Improving the Power Quality of IEEE 14 Bus AC Transmission System using UPFC with Fuzzy Logic Controller

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Abstract: *Power quality is one of the major concerns in the power system. The power quality problem occurred due to a non-linear load in the distribution network and its severe impact on sensitive loads. To overcome this problem, the new series, parallel FACTS device use. The Interline Power Flow Controller (IPFC) is avoltage source convertor based (FACTS) controller for series compensation with the unique capability of power flow management among the multiple transmission lines in the transmission system. Because of disturbance, the electromechanical oscillations will present in the transmission system and these oscillations should damp out using IPFC. The performance of the considered IEEE 14 bus system is analyzed in terms of oscillations using IPFC. In this work, we will be applying the fuzzy PI controller in combination with the Unified Power Flow Controller (UPFC) for better performance and to improve the overall THD of the existing PI IPFC system. An IEEE 14 bus system is modeled in MATLAB/SIMULINK software. Initially, the basic transmission line system model is simulated. After that connect UPFC controller is simulated in MATLAB and check the output waveform. Finally, apply a fuzzy logic controller for better performance of the transmission line oscillation then check the THD of the system with and without UPFC. This analysis is carried out using MATLAB/Simulink.*

Keywords: Flexible AC Transmission System (FACTS), Interline Power Flow Controller (IPFC), Unified Power Flow Controller (UPFC), fuzzy PI controller, MATLAB/SIMULINK.

I. Introduction

Modern power systems are highly complex and are designed as such to fulfill the growing demands of power with better power quality. High technology nowadays is being used for controlling power flow. Due to this, power quality is improved. Modern technology and new constructions of transmission lines are also needed for improving power system security, profitability, and reliability. When power systems are heavily loaded, faulted, or have reactive power shortages then voltage collapse occurs. System instability and it occurs due to many power system components due to voltage collapse. Reactive power imbalance occurs when the system is faulted, heavily loaded and voltage fluctuation is there. The investigates the performance of series-series.(Interline Power Flow Controller) and series-shunt (Unified Power Flow Controller) FACTS controllers by compensating real and reactive power flow. For analysis, the IEEE14 Bus system is used.

Shunt compensation is used in all high voltage transmission line, EHV systems to supply reactive power and improve voltage profile. Series compensation is used to increase transmission line capacity, system stability.

A) Benefits for FACTS Controllers

The loading of transmission lines nearer to their thermal limits.

- Increased dynamic and transient grid stability.
- It allows more active power in present lines by reducing reactive power flow in the line.

- Access to lower production cost.
- Upgrade of transmission lines.
- Reduce reactive power flows, allowing the lines to carry more active power.
- Loop flow control.
- Power System Stability Improvement Using FACTS Devices.

II. FACTS CONTROLLERS CAN BE DIVIDED INTO FOUR CATEGORIES

- Shunt controller-SVC and STATCOM,
- Series controller-TCSC, SSSC, and TCPAR
- Series-series-IPFC
- Series-shunt- UPFC

A) Series Controllers

Series Controllers consist of capacitors / reactors which introduce voltage in series with the line.

- Static Synchronous Series Compensator (SSSC)
- Thyristor Controlled Series Capacitor (TCSC)
- Thyristor switched series capacitor (TSSC)
- Thyristor-switched series reactor (TSSR)
- Thyristor-controlled series reactor (TCSR)

B) Shunt Controllers

Shunt controllers consist of variable impedance like capacitors / reactors which introduce current in series with the line.

- Static Synchronous compensator (STATCOM)
- Static VAR Compensator (SVC)
  - ➢ Thyristor Controlled Reactor (TCR)
  - ➢ Thyristor Switched Reactor (TSR)
  - ➢ Thyristor Switched Capacitor (TSC)
  - ➢ Mechanically Switched Capacitor (MSC)
  - ➢ Harmonic Filter

C) Series-Series-IPFC

It is a combination of series controllers. The objective of introducing this controller is to address the problem of compensating several transmission lines connected at a substation The Interline Power Flow Controller (IPFC) provides, in addition to the facility for independently controllable reactive (series) compensation of each line, a capability to directly transfer or exchange real power between the compensated lines. Simplified Schematic of Two-Converter IPFC Mode shown in fig.1.

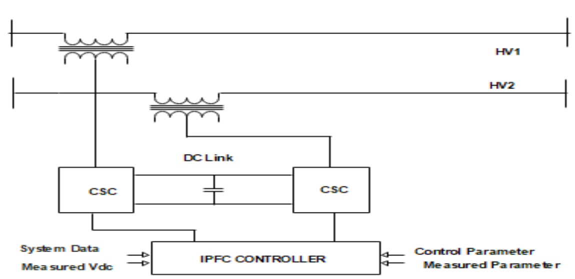

Figure 1: Simplified Schematic of Two-Converter IPFC Mode.

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D) Series-Parallel-UPFC

Unified Power Flow Controller (UPFC) is the most versatile device designed based on the concept of a combined series-shunt FACTS Controller. It can simultaneously control all the transmission parameters affecting the power flow of a transmission line i.e. voltage, line impedance, and phase angle. The simplified schematic unified power flow controller is shown in fig.2.

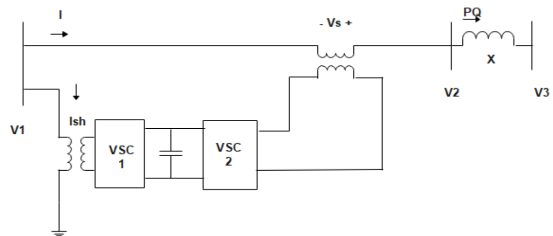

Figure 2: Simplified Schematic Unified Power Flow Controller

III. IEEE 14 Bus Power Network

IEEE 14 bus system considered for analysis is shown in Fig.3. MATLAB simulation model of IEEE 14 Bus Power Network This system includes five T-G units with IEEE type-1 exciters14 buses, three transformers, and twenty AC transmission lines. This system has 11 loads totaling. Bus 1 is selected as a slack bus. The generator G1 is considered as reference. The three synchronous compensators are considered as generators to meet the demand of real power by loads. The generators are modeled with both P and Q limits as standard PV buses, loads are considered as constant PQ loads. The output waveform of the IEEE 14 bus power network is shown in fig.4.

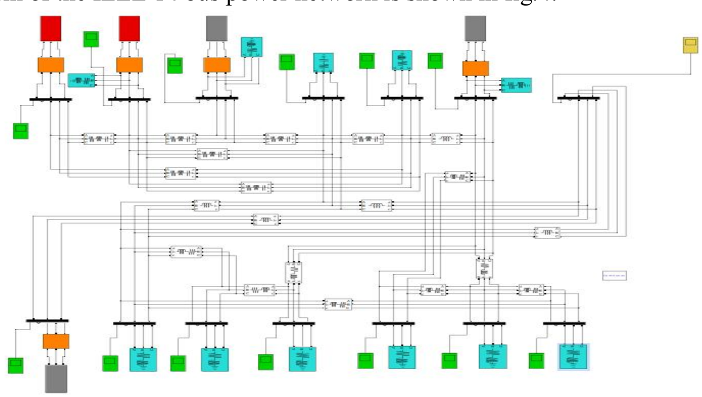

Figure 3: MATLAB simulation model of IEEE 14 Bus Power Network

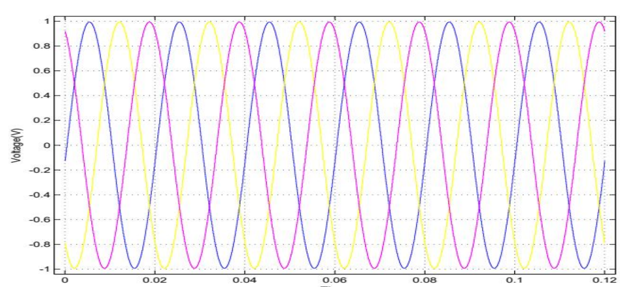

Figure 4: The output waveform of IEEE 14 Bus Power Network

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IV. IEEE 14-Bus Transmission System With UPFC

In this stage, connect the UPFC controller on IEEE 14 bus system which is shown in fig.5.MATLAB simulation model of UPFC and their output waveform result is shown in fig.6. The output waveform of UPFC .

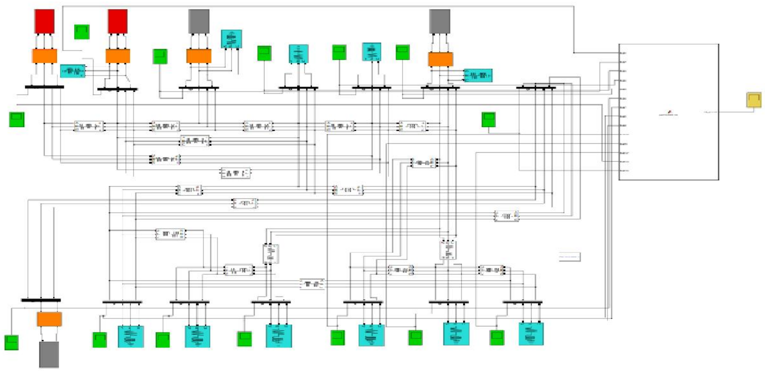

Figure 5: .MATLAB simulation model of UPFC

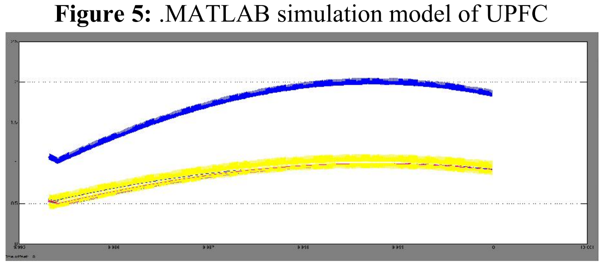

Figure 6: The output waveform of UPFC

Figure 6 shows the output waveform of IEEE 14 bus power network using UPFC. From figure it is clear that the overall output voltage is increase which is shown in blue color by absorbing the reactive power when Es < Et and generate the real power when phase Es lead Et. It injected the voltage in phase with line current, it exchange the real power qudrature of reactive exchange.

V. IEEE 14 Bus System Using UPFC With Fuzzy Control

In this stage, now we add the UPFC with Fuzzy logic controller using MATLAB which is shown in fig.7. for improving the system oscillation of the transmission line while connecting the UPFC controller in it and check the performance of the IEEE 14 bus power network. Fig.8. and Fig.9. shows the input waveform of the fuzzy logic controller and output waveform of without UPFC and with UPFC using Fuzzy Controller respectively.

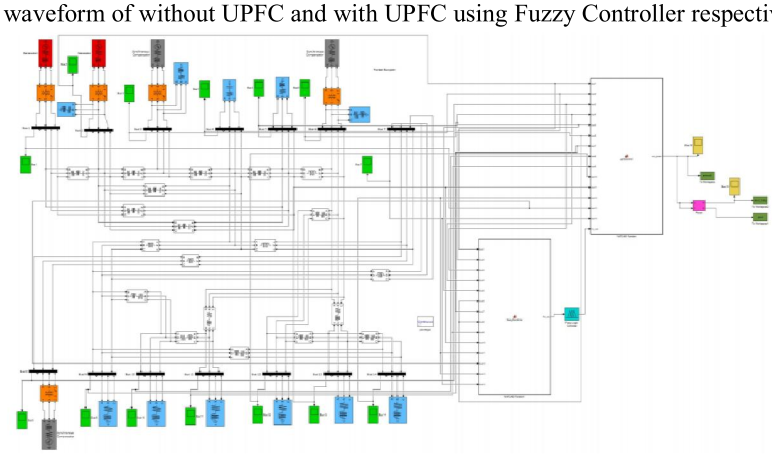

Figure 7: UPFC with Fuzzy logic controller using MATLAB

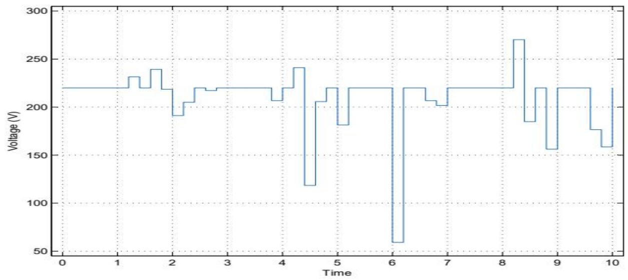

Figure 8: The input waveform of the fuzzy logic controller

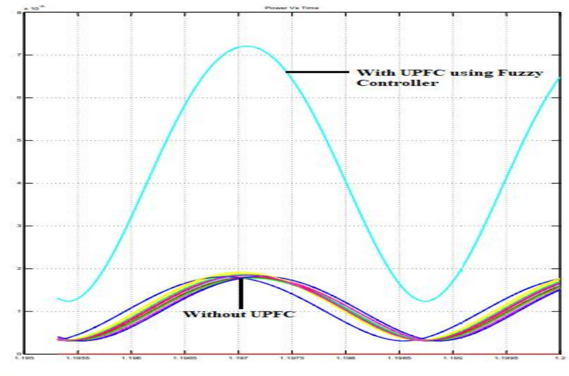

Figure 9: The output waveform of the without UPFC and with UPFC using fuzzy logic controller

When we apply the Fuzzy logic Controller to the IEEE 14 bus Ac transmission power network with UPFC we get the improve the power profile as well as the level of THD is reduce. When UPFC is activated and Fuzzy Controller is deactivated the active power is 0.0250 MW and the reactive power is 0.0083 MVAR. When the UPFC is activated and Fuzzy Controller also activated the power is 0.0750 MW and the reactive power is 0.0250 MVAR , Same for THD, when UPFC is activated and Fuzzy Controller is deactivated the THD is 0.8194 %. When the activated the THD is 0.0809 %. From this vales it is clear that the THD is reduce by 0.7375 %. It is clear that the fuzzy logic controller divides the all set valve in different level and choice the best value from it and give them the more accurate result. In this technique, the Fuzzy Logic controller performance is also compared to a PI controller. It's been observed that the Fuzzy Logic controller gives a better response PMSM drive as compared to the PI controller.

VI. Graphical Representation Of Active And Reactive Power For Normal Condition

From the below table it is more clear that what are the active and reactive power output with respect to time for normal as well as for Fuzzy Controller condition. Table 1 shows the active and reactive power for normal condition from that the figure 10. shows the graphical representation for active and reactive power for normal condition while the Table 2 shows the active and reactive power for Fuzzy Logic Controller condition from that the figure 11 shows the graphical representation for active and reactive power for Fuzzy Logic Controller condition.

Table 1 Active and reactive power for normal condition

Sr. No	Time	Active_P (Normal)	Reactive_Q (Normal)
1	0.1	0.2499	0.0833
2	0.4	0.0625	0.0208
3	0.6	0.0417	0.0139

4	0.8	0.0312	0.0104
5	1	0.025	0.0083
6	1.2	0.0208	0.007

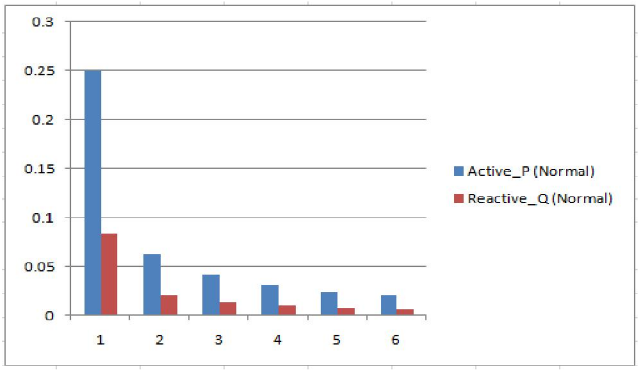

Figure 10: Graphical representation of active and reactive power for normal condition.

From above graphical representation its is clear that, in every case the reactive power is almost low as compare with the active power in normal condition i.e., using UPFC without Fuzzy Logic Controller. As long as the system run for more time duration the reactive is become low.

VII. Graphical Representation of Active and Reactive Power For Fuzzy Logic Controller Condition

Table7.3 Active and reactive power for Fuzzy logic Controller condition

Sr. No	Time	Active_P (Fuzzy)	Reactive_Q (Fuzzy)
1	0.1	0.2505	0.0843
2	0.4	0.2505	0.0843
3	0.6	0.2262	0.0796
4	0.8	0.2999	0.1
5	1	0.075	0.025
6	1.2	0.075	0.025

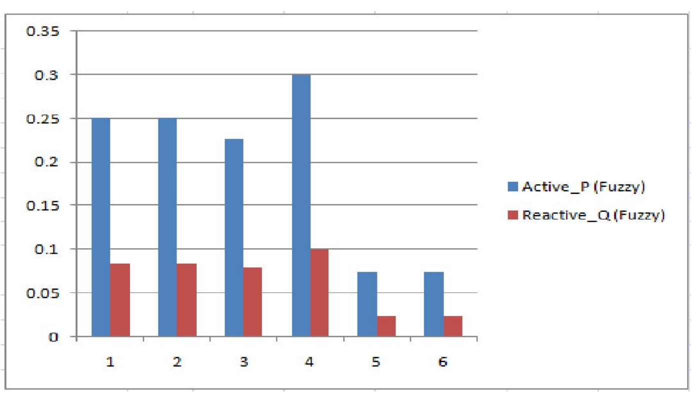

Figure 11: Graphical Representation of Active and Reactive Power For Fuzzy Logic Controller Condition.

From above graphical representation it's clear that, in every case the reactive power is almost low as compare with the active power in Fuzzy Logic Controller condition i.e., using UPFC with Fuzzy Logic Controller. As long as the system run for more time duration the reactive is become low. From this graph it also define the output reading the active are gives the larger value when compare with the normal condition and for reactive power are less value when compare with the normal condition. Our ultimate aim was reduces the reactive power as well as reduce the % of THD which is fulfill by using the UPFC with Fuzzy Logic Controller.

VIII. Conclusion

This project deals with FACTS devices known as the Unified Power Flow Controller that is used to maintain and improve power system operation and stability. The research carried out in this thesis has focused on the investigation of the performance of UPFC with Fuzzy controllers. By comparing the theoretical wave form and Output wave from getting from MATLAB simulation , it is concluded that simulation system output is correct . UPFC increases the power transfer capability of the IEEE 14-bus transmission system because in UPFC the real-power transfer between the series converter and the shunt converter .The UPFC also provides very significant damping to power oscillations. From the simulation results, when applying the Fuzzy controller the active and reactive powers are 2.1KW and 0.7KVAR respectively and when UPFC is activated and Fuzzy Controller is deactivated the THD is 0.8194 %. When the activated the THD is 0.0809 %. From this vales it is clear that the THD is reduce by 0.7375 % .

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