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Power Quality Improvement using PEMFC based Z-source DVR with fuzzy logic controller

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ABSTRACT: Power quality improvement has become one of the most important concern in present era due to introduction of various industrial devices and sensitive loads. Voltage sag and swell are one the main issues for poor power quality in distribution side. There are many different custom power devices available for power quality improvement. DVR (Dynamic Voltage Restorer) is one of the most economic, fast and popular custom power device for mitigation of voltage sag and swell. In this paper, A DVR is modelled with PEMFC (Proton Exchange Membrane Fuel Cell) and Z-source inverter and fuzzy logic controller is proposed. Simulation results are carried out with MATLAB/SIMULINK to verify the performance of the proposed model.

KEYWORDS: DVR, PEMFC, Super capacitor, fuzzy logic controller, z-source inverter.

I.INTRODUCTION

Modern power systems are very complex networks. In these complex networks many power quality problems takes place due to introduction of sensitive loads and usage of power electronic devices in industries etc. Power quality problems are categorized as short interruptions, voltage sags and swells, voltage flickers, voltage unbalance, voltage and current transients etc. The primary causes of short interruptions in distribution systems are switching of capacitors, lighting and transmission line disconnections etc. And Short circuit fault in the distribution side is mainly causes voltage sag and swell, momentarily impulses and jerk. Voltage sag and swell are commonly happened power quality problem in distribution side. [1][2] To minimize these problems reactive power compensation is required. These problems can be minimized by using recently developed custom power device is DVR (Dynamic Voltage Restorer)**.** [3]DVR is very fast, dynamic and economic device than other custom power devices.In this paper PEMFC (Proton Exchange Membrane Fuel Cell) is used as DC source and an Ultra-capacitor or Super capacitor is connected along with it to increase storage capacity of the system. In this model Z-Source inverter and fuzzy logic controller is used. Fuzzy logic controller is better than other conventional controller. So it increases the stability of the system.

II.CONVENTIONAL DVR CONFIGURATION

DVR is series connected voltage controlled custom power device which is designed to maintain a constant voltage across a sensitive load. The DVR mainly consists of: Injection transformer for voltage ejection or injection to the circuit to maintain a constant voltage, Filters for harmonic reduction, voltage source inverter for DC to AC conversion, DC source or DC storage device and a control system as shown below in Fig.1. [4]

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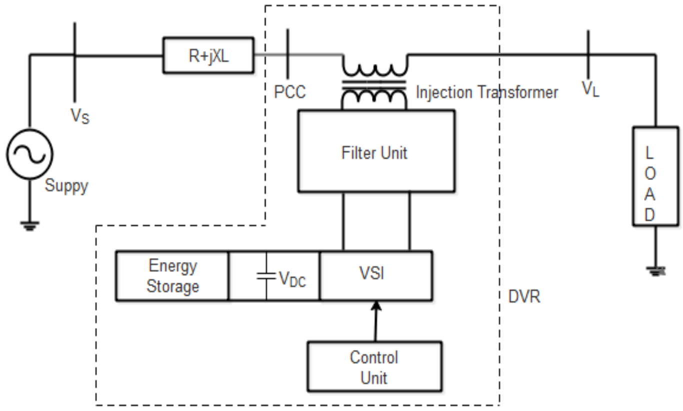

Fig.1 Conventional diagram of DVR

III.PEMFC

PEMFC (Proton Exchange Membrane Fuel Cell) is also called Polymer electrolyte membrane fuel cell. PEMFC mainly consists of three main components: A negatively charged electrode (cathode), a positively charged electrode (anode). And a solid polymer electrolyte membrane for proton exchange. Hydrated hydrogen ions are supplied at the anode and air is supplied at the cathode. [1] At the anode, Hydrogen gas is ionized in the presence of platinum catalyst into positive and negative ions.

$H_2 = 2H^+ + 2H^-$ . . . . (1)

The proton exchange membrane permits only the positive hydrogen ions to flow from anode to cathode as shown in the fig.2 [5]

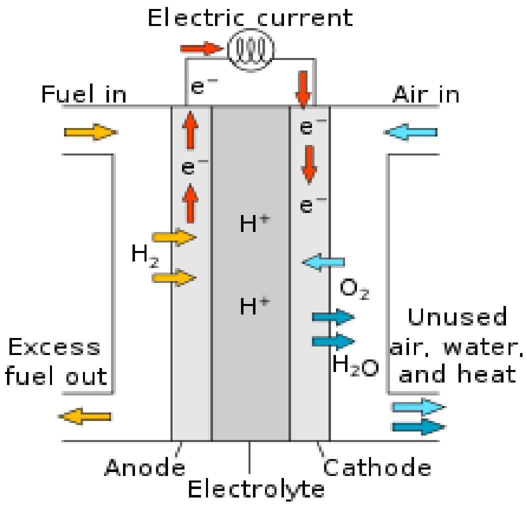

Fig.2. Basic operation of PEMFC

Many researchers have researched about PEMFC fuel cells. Different modeling methods have different complexity according to their values of parameters. Dynamic model of PEMFC can predict the transient response of the cell, temperature of the cell, Hydrogen and oxygen out flow rates, cathode or anode channel temperature or pressures under sudden change in load current. [1] So According to dynamic model of PEMFC the output voltage of a single cell is:

$$Vcell = Vnearest - Vact - Vohmic \quad - \quad Vohmic(1)$$

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Where

$$Vnearest = 1/2F\ (\Delta G - \Delta S\ (T - Tref)\ + RT\ (ln\ PH2\ + ln\ PO2/2)) \qquad (2)$$

The activation loss of PEMFC is caused by the inactive kinetics of the reactions taking place on the active surface of the electrodes. So

$$Vact = \xi 1 + \xi 2T + \xi 3T\ [ln\ (CO2)]\ + \xi 4T\ [ln\ (i)] \qquad (3)$$

Here ohmic losses due to equivalent membrane resistance (Rm) and contact resistances (Rc). If cell is fabricated then these values are constant. So it can be calculated as

$$Vohmic\ =\ I\ Rohmic\ =\ I\ (Rm + Rc)(4)$$

According to ohms law Rm can be expressed as

$$Rm\ = \frac{rml}{A} \qquad (5)$$

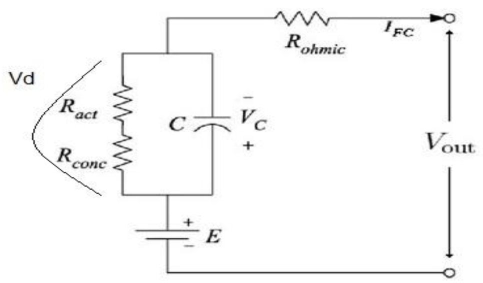

Fig.3 Equivalent Electrical circuit of PEMFC

In this circuit Rohmic, Ract, Rconc are the ohmic resistance, activation resistance, concentration resistance. C is the membrane capacitance due to double layer effect. This effect is incorporated in the output of the PEMFC. C is equivlent capacitance which can effectively smooth the voltage drop across Ract, Rconc and Vd. Here Vd is the overall voltage drop across Ract and Rconc.[5]

IV.Z-SOURCE INVERTER

A Z-Source Inverter is also called Impedence inverter.. Its main function is to convert Direct Current to Alternating Current. There are some limitations in the conventional VSI (Voltage Source Inverter) and CSI (Current Source Inverter) as AC output voltages is less than DC input voltage and Two switches in the same phase leg cannot turn on simultanously. To overcome the limitations of VSI and CSI, Z – Source Inverter is a batter choice. ZSI employes a Z network as L1=L2, C1=C2 shown in figure below. The Z-Source inverter employs Impadence network between voltage source and inverter bridge. In Z-Source Inverter, There is one more switching state as shoot through state, besides the Eight switching states (Six active states and two zero states) for traditional source inverter. With the Z-network, the shoot through state intentionally added to boostthe output voltage. In the inverter the output voltage is higher or lower than the DC-Link voltage.

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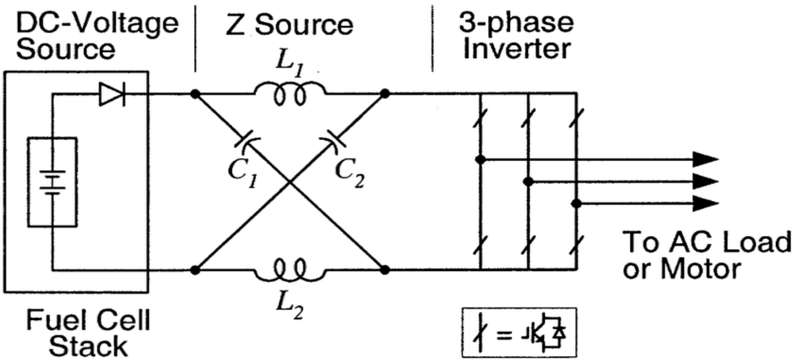

Fig.4 Three phase Z–Source Inverter

Therefore the inverter is a buck boost type converter and can give desired output voltage. With the ability to handle the shoot trough state, The reliabilty of ZSI is enhanced. And also without need of dead time, Distortion of output waveform can be avoided.

The ZSI, The output peak voltage is

$$Vac = m.B\,Vin/2 \tag{1}$$

Where

m = Modulation Index

Vin = Input Voltage

B = Boost fector and B is expressed as

$$\mathrm{B} = 1/(1-2\left(\frac{\mathrm{Tsh}}{\mathrm{T}}\right)) \tag{2}$$

Where

Tsh is the shoot through time per cycle and T is the switching time period. Therefore we can say that The inverter can buck boost the output voltage with a single stage. And the shoot through state caused by Electromagnetic Interference (EMI) can no longer distroy the inverter so the reliabilty incresed. The converter does not required deadtime so the output waveform near to sinusoidal form.

V.FUZZY LOGIC CONTROLLER

PI controller is commenly used controller in DVR. But if the range of DVR increases, then the efficiency of PI conroller decreases. So to Increase the efficiency or stabilty of the system Fuzzy logic controller is introduced. Fuzzy logic controller increases the efficiency and reliabilty of the system to greater extent. In basically Fuzzy logic controller has Three main elements: Crisp Input, membership function and crisp output as shown in figure below. The main functions of membership function is Fuzzification, Intelligence, Defuzzification.

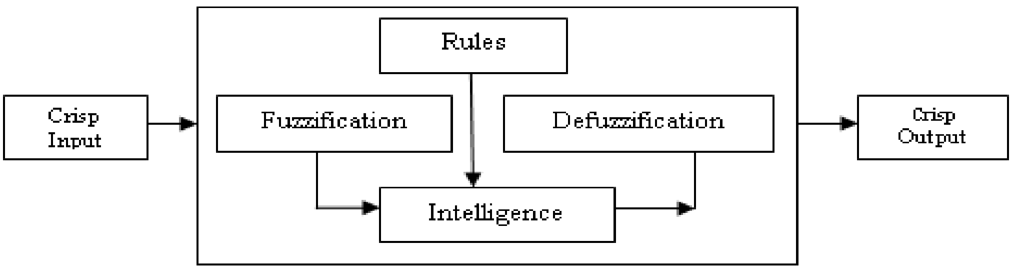

Fig.5 Basic Fuzzy logic controller

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In DVR the phase of the Voltage of the Network can be determined by using PLL (Phase lock loop). After determining the phase, a reference signal as unity is generated to supply frequency for each phase of the system. And the diffrence Between reference signal of PLL and actual supply voltage gives the error signal.When the output of the Fuzzy logic controller passing through PWM then it gives pulse. [6]

VI.PROPOSED MODEL

The proposed DVR model for voltage sag compensation is Shown in Fig.6. And proposed DVR model for voltage swell compensation is shown in Fig.7. And internal parts of Proposed DVR Model for both voltage sag and swell compensation are shown in fig.8, fig.9, fig.10, fig.11 and in fig.12. In this proposed model PEMFC is used as a DC source and Ultracapacitor or Super capacitor is connected along with it to increase system storage capacity. Z-Source inverter is used with passive filter. And Fuzzy logic controller is used to increase system stability.

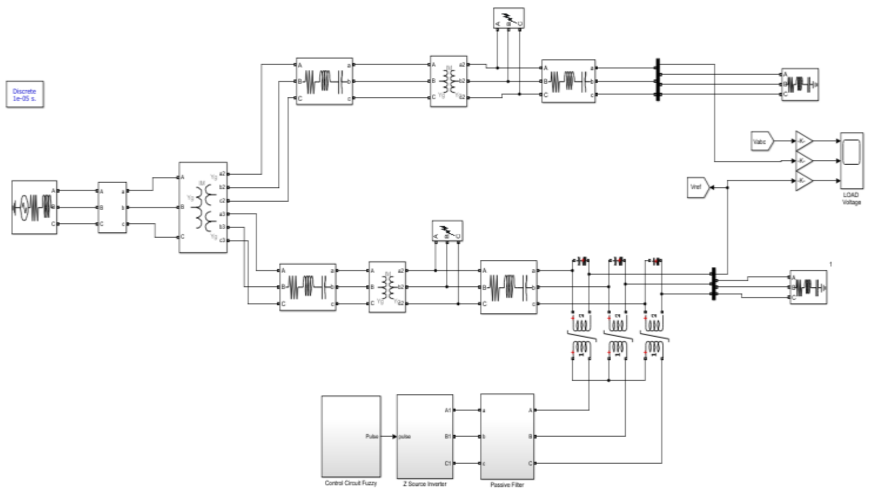

Fig.6 Proposed DVR MODEl for Voltage sag Compensation

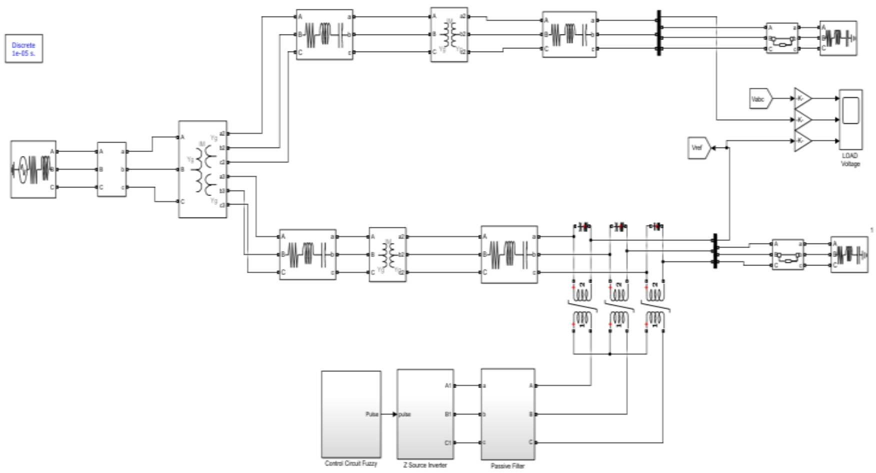

Fig.7 Proposed DVR model for voltage swell compensation

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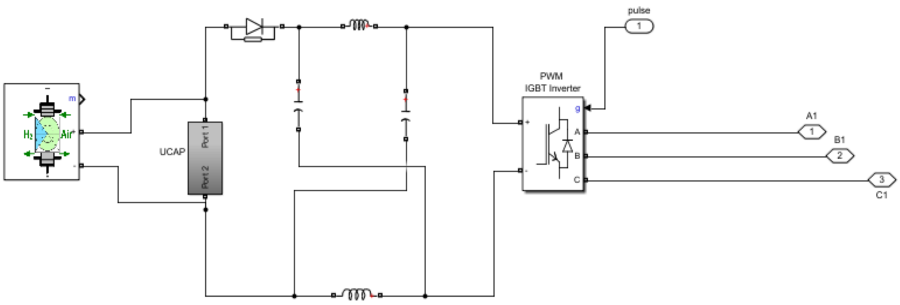

Fig.8 Z source inverter with PEMFC and Supercapacitor

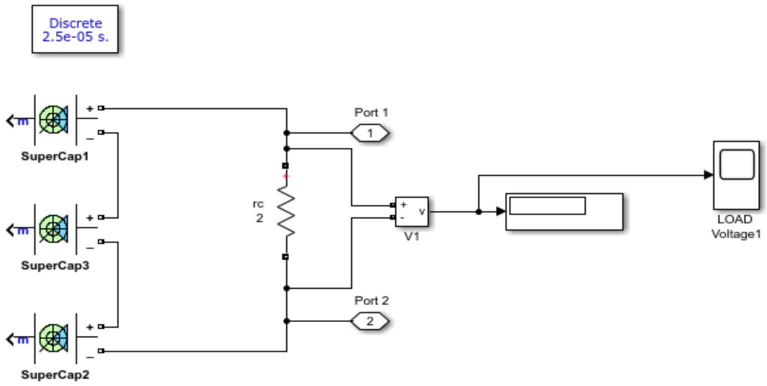

Fig.9 Supercapacitor

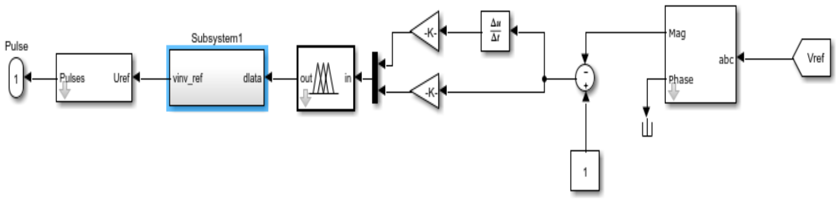

Fig.10 Fuzzy logic controller

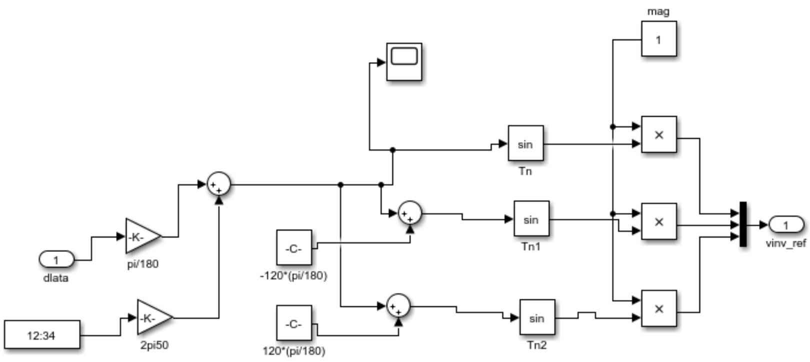

Fig.11 subsystem1

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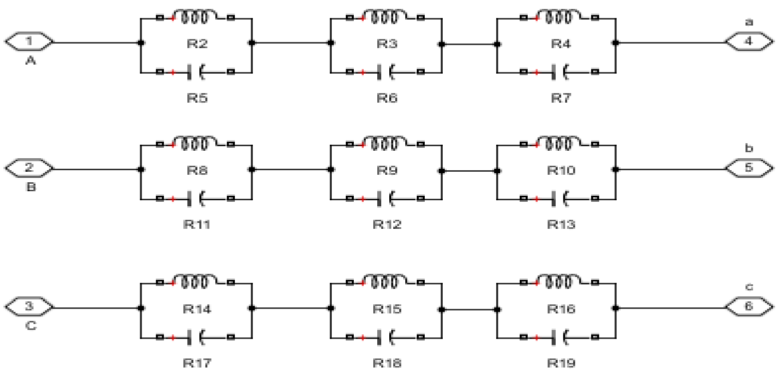

Fig.12 Passive filter

VII.SIMULATION RESULTS

The profile of supply input volage, profile for load votage network 1(faulty network) and profile for load voltage network 2 (DVR connected network) is shown below.The profile of Proposed DVR for single phase voltage sag without DVR and with DVR is shown in fig.13 and the profile of proposed DVR for two phase voltage sag without DVR and with DVR is shown in fig.14 and profile of proposed DVR for three phase voltage sag without DVR and with DVR is shown in fig. 15. Same Profile of Proposed DVR for single, two and three phase swell without DVR and with DVR is shown in fig.16, fig.17 and fig.18 below.

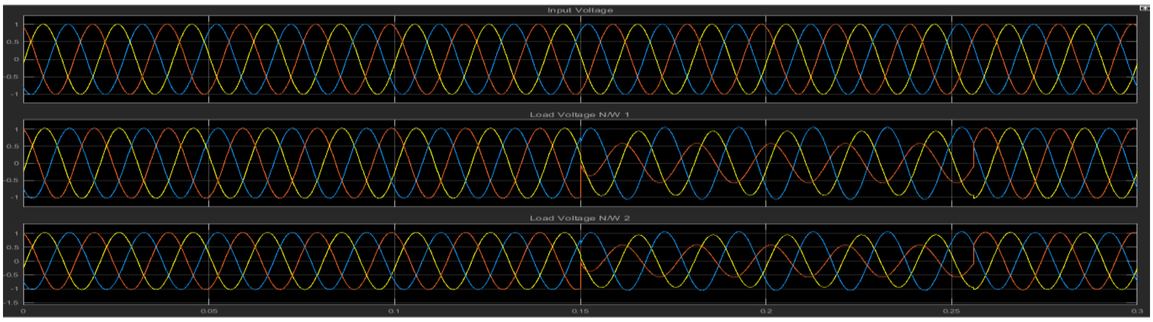

Fig.13(a) Single phase voltage sag without DVR

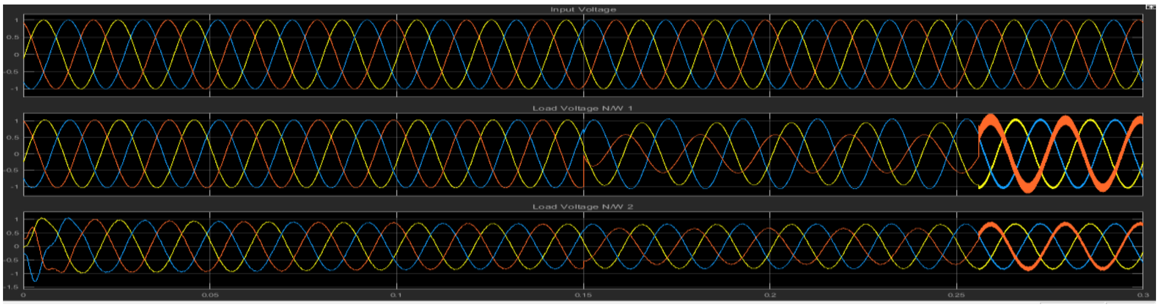

Fig.13(b) Single phase voltage sag compensation with DVR

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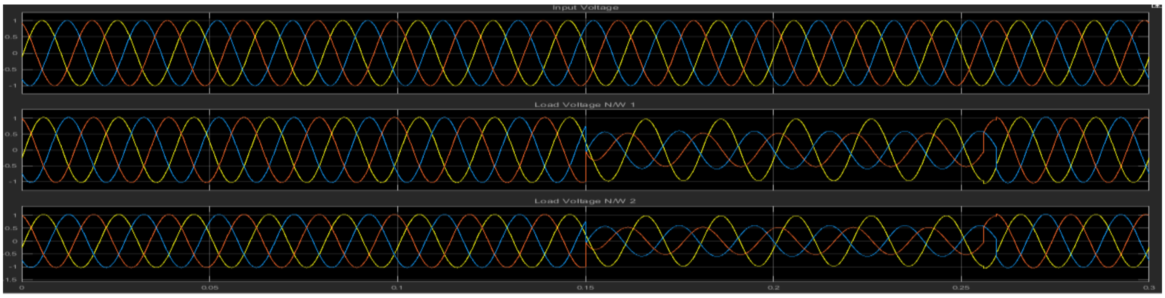

Fig.14(a) Two phase voltage sag without DVR

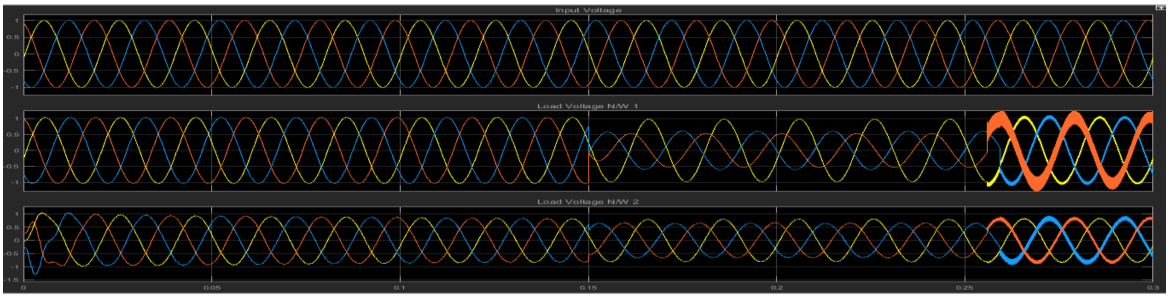

Fig.14(b) Two phase Voltage sag compensation with DVR

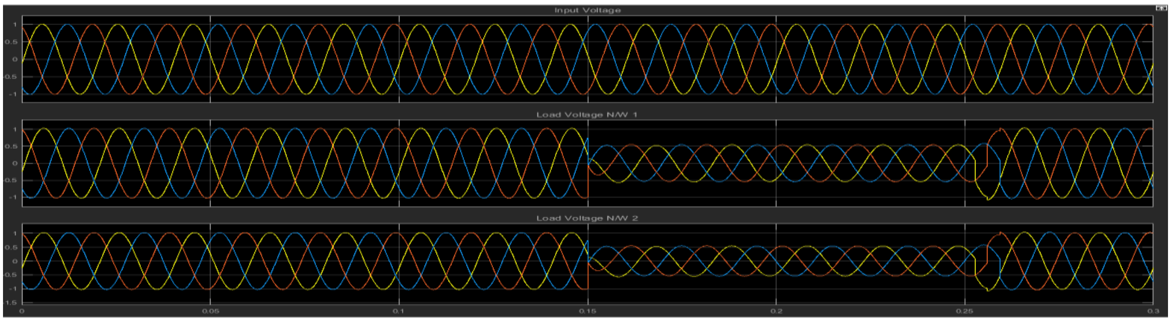

Fig.15(a) Three phase voltage sag without DVR

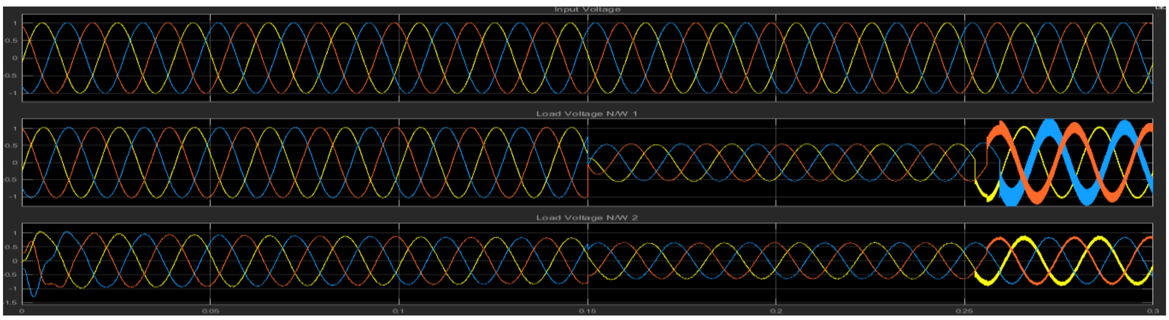

Fig.15(b) Three phase voltage sag compensation with DVR

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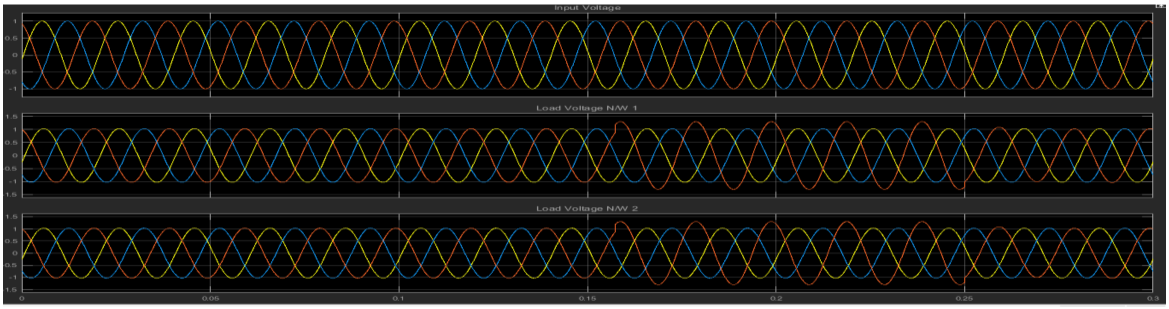

Fig.16(a) Single phase Voltage swell Without DVR

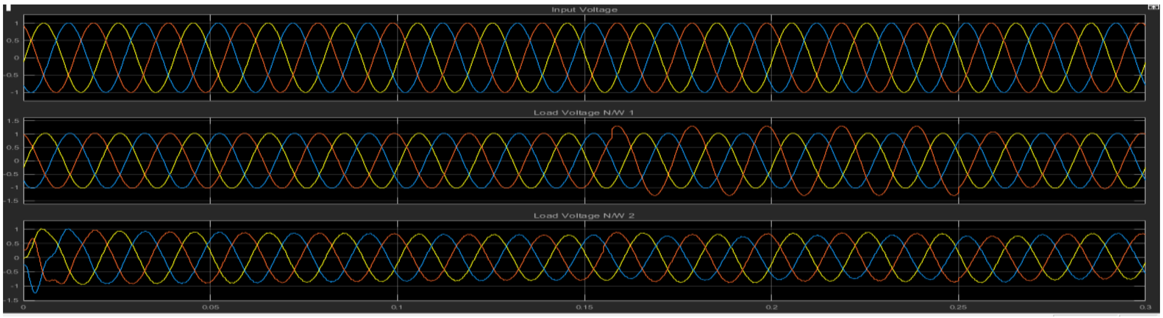

Fig.16(b) Single phase voltage swell compensation with DVR

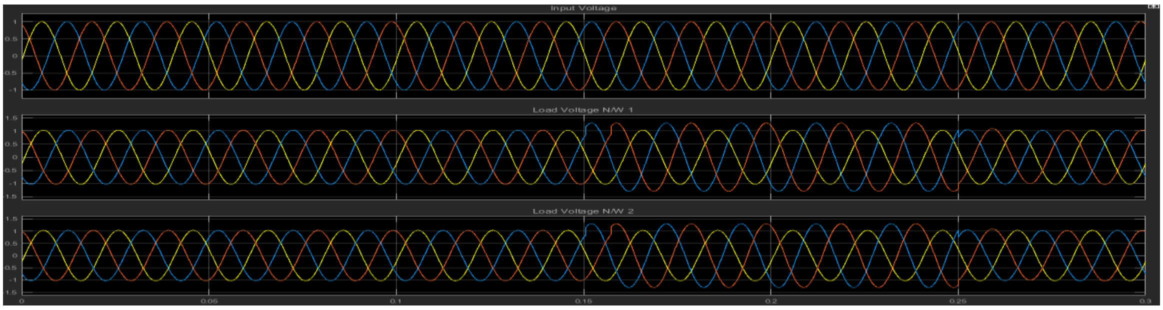

Fig.17(a) Two phase voltage swell Without DVR

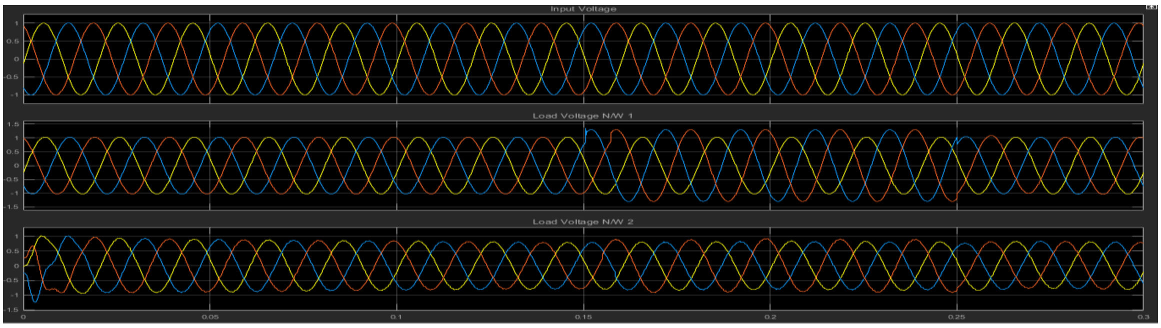

Fig.17(b) Two Phase Voltage Swell Compensation with DVR

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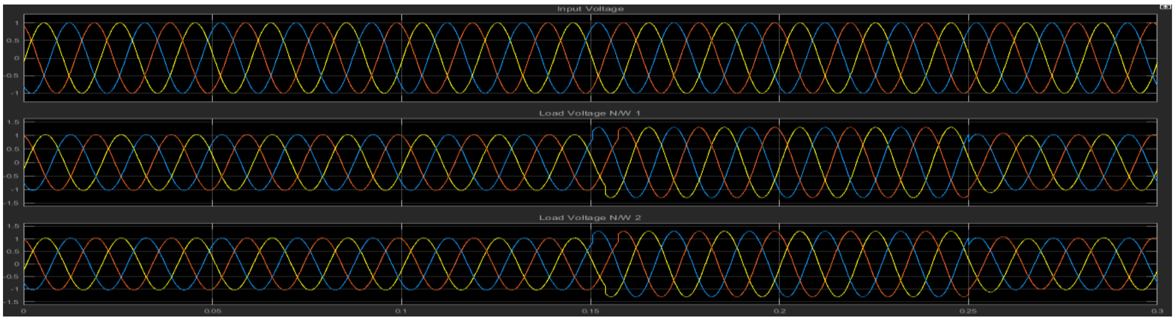

Fig.18(a) Three Phase Voltage Swell Without DVR

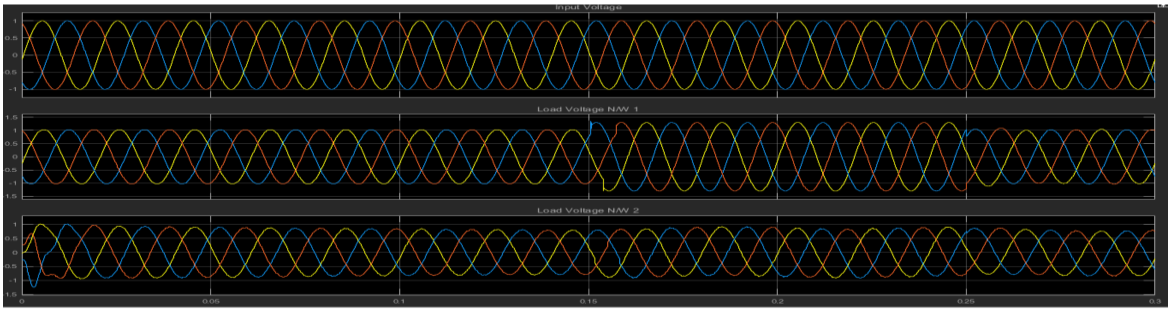

Fig.18(b) Three Phase Voltage Swell Compensation with DVR

VIII.CONCLUSION

The proposed model is simulated in MATLAB/SIMULINK. In this DVR model, A Z-source inverter with fuzzy logic controller gives improved results in voltage sag and swell compensation as Z source inverter has two degree of freedom and controller is AI based i.e. Fuzzy logic controller. It has been observed that in DVR, a PEMFC with Super capacitor and fuzzy logic controller is very efficient for improvement of power quality in power system.

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