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The Performance Evaluation Of Sag Compensation Using DVR In Multi-Feeder System Under Non-Linear Load Condition

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Abstract

This paper analyses about the power quality evaluations of DVR in multi-feeder distribution system. Three phase fault is applied to verify the capability of DVR to withstand the power quality. The synchronous reference frame controller is a simple approach over other control technique and the controller provided unique merits while comparing with PI and Fuzzy logic controller for active power control. The sag problem generated and analyzed in both faulty conditions of heavy load and three phases to ground fault. DVR is provided effective compensation scheme using simple control approach in feeder distribution system. The performance of introducing topology provides a tremendous solution over the faulty region. The simulation performance is verified in this research.

Keywords: MSRF, DVR, Sag compensation, Multi-feeder system, PEMFC, PI and fuzzy.

1. Introduction

The present days the power quality has a major impact on distribution networks are addressed in traditional schemes with respect to short circuit problems and critical and heavy load variation and through sag creation [1]. The distribution networks affected through short circuit problems swell problems, sudden load variation, and voltage transient. The FACTS (Flexible AC Transmission System) devices are uses to compensating the power quality disturbances. The FACTS devices are serious injection of Dynamic voltage restorer (DVR), shunt injection of

Distribution static compensator (DSTATCOM) and both shunt/series injection combination of unified power flow conditioner (UPQC). The DVR can able to provide and control the power to load from source by the ways of series injection. This can able to control the power quality problem such as reactive power control, sag, swell, harmonics [2] and resultant losses. The FACTS devices are design and connected to consumer end to meet out the load demand with respect to power quality standard [3].usually FACTS devices used for mitigate voltage sag and harmonics with respect to common power quality problem [4].

There are two methods of sag compensation is carried out such as effective control circuits or fault ride through capability of storage elements. The wide range of energy storage or FACTS devices are used to mitigate the faults for short duration. Many of traditional schemes are analyzed in literatures based on power quality disturbances and control [5], [6]. Voltage sag compensation is obtained by fuzzy controller with compared with PI controller, this control and circuit scheme is reliable and simple in transmission line [7]. This topology suffered from unbalancing condition and fast transient response, less number of feeder is used. So novel voltage sag compensation scheme is introduces using voltage reference control scheme [8]. This topology is capable of both high load voltages, low load voltage.

The dynamic voltage restorer is adequate solution to mitigate the sag disturbances as well as harmonics mitigation. The wide range of storage element is used to improve or maintain the DC link voltage of DVR in mitigation processes [9]. The design procedure of storage elements is carried out in traditional to maintain the power quality [10]. This paper is proposed about sag compensation using DVR with effective compensation schemes. The proposal controller deal with a simple modified synchronous reference frame (MSRF) control with fuel cell storage system for DVR power supply. The Multi-feeder distributed system is designed up to the low power consumer end. The distribution side fault mitigation has been taken by proposed DVR with control scheme. The controller has compared using modified synchronous reference frame with PI controller and fuzzy controller to verify the performance.

2. Proposed Configuration: Dynamic Voltage Restorer

The mechanical power captured by the turbine from the wind is given by the following expression Single line diagram for DVR system is shown in Fig.1, the series connected DVR is injected between the source end to load end of the system via transformer. The series connected solid state device can able to inject voltage and active power from DVR to the distribution system. Generally the DVR provides required voltage to main line with appropriate magnitude and frequency format to meet out desired waveform from the unbalanced or distorted conditions. The dynamic voltage restorer is made-up of DC-AC solid state switching circuit use to inject the synchronized form of AC voltage to the line and also maintained the constant RMS voltage across the PCC or load. It is also capable of control the real and reactive power individually. The transformer is connected in series to the main line as protective elements. Passive filter (LC) is connected series and parallel to the line used to reduce ripples in the injected voltage.

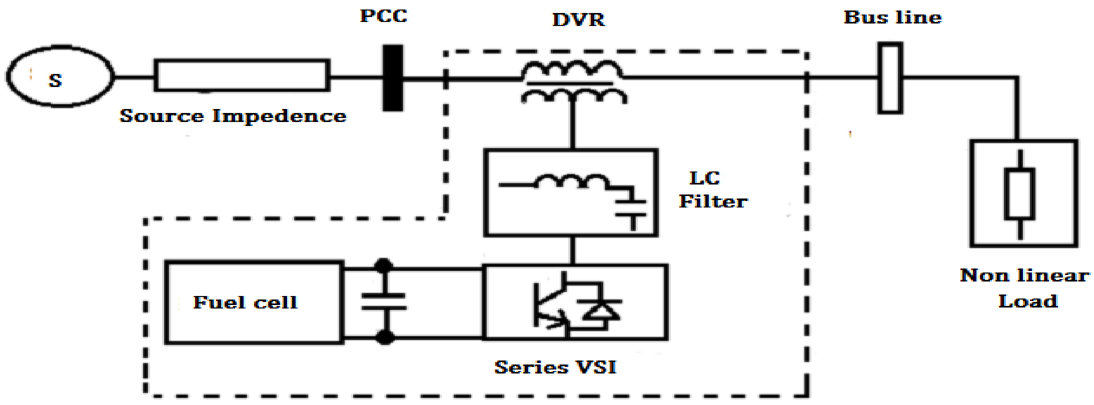


Fig. 1 The configuration of proposed system

The control strategy is depends on the type of load usage. Few loads are very sensitive to phase jump and the load however it should be protected from those types of fault [11]. Other types of loads are more tolerant to phase jump; since the main aim of the converter is to maintain the nominal voltage on all three phases.

The energy storage cell is the responsible part for DVR operation. Desired DC source is derived from fuel cell backup system. It has supplies the real power requirements of the system when DVR is used for compensation.

a) An Innovative Fuel cell power Back-Up System

Polymer Electrolyte Membrane fuel cell topology is proposed for dc power generation and it has very numerous benefits are presented in fuel cell power generation such as high power density, high efficiency, absence of greenhouse gases, reusability of heat emit , quick start-up and it has been used almost any conceivable application from powering a cell phone to a locomotive. The fuel cell topology is shown in Fig.2. Generally, the porous electrode and the polymer membrane have created a layer with catalyst particles, typically platinum supported on carbon. The principle of electrochemical reactions; it can occurs at the surface of the catalyst at the interface between the electrolyte and the membrane. Hydrogen atom is fed with one side of the membrane and it can splits into primary constituents that is grouped as protons and electrons. Every hydrogen atom should consist of one electron and proton. Protons travel through the membrane electrically conductive electrodes [12]-[13]. From the final reaction the hydrogen side is called negative and is named as anode, otherwise the oxygen side of the fuel cell is positive and is called the cathode. Through this way 650V, 50W capability of power is generated.

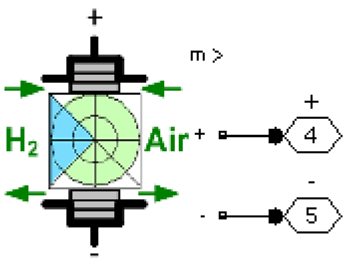


Fig. 2 Fuel cell stack

The fuel cell power is generated by applying hydrogen to fuel cell stack with respect load demand or system demand. The flow of power can be controlled by suitable placement of capacitor shown in Fig.3.

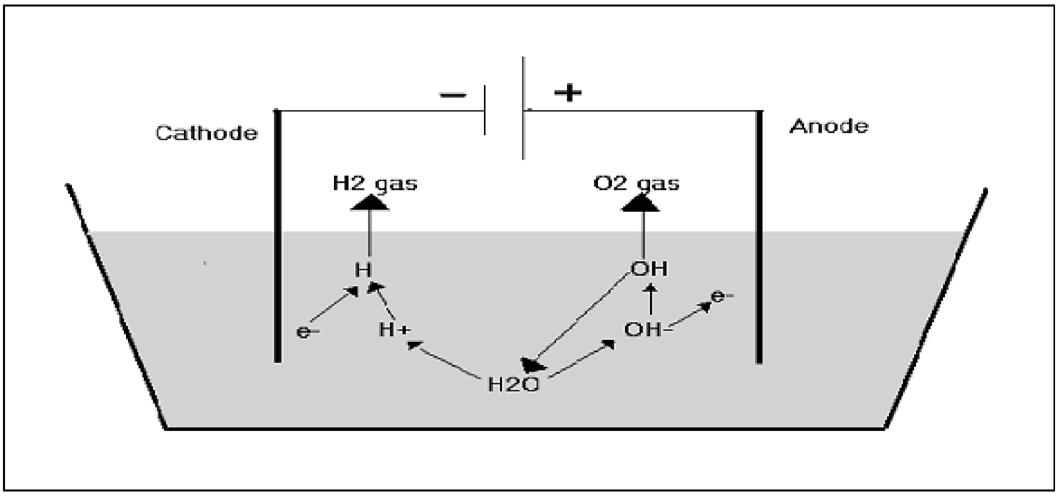


Fig.3 PEM (Proton Exchange Membrane) Fuel cell

3. A Control Philosophy

The main aim of the control strategy is to maintain constant output voltage magnitude at multi feeder connected sensitive load condition , under fault condition. The control system only measures the r.m.s voltage at load point. Therefore the multi feeder arrangement needs very sensible controller.

a) Modified reference frame control

In traditional topology there are so many active filtering methods such as reactive power control theory (p-q theory), unity power factor control, one cycle control and Fast Fourier Technique etc. the proposed scheme has used to extract the reference current generation using active filtering [14].The presented modified synchronous reference frame(MSRF) explain about harmonics and extract the harmonics component. The source current of and is detected and is transferred in to two-phase stationary frame from stationary reference frame. The detection scheme has been made by the following equation

$$\begin{bmatrix} i_\alpha \\ i_\beta \\ i_0 \end{bmatrix} = \sqrt{2/3} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \\ 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} \quad (1)$$

The two phase stationary reference frame of and is transformed into direct and quadrature axis frame by equation (2). The cos and sine angle are generated using phase lock loop (PLL) reference frame.

$$\begin{bmatrix} i_d \\ i_q \end{bmatrix} = \begin{bmatrix} \cos\theta \sin\theta \\ -\sin\theta \cos\theta \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} \quad (2)$$

The generation of dq-currents obtained by incorporated of AC and DC parts. The fundamental component of fixed DC and AC parts represents the harmonics component. The harmonics or current transient can be easily extracted using low pass filter shown in fig.4

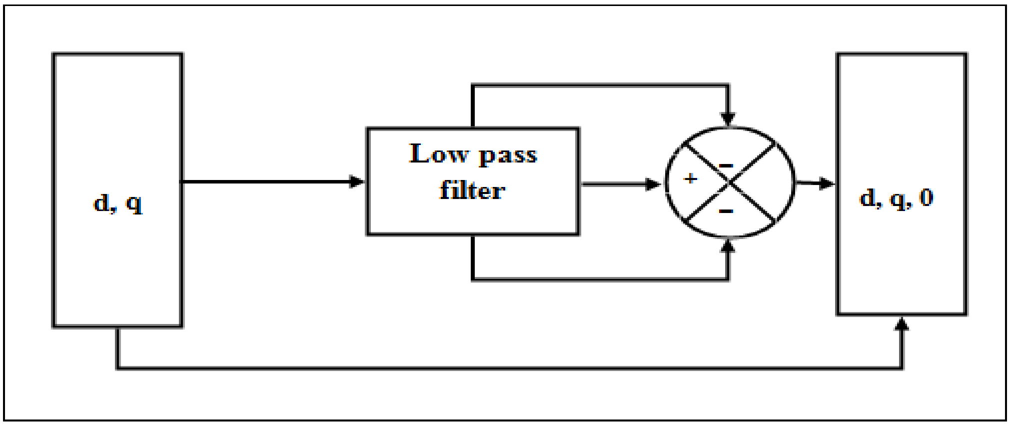


Fig.4 The block diagram for MSRF algorithm

The direct axis current is obtained from combination of active fundamental current and load current harmonics .The fundamental component is represents in synchronous reference frame. The direct axis component of harmonics is obtained by subtracting from it is presented in load. The quadrature axis harmonics current obtained by sum of reactive form of load current and load harmonics.

The reference frame is generated by following equation,

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \begin{bmatrix} \cos\theta - \sin\theta \\ \sin\theta \cos\theta \end{bmatrix} \begin{bmatrix} i_{dh} \\ i_q \end{bmatrix} \qquad (3)$$

The reference current (i_a^*, i_b^*, i_c^*) of are obtained by the following expression

$$\begin{bmatrix} i_{ca}^* \\ i_{cb}^* \\ i_c^* \end{bmatrix} = [T]_{abc} \begin{bmatrix} i_\alpha \\ i_\beta \\ i_0 \end{bmatrix} \qquad (4)$$

$$[T]_{abc} = \sqrt{2/3} \begin{bmatrix} 1 & 0 & 1/\sqrt{2} \\ -1/2 & \sqrt{3}/2 & 1/\sqrt{2} \\ -1/2 & -\sqrt{3}/2 & 1/\sqrt{2} \end{bmatrix} \qquad (5)$$

b) PI and fuzzy logic controller scheme

The effective DVR is adapted with multi-feeder distribution system. The basic nature of dynamic voltage restorer injects the reactance to suppress the reactive power which is generated in load [15] and also observed harmonics and current transient problem.

The dynamic voltage restorer can be controlled by tuning of k_p, k_i values which is presented in transfer function of PI. The simplified implementation of PI controller has some merits involves such as tuning of proportional derivatives and integral derivatives shown in Fig.5. Even though some merits involved in PI controller, it has some limitation such as k_p, k_i , values varies with respect to each load variation.

$$\frac{U(s)}{E(s)} = k_P + \frac{k_i}{S} \qquad (6)$$

Where, k_p is proportional constant, k_i is integral constant. The fuzzy control system as shown Fig. 6 consists of fuzzification, defuzzification and decision making stage [16]. The proposed fuzzy logic controller applied in phase lock loop reference schemes for improving the angle control and supplying to effective alpha, beta and d-q reference current generation. The fuzzy based PLL provides fast transient performance over the PI based PLL controller. The proposal of fuzzy logic scheme has the capability to extract the harmonics current from actual current signal and it is provided the suitable reference signal generation for pulse generation of active dynamic voltage restorer.

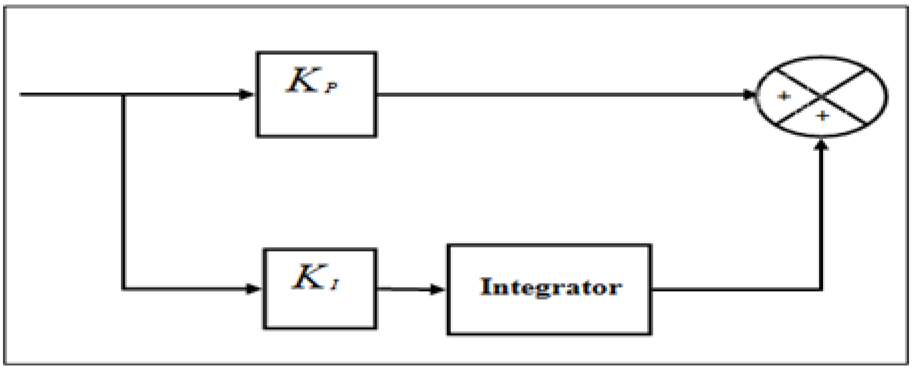
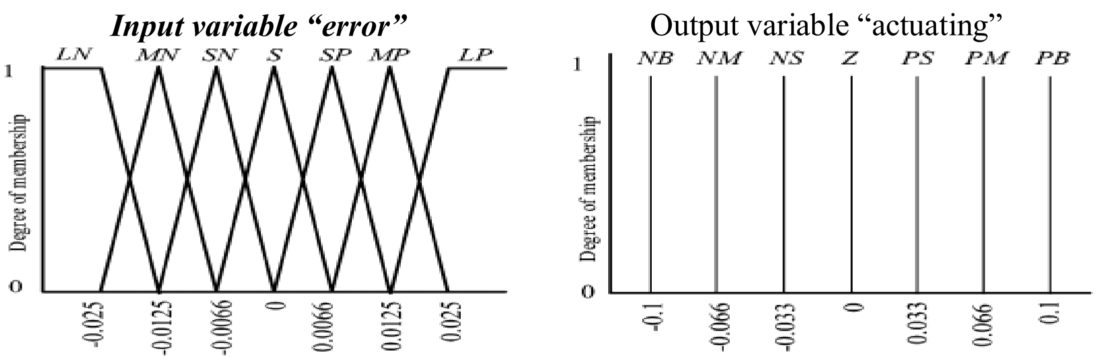
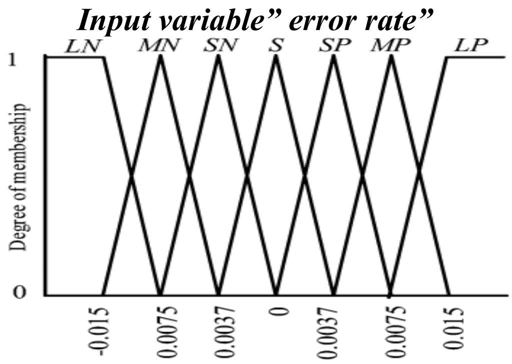


Fig.5. PI controller.

The modified reference frame controller has provided satisfactory reference signal by crucial appearance of fuzzy logic PLL scheme shown this rules Table in Fig. 4.





Fuzzy decision table

E/Δe	LP	MP	SP	S	SN	MN	LN
LP	PB	PB	PB	PM	PM	PS	Z
MP	PB	PB	PM	PM	PS	Z	NS
SP	PB	PM	PM	PS	Z	NS	NM
S	PM	PM	PS	Z	NS	NM	NM
SN	PM	PS	Z	NS	NM	NM	NB
MN	PS	Z	NS	NM	NM	NB	NB
LN	Z	NS	NM	NM	NB	NB	NB

Fig. 6 Membership functions of I/O fuzzy sets and control rules assignment.

4. Simulation Result

The simulation circuit was implemented as it is shown in Fig. 7. The 11kv of power generation of multi-feeder system is designed using MATLAB/simulink. The dynamic voltage restorer using PI based modified synchronous reference frame is implemented and the performance is compared with fuzzy based modified synchronous reference frame controller. The result was compared based on Voltage Sag compensation, fast transient response and reactive power controller. Fuel cell is deriving a great attention over conventional sources. The proposed configuration is determined by effective sag compensation capability in both PI and fuzzy schemes.

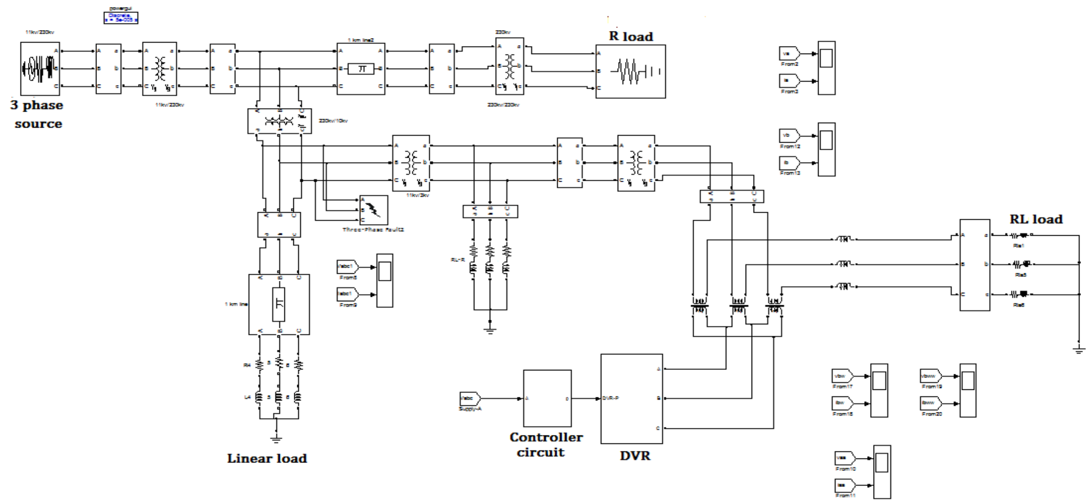


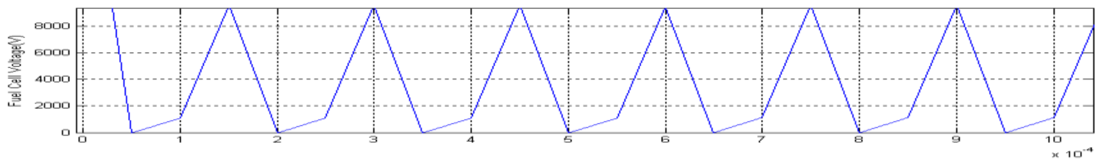
Fig. 7 simulation implementation circuit of proposed multi-feeder system

Table I Transformer parameters for proposed configuration

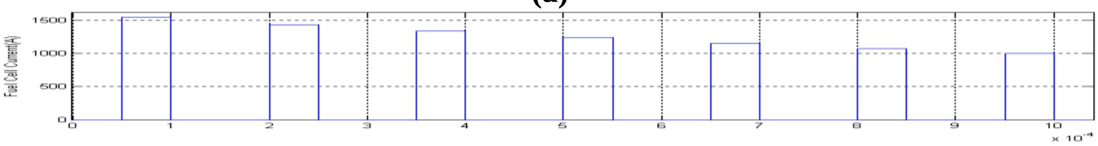
Line 1 Transformer	11kV/230kV
Line 2 Transformer	230kV/10kV
Line 3 Transformer	10kV/3kV
Line 4 Transformer	3kV/440V
Rated frequency	50Hz

Table II Fuel cell Parameters

System Quantities	Standard
Absolute temperature in K	338.15
Initial Current (A)	1500
Faradays constant(C/kmol)	96.487×10^6
Universal gas constant (J/kmol K)	8314
Ideal Standard Potential (V)	1.18
No. of Cells in series	900

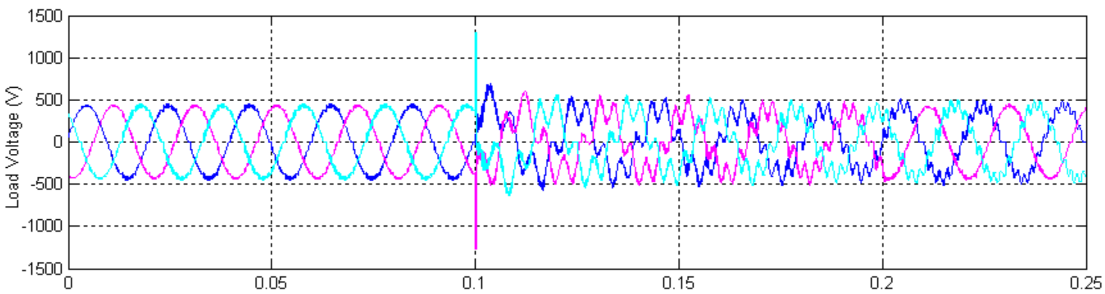


(a)



(b)

Fig. 8 Simulation results of Fuel cell: (a) Voltage. (b) Current



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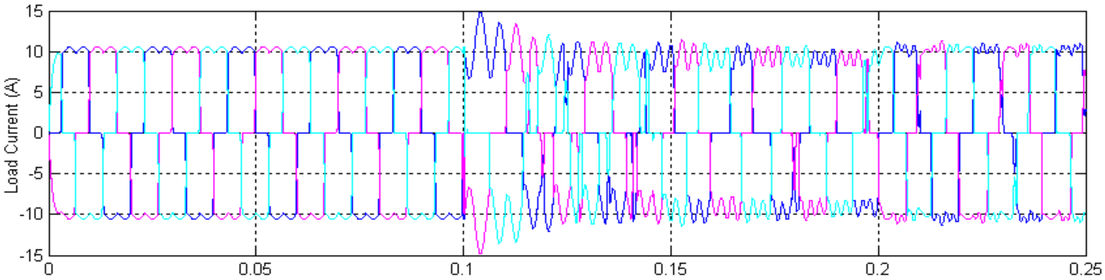

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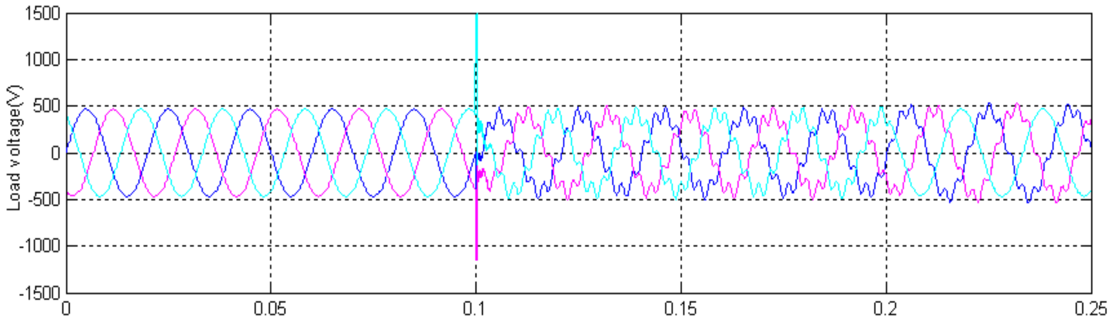

(c)

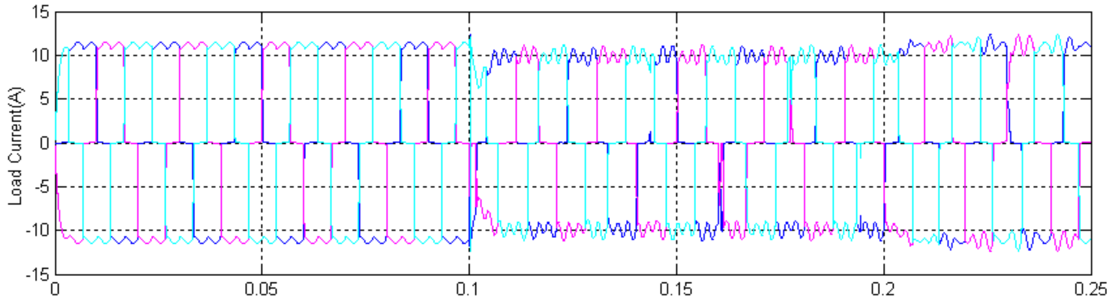

Fig. 9 compensation scheme during sag 0.1sec to 0.2sec: (a) load voltage using PI. (b) Load current using PI. (c) Load voltage using fuzzy. (d) Load current using fuzzy.

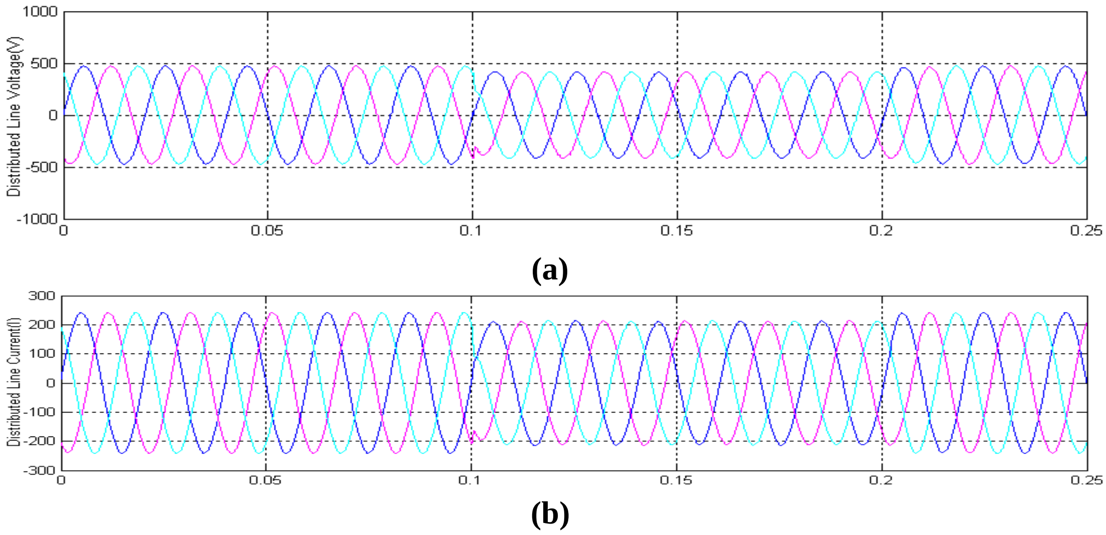

Fig. 10 Sag occur: (a) Distributed Line voltage. (b) Distributed Line Current

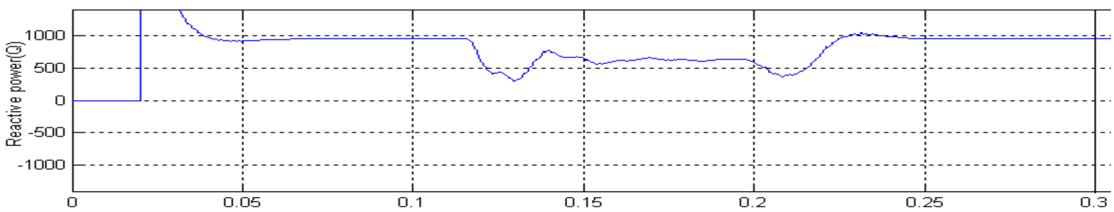

Fig. 11 reactive power compensation scheme during sag 0.1sec to 0.2sec: Load reactance using fuzzy.

5. Conclusion

The proposed configuration of a novel multi-feeder system topology is newly developed for distribution end user. The system design included the PI-line and step-up and step down transformer based on load demand. Three phase fault is applied in distribution to verify the dynamic voltage restorer performance. The modified reference frame control using fuzzy logic is proved as better choice than modified reference frame controller using PI controller. Fuzzy logic scheme has provides a smooth results in proposed configuration over PI-control scheme. The performances are obtained in sag compensation and as well as reactive power minimization is verified.

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