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Transformerless Dynamic Voltage Restorer Employing Asymmetrical Seven Level Inverter With Reduced Number of Switches

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Abstract— In this paper, a transformer less dynamic voltage restorer (DVR) based on the multilevel inverter is proposed. This multilevel inverter uses reduced number of switches. As a result, the proposed DVR has lower number of switches in comparison with other multilevel inverter based DVR topologies. Also, it has lower loss and cost due to no need for injection transformers. The performance of the proposed model is simulated in MATLAB/Simulink environment.

Index Terms— Voltage sags/swells, Dynamic Voltage Restorer (DVR), Asymmetrical multilevel inverter.

I. INTRODUCTION

Out of all voltage quality related issues, voltage sag is identified as the most frequent and dangerous. Voltage sag is defined as a momentary reduction in voltage from 0.lpu to 0.9 pu for a duration of half a cycle to few cycles. The average duration of sag is six line frequency cycles. Voltage swell is defined as a short duration increase in voltage in the range 1.1 pu to l.8 pu of the nominal power supply. Sudden removal of large loads and switching of large capacitors are the major causes. The major cause of voltage sag is short circuit faults, startup of large loads such as high power induction motors. The voltage sag leads to malfunctioning of sensitive loads and ac coil relays . The major reason for equipment failure and damage is found to be the subsequent current surge followed by a voltage sag recovery. So the voltage disturbance may cause process malfunction or complete equipment failure. This leads to big economical loss due to quality degradation of the product or complete shutdown of the plant itself.There are various types of devices which can compensate the voltage disturbances. Most of the sag correctors available are based on voltage source inverters. The voltage compensation is done through injection of current in shunt compensators and through injection of voltage in series compensators. Most of the series compensators use series-injection transformer to inject the compensating voltage. Dynamic sag correctors, DSTATCOM, DVR are few of them. The DVR is identified to be the most effective, economical and technically advanced device for this problem The main intention of the DVR is to protect sensitive loads from all supply side voltage disturbances like voltage sag, voltage swell, flicker, harmonics etc, Basic working principle of the DVR is shown in Fig. I. The DVR injects a rectifying voltage in required magnitude, frequency and phase voltage in series with the source to nullify the disturbances. The compensating voltage is injected in series to the supply using three single phase transformers or a single three-phase transformer.The type of fluctuation determines the magnitude and phase of the voltage to be injected. This is achieved by the exchange of real and reactive power between the DVR and the distribution system or the sensitive load. The magnitude and phase of the injected voltage decides the amount of real and reactive power supplied/absorbed. Only reactive power injection is required to compensate voltage sag to a certain extend. Active power injection is required when there are transients due to system disturbance. The DVR can generate the reactive power by its own, but it requires energy storage to supply real power. This decides the compensation rang of the DVR. The energy storage device can be a battery, flywheel energy storage or a super capacitor.Various topologies for the DVR have been discussed in literature. Based on energy feed to the DVR, the discussed topologies can be broadly classified as energy storage based and power from the supply based. Energy storage based DVR uses an energy storage such as Battery, super-capacitor or SMES (Superconducting Magnetic Energy Storage). For second category, an ac/dc/ac converter, which is connected either to supply side or to the load side, is used to supply power required for the DVR.Transformer less DVR is superior to conventional transformer coupled one by removing the voltage drop, phase shift and harmonic loss. Since the transformer is operating at line frequency, by eliminating the transformer, the size and the cost of the DVR also can be minimized. Also after each sag-restoration cycles, the transformer suffers from dc magnetic-flux bias. The transformer cross-sectional area of the core has to be doubled to avoid the magnetic-flux saturation. Inrush current is also a problem present in Transformer less DVR.A three-phase transformer-less DVR is discussed in this paper. The circuit configuration of conventional DVR is explained in the first section and that of transformer-less DVR in the second section. Finally the effectiveness of the proposed DVR on voltage sag compensation is verified using the simulation carried out in MATLAB/Simulink software

II. CONVENTLONAL DVR STRUCTURE

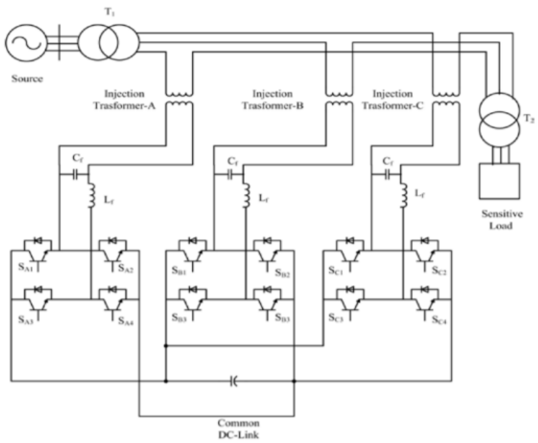

Fig.l Schematic diagram for conventional DVR.

The conventional DVR power circuit basically consists of converter, filter, energy storage device, injection transformer and by-pass switch. The basic function of the DVR is to compensate voltage disturbances in the supply. DVR detects any voltage disturbances in the supply and injects the required voltage to the supply to maintain the load voltage constant. For voltage sag DVR supplies reactive power to the load and for voltage swell reactive power is absorbed from the power supply. Fig. 1 shows the power circuit of the conventional DVR.

A. The Converter
Converter is used to produce required voltage for compensation from fixed voltage. For DC link energy storage voltage source inverter (VSI) is used. A stiff DC voltage supply of low impedance at the input is used to energize the VSI. The output voltage of the converter is independent of the load current. The capacitor used in the VSI reduces the variations in output voltage. Graetz bridge inverter and Neutral point clamp inverter are two common inverter connections used for three phase DVR. H-bridge inverter is the common method used for single phase DVRs.

B. Energy Storage Device
The required ac voltage to be injected to the grid is synthesized from a stiff dc-link. The energy storage is required to provide active power injection to the load to restore the supply voltages during deep voltage dips. Lead-acid batteries, Super Conducting Magnetic Energy Storage (SMES), flywheel or Super-capacitors can be used for energy storage. The depth and duration of the sag decides the capacity of the energy storage required for the DVR

C. Filtering Unit
The inverter output of the DVR is distorted and contains lots of harmonics due to the nonlinear characteristics of the semiconductor switches used. The filter unit is used to filter higher-order switching harmonics generated by the PWM VSC and improve the quality of the energy supply. Inverter side and line side filtering are the basic types of filtering schemes.

D. lnjection Transformer
The primary functions of the transformer are to boost the voltage generated by the VSI and to isolate and couple the DVR to the distribution system. The maximum effectiveness and reliability can only be ensured by proper selection of the electrical parameters of the injection transformer. The turns ratio, MV A rating, primary winding voltage and current ratings, and the short-circuit impedance values of trans formers are required for proper interconnection of the injection transformer into the DVR.

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III. TRANSFORMERLESS DVR

The schematic of the proposed DVR is shown in Fig. 2. Here the injection transformer is excluded. The two major problems in excluding the injection transformer are the lack of voltage boost and isolation.

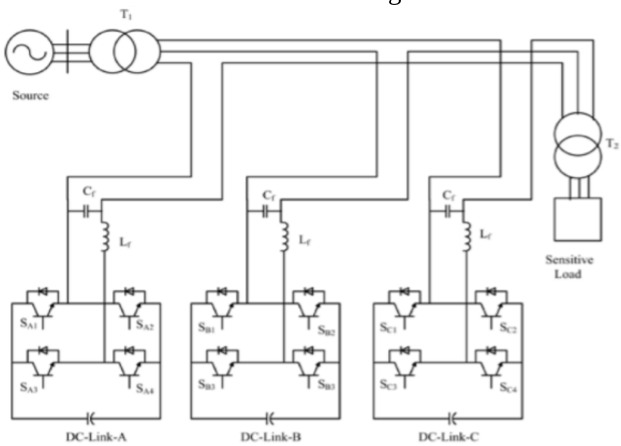

Fig.2 Transformer less DVR with separate DC-Iinks.

In a conventional three-phase DVR based on three single phase VSIs, diagonally opposite switches in the VSIs will be on/off simultaneously. There may be conduction overlapping within the three single phase inverters. Since an isolation transformer comes in between the phases, in a conventional DVR the risk of short circuit is less. This is not the case with a transformer less DVR. Once the transformer is removed from the conventional DVR circuit, the overlapping switches will make a short circuit between the phases and the dc-link. This shortcoming is overcome by using separate dc-link for each of the single phase inverters as shown in Fig. 2. The second challenge is with the boosting up the voltage. In a conventional DVR Compensation of maximum sag depth is possible with minimum DC-link voltage by properly selecting the turns ratio of the injection transformer. DC-link voltage can be adjusted flexibly for a given sag depth by properly selecting the turns ratio of the injection transformer.The maximum voltage injected by a transformer-less DVR is decided entirely by the dc-link voltage. This shortcoming can be overcome certain extent by using cascaded inverters. The major drawback of the conventional DVR is the use of a bulky and expensive injection transformer, which contributes to the total losses of the DVR. The transformer also adds complexity to DVR system from the operation and maintenance point of view.

IV.PROPOSED INVERTER

The proposed topology for 7-level inverter is as shown in Fig.3. A H – Bridge inverter circuit with combination of six unidirectional switches and two DC voltage source is used as proposed topology for developing the proposed single phase. H – Bridge.

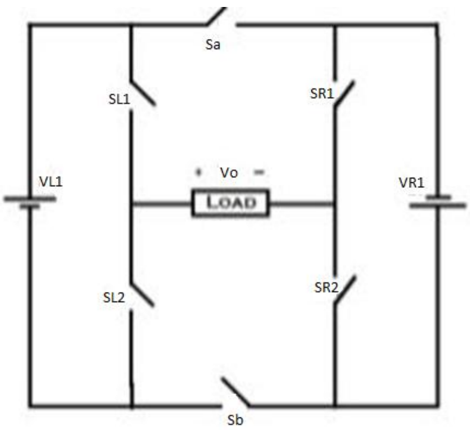

Fig 3: Proposed Inverter Topology

In proposed circuit, a IGBT with antiparallel diode is used as switch, which is capable of blocking voltage in reverse direction and allows current flow in both directions. In proposed inverter we have six unidirectional power switches (Sa, Sb, SL1, SL2, SR1 and SR2) and two DC voltage sources (VL1 and VR1). The values of DC voltage sources are different. The magnitude of VL1 and VR1 considered 1 P.U. and 2 P.U. respectively to generate more output voltage levels without increasing the number of switches and DC voltage sources. By changing the phases and cascaded three similar inverters, three phase supply is generated.

V. SIMULATLON RESULTS

This section is a demonstration of the results against voltage sag to illustrate the performance of the proposed DVR. A three phase voltage balanced source is used for the simulation study. The load is considered to be purely resistive. The voltage sag is generated creating a resistive fault at the source side. MATLAB/Simulink is used for the simulation studies. Fig. 2 shows the topology of the system used for the study. The performance of the DVR is demonstrated for a three-phase sag .Fig. 4 shows the supply voltage during voltage sag. A voltage sag of duration 0.2 s is created at an instant 0.3s. This is shown by Fig. 4.The injected voltage by the voltage restorer is shown in fig 5. It can be observed from Fig.6 that the load voltage is maintained at reference voltage amplitude during the sag condition by the injection of required voltage. The voltage injected to the system by the DVR is shown in Fig.5 and the proposed seven level inverter output is shown in Fig 7.The Simulink model of the system is shown in Fig 8.

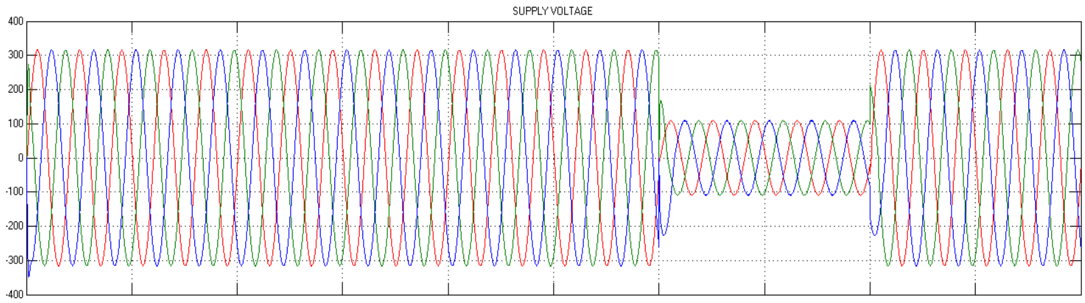

Fig 4: Simulation result of supply voltage during voltage sag

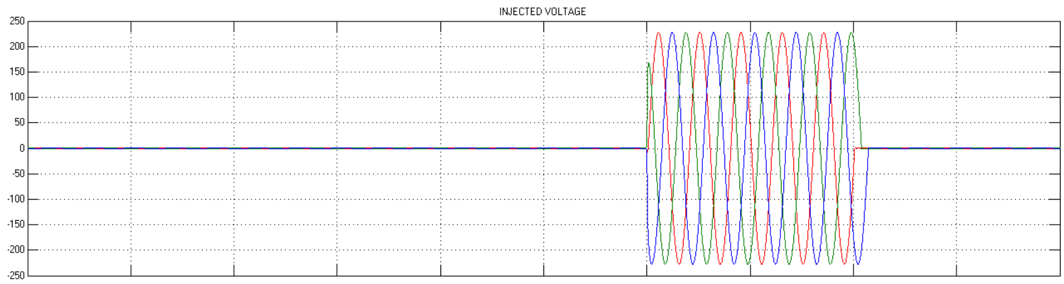

Fig 5 : Simulation result of injected voltage during voltage sag

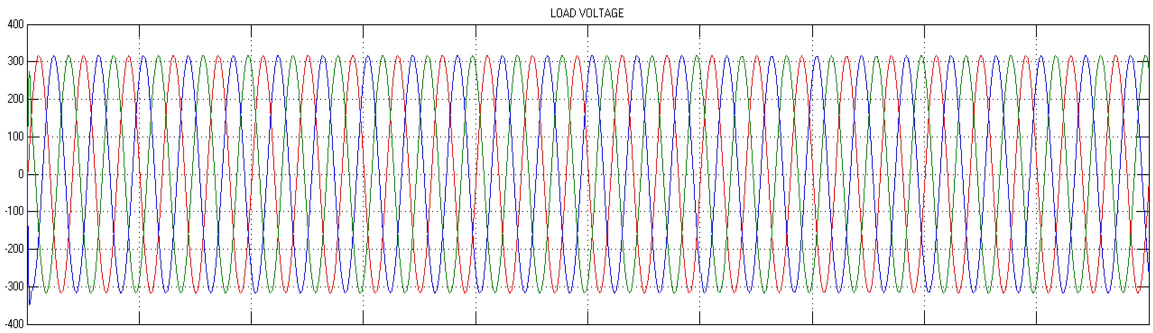

Fig 6: Simulation result of load voltage during voltage sag

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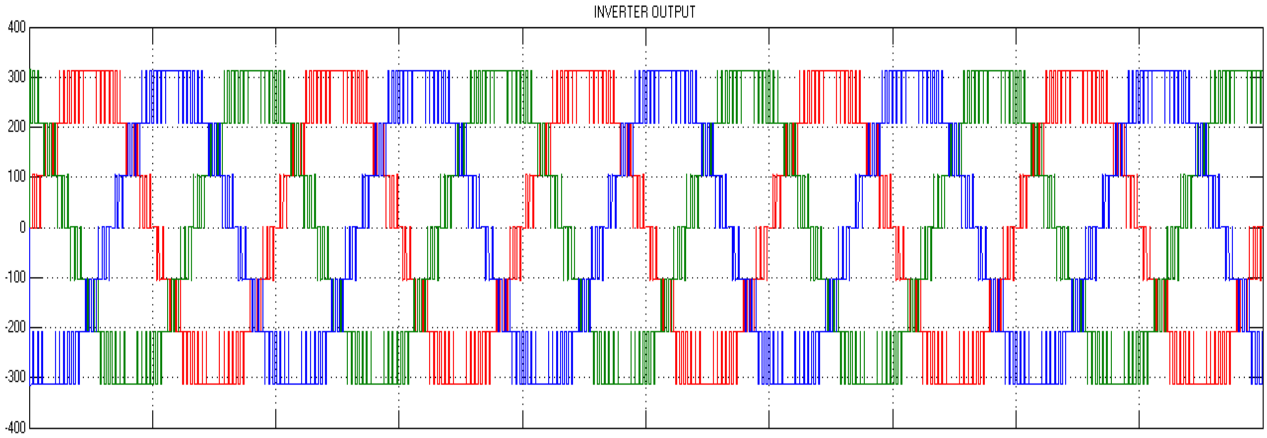

Fig 7: Simulation result of Proposed Inverter

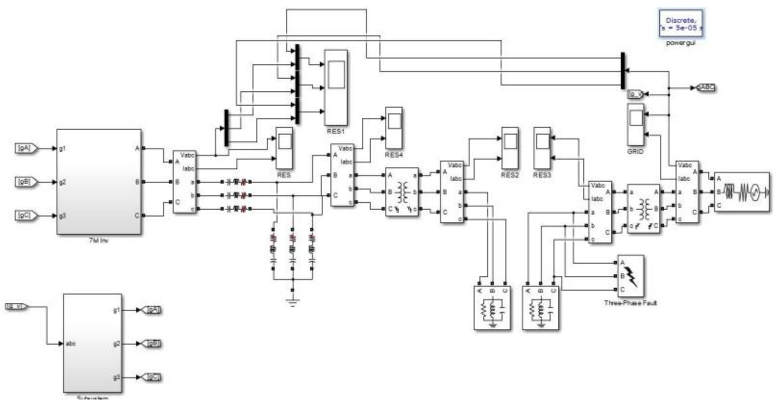

Fig 8: Simulink Model

	1Φ Symmetrical seven level H bridge inverter	1Φ Asymmetrical seven level H bridge inverter	1Φ Proposed Inverter
Number of Switches	12	8	6
Number of DC sources	3	2	2

Table 5.1: Comparison of seven level inverters

VI. CONCLUSION

Cost reduction of dynamic voltage restorers makes it more attractive. Large cost reduction is possible by the elimination of the injection transformer. The paper has analyzed the feasibility of a transformer less DVR. The operation principle and the control of the DVR have been discussed. The system also has more advantageous because of the reduction of switches. Comparison is shown in the above table The MATLAB results show that the proposed DVR can compensate the voltage sag satisfactorily. The main advantage of the transformer less DVR over the conventional DVR is the reduction in cost and size. The isolation for the proposed DVR is done with separate DC-link.

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