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Fuzzy Logic Based Wind Connected UPFC to Mitigate Voltage Sag and Reactive Power Compensation in a Transmission System

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Abstract: Power flow is one of the major problems in a transmission system. When a fault occurs in a transmission system there is said to be a drop in the voltage. Voltage sag is one of the most severe problems to be dealt with as it causes severe process disruptions and results in substantial economic loss. Decrease/increase of reactive power is also one of the main problem. FACTS devices are used to control the power flow to increase the transmission capacity and to optimize the stability of the power system. One of the most widely used FACTS devices is Unified Power Flow Controller (UPFC). Here, the sending end voltage is generated by the wind generation system. In this study, researchers are comparing two different controller's performance. The two controllers are PI and Fuzzy. On comparing, researchers can say that Fuzzy Logic Controller (FLC) based UPFC shown better voltage sag compensation than PI controller based UPFC. Matlab/Simulink is used to create the PI and FLC and to simulate UPFC Model.

Key words: FACTS, fuzzy logic controller, UPFC, capacity, voltage, India

INTRODUCTION

The growth of the power systems in the future will rely on increasing the capability of existing transmission systems rather than building the new transmission lines and the power stations for an economical and an environmental reasons.

The requirement of the new power flow controllers which is capable of increasing the transmission capability and controlling the power flow through the predefined corridors will certainly increase due to the deregulation of the electricity markets.

Additionally, these new controllers must be control the voltage levels and the flow of the real/ reactive power in the transmission line to use full capability of the system in some cases with no reduction in the system stability and security margins (Uzunovic *et al*., 1999).

In the late 1980s, the Electric Power Research Institute (EPRI) introduced a new approach to solve the problem of designing and operating power systems; the proposed concept is known as Flexible AC Transmission Systems (FACTS).

The two main objectives of FACTS are to increase the transmission capacity and control power flow over designated transmission routes.

MATERIALS AND METHODS

Wind turbine model: A wind turbine is a device that converts kinetic energy from the wind into mechanical energy. If the mechanical energy is used to produce electricity, the device may be called a wind generator or wind charger. The mechanical power output of a wind turbine is related to the wind speed by:

$$P_m = \frac{1}{2}\rho A.C_P(\lambda,\beta).V_\omega^3 \quad (1)$$

Where:

- ρ = The air density
- A = The swept area by the turbine blades
- Cp = The power coefficient is a function of both tip speed ratio λ and the blade pitch angle β
- λ = The tip speed ratio of linear speed at the tip of blades to the speed of wind is expressed as:

$$\lambda = \frac{\Omega R}{V_\omega} \quad (2)$$

Where R and Ω are the radius and the mechanical angular velocity, respectively of the wind turbine rotor. Expressions of C_p as a function of λ and β employed are:

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$$C_p(\lambda,\beta) = 0.5176\left(\frac{116}{\lambda_i} - 0.4\beta - 5\right)e^{\frac{-21}{\lambda_i}} + 0.0068\lambda$$
$$\frac{1}{\lambda_i} = \frac{1}{\lambda + 0.08\beta} - \frac{0.035}{\beta^3 + 1} \quad (3)$$

Unfied power flow controller: The UPFC is a device which can control simultaneously all three parameters of line power flow (line impedance, voltage and phase angle). It consists of two other FACTS devices: the Static Synchronous Compensator (STATCOM) and the Static Synchronous Series Compensator (SSSC). The UPFC is the combination of two voltage source converters; one converter is connected to the power system through a shunt transformer whereas the other converter is inserted into the transmission line through a series transformer (Hingorani and Gyugyi, 2000). The converters are connected to each other by a common dc link including a storage capacitor.

The shunt inverter is used for voltage regulation at the point of connection injecting an opportune reactive power flow into the line and to balance the real power flow exchanged between the series inverter and the transmission line. The series inverter can be used to control the real and reactive line power flow inserting an opportune voltage with controllable magnitude and phase in series with the transmission line. The basic UPFC structure is shown in Fig. 1.

Operating in modes of UPFC: The UPFC has many possible operating modes. In particular, the shunt inverter is operating in such a way to inject a controllable current, ish into the transmission line. The shunt inverter can be controlled in two different modes (Gupta, 2010).

VAR control mode: The reference input is an inductive or capacitive VAR request. The shunt inverter control translates the var reference into a corresponding shunt current request and adjusts gating of the inverter to establish the desired current. For this mode of control a feedback signal representing the dc bus voltage, V_{dc} is also required.

Automatic voltage control mode: The shunt inverter reactive current is automatically regulated to maintain the transmission line voltage at the point of connection to a reference value.

For this mode of control, voltage feedback signals are obtained from the sending end bus feeding the shunt coupling transformer. The series inverter controls the magnitude and angle of the voltage injected in series with the line to influence the power flow on the line. The actual value of the injected voltage can be obtained in several ways.

Direct voltage injection mode: The reference inputs are directly the magnitude and phase angle of the series voltage.

Phase angle shifter emulation mode: The reference input is phase displacement between the sending end voltage and the receiving end voltage.

Line impedance emulation mode: The reference input is an impedance value to insert in series with the line impedance.

Automatic power flow control mode: The reference inputs are values of P and Q to maintain on the transmission line despite system changes.

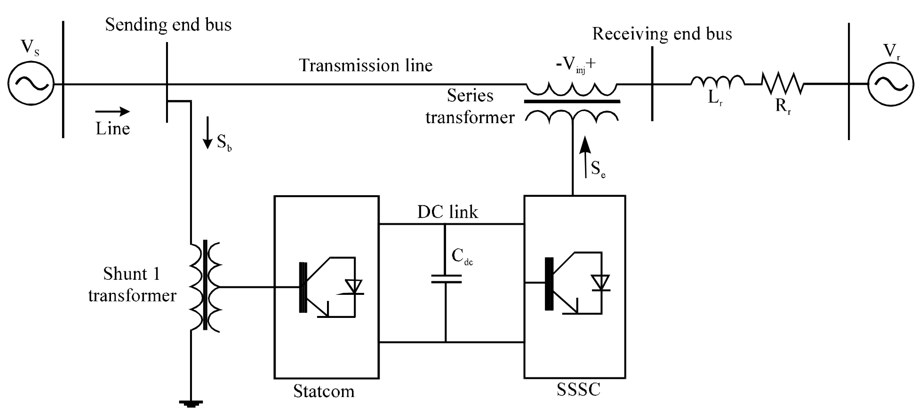

Fig.1: Basic structure of UPFC

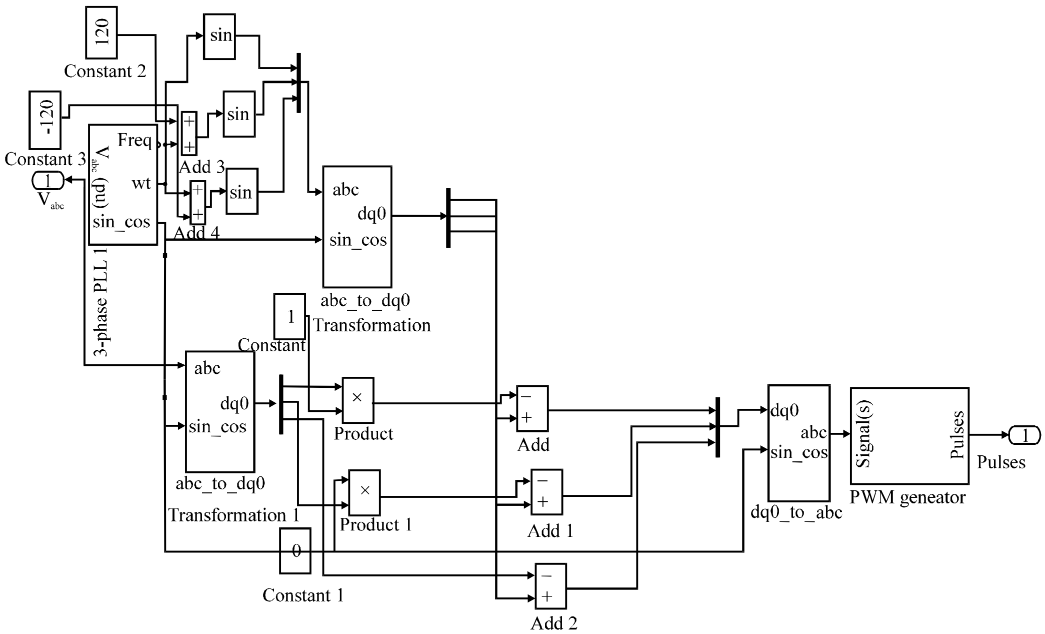

Fig. 2: Simulink model of a series controller

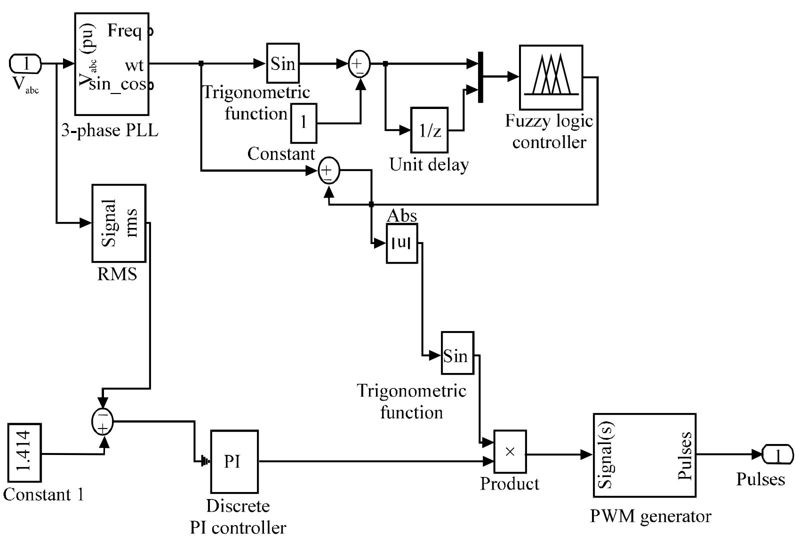

Fig. 3: Simulink model of a shunt controller

Series and shunt controller design: The Simulink Model of the series controller is shown Fig. 2. The Simulink Model of the shunt controller is shown in Fig. 3.

Design of fuzzy logic controller: Fuzzy Logic (FL) controller is one of the most successful operations of fuzzy set theory; its major features are the use of linguistic variables rather than numerical variables. This control technique relies on human capability to understand the systems behavior and is based on quality control rules. Fuzzy logic provides a simple way to arrive at a definite conclusion based upon vague, ambiguous, imprecise, noisy or missing input information. FLC are formed by simple rule based on if x and y then z. These rules are defined by taking help from person's experience and knowledge about the system behaviour.

The performance of the system is improved by the correct combinations of these rules. Each of the rules defines one membership which is the function of FLC (Saribulut *et al*., 2008; Lu-Sheng *et al*., 2007).

The general structure of an FLC is shown in Fig. 4 and comprises of 4 principal components:

- A fuzzyfication interface which converts input data into suitable linguistic values
- A knowledge base which consists of a data base with the necessary linguistic definitions and control rule set
- A decision making logic which simulating a human decision process, infers the fuzzy control action from the knowledge of the control rules and the linguistic variable definitions
- A defuzzyfication interface which yields a nonfuzzy control action from an inferred fuzzy control action

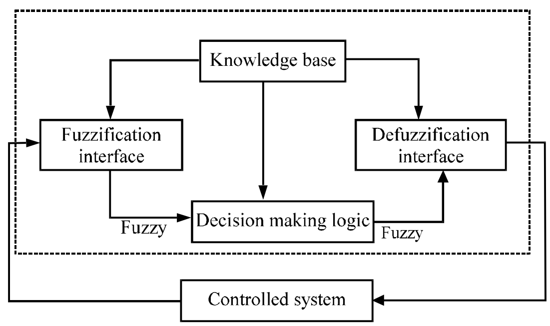

Fig. 4: Basic structure of FL controller

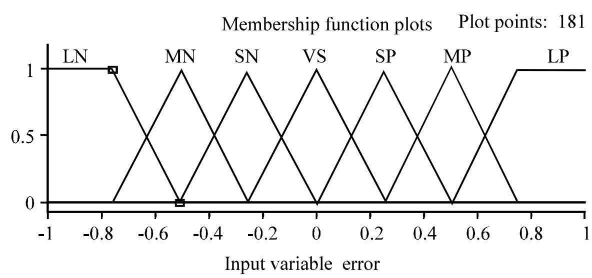

Fig. 5: Error and error rate of fuzzy membership

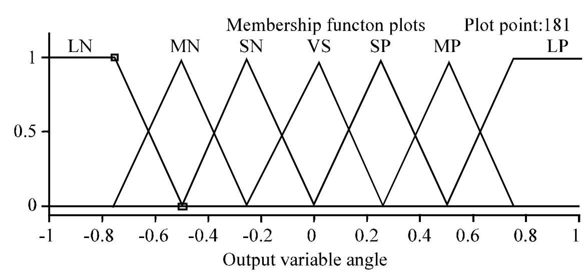

Fig. 6: Error and error rate of fuzzy membership functions

Table 1: Rule base

Error rate/error	LP	MP	SP	VS	SN	MN	LN
LP	PB	PB	PB	PM	PM	PS	Z
MP	PB	PB	PM	PM	PS	Z	NS
SP	PB	PM	PM	PS	Z	NS	NM
VS	PM	PM	PS	Z	NS	NM	NM
SN	PM	PS	Z	NS	NM	NM	NB
MN	PS	Z	NS	NM	NM	NB	NB
LN	Z	NS	NM	NM	NB	NB	NB

The inputs to the fuzzy logic controller are error and the error rate and the output is the angle (Fig. 5). The membership function for this is shown in Fig. 6. The rule table for this is shown in Table 1.

RESULTS AND DISCUSSION

Simulation studies are carried out to analyze the performance of UPFC for voltage sag conditions in a transmission system. Here researchers consider a transmission system with a voltage of 440 V and 50 Hz. A 3-phase fault with fault resistance of 0.001 Ω is said to be introduced into the system.

Due to this voltage, sag is introduced into the system for a period of 0.3-0.6 sec. The voltage sag is said to be compensated in the transmission line using UPFC with PI controller and fuzzy logic controller. For this 3 types of connections are taken:

- Without controller (Fig. 7)
- UPFC with PI controller (Fig. 8)
- UPFC with fuzzy controller (Fig. 9)

Complete simulink diagram: The complete simulink diagram of the system is shown in Fig. 10.

Comparison: Comparison of voltage magnitude in per unit with UPFC using conventional PI controller and fuzzy logic controller is shown in Table 2.

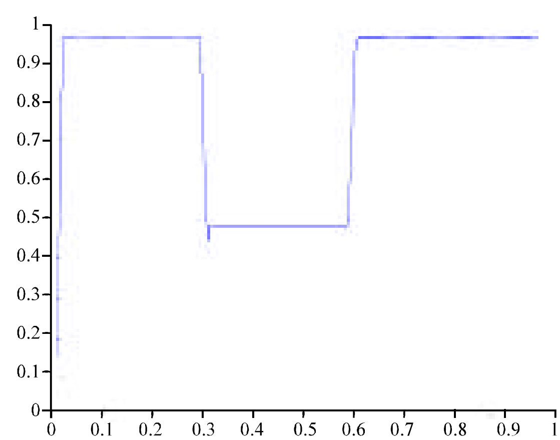

Fig. 7: Voltage sag of the system without controller

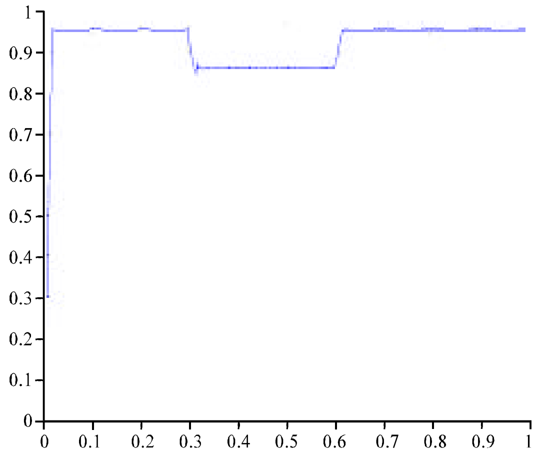

Fig. 8: Voltage sag compensation by using PI controller

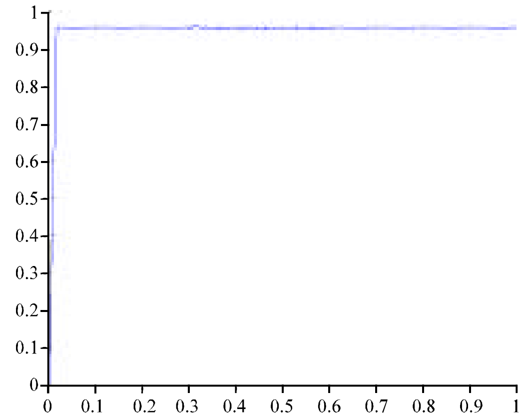

Fig. 9: Voltage sag compensation by using fuzzy controller

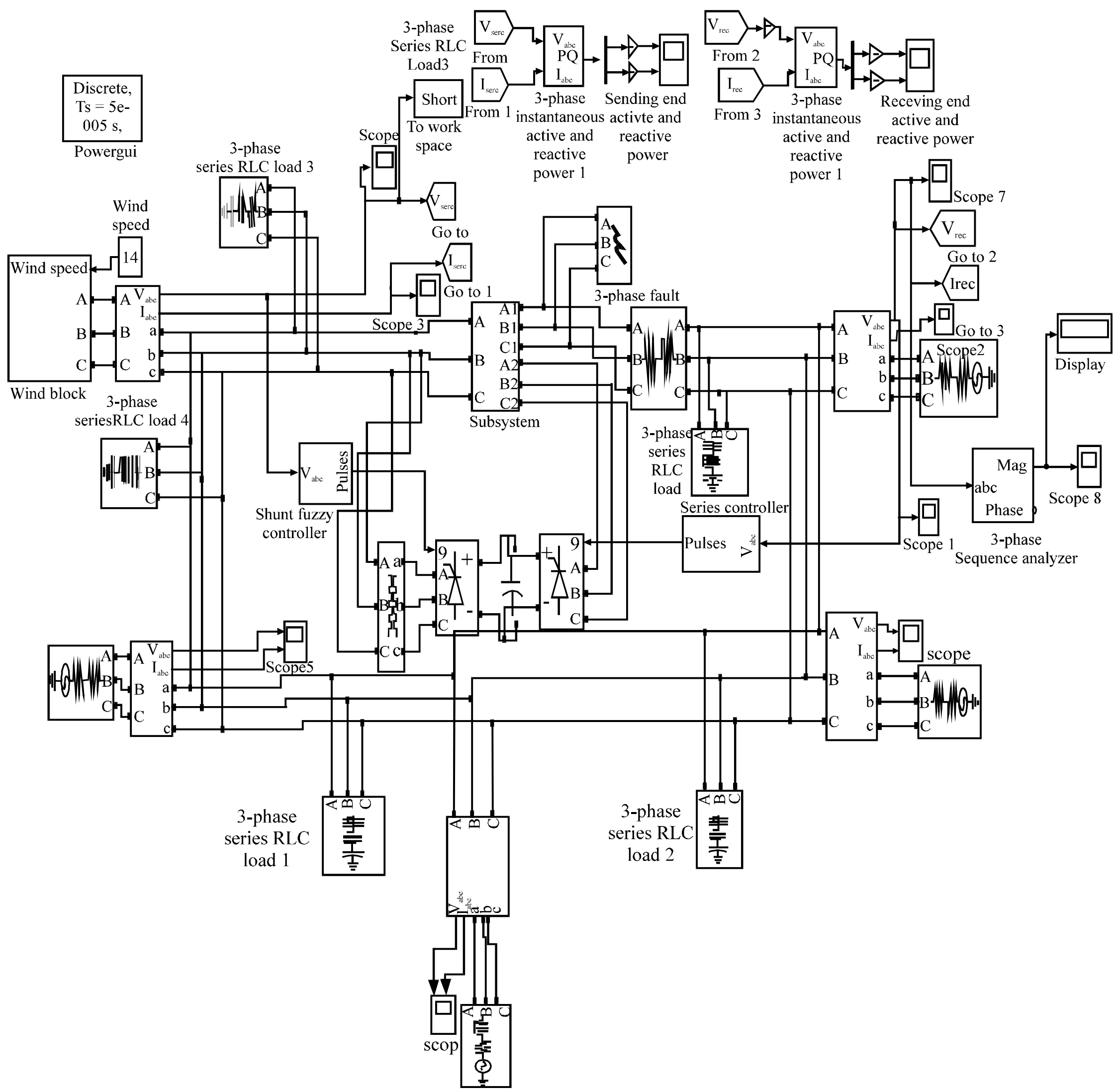

Fig. 10: Simulink diagram of the system with UPFC and FLC

Table 2: Comparison of PI and FL controller for UPFC

Conditions	Vrms (pu)
Transmission system with fault	0.4860
Transmission system with UPFC using PI controller	0.8610
Transmission system with UPFC using fuzzy logic controller	0.9548

CONCLUSION

In this study, the performance of UPFC on compensating the voltage sag in the line is examined with two control mechanisms, i.e., with PI and fuzzy controllers. In this study, 3-phase fault is applied to the test system. Results are taken by using two controllers.

According to the results researchers can say that the UPFC with fuzzy controller shown better voltage sag compensation than UPFC with PI controller.

REFERENCES

Gupta, V., 2010. Study and effects of UPFC and its control system for power flow control and voltage injection in a power system. Int. J. Eng. Sci. Technol., 2: 2558-2566.

Hingorani, N.G. and L. Gyugyi, 2000. Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems. IEEE Press, Piscataway.

Lu-Sheng, G. W. Yu-Lin and L. Sheng, 2007. Research on flexible power supply system for Arc furnace based on UPFC. Proceedings of 2nd IEEE Conference on Industrial Electronics and Applications, May 23-25, 2007, Harbin, pp: 227-230.

Saribulut, L., M. Tumay and I. Eker, 2008. Performance analysis of fuzzy logic based unified power flow controller. World Acad. Sci. Eng. Technol., 45: 320-325.

Uzunovic, E., C.A. Canizares and J. Reeve, 1999. EMTP studies of UPFC power oscillation damping. Proceedings of the North American Power Symposium (NAPS), October, 1999, San Luis Obispo, California, pp: 405-410.