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RESEARCH ARTICLE OPEN ACCESS

"Power Quality Improvement of Microgrid by using DVR"

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ABSTRACT
Power quality is defined as the degree of voltage, current, frequency and waveform of power system under designed specification of the system. While transmitting the power from one end (generation) to another (load) utility has to face some power quality issues such as voltage sag, voltage swell, harmonics, inter-harmonics, voltage imbalance, voltage fluctuation, short duration voltage variation, long duration voltage variation, transient, power frequency variation, waveform distortion etc. These power quality issues directly effect on the efficiency of the power system and performance of the load equipments. Problems like voltage sag, voltage swell occurs due to sudden removal of large load from the system, energization of large capacitor bank or system fault like single-line-to-ground fault. These types of problems directly effect on equipment performance and accuracy, especially on sensitive equipments as computer, medical instruments, some electronic devices etc. To mitigate voltage sag, voltage swell problem in power system various devices are used such as DVR (dynamic voltage restorer), some FACTS (flexible alternating current transmission system) devices like STATCOM, UPQU, UPFC, SSSC, TCSC etc. DVR is one of the most efficient and accurate device to mitigate the problem of voltage sag and voltage swell and helps to stabilize the system voltage at designed magnitude. DVR can work in both direction such as during voltage sag, we can feed the voltage to system and during voltage swell we can eject the voltage from system through single device called DVR.

Keywords: Power Quality, Single-Phase AC System, DVR, MATLAB, AC load, Voltage Sag, Voltage Swell.

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I. INTRODUCTION

A power system having three main subsystems such as generation, transmission and distribution. Power quality is one on the most important concept, because electrical utilities as well as the end users are concerned about the quality of power. The term power quality is not new in the power system but instead of finding the individual solution for individual issue now to days engineers are trying to find one solution for many power quality related problems. The new generation is very much aware about the power quality, as the end user becomes more informative about issue such as voltage sag, voltage swell, power interruption, harmonics and switching transients. They are not just collecting the information but also challenging the power industry to improve the quality of power.

There are many methods to avoid effect of such voltage fluctuation on sensitive load like computer, medical devices or some electronic equipments. The devices which are built on the basis of power converter are most efficient and reasonable devices such as DVR (dynamic voltage restorer). DVR is connected in series with PCC (point of common coupling) between load and source. We propose DVR to work in abnormal condition such as voltage sag and voltage swell, during normal or healthy condition DVR is on standby mode of operation. When there is voltage variation in the system DVR controller detects the voltage magnitude and time duration according to the signal DVR supplies desired voltage to the system to stabilize the voltage magnitude constant. [1] DVR can supply and eject the desired voltage from the system according to the system condition through only one controlling mechanism.

1.1 Power Quality

Power quality is the voltages quality in most of the ceases of power quality issue. In engineering words power is defined as the amount of energy delivered which is directly proportional to the

product of voltage and current. Our power supply system can only control the voltage magnitude we have no control for current magnitude it varies as the load changes at particular areas. So, the standards of power quality are maintained by controlling voltage magnitude constant. AC power system are designed to operate at sinusoidal voltage supply at specific frequency (typically 50 Hz or 60 Hz). Any specific variation in the sinusoidal waveform magnitude, frequency or the purity of waveform can directly become a cause of power quality problem. In practical system there is always a connection between current and voltage, while generating the power generation try to supply voltage in pure sinusoidal form, but due to impedance of the system can cause variation in disturbances such as-

1. During short circuit fault short circuit current may lead to voltage sag or voltage may completely disappear.
2. During rainy season lightning stroke may affect to the power system, due to lightning stroke high impulse voltages occurs in the system that frequently damage the insulation of system which leads to short circuit current.
3. Harmonic current (distorted current) due to harmonic producing loads also have distorted voltages which passes through system impedance and also present to the other end users.

1.2 Power Quality Issues

Impulsive Transients – Impulsive transients are defined as a unidirectional (either positive or negative) and sudden change in steady state magnitude of voltage, current or in both with non-power frequency

Oscillatory Transients – Oscillatory transients are defined as sudden change in steady state magnitude of voltage, current or both but in both directions i.e., positive and negative with non-power frequency.

Undervoltage – Undervoltage is defined as decrease in root mean square (rms) value of system voltage to less than 90% for the duration of more than 1min at power frequency.

Overvoltage - Overvoltage is defined as increase in root mean square (rms) value of system voltage to more than 110% for the duration of more than 1min at power frequency.

Interruption – Interruption in the system known as decrease in system voltage or load current less than 0.1pu over the period of less than 1min. As the voltage magnitude during volage interruption is always less than 10% of the normal system voltage so the interruption is measured depending upon their time duration.

Voltage sag (dips) – Voltage sag is defined as decrease in rms (root mean square) value of system voltage or system current between range of 0.1 to 0.9pu for the time duration of 0.5cycle to 1min at power frequency. According to IEEE standards sag is defined as "A decrease in RMS voltage or current at power frequency for 10 milliseconds to 1min, reported as remaining voltage."

Voltage swell – Voltage swell is defined as increase in magnitude of rms (root mean square) value of system voltage or current in range of 1.1pu to 1.8pu for the time duration of 10 milliseconds to 1min at power frequency.

II. METHADOLOGY

2.1 DVR (Dynamic Voltage Restorer)

To solve voltage related problem like voltage sag, voltage swell, harmonics in the power system DVR is used. DVR is connected in the series to the system to inject the compensated voltage during sag or swell condition for load side voltage regulation. The main function of DVR ids to supply voltage to the system during power quality problems like voltage sag and voltage swell. Generally, DVR is connected at end user's side between supply and the load (equipment's). DVR have various structures and many controlling technologies; basic structure of DVR is shown in Figure 1.

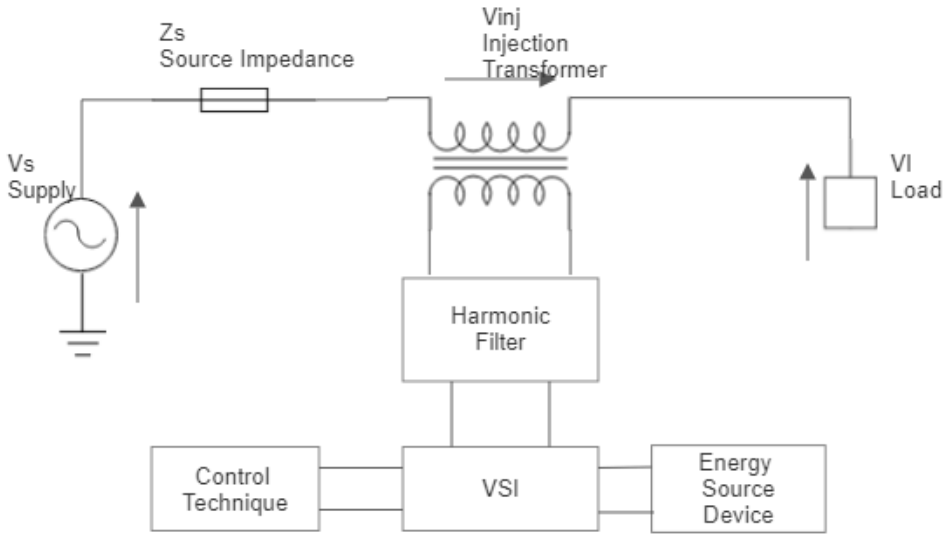

Figure.1: Structure of DVR.

DVR structure have series transformer through which voltage is injected to the AC system. Harmonic filter which helps to provide pure sinusoidal voltage waveform and eliminate the higher frequency component in the inverter output. Traditional VSI and CSI have some problems like they will work either in increasing or decreasing mode but not in both. So, to overcome such problems Boost DC-DC converters are used in this research. In ZSI circuit two inductors and two capacitors are connected in X (cross) shape. And another component in DVR structure is DC link capacitors which supplies active power to DVR during sag and swell condition, energy storage capacitors are probably used for DC link.[2]

2.2 Function of DVR

DVR performance principle shown that it injects required voltage during balanced and unbalanced voltage condition. Equivalent circuit diagram of DVR is shown in Fig.2. DVR get active power from DC source and provides reactive power as a result for voltage regulation. At abnormal system condition like voltage/ voltage swell DVR inject voltage to the system ad Vdvr shown in Figure 2. so that load voltage remains constant. Load voltage is expressed as,

$$V_L = V_S + V_{dvr} \quad (1)$$

Where V_L, V_S, V_{dvr}, are load voltage, supply voltage and DVR voltage (injected voltage) respectively.

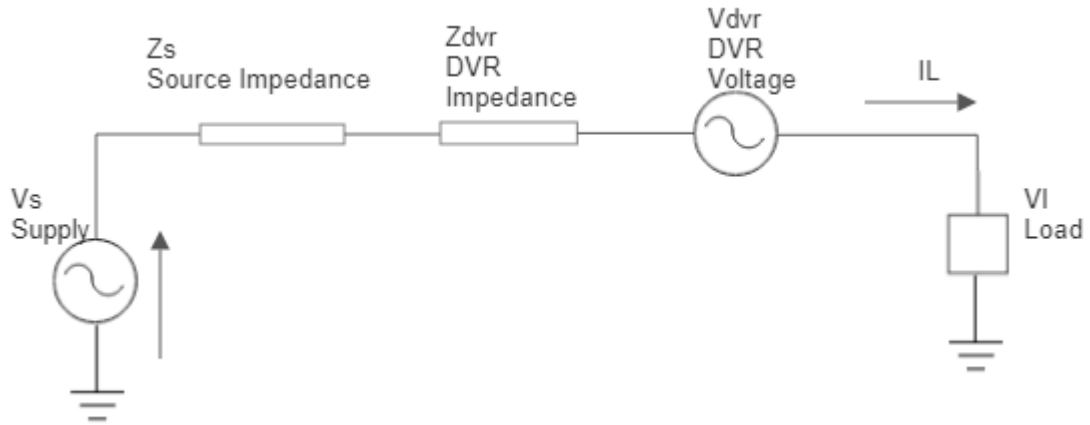

Figure 2: Equivalent Circuit of DVR.

DVR is working in main three operating modes as protection mode, standby mode, injection mode. In protection mode DVR protects itself form higher magnitude current which occurs due to faulty condition or maloperation of equipments in the system. Excess current may damage DVR circuit so it is protected by using thyristors and breakers. In standby mode DVR is not feeding any voltage to the system but keeps monitoring and analyzing the system voltage. As there is voltage variation in the system DVR suddenly operates in injection mode to feed the desired voltage to the system and keeps the system voltage at constant, designed magnitude. [3]-[7]

III. MATLAB SIMULATION

Figure 3 shows MATLAB simulation for DVR connected to single-phase AC system. Under abnormal or faulty condition in the system DVR is used to feed or eject desired voltage from the system to stabilize the load voltage at constant magnitude. Hysteresis bridge method is used as controlling mechanism for DVR and PLL (phase locked loop) is used to provide pure sinusoidal voltage with same phase as of the AC system as shown in Figure 4.
Additional DC source of magnitude 400V is connected to DVR through which DVR can provide reactive power to the AC system and makes system voltage at constant magnitude. Parameters used for MATLAB simulation are listed in Table 1. During normal condition DVR is operating on standby mode and at abnormal condition DVR injects voltage to system by comparing the reference voltage and system voltage.

Table 1: Parameters Considered for Simulation.

Sr. No	**Parameters**		**Values**
1	Single Phase Source	V_{ac}	311
2	Frequency	f	50
3	DC Source	V_{dc}	400
4	Single Phase Load (RL)	V_{rms} P Q_L Q_c	220 100000W 5000VAR 0VAR
5	Series Capacitance	C	0.0047F
6	Series Inductance	L	0.0001H
7	Voltage Sag	Switching Time	[0.15 0.27]
8	Voltage Swell	Switching Time	[0.37 0.43]

A dc voltage (400V) is provided to DVR which gives active power to DVR which is calculated according to system voltage as,

$$V_{dc} = (2/\sqrt{3}) * V_{ac} \quad (2)$$

$$L_{dvr} = V_{dc}/ (12*a*f_c*I_{ripple}) \quad (3)$$

The DVR refers the pulse signal provided by controlling mechanism and according to the signal desired voltage is injected in the system through injection transformer. DVR receives the active power from DC signal and provides it to the system for keeping the voltage at constant magnitude.

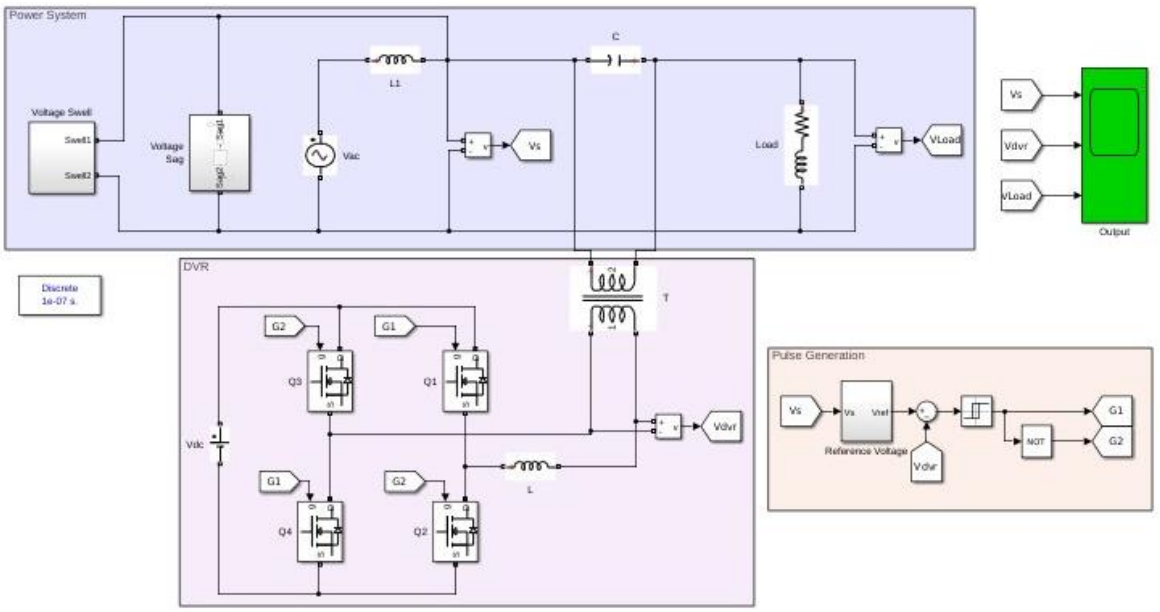

Figure 3. MATLAB Simulation for DVR connected to single-phase AC system.

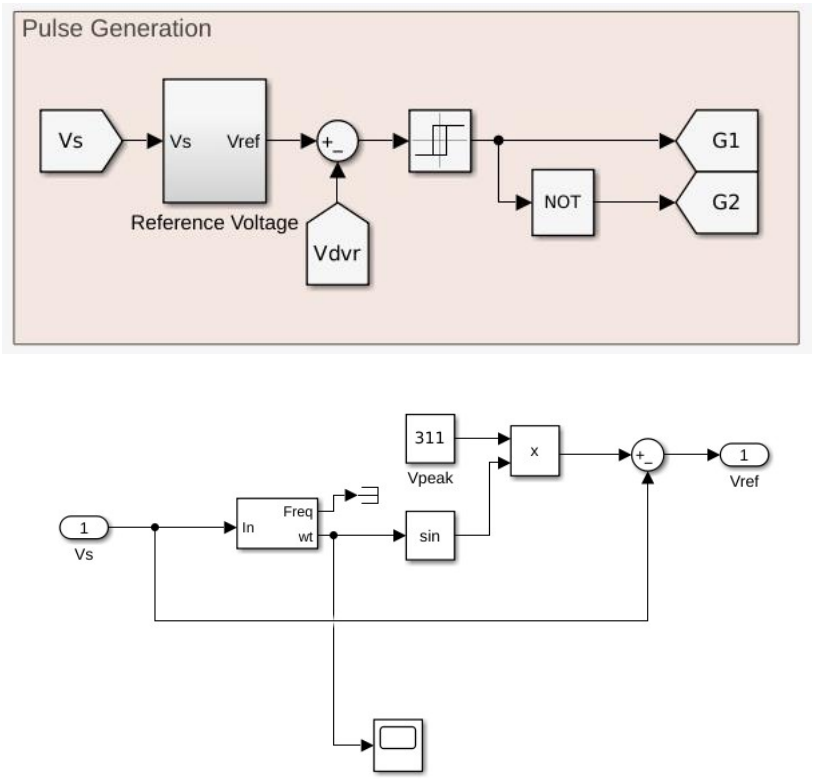

Figure 4. Controlling of DVR.

IV. RESULT AND DISCUSSION

As there is voltage variation in the source voltage DVR injects desired voltage to the system to stabilize the load voltage. The voltage waveform of source voltage, DVR voltage and load voltage are shown in Figure 5.

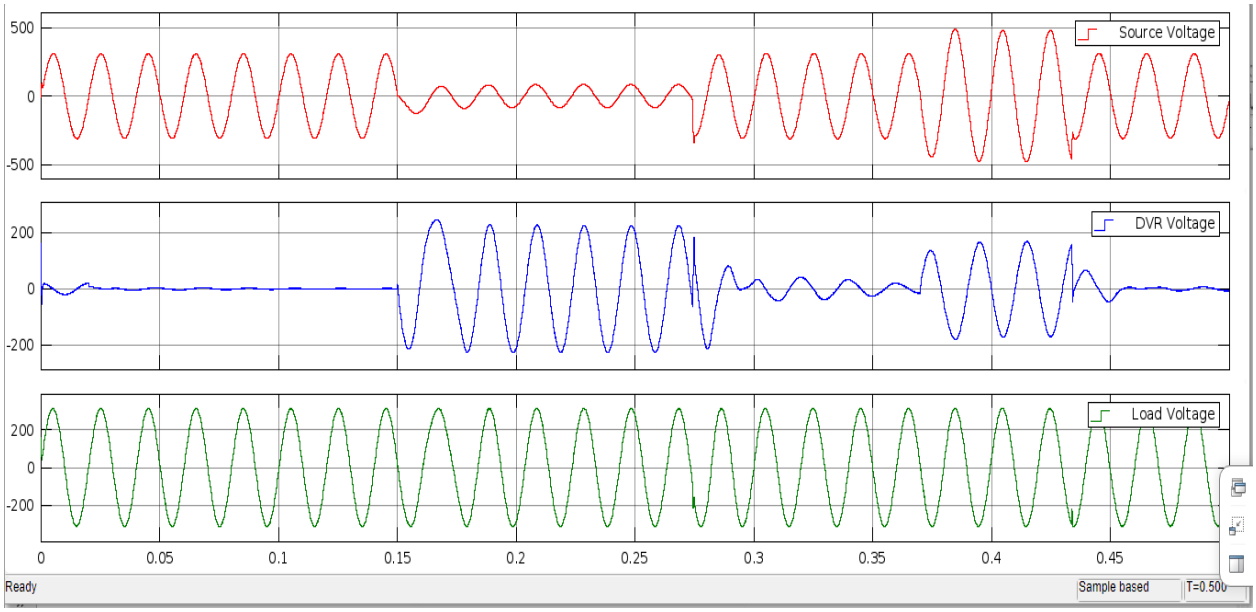

Figure 5. System voltage before and after using DVR

Table 2. THD analysis.

Parameter	**Before DVR**	**After DVR**
Voltage THD	28.66	5.88

As shown in Table 2 THD % of the system before using DVR is 28.66% while after using DVR it is reduced to 5.88%. So, the power quality of system improves with minimum %THD and constant voltage magnitude.

V. CONCLUSION

In this paper a single-phase AC system us used to address the problem related to power quality or voltage quality. A brief review regarding power quality problem is provided. The most significant part of improving power quality is voltage regulation. A single-phase AC system is upgraded with DVR unit. DVR ensures that the system voltage must be constant at desired value. When faults occur in the system or there is sudden removal of large load causes the voltage variation in the system that is voltage sag or swell happens in the system for certain time duration. Voltage variation directly effect on the sensitive load and their performance. DVR stabilizes the system voltage at designed magnitude, so that helps to improve power quality. In the MATLAB/ SIMULINK the DVR is connected to single-phase AC system, System was constructed with the purpose of enhancing voltage variation for certain time duration. The system operates extraordinary well when using DVR according to simulation results. System complies with power quality issues against voltage and harmonic distortion.

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