Scientific Journal of Impact Factor (SJIF): 4.72
e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 4, Issue 4, April -2017

Implementation of Single phase Dynamic voltage restorer with Flux vector modulation switching of Single phase inverter

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Abstract — *Dynamic Voltage Restorer is a custom power device used for the mitigation of voltage sags-swells, to improve power quality which is the major concern in power systems. DVR has good compensating capabilities when compared to commonly used compensator. Thus static series compensator (SSC), commercially known as Dynamic Voltage Restorer (DVR) is capable of compensating voltage sag-swell by injecting appropriate voltage at the supply side with the help of the series injection transformer or booster transformer. This transformer helps to maintain constant load voltage. DVR consists of injection transformer, voltage source inverter (VSI), passive filters and energy storage device. Efficiency of the DVR depends on the efficiency of control technique for the same and proper switching technique for the voltage source inverter. This thesis proposes the Simulatory implementation of single-phase Dynamic Voltage Restorer. The flux vector modulation technique will be used for inverter switching.*

Keywords- *Power Quality, Custom Power Devices, Dynamic voltage Restorer, mitigation of sag and swell, Flux vector modulation.*

I. INTRODUCTION

Power quality is a phenomenon that occurs as many type of disturbances in voltage, current and frequency of sensitive electrical loads that results in failure of end user equipment. Poor power quality output may cause shutdown of industries making significant financial loss to the industry. The reason for the degraded quality of power is not only due to utility itself but mostly due to non linear loads that cause transients. As a consequence of which many industries may suffer burning of core materials, unnecessary downtime, increased maintenance and much more. The solution to these problems can be either from utility side or from customer side. The most efficient example to those solutions are FACTS devices or Custom power Devices that are based on solid state power electronic components. To compensate the sag/swell in a system, appropriate devices needed to be interfaced at suitable locations. These system instrumentation interface devices area unit ordinarily referred to as custom power devices out of that DVR may be a powerful one for brief length voltage compensation. [1] The main objective of this thesis is to analyze the working of Dynamic voltage Restorer (DVR) for compensation of voltage sag and swells and improve power quality which is to be used by utilities and end users. Dynamic voltage preserver can offer the value effective answer to mitigate voltage sag by establishing the acceptable voltage quality level, needed by the client.

A. Power Quality Problems:

Power quality may be a vital issue because it impacts electricity suppliers, instrumentality makers and customers. Power quality distortion is delineated as “the variation or fluctuation in voltage, current and frequency of the facility system. It refers to a good kind of magnetism phenomena that characterize the voltage and current at a given time and at a given location within the power system”. Power quality improvement idea is an associate degree umbrella concept for the multitude installation disturbances.[6]

The IEEE standards classify power quality disturbances into seven different types based on waveshape:
1. Transients **2.** Interruptions **3.** Undervoltage or voltage Sag **4.** Overvoltage or Voltage Swell **5.** Waveform Distortion **6.** Voltage Fluctuations **7.** Frequency Variations
Among all these PQ problems, Voltage sag and swell are considered as significant and as a major concern for the customers.

Voltage Sag :
As per IEEE standard sag can be defined as, “a momentary decrease in the root mean square (RMS) voltage between 0.1 to 0.9 per unit, with a duration ranging from half cycle up to 1 min.” It is caused by faults in the power system or by the starting of large induction motor [3][6].

Voltage Swell :
As per IEEE standard swell can be defined as “an increase in the root mean square (RMS) voltage from 1.1 to 1.8 per unit for duration from 0.5 cycles to 1 min.” Voltage swells are not as important as voltage sag and is mainly caused due to switching of large capacitor or start/stop of heavy loads.

II. BASIC PRINCIPLES OF DVR

A. Principle:

Basic principle of DVR is to transfer the voltage sag compensation from DC aspect of the electrical converter to the injected electrical device when filter. The compensation capability of a selected DVR depends on the utmost voltage injection capability and also the active power which will be provided by the DVR. Once DVR's voltage disturbance happens, active power or energy ought to be injected from DVR to the distribution system [6]. A DC system, that is connected to the electrical converter input, contains an oversized capacitance for storage energy. It provides reactive power to the load throughout faulty conditions. once the energy is drawn from the energy storage capacitors, the capacitance terminal voltage decreases. Therefore, there's a minimum voltage needed below that the electrical converter of the DVR cannot generate the need voltage therefore, size and rating of capacitance is extremely necessary for DVR power circuit [7].

B. Components of DVR:

The basic block diagram of Dynamic Voltage Restorer is as shown in Figure 1. and the major components of DVR are as explained below

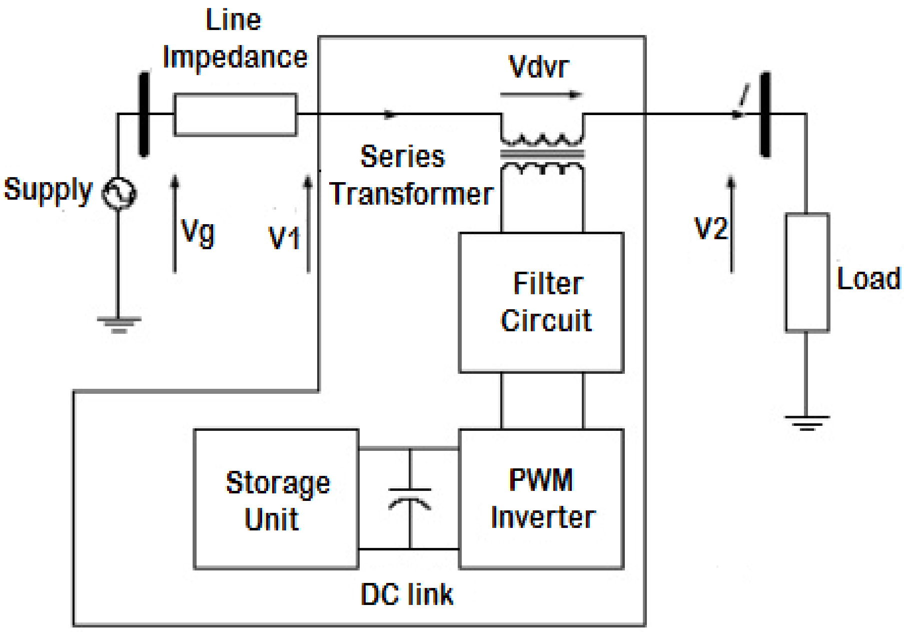

Figure 1. Basic Block diagram of Dynamic Voltage Restorer

1. DC storage Device:- It supplies necessary energy to Voltage source inverters during compensation. Voltage source inverter (VSI) will convert it into alternating quantity and fed to Injection Transformer.

2. PWM Inverter:- An inverter is used to convert DC to AC form. Its is a power electronics system consisting of switching devices which can generate sinusoidal voltage at any required frequency, magnitude or phase angle

3. Filter Unit:- The main task of the filter is to keep the harmonic content generated by Voltage Source Inverters to a permissible limit and to eliminate higher order harmonics.

4. Voltage Injection Transformer:- It consists of two side, one is high voltage and other is low voltage side. The high voltage side is normally connected in series with distribution network and low voltage side is connected to DVR. This transformer is used to isolate DVR from the distribution network system. In three phase systems, either three single phase transformer is used or one three phase transformer is used.

III. FLUX VECTOR MODULATION TECHNIQUE

The Single phase voltage source inverter is connected to the load through LC filter to filter voltage and current. The voltage primarily based modulation techniques, like SPWM, SVM, SVPWM, need some reasonably current management in LC filter to damp out the LC resonance. the most important advantage of flux vector modulation is that the voltage management loop alone will damp out the resonance of LC filter. Hence, there is no ought to use further passive elements to dump the LC resonance, neither the active damping controller is employed.
In this paper, the flux vector modulation for single-phase standalone converter is studied. The implementation steps are delegated as below. The planned modulator is employed for single-phase sine-wave output electrical converter having LC filter. The PI voltage controller for sine-wave standalone inverter is enforced in SRRF [14], [15]. The design of standalone inverter is intended supported by the stationary reference frame equivalence of SRRF PI controller.

3.1. Single phase inverter using flux vector modulation

Flux vector modulation of standalone single phase inverter is a based hysteresis modulation technique. Here the inverter Virtual flux is given as the time integral of the inverter voltage vector. This virtual measured flux is used to generate the switching pulses for the inverter. The virtual inverter flux is given as

$$\psi(t) = \int_0^t \vec{V}\, dt + \psi(0).$$

The reference flux "ψ*" is tracked by switching between appropriate inverter voltage vectors. The actual flux "ψ" tracks the reference flux "ψ*" within a specified hysteresis band of "h" and selects the appropriate voltage vector (i.e.) V1=V4=0, V2= Vdc, V3= -Vdc, to generate the output as specified in Table I below

Table 1. Selection of appropriate voltage vector

Sector	Error status	Vectors
I	$\psi^* - \psi \geq h$	V1
	$\psi^* - \psi \leq -h$	V0 or V3
	$-h < \psi^* - \psi < h$	Previous vector
II	$\psi^* - \psi \geq h$	V0 or V3
	$\psi^* - \psi \leq -h$	V2
	$-h < \psi^* - \psi < h$	Previous vector

IV. SIMULATION RESULTS

The MATLAB Simulink block diagram and waveforms are as shown in Figure 2 and 3 respectively. Below Table 2. represents the system parameters for the simulink model

Table 2. System Parameters

System Device	Parameters/Standards
Three Phase input Voltage Source	Amplitude - 440 V and Frequency-50Hz
Load (RL)	R= 10Ω and L= 1mH
PI controller	Kp=15, Ki=0.1, Sample Time = Ts
Hysteresis Band	0.0001

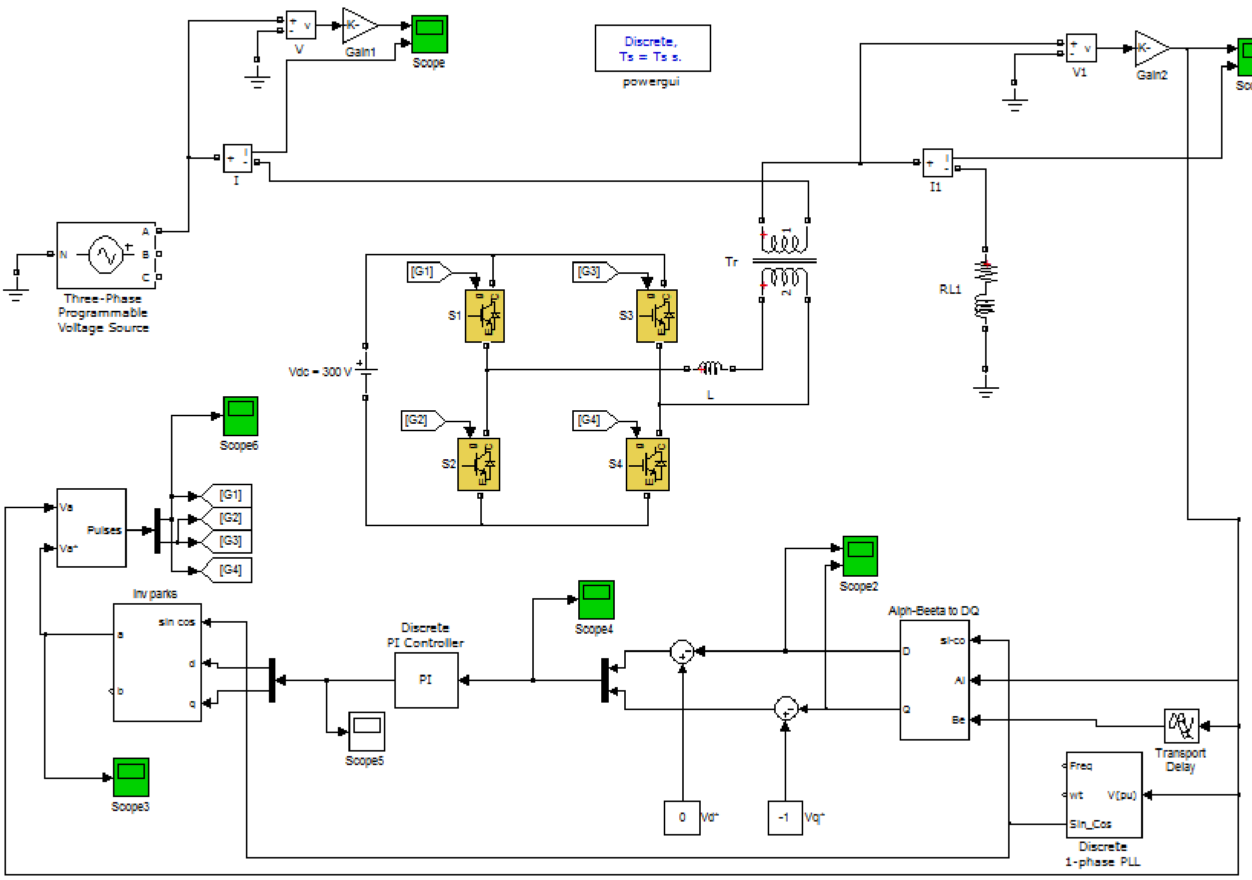

Figure 2. Simulink Block Diagram DVR with Flux vector Modulation

4.1 Simulation results

The input voltage and current Waveforms with voltage sag of "scope" in Figure 1 is as shown below

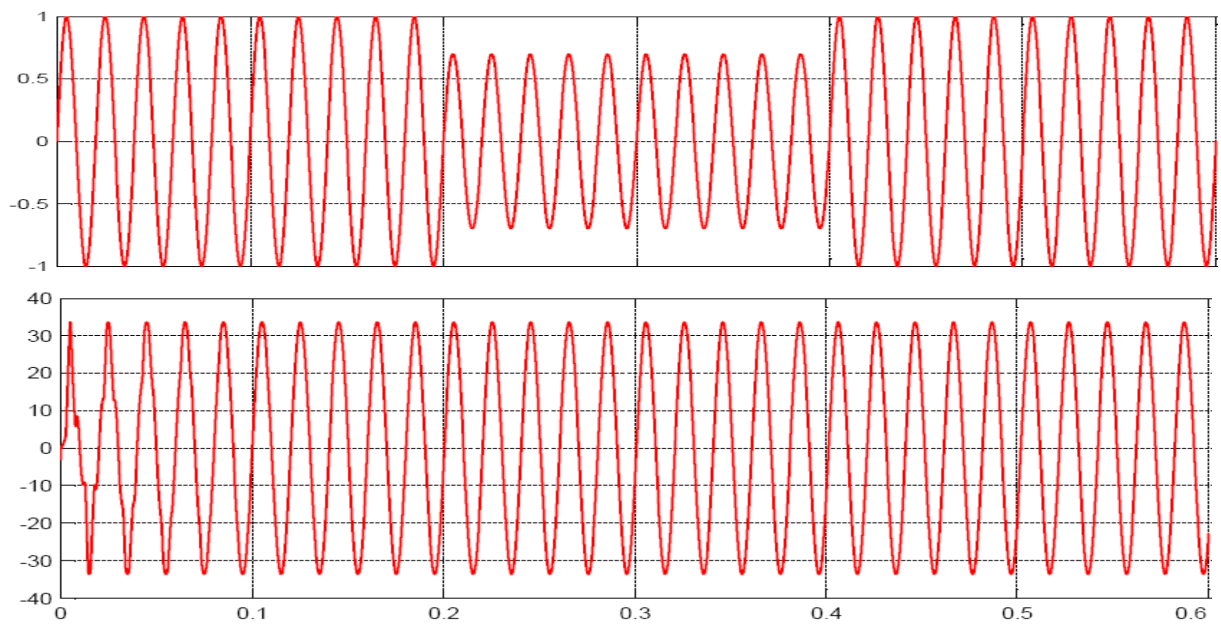

Figure 3. Input Voltage and Current waveform with voltage sag

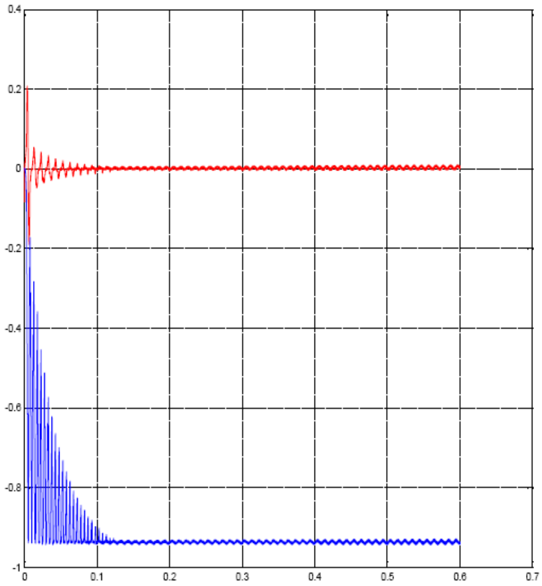

Figure 4. Output of PI Controller

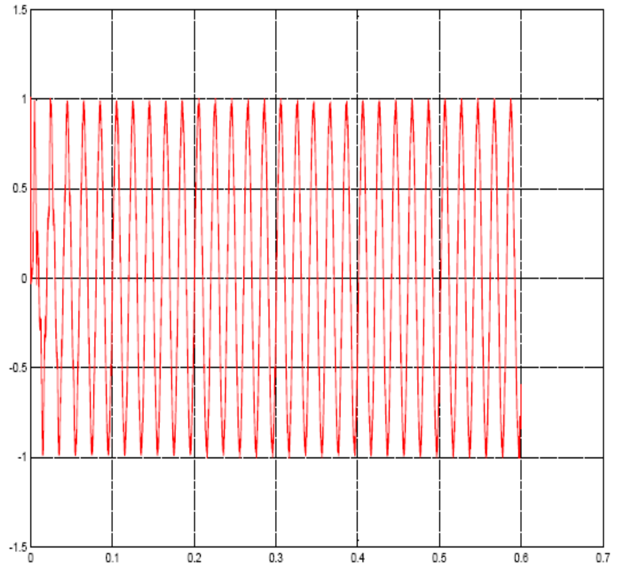

Figure 5. Output of Flux vector Modulation Block

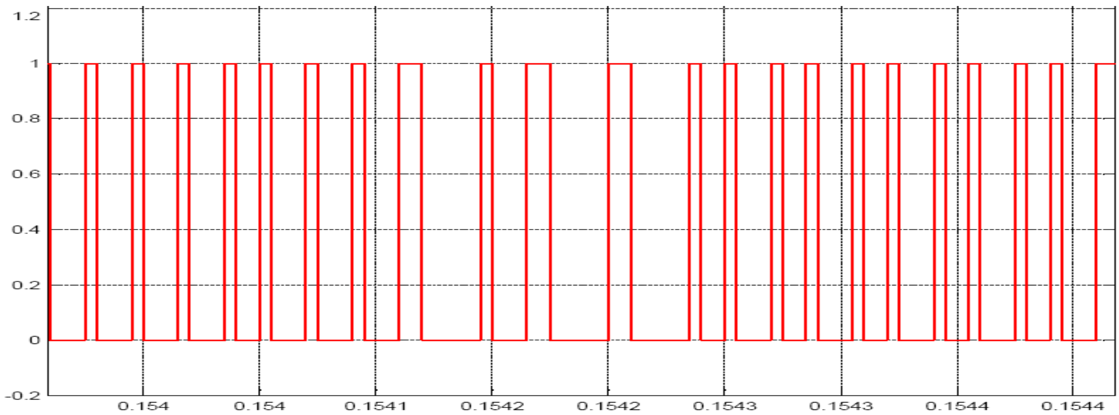

Figure 6. Generated PWM pulses for switching of inverter

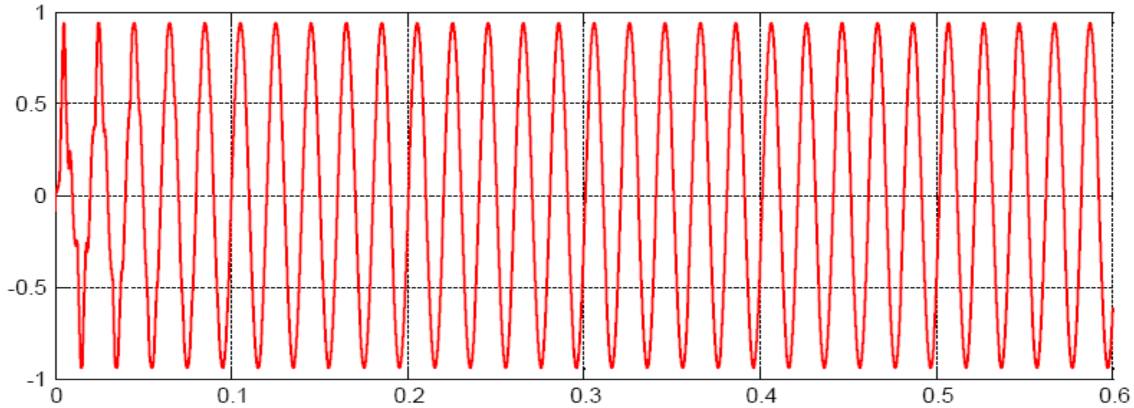

Figure 7. Voltage Sag mitigated Output Voltage Waveform

V. CONCLUSION

Power quality problems occur due to improper voltage, current or frequency, which ultimately results in failure of customer equipments. Thus in this era of custom power devices, we have studied the advantages of using Dynamic Voltage Restorer as the custom power device used to solve PQ problems like voltage sag, swell, flickers, etc. The main advantage of DVR is it is small, low in cost and has fast dynamic response to the disturbances. A DVR can reduce the risk of load tripping at major voltage distortions. With the significant importance of DVR in mitigating voltage sag and swell, it control techniques is equally important. Closed loop Flux vector modulation technique is proposed in this thesis for accurate switching of single phase grid connected inverters. The inverter switching is continuously monitored and fed back to the flux modulator via PI controllers, to maintain the sinusoidal output. The DVR is connected before the grid so as to provide distortion free voltage at the input of the distribution system. In this thesis we have studied the concept of dynamic voltage restorer, flux vector modulation and simulation of grid connected single phase inverter using flux vector modulation technique. We also plotted waveforms for the same.

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