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Comparison of Analysis of Different Controller For Real and Reactive Power Coordination of UPFC

Mr.Saleem Pasha(1),
Associate Professor, EEE Dept, BVRIT,Narsapur,Telangana
Dr G Tulasi Ram Das(2),
Professor & Vice Chancellor, JNTU, Kakinada

Abstract

This paper proposes a comparison analysis of different real and reactive power coordination controller for a unified power flow controller (UPFC). The basic control for the UPFC is such that the series converter of the UPFC controls the transmission line real/reactive power flow and the shunt converter of the UPFC controls the UPFC bus voltage/shunt reactive power and the DC link capacitor voltage. In steady state, the real power demand of the series converter is supplied by the shunt converter of the UPFC. To avoid instability/loss of DC link capacitor voltage during transient conditions, a real power coordination ANN , Fuzzy & Neuro Fuzzy controller has been designed. The need for reactive power coordination controller for UPFC arises from the fact that excessive bus voltage (the bus to which the shunt converter is connected) excursions occur during reactive power transfers. A new reactive power coordination controller has been designed to limit excessive voltage excursions during reactive power transfers. MATLAB-SIMULINK simulation results have been presented to show the improvement in the performance of the UPFC control with the real power and reactive power coordination Neuro Fuzzy controller.

Index Terms: FACTS, unified power flow controller (UPFC), coordination controller, ANN controller. Neuro Fuzzy

Introduction of UPFC

In a competitive electricity market, installation of the Unified Power Flow Controller (UPFC) can improve power transfer capability and help market participants keep their schedules very close to preferred ones and at the same time may retain the competitive behavior of participants. Putting the UPFC in service may assist system to operate within its physical limits and reduce total generation cost associated with out-of-merit order caused by constrained transmission. However, a competitive electricity market necessitates a reliable method to allocate congestion charges, transmission usage, and transmission pricing in an unbiased, open-accessed, basis. Therefore, it is usually necessary to trace contribution of each participant to line usage and congestion charges, and then to calculate charges based on these contributions. It has been a common practice to use distribution factors to calculate these contributions [4].

The present Paper derives relationships to model impact of UPFC on line flows and transmission usage where we present modified admittances and distribution factors that model impact of utilizing UPFC on line flows and system usage. The relationships derived show how bus voltage angles are attributed to each of changes in generation, injections of UPFC, and changes in admittance matrix caused by inserting UPFC in transmission lines. The relationships derived can be adopted for the purpose of allocating usage and payments to users of transmission network and owners of control devices used in the network. The relationships derived are applied to test systems, where the results illustrate how transmission usage is affected when UPFC is utilized [3].

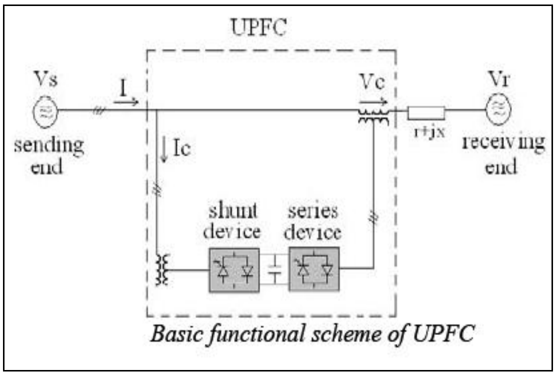


Figure 1: Basic functional scheme of UPFC

The series power converter works to obtain a constant balanced sinusoidal load voltage. The shunt converter regulates the DC link voltage and compensates for the reactive current of the source within the rated current of the converter. To design the required capacity for the series-shunt power converter, the relation between the converter capacity and the load power factor at constant compensation voltage is introduced. The required capacity of the series-shunt power converter is reduced by more than 50% compared with that of a conventional series power converter. The effectiveness of the proposed load voltage compensation technique using the series-shunt power converter .

The IEEE 39 bus system which contain total 10 generator bus and remaining load bus , a load flow analysis is carried out and found bus no 26 & 39 are weak, voltage less tan one per unit at these bus.

A UPFC is connected between 26 & 39 bus with four different controller PI and fuzzy, ANN, Neuro Fuzzy, and are presented.

Tuning of Pi Controller

A PI controller responds to an error signal in a closed control loop and attempts to adjust the controlled quantity to achieve the desired system response. The controlled parameter can be any measurable system quantity such as speed, torque, or flux. The benefit of the PI controller is that it can be adjusted empirically by adjusting one or more gain values and observing the change in system response.

Tuning of PI Controllers

Proportional-integral (PI) controllers have been introduced in process control industries. Hence various techniques using PI controllers to achieve certain performance index for system response are presented. The technique to be adapted for determining the proportional integral constants of the controller, called *Tuning,* depends upon the dynamic response of the plant[2].

This error is manipulated by the controller (PI) to produce a command signal for the plant according to the relationship.

$U(s) = K_p \, (1+1/ \tau_i s)$

Or in time domain $U(t) = K_p \, [e(t) + (1/\tau_i) \int e dt]$

Where K_p = proportional gain

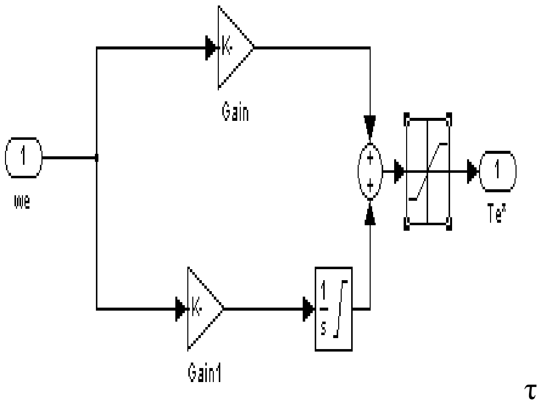
τ_i = integral time constant

Zeigler- Nichols Rules for tuning PI controllers:

First Rule: The *S*-shaped response is characterized by two constants, the dead time *L* and the time constant *T* as shown. These constants can be determined by drawing a tangent to the *S*-shaped curve at the inflection point and state value of the output. From the response of this nature the plant can be mathematically modeled as first order system with a time constant *T* and delay time *L* as shown in block diagram.

The gain *K* corresponds to the steady state value of the output C_{ss}. The value of K_p, T_i and T_d of the controllers can then be calculated as below:

$KP=1.2(T/L)$



$\tau i = 2L$

Figure 2: Mathematical Model

Introduction of ANN

Neural networks are composed of simple elements operating in parallel. These elements are inspired by biological nervous systems. As in nature, the network function is determined largely by the connections between elements. Neural network is trained to perform a particular function by adjusting the values of the connections (weights) between elements. Commonly Neural Networks are adjusted, or trained, so that a particular input leads to a specific target output. There, the network is adjusted, based on a comparison of the output and the target, until the network output matches the target. Typically many such input/target pairs are used, in this supervised learning, to train a network.

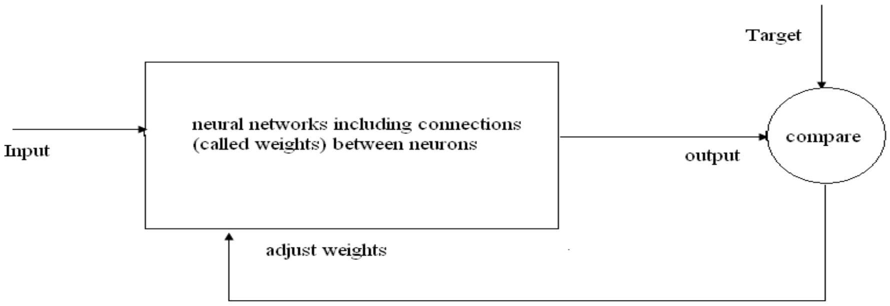


Figure 3: Block diagram of Neural Network

Batch training of a network proceeds by making weight and bias changes based on an entire set (batch) of input vectors. Incremental training changes the weights and biases of a network as needed after presentation of each individual input vector. Incremental training is sometimes referred to as "on line" or "adaptive" training. Neural networks have been trained to perform complex functions in various fields of application including pattern recognition, identification, classification, speech, and vision and control systems. Today neural networks can be trained to solve problems that are difficult for conventional computers or human beings[1].

The supervised training methods are commonly used, but other networks can be obtained from unsupervised training techniques or from direct design methods. Unsupervised networks can be used, for instance, to identify groups of data. Certain kinds of linear networks and Hopfield networks are designed directly.

Simulation Model and Its Subsystems

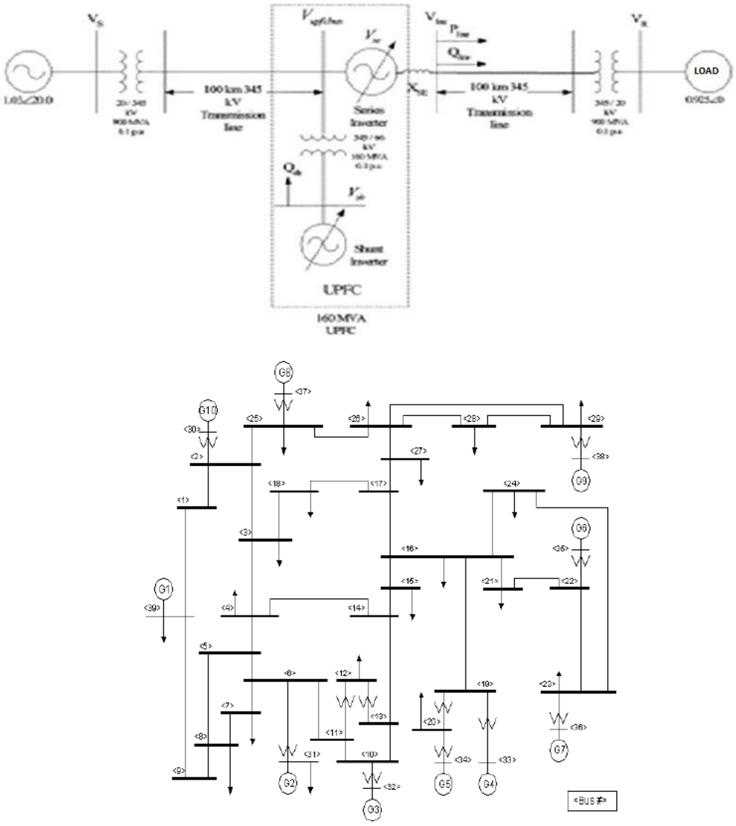


Figure 4: UPFC connected between 26 & 39 bus in IEEE 39 bus power system

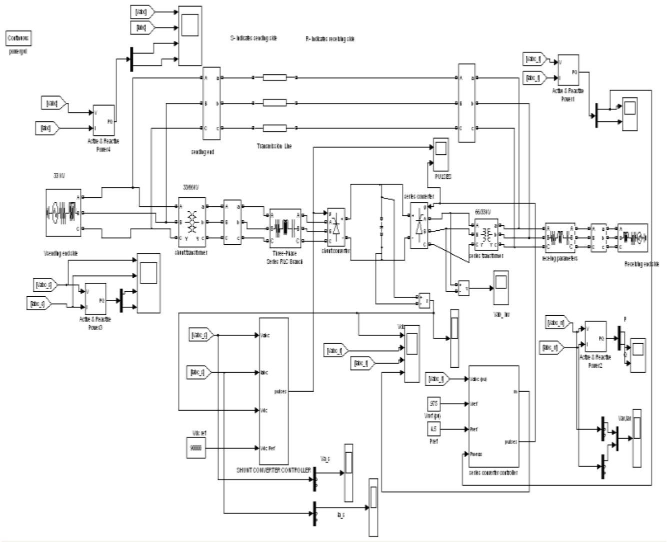


Figure 5: Simulation of PI controller

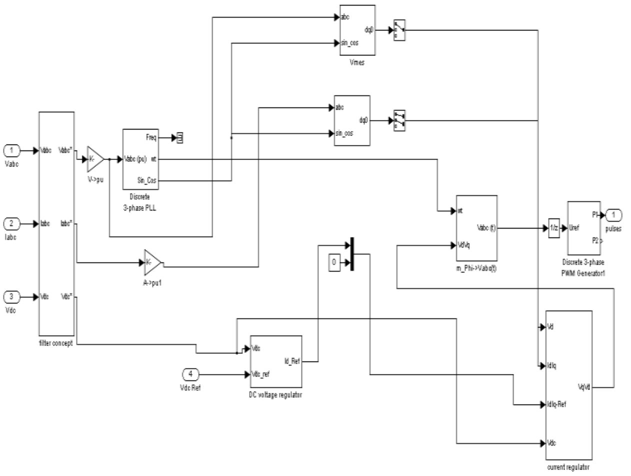


Figure 6: Shunt converter controller using PI

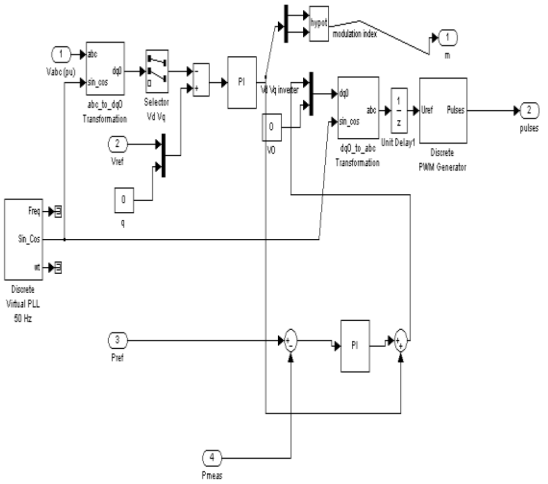


Figure 7: Series converter controller using PI

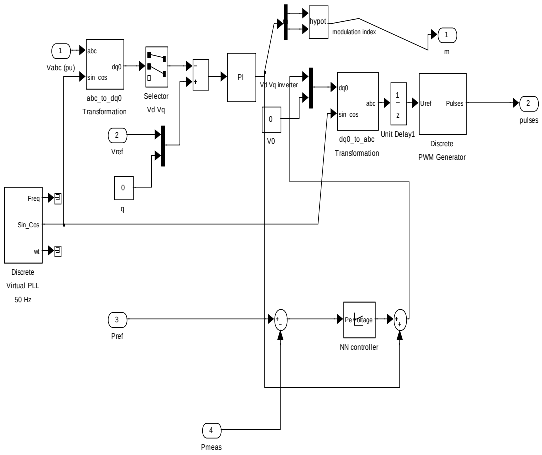


Figure 8: Series Converter Controller for NN Controller

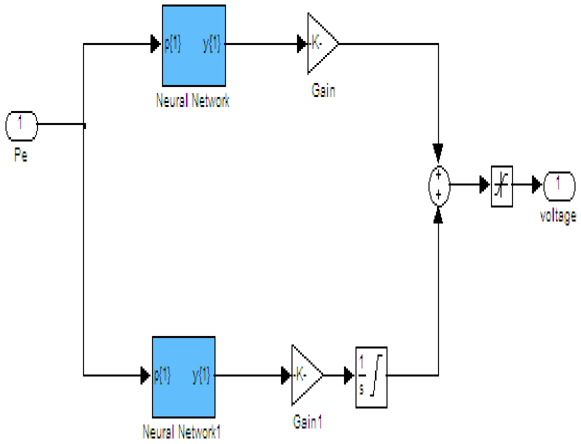


Figure 9: Subsystem for NN controller Block

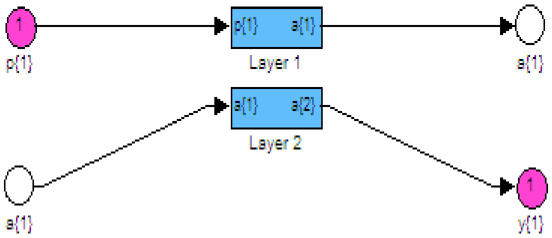


Figure 10: Subsystem for NN controller sub Block

Simulation Results

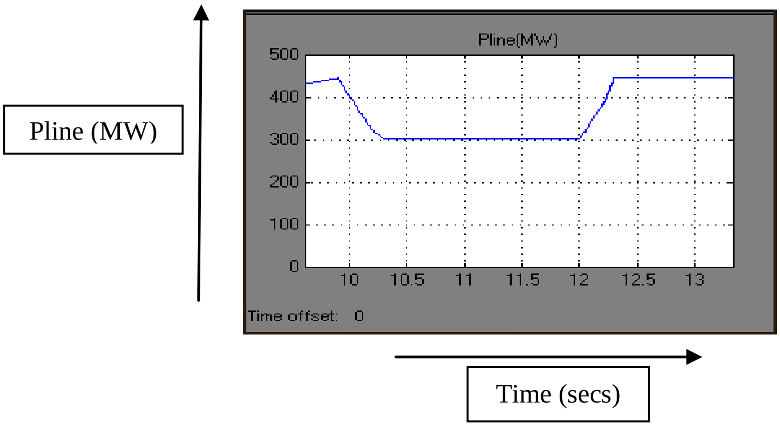


Figure 11: Response of power system to step change in transmission line Real power reference

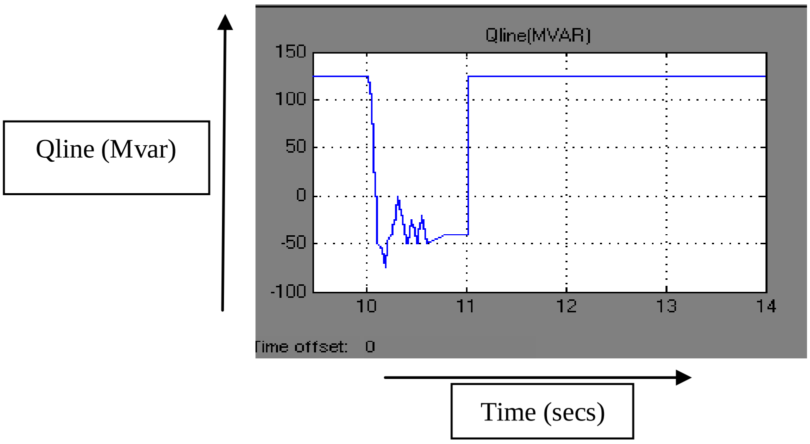


Figure 12: Response of step change in reactive power Reference

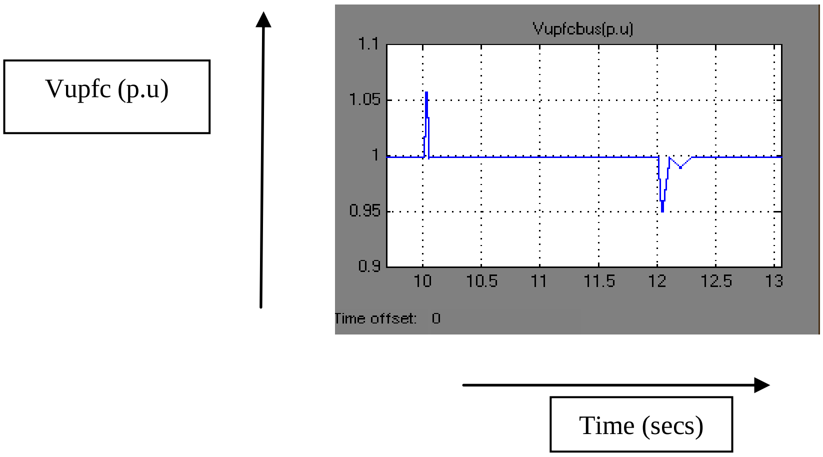
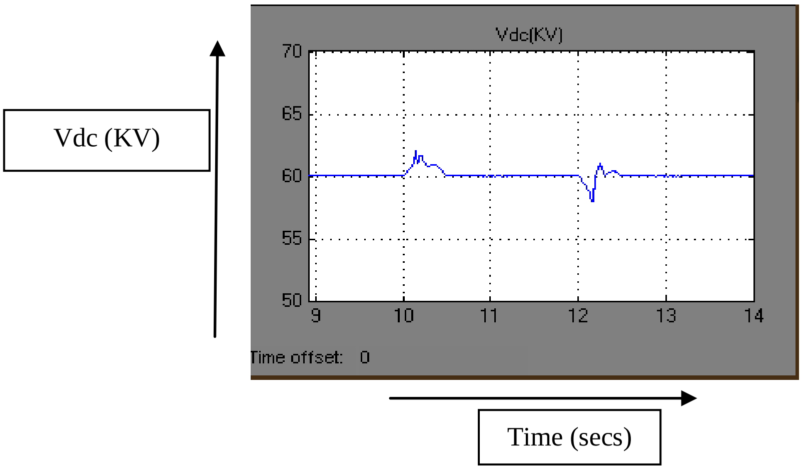


Figure 13: Response of UPFC bus voltage With out coordination



Figue 14: Response of DC link voltage With out coordination

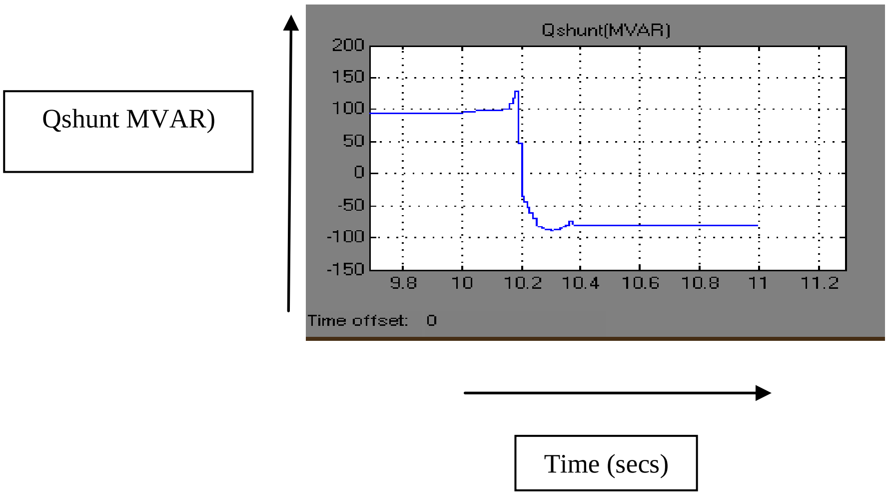


Figure 15: Response of shunt reactive power Reference

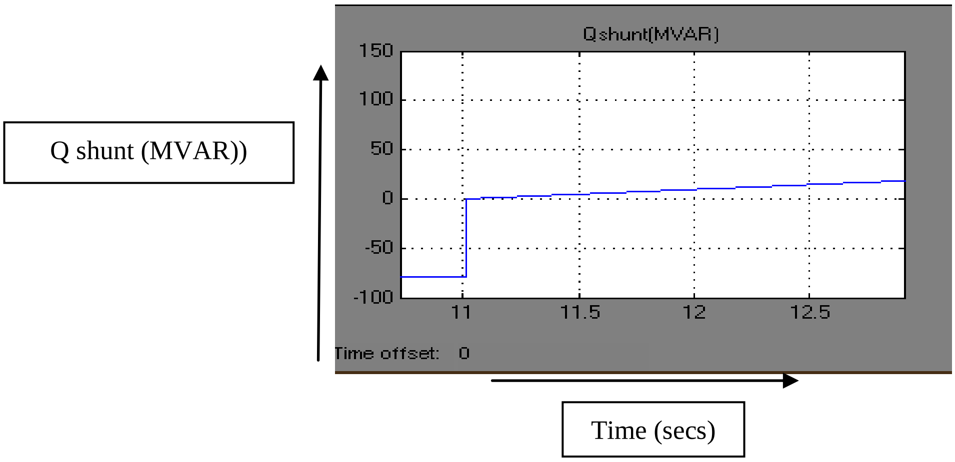


Figure 16: Response to step change in reactive power reference.

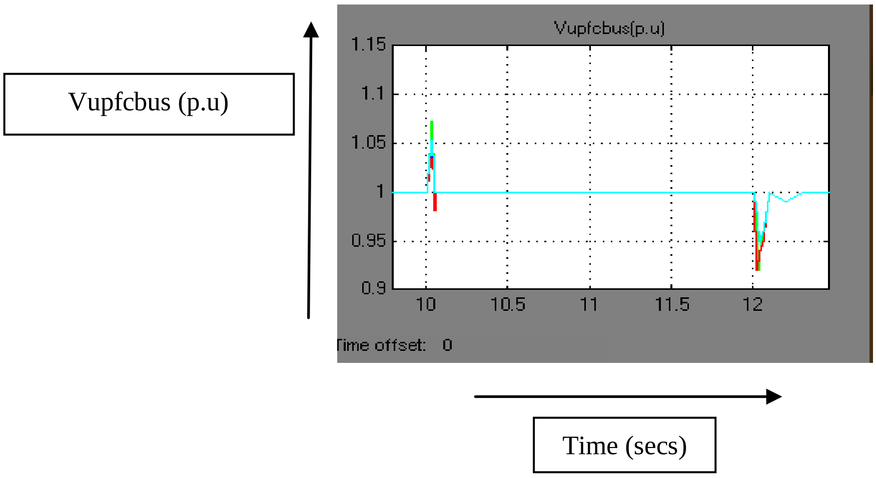


Figure 17: Response of UPFC bus voltage PI(RED), ANN& FLC(BLUE)& Neuro Fuzzy Controller (BLUE)

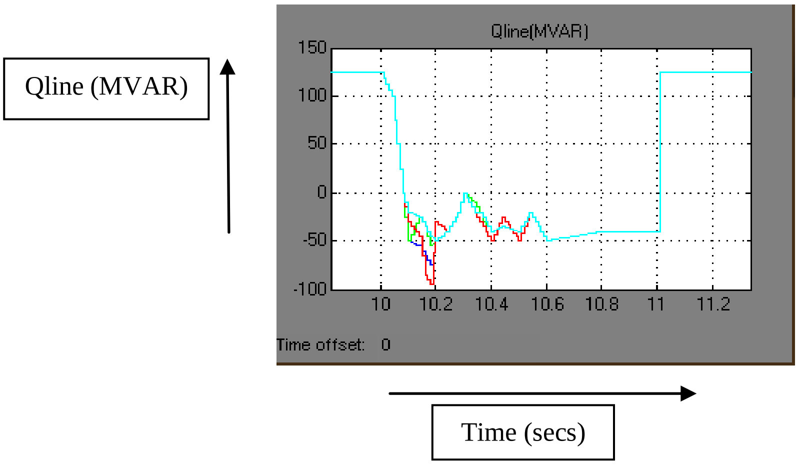


Figure 18: Impact of reactive power coordination PI(RED), ANN , FLC(BLUE) and Neuro-fuzzy controller(GREEN)

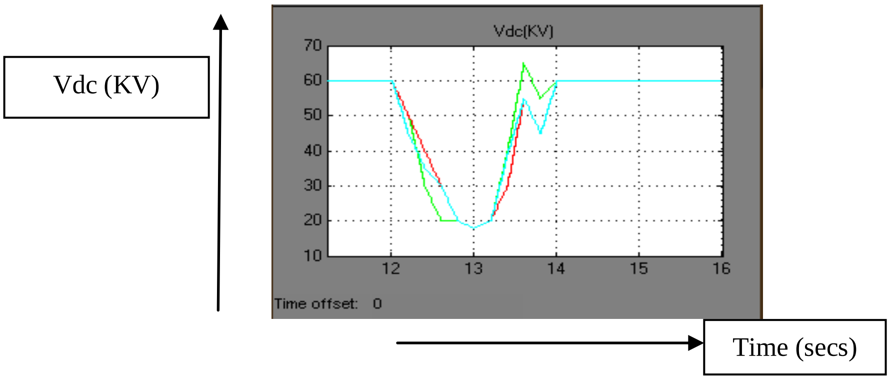


Figure 19: Response of DC link voltage with real power coordination PI(RED) , Fuzzy NN(BLUE), Neuro-fuzzy controller(GREEN))

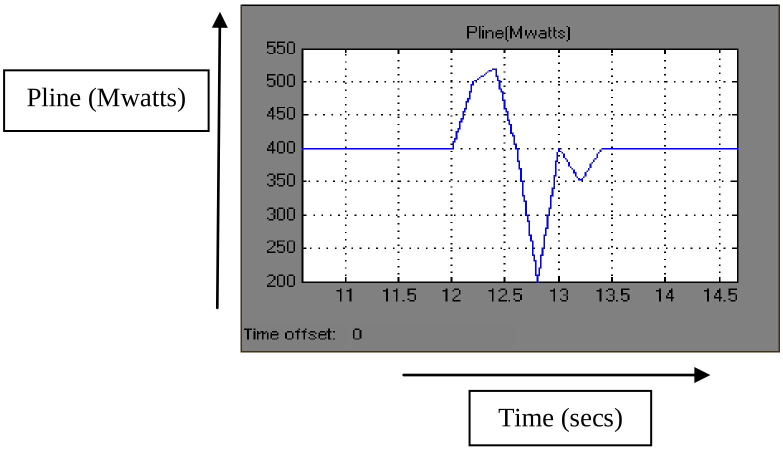


Figure 20: Response of power system with three phase fault

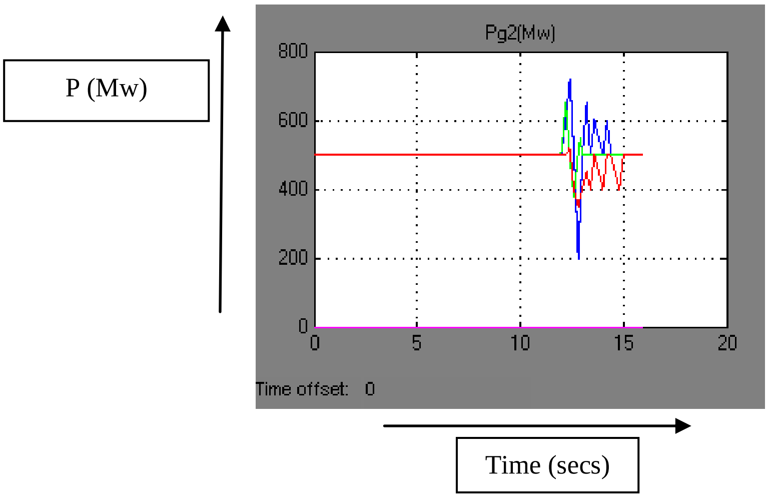


Figure 21: electrical power with (FUZZY(BLUE),ANN(GREEN) and Neuro-fuzzy controller(RED)

Results and Discussion

Performance of reactive power coordination ANN, Fuzzy, Neuro Fuzzy controller:

UPFC is connected between 26 & 39 bus in IEEE 39 bus system of 200km 345 transmission line and specification (Appendix A). Initial real power and reactive power (line) in the transmission line is 290MW &125MVAR respectively & shunt reactive power is 80MVAR. When a step change in transmission line reactive power reference Decreases/Increases at 10sec there is a equal amount of Decreases/Increases of shunt reactive power is observed as shown in figure 12, 15, 16. With out coordination controller

With reactive power coordination Neuro Fuzzy controller, the UPFC bus voltage Rise is reduced from 1.06 pu to 1.02pu as compare to PI, ANN and Fuzzy as shown in fig 17 and also the line reactive power settling time is reduced as shown in fig 18.

Performance of Real power coordination Neuro Fuzzy Controller:
At 12 sec three phase fault is applied with real power Neuro fuzzy coordination controller the excessive dc link voltage is reduced to 1.2KV and recovery time is improved with Neuro Fuzzy controller as shown in figure 19, and also the electrical power is very much stable as shown in fig 21.

Table 1: Real And Reactive Power Coordination With Ann, Fuzzy & Neuro Fuzzy Controller

S.No		**Without coordination controller**	**With Coordination Controller**			
			PI	FLC	NN	Neuro-Fuzzy
1	UPFC bus voltage(pu)	1.075	1.06	1.05	1.04	1.02
2	DC link voltage Vdc KV	5	2.5	2	1.8	1.2

Controller	**Voltage(pu) Sending receiving**	**Current(pu) Sending Receiving**	**Pmw Sending Receiving**	**Qmvar Sending Receiving**
PI	**0.975 0.96**	**0.9 0.8**	**290 290**	**125 125**
ANN	**0.975 0.97**	**0.8 0.77**	**290 290**	**125 125**
FUZZY	**0.975 0.961**	**0.9 0.88**	**290 290**	**125 125**
NEURO FUZZY	**0.975 0.960**	**0.9 0.89**	**290 290**	**125 125**

Conclusion

This paper has presented a comparison of different real and reactive power coordination controller for a UPFC. The basic control strategy is such that the shunt converter of the UPFC controls the UPFC bus voltage/shunt reactive power and the dc link capacitor voltage. The series converter controls the transmission line real and reactive power flow. The contributions of this work can be summarized as follows. Two important coordination problems have been addressed in this paper related to UPFC control with ANN Fuzzy & Neuro fuzzy controller. One, the problem of real power coordination between the series and the shunt converter control system. Second, the problem of excessive UPFC bus voltage excursions during reactive power transfers requiring reactive power coordination. Inclusion of the real power coordination Neuro Fuzzy controller in the UPFC control system avoids excessive DC link capacitor voltage excursions and improves its recovery during transient conditions as compare to ANN & Fuzzy. MATLAB simulations have been conducted to verify the improvement in dc link voltage excursions during transient conditions.

Appendix 'A'[2]:

A. *Series Converter Control Parameters*

1) Transmission line real power flow controller parameters

$$K_p = 0.1 \quad K_I = 4.0.$$

2) Transmission line reactive power flow controller parameters:
   a) Outer loop controller: $K_p = -0.1$ $K_I = -1.0$.
   b) Inner loop controller: $K_p = 0.15$ $K_I = 25.0$.

B. *Power System Parameters*

1) Generator parameters

$$L_{\text{adu}} = 1.6 \quad L_{\text{aqu}} = 1.5 \quad ll = 0.2 \quad L_{\text{ad}} = 0.835\,L_{\text{adu}}$$
$$L_{\text{aq}} = 0.835\,L_{\text{aqu}} \quad L_{\text{fd}} = 0.106\,67 \quad r_{\text{fd}} = 0.000\,565\,8$$
$$L_{1d} = 0.1 \quad r_{1d} = 0.017\,68 \quad L_{1q} = 0.456\,52$$
$$r_{1q} = 0.012\,97 \quad L_{2q} = 0.058\,33 \quad r_{2q} = 0.021\,662$$
$$H(1) = 3.15 \quad H(2) = 3.5.$$

2) UPFC parameters
   Dc link capacitor = 3000 μF.
   Shunt converter transformer is rated at
   160 MVA, 345/66 kV, $X_{\text{sh}} = 0.2$ p.u.
   Series converter transformer is rated at 160 MVA.
   38.1/66 kV, $X_{\text{SE}} = 0.04$ p.u.

3) Exciter and power system stabilizer parameters

$$K_{\text{stab}} = 9.5 \quad T_W = 10.0 \quad T_1 = 0.05 \quad T_2 = 0.02$$
$$T_3 = 3.0 \quad T_4 = 5.4 \quad T_R = 0.02$$
$$K_A = 200.0 \quad T_A = 1.5 \quad T_B = 1.0 \quad T_E = 0.02.$$

4) Synchronous motor load parameters:
   a) Rating: 900 MVA, 20 kV.
   b) Parameters

$$X_{S1} = 0.14 \quad X_{\text{MDO}} = 1.445 \quad X_{23O} = 0.0$$
$$X_{3D} = 0.0437 \quad X_{2D} = 0.2004 \quad X_{\text{MQ}} = 0.91$$
$$X_{2Q} = 0.106 \quad R_{S1} = 0.0025 \quad R_{2D} = 0.000\,43$$
$$R_{3D} = 0.0051 \quad R_{2Q} = 0.008\,42 \quad H = 1.0.$$

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