VOLTAGE SAG AND SWELL MITIGATION USING DYNAMIC VOLTAGE RESTORER

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ABSTRACT

There is increase in use of power electronic based devices in distribution system in order to minimize power quality problems. As the load increases, its nature changed. More and more electric power meant better standards of living which in turn cause to increase expectations on the quality of power supply. From last few years, power quality has become fascinating topic for many researchers as system variation causes the system to get hampered by short circuit fault. This produces many power quality problem like voltage sag, voltage swell, interruption etc. Since voltage sag and swell creating worst effect on system, researchers are more eager to find solution for this problem. The Dynamic Voltage Restorer is commercially available and popular device to reduce voltage sag and swell in distribution system. Here abc to dq0 control algorithm of DVR with PWM and SPWM inverter technique is discussed with MATLAB and simulink.

Keywords: DVR, PWM Inverter, SPWM Inverter, Voltage sag.

I INTRODUCTION

As far as quality is concerned, power should have high degree of excellence. Generally most of the businesses like continuous production factories, hospitals etc. are dependent on electricity and purity of supply. Generally in industries scarcely any one gives most consequential priority for maintaining quality of power until something goes wrong. [1] But there are in general improvement of power quality benefits i.e. reduction in I^2R losses thereby reducing electricity bills, reduction in harmonic distortion and improving profile of voltage, prevention and mis-operation of power equipment and improving life and consistency of equipment.[2] In order to improve quality of power, there is no. of mitigation devices. Out of which Dynamic Voltage Restorer (DVR) is effective power quality device which protects theses industries from disturbances like voltage sag, swell, interruption etc. Generally possibility of occurrence of voltage sag is more as compared voltage swell. This paper mainly fixates on concept of Dynamic Voltage Restorer (DVR) with its operating principle, working. Here two inverter schemes i.e. simple PWM and SPWM inverter is discussed for voltage injection in case of Dynamic voltage Restorer whose simulation is done in MATLAB software.

II THEROTICAL AND MATHEMATICAL CONCEPT OF DYNAMIC VOLTAGE RESTORER

2.1Operating Principle

The fundamental conception of DVR is to inject controlled and required amount of voltage. This voltage is generated by forced commutated converter. DVR is linked in series between distribution system and load. After occurrence of the fault, the voltage engendered by converter is given to the line by using injection transformer which in turn regains near about value of voltage equal to normal voltage value. [5] Generally PWM or SPWM technique is utilized to operate inverter which in turn determines PWM generation.

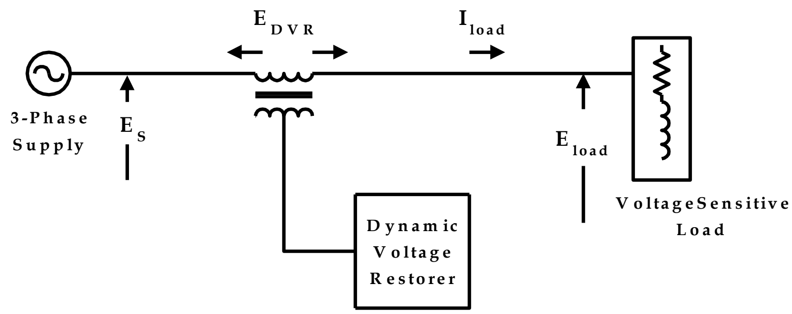

Fig 1.Basic connection diagram of DVR to the distribution line.

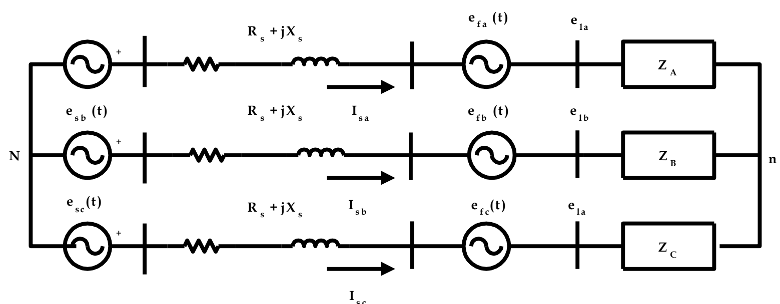

Fig.2. Single line diagram of DVR compensated system

Single line diagram of DVR compensated voltage is as shown in Fig. 2. In the Schematic diagram of DVR based compensation in distribution system is as shown in Fig. 3. Let us assume that source voltage is 1.0 pu and we have to regulate load side voltage value=1.0 pu. Ψ is the phase angle between $\overline{E_S}$ and $\overline{E_l}$. Here are certain assumptions that losses are negligible, harmonics are not considered and phase angle difference component between $\overline{E_l}$ and $\overline{I_s}$ =90^0. Apply Kirchhoff's voltage law to the Fig. 3 and assuming that $\overline{I_s} = \overline{I_l} = \overline{I}$, $R_S + jX_S = Z_s$ and $R_l + jX_l = Z_l$ we get relationship between load voltage and the source and DVR voltages can be expressed as below.

$$\bar{E}_l = \left(\frac{\bar{E}_s + \bar{E}_i}{Z_S + Z_l}\right).Z_l \qquad (1)$$

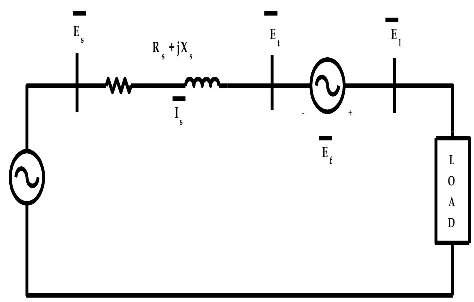

Fig.3. Schematic diagram of DVR based compensation in distribution system

2.2 Basic Configuration

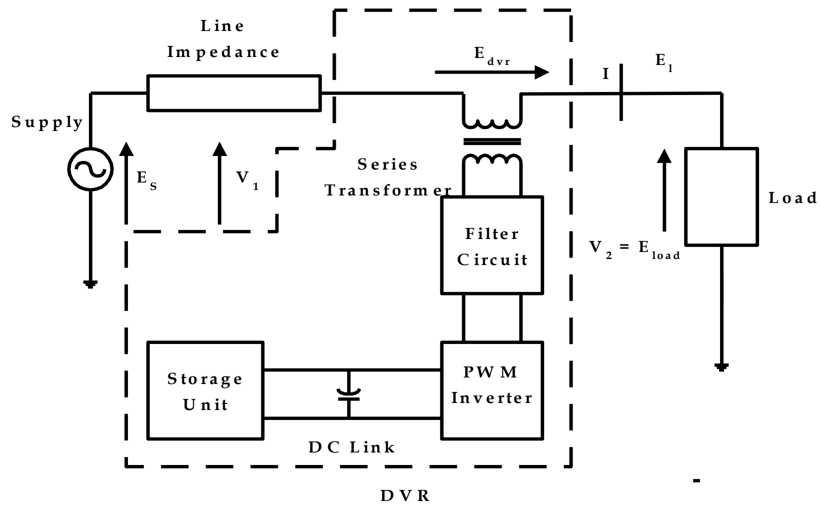

Fig.4. Basic configuration of DVR

The largest capacitor bank is used for energy storage in case of commercially available DVR. Whenever there is no fault on distribution line, i.e. at normal operating condition, capacitor gets charged through grid voltage while in case of disturbance it gets discharged to supply energy and for compensating load voltage. The difference between normal voltage and actual voltage after immediate occurrence of fault is missing voltage. This missing voltage is generated by appropriate control system which is given to inverter. [6] Generally power electronics devices used in inverter configuration i.e. IGBT, GTO, MOSFET creates distortion in waveform affiliated with high frequency harmonics at inverter output. Hence these harmonic contents which are present in the voltage generated by VSC are eliminated by harmonic filter. The missing voltage is injected through transformer which is connected between filter and transmission line. This transformer is also called as booster transformer or injection transformers that genuinely boosts the voltage after fault occurrence and try to maintain it at level equal to normal voltage. The second purpose of this transformer is to isolate load from system. In order to regulate operation of DVR, control system is mandatory. Generally DSP, microcontroller or PI controller is used for controlling operation of DVR. Here PI controller is used in simulation.

2.3 Control Technique

The fundamental part of controller in DVR is to ascertain whether there is voltage sag or swell is occurred in the system or not. If this event occurs in the system, then how much amount of voltage required for compensation is calculated by control system. [6] On the basis of compensating voltage calculation, required triggering pulses are generated by PWM inverter and once the occurrence has passed, triggering pulses gets stop. The control system employs abc to dq0 transformation and again back to abc transformation. The value of voltage is constant during normal operating condition and d-voltage is unity in per unit and q-voltage zero in Pu but the value of d-voltage and q-voltage gets changed during the abnormal condition. [7] During faulty condition, the line voltage V_a, V_b, V_c in pu is converted to dq0 frame of reference by abc to dq0 converter. This value is compared with reference dq0 frame of reference which is obtained from reference voltage V_a, V_b, V_c, when the line voltage value gets differ from reference voltage, it will generate error signal which is used for controlling purpose and to trigger PWM or SPWM inverter. [8] The error signal generated between dqo voltage of the supply or line voltage and the reference voltage is responsible for detection of sag/swell. In order to convert stationary frame to rotating frame which can detect the phase angle and magnitude of supply voltages the park's transformation (abc to dqo) has been utilized. It is often use to simplify calculation for control of three phase inverters. The difference between reference and supply voltages is applied to PWM or SPWM controlled VSC for injecting required amount of voltages in series with line by converting again this dqo to abc frame. [8]

$$\overline{V}_d = \frac{2}{3}\left[V_a \cos wt + V_b \cos\left(wt - \frac{2\pi}{3}\right) + V_c \cos\left(wt + \frac{2\pi}{3}\right)\right] \quad (2)$$

$$\overline{V}_q = \frac{2}{3}\left[V_a \sin wt + V_b \sin\left(wt - \frac{2\pi}{3}\right) + V_c \cos\left(wt - \frac{2\pi}{3}\right)\right] \quad (3)$$

$$\overline{V}_0 = \frac{1}{3}[V_a + V_b + V_c] \quad (4)$$

$$\begin{bmatrix} V_d \\ V_q \\ V_0 \end{bmatrix} = \begin{bmatrix} \cos(\theta) & \cos(\theta - \frac{2\pi}{3}) & 1 \\ -\sin(\theta) & -\sin(\theta - \frac{2\pi}{3}) & 1 \\ 1/2 & 1/2 & 1/2 \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} \quad (5)$$

III SIMULATION DIAGRAM AND RESULT

3.1 MATLAB Simulation of distribution line with Dynamic Voltage Restorer based on PWM inverter

As shown in the below Fig.5 the model of DVR has been designed in Math works Matlab. A DVR is connected to the distribution line through a series booster or injection transformer with a transformation ratio equal to 1:1. In this model, we have used three phase programmable voltage source through which we have changed conditions to generate respective voltage sag and swells. The DVR is based on three phase voltage PWM inverter with LC output filter to remove high frequency voltage components. In this circuit the DVR is connected in between supply (PCC) and load. The DVR is connected to the system through injecting transformer. Following Fig. 5 shows that simulation diagram of Dynamic voltage restorer with PWM inverter along with its results. The same DVR can be used for compensation of voltage in any one out of three phases. The operation of DVR with SPWM inverter is same. Only there is change in the THD value of voltage and/or current.

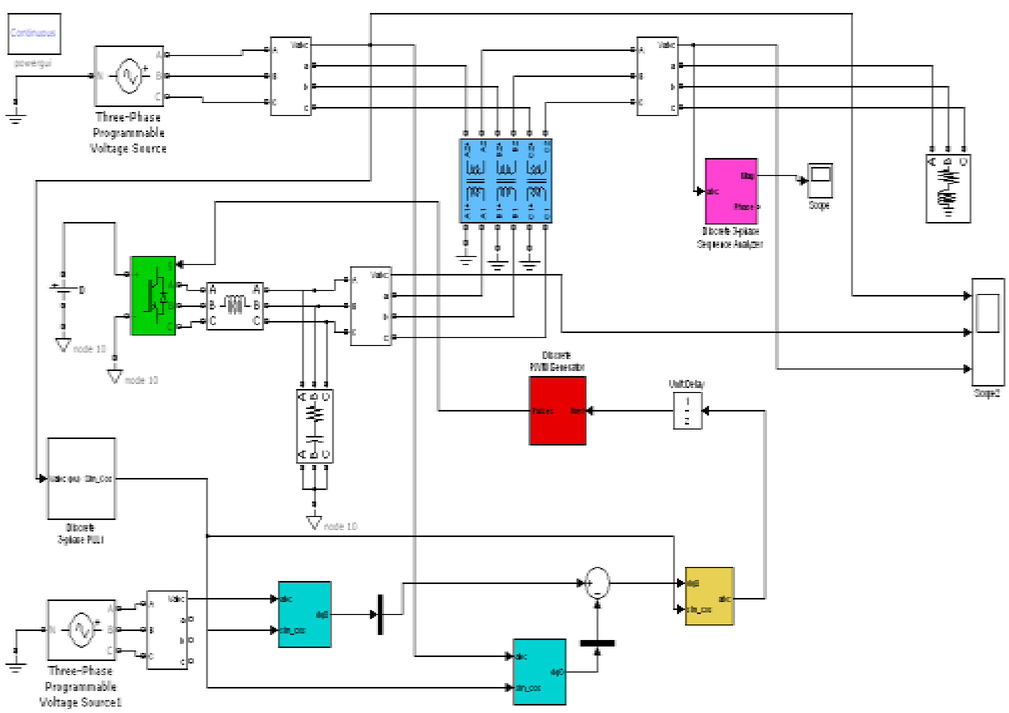

Fig.5. MATLAB Simulation of distribution line with Dynamic Voltage Restorer based on PWM inverter

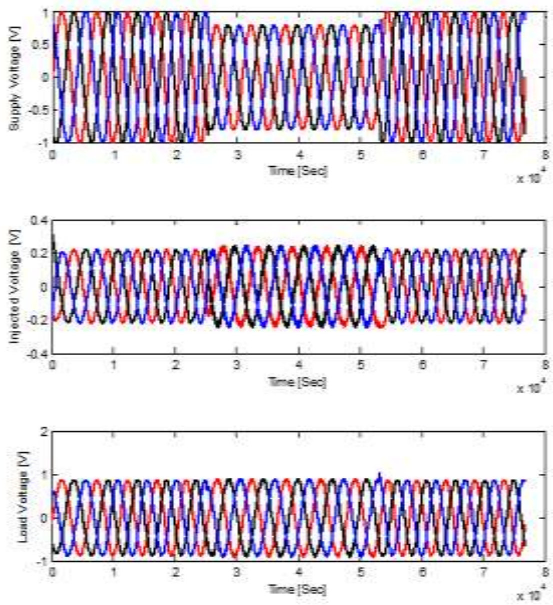

Fig .6. Simulation result of DVR response to balanced voltage sags (a) supply voltage; (b) DVR injected voltage, (c) load voltage for voltage sag up to 0.8 pu

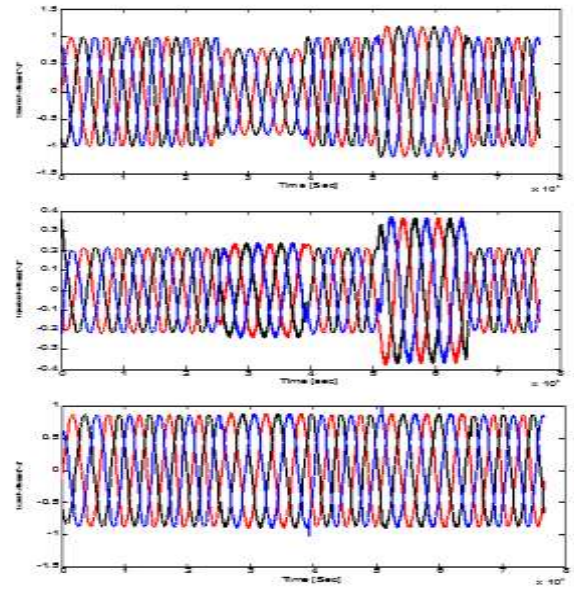

Fig .7. Simulation result of DVR response to multiple issues (a) supply voltage; (b) DVR injected voltage, (c) load voltage for voltage sag up to 0.8 pu and swell up to 1.2 pu

3.2 MATLAB Simulation of distribution line with Dynamic Voltage Restorer based on SPWM inverter

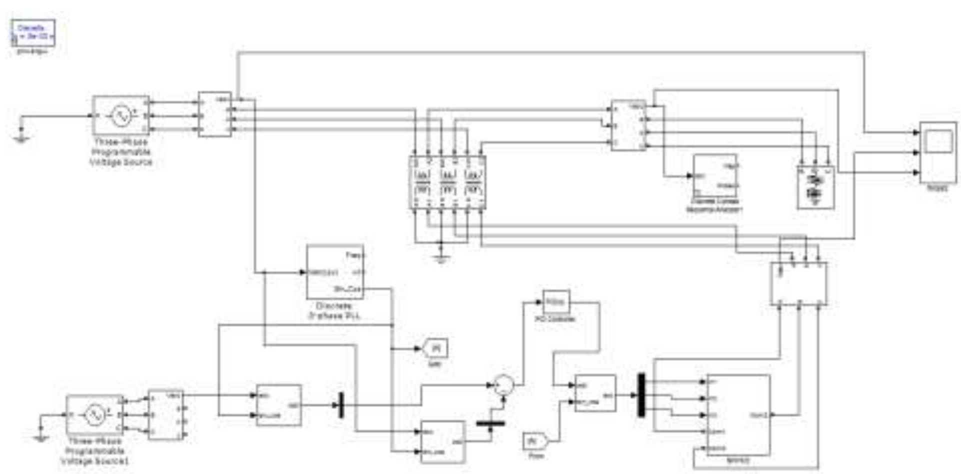

Fig.8. MATLAB Simulation of distribution line with Dynamic Voltage Restorer based on SPWM inverter

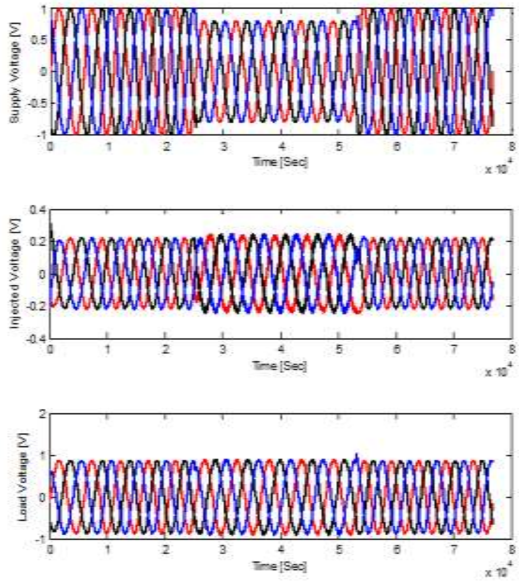

Fig .9. Simulation result of DVR response to balanced voltage sags (a) supply voltage; (b) DVR injected voltage, (c) load voltage for voltage sag up to 0.8 pu

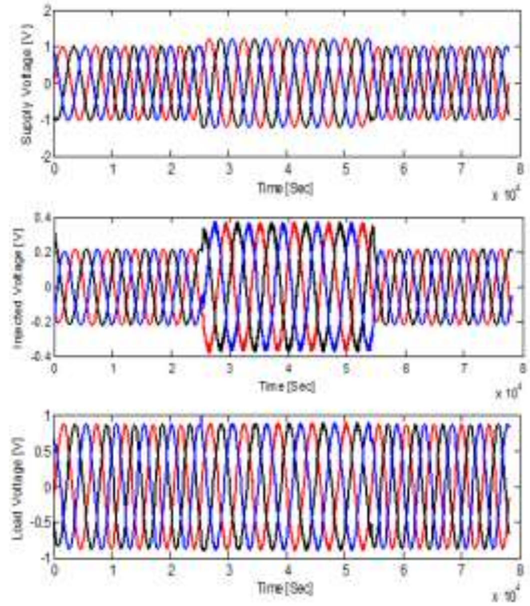

Fig .10. Simulation result of DVR response to balanced voltage swell (a) supply voltage; (b) DVR injected voltage, (c) load voltage for voltage swell up to 1.2 pu

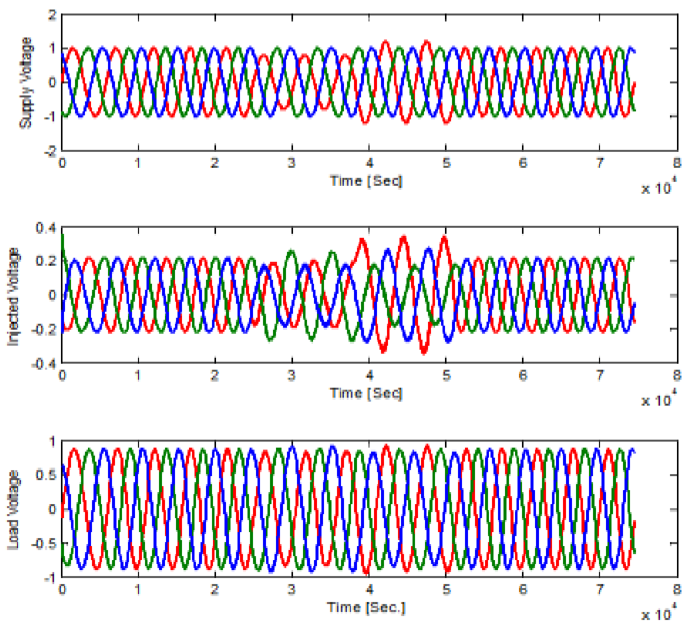

Fig. 11. Simulation result of DVR based on PWM inverter response to any one phase (a) supply voltage; (b) DVR injected voltage, (c) load voltage

3.3 THD analysis of DVR based on PWM and SPWM inverter

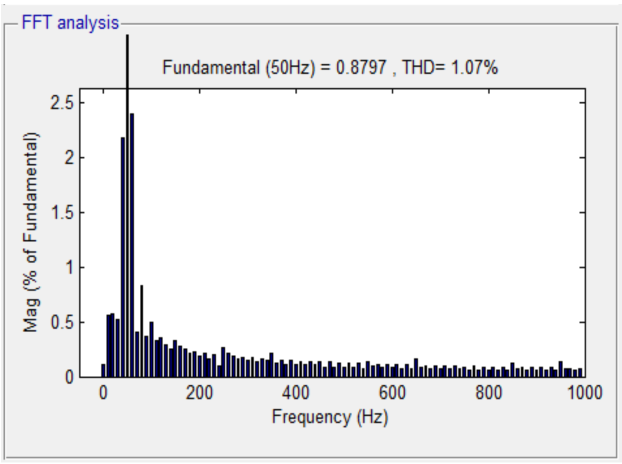

Fig.12.Voltage FFT of system connected with DVR with PWM inverter.

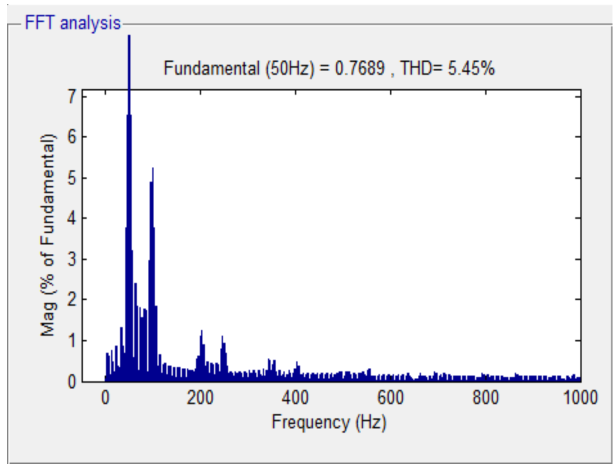

Fig.13.Voltage FFT of system connected with DVR with SPWM inverter.

IV CONCLUSION

This paper presents analysis and simulation of DVR with PWM and SPWM inverter by using MATLAB/SIMULINK. A control system based on dqo technique has been presented that can be employed which is a scaled error of the between supply side of the DVR and its reference that can be utilized for sags/swell correction. The advantage of Park's transformation is that it simplifies calculation for controlling inverter. The MATLAB simulation shows that the performance of DVR is satisfactory in mitigating voltage sags and thereby reducing PQ problem. The THD analysis of DVR load voltage is shown which is 1.07% for PWM inverter and 5.45% with SPWM inverter. This paper compares the two different inverters and it is to be suggested that PWM inverter is best suited as per THD analysis.

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