Power Quality Improvement using Dynamic Voltage Restorer For Micro Grid Applications

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Abstract - *Power quality improvement is done by using this method and also to detect and classify various disturbances experienced by the voltage on the load side. A dynamic voltage restorer is used to compensate the voltage under disturbance conditions and maintain the rated load voltage. The input and the output voltages of the DVR are both controlled by the outputs. The approximations control the input voltages to the AC –DC converter. Just a few years ago, momentary power outages, sags, and surges had relatively little effect on most industrial processes. Today, manufacturing systems, sensitive telemetry, and precision electronic equipment can be disturbed, halted, or even damaged by voltage sag of two or three electrical cycles. The control pulses of the DC-AC inverter are controlled by the details. Different types of disturbances are simulated to test the performance of the proposed control scheme the proposed scheme successfully provided fast and accurate voltage restoration form of transient disturbance. This project deals modeling and analysis of a Dynamic Voltage Restorer (DVR) with sinusoidal pulse width modulation (SPWM) based controller by using the MATLAB / Simulink. The proposed control scheme is simple to design and allows flexibility in cost or robustness constraints. In addition, the performance of the designed DVR is examined under different sag conditions*

Key Words: **Power Quality, Voltage sags, voltage swell Dynamic Voltage Restorer (DVR), sinusoidal pulse width modulation (SPWM)**

1. INTRODUCTION

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 system faults, switching of large loads or energization of transformers cause voltage disturbance. Such disturbances cause short term rapid change in amplitude of voltage. A severe disturbance in voltage may lead to system crash, hardware damage, affecting the cost of customers and utilities. The problem quality problems such as temporary voltage rise (Swell) or voltage reduction (Sag) are more frequent and have severe impact on power system. Sudden increase in supply voltage up 110% to 180% in RMS voltage is defined as swell [3]. This occurs at fundamental frequency of network and sustains for time period of 10 ms to 1 minute. Typical system events such energization of large capacitor bank or removal of inductive load causes swells. On the other hand sudden decrease in supply voltage down 90% to 10% of nominal voltage is called as sag [2]. This problem is for the short duration and for time period of 10ms to 1 minute. The rated voltage is recovered after short period of time. Voltage sag is currently the most severe power quality problem encountered because of its adverse financial impact on customers. In Peninsular Malaysia, the first case of voltage sag was reported to the electric utility of Malaysia in early 1990 in which voltage sag caused the stopping of electronic wafer fabrication process. Modernization and automation of industry involves increasing use of computers, microprocessors and power electronic systems such as adjustable speed drives.

The power electronic systems also contribute to power quality problem (generated harmonics).The electronic devices are very sensitive to disturbances and become less tolerant to power quality problems such as voltage sags, swells and harmonics. Due to the harmonics are occurring in the system it causes losses and heating of motor. The DVR is a power quality device that has gained an increasing role in protecting industries against disturbances such as voltage sags related to remote system faults .The basic operation principle of the DVR is to inject an appropriate voltage in series with the supply through injection transformer whenever voltage sag is detected. To mitigate voltage sag, DVR has been considered as effective sag mitigation equipment and many research works have been carried out focusing in the design and control of the DVR. The main function of DVR is to inject the desired voltage quantity in series with the supply with the help of an injection transformer whenever voltage sag is detected. Power transfer ability, transient stability and damping of power oscillation is improved by using DVR in transmission system. And it is capable of generating or absorbing real and reactive power at its ac terminals. The basic principle of a DVR is simple by inserting a voltage of desired magnitude and frequency, in order to restore the load-side voltage balanced and sinusoidal. This study introduces various power quality problems and basic concept of DVR (Dynamic Voltage Restorer), this study deals with overview of a Dynamic Voltage Restore (DVR) for mitigation of voltage sags.

2. POWER QUALITY PROBLEMS

The various power quality problems are as followed:

1. Transients- A transient is a temporary occurrence of a fault which is of a very short duration in a system caused by the sudden change of state.

2. Voltage sags- A voltage sag or voltage dip is a short duration reduction in RMS voltage which can be caused by a short circuit, overload or starting of electric motors. A voltage sag happens when the RMS voltage decreases between 10 and 90 percent of nominal voltage for one-half cycle to one minute.

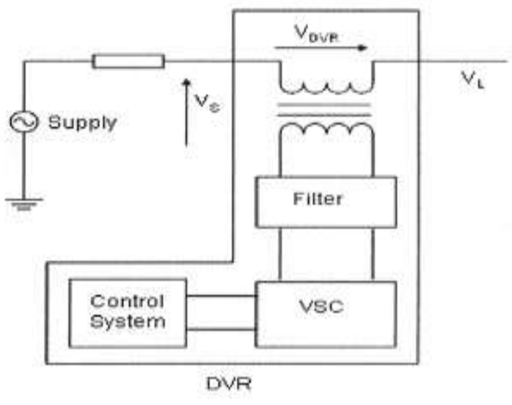
3. Voltage swells- Voltage swell, which is a momentary increase in voltage, happens when a heavy load turns off in a power system.

4. Voltage interruption- Interruptions are classified as short-duration or long-duration variation. The term interruption is often used to refer to short-duration interruption, while the latter is preceded by the word sustained to indicate a long-duration. They are measured and described by their duration since the voltage magnitude is always less than 10% of nominal.

3. BASIC CONFIGURATION OF DVR:

The general configuration of the DVR consists of:

1. An Injection/ Booster transformer.
2. A Harmonic filter.
3. Storage Devices.
4. A Voltage Source Converter (VSC).
5. DC charging circuit
6. Control and Protection System.



3.1 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. Its main tasks are:

1. It 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.

2. In addition, the Injection / Booster transformer serves the purpose of isolating the load from the system (VSC and control mechanism).

3.2 Harmonic Filter:

The main task of harmonic filter is to keep the harmonic voltage content generated by the VSC to the permissible level.

3.3 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. There are four main types of switching devices:

1. Metal Oxide Semiconductor Field Effect Transistors (MOSFET),

2. Gate Turn-Off Thyristors (GTO),

3. Insulated Gate Bipolar Transistors(IGBT), and

4. 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.

3.4 DC Charging Circuit:

The dc charging circuit has two main tasks.

1. The first task is to charge the energy source after a sag compensation event.

2. The second task is to maintain dc link voltage at the nominal dc link voltage

3.5 Control and Protection:

The control technique to be adopted depends on the type of load as some loads are sensitive to only magnitude change whereas some other loads are sensitive to both magnitude and phase angle shift. Control techniques that utilize real and reactive power compensation are generally classified as pre- sag compensation, in-phase compensation and energy optimization technique. For our study, pre-sag compensation was used where the load voltage is restored to its pre-sag magnitude and phase. Therefore, this method is suitable for loads which are sensitive to magnitude and also phase angle shift. Differential current protection of the transformer, or short circuit current on the customer load side are only two examples of many protection functions possibility.

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4. EQUATIONS RELATED TO DVR

The system impedance Z_{th} depends on the fault level of the load bus. When the system voltage (V_{th}) drops, the DVR injects a series voltage VDVR through the injection transformer so that the desired load voltage magnitude VL can be maintained.

The series injected voltage of the DVR can be written as

$$V_{DVR} = V_L + Z_{TH} I_L - V_{TH} \quad (3.1)$$

Where

$\boldsymbol{V_{DVR}}$: The desired load voltage magnitude

$\mathbf{Z_{TH}}$: The load impedance.

$\mathbf{I_L}$: The load current.

$\mathbf{V_{TH}}$: The system voltage during fault condition.

The load current I_L is given by,

$$\frac{I_L = [P_L + Q_L]}{V} \quad (3.2)$$

When V_L is considered as a reference equation can be rewritten as,

$$V_{DVR}\angle 0 = V_L\angle 0 + Z_{TH}\angle(\beta - \theta) - V_{TH}\angle\delta \quad (3.3)$$

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

$$\theta = \tan^{-1}\left(\frac{\theta_L}{p_L}\right) \quad (3.4)$$

The complex power injection of the DVR can be written as,

$$S_{DVR=}V_{DVR} I_L^* \quad (3.5)$$

It requires the injection of only reactive power and the DVR itself is capable of generating the Reactive power.

5. 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 transient 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 has three modes of operation which are:

1. protection mode,
2. standby mode,
3. Injection/boost mode.

5.1 Protection Mode:

If the over current on the load side exceeds a permissible limit due to short circuit on the load or large inrush current, the DVR will be isolated from the systems by using the bypass switches (S2 and S3 will open) and supplying another path for current (S1 will be closed).

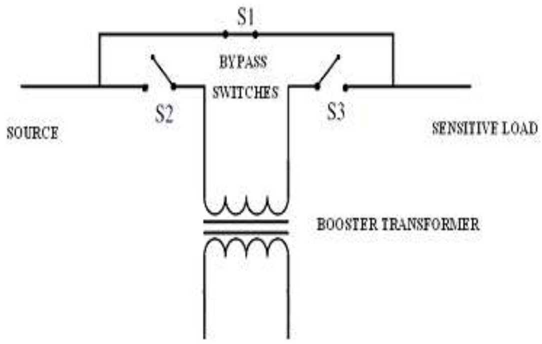

Fig. 5.1 Protection Mode

5.2 Standby Mode: (V_{DVR}= 0)

In the standby mode the booster transformer's low voltage winding is shorted through the converter. No switching of semiconductors occurs in this mode of operation and the full load current will pass through the primary.

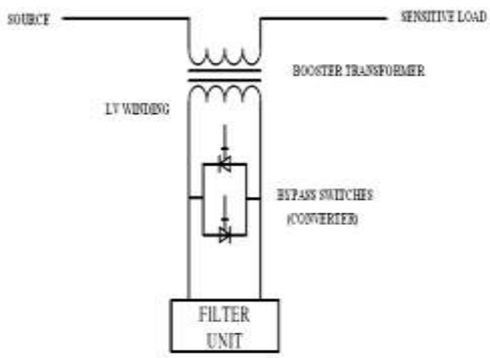

Fig. 3.5 Standby Mode

5.3 Injection/Boost Mode: (V_{DVR}>0)

In the Injection/Boost mode the DVR is injecting a compensating voltage through the booster transformer due to the detection of a disturbance in the supply voltage.

6. RESULTS

The simulation was done to remove supply sag conditions in the presence of DVR, when the circuit breaker in the circuit is closed after identifying the voltage difference between supply voltages and load voltages by the hysteresis voltage controller.

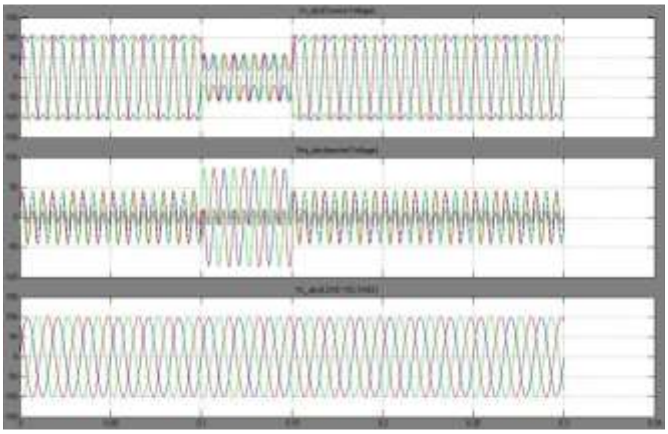

fig.6.1 DVR under sag conditions

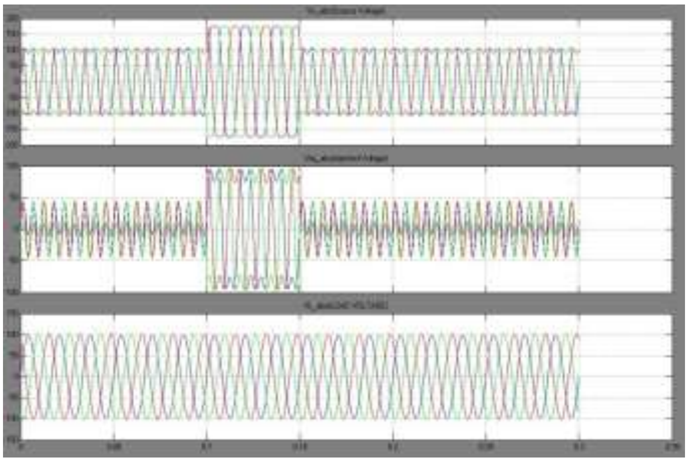

Fig.6.1 DVR under swell conditions

7. CONCLUSIONS

A new control strategy based on hysteresis voltage control for Dynamic Voltage Restorer (DVR) has been proposed to mitigate the power quality problems in the terminal voltages. The DVR is controlled indirectly by controlling the supply current. The reference supply voltages are estimated using the sensed load terminal voltages and the dc bus voltage of DVR. The control scheme is based on synchronous reference frame theory (SRFT) for the operation of a capacitor supported DVR. The proposed control scheme of DVR has been validated the compensation of sag and swell in terminal voltages. The performance of the DVR has been found very good to mitigate the voltage power quality problems. Moreover, it has been found capable to provide self supported dc bus of the DVR through power transfer from ac line at fundamental frequency. As per numerical values the sag and swell magnitudes of the supply voltage have reduced by 90%. The system performance is increased when compared to the condition of sag and swell.

8. FUTURE SCOPE

The new control strategy based on hysteresis voltage control for DVR is proposed to mitigate the power quality problems in the supply voltage. The DVR is controlled by identifying the difference between the supply voltage and the load voltage. In future this can be implemented by using a new control strategy of an Adeline (Adaptive linear element) Artificial Neural Network (ANN) can be used to control a capacitor supported DVR for power quality improvement

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