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Reduction of Voltage Sag Using Transformer less Dynamic Voltage Restorer

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ABSTRACT: DVR(Dynamic Voltage Restorer) a custom power device has been designed to give protection to the sensitive loads from the several power quality problems raised on distribution feeder. After eliminating the injection transformers, DVR is considered to be an economical device. Due to the removal of injection transformers the efficiency increases. The control strategy is implemented using Synchronous Reference Frame(SRF) theory. The reference load is estimated using unit vectors .The simulation result is obtained from MATLAB. Here PI controller and Pulse Width Modulation technique is used.

KEYWORDS: Dynamic Voltage Restorer (DVR), Voltage Source Inverter (VSI), Pulse Width Modulation (PWM), Synchronous Reference Frame (SRF).

I. INTRODUCTION

The main intention of a power system network is to provide uninterrupted power flow. Due to the presence of non-linear loads in power system especially in the distribution system, power quality problem arises. Voltage sag, voltage swell, interruptions, harmonics, transients, impulse are considered to be the power quality related issues. In order to nullify the disturbances a voltage in required magnitude, frequency and phase is injected by the DVR. Either by using a single three-phase transformer or by three single phase transformers, the compensating voltage is injected in series to the supply. The feasibility of achieving a dynamic voltage restoration without the use of the injection transformer is investigated [1]. The injection transformer used in the conventional DVR is expensive, bulky and contributes towards losses.

For the compensation of voltage sag only reactive power injection is required. When there are transients due to system disturbance active power injection is required. DVR can generate reactive power by its self, but for supplying real power it needs energy storage devices like battery, capacitor or flywheel. Voltage swell and over voltage compensation problems in a diode bridge rectifier supported transformer-less coupled DVR is discussed[2], when a swell or over voltage happens, applying a conventional in phase or phase invariant boosting method causes a rapid rise in the DC link voltage, which may damage the storage capacitors and switching devices, and increase the switching loss.

- By the reduction of voltage drop, harmonic loss and phase shift the transformer less DVR is considered to be better than that of the conventional DVR. After the removal of injection transformer the cost and size of the DVR becomes less. As the injection transformer connected to the DVR working under the same line frequency it can be easily removed. The modeling aspects of the DVR working against voltage sags by simulation have been presented[3]. The soft computing techniques like Fuzzy, Neural and other Bio-optimization algorithm based improved controller can be designed to increase the workability of the proposed design Transformer less DVR model. Now a days research is carried on renewable sources like PV, Wind ,Small hydro etc. So the proposed system can be integrated with one of those distributed generating system.

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II. CONVENTIONAL DVR

The conventional DVR circuit generally consists of the converter, energy storage device, filter, injection transformer and by-pass switch. The main purpose of DVR is to compensate the voltage disturbances in the supply. It detects the amount of voltage disturbances in the supply and injects the required voltage to the supply in order to maintain a constant load voltage. Among the power quality problems in case of voltage sag the reactive power is supplied to the load by the DVR and in case of voltage swell the reactive power is absorbed from the power supply. Fig 1 shows the schematic diagram of conventional DVR.

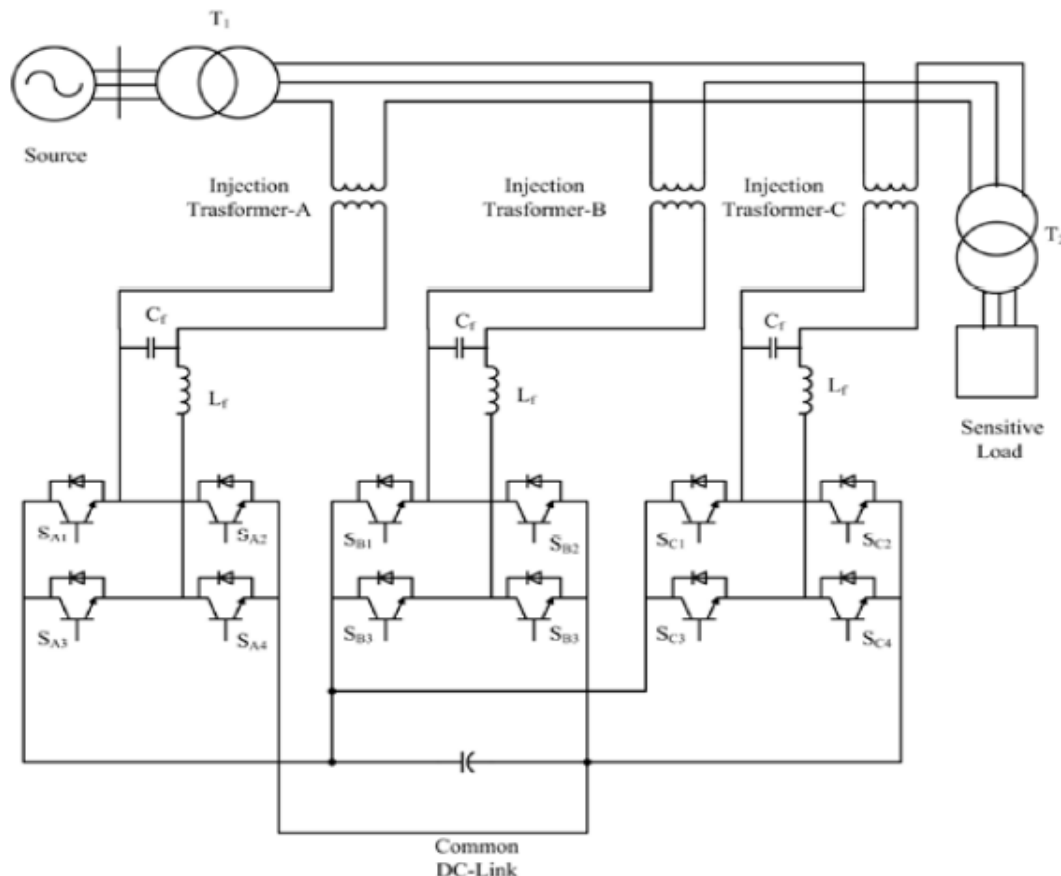


Fig 1. Conventional structure of DVR

A. THE CONVERTER

In DVR application, the VSC (Voltage Source Converter) is used to replace the supply voltage or to generate the part of supply voltage which is missing. VSC is a power electronic device consists of a storage device which can generate a sinusoidal voltage at any required frequency, magnitude and phase angle. The variations in the output voltage can be reduced by using a capacitor.

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B. ENERGY STORAGE DEVICE

The main objective of storage devices is to supply the necessary energy to the VSC via a separate DC link for the generation of injected voltages. The various types of energy storage devices are like Lead-acid batteries, Super conducting Magnetic Energy Storage (SMES), Super capacitors etc.

C. FILTERING UNIT

Its main goal is to keep the harmonic voltage content generated by the VSC to the permissible level. The higher order switching harmonics are generated by the PWM(Pulse width modulation) and the VSC can improve the power quality of the supply. Under the basic types of filtering schemes Inverter side and line side filtering comes.

D. INJECTION TRANSFORMER

The basic function of injection transformer is to boost the voltage generated by the VSC. It performs the objective of isolating the load from the system (VSC and control mechanism). It connects the DVR to the distribution network via the HV-windings. It transforms and couples the injected compensating voltages generated by the voltage source converters to the incoming supply voltage.

III. TRANSFORMER LESS DVR

In case of the Transformer less DVR the injection transformer is excluded. The schematic diagram of proposed DVR is shown in Fig .2. In case of conventional three-phase DVR based on three single phase VSIs, diagonally opposite switches in the VSIs will be on/off simultaneously. Conduction overlapping may occur within the three single phase inverters. In case of Conventional DVR the risk of short circuit is less as an isolation transformer comes in between the phases. But when the transformer is removed in case of transformer-less DVR , the overlapping switches will make a short circuit between the phases and dc link. This problem is solved by using separate dc-link for each of the single phase inverters as shown in the Fig.2. The maximum voltage injected by a transformer-less DVR is decided entirely by the dc-link voltage. By using cascaded inverters the shortcoming can be overcome . The major drawback of the conventional DVR is due to the use of a bulky and expensive injection transformer, which contributes to the total losses of the DVR. From the operation and maintenance point of view, the transformer also adds complexity to DVR system.

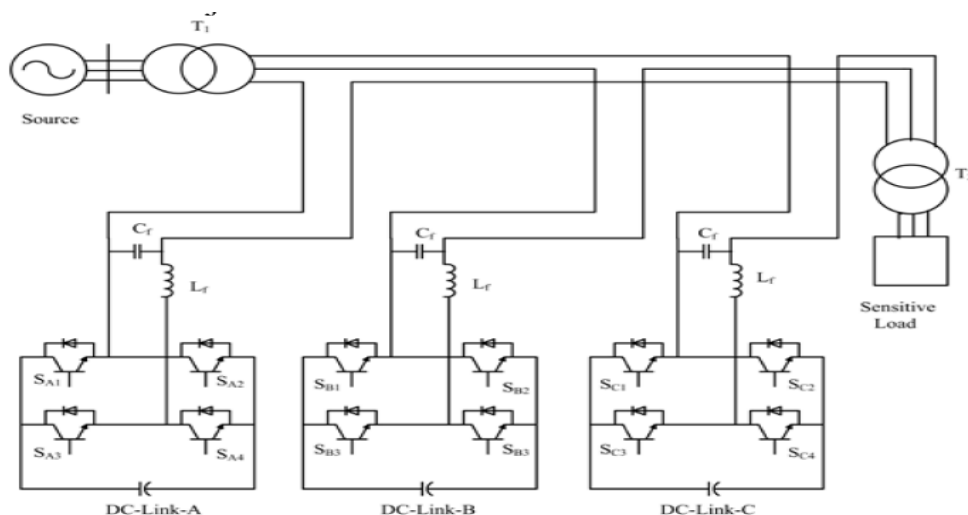


Fig.2. Schematic diagram of Transformer-less DVR with separate DC-links

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VI. CONTROL STRATEGY OF DVR

The control block using SRF theory to control the DVR is shown in Fig.3. The load voltage V_L and source voltage V_S are used to produce the PWM pulses for the VSI.

$$\begin{bmatrix} V_{Lq} \\ V_{Ld} \\ V_{L0} \end{bmatrix} = \frac{2}{3} \begin{bmatrix} \cos \theta & \cos(\theta - 2\pi/3) & \cos(\theta + 2\pi/3) \\ \sin \theta & \sin(\theta - 2\pi/3) & \sin(\theta + 2\pi/3) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix} \begin{bmatrix} V_{La} \\ V_{Lb} \\ V_{Lc} \end{bmatrix}$$

The reference load voltages (V_{La}^* , V_{Lb}^* , V_{Lc}^*) and the source voltages are also converted to the rotating reference frame in the same manner. The DVR voltages can be expressed in the $dq0$ frame as

$$V_{Dd} = V_{Sd} - V_{Ld} \quad (2)$$

$$V_{Dq} = V_{Sq} - V_{Lq} \quad (3)$$

And the reference DVR voltages in the $dq0$ frame can be expressed as

$$V^*_{Dd} = V^*_{Sd} - V_{Ld} \quad (4)$$

$$V^*_{Dq} = V^*_{Sq} - V_{Lq} \quad (5)$$

Two PI controllers are used to regulate the error between actual and reference DVR voltage. Inverse park's transformation is used to get reference DVR voltages in abc reference frame.

$$\begin{bmatrix} V^*_{dvr_a} \\ V^*_{dvr_b} \\ V^*_{dvr_c} \end{bmatrix} = \frac{2}{3} \begin{bmatrix} \cos \theta & \sin \theta & 1 \\ \cos(\theta - 2\pi/3) & \sin(\theta - 2\pi/3) & 1 \\ \cos(\theta + 2\pi/3) & \sin(\theta + 2\pi/3) & 1 \end{bmatrix} \begin{bmatrix} V^*_{Dq} \\ V^*_{Dd} \\ V^*_{D0} \end{bmatrix}$$

Gating pulses for the VSI is generated using reference DVR voltage and actual DVR voltage.

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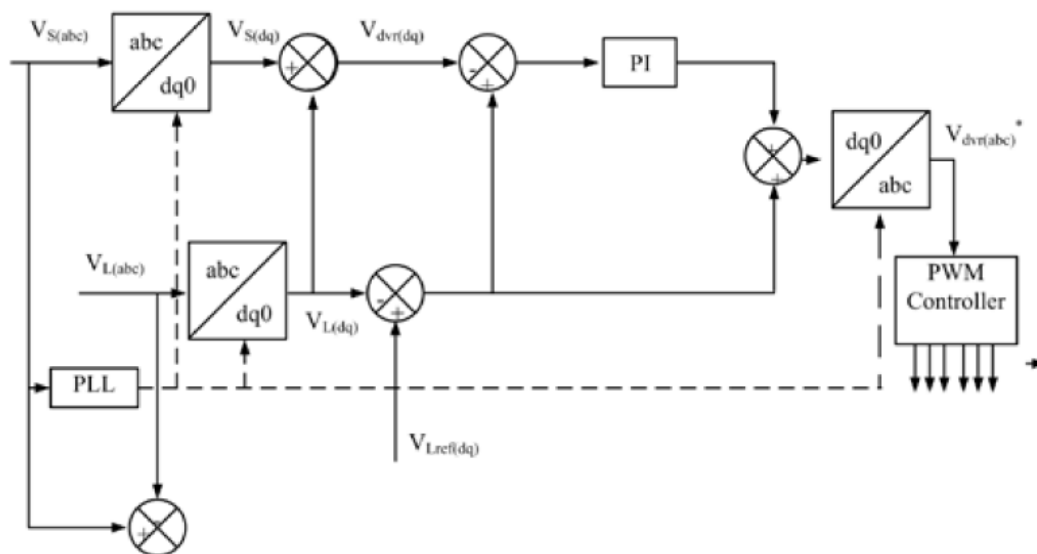
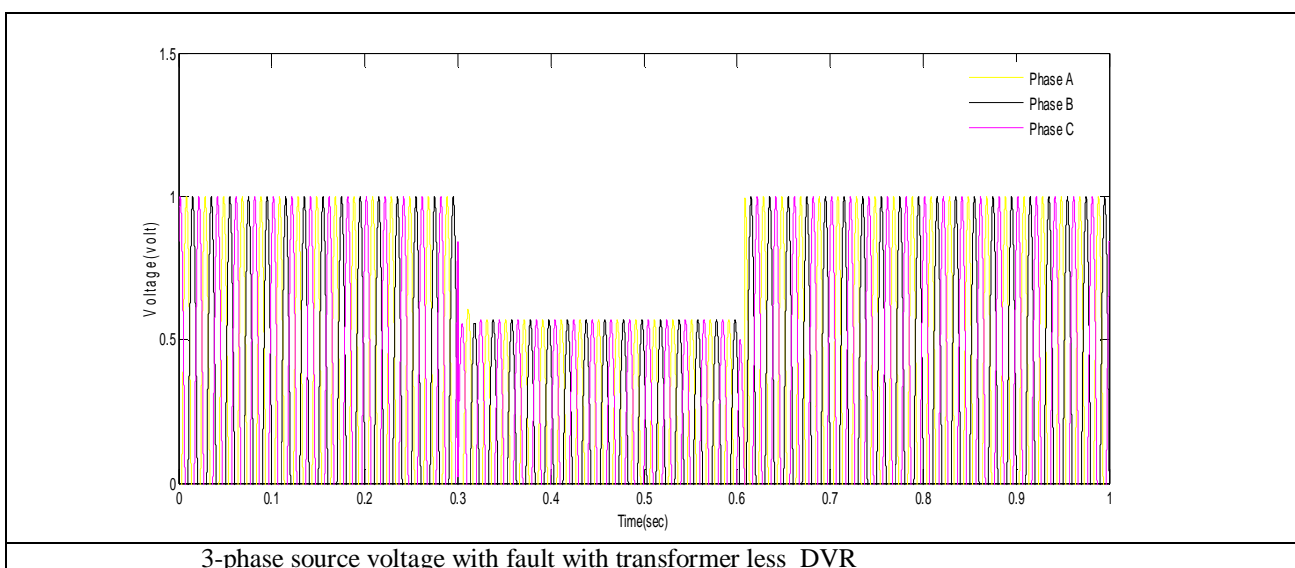


Fig.3. SRF method used for the control of the DVR

V. SIMULATION RESULTS

As per the MATLAB model a fault is initiated during the period 0.3 to 0.6 sec, the corresponding simulation results are also plotted.

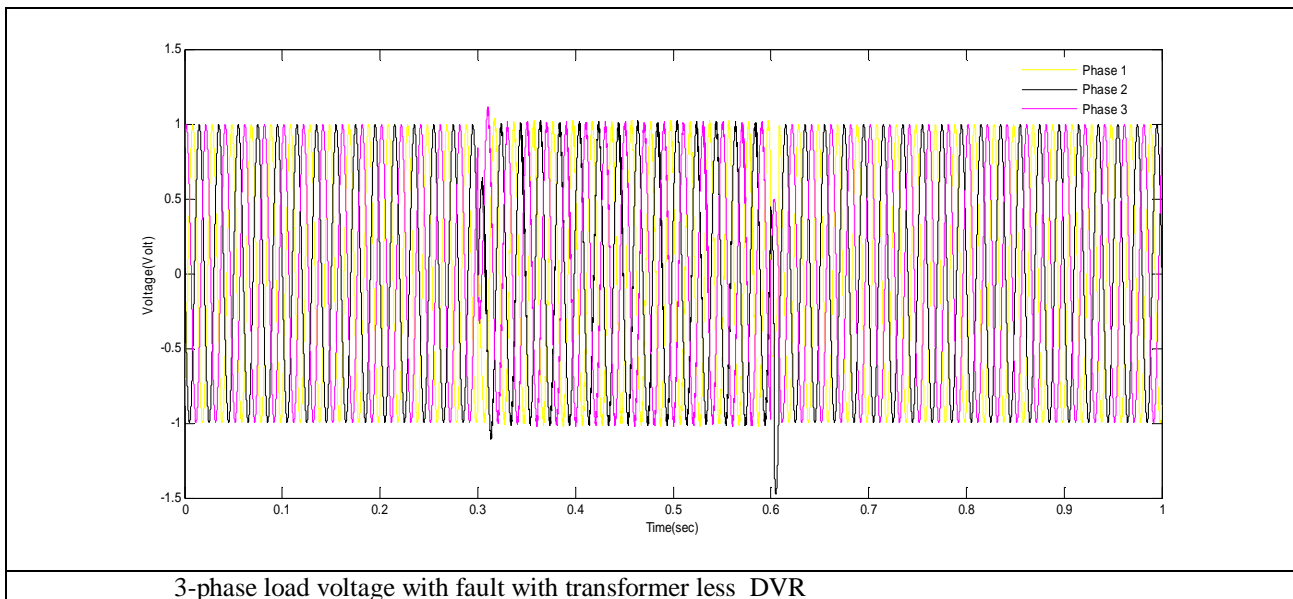


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VI. CONCLUSION

Although the number of storage devices used in case of Transformer less DVR is greater in numbers than that of the conventional DVR with Transformer model, by designing this Transformer less DVR model the percentage Total harmonic Distortion (THD) gets minimized in comparison to the conventional DVR and hence provides satisfactory output. The mitigation of voltage sags can be achieved with power electronic controllers. The series controller is recognized as a cost effective solution for voltage sag mitigation. By using separate dc-links isolation for the DVR can be proposed. By using this power device the size and cost is reduced.

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