International Journal of Modern Engineering Research (IJMER)
www.ijmer.com Vol.2, Issue.2, Mar-Apr 2012 pp-475-478 ISSN: 2249-6645

An Enhancement Method for the Compensation of Voltage Sag/Swell and Harmonics by Dynamic Voltage Restorer

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Abstract - **Now a days, the problem of voltage sags and Swells create a severe impact on sensitive loads in industries . Due to which load shedding and over voltages might occur. Several custom power devices can be used to overcome this problem. Of these power devices Dynamic Voltage Restorer (DVR) is one of the most reliable and efficient custom power devices used in power distribution network. This paper describes DVR principles and voltage compensation methods for balanced / unbalanced voltage sags and swells in a distribution system. Several methods can be included in the DVR system to overcome the voltage sag and swell. Here we use dqo algorithm. There are two important parts in the DVR one is to detect the voltage disturbance and the other is to compensate it as fast as possible. Simulation results were presented to illustrate and understand the performances of DVR under voltage sags/swells conditions. The results obtained by simulation using MATLAB confirmed the effectiveness of this device in compensating voltage sags and swells with very fast response (relative to voltage sag/swell time).**

Key words: **Dynamic voltage restorer, voltage sag/swell, power factor improvement, total harmonic reduction.**

I. INTRODUCTION

IN present days, modern industrial devices are mostly based on electronic devices such as programmable logic controllers and electronic drives. The electronic devices are very sensitive to disturbances and become less tolerant to power quality problems such as voltage sags, swells and harmonics. Voltage dips are considered to be one of the most severe disturbances to the industrial equipments.

Voltage support at a load can be achieved by reactive power injection at the load point of common coupling. The common method for this is to install mechanically switched shunt capacitors in the primary terminal of the distribution transformer. The mechanical switching maybe on a schedule, via signals from a Supervisory Control and Data Acquisition (SCADA) system, with some timing schedule, or with no switching at all. The disadvantage is that, high speed transients cannot be compensated. Some sags are not corrected within the limited time frame of mechanical switching devices. Transformer taps may be used, but tap changing under load is costly.

Another power electronic solution to the voltage regulation is the use of a Dynamic Voltage Restorer (DVR). DVRs are a class of custom power devices for providing reliable distribution power quality. They employ a series of voltage boost technology using solid state switches for compensating voltage sags/swells. The DVR applications are mainly for sensitive loads that may be drastically affected by fluctuations in system voltage.

A Sources And Effects Of Power Quality Problems

Power distribution systems, ideally, should provide their customers with an uninterrupted flow of energy at smooth sinusoidal voltage at the contracted magnitude level and frequency 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.

While power disturbances occur on all electrical systems, the sensitivity of today's sophisticated electronic devices makes them more susceptible to the quality of power supply. For some sensitive devices, a momentary disturbance can cause scrambled data, interrupted communications, a frozen mouse, system crashes and equipment failure etc. A power voltage spike can damage valuable components. Power Quality problems encompass a wide range of disturbances such as voltage sags/swells, flicker, harmonics distortion, impulse transient, and interruptions.

- Voltage sag
  Voltage sags can occur at any instant of time, with amplitudes ranging from 10 – 90% and a duration lasting for half a cycle to one minute.

- Voltage swell
  Voltage swell is defined as an increase in rms voltage or current at the power frequency for durations from 0.5 cycles to 1 min.

- Harmonics
  The fundamental frequency of the AC electric power distribution system is 50 Hz. A harmonic frequency is any sinusoidal frequency, which is a multiple of the fundamental frequency. Harmonic frequencies can be even or odd multiples of the sinusoidal fundamental frequency.

II DYNAMIC VOLTAGE RESTORER

Among the power quality problems (sags, swells, harmonics…) voltage sags are the most severe disturbances. In order to overcome these problems the concept of custom power devices is introduced recently. One of those devices is the Dynamic Voltage Restorer (DVR), which is the most efficient and effective modern custom power device used in power distribution networks.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 the critical load feeder at the Point of Common Coupling (PCC). Other than voltage sags and swells compensation, DVR can also added other features like: line voltage harmonics compensation, reduction of transients in voltage and fault current limitations.

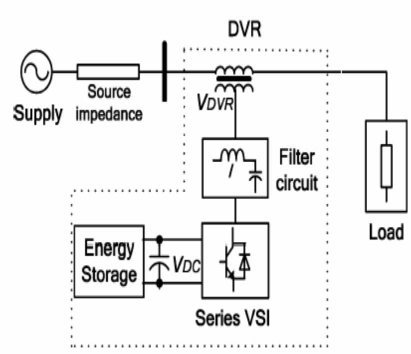


figure 1. Circuit diagram of DVR

III SYSTEM CONFIGURATION

The DVR is a custom power device that is connected in series with the distribution system as shown in figure 1. The main components of the DVR consists of an injection transformer, harmonic filter, series VSI (VSC) an energy storage and control system (as shown in Figure-1).

The basic function of the DVR is to inject a dynamically controlled voltage V_{DVR} generated by a forced commutated converter in series to the bus voltage by means of a booster transformer. The momentary amplitudes of the three injected phase voltages are controlled such as to eliminate any detrimental effects of a bus fault to the load voltage V_L. This means that any differential voltages caused by transient disturbances in the ac feeder will be compensated by an equivalent voltage generated by the converter and injected on the medium voltage level through the booster transformer.

The DVR works independently of the type of fault or any event that happens in the system, provided that the whole system remains connected to the supply grid, i.e. the line breaker does not trip. For most practical cases, a more economical design can be achieved by only compensating the positive and negative sequence components of the voltage disturbance seen at the input of the DVR. This option is Reasonable because for a typical distribution bus configuration, the zero sequence part of a disturbance will not pass through the step down transformer because of infinite impedance for this component.

The DVR has two modes of operation which are: standby mode and boost mode. In standby mode (V_{DVR}=0), the booster transformer's low voltage winding is shorted through the converter.

IV. PROPOSED METHOD

A Main circuit

Once a voltage disturbance occurs, with the aid of dqo transformation based control scheme, the inverter output can be steered in phase with the incoming ac source while the load is maintained constant. As for the filtering scheme of the proposed method, output of inverter is installed with capacitors and inductors.

B Control methods

The basic functions of a controller in a DVR are the detection of voltage sag/swell events in the system; computation of the correcting voltage, generation oftrigger pulses to the sinusoidal PWM based DC-AC inverter, correction of any anomalies in the series voltage injection and termination of the trigger pulses when the event has passed. The controller may also be used to shift the DC-AC inverter into rectifier mode to charge the capacitors in the DC energy link in the absence of voltage sags/swells. The dqo method gives the sag depth and phase shift information with start and end times. The quantities are expressed as the instantaneous space vectors. Firstly convert the voltage from a-b-c reference frame to d-q-o reference. For simplicity zero phase sequence components is ignored.

Figure-2 illustrates a flow chart of the feed forward dqo transformation for voltage sags/swells detection. The detection is carried out in each of the three phases.

The control is based on the comparison of a voltage reference and the measured terminal voltage (Va,Vb,Vc).The voltage sags is detected when the supply

$$\begin{bmatrix} V_d \\ V_q \\ V_o \end{bmatrix} = \begin{bmatrix} \cos(\theta) & \cos\left(\theta - \frac{2\pi}{3}\right) & 1 \\ -\sin(\theta) & -\sin\left(\theta - \frac{2\pi}{3}\right) & 1 \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix} \begin{bmatrix} Va \\ Vb \\ Vc \end{bmatrix}$$

The above equation defines the transformation from three phase system a, b, c to dqo stationary frame. In this transformation, phase A is aligned to the d-axis that is in drops below 90% of the reference value whereas voltage swells is detected when supply voltage increases up to 25% of the reference value.

The error signal is used as a modulation signal that allows generating a commutation pattern for the power switches (IGBT's) constituting the voltage source converter. The commutation pattern is generated by means of the Sinusoidal Pulse Width Modulation technique (SPWM); voltages are controlled through the modulation. The block diagram of the Phase Locked Loop (PLL) is illustrated in Figure-2. The PLL circuit is used to generate a unit sinusoidal wave in phase with mains voltage.

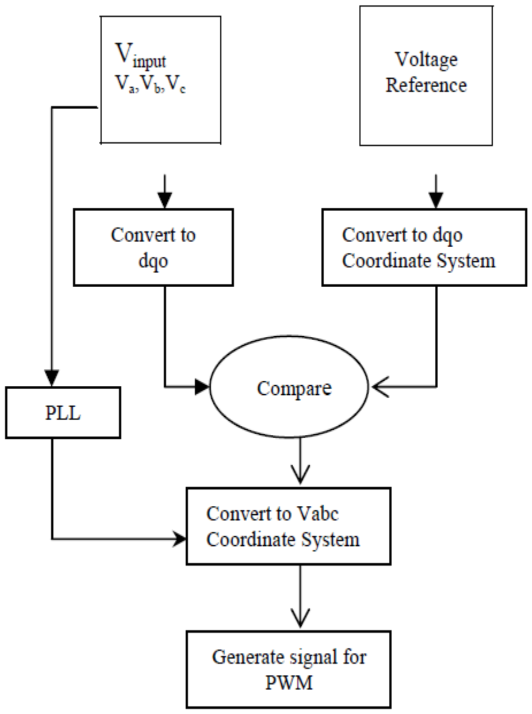
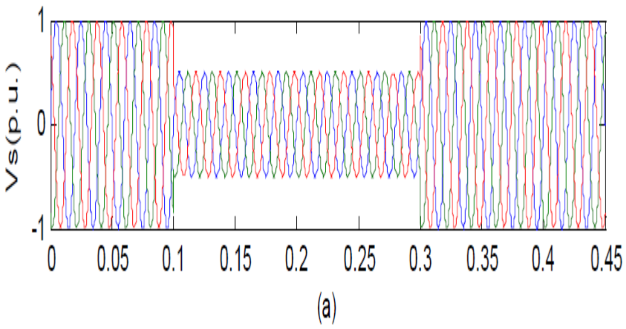


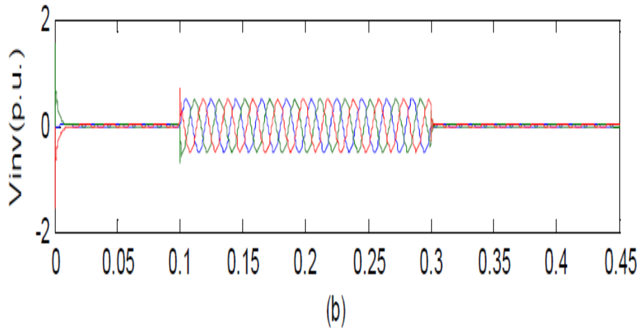
Figure.2 Flow chart of feed forward control technique For DVR based on dqo transformation

V. SIMULATION RESULTS AND DISCUSSIONS

A Voltage sags

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-3 (a). In Figure-3 (a) also shows a 50% voltage sag initiated at 0.1s and it is kept until 0.3s, with total voltage sag duration of 0.2s. Figures-3(b) and (c) show the voltage injected by the DVR and the corresponding load voltage with compensation. As a result of DVR, the load voltage is kept at 1 pu.





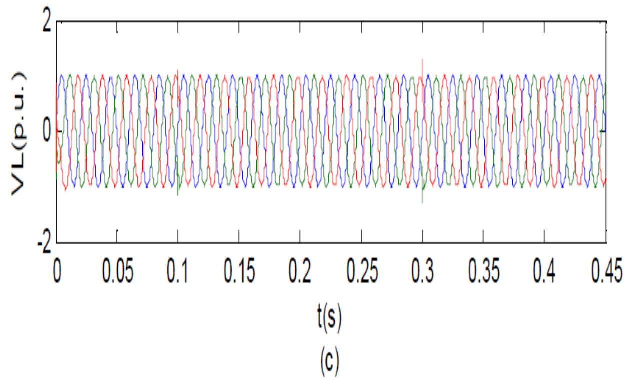
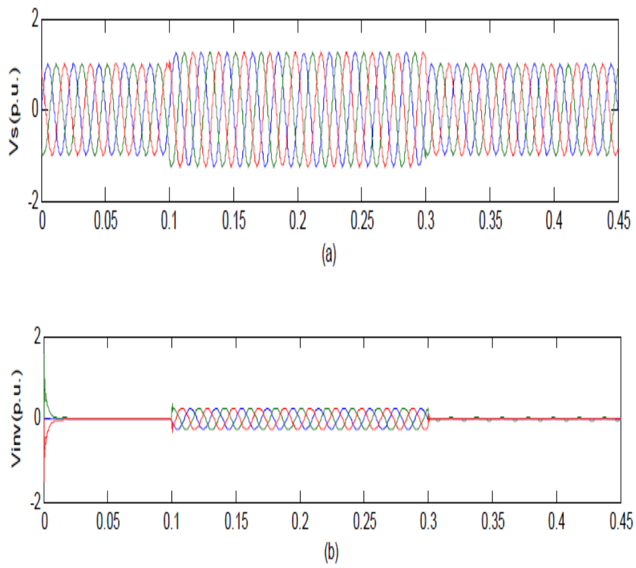


Figure-3. Three-Phase voltage sag(a)-Supply voltage,(b)voltage injected by the DVR,(c)-Load voltage



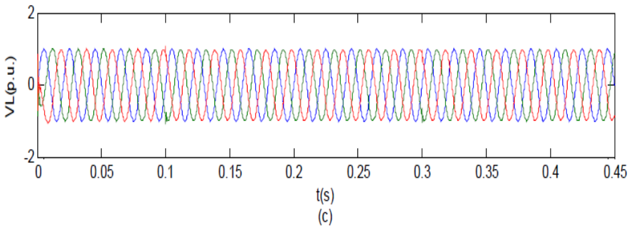


Figure-4.Three phase voltage swell (a)supply voltage,(b)voltage injection by DVR,(c)-voltage at load

B Voltage Swells

The second simulation shows the DVR performance during a voltage swell condition. The simulation started with the supply voltage swell is generated as shown in Figure-4 (a). The amplitude of supply voltage is increased about 25% from its nominal voltage. Figures-4(b) and (c) show the injected and the load voltage respectively. As can be seen from the results, the load voltage is kept at the nominal value with the help of the DVR. Similar to the case of voltage sag, the DVR reacts quickly to inject the appropriate voltage component (negative voltage magnitude) to correct the supply voltage.

C Total Harmonic Distortion Without DVR

The third simulation shows the Total Harmonic Distortion (THD) when DVR is not connected in the transmission line.THD is more than 50% when DVR is not connected which would affect the performance and efficiency of the system. Thus the power factor will be decreased.The waveform will be obtained as in fig.5.

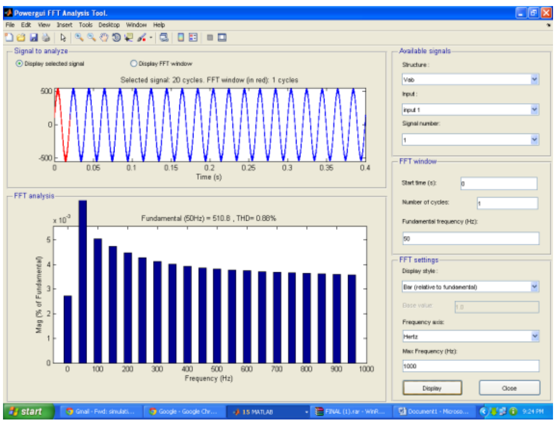


Fig 5 THD without DVR

D Total Harmonic Distortion With DVR

The fourth simulation shows the Total Harmonic Distortion(THD) when DVR is connected in the transmission system. The waveform will be obtained as in fig.6. Here the efficiency and the power factor can be increased when compared to the system without DVR

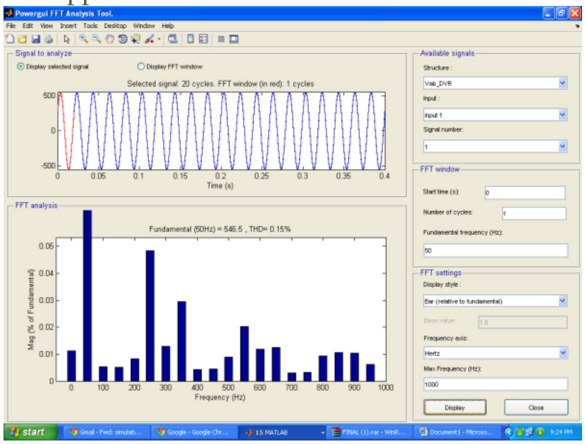


Fig 6 THD with DVR

VI .CONCLUSIONS

The modeling and simulation of a DVR using MATLAB has been presented. A control system based on dqo technique which is a scaled error of the between source side of the DVR and its reference for sags/swell correction has been presented. The simulation shows that the DVR performance is satisfactory in mitigating voltage sags/swells.

The main advantage of this DVR is low cost and its control is simple. It can mitigate long duration voltage sags/swells efficiently. Future work will include a comparison with a laboratory experiments in order to compare simulation and experimental results.

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