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Performance Comparison of DVR and D-STATCOM for Power Quality Improvement using Non-Linear Loads

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ABSTRACT

In the power system, nonlinear loads results in production of harmonics due to which load current waveform gets distorted. The power-quality problems which these compensator address include voltage sags/swells, load voltage harmonic distortions, and unbalancing. There are different types of custom power devices like Distribution Static Compensator (D-STATCOM) and Dynamic Voltage Restorer (DVR) which can effectively use for mitigation of different type of power quality problems. These two devices are very effectual devices working on the principle of Voltage Source Inverter. This paper describes the technique of correcting the supply voltage sag distributed system and also describes performance comparison are presented between DVR and DSTATCOM to know how both the devices successfully been applied to power system for regulating system voltage effectively.

Keywords*: *Distributed Static Compensator (DSTATCOM), Harmonics, Power Quality,Dynamic Voltage Restorer (DVR).

I.INTRODUCTION

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. Power quality phenomenon or power quality disturbance can be defined as the deviation of the voltage and the current from its ideal waveform. In electrical power system, voltage control performs an essential function to ensure the voltage interruptions [1] like sag, swell and harmonics can be minimized and then increase the power quality, reliability and availability. According to IEC (International Electro-technical commissions) the voltage standard should be in the range of ±6% of the specified value of voltage. Methods of voltage control are: (a) By using FACTS devices, (b) By reactive power injection, (c) By using tap changing transformer. If the provided reactive power is introduced into the system, the system voltage will increase and if the reactive power is taken from the system i.e. absorbed by the source then voltage will decrease so voltage and reactive power are related with each other. In the industries as well as in the offices, Uninterruptable Power Supply (UPS) plays an important role. However, UPS systems are quite expensive, and while they do a good job in protecting their own load, they are also the major power system polluters and often cause problems for neighboring loads. Thus, there exists the need to modify or design new and innovative circuits that can be placed at the user end to reduce the distortion level or to cancel the effect of transient phenomena, and provide back up for end users which we get now through UPS systems. Thus, harmonics in the supply varies arbitrarily and hence various compensating techniques are being used such as passive filter, active filter or hybrid filter to eliminate harmonics at a particular frequency [2], also various configurations of these filters have been adopted depending upon the system configuration and its control strategy. After filters, advanced power electronics technology came into action known as custom power device technology. So, power quality improvement is possible either by harmonic cancellation or reactive power compensation by injecting current to improve the load current at PCC using these devices.

Two types of VSI-based compensators have been commonly used for mitigation of the voltage sags and swells and regulating the load voltage. The first one is a shunt device, which is commonly called DSTATCOM, and the second one is a series device, which is commonly called DVR [3]. These compensators can address other PQ issues, such as load voltage harmonics, source current harmonics, unbalancing, etc., under steady state to obtain more benefits out of their continuous operation. There have been a variety of control strategies proposed for load voltage control using the aforementioned two devices. For DSTATCOM, this includes reactive power compensation and voltage-control mode operation of DSTATCOM. For DVR, it includes open-loop and closed-loop load voltage-control methods [4]. The closed-loop voltage-control mode operation of the two devices is considered best from the point of view of precise and fast control against sudden variations in the supply voltage and the load. In this paper, the performance and comparison of the DSTATCOM and the DVR used for non-linear loads. Both of these compensators are used under closed-loop voltage-control mode. The control performance of the compensator and attenuation properties against perturbations has been obtained using closed-loop frequency-response characteristics. A simple output voltage feedback control and a fixed switching frequency linear modulation have been used for the operation of the VSI under closed loop. It is shown that the performance of two compensating devices depends upon the feeder impedance. The performance study for the DSTATCOM and the DVR has been obtained for the weak and strong ac supply systems.

II. VOLTAGE SOURCE INVERTER

A voltage-source inverter is a power electronic device, which can generate a sinusoidal voltage with any required magnitude, frequency and phase angle. The VSI is used to either completely replace the voltage or to inject the ‘missing voltage’. The ‘missing voltage’ is the difference between the nominal voltage and the actual. The converter is normally based on some kind of energy storage, which will supply the inverter with a DC voltage. A widely used method is the two level or multilevel three-phase converters which shares a dc capacitor between all phases. The purpose of this capacitor is mainly to absorb harmonic ripple and hence it has a relatively small energy storage requirement, particularly when operating in balanced conditions. The size of this capacitor has to be increased if needed to provide voltage support in unbalanced conditions. The solid-state electronics device i.e. MOSFET, GTO, IGBT etc. in the inverter is then switched to get the desired output voltage [5]. 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. Normally the VSI is not only used for voltage dip mitigation, but also for other power quality issues, e.g. flicker and harmonics.

The VSI connected in shunt with the ac system provides a multifunctional topology which can be used for up to three quite distinct purposes:

1. Voltage regulation and compensation of reactive power.
2. Correction of power factor.
3. Elimination of line harmonics.

III. CONTROLLER ALGORITHM

The aim of the control scheme is to maintain constant voltage magnitude at the point where a sensitive load is connected, under system disturbances. The control system only measures the R.M.S. voltage at the load point i.e. no reactive power measurements are required. The VSI switching strategy is based on a PWM technique which offers simplicity and good response also PWM is used to vary the amplitude and the phase angle of the injected voltage. Since custom power is a relatively low-power application, PWM methods offer a more flexible option than the Fundamental Frequency Switching (FFS) methods favored in FACTS applications [6]. Besides, high switching frequencies can be used to improve on the efficiency of the converter, without incurring significant switching losses.

IV.A DYNAMIC VOLTAGE RESTORER

Among the different types of custom power devices, DVR is one of the most effective and efficient compensating device. DVR is a series connected device. This device are concerned with the power quality issues such as voltage sag, voltage swell, harmonic blocking, and voltage balancing. It is mainly used in compensating the problem of voltage sag observed by sensitive loads in industries. The rating of DVR is maximize up to 2MVA till now with ability to overcome power quality problems up to 40 %. It is connected in series through boost transformer. In normal operation, DVR didn't inject any voltage into the system and remains in standby mode. Whenever voltage sag comes [7], DVR going to inject required voltage into the system as per the requirement. DC link is connected in series to provide active power as per the requirement of system at the time of voltage sag. The block diagram fig.1. Dynamic Voltage Restorer provides compensation for voltage sag and swell, but the condition applied is the supply to grid should not be entirely shut down. DVR injects voltage into the system as per the demand. In order to inject the three phase voltage, three phase multilevel inverters are used. These three phase inverters are the back bone of

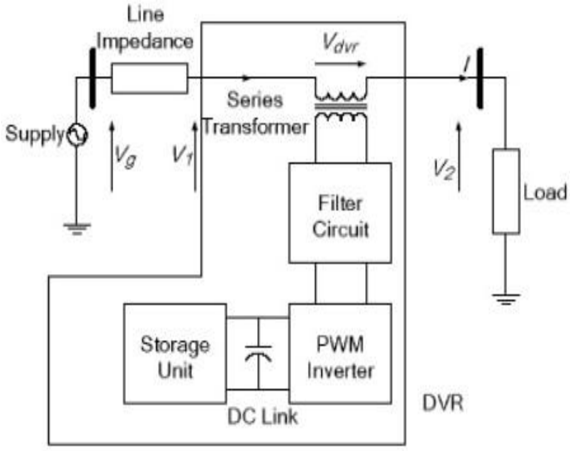

Fig.1: Schematic Diagram of DVR

the DVR. To control these inverters, PWM technique is employed. Controlling of the DVR is very important. PI controllers are mainly used as their integral outputs reduce the steady state error to zero for step input.

V.DISTRIBUTION STATIC COMPENSATOR

A Distribution-STATCOM consists of a two-level VSI, a dc energy storage device, a coupling transformer connected in shunt to the distribution network through a coupling transformer as shown in Fig.2. The VSI converts the dc voltage across the storage device into a set of three-phase ac output voltages. These voltages are in phase and coupled with the ac system through the reactance of the coupling transformer. Suitable adjustment of the phase and magnitude of the DSTATCOM output voltages allows effective control of active and reactive power exchanges between the DSTATCOM and the ac system [8]. Such configuration allows the device to absorb or generate controllable active and reactive power.

In DSTATCOM the compensation is done mainly by exchanging the reactive power between the device and the main distribution line. Voltage source converter inverts the DC voltage supplied by the energy storage system (dc link capacitor) into three phase ac voltage. This injected voltage is in phase with the system voltage [9]. The operation of VSC is controlled by various controlling strategies such as PID. Fuzzy etc. controllers are required in DSTATCOM for controlling the phase and magnitude of injected voltage and current. Coupling transformer also play a very important role. The required voltage is injected by using injecting transformer which connects the output of VSI directly to the system.

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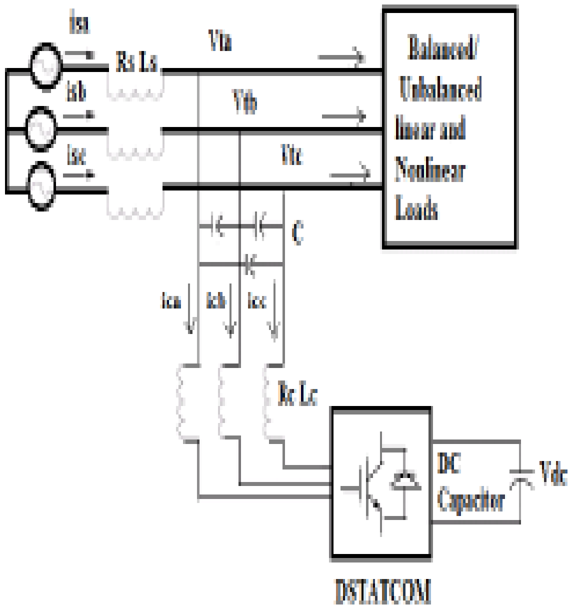

Fig.2. Schematic Diagram of DSTATCOM

VI.MATLAB MODELING AND SIMULATION

6.1 Simulink Model of DVR

The Simulink model of the DVR connected system is represented in Fig.3 is modeled in MATLAB /Simulink environment with the help of sim power system toolbox. The three-phase ac voltage source is associated to the three-phase load through Dynamic Voltage Restorer with the objective of improving the performance of voltage. DVR [10] comprises three phase inverter module, capacitor, ac filter, injection transformer and a control technique. PWM switching technique has been implemented for the purpose of controlling the electronic valves in the three level voltage source inverter. The battery on the dc side is used to determine the amount of energy required to supply by the capacitor i.e. the energy storage device.

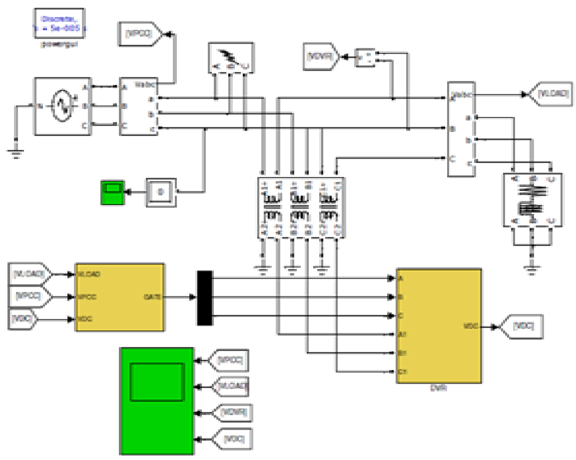

Fig.3. MATLAB model of DVR connected system

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6.2. Simulink Model of DSTATCOM

The Simulink model of the DSTATCOM connected system shown in Fig.6 is modeled in MATLAB /Simulink environment with the help of sim power system toolbox. The three-phase ac voltage source is associated to the three-phase load through D-STATCOM with the objective of improving the power quality of non-linear loads. This reactive power transfer is done through the leakage reactance of the coupling transformer by generating a secondary voltage in phase with the primary voltage (network side). This voltage is provided by a voltage-sourced PWM inverter. When the secondary voltage is lower than the bus voltage, the D-STATCOM acts like an inductance absorbing reactive power. When the secondary voltage is higher than the bus voltage, the DSTATCOM acts like a capacitor generating reactive power.

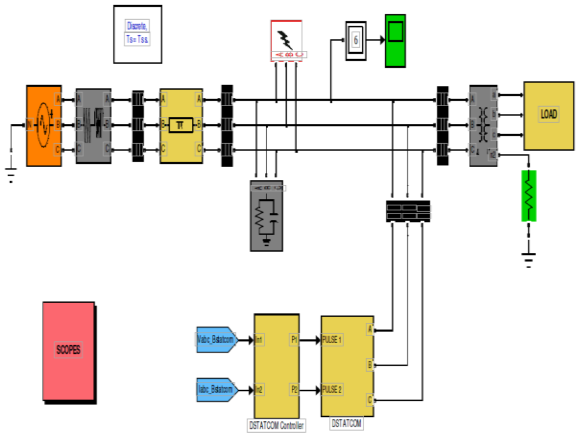
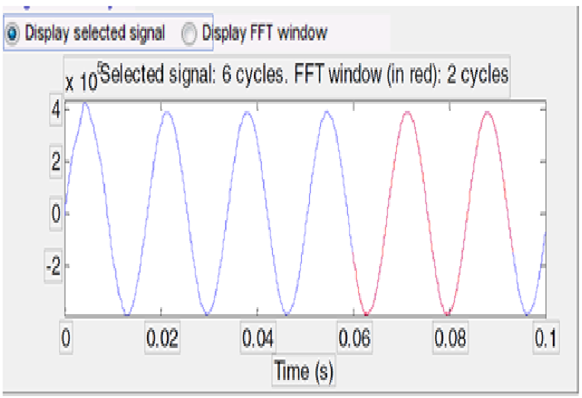


Fig.4. MATLAB model of DSTATCOM connected system

VII.RESULTS

Total harmonic distortion is an important criterion for power quality improvement. For the basis of presented harmonics in a power line THD is being calculated. Shown the fig. 5 is a THD analysis of DVR. This is load voltage THD during fault. Shown the fig.6 is a THD analysis of D-STATCOM. This is load voltage THD during fault.

7.1. THD Analysis of DVR



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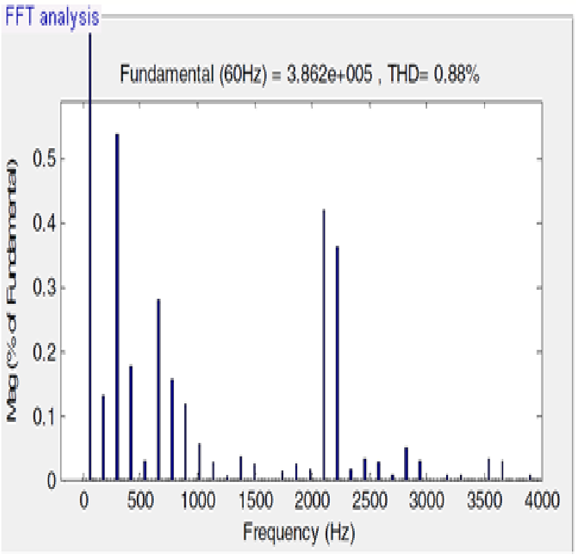
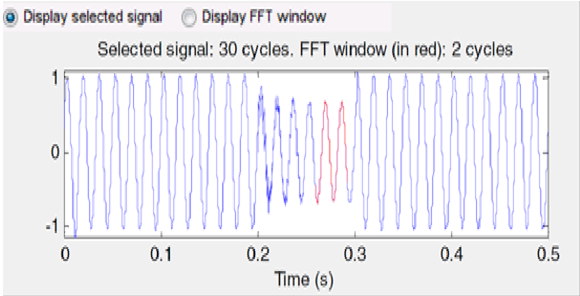


Fig.5. Load Voltage THD during Fault

Total harmonic distortion (THD) = 0.88%

7.2. THD Analysis of DSTATCOM



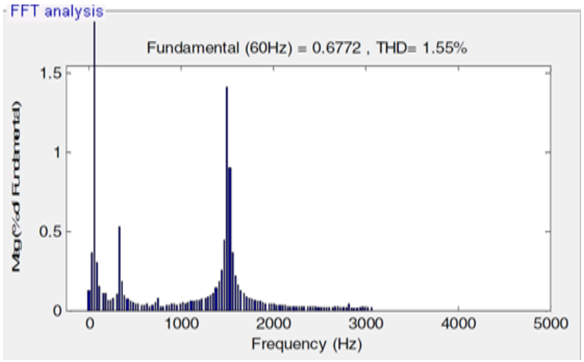


Fig.6. Load Voltage THD during Fault

Total harmonic distortion (THD) = 1.55%

VIII.CONCLUSIONS

In this paper, the performance comparison of DVR and D-STATCOM is made using the MATLAB/ Simulink and sim power system toolboxes. The controlling of DVR and DSTATCOM is done by using PWM controller. The simulation results clearly represent the performance of the Distributed Static Compensator and Dynamic Voltage Restorer for harmonic mitigation, caused by the occurrence of fault in distribution systems. This paper has presented the power quality problems such as voltage dips, swells and harmonic, consequences, and mitigation techniques of custom power electronic devices DVR, D-STATCOM. A new PWM-based control scheme has been implemented to control the electronic valves in the VSI used in the D-STATCOM and DVR. As opposed to fundamental frequency switching schemes already available in the MATLAB/ SIMULINK. So, by use of custom power devices, the harmonic distortion in non-linear loads can be improved as per these standards thereby reducing the reactive power of the system and hence system losses can be avoided.

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