The Role of Dynamic Voltage Restorer (DVR) in Improving Power Quality and Reliability

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***Abstract-* Power quality is major issue in power transmission; this affects majorly the consumers. Especially, with the introduction of sophisticated devices, the performance is very sensitive to the quality of power utility. To overcome this problem design of solar energy based dynamic voltage compensator, which is an efficient and effective modern customized power device used in distribution networks. Its appeal includes lower cost, smaller size, and its fast dynamic response to the disturbance. This paper introduces power quality problems and overview of Dynamic Voltage Restorer so that its functions, configurations, components, compensating strategies and control methods are reviewed along with the device capabilities and limitations.**

***Index Terms-* Dynamic Voltage Restorer (DVR), Power Quality, Voltage Sags.**

I. INTRODUCTION

Nowadays, modern power systems having huge circuit including lots of sources and lots of loads are internally connected through long power transmission and distribution lines the actual view of users is to get the quality of power and reliability of power supplies at the load centers in the area where they are located. Of course the generation of power in most of the countries which are already developed is reliable, but we can't conclude that the quality of the power supply is that much reliable. Actually the users of Power systems should be provided an continuous flow of energy with trouble free sinusoidal voltage at the promised magnitude level and frequency but, in reality the criteria is totally different, means that the systems, particularly the distribution systems are having huge number of nonlinear loads like induction motors, because of which significant affect will be there on the power system quality. Because of the loads like those which are needed high current at starting, since they will dip the voltage level due to high current requirement, the quality of the waveform of supplies is going to be lost. Again in sequence it is going to create many power quality issues. Not only the nonlinear loads, also some incidents like capacitor switching, motor starting faults can a Voltage Sag is a momentary decrease in the root mean square (RMS) voltage 0.1 to 0.9 per unit, with a duration ranging from half cycle up to 1 min. It is caused by faults in the power system or by the starting of large induction motor also influences the power quality issues.

A sever disturbance in voltage may lead to system crash, hardware damage, affecting the cost of customers and utilities. The problem quality problems such as temporary voltage rise (Swell) or voltage reduction (Sag) are more frequent and have severe impact on power system. Sudden increase in supply voltage up 110% to 180% in RMS voltage is defined as swell [1]. This occurs at fundamental frequencyof network and sustains for time period of 10 ms to 1 minute. Typical system events such energization of large capacitor bank or removal of inductive load causes swells. On the other hand sudden increase in supply voltage down 90% to 10% of nominal voltage is called as sag. This problem is for the short duration and for time period of 10ms to 1 minute. The rated voltage is recovered after short period of time. Voltage sag is currently the most severe power quality problem encountered because of its adverse financial impact on customers.

The power quality has serious economic implications for customers, utilities and electrical equipment manufacturers. The power electronic systems also contribute to power quality problem (generated harmonics). The electronic devices are very sensitive to disturbances and become less tolerant to power quality problems such as voltage sags, swells and harmonics. Due to the harmonics are occurring in the system it causes losses and heating of motor. The DVR is a power quality device that has gained an increasing role in protecting industries against disturbances such as voltage sags related to remote system faults [2][3]. The basic operation principle of the DVR is to inject an appropriate voltage in series with the supply through injection transformer whenever voltage sag is detected.

This Paper presents power quality problems and a simulation model of a PV based dynamic voltage restorer capable of handling 10% voltage sags on a low voltage distribution system. In the daytime, DVR will act as online UPS to feed the generated power in PV system to battery and load [4].

II. POWER QUALITY PROBLEMS, CAUSES AND EFFECTS

A. Power Quality Problems

Various power quality problems are as followed:

- Transients- A transient is a temporary occurrence of afault which is of a very short duration in a systemcaused by the sudden change of state.
- Voltage sags- A voltage sag or voltage dip is a short duration reduction in RMS voltage which can be caused by a short circuit, overload or starting of electric motors. Voltage sag happens when the RMS voltage decreases between 10 and 90 percent of nominal voltage for one-half cycle to one minute.
- Voltage swells- Voltage swell, which is a momentary increase in voltage, happens when a heavy load turns off in a power system.
- Voltage interruption- Interruptions are classified as short-duration or long-duration variation. The term interruption is often used to refer to short-duration interruption, while the latter is preceded by the word sustained to indicate a long-duration. They are measured and described by their duration since the voltage magnitude is always less than 10% of nominal.
- Harmonics- Harmonics is the integral multiple of frequencies voltages and currents in an electric power system due to nonlinear loads. Harmonic frequencies in the power grid are a frequent cause of power quality problems.

B. Causes of Power Quality Problems

- Transient – Due to Lightning, turning major equipment on or off, back to back capacitor energization.
- Voltage Sags– Due to starting of large motors, energization of heavy loads, incorrect VAR compensation.
- Voltage Swells – Energizing a large capacitor bank, Switching off a large load, incorrect VAR compensation.
- Interruption – Faults (Short circuit), Equipment failures, Control malfunctions (attempting to isolateelectrical problem).
- Harmonics – IT equipment, Variable frequency drives, Electro Magnetic Interference from appliances, fluorescent lighting, Arc Furnace (Anynonlinear load).

C. Effects of Power Quality Problems

- Transient – Tripping, Processing error, Data loss, hardware reboot required, Component failure.
- Voltage Sags – Dim lights, Equipment shutdown, Data error, shrinking display screens, Memory loss.
- Voltage Swells – Bright lights, Data error, shrinking display screens, Memory loss.
- Interruption – Faults, Equipment failures, Control malfunctions.
- Harmonics – Line current increases, Losses increase, transformer and neutral conductor heating leading to reduced equipment life span [5].

III. DVR MODELLING

DYNAMIC VOLTAGE RESTORER (DVR)

DVR is a series connected solid state device that is used for mitigating voltage disturbances in the distribution system by injecting voltage into the system in order to regulate the load side voltage [6]. DVR maintains the load voltage at a nominal magnitude and phase by compensating the voltage sag/swell, voltage unbalance and voltage harmonics presented at the point of common coupling [7] [8] [9]. The DVR is a series conditioner based on a pulse width modulated voltage source inverter, which is generating or absorbing real or reactive power independently. It is normally installed in a distribution system between supply and critical load feeder [10]. These systems are able to compensate voltage sags by increasing the appropriate voltages in series with the supply voltage, and therefore avoid a loss of power. Voltage sags caused by unsymmetrical line-to line, line to ground, double-line-to-ground and symmetrical three phase faults is affected to sensitive loads, the DVR injects the independent voltages to restore and maintained sensitive to its nominal value. Its primary function is to rapidly boost up the load side voltage in the event of a disturbance in order to avoid any power disruption to load [11] [12].

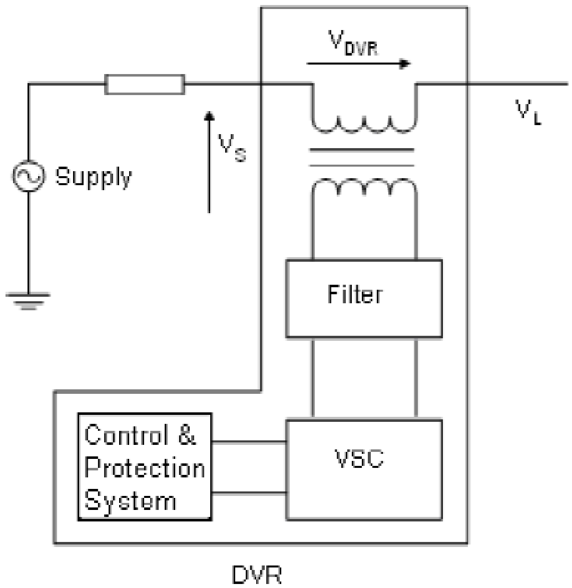

Fig.1.Conventional circuit configuration of DVR

A. *PROPOSED DYNAMIC SAG COMPENSATOR*

The general configuration of the DVR consists of DC charging unit, a Voltage Source Converter, an Injection/Booster transformer, a Harmonic filter and a Control and Protection system as shown in Fig. 2. Here the DVR is also known as SSC (Static series compensator). The in phase compensation method is used to inject the voltage. This method used for limited range of sag [13] [14] [15]. In the DC charging unit where we have implemented the renewable source(solar energy). The control loop of DVR and the various components are explained below in detail. Here the various components of the DVR are shown in Fig.2

In the Boost mode of the Dynamic Voltage Restorers injecting a compensating voltage through the booster transformer after the detection of a disturbance in the supply voltage and compensate the voltage sag.

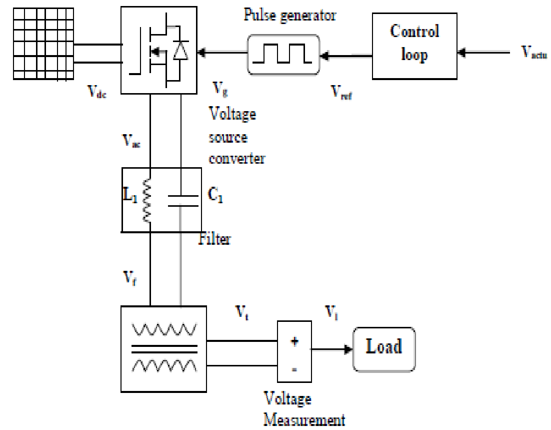

Fig. 2 Inverter, filter circuit and injection transformer

A source voltage of 230 V AC (Vs) is supplied and passed through the transformer. When the voltage sag occurs where the control loop senses the voltage and passed the reference pulses to an inverter. From the control loop where the voltage (Vc) is obtained and they are used to trigger the device. The storage unit supplies the voltage (Vdc) and they converted into voltage (Vac). It passes to the filter and the distortion gets eliminated. From the filter it will passed through the injection transformer (Fig.3). The DVR are less expensive, compact structure and effectively used in mitigation operation.

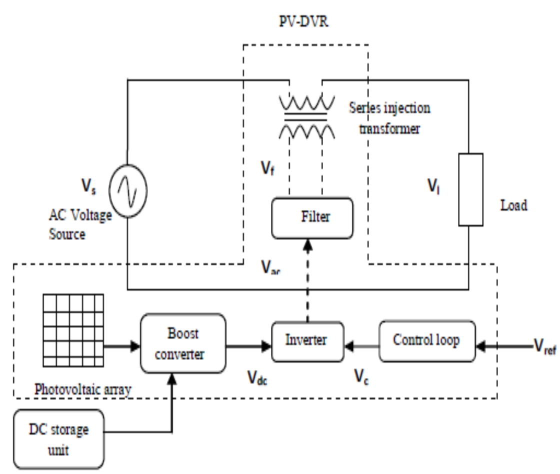

Fig. 3.Dynamic Voltage Restorer with PV and DC source.

B. *CONTROL OF PROPOSED DYNAMIC SAGCOMPENSATOR*

A Proportional Integral controller was used to regulate the error between the supply voltage and the reference phase angle to zero. The additive combination of proportional and integral control actions is known as PI control.

A. Tuning of the PI Controller

The parameters proportional gain (Kp) and the integral time constant (Ki) directly affect the performance of the PI controller. The tuning process should be made within two Parameters.

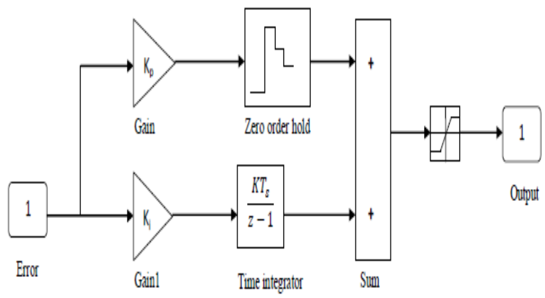

Fig. 4.Block diagram of PI controller

IV. OPERATING PRINCIPLE OF DVR

The basic function of the DVR is to inject a dynamically controlled voltage VDVR 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 effects of a bus fault to the load voltage.

The DVR has three modes of operation which are: protection mode, standby mode, injection/boost mode.

- Protection Mode : 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 systems by using the bypass switches (S2 and S3 will open) and supplying another path for current (S1 will be closed).

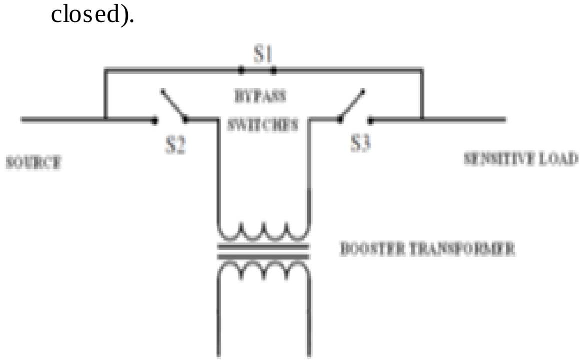

Fig. 5.Protection Mode

- Standby mode (VDVR= 0): In the standby mode the booster transformer's low voltage winding is shorted through the converter. No switching of semiconductors occurs in this mode of operation and the full load current will pass through the primary.

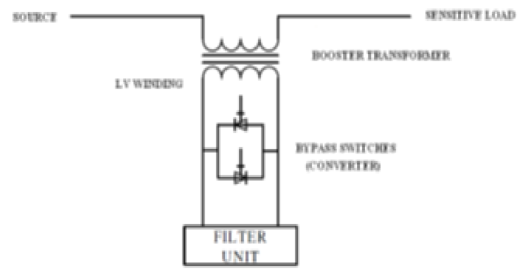

Fig. 6.Standby Mode

- Injection/Boost Mode (VDVR>0): In the Injection/Boost mode the DVR is injecting a compensating voltage through the booster transformer due to the detection of a disturbance in the supply voltage.

COMPENSATION TECHNIQUES IN DVR:

Concept of compensation techniques which are applied in DVR can be divided into categories as follows:

(a) Pre-Sag Compensation:

In this method it is important for both magnitude and the phase angle to be compensated. The difference during sag and pre-sag voltage are detected by DVR and it injects the detected voltage, hence phase and amplitude of the voltage before the sag has to be exactly restored [16] [17]. Figure.7 shows the pre-sag compensation technique before and after the voltage sags [18] [19].

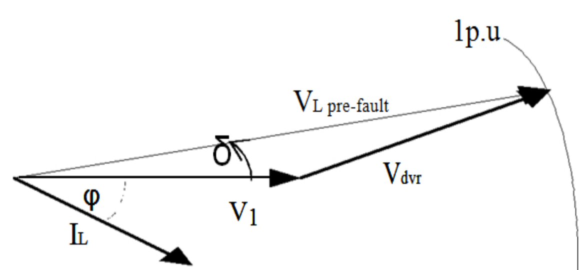

Fig. 7.Pre Sag Compensation

(b) In- Phase Compensation:

In this method, injection voltage is in phase with the source voltage [20]. When the source voltage is drop due to sag in the distribution network, then injection voltage produced by the Voltage Source Inverter (VSI) will inject the missing voltage according to voltage drop magnitude [17] [19]. This method can be shown in Figure. 8[18]

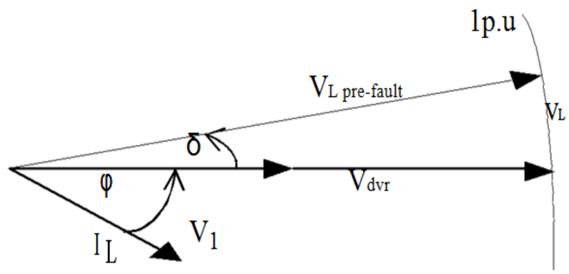

Fig. 8.In-Phase Compensation

(c) Phase Advanced or Minimum Energy Compensation:

This method reduces the energy storage size. Active power PDVR depends on the angle α. During the sag, phase of load voltage jump's a certain step that causes difficulties for load [17] [19] [21]. The magnitude of the restored load voltage that is maintained at pre-fault condition is shown in fig.9. [22]

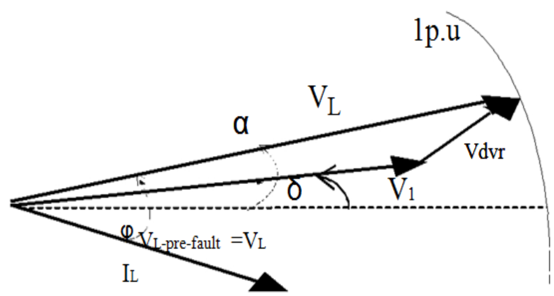

Fig. 9. Phase Advanced Compensation

V. RESULTS

The three phase voltage sag which is occurred due to the 3 phase to ground fault which occurred after 0.2 sec up to 0.4 sec after that system continues to run. Hence here created the 20% sag. To compensate this sag we have to inject the proper voltage during the duration 0.2 sec to 0.4 sec. By injecting the voltage the system will continues to run in proper manner also voltage is draw from the system during swell and system will run in normal condition. The load voltage and the injected voltage by the proposed control strategy is able to drive the DVR to inject the appropriate three phase voltage component with correct phase to remove the supply voltage anomalies due to three phase fault. It quickly injects necessary voltage components to smoothen the load voltage upon detecting voltage sag.

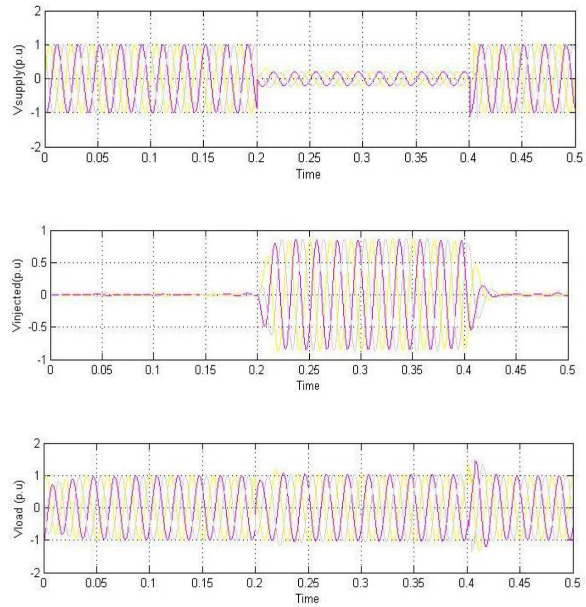

Fig.9. Three phase balanced Voltage sag

VI. CONCLUSION

In this paper, literature review of the DVR for mitigating the problem of voltage sags in presented. The DVR performance is satisfactory in mitigating voltage sags. The DVR handled both balanced and unbalanced situation without difficulties and injects the appropriate voltage component to correct rapidly and deviation in supply system to keep the voltage balanced and constant at the normal value.

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