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Optimal placement of UPFC in the power system

Soumya latha. B,
PG Student, Sri Krishna College of Engineering andTechnology, Coimbatore, India.

Amuda.A
HOD/Associate Professor, Sri Krishna College of Engineering and Technology, Coimbatore, India.

***Abstract*- Nowadays the increase in the power demand has led the power systems to operate under pressurized conditions. Also the system stability gets disturbed under any fault conditions or due to sudden increase in the load power. Hence maintaining the stability of the system has become mandatory. In the recent times, the Flexible Alternating Current Transmission Systems (FACTS) controllers play an important role in maintaining the stability of the system. Here the Unified Power Flow Controller (UPFC) has been fixed in the power system in order to reduce the losses and hence enhance the stability. Finding the optimal location for placing the UPFC is a problem. An intelligent technique is used to find the optimal location. This has been tested on an IEEE 9 bus system. The results are discussed.**
Keywords- UPFC, Stability, intelligent technique

I.INTRODUCTION

The increase in power demand has led the modern power system networks to operate under stressed conditions. Due to this, the systems have been facing voltage instability problems and thus maintaining the required bus voltage has become mandatory. Voltage stability refers to the ability of the system to maintain the sufficient voltage under normal operating conditions. When this stability is disturbed, it results in decrease or increase of voltage. This stability can be enhanced by placing FACTS devices in the appropriate locations.

The FACTS devices have flexibility and fast control characteristics, thus can control active and reactive power, simultaneously adapting the voltage-magnitude control. These devices are used for reducing the transmission losses and increasing the static and dynamic stability.

FACTS devices include Static Var Compensator (SVC), Static Compensator (STATCOM), Static Synchronous Series Compensator (SSSC), Thyristor Controlled Phase

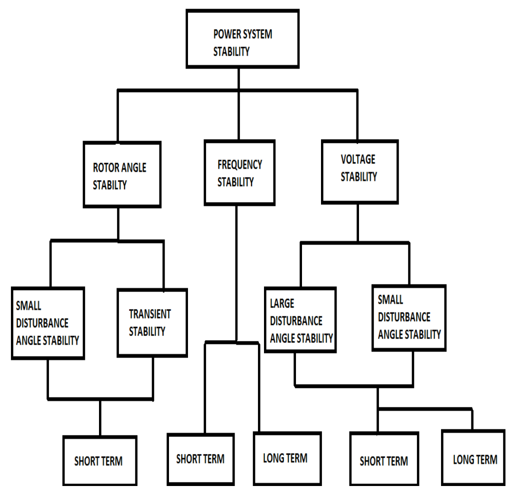

Fig 1. Classification of power system stability in power system environments

Shifter (TCPS), Thyristor Controlled Series Capacitor (TCSC) and Unified Power Flow Controller (UPFC). Identifying the optimal location for fixing the FACTS devices is the major problem. Certain algorithms can be used to provide solution for this problem. The power system stability problems are classified for identifying the causes of instability, for applying suitable analysis tools and developing the corrective measures. Sometimes the solution for one instability problem should not cause another problem, care should be taken to maintain overall stability.

II. UNIFIED POWER FLOW CONTROLLER (UPFC)

The UPFC is the combination of Static Synchronous Compensator (STATCOM) and Static Synchronous Series Compensator (SSSC). Among all available FACTS devices the UPFC is the most promising and powerful device. The UPFC is capable of both absorbing and supplying real and reactive power. There are two voltage source converters:series and shunt converter, which are connected to each other through a common DC link.

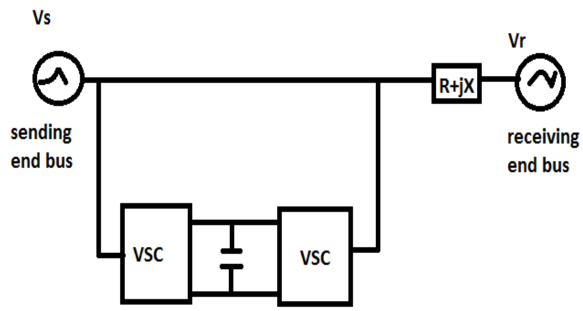

Fig 2. Representation of UPFC in transmission line

There is a large amount of work done in the fields of voltage stability, FACTS devices and the intelligent techniques. Mello and Laskowski (1979) proposed a conventional lead-lag controller for UPFC. This is used for improving the oscillation damping of a single-machine infinite bus system. The controller input is the generator speed deviation. The damping function of the UPFC is investigated in this paper with reference to the linearized model [1]. By installing the UPFC in the network Li and Ma proposed to reduce the active losses in the power systems. Here the UPFC is applied as a series element to work as a series compensator and/or to work as a phase shifter. The optimal values of the phase angles and the series reactance for the phase shifters and the series compensators are found using the Genetic algorithm. The required criteria have been achieved and applied on IEEE 30 bus system [2].

Makombe and Jenkins (1999) proved that a UPFC can control the three control parameters. This is done either individually or in appropriate combinations at its series-connected output simultaneously maintaining reactive power support at its shunt-connected input [3]. The UPFC induces high frequency power fluctuations. This has been investigated by Fujita et al (1999) and trials for modeling the UPFC for steady-state and transient studies have been done [4]. Wang (1999) developed two UPFC models which was linearized and incorporated into the Phillips-Heffron model. It was shown that if the UPFC was not equipped with a damping controller, the voltage control of the DC link capacitor might interact negatively with PSSs installed in the power system [5]. Mori and Goto (2000) used the Parallel Tabu Search (PTS) based method to find the optimal location for the modeled UPFC. This proposed method is compared with the GA, Simulated Annealing and Tabu Search methods. The initial conditions do not affect the system and gave higher quality problems [6]. For improving the dynamic performance of a power system, a current injected UPFC model was developed by Meng and So (2000). Here the UPFC is represented by an equivalent circuit with a shunt current source and a series voltage source. By adding supplementary controller to the UPFC, the power system damping can be enhanced [7].

Optimal power flow with the presence of the UPFC was focused by Leung and Chung (2000). Here Genetic algorithm has been used to find the optimal dispatch of the generation powers which led to the achievement of the total minimum cost. This was tested on an IEEE 14 bus system and proved that it can be used in controlling and increasing the feasibility of the power network [8]. Mok et al (2000) presented a design of fuzzy damping controller of UPFC through Genetic algorithm. A fuzzy controller is applied as external controller which provides the supplementary damping signal to the UPFC. In the scaling portion of the fuzzy controller the Genetic algorithm is used to optimize the scaling factors. A four machine interconnected power system is used for testing. A comparison between the fuzzy controller and the conventional controller is done [9].

Hao et al (2004) have developed an improved evolutionary programming technique for optimal location and parameter settings of the UPFCs. This was done to maximize the system load ability in the transmission line [10]. Ippolito et al (2006) has developed a methodology for identifying the optimal number and location of UPFC with the use of GA. This increased system capabilities, social welfare and also to satisfy the contractual requirements in an open market [11]. Genetic algorithm was used by Kazemi et al (2006) for finding optimal location of UPFC in power systems to increase the load ability. Analysis of installing one, two or three UPFC in the system has been done. The simulations are tested on the IEEE 14 bus system. With some more case studies the active and reactive power can be increased [12]. Shaheen et al (2007) has proffered GA to optimally allocate UPFC for effectively controlling power flow and regulating bus voltage in the power system. This resulted in an increased transfer capability, low system losses and improved stability [13].

III. PROCESS OF FINDING THE OPTIMAL LOCATION FOR FIXING UPFC

3.1 Computing Load Flow between the Buses

Power flow into and out of each of the buses which are network terminals gives the sum of Load flows of all of the lines connected to that bus. The Newton raphson technique is used for computing flow among the buses. The equations given below are used to calculate the actual and responsive power flows between the buses.

The foraging process begins in a colony by scout bees being sent out to search for promising flower patches. Scout bees move randomly from one patch to another. During the harvest season, a colony continues its exploration, keeping a percentage of population as scout bees. When the scout bees return to the hive, those that found a patch wshich is rated above a certain quality threshold deposit their nectar or pollen and go to the "dance floor" to perform a dance known as waggle dance. The waggle dance is essential for colony communication, and contains three pieces of information regarding a flower patch:

- The **direction** of food source
- Its **distance** from the hive
- Its **quality rating** (or fitness)

This information helps the colony to send its bees to flower patches precisely without using guides or maps. After the waggle dance on the dancing floor, the dancers go back to the flower patch with follower bees that are waiting inside the hive. More follower bees are sent to more promising patches.

$$P_i = \sum V_i * V_k \,(G_{ik} *\cos\theta_{ik} + B_{ik} *\sin\theta_{ik})$$

$$Q_i = \sum V_i * V_k \,(G_{ik} *\cos\theta_{ik} - B_{ik} *\sin\theta_{ik})$$

where, N is the total number of bus, is the sending end bus, V_i &V_k are the voltage at i &k bus respectively, k is the receiving end bus, G_{ik} & B_{ik} are the conductance and susceptance values respectively and q_{ik} is the angle between i & k bus.

3.2 Bees Algorithm for Finding Location

The Newton-Raphson method is broadly used for solving non-linear equations. It transmutes the original non-linear problem into a sequence of linear problems whose solutions approach the solutions of the original problem. Here, the preeminent place for fixing UPFC is recognized by the Bees algorithm in order to reduce the transmission losses thereby maintaining the stability of the system.

3.2.1 Bees in nature

A colony of honey bees can extend itself over long distances and in multiple directions simultaneously to exploit a large number of food sources. In principle, flower patches with plentiful amount of nectar or pollen that can be collected with less effort should be visited by more bees, whereas, patches with less nectar or pollen should receive fewer bees.

3.2.2 Implementation of Bees algorithm to find optimal location for fixing UPFC

In Bees algorithm, the colony of bees contains three groups of bees:

- employed bees
- unemployed bees (onlookers and scouts)

The number of the employed bees is equal to the number of food sources, each of which also represents a site, being exploited at the moment or to the number of solutions in the population.

- The position of the food source corresponds to the location in this problem
- The nectar amount or quality is related to the real power loss

In the proposed method, the Bees algorithm is used to identify the amount of voltage, the angle to be injected and location of UPFC. The Bees algorithm consists of the following steps:

Step 1 Generating initial inhabitants are the preliminary process in Bees algorithm. The initial process of bee is generating initial population of n scout bees. In the proposed method, the initial particles are voltage, angle and location injecting values. After producing these values, they are evaluated using the fitness function.

Step 2 The fitness computation process is carried out for each site visited by the bee by evaluating the evaluation function. The evaluation function is the Total Power Loss.

Step 3 Bees that have the highest fitnesses are chosen as "selected bees" and the sites visited by them are chosen for neighborhood search. Here the highest fitness means the minimum total power loss.

Step 4 and 5 The algorithm conducts searches around the selected sites based on size determined. More bees are assigned to search in the vicinity for the best e sites.

The fitness values are used to determine the probability of the sites being selected. Searches in the neighborhood of the best e sites which represent the most promising solutions are made more detailed by recruiting more bees.

Step 6 The remaining bees (n-m) are sent for random search to find the other potential sites.

Step 7 Steps 3-6 are repeated until the requirement is met, else terminated.

Step 8 Randomly initialize a new population.

Step 9 Find the global best point

By fixing the UPFC in the optimal location the losses are reduced thereby maintaining the system stable.

IV. RESULTS AND DISCUSSION

The proposed technique is tested using the IEEE 9 bus system. The IEEE 9 bus system taken from dataset is shown in Fig 3.

In the IEEE 9 bus system, bus 1 is considered as the slack bus, buses 2 and 3 are considered as the generator buses and other buses are said to be the load buses. In the proposed method the base MVA used is 100 MVA. The optimal location was specified to be between buses 4 and 5. The series injected voltage and the real power loss are found to be 0.005p.u and 0.002765p.u respectively.

This proved to be obvious that the proposed method is efficient in maintaining the system stability as well as in reducing the total power losses of the system.

The proposed method classifies the best possible locality for fixing FACTS controller in the power system where the losses can be reduced, and also it determines the amount of voltage and angle to be injected to make the system stable.

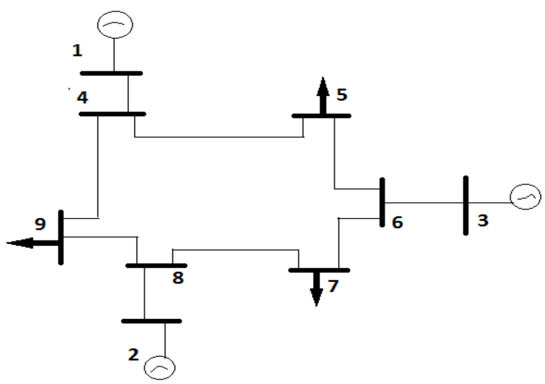

Fig 3. IEEE 9 Bus System

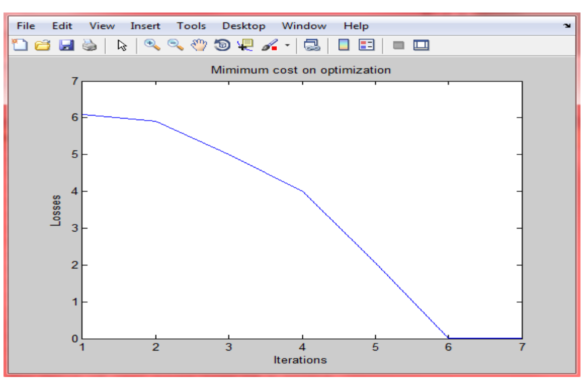

Fig 4. Curve depicting the losses in a system

Fig 4 shows the curve depicting the losses in a system and the minimum loss was found to be 0.002765p.u.

V. CONCLUSION

There are many causes for the occurrence of the voltage instability problems. They may include: difference in transmission of reactive power under heavy loads, higher reactive power consumption at heavy loads, occurrence of contingencies, voltage sources may be too far from the load centers, improper location of FACTS controllers, poor coordination between multiple FACTS controllers, presence of constant power loads and reverse operation of On Load Tap-Changer (OLTC). These instability problems can be prevented by many means that include: placement of series and shunt capacitors, installation of synchronous condensers, placement of FACTS controllers, coordination of multiple FACTS controllers, under voltage load shedding, blocking of tap-changer under reverse operation and generation rescheduling [14].

The losses occurring in the system is taken into consideration. In this paper, the proposed technique is implemented in MATLAB and is tested for an IEEE 9 bus system. From the above results, it is clear that the proposed method determines the optimal location for placing FACTS controller in the system as well as to compute the voltage and angle injecting values for maintaining the stability of the system. Using the proposed technique, the voltage remains stable as well as the total power losses in the system gets reduced. Thus, the proposed technique has made the system to remain stable by diminishing the total power losses in the system.

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