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In Phase Compensation of Sag and Swell Voltage by using Dynamic Voltage Restorer

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ABSTRACT

Today most of the industries and customers are using sensitive and sophisticated electrical equipment based on semiconductor devices, these may causes power quality disturbance. The major problems are voltage sag and swell. The sag and swell not only occur by disturbed power quality but also due to high system tapping at point of common coupling. To overcome this problem and to improve power quality the distribution companies uses various custom power devices. Among the various custom power devices Dynamic voltage restorer is used for compensation in this paper, which is most popular and widely used method. Here, In phase compensation technique of DVR is used with battery energy storage system. The voltage at PCC have been observed. The control technique employed here is SRF theory with PI controller. The overall work is carried out in MATLAB Simulink.

Keywords : DVR, voltage sag, voltage swell, In Phase compensation, Battery Energy storage ,SRF controller

I. INTRODUCTION

The electric power industry comprises electricity generation, transmission, and distribution. The electricity then moves through wiring system of end user until it reaches the load During this quality of power may changes and disturbance or called power quality problem occur .Power quality involve voltage, frequency, and waveform. Good power quality can be defined as steady supply voltage that stays within the prescribed range, steady ac frequency closed to rated value and smooth voltage curve waveform. Without proper power electrical device or load may malfunction, fail prematurely or not operate at all .There are many ways in which electric power can be of poor quality and many more causes of such poor quality power. The number of power quality issues including voltage sag, swell, flicker, harmonics, transients etc. has different causes.

The most of the common power disturbance that impact sensitive equipment is voltage sag .The main sources of sag are large increase in current due to faults and abrupt increase in system impedance. Voltage sag are caused by reduction in the load with poor voltage regulation. Voltage sag means that decrease in normal voltage from 10% to 90% of its RMS value which last for a cycle less than one minute .Voltage swell, in contrast, can be defined as increase in RMS voltage above the nominal value which last for a cycle greater than one minute. Switching off of large load, energization of capacitor bank are considered as a causes of voltage swell.

In this scenario power quality is directly related to distribution system because of it is situated at the end power system and directly connected to

customer. If any disturbance is occur in distribution system, a huge amount of losses may happen, therefore loss of productivity and competitiveness. Hence it is necessary to improve quality of power. In order to improve quality of power, there is number of custom power devices are available which protects the load from voltage sag, swell harmonics etc. DVR is a series connected device installed between source and load. DVR inject the voltage in to the system to compensate the disturbances occur due to supply.

This paper represent analysis of DVR with battery energy storage system for sag swell compensation. The energy storage such as battery is responsible to supply energy source in DC form. The DC energy storage provide real power requirement of DVR during compensation. SRF control technique is used for control of DVR.

II. INTRODUCING DVR

DVR is a series connected device. It is connected in utility distribution feeder at point of common coupling. The main objective of DVR is to increases power utilization capacity of a distribution feeder and protect the loads from voltage sag and swell coming from the network. In addition to its main task which is voltage sag and swell compensation, DVR can also added other feature such as harmonic compensation. These are a problem because spikes consume power and sags reduces efficiency of some devices. DVR saves energy through voltage injections that can affect phase and wave shape of power being supplied.

The basic principle of DVR is to inject voltage of magnitude and frequency necessary to restore load side voltage to desired amplitude and waveform, even when source voltage is unbalance and distorted. Generally DVR generate or absorb independently controllable real and reactive and reactive power at load side. In other words DVR is a solid state DC to AC switching power converter that inject set of three phase AC output voltage in series with transmission line. DVR is design according to voltage needed in secondary of transformer.

2.1 Components of DVR

The conventional DVR consist of:

1. Series injection transformer: Basic function of injection transformer is to increases voltage supplied by filtered VSI output to desired level while isolating DVR circuit from distribution network.

2. Energy storage device: The energy storage such as capacitor, battery is responsible to supply energy source in DC form .Energy source may vary according to design and manufacturer of DVR. Energy storage consist of two type form. One using stored energy to supply the delivered power and other having no significant internal energy storage nut instead energy is taken from faulted grid supply during sag.

3. Filter: Filter is used to eliminate unwanted harmonics components generated in VSI section. And also to keep harmonic voltage generated by VSI to permissible level.

4. Inverter: The function of an inverter system in DVR is used to convert the DC voltage supplied by energy storage device in to AC voltage. The variable output voltage is achieved by voltage source inverter (VSI). Solid state semiconductor devices with turn on capability are used in inverter circuit.

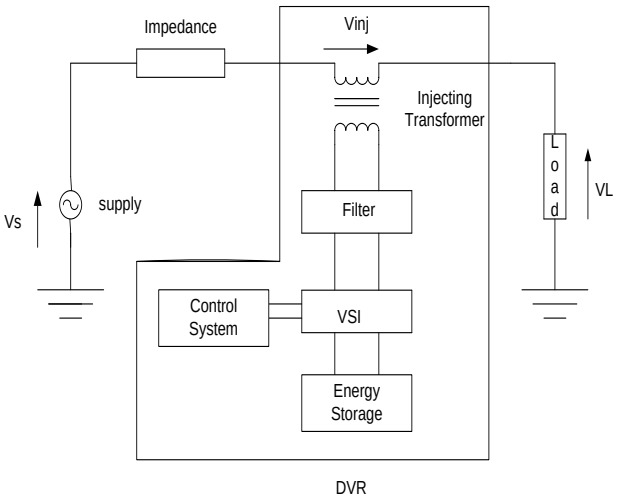

Fig 1: Structure of DVR

2.2 DVR with Energy storage

Storing of electrical energy is high priced but for certain type of voltage dip the performance of DVR can be improved and damage on the grid connection is lower. Constant DC link voltage or direct energy storage method such as batteries can be used in a DVR by adding high power rating converter to system. Energy transferred from large energy storage to dc link storage using this converter during sag. Hence DC link voltage remains constant.

III. COMPENSATION TECHNIQUES

Voltage compensation methods depend on DVR power ratings, various conditions of load, and different types of voltage sag and swell. There are 4 types of DVR voltage injection methods are as follow

1) Pre sag compensation method
2) In phase compensation method
3) Phase advanced compensation method
4) Energy optimization method

3.1 In phase Voltage Compensation method

The compensation strategy adopted here is in phase compensation. In this method injected voltage in secondary of series injection transformer is in phase with supply voltage irrespective of load current and prefault voltage as shown in fig. 2.

In normal condition, supply voltage (Vpresag) is equal to load voltage with zero phase angle. During the voltage sag swell, the supply voltage decreases or increases to a value less than or greater than its normal value. [10] .The DVR reacts to sag /swell event and injects the compensated voltage in phase with supply voltage to restore the voltage at nominal value.

The injected voltage of DVR can be expressed as

$$V_{inj}=V_{presag}-V_{sag}$$

$$V_{DVR}=V_{inj}$$

$$V_{DVR}=V_{presag}-V_{sag}$$

The angle of injected voltage can be calculated as follows:

$$<V_{inj}=\theta_{inj}=\theta_s$$

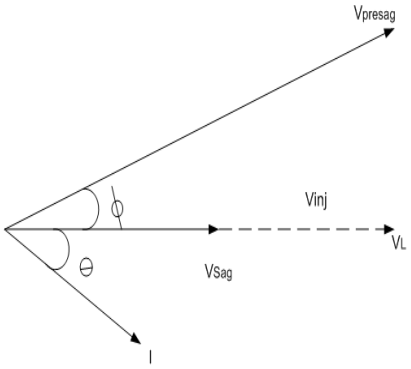

Fig.2 In phase compensation method

IV. PROPOSED SYSTEM CONFIGURATION

The proposed system configuration of self-supported DVR connected to distribution system to restore the voltage of three phase critical load is as shown in fig 3 and has been modelled in MATLAB Simulink. DVR connected system consist of source, inverter, control block, filter, injection transformer and load. Three phase voltage source is connected to the load through three phase series injection transformer. The equivalent voltage supply of each phase is connected to PCC through short circuit impedance or we called series RL branch. The three phase DVR is connected to the line to inject voltage in series using three phase transformer. Lf is a filter component used to filter out ripples in the injected voltage. A three leg VSC with IGBT is used and capacitor as a storage is connected to its dc bus.

The different supply voltage disturbance are generated by using source. The disturbance at source side affect the performance of load. The disturbance can be compensated by DVR. The compensated voltage obtained from DVR is injected in to the system through injection transformer. The voltage is inserted in such a way that load voltage is constant in magnitude and is undistorted, although supply

voltage is not constant in magnitude or is distorted. DVR is built with VSI, the operation of VSI depends on control signal is received from control unit. The reference voltages required for VSI are generated from control unit. SRF theory is used for controlling of DVR. The active power injection to compensator is coming from super capacitor.

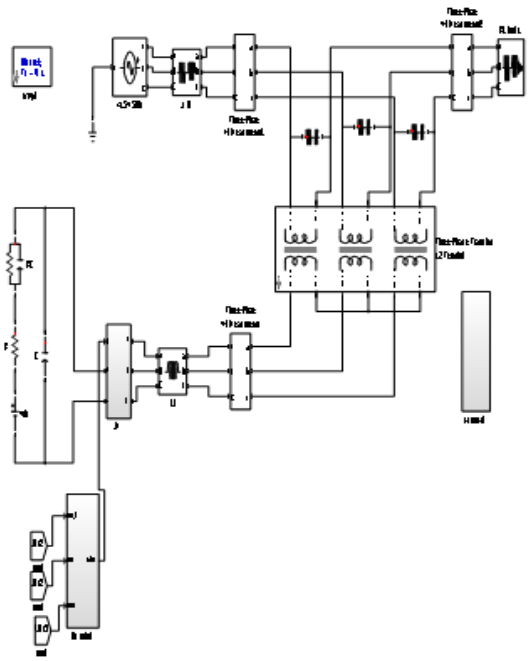

Fig 3. DVR Connected System with In Phase Compensation

V. CONTROL SCHEME FOR DVR

The control strategy of DVR is as shown in fig 4. SRF theory is used for control of self supported DVR. Volatge at PCC are converted to rotating reference frame using parks transformation .The dqo frame express voltage error and phase shift information as instantaneous space vector with start and end times.Voltage is converted from abc reference frame to dqo reference. The harmonic and ocillatory componenets are elimanated using low pass filter. In order maintain DC bus volatge of self supported capacitor,a PI controller is used at DC bus voltage. The ampliude of load voltage terminal V_L is controlled to its reference voltage V_L^* using another PI controller. The output of PI controller is considered as a reactive componenet for voltage regulation of load terminal voltages. Amplitude of load voltage V_L at PCC is calculated from AC voltages. Reference load voltages in abc frame are obtained from reverse parks transformation.The error between sensed load voltages and reference load voltages are used over a controller to generate gating pulses to VSI of DVR.

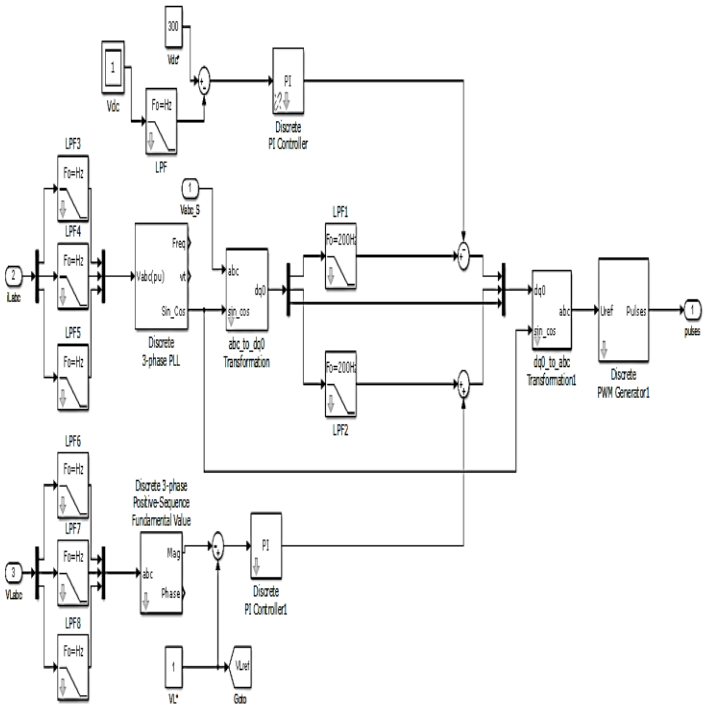

Fig.4 Control Scheme For IN Phase Compensation

VI. VSI BLOCK OF PROPOSED SYSTEM

The system uses a model of structure to envisage, on every sampling intermission, the behaviour of the output voltage for each possible switching state, and then, a cost function is used as a criterion for selecting the switching state that will be applied during next sampling interval.Fig 5 shows VSI section of DVR

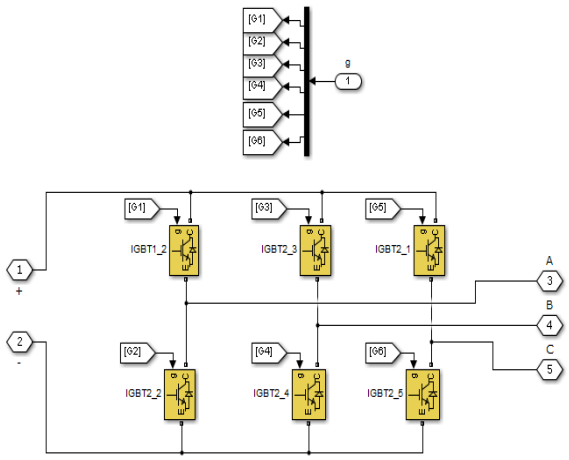

Fig.5 Structure of VSI Block

VII. SYSTEM PARAMETER

Sr.No	System Quantity	Specification
1	Supply voltage	415V,50Hz,3-phase
2	Impedance	R=0.01Ω,L=3mH
3	3-phase injection transformer	10KVA 200V,300V
4	Inverter Sample time Snubber resistance	3Arms,IGBT/Diode based. 1μs,2μs 1 MΩ
5	Capacitance	10 μF
6	DC Voltage of DVR	300 v
7	AC Inductor	2.0 mH
8	Battery	R=0.02Ω,c=10μF R=0.01Ω V=500 V (amplitude)
9	PI controller	K_{p1}=0.5,K_{i1}=0.35,ts=10 μs K_{p2}=0.1,K_{i2}=0.5,ts=Ts
10	PWM frequency	10KHZ
11	PLL	Kp=180,Ki=3200,Kd=1 50Hz

The test system employs to take out simulation regarding DVR actuation

VIII.SIMULATION RESULTS

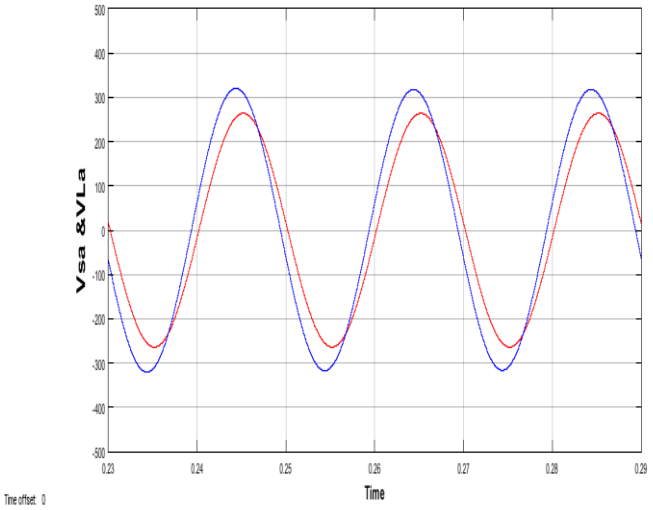

Fig. 6 Load voltage and PCC voltage

The load and PCC voltage of phase A are shown in fig.6, which shows the in phase injection voltage by DVR. The performance of DVR for in phase compensation for voltage sag and swell with battery energy storage is as shown in fig.7 It is observed that injected voltage is n quadrature with supply current. From the above figure it is observed that sag is created for a time duration 0.2 to 0.3.Similarly swell is created for a time duration of 0.4to 0.5.DVR respond to sag and swell and inject appropriate amount of voltage during sag and swell event at t-0.2 to 0.3 sec and t=0.4 to 0.5 sec respectively. Therefore sag /swell is mitigated and voltage level is boosted up to few extent level. It is observed that load voltage is regulated to constant amplitude under both sag and swell condition.

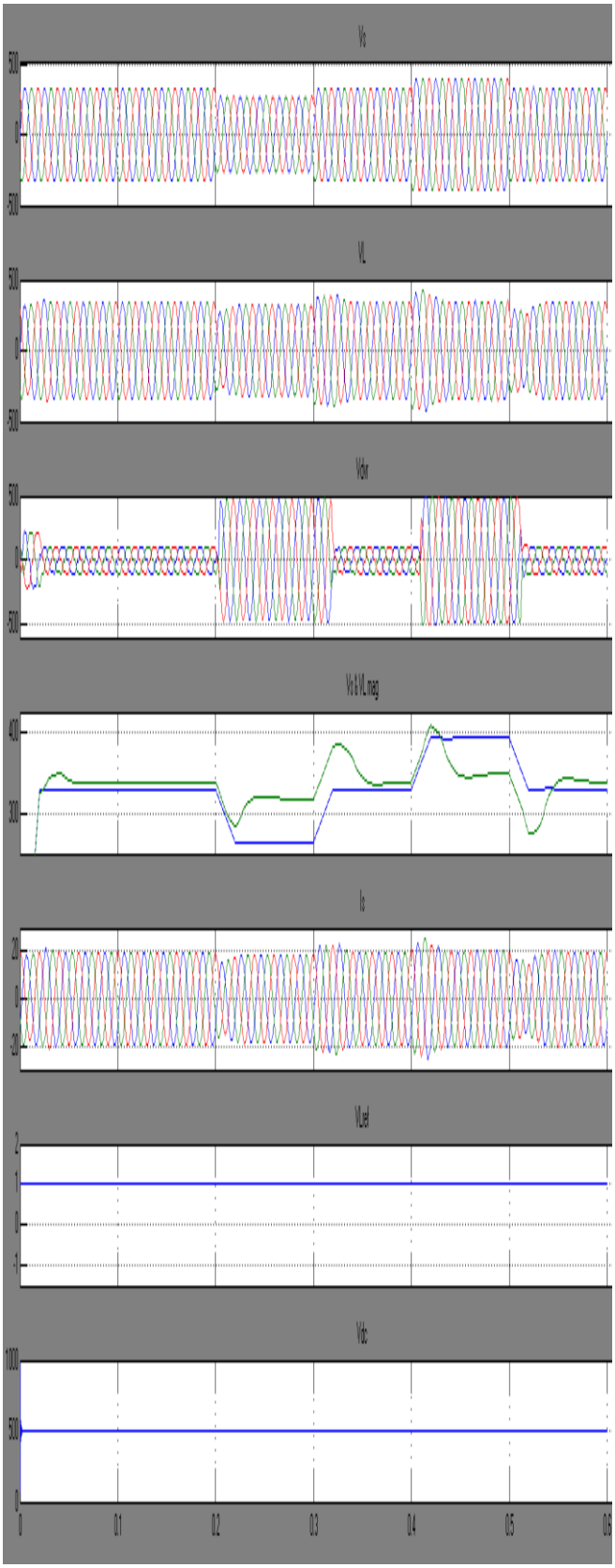

Fig.7 Performance of DVR for In Phase compensation during both sag and swell condition

IX CONCLUSION

It is concluded that DVR handles both sag and swell situation without any difficulties and injects the appropriate voltage component to correct rapidly any deviation in the supply voltage to keep the load voltage balanced and constant at the nominal value during disturbance. The voltage injection in phase with the PCC voltage results in minimum rating of DVR but at the cost of energy source at its DC bus.

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