimal location of SVC	Optimal location of svc
Bus number	_	7,9	5,11
Voltage stability index(p.u.)	0.8278	0.8056	0.4306

Conclusion

In proposed paper, a heuristic techniques known as queen bee assisted GA is presented to optimize the placement and setting of SVC. The effectiveness of proposed has been checked at IEEE 14 bus test system. The mentioned algorithm converges more rapidly in comparison with the standard Genetic Algorithm with few numbers of parameters and minimize large computational load. The simulation result shows the efficiency of represented method and also shows that proposed algorithm is a reliable. The proposed algorithm is capable to investigate in various objectives associated with power system optimization by means of placement and sizing of SVC. Proposed technique may be plays an important role for improvement in power system in term of stability.

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