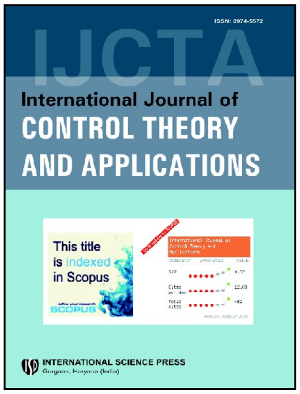

International Journal of Control Theory and Applications

ISSN : 0974-5572

Volume 10 • Number 11 • 2017

Intelligent Based Unified Power Flow Controller for Improvement of Voltage at Distribution Network

D. Jayalakshmi[1] and S. Sankar

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

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 the voltage profile in a radial distribution power network under various power system faults. The objective of this paper to improve the voltage profile using an intelligent controller based UPFC device. The operation of UPFC devices to be analysis various types of intelligent controller (Fuzzy and firefly) various fault conditions. The intelligent 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, Firefly, Voltage improvement and Matlab

I. INTRODUCTION

The unified power flow controller (UPFC) is able to control,simultaneously or selectively, all the parameters affectingpower flow in the transmission line (i. e. , voltage magnitude,impedance, and phase angle). The conventional UPFCconsists of two back-to-back connected voltage source invertersthat share a common DC link, as shown in Fig. 1. The injectedseries voltage of inverter-2 can be at any angle with respectto the line current, which provides complete flexibility and controllabilityto control both active and reactive power flows overthe transmission line[1 -5]. The resultant real power at the terminalsof inverter-2 is provided or absorbed by inverter-1 through thecommon DC link. As a result, UPFC is the most versatile andpowerful, flexible AC transmission system device. It can effectivelyreduce congestions and increase the capacity of existingtransmission lines. This allows the overall system to operateat its theoretical maximum capacity. The basic control methods, transient analysis, and practical operation considerationsfor UPFC have been investigated in. The conventional UPFC has been put into several practicalapplications, which has the following features: 1) both inverters share the same DC link; 2) both inverters need to exchangereal power with each other and the transmission line; 3)a transformer must be used as an interface between the transmissionline and each inverter. In addition, any utility-scale UPFCrequires two high-voltage, high-power (from the several MVA tohundreds of MVA) inverters. This high-voltage, high-power invertershave to use bulky and complicated zigzag transformers toreach their required VA ratings and desired voltage waveforms. The zigzag transformers are: 1) very expensive (30–40% of totalsystem 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 tolarge time constant of magnetizing inductance over resistanceand pose control challenges because of transformer saturation, magnetizing current, and voltage surge. Recently, there are two new 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 converterreplacing the back-to-back inverter to eliminate the DC capacitorwith AC capacitor on one side of the matrix converter. The DPFCemploys many distributed series inverters coupled to the transmissionline through single-turn transformers, and the common DC link between the shunt and series inverters is eliminated. Thesingle-turn transformers lose one design freedom, thus makingthem even bulkier than a conventional transformer given asame VA rating. In summary, both UPFCs still have to use thetransformers, which inevitably cause the same aforementionedproblems 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 optimizationof 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, andconnected to the power system through couplingtransformers. One VSI is connected to in shunt to thetransmission system via a shunt transformer, while the otherone 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 andphase angle in series with the line to control active andreactive power flows on the transmission line. So, thisinverter will exchange active and reactive power with theline. The reactive power is electronically providedby the series inverter, and the active power is transmitted to the DC terminals. The shunt inverter operates in such away as to demand this DC terminal power (positive ornegative) from the line keeping the voltage across thestorage capacitor Vdc constant. So, the net real powerabsorbed from the line by the UPFC is equal only to thelosses of the inverters and their transformers. The remainingcapacity of the shunt inverter can be used to exchangereactive power with the line so to provide a voltageregulation at the connection point[11-14]. The two VSI's can work independently of each other byseparating the DC side. So in that case, the shunt inverter isoperating as a STATCOM that generates or absorbs reactivepower to regulate the voltage magnitude at the connectionpoint. Instead, the series inverter is operating asSSSCregulate the current flow, and hence the power flowon the transmission line. The UPFC has many possible operating modes. Inparticular, the shunt inverter is operating in such a way toinject 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 VARrequest. The shunt inverter control translates the VARreference into a corresponding shunt current request andadjusts 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 automaticallyregulated to maintain the transmission line voltage at thepoint of connection to a reference value. For this mode ofcontrol, voltage feedback signals are obtained from thesending end bus feeding the shunt coupling transformer[18-21]. Theseries inverter controls the magnitude and angle of thevoltage injected in series with the line to influence thepower flow of the line. The actual value of the injectedvoltage can be obtained in several ways

***Direct Voltage Injection Mode*: ** The reference inputs aredirectly the magnitude and phase angle of the series voltage[17].

***Phase Angle Shifter Emulation mode*: ** The reference inputis phase displacement between the sending end voltage andthe receiving end voltage.

Line Impedance Emulation mode:The reference input isan impedance value to insert in series with the lineimpedance.

Automatic Power Flow Control Mode: The referenceinputs are values of P and Q to maintain on the transmissionline despite system changes.

III. MATLAB SIMULATION AND RESULT ANALYSIS

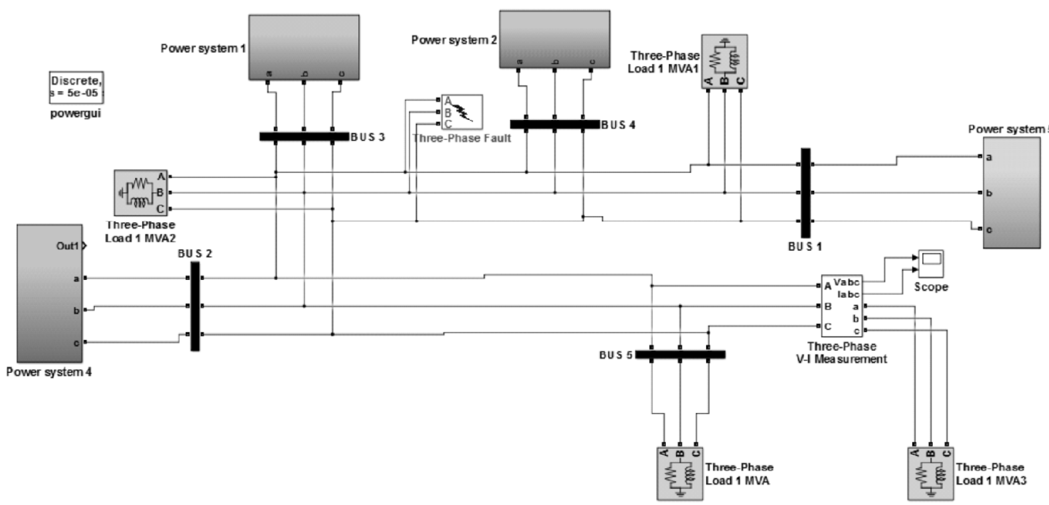

Figure 1: Radial distributed network without UPFC and intelligent controller

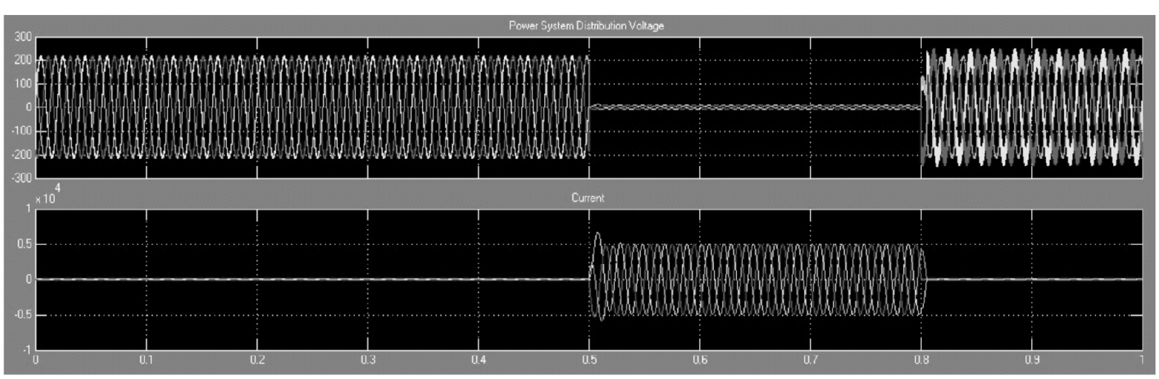

Figure 2: Three phase fault without UPFC

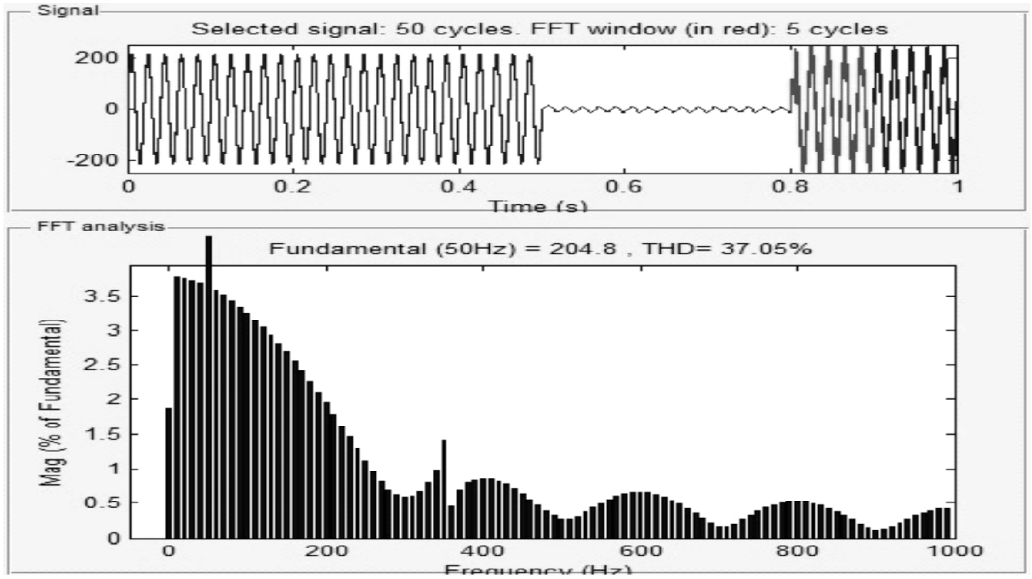

Figure 3: THD for Three phase fault without UPFC

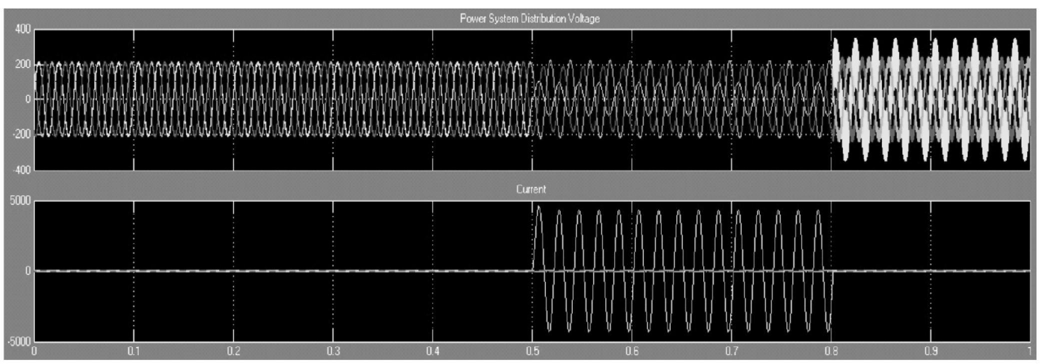

Figure 4: Line to ground fault without UPFC

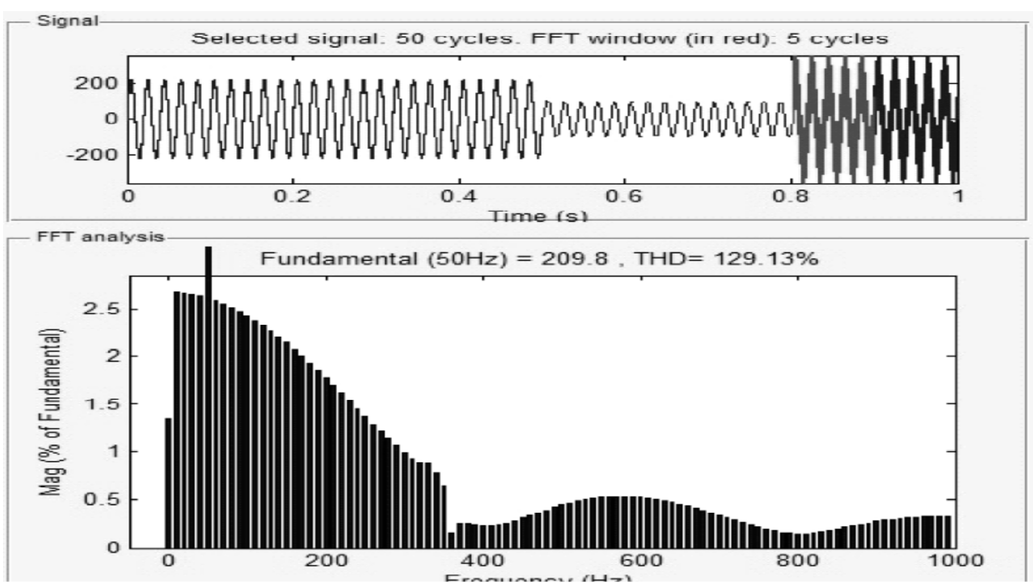

Figure 5: THD for Line to ground fault without UPFC

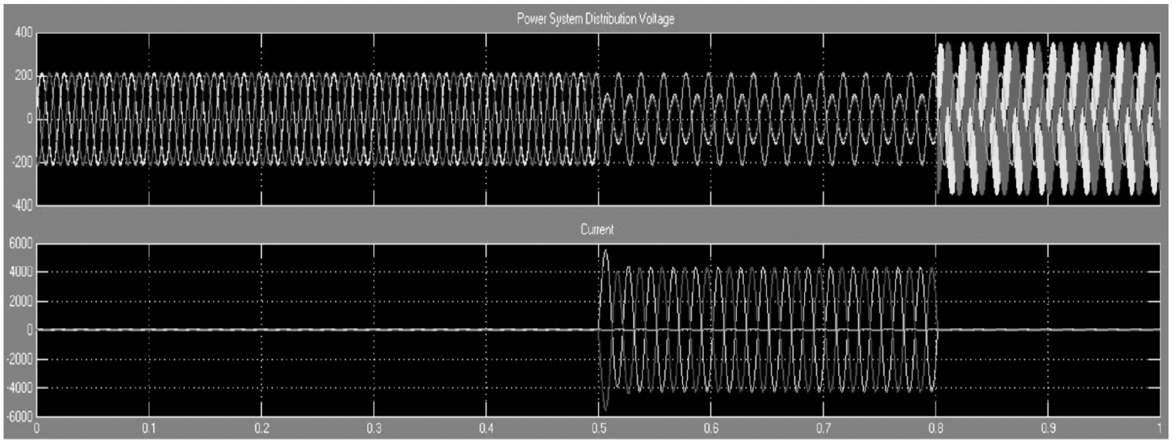

Figure 6: Line to Line fault without UPFC

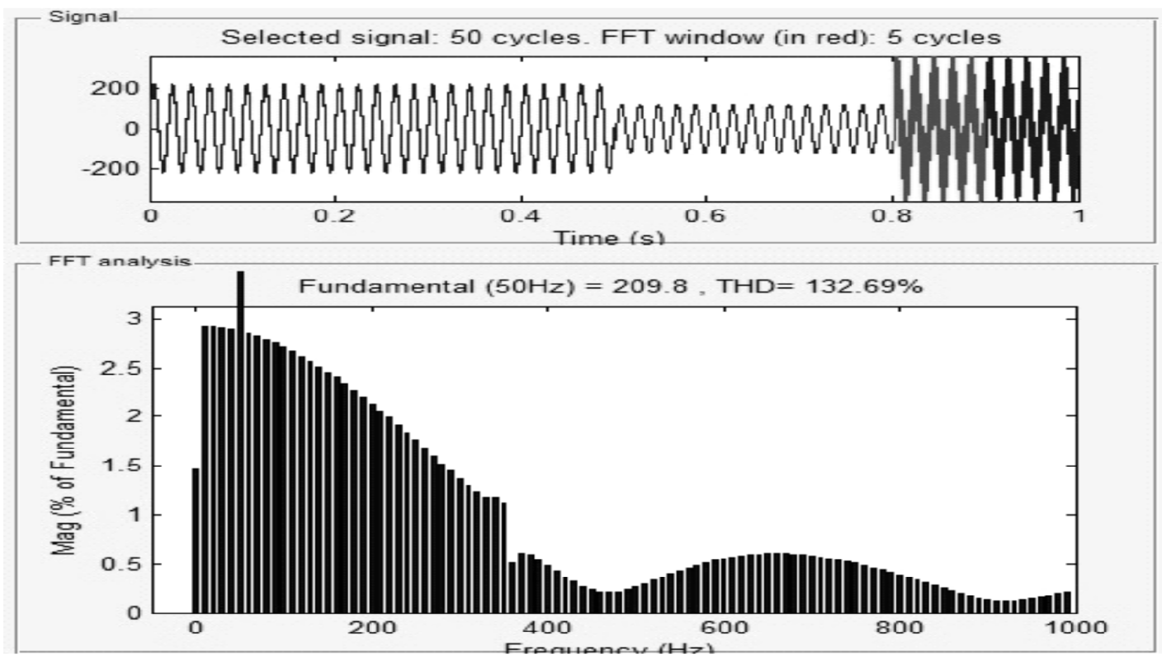

Figure 7: THD for Line to Line fault without UPFC

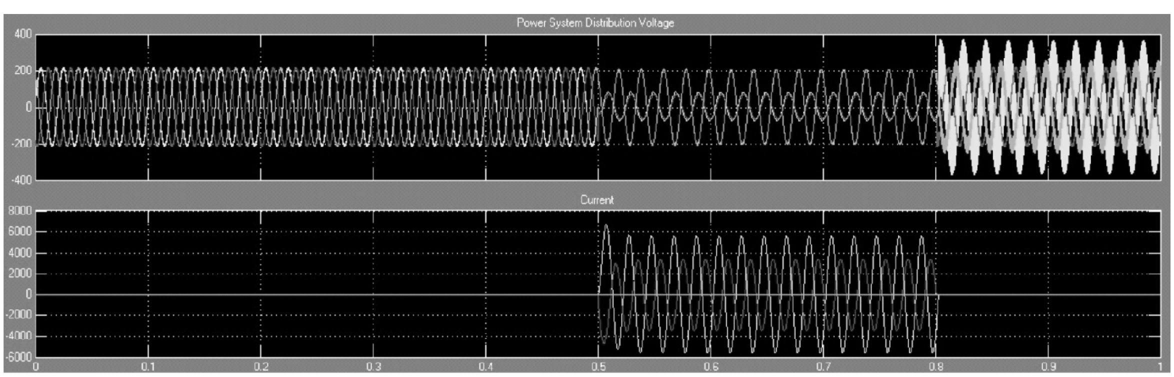

Figure 8: Double Line to ground fault without UPFC

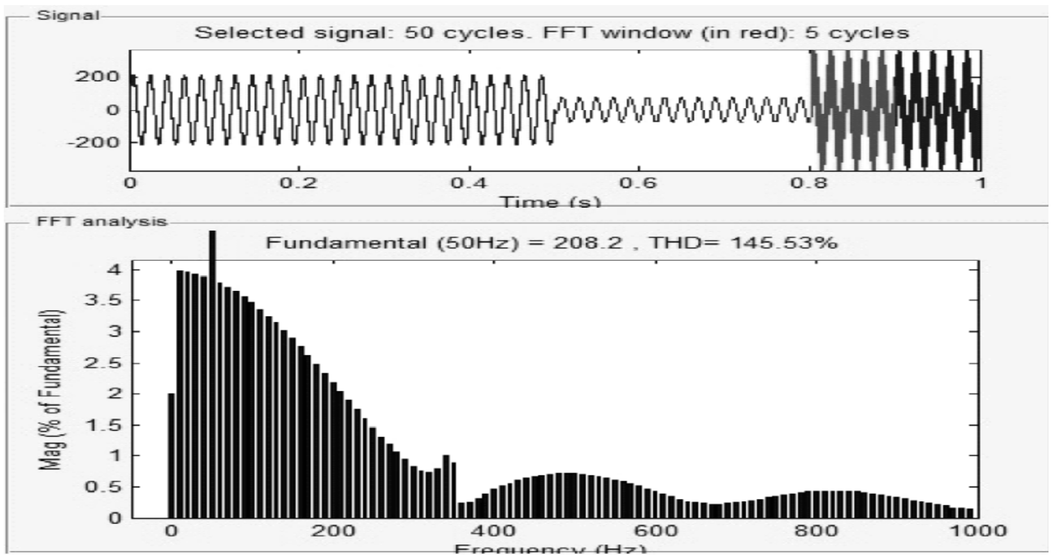

Figure 9: THD for Double Line to ground fault without UPFC

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. 5sec 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

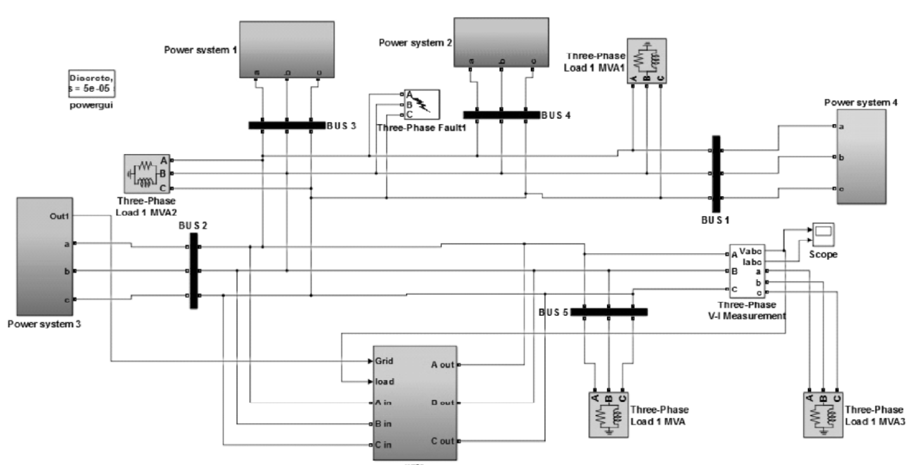

Figure 10: Simulation Model of UPFC with Fuzzy Controller

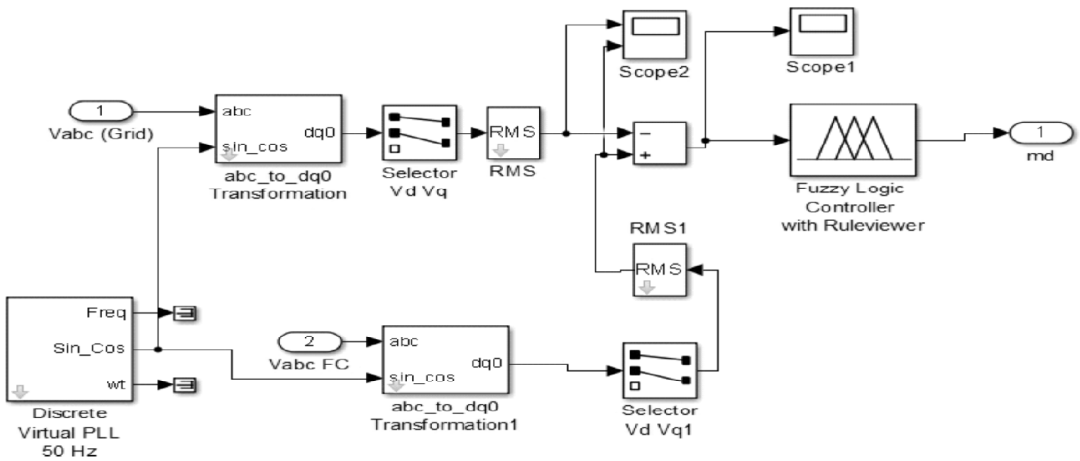

Figure 11: Fuzzy logic controller for UPFC

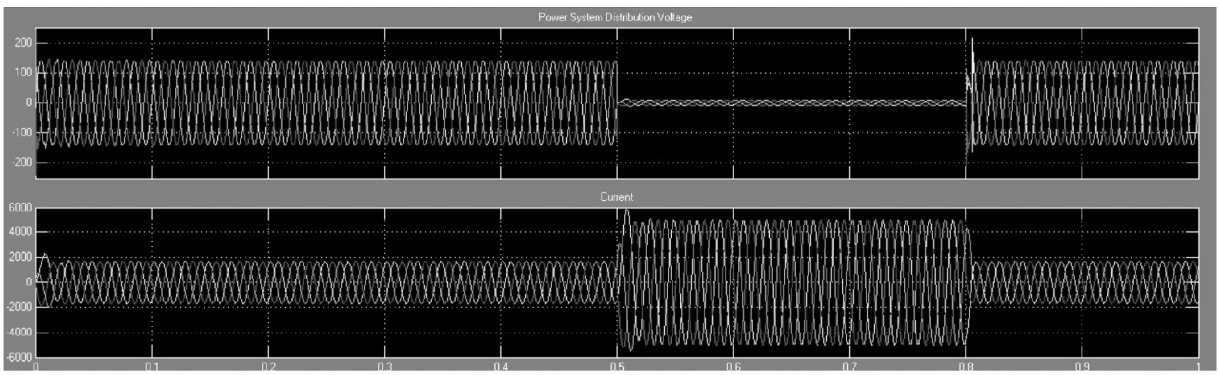

Figure 12: Three phase fault with UPFC + fuzzy controller

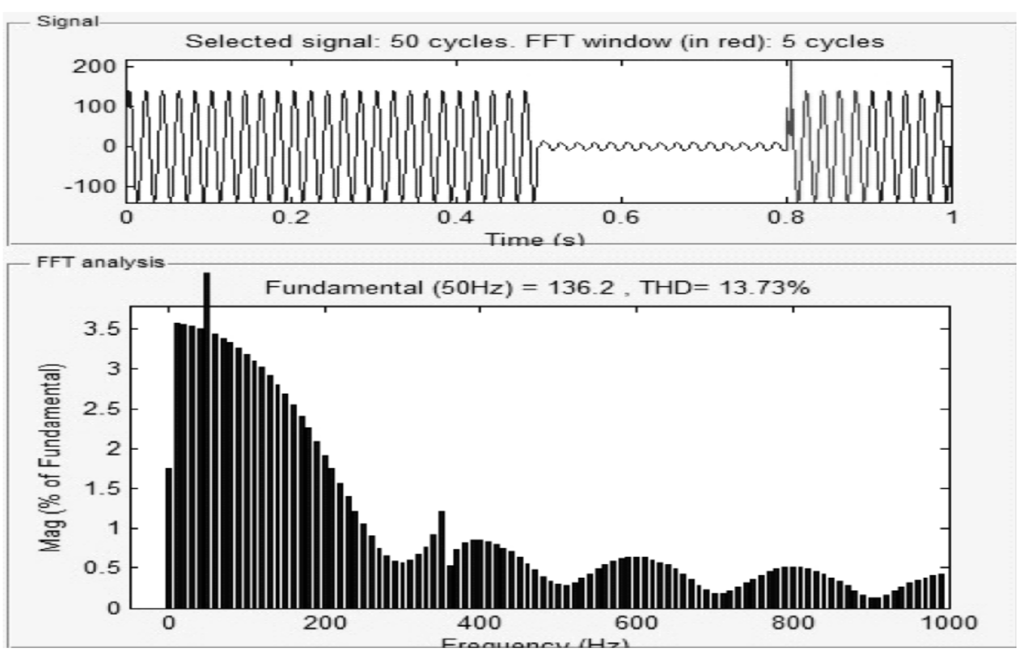

Figure 13: THD for Three phase fault with UPFC + fuzzy controller

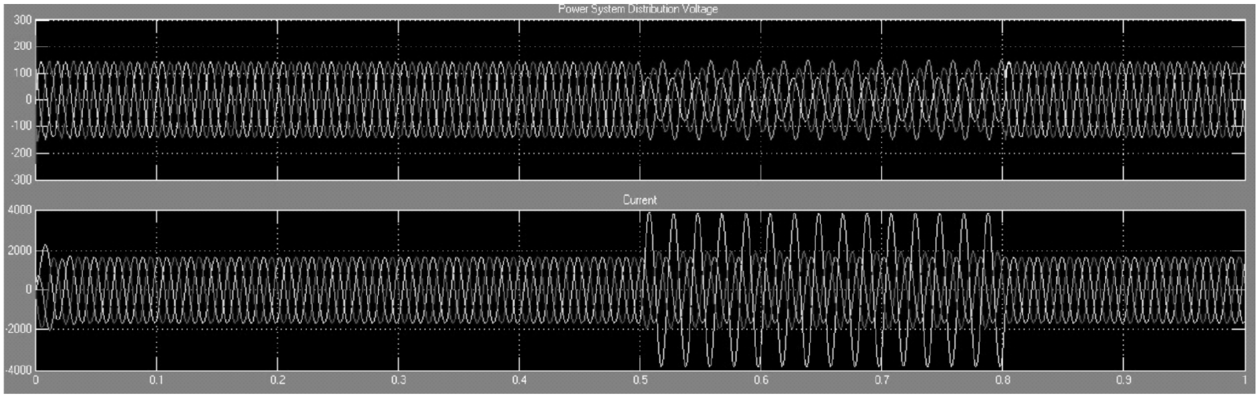

Figure 14: Line to ground fault with UPFC + fuzzy controller

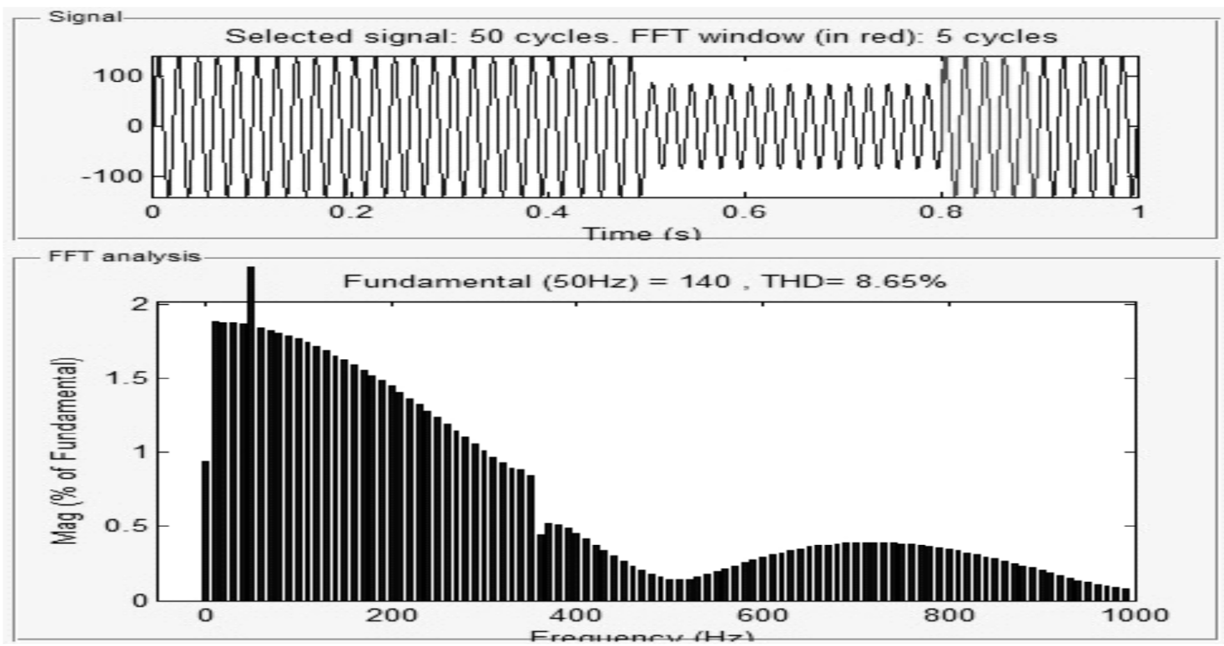

Figure 15: THD for Line to ground fault with UPFC + fuzzy controller

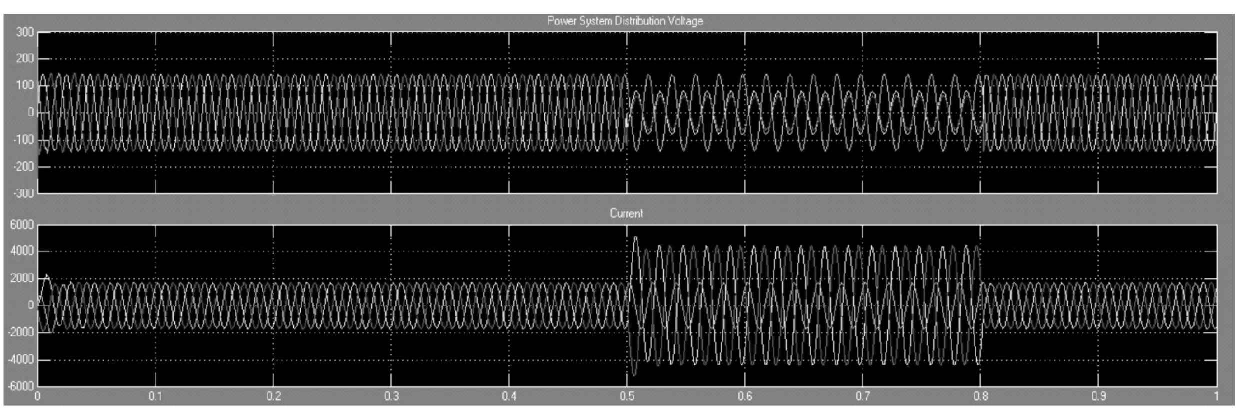

Figure 16: Line to Line fault with UPFC + fuzzy controller

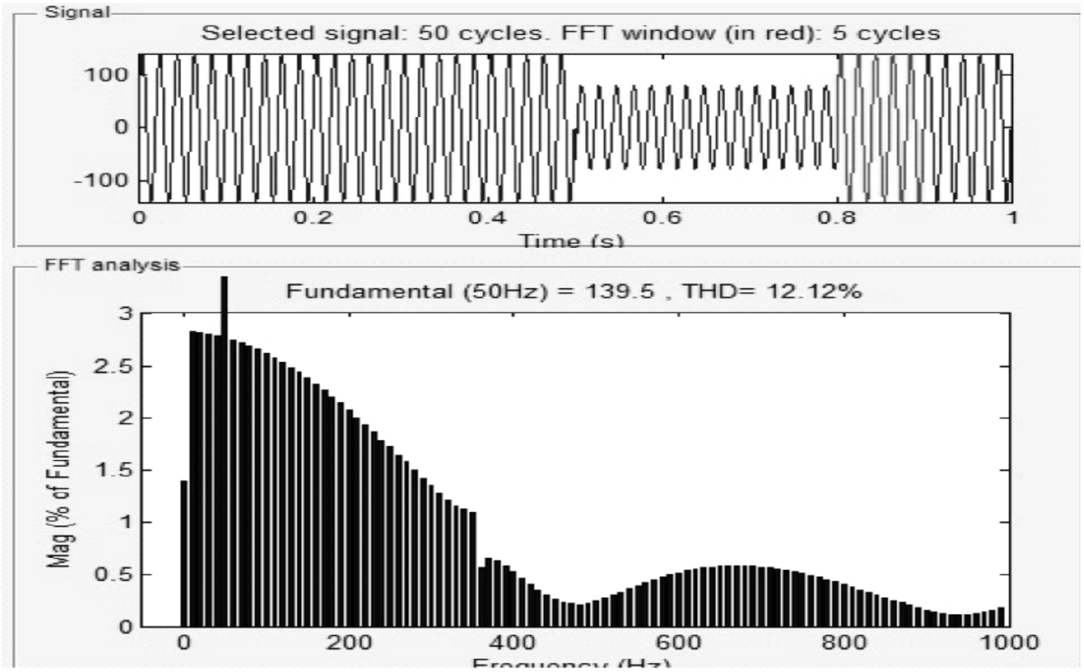

Figure 17: THD for Line to Line fault with UPFC + fuzzy controller

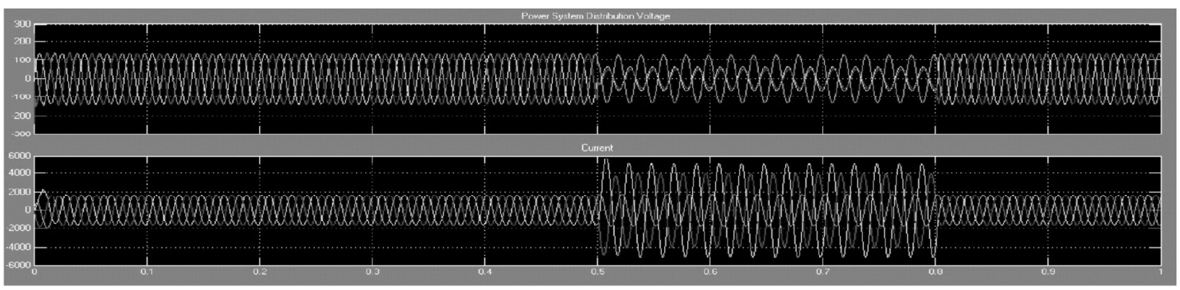

Figure 18: Double Line to ground fault with UPFC + fuzzy controller

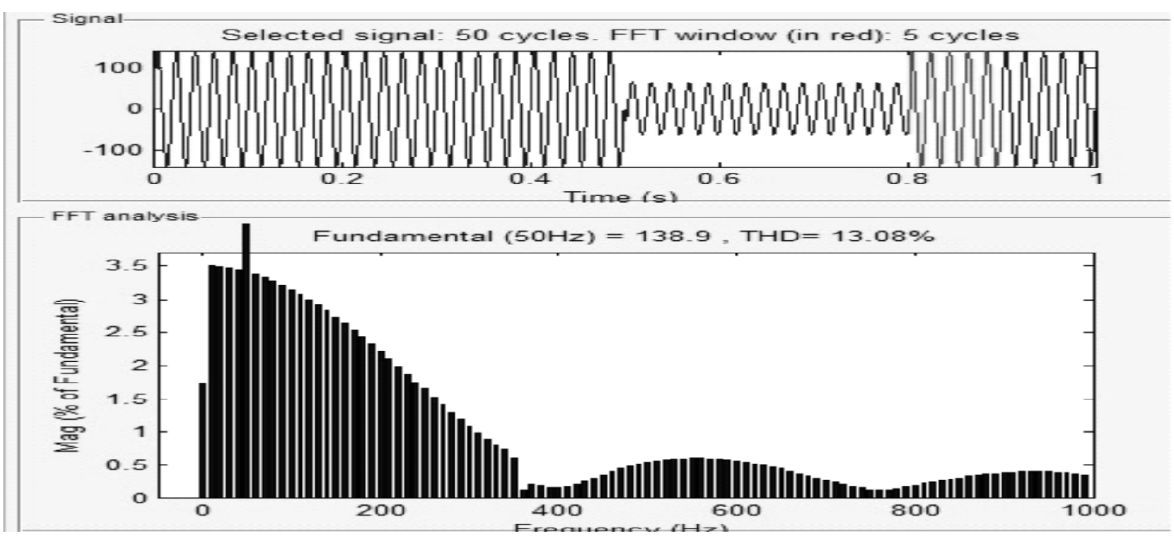

Figure 19: THD for Double Line to Ground fault with UPFC + fuzzy controller

The 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 fault 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.

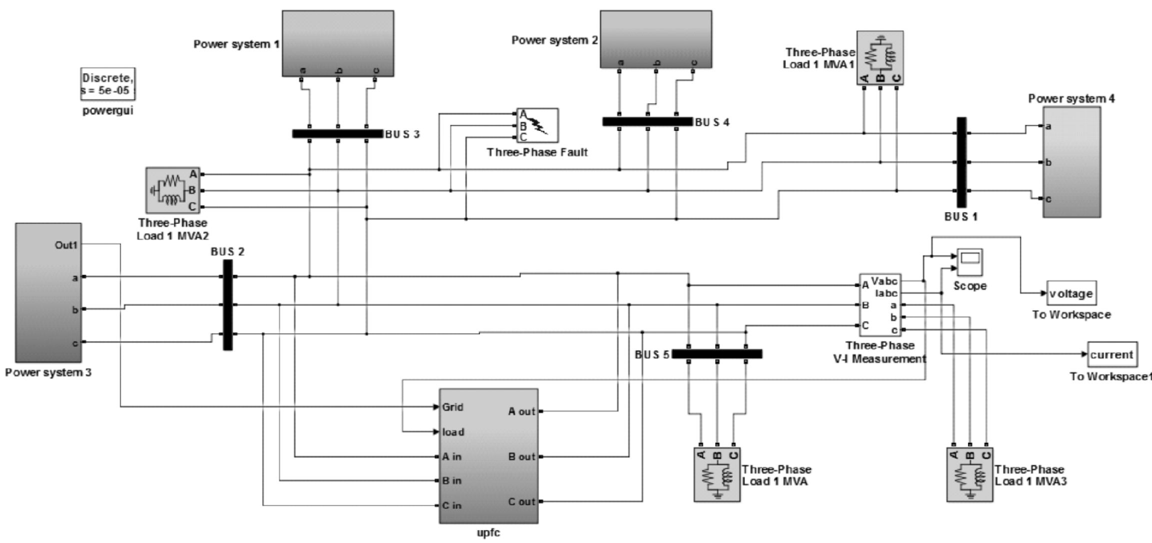

Figure 20: Simulation Model Of UPFC with Firefly Controller

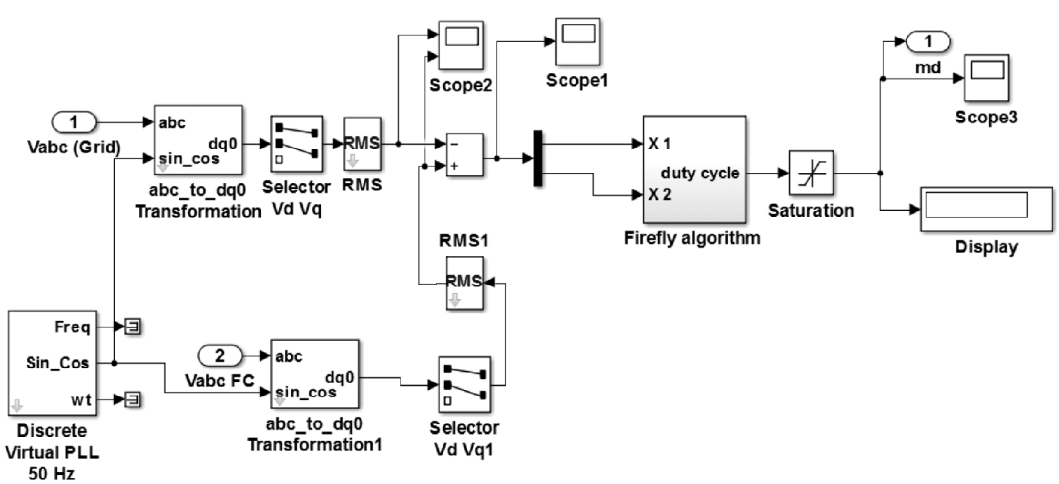

Figure 21: Firefly controller for UPFC

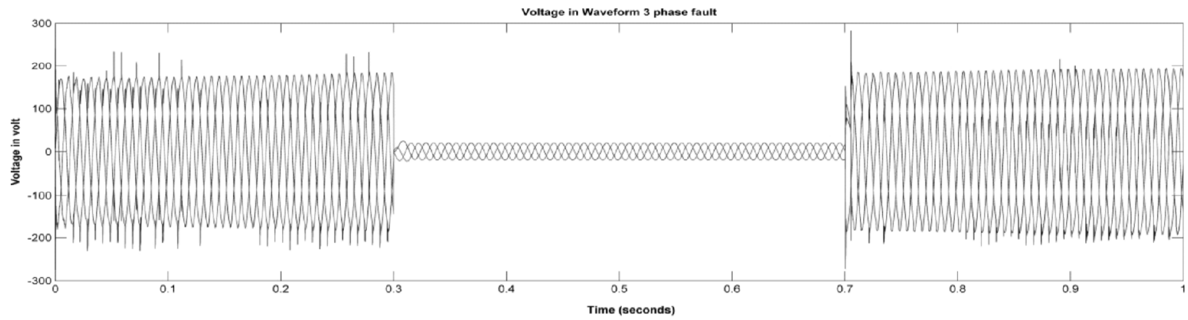

Figure 22: Three phase fault with UPFC + firefly controller

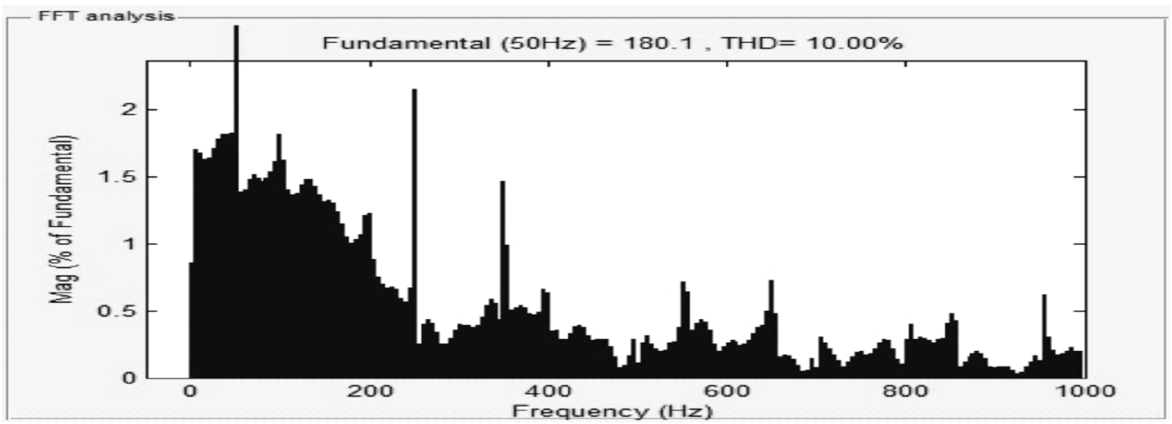

Figure 23 : THD value for Three phase fault with UPFC + firefly controller

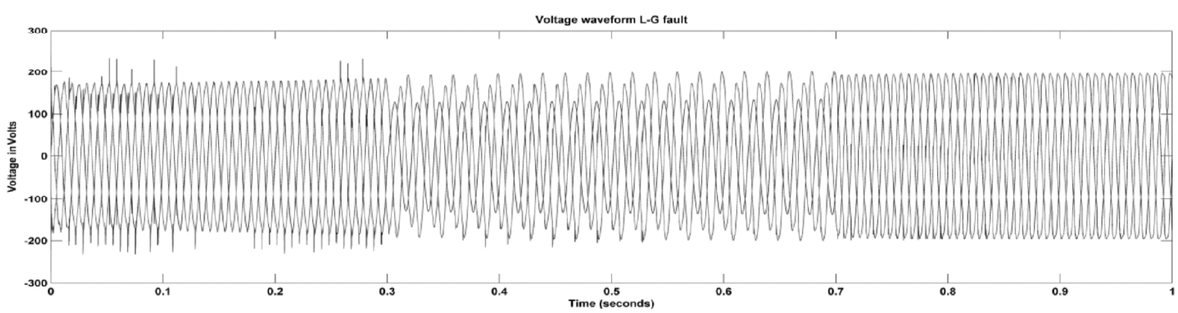

Figure 24: Line to Ground fault with UPFC + firefly controller

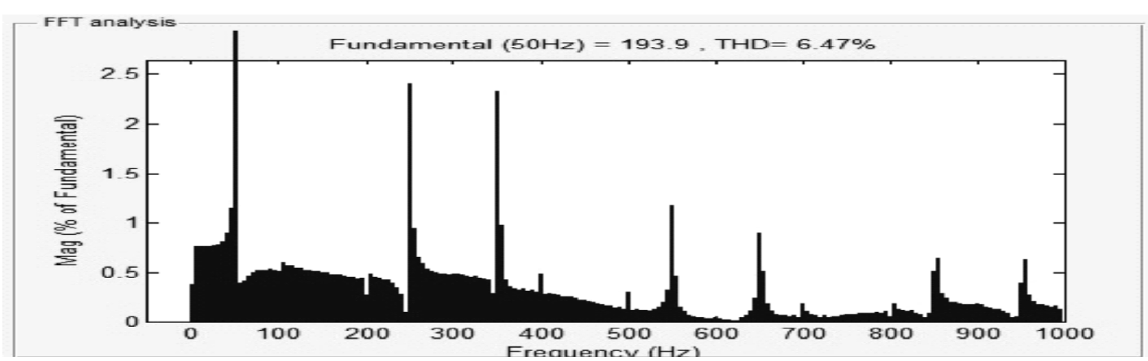

Figure 25 : THD value for Line to Ground fault with UPFC + firefly controller

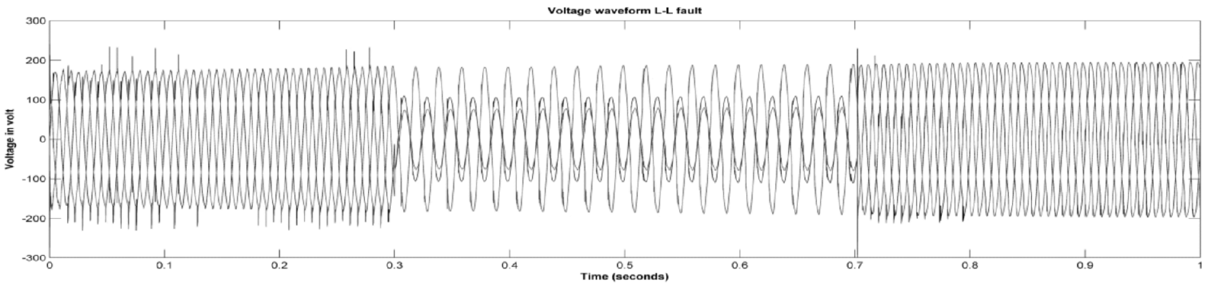

Figure 26: Line to Line fault with UPFC + firefly controller

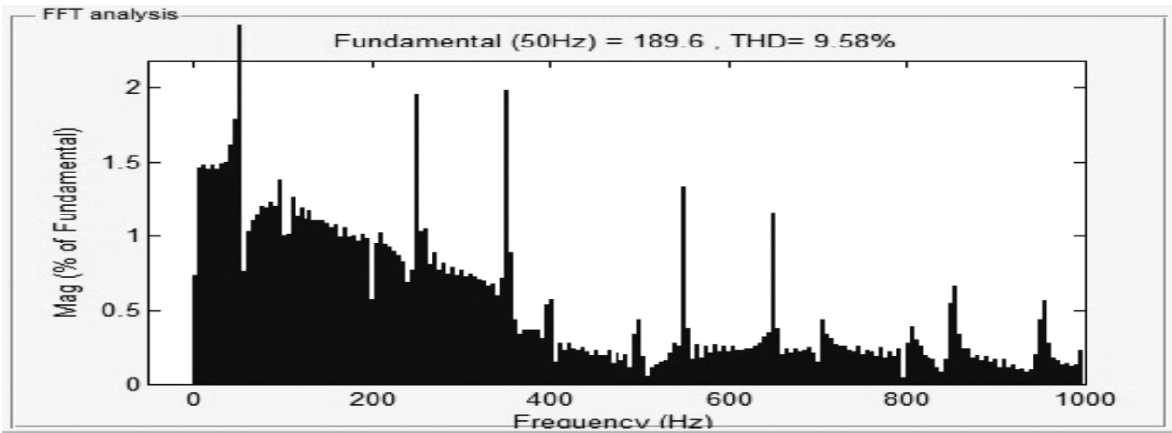

Figure 27 : THD value for Line to Line fault with UPFC + firefly controller

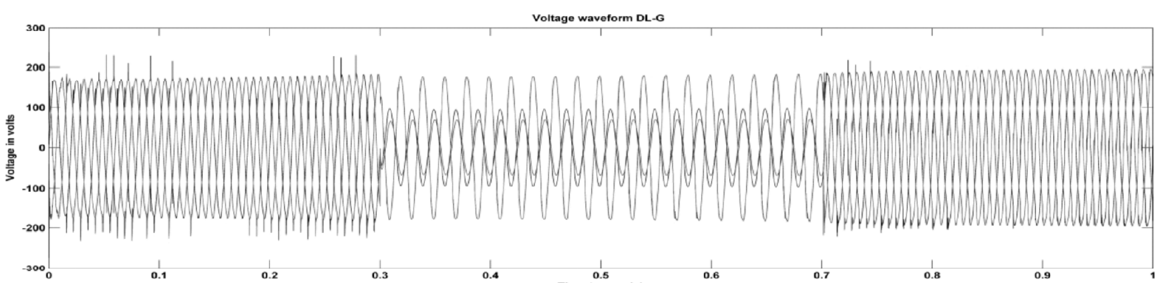

Figure 28: Double Line to Ground fault with UPFC + firefly controller

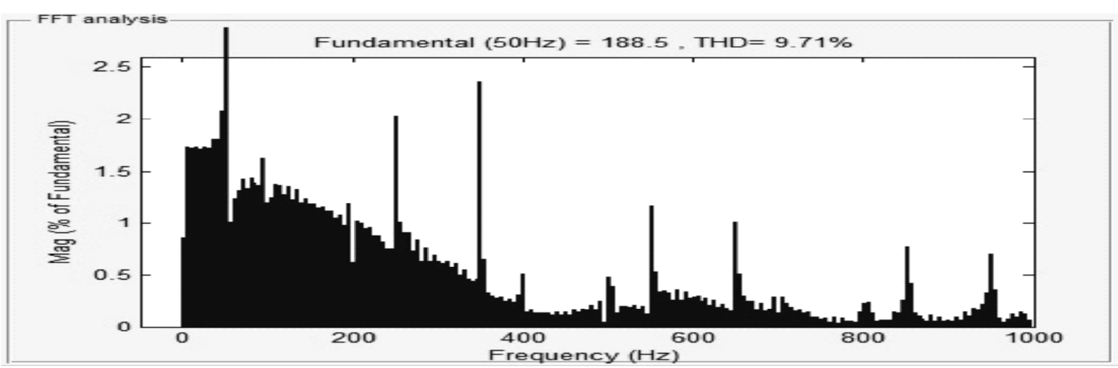

Figure 29 : THD value for Double Line to Ground fault with the UPFC + firefly controller

The proposed simulation model of UPFC tofirefly controller is shown in fig 20. The fig 21 is represented the firefly controller in UPFC system. The firefly controller has generated duty cycle of the PWM pulse to UPFC based on grid voltage and the reference voltage during fault conditions. The proposed model is simulated under different fault conditions. The 3 phase fault voltage waveform and its THD values 10. 00 % are shown in fig 22 and fig 23 respectively. The Line to ground faults, it's introduced in phase A and Ground as shown in fig 24 and its THD value is 6. 47% presented in fig 25. The line to ground faults occurs at 0. 3Sec to 0. 7Sec and after 0. 7Sec the system settled under normal condition as shown in fig 24. The Line to Line faults, it's introduced in phase A and Phase B as shown in fig 26 and its THD value is 9. 58% presented in fig 27. The line to line faults occurs at 0. 3Sec to 0. 7Sec and after 0. 7Sec the system settled under normal condition as shown in fig 26. The Double Line to ground faults, it's introduced in phase A, Phase B and Ground as shown in fig 28 and its THD value is 9. 71% presented in fig 29. The double line to ground faults occurs at 0. 3Sec to 0. 7Sec and after 0. 7Sec the system settled under normal condition as shown in fig 28. The above analysis is clearly represented after a fault occurs the system did not lose the voltage stability and support to improve the voltage usinga firefly controller based UPFC device. The proposed system has effectively maintained the power system stability under fault conditions. The comparative analysis of fuzzy and firefly based UPFC system in table 1.

Table 1
Comparison of THD values for radial distributed voltage with different controller

Faults	*Without UPFC*	*With UPFC and fuzzy*	*Firefly*
3 Phases	37. 05 %	13. 7 %	8. 06 %
L-G	129. 1%	8. 65%	4. 01 %
L-L	132. 6 %	12. 12%	7. 84 %
DL-G	145. 5 %	13. 08%	8. 24 %

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 different intelligent 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 voltage improvement radial distribution network.

REFERENCE

[1] F. M. Albatsh, S. Ahmad, S. Mekhilef, H. Mokhlis and M. A. Hassan, "D - Q model of fuzzy based UPFC to control power flow in transmission network," *Power Electronics, Machines and Drives (PEMD 2014), 7th IET International Conference on*, Manchester, 2014, pp. 1-6.

[2] S. Zhang, X. Lu, Y. Liu, B. Ge and F. Z. Peng, "Nine IGBTs based UPFC topology and control for renewable power integration," *Applied Power Electronics Conference and Exposition (APEC), 2013 Twenty-Eighth Annual IEEE*, Long Beach, CA, 2013, pp. 1294-1300.

[3] S. Yang, Y. Liu, X. Wang, D. Gunasekaran, U. Karki and F. Z. Peng, "Modulation and Control of Transformerless UPFC," in *IEEE Transactions on Power Electronics*, vol. 31, no. 2, pp. 1050-1063, Feb. 2016.

[4] S. S. Shrawane, M. Diagavane and N. Bawane, "Concoction of UPFC for optimal reactive power dispatch using hybrid GAPSO approach for power loss minimisation," *Power India International Conference (PIICON), 2014 6th IEEE*, Delhi, 2014, pp. 1-4.

[5] H. Rafiq *et al.* , "Control system design of UPFC for optimal power flow control," *Open Source Systems and Technologies (ICOSST), 2013 International Conference on*, Lahore, 2013, pp. 23-27. doi: 10. 1109/ICOSST. 2013. 6720600.

[6] A. Murugan and S. Thamizmani, "A new approach for voltage control of IPFC and UPFC for power flow management," *Energy Efficient Technologies for Sustainability (ICEETS), 2013 International Conference on*, Nagercoil, 2013, pp. 1376-1381.

[7] S. L. S. Lima, R. F. S. Dias and E. H. Watanabe, "Direct voltage control in grids with intermittent sources using UPFC," *2013 Brazilian Power Electronics Conference*, Gramado, 2013, pp. 974-980. doi: 10. 1109/COBEP. 2013. 6785233

[8] S. R. Paital, S. Patra, A. K. Singh, A. Mohanty and P. K. Ray, "Reactive power compensation using PSO controlled UPFC in a microgrid with a DFIG based WECS," *2015 Annual IEEE India Conference (INDICON)*, New Delhi, 2015, pp. 1-5.

[9] Y. Liu, S. Yang, X. Wang, D. Gunasekaran, U. Karki and F. Z. Peng, "Application of Transformer-Less UPFC for Interconnecting Two Synchronous AC Grids With Large Phase Difference," in *IEEE Transactions on Power Electronics*, vol. 31, no. 9, pp. 6092-6103, Sept. 2016.

[10] Y. Xiang, Y. Zhang, L. Wang and W. Sun, "Impact of UPFC on power system reliability considering its cyber vulnerability," *2014 IEEE PES T&D Conference and Exposition*, Chicago, IL, USA, 2014, pp. 1-5.

[11] P. Acharjee, "Optimal power flow with UPFC using self-adaptive differential evolutionary technique under security constraints," *Recent Developments in Control, Automation and Power Engineering (RDCAPE), 2015 International Conference on*, Noida, 2015, pp. 177-182.

[12] S. Yang, D. Gunasekaran, Y. Liu, U. Karki and F. Z. Peng, "Application of transformer-less UPFC for interconnecting synchronous AC grids," *2015 IEEE Energy Conversion Congress and Exposition (ECCE)*, Montreal, QC, 2015, pp. 4993-4999.

[13] A. Ray and J. O. Chandle, "Voltage stability enhancement during excess load increments through optimal location of UPFC devices," *Advancements in Power and Energy (TAP Energy), 2015 International Conference on*, Kollam, 2015, pp. 443-448.

[14] S. Dawn and P. K. Tiwari, "Maximization of social welfare by optimal allocation of UPFC with wind power generator in deregulated electricity market," *Advanced Communication Control and Computing Technologies (ICACCCT), 2014 International Conference on*, Ramanathapuram, 2014, pp. 314-318.

[15] L. N. Tripathy, S. R. Samantaray, M. K. Jena and S. K. Mishra, "Fast discrete S-transform based differential relaying scheme for UPFC compensated parallel line," *Electrical, Electronics, Signals, Communication and Optimization (EESCO), 2015 International Conference on*, Visakhapatnam, 2015, pp. 1-6.

[16] O. Rodríguez, A. Medina and G. Andersson, "Analytical characterization of nonlinear modal interaction in power systems with UPFC," *PowerTech, 2015 IEEE Eindhoven*, Eindhoven, 2015, pp. 1-6. doi: 10. 1109/PTC. 2015. 7232831

[17] R. Selvarasu and M. S. Kalavathi, "UPFC placement: A new self adaptive firefly algorithm," *Sustainable Energy and Intelligent Systems (SEISCON 2013), IET Chennai Fourth International Conference on*, Chennai, 2013, pp. 204-209.

[18] A. R. Bhowmik, A. K. Chakraborty and P. N. Das, "Placement of UPFC for minimizing active power loss and total cost function by PSO algorithm," *Advanced Electronic Systems (ICAES), 2013 International Conference on*, Pilani, 2013, pp. 217-220.

[19] Y. I. Djilani Kobibi, S. Hadjeri and M. A. Djehaf, "Independent Power Flow Control and dynamic performance enhancement by the UPFC," *Electrical and Information Technologies (ICEIT), 2015 International Conference on*, Marrakech, 2015, pp. 71-76.

[20] Z. Moravej, M. Pazoki and M. Khederzadeh, "Impact of UPFC on Power Swing Characteristic and Distance Relay Behavior," in *IEEE Transactions on Power Delivery*, vol. 29, no. 1, pp. 261-268, Feb. 2014. doi: 10. 1109/TPWRD. 2013. 2270408

[21] M. Sarkar, "Effect of UPFC allocation on transmission system power loss," *Energy Efficient Technologies for Sustainability (ICEETS), 2013 International Conference on*, Nagercoil, 2013, pp. 1185-1188. doi: 10. 1109/ICEETS. 2013. 6533555.