DYNAMIC VOLTAGE RESTORER

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ABSTRACT

This paper gives a systematic procedure of the design and simulation of Dynamic Voltage Restorer (DVR) using PID controller and Pulse Width Modulation (PWM). Though power quality related problems like voltage sags/swells occur both on the transmission side as well as the distribution side, the terminology used for the compensation devices is different. DVR is a series connected device used for compensating voltage sags and swells on the distribution side. In this work, a step by step procedure is given to figure out the components that are required for the design and simulation of DVR. The detection of sags/swells is carried out with the help of dqo theory, whereas the control of the voltage source inverter is done with the help of PWM. The VSI has been implemented with the help of PWM. The simulation was carried out with the help of SIMULINK & MATLAB and the results were found to be in accordance with theory.

Keyword : - *Voltage Sag/Swell, DVR, PID Voltage controller, small signal equivalent circuit, PWM inverter.*

1. Introduction

The term Power Quality is something that tells about the quality of power. While "power quality" is a convenient term for many, it is the quality of the voltage rather than power or current that is actually described by the terms. Ideally any electric utility is supposed to supply a pure sinusoidal voltage of required magnitude and frequency for all the time without any deviation. But in reality it is not possible to meet the ideal requirements. Thus, practically there are deviations in the voltages which can have adverse

effects on the load. All the power quality problems, 92% of the interruptions in industrial installations are due to voltage sags. According to IEEE Std. 1159-1995, sag is defined as a decrease in rms voltage or current between 0.1pu and 0.9 pu at the power frequency for durations from 0.5 cycles to 1 min. Sags and swells are characterized by their magnitude as well as time duration. These voltage problems can be solved using a series connected custom power device called dynamic voltage restorer (DVR). In this paper, the implementation of DVR and its simulation are discussed in detail. The emphasis has been given for switching control strategy i.e. pulse width modulation scheme and their detailed results are presented.

1.1 Principle of DVR:

The principle of DVR is simple i.e. whenever the source voltage is unbalanced or distorted the DVR restores the loadside voltage to the desired amplitude by injecting a voltage of required magnitude. In other words we can say that the main function of the DVR is to regulate the load voltage waveform constantly and if any sag or swell occurs, the required voltage will be injected to the load point. During the period of voltage sag or swell, DVR injects the voltage so as to restore the load voltage to its normal value. During this operation, the DVR exchanges the active and reactive power with the load.

1.2 Block Diagram:

Now the important thing is to figure out the components that are required for the implementation of DVR. The following steps are used to implement the DVR in injection mode.

Step 1: To find out whether there is any sag/swell in the source voltage. It is done by comparing the terminal source voltages with reference load voltages. The difference between the source voltages and reference load voltages is the required amount of voltage that has to be injected by the DVR.

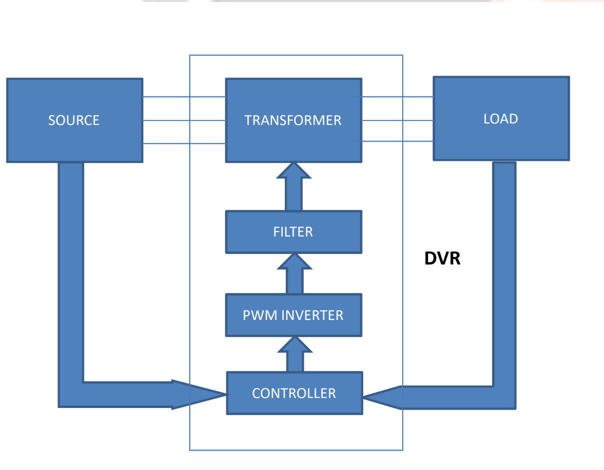

Fig 1: Block diagram of DVR

Step 2: To generate switching commands to the VSI in order to track the reference voltages (generated in step 1) using a suitable switching scheme such as PWM.

Step 3: To filter out the harmonics that are present in the output of the voltage source inverter. Step 4: To inject the filtered output through the three single phase series isolation transformers present between the source and the load.

The first component of the DVR is the detection and control block. All it needs to do is to monitor the terminal source voltage and the reference load voltages in the dq reference frame. Whenever, there is any sag/swell in the source voltage there will be deviation in the dq components of the source voltage from those of the reference load voltages.

2. Mathematical Model:

To overcome poor power quality, two objective functions must be minimized, sag and swell, and below circuit is implemented. Figure shows a power system that is assisted by DVR. The system consists of power supply, supplying sensitive RL load, masked control circuit, battery powered inverter connected to the injecting transformer for voltage compensation during fault. The other parts of the circuit are connected in such a way that voltage sags and swells are created to the system for experiment purpose. The purpose of the control circuit is to sense a type of fault from the power system circuit and be able to send a signal to the inverter. The control system uses Phase Locked Loop (PLL) system to sense fault and to synchronize the load voltage level. It can also be noticed that the injected voltage by transformer passes through the series capacitor where the voltage is filtered before being passed to the load . During normal operation of the system, the voltage across the sensitive RL load is expressed as below:

$$VRL = Vsp \times \sin(2 \pi f t) \qquad \ldots(1)$$

where,

V_L = sensitive RL load voltage in volts (V),

V_{SP} = the supply voltage from the AC source in volts (V),

f = the ac voltage supply frequency in hertz (Hz)

t = time in seconds (s)

Following is the expression during abnormal operation of the system caused by voltage sags due to heavy load switching.

$$V_{LSAG} = \{V_{RL} - V_F \times [H_{(t-t1)} - H_{(t-t2)}]\} \times \sin(2\pi f t)$$

where,

V_{LSAG} = sensitive RL load voltage during voltage sag disturbance in volts (V),

V_F= the reduction or increment voltage level in volts (V) due to disturbance

H = Heaviside step response,

t1 = time when the sag disturbance starts in seconds (s),

t2 = time when the sag disturbance ends in seconds

In the case of voltage swells disturbance, VF is added for a period of (t1 – t2), as expressed in the following equation,

$$V_{LSWELL} = \{V_{RL} + V_F \times [H_{(t-t3)} - H_{(t-t4)}]\} \times \sin(2\pi f t)$$

where,

V_{LSWELL} = sensitive RL load voltage during voltage swell disturbance in volts (V),

Following are equations for DVR’s action during the voltage compensation for

voltage sags $0 = VF - VC \qquad \ldots(4)$

$$VF = -VC \qquad \ldots(5)$$

$$VCOMP = \{-VC \times [H(t-t1) - H(t-t2)]\}$$

$$\sin(2\pi f t) \qquad \ldots(6)$$

where,

V_C = the added voltage for compensation or counterbalancing of operational voltage level during DVR action.

V_{COMP} = DVR voltage compensation for voltage sags Therefore VC is variable during DVR action in order to certify the objective requirements. The load voltage after compensation becomes as follows,

$$VL = VLSAG - VCOMP \qquad \ldots(7)$$

For voltage swell correction on the system, the similar action as of voltage sag compensation is performed by DVR for operational voltage level correction during voltage swell disturbance. In this case the action happens in opposite polarity from the voltage sag compensation.

$$0 = -VF + VC \qquad \ldots(8)$$

$$VF = -VC \qquad \ldots(9)$$

$$VCORR = \{VC \times [H(t-t3) - H(t-t4)]\}\sin(2\pi f t) \qquad (10)$$

where,

V_{CORR} = DVR operational voltage level correction for voltage swells.

Therefore the load voltage after correction becomes as follows.

$$VL = VLSWELL - VCORR \qquad \ldots(11)$$

For voltage sag and swell optimization based on DE, the equations becomes as follows,

$$VSAGmin = VL - VLSAG \qquad \ldots..(12)$$

$$J1 = VSAGmin + VCOMP \qquad \ldots.(13)$$

$$VSWELLmin = VL - VLSAG \qquad \ldots(14)$$

$$J2 = VSWELLmin + VCORR \qquad \ldots(15)$$

2.1 Simulation Scheme

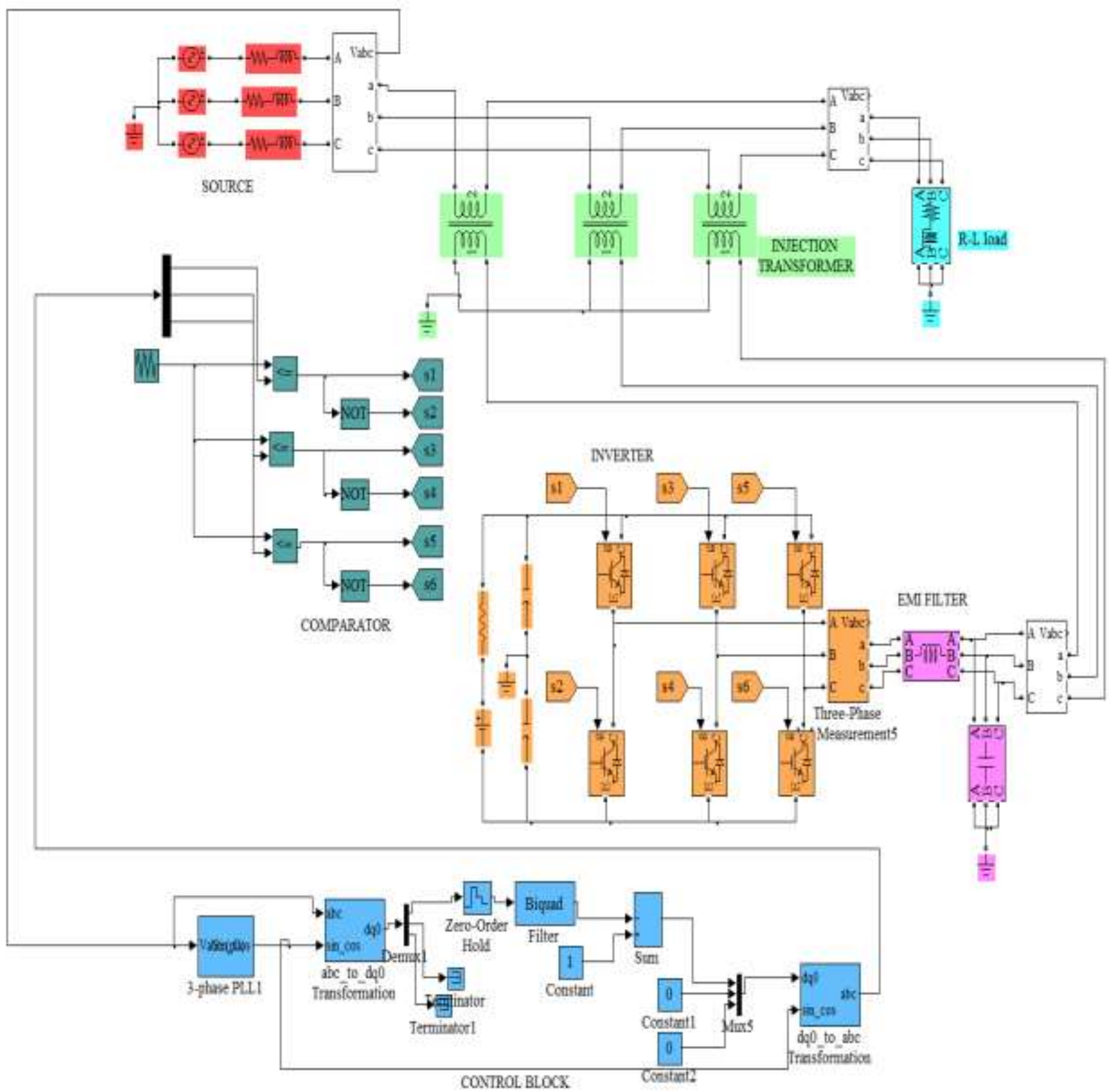

Fig.2

2.2 Result of Simulation

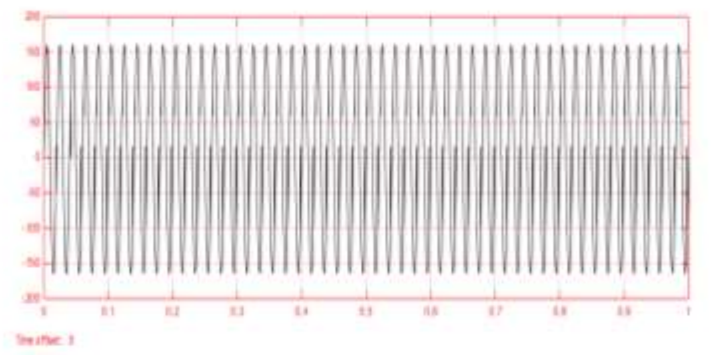

Fig 3.Source Voltage

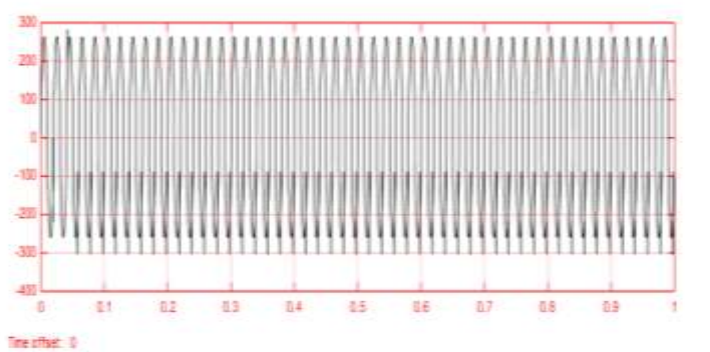

Fig 4. Load Voltage

4. CONCLUSIONS

Power quality issues can be treated with use of DVR the focus has been on voltage sags, interruptions and the power electronic controllers for voltage sag mitigation. The DVR is recognized as a cost effective solution for voltage sag mitigation as well as other voltage disturbances. This paper has presented mathematical analysis and simulation of single phase DVR. The results obtained are satisfactory.

5. REFERENCES

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