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Compensation of Power Quality Issues Using Reduced Rating Dynamic Voltage Restorer

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Abstract - *Power quality issues such as voltage sags, swells and harmonics are becoming more significant in present days because of the increasing number of power electronic devices. In order to mitigate the power quality issues to introduce compensation device like dynamic voltage restorer (DVR). This paper describes the reduced rating DVR which is acts as series compensator that can be used to mitigate the voltage sags, swells, and harmonics. This paper discusses the synchronous reference frame theory (SRF) based control method is used to mitigate the power quality issues in the system and regulate the load voltage. PWM controller is used to control the voltage source converter (VSC). The proposed control technique is modeled using MATLAB/SIMULINK software and simulation results are presented to validate this proposed control technique.*

Key Words: DVR, BESS, SRF, Power quality issues, critical loads, rating of DVR

1. INTRODUCTION

In present days, with increasing the usage of power electronic devices which behave like non-linear loads power quality issues like voltage sags, swells, and harmonics become serious issues [1]. Dynamic voltage restorer is the effective device to compensate the voltage sags and swells among the custom power devices. The main aim of the DVR is to regulate the voltage at load terminals. DVR consist of three phase source, injection transformer, VSC, DC link, critical loads [2]. The main aim of this paper is rating of DVR is reduced and mitigating the voltage disturbances.

In this paper, the proposed control technique is tested under unbalanced load conditions using Matlab/Simulink software. Proposed system DVR rating is tested in two different cases such as DVR with battery energy storage system (BESS) and self supported DVR. Control block gives PWM pulses to control the VSC and output of VSC is given to the injection transformer is used to eliminate the unwanted signals at load terminals [3].

1.1 DYNAMIC VOLTAGE RESTORER

DVR is the most attractive solution for solving voltage disturbances at point of common coupling (PCC) terminals and meet the required voltage at load terminals. It is also used to prevent harmonics present in the system. Fig.1 shows the basic configuration of dynamic voltage restorer.

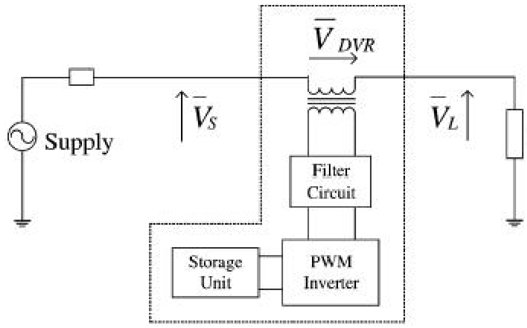

Fig-1: Basic configuration of DVR

It contain storage unit, VSC with PWM controller, injection transformer are used to mitigate the voltage disturbances and harmonics at supply side and to regulate the load voltage.

2. CONTROL OF DVR BASED ON SRF THEORY

SRF method can be used for the compensating the supply voltage and meet the required load voltage [2]. In DVR with BESS case, voltage across storage device is not controlled, and injected voltage is in-phase with the current. In self supported DVR case, voltage across DC link is controlled, and injected voltage is quadrature with the current. Same critical loads are applied at supply side and observe the rating of DVR in both cases.

2.1 Control block for DVR with BESS

Control block mainly consisting of abc-dq0 block on Parks's transformation, PI controllers to reduce the error between two signals, PWM controller to generate the gating pulses to control the VSC, and dq0-abc block based on reverse Park's transformation. The Fig.2 shows the control block of the DVR with BESS.

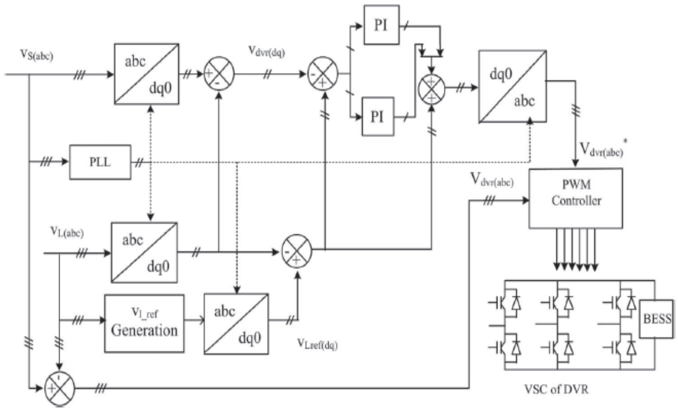

Fig-2: control block of DVR with BESS using SRF theory

The SRF control is used to obtain the direct axis and quadrature axis components of load voltage. A three phase PLL (phase locked loop) block is used to synchronize the load voltage to terminal voltage at PCC.

2.2 Control block for self supported DVR

Control block is used to control the VSC and maintaining the DC link voltage constant. Fig.3 shows the control block of self supported DVR mainly consisting of PLL, low pass filters (LPF), abc-dq0 block, PI controllers, dq0-abc block, and PWM generator.

The amplitude of load terminal voltage is generate from the ac voltages such as V_{La}, V_{Lb}, V_{Lc} .

$$V_L = (2/3)^{1/2} (V_{La}^2 + V_{Lb}^2 + V_{Lc}^2)^{1/2} \quad (1)$$

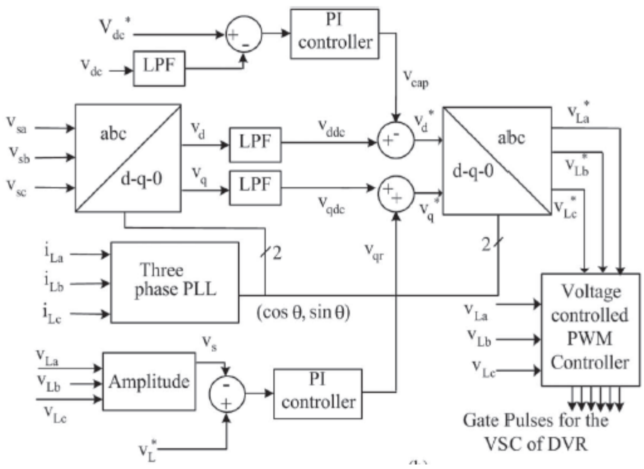

Fig-3: control block of the self supported DVR using SRF theory

The amplitude of voltages at load terminals (V_L) is compared with the reference amplitude V_L^* and output is given to the PI controller to reduce the error. Reference load voltages generated from the control of DVR and actual load voltages are controlled using PWM generator. PWM generator is operated with a switching frequency of 10 kHz.

3. MODELLING AND SIMULATION

Fig.4 shows the simulation model of DVR with BESS and Fig.5 shows the simulation model of self supported DVR at different sag conditions connecting critical loads at supply terminals. During the connecting loads voltage sag is obtained. DVR is operated and mitigate this sag and maintain the rated voltage at load terminals.

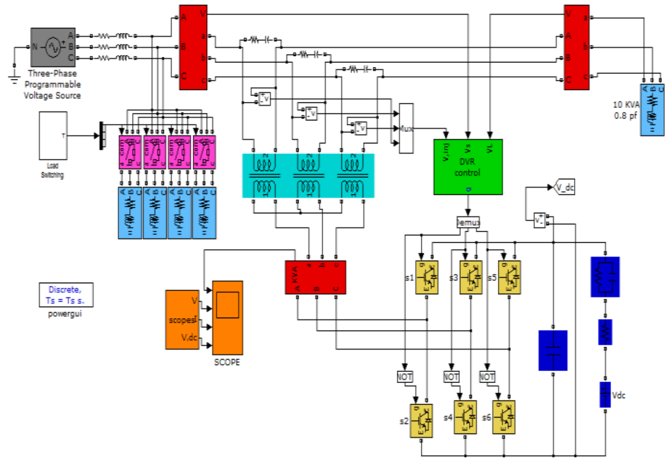

Fig-4: simulation model of the DVR with BESS in matlab

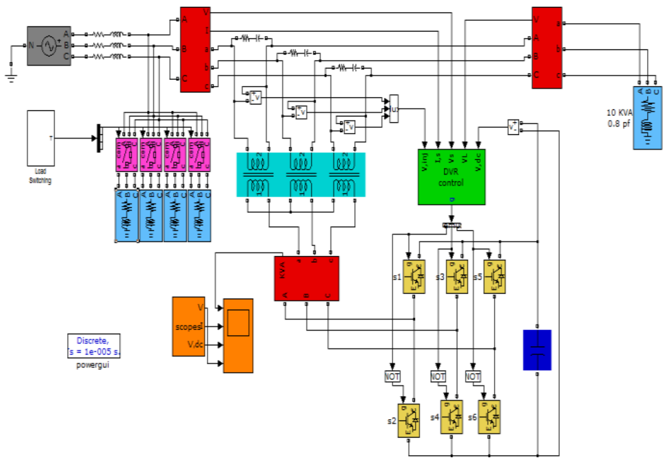

Fig-5: simulation model of the self supported DVR in matlab

4. RESULT AND DISCUSSION

Fig.6 and Fig.7 shows the load voltage and injected voltage of DVR in both cases.

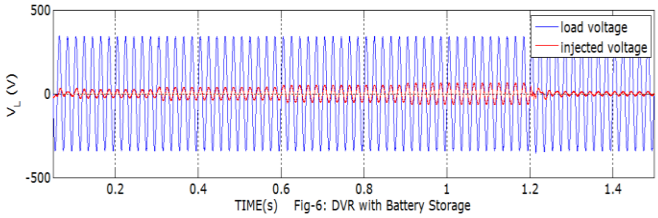

Fig-6: DVR with Battery Storage

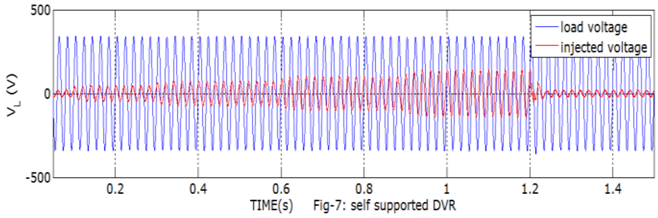

Fig-7: self supported DVR

Voltage sag is created while connecting loads during 0.1 to 1.2 sec in both cases are same, so magnitude of the voltage sag is same in both cases but injecting voltage of DVR is more in self supported DVR than DVR with BESS.

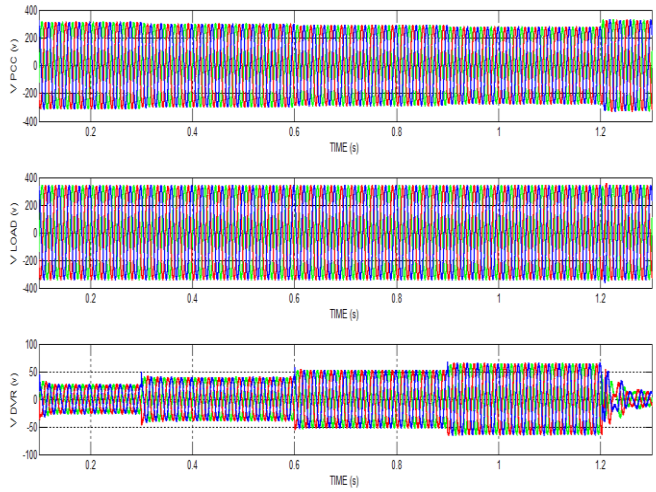

Fig-8: performance of DVR with BESS during voltage sags

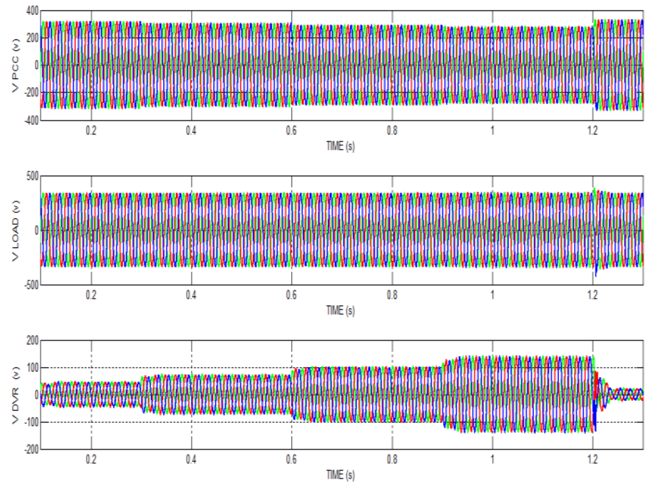

Fig-9: performance of self supported DVR during voltage sags

Fig.10 shows the performance of DVR with BESS during voltage swell from 0.2 to 0.3 sec.

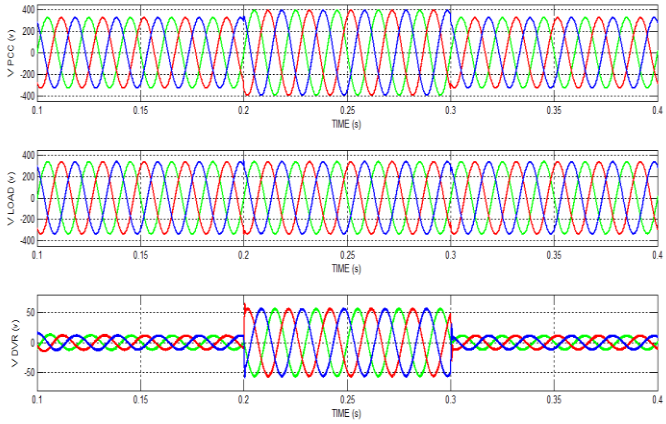

Fig-10: Performances of DVR with BESS during voltage swell

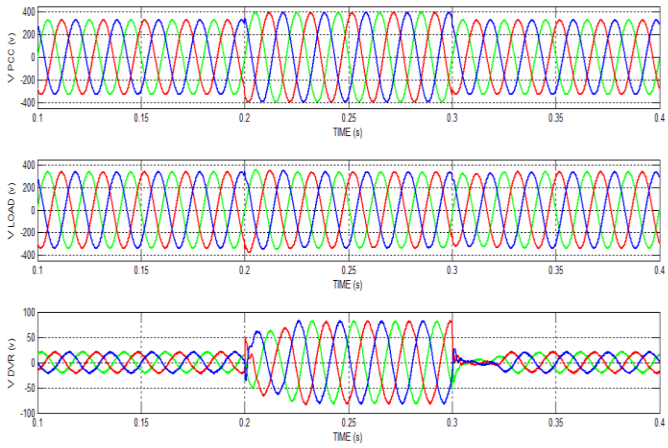

Fig-11: performance of the self supported DVR during voltage swell

Fig.11 shows the performance of self supported DVR during voltage swell from 0.2 to 0.3 sec. Fig.12 (a), 12(b), and 12(c) shows the FFT analysis of DVR at PCC and load terminals during disturbances.

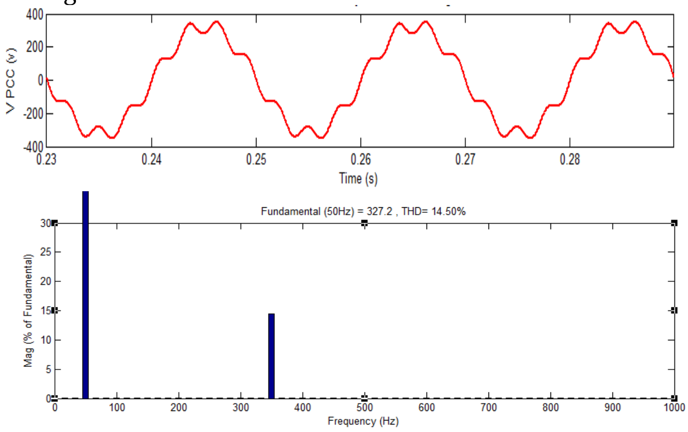

Fig-12 (a): FFT analysis of voltage at PCC terminals

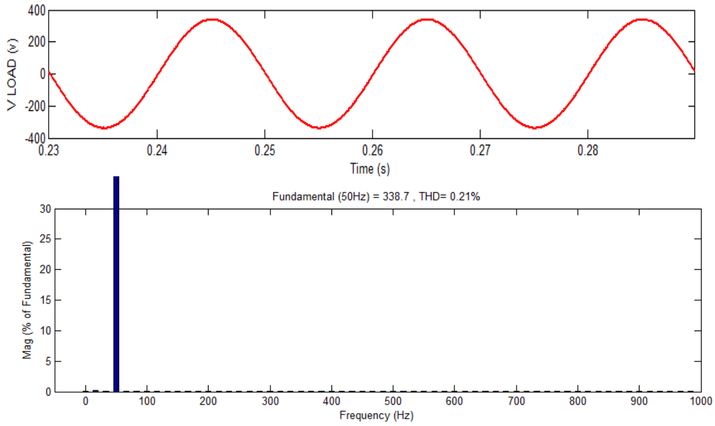

Fig-12 (b): FFT analysis of voltage at load terminals

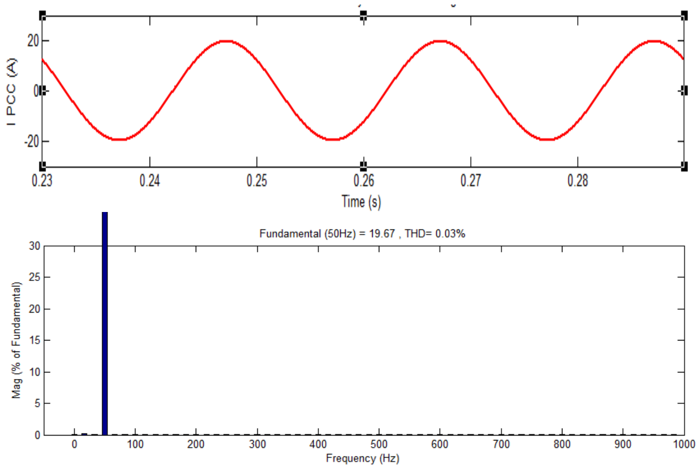

Fig-12(c): FFT analysis of current at PCC terminals

Voltage harmonics are present in the system during 0.23 to 0.3 sec DVR is reduced total harmonic distortion from 14.50% to 0.21%. Current harmonics are also mitigating as shown in Fig.12(C). THD value of current at PCC terminals is 0.03%. Fig.13 shows the rating of DVR in both cases while creating the voltage sags with different magnitudes. Rating of DVR with BESS is less when compared with self supported DVR.

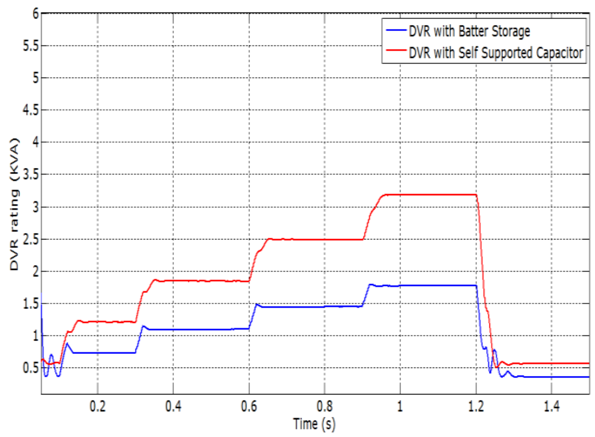

Fig-13: KVA Rating of DVR

4. CONCLUSIONS

For every power delivery system reliability of supply and power are the important factors. In present days, consumers want quality of supply but not only supply. So it is necessary to mitigate the power quality issues. To solve these issues we are using different techniques. In this paper we introduced a device known as dynamic voltage restorer with reduced rating to solve the power quality issues such as voltage sags, swells, and harmonics. SRF theory is used to maintain the constant load voltage without fluctuating. Rating of DVR is tested in both cases and finally concluded DVR with BESS having less rating.

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