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Mitigation of Voltage Sag and Swell by Using Magnitude Tracking Method

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Abstract: Our project proposes a concept to mitigate the voltage sag and swell. There are three types of voltages is being considered. Normal voltage, Lower voltage (sag), Higher voltage (swell) .Normal voltage is being considered so as to keep it constant throughout. Our project deals that if sag or swell happens, the automatic correction with comparison of magnitude voltage using DVR and this mitigation of voltages controlled by a PIC controller. The voltage inverter operation is much reduced and thus the efficiency and reliability of the system is improved in an effective manner.

Keywords: DVR, PIC, SAG, SWELL, Voltage.

1. Introduction

Power Quality problems encompass a wide range of disturbances such as voltage sags/swells, flicker, harmonics distortion, impulse transient, and interruption. 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 described by its remaining voltage, in this case, always greater than 1.0.

Voltage swells are not as important as voltage sags because they are less common in distribution systems. 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 **Ac supply** 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 paper introduces a magnitude tracking method for mitigation of voltage sag and swell. The Dynamic Voltage Restorer (DVR) is an effective device for power quality enhancement due to its quick response and high reliability. At the end, Cathode Ray Oscilloscope (CRO) results were presented to validate the effectiveness of the proposed control method.

2. Block diagram

2.1 Existing System



Figure 2.1: Block Diagram of Existing System.

2.2 Explanation- Existing System

There are two major challenges that the modern power grid must deal with: voltage fluctuations and short circuit faults. With wide use of nonlinear loads, the grid suffers from voltage fluctuation, voltage unbalance, and other power quality problems. At the same time, many power loads become more sensitive to these disturbances. The rapid proliferation of renewable power generation sources in the grid has aggravated these power quality problems. Furthermore, short-circuit faults remain one of the most common faults in the grid and cause great concerns for grid security and stability. A solid-state fault current limiter (FCL) can be used to limit fault currents in the grid. When a shortcircuit fault occurs, the solid-state FCL inserts a high series impedance in the power loop and thus effectively limits the fault current. However, during normal operation of the grid the FCL operate in a no-load mode, resulting in compromised energy conversion efficiency and equipment utilization efficiency. On the other hand, a dynamic voltage restorer (DVR) can be used to compensate for the fluctuations of the grid voltage. For many power systems, it would be tremendously advantageous to provide both voltage compensation and fault current limiting functions by a single power electronic apparatus. In, the control strategy of a conventional DVR is expanded to offer additional fault current interruption features. However, this approach requires a three-fold increase in power rating of the DVR, leading to a sharp increase in system cost. In this paper, a new concept of fault current limiting dynamic voltage restorer (FCL-DVR) is proposed.

The new topology can operate in two operational modes:

- 1. Compensation mode for voltage fluctuation and unbalance
- 2. Fault current limiting mode.

It should be noted that only one additional crowbar bidirectional thyristor switch is added across the output terminals of each phase of the conventional DVR, greatly simplifying its implementation. Furthermore, the new FCL-DVR can maintain the same power rating as the conventional DVR without FCL function. This paper is organized as the following. In Section II, the topology, principle and the control strategy are proposed. In Section III, the design methodology of important system parameters of FCL-DVR is discussed. In Section IV, the FCL-DVR is validated by simulation and experimental results.

2.3 Proposed System



Figure 2.2: Block Diagram of Proposed System.

2.3 Block Description – Proposed System

The ac supply is taken from the main and it is given to the single phase diode rectifier. It converts input ac voltage to a fixed dc output voltage. And the input voltage is fed to the PIC controller for feedback voltage through potential transformer. The PIC controller had a set voltage and the feedback voltage. Corresponding to the control program, the voltage magnitude values are compared and check the voltage is normal or sag or swell.

According to the voltage range i.e., normal voltage or sag or swell.., the controller gives the signal to the MOSFET driver circuit which drives the MOSFET switches in the inverter. If the voltage magnitude is same as the set voltage, DVR is in standby mode, the input voltage is normal then it is send to the load through series injection transformer. If any sag or swell occurs, DVR operates in boost mode and then the desired voltage gets added to the source voltage to compensate for normal voltage magnitude. Here, if the voltage is sag, the V_{load} is positive. If it is swell, the V_{load} is negative. The LC filter filters the output voltage from the inverter and it is fed to the series injection transformer and to the load.

3. Hardware Description

3.1 Power supply

The ac voltage, typically 220v rms, is connected to a transformer, which steps that ac voltage down to the level of the desired dc output. A diode rectifier then provides a full wave rectified they is initially filtered by a simple capacitor voltage filter to produce a dc voltage.

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Figure 3.1: +5v and +12v power supply

This resulting dc voltage usually has some ripple or ac voltage variation. A regulator circuit removes the ripples and also remains the same dc value even if the input voltage varies, or the load connected to the output dc voltage changes. This voltage regulation is usually obtained using one of the popular voltage regulator IC units.

3.2 Potential transformer

The potential transformer will step down the power supply voltage (0- 230V) to (0-6V). Then the secondary of the potential transformer will be connected to the precision rectifier, which is constructed with the help of op-amp. The advantages of using precision rectifier are it will give peak voltage output as DC, rest of the circuits will give only RMS output.

3.3 Bridge rectifier

When four diodes are connected are shown in figure , the circuit is called as bridge rectifier .The input to the circuit is applied to the diagonally opposite corners of the network ,and the output is taken from the remaining two corners.

Let us assume that the transformer is working properly and there is a positive potential, at point A and a negative potential point B.the positive potential point A will forward bias D3 and reverse bias D4.

The negative potential at point B will forward bias D1 and reverse D2.at this time D3 and D1 are forward biased and will allow current flow to pass through them;D4 andD2 are reverse biased and will block current flow.

The path for current flow is from point B through D1 ,up through RL ,through D3, through the secondary of the transformer back to point B this path is indicated by the solid arrows, waveforms (1) and (2) can be observed across D1 and D3.

One half cycle later the polarity across the secondary of the transformer reverse, forward biasing D2 and D4 and reverse biasing D3 and D1.current flow will now be from point A through , up through RL ,through D2, through the secondary of T1,and back to point A. this path is indicated by the broken arrows. Waveforms(3) and(4) can be observed across D2 and D4.the current flow through RL is always in the same direction .in the flowing through RL this current develops a voltage corresponding to that shown waveform (5).since current flows though the load(RL) during both half cycles of the applied voltage ,this bridge rectifier is a full wave rectifier.

The maximum voltage that appears across the load resistor is nearly but never exceeds 500 volts ,as result of the small voltage drop across the diode .In the bridge rectifier shown in view B, the maximum voltage that can be rectified is the full secondary voltage ,which is 1000volts.therefore the peak voltage across the load resistor is nearly 1000 volts. With both circuits using the same transformer, the bridge rectifier circuit produces a higher output voltage than the conventional full wave rectifier circuit

3.4 Voltage regulators

Voltage regulators comprise a class of widely used ICs. Regulator IC units contain the circuitry for reference source, comparator, amplifier, control device, and overload protection all in a single IC.IC units provide regulation of either a fixed positive voltage ,a fixed negative voltage , or an adjustable set voltage.

The regulators can be selected for operation with load currents from hundreds of milli- amperes to tens of amperes, corresponding to power ratings from milli-watts to tens of watts. A fixed three terminal voltage regulator has an unregulated dc input voltage VI, applied to one input terminal a regulated dc output voltage, v0 from a second terminal, with the third terminal connected to the ground. The series 78 regulators provide fixedpositive regulators provide fixed negative voltages from 5 to 24 volts similarly the series 79 regulators provide fixed negative voltages from 5 to 24 volts.

3.5 LC Filter

Then on linear characteristics of semiconductor devices causes distorted waveforms associated with some high frequency harmonics with inverter output. To overcome this problem and provide high quality energy supply We use LC filters.

3.6 Series injection transformer

It is used to inject the missing voltage to the system at the load bus when comparing angle and magnitude to obtain the same load voltage as pre fault voltage. To integrate the injection transformer correctly into DVR MVA rating, primary winding voltage, and current rating turns ratio and short circuit impedance values of transformer are required.

3.7 Dynamic voltage restorer

Among the power quality problems (sags, swells, harmonics...) 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.



3.8 The general configuration of the dvr consists of:

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

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

3.10 Harmonic filter

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

3.11 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: 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.

The purpose of storage devices is to supply the necessary energy to the VSC via a dc link for the generation of injected voltages. The different kinds of energy storage devices are Superconductive magnetic energy storage (SMES), batteries and capacitance.

3.12 DC Charging circuit:

The dc charging circuit has two main tasks. The first task is to charge the energy source after a sag compensation event. The second task is to maintain dc link voltage at the nominal dc link voltage.

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3.13 Control and protection:

The control mechanism of the general configuration typically consists of hardware with programmable logic. All protective functions of the DVR should be implemented in the software. Differential current protection of the transformer, or short circuit current on the customer load side are only two examples of many protection functions possibility.

4. Components and Description

4.1 PIC Components used

- PIC 16F877A
- 20mHZ crystal
- 22pf disc
- 7805 voltage regulator
- 1A,Bridge rectifier
- 40 pin IC base
- LCD display (16*2)
- Power supply(+5v DC)

4.2 Driver components used

- Driver IC(7667)
- Opto Isolator(6N135)
- Transistor(BC557)
- 7815
- 102 s polyester
- 104 disc
- 1000mf,25v

4.3 Power circuit components

- Tap changing Transformer(230/9,12,15)
- Linear Transformer(1:1)
- IRF840
- 230/0-12v,1A
- Diode bridge rectifier
- Resistive load

4.4 PIN diagram and description



Figure 4.1: Pin diagram

• PIC16F877A is a 40pin, 5port Microcontroller.

- The first pin is for MCLR.
- 11 TH AND 32 ND PIN Power supply +5 DC
- For initialization 7pins are allotted.
- 16*2 LCD display needs 8pins(RD0-RD7)
- 3pins required for R/W/E.
- The input supply voltage through potential transformer 1 and 2 is connected to the RA0, RA1.
- The output requires 4 pin RC0 to RC3.

5. Circuit Diagram and Operation

5.1 Circuit diagrams



Figure 5.1: Circuit diagram of the proposed system







Figure 5.3: Supply for driver circuit



Figure 5.4: Driver circuit

5.2 Principle of operation

The main ac supply is taken through the tap changing transformer and here the taps are set as 15,12, and 9. Here the taps are selected by the switches for the operation. If the incoming voltage is at 12 then it is consider as normal voltage. If it is 15 it is called swell or it is 9 it is called sag and the swell or sag feedback voltage is given to the PIC16F877A through the potential transformer. The PIC controller has a set voltage and a feedback voltage, it compares the magnitude values of both voltages and it decides the rate of magnitude value added to the input voltage.

According to the coding, the PIC controller decides the magnitude value for the compensation. And this magnitude signal is given to the driver circuit, which drives the MOSFET switches in the inverter. The MOSFET driver converts the voltage magnitude theta values into the PWM sine theta values for inverter operation.

If sag occurs, the PIC controller decides the rate of voltage gets added to the input voltage and this signal is send to the driver. The MOSFET driver drives the single phase inverter in forward direction and thus the desired voltage (V load) gets added to the source voltage (Vs).

If the input voltage is greater than the set voltage in the PIC Controller is called swell voltage. Then the desired voltage magnitude gets reduced from the source voltage (swell voltage) to compensate the swell voltage to the normal voltage. The MOSFET driver drives the single phase inverter in reverse direction and thus the desired voltage (V load) gets reduced from the source voltage(Vs).

6. Results and Discussions

The power supply 230V is given to the tap changing transformer. Here we use two switches for normal, sag and swell voltage conditions. There are four input transformer are used. One is for PIC controller and reaming transformers are used as a input for MOSFET driver circuit. The potential transformer is used to give the feedback voltage to the PIC controller. In the PIC controller, the set voltage and the feedback voltage are compared. If the feedback voltage is less than the set voltage in the PIC its consider as swell. The hardware diagram is shown in figure



Figure 6.1: Shows a hardware picture of proposed system.

If switch 1 and 2 are kept in off condition, then the input voltage is normal then it is given to the load.



Figure 6.2: Display shows normal voltage

If switch 1 is in off condition and the switch 2 is in on condition, then the input voltage is sag, then it is given to the PIC controller for DVR operation.



Figure 6.3: Display shows Sag voltage.

If switch 1 and 2 are kept in on condition, then the input voltage is swell then it is given to the PIC controller for DVR operation.



Figure 6.4: Display shows swell voltage.

7. CRO Result



Figure 7.1: Output waveform of the switch s1 in the inverter

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Figure 7.2: Output waveform of the switch s2 in the inverter







Figure 7.4: Output waveform of the switch s4 in the inverter



Figure 7.5: Input voltage and set voltage in PIC controller, normal voltage



Figure 7.6: Input voltage and set voltage in pic controller, sag voltage



Figure 7.7: Input voltage &set voltage in PIC controller, swell voltage



Figure 7.8: Inverter output at normal voltage







Figure 7.10: Inverter injection output at swell voltage.

7.1 Applications of the proposed system

LED lighting
Hybrid vehicle
Battery charging
Telecommunications
Power factor improvement

8. Conclusions and Future scope

8.1 Conclusion

In today's world, electric power plays a vital role. The world is unimaginable without electric power. How far it is used, the risk of electric power gets increases due to voltage sag and swell. Hence this project paves a better way to mitigate the risk due to sag and swell voltage. The Dynamic Voltage Restorer (DVR) is an effective device for power quality enhancement due to its quick response and high reliability. The conclusion is that it is an effective apparatus to protect sensitive load from short duration of voltage sag and swell. The effectiveness of the DVR depends upon rating of energy storage device and loads. In this project, Magnitude tracking is the method to mitigate the voltage sag and swell. The main advantage of this project is there low switching power loss, 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.

8.2 Future scope

In future the proposed circuit diagram can be implemented in,.

- Solar energy system.
- Wind energy system.
- Power factor correction.
- Telecommunication system(the voltage is 48V dc.)

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