Modeling of Dynamic Voltage Restorer to Improve the Voltage Quality in Distribution Network

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Abstract: ***The problems faced by a power system are sudden variations in voltage, transient currents, short circuits e.t.c. among all these sudden variations in voltage is the major and frequent problem which occurs mainly in distribution networks. This problem results in the damage of sensitive load. This problem can be solved by means of using capacitor banks, but this doesn't provide an accurate solution. Hence this paper provides an effective solution to this problem by using the FACT devices which are efficient. This paper also provides the modeling and simulation results by which the working and performance of Dynamic Voltage Restorer (DVR) in the conditions of both balanced and unbalanced voltage sags and swells can know. Hence the voltage Quality in distribution networks can be improved.***

Keywords: distribution network, DVR, FACTS devices, modeling, voltage quality.

1. Introduction

Now a day's all the equipment either industrially or domestically are of low power electronic devices, which are very sensitive and less tolerant. The main problem which will damage this type of equipment is variation in voltage supplied. Voltage sags and swells may result in the damage or shutdown of sensitive load. This voltage variation is the frequently occurring problem in the distribution network because of sudden increase or decrease of load continuously.

There are different solutions to this problem; some of them are usage of capacitor banks, shunt capacitors, series or shunt compensators and usage of power electronic equipment (custom power devices). We have different types of power electronic equipment like SVC, UPS, DSTATCOM, DVR. Among all these DVR is most preferable because it is highly economical, have higher energy capacity, occupies less space. Drawbacks of other devices are SVC has no capability to control the flow of active power. UPS costs more and DSTATCOM is a bulk one and operation is typical when compared to DVR.

This paper gives the regarding the working of DVR, it's functionality in different situations like voltage sag and swell by means of MATLAB SIMULINK model. The results obtained from simulation are also shown.

2. Basic Principle of DVR

2.1 Introduction

All the existing FACTS devices like STATCOM (Static Synchronous Compensator), SSSC (Static Synchronous Series Compensator), IPFC (Interline Power Flow Controller) and UPFC (Unified Power Flow Controller) all are used for the improvement of power quality in case of transmission system. But there is a need to control the power flow in case of Distribution Network, it is very important because all the end loads and different customers are fed form this only, hence we need to take care of the quality of power that is fed from the distribution network. The existing FACTS devices can be modified and these high power electronic controllers can be used to get the better performance of Distribution Network. These improved devices are known as Custom Power Devices.

Some of them are DVR (Dynamic Voltage Restorer), UPQC (Unified Power Quality Conditioner), AF (Active Filter) etc.

2.2 Principle of DVR

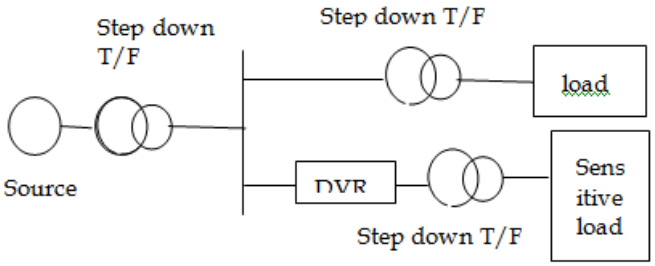

Figure 1: Location of DVR

It is a compensating device connected in series that helps in compensating the sags or reduces the swells in the load side voltage leading to voltage regulation. Other features included in the DVR are harmonic compensation and also can reduce the transients present in the voltage. Generally the DVR is located between the input supply and the common coupling point. When we consider the configuration of the Dynamic Voltage Restorer this include a harmonic filter, voltage source converter, booster transformer, some means of storage,

charging unit to supply the power and a means of protection circuit. The necessity and functions of all these will be discussed. The configuration of the DVR is as follows:

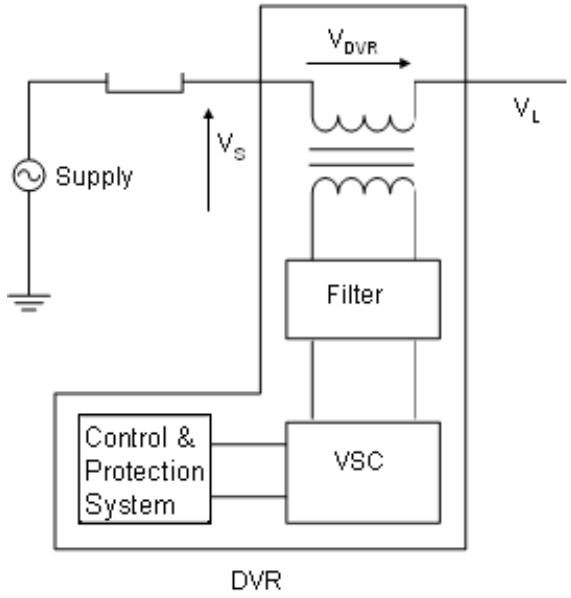

Figure 2: Block diagram of DVR

The main idea othe DVR is to inject the output voltage obtained from the voltage source converter in to the line by means of a boosting transfomer. The output voltage of the converter can be adjusted to the required amount by varying the firing angles of power electronic devices either they may be thyistor, MOSFET, IGBT etc. The process followed for varying the condution periods of these devices is forced commutation process. When there is no fault the DVR will compensate the voltage variations occurred by means of internal loses of the device. When there is a redcution in voltage the amount of voltage to be induced is caluculated by means of following equations:-

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

Where

V_{DVR} : the desired load voltage magnitude

Z_{TH} : the load impedance

I_L : the load current

V_{TH} : the voltage during fault condition

The load curresint is given by:

$$I_L = \frac{[P_L + jQ_L]}{V} \qquad (2)$$

When V_L is considered as a reference equation it can be written as,

$$V_{DVR}\angle\alpha = V_L\angle 0 + Z_{TH}\angle(\beta - \theta) - V_{TH}\angle\gamma \qquad (3)$$

α, β, γ are angles of V_{DVR}, Z_{TH}, V_{TH} respectively and θ is the Load power angle

$$\theta = \tan^{-1}\frac{Q_L}{P_L} \qquad (4)$$

The power injected by the DVR is given by:

$$S_{DVR} = V_{DVR} I_L^* \qquad (5)$$

2.3 Modelling of DVR

The simulink model of the this coustom power device that is Dynamic Voltage Restorer is presented below. The simulink model is prepared using the MATLAB software. We have used a PWM based Voltage Source Inverter so as to produce the required voltage by the load to overcome the voltage variations occurred due to the faults. We also have another circuit configaration to gnerate gate signals for each and every switching device we have used. The amplitude, phase and frequency of the pulses generated by this firing circuit are controllable depending on the magnitude of sag or swell.

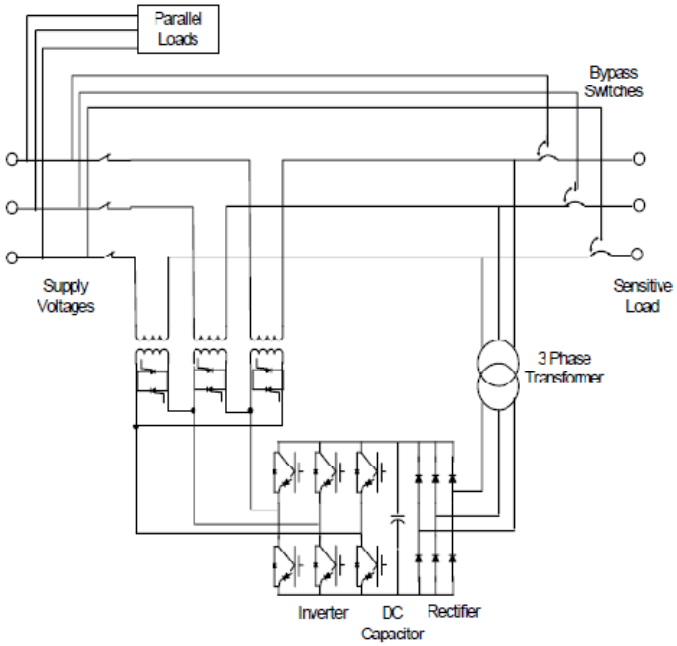

Figure 3: Architecture of Designed system

The main advantage to opt this method of idemnification of voltage is, in this model we have used the DQ method to know the phase shift (q) and depth (d)of voltage sag with both start and end times. The process we need to follow is, initially we need to convert the phase voltages into DQ reference frame. To simplify this process we can eliminate (ignore) the zero sequence value.

$$V_0 = \frac{1}{3}(V_a + V_b + V_C) = 0 \qquad \text{(assumption)} \qquad (5)$$

$$V_d = \frac{2}{3}\left[\begin{array}{l} V_a \sin\omega t + V_b \sin\left(\omega t - \frac{2\pi}{3}\right) + \\ V_c \sin\left(\omega t + \frac{2\pi}{3}\right) \end{array}\right]$$

$$V_q = \frac{2}{3}\left[\begin{array}{l} V_a \cos\omega t + V_b \cos\left(\omega t - \frac{2\pi}{3}\right) + \\ V_c \cos\left(\omega t + \frac{2\pi}{3}\right) \end{array}\right] \quad (6)$$

The gate pulse circuit of the this system is as follows:

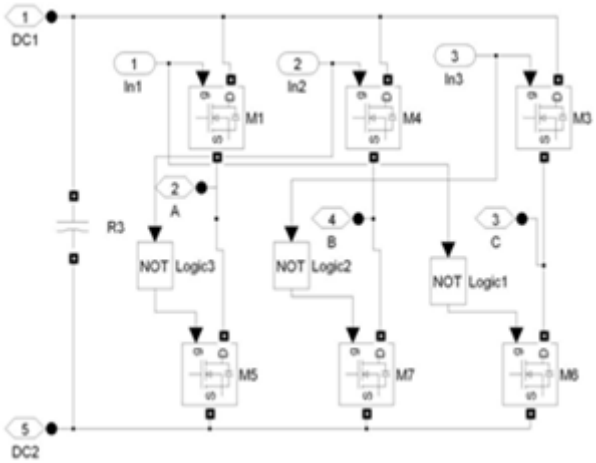

Figure 4: Gate driven circuit

We have used the pulse width moudulation based scheme of control to achieve a good level of compensation of voltage sags. The necessity and feature of this particula control scheme is to maintain the healthy and constant voltage at the load coupling point even at fault condition. The above represented gate circuit is designed to controll the conduction periods of the switching devices and hence the ouput voltage is regulated according to the requirement.

The correction of phase angle is done as follows: intially comparision betweeen the a preset reference voltage and the rms voltage at the load coupling point is done and the difference between the two is generated as an error signal and the corresponding angle which required to make this difference zero is generated.

3. Simulation and Results

Finally the DVR is designed using voltage source interver, PWM based control. First before the practical implementation of the ciruit the simulink model is tested and these results are analysed.The performance of DVR in different possible conditions like voltage sag and volatge swell is tested. The voltage at the laod point with and with out the DVR are differentiated and shown in the result.

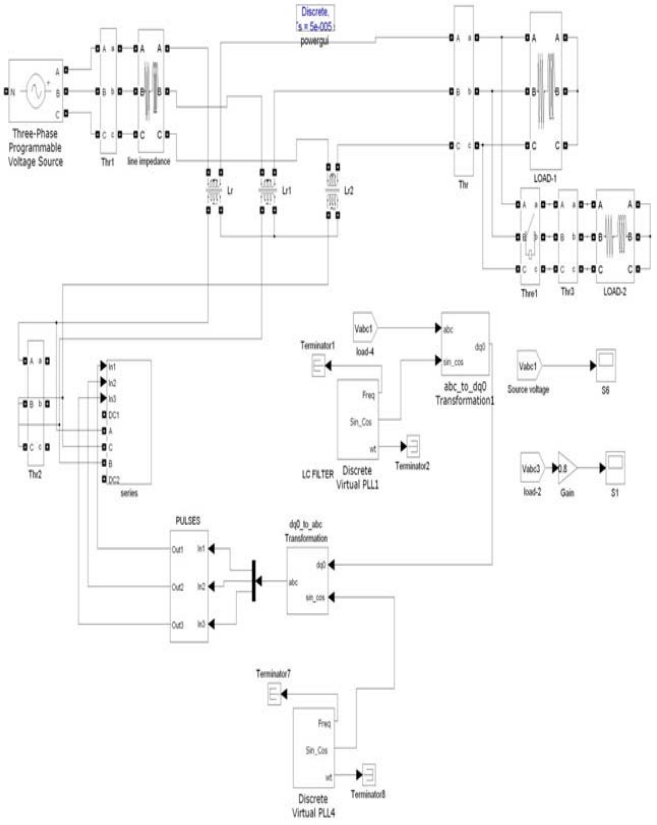

Figure 5: Simulink model of DVR

The results of the circuit are as follows:

Figure 6 represents the the wave form of supply voltage during sag in the voltage.

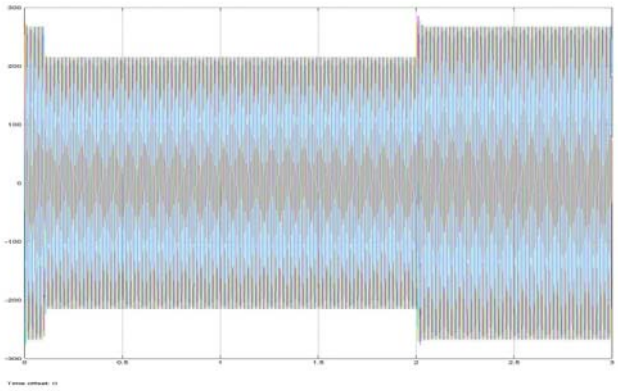

Figure 6: Wave form representing sag in supply voltage

Now we will see the result that we can obtain by using DVR in the above situation. The reduction in the voltage is measured and the corresponding voltage generated by the VSI is injected into the power line and hence it can be mitigated. It is show by below figure (7).

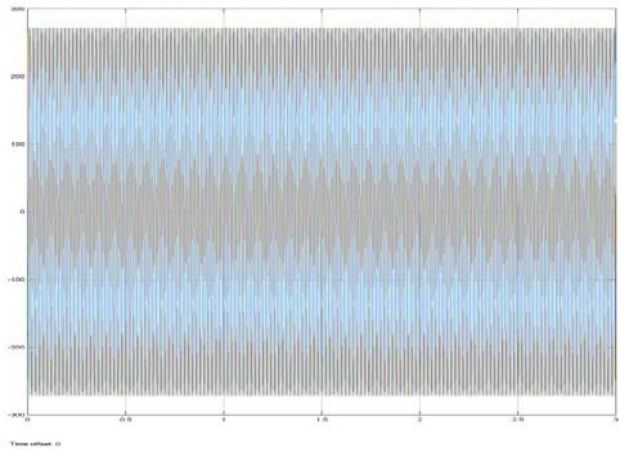

Figure 7: Output of DVR duing the condition of Voltage sag

Volatge swell in the supply voltage is represented by the figure 8.

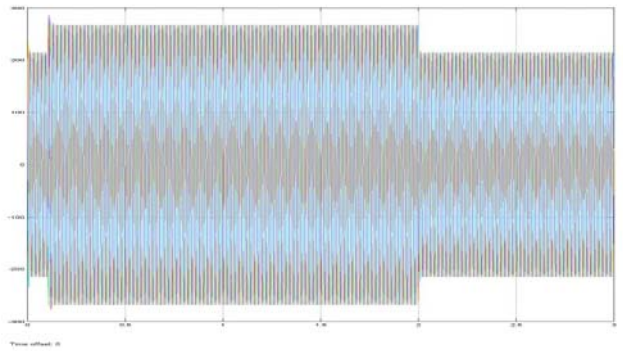

Figure 8: Wave from representing the voltage swell

The result obtained by the usage of DVR is shown below:

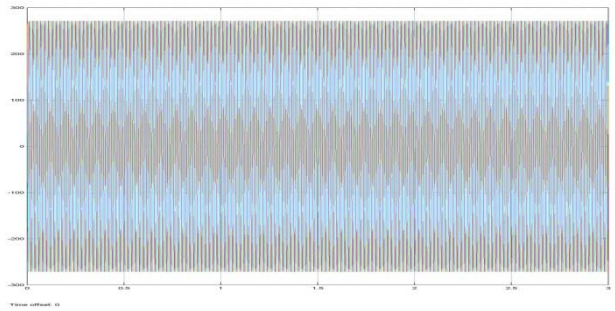

Figure 9: Result obtained by the usage of DVR

4. Conclusion

From the results obtained above we can conclude that the DVR is the effective device in improving the voltage quality of the distribution network. It is also produce fast dynamic response. DVR can control both balanced and unbalanced situations easily.

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