Neelam Rani et al. Int. Journal of Engineering Research and Applications www.ijera.com
ISSN : 2248-9622, Vol. 4, Issue 12(Part 1), December 2014, pp.89-93

RESEARCH ARTICLE OPEN ACCESS

Sag mitigation in distribution system by using Dynamic voltage Restorer (DVR)

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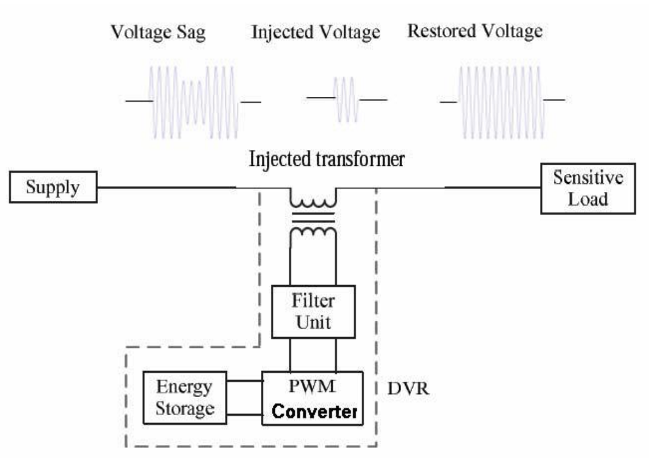
Abstract—
Power quality is most important concern in the current age. It's now a day's necessary with the refined devices, where performance is very perceptive to the quality of power supply. Power quality crisis is an incidence manifest as a typical voltage, current or frequency that results in a failure of end use equipments. One of the major crises dealt here is the power sag. Perceptive industrial loads and distribution networks suffer from different types of service interruptions and outages which results in a major financial loss. To improve the power quality, custom power-devices are used. The device considered in this work is Dynamic Voltage Restorer. This paper shows modelling, analysis and simulation of a DVR test systems using MATLAB.
I have considered single line to ground fault for linear load. The role of DVR is to "compensate load voltage" is examined during the different fault conditions like voltage sag, single phase to ground faults.

I. INTRODUCTION:-

Power quality is certainly a major concern in the present era. The IEEE Standard Dictionary of Electrical and Electronics defines power quality as "the concept of powering and grounding sensitive electronic equipment in a manner that is suitable to the operation of that equipment."[1]. The power quality problem include voltage sag ,swell, harmonics, transients, flickers are the most severe disturbances. Voltage sag is a decrease to between 0/1 and 0/9 pu in rms voltage or rms current at the power frequency for durations of 0/5 cycles to 1 minute. In order to overcome these problems the concept of custom power devices is introduced recently. Custom power is the employment of power electronic or static controllers in medium voltage distribution systems for the purpose of supplying a level of reliability and/or power quality that is needed by electric power customers sensitive to power quality variations[2]. Out of the various approaches that have been have been proposed to limit the cost causes by voltage sag, dynamic voltage restorer (DVR) is one of the best methods to address voltage sag problems. This method is briefly discussed in this paper and it can be used to correct voltage sag at distribution level. _Each of Custom Power devices has its own benefits and limitations. Dynamic Voltage Restorer (DVR) is one of the most effective type of these devices. The dynamic voltage restorer (DVR) is a series custom power device intended to protect sensitive loads from the effects of voltage sags at the point of common coupling (PCC). Together with voltage sags and swells compensation, DVR can also have other features like: line voltage harmonics compensation, reduction of transients in voltage and fault current limitations [3,4].

II. Principle of DVR:-

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 gate turn off thyristor (GTO) 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[5]. The fidelity of the DVR output voltage depends on the accuracy and dynamic behavior of the pulse width modulated (PWM) synthesis scheme and the control system adopted. Traditionally, closed loop control PWM schemes have been used for various types of ac power conditioning systems. The general requirement of such control scheme is to obtain an ac waveform with low total harmonic distortion and good dynamic characteristics against supply and load disturbances. Although conventional sinusoidal PWM schemes and programmed optimal PWM schemes have performed as reasonably well for linear loads, the voltage waveforms tend to get distorted for nonlinear loads. The structure of DVR is shown below[6]



SCHEMATIC DIAGRAM OF DVR

III. DVR Structure:-

DVR is a series connected FACTS device or it is voltage stability device which is able to protect a susceptible load against the abnormal and transient disturbances in power system. Basically the DVR consists of two types of circuits, one is power circuit and another one is control circuit. Control circuit is used to derive the parameters as like magnitude, frequency, phase shift, etc. of the control signal that has to be injected by the DVR [7]. Due to control signal, the injected voltage is generated using switching in power circuit. The power circuit of DVR consists of

- An Injection Transformer
- Ac Harmonic Filter
- Voltage source converter
- Switching device
- Storage device

IV. Injection / Booster Transformer:-

The Injection / Booster transformer is a specially designed transformer that attempts to limit the coupling of noise and transient energy from the primary side to the secondary side [8]. Its main tasks are: connects the DVR to the distribution network via the HV-windings and transforms and couples the injected compensating voltages generated by the voltage source converters to the incoming supply voltage. In addition, the Injection / Booster transformer serves the purpose of isolating the load from the system (VSC and control mechanism).

V. Harmonic Filter:-

The main task of harmonic filter is to keep the harmonic voltage content generated by the voltage source converters to the permissible level (i.e. eliminate high frequency switching harmonics).It has a small rating approximately 2% of the load MVA [9].

VI. Voltage Source Converter:-

A VSC is a power electronic system consists of a storage device and switching devices, which can generate a sinusoidal voltage at any required frequency, magnitude, and phase angle. In the DVR application, the VSC is used to temporarily replace the supply voltage or to generate the part of the supply voltage which is missing [10].

Numerous circuit topologies are available for the VSC [11, 12]. A widely used method is the two level or multilevel three-phase converters which shares a dc capacitor between all phases. The purpose of this capacitor is mainly to absorb harmonic ripple and hence it has a relatively small energy storage requirement, particularly when operating in balanced conditions.

VII. Switching Devices

There are four main types of switching devices: Metal Oxide Semiconductor Field Effect Transistors (MOSFET), Gate Turn-Off thyristors (GTO), Insulated Gate Bipolar Transistors (IGBT), and Integrated Gate Commutated Thyristors (IGCT). Each type has its own benefits and drawbacks. The IGCT is a recent compact device with enhanced performance and reliability that allows building VSC with very large power ratings. Because of the highly sophisticated converter design with IGCTs, the DVR can compensate dips which are beyond the capability of the past DVRs using conventional devices.

VIII. Storage Devices:-

The purpose is to supply the necessary energy to the VSC via a dc link for the generation of injected voltages. Batteries and Ultra capacitors are the most common types of energy storage devices. In fact, the capacity of the stored energy directly determines the duration of the sag which can be mitigating by the DVR. Batteries are the common choice and can be highly effective if a high voltage battery configuration is used. Certain ultra capacitors (unsymmetrical electrochemical) can hold charge over extended periods of time, so as to act like a battery. However, unlike batteries, these ultra-capacitors have a short charge time and much longer lifetime.

IX. Operating modes of DVR:-

The basic function of the DVR is to inject a dynamically controlled voltage *VDVR* generated by a forced commutated converter in series to the bus voltage by means of a booster transformer. The momentary amplitudes of the three injected phase voltages are controlled such as to eliminate any detrimental effects of a bus fault to the load voltage *VL*. This means that any differential voltages caused by disturbances in the ac feeder will be compensated by an equivalent voltage generated by the converter and injected on the medium voltage level through the booster transformer. The DVR works independently of the type of fault or any event that happens in the system, provided that the whole system remains connected to the supply grid, i.e. the line breaker does not trip. For most practical cases, a more economical design can be achieved by only compensating the positive and negative sequence components of the voltage disturbance seen at the input of the DVR (because for a typical distribution bus configuration, the zero sequence part of a disturbance will not pass through the step down transformer which has infinite impedance for this component)

X. The DVR has two modes of operation which are: -

Protection mode
Standby mode
Boost mode

XI. Protection mode

If the current on the load side exceeds a permissible limit due to a short circuit on the load or large inrush current, the DVR will be isolated from the systems by using the bypass switches

XII. Standby mode

In standby mode (VDVR=0), the booster transformer's low voltage winding is shorted through the converter. No switching of semiconductors occurs in this mode of operation, because the individual converter legs are triggered such as to establish a short-circuit path for the transformer connection. Therefore, only the comparatively low conduction losses of the semiconductors in this current loop contribute to the losses. The DVR will be most of the time in this mode.

Boost mode

In boost mode (VDVR>0), the DVR is injecting a compensation voltage through the booster transformer due to a detection of a supply voltage disturbance

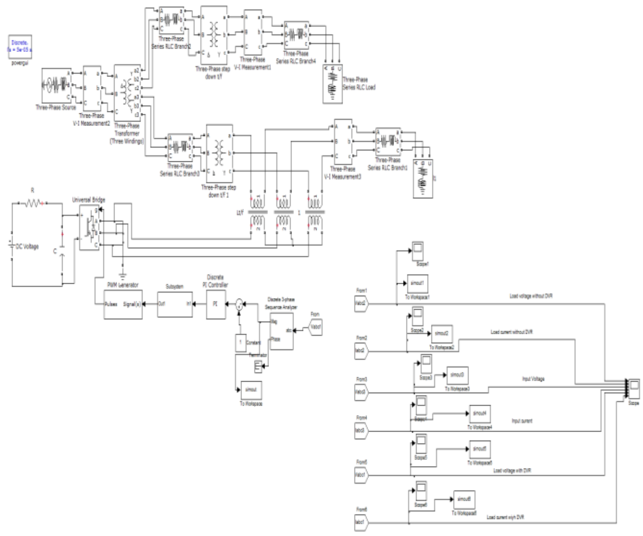
XIII. Parameter of DVR test system:-

The test system employed to take out the simulations regarding the DVR actuation. This System is composed by a 11 KV, 50 Hz generation system, represented by a Thevenin's equivalent, feeding two transmission lines through a three winding transformer connected in Δ/Δ/Y 11/115/115 kV. Such transmission lines feed two distribution networks through two transformers connected in Δ/Y, 115/11 kV.

In this test system we have a generating unit of 11kv, 50 Hz. The test system employed to carry out the simulations concerning the DVR actuation. The output from generating unit is fed to the primary of the three winding transformer. Further two parallel feeders of 11kv each are drawn. In one of the feeder DVR is connected in series and other feeder is kept as it is. For this system single load is considered by without any fault and one with single line to ground fault . The load is linear load in this section . PI controller is used for the control section.

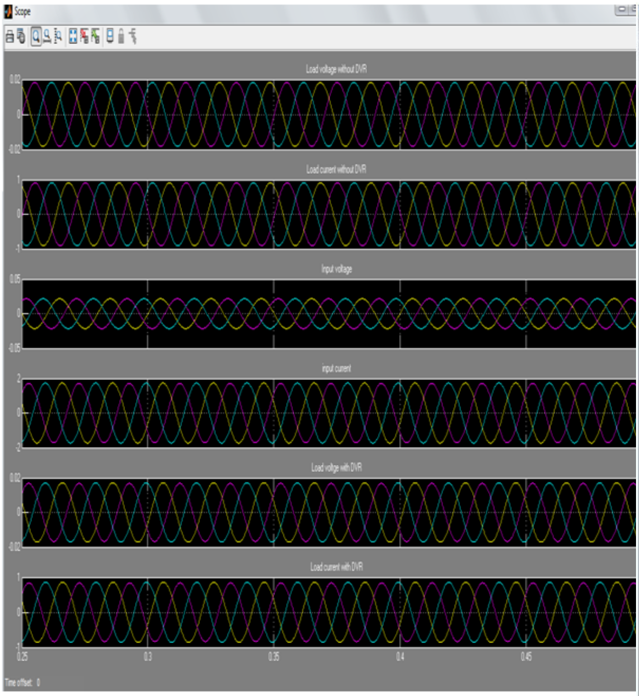
XIV. Simulink Model of Test System Connected On Linear Load:-

In this simulink model we have a system in which two parallel feeders are shown. In both the feeders further loads are also connected in parallel. In one feeder DVR is connected in series with line and the other feeder is kept as it is. PI controller is used for the control purpose. Here, DVR system is connected to the distribution system using a booster transformer.



Simulink Model of Linear Load without any Fault Condition

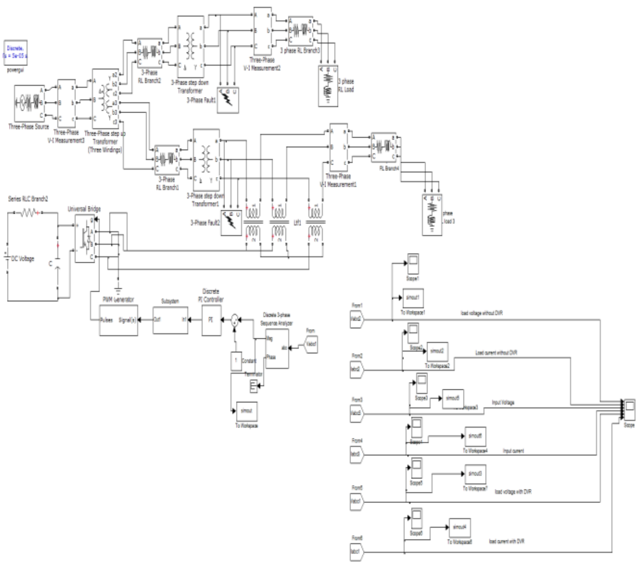
Result for the above system in which no fault is created is given below. The output voltage for both the conditions with DVR and without DVR is same. The first two wave shapes in figure below represent uncompensated load voltage and load current. The next two wave shapes are for input voltage and current w.r.t. time. The last two wave shapes represent load voltage and load current when DVR is connected.



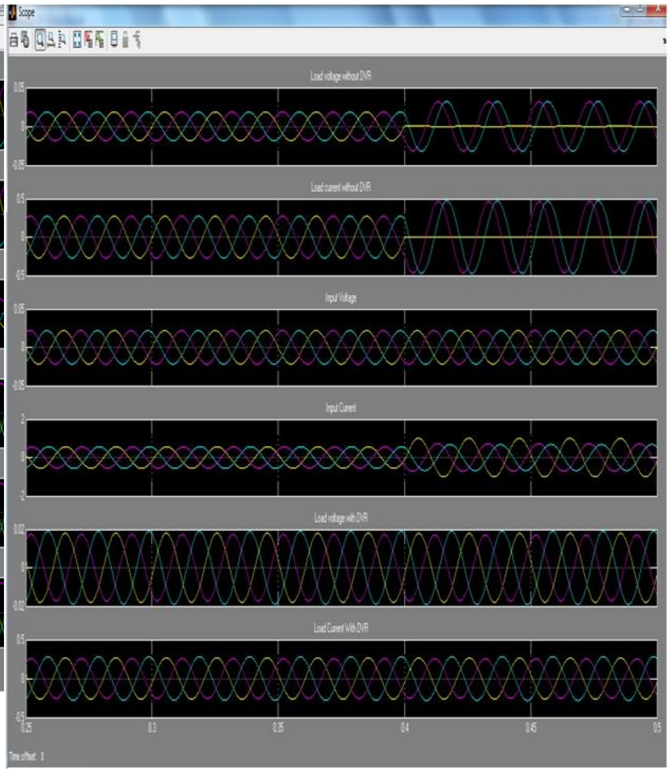
Waveform of Above Simulink Model

XV. Simulink model of proposed system with single line to Ground fault:-

In this model a single phase line to ground fault is created in both the feeders. Here the fault resistance is 0.66 ohms and the ground resistance is 0.001 ohms. The fault time is 0.4s to 0.6s. The result of the load voltage in both feeders (with DVR and without DVR) for system is given below



Simulink Model of Linear Load with single line to ground Fault Condition



Waveform of Above Simulink Model

XVI. Conclusion:-

In this paper, an improved and cost efficient Dynamic Voltage Restorer (DVR) has been proposed for extenuating the problem of voltage sag or dip and rest fault conditions in industrialized distribution systems, . A director which is based on feed foreword technique is used which utilize the error signal which is the difference between the reference voltage and actual measured load voltage to trigger the switches of an inverter using a PWM scheme. Here, investigation was carried out for many case of load at 11kv feeder. It's clear from results that the "power quality of the system with linear load" is increased in the sense that the THD and the amount of un-balance in load voltage are decreased with application of Dynamic Voltage Restorer. It is clear from the resultS waveform that it met the all " power quality standards " .

The usefulness of DVR using P-Icontroller is established for linear static load

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