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MAINTAINING POWER SYSTEM STABILITY WITH FACTS CONTROLLER USING BEES ALGORITHM AND NN

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ABSTRACT

Maintaining system stability is one of the most critical problems in power system. Mainly, the stability problems arise when any fault occurs in the system or due to sudden increase in the load power. Thus, to maintain the stability of the system, different types of controllers are used in the literature; among them FACTS controller plays a major role. Among the different types of FACTS controllers, STATCOM, SSSC, UPFC, TCSC etc, are the most commonly used controllers. To maintain the system stability, the major problem is identifying the optimal location for fixing FACTS controller and also computing the amount of voltage and angle to be injected in the system. By considering the abovementioned drawback, here a hybrid technique is proposed for identifying the optimal location for fixing FACTS controller and also for computing the amount of voltage and angle to be injected in the system in order to uphold the system stability. The hybrid technique includes neural network and Bees algorithm. Here, the neural network is used to identify the optimal location for fixing FACTS controller, and the Bees algorithm is used to compute the amount of voltage and angle to be injected in the system. The proposed method is tested for IEEE 30 bus system and the result exhibits the performance of the proposed method in maintaining the stability of the system.

Key words: *UPFC, Bees Algorithm, Neural Network, Stability, Load flow*.

1. INTRODUCTION

Nowadays, the major problem in power system is upholding a steady acceptable voltage under normal operating and anomalous conditions, which is usually referred as voltage regulation problem [17]. In stable power system, the synchronous machines when disturbed, will either go back to their original state if there is no net change of power or will reach a new state without loss of synchronism [4]. Power system stability represents the competence of an electric power system, for a given initial operating condition, to retrieve a state of operating equilibrium after being subjected to a physical interruption [20]. Due to the heavy loading of long transmission lines, the problem of transient stability after a severe fault can become a limiting factor for power transmission [1].

Voltage stability refers to the potency of the system in maintaining the sufficient voltage under normal operating condition, whereas the Voltage instability refers to the lack of voltage stability, which leads to continuous voltage decrease or increase [18]. Voltage stability and system security are the two significant emerging issues in the operation of strained power system [16]. In order to improve the voltage stability in a power network, network reconfiguration is done by changing the topological structure of power lines [2]. With the aid of Flexible Alternating Current Transmission System (FACTS) devices, the voltage stability as well as the steady state and transient stabilities of a stressed power system can be enhanced effectively [5].

Generally, FACTS devices are connected to a transmission line in different ways, such as in series, shunt, or a fusion of series and shunt [7].

FACTS devices have the ability to control the active and reactive power, and they are proficient in voltage-magnitude control simultaneously, because of their flexibility and fast control characteristics [3]. FACTS devices are extensively used in power systems, which not only increases the power transmission capability, but also enhance the static and dynamic stability, increase the availability, as well as reduce the transmission losses [8] [13]. Moreover, FACTS devices has the capability to control the parameter and variables of the

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transmission line, such as line impedance, terminal voltages, and voltage angle in a rapid and effective manner [15].

Using FACTS technology, namely Static Var Compensator (SVC), Static Synchronous Compensator (STATCOM), Thyristor Controlled Series Capacitor (TCSC), Thyristor Controlled Phase Shifter (TCPS), Static Synchronous Series Compensator (SSSC) and Unified Power Flow Controller (UPFC) etc., the bus voltages, line impedances and phase angles in the power system are controlled swiftly and flexibly [6] [10] [14]. The control settings of TCSC and TCPS are essential to maintain the specific line flows [9]. Low Frequency Oscillation (LFO) modes have been realized when power systems are unified through weak tie-lines [11]. In order to uphold the system stability, these oscillations need to be controlled [19]. For this reason, a large interconnected system has been constructed to achieve a high operational efficiency and network security [12].

In this paper, a hybrid technique is used for identifying the locality for fixing FACTS controller in the system and also the amount of voltage and angle to be injected in the system. The rest of the paper is organized as follows: Section 2 reviews the recent related works briefly; Section 3 details the proposed technique with sufficient mathematical models and illustrations; Section 4 discusses the implementation results; and Section 5 concludes the paper.

2. RELATED WORKS

A few recent research works on the topic of power stability using FACTS controller are discussed in this section.

Sharma et al. [21] have aimed to reduce the oscillations of the single- and multi- machine power system via STATCOM with combined PI and Fuzzy Logic controlled voltage regulator. Here, the utility and performance of the STATCOM have been analyzed by the rate of dissipation of transient energy in post fault time, which providing additional damping. The main function of the STATCOM is to maintain the bus bar voltage by injecting relevant reactive power, and also it enhances the dynamic performance of the power system.

For solving the optimal reactive power dispatch (ORPD) problem, Marouani et al. [22] have proposed a multi-objective evolutionary algorithm (MOEA) with FACTS devices. This nonlinear multi-objective problem (MOP) has been solved by reducing the real power loss in transmission lines and voltage deviation at load buses simultaneously, by changing the parameters and searching optimal position for FACTS devices. The constraints of this MOP have been spitted to equality constraints represented by load flow equations and inequality constraints such as, generation of reactive power sources and security limits at load buses. They have utilized two types of FACTS devices namely, SSSC and UPFC.

Moses et al. [23] have developed a Service Oriented Architectural (SOA) model for maintaining the transient stability of a large interconnected power system and tested for a sample of 14, 30 and 39 bus systems. The proposed model was applicable for numerous power system clients and also the stability services have been invoked by the clients without any restriction in this service oriented environment. The different power system services have been plugged into this model and the services have been made accessible at anytime and anywhere for the power system operations.

For enhancing the transient stability performance of a single machine-infinite-bus power system, a neuro-fuzzy based UPFC has been proposed by Jegatheesan et al. [24]. Based on the pre-disturbance operating conditions of the power system, the centers of the fuzzy scheme have been generated from the trained Radial Basis Function Neural Networks (RBFNN). The segregation of RBFNN and fuzzy scheme has presented an adaptive fuzzy controller. Both the parameters of the PI controller and optimal centers of the FLC at a certain operating condition have been determined with integral absolute error (ITAE) criteria.

Farahani et al. [25] have presented the application of UPFC to maintain the voltage as well as to improve the stability at a Multi-Machine electric power system installed with UPFC. PI type controllers have been utilized for UPFC control and the parameters of these PI type controllers have been tuned by means of PSO. The potency of UPFC in voltage control as well as in stability improvement has been demonstrated by comparing the results of the proposed UPFC based system with the results without UPFC. The nonlinear time domain simulation results have proved that the UPFC was efficient in controlling the voltage as well as enhancing the stability simultaneously.

For a two area interconnected reheat thermal power system, B. Paramasivama et al. [26] have

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proposed a sophisticated Load Frequency Control by Redox Flow Batteries coordinated with UPFC controller. Here, the optimal parameters have been obtained by using the Artificial Bee Colony (ABC) algorithm. The ABC algorithm was simple to implement and it has no computational complexity. This algorithm has superior solution quality in satisfying the objective. The capability of ABC rises from the greedy selection process and the timely abandonment of used up food sources integrated in it. These basic procedures in the ABC prevent stalling of solutions and made the algorithm more functional in nature.

Murali et al. [27] have evaluated the augmentation of transient stability of a two-area power system by means of UPFC, which is an efficient FACTS device able to control the active and reactive power flows in a transmission line by properly controlling its series and shunt parameters. For this two-area power system model with UPFC, the simulations have been performed in MATLAB/SIMULINK platform in order to evaluate the effects of UPFC on transient stability performance of the system. Moreover, the performance of UPFC has been compared with other FACTS devices namely, SSSC, TCSC and SVC respectively.

3. MAINTAINING SYSTEM STABILITY USING NN AND BEES ALGORITHM

Maintaining stability in power system is one of the imperative processes. There are different types of controllers employed to maintain the stability of the power system. The main reason for occurring stability problem in the system is due to sudden increase in load, fault occurs in the system, etc. For maintaining stability in the system, there are different controllers FACTS controller plays a major role. Different types of FACTS controllers are employed in the literature, some of them are STATCOM, SSSC, UPFC, TCSC, etc. The main problem in the FACTS controllers is identifying the place for fixing FACTS controller and the amount of voltage and angle to be injected in the FACTS controller to maintain the stability of the power system. By considering the abovementioned drawback, here we proposed a hybrid technique to identify the optimal location for fixing FACTS controller and also to determine the amount of voltage & angle to be injected in the system. By considering the aforesaid problem, here a hybrid technique is proposed to maintain the stability of the system. The proposed hybrid technique comprises neural network and Bees algorithm. Here, the neural network is subjugated for identifying the optimal location for fixing FACTS controller, and the Bees algorithm computes the amount of voltage and angle to be injected. The FACTS controller used here neural network, initially, we see about the mathematical model used for injecting real and reactive power using Bee algorithm. The process that takes place in the proposed method is explained briefly in the below sections.

3.1. Computing Load Flow between the Buses

Power flow into and out of each of the buses that are network terminals is the sum of Load flows of all of the lines connected to that bus. The Newton raphson technique is computed computing flow among the buses. The actual and responsive power flows between the buses are calculated by using the equation given below.

$$P_i = \sum_{k=1}^{N} V_i * V_k \left(G_{ik} * \cos\theta_{ik} + B_{ik} * \sin\theta_{ik} \right) \quad (1)$$

$$Q_i = \sum_{k=1}^{N} V_i * V_k \left(G_{ik} * \sin\theta_{ik} - B_{ik} * \cos\theta_{ik} \right) \quad (2)$$

where, N is the total number of bus, i 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 θ_{ik} is the angle between i & k bus.

Using the above equation 1 & 2, the real and reactive power flow between the buses are computed.

3.2. UPFC Model Used in the Proposed Method

In our proposed technique, UPFC, a type of FACTS controllers, is working for maintaining the system stability. The universal UPFC model is shown in the figure 1.

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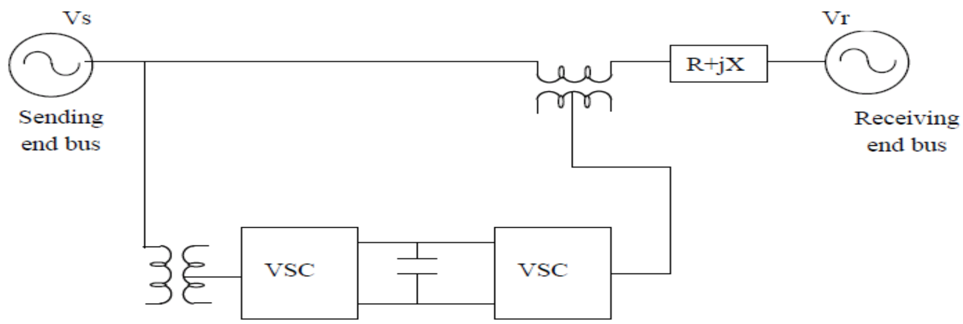

Figure 1: General UPFC Model

The above figure represents the general structure of UPFC model. The mathematical model of UPFC used in the proposed technique is given in the equations 3, 4, 5 & 6.

$$\Delta P_k = -V_k * V_{inj} \begin{bmatrix} G * \cos(\delta_i - \delta_{inj}) - \\ B^{new} * \sin(\delta_i - \delta_{inj}) \end{bmatrix} \quad (3)$$

$$\Delta Q_k = -V_k * V_{inj} \begin{bmatrix} G * \sin(\delta_i - \delta_{inj}) \\ - B * \cos(\delta_i - \delta_{inj}) \end{bmatrix} \quad (4)$$

$$\Delta P_i = -V_k * V_{inj} \begin{bmatrix} G * \cos(\delta_k - \delta_{inj}) - B * \\ \sin(\delta_k - \delta_{inj}) \end{bmatrix} + G^{new} * V_{inj}^{2} + 2 * V_i * V_{inj} * G^{new} * \cos(\delta_k - \delta_{inj}) \quad (5)$$

$$\Delta Q_i = V_k * \begin{bmatrix} G^{new} * \sin(\delta_i - \delta_{inj}) - \\ B^{new} * \cos(\delta_i - \delta_{inj}) \end{bmatrix} - V_i * I_q \quad (6)$$

where, ΔQ_i , ΔQ_k , ΔP_i , ΔP_k are the real and reactive injecting powers from and to bus respectively, I_q is the transformer reactive current, $G^{new} = gik + G$,and $B^{new} = bik + B$. V_{inj} and δ_{inj} are the injecting voltage and angle respectively.

The proposed hybrid technique includes neural network. Here, neural network is used to find the voltage and angle to be injected and the best location for fixing UPFC in the system are identified using the proposed hybrid technique and the Bees algorithm classifies the amount of voltage and angle to be injected in the arrangement in order to preserve the stability of the power system. We appreciate about this process that takes place for identifying the optimal location for fixing UPFC using the neural network.

3.3. Obtaining Optimal Location for Fixing UPFC Using NN

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 recognised by the neural network in order to maintain the stability of the system. Normally, neural network structure consists of two layers: training, and testing layer. In training stage, the neural network is trained based on the training dataset, while in the testing stage, if we give the input variables, it delivers the corresponding variables as output.

3.3.1. Learning NN to obtain B_i & B_j

Generally in the training stage, the neural network consists of three layers namely, input layer, hidden layer, and output layer. Here, the neural network structure is composed of two input layers, hidden layers, and four output layers. In the proposed technique, input layer and output layer consists of two variables, and hidden layer contains of n variables. The input variables are the fault occurred bus & the power error, while the output variables are the buses where UPFC to be associated. We have used proposed method structure of neural network. The network training process is described below in the figure 2.

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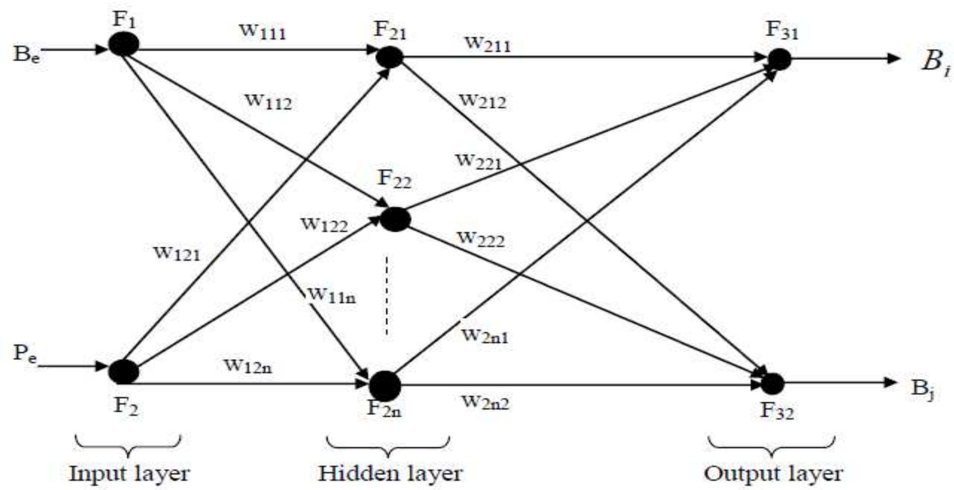

Figure 2: Structure Of Proposed Neural Network Method

The Power flow into and out of each of the buses connections are given as input to the neural network and the output.

The steps involved intake places the neural network training are as follows:

Step 1: Initialize the input weight for each neuron.

Step 2: Apply a training dataset to the network. Here, B_e and P_e are the input to the network and B_i and B_j are the output of the network.

$$B_j = \sum_{r=1}^{n} W_{2r2}\theta_i(r) \quad (7)$$

$$B_i = \sum_{r=1}^{n} W_{2r1}V_i(r) \quad (8)$$

where $$y(r) = \frac{1}{1+\exp(-w_{11r}\cdot(V_e + B_e))} \quad (9)$$

Equation 7, 8 & 9 represents the stimulation function complete in the input and output layer respectively.

Step 3: Adjust the weights of all neurons.

Step 4: Determine the buses to be connected.

3.3.2. Testing Neural Network to Obtain B_i & B_j

In the testing stage, if the fault bus and power error are given as input, the neural network gives the optimal location for fixing UPFC in the system as output. After connecting the UPFC in the beyond obtained location, the next step is computing the voltage and angle values injected in UPFC .In the proposed method, the voltage, angle, and reactance to be injected are computed using neural network. The next process is computing voltage and angle injecting values using bee algorithm.

3.4. Bees Algorithm to Identify V_i and θ_i

A colony of honey bees can extend itself over long distances and in multiple directions simultaneously to exploit a large number of foodsources [28].A colony prospers by deploying its foragers to good fields. In standard, flower patches with plentiful amounts 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. In the proposed method, Bees algorithm is used to identify the amount of voltage and angle to be injected in UPFC for the location identified using neural network in the above section. Normally, Bees algorithm consists of three stages, namely

- ✓ Initialize population
- ✓ Evaluate the fitness function
- ✓ Identifying the best Bees

I) Initialize population

Generating initial inhabitants is the preliminary process in Bees algorithm. Normally, Bee algorithm consists of three stages namely, generating Initialize population. The initial process of Bee is generating initial population. In the proposed method, the initial particles are voltage and angle injecting values. The inoculating voltage and angle are generated as $V_i^{max} \le V_i \le V_i^{min}$ and $\theta_i^{max} \le \theta_i \le \theta_i^{min}$. After producing the voltage

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and angle injecting values, these values are then evaluated using the fitness function.

II) Evaluating the fitness function

Fitness function is one of the most important processes in genetic algorithm, applied to identify the best chromosome. In the proposed method, the voltage, angle, and reactance injecting values generated in the above stage are injected to the system, and after injecting the values, the power loss is computed. The evaluation function is used to evaluate the initialized particle. The evaluation function employed in the proposed method is as follows,

$$Fitness\ \ function = \sum_{i,j=1}^{N} \mathrm{Re}\,al \begin{bmatrix} Conj \\ ((V_m(i))*(V_m(j))) \\ *Y_{ij} * B \end{bmatrix} \quad (10)$$

where, V_m is the voltage magnitude, B is the base MVA value and Y_{ij} is the Y-bus matrix. After the completion of fitness function, then select the nearest path and repeat the above process. After the completion of visiting the possible path, the next step is to select the best path.

III) Identifying the best bees

For one destination, different paths are computed and from the possible paths, the best path is identified based on the fitness function. After the completion of fitness function, we obtain the best voltage, angle, and reactance injecting values based on the fitness function. Then, the above process is repetitive for classifying the best path. In the proposed method, the voltage and angle injecting values are obtained as output.

By using the proposed method, fixing the UPFC in the optimal locations identified using the neural network and the amount of voltage, angle to be injected is computed using the Bees algorithm. Then injecting the voltage, angle, and reactance values computed using the proposed method, the amount of voltage and angle to be injected is computed using the Bees algorithm.

4. RESULT AND DISCUSSION

The proposed hybrid technique is implemented in the working platform of mat lab 7.12 and tested using the IEEE 30 bus system. The IEEE 30 bus system is taken from dataset is shown in figure 3.

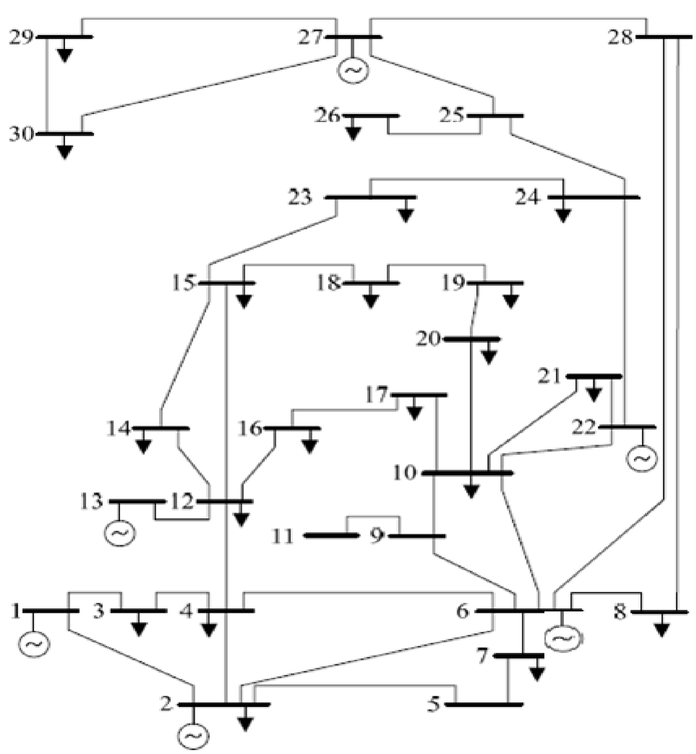

Figure 3: IEEE 30 bus system

Figure 3 shows the IEEE 30 bus system used in the proposed method. In the IEEE 30 bus system, bus 1 is considered as slack bus, buses 2, 6, 13, 22, and 27 are considered as the generator bus, and all

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other buses are load bus. The base MVA used in the proposed method is 100 MVA. First of all, we see about the voltage profile (i) for normal load condition, (ii) after abrupt increase in the power in bus 3 & 5, and(iii) voltage obtained after connecting FACTS controller. The load conditions considered in the proposed method are sudden load increase in bus 5 and 3. Initially, the voltage profile at normal load condition is given and after sudden increase in load in buses 3 and 5individually, the voltage profile of the system get reduced. Then, using the proposed method.

Table.1 Voltage For Different Load Conditions

Bus number	Voltage at each bus using				
	Conventional NR method (p.u)	After sudden increase in power in bus 5 (p.u)	Proposed method with UPFC connected in buses 2 & 5 (p.u)	After sudden increase in power in bus 3 (p.u)	Proposed method with UPFC connected in buses 3 & 4 (p.u)
1	1.06	1.06	1.06	1.06	1.06
2	1.033	1.033	1.023	1.033	1.033
3	1.0228	1.0224	1.0217	1.0207	1.0401
4	1.0136	1.0132	1.0123	1.0127	1.0083
5	1.0044	0.9934	1.0284	1.0045	1.0044
6	1.01	1.01	1.01	1.01	1.01
7	0.9999	0.9952	1.0098	1	0.999
8	1.0103	1.0103	1.0103	1.0103	1.0103
9	1.0458	1.0458	1.0458	1.0458	1.0455
10	1.0367	1.0366	1.0366	1.0366	1.0362
11	1.0771	1.0771	1.0771	1.0771	1.0768
12	1.0572	1.0572	1.0567	1.0569	1.0558
13	1.071	1.071	1.071	1.071	1.071
14	1.0414	1.0414	1.041	1.0411	1.0401
15	1.0355	1.0354	1.0352	1.0353	1.0343
16	1.0411	1.0411	1.0409	1.0409	1.0401
17	1.0326	1.0325	1.0352	1.0325	1.0319
18	1.0236	1.0235	1.0409	1.0235	1.0227
19	1.0198	1.0197	1.0325	1.0197	1.019
20	1.0232	1.0231	1.0234	1.0231	1.0225
21	1.0228	1.0227	1.0227	1.0227	1.0222
22	1.03	1.03	1.03	1.03	1.03
23	1.0229	1.0228	1.0228	1.0228	1.0223
24	1.0158	1.0157	1.0157	1.0157	1.0156
25	1.0069	1.0069	1.0069	1.0066	1.0068
26	1.0989	0.989	0.989	0.989	0.989
27	1.01	1.01	1.01	1.01	1.01
28	1.0094	1.0094	1.0094	1.0094	1.0094
29	0.9899	0.9899	0.9899	0.9899	0.9899
30	0.9782	0.9782	0.9782	0.9782	0.9782

The voltages attained after increase in load and after concerning UPFC using proposed method are compared. Since the above table, this is clear that after abrupt increase in load power controller using proposed method, the voltage profile becomes decreased while comparing with normal load case, and after connecting UPFC using the proposed method, the voltage profile in most of the buses remains as stable. Resulting, we see about the total power loss in the system for different load power conditions i.e., for normal case, abrupt increase in load power case, and after connecting FACTS controller using proposed method.

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Table.2 Total Power Loss For Different Load Conditions

	Total power loss using proposed method MW	Total power loss using PSO and NN MW
Normal load condition	10.809	10.809
After sudden increase in power in bus 5	14.42	14.42
Proposed method after connecting UPFC in bus 5 & 7	9.21	10.10
After sudden increase in power in bus 3	12.365	12.365
Proposed method after connecting UPFC in bus 3 & 4	9.40	10.42

The above table demonstrations that the total power loss occurred for normal load condition is 10.809 MW. Next sudden raise in the load power in bus 5, the total power loss is improved to 14.42 MW and then using proposed method with FACTS controller, the total power loss get reduced to 10.233 MW. Similarly, we tested for the total power loss in bus 3. After sudden raise in the load power in bus 3, the total power loss is increased to 11.54 MW and then using proposed method with FACTS controller, the total power loss get reduced to 10.748 MW. Here, from the above results, it was obvious that the proposed method was efficient in maintaining the system stability as well as in reducing the total power losses of the system. Moreover, the proposed method is superior to PSO and neural network technique. In addition, the proposed method classifies the best possible locality for fixing FACTS controller when a sudden raise in load power happens at any bus, and also it determines the amount of voltage and angle to be injected to make the system stable. The results obtained by the proposed method are compared with the system connecting UPFC using Bees algorithm & neural network, and PSO & neural network. From the comparison results, it is clear that the proposed method is better than the other methods.

5. CONCLUSION

In this paper, the proposed technique was implemented in MATLAB and tested for IEEE 30 bus system. From the above results, it is clear that the proposed method improves the available transfer capability and also increasing the load power in the system. An efficient hybrid technique was devised to determine the optimal location for placing FACTS controller in the system as well as to compute the voltage and angle injecting values for maintaining the system stability. The performance of the proposed technique was tested by considering the conditions such as sudden increase in power in bus 3 & 5 individually. The total power loss was increased to 14.42 MW and then using the proposed method, the total power loss in the system was reduced to 10.233 MW. Moreover, the proposed technique was compared with the PSO and NN method. Due to the reduction of linear and reactive values, the FACTS in the lines was improved. But, 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 increasing the voltage at all buses and diminishing the total power losses in the system. Finally, the proposed method has identified the FACTS controller used for maintaining the system stability and also the amount of voltage and angle to be injected in the system. Thus the two different techniques namely, PSO & NN and Bees algorithm & NN. The implementation results were compared with the general power losses analysis and it was give better result than the other methods.

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