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Improving the Voltage Profile at Load End using DVR

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***Abstract*—Voltage drop in the power carrying conductors and voltage sag due to sudden faults are the major problems in secondary distribution network. There are different methods to compensate voltage sag and voltage drop but the application of Dynamic Voltage Restorer (DVR) is the most preferred method in secondary distribution network. A new DVR model is proposed and developed with dq0 controller. This paper gives investigation results which are very acceptable value of voltage ($\pm$ 5%) after the application of DVR with dq0 controller in secondary distribution network. The DVR with dq0 controller structure which is designed for improving voltage at load end under sag conditions were verified in MATLAB/SIMULINK with Simscape Power Systems tool box.**

***Index Terms*— DVR, Voltage Sag, Voltage drop, Distribution network.**

I. INTRODUCTION

The performance of any machine in modern industries for a particular application depends on the input sinusoidal wave for those machines. Now a day the power quality in the secondary distribution network is the major issue to be solved to improve the performance of any equipment. The modern industrial equipment are designed by power electronic devices such as electrical drives and PLC (programmable logic controller) etc. The equipment designed with power electronic devices is too sensitive for the disturbances also less lenient to power quality issues like voltage sags and voltage drops.
The major power quality problems to be solved are voltage sag, voltage swell, harmonics in sinusoidal wave and transients [5].
Voltage improvement at a load end is achieved by injecting reactive power [4]. The most common method employed for improving the voltage profile is mechanically operated shunt capacitors. The mechanical operation may include receiving signals from the supervisory control and data acquisition system.
Alternate power electronic solution to improve the voltage is by using custom power devices like Unified power quality conditioner (UPQC), and Dynamic voltage restorer (DVR) [3]. DVR is one of the most effective devices which inject voltage in series with the line to regulate the voltage at the load end [1].

II. DVR STRUCTURE AND OPERATION

The single line diagram of DVR is shown in Fig. 1. Dynamic voltage restorer consist an injection transformer, a ripple filter, a voltage source converter, energy storage unit and a control system. Equivalent circuit of DVR is given in Fig.2.

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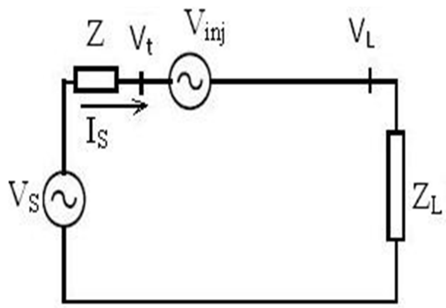


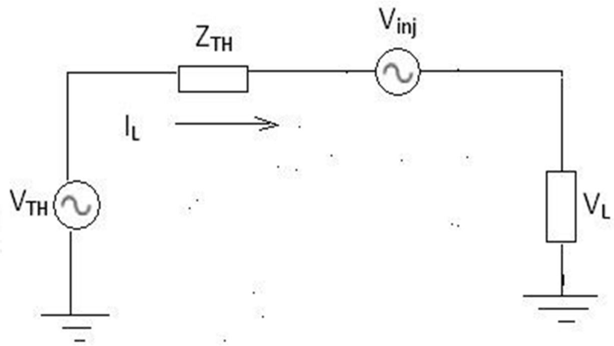


Fig. 1 Single line diagram of Dynamic Voltage Restorer

Fig. 2 Equivalent circuit of DVR

Voltage injected by DVR in series with line is written as

$$V_{inj} = V_L + Z_{TH} I_L - V_{TH} \qquad (1)$$

Where, Z_{TH} **:** The load impedance

V_{TH} **:** The system voltage under fault condition.

I_L **:** Load current

V_L **:** The desired load voltage magnitude

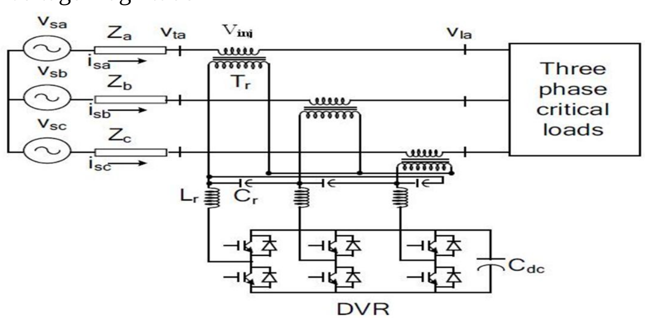


Fig. 3. Three phase DVR scheme

A three phase DVR structure connected to a 3-phase, 3-wire system is shown in Fig. 3. ($Z_{\mathbf{a}}$, $Z_{\mathbf{b}}$, $Z_{\mathbf{c}}$) are the Impedances between source voltage and the terminal voltage. A DVR uses three phase transformer ($T_{\mathbf{r}}$) to inject voltage in series with the line. A voltage source Inverter with energy storage unit (C_{dc}) is used to realize a DVR. An LC filter is used to reduce harmonics in the injected voltage.

III. CONTROLLER STRUCTURE OF DVR

The proposed controller structure is based on evaluation of reference supply voltages. The proposed controller structure for DVR is shown in Fig. 4.

Three phase reference supply voltages are evaluated from the measured load voltages (V_{load}) and supply voltages (V_{abc}**)** of the DVR as feedback signals. The synchronous reference frame theory method is used to estimate the direct and quadrature axis components of the load voltages [2] .

The three phase load voltages are converted into the d-q-0 frame using the park's transformation as,

$$\begin{bmatrix} V_d \\ V_q \\ V_0 \end{bmatrix} = \frac{2}{3} \begin{bmatrix} \cos(\omega t) & \sin(\omega t) & 1 \\ \cos\left(\omega t - \frac{2\pi}{3}\right) & \sin\left(\omega t - \frac{2\pi}{3}\right) & 1 \\ \cos\left(\omega t + \frac{2\pi}{3}\right) & \sin\left(\omega t + \frac{2\pi}{3}\right) & 1 \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix}$$

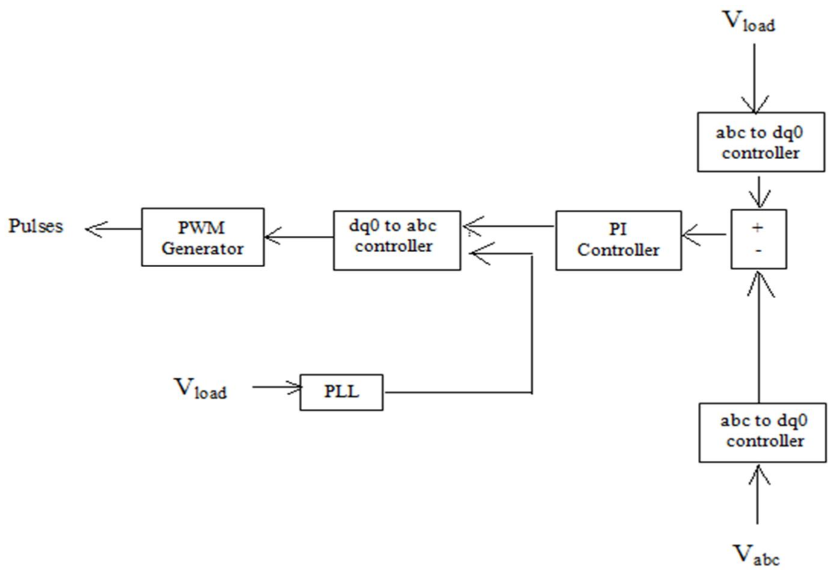


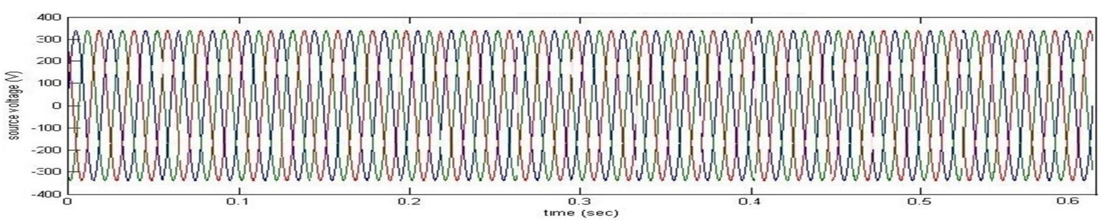
Fig. 4. Controller structure of DVR

A three phase, phase locked loop (PLL) is used to synchronize measured load voltages with the supply voltages. A PI controller is used to regulate the reference voltage are again converted into the reference supply voltage using the reverse Park's transformation. The d-q component is passed through filters to remove the ripple component of v_d and v_q.

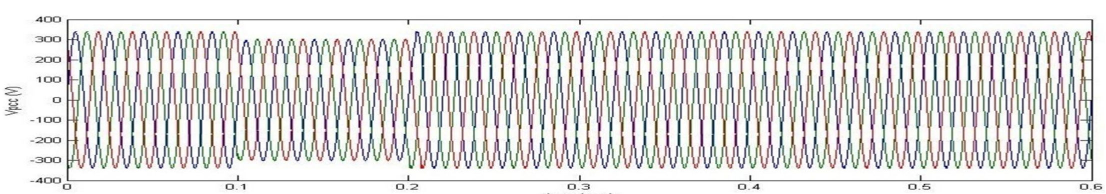
IV. Modelling and Simulation of Proposed System

The proposed DVR is simulated in the MATLAB / Simulink. A pulse width modulation (PWM) controller is used to generate gating signals for the IGBT's of the VSI of DVR. A lagging power factor load is taken in the simulation of test system. The VSC of DVR is connected to the distribution system using an injection transformer. A ripple filter is used for filtering the switching ripple in the voltage of the secondary of the injecting transformer.

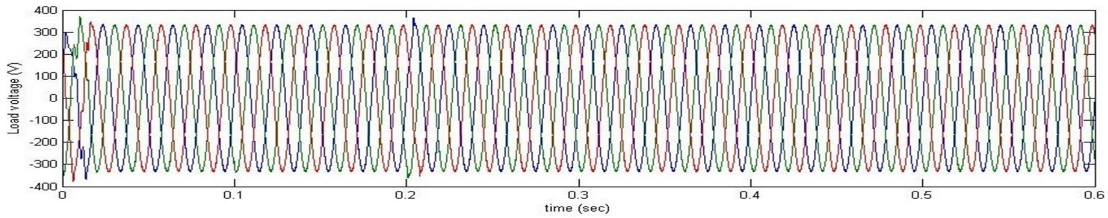
V. Results and Discussion



(a)



(b)



(c)

Fig.6.1 Dynamic behavior of DVR for Voltage sag compensation

A. During sag

In Fig. 6.1 (b) the load voltage has a sag at 0.1 sec and continue up to 0.2 sec. The DVR injects a voltage in series with the line voltage. The load Voltage which is maintaining at rated value from 0.1 sec to 0.2 sec after DVR compensation is shown in Fig. 6.1 (c). The load voltage is observed to be satisfactory after DVR compensation.

VI. CONCLUSION

In this project a new controller structure based on synchronous reference frame (SRF) theory has been used for the DVR for three phase three wire distribution system to improve the voltage profile at load end side. The performance of the DVR has been perceived to be satisfactory using MATLAB SIMULINK (Sim Power Systems tools) software for compensation of voltage sag.

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