HARDWARE IMPLEMENTATION OF SINGLE PHASE DYNAMIC VOLTAGE RESTORER IN MITIGATING VOLTAGE SAG & SWELL

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Abstract— Voltage sag disturbances are the most frequently occurring Power Quality problems in the distribution system. Dynamic Voltage Restorer is normally employed as a solution for mitigation of voltage sag. The proposed system has less number of switching devices and has good compensating capability in comparison with commonly used compensators. The Static Series Compensator (SSC), commercially known as Dynamic Voltage Restorer (DVR), is best suited to protect sensitive loads against such incoming supply disturbances. This project presents the hardware implementation of single phase Dynamic voltage restorer in mitigating voltage sag and swell. A simple fault generated is created which intentionally creates four levels of Voltage disturbances .Single phase inverter based on MOSFET was designed and firing pulse to the device using micro controller based PWM generation. Energy storage device used in this work is Battery (12 V) which acts as input to the inverter.DVR model compensates the voltage sag and swell with efficient and effective manner, because of its lower cost, smaller size, and fast dynamic response to the disturbance.

IndexTerms—Dynamic voltage restorer (DVR),Battery energy storage –MOSFET,sag,swell and harmonic voltages generator-micro controller.

Introduction
The power quality problems in industrial applications concern a wide range of disturbances such as voltage sag and swell. Preventing such phenomena is particularly important because of increasing heavy automation in almost all the industrial processes. The use of important electrical and electronic equipments, such as computers, programmable logic controllers, variable speed drives industrial motors etc, very often requires interruption free of power supplies with very high quality. The voltage sag as defined by IEEE standard 1159. IEEE recommended practice for monitoring electric power quality is: "a decrease in RMS voltage or current at the power frequency for durations from 0.5 cycles to 1 min, reported as the remaining voltage". Typical values are between 0.1 and 0.9 per unit and typical fault clearing times range from three to thirty cycles depending on the fault current magnitude and the type of over current detection and interruption.
Voltage deviations, commonly in the form of voltage sag and swell can cause severe process disruptions result in substantial production loss. Several recent surveys attribute that 92% of the disturbances in electrical power distribution systems are due to voltage sag and swell. These system-equipment interface devices are commonly known as custom power devices which DVR is a powerful one for short duration voltage compensation. The filter parameters are designed according to certain design aspects such as depth of the sag and swell mitigated and load voltage. Its prototype hardware implementation model is analyzed for single phase voltage sag and swell mitigation in a power system. The results showed the effectiveness and efficiency of DVR mitigating voltage sag and swell in a voltage distribution system. Apart from non-linear loads, some system events, both usual (capacitor switching, motor starting) and unusual (faults) could also inflict power quality problems. The consequence of power quality problems could range from a simple nuisance flicker in electric lamps to a loss of thousand of rupees due to power shutdown. A power quality problem is defined as any manifested problem in voltage or current of leading to frequency deviations that result in failure or miss operation of customer equipment. Power quality problems associated with an extensive number of electromagnetic phenomena in power systems with broad ranges of time frames such as long duration variations, short duration variations and other disturbances.
Voltage sag and swell can cause loss in production in automated processes since voltage sag can trip a motor or cause its controller to malfunction. Voltage swell is defined as sudden increase in supply between 110% and 180% of the nominal value . Switching off a large inductive load or energizing a large capacitor bank is a typical system event that causes swell. To compensate the sag/swell in a system, appropriate devices need to be installed at suitable locations. power quality problems challenging the utility industry can be compensated and power is injected into the distribution system.
2.1 A Simple Sag Generator Using SSRs
Significant deviations from the nominal voltage are a problem for sensitive consumers in the grid system. Interruptions are generally considered to be the worst case with the load disconnected from the supply. Voltage sag are characterized by a reduction in voltage, but the load is still connected to the supply. Sag are in most cases considered less critical compared to interruptions, but they typically occur more frequently.

2.2 The System Research and Implementation of Dynamic Voltage Restorer
Sag are impossible to avoid because of the finite clearing time of the faults causing the voltage sag. The wide propagation of sag from the equipment can be made more tolerant of sag either via more intelligent control of the equipment or by storing more energy in equipment. Instead of modifying each component, for instance, a factory to be very tolerant to voltage sag, a better solution might be to install one Dynamic Voltage Restorer (DVR) to mitigate voltage sag. A DVR can eliminate severe sag and minimize the risk of load tripping at very deep sag.

Power quality has a significant influence on high – technology equipment related to communication, advanced control, automation, precise manufacturing technique and online service. For example, voltage sag can have a bad influence on the products of semiconductor fabrication with considerable financial losses. Power quality problems include transients, sag, interruptions and other distortions to the sinusoidal waveform. One of the most important power quality issues is voltage sag that is a sudden short duration reduction in voltage magnitude between 10 and 90% compared to nominal voltage.

Deep voltage sag, even of relatively short duration, can have significant costs because of the proliferation of voltage sensitive computer-based and variable speed drive loads. The fraction of load that is sensitive to low voltage is expected to grow rapidly in coming decades.

2.3 Design and analysis of dynamic voltage restorer for deep voltage sag and harmonic compensation
Studies have shown that transmission faults, while relatively rare, can cause widespread sag that may constitute major process interruptions for very long distances from the faulted point. The DVR can correct sag resulting from faults in either transmission or distribution system.

Power distribution system should ideally provide their customers an uninterrupted flow of energy with smooth sinusoidal voltage at the contracted magnitude and frequency. However, in practice power system especially the distribution system, have numerous non linear loads, which are significantly affect the quality of power supply. As a result, the purity of waveform of supply lost.

This ends up producing many power quality problems. Apart from nonlinear loads, some system events, both usual (capacitor switching, motor starting) and unusual (faults) could also inflict power quality problems. The consequence of power quality problems could range from a simple nuisance flicker in electric lamps to a loss of thousand of rupees due to power shutdown.

A power quality problem is defined as any manifested problem in voltage or current of leading to frequency deviations that result in failure or miss operation of customer equipment. Power quality problems associated with an extensive number of electromagnetic phenomena in power systems with broad ranges of time frames such as long duration variations, short duration variations and other disturbances.

Short duration variations are mainly caused by either fault conditions or energisation distance related to impedance type of grounding and connection of transformer between the faulted location and node, there can be temporary load of voltage reduction (sag) or voltage rise (swell) at different nodes of the system.

2.4 Effects of Voltage Sag, Swell and other disturbances on Electrical Equipment and their Economic Implications,” 20th International Conference on Electricity Distribution, Prague.

Voltage sag is defined as a sudden reduction in supply voltage to between 90% and 10% of the nominal value, followed by a recovery after a short interval. The standard duration of sag is between 10 milliseconds and 1 minute. Voltage sag can cause loss in production in automated processes since voltage sag can trip a motor or cause its controller to malfunction.

Voltage swell is defined as sudden increase in supply between 110% and 180% of the nominal value of the duration of 10milliseconds to 1 minute. Switching off a large inductive load or energizing a large capacitor bank is a typical system event that causes swell. To compensate the sag/swell in a system, appropriate devices need to be installed at suitable locations.

Voltage sag/swell is most important power quality problems challenging the utility industry can be compensated and power is injected into the distribution system. By injecting voltage with a phase advance with respect to the sustained source-side voltage, reactive power can be utilized to help voltage restoration. Dynamic Voltage Restorer, which consists of a set of series and shunt converters connected back-to-back, three series transformers, and a dc capacitor installed on the common dc link.

2.5 Sensitive load voltage compensation against voltage sag/swell and harmonics in the grid voltage and limit downstream fault currents using DVR
Power quality (PQ) is an issue which is nowadays gaining significant interest to both electric utilities and end-users. Lack of PQ causes huge economical losses all over the world which makes it more important. Voltage quality is the most important part of PQ from the viewpoint of sensitive load.

Voltage disturbances mainly include voltage sag, voltage swell and voltage harmonics.
Different power-electronic based techniques can be used to mitigate PQ problems. They can be divided into two groups, series and shunt compensators. Series compensators are usually used for voltage quality improvement where shunt compensators are well suited for current quality improvement.

**Hardware Implementation Of Single Phase Dynamic Voltage Restorer**

In the DVRs that employ ac/dc/ac conversion, it is required to use a large capacitor in the dc link to smooth the dc link voltage. Hereafter these topologies are called conventional DVRs. A considerable amount of technical works has been done on the conventional DVRs concerning both hardware circuit topology, control strategy and voltage disturbances detection methods. The topologies of DVRs vary from both viewpoints of how to connect to the system and the used inverter topology in the DVR structure.

The DVRs can operate in both low voltage and medium voltage distribution systems. Application of multilevel inverters in the conventional DVRs has been presented as a solution to handle high voltage and high power by the DVRs. Beside the voltage sag and swell compensation, the DVR has been successfully used for voltage harmonic compensation and downstream fault current limitation.

**OPERATING PRINCIPLE OF DVR:**

The DVR is designed to inject the missing voltage into the distribution line. Its basic idea is to dynamically inject a voltage \( u_c(t) \) as shown in Fig.1. The upper part of Figure shows a simplified single-phase equivalent circuit of a distribution feeder with a DVR, where the supply voltage \( u_s(t) \), the DVR injection voltage \( u_c(t) \) and the load voltage \( u_L(t) \) are in series. So, the DVR is considered to be an external voltage source where the amplitude, the frequency and the phase shift of \( u_c(t) \) can be controlled. The purpose is to maintain the amplitude of the load voltage fixed and prevent phase jumps.

**BLOCK DIAGRAM OF DVR:**

A schematic diagram of the DVR incorporated into a distribution network is shown in Fig. V1 is the source voltage, V1 is the incoming supply voltage before compensation, V2 is the load voltage after compensation, DVR is the series injected voltage of the DVR, and I is the line current. The DVR typically consists of an injection transformer, the secondary winding of which is connected in series with the distribution line. The injection of an appropriate DVR in the face of an upstream voltage disturbance requires a certain amount of real and reactive power supply from the DVR.
Typical schematic of a power distribution system compensated by a DVR. The mostly control of industrial loads is mainly based on semiconductor devices, which causes such loads to be more sensitive against power system disturbances. Power electronic loads inject harmonic currents in the AC system and increase the overall reactive power demanded by the equivalent load, also, modern industrial equipments are more sensitive to these power quality problems than before and need higher quality of electrical power. Spurious tripping of voltage sensitive loads such as PLCs and adjustable-speed drives due to voltage sag is a serious power quality concern for industrial customers.

**DVR:**
The block diagram for prototype laboratory model of DVR along with other components is shown in Fig. 9 and the hardware circuit is shown in Fig. During normal condition, the normal voltage appears across the load. The comparator-2 senses whether the load is in normal state or not. The comparator-1 senses the load continuously. When an extra load is added, the voltage sag problem arises. “VOLTAGE SAG OCCURRED”. Then the Comparator-1 gives a signal to the microcontroller. The microcontroller gives the pulses to the relay circuit and DVR circuit. The relay circuit gets closed and the DVR injects voltage to the load. The voltage sag problem is thus eliminated. When the extra load is removed, the voltage comes to normal value, but DVR injects voltage to the load continuously. The comparator-3 senses load voltage and gives a signal to the microcontroller which trips the relay circuit and stops the pulses to the DVR. The LCD display then indicates “LOAD REMOVED”.

**Market based methods** are based on market mechanisms and hence give an indication of the value of the scarce resource of transmission capacity. These methods are briefly discussed below.

**STEPS:**
Step 1: Start the program.
Step 2: Initialize the Port C and Port B of microcontroller.
Step 3: Initialize LCD connected to Port D.
Step 4: Clear the LCD display.
Step 5: Display the “WELCOME”.
Step 6: Check whether voltage sag problem occurred or not.
Step 7: If “yes”, go to next Step, otherwise go to Step 11.
Step 8: Microcontroller passes signals to Relay, Comparator and activates DVR Circuit.
Step 9: Repeat Step 3 and Step 4.
Step 10: Display “VOLTAGE SAG OCCURS” and “VOLTAGE TO BE ADDED”.
Step 11: Check whether the voltage is in Normal condition or not.
Step 12: If “yes”, go to next step, otherwise go to Step 14.
Step 13: Repeat Step 3 & Step 4 and display “NORMAL STATE”.
Step 14: Check whether the voltage is above the Normal level.
Step 15: If “yes”, go to next Step, otherwise go to Step 6.
Step 16: Repeat Step 3 & Step 4 and display “LOAD REMOVED”.

**DVR SAG GENERATOR:**
Power line voltage sag may typically be triggered by natural causes (by lightning or by icing of transmission lines) or by some loading conditions (start-up of large motor drives or rectifiers without soft starters/precharge circuits which draw large inrush currents, and arc furnaces exhibiting low impedance and imbalanced load characteristics and drawing large magnitude imbalanced currents). They are the most frequent power quality problems in the power grid, and they usually have high economical impact on the voltagesensitive loads. In process control systems, control boards and motor drives, which are sensitive to sag, may be adversely affected due to voltage sag, and processes may be halted. Repair and restart of the processes usually are involved and costly.

In the class of electronic loads, which includes power-electronic-based motor drives (inverter drives), constant-power-type loads draw large current during deep voltage sag and trip the drive (due to current overloading) or blow the fuses, bringing the system to a halt. During a deep sag, constant-impedance-type loads may be forced out of their intended operating region, rendering the load partially ineffective or more drastically leaving it out of operation. In addition to the downtime of the installation using the sag-affected equipment, the equipment damages and hazards are often very high. In manufacturing lines, processes, public infrastructures, etc., the cost of voltage-sag-based failure is usually unacceptable that a method to mitigate the sag effect is mandatory. In order to avoid the voltage sag problems, the sensitivity of the equipment fed from the ac grid to voltage sag can be decreased to sufficient levels by design or by utilization of auxiliary devices.
For example, an energy storage unit may be interfaced with the dc bus of the rectifier (using a power electronic converter) and transfer energy to the dc bus of the load during the sag such that the rectifier dc bus is sustained at/above the critical level for proper operation. In the more radical and usually more expensive approach, sag compensating power quality conditioning devices (sag correctors, uninterruptible power supplies (UPSSs), dynamic voltage restorers, series active filters (SAFs), etc.) are inserted between the ac grid and the sensitive loads. Regardless of the method for sag mitigation, based on the equipment classifications involved, the sag sensitivity of equipment must meet certain standards.

Block Diagram of DVR

Circuit Description:
The chargeless device control using cell phone is designed using ring counts. The ring is connected by using ring detector circuit. The IC 4017 based ring detector circuit gives sequence pulses to capacitor charger based comparator circuit. Where capacitor provide input values for each comparator. For each ring any one of the comparator is selector and capacitor starts to charge. The 1K and 10K based voltage divider circuit provide reference values for each comparator. In our demo version we choose rings 3, 5 and 7 for operating the electrical device. After making required ring the corresponding RC network charger and produce pulses to next stages. In microcontroller, toggle operation is carried on.

Fig: PIC16F877A

RESULTS AND OUTPUTS

DVR with Sag Generator
Images indicates the lamp glow very dim while low sag

Image shows the output low swell voltage

Image shows the low output sag voltage

Image shows the output high swell voltage

Images indicates the lamp glow dim while High sag

Image shows the without swell voltage
**SAG**

<table>
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<tr>
<th>S. N</th>
<th>OUTPUT VOLTAGE</th>
<th>TO BE INJECT</th>
<th>COMPENSATION</th>
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<tr>
<td>1</td>
<td>LOW SAG 96V</td>
<td>129 V</td>
<td>96+129=225V</td>
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<tr>
<td>2</td>
<td>HIGH SAG 148V</td>
<td>77 V</td>
<td>(148+77)=225V</td>
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**SWELL**

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<th>S. N</th>
<th>OUTPUT VOLTAGE</th>
<th>TO BE OBSERVE</th>
<th>COMPENSATION</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>LOW SWELL 96V</td>
<td>19 V</td>
<td>(244-19)=225V</td>
</tr>
<tr>
<td>2</td>
<td>HIGH SWELL 148V</td>
<td>37 V</td>
<td>(262-37)=225V</td>
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**CONCLUSION**

In this project, the hardware implementation of a DVR has been presented. The hardware results showed clearly the performance of the DVR in mitigating voltage sag as well as swell. The DVR handles the situation without any difficulties and injection or absorption the appropriate voltage component to correct rapidly any changes in the supply voltage thereby keeping the load voltage balanced and constant at the nominal value. In this study, the DVR has shown the ability to compensate for voltage sag and swell; this has been proved through hardware implementation. The efficiency and effectiveness on voltage sag and swell compensation showed by the DVR makes it an interesting power quality device compared to other custom power devices. It is planned to implementation of DSP based for the Dynamic Voltage Restorer in future work.

**REFERENCES:**


