Performance of Distributed Power Flow Controller in Transmission System Based on Fuzzy Logic Controller

Rajareddy.Duvvuru, N.Rajeswaran, T.Sanjeeva Rao

Abstract*: Many of the Power Flow Controlling Devices are mostly used in the Transmission Lines in order to monitor the real as well as reactive power-flow variations. In this work provide an innovative power flow controlling device such as Distributed Power Flow Controller, this device also belongs to the FACTS family. This device is emerged from the Unified Power Flow Controller, there is a small differentiation between both these devices that is the common dc-link. In case of DPFC there is no existence of the dc link which connects both the converters. By design a DPFC device in MATLAB/Simulink to analyze the transmission line parameters.

***Keywords* : electronics devices, Unified Power Flow Controller ,Distributed power flow controller.**

I. INTRODUCTION

The increasing difficulty of the current power systems is largely due to the everyday change in the system arrangement in organize to meet the ever growing demand of electrical energy, through the development of installation of new units of generation, interconnectivity of the transmission lines, extra high voltage tie line etc. The combined controllers of FACTS and Power-Electronics are one of the most appropriate devices which are utilized in managing power-flow [1]-[2]. The series-compensated FACTS controller is known as UPFC which can be treated as one of the commanding Power Flow Controlling Devices which can be used to control the all parameters [3].

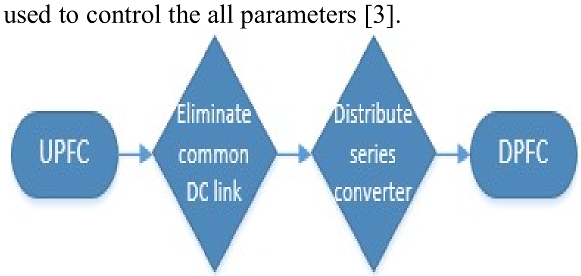

Figure 1. Conversion from UPFC-device to DPFC-device

Enlarging the Unified-PFC into the innovative controller known as Distributed-PFC is ended by apart from the common DC-link and series converter distribution as given away in Fig. 1.The new concept Distributed FACTS is employed in the series converter design. Here many number of low power rating converters are adopted as a replacement for a large 3-phase rated converter which results in low cost and increases the reliability [4].

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Raja Reddy. Duvvuru*, Department of Electrical Engineering, Malla Reddy Engineering College, Hyderabad. Email: rajajntuacep@gmail.com.

Dr. N. Rajeswaran , Department of Electrical Engineering, Malla Reddy Engineering College,Hyderabad. Email: rajeswarann@gmail.com.

T. Sanjeeva Rao, Department of Electrical Engineering, Malla Reddy Engineering College, Hyderabad. Email: sanjeev707@gmail.com.

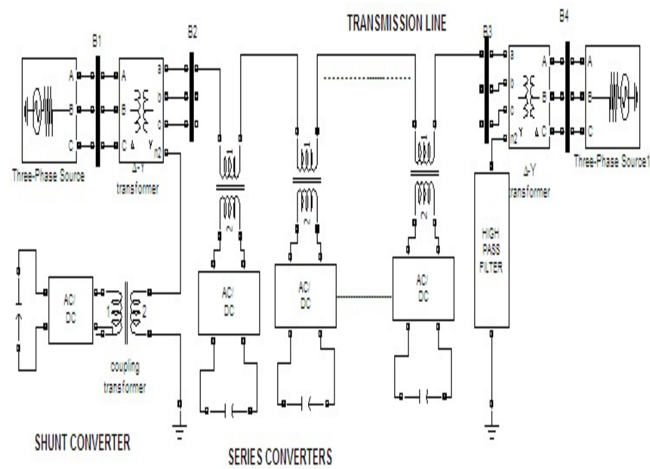


Figure 2. DPFC configuration

These are considered as the most important advantages of DPFC compared to UPFC. Figure 2 shows the configuration of Distributed-PFC consisting shunt along with series converters as in case of UPFC. In DPFC each-converter have their individual DC-capacitor that contributes necessary DC-voltage.

II. DPFC PRINCIPLE

Ac terminals of shunt-converter are connected with series converter via transmission line through which active power is interchanged. Power-theory of the non-sinusoidal components is adopted in this method. In Fourier analysis the non-sinusoidal current and voltage is articulated as summation of sinusoidal-functions in different frequencies by means of dissimilar amplitudes. This results in the true-power as shown in equation (1).

$$P=\sum_{i=1}^{\infty} V_i I_i \cos\phi_i \qquad (1)$$

Where I_i , V_i are current as well as voltage at the i^{th}-harmonic-frequency correspondingly, where as ϕ_i be the phase-angle among the current as well as voltage. DPFC mainly comprises of a many number of low power rating series-converters and also a shunt-converter is also utilized. Here shunt-device is operated as the Static-compensator where as the series converter acts as a Distributed-FACTS controller [5]. Using the PWM (Pulse Width Modulation) technique inject the current into the shunt converter to organize reactive-power and also the voltage is injected into the series converter through a dc link to monitor real-power variations in order to inject voltage into the series converter. There are many advantages regarding D-FACTS controller, the price of the apparatus gets minimized and the reliability of the system is improved [6]. By using a single bulky controller with high rating, there is an availability of using number of low rated controllers so this the cost the equipment may get reduced.

Each and every Distributed-FACTS component is self employed and they are monitored tenuously by the PLC's (power-line communications) or wireless communication. Since the unit does not need support of phase to ground isolation, it is capable of adopted at all voltage levels. During single module failure, the Distributed-FACTS redundancy offers an unremitting process, thus giving higher reliability compared to other FACTS devices [7].

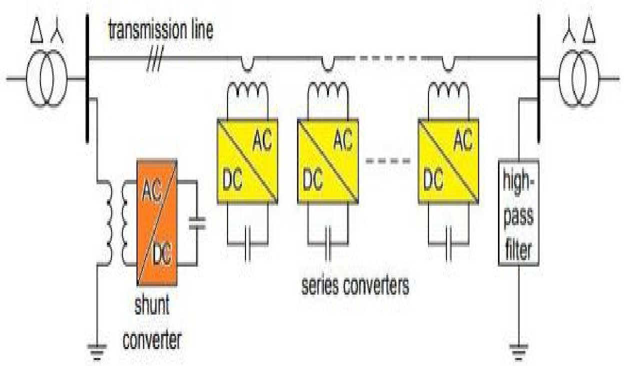


Figure 3. Block diagram of DPFC control

III. DPFC CONTROL

Fig. 3 shows the 3- types of controllers, namely series controller, shunt controller and central control. The constraints that are used in shunt in addition to series control is sustained by themselves sometimes is called a local controllers. By the side of the system's level the central control regulates the DPFC functions [8].

3.1. Central Control

Mainly in this control is adopted to produce the ref signals to other controllers. These are generated next to the fundamental-frequency. Reactive current signal and voltage reference signal is provided for the shunt converter along with the series-converters respectively. At power system level, the central-control is used to minimize the systems oscillations, and also monitors the power-flows and also balances the components which are asymmetrical.

3.2 . Series Control

This control in adopted in DPFC in order to inject the voltages into the line when required. Here the voltage is inserted into the at the 3rd harmonic-frequency. Here Vector control principle used to maintain the voltage across capacitor.

3.3 . Shunt Control

In order to transfer the real-power, 3rd harmonic-current is inserted into the three phases of the transmission line with the help of the transformer which is connected to the AC terminals of the shunt-device. This is the main objective of this control technique. And also it maintains the constant voltage-levels across the dc-capacitor [9].

IV. COMPARISON OF PI AND FUZZY CONTROLLER

Here fuzzy as well as PI controllers are utilized. The responses obtained by both the controllers are studied under this section.

4.1. Proportional Integral Controller

The controller is utilized; the DC link voltage is observed at normal intervals and is correlated with a ref value. Here an error signal can be generated which is handled in a PI controller as shown in figure below [10]-[11].

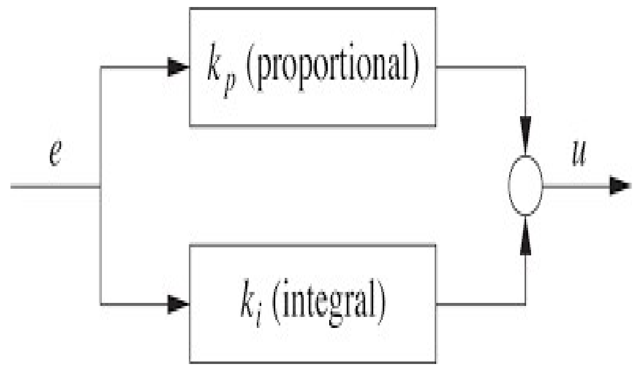


Figure 4. Block diagram of PI controller

4.2. Comparision of PI and Fuzzy Logic Controller (FLC)

The following are some the advantages of fuzzy- logic controllers when compared with the proportional integral (PI) controllers,

- perfect mathematical model is not mandatory
- Fuzzy controllers can handle the inputs which are unknown.
- Fuzzy controllers have enough capability to work with non-linearities.

Fuzzy-inference systems are applied in numerous applications namely computer-vision techniques, control-data categorization etc. Mainly the FIS are classified into two types they are as follows;

- Mamdani-techique and
- Sugeno-techique

Among both the methods, Mamdani' technique is adopted frequently when compared to sugeno method and also this method gives more accurate results when compared with PI controller.

The sampling time of this method is very low so due to this reason we are not adapting this method for real time applications. Block diagram of fuzzy-logic controller is given away in Fig.4. The control-action that is carried out by fuzzy-logic controller is determined by evaluating the linguistic rules. The different components of a fuzzy control system are fuzzification, rule base, defuzzification, and inference mechanisms.

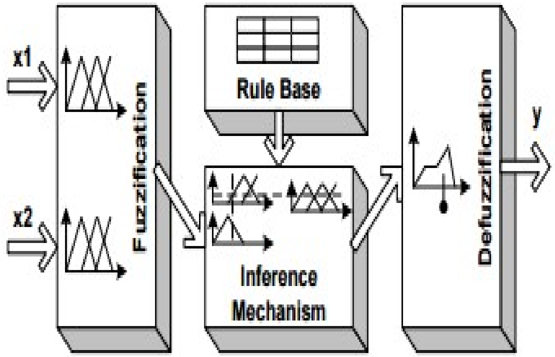


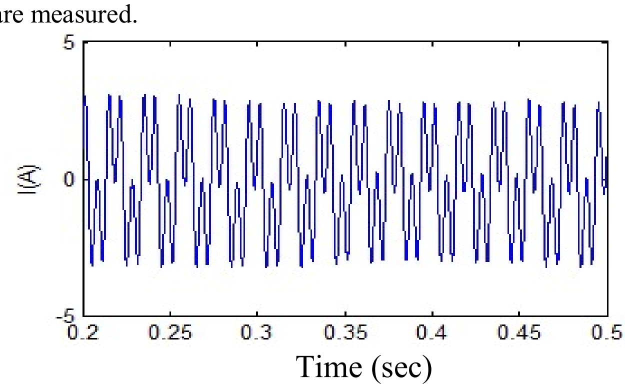
Figure 5. Block diagram of Fuzzy controller

Under fuzzification procedure the crisp-values are transformed to fuzzy-values. Where as in de-fuzzification procedure fuzzy-values are changed to crisp-values. Rule base consists of different rules which are applied to solve a problem. Inference mechanism mainly consists of two techniques such as mamdani and sugeno techniques by considering these two techniques we will solve a problem [12]-[13].

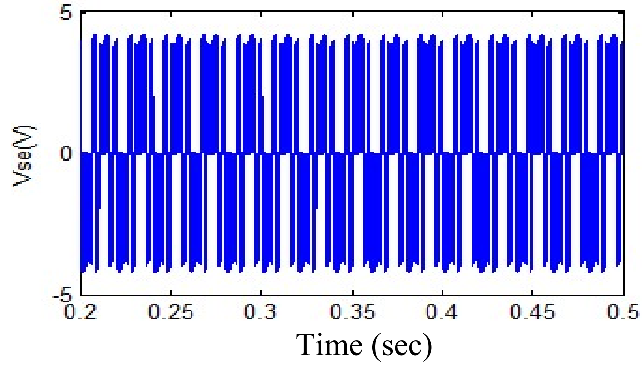
V. SIMULATION RESULTS

Simulation is carried out in MAATLAB/SIMULINK software. Here mainly we are analyzing two situations they are steady-state in addition to step-response conditions. In first case using series control we are inserting a voltage -vector with d-axis and q-axis components, namely $V_{se,d,ref}$=0.30V and $V_{se,q,ref}$=−0.10V. The responses of DPFC under the steady-state are shown in figures 6(a), 6(b), 6(c) where only the waveforms of one phase are shown for clarity. When a fault occurs on a power system a third harmonic current component is produced in order to eliminate the third frequency component by using a shunt converter we are introducing another third frequency component in the negative direction now both of the harmonics currents gets cancelled out then the fault can be easily rectified.

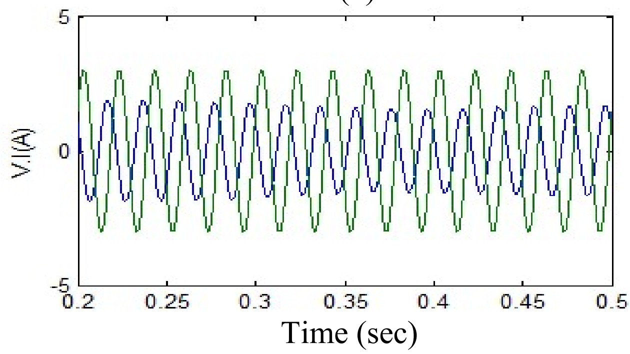
Fig 6(a) represents the 3rd harmonic current, subsequent to nullify the component of harmonic current by use of shunt converter the results are shown in fig.6(c). It is observed that fig 7.(a) step-change of a series converter ref-voltage is shows real as well as the reactive power variation and Direct Current voltage is alleviate previously and after the step changes. fig.7 (b) and 7(c) are power from the voltages and currents which are measured.



(a)

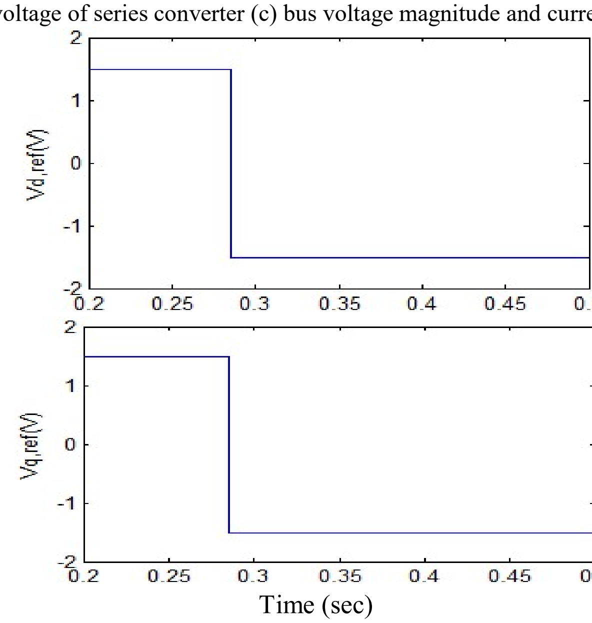


(b)

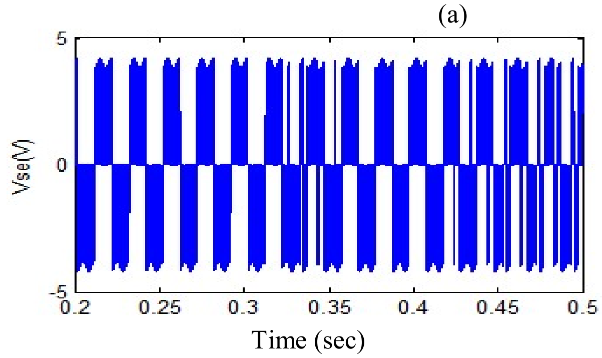


(c)

Figure 6. Steady-state operation of DPFC (a) line- current (b) voltage of series converter (c) bus voltage magnitude and current



(a)



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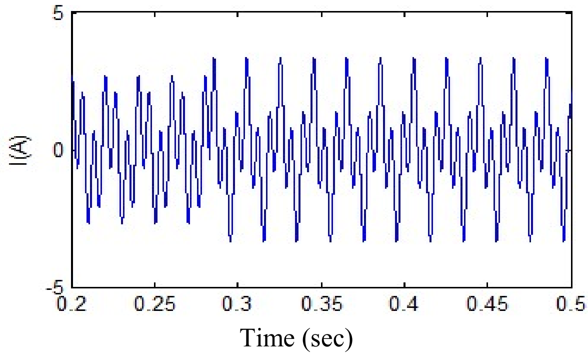

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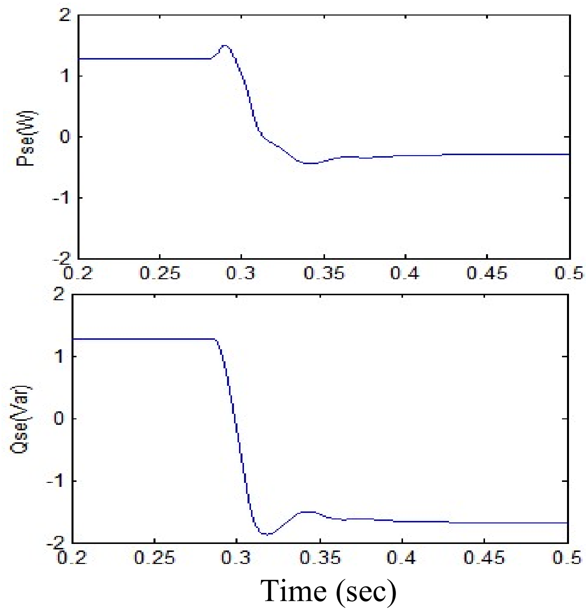


(d)

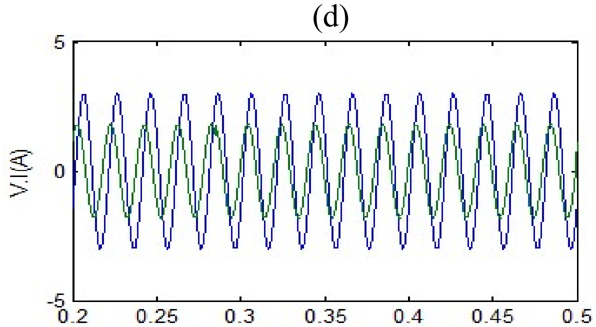
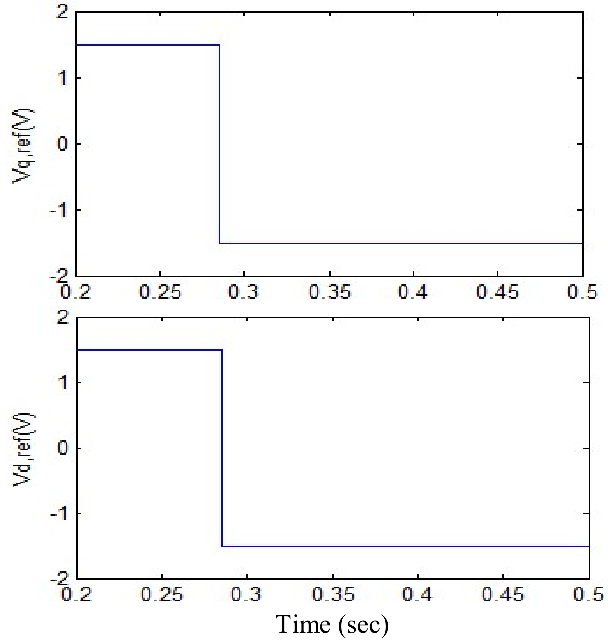


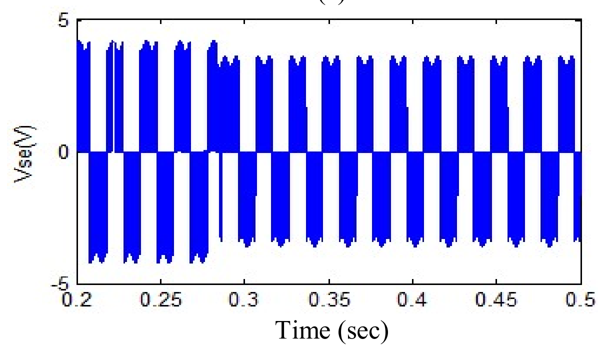
Figure 7. Step-response of DPFC: (a) ref voltages (b) series-Converter voltage (c) line-current (d) active & reactive powers (e) bus voltage and current of PI controller

The data is measured in 3 phases but only 1- phase data is progressed in computer system using MATLAB software. A LPF (low-pass filter) with 50-Hz cut-off frequency filters the measured data containing harmonic distortion in order to examine the current along with voltage at fundamental-frequency.

This filter causes a 1.5 cycle delay of calculated voltage and current to the real values thus cause of delay of measured real-power in addition to reactive-power. Fig.7.(d) shows the series-converter injecting real-power along with reactive-power at fundamental- frequency. The receiving end side waveforms are represented in fig.7 (e).



(a)



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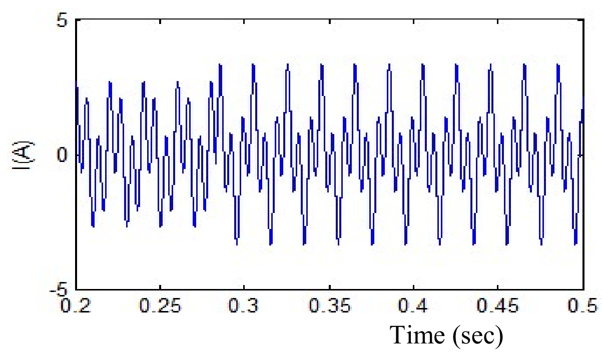

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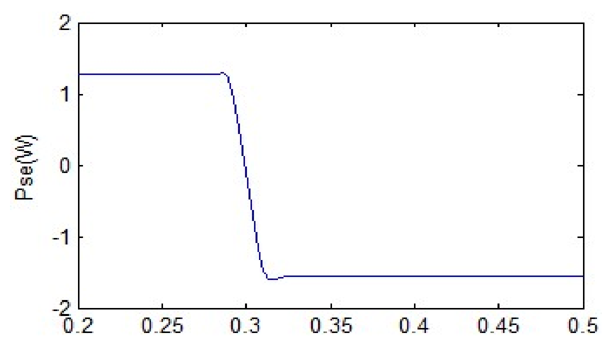
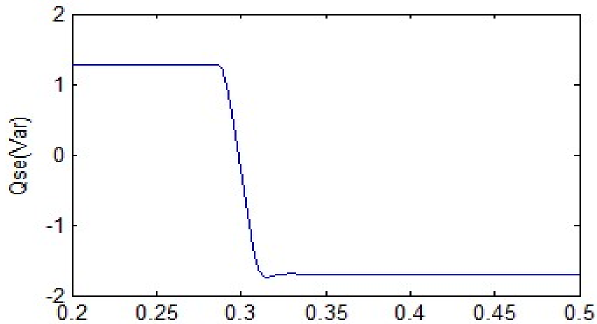
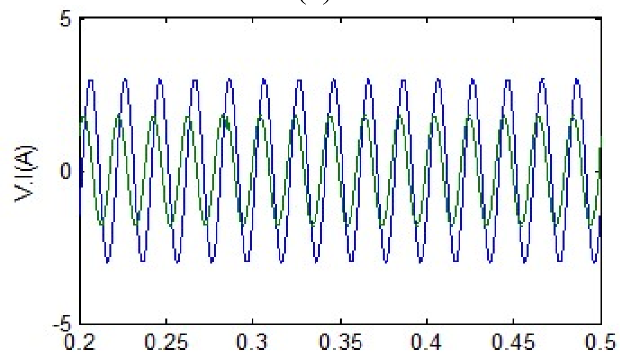




Time (sec)

(d)



Time (sec)

(d)

Figure 8. Step-response of the DPFC: (a) ref voltages (b) series converter voltage (c) line current (d) active & reactive powers (e) bus voltage and current of Fuzzy controller

Above fig.8 (a), 8(b), 8(c), 8(d), 8(e) demonstrate the step response of the DPFC using fuzzy logic controller. Here the delay of measured active and reactive power is reduced compared to PI controller.

VI. CONCLUSION

In this work a new PFCD from FACTS Family called DPFC was presented. Here using Fuzzy Logic Controllers instead of using Conventional Proportional Integral (PI) Controllers, these Fuzzy Controllers gives better response and we get accurate results compared with conventional PI Controllers. Fuzzy Controllers control the real-Power, Reactive-Power; bus Voltages along with bus currents. The D-FACTS concept is operated in the DPFC resulting in cost reduction and high reliability compared to UPFC.

REFERENCES

1. A.Johns and Y.H.Song "Flexible AC Transmission Systems" (IEE Power and Energ Series), vol.30.London, U.K: Institution of Electrical Engineers, 1999.
2. L.Gyugyi and N.G. Hingorani "Understanding FACTS : Concepts and Technology of Flexible AC Transmission Systems" New York: IEEE Press-2000.
3. C.D. Schauder, L.Gyugyi, T. R. Rietman, S. L.Williams "The unified power flow controller: Anewapproach to Power transmission control," IEEE Trans. Power Del., vol. 10, no. 2, pp. 1085– 1097, Apr. 1995.
4. A. Edris, "Proposed terms and definitions for flexible ac Transmission system (facts)" IEEE Trans. Power Del., vol. 12, no. 4, pp. 1848–1853, Oct-1997.
5. K. K. Sen, "Static Synchronous Series Compensator: Theory, modeling, and application," IEEE Trans. Power Del., vol. 13, no. 1, pp. 241–246, Jan-1998.
6. E. B. Wiliam, M. D. Depak, S. S.Roberte, T. B. Dal and R.I.Michaeel, "A distributed static series-compensator System for realizing active power flow control on existing Power lines," IEEE Trans. Power Del., vol. 22, no. 1, pp. 642–649, Jan- 2007.
7. H. Johal and D. Divan "Distributed facts-A new concept For realizing grid power flow control" in Proc. IEEE 36th Power Electron. Spec. Conf. (PESC), 2005, pp. 8–14.
8. [8] S.W de Haan, Y. Zhihui and B. Ferreira, "Utilizing Distributed power flow controller (dpfc) for power Oscillation damping," in Proc. IEEE Power Energy Soc. Gen. Meet. (PES), 2009, pp. 1–5.
9. S. de Haan,Y. Zhihui and B. Ferreira, "DPFC control during Shunt converter failure," in Proc. IEEE Energy Convers. Congr. Expo. (ECCE), 2009, pp. 2727– 2732.
10. Cheng Qiming, Hu Xiaoqing," Application of UPFC Based on improved double-loop decoupling PI control in photo-voltaic system" Internayopnal conference on Computer distributed control and intelligent Environmental monitoring" pp: 153-157, DOI: 10.1109-2012.
11. R.A Mohammad and V.G. Sardar, "UPFC online PI Controller design using particle swarm optimization Algorithm and artificial neural networks" power and Energy conferencer, PECON-2008.IEEE 2nd international Conference DOI: 10.1109
12. M.J Gibbard" Robust design of Fuzzy controllers in Power systems over a wide range of operating Conditions" IEEE Trans Power Syst 1991; 6:794–800.
13. T.Yalcinoz and U .Yolac, "Comparison of fuzzy logic and PID controllers for TCSC using MATLAB" in Proc. 2004 IEEE 39th International Universities Power Engineering Conf., UPEC-2004, Vol. I, pp. 438-442.

AUTHORS PROFILE

Dr. Raja Reddy. Duvvuru is presently working as an Assistant Professor in Department of Electrical Engineering, Malla Reddy Engineering College (Autonomous), Hyderabad. He did his Bachelors in Electrical and Electronics Engineering in JNTU Ananthapuramu and also obtained Masters Degree in Electrical Power Engineering from JNTU Ananthapuramu. He received doctoral degree from Jawaharlal Nehru Technological University Ananthapuramu, Andhra Pradesh, India. He has published more than 30 research papers in various International journals and conferences. His area of research interest includes Electrical Power Systems and Renewable Energy Systems. He is a life time member of various professional bodies like ISTE, IAENG and ISRD.

Dr. N. Rajeswaran is presently working as Professor and Head of the Department (HOD) in Electrical and Electronics Engineering at Malla Reddy Engineering College (Autonomous), Hyderabad. He did his Bachelors in Electrical and Electronics Engineering in Government College of Engineering., Bargur (Madras University) and also obtained Masters Degree in Applied Electronics from Anna University Chennai, Tamilnadu. He received doctoral degree from Jawaharlal Nehru Technological University Hyderabad, Telangana, India. He has published more than 35 research papers in various International journals and conferences. His area of research interest includes Electrical Machines, Soft Computing and VLSI Design. He is a life time member of various professionl bodies like ISTE, IAENG and IACSIT.

T.Sanjeeva Rao received the B.Tech degree in 2005, and M.Tech degree from JNTU College of Engineering, Ananthapur, A.P, India, in 2008. His having 10 years experience, currently he is working as an Associate professor in Malla Reddy Engineering College (Autonomous), Kompally, Secunderabad. His research interests include power systems, Renewable energy sources, Power quality and Electrical vehicles.