International Journal of Engineering Research-Online
A Peer Reviewed International Journal
Articles available online http://www.ijoer.in

Vol.3., Issue.4., 2015 (July-Aug)

RESEARCH ARTICLE

ISSN: 2321-7758

# POWER QUALITY IMPROVEMENT BY USING DYNAMIC VOLTAGE RESTORER IN DISTRIBUTION SYSTEM

**SHITAL SHANKAR MORE[1], KALPESH MAHAJAN[2]***

[1]Electrical Department, KCES's COEIT,Jalgaon, Maharashtra. India

[2]Electrical Department, KCES's COEIT,Jalgaon, Maharashtra. India

**SHITAL SHANKAR MORE**

**ABSTRACT**

Power quality is a serious problem in power system. Sag and swell is most severe problem in distribution system. Dynamic voltage restorer (DVR) can provide the most commercial solution to mitigate voltage sag by injecting series voltage into the system distribution systems at sensitive loads. This paper describes the minimization of total harmonic distortions in a distribution line. DVR voltage injection is done by two different controllers: PI and posicastcontroller with dqo transformation. A comparative simulation result of DVR are present in these paper with MATLAB for these two different controllers under the sag and swell voltage condition of power system.

**Keywords:** Voltage sag, Voltage swell, Dynamic voltage restorer, PI controller, Posicast controller, Total harmonic distortion.



## 1. INDRODUCTION

Modern power system is a complex system where the generating station and load centre are interconnected through long transmission and distribution networks. Utility grid produce a pure sinusoidal voltage for a consumer. But there are large number of nonlinear load, suddenly on-off heavy load, lighting, short circuit etc. present in the system it produce a distorted waveform and it causes a malfunction of sensitive equipment. Power quality is an increasingly important thing in many different application. Consumer need pure sine wave shape, constant frequency with a constant root mean square value to continue and reliable power supply. For fulfill to satisfy these demands, the disturbances must be eliminated from the system. Power quality problems has different type of disturbances such as voltage sags/swells, flicker, harmonics distortion, impulse transient, and interruptions. The two most important power quality problems that occurs in almost 80% of the distribution system is the voltage sags and voltage swells[1].Power quality phenomenon can be defined as the deviation of the voltage and the current from its ideal waveform. The voltage dip magnitude is ranged from 10% to 90% of nominal voltage and with duration from half a cycle to 1 min and *swell* is defined as an increase in rms voltage at the power frequency for durations from 0.5 cycles to 1 min. typical magnitudes are between 1.1 and 1.8 p.u[2].The concept of custom power was introduced to distribution systems for improving the system performance. The use of a DVR is considered to be the most cost efficient method. The Dynamic Voltage Restorer (DVR) is an effective custom power device for the enhancement of power quality due to its quick response, high reliability and nominal cost. It is efficiently capable of protecting sensitive loads against the voltage variations or disturbances. This paper introduces dynamic Voltage Restorer (DVR) and its operating principle, also presents the different controllers of PI and posicast controllers with dqo transformation for extracting reference voltage. MATLAB simulation model presented in this paper for two method with variation in voltage sag as well as voltage swell. Compensation of these methods with result and conclusion are given in this paper.

**2. DYNAMICVOLTAGE RESTORER:**

A Dynamic Voltage Restorer (DVR) is a series connected solid state device that injects voltage into the system in order to regulate the load side voltage. The general configuration of the DVR consists of a voltage injection transformer, an output filter, an energy storage device, Voltage Source Inverter (VSI), and a Control system.

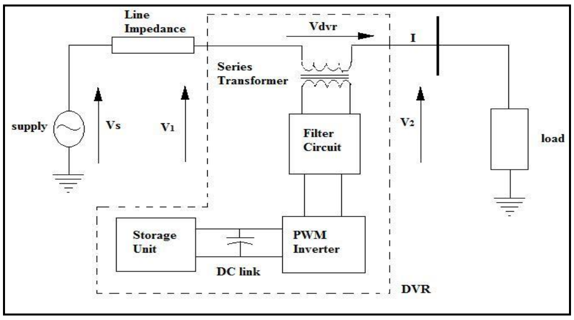


Figure1. Structure of DVR

**a)Injectiontransformers:**Theinjectiontransformerisa speciallydesignedtransformerthatattempts to limit the coupling of noise and transient energy from the primary side to the secondary side[3]. If the transformer is not designed properly, the injected voltage may saturate the transformer and result in improper operation of the DVR[4].

**b) Output filter:** filters are placed at the high voltage side of the DVR to filter the harmonics.

**c)Voltage source inverter:** It is a power electronic device. The VSI have low voltage and high current ratings as step up transformers are used to boost up the injected voltage. In the DVR application, the VSI is used to temporarily injection of the supply voltage.

**d) Energy storage:** Batteries, flywheels or super-conducting magnetic energy storage (SMES) can be used to provide real power for compensation Energy storage is in DC form. Energy storage, (SMES) and Super capacitors have the advantage of fast response.

**e)Control system:** The aim of the control system is to maintain constant voltage magnitude and generate reference voltage for DVR.

**3. EQUATION RELATED DYNAMIC VOLTAGE RESTORER**

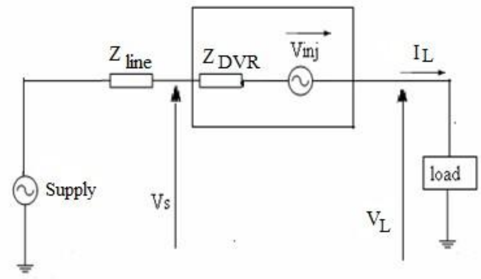


Figure 2. Equivalent circuit of DVR

The system impedance $Z_{th}$ depends on the fault level of the load bus. When the system voltage ($V_{th}$) drops, the DVR injects a series voltage $V_{DVR}$ through the injection transformer so that the desired load voltage magnitude $V_L$ can be maintained. The series injected voltage of the DVR can be written as,

$V_{DVR}=V_L+Z_{th}I_L-V_{th}$...(1)

$V_L$: The desired load voltage magnitude

$Z_{th}$: The load impedance.

$I_L$: The load current

$V_{th}$: The system voltage during fault condition.

The load current $I_L$ is given by

$I_l= (P_l +jQ_l)/V_l$...(2)

When $V_L$ is considered as a reference equation

$\Theta= tan^{-1} (\vartheta_l/P_l)$ ...(3)

The complex power injection of the DVR can be written as,

$S_{dvr}= V_{dvr} I_L^*$...(4)

It requires the injection of only reactive power and the DVR itself is capable of generating the reactive power.

**4.OPERATING MODE OF DVR**

**1. Protection mode**

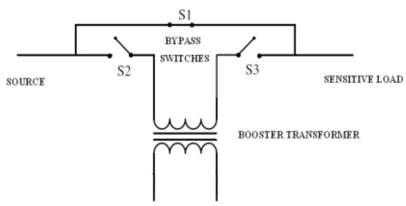


Figure 3. Protection mode

The DVR will be isolated from the system if the system parameters exceed the predetermined limits primarily current on load side. The main reason for isolation is protecting the DVR from the overcurrent in the load side due to short circuit on the load or large inrush currents. The control system detects faults or abnormal conditions and manages bypass (transfer) switches to remove the DVR from system thus preventing it from damages as shown in Figure 3.

**2. Standby mode: ($v_{dvr}$= 0)**

In the standby mode the booster transformer's low voltage winding is shorted through the converter. No switching of semiconductors occurs in thismode of operation and the full load current will pass through the primary.

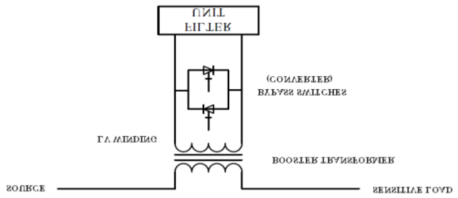

Figure 4. Standby mode

**3 Injection/boost mode: ($v_{dvr}$>0)**

In the Injection/Boost mode the DVR is injecting a compensating voltage through the booster transformer due to the detection of a disturbance in the supply voltage.

**5.CONTROL STRATEGY USED IN DVR**

A) PI controller

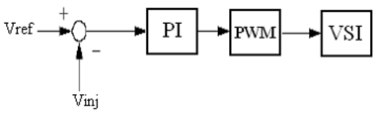


Figure 5. PI controller

The control strategy for DVR for controlling purpose is shown in Figure 5. The controller provides the pulses to converter in order to control the operation of DVR. The control strategy shows that at the voltage input signal ($v_{inj}$) is compared with the voltage reference signal ($v_{ref.}$) and error signal is applied to PI controller. The controller input is an error given to by a PI controller then the output is provided to the PWM signal generator that controls the DVR inverter to generate the required injected voltage [7].

B) Posicast controller

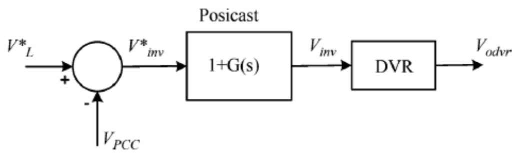


Figure 6. Control using the Posicast Controller

The Posicast controller is used to improve the transient response. Figure 6 shows a typical control block diagram of the DVR. The voltage on the source side arrangement of the DVR is associated with a load-side required reference voltage so that the essential addition voltage is calculated. A simple technique to continue is to maintain the error indication into the PWM modulation technique of the DVR. But the difficult with this is that the transient fluctuations introduced at the start immediate from the voltage sag might not be damped adequately. As shown in the Figure, in the open-loop control, the voltage on the source side of is compared with a load-side reference voltage($V_L$)and injection voltage($V_{inj}$) is obtained. There is simple method is to provide anerror signal into the PWM inverter of the DVR. The problem with is that the transient oscillations initiated at the start point from to improve the damping, as shown in Figure 7. The transfer function of the controller can be described as follows:

$$1 + G(s) = 1 + \frac{\delta}{1+\delta}\left(e^{-sT_d/2} - 1\right) \quad ...(1)$$

To eliminate the steady-state voltage tracking error($V_L$*-$V_L$) a computationally less intensive P+Resonant compensator is added to the outer voltage loop. The ideal P+Resonant compensator can be mathematically expressed as[8].

$$G_R(s) = \mathrm{K_p} + \frac{2K_I s}{s^2 + \omega_o^2} \quad ...(2)$$

**6. SIMULATION AND RESULT**

Table-I Simulation parameters

| | |
|---|---|
| Main Supply Voltage per phase | 200V |
| Series transformer turns ratio | 1:1 |
| DC Bus Voltage | 600 V |
| Filter Inductance | 1mf |
| Filter Capacitance | 20mf |

| | |
|---|---|
| Switching Frequency | 2000Hz |
| Line Frequency | 50Hz |
| Load | 50kw |
| Sampling time | 50µs |
| Inverter parameter | IGBT based, 3 arms , 6Pulse, |
| PI controller | Kp=1, Ki=1, Sample time=50µs |
| Posicast controller | Kp= 100 ,ki = 1 |

**A) SIMULATION OF DVR WITH PI CONTROLLER**

In figure 8, DVR is connected in series between the source and load. The control system requires when DVR operates. Whenever fault occurs in transmission line, generate pulse through PWM generator. Then this pulses applies to the VSC and inject a voltage through a injection transformer. (Sag means inject voltage, swell means absorb the voltage). The reference voltage generate by different controller techniques. Here PI and Posicast controller with dqo transformation is used for generation of reference voltage. The input reference is also in Pu. Then convert three phase $V_a$, $V_b$, $V_c$ into $V_d$, $V_q$. The actual supply voltage also converted into $Vd$ and $Vq$form. The supply voltage and reference voltage both are compared and error signal is obtained which is given to controller. Angle is obtained from phase lock loop.

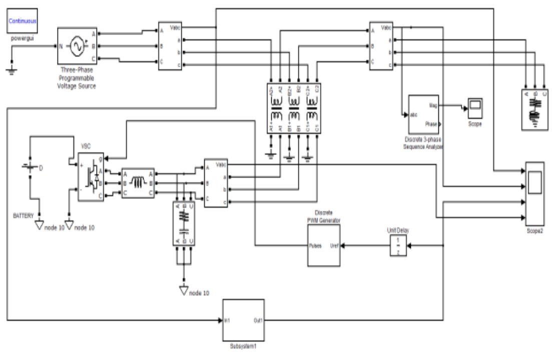

Figure8.simulation of dynamic voltage restorer with PI controller

The first simulation of three phase voltage sag is simulated and a 50% three-phase voltage sag occurring at the utility grid is shown in Figure 9 (a). In Figure- 9(a) also shows a 50% voltage sag initiated at 0.1s and it is kept until 0.2s, with total voltage sag duration of 0.1 s. Figures-9 (b) and (c) show the corresponding load voltage with compensation and the voltage injected by the DVR .As a result of DVR, the load voltage is kept at 1 pu respectively.

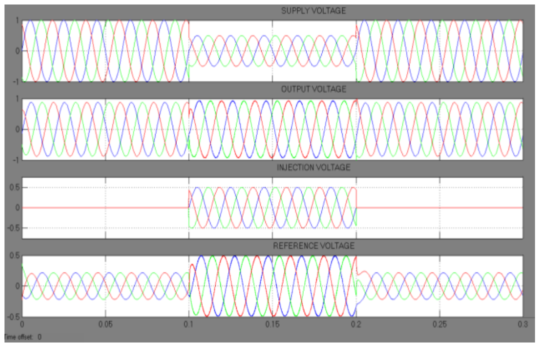


Figure 9Three phase voltage sag (a) Supply voltage (b) Output voltage (c) Injection voltage (d) Reference voltage

The second simulation shows the DVR performance during voltage swell condition. The simulation started with supply voltage swell is generated as shown in Figure 10(a).As observes this figure the amplitude of supply voltage is increased about from its nominal voltage. Figure 10(b) shows the output voltage. Figure 10(c) and (d) shows injected voltage and reference voltage respectively.

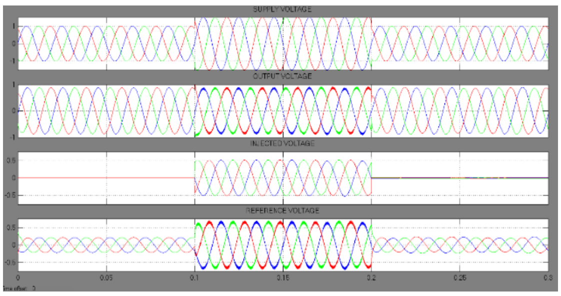

Figure 10. Three phase voltage swell(a) Supply voltage (b) Output voltage (c) Injection voltage (d) Reference voltage

The comparison of FFT analysis of the voltage waveform at the load side of the system. By using PI controller, DVR gives the total harmonic distortion 2.94%.as shown in Figure 11.

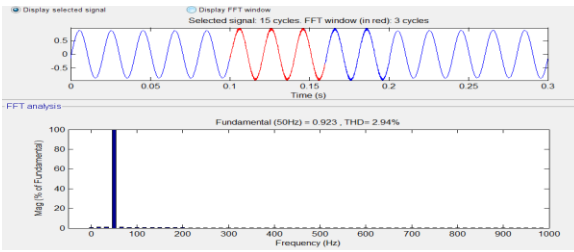


Figure 11.Output of FFT analysis for output voltage compensation

**B) SIMULATION OF DVR WITH POSICAST CONTROLLER**

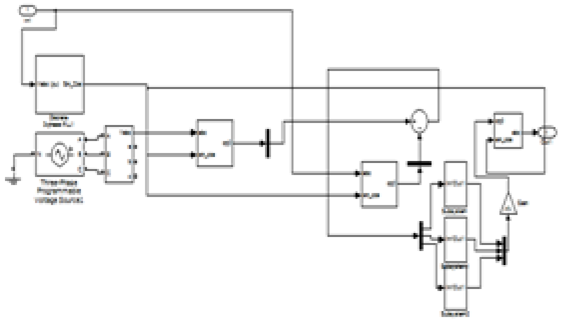

Figure 12. Subsystem of reference voltage generation by using dqo with posicast controller

The first simulation of three phase voltage sag is simulated and a 50% three-phase voltage sag occurring at the utility grid is shown in Figure 13 (a). In Figure- 13(a) also shows a 50% voltage sag initiated at 0.1s and it is kept until 0.2s, with total voltage sag duration of 0.1 s. Figure-13 (b) and (c) show the corresponding load voltage with compensation and the voltage injected by the DVR.As a result of DVR, the load voltage is kept at 1pu respectively.

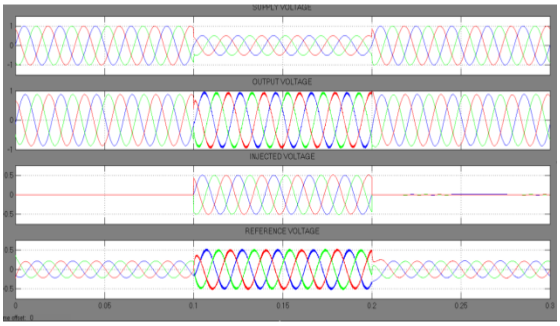

Figure 13. Three phase voltagesag(a) Supply voltage (b) Output voltage (c) Injection voltage (d) Reference voltage

The second simulation shows the DVR performance during voltage swell condition. The simulation started with supply voltage swell is generated as shown in Figure.13 (a).As observes this figure the amplitude of supply voltage is increased about from its nominal voltage. Figure (b) shows the output voltage. Figure (c) and (d) shows injected voltage and reference voltage

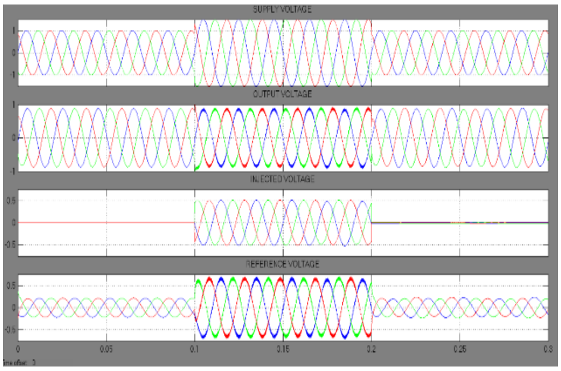

Figure 14.Three phase voltage swell(a) Supply voltage (b) Output voltage (c) Injection voltage (d) Reference voltage

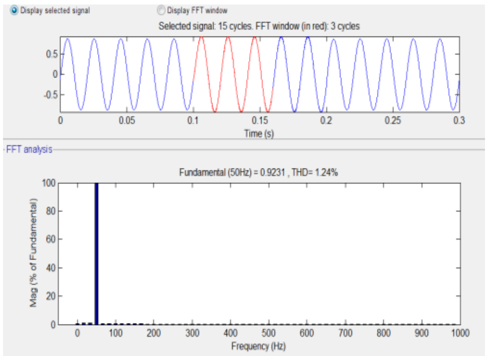


Figure 15.Output of FFT analysis for output voltage compensation

Table-II: THD Comparison for sag and swell

| Types of controller | THD value for sag | THD value for swell |
|---|---|---|
| PI controller | 2.94% | 3.12% |
| Posicast controller | 1.24% | 1.35% |

**7. CONCLUSION:**

The controlling of DVR is done with the help of PI controller and posicast controller. Simulation results also show that the DVR compensates the sags/swells quickly and provides excellent voltage regulation. It is concluded that compared to PI, posicast controller is giving better performance. The THD with PI is 2.94% is reduced to 1.24% in sag and 3.12% is reduced 1.35% in swell condition by using posicast controller. Posicast controller gives better THD level.

**REFERENCES**

[1]. K.R. Padiyar, “Facts Controllers in Power Transmission and Distribution”, New Age International Publishers,2007.

[2]. D. Bhanumurthy and Prashanth “Power quality improvement at distribution

level",Proc.IJERA,vol.2,Issue3,pp.970975,Jun 2012

[3]. ArindamGhoshandGerardledwhich,"Power QualityEnhancementUsingCustomPower Devices",KluwerAcademicPublishers, 2002

[4]. Chsrisailam, Asreenivas "Mitigation of Voltage Sags/Swells by Dynamic Voltage Restorer Using Pi and Fuzzy Logic Controller" IJERA Vol. 2, Issue 4, July-August 2012, pp.1733-1737

[5]. Kumar R, Nagaraju S, "Simulation of D-Statcom and DVR inPower Systems", RPN Journal of Engineering and Applied Sciences, 2007.

[6]. SwapnaliHazarikaSwagataSingha Roy "Application of Dynamic Voltage Restorer in Electrical Distribution System for Voltage Sag Compensation"IJESVolume2 Issue 7 Pages 30-38,2013.

[7]. B.Rajesh. Kumudwathim "A latest Approach to Multifunctional Dynamic Voltage Restorers Implementation for Emergency Control and Protect Consumers in Distribution Systems" IRJESVolume 2, Issue 11 November 2013.