IJCTA, 9(25), 2016, pp. 139-149 ISSN: 0974-5572

Control and Analysis for Distributed Power Flow Controller Using Fuzzy and Neural Techniques

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ABSTRACT

Control of system stability is one of the biggest problems in power system. Primarily, stability issue arises when all faults occur in the system or suddenly increase the load power. So to control the stability of the power system, various types of controllers are used in the review. FACTS devices are playing a major role. Apart from that, various kinds of FACTS devices are SVC, TCSC, STATCOM, nowadays in advanced most commonly uses this kind of FACTS devices IPFC, UPFC, DPFC etc., To control the stability analysis is diagnose the optimal location for adapting these controllers and also computes the volume of voltage angle to inject current in the system. Here presented fuzzy and Neural Network technique is suggested the optimal location for adapting FACTs devices and also computes the volume of voltage angle and to inject current in the system to regulate the system stability. The proposed methods is an analysis of IEEE 30 bus system and performance of result in this method to regulate the system stability.

Keywords: Stability, Fuzzy, Neural Network UPFC, DPFC, power flow

1. INTRODUCTION

The Recent days, the important problem in power system is justify a regular adequate voltage under normal operating and abnormal conditions, which is generally referred as regulation the voltage. The system stability is defined as the capacity of a system to recover equilibrium condition when subjected to disturbance. FACTs devices have advanced in power system because of the growth of power electronics elements for high power and voltage. Thus a FACTS device use to provide good operating conditions and improves the power transfer capability.

In steady 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 . Power system stability represents the competence of an electric power system, for a given initial operating Condition, to retrieve a state of operation equilibrium after being subjected to a physical interruption. Due to the heavy loading of long transmission lines, the problem of transient stability after a severe fault can become a limiting factor in power transmission [1].Voltage stability assigns to the efficacy of the system in protecting the tolerable voltage under normal operating status, whereas the voltage fluctuation assigns to the absence of voltage fluctuation, which advantage of the voltage increase or decrease.

System security and voltage stability are the two important problems in the operation of constrained power system [16]. To enhance the voltage stability in the power grid. The grid restructures is finished by

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dynamic the topological design of power lines [2]. To accompany of FACTS devices, the voltage stability further transient and steady state stability of an underline power system can reinforce completely [5]. Widely, Flexible Alternating Current Transmission system is linked to a transmission line in various approaches, as in shunt and series [7]. These devices ability to control reactive and active power, and they are adept at the voltage magnitude control together, because of their fast control characteristics, flexibility and also enhance dynamic stability, power transmission capability, availability and curtail the transmission line losses [8][13].Furthermore, Flexible Alternating Current Transmission system devices has the effectiveness to variable of the transmission line and control the parameter, such as terminal voltage, voltage angle and line impedance in a fast forceful manner[15].

Using Various FACTS Devices Static VAR Compensator (SVC), Thyristor Controlled Series Capacitor (TCSC), Static Synchronous Compensator (STATCOM), Static Synchronous Series Compensator (SSSC), Thyristor Controlled Phase Shifter (TCPS), Interline Power Flow Controller (IPFC), Unified Power Flow Controller (UPFC), Distributed Power Flow Controller (DPFC). The line impedances, phase angles and bus voltage in power network are controlled flexibly and swiftly [6] [10]. The control of the TCPS and TCSC are necessary to protect the peculiar line flows [9].Power oscillation modes have been performed when power network is unified over weak tie-line [11]. In order to endorse the stability and power oscillation commitment to be controlled. Because a wide interconnected system has been built to enact a high operational performance and network security [12].

In this paper, a fuzzy logic and Neural Network is used for DPFC. The other section of the paper is organized as follows: Section II Operating Principle of UPFC & DPFC; Section III deal with Fuzzy and Neural Network Technique with Mathematical Models; Section IV discusses the Simulation Results for IEEE 30 Bus system; Section V concludes of DPFC.

2. A. OPERATING PRINCIPLE OF UPFC

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

The above figure represents the general structure of UPFC model. 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.

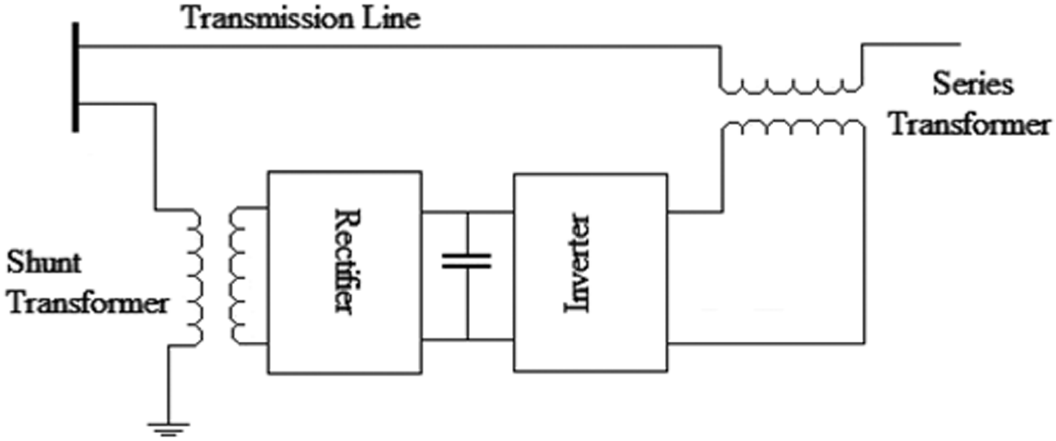

Figure 1: UPFC Configuration

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

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

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, *Gik* & *Bik* are the conductance and susceptance values respectively and Δik is the angle between *i* & *k* bus. Using the above equation 1 & 2, the real and reactive power flow between the buses are computed. The mathematical model of UPFC used in the proposed technique is given in the equations 3, 4, 5 & 6.

$$\Delta P_k = -V_k * V_{inj} [G^* \cos(\delta_i - \delta_{inj}) - B^{new} * \sin(\delta_i - \delta_{inj})] \tag{3}$$

$$\Delta Q_k = -V_k * V_{inj} [G^* \sin(\delta_i - \delta_{inj}) - B * \cos(\delta_i - \delta_{inj})] \tag{4}$$

$$\Delta P_k = -V_k * V_{inj} [G^* \cos(\delta_k - \delta_{inj}) - B^* \sin(\delta_i - \delta_{inj})] + G^{new} * V_{inj}^{2} + 2^* V_i * V_{inj} * G^{new} * \cos(\delta_k - \delta_{inj}) \tag{5}$$

$$\Delta Q_i = V_k * [G^{new} * \sin(\delta_i - \delta_{inj}) - B^{new} * \cos(\delta_i - \delta_{inj})] - V_i * I_q \tag{6}$$

where, ΔQi , ΔQk , ΔPi , ΔPk are the real and reactive injecting powers from and to bus respectively, $I\,q$ is the transformer reactive current, *Gnew = gik + G*, and *Bnew = bik + B*. *Vinj* and δinj are the injecting voltage and angle respectively.

2.1. Operating Principle of DPFC

Multiple individual converters cooperate together and compose the DPFC, see Fig. 2. The series converters consist of multiple units that are connected in series to the transmission lines. They can inject a voltage where the phase angle is controllable over 360° and where the magnitude is controllable as well. Consequently they control the power flow through the line.

The converter connected between the line and ground is the shunt converter. The function of the shunt converter is to compensate reactive power to the grid, and to supply the active power required by the series converter. In a normal UPFC, there is active power exchange through the DC link that connects the series converter with the shunt converter. Since there is no standard dc link betwixt the shunt and series converters in the Distributed Power Flow Controller, the active power is exchanged by harmonics and through the ac network. The principle is based on the definition of active power, which is the mean value of product of the voltage and current, where the voltage and current comprise fundamental and harmonics. Finally integral of all the cross-product of terms along various frequencies is zero, the time average active power can be expressed by:

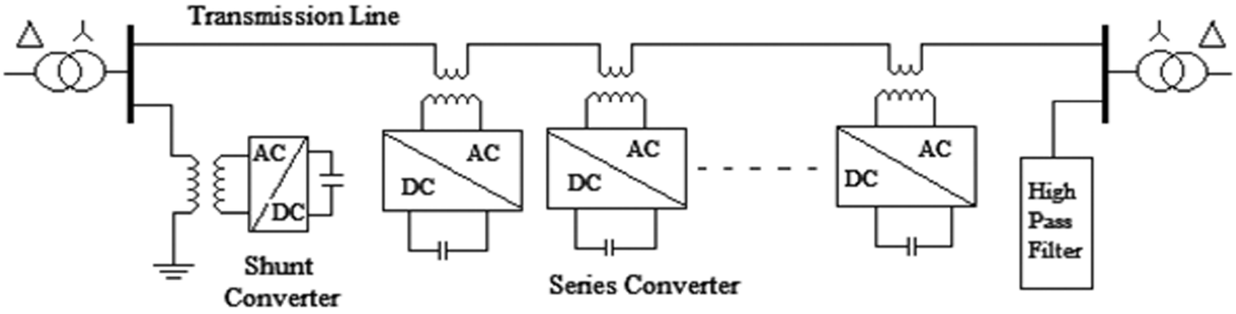

Figure 2: DPFC Configuration

$$P = \sum_{n-1}^{\infty} V_n I_n \cos\phi_n \qquad (7)$$

Where n is the order of the harmonic frequency and $\phi\, n$ is the angle between the current and voltage of the n^{th} harmonic. Equation 1 describes that active powers at different frequencies are isolated from each other and that voltage or current in one frequency have no influence on other frequency components. The 3rd harmonic is chosen here to exchange the active power, because it can easily be filtered by Y-Δ transformers.

2.2. DPFC Control Principle

The DPFC system consists of different type of converters, and each type of converter requires a different control scheme. The block diagram of the DPFC and its control is shown in Fig. 3. The shunt converter is restrained to interject a constant 3rd harmonic current into the transmission line, which is intended to amount of active power for the series converters. The shunt converter extracts some active power from the network at the fundamental frequency to maintain its dc voltage. The dc voltage of the shunt converter is controlled by the d component of the current at the fundamental frequency, and the q component is utilized for reactive power compensation. The series converters generate a voltage with controllable phase angle at fundamental frequency, and use the voltage at the 3rd order frequency to absorb active power to maintain its dc voltages at a constant value. The power flow control function is realized by an outer control loop, the power flow control block. This block gets its reference signals from the system operator, and the control signals for DPFC series converters are sent remotely via wireless or PLC communication method.

The function of each control block shown in Fig. 3 can be described as:

- Power flow control: receives the set point for power flow from the system operator, and calculate the fundamental frequency voltage that should be injected by the series converters.

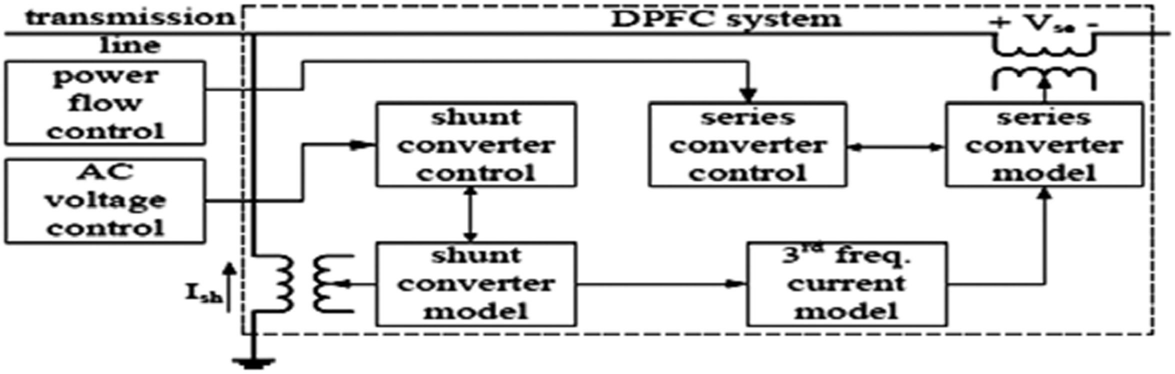

Figure 3: Block diagram of the control of a DPFC

- Series converter control: generates switching signals according to the received data, and stabilizes dc capacitor voltage by controlling 3rd harmonic components.
- AC voltage control: gives the set points to shunt converter for reactive power compensation at the fundamental frequency.
- Shunt converter control: generates 3rd harmonic current, the reactive current at the fundamental frequency and stabilize the dc voltage.

3. FUZZY LOGIC CONTROL

Fuzzy logic control uses non mathematical decision based algorithms that use operators' experience. This kind of control method is well suited for non-linear system. Fuzzy logic control is evolving in this work to attain desired output voltage of the chosen inverter. In order to obtain the fuzzy control surface for non-linear, time varying and complex dynamic systems, there are a number of steps to be followed as discussed below. The block diagram of fuzzy logic control scheme developed for the FLC is divided into five modules: fuzzifier, database, rule base, decision maker and dufuzzifier. The computational formation of fuzzy logic control scheme is composed to the following:

3.1. Identification of Input and Output

The input of the FLC are the error e = Vref-Vo and the change in error ce = en-en-1 where vo is the actual output voltage and desired output voltage and subscript n denotes sampling instances. δm_a is the change of modulation index inferred by the FLC at the nth sampling instant. Using δm_a the updated modulated signal m_s is attained and fed to the PWM generator which provides appropriate PWM signals m_n

3.2. Rule Table and Inference Mechanism

The fuzzy rules are in the mode

R_i = If e is A_i and ce is B_i then δm_i is C_i

Where A_i, B_i, and C_i are fuzzy subsets in their universe of monologue. Each universe of monologue is divided into seven fuzzy subsets name PB (Positive Big), PS (Positive Small),PM (Positive Medium),ZE

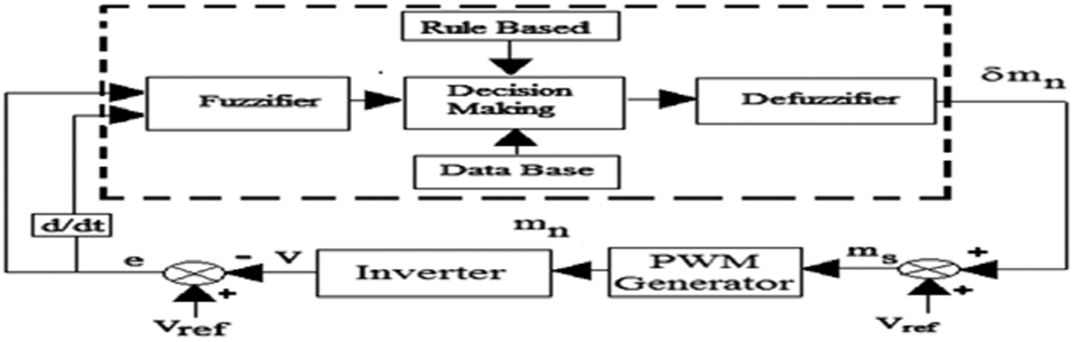

Figure 4: Fuzzy logic control scheme

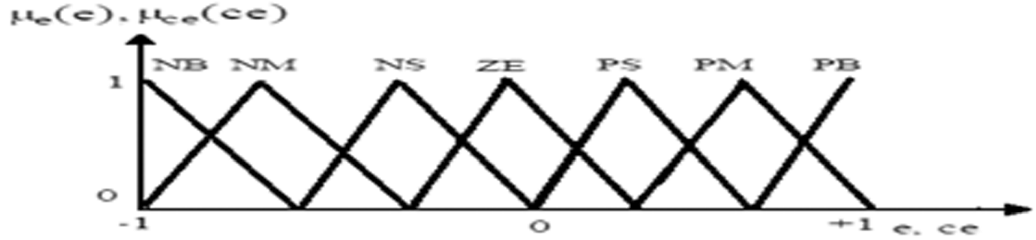

Figure 5: Membership function for e and ce

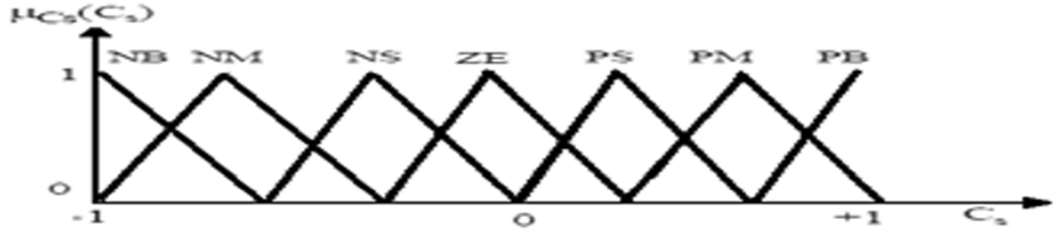

Figure 6: Membership function for change in modulating signal (C_s)

(zero), NS (Negative Medium), NM (Negative Medium), NB (Negative Big) as shown in Figs. 5 and 6. The Values of e and ce are normalized to [-1 1] as in Fig. 5 and values of äm$_i$ have the range [-1 1] as in Fig. 6. For any combination of e and ce a maximum of four rules are adopted.

The derivation of fuzzy control rules for chosen inverter is heuristic in quality and is based on the following yardstick:

i. When the output of the inverter differ far from the reference, the change of modulation index must be wide so as to bring the output of the reference quickly.
ii. When the output of the inverter is impending the reference, a slight change of modulation index is necessary.
iii. When the output of the inverter is nearby the swiftly, the modulation index must be kept constant so as to preclude further variation.
iv. When the reference is attained and the output is still fickle, the modulation index must be change a little bit to preclude the output from moving away.
v. When the reference is attained and the output is steady, the modulation index remains unchanged.
vi. When the output is larger than the reference, the sign of the change of modulation index must be negative and vice versa. According to these yardstick, a rule base is derived as in Table

The assumption result of each rule consists of two segments, the weighting factor W_i of the specific rule and the degree of variation of modulation index C_i conferring to the rule and it is written as

Where Z_i denotes the change in modulation index inferred by the ith rule and C_i is looked up from the rule table which shows the mapping from the product space of e and ce to C_i

3.3. Defuzzification

The resulting fuzzy set is defuzzified into a crisp control signal. A crisp value for the change in modulating signal is calculated in this work using the bisector of area method

Table 1
Rule Base

e/ce	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NB	NM	NS	ZE	PS
NS	NB	NB	NM	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PM	PB	PB
PM	NS	ZE	PS	PM	PB	PB	PB
PB	ZE	PS	PM	PB	PB	PB	PB

3.3.1. Neural Network

The Neural Network consists of two layer, one testing and another one training layer. Its consists of three layers, first one input layer, second hidden layer, and output layer. In this layer consists of two input layer and two hidden layer and four output layers. The input variable are the fault occurred bus and power error, while the output variable are the buses where DPFC to be associated. In the training part, while in the testing stage if give the input variables, it delivers the corresponding variables as output.

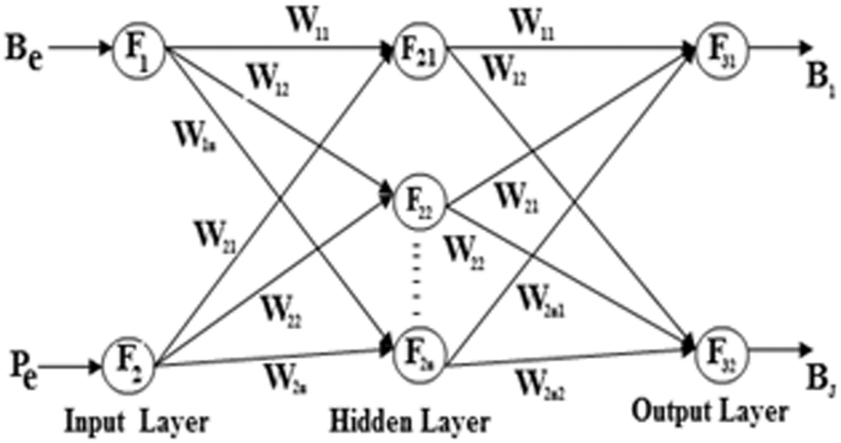

Figure 7: Proposed structure of Neural Network

The proposed structure of neural network training part is given blow

Step 1: Initialize weights

Step 2: Training, Input layer = B_e and P_e

Output layer = B_j and B_i

$$B_j = \sum_{r=1}^{n} W_{2r2}\theta_i(r) \tag{8}$$

$$B_i = \sum_{r=1}^{n} W_{2r1}V_i(r) \tag{9}$$

$$y(r) = \frac{1}{1+\exp(-w11r.(V_e + B_e))} \tag{10}$$

Above the three equations are represents the simulation complete in the input layer and output layer.

Step 3: Adjust the weights of all neurons.

Step 4: Determine the buses to be connected.

4. SIMULATION RESULTS

First of all, we see about the voltage profile (i) for normal load condition, (ii) after abrupt increase in the power in bus 9 & 11, and (iii) voltage obtained after connecting FACTS controller. The load conditions considered in the proposed method are sudden load increase in bus 11 and 9. Initially, the voltage profile at normal load condition is given and after sudden increase in load in buses 9 and 11 individually, the voltage profile of the system get reduced. Then, using the Fuzzy technique. The voltages attained after increase in

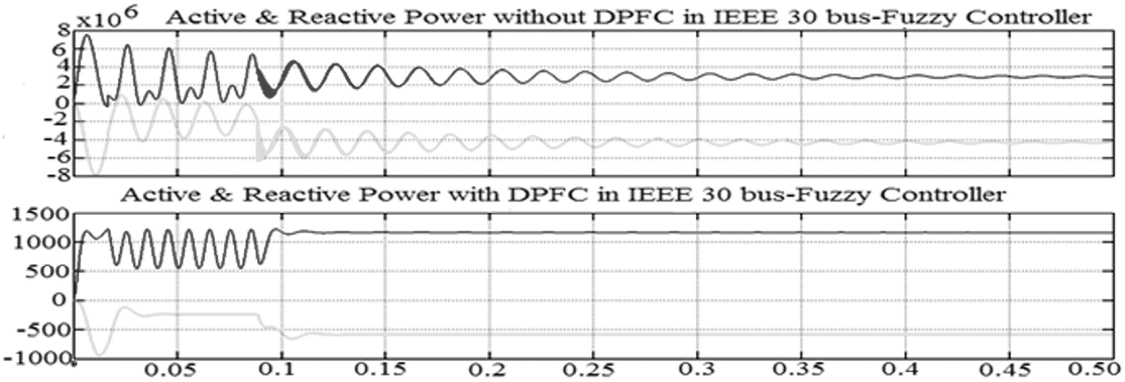

Figure 8: Active and Reactive Power with & without DPFC in IEEE 30 Bus system- Fuzzy Controller

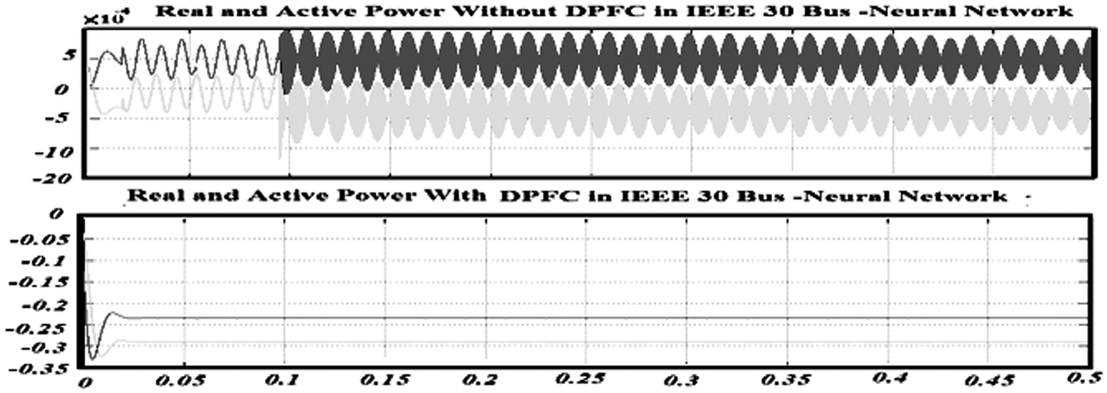

Figure 9: Active and Reactive Power with & without DPFC in IEEE 30 Bus system- Neural Network Controller

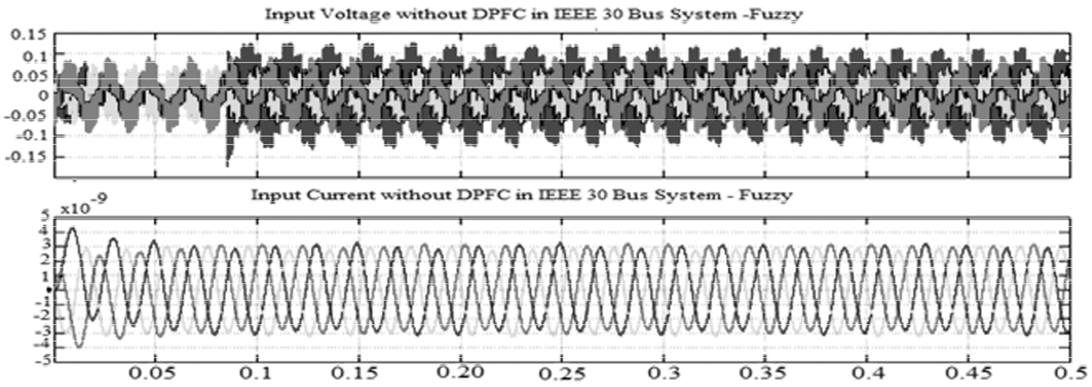

Figure 10: input voltage and Current without DPFC in IEEE 30 Bus system- Fuzzy

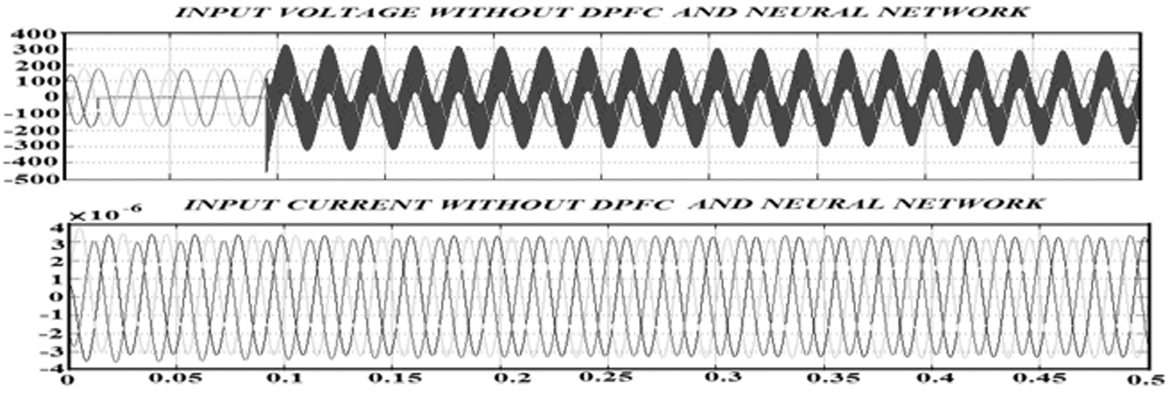

Figure 11: input voltage and Current without DPFC in IEEE 30 Bus system- Neural Network

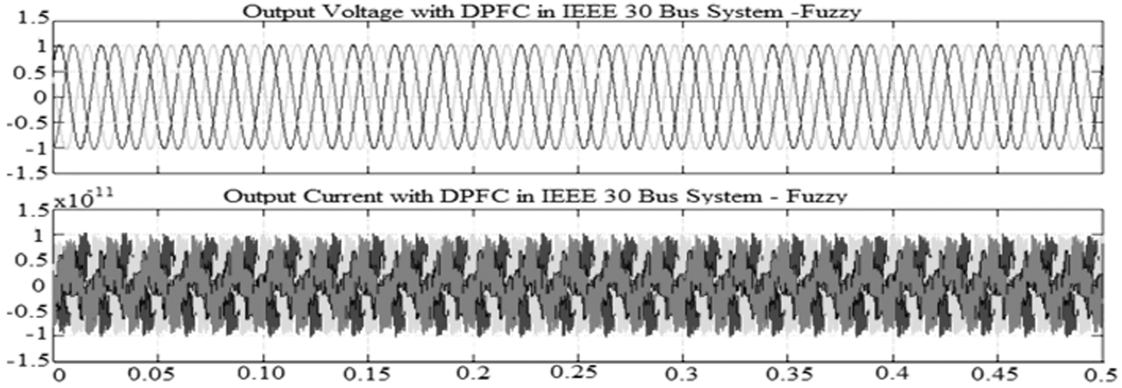

Figure 12: Output voltage and Current with DPFC in IEEE 30 Bus system-Fuzzy

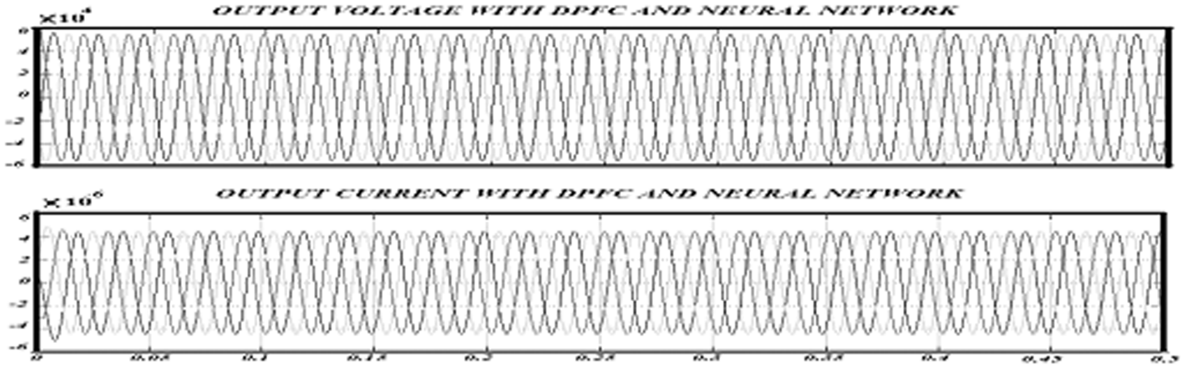

Figure 13: Output voltage and Current with DPFC in IEEE 30 Bus system-Neural Network

load and after concerning DPFC 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 DPFC 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.

	Voltage at each bus using		
	Conventional NR method (p.u)	*Proposed method Fuzzy with DPFC connected in buses 9 &11 (p.u)*	*Proposed method Neural network with DPFC connected in buses 9 &11(p.u)*
1	1.06	1.06	1.0665
2	1.033	1.0379	1.0375
3	1.0228	1.0370	1.037
4	1.0136	1.0295	1.0287
5	1.0044	1.006	1.0375
6	1.01	1.022	1.0714
7	0.9999	0.9999	0.9883
8	1.0103	1.0150	1.0121
9	1.0458	1.0132	1.0061
10	1.0367	1.0458	0.9922
11	1.0771	1.0800	1.0231

(*contd...*)

(*Table 1 contd...*)

	Voltage at each bus using		
	Conventional NR method (p.u)	*Proposed method Fuzzy with DPFC connected in buses 9 &11 (p.u)*	*Proposed method Neural network with DPFC connected in buses 9 &11(p.u)*
12	1.0572	1.0333	1.0329
13	1.071	1.0388	1.0384
14	1.0414	1.0315	1.0306
15	1.0355	1.0329	1.0321
16	1.0411	1.0227	1.022
17	1.0326	0.9966	0.9905
18	1.0236	1.0294	1.0279
19	1.0198	1.0154	1.014
20	1.0232	1.0194	1.0176
21	1.0228	1.0144	1.0131
22	1.03	1.0135	1.0123
23	1.0229	1.0009	1.0001
24	1.0158	1.0682	1.0672
25	1.0069	1.0618	1.0604
26	1.0989	1.0609	1.0599
27	1.01	1.1018	1.1004
28	1.0094	1.0489	1.047
29	0.9899	1.0016	1.0004
30	0.9782	1.0253	1.0241

6. CONCLUSIONS

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 fuzzy and neural 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 Moreover, the proposed technique was compared with the NR and Fuzzy and neural 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, DPFC 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 then this DPFC compared with UPFC as low rated components and cost wise also low. 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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