A Review on Application of PI and Fuzzy Logic Controller Based DVR to Reduce Voltage Sag and Harmonic Distortion

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***Abstract*-A Dynamic voltage restorer (DVR) is a method that prevents sensitive loads from voltage disturbances and harmonic distortion within a few milliseconds. Voltage sag and harmonics are major problems that affects the power quality thereby causes severe damage to sensitive loads are electronic devices.Consumers demands power that is free of interruption or disturbance.Voltage sag extremely affected by zero sequence component, it can be avoided by using DVR which employs zero blocking method using delta-connected blocking transformer installed between the supply and the booster transformer. Can avoid this paper describes application of two control methods namely, PI Controller and Fuzzy Logic Controller based DVR to mitigate voltage sag and harmonic distortion using MATLAB/SIMULINK.**

***Keywords*-Voltage Sag, Total Harmonics Distortion (THD), Dynamic Voltage Restorer (DVR), PI Controller, Fuzzy Logic Controller.**

I. INTRODUCTION

Present day society is fully dependent on the Power generated by generating station. Voltage fluctuation is one of the important factor that determine the quality of electrical power and it is necessary to improve the quality of power before further used. While power disturbances occur on all electrical systems, the sensitivity of today's sophisticated electronic devices makes them more susceptible to the quality of power supply[1].Voltage sag is one of the most severe disturbances to the industrial equipments which contributes60% of overall power quality issues[2]. A voltage sag occurs when a fault in the utility system, a fault within the customer's facility or a large increase of the load current, such as starting a motor or transformer energizing. Harmonics occurs in power converters, transformers, rotating machines, arc furnaces, fluorescent lightings, and abnormal system conditions[3].There are various types of voltage sag and harmonics mitigation techniques and equipments are available among them, one of the most important devices is Dynamic Voltage Restorer also known as Custom Power Device.

Control Unit is the main part of the DVR which detect the voltage disturbances (sag or swell) and harmonics in the electrical distribution system and generate gate signal which is given to operate the Voltage Source Converter (VSC) for supplying required amount of compensating voltage.

II. DYNAMIC VOLTAGE RESTORER TOPOLOGY

Dynamic Voltage Restorer (DVR) is a custom power device installed in series with distribution system line as can be seen in Figure1.To maintains voltage of sensitive load by injecting voltage whose magnitude, phase, and frequency can be controlled by using semiconductor device in Dynamic voltage restorer topology. The basic principle of DVR is to supply desired voltage so as to maintain voltage at the loads. Whenever there is a any voltage variation in the system, the dynamic voltage senses that and then corrects it according to the nominal set voltage, if it varies very much then it supplies or absorbs variable voltage and is supplied to the loads. DVR actively corrects the voltage and also compensates active and reactive power. How DVR works to mitigate harmonics is shown in Figure 2. From Figure 1 and Figure 2 it can be seen that, DVR can compensate both voltage sag and voltage distortion caused by harmonics [4].

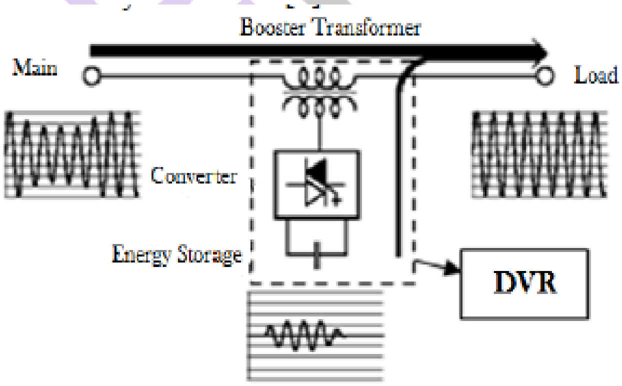

Fig. 1. DVR topology for voltage sag compensator

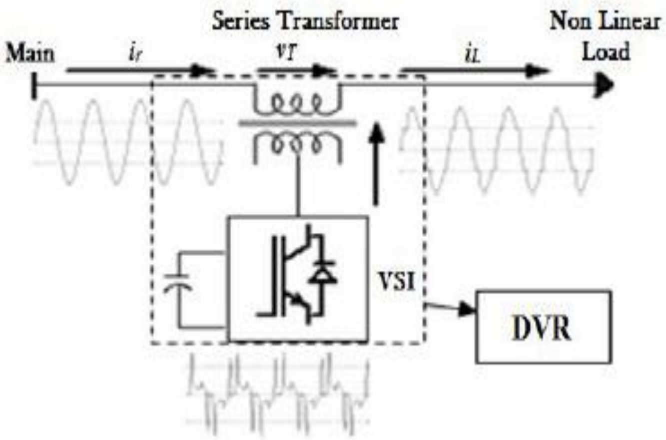

Fig. 2. DVR topology as harmonics compensator

III. FLOW CHART OF DVR CONTROL SCHEME

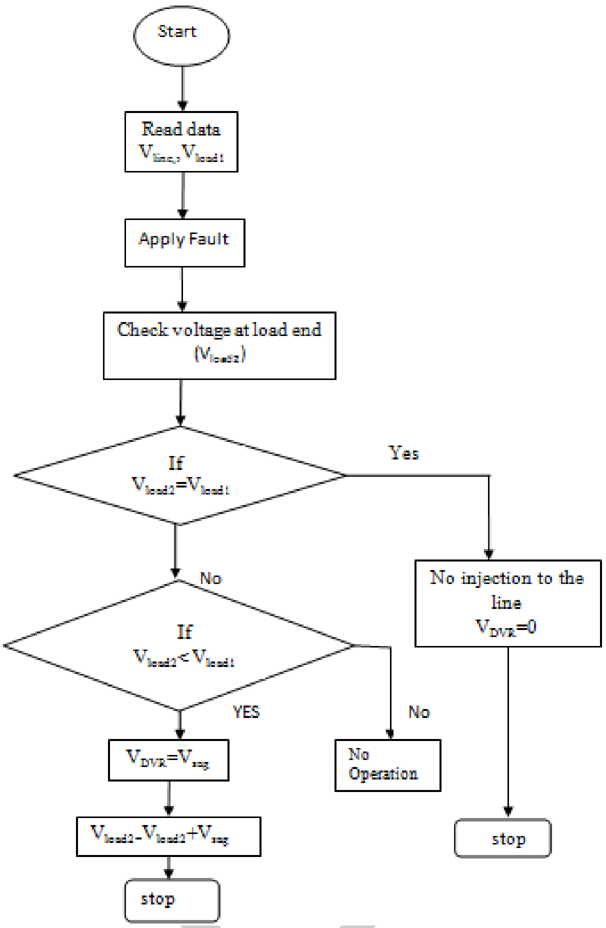

Fig.3 Flow chart of control scheme of DVR

The flow chart DVR control method implemented in this paper[5]. At the beginning magnitude of line voltage V_{line} and load voltage $V_{load1}$are measured those values are found to be equal. Then a fault is applied the magnitude of load voltage reduce suddenly to a great extent, that magnitude of the load voltage is measured again and it becomes V_{load2}. Then V_{load2} is compared with V_{load1}.If V_{load2} is equal to V_{load1}then DVR will not operate and no injection of voltage to the line ,but if V_{load2} is less than V_{load1} then DVR will inject the sag voltage V_{sag} and if V_{load2} is greater than V_{load1} DVR will not operate. The new voltage will be $V_{load2}=V_{load2}+V_{sag}$afterinjection.The DVR will inject voltage to maintain the load in balance condition.

IV. CONTROL METHODS

A. Proportional-Integral (PI) controller

The controller is used to maintain constant voltage magnitude at sensitive load during supply disturbances and this control method is based on comparing source and load voltage. The three phase voltage is transformed to dqo, using park transformation, then voltage is constant with d-voltage is 1 in p.u and q-voltage is 0 in p.u under the normal and balanced condition but varies under abnormal condition. The difference in voltage is enhanced by using PI controller when after comparison of d-voltage and q-voltagewith the desired voltage , after it go to abc transformation through dqo to convert into abc component which is the main signal to generate switching pulses of voltage source PWM inverter. The main goal of controller is to detect the voltage sag, inject voltage deviation and turn off inverter, when voltage sag event in the system is removed. Fig.4 PI controller placed in feed back path [6].

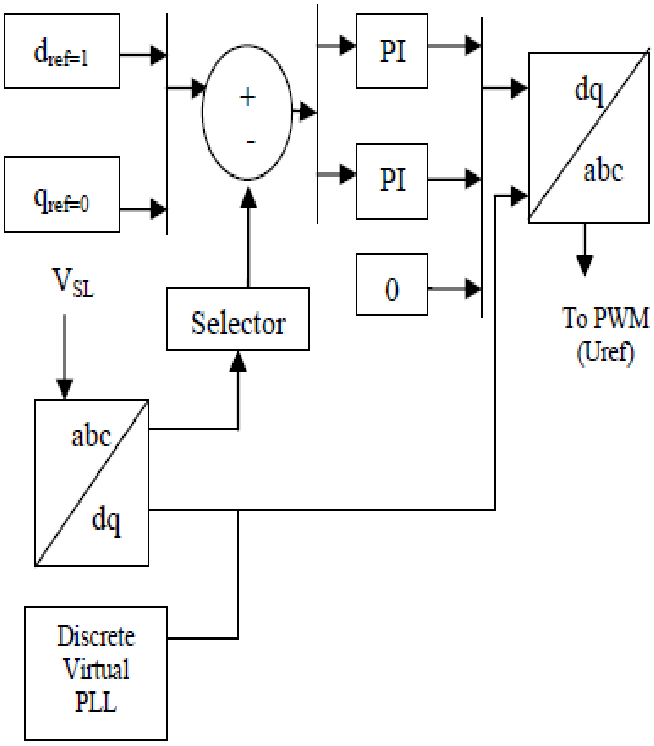

Fig.4 Conventional PI controller

The input of the controller from the Sensitive loadvoltage, V_{SL} measured by three-phase V-I measurement at Sensitive Load in p.u and it is transformed to dq term. The voltage sag is detected by measuring the error between the dq-voltage and the reference values. Such error is processed by a PI controller and then d-reference is set to rated voltage as unity in p.u while q-reference is set to zero.

B. Fuzzy Logic controller (FLC)

FL controllers are a smart choice when exact mathematicalformulations are time consuming. A detailed understanding of the system isrequired for construction rules to be controlled. Fig.5. represents the FL controller which can be characterized as follows: 2 linguistic variables for derivative error are two inputs ,13 linguistic variables for output and 8 linguistic variables for error. Triangular and trapezoidal membership functions for error in terms of voltage, trapezoidal membership used for derivative error in terms of voltage and triangular membership functions for output variables are considered. A rule base of 16 rules is selected to establish the fuzzy controller [7] and with the use of Mamdani's implication and with defuzzification by a centroid method, the FL controller provides the switching function to carry out best control action and each rule explicit an operating condition in the system.

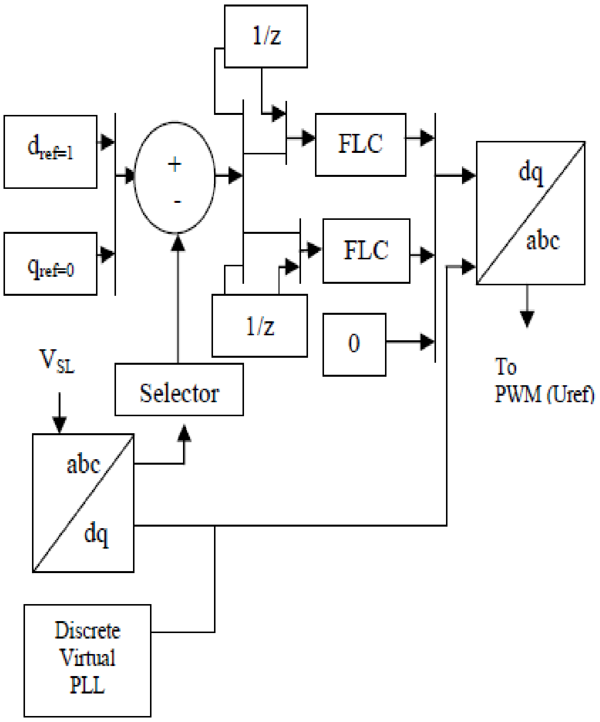

Fig.5 Fuzzy Logic Controller

In this paper, the inputs of the first FL controller are the error in terms of voltage(V_d) and the derivative of error in terms of voltage (ΔV_d) are considered and the error in terms of voltage (V_q) and the derivative of error in terms of voltage (ΔV_q) are considered as the inputs of the second FL controller. The reference voltages for the voltage regulator are the voltages V_{dref} and V_{qref} . FLcontroller consists of 8 linguistic variables from Error which is; Negative (N), Zero (Z), Very Small Positive (VSP), Small Medium Positive (SMP), Medium Positive (MP), Large Medium Positive (LMP), large Positive (LP), and Very large Positive (VLP) and for derivative error, there are two linguistic variables, Negative (N) and Positive (P).

V. SIMULINK RESULTS AND DISCUSSION

The simulation result was done DVR using PI controller and FL controller with a three phase to ground fault.

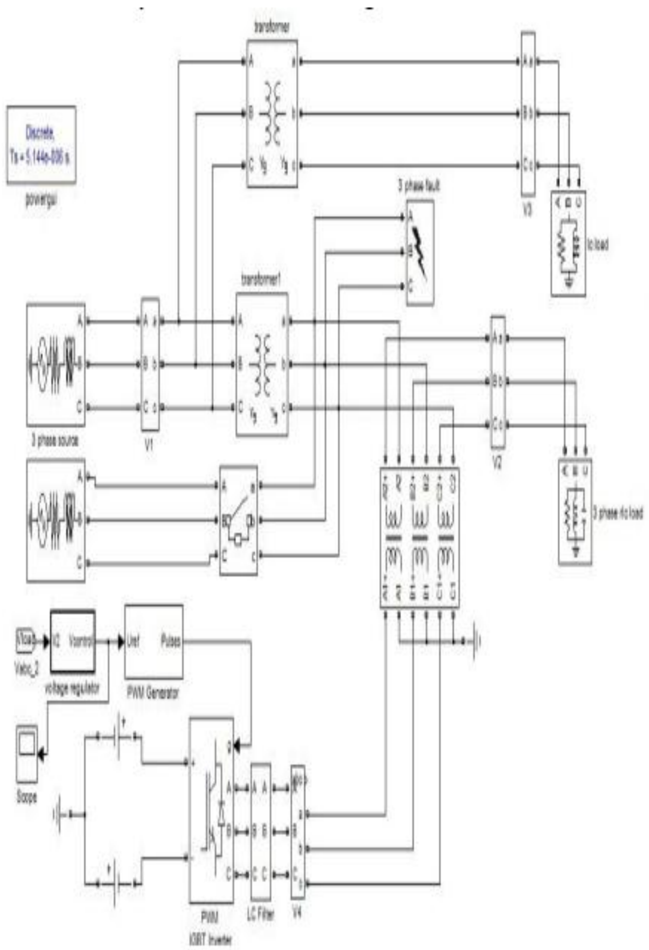

Fig.6 Simulink model of DVR

A. Proportional-Integral (PI) controller

The input of the controller is the load voltage and it is then transformed in dq term and compared with the reference values and the error signal is then given to PI controller. Two PI controller block are used for error signal-d and error signal-q separately as shown Simulink model in Fig.7.

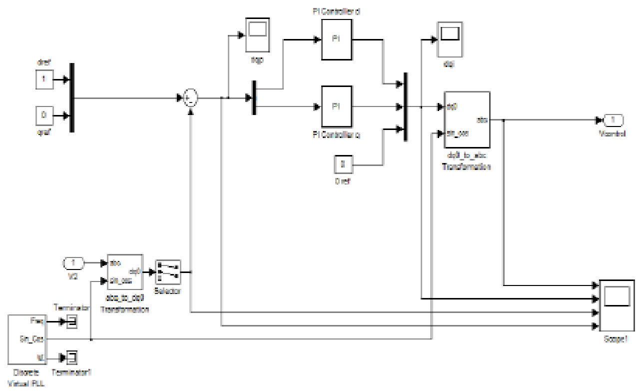

Fig.7 Simulink model of PI controller

The source voltage, load voltage and injected voltage of DVR with Three Phase Fault Using PI Controller output waveforms are shown in Fig.8.

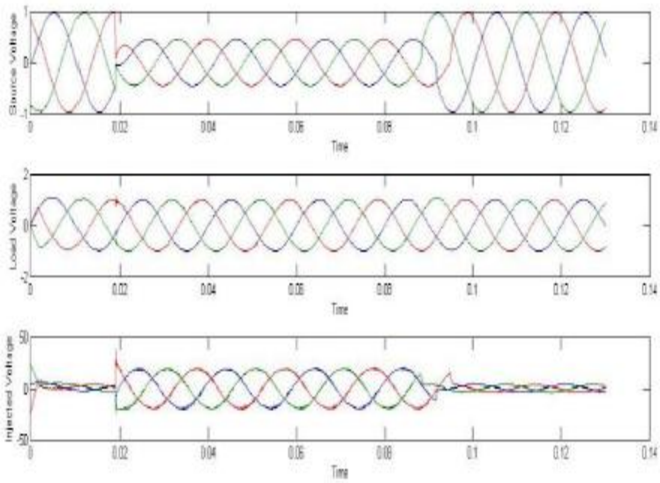

Fig.8. Sag Mitigation Using DVR with PI controller for three phase to Ground Fault.

Source Voltage for Three Phase Fault:

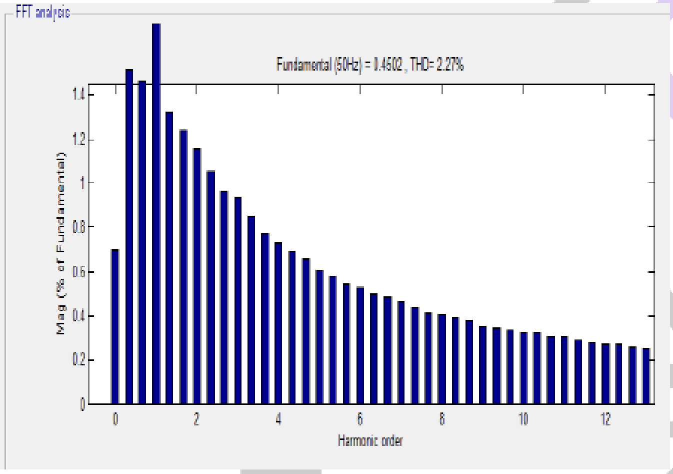

Fig.9. THD value is 2.27% is obtained with pi controller

Load Voltage for Three Phase Fault:

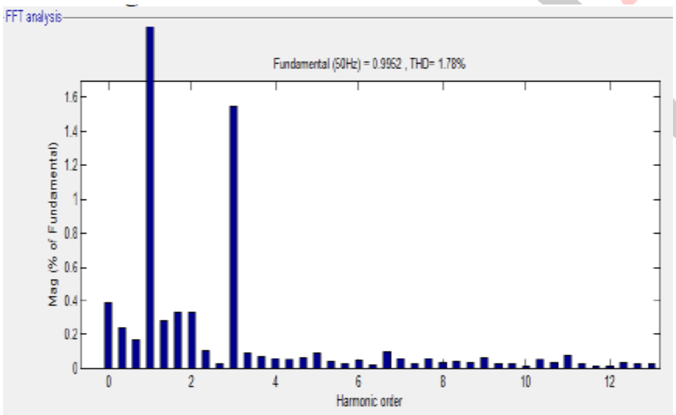

Fig.10. THD value is 1.78% is obtained with pi controller

Injected Voltage for Three Phase Fault:

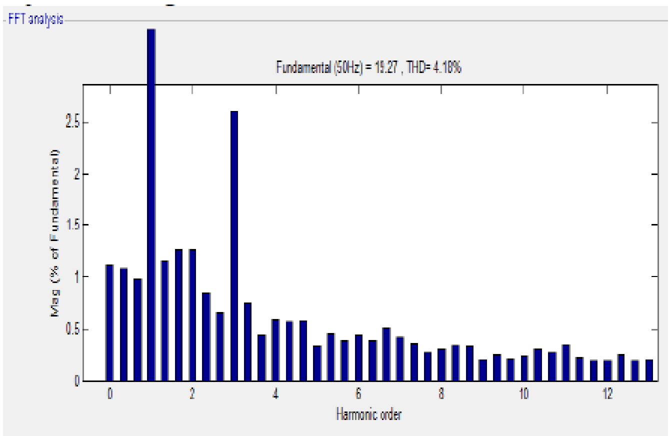

Fig.11. THD value is 4.18% is obtained with pi controller

B. Fuzzy Logic controller (FLC)

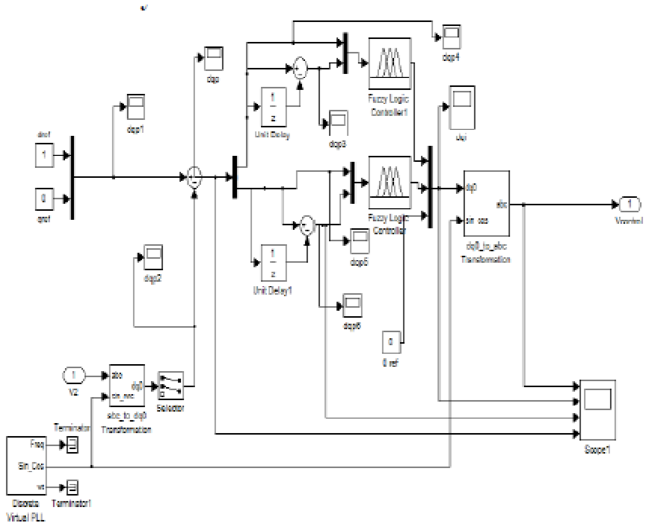

Fig.12. Simulink model of Fuzzy Logic Controller

Fig.12 shows Simulink model of Fuzzy Logic Controller. The output waveforms of source voltage, load voltage and injected voltage of DVR with Three Phase Fault Using PI Controller is shown below Fig.13.

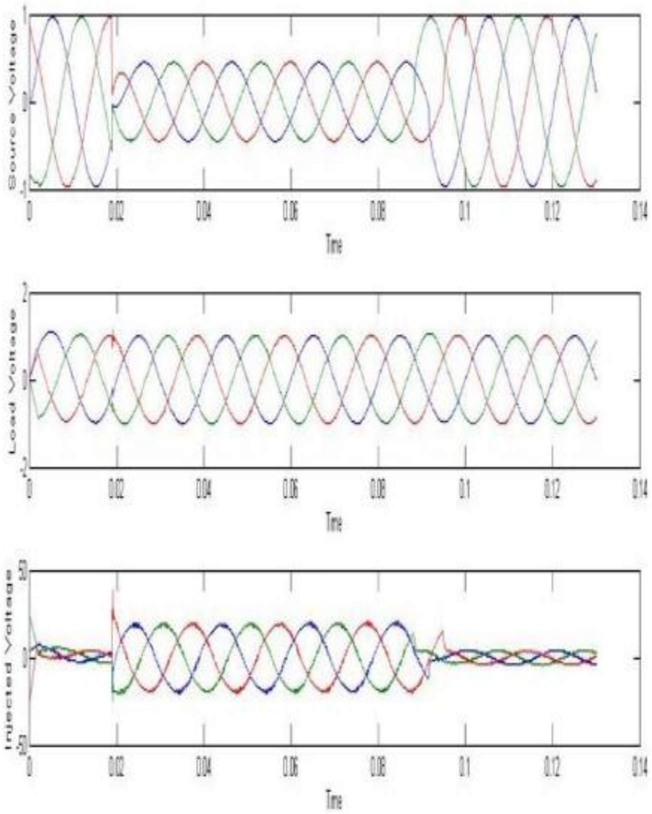

Fig.13. Sag Mitigation using DVR with FL Controller for Three Phase to Ground Fault.

Source Voltage:

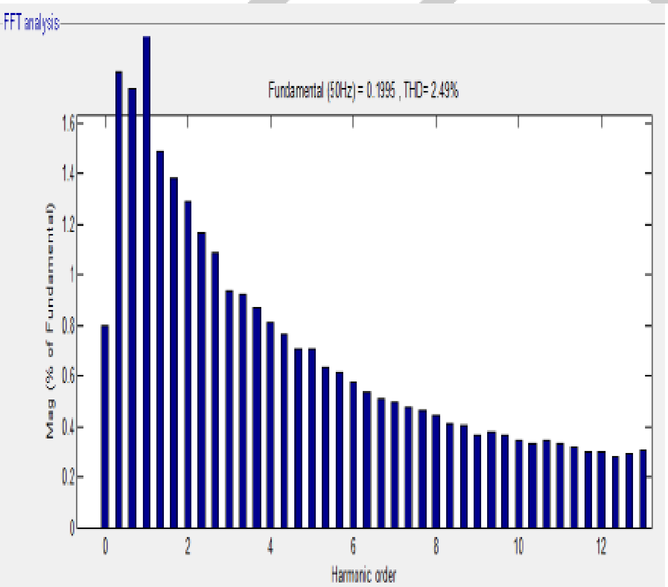

Fig.14. THD value is 2.22% is obtained with fuzzy controller

Load Voltage:

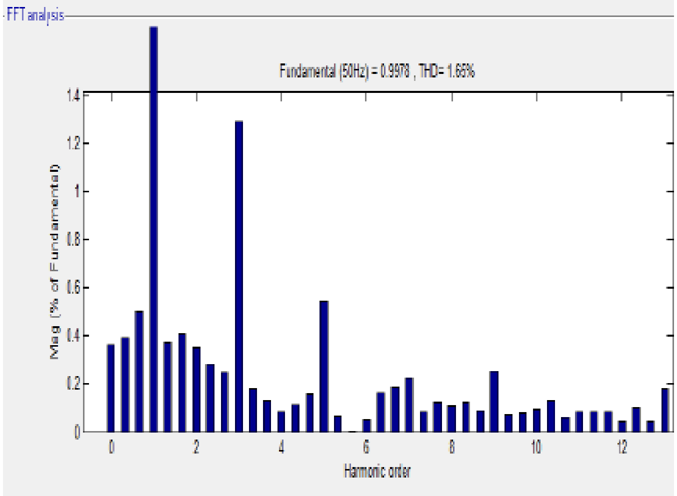

Fig.15. THD value is 1.68% is obtained with fuzzy controller

Injected Voltage for Three Phase Fault:

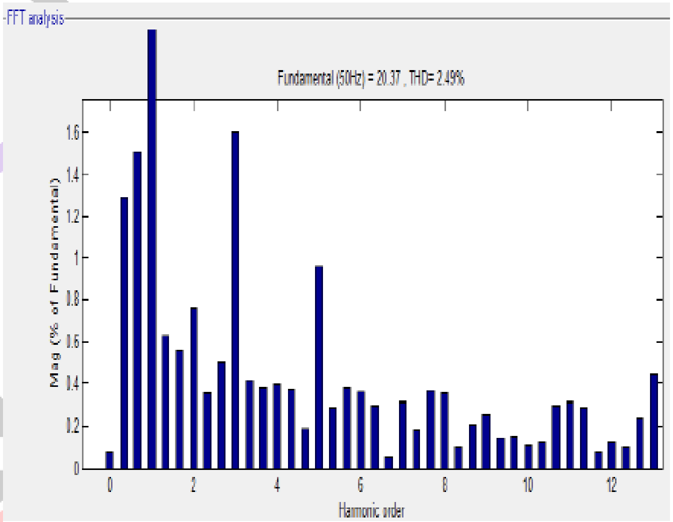

Fig.16. THD value is 2.91% is obtained with fuzzy controller

THD analysis of source voltage, load voltage and injected voltage using different controllers for the L-G fault condition is shown in the table1.

control	Source Voltage	Load Voltage	Injected Voltage
PI	2.22%	1.78%	3.15%
Fuzzy	2.19%	1.38%	2.79%

TABLE 1: THD Analysis for L-G Fault

THD analysis of source voltage, load voltage and injected voltage using different controllers for the L-L-G fault condition is shown in the table 2.

	Source Voltage	Load Voltage	Injected Voltage
PI	2.24%	1.23%	2.93%
Fuzzy	2.23%	1.47%	2.85%

TABLE 2: THD Analysis for L-L-G Fault

THD analysis of source voltage, load voltage and injected voltage using different controllers for the L-L-L-G fault condition is shown in the table 3.

	Source Voltage	Load Voltage	Injected Voltage
PI	2.27%	1.78%	4.18%
Fuzzy	2.22%	1.68%	2.91%

TABLE 3: THD Analysis for L-L-L-G Fault

From the above three tables we can say that the THD is reduced drastically with the Fuzzy Logic controllercompared to PI controller for different fault like single line to ground, double line to ground fault and three phase fault[8].

VI. CONCLUSION

In this work, cost effective dynamic voltage restorer (DVR) is proposed to reduce the problem of voltage sag and harmonics in fault conditions in industrial distribution systems, specially consisting of sensitive loads. The effectiveness of DVR using PI and Fuzzy Logic controller compared with the simulation results. The simulation results clearly showed the more efficient performance of the DVR with fuzzy logic controller than with PI controller.

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