Distribution Systems Voltage Regulation using Multifunctional DVR Implementation for Emergency Control and Protect Consumers System

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ABSTRACT: *Power quality is one of major concerns in the present era. It has become important, especially, with the introduction of sophisticated devices, whose performance is very sensitive to the quality of power supply. Power quality problem is an occurrence manifested as a nonstandard voltage, current or frequency that results in a failure of end use equipments. One of the major problems dealt here is the power sag. To solve this problem, custom power devices are used. One of those devices is the Dynamic Voltage Restorer (DVR), which is the most efficient and effective modern custom power device used in power distribution networks. The dynamic voltage restorer (DVR) is one of the modern devices used in distribution systems to protect consumers against sudden changes in voltage amplitude. Its appeal includes lower cost, smaller size, and its fast dynamic response to the disturbance. This paper presents modeling, analysis and simulation of a Dynamic Voltage Restorer (DVR) using MATLAB. In this model a PI controller and Discrete PWM pulse generator was used.*

Keywords — Dynamic Voltage Restorer (DVR), Power quality, power sag.

1, INTRODUCTION

Voltage sag and voltage swell are two of the most important power-quality (PQ) problems that encompass almost 80% of the distribution system .voltage sag, it can be found that this is a transient phenomenon whose causes are classified as low- or medium-frequency transient events. In recent years, considering the use of sensitive devices in modern industries, different methods of compensation of voltage sags have been used. One of these methods is using the DVR to improve the PQ and compensate the load voltage. The state feed forward and feedback methods, symmetrical components estimation, robust control, and wavelet transform have also been proposed as different methods of controlling the DVR In all of the aforementioned methods, the source of disturbance is assumed to be on the feeder which is parallel to the DVR feeder. In this paper, a multifunctional control system is proposed in which the DVR protects the load voltage using Posicast and P+Resonant controllers when the source of disturbance is the parallel feeders. On the other hand, during a downstream fault, the equipment protects the PCC voltage, limits the fault current, and protects itself from large fault current. Although this latest condition has been described in using the flux control method, the DVR proposed there acts like a virtual inductance with a constant value so that it does not receive any active power during limiting the fault current. But in the proposed method when the fault current passes through the DVR, it acts like series variable impedance (unlike where the equivalent impedance was a constant). DVR The major objectives are to increase the capacity utilization of distribution feeders (by minimizing the rms values of the line currents for a specified power demand), reduce the losses and improve power quality at the load bus. The major assumption was to neglect the variations In the source voltages. This essentially implies that the dynamics of the source voltage is much slower than the load dynamics.

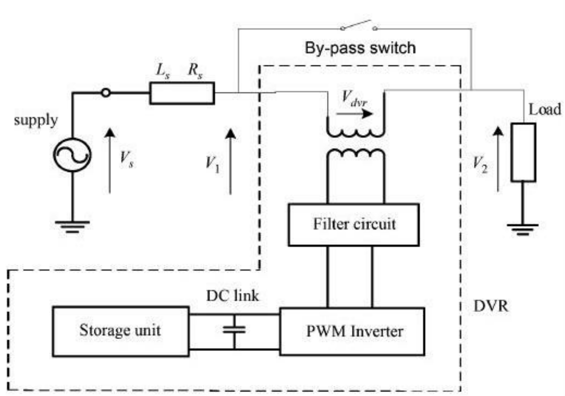

Figure.1Typical DVR-connected distribution system

2, POWER QUALITY PROBLEMS

sources and Effects of Power Quality Problems

Power distribution systems, ideally, should provide their customers with an uninterrupted flow of energy at smooth sinusoidal voltage at the contracted magnitude level and frequency However, in practice, power systems, especially the distribution nonlinear loads, which significantly affect the quality of power supplies. As a result of the nonlinear loads, the purity of the waveform of supplies is lost. This ends up producing power quality problems. Power distribution systems, ideally, should provide their customers with an uninterrupted flow of energy at smooth sinusoidal voltage at the contracted magnitude level and frequency however, in practice, power systems[4-5], especially the distribution systems, have numerous nonlinear loads, which significantly affect the quality of power supplies. As a result of the nonlinear loads, the purity of the waveform of supplies is lost. This ends up producing disturbance. While power disturbances occur on all electrical systems, the sensitivity of today's sophisticated electronic devices makes them more susceptible to the quality of power supply. For some sensitive devices, a momentary disturbance can cause scrambled data, interrupted disturbances occur on all electrical systems, the sensitivity of today's sophisticated electronic devices makes them more susceptible to the quality of power supply. For some sensitive devices, a momentary disturbance can cause scrambled data, interrupted. Power distribution systems, ideally, should provide their customers with an uninterrupted flow of energy at smooth sinusoidal voltage at the contracted magnitude level and frequency. Power distribution systems, have numerous power supplies. As a result of the nonlinear loads, the purity of the waveform of supplies is lost. This ends up producing many disturbances occur on all electrical systems, the sensitivity of today's sophisticated electronic devices makes them more susceptible to the quality of power supply. For some sensitive devices, a momentary disturbance can cause scrambled data, interrupted communications, a frozen mouse, system crashes and equipment failure etc. A power voltage spike can damage valuable components [10]. Power Quality problems encompass a wide range of disturbances such as voltage sags/swells, flicker, harmonics distortion, impulse transient, and interruptions.

Causes of Dips, Sags and Surges:

1. Rural location remote from power source
2. Unbalanced load on a three phase system

3.Switching of heavy loads

4. Long distance from a distribution transformer with interposed loads

5. Unreliable grid systems

6. Equipments not suitable for local supply

Causes of Transients and Spikes:

1. Lightening
2. Arc welding
3. Switching on heavy or reactive equipments such as motors, transformers, motor drives
4. Electric grade switching

2.4. Solutions to Power Quality Problems*:*

There are two approaches to the mitigation of power quality problems. The solution to the power quality can be done from customer side or from utility side First approach is called load conditioning, which ensures that the equipment is less sensitive to power disturbances [6], allowing the operation even under significant voltage distortion. The other solution is to install line conditioning systems that suppress or counteracts the power system disturbances. Currently they are based on PWM converters and connect to low and medium voltage distribution system in shunt or in series. Active power filters must operate in conjunction with shunt passive filters in order to compensate load current harmonics. Shunt active power filters operate as a controllable current source and series active power filters operates as a controllable voltage source. Both schemes are implemented preferable with voltage source PWM inverters [7], with a dc bus having a reactive element such as a capacitor. However, with the restructuring of power sector and with shifting trend towards distributed and dispersed generation, the line conditioning systems or utility side solutions will play a major role in improving the inherent supply quality, some of the effective and economic measures can be identified as following:

2.5 Lightening and Surge arresters

Arresters are designed for lightening protection of transformers, but are not sufficiently voltage limiting for protecting sensitive electronic control circuits from voltage surges.

2.6.Thyristor based Static Switches

The static switch is a versatile device for switching a new element into the circuit when the voltage support is needed. It has a dynamic response time of about one cycle. To correct quickly for voltage spikes, sags or interruptions, the static switch can used to switch one or more of devices such as capacitor, filter, alternate power line, energy storage systems etc. The static switch can be used in the alternate power line applications.

2.7 Energy Storage Systems

Storage systems can be used to protect sensitive production equipments from shutdowns caused by voltage sags or momentary interruptions. These are usually DC storage systems such as UPS, batteries, superconducting magnet energy storage (SMES), storage capacitors or even fly wheels driving DC generators .The output of these devices can be supplied to the system through an inverter on a momentary basis by a fast acting electronic switch. Enough energy is fed to the system to compensate for the energy that would be lost by the voltage sag or interruption. Though there are many different methods to mitigate voltage sags and swells, but the use of a custom Power device is considered to be the most efficient method. For example, Flexible AC Transmission Systems (FACTS) for transmission systems, the term custom power pertains to the use of power electronics controllers in a distribution system, specially, to deal with various power quality problems. Just as FACTS improves the power transfer capabilities and stability margins [3], custom power makes sure customers get pre-specified quality and reliability of supply. This pre-specified quality may contain a combination of specifications of the following: low phase unbalance, no power interruptions, low flicker at the load voltage, low harmonic distortion load voltage, magnitude and duration of overvoltage and under voltages within specified limits, acceptance of fluctuations, and poor factor loads without significant effect on the terminal voltage There are many types of Custom Power devices. Some of these devices include: Active Power Filters (APF), Battery Energy Storage Systems (BESS), Distribution STATic synchronous COMpensators (DSTATCOM), Distribution Series Capacitors (DSC), Dynamic Voltage Restorer (DVR) [2], Surge Arresters (SA), Super conducting Magnetic Energy Systems (SMES), Static Electronic Tap Changers (SETC), Solid-State Transfer Switches (SSTS), Solid State Fault Current Limiter (SSFCL), Static Var Compensator (SVC), Thyristor Switched Capacitors (TSC), and Uninterruptible Power Supplies (UPS).

3,DYNAMIC VOLTAGE RESTORER

Among the power quality problems like sags, swells, harmonics and so on, voltage sags are the most severe disturbances. In order to overcome these problems the concept of custom power devices is introduced recently. One of those devices is the Dynamic Voltage Restorer (DVR), which is the most efficient and effective modern custom power device used in power distribution networks. DVR is a recently proposed series connected solid state device that injects voltage into the system in order to regulate the load side voltage. It is normally installed in a distribution system between the supply and the critical load feeder at the point of common coupling (PCC). Other than voltage sags and swells compensation, DVR can also added other features like: line voltage harmonics compensation, reduction of transients in voltage and fault current limitations.

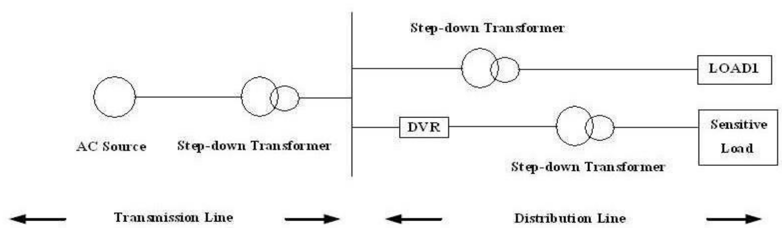

Figure. 2. Location of DVR

Basic Configuration of DVR: The general configuration of the DVR consists of:

i. An Injection/ Booster transformer
ii. Storage Devices
iii. A Voltage Source Converter (VSC)
iv. DC charging circuit
v. A Control and Protection system.

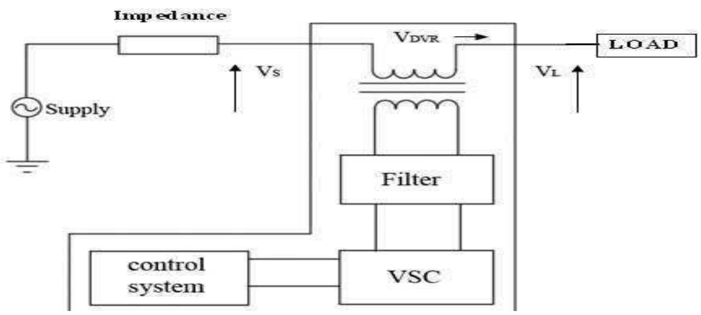

Figure.3 Schematic diagram of DVR

DVR consists of essentially a series-connected injection transformer, a voltage-source inverter, an inverter output filter, and an energy storage device that is connected to the dc link. Before injecting the inverter output to the system, it must be filtered so that harmonics due to switching function in the inverter are eliminated. It should be noted that when using the DVR in real situations, the injection transformer will be connected in parallel with a bypass switch. When there is no disturbances in voltage, the injection transformer (hence, the DVR) will be short circuited by this switch to minimize losses and maximize cost effectiveness. Also, this switch can be in the form of two parallel thyristors, as they have high on and off speed A financial assessment of voltage sag events and use of flexible ac transmission systems (FACTS) devices [8], such as DVR, to mitigate them is provided in It is obvious that the flexibility of the DVR output depends on the switching accuracy of the pulse width modulation (PWM) scheme and the control method. The PWM generates sinusoidal signals by comparing a sinusoidal wave with a saw tooth wave and sending appropriate signals to the inverter switches.

3.1 Basic Operational Principle of DVR.

The DVR controls the load voltage by injecting an appropriate voltage phasor in series with the system using the injection series transformer. In most of the sag compensation techniques, it is necessary that during compensation the DVR injects some active power to the system Therefore the capacity of the storage unit can be a limiting factor in compensation, especially during long-term voltage sags. The phasor diagram in Figure. 4 shows the electrical conditions during voltage sag, where, for clarity, only one phase is shown. Voltages, and are the source-side voltage, the load side voltage, and the DVR injected voltage, respectively. Also the operators I and are the load current, the load power factor angle, the source phase voltage angle, and the voltage phase advance angle, respectively. It should be noted that in addition to the in-phase injection technique, another technique, namely "the phase advance voltage compensation technique" is also used. One of the advantages of this method over the in-phase method is that less active power should be transferred from the storage unit to the distribution system [9]. This results in compensation for deeper sags or sags with longer durations. Due to the existence of semiconductor switches in the DVR inverter, this piece of equipment is nonlinear. However, the state equations can be lineaized using linearization techniques. The dynamic characteristic of the DVR is influenced by the filter and the load. Although the modeling of the filter easy to do, the load modeling is not as simple because the load can vary from a linear time invariant one to a nonlinear time- variant one.

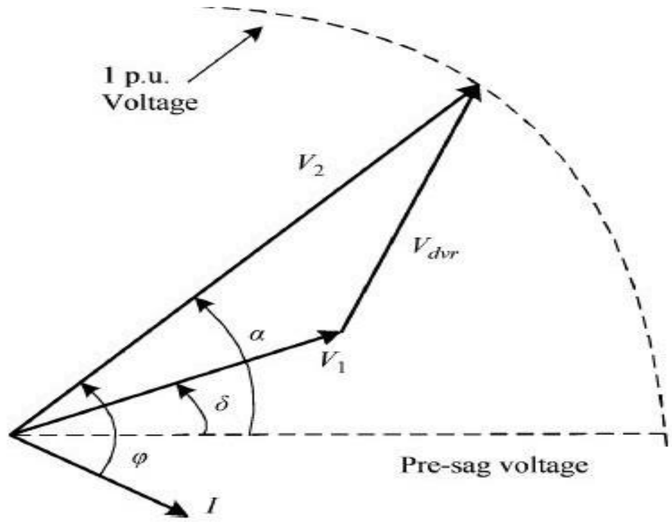

Figure. 4. Phasor diagram of electrical conditions during voltage sag.

4,PROBLEMS FORMATION

For the simulation 3 phase transmission line of 240v is considered. This line is energised by 3 phase source of 240v, 50 hz supply. This line is normal loaded by a RL load of 10 ohms and 60 mh, and heavily loaded by connecting additional RL load of 6 ohms and 40 mh. For heavy loaded condition voltage sag is created without DVR. To eliminate this sag DVR is connected to the line through the 3 phase terminal connection. This DVR acts during heavy load condition and eliminate voltage sag and provide better regulation.

5,SIMULATION RESULTS

Simulation of the proposed work is done for a transmission line system with and without DVR. Figure.4 show simulation circuit without DVR. Figure.5 shows simulation circuit with DVR. In the simulation for the circuit without DVR, fault is created at 0.3sec and fault cleared at 0.7sec, during this time voltage sag is created.

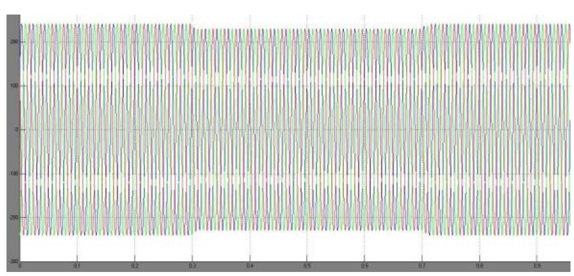

Figure.5 Voltage sag without DVR

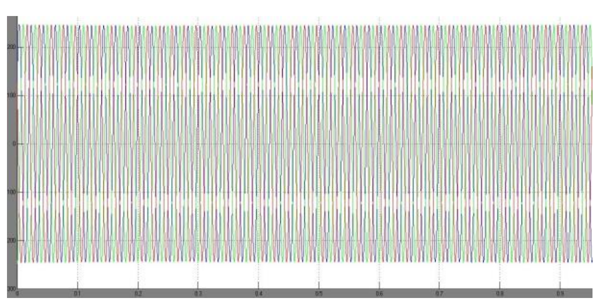

Figure. 6 Voltage with DVR

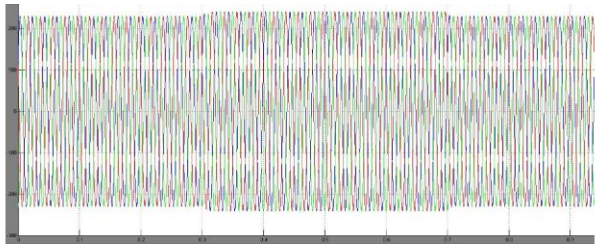

Figure. 7 Voltage swells without DVR

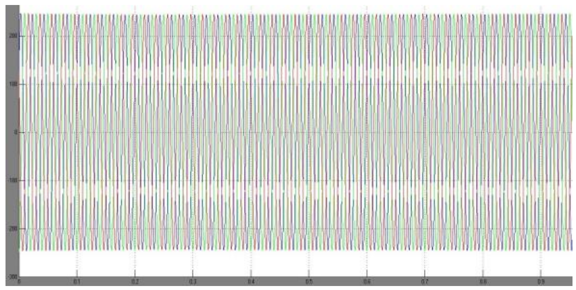

Figure.8. Voltage with DVR

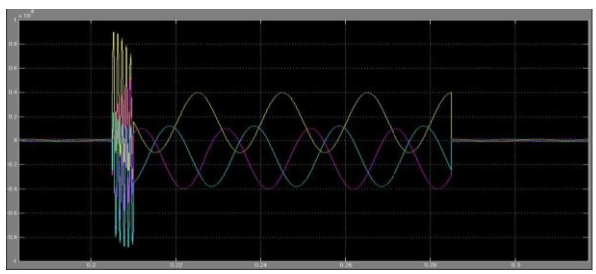

Figure.9 Current wave shape due to the three-phase short-circuit fault without DVR compensation.

To eliminate this voltage sag the DVR is implemented in the circuit and which eliminates voltage sag during the time period 0.3sec to 0.7sec and it is shown in figure 6. In the simulation for the circuit without DVR, fault is created at 0.3sec and fault cleared at 0.7sec, during this time voltage swell is created as shown in figure 7. To eliminate this voltage swell the DVR is implemented in the circuit and which eliminates voltage swell during the time period 0.3sec to 0.7sec and it is shown in figure 8. The figure shows the Current wave shape due to the three-phase short-circuit fault without DVR compensation.

6, CONCLUSION

This paper has presented the power quality problems such as voltage dips, swells, distortions and harmonics. Compensation techniques of custom power electronic devices DVR was presented. As the second function of this DVR, using the flux-charge model, the equipment is controlled so that it limits the downstream fault currents and protects the PCC voltage during these faults by acting as variable impedance. The problem of absorbed active power is solved by entering impedance just at the start of this kind of fault in parallel with the dc-link capacitor and the battery being connected in series with a diode so that the power does not enter it. The design and applications of DVR for voltage sags and comprehensive results were presented. A PWM-based control scheme was implemented. As opposed to fundamental frequency switching schemes already available in the MATLAB/ SIMULINK, this PWM control scheme only requires voltage measurements. This characteristic makes it ideally suitable for low-voltage custom power applications.

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BIOGRAPHY

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