An Advanced Approach Of A Multi Level DVR

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ABSTRACT: Dynamic Voltage Restorers are utilized to protect sensitive loads from voltage sags and swells which take place in the distribution systems with a multi level inverter. In this paper, a Dynamic Voltage Restorer (DVR) based on hysteresis voltage control is proposed. The DVR is modeled using Simulink Sim Power System Toolbox. Discrete Fourier Transform (DFT) is used to detect the magnitude and phase jump of the voltage sag and swell. The influence of the band of the hysteresis voltage controller on the quality of the load voltage and DVR voltage is studied. The DVR is tested for three phase voltage sag and swell with phase jump to validate the proposed control scheme.

INTRODUCTION

Flexible AC Transmission Systems, called FACTS, got in the recent years a well known term for higher controllability in power systems by means of power electronic devices. Several FACTS-devices have been introduced for various applications worldwide. A number of new types of devices are in the stage of being introduced in practice.

In most of the applications the controllability is used to avoid cost intensive or landscape requiring extensions of power systems, for instance like upgrades or additions of substations and power lines. FACTS-devices provide a better adaptation to varying operational conditions and improve the usage of existing installations.

SAG: External causes of sags primarily come from the utility transmission and distribution network. Sags coming from the utility have a variety of cause including lightning, animal and human activity, and normal and abnormal utility equipment operation. Sags generated on the transmission or distribution system can travel hundreds of miles thereby affecting thousands of customers during a single event. Sometimes externally caused sags can be generated by other customers nearby.

SWELL: A swell is the opposite of sag - an increase in voltage above 110% of nominal for one-half cycle to one minute. Although swells occur infrequently when compared to sags, they can cause equipment malfunction and premature wear. Swells can be caused by shutting off loads or switching capacitor banks on.

BASIC PRINCIPLE OF DVR

A DVR is a controlled reactive source, which includes a Voltage Source Converter (VSC) and a DC link capacitor connected in shunt, capable of generating and/or absorbing reactive power. The operating principles of a DVR are based on the exact equivalence of the conventional rotating synchronous compensator. The AC terminals of the VSC are connected to the Point of Common Coupling (PCC) through an inductance, which could be a filter inductance or the leakage inductance of the coupling transformer, as shown

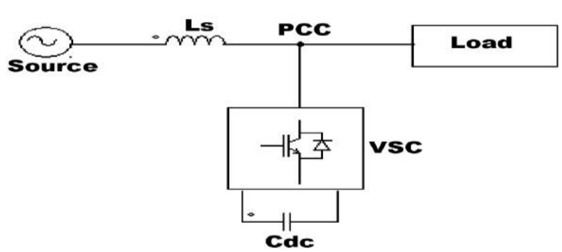

Fig.1 line diagram of DVR

The DC side of the converter is connected to a DC capacitor, which carries the input ripple current of the converter and is the main reactive energy storage element. This capacitor could be charged by a battery source, or could be pre-charged by the converter itself . If the output voltage of the VSC is equal to the AC terminal voltage, no reactive power is delivered to the system. If the output voltage is greater than the AC terminal voltage, the DVR is in the capacitive mode of operation and vice versa. The quantity of reactive power flow is proportional to the difference in the two voltages.

It is to be noted that voltage regulation at PCC and power factor correction cannot be achieved simultaneously. For a DVR used for voltage regulation at the PCC, the compensation should be such that the supply currents should lead the supply voltages; whereas, for power factor correction, the supply current should be in phase with the supply voltages. The control strategies studied in this paper are applied with a view to studying the performance of a DVR for power factor correction and harmonic mitigation.

MULTILEVEL CONVERTER:

An inverter is an electrical device that converts direct current (DC) to alternating current (AC); the converted AC can be at any required voltage and frequency with the use of appropriate transformers, switching, and control circuits.

Static inverters have no moving parts and are used in a wide range of applications, from small switching power supplies in computers, to large electric utility high-voltage direct current applications that transport bulk power. Inverters are commonly used to supply AC power from DC sources such as solar panels or batteries.

A single-phase structure of an m-level cascaded inverter is illustrated in Figure 31.1. Each separate dc source (SDCS) is connected to a single-phase full-bridge, or H-bridge, inverter. Each inverter level can generate three different voltage outputs, $+V_{dc}$, 0, and $-V_{dc}$ by connecting the dc source to the ac output by different combinations of the four switches, S_1, S_2, S_3, and S_4. To obtain $+V_{dc}$, switches S_1 and S_4 are turned on, whereas $-V_{dc}$ can be obtained by turning on switches S_2 and S_3. By turning on S_1 and S_2 or S_3 and S_4, the output voltage is 0. The ac outputs of each of the different full-bridge inverter levels are connected in series such that the synthesized voltage waveform is the sum of the inverter outputs. The number of output phase voltage levels m in a cascade inverter is defined by m = 2s+1, where s is the number of separate dc sources. An example phase voltage waveform for an 11-level cascaded H-bridge inverter with 5 SDCSs and 5 full bridges is shown in Figure 31.2. The phase voltage $v_{an} = v_{a1} + v_{a2} + v_{a3} + v_{a4} + v_{a5}$.

For a stepped waveform such as the one depicted in Figure 31.2 with s steps, the Fourier Transform for this waveform follows

$$V(\omega t)=\frac{4V_{dc}}{\pi}\sum_{n}\left[\cos(n\theta_1)+\cos(n\theta_2)+\ldots+\cos(n\theta_s)\right]\frac{\sin(n\omega t)}{n},\quad \text{where } n=1,3,5,7,\ldots$$

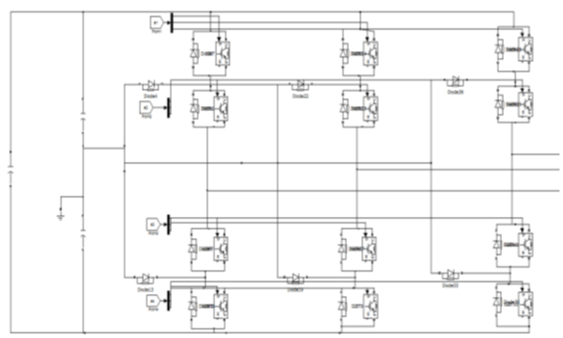

Fig.2 three level DVR

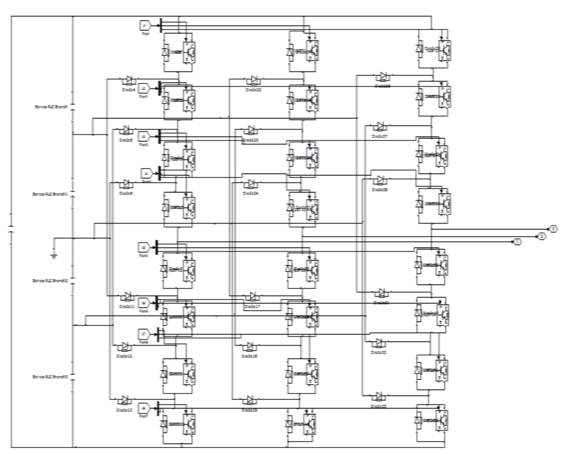

Fig.3 five level DVR

The magnitudes of the Fourier coefficients when normalized with respect to V_{dc} are as follows:

$$H(n) = \frac{4}{\pi n}\left[\cos(n\theta_1) + \cos(n\theta_2) + \ldots + \cos(n\theta_s)\right], \quad \text{where } n = 1, 3, 5, 7, \ldots$$

The conducting angles, θ_1, θ_2, ..., θ_s, can be chosen such that the voltage total harmonic distortion is a minimum. Generally, these angles are chosen so that predominant lower frequency harmonics, 5th, 7th, 11th, and 13th, harmonics are eliminated. More detail on harmonic elimination techniques will be presented in the next section. Multilevel cascaded inverters have been proposed for such applications as static var generation, an interface with renewable energy sources, and for battery-based applications. Three-phase cascaded inverters can be connected in wye, as shown in Figure, or in delta. Peng has demonstrated a prototype multilevel cascaded static var generator connected in parallel with the electrical system that could supply or draw reactive current from an electrical system.

CONTROL STRATEGIES

Satisfactory performance, fast response, flexible and easy implementation are the main objectives of any compensation strategy. The control strategies of a DVR are mainly implemented in the following steps: Measurements of system variables and signal conditioning, Extraction of reference compensating signals, Generation of firing angles for switching devices

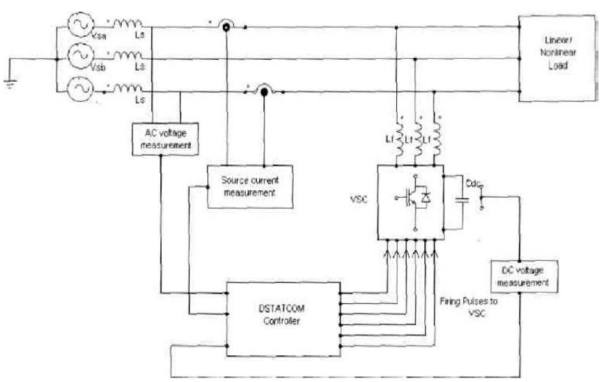

Figure.4 schematic diagram of DVR

Figure.3 shows the schematic diagram of DVR control taking into consideration the above steps. The generation of proper pulse width modulation (PWM) firing is the most important part of DVR control and it has a great impact on its compensation objectives, transient as well as steady state performance. Since a DVR shares many concepts with that of a STATCOM at the transmission level, a few control techniques have been directly implemented to a DVR, incorporating PWM switching, rather than fundamental frequency switching (FFS) methods. A PWM based distribution static compensator offers faster response and capability for harmonic elimination. This paper is an attempt to compare the following schemes of a DVR for power factor correction and harmonic mitigation based on:

Phase shift control

1. Indirect decoupled current control
2. Regulation of AC bus and DC link voltage
   The schematic diagram of phase shift control is shown in figure.
3. In this method, the compensation is achieved by the measuring of the rms voltage at the load point, whereas no reactive power measurements are required. Sinusoidal PWM technique is used with constant switching frequency. The error signal obtained by comparing the measured system rms voltage and the reference voltage is fed to a proportional integral (PI) controller, which generates the angle for deciding the necessary phase shift between the output voltage of the VSC and the AC terminal voltage.

   This angle is summed with the phase angle of the balanced supply voltages, assumed to be equally spaced at 120 degrees, to produce the desired synchronizing signal required to operate the PWM generator. In this scheme, the DC voltage is maintained constant,using a separate battery source.

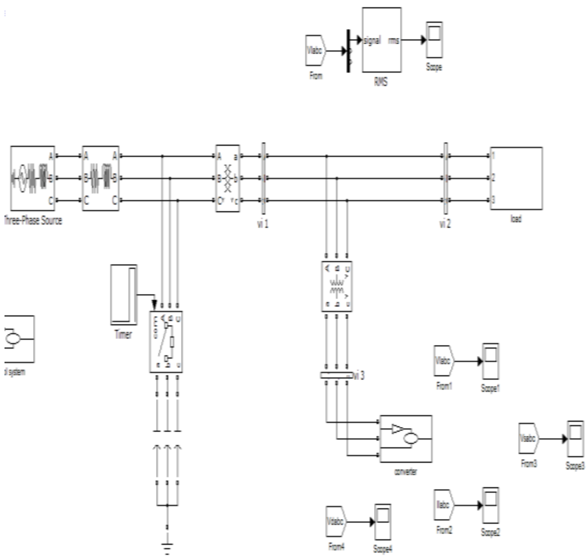

Fig.5 simulation model of three level DVR

Figure a and figure b show the simulation results obtained using phase shift control for reactive power compensation and harmonic mitigation for a balanced varying linear load and for a non linear load respectively. It is observed that the source current and the source voltage are in phase, correcting the power factor of the system in case of a linearly varying load; whereas, complete compensation is not achieved in case of nonlinear load (source current THD 24.34%). The frequency spectrum of the source current for a nonlinear load, before and after compensation, is shown in Figure a and Figure b. Though this strategy is easy to implement, is robust and can provide partial reactive power compensation without harmonic suppression, it has the following major disadvantages:

- The controller does not use a self supporting DC bus and thus requires a very large DC source to pre charge the capacitor.
- Balanced source supply as rms voltage is assumed and the supply phase angle are calculated over the fundamental only.
- No harmonic suppression and partial compensation is achieved in case of nonlinear loads.

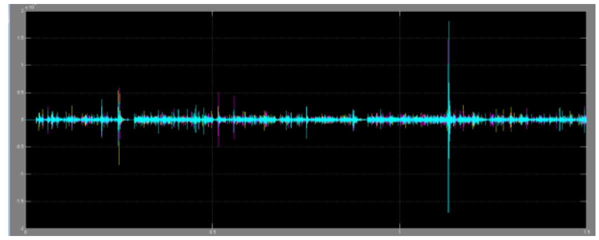

Fig.6 five level DVR source voltage

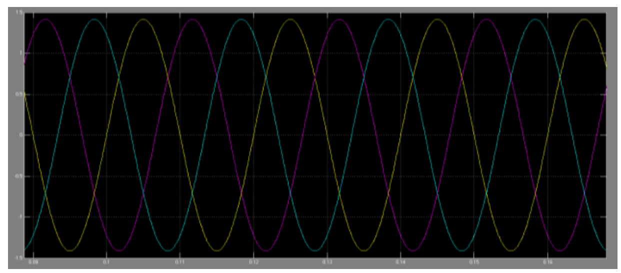

Fig: 7 five level DVR load votage

- **Indirect Decoupled Current Control**

This scheme is based on the governing equations of advanced static var compensator. It requires the measurement of instantaneous values of three phase line voltages and current. Figure shows the block diagram representation of the control scheme. The control scheme is based on the transformation of the three phase system to a synchronously rotating frame, using Park's transformation.

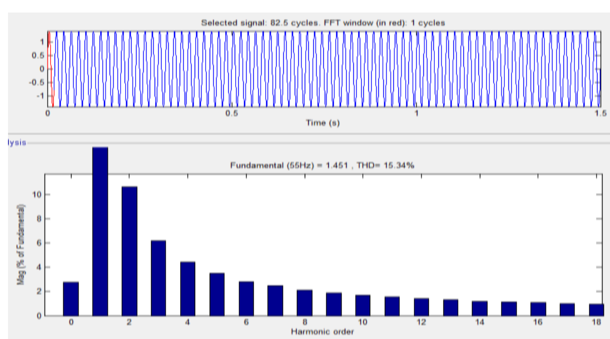

Fig. 8 THD of three level DVR

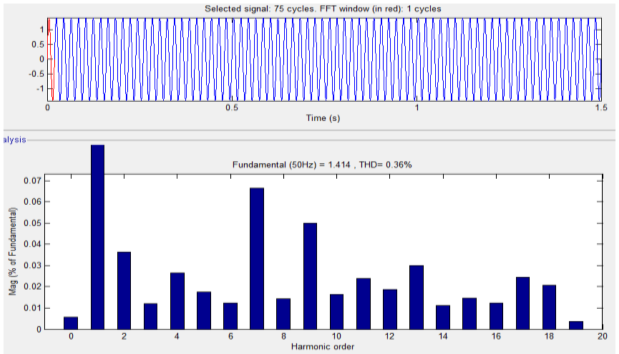

Fig. 9 THD of five level DVR

CONCLUSION

This paper has proposed and modeled a Dynamic Voltage Restorer (DVR) Based on multi level converter .The steps of developing the model of the DVR have been explained in details. The influence of the hysteresis band on the quality of the load and DVR voltage has been studied under voltage sag and swell. It has been found that selecting the hysteresis band should be based on the value THD of the DVR voltage and voltage sag test. The ability of the DVR to maintain the load voltage under different voltage sags and swells has been verified using time domain simulations. The model of the DVR with the hysteresis control can be further enhanced by having fixed frequency hysteresis voltage controller. In addition, a faster sag/swell detection technique can be also developed and modeled to improve the response of the DVR. These issues are subject of future research.

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BIBLIOGRAPHY

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