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Mitigation Of Voltage Sag With PEMFC Supported IDVR

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Abstract - *The distribution system contains various types of loads. These loads can be broadly classified as sensitive loads and non-sensitive loads. The sensitive loads are easily affected with power quality problems. Hence, power quality improvement is major concern in the distributed system. The power quality problems that are faced in the distribution side are voltage sag/swell, harmonics, flickering, distortions etc. One of the major power quality issue that is considered in this paper is voltage sag. To handle these power quality issue Flexible AC Transmission Systems (FACTS) devices are considered. One of the FACTS device at the distribution side called Interline Dynamic Voltage Restorer (IDVR) is proposed to mitigate the voltage sag. The building blocks of IDVR used for injecting the voltage by current source inverter (CSI). In this paper, IDVR with two CSI as its building blocks is considered to mitigate voltage sag. Proton Exchange Membrane Fuel Cell (PEMFC) is used at the DC link of IDVR to provide the necessary energy to mitigate sag. The simulations are performed in MATLAB environment.*

Key Words: *Interline Dynamic Voltage Restorer ,current source inverter, Proton Exchange Membrane Fuel Cell (PEMFC),* Dynamic Voltage Restorer

1.INTRODUCTION

Electrical energy is the simple and well regulated form of energy, can be easily transformed to other forms. Along with its quality and continuity has to maintain for good economy. Power quality has become major concern for today's power industries and consumers. Power quality issues are caused by increasingly demand of electronic equipment and non-linear loads. Many disturbances associated with electrical power are voltage sag, voltage swell, voltage flicker and harmonic contents. This degrades the efficiency and shortens the life time of end user equipment. It also causes data and memory loss of electronic equipment like computer.

Due to complexity of power system network voltage sag/swell became the major power quality issue affecting the end consumers and industries. It occurs frequently and result in high losses. Voltage sag is due to sudden disconnection of load, fault in the system and voltage swell is due to single line to ground fault results in voltage rise of un faulted phases. The continuity of power supply can be maintained by clearing the faults at faster rate. Other power quality issues i.e. voltage flickering, harmonics, transients etc. has to be compensated to enhance the power quality.

The alternative solution to these traditional devices is Flexible AC Transmission Systems (FACTS) devices. FACTS devices are static power electronic devices which are used to eliminate the power quality issues. The FACTS devices used at the distribution side are Dynamic Voltage Restorer (DVR) and Unified Power Quality Conditioner (UPQC). Both of the devices detect the level of voltage drop in the system and restore by injecting the required voltage into the system. The main disadvantages of these devices are requirement of large DC link to mitigate large voltage sags and also the devices are restricted to be connected to only one feeder.The solution to the drawbacks of DVR and UPQC is extended version of DVR called Interline Dynamic Voltage Restorer (IDVR).

2.PROTON EXCHANGE MEMBRANE FUEL CELL

PEMFC uses a solid polymer electrolyte which has an exemplary behaviour in proton absorption an electron rejection. At the anode, hydrogen atoms split into electrons and positive ions in the presence of platinum catalyst. The positive ions travel through the membrane and are engrossed to the cathode, while the electrons ramble through the external load, generating a voltage across the load. Recombination of positive and negative ions takes place again with the help of the catalyst. The schematic diagram of PEMFC is taken from and is shown in fig3.2. The chemical reaction entangled in the PEMFC is given by the equ. (1), equ. (2) equ. (3).

$$H_2 = 2H+ + 2e- \quad (1)$$

$$½\ O_2 + 2\ H+ + 2e- = H_2O \quad (2)$$

$$H_2 + ½\ O2 = H_2O \quad (3)$$

The number of fuel cells are combined together to form a fuel cell stack. Fig 3.2. Schematic diagram of PEMFC Due to the chemical reactions involved in the fuel cell, charged layers of opposite polarity are formed across the periphery of the porous cathode and the membrane. These layers are known as electrochemical double layer which behaves like a super-capacitor and stores electrical energy.

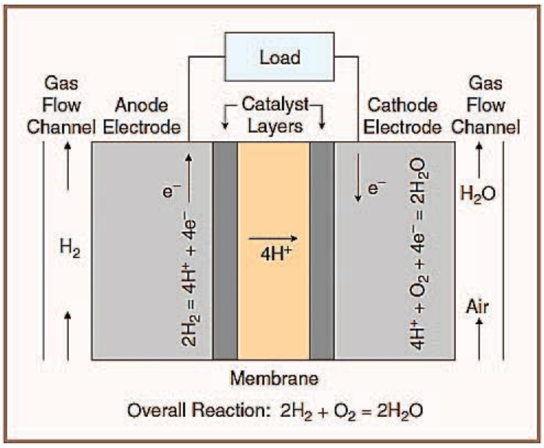

Fig-1: PEMFCs

3 .INTERLINE DYNAMIC VOLTAGE RESTORER

The drawbacks of DVR and UPQC is extended version of DVR called Interline Dynamic Voltage Restorer (IDVR). IDVR consists of two dvrs connected with a common DC link where each DVR is connected in series with different distribution lines [3-4]. When one DVR of IDVR mitigates voltage sag in one power line it consumes the energy from the DC link, while other DVR replenishes required energy at DC link through the PEMFC.

The schematic diagram of IDVR is shown in Fig 2. A two line IDVR is considered in this project. The IDVR consists of two DVRs connected to two different feeders. PI controller along with CSI and filter is present inside the building blocks of IDVR. In Fig.1 V_{s1} and V_{s2} are source voltages while V_{b1} and V_{b2} are voltages of bus 1 (B1) and bus 2 (B2) at the distribution side where IDVR is connected. Z_{L1} and Z_{L2} are impedances of feeder 1 and feeder 2 respectively. Load 1 and load 2 are connected to each of the buses as shown with V_{L1},I_{L1} and V_{L2},I_{L2} as the load voltages and currents. Both these loads are assumed to be sensitive and they need protection from voltage sag and harmonics. Vinj1 and Vinj2 are voltages injected by DVR1 and DVR2 respectively during the voltage sag conditions. The building blocks of IDVR, CSI is discussed in the following section.

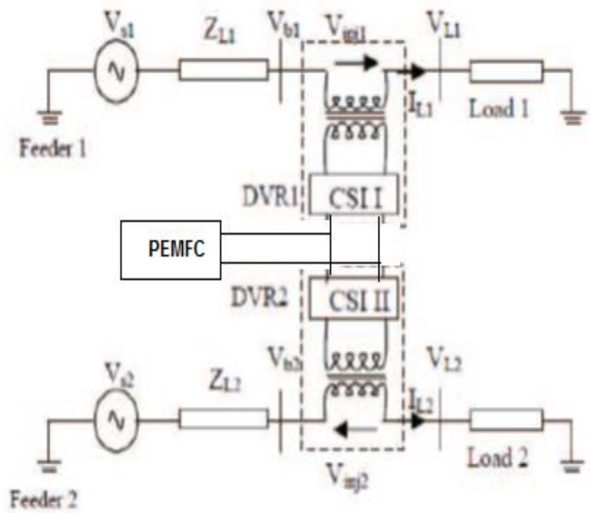

Fig-2: Schematic layout of Interline Dynamic Voltage Restorer WITH PEMFC

Therefore, IDVR is able to compensate even at longer voltage sags due the availability of amount of energy from DC link. Each DVR of the IDVR consists of current source inverter (CSI) as its building blocks, a proportional integral (PI) controller as its control system and a filter. The purpose of srf base controller is to compare the actual or load voltage component with set or reference voltage component..

By using Clark's and park's the voltage signals v_a,v_b,$v_{c(abc)}$ are converted to v_d,$v_{q(dqo)}$ (stationary quantity) . the PLL which supplies the sine and cosine value to the abc to dq and dq to abc transformation. the reference signal is generated by the use of abc to dq and During normal condition and symmetrical condition both d and q voltages remain constant but during the abnormal conditions it varies. After comparison with the reference d and q voltages, resultant d and q voltages are generated. These components using dq to abc transformation block converts to abc frame which is known as inverse Park's Transformation and thus modulation signal for PWM technique is generated.

The error between actual and reference voltage is given as input to PWM generator which generates gate pulses to inverter switches of CSI. The inverter injects voltage to the line through injection transformer

CSI are chosen as the building block of IDVR instead of VSI because CSI have some advantages over VSI like directly controlling the output current of the inverter and high reliability.

4 CURRENT SOURCE INVERTER

CSI are the type of inverters fed with a current source with high impedance. The source at the AC side of the inverter may be a current source or inductor in series with a DC source. As the input voltage is constant in VSI, in CSI the input current is constant but adjustable. The amplitude of the output current is independent of load. The waveform and magnitude of the output voltage depends on nature of load.

Fig.3 represents the three phase CSI. In Fig.3 , S1 to S6 represents the switches (MOSFET or IGBT) and D1 to D6 are the diodes connected in series to the switches to block the reversal of current. The advantages of CSI are its excellent current control capability, easy protection from short circuit or overcurrent, and output current is ripple free though it is Costlier than VSI.

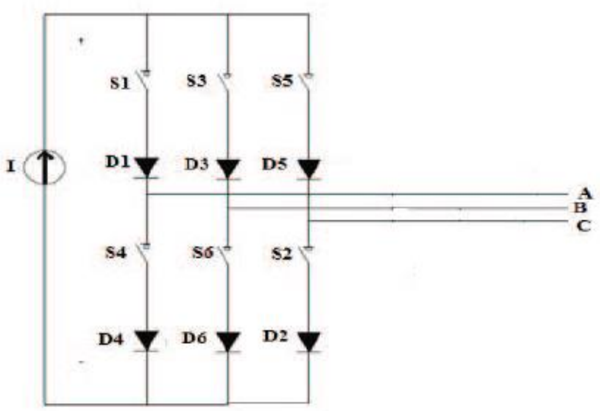

Fig-3: Schematic diagram of CSI

A PEMFC source is used at the DC link of IDVR to provide necessary energy while IDVR is mitigating the voltage sag. The next section covers total simulation results of IDVR System.

5 MAT LAB SIMULATION RESULTS

The total system of IDVR with PEMFC source connected to two feeders simulated in MATLAB is shown below in Fig-4, IDVR is connected between feeder 1 and feeder 2

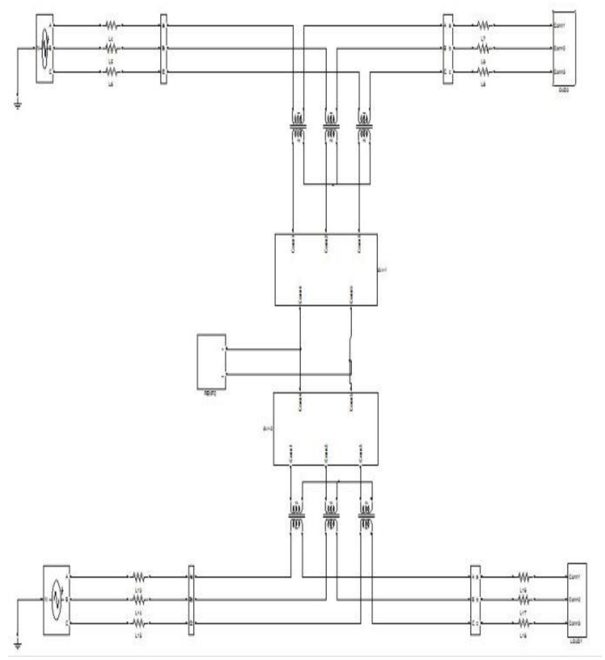

Fig-4: IDVR IS CONNECTED BETWEEN FEEDER 1 AND FEEDER 2

In Fig-4, feeder 1 and feeder 2 are at different voltage levels. The PEMFC source is connected IDVR and the total set up gives the required energy at the DC link energy. Whenever IDVR mitigates the voltage sag in the system, the energy to mitigate the voltage sag is taken from the PEMFC source. Which is connected to the PEMFC source has it energy maintained at the constant level even at the time of mitigation of voltage sag. Here voltage sag is created in three different conditions which is listed below

CASE 1: fault occur in feeder 1

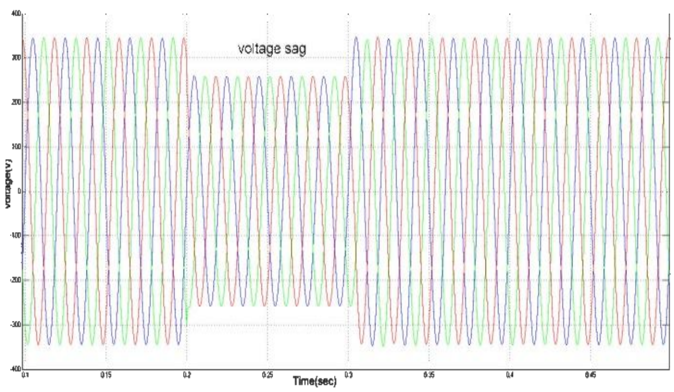

Fig-5: Load voltage at feeder 1 without IDVR.

In this case it is assumed that 23% Voltage sag occurs on in intervals of time 0.2 sec to 0.3sec at feeder1

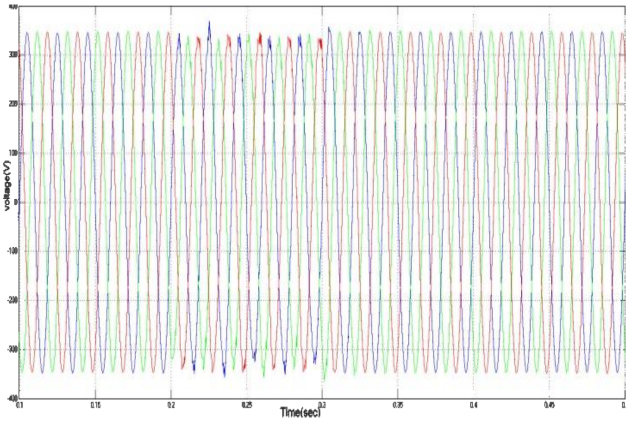

Fig-6: Load voltages at feeder 1 with IDVR

Case 2 : Multiple sags in feeder 2

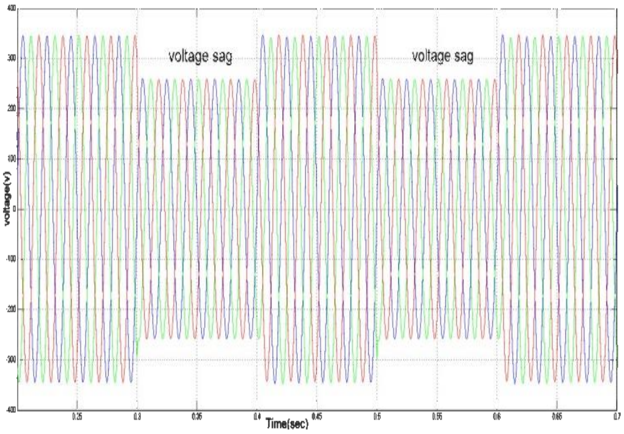

Fig-7: Load voltage at feeder 2 without IDVR.

In this case it is assumed that 23% Voltage sag occurs on in intervals of time 0.3 sec to 0.4sec and 0.5 sec to 0.6 sec at feeder2

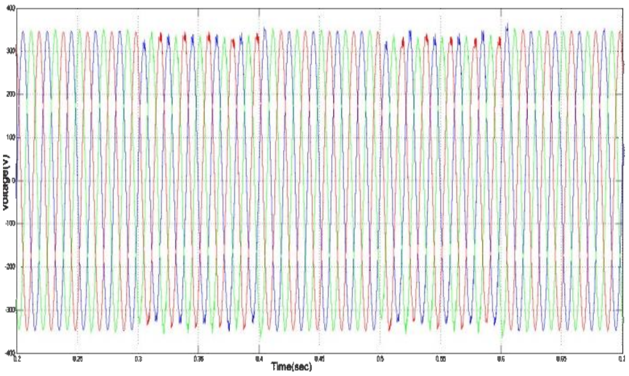

Fig-8: Load voltage at feeder 2 with IDVR...

Case 3: Simultaneous Voltage Sag occurred in Both Feeders

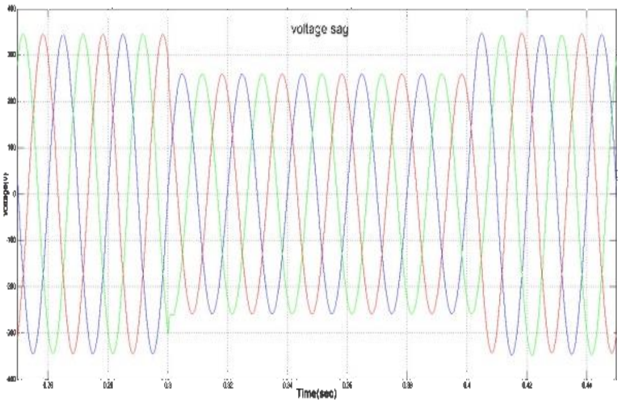

Fig-9: Load voltage at feeder 1 without IDVR.

In this case it is assumed that 23% Voltage sag occurs on in intervals of time 0.3 sec to 0.4sec at feeder1

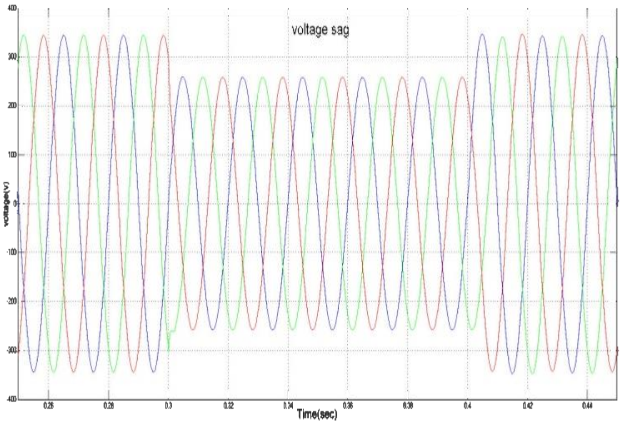

Fig-10: Load voltage at feeder 2 without IDVR.

In this case it is assumed that 23% Voltage sag occurs on in intervals of time 0.3 sec to 0.4sec at feeder2

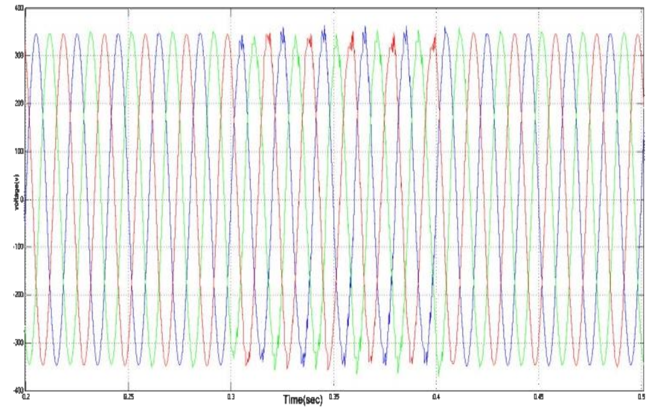

Fig-11: Load voltage at feeder 1 with IDVR

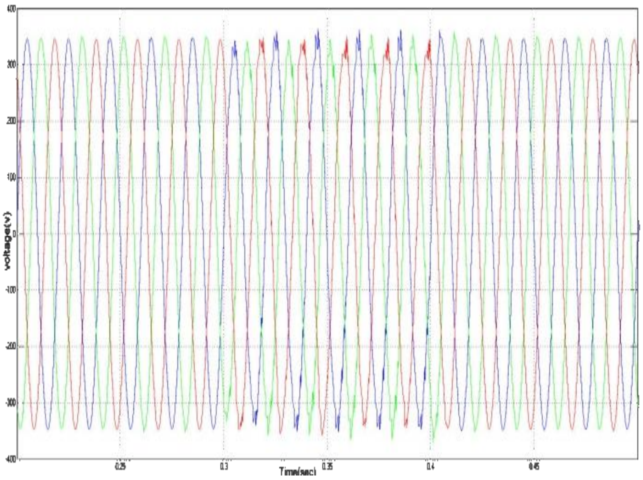

Fig-12: Load voltage at feeder 2 with IDVR.

6. CONCLUSIONS

In this paper the performance of IDVR with CSI at its building block along with a PEMFC at its DC link is proposed. The purpose of IDVR is to mitigate the voltage sag which occurs at the load end. To provide necessary energy for IDVR to mitigate voltage sag, a PEMFC source is provided at the DC link of IDVR .thus mitigates the voltage sags which are occurred in both feeders. Therefore a conclusion can be drawn that the IDVR along with PEMFC source is able to mitigate the voltage sag in all the proposed condition.

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