International Journal of Engineering Research
Volume No.4, Issue No.11, pp : 582-585

ISSN:2319-6890)(online),2347-5013(print)
01 Nov. 2015

Performance Analysis of Closed Loop and Open Loop Control Methods in Dynamic Voltage Restorer

Mustafa İnci, Tuğçe Demirdelen, Mehmet Tümay
Çukurova University, Electrical and Electronics Engineering, Adana, Turkey
Corresponding Email: minci@cu.edu.tr

***Abstract:**The most severe power quality problems in electrical systems are called as voltage sag and swell. These power quality problems must be compensated accurately. There are two voltage injection strategies to inject controlled voltage via dynamic voltage restorer (DVR) in electrical systems. This paper compares and examines performance results of two control strategies calles as closed loop and open loop.*

Keywords:Voltage Sag/Swell; Voltage Control Method, Dynamic Voltage Restorer, Review

I. Introduction

Voltage sags and swells are the most common power quality problems in electrical distribution systems. Voltage sag is defined as decrease in the rms value of voltage magnitude. Voltage swell is defined as increment in the rms value of voltage magnitude. Custom power devices are used to compensate these power quality problems in the systems. The most well-known topology is called as dynamic voltage restorer which is located between grid and sensitive load. It injects controlled voltage to keep dc link voltage constant at load-side.

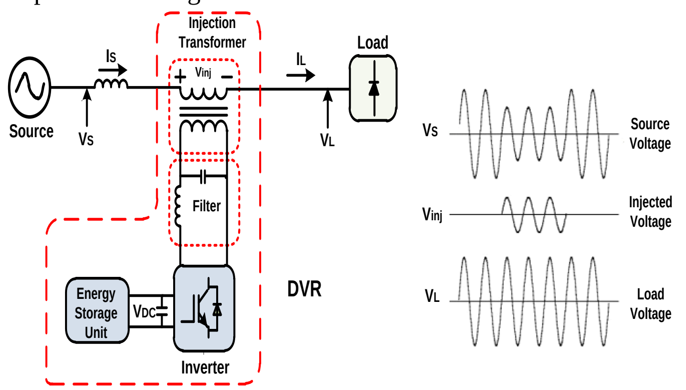

Figure 1. Conventional DVR

The basic structure of DVR is shown in Figure 1. Conventional DVR includes four basic elements: inverter, filter, injection transformer and energy storage unit[1]–[3].

The most important subject in DVR is voltage injection strategy under voltage distortion conditions. There are two methods to inject voltage called as “Closed Loop” and “Open Loop”. In this paper, comparison and performance analysis of two control methods are examined in dynamic voltage restorer.

II. Methodology

Dynamic voltage restorers (DVRs) generate controlled voltage in series to mitigate the impacts of upstream voltage disturbances on sensitive loads. In proposed system, DVR is connected between three phase sources and nonlinear load as shown in Figure 2. DVR is designed using multilevel inverter on medium voltage level system. In proposed system, DVR is connected between three phase sources (11 kVpp) and nonlinear load (1 MVA) as shown in Figure 2. The proposed DVR is designed using 5-level diode clamped multilevel inverters to compensate balanced and unbalanced voltage sags. Conventional SRF based control is implemented to generate PWM signals of solid-state devices used in multilevel inverters. The compensation capability of DVR has a depth up to 30% for three phase balanced voltage sag.

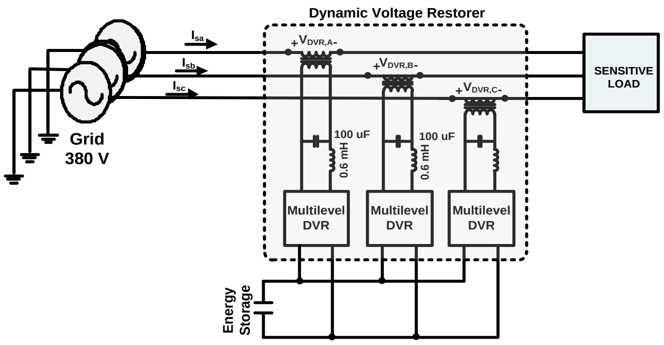

Figure 2. DVR structure

The main components in DVR are inverter and output filter. The inverter generates switched voltages. Output filter is applied to eliminate unwanted components in switched voltages. However, filter causes time delay and resonance problems. Also, components of filter and inverter in DVR generate power losses. This condition influences the magnitude of injected voltage in DVR. Therefore, proper control methods are required to get the output compensation voltage according to a reference value[4]. The accuracy and dynamic operation of DVR is the most important issue to compensate voltage disturbances. Basically, there are two voltage control strategies used in the dynamic voltage restorer: open loop and closed-loop.

Open loop control method has poor dynamic response, uncontrolled and simple structure as shown Figure 3. In this method, the control signal V_i, is simply compared supply voltage against a reference voltage. The another drawback of open loop control strategy is that the steady-state load voltage cannot be compensated to the desired value because of inverter switching losses, voltage drop in injection transformer and output filter[5]–[8].

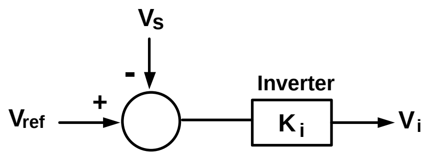

Figure **Ошибка! Текст указанного стиля в документе отсутствует.**. Open loop control method

$$V_i = k_i\left(V_{ref} - V_s\right) \qquad (1)$$

k_i is inverter gain.

ISSN:2319-6890)(online),2347-5013(print)
01 Nov. 2015

Closed loop control is preferred due to its strong dynamic behaviour compared to open loop. The control scheme of closed loop is presented in Figure 4. To track and compensate load voltage smoothly, feedback of load voltage is necessary. If the filter capacitor current is fed back to achieve a sinusoidal capacitor current while an outer voltage loop is used to regulate the output voltage[8]–[10]. A feedforward loop will also be incorporated to improve dynamic response of the load voltage[11]. After a voltage sag/swell is detected, the difference between the reference voltage and measured load voltage is calculated in per unit. The DVR injected voltage feedback (V_l) is compared with its reference (V_{ref}) and the capacitor current(Ic) is used to improve dynamic performance of DVR. Then, the error is used to generate PWM signals.

In closed loop control scheme, two feedback loops are used called as an outer voltage loop and inner current loop. Filter capacitor current is used in the inner current loop. Due to the inherent delay in the feedback loops, additional feedforward loop is added to the control system in order to respond instantaneously for upstream supply voltage disturbances [12]. Figure 4 presents the block diagram representation of closed loop controller in DVR.

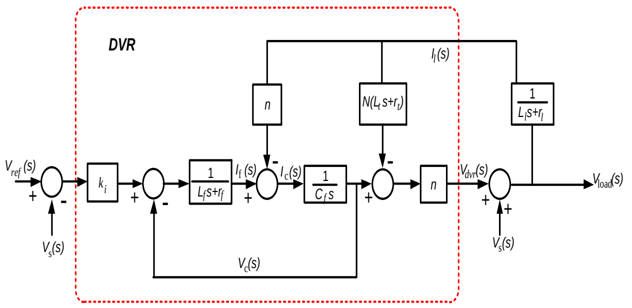

Figure 4. Closed loop control method

The natural damping frequency of closed-loop $\omega_{damping}$,

$$\omega_{damping} = \sqrt{(1+nk_i k_c k_v)}\sqrt{\frac{1}{L_f C_f}} \qquad (1)$$

The natural damping frequency in closed loop system is therefore approximately $\sqrt{(1+nk_i k_c k_v)}$ times filter resonance frequency. The value of LC cutoff frequency is about 300 Hz in open loop control method.

By choosing $n=2, k_i=1, k_v=50, k_c=0.15$ in proposed controller, Figure 4 explains the effect of closed loop method compared to open loop.

II. Results

The proposed DVR model is simulated by PSCAD/EMTDC to compensate voltage sag and voltage swell at the source side. Simulation parameters used in PSCAD/EMTDC are given in Table 1. Parameters of system, load and diode clamped multilevel inverter based DVR are presented in Table 2.

In simulation results, three phase balanced fault occurs. A, B and C phase source voltages decrease to 70% from its nominal value during the period of 0.3-0.4 s. Figure 5 shows the simulation results of source-side, injected and load-side voltages under three-phase to ground fault using open loop and control methods, respectively.

Figure 7 and Figure 8 shows performance results of open loop and closed loop control strategies in DVR, respectively. Closed loop shows better performance than open loop method compared to open loop. Closed loop regulates the output voltage and keeps it constant at the side where a nonlinear load is connected.

Table 1.Modelling parameters

PSCAD/EMTDC Parameters	
Solution Time Step	20 µs
Channel Plot Step	20 µs
Duration of Simulation Run	2 s
System Parameters	
Fundamental Frequency	50 Hz
Voltage Source (V_{S1})	11 kV (L-L, rms), phase angle 0^o

Table 2.DVR parameters

DVR (VSI)	
Compensation Rating	30%
Filter Inductor	1.5 mH
Filter Capacitor	150 uF
Filter Resistance	0.05 ohm
Power Rating	1230 kVA

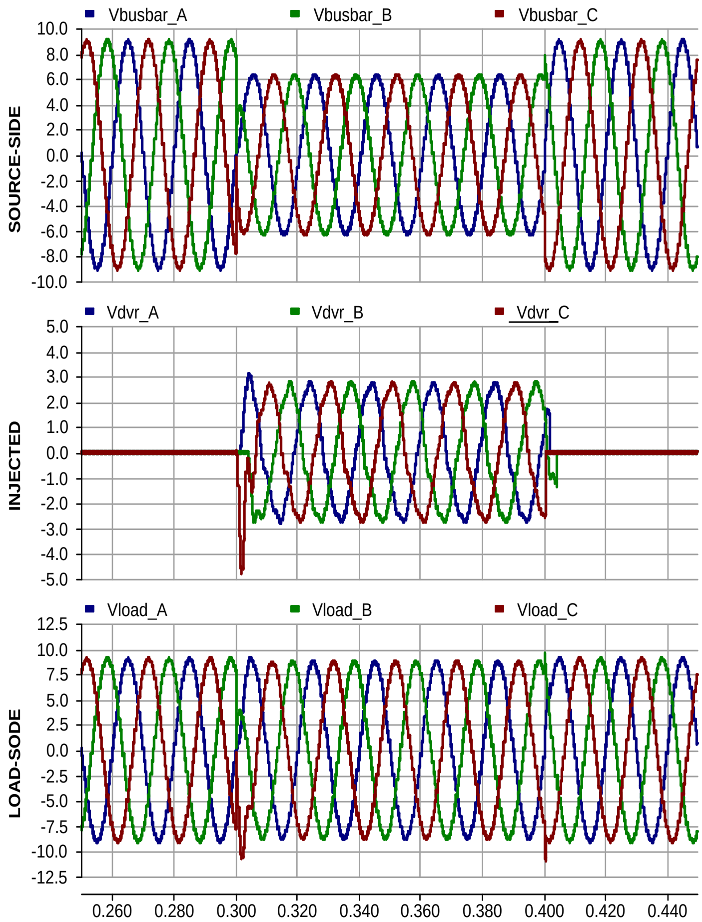

Figure 5. Voltage waveforms of DVR in open loop

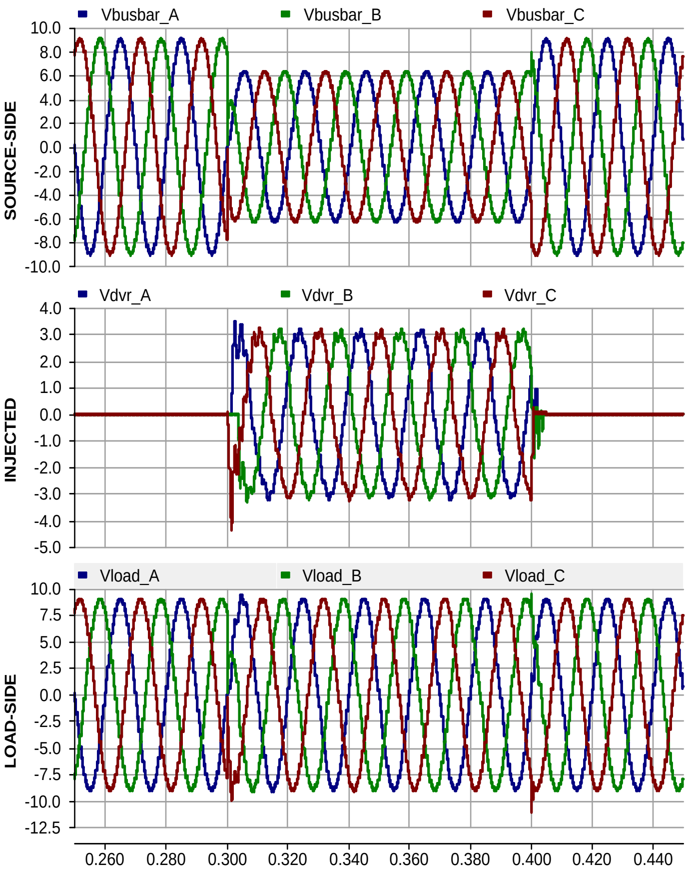

Figure 6. Voltage waveforms of DVR in closed loop

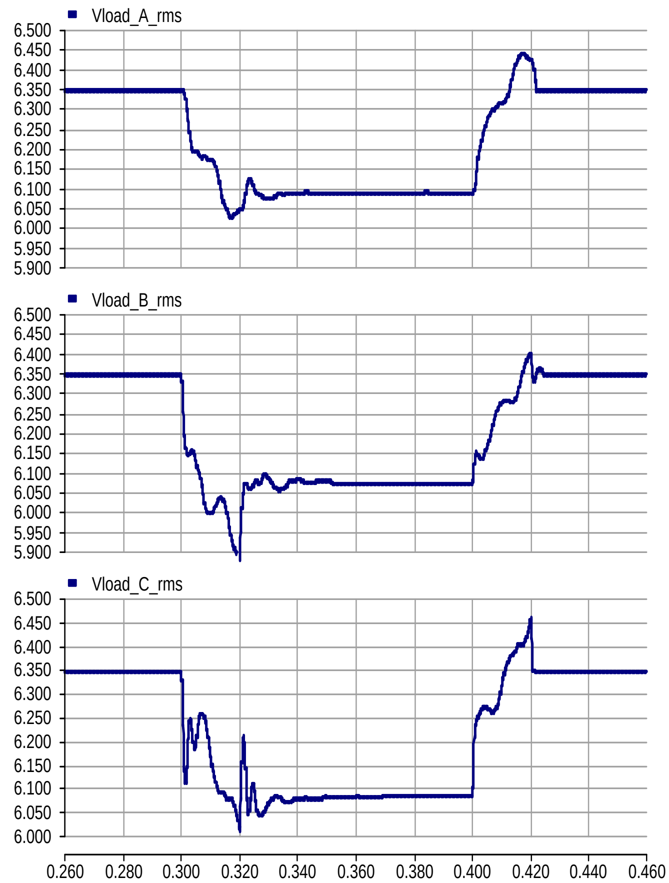

Figure 7. Load side rms values in open loop

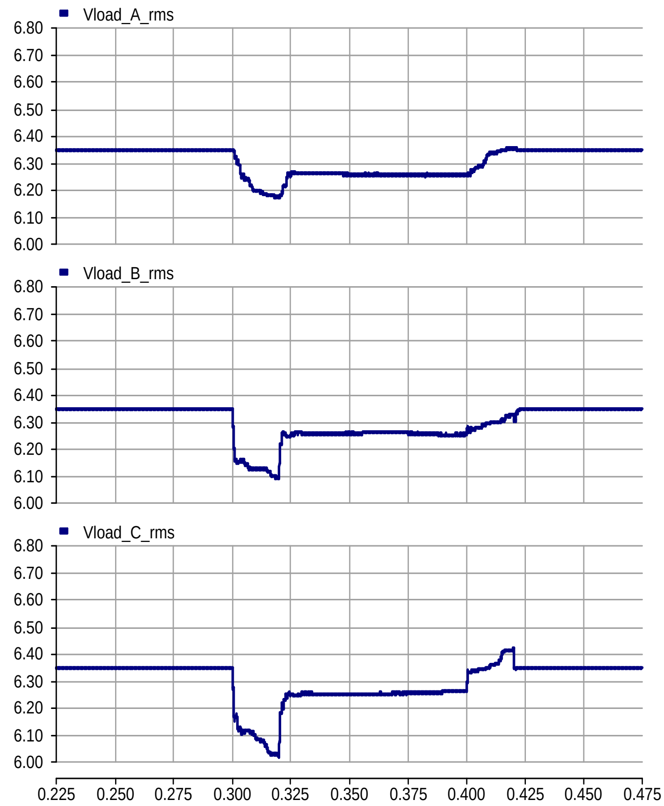

Figure 8. Load side rms values in closed loop

IV. Conclusion

In performance results, closed loop shows better performance than open loop control method. Also, simulation results show the effectiveness of closed loop control method against open loop method. It is clear that injected voltage in close loop has more sinusoidal shape than injected voltage than open loop. Closed loop regulate the output voltage and keeps it constant at the side where a nonlinear load is connected.

References

i. *A. M. Rauf and V. Khadkikar, "An Enhanced Voltage Sag Compensation Scheme for Dynamic Voltage Restorer," IEEE Trans. Ind. Electron., vol. 62, no. 5, pp. 2683–2692, May 2015.*

ii. *Z. Shuai, P. Yao, Z. J. Shen, C. Tu, F. Jiang, and Y. Cheng, "Design Considerations of a Fault Current Limiting Dynamic Voltage Restorer (FCL-DVR)," IEEE Trans. Smart Grid, vol. 6, no. 1, pp. 14–25, Jan. 2015.*

iii. *D. Somayajula, M. L. Crow, and A. P. Stage, "An Integrated Dynamic Voltage Restorer-Ultracapacitor Design for Improving Power Quality of the Distribution Grid," vol. 6, no. 2, pp. 616–624, 2015.*

iv. *H. Kim, S. Sul, S. Member, and A. P. S. Analysis, "Compensation Voltage Control in Dynamic Voltage Restorers by Use of Feed Forward and State Feedback Scheme," vol. 20, no. 5, pp. 1169–1177, 2005.*

v. *K. Ç. Bayindir, A. Teke, and M. Tümay, "A Robust Control of Dynamic Voltage Restorer Using Fuzzy Logic," pp. 0–5, 2007.*

vi. *A. Teke, K. Bayindir, and M. Tümay, "Fast sag/swell detection method for fuzzy logic controlled dynamic voltage restorer," IET Gener. Transm. Distrib., vol. 4, no. 1, p. 1, 2010.*

vii. *F. M. Mahdianpoor, R. A. Hooshmand, and M. Ataei, "A New Approach to Multifunctional Dynamic Voltage Restorer Implementation for Emergency Control in Distribution Systems," IEEE Trans. Power Deliv., vol. 26, no. 2, pp. 882–890, Apr. 2011.*

viii. *Y. W. Li, P. C. Loh, F. Blaabjerg, D. M. Vilathgamuwa, and S. Member, "Investigation and Improvement of Transient Response of DVR at Medium Voltage Level," vol. 43, no. 5, pp. 1309–1319, 2007.*

ix. *R. Gupta, A. Ghosh, and A. Joshi, "Performance Comparison of VSC-Based Shunt and Series Compensators Used for Load Voltage Control in Distribution Systems," IEEE Trans. Power Deliv., vol. 26, no. 1, pp. 268–278, Jan. 2011.*

x. *P. Roncero-sánchez, E. Acha, and S. Member, "Dynamic Voltage Restorer Based on Flying Capacitor Multilevel Converters Operated by Repetitive Control," vol. 24, no. 2, pp. 951–960, 2009.*

xi. *M. Vilathgamuwa, S. Member, A. A. D. R. Perera, and S. S. Choi, "Performance Improvement of the Dynamic Voltage Restorer With Closed-Loop Load Voltage and Current-Mode Control," vol. 17, no. 5, pp. 824–834, 2002.*

xii. *D. M. Vilathgamuwa, H. M. Wijekoon, and S. S. Choi, "A Novel Technique to Compensate Voltage Sags in Multiline Distribution System — The Interline Dynamic Voltage Restorer," vol. 53, no. 5, pp. 1603–1611, 2006.*