Mitigation of Voltage Sag and Swell Using Battery Based Dynamic Voltage Restorer

J. Bangarraju, V. Rajagopal, A. Jayalaxmi,G.Rohit Kumar and K.R.Mahanth Reddy

Abstract—**This paper describes the mitigation of voltage sag and swell using battery based dynamic voltage restorer (DVR). The DVR is a power electronic based converter that provides three-phase controllable voltage source, whose magnitude of voltage and angle adds/subtracts to the source voltage during sag/swell. The DVR can inject a voltage at fundamental frequency in each phase of required magnitude and phase. The DVR can restore the load voltage within few milliseconds. DVR is a fast and efficient solution to voltage sag and voltage swell problems. The estimation of references voltages are based on Synchronous Reference Frame Theory (SRFT) and gate pulses are generated by sensing the source, load terminal voltages and supply currents. The Mitigation of voltage sag and swell using SRFT for Battery based DVR is simulated by using MATLAB/ SIMULINK and power system Block set (PSB) toolboxes.**

Keywords— **DVR, Voltage Sag and Swell, Power Quality, Voltage harmonics.**

I. Introduction

The power quality problems of distribution systems are effects sensitive loads and critical equipments. However the abundant increase in the use of computers, microprocessors and power electronic systems has resulted in power quality issues voltage sag/ swell, waveform and frequency. Increasing automation in modern industry and deregulation has required the improvement on power quality [1-3].Power quality problem is defined as "Any problem manifested in voltage, current or frequency deviation that results in failure of customer equipment [4-5]. The voltage sags and swells, harmonic distortion, flicker and interruption of power supply are the most common problems. Voltage sags are mainly due to system faults and its magnitude caused by faults depend upon the distance of the fault location from the bus here the sag is measured [6]. The most severe power quality problem based by industrial customers is voltage sag and IEC defines voltage sag as a voltage dip. According to IEE standard 1159 voltage sag is a decrease of rms voltage to a value between 0.1 to 0.9p.u and lasting for duration between 10milli secs to one minute.

J. Bangarraju,V.Rajagopal,
G.Rohit Kumar, K.R.Mahanth Reddy
Padmasri Dr. B. V. Raju Institute of Technology,Narsapur,

A.Jayalaxmi
JNTU College of Engineering,Hyderabad

A voltage swell is defined as an increase between 1.1p.u to 1.8p.u in terminal voltage at the power frequency and lasting for duration between 10milli seconds to one minute. Swells result from energizing large capacitor bank and its magnitude depends on the system impedance, fault location and grounding [7- 9].To mitigate the problems caused by poor quality of power supply the Dynamic Voltage restorer (DVR) is used. DVR is a series connected compensator and its primary application is to compensate for voltage sag and voltage swell. A DVR is connected in series with the non-linear loads to compensate for the harmonics and unbalance in the source voltages and improve the power factor on the source side. The performance of DVR depends on efficient control method used for switching of voltage source converter (VSC). This paper proposes synchronous reference frame theory based control strategy for generation of reference source currents by indirect voltage control of battery based DVR. The battery based DVR is less complex in control and free from dc bus capacitor failure. The utilities and industry provided for more flexibility in system operation and planning when power conditioner added with a battery [10].

II. Principle and operation of DVR

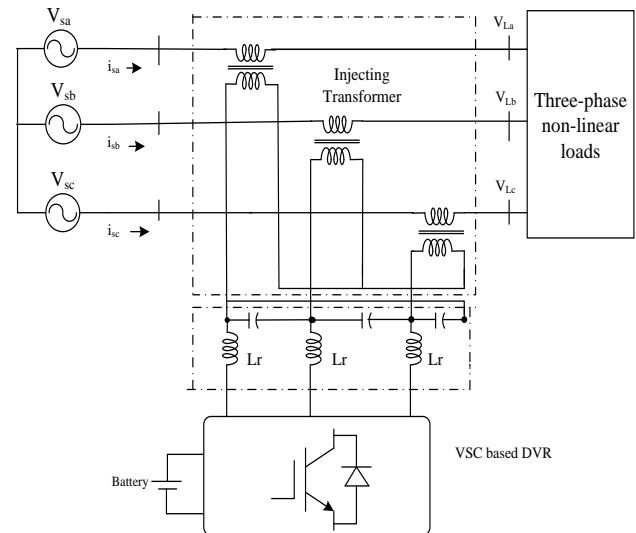Fig.1. shows the basic schematic diagram of three-phase battery based DVR.

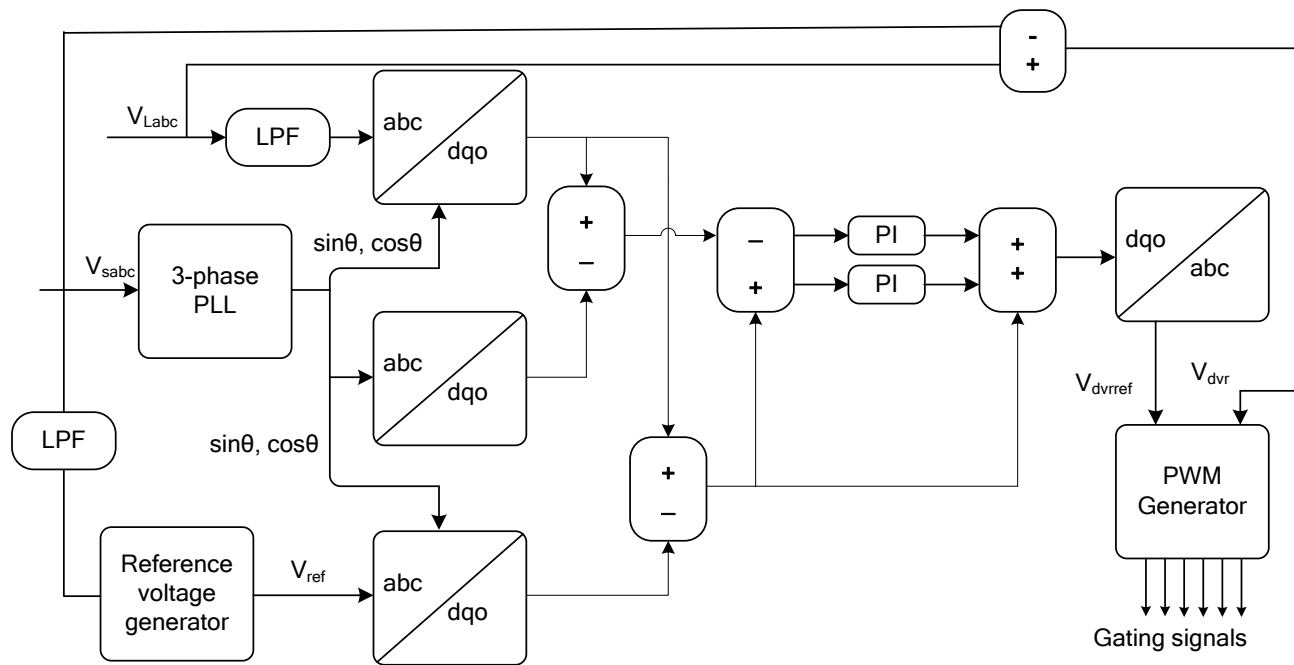Fig.1. Basic schematic diagram of Battery based DVR.

Fig.2. Proposed SRFT Control Algorithm

The DVR is series connected custom power device for power quality improvement and connected between three source and consumer loads by using injection transformer. The main objective of a DVR is to regulate the load bus voltage such that any power disruption to the load in the event of load side voltage disturbance can be avoided. There are many control strategies used to implement DVR for improving power quality. A DVR can also work as harmonic eliminator to prevent the harmonics in the source voltage reaching the load in addition to balancing the voltages and voltage regulation. The DVR consisting of a injection transformer, VSC, battery and control algorithm.

The injection transformer is a three-single phase transformers are connected in series with the distribution feeder to couple the VSC at lower voltage level higher distribution voltage level to boost voltages in series with the load terminal voltages. The VSC consists of three phase, six pulse converter connected in series to provide the required voltage rating. A VSC with a Battery is used instead of capacitor at dc bus of the DVR and disadvantage of using dc capacitor may damage due to high voltage. The series inductor and capacitor is used to reducing the ripples in injected voltage in to lines.   DVR is series connected custom power device for power quality improvement and connected between three source and consumer loads by using injection transformer. your paper as one part of the entire proceedings, and not as an independent document. Please do not revise any of the current designations.

III. **Proposed Control Strategy**

The proposed SRFT control algorithm based DVR is used for harmonic current compensation, load current balancing and power factor correction [11-12].The proposed SRFT control algorithm is shown in Fig.2 for estimation of reference voltages by using parks transformation is used to convert load voltages(v_{La},v_{Lb},v_{Lc}) in to d-q-0

$$v_{Ld} = \frac{2}{3}\left[v_{La}\cos\theta - v_{Lb}\sin\theta + \frac{1}{2}v_{Lc} \right] \tag{1}$$

$$v_{Lq} = \frac{2}{3}\left[v_{La}\cos\left(\theta - \frac{2\pi}{3}\right) - v_{Lb}\sin\left(\theta - \frac{2\pi}{3}\right) + \frac{1}{2}v_{Lc} \right] \tag{2}$$

$$v_{Lo} = \frac{2}{3}\left[v_{La}\cos\left(\theta + \frac{2\pi}{3}\right) + v_{Lb}\sin\left(\theta + \frac{2\pi}{3}\right) + \frac{1}{2}v_{Lc} \right] \tag{3}$$

The feedback load voltages are (v_{La},v_{Lb},v_{Lc}) and source voltages are (v_{Sa}, v_{Sb}, v_{Sc}).To generate sinθ and cosθ components are derived from source voltages by using Phase Locked Loop (PLL). The currents at PCC are synchronized with signals using three phase PLL.The two proportional-integral (PI) controllers used to estimate the in-phase and quadrature components of the injected fundamental voltage to DVR. The harmonic voltage to be injected is estimated from the sensed supply voltage (v_{Sa}, v_{Sb}, v_{Sc}) by extracting the fundamental component (v_{Sa1},v_{Sb1},v_{Sc1}) of it.Two proportional–integral controllers are used for controlling the active and reactive components of DVR voltages. To generate reference voltages are obtained by using Inverse parks transformation.

$$v_{La}^{*} = \left[v_{Ld}\cos\theta + v_{Lq}\sin\theta + v_{Lo} \right] \tag{4}$$

$$v_{Lb}^{*} = \left[v_{Ld}\cos\left(\theta - \frac{2\pi}{3}\right) - v_{Lq}\sin\left(\theta - \frac{2\pi}{3}\right) + v_{Lo} \right] \tag{5}$$

$$v_{Lc}^{*} = \left[v_{Ld}\cos\left(\theta + \frac{2\pi}{3}\right) + v_{Lq}\sin\left(\theta + \frac{2\pi}{3}\right) + v_{Lo} \right] \tag{6}$$

2

The reference voltages on the output of the PI controllers and gating signals are generated from the reference DVR voltages and load voltages.

IV. MATLAB Modeling

The DVR is modeled and simulated using MATLAB/SIMULINK and Power System Block set (PSB) toolboxes. The MATLAB model of the DVR with Battery connected system is shown in Fig. 3. The three phase source is connected to the three phase load considered at lagging power factor through series impedance and the DVR. The six-leg IGBT based VSC is connected to the system using Injection

transformer and ripple filter is connected across the terminals of secondary of the transformer.

V. Results and Discussion

The performance of a DVR based on SRF Theory during voltage sag/swell is shown in Fig.4 and Fig.5. The source voltage is such that the objective of a DVR is to regulate the voltage at the load bus, it remains in stand-by mode during which converter is by passed and the source voltage at its at rated value. At time t = 0.5 s in the Fig. 4, the source voltage is decreased by 50% from its rated value. The DVR compensates
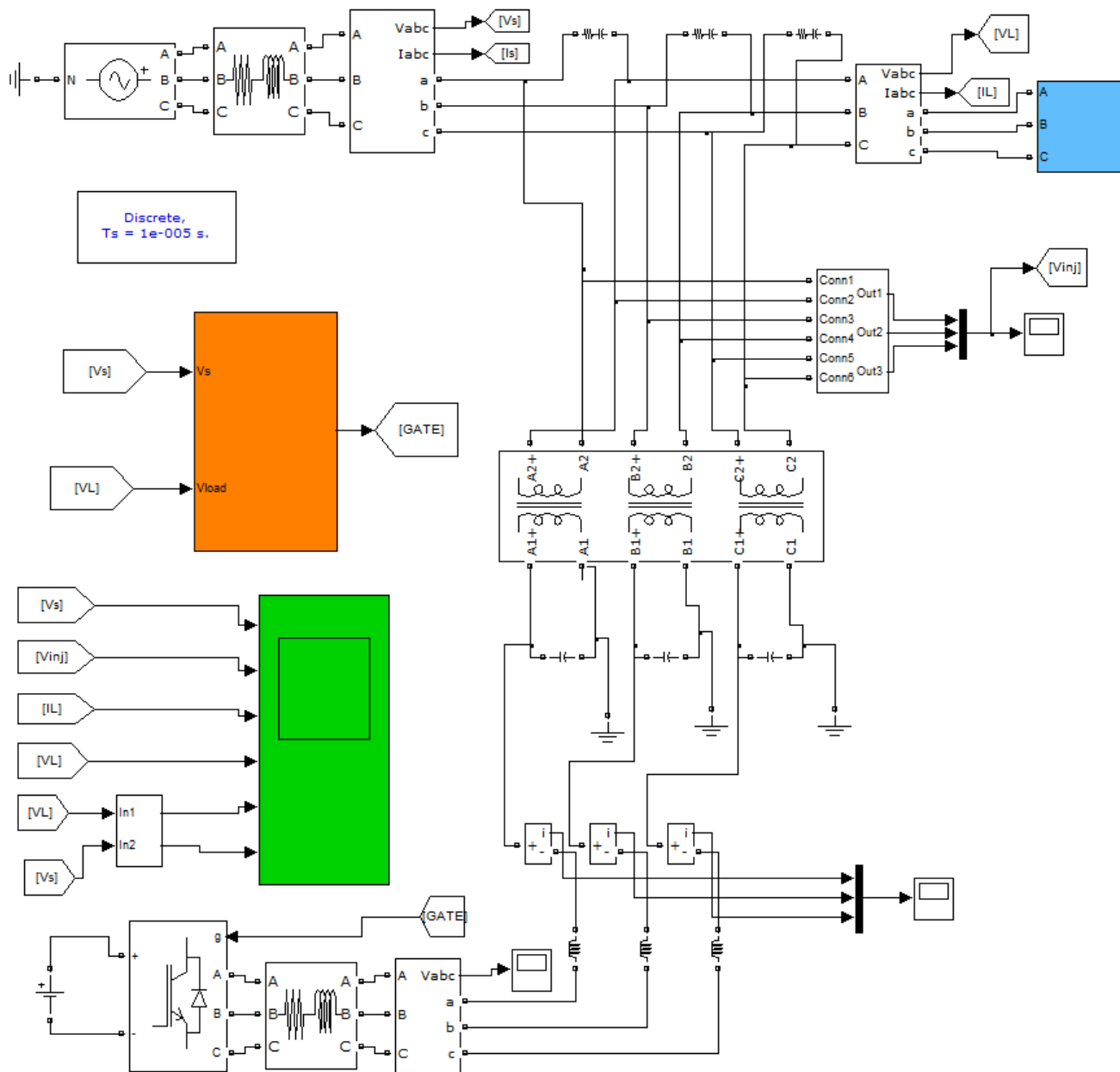

Fig.3. MATLAB based model of Three Phase battery connected DVR.

3

for this voltage increase by injects a voltage of required magnitude. At t = 0.3s in the Fig.5 the source voltage is increased by 50% from its rated value.The DVR compensates for this voltage decrease by injects a voltage of required magnitude. The DVR inject a series voltage of required magnitude to maintain balanced voltages. The results from the system simulation demonstrate the effectiveness of the DVR in providing balanced, sinusoidal voltages at the load bus, even though the supply voltages are unbalanced and contain appreciable harmonics. The results have shown in Fig.4 and Fig.5 shows for voltage sag/swells. It has been observed that even though the load currents are highly non-linear, the load voltage is harmonic free hence the power quality is improved.

VI. **Conclusion**

The performance proposed SRFT control algorithm based DVR to mitigate current harmonics, total harmonic distortion, voltage sag and swells. It has been observed that the load currents are highly non-linear, the load voltage is harmonic free hence the power quality is improved. These SRFT control algorithm based DVR is gives satisfactory results according to IEC and IEE standard.

VII. APPENDIX

The parameters of the system considered as:
Three phase source: Vs=415V,50Hz
Line Impedance: Ls = 1mH, Rs = 0.01Ω
Load: Diode bridge rectifier with RL load on DC link.
Ripple Filter:, Rf=3Ω and Cf = 1.5mF
Interface Inductor Lr = 0.5mH
Battery Voltage = 700V.

References

[1] Math H.J. Bollen, "Understanding Power Quality Problems-   Voltage Sags and Interruptions," Wiley-IEEE Press, 2000.

[2] A. Ghosh and G. Ledwich, "Power Quality Enhancement using Custom Power Devices," Kluwer Academic Publisher, London, 2002.

[3] Math H.J. Bollen and Irene Gu, "Signal Processing of Power Quality Disturbances," Wiley-IEEE Press, 2006.

[4] K. R. Padiyar, "FACTS Controller in Transmission and Distribution," New age International, New Delhi, 2007.

[5] R. C. Dugan, M. F. McGranaghan and H. W. Beaty, "Electric Power systems Quality," New York, McGraw Hill, 1996.

[6] P. Jayaprakash , B. Singh and D. P. Kothari, " Current Mode Control of Dynamic Voltage Restorer for Power Quality Improvement in Distribution System," PECon 2008, IEEE 2nd International.

[7] Rosli Omar and Nasrudin Abd Rahim, "Modeling and Simulation for Voltage Sags/Swells Mitigation using Dynamic Voltage Restorer (DVR)," Australian Univerisities Power Engineering Conference (AUPEC'08) .

[8] R. A. Kantaria, S. K. Joshi and K. R. Siddhapura, "A Novel Technique for Mitigation of Voltage Sag/swell by Dynamic Voltage Restorer (DVR)," IEEE International Conference, 2010.

[9] N. Hingorani, "Introducing Custom Power, " IEEE Spectrum, vol.32, n.6, June 1995; pp. 41-48.I. Papic, P. Zunko, A. Krajnc, D. Povh, M. Weinhold and

[10] R. Zurowski, "300 kW Battery Energy Storage System using an IGBT Converter," Power Engineering Society Summer Meeting, IEEE 1999.

[11] A. Chandra, B. Singh, B.N. Singh and K. AI-Haddad, "An improved control algorithm of shunt active filter for voltage regulation, harmonic elimination, power-factor correction, and balancing of nonlinear loads",

IEEE Trans. on Power Electronics,vol. 15 no. 3, pp 495 –507, May 2000.

[12] S. Bhattacharya and D. Diwan, "Synchronous Frame Based Controller Implementation for a Hybrid Series Active Filter System'', in Proc. of IEEE IAS Meeting I995, pp 2531-2540.
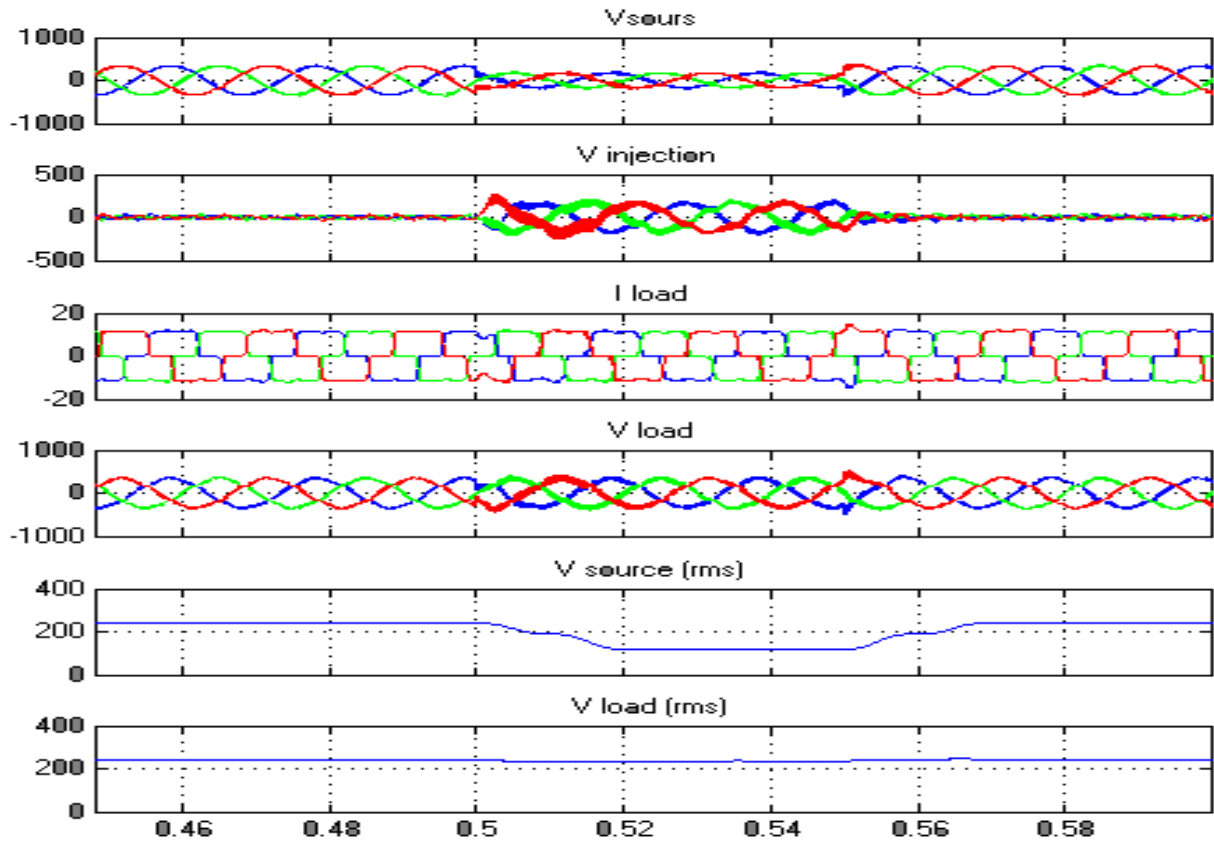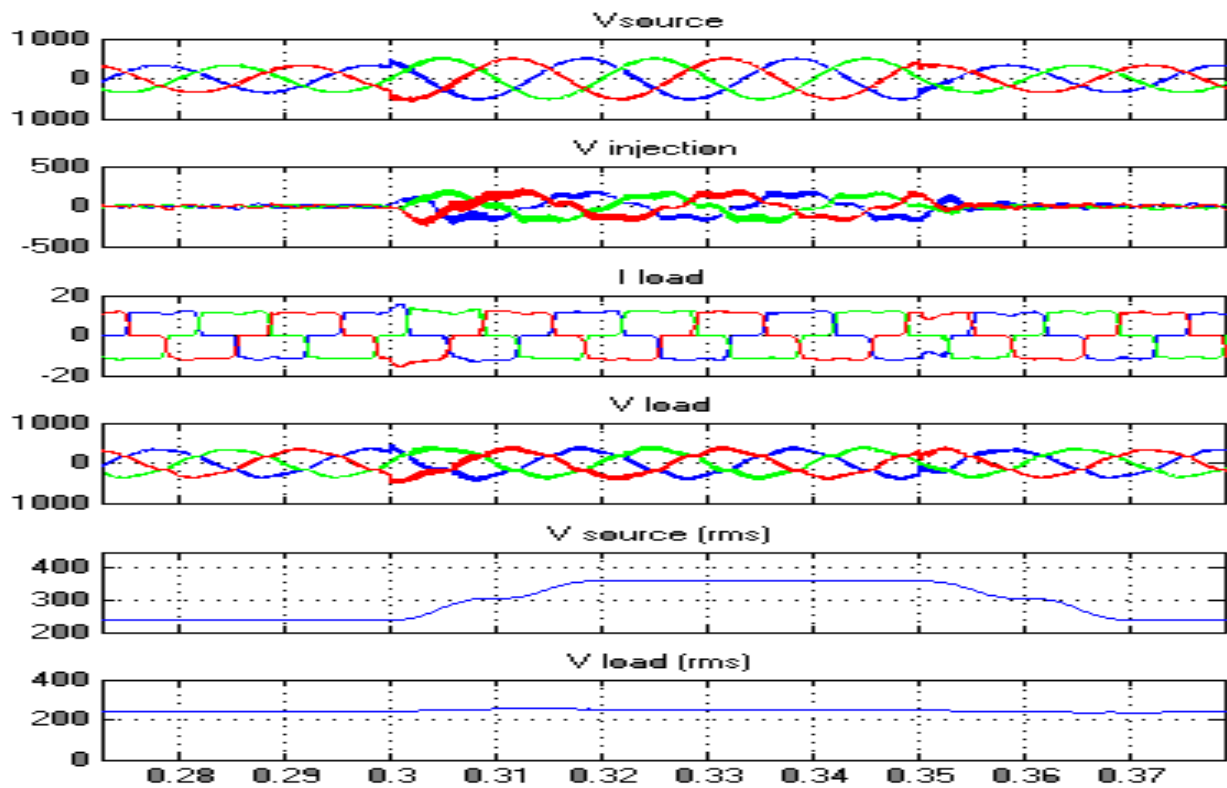
Fig. 4 Performance for DVR with voltage sag

Fig. 5 Performance for DVR with voltage swells