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DESIGN AND DEVELOPMENT OF SMES BASED DVR MODEL IN SIMULINK

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Abstract: **In this paper, A SMES based DVR model is presented and Modelled with the help of simulink block. Superconducting magnetic energy storage (SMES) is considered as the future energy storage devices. In this work SMES is used for storing the DC energy and at the time of Requirement provide this energy to the main line with the help of DVR (Dynamic Voltage restorer). Simulation Result shows the compensation ability of this DVR**

Keywords: **PI (Proportional Integration), VSC (Voltage Source Converter), DVR (Dynamic Voltage Restorer), SPWM (Sinusoidal Pulse Width Modulation).**

1. INTRODUCTION

Now day's power systems have been witnessing tremendous changes and drastic disturbances in electric power generation and system, power Transmission, distribution of power, and end-user facilities. Wide applicability of power electronic devices in power system engineering makes the quality of the power an important aspect in today's power scenario [1]. It is the responsibility and duty of the utility to provide a pure sinusoidal voltage of necessary magnitude and frequency at all the time and without any delay to its consumers. But, in realism, it is not feasible to see ideal waveforms. The waveform of the voltage gets disturbed from ideal waveform cycle due to frequent occurrence of supply distortion like voltage sag, voltage swell, interruptions, flicker fluctuations etc. and also due to the heavy use of non-linear nature loads. Such voltage disturbance badly affects the performance of equipments connected in the system [2]. The industries such as process industries, semiconductor industries, petrochemical industries, chemical industries, paper mills etc. use apparatus and equipment's which are very sensitive to voltage disturbances. Poor quality of the voltage may cause in termination of the process, data loss in digital devices etc., and hence produce huge financial loss to consumer [3-6]. Out of the different voltage distortions, voltage sag is a frequent disturbance which in power system. Voltage sag is responsible for 92% of the interruptions in industrial installations. So with the aim of overcoming this deficiency SMES based DVR is used for improving the performance of power system as it is of high power rating with optimum efficiency than any other energy storage devices [7]. This paper presents a super conducting magnetic energy storage unit, as the energy storage unit of DVR.

Proposed DVR:

A. Configuration of SMES based DVR:

Dynamic Voltage Restorer (DVR) is one of the efficient customizable power devices that can be used for improving power quality from any kind of electrical disturbances in the distribution line. The DVR can be used for protecting and recovering or restoring the voltage quality to the sensitive load. A set of three phase voltages with a suitable amplitude and period can be injected through injection transformer and must be in phase with the grid voltage. A DVR is a solid state power electronics switching device consisting of either GTO or IGBT, a bank of capacitor as an energy storage tool and injection transformers.

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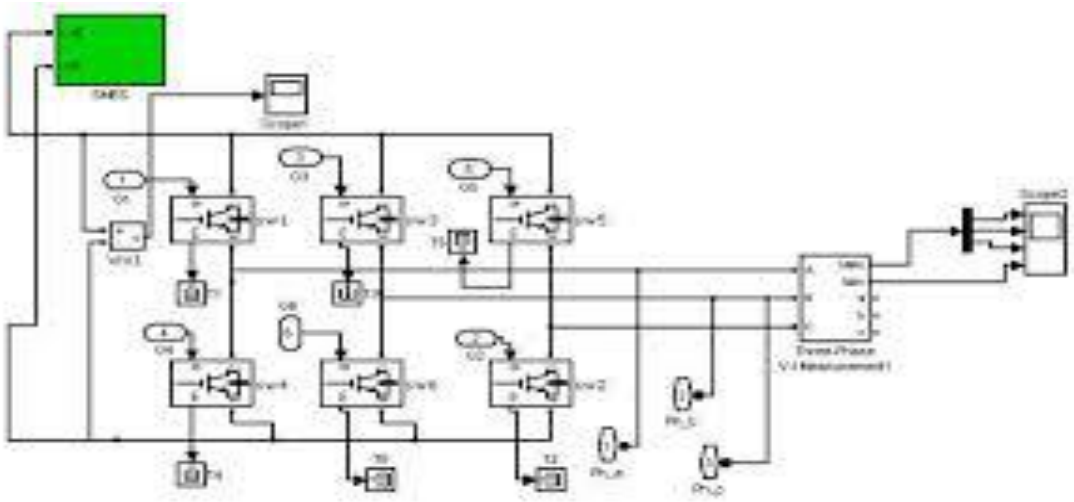

Figure.1: SMES based DVR

B. SMES Device:

SMES systems are a budding technology which exploits the properties of superconducting material to store energy in magnetic fields. SMES systems have very fast charging and discharging times which build them an attractive energy storage system for mitigation of sag. Another benefit of SMES systems is the very low losses due to the superconducting characteristics. It consists of super conducting magnetic energy storage unit, bank of capacitor, VSI, low pass filter and voltage induction transformer. It composes of main system and its sub systems. The super conducting coil is the important section of SMES system, which is placed in a cryostat or dewar which consist of a vacuum vessel and a liquid vessel. Liquid vessel keeps the system temperature under control by providing proper cooling setup cryogenic system; it also keeps the temperature below the critical temperature. Finally a transformer is also used which perform the power system connection and co-ordination and PCS operating voltage will trim down to acceptable levels.

C. Control Section:

Sag in Voltage is artificially created in a simulation at load terminals by three phase faults block which is used for this vary purpose. In the next step, Load voltage is converted into a per unit voltage quantity. Comparison of the applied voltage with the reference voltage is then performed which generate the error signal which is then again fed to the PI (Proportional Integration) controller.

The output voltage is then given to the SPWM (Sinusoidal Pulse Width Modulation) control based triggering circuit. In this control circuit, three phases sinusoidal voltage is produced which is fed to the load voltage. Error signal is processed by the PI (Proportional Integration) controller to generate the appropriate angle δ to drive the error to zero. The input to the PI controller is the actuating signal which is the difference voltage between V_{ref} and V_{in}

The output of the controller gives the required firing sequence. Main job of the controller in the DVR circuit is to detect the voltage sag/swell in a system. Calculation of the correcting voltage, generating the trigger pulse, correction of the any anomalies in the series voltage injection along with the terminate the triggering pulse after events is over are some other function performed by the controller. Controller also take care of charging and discharging of the capacitor in the DC energy link during the absence of Voltage sag/swell , by shifting DC-AC inverter in to rectifier mode. The dqo transformation or Park's transformation is used in this simulation to perform DVR controlling.

The depth of the sag and amount of phase shift information is given by the dqo method. In this method, first of all a-b-c reference voltage is converted in to a d-q-0 reference. Zero phase sequence of the d-q-0 is ignored here for simplicity. The detection of the sag and Swell is carried out in each of the three phases. Measured terminal voltage is denoted by V_a, V_b,V_c . Voltage detection is carried out when the supply voltage drops below to 90% of the reference voltage while the voltage swell is detected when the supply voltage goes up to 25% of the reference voltage. The error signal from the control is used here as a modulation signal for producing the commutation pattern for the switching the power switches (IGBT's) of the voltage source converter.

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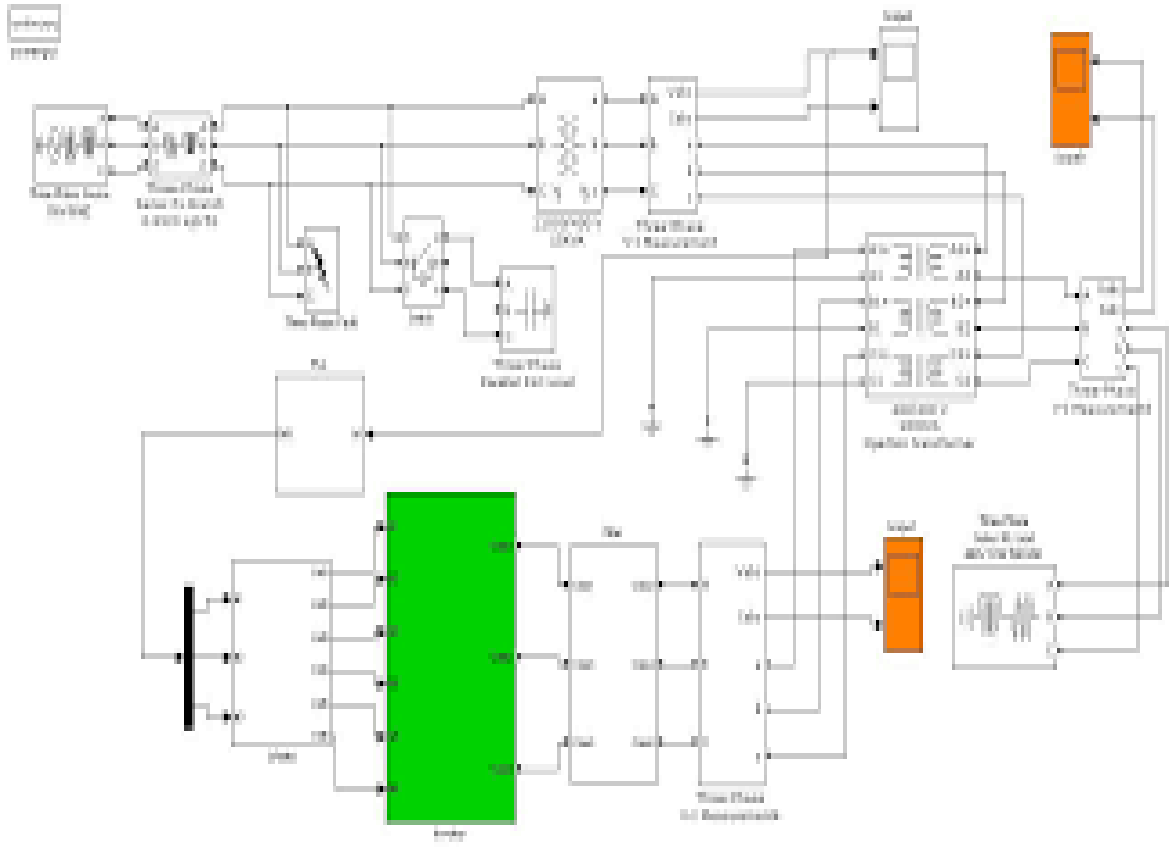

Figure.2: Proposed Simulink Block of SMES based DVR

This commutation pattern is generated with the help of the sinusoidal pulse width modulation method. PLL circuit is used to generate the sinusoidal voltage of unit amplitude and in phase with the line voltage.

2. SIMULATION RESULTS

To validate the proposed technique for implementation of SMES based DVR a MATLAB simulation is carried out. A MATLAB simulation is carried out in following steps for analysis purpose from fig 4.3.2. The first simulation was done without DVR and a three phase fault is applied to the system at point with fault resistance of 0.001ohm and for a time duration for 0.2-0.7 secs The second simulation is carried out at the same scenario as above but based DVR is now introduced at the load side to compensate the voltage sag occurred due to the three phase fault applied.. The working of SMES based DVR for voltage compensation at 0.001Ω fault resistance. The DVR performance in presence of SMES is analysed for symmetrical 3phase fault.

Step1. Generation of voltage sag due a three phase fault in the transmission line without SMES based DVR. Triple line to ground fault.

Step2. Generation of compensating voltage using d − q theory.

Step3. Implementation of SMES based DVR.

Step4. Compensation of voltage sag for type of fault using SMES based technology.

Triple line to ground fault.

In order to carry out the testing of the above mentioned method of DVR, simulation model was designed and developed under the MATLAB environment in SIMULINK. Simulation of the simulink model is carried out in MATLAB.

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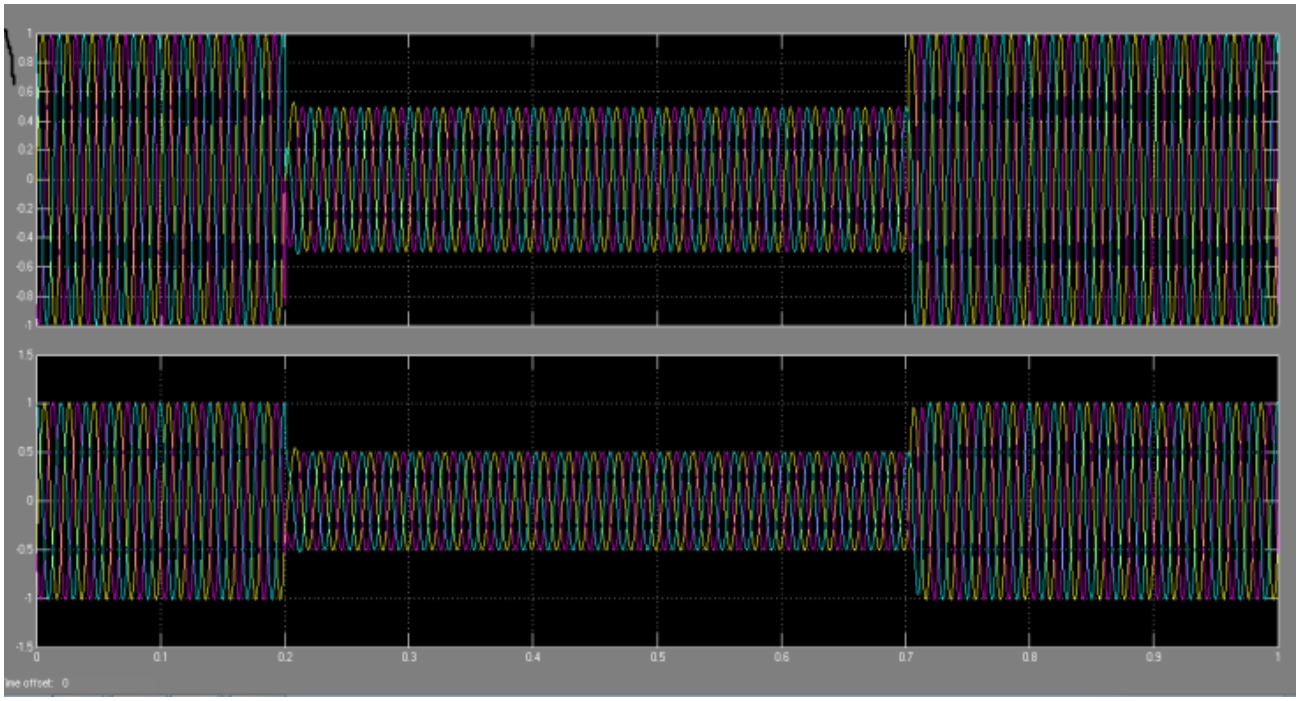

Figure.3: Simulation of three phase load voltage & current without DVR with three phase fault

Fig 3 represents the compensation without DVR with simulated three phase fault using SMES coil as storage coil. Here transition time of 0.2-0.7 seconds of fault occurrence is taken with fault resistance of 0.001 ohm is taken. On occurrence of 3 phase fault the voltage profile of the system reduced from +1 pu to-1 pu then to 0.5 pu to -0.5 pu . Thus reducing the entire voltage profile to 50% of the fault .On removal of three phase fault voltage profile has recovered as system is able to withstand these transients and able to retain its stability.

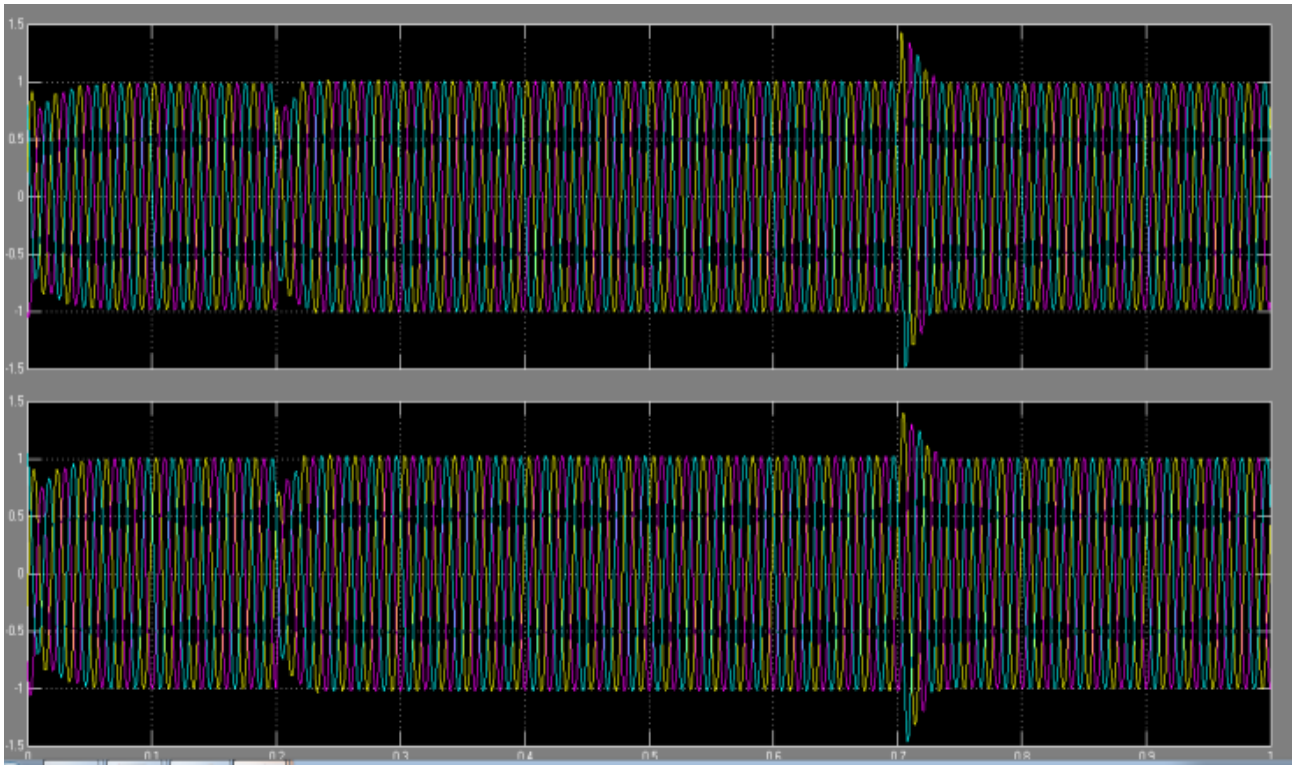

Figure.4: Load Voltage with Compensation using DVR with three phase fault

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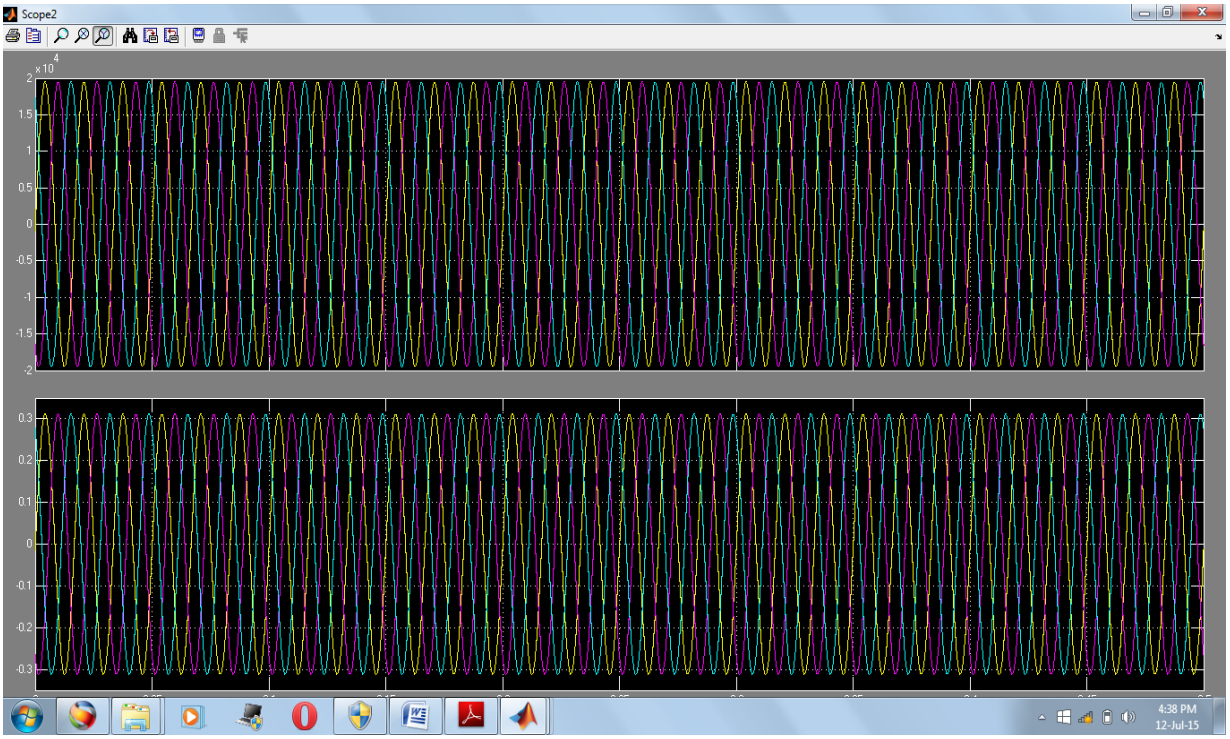

Figure.5: Compensation with DVR without three phase fault from

Fig 5 represents the compensation using DVR without simulated three phase fault using SMES coil as storage coil..Thus the entire voltage profile remain same to 100% (+22 kv to -22 KV) despite DVR remain in standby mode & the injection voltage in place of missing voltage is zero as the entire voltage profile is maintained.

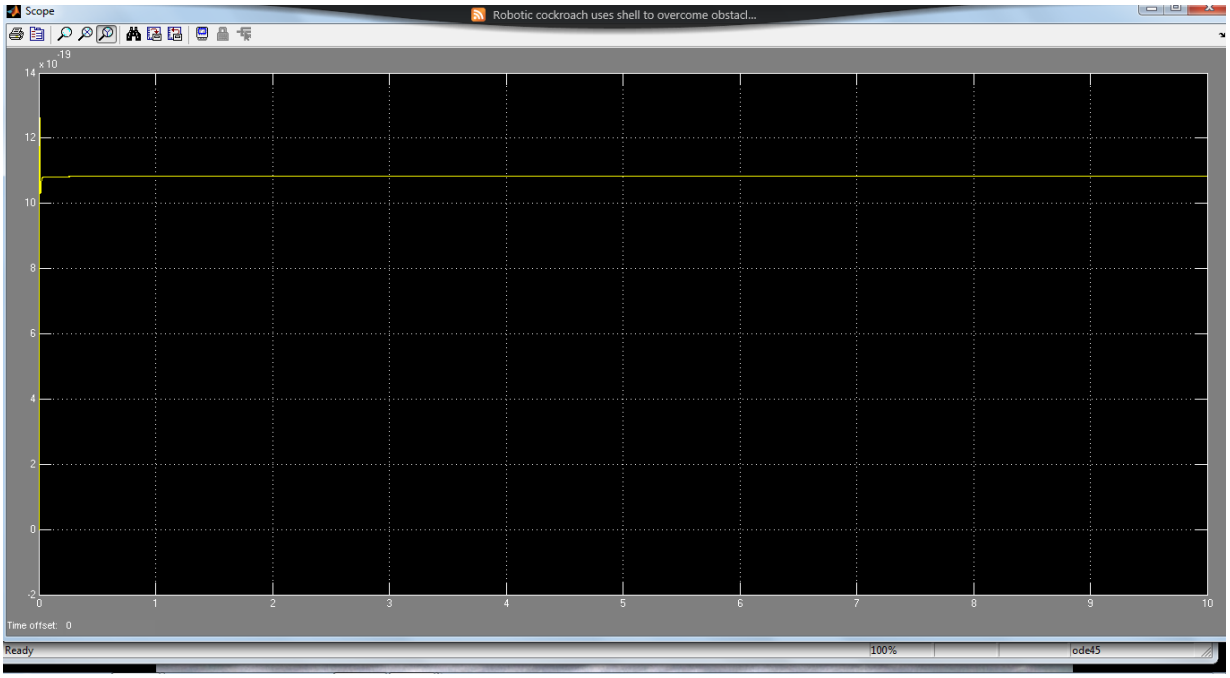

Figure.6: DC Current through SMES coil during standby mode

Figure 6 Represents the DC current flowing through SMES coil during normal mode .The coil having charging and discharging time as 0.3 sec/0.7 sec

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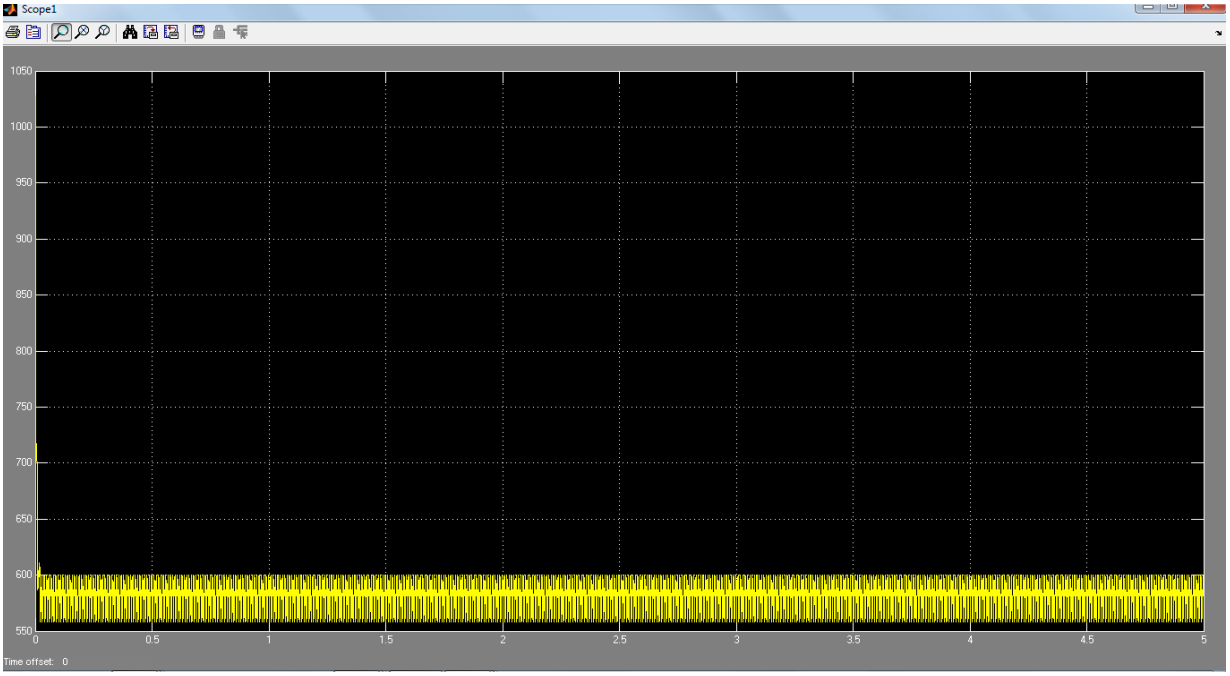

Figure 7 DC link voltage of SMES coil

Figure 7 Represents the DC voltage across capacitor .This is the dc link to link voltage feed to dc-dc chopper is basically a pulsating DC converted into pure DC at chopper output terminal.

3. CONCLUSION

This paper present the SMES (superconducting magnetic energy storage) based dynamic voltage restorer (DVR) for mitigating the voltage sag/Swell in line voltage. In this model SMES is used as a DC storage unit which store the DC energy during the normal mode of DVR operation and at the time of Voltage sag/Swell this SMES unit provide the compensation voltage to the line with the help of Controller. The result obtained from the simulation reveals that this SMES based DVR is able to compensate the voltage sag/Swell during the line faults and at the same time able to give e3xcellent voltage regulation. This SMES based DVR compensate the voltage sag/swell in both balanced and un-balanced load.

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