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Comparative Analysis of Power System Total Harmonics During Fault using Overcurrent Relay Implementing Fuzzy Logic Controller

Ravindra Nath[1], Department of Electrical Engineering, Arya Institute of Engineering & Technology, Jaipur, India

E-Mail Id : ravindranath67@gmail.com

Deepak Sharma[2], Department of Electrical Engineering, Arya Institute of Engineering & Technology, Jaipur

E-Mail id: deepak.sharma581@gmail.com

Rajkumar Kaushik[3], Asst. Professor, Department of Electrical Engineering, Arya Institute of Engineering & Technology, Jaipur

E-Mail id: rajkaushik1812@gmail.com

Abstract

To manage overcurrent, relay is used namely overcurrent relay and to optimize reactive power FACTS devices are in trend. In this work, four-unit system is created and a fault is introduced for analysis. To manage reactive power STATCOM is implemented. The reason to work with these traditional controllers is to optimization their performance using latest technologies. Similarly, in this work overcurrent relay is optimized using additional trip mechanism and STATCOM is optimized its performance using PID and Fuzzy logic controller (FLC). Comparative analysis is conducted for PID and fuzzy logic controller for output results. Parameter considered for these comparisons is voltage, current, Total harmonic distortion (THD), active power and reactive power.

The system is designed in MATLAB/ Simulink software with separate modelling of PID and Fuzzy logic controller.

Keyword: Over current Relay, FACTS, STATCOM, Fuzzy Logic Controller, THD

Introduction

Relays play an important role in protection of any electrical system. Relay prevents the system by separation from faulty area / part so it can’t damage health area. Proper use of relay and its tuning gives a strong system and prevent from break down. FACTS devices along with relay are best to increase the efficiency of power system.

Power System Structure

As shown in Fig. 1.1, a specific power system consists of generation units, transmission networks, distribution networks and loads. Electric power is produced by the synchronous generator located in the power plants, which convert a primary source of energy to electrical power. Generally, the generated voltage of power is running from 10kV to 25kV. This voltage has then increased from 230kV to 765kV high voltage level through step-up transformer. After this, the electrical power transmission on these high voltages is transmitted through the network. In the substation, the voltages run down to the lower level. There, electric energy is distributed on the basis of the needs of the customers to load through primary and secondary distribution feeders.

Overcurrent protection

There are three different types of overcurrent-protection relays operating principles for short circuit, semantic-fault and overload all three applications are based on the comparison of current as seen by relay and preset value. The relay is operated when the stream exceeds the threshold. Both transient and time-delayed trips are common. Overcurrent protection is simple, cheap and reliable. Although it performs best in the radial system because the selection system is difficult or sometimes it is impossible to obtain in fake system configuration.

Short Circuit Overcurrent Protection

Normally, during the event of a mistake, there is a considerable increase in the normal operation in respect of normal operation. This behavior is used by short circuit overcurrent protection so that the operation of the fault can be separated from normal operation.

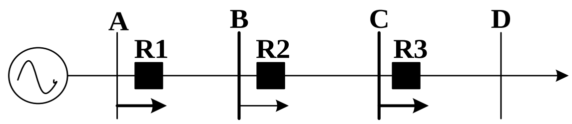

Fig. 1. A Radial Fed System Equipped with Non-Directional Overcurrent Protection.

In Figure 1, a radial fade system is shown where each line section is equipped with a non-directional overcurrent relay. In order to achieve proper operation, each relay should be given an operation current, which is larger than the largest possible surcharge, obviously the operation current should be less than the smallest possible fault current. To calculate the smallest possible mistake, a phase-to-phase fault in the current stage is usually applied to the remote terminal for the shortest possible short circuit power in the feeding terminal. To achieve selectivity, a high operational value relay is given closer to the source where the relay is located. Typically, selectivity cannot be achieved exclusively by current settings. To ensure satisfactory selectivity, a certain time delay is given to the relay. Generally, the relay in the busiest distance is operated immediately, whereas the time delay for feeder near the feeder increases.

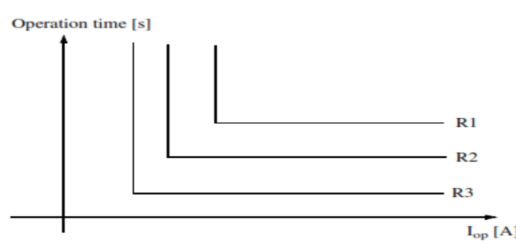

Fig. 2. Overcurrent Device Coordination for the Relays

In case of lattice system configurations, it may be impossible to give overcurrent protection settings as discussed above, which provides a selective security system. Therefore, the overcurrent unit which is specially based on the current magnitude, is complemented by a directional element. The name of this application is usually "Directional overcurrent protection". Often fixed overcurrent relay relays are replaced by an inverse-time feature as shown in 2. With the delayed time of the inverse time, the time of increasing relay increases with increasing time. Therefore, a large fault current will be tripped faster than a small fault current. An inverse-time overcrowd relay enables the combination of short-circuit protection and overload protection in the same device.

Statcom (Static Synchronous Compensator)

The first SVC with the voltage source converter, which was known as the situation in 1999, has the basic features of STATCOM in line with the synchronous condenser, but it is an electronic device and has no inertness, hence it is better than the synchronous condenser.In many ways, there is better mobility in it, along with less cost of maintenance, along with investment costs and operating costs also decreases. The operating structure and basic structure of STATCOM is shown in Figure 3. Where V is the voltage and I have the source current.

The reactive power is completely independent from the actual generated voltage at the connection point; This is the main advantage of STATCOM, due to which STATCOM maintains its full potential at the most critical contingencies, the use of voltage source converters for grid interconnection in today's distributed energy field is common. The combination of energy storage on the DC-side of the converter is the next step of STATCOM development. [2-3]

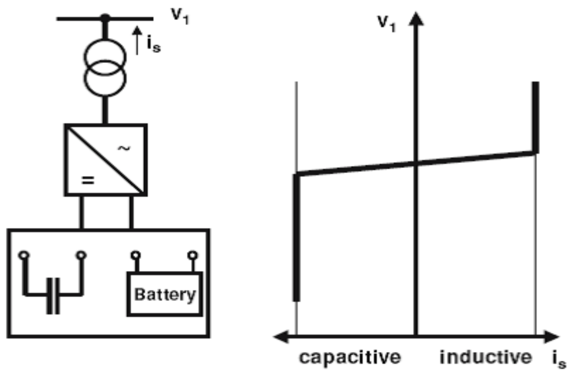

Fig.3. STATCOM structure and voltage / current characteristic

Fuzzy Logic Controller (Optimization Techniques)

Fuzzy control takes an advantage of fuzzy set theory to state a non-linear controller that was first developed by Mamdani in 1975.

A fuzzy controller has three components:

1. A fuzzyfier,
2. A rule base and
3. A de-fuzzyfier.

The inputs given to the controller are numbers and the outputs are also the numbers, but all complications inside the controller is done with the help of fuzzy variables. The first step is preceded by transforming the crisp inputs to memberships of each fuzzy set defined for the inputs. This operation is called fuzzyfication and the block which is responsible for this operation is called a fuzzyfier. These membership functions are used in the rule base that co-relates fuzzy values of the given inputs to the output of the rule base. The output of the rule base is also a set of membership tools of the fuzzy sets those known for the variables of the output. The fuzzy variable requires to be converted back to a perfect number in order to interface with the physical world. This process is perfected by the Defuzzyfier.

Design And Implementation

Over current replay is designed for four generating sources. The system is controlled using relay and a STATCOM device for reactive power. Modeling of system is designed in MATLAB / Simulink. Voltage source of 735 mw each is implemented with 6 Bus system. Fault is applied offer relay at 0.04 Ts. Relay will operate offer fault occurs in the system and the result in the form of waveform and analysis is performed using controller of Fuzzy Logic at STATCOM terminals and represented in next chapter of thesis.

The implementation of proposed system in MATLAB / Simulink. This system is designed with four area voltage source of 735 MW each connected with transmission line. Load of 200MW each is connected before fault, near to sending point after load. As represented for controlling reactive power STATCOM is used with its controlling system.

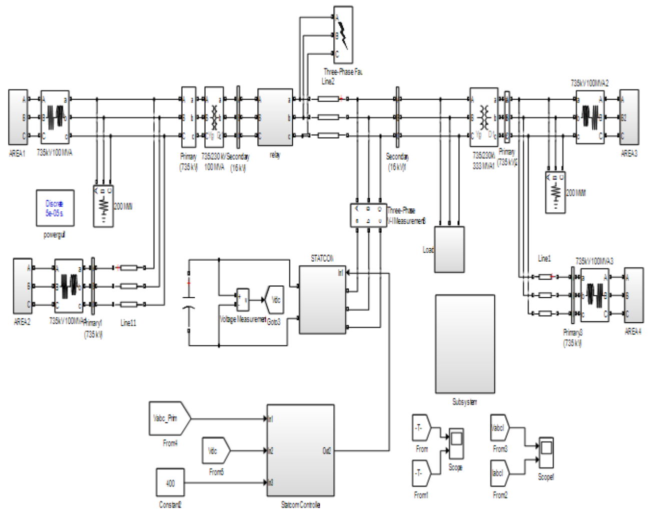

Fig. 4.MATLAB Model for proposed system.

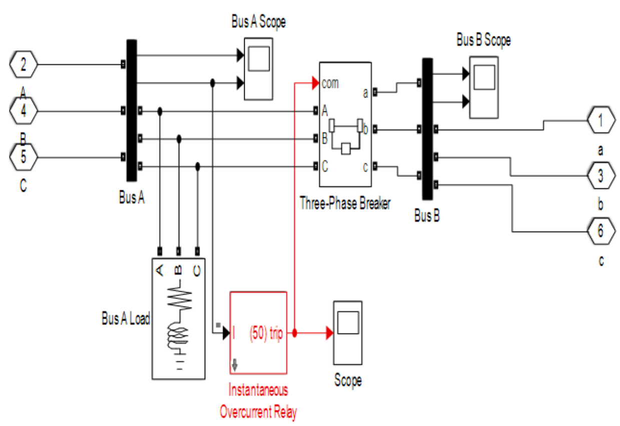

Fig. 5. MATLAB diagram of overcurrent relay in system.

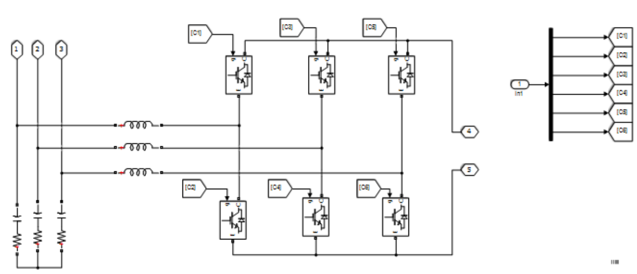

Fig 6. STATCOM Structure in MATLAB.

Implementation of overcurrent relay with breaker is shown in figure 6 with bus A and Bus B. over current relay reacts to the fault occur at 0.04 Ts and disconnects the system for protection. The relay is tuned at 50% TPS that reacts with the current value reactive from line. Instantaneous overcurrent relay works for the system at current parameter rating exceeds then rated current line seviour fault occur due to lightening etc.

STATCOM is used to control reactive power generated in line. As show in figure 7 it is designed in MATLAB / Simulink with semi controller devices.

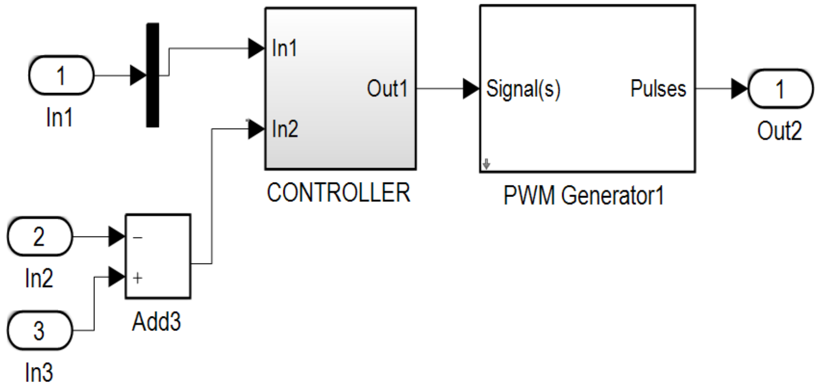

Fig.7. MATLAB model for STATCOM Controller.

STATCOM controller with PWM generator and its controller is represented in figure 7 its output is used as triggering pulses for STATCOM.

Figure 8 represents the control circuit for STATCOM controller by implementing PI controller. This circuit is designed with voltage input from line as reference for controlling and PI controller used to controller pulses for it.

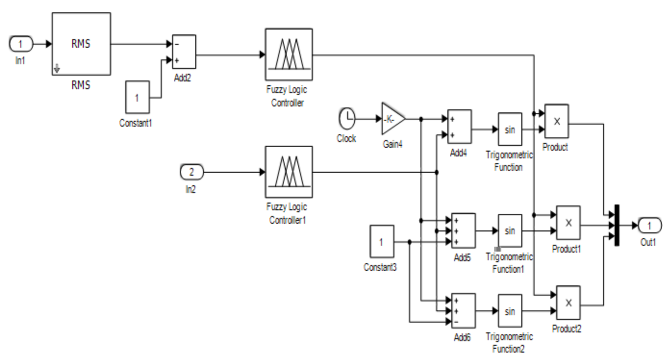

Fig. 8. STATCOM model with fuzzy logic Controller.

Table 1: Parameter used in power system.

S.No	Parameter	value
1	Voltage Source	735 MW
2	load	200 MW
3	Line Load	300MW
4	relay	Instantaneous Overcurrent relay

5	Fault time	0.04
6	System	4 Generator system
7	total Bus	6 Bus

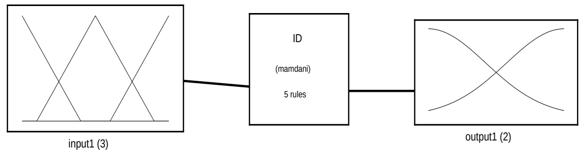

Fig.9. FLC System for Controller of Vref.

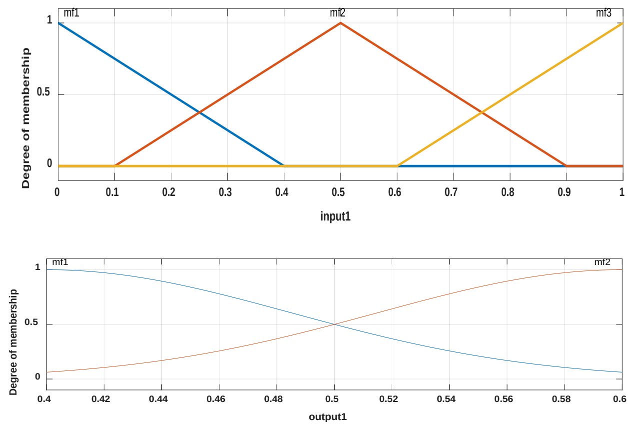

Fig. 10. FLC input membership functions.

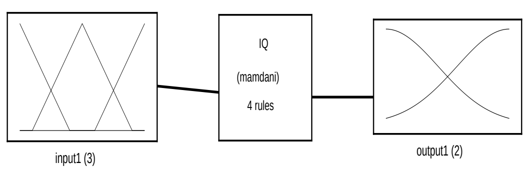

Fig. 11. FLC System for Controller for Vdc.

Results And Analysis

Power system is designed in MATLAB/Simulink software. Overcurrent relay is used to trip system in case of fault. Fault is injected in the system to analysis of parameter performance. STATCOM is connected to control reactive power in system and manage distortions. For better performance PID and Fuzzy logic controllers(FLC) are compared and analysis is performed in the form of waveforms shown in this chapter. Overall results represent better performance of FLC with parameters as bus voltage and current, Total Harmonic Distortion (THD) and active & reactive powers in the system.

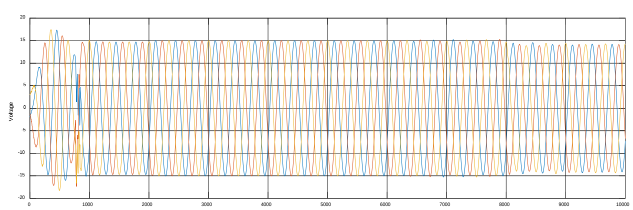

Fig. 12. Bus Voltage before relay with PID

3	Line Load	300MW
4	relay	Instantaneous Overcurrent relay
5	Fault time	0.04
6	System	4 Generator system
7	total Bus	6 Bus

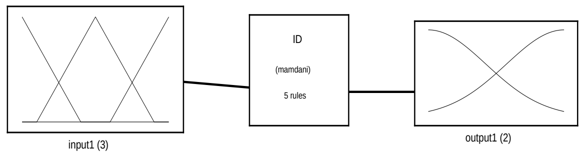

Fig. 13. FLC System for Controller of Vref.

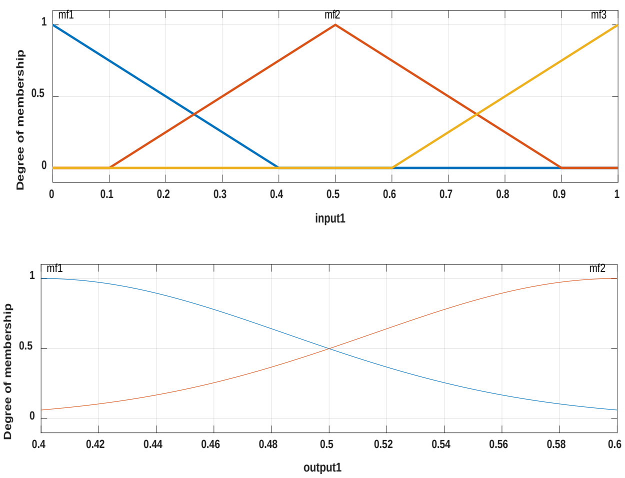

Fig. 14. FLC input membership functions.

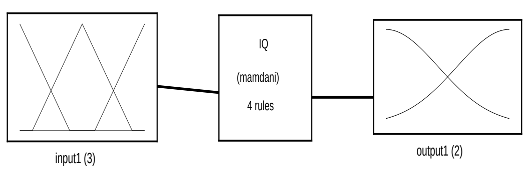

Fig. 15. FLC System for Controller for Vdc.

Results and Analysis

Power system is designed in MATLAB/Simulink software. Overcurrent relay is used to trip system in case of fault. Fault is injected in the system to analysis of parameter performance. STATCOM is connected to control reactive power in system and manage distortions. For better performance PID and Fuzzy logic controllers(FLC) are compared and analysis is performed in the form of waveforms shown in this chapter. Overall results represent better performance of FLC with parameters as bus voltage and current, Total Harmonic Distortion (THD) and active & reactive powers in the system.

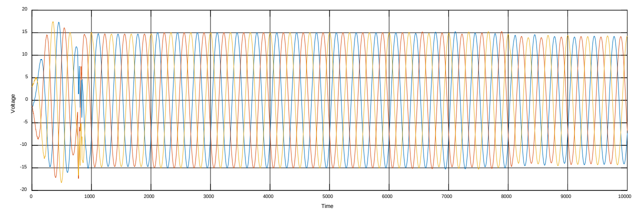

Fig. 16. Bus Voltage before relay with PID

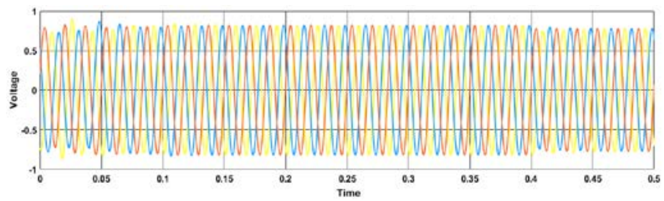

Fig.17. Bus voltage before relay with FLC

Figure 14 & figure 15 represented the bus voltage of bus before relay with PID and FLC respectively it shows that the voltage in PID circuit is not controlled by rating as compared with circuit connected with Fuzzy Logic Controller. FLC used with STATCOM also controls the voltage Parameter in power system.

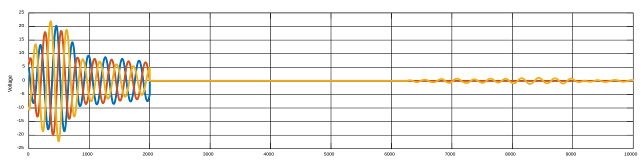

Fig. 18. Bus voltage after relay with PID

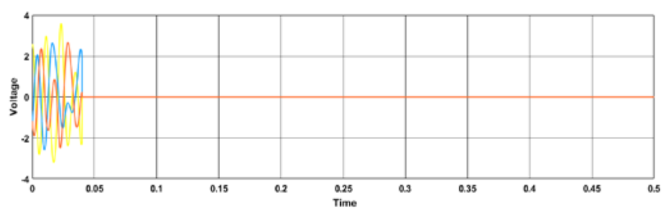

Fig. 19. Bus voltage after relay with FLC

Figure 16 & Figure 17 represented bus voltage of bus connected after relay with PID and Fuzzy Logic Controller respectively. These waveform shows the control of voltage and relay operation after fault condition. As in PID there is leakage in voltage where as in FLC the voltage is completely cutoff as relay is operating condition. Overcurrent relay oprates at 0.05 µs in FLC.

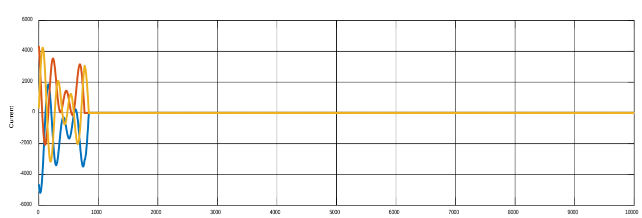

Fig. 20. Current in bus before relay in PID

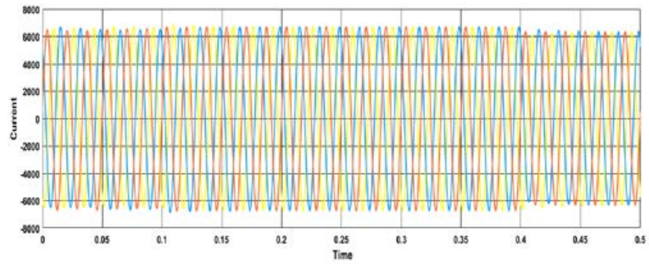

Fig. 21. Current in bus before relay with FLC

Figure 18 & figure 19 shows current parameter of bus connected before over current relay and fault with PID and FLC respectively. This shows that with PID the current gets zero before relay conditions, due to fault but in condition of FLC it will remain in normal condition as the fault occur after this bus. So FLC is working more effectively in the System.

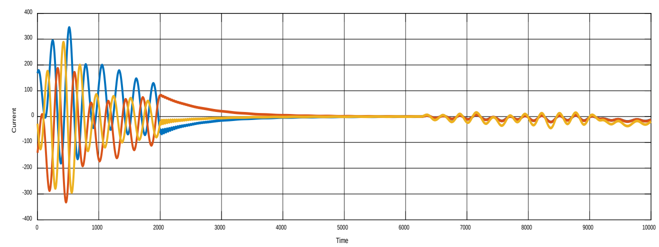

Fig. 22. Bus current after relay in PID

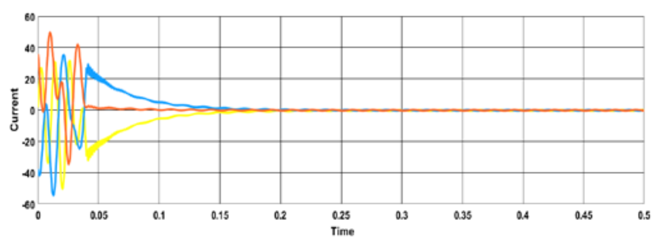

Fig. 23. Bus current after relay in FLC

Working condition of bus current in case of PID & FLC is represented in fig. 20 & fig. 21 respectively. It shows that there is leakage current in case of PID where in FLC it is controlled.

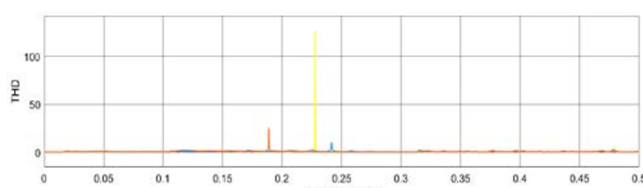

Fig. 24. THD in bus voltage before relay in PID

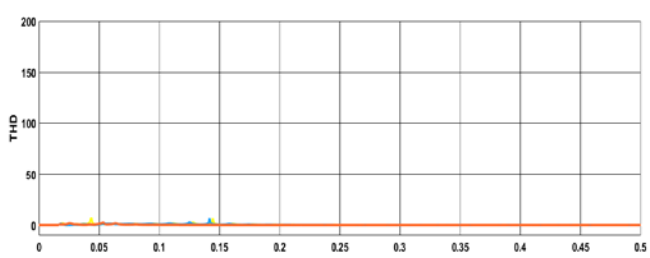

Fig. 25. THD in bus voltage before relay in FLC

Total harmonics Distortions (THD) in bus voltage connected before relay and fault is shown in figure 22 & figure 23. It shows that with PID level of distortions is high whereas with FLC it is almost zero.

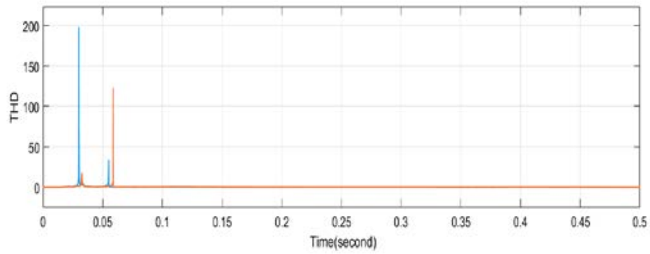

Fig. 26. THD in bus voltage after relay in PID

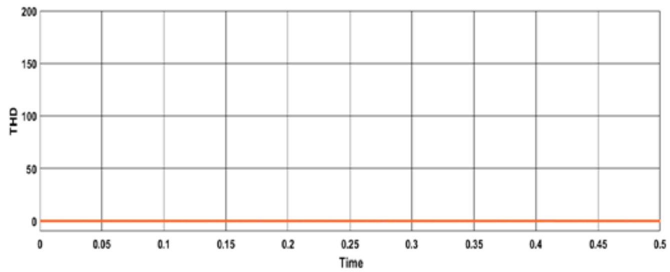

Fig. 27. THD in bus voltage after relay in FLC

Total harmonics Distortions (THD) in bus voltage connected before relay and fault is shown in figure 24& figure 25. It shows that with PID level of distortions is high whereas with FLC it is almost zero.

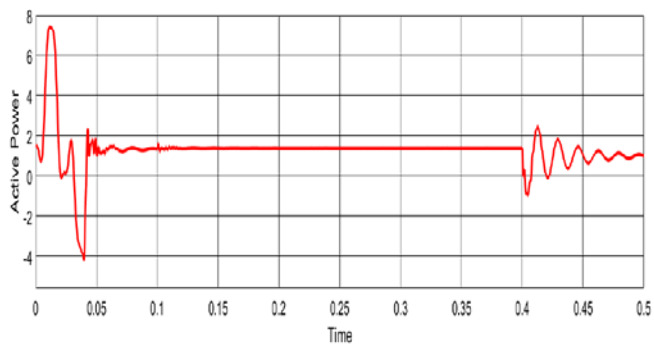

Fig. 28. Active Power of system with PID

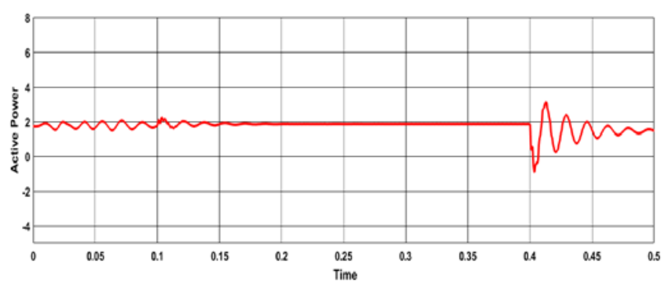

Fig. 29. Active Power of system with FLC

Active power of system is represented in figure 26 & figure 27 with PID and FLC respectively. These waveform shows that with PID there is variation at system output power whereas with FLC this variation is negligible. So working of FLC is more accurate and precise as compared to PID system.

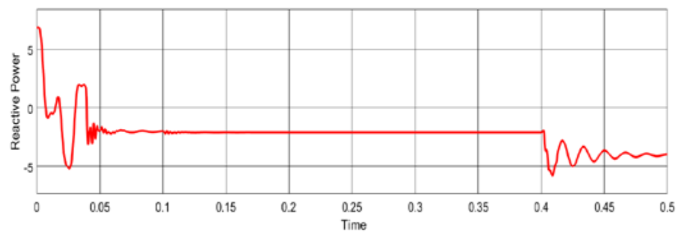

Fig. 30. Reactive Power of system with PID

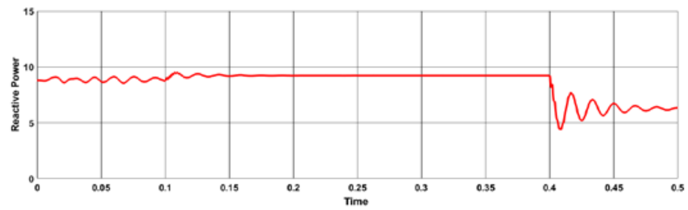

Fig. 31. Reactive Power of system with FLC

As shown in figure 28 & figure 29, reactive power of system with PID and FLC respectively. The waveform shows that with FLC there is decreased in distortions as compared with PID system.

Conclusion

The proposed system is designed for analysis of overcurrent relay and STATCOM for micro grid system with four units. System that is designed in MATLAB/ Simulink is using PID and fuzzy logic controller for optimization of reactive power and working of overcurrent relay in case of fault.

Overview of system is presented in chapter-4 with mathematical modelling and its analysis using comparison of PID and FLC is in chapter-5 with waveforms. The overall analysis of proposed system shows that fuzzy logic controller is more optimized as compared to PID.

While using PID controller relay works with either buses connected to and fro where it contains harmonics in its output. Similarly, on other hand fuzzy logic controller works for that bus where fault occurs and it controls active and reactive power also in optimized conditions.

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