Transmission Congestion and voltage profile management in long transmission Lines using UPFC with Fuzzy Logic Controller

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Abstract: Modern power systems having many challenges because load on system will not be constant ever and more over it could always subjected to contingencies which are undesirable. Due to the development in advanced power electronics and their control schemes flexible AC transmission system (FACTS) technology has been introduced. These devices used with modern power electronics components for simple and easy controlling these type controllers provides excellent performance and better solution for AC power system from power quality and contingency problems such as line outage, generator outage, system blackouts congestion problems ect. Even though there several types of FACTS controllers are presented but there is better performance, reliable device even under big contingencies it gives better performance is (UPFC) unified power flow controller having more advantages over conventional types such as synchronous compensators (STATCOMs),Thyristor controlled series compensators (TCSCs), Static series synchronous compensators (SSSCs) and Static VAR compensators (SVCs), such a device can able to control voltage, line reactance, phase angle at particular bus in a system. The (UPFC) is the most versatile and dynamic complex power electronic device that has emerged for the control and optimization of real and reactive power flow in electrical power long transmission lines. In this paper we have shown that UPFC performance for increases the transmission power transfer capacity and reduce the power congestion problem in the transmission lines. Final results obtained through MATLAB-Simulink tool box.

Key Words: FACTS, UPFC, AC Transmission System, Power Flow Control, Congestion, STATCOM, SSSC.

I.INTRODUCTION

Modern power system is a complex dynamic inter connecting network, where large number of generating stations and their loads are connected to gather by means long over head power transmission lines and finally in contact with distribution networks. The unified power flow controller (UPFC) is the most advanced dynamic power electronic based device which is widely used FACTs controller used for obtaining the solution from various power system contingencies. Main advantage for the use of UPFC is a single device cans able control the voltage, phase angle and impedance of the line in power system there by reduction of the line reactance as well as controlling the real power flow in the transmission line. The basic elements of the UPFC having two voltage source converters (VSCs) are connected by a common dc storage capacitor which is connected to the power transmission system through coupling transformers at both ends. One (VSC) must be connected in shunt in the transmission system through a shunt connected coupling transformer, while the other (VSC) must be connected in series with power transmission system through a series coupling transformer. Three phase system voltages with controllable magnitude and phase angle (V_C) are inserted in series with the power transmission line in order to control both active and reactive power in the transmission system. Such that, inverter will output used to exchange active and reactive powers within the line. The shunt inverter is operated in such a way that demand of dc terminal power (positive or negative) from the line keeping the voltage across the storage capacitor (V_{dc}) will be maintained constant. So, the net real power absorbed from the line by the UPFC must equal to the losses of the inverters and the transformers. The remaining capacity of the shunt inverter can be used to exchange reactive power in the transmission line so to provide better voltage regulation at the connection point. These two VSC should work independently from each other by separation of dc side. So in that case, the shunt connected VSC operates as a (STATCOM) that generates or absorbs reactive power to regulate the voltage magnitude at the connection point. The series inverter is operating as (SSSC) that generates or can able to absorb and generate the reactive power to regulate the current flowing in the transmission line and hence regulate the power flows in the transmission line. The UPFC has many possible operating modes. (1) VAR control mode: The reference input is a simple VAR request that is maintained by the control system regardless of bus voltage variation. (2) 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 with a defined slope characteristics the slope factor defines the per unit voltage error per unit of inverter reactive currents are within the current range of the inverter. In Particular, the shunt inverter is operating in such a way to inject a controllable current into the transmission line. The fig.1 shows how the (UPFC) is connected to the transmission line.

2. Modeling of UPFC

The UPFC, shown in FIG-1 which consists of two switching converters operated from a single common mode DC link. VSC-2 used to performs the main function of the UPFC by injecting an AC voltage with proper controllable magnitude and phase angle in series with the transmission line. The basic function of VSC-1 used to generate or absorb the active power demanded by VSC-2 at common DC link. Converter-1 can also generate or absorb controllable reactive power and provide independent shunt reactive compensation in the transmission line. This is represented by the current. A UPFC can regulate active power and reactive powers simultaneously. In principle, a UPFC can perform voltage support, voltage stability, power flow control and dynamic stability improvements with help of device.

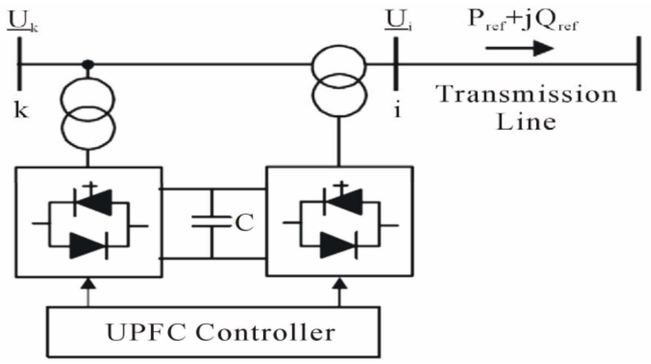

Fig 1. Schematic Diagram of UPFC

Fig.2 shows that Single line diagram of a 500kv/230kv transmission line with UPFC. The power flow in a 500 kV /230 kV transmission systems is shown in single line system is connected in as loop configuration, consists of five busses i.e (B1 to B5) interconnected through three transmission lines such as (L1, L2, L3) and two 500 kV/230 kV transformer banks Tr-1 and Tr-2. Two power plants located on the 230 kV system can able to generate a total of 1500 MW which is transmitted to a 500 kV, 15000 MVA equivalent and to a 200 MW load connected at bus B3. Each plant model includes speed governors, an excitation system as well as a power system stabilizer (PSS). In normal operation, most of the 1200 MW generating capacity power plant P1 is exported to the 500 kV equivalents through two 400 MVA transformer connected between buses B4 and B5.

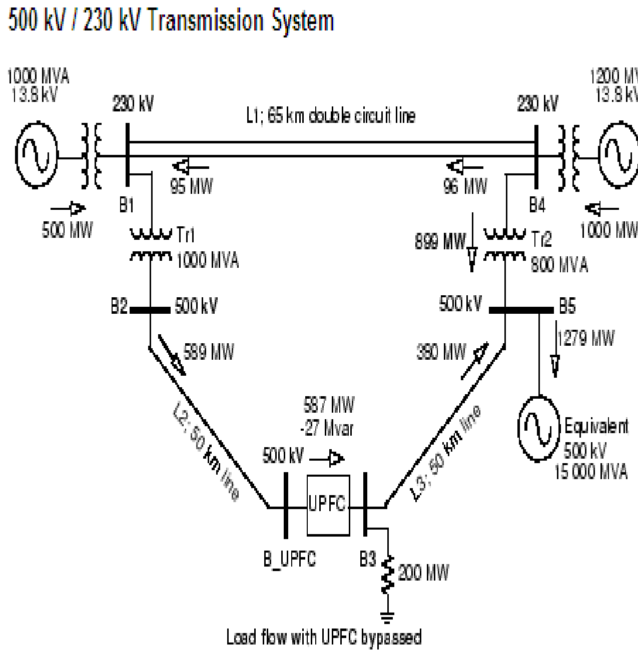

Fig.2.Single line diagram of a 500kv/230kv inter connected transmission system using UPFC.

UPFC is connected at the right end of line L-2 is used to regulate both active and reactive powers at the 500kv bus B3 the UPFC used here include two 100 MVA, IGBT based converters (one series converter and one shunt converter) both the converter are interconnected through a DC bus two VSCs connected by a capacitor charged to a DC voltage realize the UPFC the converter number one which is a shunt converter draws real power from the source and exchange it (minus the losses) to the series connected VSCs can be used for power balance between the shunt and series connected VSCs maintained to keep the voltage across the DC link capacitor must be constant. The single line diagram is implemented on MATLAB Simulink. The series VSC is rated 100MVA with a maximum voltage injection of 0.1pu the shunt VSC also rated at 100MVA the shunt VSC is operated in voltage control mode and the series converter is operated in power flow control mode the series converter can inject a maximum of 10% of nominal line to ground voltage. The real and reactive power equations are as follows:

$$P = \frac{V_1 V_2}{X} \sin(\delta_1 - \delta_2)$$

$$Q = \frac{V_2}{X}(V_1 - V_2)$$

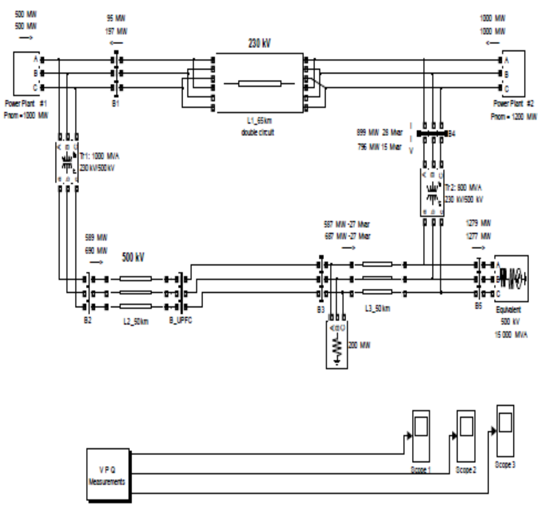

Fig.3.1.MATLAB Simulink model of single line diagram transmission system with UPFC

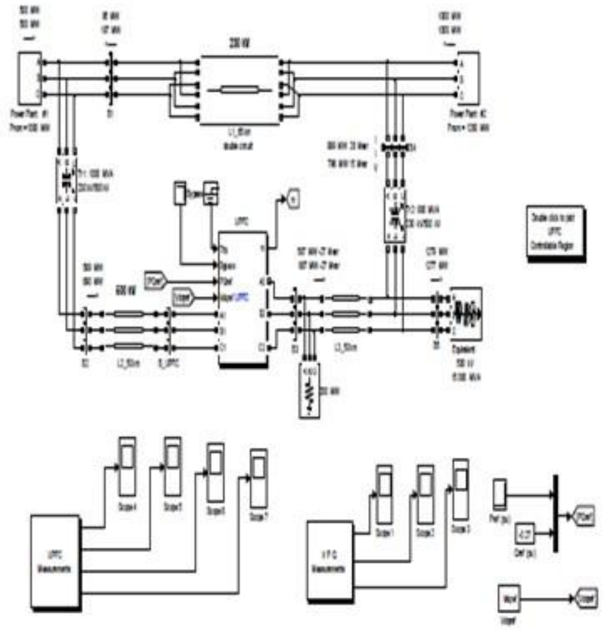

Fig.4.1.MATLAB Simulink model of transmission system without UPFC

Series injected voltage in pu by (VSCs) connected in series at different location in to transmission system Through a series coupling transformer without using UPFC as shown in Fig.4.

Note: X-axis represents time in seconds and Y-axis represents series injected voltage in p.u For both with UPFC and without UPFC.

3. CONSTRUCTION OF FUZZY CONTROLLER

The control scheme consists of Fuzzy controller, limiter, and three phase sine wave generator for reference current generation and generation of switching signals. The peak value of reference currents is estimated by regulating the DC link voltage. The actual capacitor voltage is compared with a set reference value. The error signal is then processed through a Fuzzy controller, which contributes to zero steady error in tracking the reference current signal.

A fuzzy controller converts a linguistic control strategy into an automatic control strategy, and fuzzy rules are constructed either by expert experience or with a knowledge database. Firstly, the input Error 'E' and the change in Error 'ΔE' have been placed with the angular velocity to be used as the input variables of the fuzzy logic controller. Then the output variable of the fuzzy logic controller is presented by the control Current I-max.

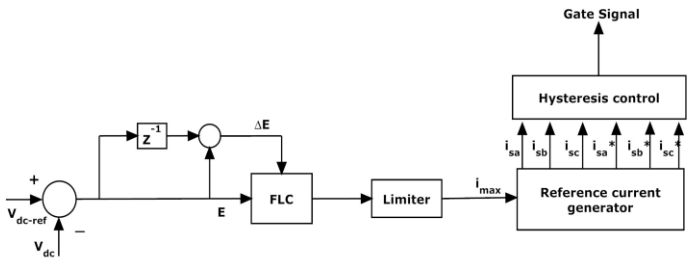

Fig3.2: Conventional fuzzy controller

To convert these numerical variables into linguistic variables, the following seven fuzzy levels or sets are chosen: NB (negative big), NM (negative medium), NS (negative small), ZE (zero), PS (positive small), PM (positive medium), and PB (positive big), as can be seen in Fig.3.14.

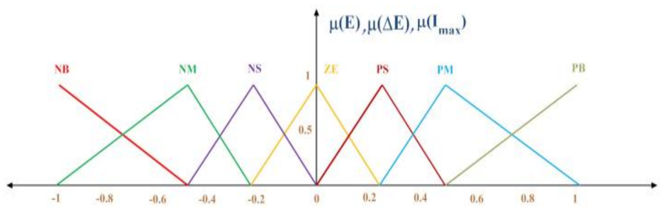

Fig 3.3: Membership functions for Input, Change in input, Output

4. Modified IEEE 5-Bus System with Congestion:

As it can be seen in **Figure 3.4**, under normal condition, maximum real power is transferred through line 2-1 by amount of 88% of the permissible line capacity. Voltage profile of modified IEEE 5-bus system is shown in

Figure 4.1, where at bus 5 the magnitude of bus voltage is 0.747 p.u. Congestion can be taken into account if real power transfer increases 80% of the line thermal capacity By considering congestion condition, it can be said that from congestion point of view there is no security violation while from voltage profile point of view this system needed to be compensated.

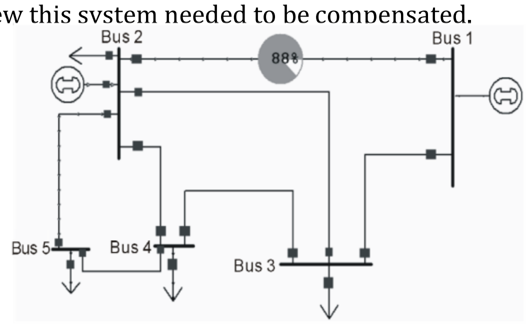

Fig:3.4: Modified IEEE 5- Bus system with congestion.

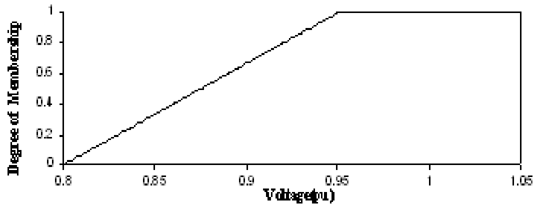

Figure 5. Membership of bus voltages.

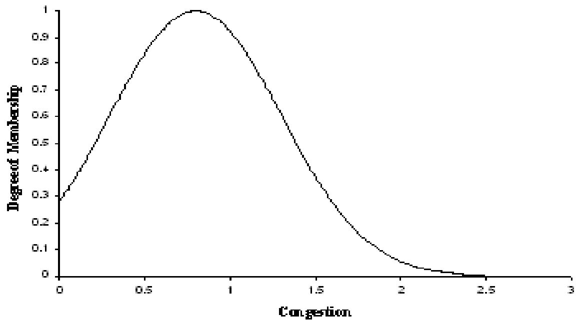

Figure 6. Membership of congestion value.

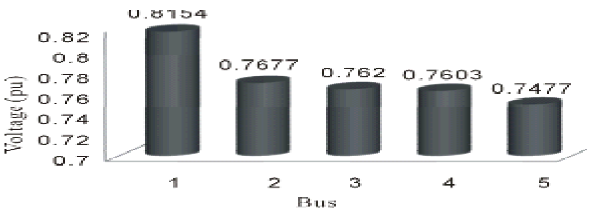

Figure 4. Buses voltage profile.

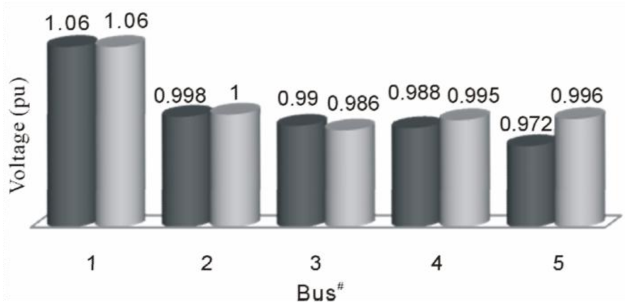

Fig7. Bus voltage profile management using UPFC.

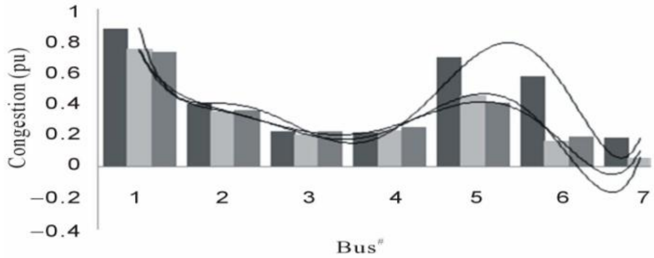

Fig8. Congestion management under normal condition using UPFC.

Total power loss before connecting UPFC FACTS controller is 0.066402 MW and after connecting with UPFC controller is reduces to be 0.04362 MW. And connecting Fuzzy controller in combination with UPFC controller then power loss is fatherly reduced to 0.02421 MW.

5. CONCLUSIONS:

Transmission Congestion management is an important issue in De-regulated power systems. Congestion must be relieved in order to have maximum power transfer capacity in transmission networks. It could be well known that recent FACTS technology can able to provide better methodology of control phase angle, voltage magnitude, and line reactance clearly. Using these types of controllers may rearrange the load flow associated with control bus voltages. Therefore, it is useful to investigate the effects of FACTS devices on the congestion management.

UPFC is a commercially available FACTS controller. This paper presents an implementation of the UPFC with fuzzy controller used in order to the power loss and improves the flat voltage profile even under contingency conditions. The proposed methodology employed obtains the better solution. Results show the effectiveness of the suggested criterion significantly.

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Line	From	To	Congestion without UPFC	Congestion UPFC with Fuzzy	Congestion only with UPFC
1	1	2	80%	74%	73%
2	1	3	40%	35%	36%
3	2	3	22%	20%	22%
4	2	4	22%	23%	25%
5	2	5	69%	45%	40%
6	3	4	57%	16%	18%
7	4	5	18%	5%	10%

Appendix 1