IJRISE International Journal of Research In Science & Engineering e-ISSN: 2394-8299
Volume: 3 Issue: 4 July-August 2017 p-ISSN: 2394-8280

HARDWARE INSTALLATION AND WORKING OF SINGLE PHASE DYNAMIC VOLTAGE RESTORER

Shweta titre[1], Dr. Harikumar naidu[2], Prof. Pratik ghutke[3]

Student- (M. tech), IPS, Dept. of Electrical Engineering. TGPCET, Nagpur
HOD, Dept. of Electrical Engineering, TGPCET Nagpur
Assistant professor, Dept. of Electrical Engineering, TGPCET, Nagpur

ABSTRACT

Power quality problems become a major issue of industries due to enormous loss in terms of time and money. The power quality consists of a huge number of disturbances such as voltage sags, swells, harmonics, etc. There are the various methods to reduce the power quality problems, but the FACTS devices are the most excellent solution to reduce this problem. One of the most powerful FACTS devices is the DVR to alleviate the voltage sag and swell. This paper describes the study and performance on DVR and various compensation method of DVR which are used to mitigate the voltage sag and swell.

Index Terms— ***DVR, IGBT, MATLAB/SIMULINK, Power Quality, Synchronous Reference Frame Theory, Voltage sags/swells, VSI,***

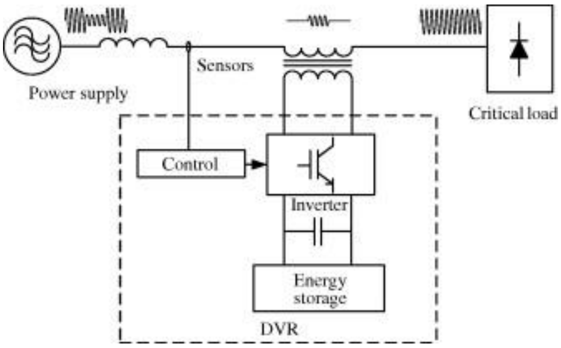
INTRODUCTION

A power distribution system is a very complex system. It is important to remove any sort of fault so as to protect the power system properly. Our distribution systems, ideally, should provide their customers with an uninterrupted flow of energy at smooth sinusoidal voltage at the contracted magnitude level and frequency [1] however, in practice, power systems, especially the distribution systems, have numerous nonlinear loads, which significantly affect the quality of power supplies. As a result of the nonlinear loads, the purity of the waveform of supplies is lost. This ends up producing many power quality problems. Apart from nonlinear loads, some system events, both usual (e.g. capacitor switching, motor starting) and unusual (e.g. faults) could also inflict power quality problems [2]. Power quality phenomenon or power quality disturbance can be defined as the deviation of the voltage and the current from its ideal waveform. Faults at either the transmission or distribution level may cause voltage sag or swell in the entire system or a large part of it. Also, under heavy load conditions, a significant voltage drop may occur in the system. Voltage sag and swell can cause sensitive equipment to fail, shutdown and create a large current unbalance. These effects can incur a lot of expensive from the customer and cause equipment damage [1]. 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 or current at the power frequency for durations from 0.5 cycles to 1 min. typical magnitudes are between 1.1 and 1.8 p.u. There are many different methods to mitigate voltage sags and swells, but the use of a custom power device is considered to be the most efficient method, e.g. FACTS for transmission systems which improve the power transfer capabilities and stability margins. The term custom power pertains to the use of power electronics controller in a distribution system [10], especially, to deal with various power quality problems. There are different types of Custom Power devices used in electrical network to improve power quality problems. Each of the devices has its own benefits and limitations. A few of these reasons are as follows. The SVC pre-dates the DVR, but the DVR is still preferred because the SVC has no ability to control active power flow [3]. Another reason include that the DVR has a higher energy capacity compared to the SMES and UPS devices. Furthermore, the DVR is smaller in size and cost is less compared to the

DSTATCOM and other custom power devices. Based on these reasons, it is no surprise that the DVR is widely considered as an effective custom power device in mitigating voltage sags. In addition to

voltage sags swells compensation, DVR can also add other features such as harmonics and Power Factor correction. Compared to the other devices, the DVR is clearly considered to be one of the best economic solutions for its size and capabilities [4].
The voltage injection schemes and design of the self- supported DVR and the different control strategies for the controllers of the DVR have been discussed in [14-16]. E.g, adaline based fundamental extraction have been implemented in [14]. Instantaneous symmetrical component theory [16], space vector modulation, synchronous reference frame theory (SRFT) [15] based control techniques for a DVR are reported in this literature. In this paper, a new control algorithm is suggested based on SRF theory which includes P-I Controller for the generation of reference Vd and Vq. Reference load signal generation involves the conversion from three-phase to two-phase and vice versa. Moreover low pass filters are essential part of this algorithm which has slow dynamic response of the compensator.
The organization of the paper is as follows. In section 2, the constructional part of the DVR is briefly described, the operating principle and the voltage injection capabilities of the DVR is discussed in section 3, proposed control algorithm enumerated in section 4 and the detailed description of MATLAB Simulation model along with its performance in electrical network for different power quality problems discussed in section 5 and section 6 respectively.

DYNAMIC VOLTAGE RESTORER



A Dynamic Voltage Restorer (DVR) is a recently proposed series connected solid state device that injects voltage into the system in order to regulate the load side voltage. It is normally installed in a distribution system between the supply and critical load feeder [9]. The basic structure of a DVR is shown in Fig.1.

Figure-1: ***DVR series connected topology***

It is divided into six categories [9]: (i) *Injection Transformer:* The Injection transformer is a specially designed transformer that attempts to limit the coupling of noise and transforms energy from the primary side to the secondary side. (ii) *Harmonic Filters:* Filters are used to convert the inverted PWM waveform into a sinusoidal waveform by eliminating the unwanted harmonic components generated by VSI action. (iii) *Inverter:* A VSI is a power electronic system which consists of a storage device and switching device, which can generate a sinusoidal voltage at any required frequency, magnitude, and phase angle from dc storage. IGBT is a three terminal controllable switch that combines the fast switching times of the MOSFET with the high voltage capabilities of the GTO used as a switching device in VSI. The voltage and current rating of IGBT is 4500 volts and 1200 Amps respectively. [6]. (iv) *Energy Storage Unit:* The purpose is to supply the ne- cessary energy to the VSI via a dc link for the generation of injected voltages (v) *Capacitor:* DVR has alarge DC capacitor to ensure stiff DC voltage input to inverter. (vi) *By-Pass Switch:* If the over current on the load side exceeds a permissible limit due to short circuit on the load or large inrush current, the DVR will be isolated from the system by using the bypass switches and supplying another path for current.

OPERATING PRINCIPLE OF DVR

The schematic diagram of a self-supported DVR is shown in Figure-2[5]. Three phase source voltages (Vsa, Vsb, and Vsc) are connected to the 3-phase critical load through series impedance (Za, Zb, Zc) and an injection transformer in each phase. The terminal voltages (Vta, Vtb, Vtc) have power quality problems and the DVR injects compensating voltages (VCa, VCb, VCc) through an injection transformer to get undistorted and balanced load voltages (VLa, VLb, VLc). The DVR is implemented using a three leg voltage source inverter with IGBTs along with a dc capacitor (Cdc). A ripple filter (Lr, Cr) is used to filter the switching ripple in the injected voltage. The considered load, sensitive to power quality problems is a three-phase balanced lagging power factor load. A self-supported DVR does not need any active power during steady state because the voltage injected is in quadrature with the feeder current.

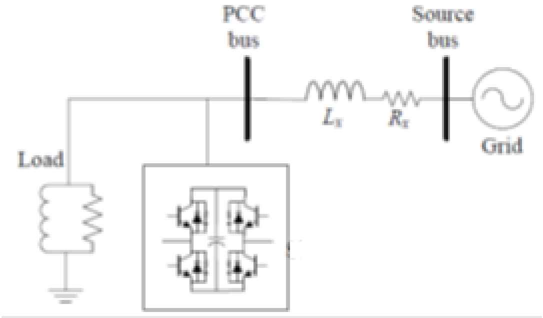


Figure-2: ***Schematic diagram of self-supported DVR***

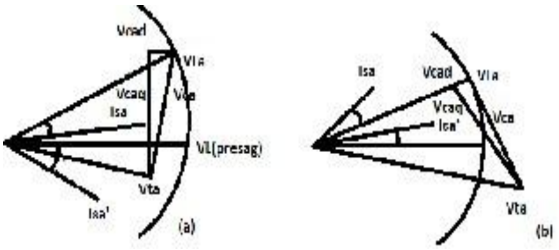


Figure-3: Phasor Diagram for (a) Voltage Sag (b) Voltage Swell

The DVR operation for the compensation of sag, swell in supply voltages is shown in Figure-3. Before sag the load voltages and currents are represented as VL (presag) and Isa’ as shown in Figure-3(a). After the sag event, the terminal voltage (Vta) is gets lower in magnitude and lags the presag voltage by some angle. The DVR injects a compensating voltage (VCa) to maintain the load voltage (VL) at the rated magnitude. VCa has two components, VCad and VCaq. The voltage in-phase with the current (VCad) is required to regulate the dc bus voltage and also to meet the power loss in the

VSI of DVR and an injection transformer [5]. The voltage in quadrature with the current (VCaq) is required to regulate the load voltage (VL) at constant magnitude. During swell event, the injected voltage (VCa) is such that the load voltage lies on the locus of the circle as shown in Figure-

DESIGN CRITERIA AND RATED POWER CALCULATIONS:

1) Design criteria:

The design of the DVR is affected by the load, the supply characteristics and by the expected voltage-dip characteristics.

When designing for a DVR for certain application, the following items should be considered:

- **Maximum load power and power factor:**

The load size strongly affects the current rating of thevoltage-source converter and the injection transformer aswell as the amount of energy storage needed.

- **Maximum depth and duration of voltage dips to be corrected:**

These characteristics, together with the load size, dictates the necessary storage capacity of the energy storage device.

The maximum depth and duration of voltage dips to be corrected is determined by the statistics of the voltage dips
at the DVR location and by the acceptable number of equipment trips.

- **Maximum allowed voltage drop of the DVR during the standby mode:**

This affects the control mode during normal operation and indirectly the reaction speed at the beginning of a voltage dip.

- **Parameters of the step-down transformers:** Coupling ofthe step-down transformer (*CIA* or *YIY*,. . .etc.) at input and output sides of the DVR.
- **Harmonic requirements of the load and of the system:**

These affect the harmonic filtering needed for the DVR and also influence the choice of charging method for the capacitors. At the first instance when designing a DVR,some assumption could be made to simplify the analysis,such as:

- Ideal switches
- DC-side capacitors are large enough to maintain a ripplefree DC bus voltage, even for unbalanced input voltage.
- Series transformer and output filter components areideal.

In order to design a DVR, the concept of “boost rating” is introducedto define the maximum voltage that the DVR is capable to inject intothe power line with respect to the nominal distribution systemvoltage. This boost ratio is defined as

$$B=\frac{Uc}{Usl/\sqrt{3}}$$

Here, Usl, is the nominal line-to-line voltage of the supply.

2) Rated power calculations:

The DVR function, in case of voltage dips, is to exchange real power between the power system and the energy storage device. The real power injected by the DVR is an important feature to precede its design process. To calculate the active and the reactive power, a factor is defined to indicate the reduction of the positive sequence voltage with respect to the nominal voltage of the load. For a certain supply voltage U, and required load voltage U, the DVR injected voltage written as:

$Uc= U_L – U_{LS} = (1-M_f\ )$ The range of the modulus of M_F is defined by the maximum variation of U_S, for which the DVR is designed. So, in normal operation MFs will be unity and U is zero

$.M_F = Us/ U_L$

Considering the fact that the DVR current should be designed to be the same as the rated load current, the apparent power required by the DVR is then calculated in terms of the apparent load power, S_L and M_F by the following formula.

$S_{C=}S_L(1- M_F)$

Consequently, the active and reactive powers are calculated by separating S_C into its real and imaginary parts
DVR depends on the magnitude and the phase-angle jump ofthe supply voltage as well as the load power factor.

HARDWARE DESIGN:

This is the hardware implementation of Dynamic Voltage Restorer (DVR) designed for mitigation of voltage sags. In
this the arrangement is of 10 sub circuits as shown in the model 4 IGBT"s, DVR coupling network, Opto coupler
circuit, Isolated power supply circuit, Lamp load, Line Impedance, microcontroller circuit,1:1 isolated transformer,and the 3 transformers are:

1) for DVR DC Supply,
2)for trigger circuit,
3) for control circuit.

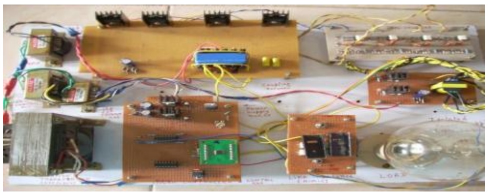


Fig.9. Hardware module of Dynamic Voltage Restorer (DVR) Top view.

In the block diagram, the 230V, 50 HZ supply is isolated by means of a 1:1 (230/230), 150VA isolation transformer. This isolated voltage is treated as the line voltage, which supplies power to the load, through simulated line impedance. The simulated line impedance is simply a wire
wound resistor. To have maximum effect of voltage drop across the line impedance, the resistance value considered isof very high value, 120 Ohms. After this simulated line impedance, a switch is connected, through which the load can be connected or disconnected. In the return path, the DVR output is connected, by means of the output winding of the coupling transformer developed. This output from the DVR is connected in series with the load, and mitigates the line impedance effects, i.e. in this case the voltage drop caused by it. The DVR circuit has to check the load voltage and need tobe connected to the micro controller circuit and correct the voltage if there is any shortage or excess when compared to a Reference voltage, by injecting appropriate voltage into the circuit by means of the coupling network.

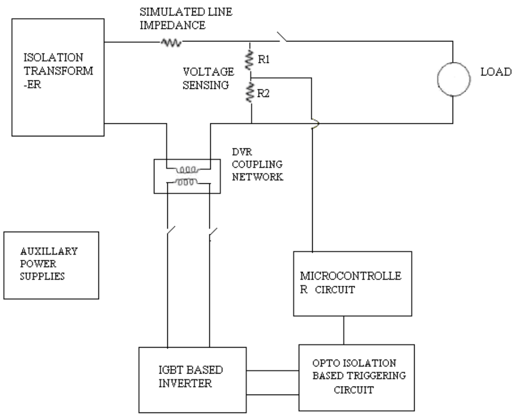


Fig.10. The basic block diagram of the proposed DVR system

The micro controller can't read voltages more than 5V. As the 230v2 V of positive and negative peak voltage cannot be directly fed to the micro controller circuit, this voltage is attenuated to 2.5V at peak points by means of a potential divider. The potential divider is basically a resistor divider network, with resistors R1 and R2 as shown in the figure. One of these resistor values is arbitrarily chosen and the other value is calculated, as explained below.

Initially, the R2 value is assumed and is 1.8KΩ. The supply peak voltage, output voltage, R1 and R2 values are related by the following equation.

$$(R2 \div (R1+R2)) \times 230v2 = 2.2\ V$$

Here, the R1 value is calculated and is 2.6k

The output voltage is considered to be 2.2V, instead of 5V that can be accepted by the micro controller circuit. The micro controller has to sense both positive and negative voltages, and the range it can accept is only 0 to 5V. Thus, for positive and negative peaks if 2.5 V is generated as the output, then if 2.5 V is added then the output remains in the range of 0 to 5V. But, the input supply voltage can have a value more than 230V rms. In order to accommodate the excess voltages, instead of 2.5 V for peak voltages 2.2V is generated. Thus, another 0.3 V is there to meet the higher voltages. If the lampload is not connected, the output of the isolation transformer does not have any drop, and the full voltage appears across the sensing circuit, and there is no need of any correction by the DVR circuit. When the load is connected, the lamp glows andcurrent flows through the simulated line impedance, and there is an appreciable voltage drop across the line impedance, and this drop in voltage need to be injected by the DVR circuit.

Dynamic Voltage Restorer:

The functioning and designing of different blocks of dynamic voltage restorer is discussed herewith.

a) Single phase voltage source bridge inverter:

The voltage source inverter used in the DVR circuit makes the induction of required voltage with required phase
possible. This inverter uses dc capacitors as the supply and can switch at a high frequency to generate a signal which will

mitigate the voltage sags and swells across the load.

b) Micro controller circuit:

The microcontroller circuit is the heart of the system, and is responsible for generating the reference voltage waveform from the voltage waveform that is sampled from the sensing network, which it has obtained from the reference voltage sensing circuit. This reference voltage waveform is generated keeping the zero crossing as the reference to maintain the phase relationship of the load and correcting voltage. As the voltage induced through the coupling transformer, generated by the bridge Inverter, the resulted voltage across the load will be a pure sinusoid of required voltage.

c) Opto coupler and driver circuits:

Opto couplers are capable of transferring an electrical signal between two circuits while electrically isolating the circuits from each other. They generally consist of an infrared LED, light emitting section at the input and a silicon photo detector at the output. The input for opto couplers can be either AC or DC, which can drive the LED.

d) Coupling network:

The voltage waveform for mitigating the voltage variations in the load circuit is achieved with the voltage source inverter, coupling transformer and an interfacing filter. The coupling transformer needs to transfer energy from the voltage source inverter to the load and at the same time need to provide low impedance on the load side, so that the transformer winding itself doesn't provide a voltage drop across the load.

e) Inverter driving circuitry:

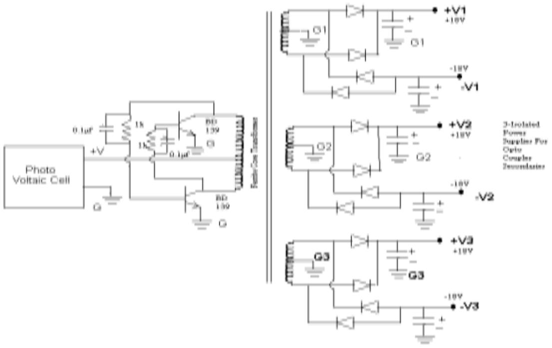


Fig.1Inverter Driving circuit

In order to trigger the IGBTs, it is required to apply a +12Vpulse to make it turn „ON‟ and -12V pulse to turn it „OFF‟ to the gate with respect to its emitter. Thus, in order to provide triggering pulses to each and every MOSFET, it is required to have four isolated power supplies of ±12V which can be used to apply trigger pulses to the respective MOSFETs.

This inverter provides the required outputs, which can be used to drive the opto-coupler secondary side, which is meant for driving the IGBT gate.

f) Isolated power supplies for filter elements:

Three different power supplies are required, to provide power to various blocks of the over-all DVR circuit. The micro controller requires basically a 5-V supply. But, the op-amp circuit associated with the potential divider circuit requires a ±12 volts supply. This supply is generated from a step-down transformer connected to the mains. The DVR inverter requires a separate power supply, and this generated from another step-down transformer and another12-V supply is generated using another step-down transformer, which is mainly to power the isolated power generator circuit. This circuit is shown in the Fig.13

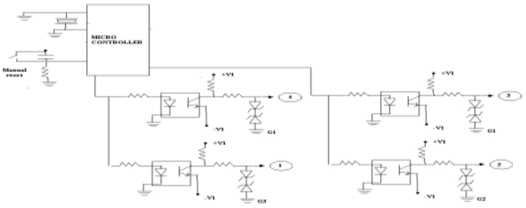


Fig.13 Circuit diagram of Isolated power supply

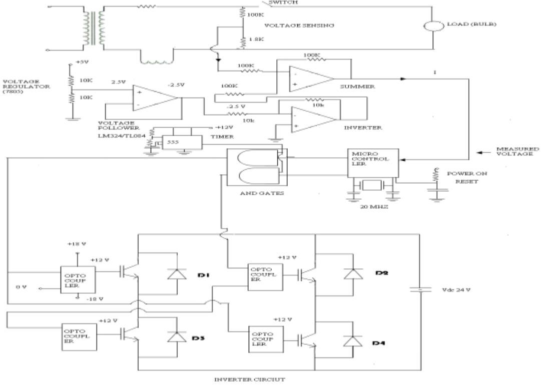


Fig.14 The total circuit diagram of the DVR

RESULTS:

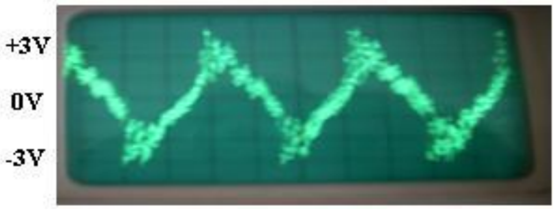


Fig. 15 Voltage waveform at the DVR Coupling network

The voltage waveform when when the DVR is ON , the observed waveform is at the coupling network is clearly shown in fig. 15.

Fig. 16 Voltage waveform when the supply is given without any load connections

The voltage waveform when initially the supply is given without any load connections shown in fig. 16.

Fig.17 Voltage waveform after switching ON of Lamp load

The voltage waveform when the lamp load (200) is connected the drop in voltage is 1.2V as shown in fig. 17.

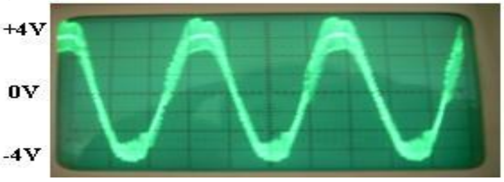


Fig.18 The compensation Voltage waveform after switching ON of the DVR when the DVR is ON.

The obtained sag is compensated the compensation of voltage waveform with clear graphical fluctuations are shown in the fig. 18.

Conclusions:

CONCLUSION

This paper presents various issues relevant to the design and evaluation of DVR for voltage sag compensation. In this paper, hardware protocol model of DVR is setup. The proposed technique could identify the voltage sag and is capable of mitigating the sag by maintaining the load voltage magnitude at desired voltage and THD within limits. The proposed technique is simple and uses only one switching per phase. Hence the system is simple, economical and does not require energy storage device as compared to commonly used DVR. Performance of the proposed device is verified by theoretical results and is found to be satisfactory. Best control strategy for sensitive loads which can't with stand for phase angle jumps is pre-sag compensation. For minimum voltage injection, in-phase injection compensation is the best. For minimum energy injection by the DVR, phase advance compensation is best but requires more voltage injection.

The major factors and their impact on DVR performance are presented in a way which is useful in selection of a DVR system for a specific application.

REFERENCES

[1]. Sajid Ali and Yogesh Chauhan, **"Study & Performance of DVR for Voltage Quality Enhancement**,"IEEE 978-1-4673-6150. 7 July 2013.

[2] "Control and Testing of a Dynamic Voltage Restorer (DVR) at medium Voltage Level,"IEEE Transactions on Power Electronics.Vol.19, no.3, MAY 2004.

[3]. K.K.Vasishta Kumar, Ch. Prasad, and D.Satish Reddy "**Power Quality Enhancement using Dynamic Voltage Restorer**" Int. J. of Recent Trends in Engineering and Technology, Vol. 4, No. 3, Nov 2010.

[4]. N.G.Hingorani, "Introducing custom power", IEEE Spectrum, pp.41-48, June 1995.

[5]. M.F.McGrandghan, D.R.Mueller, and M.J.Samotyj."Voltage sags in Industrial systems", IEEE Trans. On industry applications, Vol.29, no.2,pp.397-402,March/ April 1993.

[6] C. S. Chang, S. W. Yang, and Y. S. Ho, "Simulation and analysis of series voltage restorer (SVR) for voltage sag relief," *in Proceedings IEEE Power Electron*ics *System Winter Meeting*, vol. 4, pp. 2476–2481, Jan. 2000.

[7] Y.W. Li, F. Blaabjerg, D. Mahinda Vilathgamuwa and P.C. Loh, "Design and Comparison of High Performance Stationary-Frame Controllers for DVR Implementation," *IEEE Transcations on Power Electronics*, vol. 22, no. 2, Mar. 2007.

[8] M. J. Ryan, W. E. Brumsickle and R. D. Lorenz, "Control topology options for single-phase UPS inverters," *IEEE Transactions Industrial Applications*, vol. 33, pp. 493–501, Mar./Apr. 1997.

[9] Chris Fitzer, Mike Barnes and Peter Green, "Voltage Sag Detection Technique for a Dynamic Voltage Restorer," *IEEE Transactions on Industry Applications*, vol. 40, no. 1, Jan./Feb. 2004.

[10] J. G. Nielsen, F. Blaabjerg, and N. Mohan, "Control strategies for dynamic voltage restorer compensating voltage sags with phase jump*," in Proceedings IEEE APEC'01*, vol. 2, pp. 1267–1273, 2001.