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Simulation of Dynamic Voltage Restorer for Voltage Sag Compensation

B. Eswara Rao
JNTUK PG Scholar,
JNTU Kakinada, Andhra Pradesh 533 003, India.

Abstract:

One of the major concerns in electricity industry today is power quality. It becomes especially important with the introduction of advanced and complicated devices, whose performance is very sensitive to the quality of power supply. The electronic devices are very sensitive to disturbances and thus industrial loads become less tolerant to power quality problems such as voltage dips, voltage sags, voltage flickers, harmonics and load unbalance etc. At present, a wide range of very flexible controllers, which capitalize on newly available power electronics components, are emerging for custom power applications. Among these, the distribution static compensator (D-STATCOM), dynamic voltage restorer (DVR) and unified power quality conditioner (UPQC) which is based on the VSC principle are used for power quality improvement. The main aim of my project is to design DVR which is used to compensate voltage quality problems and fuzzy logic controller is used to control the inverter. A new fuzzy PID controller is developed to improve the magnitude of load voltage. The results are compared with conventional controller. The results will be analyzed using mat lab / Simulink software.

Index Terms: DVR, Active Power Filter (APF), Hysteresis Control, DC Capacitor.

INTRODUCTION:

A DVR is used to compensate the supply voltage disturbances such as sag and swell. The DVR is connected between the supply and sensitive loads, so that it can inject a voltage of required magnitude and frequency in the distribution feeder. The DVR is operated such that the load voltage magnitude is regulated to a constant magnitude, while the average real power absorbed/ supplied by it is zero in the steady state. The capacitor supported DVR is widely addressed in the literature [11]. The instantaneous reactive power theory (IRPT) [6], sliding mode controller [9], instantaneous symmetrical components [2] etc., are discussed in the literature for the control of DVR. In this project a new control algorithm is proposed based on the current mode control and proportional-integral (PI) controllers for the control of DVR. The Injection / Booster transformer is a specially designed transformer that attempts to limit the coupling of noise and transient energy from the primary side to the secondary side. Its maintasks are:

1. It connects the DVR to the distribution network via the HV-windings and transforms and couples the injected compensating voltages generated by the voltage source converters to the incoming supply voltage.
2. In addition, the Injection / Booster transformer serves the purpose of isolating the load from the system (VSC and control mechanism).

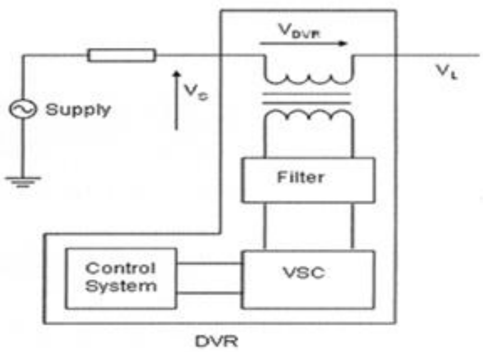

Figure 1.Block diagram of DVR

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DVR Control Strategy

The proposed algorithm is based on the estimation of reference supply currents. It is similar to the algorithm for the control of a shunt compensator like DSTATCOM for the terminal voltage regulation of linear and nonlinear loads [6]. The proposed control algorithm for the control of DVR is depicted in Fig 5.1.

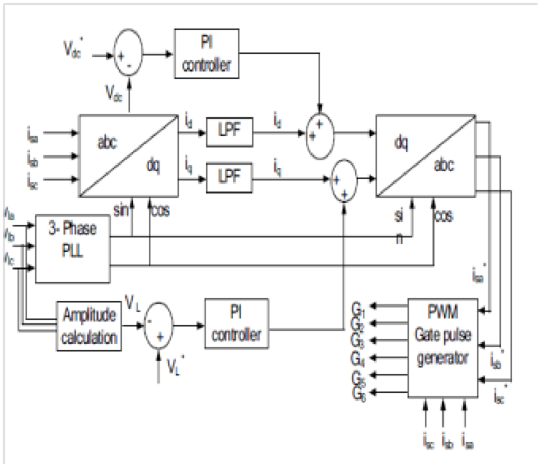

Figure 2. Control scheme of the DVR

The series compensatorknown as DVR is used to inject a voltage in series withthe terminal voltage. The sag and swell in terminal voltages are compensated by controlling the DVR and theproposed algorithm inherently provides a self-supportingdc bus for the DVR. Three-phase reference supplycurrents (i_{sa}^*, i_{sb}^*,i_{sc}^*) are derived using the sensed loadvoltages (v_{la}, v_{lb}, v_{lc}), terminal voltages (v_{ta}, v_{tb},v_{tc}) and dcbus voltage (v_{dc}) of the DVR as feedback signals.The synchronous reference frame theory based methodis used to obtain the direct axis (i_d) and quadrature axis (i_q)components of the load current. The load currents in thethree-phases are converted into the d-q-0 frame using thePark's transformation as,

$$\begin{bmatrix} i_d \\ i_q \\ i_0 \end{bmatrix} = \frac{2}{3}\begin{bmatrix} \cos\theta & -\sin\theta & \frac{1}{2} \\ \cos\left(\theta-\frac{2\pi}{3}\right) & -\sin\left(\theta-\frac{2\pi}{3}\right) & \frac{1}{2} \\ \cos\left(\theta+\frac{2\pi}{3}\right) & \sin\left(\theta+\frac{2\pi}{3}\right) & \frac{1}{2} \end{bmatrix}\begin{bmatrix} i_{la} \\ i_{lb} \\ i_{lc} \end{bmatrix} \quad (5.1)$$

A three-phase PLL (phase locked loop) is used tosynchronies these signals with the terminal voltages (v_{ta}, v_{tb},v_{tc}). The d-q components are then passed through lowpass filters to extract the dc components of $i_d$andi$_q$. Theerror between the reference dc capacitor voltage and thesensed dc bus voltage of DVR is given to a PI (proportional-integral) controller of which output isconsidered as the loss component of current and is addedto the dc component of id. Similarly, a second PI controller is used to regulate the amplitude of the loadvoltage (V_t). The amplitude of the load terminal voltage isemployed over the reference amplitude and the output ofPI controller added with the dc component of i_q. Theresultant currents are again converted into the referencesupply currents using the reverse Park's transformation.Reference supply currents (i_{sa}^*, i_{sb}^*,i_{sc}^*) and the sensedsupply currents (i_{sa}, i_{sb},i_{sc}) are used in PWM currentController to generate gating pulses for the switches. The PWM controller operates at a frequency of 10 kHz and the gating signals are given to the three-leg VSC for the control of supply currents.

PWM CONTROL OF ACTIVE POWER FILTER:

The main aim of an active power filter (APF) is to generate compensating currents into the power system for canceling the current harmonics contained in the nonlinear load current. This will thus result in sinusoidal line currents and unity power factor in the input power system.

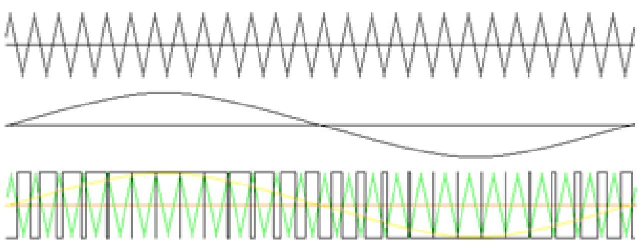

Figure 3. PWM technique

PI Controller shown in Fig. 4 is a feedback controller which drives the plant to be controlled with a weighted sum of the error and the integral of that value [8].

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The proportional response can be adjusted by multiplying the error by constantK_p, called proportional gain. The contribution from integral term is proportional to both the magnitude of error and duration of error. The error is first multiplied by the integral gain, Ki and then was integrated to give an accumulated offset that have been corrected previously [8].

1) Proportional-Integral (PI) Controller

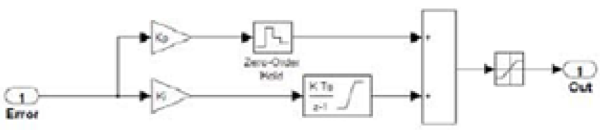

Figure 4. Discrete PI controller

SIMULATION RESULTS

Base System

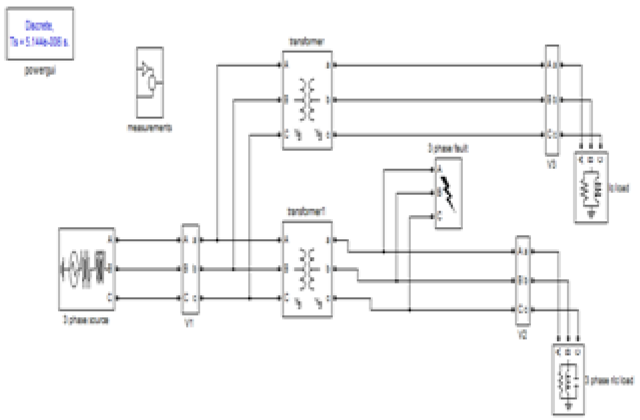

Figure 7.Base System

This is the block diagram showing source, load and transmission line in faulty conditions. The fault can be of any nature like L-G, L-L-G, L-L or 3-PHASE FAULT. In these conditions severe fault currents flow through the lines and there is a drastic drop in line and load voltages.

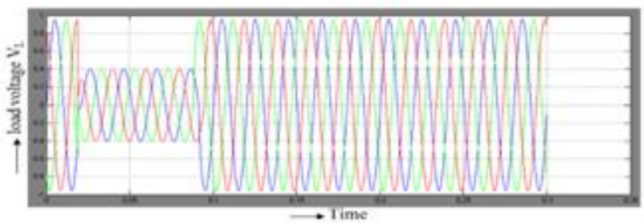

Figure 8. Load Voltage

The drop in the load voltage can be seen in above wave form due to fault in transmission line.

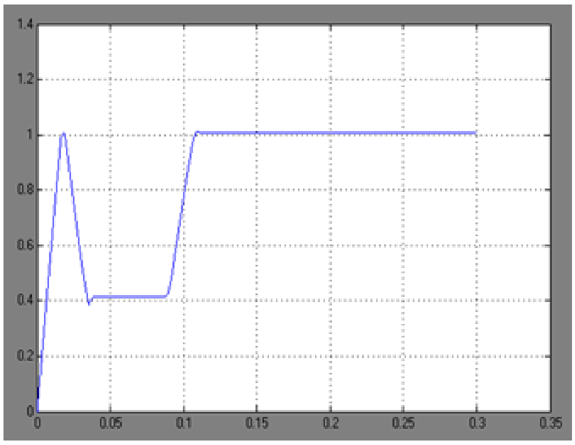

Figure 9. Voltage Sag

The sag in the voltage waveform which can be clearly observed in the above figure which is deviating from the actual voltage curve.

Base System with PI Controller

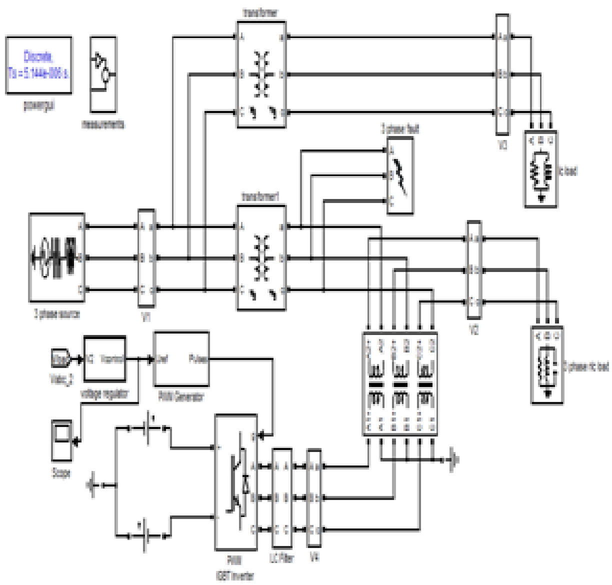

Figure 10. Base System with PI Controller

This is the block diagram showing source, load and transmission line in faulty conditions. The type and intensity of fault can be identified and corrected with the DVR and its control mechanism.

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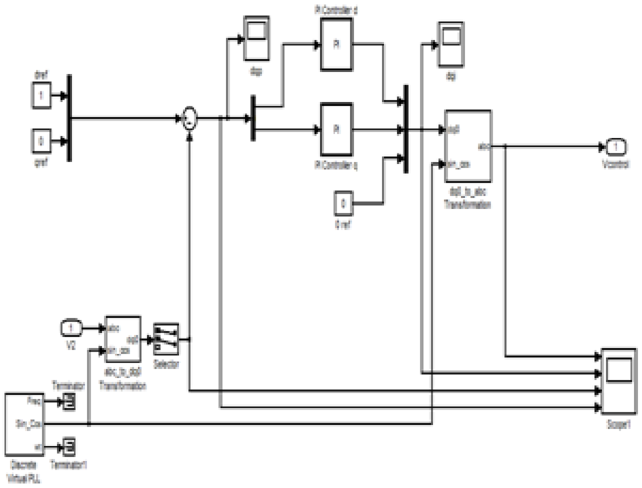
And bring back the voltage levels to the normal operating value before the occurrence of fault.



The controller used in the above simulation circuitry is **pi controller**. Since pi being a conventional controller there is a difficulty in tuning the controller.

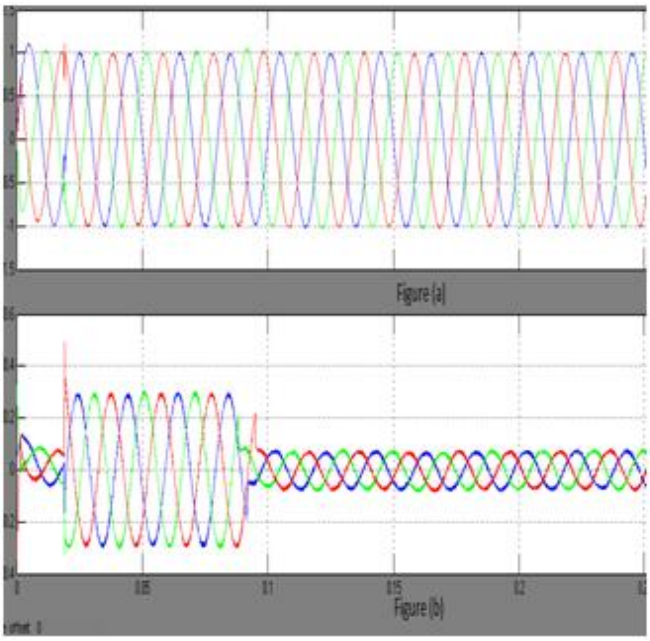


Figure 11. Injected voltage by the DVR

In the above figure the first waveform implies the compensated load voltage at the consumer side. The second waveform implies the injected voltage by the DVR into the lines to compensate the voltage drop.

CONCLUSION

In this study, the modeling and simulation of DVRcontrolled by PI has been developed usingMat lab/Simulink. For both controller, the simulation resultshows that the DVR compensates the sag quickly (70µs) andprovides excellent voltage regulation. DVR handles all types,balanced and unbalanced fault without any difficulties andinjects the appropriate voltage component to correct any faultsituation occurred in the supply voltage to keep the loadvoltage balanced and constant at the nominal value. Bothcontrollers show an excellent performance and generate lowTHD (<5%).

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