International Journal of Engineering & Technology, 7 (4.19) (2018) 445-446

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Design and Analysis of Fuzzy Controller for UPFC system

L. Udaya Kumar[1], K. C. Ramya[2*], S. Sivaranjani[3], S. Sheeba Rani[4]

[1, 3]Assistant Professor, Department of Electrical and Electronics Engineering, Sri Krishna College of Engineering and Technology, Coimbatore, Tamil Nadu, India
[2, 4]Associate Professor, Department of Electrical and Electronics Engineering, Sri Krishna College of Engineering and Technology, Coimbatore, Tamil Nadu, India
**Corresponding Author Email: ramyakc@skcet.ac.in*

Abstract

The stability and the transmission ability of a power system can be improved using a Flexible AC Transmission Systems (FACTs) devices. Amongst the various types of FACTs devices, Unified Power Flow Controller (UPFC) provides better controlover the power flow in the transmission line and also increases the stability of the system. At the same time, it also effectively suppress the low frequency oscillations by controlling the voltage and power. Hence in this work, a linearized power system with an UPFC is evaluated. This proposed fuzzy-based UPFC controller affords an effective damping control. The results obtained through simulation shows that the proposed UPFC with fuzzy controller is more effective compared to that of conventional PID controllers.

Keywords: *FACTS, UPFC, STATCOM, Control Strategy*

1. Introduction

The FACTs devices like Static Compensator (STATCOM),Unified Power Flow Controller (UPFC), and Thyristor Controlled Static Compensator (TCSC), etc. have been utilized to improve the voltage and angle stability of the system and also implemented to reduce the electromechanical oscillations occurring in power systems. Among these, UPFC is the well-known FACTS device which is appliedfor controlling power flow in the transmission systems. It can carried out by modifiable impedance, phase angle and voltage magnitude. Thus, an UPFC strategy comprises of Voltage Source Inverters/Converters (VSI/VSC) connected back to back which are identified as shunt and series converter. This is nothing but an arrangement of FACTs device, such as STATCOM (Static Synchronous Compensator) and SSSC (Static Series Synchronous Compensator) in back to back configuration. SSSC is utilized to inject the voltage in the line. While STATCOM is employed to deliver reactive power to the system. Together with the reactive power supply, it also supplies the DC power required for both the inverters [1,2].However, the UPFC should be installed such a way that it have to control both the reactive /active power and the voltage in the transmission line.

Many investigations on the techniques implemented to control the UPFC have been successfully proposed to obtain improved performance. [2],[7],[8],[9]-[11]. However, they reveal poor dynamic performance under the heavy load condition and during the occurrence of sag/swell occurs in the transmission line. Moreover, the designing of conventional controllers require mathematical models of the transmission system which are challenging one to obtain.

Hence in order overcome the above said problems, artificial intelligent controls such as fuzzy logic has been developed as an alternative to the conventional control methods.

Hence in this work, a new fuzzy approach is proposed to design a UPFC controller. This in turn controls the power flow a transmission system. Thus the proposed controller is more suitable for practical implementation. The following fragments of this work are organized as follows. In Section 2, design of an UPFC is defined. The design of the fuzzy controller is proposed in Section 3. In Section 4, the results obtained through simulation are discussed. Finally, in the last section, concluding observations are signified.

2. Unified Power Flow Converter

Figure 1 illustrates a schematic representation of a UPFC system, An UPFC comprises of a back to back connected VSCs interconnected via a mutual DC-link, A series VSC is attached to the AC network by means of a series transformer. Similarly, the shunt converter is combined by way of a shunt transformer.

An UPFC has the capability to maintain the stability of the transmission line by regulating the factors such as the reactance of a line, voltage in the bus and also by modifying the phase angle difference between the two buses. This voltage regulation can be carried out by controlling quadrature voltage, controlling in-phase voltage and through shunt compensation. The adoption of these methods will results in enhanced reduction of damping present in the power system [3].

A main role of an UPFC in transmission line is to regulate both the reactive and real power flow by introducing a series voltage to the line voltage.

Thus to achieve this control over power flow, both the phase angle and the voltage on the line is altered individually. Fig.1 illustrates the schematic representation of the 3 phase UPFC system connected with the transmission line.

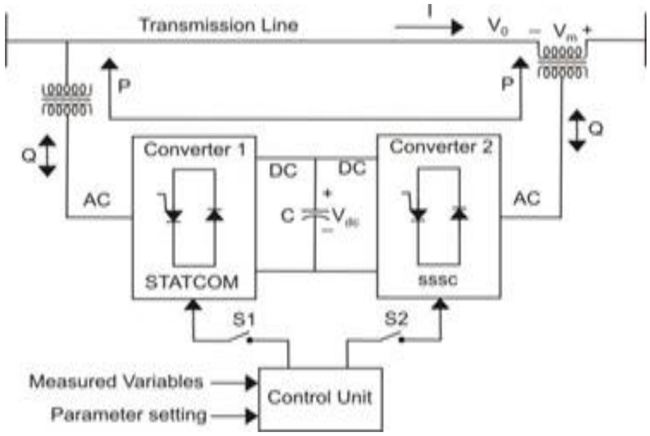

Fig. 1: Schematic of UPFC

3. Control Strategy Adopted for UPFC

3.1. DC Voltage Controller (DC)

When real power present in the line is communicated to the far-off end user by means of SSSC, there will be a fall in voltage level of the DC link capacitor voltage. Hence in order to retain this DC voltage at a constant value, nevertheless of a real power flow through SSSC, a controller is implemented. The main task of the controller is to maintain a voltage at a constant value and is achieved by monitoring the actual Vdc across the capacitor. The controller compares the actual value with the set value. The difference between these two values is fed as input of the controller. Then, the output obtained from the controller acts as a reference current for the real current which is taken by the STATCOM. Hence during the transfer the real power, a Direct Component of current plays a vital role. Hence, the output of the voltage controller is considered as reference direct component. At the same time, the reference q component is considered as zero.

Then, these obtained reference quantities are matched with the physical Iq and Id values using a cross coupled controller. Using the output obtained from the cross coupled controller, the Vabc reference is generated. The Vabc is the three phase reference activates the pulse generating unit of the STATCOM. For this controller action, fuzzy controller is implemented.

3.1.1. Design of fuzzy controller

The design of fuzzy logic controller is described as follows

- For each input and output variables, 7 fuzzy sets (NBI, NME, NSS, ZE, PSS, PME, PBI) are designed.
- Triangular membership function is utilized.
- Implication is done using Mamdani-type min-operator
- Defuzzification carried with the centroid method.

Thus the membership functions designed for fuzzy values are represented in Fig.2 to Fig.4.

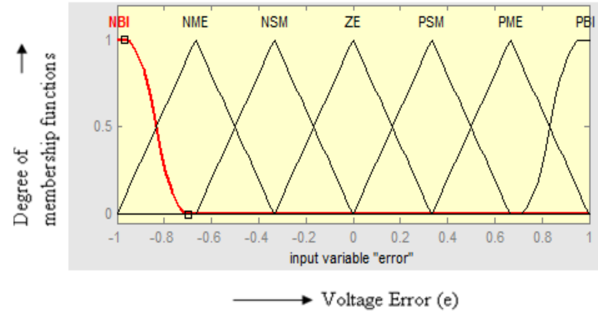

Fig. 2: Representation of Membership functions for input1

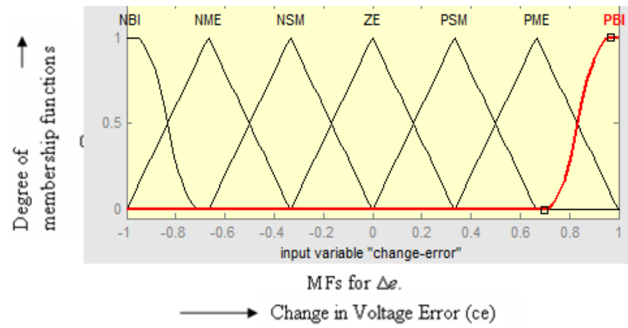

Fig. 3: Representation of Membership functions for input2

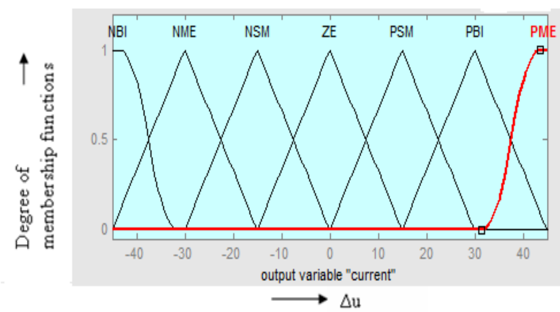

Fig. 4: Representation of Membership functions Membership functions for output

The 49 Rule base formulated using the membership functions are depicted in Table 1.

Table 1: Rule base formulated for the deliberated fuzzy controller

Δe/e	**NBI**	**NME**	**NSM**	**ZE**	**PSM**	**PM**	**PBI**
NBI	NBI	NBI	NBI	NME	NME	NSM	ZE
NME	NBI	NBI	NME	NSM	NSM	ZE	PSM
NSM	NBI	NME	NSM	NSM	ZE	PSM	PM
ZE	NME	NSM	NSM	ZE	PSM	PS	PM
PSM	NME	NSM	ZE	PSM	PSM	PME	PBI
PME	NSM	ZE	PSM	PSM	PM	PBI	PBI
PBI	ZE	PSM	PME	PME	PBI	PBI	PBI

4. Results and Discussion

The effective performance of the designed UPFC with fuzzy controller for is valued through MATLAB simulations. The proposed controller can be applied to a UPFC connected between any two buses of the power system irrespective of the interaction of these two buses. From the simulation results, it is proven that the proposed system designed with UPFC reveals an enhanced performance, in terms of maintaining constant DC link voltage, effective power flow and a regulated AC voltage profile. Thus the

Simulink model and output of the UPFC at various locations are displayed in the Figure 5 to Figure 10.

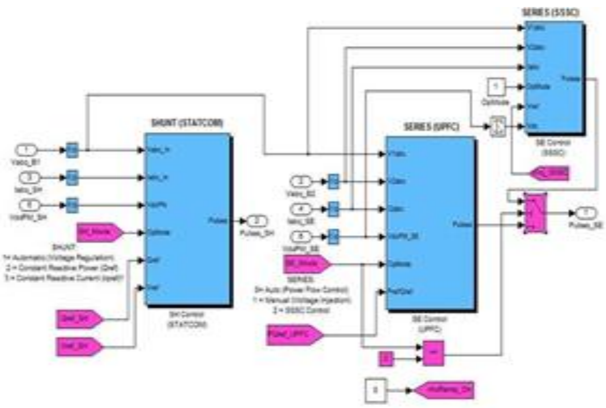

Fig. 5: Simulation diagram of the STATCOM present in the proposed UPFC

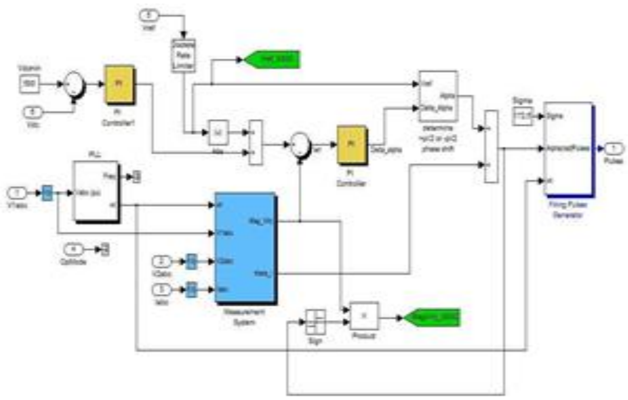

Fig.6: Simulation diagram of the SSSC present in the proposed UPFC

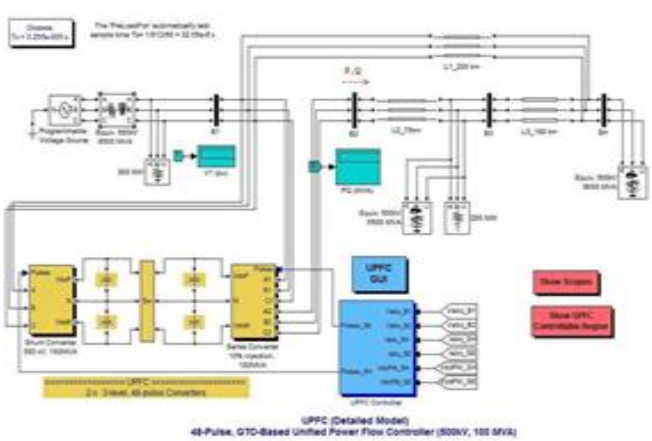

Fig.7: Overall simulation of the designed UPFC

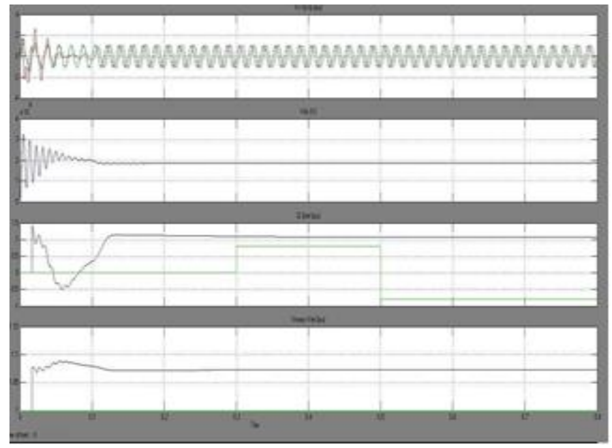

Fig. 8: STATCOM with Fuzzy controller

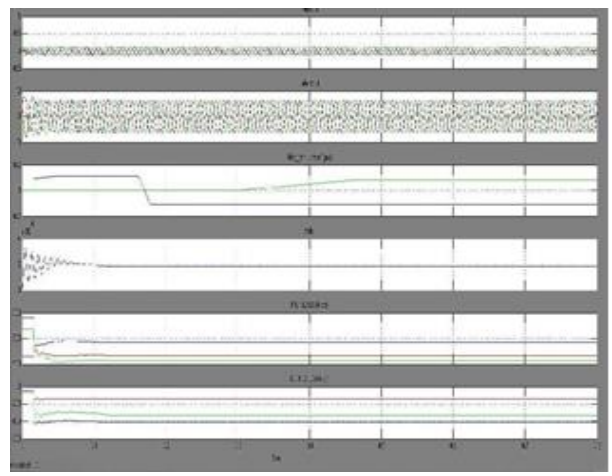

Fig. 9: SSSC with fuzzy controller

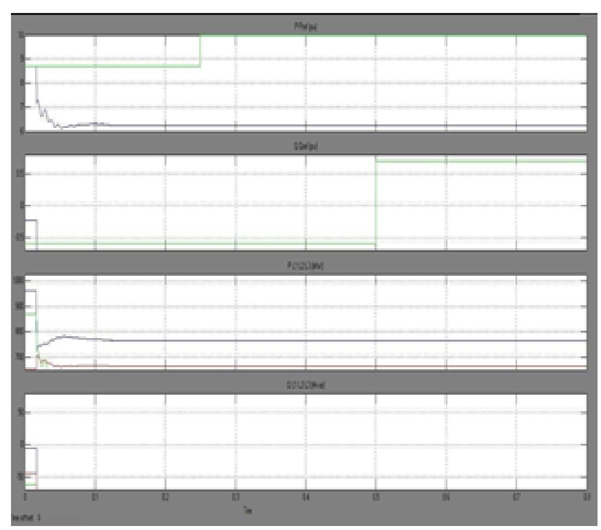

Fig. 10: UPFC with fuzzy controller

From the simulation results, it is proven that the modeled transmission system with UPFC reveals an enhanced performance in terms of DC link voltage, AC voltage profile and power flow.

Table 2: A Comparative study of Dynamic Performance of UPFC with various controllers

Parameters	PID Controller	Fuzzy Controller
Peak Overshoot	19V	129V
Settling time	4 milliseconds	2 milliseconds
Steady state error	0.4V	0.23V

From the above comparison, it could be concluded that the Fuzzy controller reveals superior performance in relation to settling time, peak overshoot/ steady state error. Hence the Fuzzy controller based UPFC system quickly directs the system to its steady state condition and also enhances the transient stability of the power system comparatively than the conventional PI controller.

5. Conclusion

In this proposed work, a fuzzy controller has been implemented to control a UPFC, which in turn controls the voltage, power flow and DC voltage regulation of a transmission system. Thus the proposed control is robust and does not need any information regarding the mathematical model of the system. Thus, the performance of the proposed controller has been evaluated through simulations and is compared with a conventional controller. From the results obtained, it is concluded that the proposed system exhibits the improved dynamic control of UPFC system.

References

[1] Padiyar.K.R.Kulakarni, A.M, Control Design and Flow Controller, IEEE Simulation of Unified Power Delivery, 13(4), (1998), pp.1348.1354.
[2] L.Gyugyi,C.D.Schauder,S.L. Williams, T.R. Rietman, D.R. Torgerson, A.Edris,. The Unified Power Flow Controller: A New Approach to Power Transmission Control, IEEE Trans. on Power Delivery, 10(2), (1995), pp. 1085-1097.
[3] L.Gyugyi,. Unified Power Flow Concept for Flexible AC Transmission Systems, IEEE Proc-c, 139(4), (1992), pp-323-332.
[4] C. Schauder and H.Mehta, Vector Analysis and Control of Advanced Static Var Compensator,IEEE Proc-c, 140(4), (1993),pp-299-306.
[5] H.Fujita.Y.Watnabe, H. Akagi,, Control and Analysis of a Unified Power Flow Controller, IEEE Trans. on Power Electronics, 14(6), (1999).
[6] I.Papic, P.Zunko, D.Povh, M.Weinhold. Basic Controller,IEEE Control of Unified Power Flow Transactions on Power Systems,12(4), (1997).
[7] K.R.Padiyar, K.UmaRao. Modeling and Controller for Transient Control of Unified Power Flow Stability,A Journal on Electrical Power and Systems, 21, (1999) pp.1-11.
[8] SanbaoZherga and Yoke Lin Tan. Dynamic Character Study of UPFC Based on Detailed Simulation Model, IEEE Power conference 2000.
[9] D.Povh, R.Mihalic, I.papic, FACTS equipment for Load Flow Control in High Voltage Systems, Ci-gre Symposium, Power Electronics in Power Systems, Tokyo, (1995)..
[10] R.Mihalic, P.Zunko, D. Povh, Modelling of Unified Power Flow Controller and its impact on Power Oscillation damping, Cigre Symposium, Power Electronics in Power Systems, Tokyo, (1995).
[11] K.R.Padiyar and K. Uma Rao, “A Control Scheme for U nified Power Flow Controller to improve Stability of Power Systems”, Ninth National Power Systems Conference, Kanpur, India, (1996).
[12] K.R.Padiyar, Power Sstem Dynamics- Stability and Control, John Wiley and Sons (SEA) Pte Ltd, Singapore, (1996).
[13] Loren H. Walker, 10-MW GTO Converter for Battery Peaking Service, IEEE Trans. on Industry Applications, 1(1),(1990), pp-63-72.