ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 7, July 2017

Dynamic Voltage Restorer with a Battery Energy Storage System Using PI Controller

N. Kesava Varma[1], S.V.R Lakshmi Kumari[2]

PG Student [PSEG], Dept. of EEE, V.R.S.E.C, Vijayawada, India[1]

Associate Professor, Dept. of EEE, V.R.S.E.C, Vijayawada, India[2]

ABSTRACT: Power Quality is an occurrence as a non-accurate current, voltage or frequency that creates a failure in or mal operation of end user equipment. Power Quality problems include voltage sags, swells, momentary disruptions, spikes, surges and harmonic distortions. Voltage swells and sags are common eventsof power quality problems in electric power systems. A dynamic voltage restorer (DVR) is a series-connected FACTS controller used for mitigatingvoltage sags, swells and also harmonics in power system network. In this paper, the dynamic voltage restorer is operated with a battery energy storage system and compared with the self-supported DVR. SRF theory is used for converting the voltages to the stationary frame from rotating vectors. The mitigation of voltage swell, sag and harmonics using DVR with a battery energy storage system is simulated in MATLAB.

KEYWORDS: Dynamic voltage restorer (DVR), power quality, unit vector, voltage harmonics, voltage sag, voltage swell.

I.INTRODUCTION

In the present-daypower quality problems in distribution systems are addressed in the literature [1]–[6] due to the excessive use of critical equipment pieces and sensitive such as process industries, communication network and precise manufacturing processes. Power quality problems such as swells, sags, transients, and some other distortions for the fundamental waveform of the source voltage effect these equipment pieces. Technologies such as custom power devices are introduced to give protection against power quality problems [2]. FACTS devices are mainly three categories, they are series-connected compensators known as dynamic voltagerestorers (DVRs), shunt-connected compensators such as distributed staticcompensators, a combination of seriesandshunt-connected compensators known as UPFC and a combination of series-series connected compensators known as IPFC. The Dynamic Voltage Regulator can regulate the load side voltage from the faults such as swell, sag, and harmonics in the supply voltages. Hence, it can cover the critical customer loads from tripping and frequent losses [2]. The FACTS devices are introduced and installed at customer point to reach the electric power quality standards such as IEEE-519 [7]. Voltage sags in an electrical power system are not always possible to be avoided because of the finite clearing time of the faults that causes the voltage sags and the production of sags from the transmission and also distribution systems to the low voltage loads. Voltage sags are common problemsfor interrupting in producing plants and also for end-user apparatus mis-operation in general. particularly, tripping of the end-user equipment in a production line could cause production interruption and significant prices due to the loss of generation. One answer to this fault is to do the equipment itself more tolerant to sags, either by bettercontrol or by keeping “ride-through” energy in the apparatus. another solvingmethod, instead of correcting each equipment in a plant to be withstand against the problem voltage sags areto use a plantwide uninterruptible electric power supply system for thelongest periodspower interruptions or a DVRon incoming supply to mitigatevoltage sags for short durations [3]–[4]. DVRs can remove most of the sags and decrease the risk of load tripping for the deepest sags, but their main disadvantages are their standby losses, the equipment price, and also the protectablescheme needed for downstream short circuits. Many solving techniques and their disadvantages using DVR are showed, they are voltages in a three-phase electric power system are to be balanced [8] and also an energy-optimized DVR is studied in [6].

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 7, July 2017

II. OPERATION OF DVR

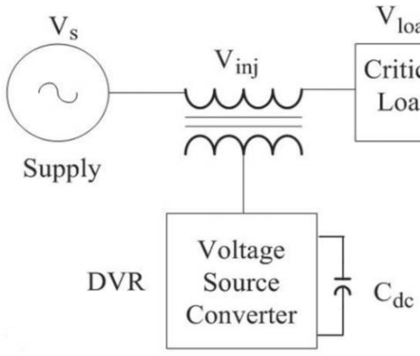

Fig. 1. Basic circuit of DVR.

The figure of a DVR connected system is shown in Fig. 1. $V_{inj}$is the inserted voltage of the DVR then the load voltage V_{load} is to be maintained same magnitude and is not distorted, even though the supply voltage $V_s$is not to be maintained constant magnitude or is distorted.Fig. 2. Showsa figure of a three-phase DVR connected to rebuild the voltage of three-phase load. A three-phase supply is connected critical and sensitive load through a three-phase series transformer. the supply of phase A V_{Ma} is connected to the (PCC) point of common couplingV_{Sa} through a short-circuit impedance Z_{sa}. The voltage inserted by the DVR in phase A V_{Ca} is that the load voltage $V_{La}$is of same magnitude and not distorted. A three-phase DVR is connected to transmission line to insert a voltage in series using three phase transformers. T_r, $C_r$and $L_r$are represented the filter components used for eliminating the ripples in theinserted voltage. A three-leg VSC with insulated-gate bipolartransistors (IGBTs) is used as a DVR, and a battery is connected to its dc link.

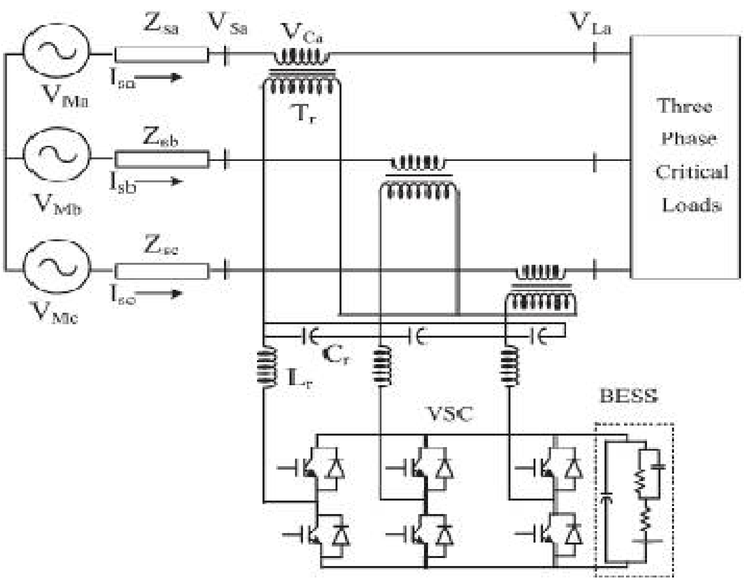

Fig. 2. Schematic of the DVR-connected system

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 7, July 2017

III. CONTROL OF DVR

The mitigation for voltage sags using a DVR can be performed by inserting or absorbing the reactive power or the active power. When the inserted voltage is in quadrature with the current at the fundamental frequency, the compensation is done by inserting reactive power and the Dynamic Voltage Restorer is with a capacitor-supported dc bus. However, if the inserted voltage is same phase with the current, DVR inserts active power, and hence, a battery is needed at the dc bus of the VSC. The control technique considers the limitations, they are the voltage injection capacity (transformer rating and converter) and optimization of the energy storage device.

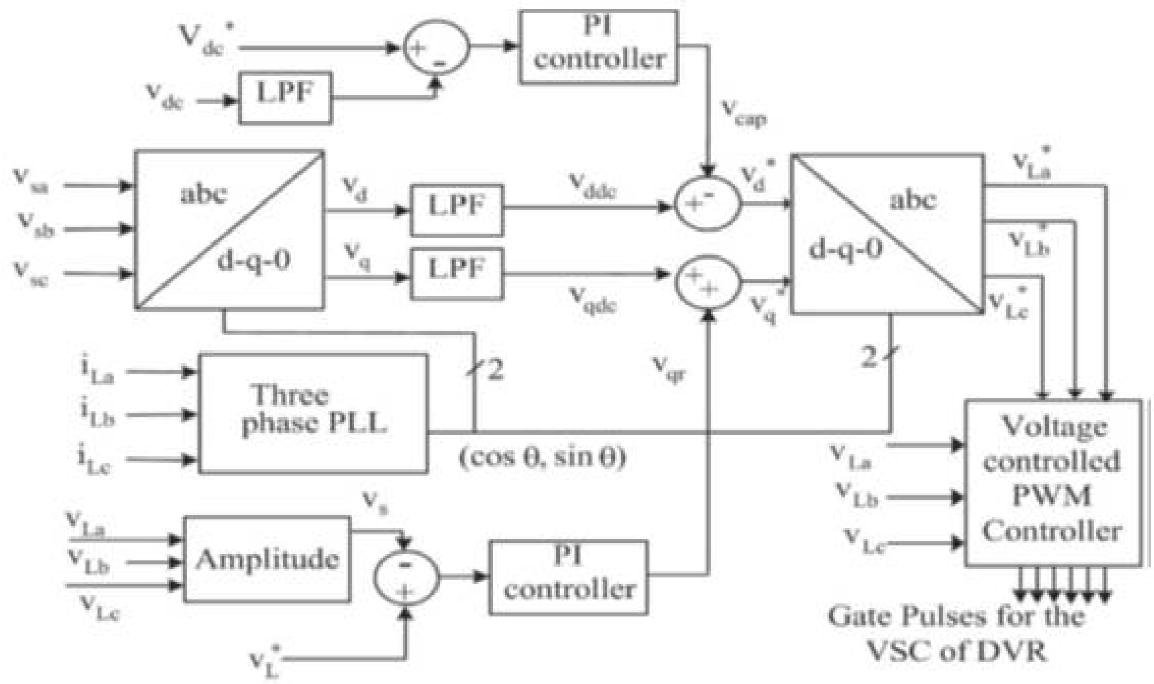

Fig. 3. Control block of the DVR uses SRF method

Fig. 3. shows a control block of the DVRin which the SRF theory is used for reference signal estimation. Voltage at where DVR is connected to the transmission line (PCC) V_s are to be converted to the rotating reference using Park's transformation. The unwanted components and the harmonics of the voltage are removed by using LPFs. The components of voltages in the q-axes and d-axes. The compensating strategy for power quality problems considers that the load voltage should be maintained magnitude and not distorted. To be maintained the dc bus voltage of the DVR and the output voltage $V_{cap}$for reaching its losses. The difference between source voltages in dq0 and capacitor voltage gives reference d-axes load voltage.The load voltages and reference load voltages are given to PI controller and then the output is added to the source voltage in dq0 frame and we will get the output as reference q-axes load voltage and then these reference load voltages are converted to abc frame by using reverse park's transformation the error between sensed load voltages and reference load voltages are given to PWM controller for generating the gating pulses to the VSC of the DVR. The PWM controller has operated with a switching frequency 10 kHz.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 7, July 2017

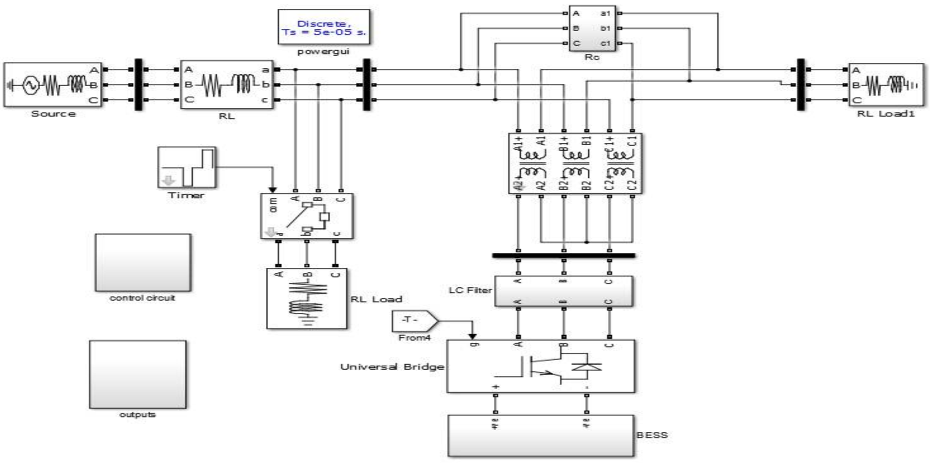

Fig. 4. Simulink Model of battery-supported DVR-connected system

IV. MODELING AND SIMULATION

The DVR connected system consists of a three-phase power supply, three-phase critical loads, and the three-phase series injection transformer shown in Fig. 2 is modeled in MATLAB/Simulink software along with a sim power system toolbox and is shown in Fig. 4. An equivalent load considered is a 10-kVA 0.8-pf lag linear load. The parameters of the considered system for the simulation study are given in the Appendix.The control algorithm for the Dynamic Voltage Restorer shown in Fig. 3 is also modeled in MATLAB software. The reference DVR voltages are obtained from sensed PCC voltages (v_{sa}, v_{sb}, v_{sc}) and load voltages (v_{La}, v_{Lb}, v_{Lc}). A PWMcontroller is used over the reference and sensed DVR voltages to generate the gating signals for the Insulated Gate Bipolar Transistors (IGBTs) of theVSC of the DVR.The capacitor-supported DVRis also modeled and simulated in MATLAB, and the performances of the systems are compared in three conditions of the DVR.

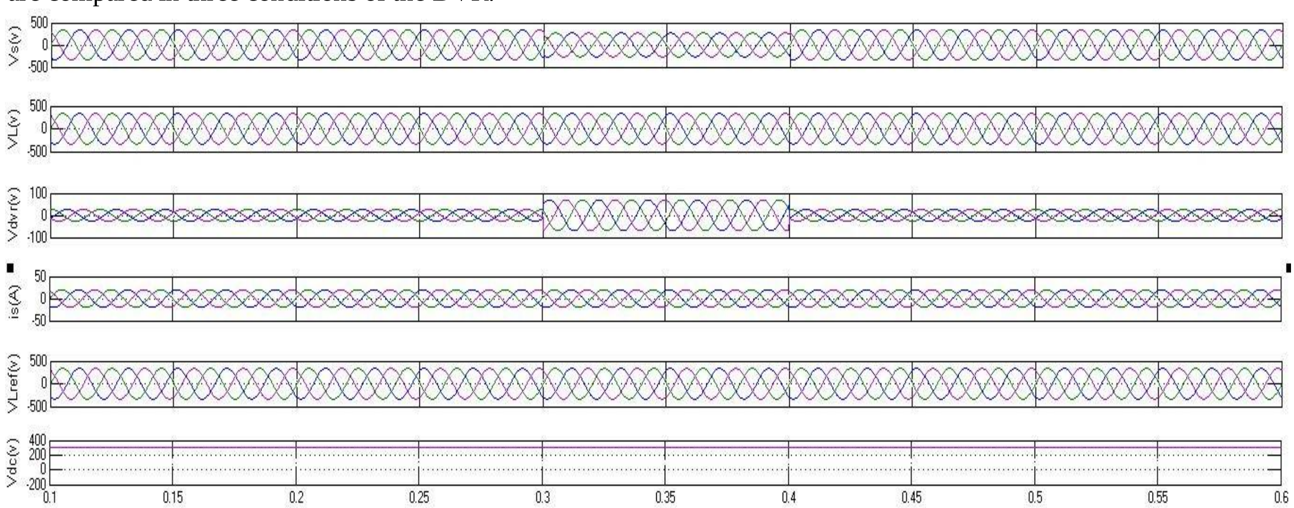

Fig. 5. DVR with battery during voltage sag

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 7, July 2017

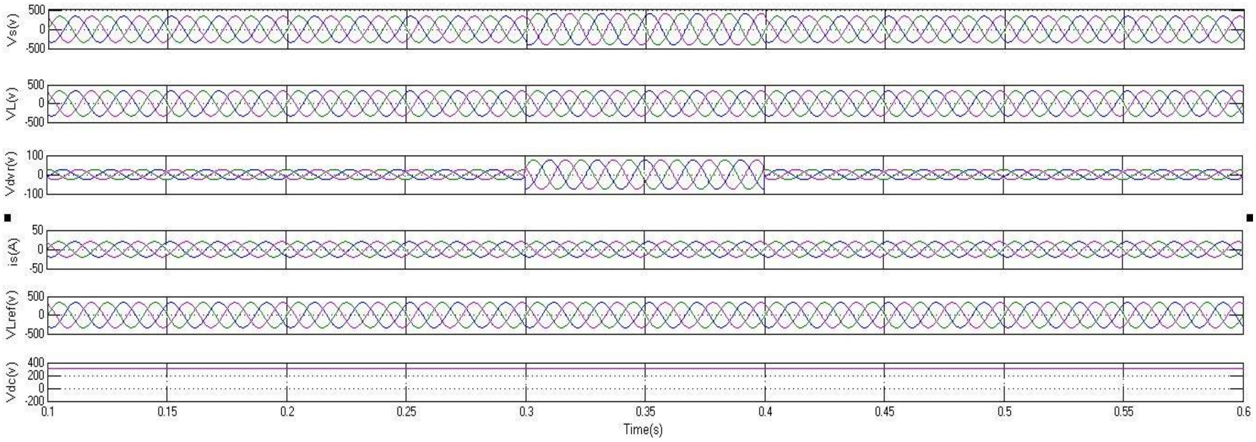

Fig. 6. DVR with battery during voltage swell

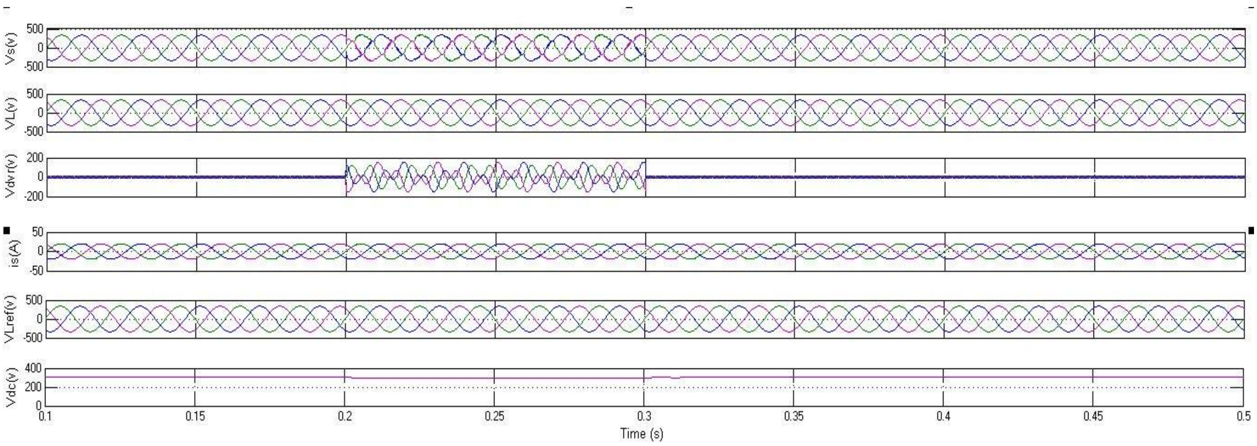

Fig. 7. DVR with battery during harmonics

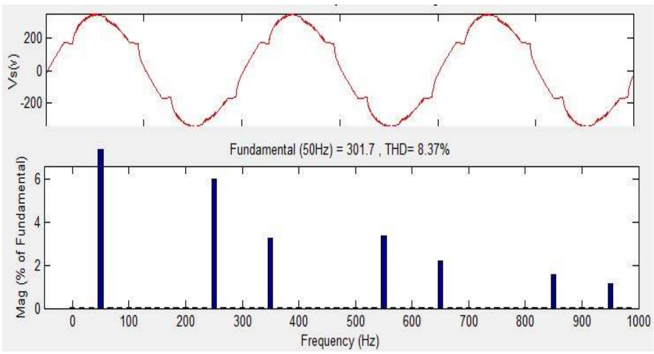

Fig. 8.PCC voltage harmonics during the disturbance

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 7, July 2017

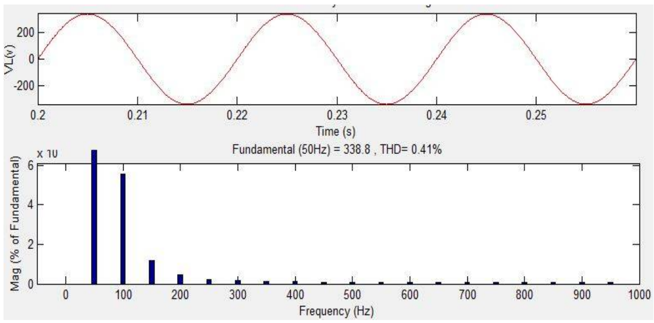

Fig. 9. Load voltage and harmonics during disturbance

V. PERFORMANCE OF THE DVR SYSTEM

The performance of the DVR is simulated in MATLAB software for different supply voltage power quality problems such as voltage swell, sag. Fig. 5. Shows the transient performance of the system under voltage sag condition. At 0.3 s, a sag is applied for 5 cycles and in fig. 6. Shows the performance of the system under swell condition. A swell is applied at 0.3 s for 5 cycles. It is observed that the load voltage maintained same magnitude and undistorted under both sag and swell conditions. load voltages v_L, PCC voltages v_s, source currents is reference load voltages v_{Lref} and dc bus voltages v_{dc} are also depicted in fig. 5&6. The compensation of harmonics in the supply voltages is shown fig. 7. At 0.2 s the supply voltage is distorted and continued for five cycles. After injecting the DVR voltage, the load voltage is maintained at same magnitude and not distorted. The total harmonics distortions (THDs) of the voltages at the PCC and load voltages are shown in fig. 8-9, respectively. It is observed that the load voltage total harmonic distortion is decreased to a level of 0.41% from the PCC voltage of 8.37%.

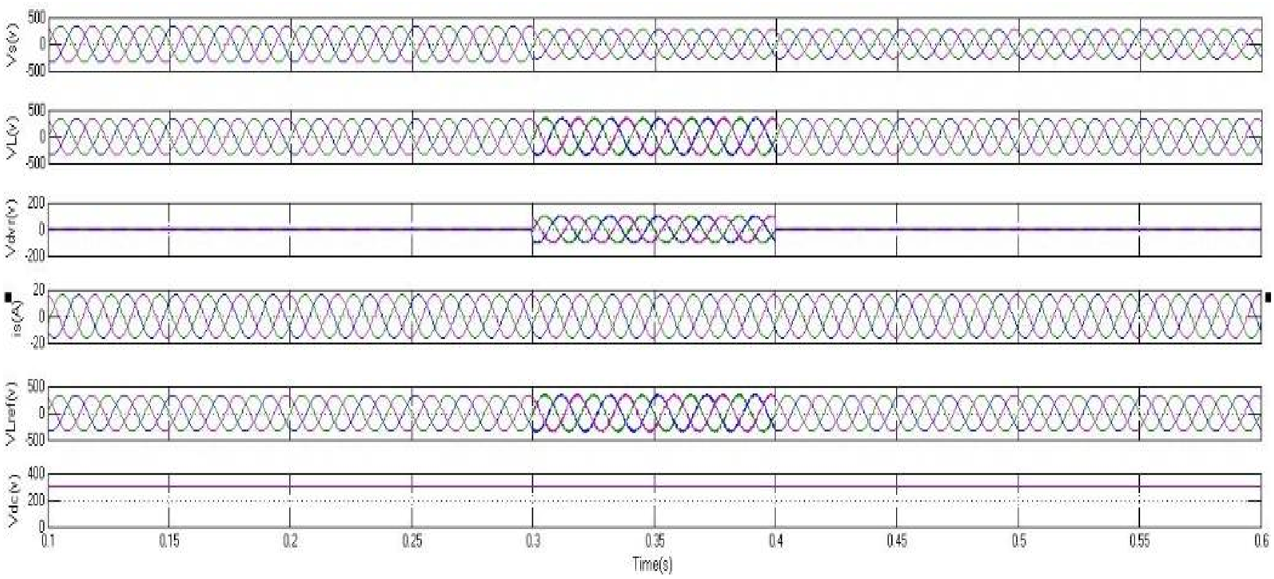

Fig. 10. DVR with capacitor during voltage sag

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 7, July 2017

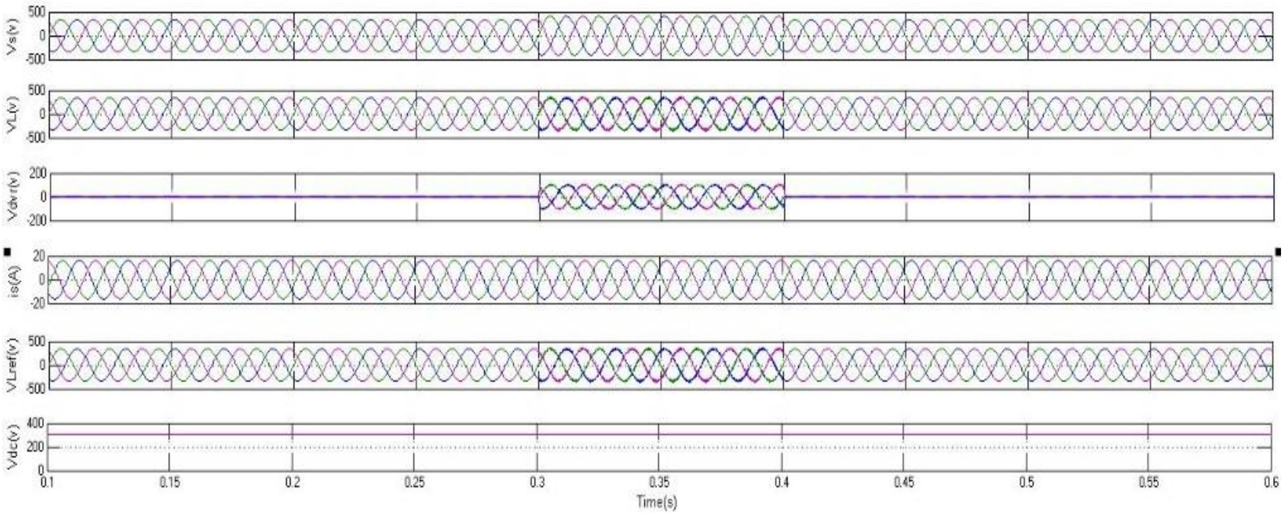

Fig. 11. DVR with capacitor during voltage swell

VI. CONCLUSION

The operation of a DVR has been demonstrated with a battery energy storage system and compared with the capacitor supported DVR. The reference load voltages estimated using the method of unit vectors, Synchronous reference frame theory (SRF) is used for converting the voltages to the stationary frame from rotating vectors. It is concluded that compensation of voltage sag, swell and harmonics using DVR with a battery is show better results compared to capacitor supported Dynamic Voltage Restorer.

APPENDIX

AC line voltage	:	415 V, 50 Hz
Line impedance	:	L_s= 3.0 mH, R_s= 0.01 Ω
Linear loads	:	10-kVA 0.80-pf lag
Ripple filter	:	C_f= 10 μF, R_f= 4.8 Ω
DVR with BESS		
DC voltage of DVR	:	300 V
AC inductor	:	2.0 mH
Gains of the *d*-axis PI controller	:	K_{p1} = 0.5, K_{i1} = 0.35
Gains of the *q*-axis PI controller	:	K_{p2} = 0.5, K_{i2} = 0.35
PWM switching frequency	:	10 kHz
DVR with dc bus capacitor supported		
DC voltage of DVR	:	300 V
AC inductor	:	2.0 mH
DC bus voltage PI controller	:	K_{p1} = 0.5, K_{i1} = 0.35
AC load voltage PI controller	:	$Kp2$ = 0.1, K_{i2} = 0.5
PWM switching frequency	:	10 kHz
Series transformer	:	three-phase transformer of rating 10 kVA, 200V/300 V.

REFERENCES

[1] M. H. J. Bollen, *Understanding Power Quality Problems—Voltage Sags and Interruptions*. New York, NY, USA: IEEE Press, 2000.
[2] A. Ghosh and G. Ledwich, *Power Quality Enhancement Using Custom Power Devices*. London, U.K.: Kluwer, 2002.

[3] M. H. J. Bollen and I. Gu, *Signal Processing of Power Quality Disturbances*. Hoboken, NJ, USA: Wiley-IEEE Press, 2006.[4] R. C. Dugan, M. F. McGranaghan, and H. W. Beaty, *Electric Power Systems Quality*, 2nd ed. New York, NY, USA: McGraw-Hill, 2006.
[4] A. Moreno-Munoz, *Power Quality: Mitigation Technologies in a Distributed Environment*. London, U.K.: Springer-Verlag, 2007.
[5] K. R. Padiyar, *FACTS Controllers in Transmission and Distribution*. New Delhi, India: New Age Int., 2007, *IEEE Recommended Practices and Recommendations for Harmonics Control in Electric Power Systems*, IEEE Std. 519, 1992.
[6] V. B. Bhavraju and P. N. Enjeti, “An active line conditioner to balance voltages in a three phase system,” *IEEE Trans. Ind. Appl.*, vol. 32, no. 2, pp. 287–292, Mar./Apr. 1996.
[7] S. Middlekauff and E. Collins, “System and customer impact,” *IEEE Trans. Power Del.*, vol. 13, no. 1, pp. 278–282, Jan. 1998.