Fuzzy Logic based Unified Power Flow Controller for Improvement of Power System Stability

D. Jayalakshmi[1] **and S. Sankar**

ABSTRACT

This paper describes the modelling and control of Flexible Alternating Current Transmission Systems (FACTS) devices. In this paper, the authors presented the modelling of unified power flow controller (UPFC) based power system network for improving power system stability and reliability under various power system faults. The objective of this paper to improve the power system stability and reliability using an intelligent controller based UPFC device. The UPFC devices to be controlled by a fuzzy logic controller under various fault conditions. The fuzzy logic controller compares the power system parameters such as voltage and phase angle with the reference value and it will generate the triggering pulses for a voltage source converter of UPFC system. The proposed model will be simulated in Matlab environment. The simulation results are evaluated with IEEE standards and compare to existing models for strong impact of the proposed model.

Key words: UPFC, Fuzzy, Stability, Reliability, Matlab

I. INTRODUCTION

The unified power flow controller (UPFC) is able to control, simultaneously or selectively, all the parameters affecting power flow in the transmission line (i.e., voltage magnitude, impedance, and phase angle). The conventional UPFC consists of two back-to-back connected voltage source inverters that share a common DC link, as shown in Fig. 1. The injected series voltage of inverter-2 can be at any angle with respect to the line current, which provides complete flexibility and controllability to control both active and reactive power flows over the transmission line[1 -5]. The resultant real power at the terminals of inverter-2 is provided or absorbed by inverter-1 through the common DC link. As a result, UPFC is the most versatile and powerful, flexible AC transmission system device. It can effectively reduce congestions and increase the capacity of existing transmission lines. This allows the overall system to operate at its theoretical maximum capacity. The basic control methods, transient analysis, and practical operation considerations for UPFC have been investigated in. The conventional UPFC has been put into several practical applications, which has the following features: 1) both inverters share the same DC link; 2) both inverters need to exchange real power with each other and the transmission line; 3) a transformer must be used as an interface between the transmission line and each inverter. In addition, any utility-scale UPFC requires two high-voltage, high-power (from the several MVA to hundreds of MVA) inverters. This high-voltage, high-power inverters have to use bulky and complicated zig zag transformers to reach their required VA ratings and desired voltage waveforms. The zig zag transformers are: 1) very expensive (30–40% of total system cost); 2) lossy (50% of the total power losses); 3) bulky (40% of system real estate area and 90% of the system weight); and 4) prone to failure. Moreover, the zigzag transformer based UPFCs are still too slow in dynamic response due to large time constant of magnetizing inductance over resistance and pose control challenges because of transformer saturation, magnetizing current, and voltage surge. Recently, there are two new

* Research Scholar, St. Peter's University, *E-mail: jayaeec28@gmail.com*

UPFC structures under investigation: 1) the matrix converter-based UPFC and 2) distributed power-flow controller (DPFC) derived from the conventional UPFC[6-10]. The first one uses the matrix converter replacing the back-to-back inverter to eliminate the DC capacitor with AC capacitor on one side of the matrix converter. The DPFC employs many distributed series inverters coupled to the transmission line through single-turn transformers, and the common DC link between the shunt and series inverters is eliminated. The single-turn transformers lose one design freedom, thus making them even bulkier than a conventional transformer given a same VA rating. In summary, both UPFCs still have to use the transformers, which inevitably cause the same aforementioned problems associated with transformers (such as bulky, loss, high cost, and slow in response).

II. MODELLING OF UPFC

The Unified Power Flow Controller (UPFC) is a typical FACTS (Flexible AC Transmission Systems) device that is the most sophisticated and complex power electronic equipment and has emerged for the control and optimization of power flow and also to regulate the voltage in the electrical power transmission system.

(A) Operating Principal of UPFC

The basic components of the UPFC are two voltage source inverters (VSIs) sharing a common DC storage capacitor, and connected to the power system through coupling transformers. One VSI is connected to in shunt to the transmission system via a shunt transformer, while the other one is connected in series through a series transformer.

The series inverter is controlled to inject a symmetrical three phase voltage system (Vse), of controllable magnitude and phase angle in series with the line to control active and reactive power flows on the transmission line. So, this inverter will exchange active and reactive power with the line. The reactive power is electronically provided by the series inverter, and the active power is transmitted to the DC terminals. The shunt inverter operates in such a way as to demand this DC terminal power (positive or negative) from the line keeping the voltage across the storage capacitor Vdc constant. So, the net real power absorbed from the line by the UPFC is equal only to the losses of the inverters and their transformers. The remaining capacity of the shunt inverter can be used to exchange reactive power with the line so to provide a voltage regulation at the connection point[11-14]. The two VSI's can work independently of each other by separating the DC side. So in that case, the shunt inverter is operating as a STATCOM that generates or absorbs reactive power to regulate the voltage magnitude at the connection point. Instead, the series inverter is operating as SSSC regulate the current flow, and hence the power flow on the transmission line. The UPFC has many possible operating modes. In particular, the shunt inverter is operating in such a way to inject a controllable current, is in the transmission line. The shunt inverter can be controlled in two different modes:

(B) 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, Vdc, is also required [15-16].

(C) 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 [18-21]. The series inverter controls the

magnitude and angle of the voltage injected in series with the line to influence the power flow of 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[17].

*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.

III. MATLAB SIMULATION AND RESULT ANALYSIS
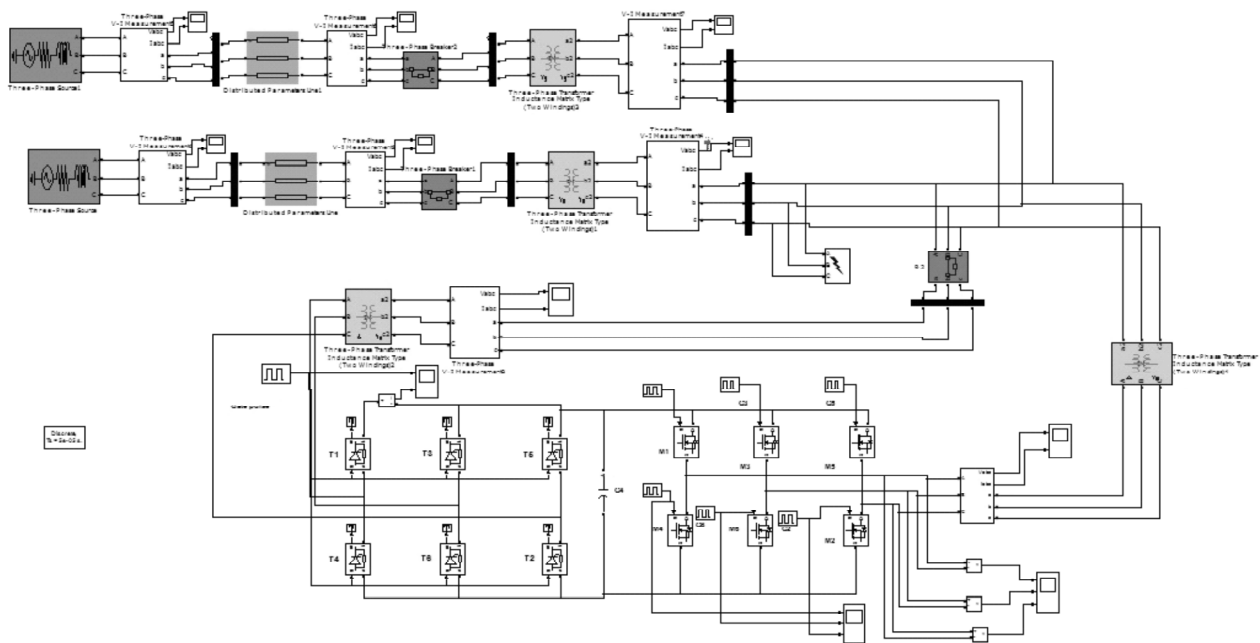
Figure 1: Simulation model of UPFC without fuzzy controller
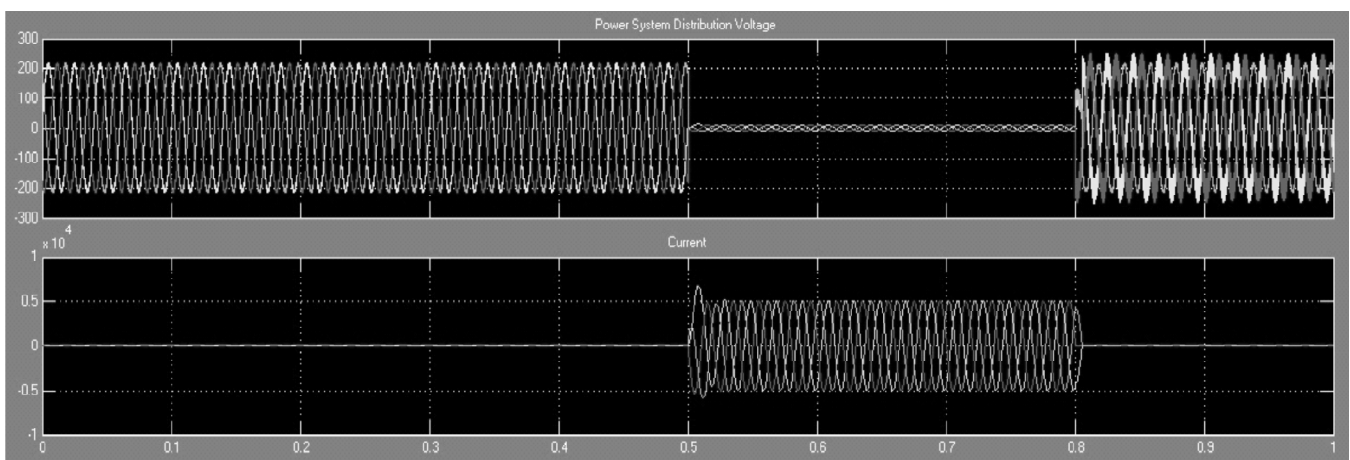
Figure 2: Three phase fault without UPFC
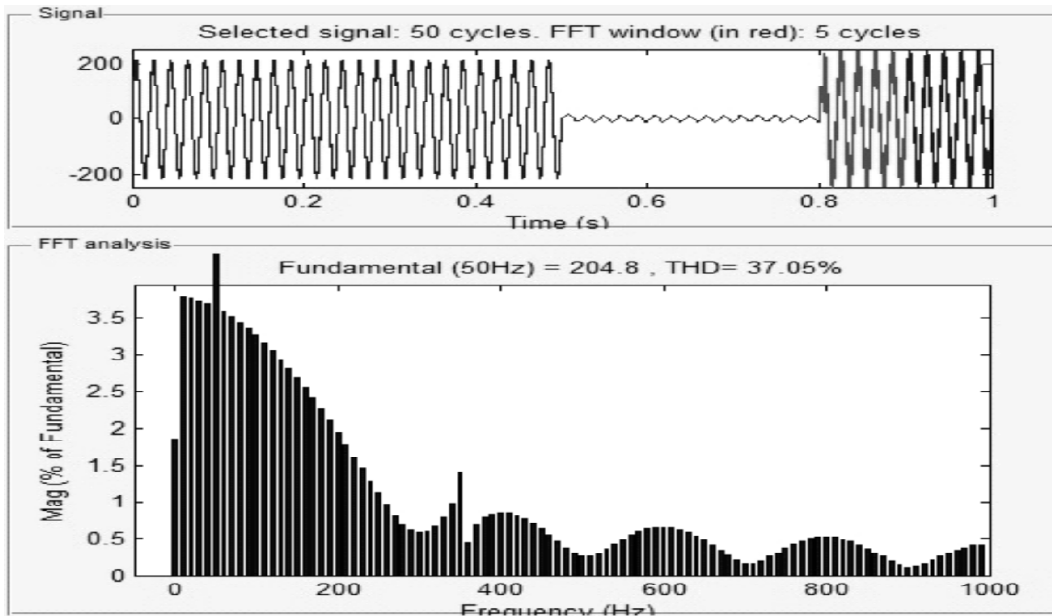
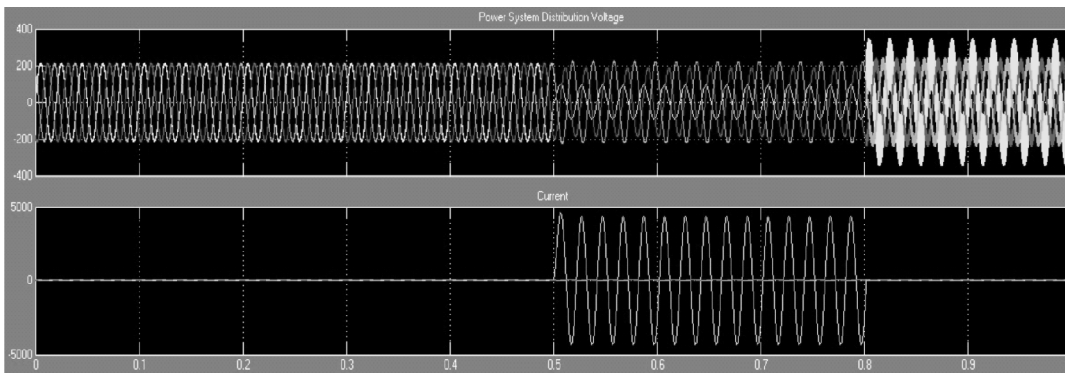**Figure 3 : THD for Three phase fault without UPFC**

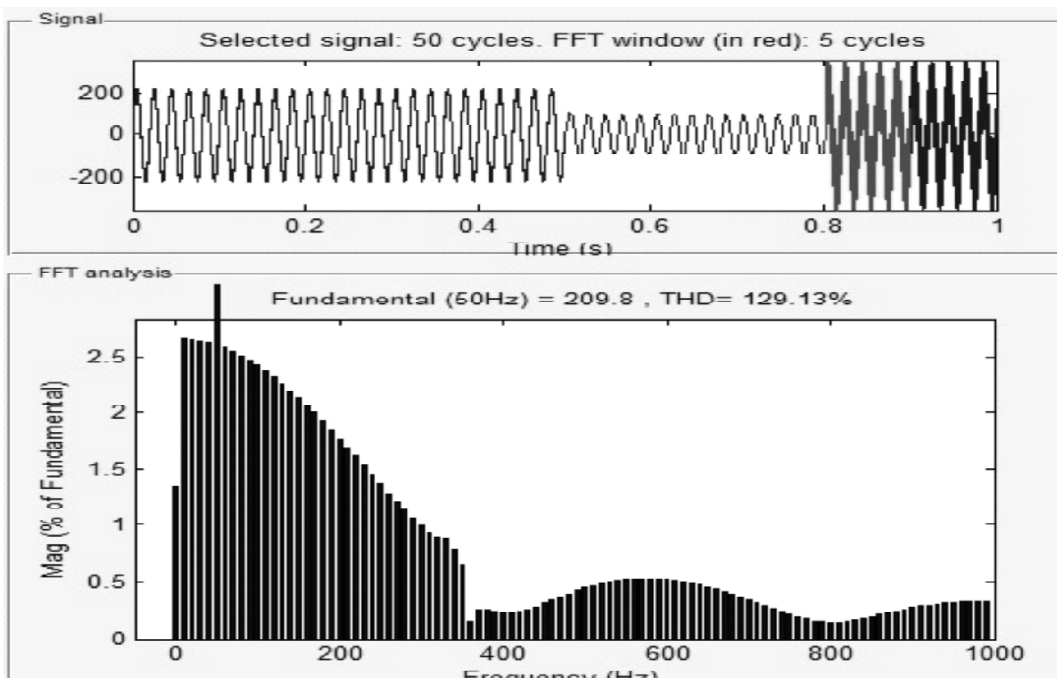**Figure 4: Line to ground fault without UPFC**

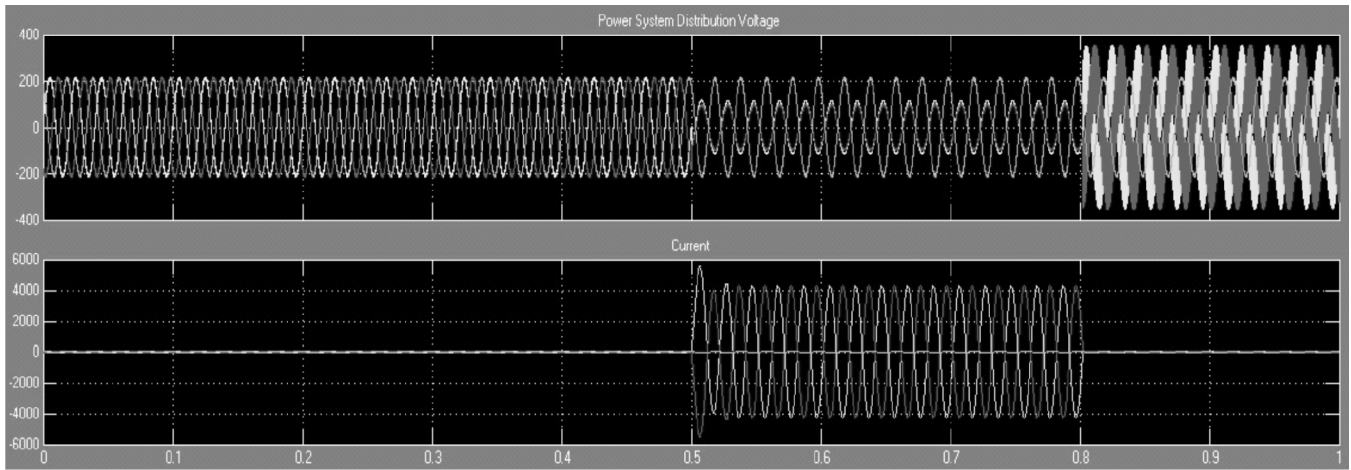**Figure 5 : THD for Line to ground fault without UPFC**

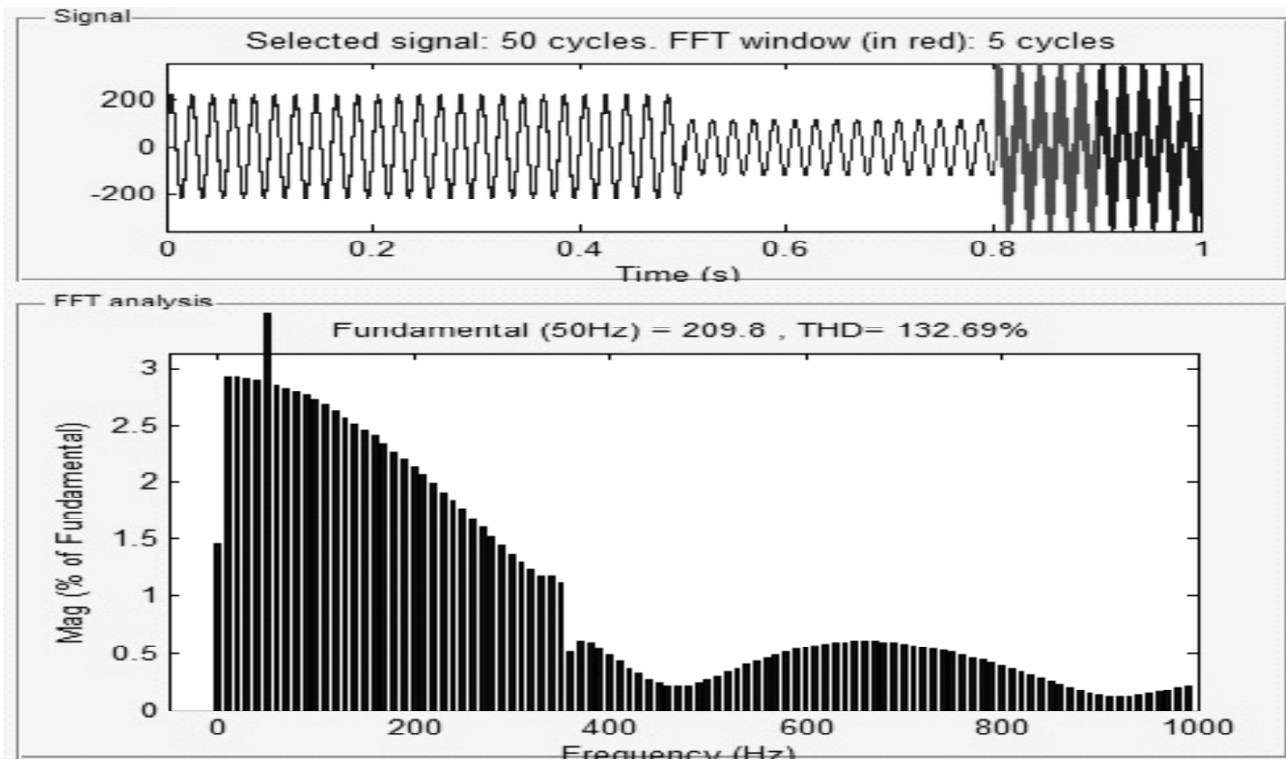**Figure 6: Line to Line fault without UPFC**

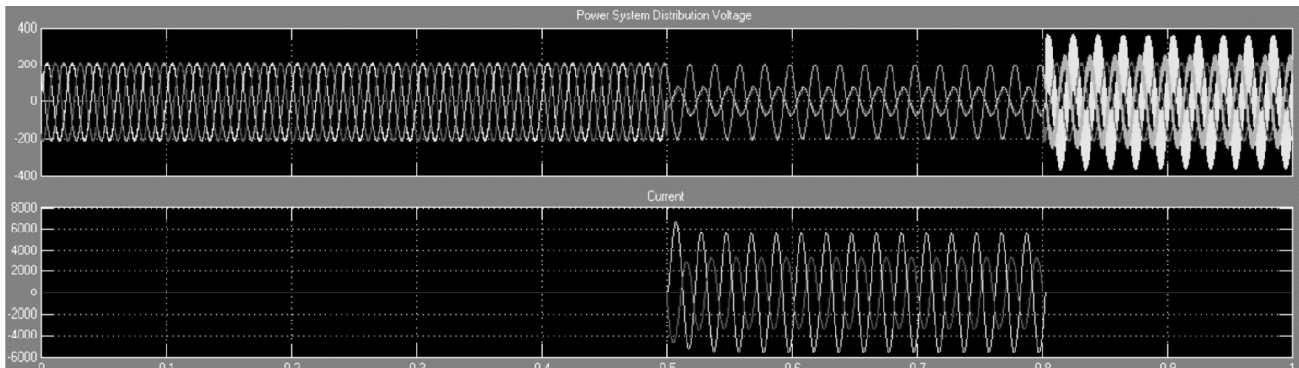**Figure 7: THD for Line to Line fault without UPFC**

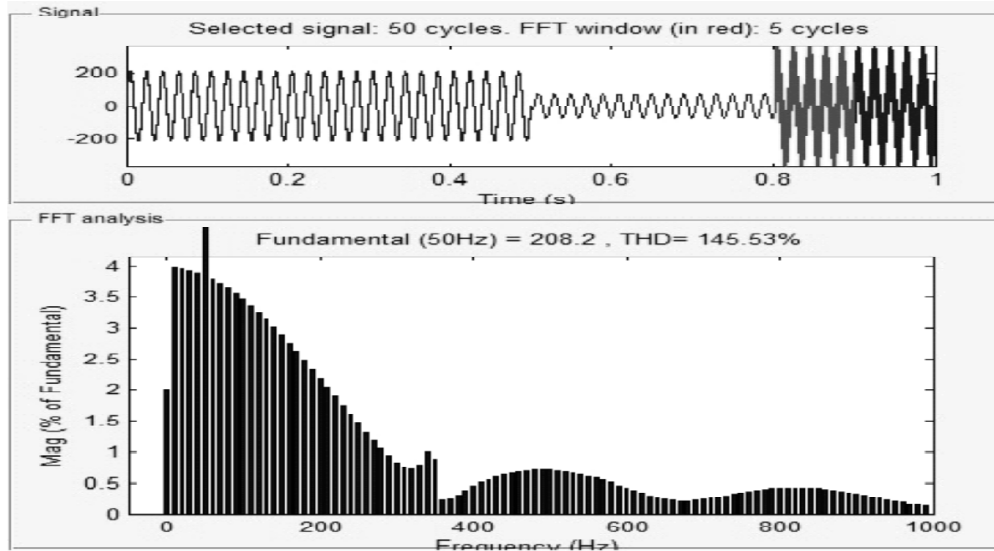**Figure 8: Double Line to ground fault without UPFC**

Figure 9: THD for Double Line to ground fault without UPFC

The figure 1 represented the simulation model of UPFC without fuzzy controller. We have simulated the above power system, network under different fault conditions. The 3 phase fault and its THD values are shown in fig 2 and fig 3 respectively. The THD value of 3 phase faults has very huge level 37.05% it's possible to damage the nearby the systems. The Line to ground faults, it's introduced in phase A and Ground as shown in fig 4 and its THD value is 129.1 % presented in fig 5. The line to ground faults occurs at 0.5 sec to 0.8 sec and after 0.8 Sec the system does not settle as shown in fig 4. The Line to Line faults, it's introduced in phase A and Phase B as shown in fig 6 and its THD value is 132.6% presented in fig 7. The line to line faults occurs at 0.5 sec to 0.8 sec and after 0.8 Sec the system does not settle as shown in fig 6. The Double Line to ground faults, it's introduced in phase A, Phase B and Ground as shown in fig 8 and its THD value is 145.5 % presented in fig 9. The double line to ground faults occurs at 0.5 sec to 0.8 sec and after 0.8 Sec the system does not settle as shown in fig 8. The above analysis is clearly represented after faults occurs the system will be loose the stability and provided huge amount harmonics in power systems. We need to avoid this kind of above problems using FACTS devices operated with intelligent controllers.
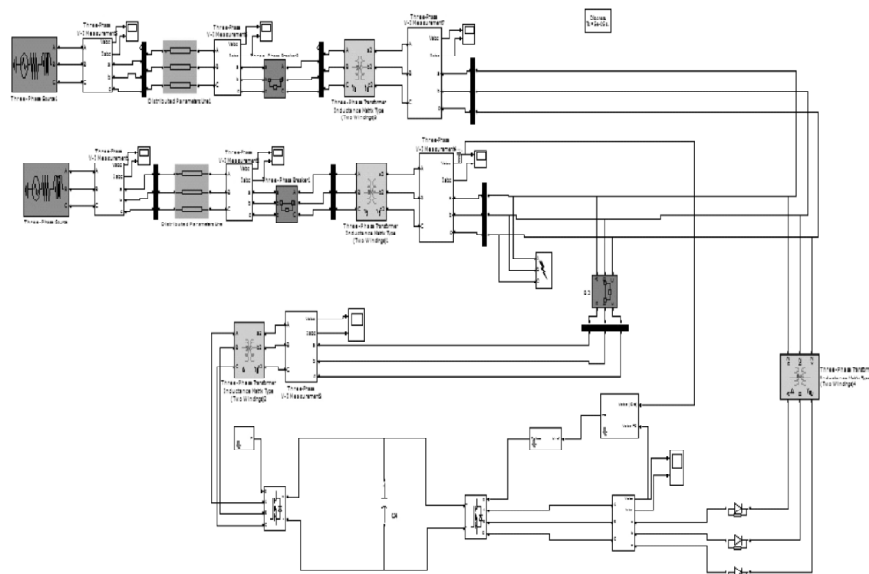
With UPFC and fuzzy controller

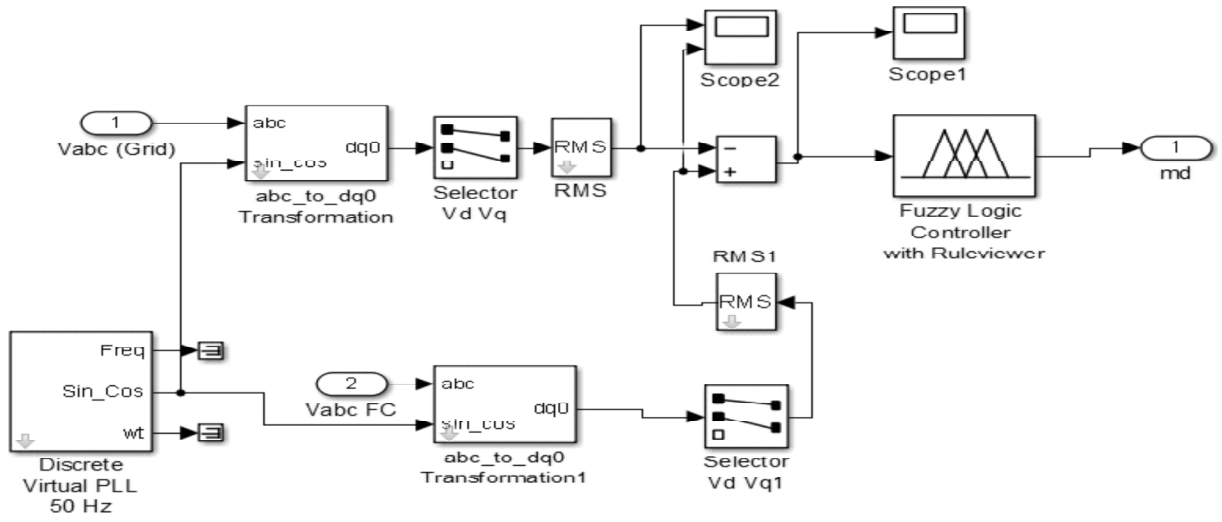Figure 10: Simulation model of UPFC with fuzzy controller
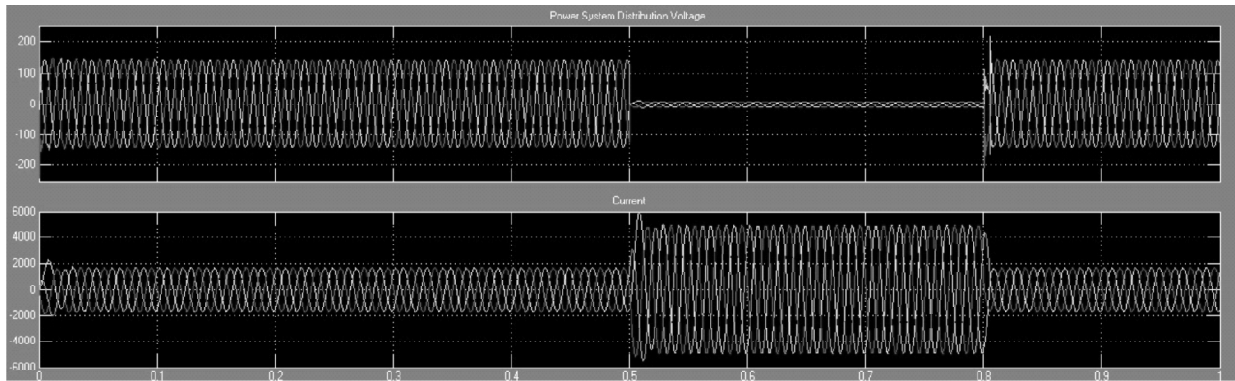
Figure 11: Fuzzy logic controller for UPFC

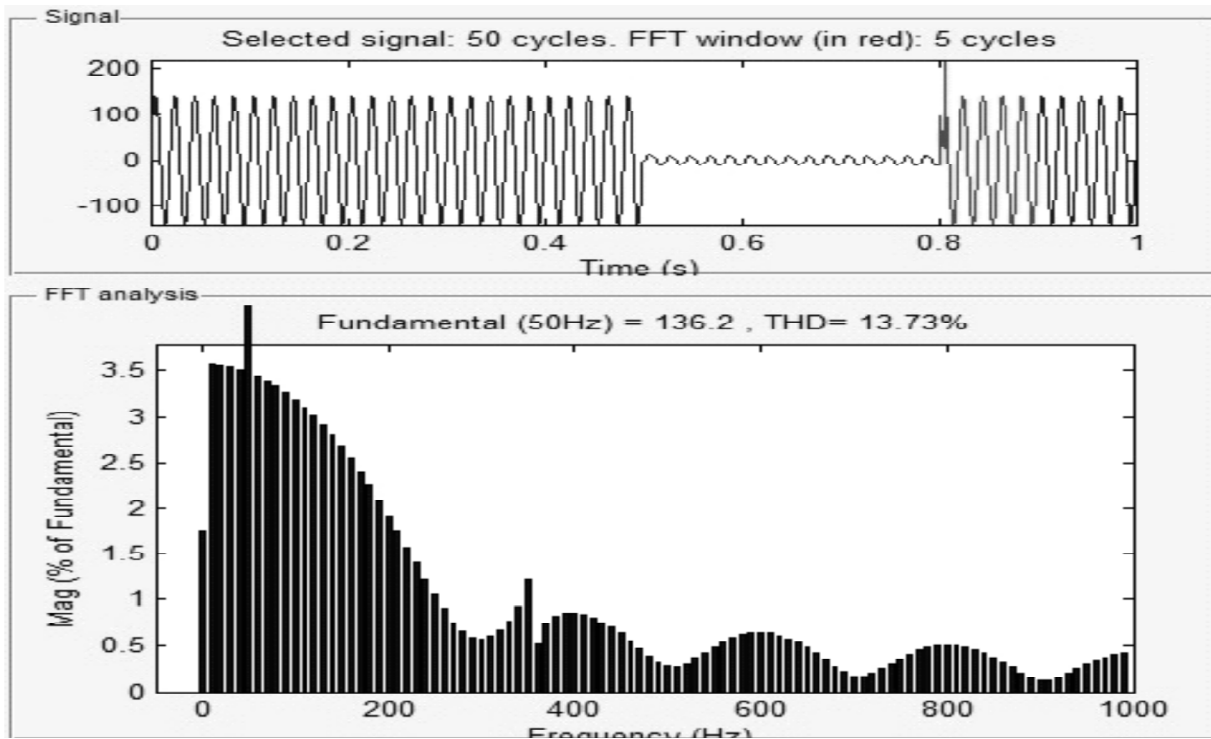**Figure 12: Three phase fault with UPFC + fuzzy controller**

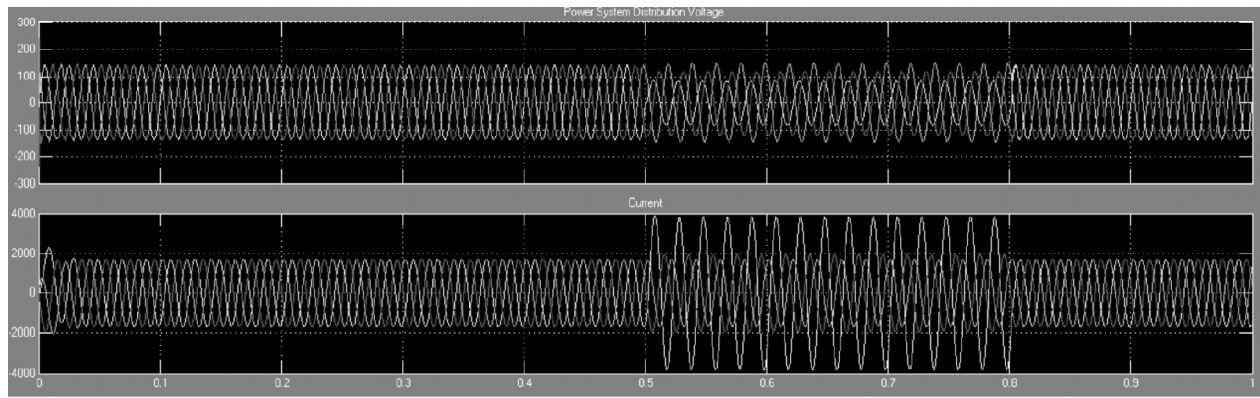**Figure 13: THD for Three phase fault with UPFC + fuzzy controller**

Figure 14: Line to ground fault with UPFC + fuzzy controller
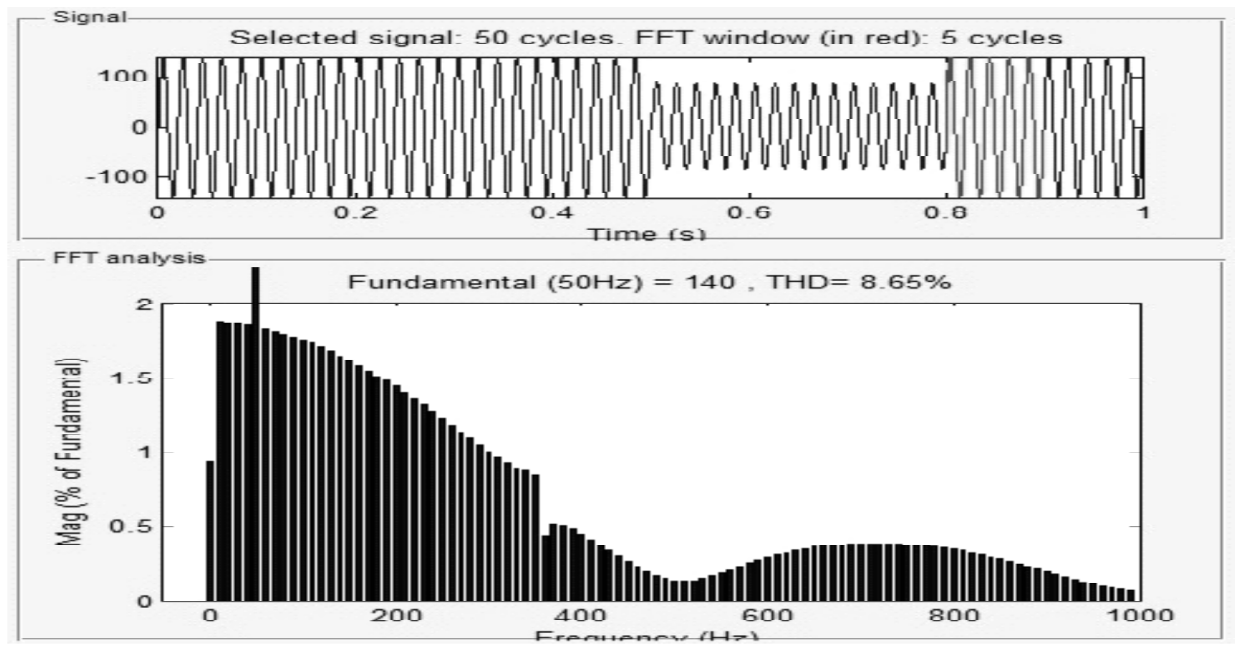

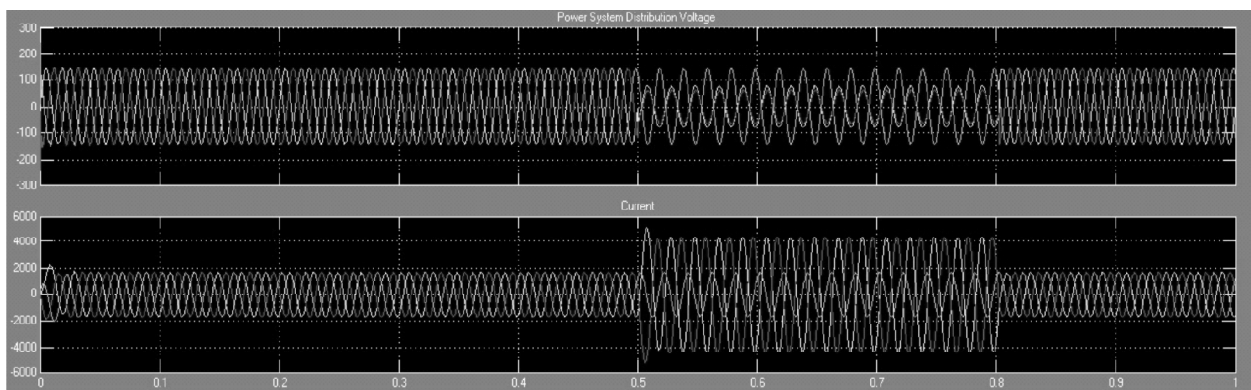**Figure 15: THD for Line to ground fault with UPFC + fuzzy controller**

Figure 16: Line to Line fault with UPFC + fuzzy controller
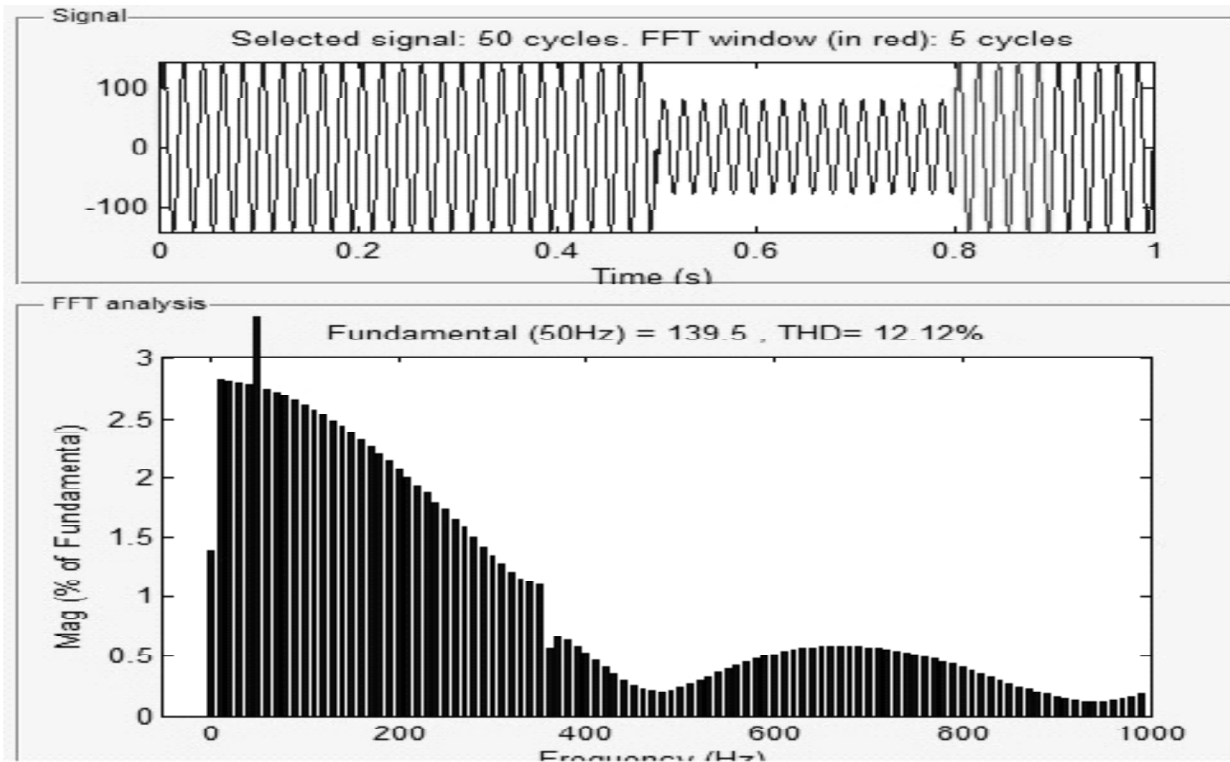
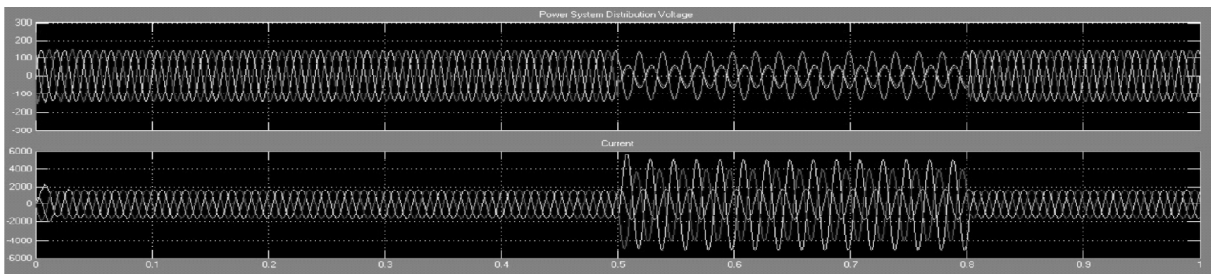**Figure 17: THD for Line to Line fault with UPFC + fuzzy controller**

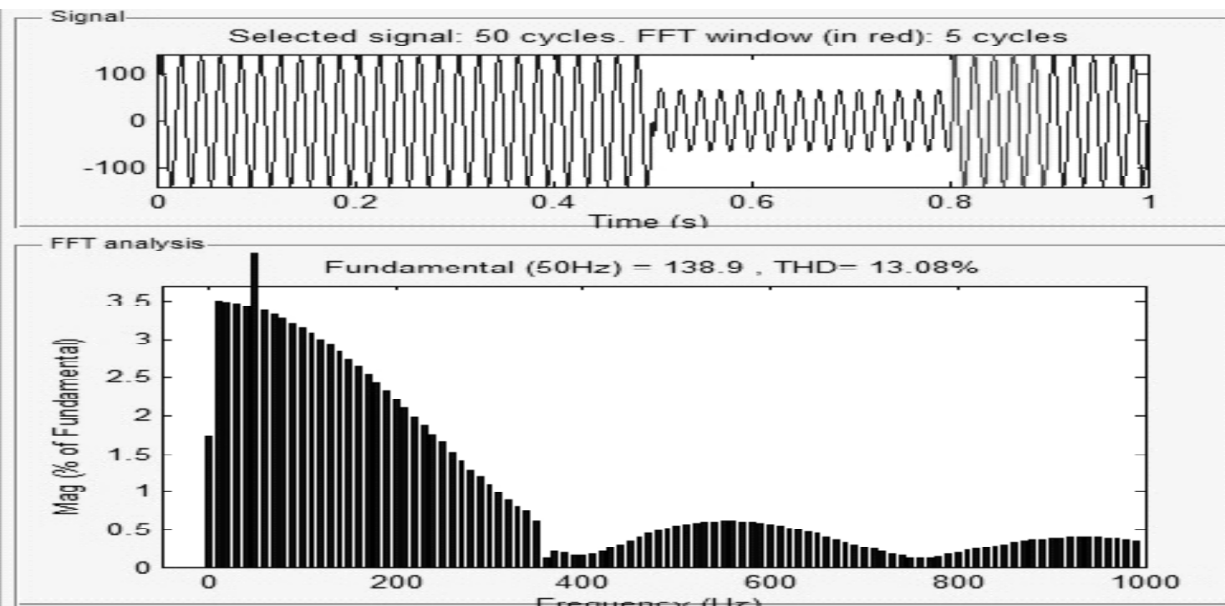**Figure 18: Double Line to ground fault with UPFC + fuzzy controller**

Figure 19: THD for Double Line to Ground fault with UPFC + fuzzy controller

The proposed simulation model of UPFC with fuzzy controller is shown in fig 10. The fig 11 is represented the fuzzy controller in UPFC system. The fuzzy controller has generated duty cycle of the PWM pulse to UPFC based on grid voltage and the reference voltage during faults conditions. The proposed model is simulated under different fault conditions. The 3 phase fault and its THD values 13.7 % are shown in fig 12 and fig 13 respectively. The Line to ground faults, it's introduced in phase A and Ground as shown in fig 14 and its THD value is 8.65% presented in fig 15. The line to ground faults occurs at 0.5 sec to 0.8 sec and after 0.8 sec the system settled under normal condition as shown in fig 14. The Line to Line faults, it's introduced in phase A and Phase B as shown in fig 16 and its THD value is 12.12% presented in fig 17. The line to line faults occurs at 0.5 sec to 0.8 sec and after 0.8 sec the system settled under normal condition as shown in fig 16. The double Line to ground faults, it's introduced in phase A, Phase B and Ground as shown in fig 8 and its THD value is 13.08% presented in fig 19. The double line to ground faults occurs at 0.5 sec to 0.8 sec and after 0.8 sec the system settled under normal condition as shown in fig 18. The above analysis is clearly represented after a fault occurs the system did not lose the stability using a fuzzy logic controller based UPFC device. The proposed system has effectively maintained the power system stability under fault conditions.

Table 1
Comparison of THD values with and without UPFC and fuzzy

Faults	Without UPFC	With UPFC and fuzzy
3 Phases	37.05 %	13.7 %
L-G	129.1%	8.65%
L-L	132.6 %	12.12%
DL-G	145.5 %	13.08%

CONCLUSION

This paper the modelling and analysis of UPFC based power system under various fault condition such as symmetrical and unsymmetrical faults. The above system is simulated with Matlab simulation environment with and without UPFC power system at various fault conditions. The design and simulation of proposed fuzzy controller based UPFC power system were analyzed with various fault conditions. The simulated results are evaluated and validated with existing systems as shown in table 1. Finally, the proposed system has proved the effectiveness of the operation and recommended for the power system

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