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Voltage Regulation by Using Fuzzy Controller in UPFC

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Abstract:- *Voltage regulation and line loss minimization in distribution networks are challenging problems, particularly when it is not economic to upgrade the entire feeder system. This projects a new method achieving line loss minimization and all nodes voltage regulation in the loop distribution systems, simultaneously, by using Unified Power Flow Controller (UPFC) by using Fuzzy Controller. First, the line loss minimum conditions in the loop system are presented. Then, load voltage regulation is applied under line loss minimum conditions. Reference voltage of the controlled node is determined based on the assumption that this voltage can subsequently improve all node voltages to be within the permissible range. The proposed control scheme of the UPFC is series converter by Sub synchronous Series Compensator (SSSC) and shunt converter by Static Synchronous Compensator (STATCOM).*
Index: *UPFC-Unified Power Flow Controller, FLC-Fuzzy Logic Controller, VSI-Voltage Source Inverter, FACTS-Flexible AC Transmission System, THD-Total Harmonics Distortions*

I. Introduction

The large interconnected transmission networks (made up of predominantly overhead transmission lines) are susceptible to faults caused by lightning discharges and decrease in insulation clearances by undergrowth. The power flow in a transmission line is determined by Kirchhoff's laws for a specified power injection (both active and reactive) at various nodes. While the loads in a power system vary by the time of the day in general, they are also subject to variations caused by the weather (ambient temperature) and other unpredictable factors. The generation pattern in a deregulated environment also tends to be variable (and hence less predictable). Thus, the power flow in a transmission line can vary even under normal, steady state conditions.

The occurrence of a contingency (due to the tripping of a line, generator) can result in a sudden increase/decrease in the power flow. This can result in overloading of some lines and consequent threat to system security. FACTS controllers in power transmission and distribution.

A major disturbance can also result in the swinging of generator rotors which contribute to power swings in transmission lines. It is possible that the system is subjected to transient instability and cascading outages as individual components (lines and generators) trip due to the action of protective relays. If the system is operating close to the boundary of the small signal stability region, even a small disturbance can lead to large power swings and blackouts.

Two Voltage Source Inverter's (VSI) can work independently by separating the DC side. So in that case, the shunt inverter is operating that generates or absorbs reactive power to regulate the voltage magnitude at the connecting point. The series inverter is operating as that generates or absorbs reactive power to regulate the current flow, and hence the power flow on the transmission line regulated.

The Unified Power Flow Controller (UPFC) can be used to improve the power quality due to the separate controlling capability of real and reactive power.

The real and reactive power is investigated and observed that the real power increases with the increase in the angle of injection. The reactive power increased with the shunt voltage injection.

II. Power Quality

The term power quality is applied to a wide variety of electromagnetic phenomena on the power system. The increasing application of electronic equipment and distributed generation has heightened the interest in power quality in recent years, and this has been accompanied by the development of a special terminology to describe the phenomena.

Unfortunately, this terminology has not been consistent across different segments of the industry. This has caused a considerable amount of confusion as both vendors and end users have struggled to understand why electrical equipment is not working as expected. Likewise, it is confusing to wade through the vendor jargon and differentiate between a myriad of proposed solutions. Many ambiguous words have been used that have multiple or unclear meanings.

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III. Facts Controllers

The increase in the loading of the transmission lines sometimes can lead to voltage collapse due to the shortage of reactive power delivered at the load canters. This is due to the increased consumption of the reactive power in the transmission network and the characteristics of the load (such as induction motors supplying constant torque). The factors mentioned in the previous paragraphs point to the problems faced in maintaining economic and secure operation of large interconnected systems. The problems are eased if sufficient margins (in power transfer) can be maintained. This is not feasible due to the difficulties in the expansion of the transmission network caused by economic and environmental reasons. The required safe operating margin can be substantially reduced by the introduction of fast dynamic control over reactive and active power by high power electronic controllers. This can make the AC transmission network `Flexible' to adapt to the changing conditions caused by contingencies' and load variations. Flexible AC Transmission System (FACTS) is defined as `Alternating current transmission systems incorporating power electronic-based and other static controllers to enhance controllability and increase power transfer capability'.

The FACTS controller is defined as `a power electronic based system and other static equipment that provide control of one or more AC transmission system parameters'.
The FACTS controllers can be classified as
1. Shunt connected controllers
2. Series connected controllers
3. Combined series-series controllers
4. Combined shunt-series controllers

Advantages of FACTS technology
- Rapid response
- Decreases DC offset voltages
- Reduction of short circuit current
- Frequent variation in output.

Unified Power Flow Controller (UPFC)

Line outage, congestion, cascading line tripping, power system stability loss are the major issues where capability and utilization of FACTS are noticed. Representative of the last generation of FACTS devices is the Unified Power Flow Controller (UPFC). The UPFC is a device which can control simultaneously all three parameters of line power flow (line impedance, voltage and phase angle). Such "new" FACTS device combines together the features of two "old" FACTS devices. The Static Synchronous Compensator (STATCOM) and the Static Synchronous Series Compensator (SSSC). In practice, these two devices are two Voltage Source Inverters (VSI's) connected respectively in shunt with the transmission line through a shunt transformer and in series with the transmission line through a series transformer, 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.

Basic UPFC functional scheme:

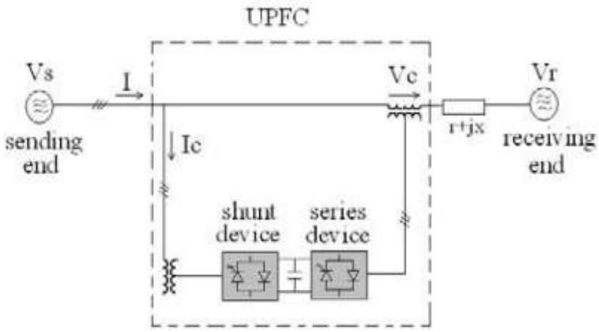

Fig.1 Basic UPFC diagram

Figure 1 shows the basic UPFC diagram. 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 asymmetrical three phase voltage system (Vc), 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. The shunt inverter is operated 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.

IV. Proposed Method

Design of Fuzzy Logic Controller

Vagueness is the meaning of FUZZY. It is used to solving the uncertainty in the problem. It uses the interval between 0 and 1 for human reasoning. The FUZZY operation works by two stages and are Fuzzification and Defuzzification. The process of converting the crisp input to a fuzzy value is called as Fuzzification. The output of the fuzzy is developed with the rules. The basic operation of the FLC is constructed from fuzzy control rules utilizing the value of fuzzy sets in general for the error and change of error and control action. The results are combined to provide a crisp output controlling the output variable and this process is called as defuzzification. The figure 2 and 3 shows the adding variable and membership function of fuzzy in mamdani. The sign of the error signal and the output from linguistic codes given in the table 1.

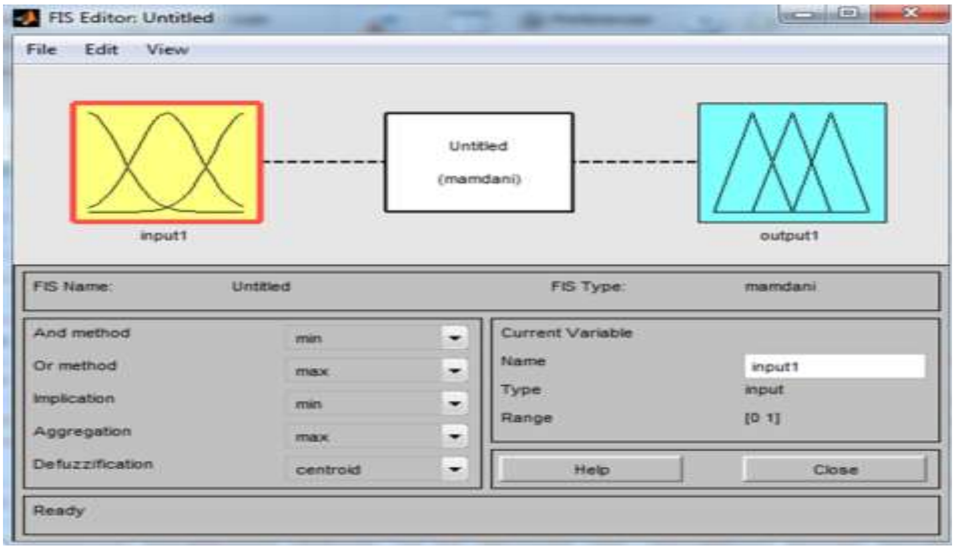

Fig.2 Adding Variable

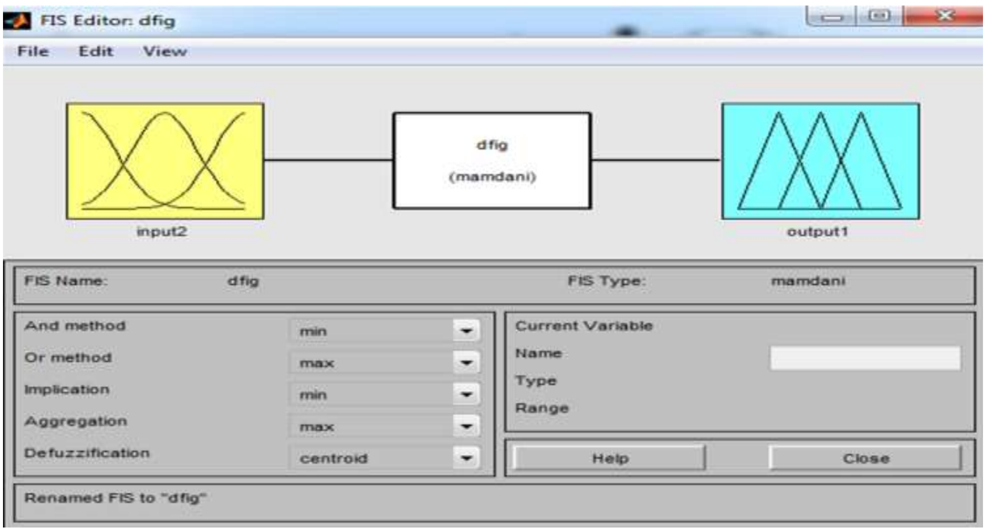

Fig. 3 Membership function

Table 1 Basi2 truth table for 7*7 Fuzzy

	ERROR							
		NB	NM	NS	Z	PS	PM	PB
CHANGE IN ERROR	NB	NB	NB	NB	NB	NM	NS	Z
	NM	NB	NB	NB	NM	NS	Z	PS
	NS	NB	NB	NM	NS	Z	PS	PM
	Z	NB	NM	NS	Z	PS	PM	PB
	PS	NM	NS	Z	PS	PM	PB	PB
	PM	NS	Z	PS	PM	PB	PB	PB
	PB	Z	PS	PM	PB	PB	PB	PB

Advantages of Using Fuzzy

- High efficient than proportional integral (PI) controller.
- Fast response than PI Controller
- Fault duration is reduced when using fuzzy controller.
- Fuzzification and Defuzzification is easy.

V. Simulation Results

MATLAB/Simulink has become a very powerful tool for industrial application as well as in academics, now- a- days. It is now essential for an electrical engineer to understand the concept of simulation and learn its use in various applications. Simulation is one of the best ways to study the system or circuit behavior without damaging it. The tools for doing the simulation in various fields are available in the market for engineering professionals. Many industries are spending a considerable amount of time and money in doing simulation before manufacturing their product. In most of the research and development (R&D) work, the simulation plays a very important role. Without simulation it is quiet impossible to proceed further. It should be noted that in power electronics, computer simulation and a proof of concept hardware prototype in the laboratory are complimentary to each other.

5.1 Simulation Diagram of Transmission Line With Output Waveform Under Fault Condition:

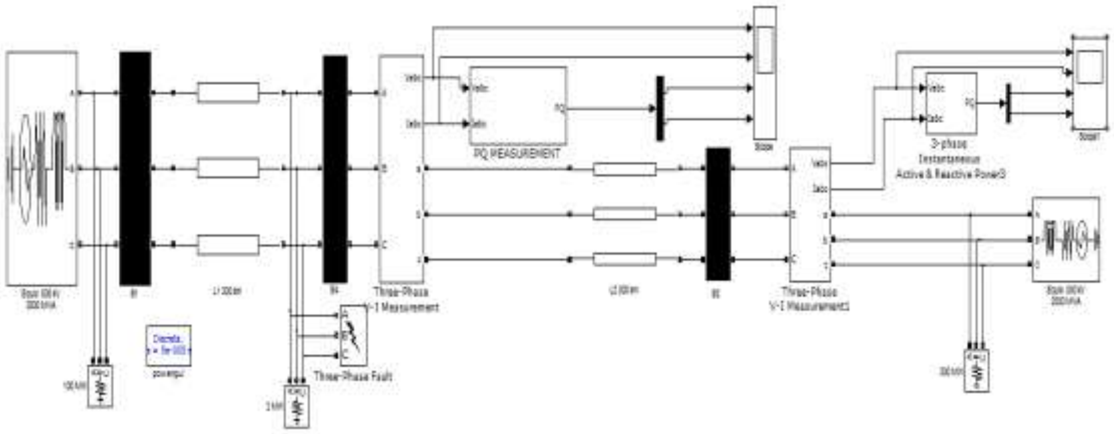

Fig.4: Transmission line simulation diagram under L-G fault condition

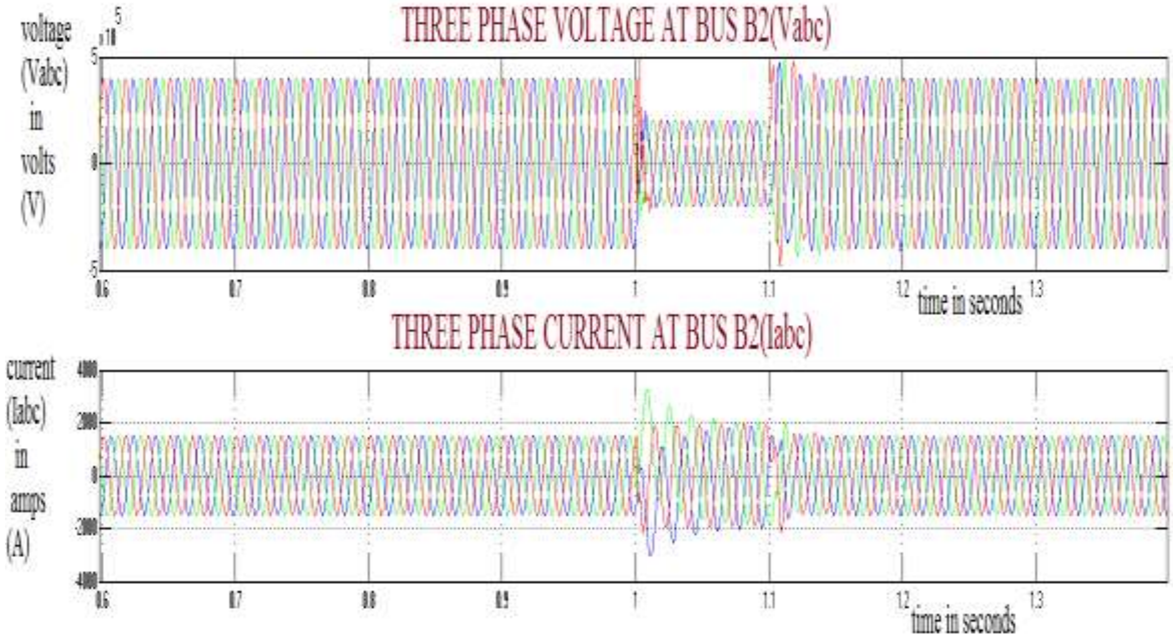

Fig 5: HV side(grid) three phase voltages and currents($V_{ab}c$,I_{abc}) under L-G fault condition without UPFC

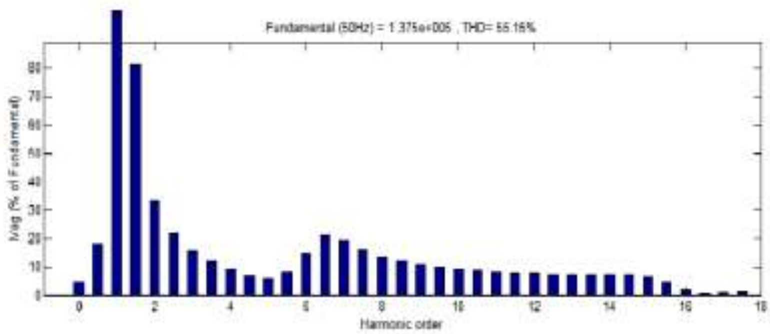

Fig 6: FFT analysis for voltage in transmission line without STATCOM

Fig. 6 shows the FFT Analysis of voltage in transmission line, we get 55.15%, without using compensating device.

5.2 Simulation Circuit for Closed Loop with Fault (Fuzzy Logic Controller)

In this section the compensation device is added to compensate (inject or to absorb) the voltage in order to have a compensated voltage at the load end. To achieve the compensation Fuzzy sets are used to produce the Fuzzy logic controller which makes it more perfect. Figure 7 consist of UPFC fed by the fuzzy logic controller to regulate the voltage levels.

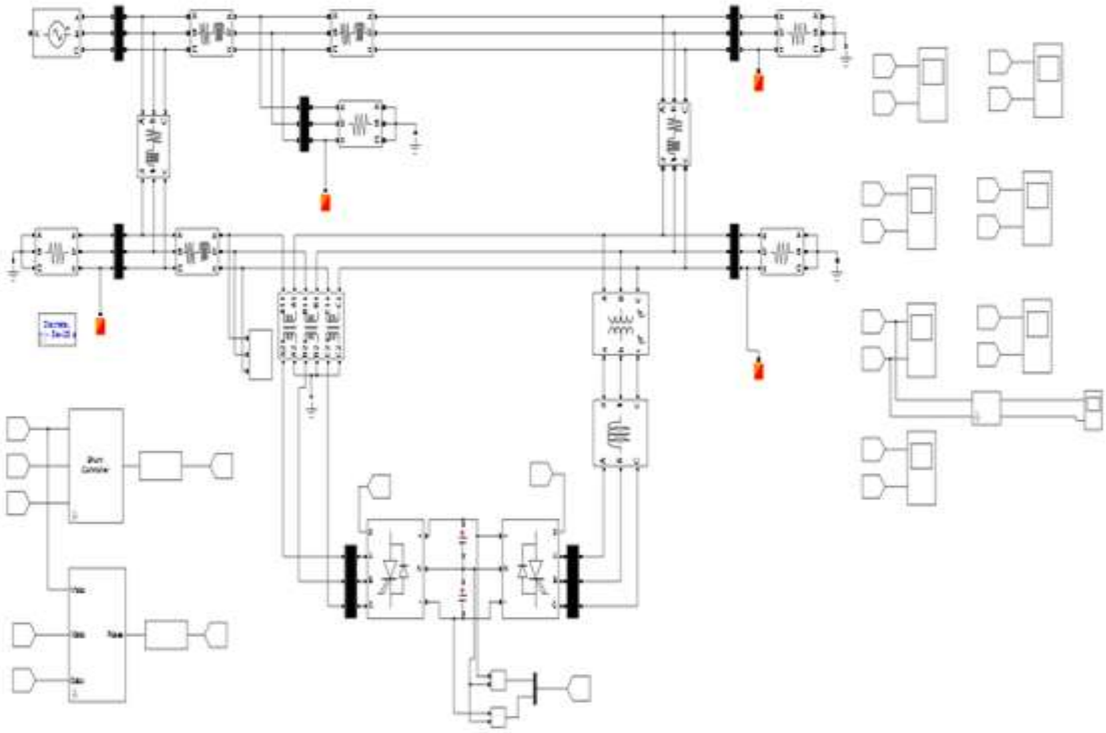

Fig. 7 Simulation Circuit for Closed Loop with Fault

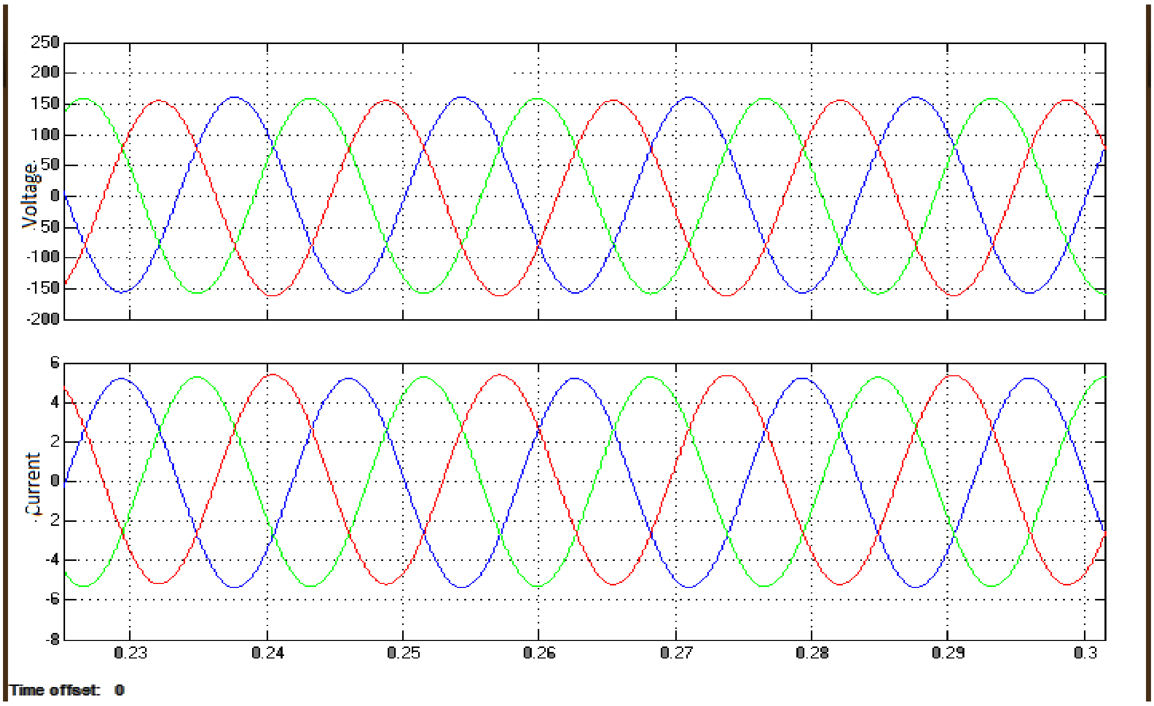

Fig. 8 Output Voltage& Current waveform with fault with UPFC

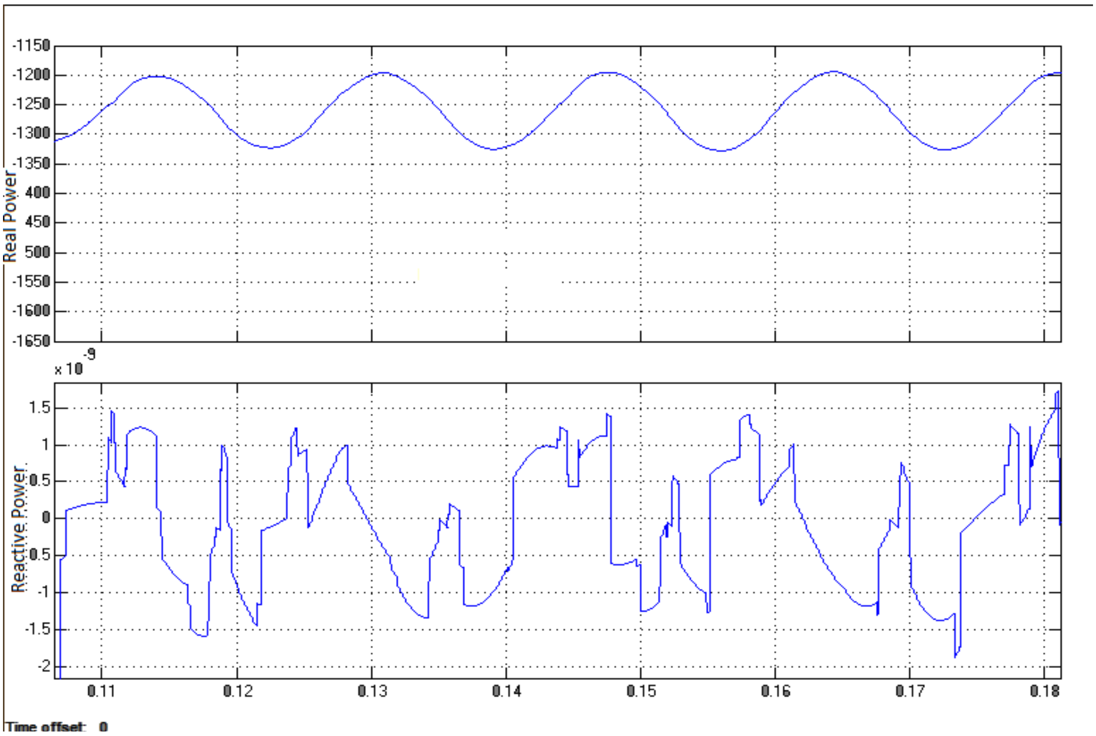

Fig. 9 Output Real and Reactive Power waveform with UPFC with fault

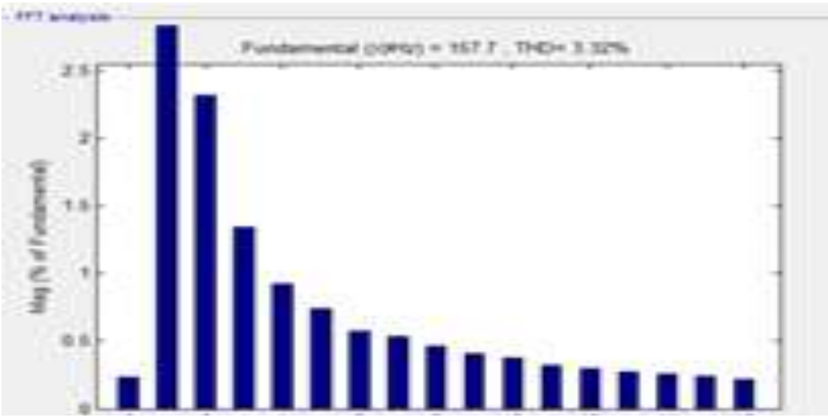

Fig. 10 THD for with UPFC for closed loop-Fuzzy

VI. Conclusion

This project has presented the line loss minimum conditions and the control scheme of UPFC to regulate all node voltages to be within the permissible voltage range under loss minimization in the closed loop distribution systems. Regulating node voltages under line loss minimization has been achieved by controlling the phase angle of the controlled voltage. Installing UPFC to minimize the total line loss or to regulate the load voltage to be equal in magnitude to the nominal source voltage under loss minimization is guaranteed all node voltages to be within the permissible voltage limit. As the implementation of FLC in UPFC reduces the THD by 3.73%.

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