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Compensation of Power Quality Issues During Fault Condition Using DVR Based On Electric Vehicle Charging System

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Abstract
The paper presents a SESD (Separate Energy Storage Devices) based dynamic voltage restorer, where electric vehicle charging system is the primary source for energisation of DVR. The SESD based DVR protects the distribution lines and the consumer terminal equipments from power quality issues such as voltage sag. Based on the duration of voltage variation (short duration voltage variation and long duration voltage variation) the DVR is energised. For a short term voltage variation a hybrid combination of fuel cell and super capacitor is used. For long term voltage variations, Electric vehicle charging systems is used. This paper analyses the principle and operation of SESD based DVR and designs the output voltage of DVR using MATLAB Simulink version 8 with e3 solver.
Keywords: *SESD- DVR–EV charging systems- PWM inverter- point of common coupling-compensation of voltage variation*

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I. INTRODUCTION

Voltage sag is a short term voltage variation, which is a reduction of fundamental voltage from 0.9p.u – 0.1p.u. for a time period of 0.5 cycles to less than a minute. To solve the voltage sag issues custom power devices are used. In this paper we have discussed about the DVR. DVR (Dynamic Voltage Restorer) a series connected solid state device which injects voltage into the power system in order to compensate the voltage sag occurrence in the load side voltage. DVR is installed between supply and the load end at the point of coupling. DVR is considered as a variable voltage source, which consists of a energy storage system and DC- link, injection transformer, converter, by pass equipment, filter and a control unit. It employs solid state power electronics switches like GTO (Gate Turn on Thyristors) in a Pulse Width Modulation Inverter infrastructure to restore the load side voltage by inject a voltage of required magnitude and frequency when the source voltage is unbalanced or distorted. DVR is capable of absorbing and generating reactive power whereas injecting active power is done by a external energy storage system. In this paper DVR is powered by separately energised storage devices (SESD) which includes a hybrid combination of fuel cells and super capacitors and electric vehicle charging system with PV arrays, which serve as the main source for mitigating severe voltage sags.

II. CONVENTIONAL SYSTEM

The energy storage systems of DVR provide compensation in dynamic nature. Conventional energy storage system includes sources such as battery, SMES (Superconducting magnetic energy storage), super capacitors, flywheel and fuel cells. DVRs are also powered by different hybrid energy storage systems based on the installed load MVA. To compare the efficiency, capabilities and benefits from other energy storage devices four energy which includes pumped hydro energy storage systems, flywheels, batteries and compressed air systems are considered. Pumped hydro energy storage systems generates power by dropping water from the higher elevated points to the water turbines in lower elevated point with a roundtrip efficiency of 60%. It requires reservoirs and due to its huge machineries its responds slowly. Whereas compressed air storage systems releases the compressed air to turn on a combustion turbine which operates on either full off /on condition with efficiency of about 70%. Battery store energy in electrochemical form and has an efficiency of about 80%, due to chemical kinetics handling for long term is not possible and may be hazardous when not disposed with proper care. In flywheel system, the charging and discharging of high power require high torque for the rotations. Flywheel and super capacitors have less power and energy ratings and thus they cannot be used for high power applications and during severe voltage sags. In-order to overcome this limitation, hybrid combination of super capacitor and fuel cells are used for short range of voltage sags and EV charging system is used to power the DVR for long duration voltage sags.

III. PROPOSED SYSTEM

SESD BASED DVR

The proposed system consists of a hybrid combination of fuel cells and super capacitors and electric vehicle charging systems with integration of PV arrays for energising the DVR. Based on the duration of voltage variation the selection of energy storage/source is being chosen by means of a decision making switch which involves power electronic switches and timer for the determination of duration of voltage variation.

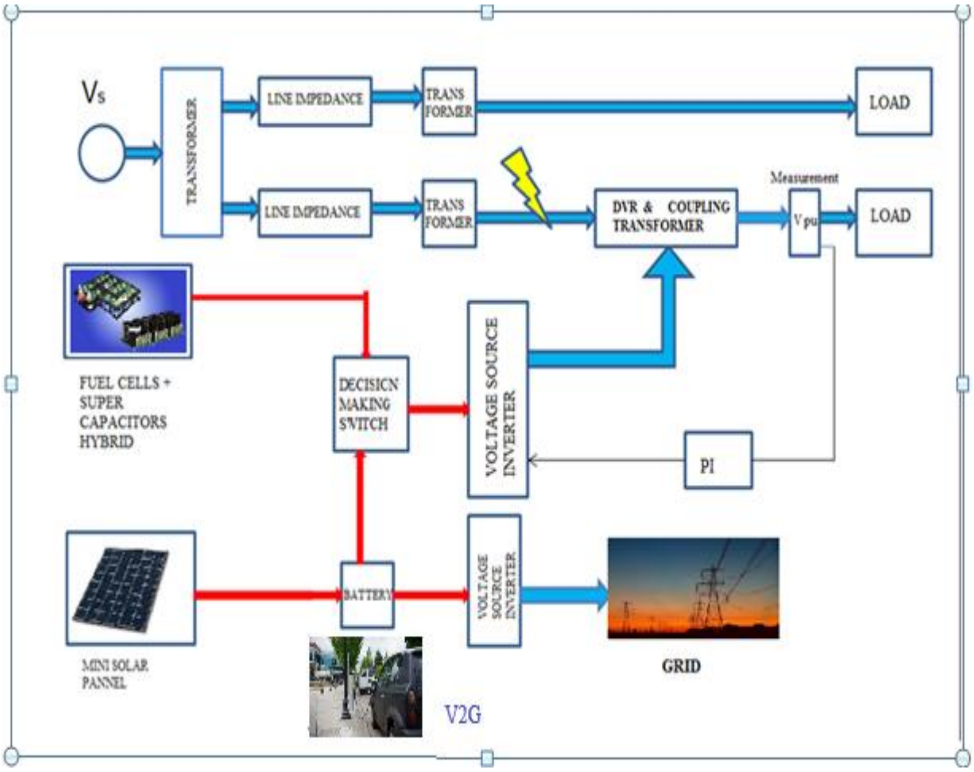

Figure 1: Block diagram for proposed system

Bidirectional Isolated DC-DC converter for Hybrid system.

A converter system has to be capable of harvesting power from two different power sources efficiently for wide input voltage ranges and load condition. Many configurations of hybrid DC power system related to FC's and SC's are available. In this paper we have considered a simple configuration by paralleling FC's and SC's directly as a single power source. The BHB structure of the converter is located on the primary side of the transformer T1(Figure II) which is associated with switches S1 and S2 that works on 50% duty cycle. The Super capacitor bank is an auxiliary energy storage system is connected on the LV side of DC bus winding across capacitance C1 and C2. Switches S3 and S4 are controlled by duty cycles to reduce current stress and AC RMS value. To avoid saturation of transformer, caused by asymmetric operation of full bridge, a DC blocking capacitor is added in series with primary winding of the Transformer T2. A voltage divider is used in secondary winding of the winding to enhance the voltage conversion ratio.

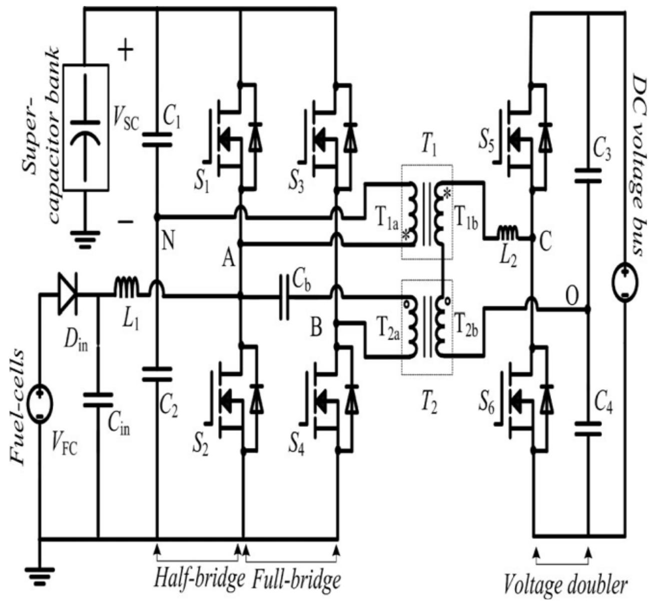

Figure 2: Proposed hybrid bidirectional dc–dc converter topology

Based on the direction of power flow proposed converter has three modes of operation. The three modes of operation are Boost mode, SC power mode and SC recharge mode. In boost mode, power is delivered from the SC's and FC's to the DC voltage bus. In SC power mode, only SC's are connected to the system. In SC recharge mode, power flow is reversed, where it flows from HV side to HV side, so the SC is in recharging mode

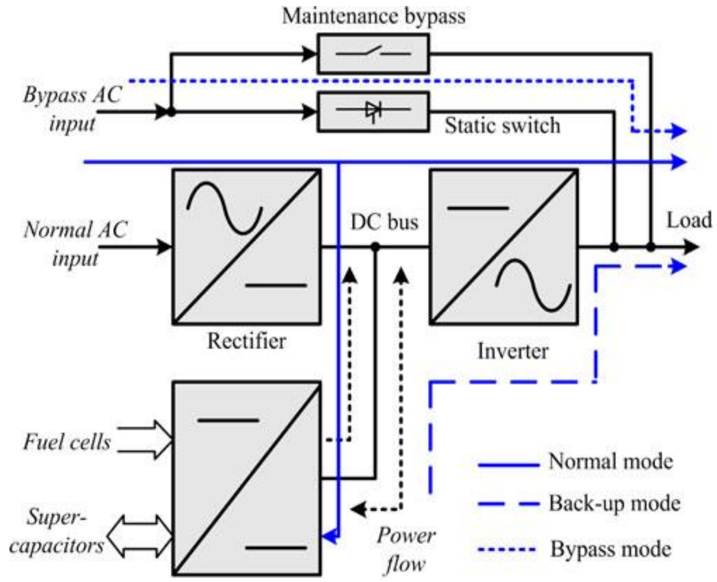

Figure 3: Block diagram of a dual-conversion UPS system based on FC and SC

Integration of SESD with DVR

A discrete PWM based control scheme is used to mitigate the simulated voltage sag in practical application. The control scheme aims on maintaining a constant magnitude of voltage at the load point in case of system disturbance.

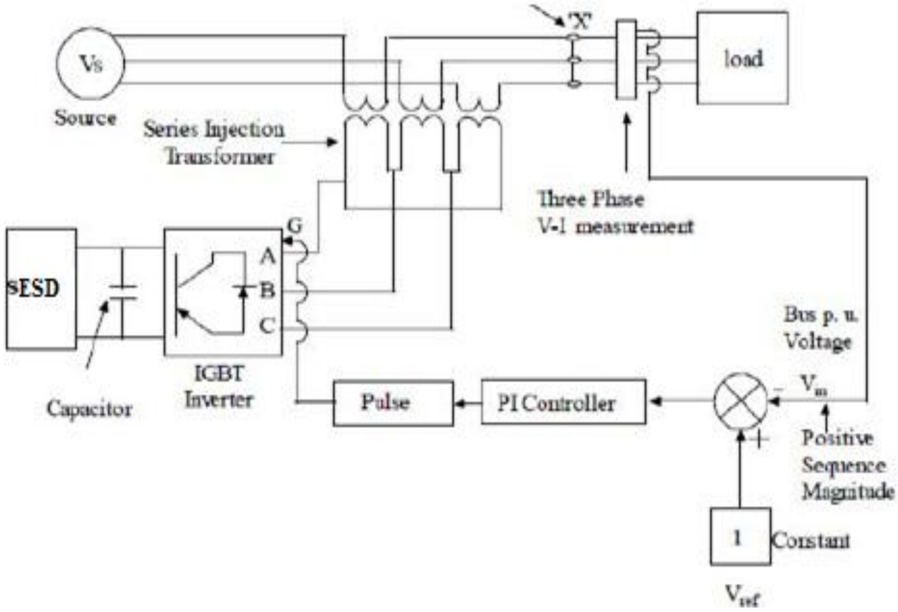

Figure 4: Integration of SESD with DVR

A three phase fault creates voltage sag as shown in the figure 4. The load voltage is converted into p.u. quantity. The Error signal is fed to PI controller after comparison with the reference voltage (Vref) and then it is fed to the triggering circuit.

IV. RESULTS AND DISCUSSION

Simulation 1 : **Analysing the Output voltage of Hybrid System**
Simulation Data:
Fuel cell stack-1.26kw,24vdc
No of cells-41
Flow of hydrogen level-85
Fuel cell output-30v
Super capacitor-22e-6,60v
Linear transformer (2e3 VA,100e3Hz)
N1 10v-400v N2
N11 10v-200v N22
Output of hybrid system-500v
Simulation II : **Fault Time Interpretation**
Simulation Data
Generation – 13KV
Transmission – 115KV
Distribution – 11KV & 500V
Line parameters
R – 0.001 ohm , L – 0.005 H
Load
R – 1500 ohm , L – 0.01 H
Frequency – 50 Hz
Transformer Rating – 250 MVA & Y/ Delta
Fault time – 0.2 to 0.28 & 0.4 to 0.7 sec

Simulation III-short term Voltage variation mitigation
Simulation Data
DVR (linear transformer)
power rating – 19.5 MVA
Primary voltage – 735 KV
secondary voltage – 315 KV
Breaker

T1 – (close) open time = fault time

T2 – (open) close time = fault time

PI controller

Proportional gain – 0.5

integral gain – 50

Discrete PWM Generator

carrier frequency - 1080 Hz

Simulation IV- long term and short term Voltage mitigation

Simulation Data

Grid

supply – 120KV

load – 30MW , 2MW , 2MVA

transmission line – 14Km + 5 Km

VSC control based converter

Power – 100KVA

Frequency– 50 Hz

primary – 25KV

secondary – 260V

DC – 500V

Rxfo=.002ohm

Lxfo=.06H

R=2e-3Ω

L=250e-6H

Vdc gain – Kp=7

Ki=800

Current gain – Kp=0.3

Ki=20.

Simulation I Results

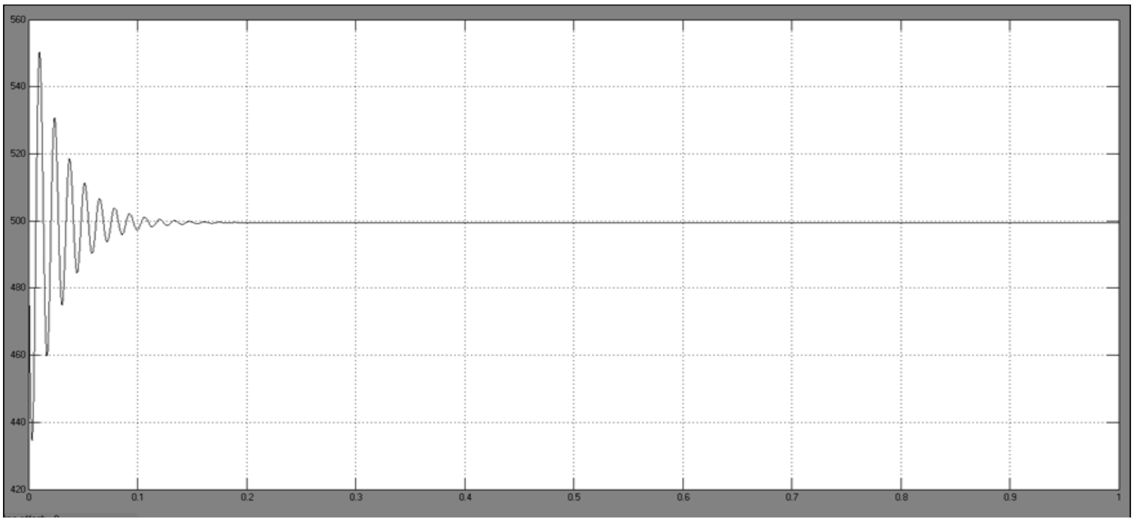

Figure 5.1: Simulation of output of the fuel stack cells

Simulation II Results

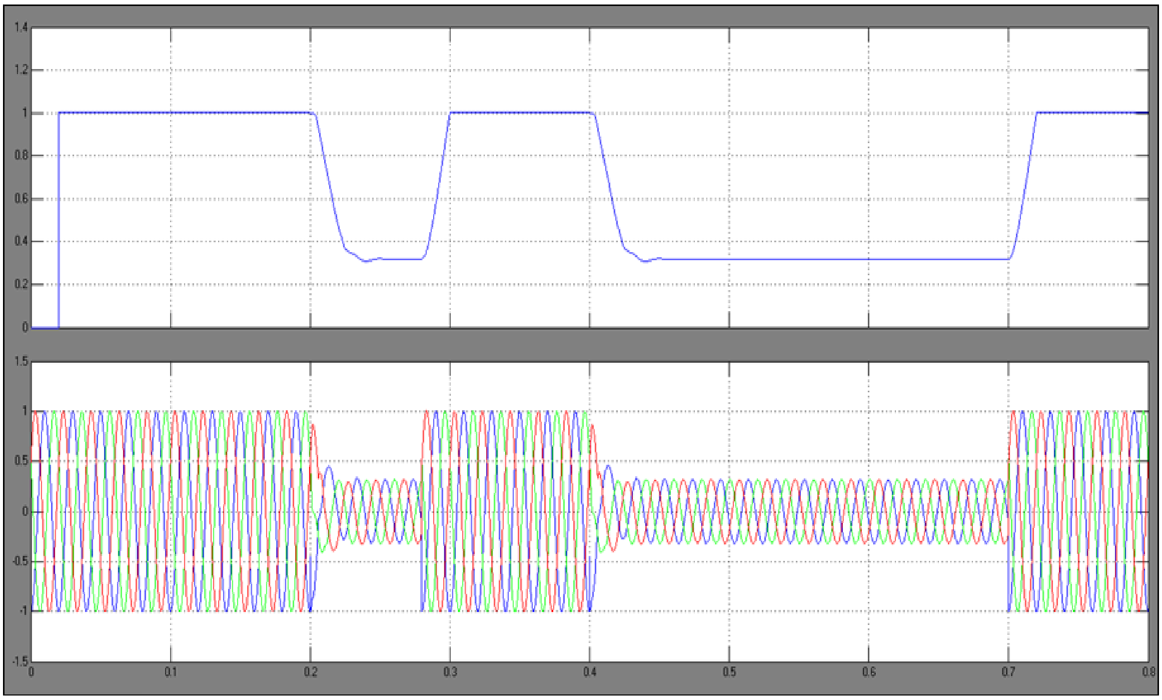

Figure5.2: Simulation of interpretation of fault time

Simulation III Result

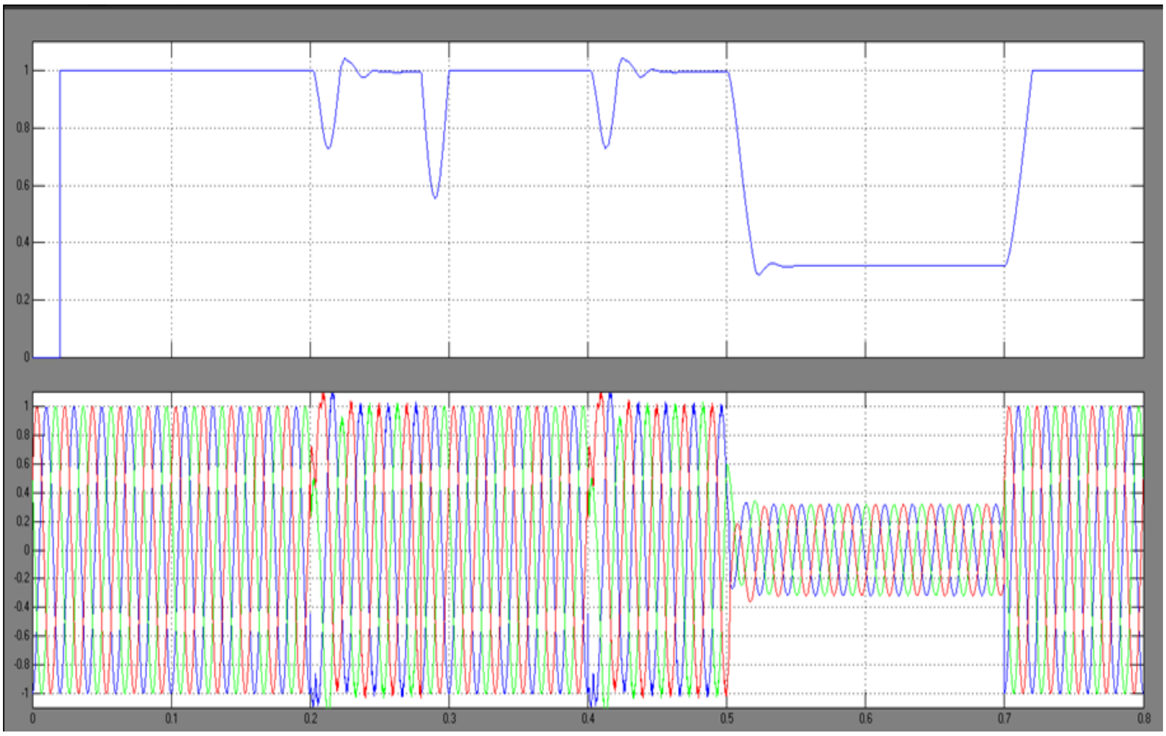

Figure 5.3: Simulation of short term voltage variation mitigation

Simulation IV Result

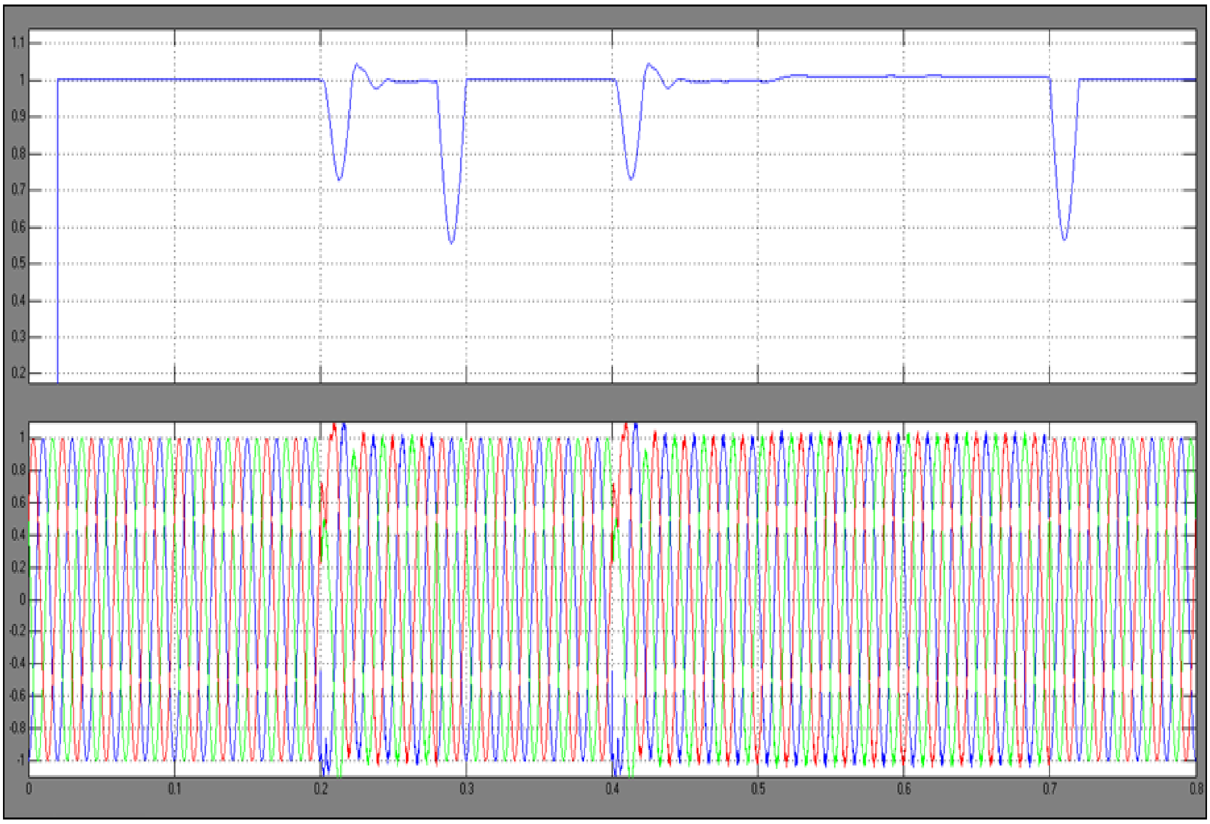

Figure 5.4: Simulation of long term and short term Voltage mitigation

V. CONCLUSION

The power quality problems such as short and long term voltage variations are discussed in this project and Compensation techniques using custom power electronic devices are presented. Dynamic Voltage Restorer (DVR) comprises of PWM based PI controller which is are emerging device used in general for power quality improvement. Hence in this work, a compensation technique is arrived by mainly use of DVR and SESD. A new design which incorporates a SESD module as a DC voltage source to mitigation voltage variations and enhances power quality of a distribution system based on DVR is used in this work. The Simulation results prove that the SESD can be a useful DC source for the DVR.

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