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# MODELING AND SIMULATION F DVR WITH MULTI LEVEL INVERTER TO MITIGATING THE SAG, SWELL AND HARMONICS

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**ABSTRACT:** The design and implementation of multilevel volta ge source converter based dynamic voltage restorer (DVR) is dealt with in MATLAB Simulink. The objective of this study is to stabilize the voltage by compensating the sag, swell and harmonics in the system. Cascaded Multilevel Converter based DVR is used for harmonics control.. This work proposes the enhancement of power transfer capability and maintaining unity power factor. Relative Harmonic analysis is also discussed based on the total harmonic distortion (THD) calculations. Now days the use of sensitive electronic equipment has increase which has lead to power quality problems. The various power quality disturbances are transients, interruptions, voltage sag, voltage swell, voltage collapse, harmonics etc. To solve these power quality problems various custom power devices are used. Dynamic voltage restorer (DVR) is a custom power device used for the Compensation of voltage sag and swell. Power quality problem is an occurrence manifested as a non-standard voltage, current or frequency. One of the major problems dealt here is the voltage sag. Dynamic Voltage Restorer provides a cost effective solution for protection of sensitive loads from voltage sags currents, although the applied voltage being sinusoidal. MATLAB/SIMULINK tool is used for evaluating the performance of the proposed control scheme.

**Keywords-** DVR; MLI; Power-Factor Correction, power system, Total Harmonic Distortion (THD)



## I. INTRODUCTION

The exponential growth in nonlinear loads has generated a prime concern in the power supply systems. Power electronics based applications draw non-sinusoidal currents, although the applied voltage being sinusoidal. Because of the non-ideal characteristics of voltage source, harmonic currents create voltage distortion. Various nonlinear loads such as arc furnaces, cycloconverters, rectifiers, variable speed drives and other asymmetrical loads can cause huge disturbances in the power supply system. In order to retain harmonic disturbances at reasonable levels, to comply with present standards, we can go through various solutions applicable to supply systems and to harmonics sources. Conventional solutions like passive filters (PF) for mitigating the harmonic pollution are ineffective due to fixed compensation, large size, and resonance [1]. Furthermore, standard regulations and recommendations regarding the harmonics,. With the enormous growth of power electronics and applications, design and development of Active Power Filter (APF) to improve the power quality has been the focus of many papers presented in literature. In recent times, various publications have appeared on the harmonics, reactive power, load balancing, and neutral current compensation related with linear and nonlinear loads.

The basic Bridge Inverters suffers many of the disadvantages from following drawbacks. They have high ripple content in the output. The series parallel operation of the switching devices for high power voltage applications are difficult tasks. Switching devices for higher ratings are difficult to fabricate. Harmonic content is high. Multilevel Inverters overcome many of the above mentioned drawbacks. In high power systems, the multilevel inverters can appropriately replace the existing systems that use traditional multi pulse converters without the need of transformers. The key features of a multi-level structure are as follows: Harmonics content decreases as the number of levels increases thus reducing the filtering requirements and avoiding switching losses (because of the absence of PWM techniques). Only with an increase in the rating of an individual device, the output voltage and power can

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be increased. The switching devices encounter no voltage sharing problems [3]. Thus, multilevel inverters can easily be applied for high power applications such as large motor drives and utility supplies. Because the devices can be switched at low frequency as they have higher efficiency

## II. DYNAMIC VOLTAGE RESTORER

Dynamic voltage restorer is a static var device that has applications in a variety of transmission and distribution systems. It is a series compensation device, which protects sensitive electric load from power quality problems such as voltage sags, swells, unbalance and distortion through power electronic controllers that use voltage source converters (VSC). The first DVR was installed in North America in 1996 - a 12.47 kV system located in Anderson, South Carolina. Since then, DVRs have been applied to protect critical loads in utilities, semiconductor and food processing. Today, the dynamic voltage restorer is one of the most effective PQ devices in solving voltage sag problems.

The basic principle of the dynamic voltage restorer is to inject a voltage of required magnitude and frequency, so that it can restore the load side voltage to the desired amplitude and waveform even when the source voltage is unbalanced or distorted. Generally, it employs a insulated gate bipolar transistor (IGBT) solid state power electronic switches in a pulse width modulated (PWM) inverter structure. The DVR can generate or absorb independently controllable real and reactive power at the load side. In other words, the DVR is made of a solid state DC to AC switching power converter that injects a set of three phase AC output voltages in series and synchronism with the distribution line voltages. Dynamic voltage restorer is a series connected device designed to maintain a constant RMS voltage across a sensitive load[12]. The structure of DVR is shown in Fig.1.



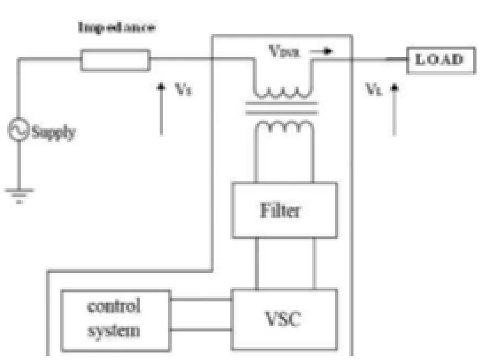



Fig:1 Schematic diagram of DVR

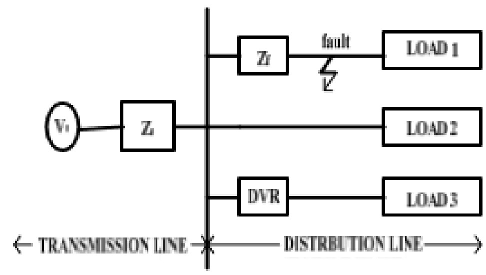



Fig 2. Location of DVR

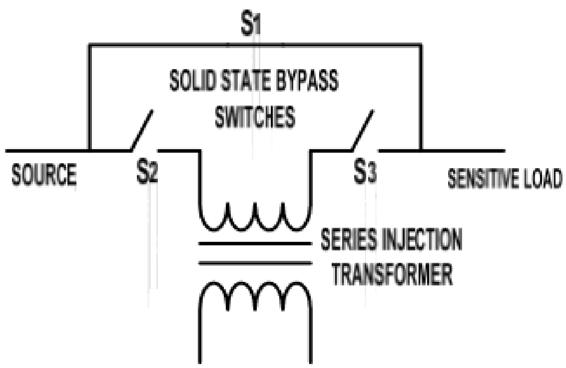
## III. CONFIGURATION OF DVR Converter:

The converter is most likely a voltage source converter (VSC) which pulse width modulates the DC from dc link/ storage to ac voltage injected in to the system. VSC is a power electronics system consisting of a storage device and switching devices, which can generate a sinusoidal voltage at any required frequency, magnitude and phase angle. In DVR application the VSC is used to temporarily replace the supply voltage or to generate the part of the supply voltage which is missing. Filter unit: Line filter is inserted to reduce the switching harmonics generated by PWM VSC. Injection transformer: In most of the DVR applications the DVR is equipped with injection transformer to ensure galvanic isolation and simplify the converter topology and protection equipment. There are two main purposes of isolation transformer. First, it connects the DVR to the distribution network and couples the injected compensating voltage generated by the voltage source converter to the incoming supply voltage and second, it serves the purpose of isolating the load from the system. Energy storage & DC link voltage: A DC link voltage is used by the VSC to synthesize an ac voltage into the grid and during the majority of voltage dips, active power injection is necessary to restore the supply voltage. The DC charging circuit has two main tasks, first is to charge the energy source after compensation events, and second is to maintain dc link voltage. Bypass Equipment: During fault, overload and service a bypass path for the load current has to be ensured, which is illustrated in Fig. 3 as a mechanical bypass and a thyristors bypass

**OPERATING MODES** Generally, the DVR operation is categorized into three different modes, such as protection mode, standby mode (during steady state) and injection mode (during sag) Protection Mode: The DVR is protected from over current due to short circuit on the load side or large inrush currents.

The bypass switches remove the DVR from system by providing another path for current as shown in Fig. 3.

**Fig.3**




**Standby Mode:** In standby mode (normal steady state conditions), the DVR may either go into short circuit operation or may inject small voltage to compensate the voltage drop on transformer reactance or losses as shown in Fig. 4

**Injection Mode:**
The DVR goes into injection mode as soon as the sag is detected. Three single phase ac voltages are injected in series with required magnitude; phase and wave shape for compensation. The types of voltage sag, load conditions and power rating of DVR will determine the probability of successful compensation of voltage sag. The DVR should ensure fairly constant load voltage with minimum energy dissipation for injection considering
high cost of energy storage capacitors. The available voltage injection strategies are pre-sag, phase advance, voltage tolerance and in phase method [3].

## 5. VOLTAGE INJECTION METHODS

Pre-sag compensation method: This method injects the voltage difference between sag and pre-fault voltages to the system. It is the best solution to obtain the same load voltage as the pre-fault voltage but there is no control on injected active power so high capacity energy storage is required. Phase advance method: The real power spent by DVR is minimized by decreasing the power angle between the sag voltage and load current. The values of load current and voltage are fixed in the system so we can change only the phase of the sag voltage. Voltage tolerance method with minimum energy injection: Generally the voltage magnitude between 90%- 110% of nominal voltage and phase angle variation between 5%-10% of normal state do not disturb the operation characteristics of loads. This method can maintain load voltage in the tolerance area with small change of voltage magnitude. In phase voltage injection method: The injected voltage is in phase with supply voltage. The phase angles of the pre-sag and load voltage are different but the most important criteria for power quality that is the constant magnitude of load voltage are satisfied. VL = VLprefault

## IV. MULTILEVEL INVERTER

An overview of the system is shown in Fig. The core component of this inverter design is the four-switch combination shown in Fig. . By connecting the DC source to the AC output by different combinations of the four switches, Q11, Q12, Q13, and Q14, three different voltage output levels can be generated for each DC source, +Vdc, 0, and -Vdc. A cascade inverter with N input sources will provide (2N+1) levels to synthesize the AC output waveform. The DC source in the inverter comes from the PV arrays, and the switching signals come from the multicarrier sinusoidal pulse width modulation (SPWM) controller. The 11-level inverter connects five H-bridges in series and is controlled by five sets of different SPWM signals to generate a near sinusoidal waveform.

Numerous industrial applications have begun to require higher power apparatus in recent years. Some medium voltage motor drives and utility applications require medium voltage and megawatt power level. For a medium voltage grid, it is troublesome to connect only one power semiconductor switch directly. As a result, a multilevel power converter structure has been introduced as an alternative in high power and medium voltage situations. A multilevel converter not only achieves high power ratings, but also enables the use of renewable energy sources. Renewable energy sources such as photovoltaic, wind, and fuel cells can be easily interfaced to a multilevel converter system for a high power application.
A multilevel converter has several advantages over a conventional two-level converter that uses high switching frequency pulse width modulation (PWM). The attractive features of a multilevel converter can be briefly summarized as follows.

● Staircase waveform quality: Multilevel converters not only can generate the output voltages with very low distortion, but also can reduce the dv/dt stresses; therefore electromagnetic compatibility (EMC) problems can be reduced.

● Common-mode (CM) voltage: Multilevel converters produce smaller CM voltage; therefore, the stress in the bearings of a motor connected to a multilevel motor drive can be reduced. Furthermore, CM voltage can be eliminated by using advanced modulation strategies such as that proposed in [14].

● Input current: Multilevel converters can draw input current with low distortion.

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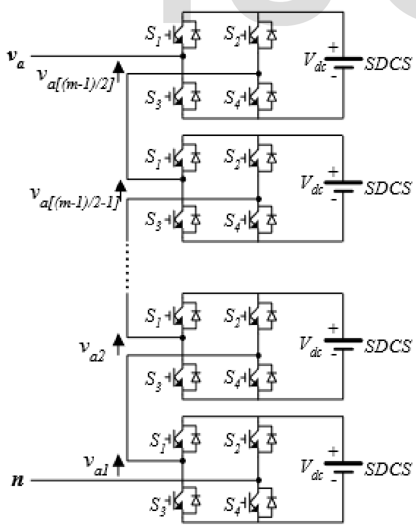
● Switching frequency: Multilevel converters can operate at both fundamental switching frequency and high switching frequency PWM. It should be noted that lower switching frequency usually means lower switching loss and higher efficiency.

**Cascaded H-Bridges**

A single-phase structure of an m-level cascaded inverter is illustrated in Figure . 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, +Vdc, 0, and –Vdc by connecting the dc source to the ac output by different combinations of the four switches, S1, S2, S3, and S4. To obtain +Vdc, switches S1 and S4 are turned on, whereas –Vdc can be obtained by turning on switches S2 and S3. By turning on S1 and S2 or S3 and S4, 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.




Fg4:Single-phase structure of a multilevel cascaded H-bridges inverter.

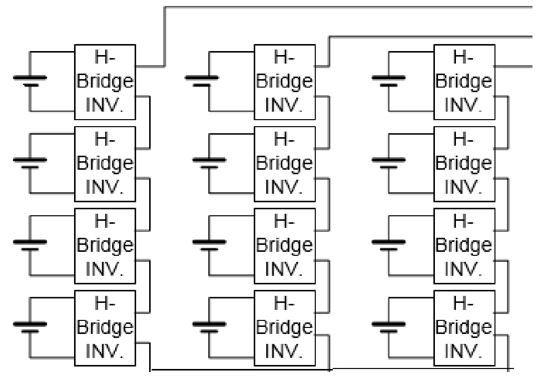



Fig5: multi level voltage source converter structure of DVR

**Proposed System working Principle**

In this paper used in DVR for mitigate sag,swell and harmonics.DVR consists of DC Source,VSC(voltage source converter) and coupling transformer ,so it is connected in series.VSC is multilevel inverter(MLI), it is used for power quality improvement. In previous paper normal VSC converter is used so that the THD(Total Harmonic distortion) is **19.84**.In my paper i am using Cascaded H Bridge Multilevel Inverter in place of normal VSC to reduce the harmonics (THD) is **2.02**.MLI are 3 types1)Flying MLI2)cascaded MLI and 3)Clamped MLI.

In this proposed system we are using MLI type DVR to reducing harmonics at inverter output side in previous paper there are used normal VSC type DVR .Draw backs are 1)The normal VSI(voltage source inverter) output is not pure sine wave i.e quasi square wave ,in this wave forms contains the harmonics.2)now our requirement waveform will be sine wave if you want convert quasi square to sine waveform we can required the fillter that is (LC,LLC)due to the inductance &capacitance of this filter reactive losses will be occurred due to this reactive losses circuit efficiency will be decreasing .The output of VSC contains the harmonics due to this harmonics our VSC converter out put voltage phase sequence will be destroyed and some way harmonic current will be developed in the system due to harmonic currents heat losses will be developed in the system due to this heat losses our system life time be decreasing & power factor(PF) will be decreasing so due to this all reasons over all power systems efficiency will be decreasing at distribution side. To overcome all above draw backs we can go for the our proposed systems, In this proposed system we are using cascaded H bridge MLI to improving the power quality(harmonics,PF,losses and efficiency).

In existing sysyetm that THD is **19.84**.So by using proposed systems (MLI type VSC) we are reduced THD **2.02**.

In this paper we are using cascaded type H bridge 9 level MLI so compared to the remaining two MLI (diode clamped and flying MLI)having more advantages like complexity and no.of switching components ,reliability and working principle and working operation simple. In this proposed system we are using SPWM(sine soidal pulse width modulation) are used to MLI ,because SPW having more advantages compared to alternative method.

SIMULATION-RESULTS

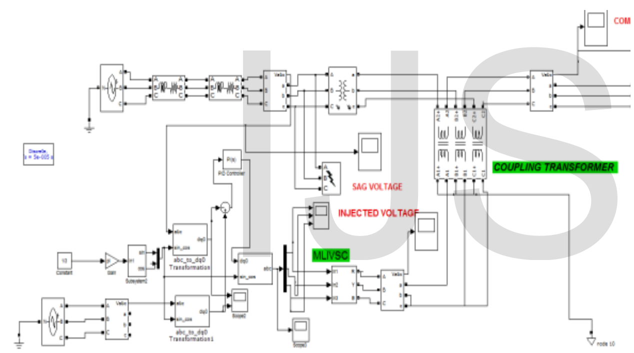



Fig6: simulation diagram

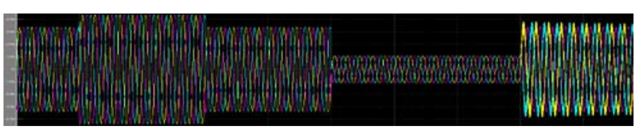


Fig7: Voltage sag and swell at source side

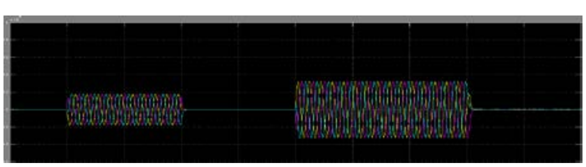


Fig8:Injected voltage from DVR

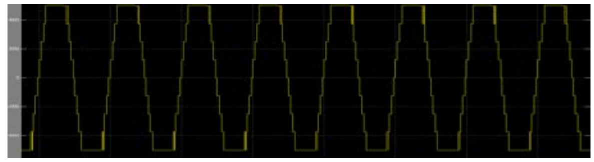


Fig: 9-level out put voltage in VSC

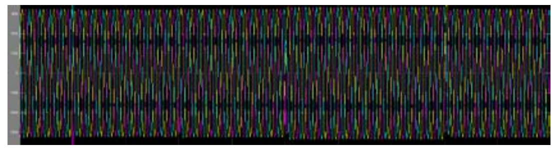


Fig10: compensated voltage at load side

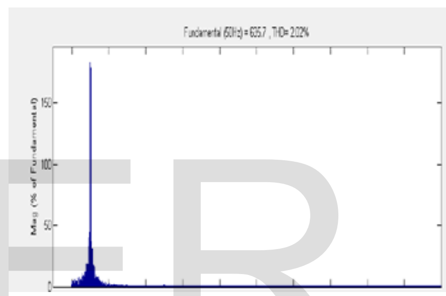


Fig11: harmonic spectrum with MLI

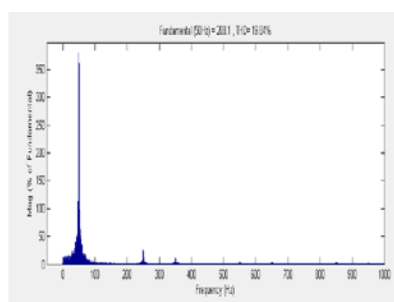


Fig12: harmonic spectrum with out MLI

TABEL-1

| S.NO | TYP OF DVR | THD(%) |
|---|---|---|
| 1 | WITH OUT MLI | 19.84 |
| 2 | WITH MLI | 2.02 |

## CONCLUSION

The simulation results showed clearly the performance of the dynamic voltage restorer (DVR) in compensation voltage sag and swell. The DVR handled both balanced and unbalanced situations without any difficulties and injected the appropriate voltage component to correct rapidly any disturbance in the supply voltage to keep the load voltage balanced and constant at the nominal value.

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