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Modelling and design of cascaded 9 level voltage source converter based DVR for mitigating the voltage sag, swell, harmonics, transients and flickers in distributed power system

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Abstract: *The objective of thispaper is to stabilize the voltage by compensating the sag swell,harmonicstransients and flicker in the system. Cascaded Multilevel Converter basedDVR is used for harmonics control.. This work proposes the enhancement of power transfer capability and maintaining unity power factor. Relative Harmonie analysis is also discussed based on the total harmonie distortion (THD) calculations and reducing the transients power fluctuations at the distribution side. 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.In this paper we are concentrated to overcome sag, swell harmonics,flickers and transients and finally we compared the powerfactor at load side with and without DVR.*
Keywords: *DVR,MLI, Power-Factor Correction, powersystem, Total Harmonic Distortion (THD)*

I. Introduction

Power distribution systems, should ideally 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 the power supply. As a result of these nonlinear loads, the purity of the supply waveform is lost in many places. This ends up producing many power quality problems [1], [2]. Voltage sags (dips) are one of the most occurring power quality problems. They occur more often and cause severe problems and economical losses. There are different ways to mitigate voltage dips in power systems. Among these, the distribution static compensator and the dynamic voltage restorer are the most effective devices; both of them based on the voltage source converter (VSC) principle [3]. Faults at either the transmission or distribution level may cause transient voltage sag in the entire system or a large part of it. Also, under heavy load conditions, a significant voltage drop may occur in the system. Voltage sag (dip) is a short duration reduction in voltage magnitude between 10% to 90% compared to nominal voltage from half a cycle to a few seconds [4]. Voltage sag can case loss of production in automated process since voltage sag can trip a motor or cause its controller to malfunction. To compensate the voltage sag in a power distribution system, appropriate devices need to be installed at suitable location [5]. These devices are typically placed at the Point of Common Coupling (PCC) which is defined as the point of the network changes [6]. There are many different methods to compensate voltage sags, but the use of a custom Power device is considered to be the most efficient method. For example, Flexible AC Transmission Systems (FACTS) for transmission systems, the term custom power pertains to the use of power electronics controllers in a distribution system, specially, to deal with various power quality problems [7]. In thispaper, the applications of dynamic voltage restorer (DVR) on power distribution systems for mitigation of single-phase and three-phase voltage sags at critical loads are presented. This paper is structured as follows: Section 2 describes briefly the Conventional of DVR model, Basic DVR configuration and the main components. Section 3 presents the principle of operation and modes of DVR. The compensation strategies or available voltage injection strategies are described in section 4. The proposed control system of the DVR output voltage is presented in section 5. Section 6 presents simulation results using MATLAB / Simulink for single-phase and three-phase load voltage compensation.

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.

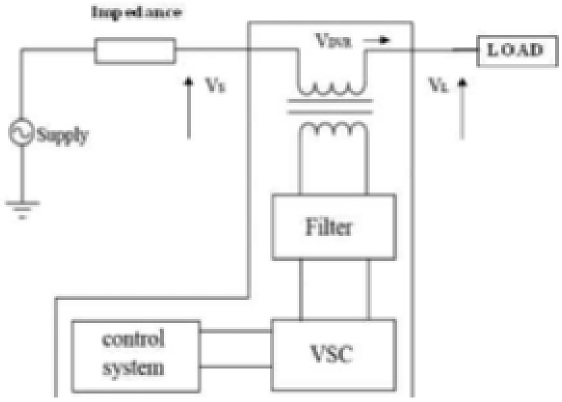


Fig:1 Schematic diagram of DVR

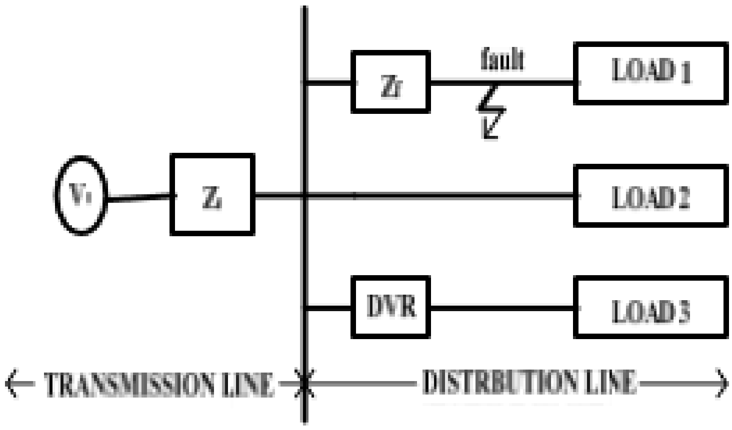


Fig 2. Location of DVR

III. Conventional Dynamic Voltage

Depicts a typical connection of a sensitive load in the distribution system. The electrical system viewed from the Point of Common Coupling (PCC) has been modelled as a 3-phase voltage source with a short-circuit impedance. The connection includes a transformer and a conventional DVR that is composed of an inverter and a series connected transformer. The DVR can compensate voltage sags by means of the injection of the inverter voltage through the series connected transformer. The DVR works independent of the type of fault or any event that happens in the system. Its primary function is to rapidly boost up the load-side voltage in the event of voltage sag in order to avoid any power disruption to that load

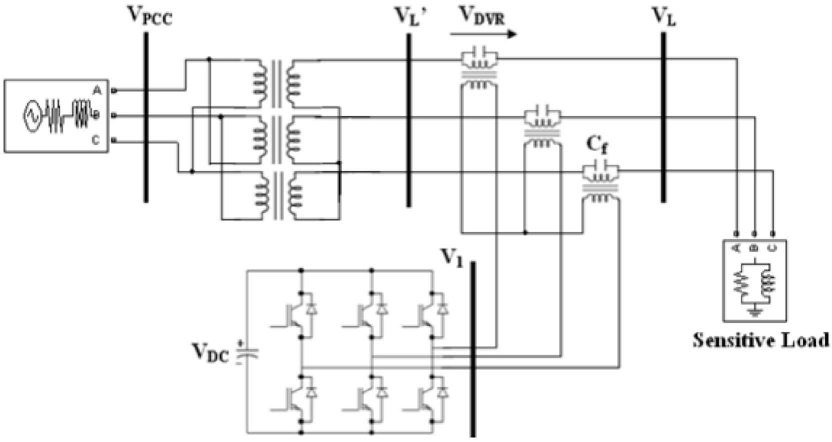


Fig. 3 Schematic diagram of Conventional dynamic voltage restorer

Series InjectionTransformer

The three single-phase injection transformers are used to inject missing voltage to the system at the load bus. To integrate the injection transformer correctly into the DVR, the MVA rating, the primary winding voltage and current ratings, the turn-ratio and the short–circuit impedance values of transformers are required.

Output Filter

The main task of the output filter is to keep the harmonic voltage content generated by the voltage source inverter to the permissible level.(i.e. eliminate high-frequency switching harmonics) [4]. These filters can be placed either in the inverter side or in the line side as shown in Figure 1.

Energy Storage Unit

The DC energy storage device provides the real-power requirements of the DVR during compensation. Various storage technologies have been proposed including flywheel energy storage, superconducting magnetic energy storage (SMES) and super capacitors. These have the advantage of fast response

Voltage Source Converter (VSC)

Voltage source converters are widely used in Variable-speed drives (VSD), but can also be used to compensate voltage dips. The VSC is used to either completely replace the supply voltage or to inject the 'missing voltage'. The 'missing voltage' is the difference between the nominal voltage and the actual one. Normally the VSC is not only used for voltage dip compensation, but also for other power quality issues, e.g. flicker and harmonics

IV. 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

V. 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.

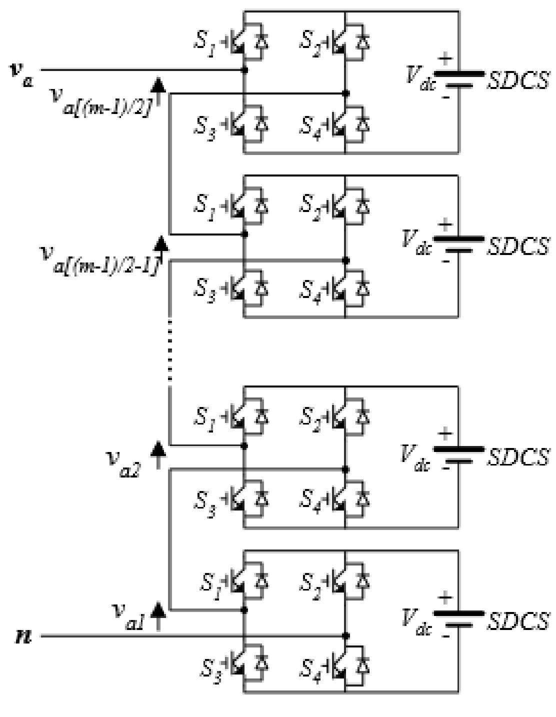
● Staircase waveform quality: Multilevel converters not only can generate the output voltages with very low distortion, but also can reduce the dv/dt stresses; therefore electromagnetic compatibility (EMC) problems can be reduced.

● 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.

● 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 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, +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.



Fg:4 Single-phase structure of a multilevel cascaded H-bridges inverter.

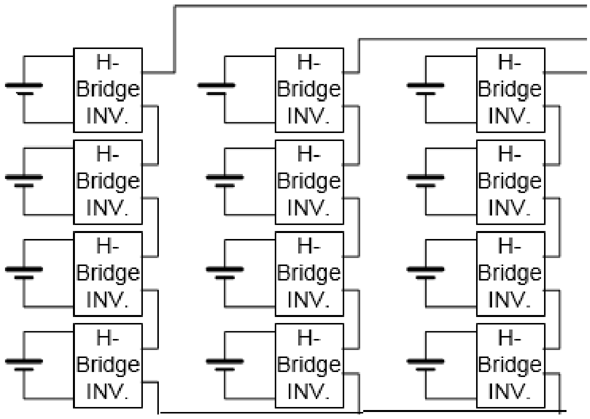


Fig:5 multilevel voltage source converter structure of DVR

Working Principle of proposed Systems

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 filter 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 atdistribution 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 system 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.

Flickers

Since the inception of electric lighting, the dimming and flickering of lights has been a reality for most consumers. In general, the main cause of these effects is switching operations of industrial processes and electrical appliances connected to the supply system. As shown in Figure 1, the current drawn by an appliance causes a voltage drop across the impedance of the electricity supply network, which results in a lower voltage supplied to the lighting system.

Electrical equipment can often have complex program cycles which cause the current drawn from the supply to fluctuate. For example, a washing machine will switch on and off current to heat the water; there will be a surge of current as the motor starts to turn and varying current as the motor speed is controlled. The fluctuating current flows through the network impedance and induces a voltage drop which changes at the same rate as the current.

Transients

As per the classic definition is concerned, an instantaneous change in the state leading to a burst of energy for a limited time is termed as a transient event. The causes can be both external and internal, with the aftermath being sequential and affecting the other parts too.

As per classification, we have the impulsive and oscillatory transients. There is a further 3 tier subdivision of impulsive and oscillatory transients.

VI. Simulation Results

With out DVR

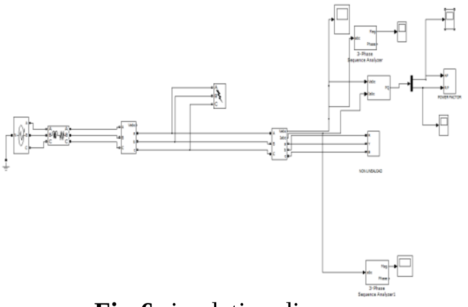


Fig:6 simulation diagram

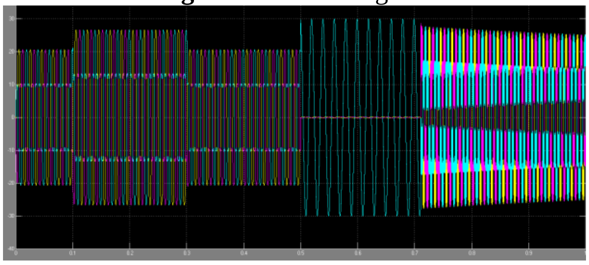


Fig:7 Voltage sag and swell at source side

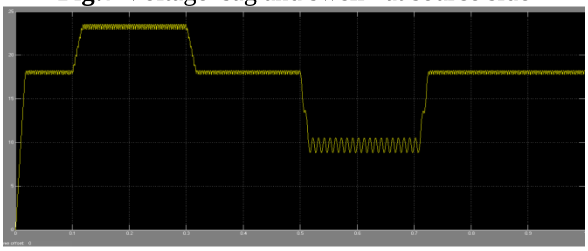


Fig: 8 voltage magnitude at load side

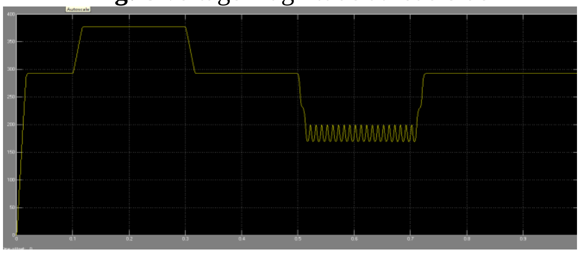


Fig:9 voltage magnitude at load side

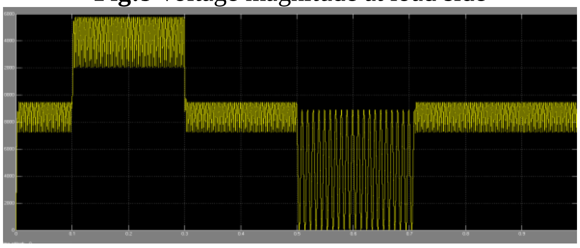


Fig:10 Active power at load side

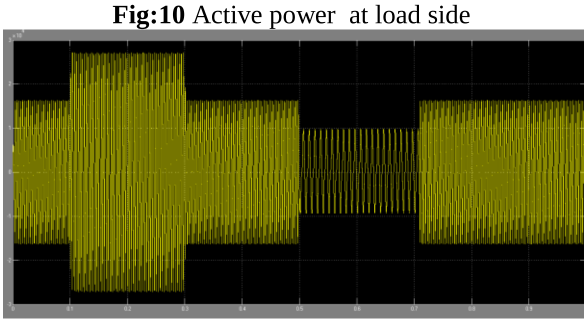


Fig:11 Reactive power at load side

With DVR simulation results

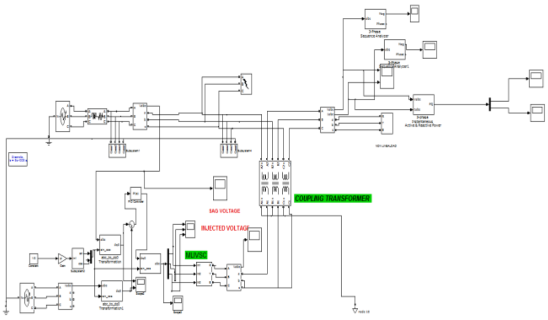


Fig:12 simulation diagram

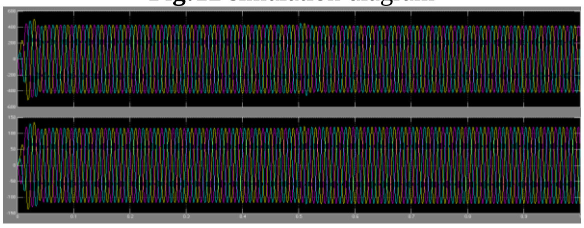


Fig:13 Voltage and currentswell load side

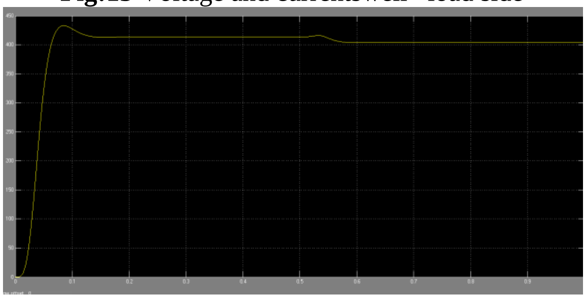


Fig: 14 Voltagemagnitude at load side

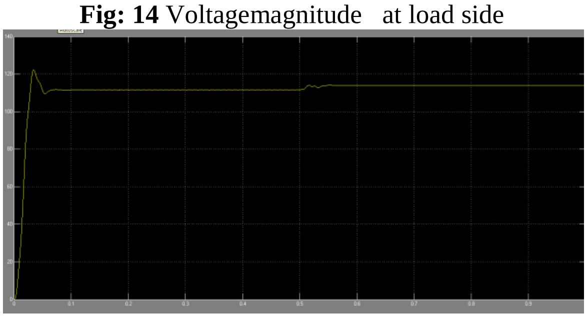


Fig:15 Voltage magnitude at load side

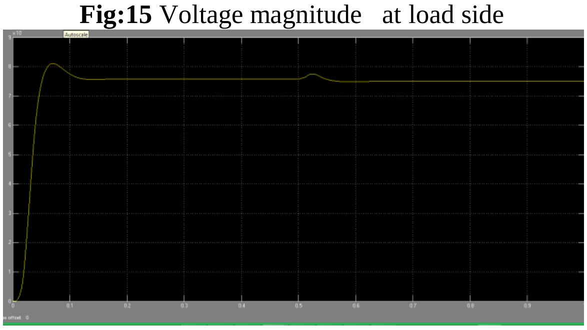


Fig:16 Active power at load side

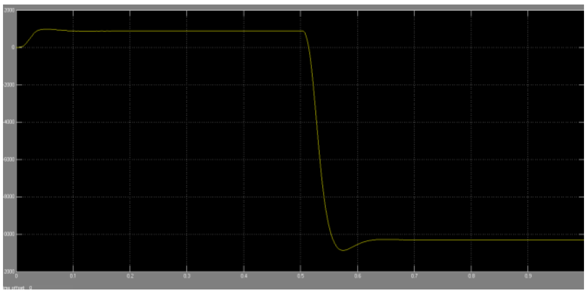


Fig:17 Reactive powerat load side

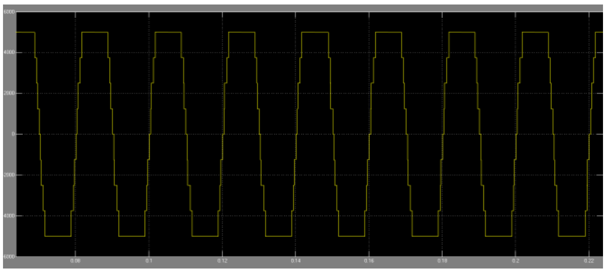


Fig:18 Voltage of CHBMLI(cascaded H bridge MLI)

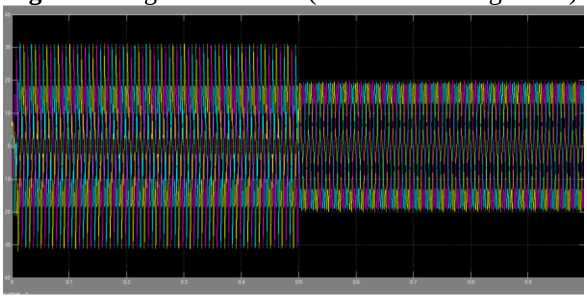


Fig:19 Voltage swell sourceside

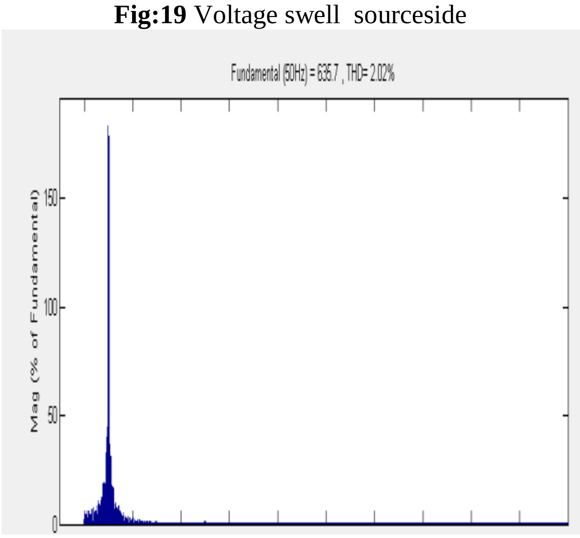


Fig:20 Harmonic spectrum with MLI

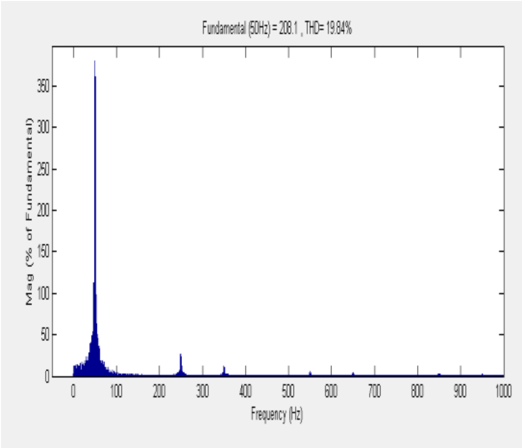


Fig 21: harmonic spectrumwithout MLI

Table-1

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

Tabel-2

S.NO	TYP OF DVR	Power factor
1	WITH OUT DVR	0.78
2	WITH DVR	0.9907

VII. Conclusion

This paper deals with the dynamic model of DVR and is one of the effective custom power device for voltage sags, swells ,transients and flickers mitigation. The impact of voltage sags on sensitive equipment is severe. Therefore, DVR is considered to be an efficient solution due to its relatively low cost and small size, also it has a fast dynamic response. The simulation results show clearly the performance of a DVR in mitigating voltage sags and swells. The DVR handles both balanced and unbalanced situations without any difficulties and injects the appropriate voltage component to correct rapidly any anomaly in the supply voltage to keep the load voltage balanced and constant at the nominal value.

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