Power Quality Enhancement In Distribution System Using Fuel Cell Based DVR

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Abstract*-This paper focus on model of dynamic voltage restorer (DVR) which is used to mitigate the short duration voltage disturbances like voltage sag and swell occur in power system due to various factors. The basic principle of dynamic voltage restorer is to inject the voltage of required magnitude and frequency, so that it can restore the load side voltage to the desired amplitude and waveform. The most occurrence power quality issue "voltages sag and voltage swell" can be mitigated by using custom power device (DVR) which employs compact controller and harmonic filter. The proposed DVR system includes the energy Storage device (Fuel Cell), PWM inverter, harmonic filter. The overall system is developed and Mitigated using in MATLAB Simulink tool.*

Keywords-Power Quality (PQ), voltage sag and voltage swell, Polymer Electrolyte Membrane (PEM)Fuel cell, DVR, design of VSI.

I. INTRODUCTION

The quality of power can have a direct economic impact on many industrial consumers. There has recently been a great emphasis on revitalizing industry with more automation and more modern equipment. This usually means electronically controlled, energy efficient equipment that is often much more sensitive to deviations in the supply voltage.

In [1], controlling the PV based Dynamic Voltage Restorer for adaptive fuzzy membership function tuning algorithm. In [2] , control scheme for DVR topologies with an ac–ac converter, based on the characterization of voltage sags is proposed to mitigate voltage sags with phase jumps and real-time testing of the scheme on a single-phase model of the topology to compensate various sag types using DSPF28335.

Power quality is an abnormal behavior on a power system arising in the form of voltage and/or current, which adversely affects the normal operation of electrical or electronic equipment. It is defined in another way; power quality is any deviation of the voltage or current waveform from its normal sinusoidal wave shape. These disturbances include, but are not limited to sag, under voltage, interruption, swell, over voltage, transients, harmonics, voltage flicker and any other distortions is called a power quality event.

The power supply system can control only the voltage quality. It has no control over the currents that particular load might draw. There is always a close relationship between voltage and current in any practical power system. Although the generators may provide a near perfect sine-wave voltage, the current passing through the impedance of the system can cause a variety of disturbances to the voltage.

(i) The current resulting from a short circuit causes the voltage to sag or disappear completely, as the case may be.
(ii) Currents from lightning strokes passing through the power system causes high impulse voltages that frequently flash over insulation and lead to other phenomena.
(iii) Distorted currents from harmonic-producing loads also distort the voltage as they pass through the system impedance. Thus a distorted voltage is presented to other end users.

II. POWER QUALITY

Any power problem manifested in voltage, current, or frequency deviations that results in failure or mis-operation of customer equipment. As per IEEE standard Power Quality is defined as the concept of powering and grounding sensitive equipment in a manner that is suitable to the operation of that equipment. The power quality problems can be classified into three classes: Problems Generated by the Electric Utility Causing Problems at the Consumers 'Premises,Problems Generated by a Consumer Causing Problems to Other Consumers, Problems Generated by a Consumer Causing Problems to His or Her Own Equipment.

The power quality variations due to these problems can be categorized as: Transient disturbances (very short duration), Fundamental frequency disturbances (short and long duration), and Variations in steady state (harmonics, inter-harmonics, D.C offset, noise and notching).

1) VOLTAGE SAG:

A sag is a decrease between 0.1 and 0.9pu in rms voltage or current at the power frequency for durations from 0.5 cycle to 1 min.

2) VOLTAGE SWELL:

A swell is defined as an increase to between 1.1 and 1.8 pu in rms voltage or current at the power frequency for durations from 0.5 cycle to 1 min.

3) INTERRUPTION:

An interruption occurs when the supply voltage or load current decreases to less than 0.1 pu for a period of time not exceeding 1 min.some interruptions can be proceeded by a voltage sag when these interruptions are due to faults on source systems.

4) VOLTAGE IMBALANCE:

Voltage imbalance or unbalance is defined as the maximum deviation from the average of the three phase voltage or current, divided by the average of the three phase voltage or currents, expressed in percent imbalance is more rigorously defined using symmetrical components.

5) OVER VOLTAGE:

An overvoltage is an increase in the rms ac voltage greater than 110 percent at the power frequency for a duration of longer than 1 min.

6) UNDER VOLTAGE:

An undervoltage is a decrease in the rms ac voltage to less than 90 percent at the power frequency for a duration of longer than 1 min.

7) SUSTAINED INTERRUPTION:

When the supply voltage has been zero for a period of time in excess of 1 min, the long duration voltage variation is considered a sustained interruption.

III. DYNAMIC VOLTAGE RESTORER

Dynamic voltage restorer is a method of overcoming voltage sag which occur in electrical power distribution. It is a power electronic switching device which is connected in series to the load voltage bus in order to inject a dynamically controlled voltage. Typical Block diagram of DVR is shown in Fig.1.It consists of the following units:

Energy storage unit: This is DC storage energy with a proper capacity which supplies to the DVR during compensation required. It can be a capacitor or a battery.

Injection transformer: the DVR transfers the voltage which is required for the compensation from the voltage source converter to the distribution network through the injection transformer. The high voltage side is normally connected in series with the distribution network while its low voltage side is connected to the power circuit of the DVR.

Voltage source inverter (VSI): this is a power electronic configuration which is used to generate a sinusoidal voltage with the required magnitude, phase, and frequency.

LC passive filter: A simple output filter composed of passive elements such as a resistance R, inductance L, capacitance C. it is used to reduce the undesired harmonic components of the waveform generated by the converter to their permissible limit and .its output is a sinusoidal waveform with low total harmonic distortion.

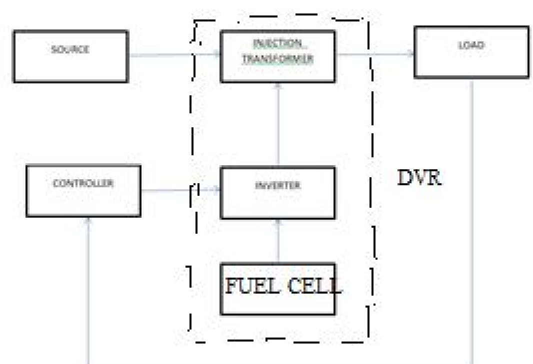

Fig.1 Block diagram of DVR

Control unit: this system is used to detect the presence of voltage sag in the system. In other words, it is considered as a monitor of the load bus voltage. If a sag voltage is sensed, the controller will be initiated in order to inject the missing voltage after determination of its magnitude and phase.

The DVR has two main modes of operation, which are as follows:

(i) Standby mode: This is the monitoring action of the load bus voltage. No voltage is injected and the transformer low voltage side is shorted through the converter.
(ii) Injection mode: The DVR in this mode injects the required voltage to the system to correct the sag.

IV. FUEL CELL

A fuel cell is a device that converts the chemical energy from a fuel into electricity through a chemical reaction of positively charged hydrogen ions with oxygen or another oxidizing agent.

Fuel cells are different from batteries in requiring a continuous source of fuel and oxygen or air to sustain the chemical reaction, whereas in a battery the chemicals present in the battery react with each other to generate an electromotive force (emf). Fuel cells can produce electricity continuously for as long as these inputs are supplied.

There are many types of fuel cells, but they all consist of an anode, a cathode, and an electrolyte that allows positively charged hydrogen ions (protons) to move between the two sides of the fuel cell. The anode and cathode contain catalysts that cause the fuel to undergo oxidation reactions that generate positively charged hydrogen ions and electrons. The hydrogen ions are drawn through the electrolyte after the reaction.

(1) Polymer Electrolyte Membrane (PEM) fuel cells or PEMFCs (also called PEFCs),
(2) Solid Oxide Fuel Cells (SOFCs),
(3) Alkaline Fuel Cells (AFCs),
(4) Phosphoric Acid Fuel Cells (PAFCs),
(5) Molten Carbonate Fuel Cells (MCFCs).

At the same time, electrons are drawn from the anode to the cathode through an external circuit, producing direct current electricity. At the cathode, hydrogen ions, electrons, and oxygen react to form water.

As the main difference among fuel cell types is the electrolyte, fuel cells are classified by the type of electrolyte they use and by the difference in startup time ranging from 1 second for proton exchange membrane fuel cells (PEM fuel cells, or PEMFC) to 10 minutes for solid oxide fuel cells (SOFC).

Individual fuel cells produce relatively small electrical potentials, about 0.7 volts, so cells are "stacked", or placed in series, to create sufficient voltage to meet an application's requirements.

In addition to electricity, fuel cells produce water, heat and, depending on the fuel source, very small amounts of nitrogen dioxide and other emissions. The energy efficiency of a fuel cell is generally between 40–60%, or up to 85% efficient in cogeneration if waste heat is captured for use.

V.PWM INVERTER

Pulse Width Modulation or PWM technology is used in Inverters to give a steady output voltage of 230 or 110 V AC irrespective of the load.The Inverters based on the PWM technology are more superior to the conventional inverters.The use of MOSFETs in the output stage and the PWM technology makes these inverters ideal for all types of loads.

In addition to the pulse width modulation, the PWM Inverters have additional circuits for protection and voltage control is shown in Fig.2.

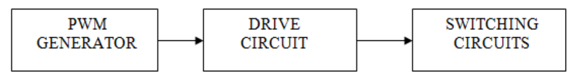

Fig.2.Block diagram of PWM Inverter

In these inverters the input dc voltage is essentially in magnitude, where diode rectifier is used to rectify the line voltage.

Therefore, the inverter must control the magnitude and the frequency of the ac output voltages.

This is achieved by PWM of the inverter switches and hence such inverters are called PWM inverters is shown in Fig.3.There are various schemes to pulse width modulate the inverter switches in order to shape the output ac voltages to be as close to a sine wave as possible. MOSFET are used as a switching devices for inverters due to their capability which has high switching frequency. Metal Oxide Semiconductor Field Effect Transistors (MOSFETs) with appreciable on-state current carrying capability and off-state blocking voltage capability. Thus the potential for power electronics applications. The applications in electronics where high switching speed required can utilize MOSFET. But they can be used for low power applications only. In order for high power applications, power MOSFET are used. The main drawback of this cost of the device. For increasing higher ratings the cost also increased rapidly.

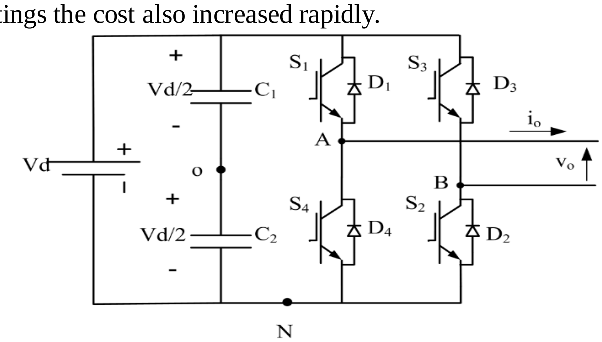

Fig.3.PWM Inverter Circuit

VI. FILTER

The filter is a circuit which removes unwanted dc or ac components in the output of the inverter. The output from the inverter may contains some dc components and harmonics components, these components are eliminated using filter circuits.

There are many types of filters which composed of passive elements i,e. inductors, capacitors, resistors.

The filtering action depends upon the basic electrical properties of passive circuits elements.

Some of the important filters used in the field of electronics are:
a) Inductor filter
b) Capacitor filter
c) Inductor-Capacitor filter
d) pi filter

VII. SIMULATION RESULTS

The Fig4.shows the MATLAB Simulink diagram of Fuel cell based DVR. In Fig.5.shows the Simulink diagram of Fuel cell. In Fig.6. Shows the simulation waveform of grid voltage, load voltage and DVR injected voltage. In Fig.7 shows the simulation waveform of Fuel flow rate, utilization, stack consumption, stack efficiency. In Fig.8.shows the voltage and current waveform.

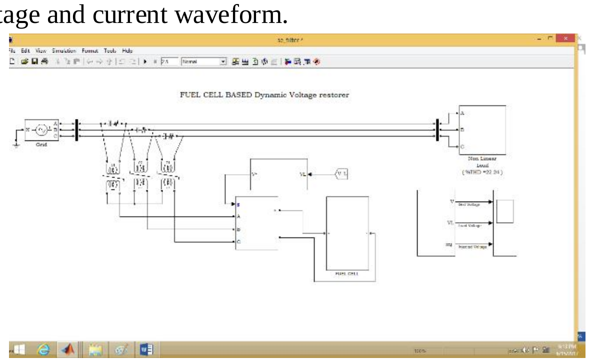

Fig.4. Fuel cell based DVR

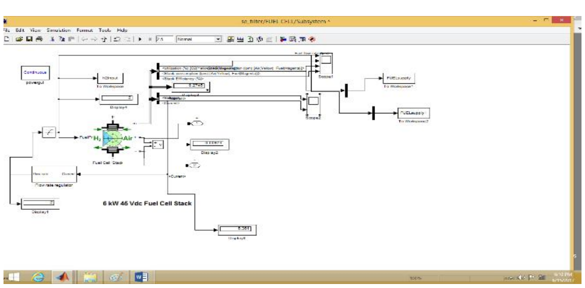

Fig.5.Fuel cell Simulink diagram

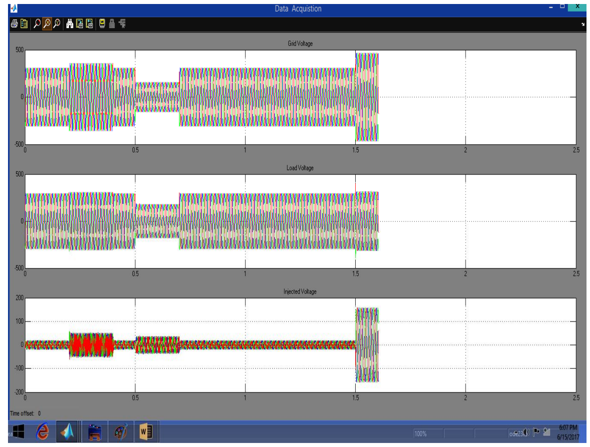

Fig.6. grid voltage, load voltage and DVR injected voltage

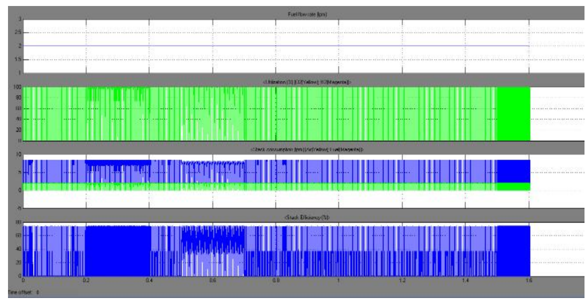

Fig.7 Fuel flow rate, utilization, stack consumption, stack efficiency

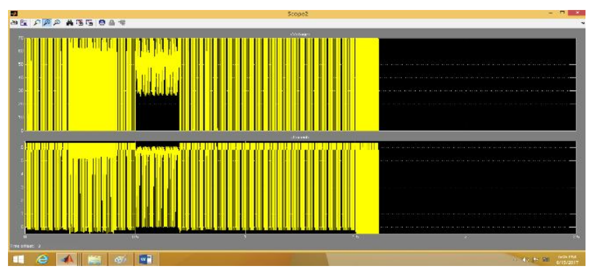

Fig.8.voltage and current waveform

VIII. CONCLUSION

In this article, the Fuel cell based DVR as a custom power device are effectively used to mitigate the voltage sag and voltage swell which most common occurrence disturbances in the system. Here, Fuel cell based DVR as a custom power device is efficientsimulation results and prove that the PEMFC can be a useful another DC source for the DVR.

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