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Mitigation of a Voltage Sag Swell by DVR using ANN Techniques for Renewable Energy Resources

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Abstract:

Voltage sags and swells in the medium and low voltage distribution grid are considered to be the most frequent type of power quality problems based on recent power quality studies. Their impact on sensitive loads is severe. The impact ranges from load disruptions to substantial economic losses up to millions of dollars. Different solutions have been developed to protect sensitive loads against such disturbances but the DVR is considered to be the most efficient and effective solution. Even the conventional concept suffers with effective controller problems.

This proposed concept describes the techniques for compensation of voltage sag and voltage swell by DVR based on Voltage Source Converter (VSC). Voltage source inverters are capable of generating accurate high quality voltage waveforms and form the power electronic heart of the custom power device. The model has to be simulated with MATLAB/Simulink program to demonstrate system behavior of dynamic voltage restorer with hysteresis controller. The operation of the DVR can be explained with non-linear loads. The DVR are also to be demonstrated on the practical distribution bus system.

Keywords:- Matlab/Simulink, Voltage Source Converter (VSC), Uninterruptible Power Supplies (UPS), Transformer Tap Changer, Resonant, Transformers,

Introduction

Power Quality problems encompass a wide range of disturbances such as voltage sags/swells, flicker, harmonics distortion, impulse transient, and interruptions. Voltage sags can occur at any instant of time, with amplitudes ranging from 10 – 90% and a duration lasting for half a cycle to one minute. Voltage swell, on the other hand, is defined as a swell is defined as an increase in rms voltage or current at the power frequency for durations from 0.5 cycles to 1 min. Typical magnitudes are between 1.1 and 1.8 up. Swell magnitude is also is described by its remaining voltage, in this case, always greater than 1.0up

Voltage sag and swell can cause sensitive equipment (such as found in semiconductor or chemical plants) to fail, or shutdown, as well as create a large current unbalance that could blow fuses or trip breakers. These effects can be very expensive for the customer, ranging from minor quality variations to production downtime and equipment damage. 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. Switching off a large inductive load or Energizing a large capacitor bank is a typical system event that causes swells. This project introduces Dynamic Voltage Restorer and its operating principle. Then, a simple control based on dqo method is used to compensate voltage sags/swell.
At the end, MATLAB/SIMULINK model based simulated results were presented to validate the effectiveness of the proposed control method of DVR.

Solutions to Voltage Sag Problems:
First Identify the Problem:
Equipment Identification:

In order to provide a optimal and cost effective solution to voltage sag problems it is necessary to determine which equipment is susceptible to unplanned stoppages. In most industries there is still a significant amount of electrical equipment which is not sensitive to voltage variation or which can be restarted at little or no cost.

Identify the Voltage Sags:

The next stage is to determine the frequency, depth and duration of the voltage sags. These can vary widely even in apparently similar industrial facilities. Collection of this data is essential if the optimal solution is to be identified. In North America, only a small proportion of manufacturing businesses have installed electrical metering which is capable of measuring and recording the voltage variations, which are responsible for the majority of their very costly Unplanned Production Stoppages.

Measure the Problem:
Install Metering:

To identify the depth of the voltage sags and their duration, the sag events need to be measured and recorded for subsequent analysis. As a typical voltage sag events last only a few cycles, the most cost effective way to measure these is by installation of an electronic meter with waveform capture capability.

The data is captured automatically and is downloaded to a computer for later analysis.

Record Unplanned Production Stoppages:

It is extremely helpful to record precisely the time and date of unplanned production stoppages and then to compare these against voltage variations recorded by the meter, as not all voltage sags lead to stoppages. This analysis will show the value of the sag voltage which typically causes production problems and equally those events which have not caused problems. Surprisingly in many industries, people are so busy trying to restart the process they fail to record the time of the stoppage with any formal system.

Meter Cost vs. Cost of Unplanned Production Stoppage:

The cost of an installation with a meter capable of wave form capture and its software is typically a few thousand dollars. This is often only a small fraction of the cost of even one unplanned production stoppage. Unfortunately installation of such meters has not become commonplace in many industries as “there is no money in the budget for this”.

Choose a Solution:

If it is possible to correct the problem by changing some sensitive components, this may well be the least expensive solution. This approach has been widely adopted in the semi-conductor industry and it is notable that this industry has invested heavily in high quality meters to identify the problems. This is an industry where an unplanned stoppage may cost $1 million per event or more. If component substitution is not practical, it is necessary to identify the size of the load to be protected in kVA and its supply voltage. This may be an entire plant at medium voltage or a critical machine at low voltage or anything in between.

There is Voltage Sag Correction Devices Available:
Traditional Solutions:

Traditional methods of Voltage Control included Transformer Tap Changers both mechanical and SCR switched units, Servo-Varies technology and Ferro-Resonant Transformers (constant voltage transformers).

UPS Solutions:

Uninterruptible Power Supplies (UPS) technology has been available for over 20 years and is ideally suited for those applications such as high-speed data processing where continuous protection against any power variation and more importantly against any power interruption is essential. Industrial UPS units are widely used to protect electronic process control equipment and to allow for an orderly shutdown of the process but it is rarely economic to install large UPS systems with their attendant large battery banks for high power electrical equipment such as high horsepower drives, extruders etc.

Electronic Voltage Regulators:

There are several manufacturers of devices designed specifically for voltage sag correction in industrial applications. These devices use a combination of an inverter plus short term electrical storage or an inverter with a specially designed injection transformer to provide voltage correction against voltage sags as they arise. These devices provide excellent protection against both 3 phases and single-phase voltage sags. Some manufacturers offer small single-phase devices at low voltage 120V or 220V typically with small kVA ratings. A few manufacturers offer solutions in the 50MVA to 100+MVA range at medium voltage but demand for these occurs infrequently.

Signals & Data Transfer:

In complicated block diagrams, there may arise the need to transfer data from one portion to another portion of the block. They may be in different subsystems. That signal could be dumped into a go to block, which is used to send signals from one subsystem to another. Multiplexing helps us remove clutter due to excessive connectors, and makes matrix (column/row) visualization easier

Making subsystems:

Drag a subsystem from the Simulink Library Browser and place it in the parent block where you would like to hide the code. The type of subsystem depends on the purpose of the block. In general one will use the standard subsystem but other subsystems can be chosen. For instance, the subsystem can be a triggered block, which is enabled only when a trigger signal is received. Open (double click) the subsystem and create input / output PORTS, which transfer signals into and out of the subsystem

Setting Simulation Parameters:

Running a simulation in the computer always requires a numerical technique to solve a differential equation. The system can be simulated as a continuous system or a discrete system based on the blocks inside.. Simulation step size must be decided based on the dynamics of the system.

PROPOSED METHOD:

Main Circuit:

The configuration of the proposed DVR designs using MATLAB/SIMULINK, where the outputs of a three-phase half-bridge inverter are connected to the utility supply via wyes-open connected series transformer. Once a voltage disturbance occurs, with the aid of duo transformation based control scheme, the inverter output can be steered in phase with the incoming ac source while the load is maintained constant.

ControlAlgorithm:

The basic functions of a controller in a DVR are the detection of voltage sag/swell events in the system; computation of the correcting voltage, generation of trigger pulses to the sinusoidal PWM based DC-AC inverter, correction of any anomalies in the series voltage injection and termination of the trigger pulses when the event has passed. The controller may also be used to shift the DC-AC inverter into rectifier

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mode to charge the capacitors in the DC energy link in the absence of voltage sags/swells.

The duo transformation or Park's transformation is used to control of DVR. The control scheme for the proposed system is based on the comparison of a voltage reference and the measured terminal voltage (Va, Vb, Vc).The voltage sags is detected when the supply drops below 90% of the reference value whereas voltage swells is detected when supply voltage increases up to 25% of the reference value. The error signal is used as a modulation signal that allows to generate a commutation pattern for the power switches (IGBT's) constituting the voltage source

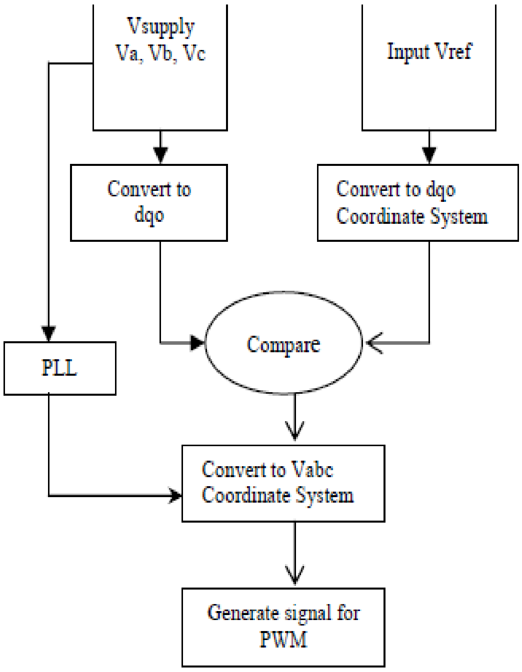


Figure: Flow chart of feed forward control technique for DVR based on dqo transformation.

SIMULATION RESULTS:

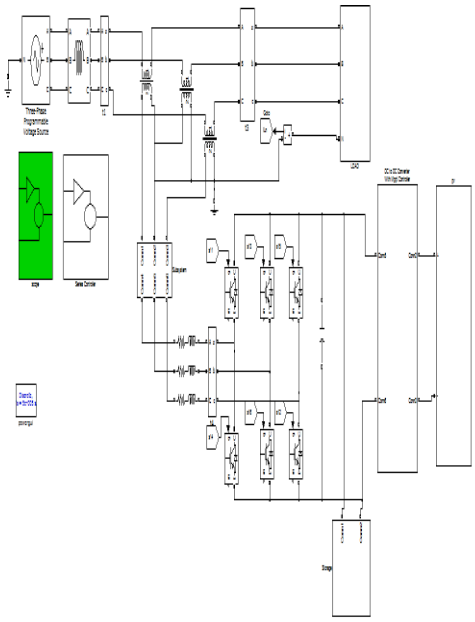


Figure Simulation Circuit of sag/swell

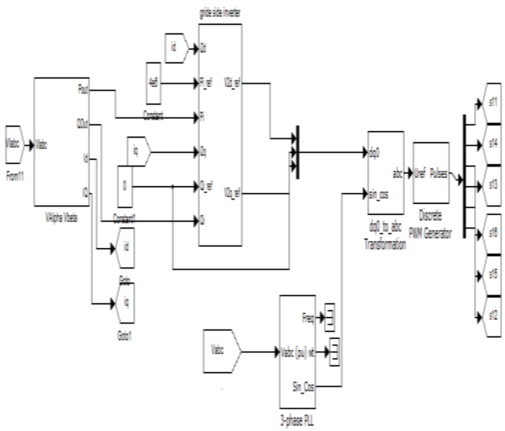
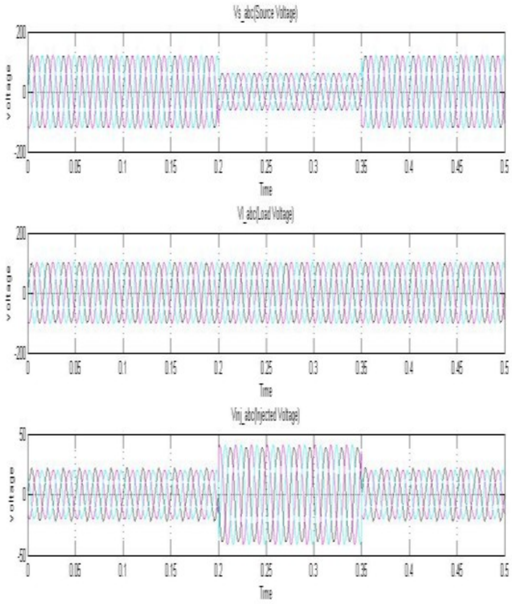


Figure. Subsystem of artificial neural network

A detailed system as shown in Figure 7.3 has been modeled by MATLAB/SIMULINK to study the efficiency of suggested control strategy . It is assumed that the voltage magnitude of the load bus is maintained at 1 pu during the voltage sags/swells condition. The results of the most important simulations are represented in Figures. The load has been assumed linear with power factor pf =0.85 lagging and its capacity of 5 KVA.



FigureThree-phase voltages sag: (a)-Source voltage, (b)-Injected voltage, (c)-Load voltage

The first simulation show of three phase voltage sag is simulated. The simulation started with the supply voltage 50% sagging as shown in Figure (a).In Figure (a) also shows a 50% voltage sag initiated at 0.15s and it is kept until 0.35s, with total voltage sag duration of 0.2s. Figures (b) and (c) show the voltage injected by the DVR and the corresponding load voltage with compensation. As a result of DVR, the load voltage is kept at 1 pu. The effectiveness of the DVR under unbalanced conditions is shown in figure, in figure also shows the occurrence of 50% single phase voltage sag on a utility grid. Through simulation the supply voltage with one phase voltage dropped down to 50% as shown in Figure (a). The DVR injected voltage and the load voltage are shown in Figures (b) and (c) respectively. Its corresponding load voltages are shown in Figure (c) where it is possible to see that the compensation method is keeping the load voltages constant at 1 p.u.

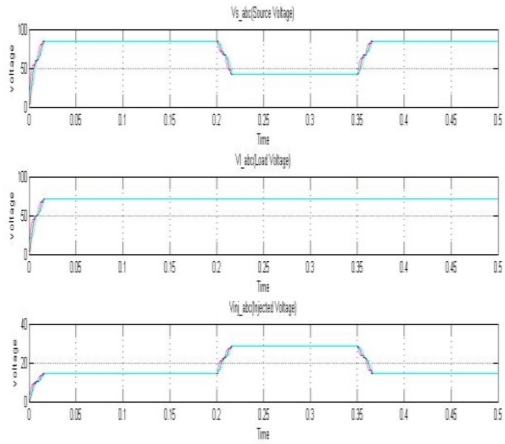


Figure Three-phase rms voltage sag: (a)-Source voltage, (b)-Injected voltage, (c)-Load voltage

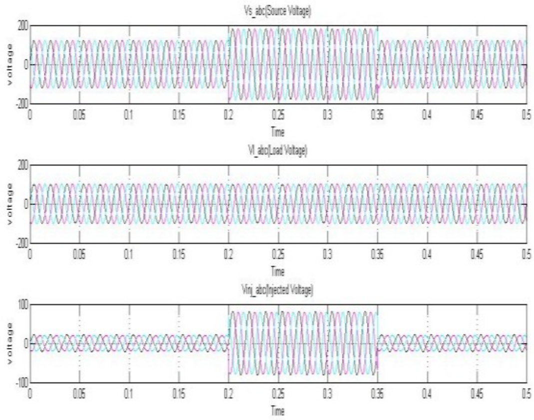


Figure Three-phase voltages swell: (a)-Source voltage, (b)-Injected voltage, (c)-Load voltage

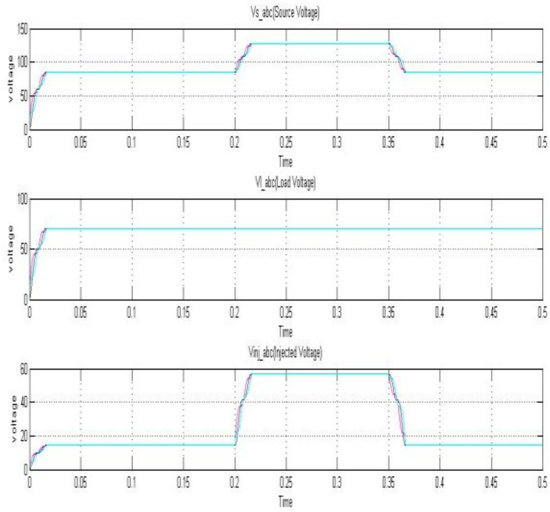


Figure Three -phase rms voltages swell: (a)-Source voltage, (b)-Injected voltage, (c)-Load voltage

The second simulation shows the DVR performance during a voltage swell condition. The simulation started with the supply voltage swell is generated as shown in Figure (a). As observed from this figure the amplitude of supply voltage is increased about 25% from its nominal voltage. Figures (b) and (c) show the injected and the load voltage respectively. As can be seen from the results, the load voltage is kept at the nominal value with the help of the DVR. Similar to the case of voltage sag, the DVR reacts quickly to inject the appropriate voltage component (negative voltage magnitude) to correct the supply voltage. Figure shows that the performances of the DVR with an unbalanced voltage swell. In this case, two of the three phases are higher by 25% than the third phase as shown in Figure (a). The injected voltage that is produced by DVR in order to correct the load voltages and the load voltages maintain at the constant are shown in Figures (b) and (c), respectively.

CONCLUSION

The modeling and simulation of a DVR using MATLAB/SIMULINK has been presented. A control system based on dqo technique which is a scaled error of the between source side of the DVR and its reference for sags/swell correction has been presented. The simulation shows that the DVR performance is satisfactory in mitigating voltage sags/swells. The operating principle of dynamic voltage restorer and the voltage compensation methods are presented. The main function of the shunt converter is to maintain and control the dc voltage of the inverter during voltage sag. This will allow the DVR to compensate deep and long duration voltage sags and swells.

From simulation results also show that the DVR compensates the sags/swells quickly and provides excellent voltage regulation. The DVR handles both balanced and unbalanced situations without any difficulties and injects the appropriate voltage component to correct rapidly any anomaly in the supply voltage to keep the load voltage balanced and constant at the nominal value

The main advantage of this DVR is low cost and its control is simple. It can mitigate long duration voltage sags/swells efficiently. Future work will include a comparison with a laboratory experiments in order to compare simulation and experimental results. Source side shunt converter is replaced by Solar Power and controlling by ANN technique.

The simulation results clearly show the performance of a DVR in mitigating voltage sags and swells. In case of voltage sag, the DVR injects an equal positive voltage component in all three phases. For voltage swell, the DVR injects a negative voltage in all the phases. The DVR injects the appropriate voltage for both sag and swell in order to keep the load voltage balanced and constant at the nominal value.

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