

Compensation of Voltage Sag and Voltage Swell by using the power electronic device Dynamic Voltage Restorer (DVR)

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Abstract - The electrical energy is one of the easily used and available forms of energy. For electrical engineering, power quality is a noteworthy topic. At present day, the problem of power quality has become one of the major problems which have to be taken into account for the maintenance of power supply quality. For the power generation companies and customer, the most important issue is the power quality. Today's generation mainly depends on electrical energy for maintaining their life style. Today's equipment like electric motors, computers, machines, etc. cannot be used without electricity. In order to improve the technical performance, quality of supply is demanded by the equipment. The problem of power quality is an occurrence which is actually demonstrated as a nonstandard frequency, voltage or current. Service disruption and failure of electricity can be easily found in sensitive industrial loads, utility distribution networks and detracting commercial which causes great financial losses. The power quality disturbing points are voltage swell, sag, spike, notch and transients etc. In this paper, we will be dealing with voltage sag which is a major problem.

The voltage sag and swell is one of the severe problems for an industrial customer which has to be dealt with urgent attention for its compensation. There are many methods which can compensate the problems of voltage sag and swell. Today the most popular methods of sag and swell mollification is Dynamic Voltage Restorer (DVR), which can used in low voltage as well as medium voltage applications. Dynamic Voltage Restorer is a cascaded connected device; which is based on the principles of power electronics which can immediately mitigate the voltage sag in the system and will be restoring the load voltage to the pre-fault system value.

The problem of power quality compensation is made possible with the increase in the development in power electronics. This paper work gives a brief focus on the major problems of voltage sag. The compensation of voltage sag problem is done with the help of devices such as DVR, UPFC, STATCOM and tap changing transformer. Our of all these power electronic devices dynamic voltage restorer provides the most convenient, economical and commercial answer to compensate voltage sag by the injection of power as well as voltage into the system. This paper gives an introduction to power quality problems for DVR as well as power electronics controllers for voltage sag compensation. Then operation of hardware and elements in DVR is explained with their ratings. Dynamic voltage restorer (DVR):

It is a voltage source converter which is connected to the circuit in cascade with supply through the help of injection transformer where voltage swell or voltage sag takes place. For the compensation of voltage sag and voltage swell in the distribution system, DVR is the most technically advanced, convenient and economical device. Dynamic voltage restorer stores energy that is responsible for the supply of active power needed during the voltage sag & gain at swell.

This paper gives the idea of usage of the error signal that can be controlled by the triggering of the switches of an inverter with the help of using Sinusoidal Pulse Width Modulation (SPWM) technique.

Key Words: Static Series Compensator (SSC), Dynamic Voltage Restorer (DVR), Mollification, Peripheral Interface Controller (PIC).

1. INTRODUCTION

Electrical energy is the simple and well-regulated form of energy, can be easily transformed to other forms. Along with its quality and continuity has to maintain for good economy. Power quality has become major concern for today's power industries and consumers. Power quality issues are caused by increasingly demand of electronic equipment and non-linear loads. Many disturbances associated with electrical power are voltage sag, voltage swell, voltage flicker and harmonic contents. This degrades the efficiency and shortens the life time of end user equipment. It also causes data and memory loss of electronic equipment like computer.

Due to complexity of power system network voltage sag/swell became the major power quality issue affecting the end consumers and industries. It occurs frequently and results in high losses. Voltage sag is due to sudden disconnection of load, fault in the system and voltage swell is due to single line to ground fault results in voltage rise of unfaulted phases. The continuity of power supply can be maintained by clearing the faults at faster rate. Other power quality issues i.e. voltage flickering, harmonics, transients etc. has to be compensated to enhance the power quality.

The typical power quality disturbances are voltage sags, voltage swells, intermission, phase shifts, harmonics and transients. Among the interference, voltage sag is considered

the most severe since the sensitive loads are very impressionable to temporary changes in the voltage.

“Authenticity” is a key word for utilities and their customers in general, and it is very important to companies operating in a highly competitive business environment, it affects profitability and also is a driving force in the industry. A very high level of authenticity has been reached by the electrical transmission and distribution systems; there cannot be any disturbances that can be avoided. Problems related with operation of electrical and electronic devices can be caused by any disturbances to voltage. There is a need of constant frequency, constant sine wave shape and symmetrical voltage with a constant peak to peak value to continue the production.

The wide area solution is required to alleviate voltage sags and improve power quality. One of the newest approaches is using a DVR. The basic operational principle is injecting the missing voltage in series to the bus and detecting the voltage sag by zero crossing detectors. DVR has become a cost effective solution for the protection of non-linear loads from voltage sags. The DVR is efficient, quick and flexible solution to voltage sag problems. DVR consists of capacitor bank storage unit, PWM inverter, and filter and booster transformer.

It is well known that power quality is facing various difficulties such as voltage sags/swells, flicker, surge, voltage imbalance, harmonic distortion and interruptions, fretting fatigue. Voltage sags/swells can occur more regularly than other power quality problems, also these sags/swells are the most serious power quality disturbances in the power distribution system. Dynamic Voltage Restorer (DVR) is one of the most important custom power devices that have been created to improve the performance of power quality. The DVR balances the load voltage at a nominal magnitude and phase by settling the voltage sag/swell. These systems can compensate voltage sags by increasing the appropriate voltages in cascade with the supply voltage, and therefore prevent loss of power.

Power electronic devices i.e. Distribution Static Compensator (D-STATCOM) and Dynamic Voltage Restorer (DVR) been recently used for voltage sag/swell compensation. In this project DVR is proposed which can protect the end-consumer load from any unbalance of voltage supply. It is a series compensating device, can maintain the load voltage profile even when the source side voltage is distorted.

2. METHODOLOGY

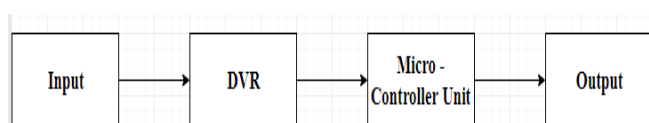


Fig -1: Block diagram of the role of dynamic voltage restorer in improving power quality.

This block diagram explains that when a supply input is given to the system, the dynamic voltage restorer reads the input as well as output. The sensing of the input and output supply is done with the help of a micro-controller unit. This micro-controller then gives the necessary commands to the dynamic voltage restorer which in turn gives an improved output.

2.1.1 Basic Configuration:

Some of the basic elements of a DVR are as follows:

- Converter
- L&C filter
- Booster transformer DC-link and paper capacitor storage unit
- DC-link and energy storage
- By-pass equipment
- Disconnecting equipment

2.1.2 Converter:

The converter is most likely a Voltage Source Converter (VSC), which sinusoidal Pulse Width modulates (SPWM) the DC from the DC-link/storage to AC-voltages injected into the system. A VSC is a power electronic system, which consists of capacitor storage and switching devices, which can generate a sinusoidal voltage at required constant frequency, magnitude, and phase angle. In the DVR application, the VSC is used to transitory replace the supply voltage or to generate the part of the supply voltage which is missing. There are four main types of switching devices: Light Activated Silicon Controlled Rectifier (LA-SCR), Gate Turn-Off thyristor (GTO), Power Metal Oxide Semiconductor Field Effect Transistors (P-MOSFET), Integrated Gate Commutated Thyristor (IGCT) and Insulated Gate Bipolar Transistors (IGBT). Each type of power electronic device has its own advantages and limitation. The IGCT is a newly compact device which is having authenticity and enhanced performance that allows VSC to build with very large power ratings. Because of the highly practiced converter design with IGCTs, the DVR can balance dips which are above the capability of the past DVRs using conventional devices. The purpose of such devices is to supply the necessary energy to the VSC using a dc link for the generation of injected voltages.

2.1.3 L&C Filter:

To reduce the switching harmonics generated by the SPWM VSC L&C filters are used.

2.1.4 Booster Transformer:

In most DVR applications the DVR is equipped with injection transformers to certify galvanic isolation and protection equipment and for simplification of the converter topology. The Booster transformer is a specially designed transformer that tries to limit the coupling of transient

energy and noise from the primary side to the secondary side.

The key tasks are:

1) It connects the DVR to the distribution network using the HV-windings. The voltage source converter to the incoming supply voltage generates injecting series compensating voltage.

2) Also, the Booster transformer can be used for the purpose of isolating the load from the system.

2.1.5 DC-Link and Energy Storage:

The VSC uses a DC-link voltage to synthesize an AC voltage into the grid. During a majority of voltage immersion, restoration of supply voltage is necessary for active power injection. The dc charging circuit has two important tasks.

- 1) The first task of the DC-link and storage is to charge the energy source after a sag compensation incident.
- 2) The second task is to maintain dc link voltage at the apparent dc link voltage.

2.1.6 By-Pass Equipment:

During faults, overload and service a circumvent path for the load current has to be secured. When the sag on line is detected, DC storage unit is fed to PWM inverter.

2.1.7 DVR topology with no energy storage:

DVR topologies used with no energy storage on dc link, Part of the supply voltage remains present during the sag and this residual supply can be used to provide the capacitor boost energy required to maintain full load power at rated voltage. A passive shunt converter is used because only unidirectional power flow is required necessary and it is cheap solution for voltage sag. Two main topologies can be used, which are required to be categorized here according to the location of shunt converter with series compensation.

2.1.8 Dynamic Voltage Restorer:

In year of 1994, L. Gyugyi proposed a device and a method for dynamic voltage restoration of utility as per required in distribution network. This method uses active power in order to inject the faulted supply voltages and is locally known as the Dynamic Voltage Restorer. In this paper, a DVR design is essentially contains a voltage source inverter (VSI), a series injection transformer connected between the AC voltage supply and the non-linear load, a DC energy storage capacitor, and a control system as shown in Figure 2.

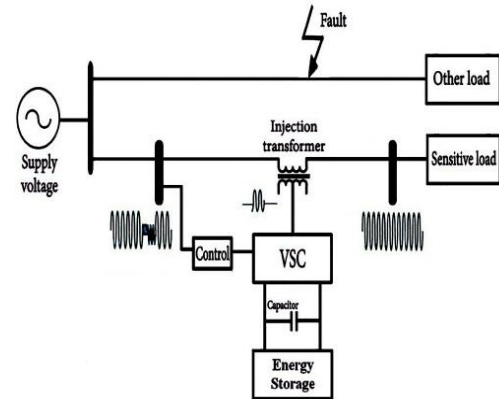


Fig -2: Basic DVR topology

The main function of the DVR is the protection of non-linear loads from voltage sags/swells expected from the network. The DVR is connected in series between the source voltage or grid of distribution and non-linear loads through series injection transformer. There are one of several types of energy storage that has been used in the DVR such as battery, paper capacitance and superconducting coil. These types of energy storages are very important in order to supply real and imaginary power to the DVR. The controller is more important part of the DVR for switching purposes. The switching converter is responsible to conversion process from DC to AC and to make sure that's only the swell or sag voltage is injected to the series injection transformer. The three-phase transformers connection used in the three-phase DVR can be constructed either in delta/open or star/open connection. In case of asymmetrical fault on high voltage side, the zero sequence current flowing almost zero, if the distribution transformer connection in Δ -Y with the grounded neutral. In such a way of connection, the DVR is only used for the allegation of the positive and negative sequence.

3. BLOCK DIAGRAM OF DVR

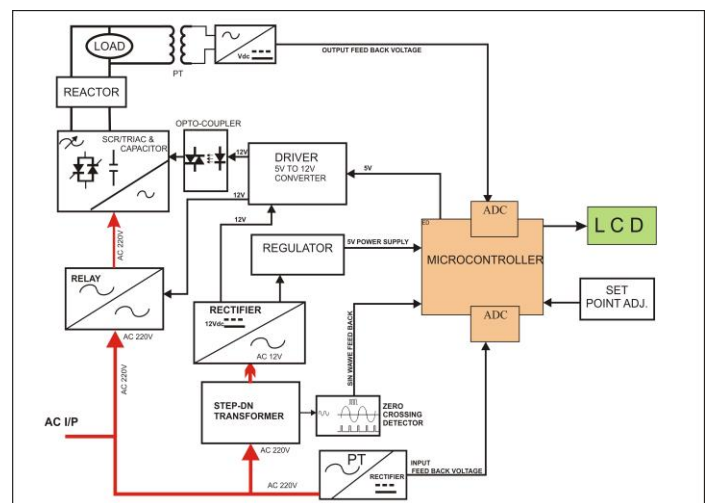


Fig -3: Block diagram of DVR

In this paper, we are using a power electronics device like Dynamic Voltage Restorer to control the power. Use of power electronics reduces the mechanical arching and fast reaction time. In addition to this we also make a provision for Under/Over voltage protection, which doesn't have any existing Energy Meters.

The main aim of this project is to control and keep balance of the voltage across load. Initially controller checks the incoming voltage coming from line with the help of ADC (analog to digital converter) present inside the Microcontroller. Our aim is to control a positive as well as negative. Half cycle of incoming AC for that a firing angle control method is used. For controlling a firing angle of any AC voltage, it is necessary to monitor every positive/negative half cycles; hence a Sine Wave Cycle Monitor (Zero Crossing Detector) block is used in our project, which informs a controller about start point of every cycle. Once controller knows the voltage across the load and signals from sine wave cycle monitor, controller calculate the firing angle and gives firing pulse to the AC to AC converter in which a static switch formed by a TRIAC is used. Static switch can be operated on high voltage and high frequency as compared to the mechanical switches like relay. The output of AC to AC converter is further give to Reactor which is nothing but a type of single core step-up transformer. (220V to 300V transformer), which gives a 220V output at140VAC input. The output of 220V is further used by various loads. The voltage across load is measured by the controller with the help of PT. Potential transformer is used to step down the voltage across the load to be measured and rectified to DC, because microcontroller can read a voltage upto 5V DC only. In this we are using a Relay for tripping the input voltage in case of very high voltage and low voltage which is beyond controllable limits.

The relay used in our project is of 12V and controller can give maximum of 5V, hence it is necessary to amplify the 5V to 12V for which a Driver circuit is used. Microcontroller requires a 5V DC to work, and same will be generated with the help of Power Supply which comprises of a step-down transformer, rectifier, filter and regulator. Transformer steps down the 220VAC to 12VAC, rectifier and filter convert this 12VAC to 12V DC, and regulator converts a 12V DC to a constant of 5V DC.

4. CIRCUIT DIAGRAM OF DVR

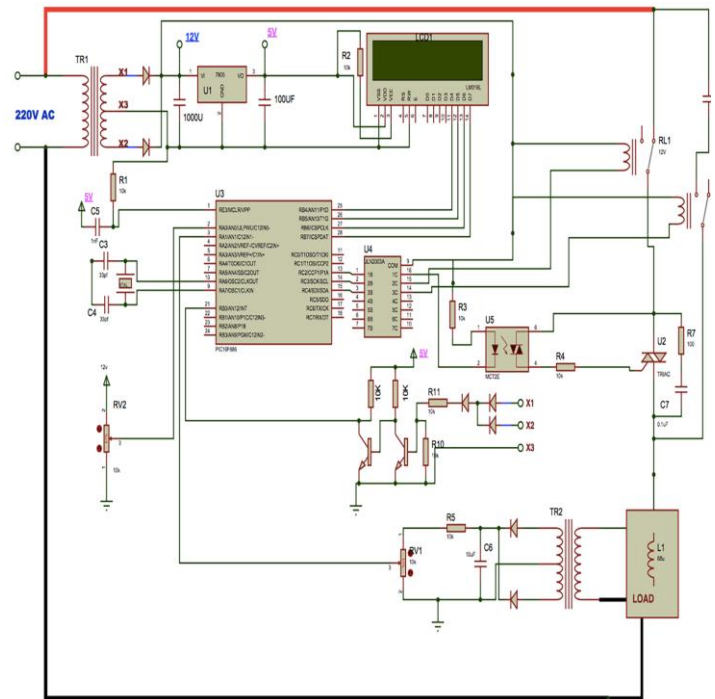


Fig -4: Circuit diagram of DVR

The 220V input supply is given to DVR through relay which is operated on 12V given to 5V DC. The load is connected to the DVR output terminal. The DVR output is measured through P. T. The Micro-Controller requires 5V DC, hence input 230V AC is step down to 12V ac & 12V ac converted to DC with the help of full wave rectifier. Capacitor is used to get pure DC output.

The Micro-Controller requires constant 5V DC. Hence this unregulated supply given to regulator IC 7805 which gives constant 5V DC to Micro-Controller. If input Voltage of IC is varied then output of IC 7805 is constant. This 5V DC is given to Micro-Controller, LCD, this 5V DC is given to Micro-Controller, LCD, Opto-coupler, Driver & Zero Crossing Detector. The IC 7805 is loaded and output of IC is reduced to 4V then Micro-Controller will reset or restart. So that in such condition the current will not work properly.

When capacitor is connected, it stores the charge, available in its potential. When output of IC is less than 5V then capacitor provides charge. This capacitor gives fractional output, i.e. 200 to 300 nF. The capacitor is electrolytic capacitor having polarity.

Two suppressor capacitors (C₃& C₄) are connected to crystal oscillator which maintain 50% duty cycle of crystal oscillator. It means ON time is equal to OFF time exactly 50% symmetrical output of frequency. The crystal oscillator is use to provide clock frequency to the microcontroller.

The microcontroller controls every positive and negative cycle of sine wave; hence zero crossing detector is used in

our project. The zero crossing detectors consist of two NPN transistors and three diodes. The snubber circuit is used to suppress the rapid rise in voltage across the DVR.

5. HARDWARE PARTS DESCRIPTION

5.1 AT89S52 Micro-Controller

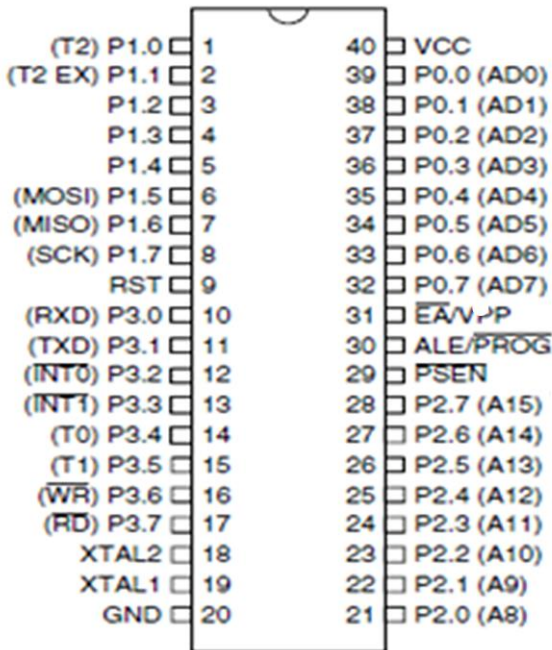


Fig -5.1: Pin Diagram of AT89S52 Micro-Controller

The whole processing of the device is done by a microcontroller. The micro-controller 89s52 is a small but powerful micro-controller. The AT89S52 is a low-power, high performance CMOS 8-bit microcontroller with 8Kbytes of in-system programmable Flash memory. The device is manufactured using Atmel's high-density nonvolatile memory technology and is compatible with the industry standard 80C51 instruction set and pin out. The on-chip Flash allows the program memory to be reprogrammed in-system or by a conventional nonvolatile memory programmer. In addition, the AT89S52 is designed with static logic for operation down to zero frequency and supports two software selectable power saving modes. The idle Mode stops the CPU while allowing the RAM, timer/counters, serial port, and interrupts system to continue functioning. The Power down mode saves the RAM contents but freezes the oscillator, disabling all other chip functions until the next interrupt or hardware reset.

5.2 ULN 2003 (Driver)

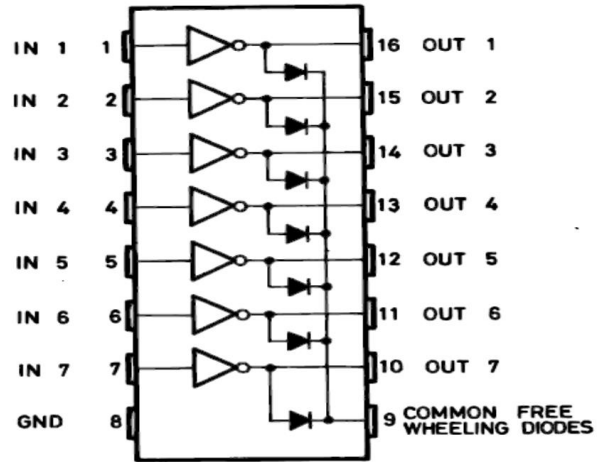


Fig -5.1: Internal Structure of IC ULN2003

The ULN2001A, ULN2002A, ULN2003 and ULN2004A are high voltage, high current darlington arrays each containing seven open collector darlington pairs with common emitters. Each channel rated at 500mA and can withstand peak currents of 600mA. Suppression diodes are included for inductive load driving and the inputs are pinned opposite the outputs to simplify board layout. These versatile devices are useful for driving a wide range of loads including solenoids, relays DC motors; LED displays filament lamps, thermal print-heads and high power buffers.

5.3 Crystal Oscillator

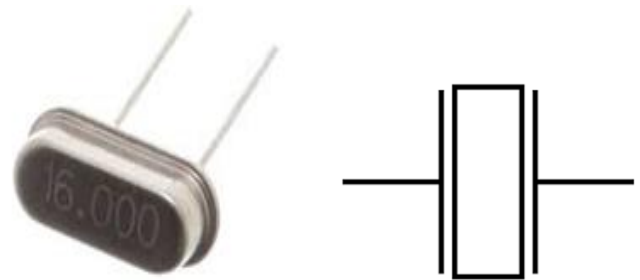


Fig -5.3: Crystal oscillator

A crystal oscillator is an electronic oscillator circuit that uses the mechanical resonance of a vibrating crystal of piezoelectric material to create an electrical signal with a very precise frequency. This frequency is commonly used to keep track of time (as in quartz wrist watches), to provide a stable clock signal for digital integrated circuits and to stabilize frequencies for radio transmitters and receivers. The most common type of piezoelectric resonator used is the quartz crystal, so oscillator circuits designed are known as "crystal oscillator". Quartz crystals are manufactured for frequencies from a few tens of KHz to tens MHz. The crystal oscillator is used to provide clock frequency to the micro-controller for operation.

5.4 Power Supply Circuit

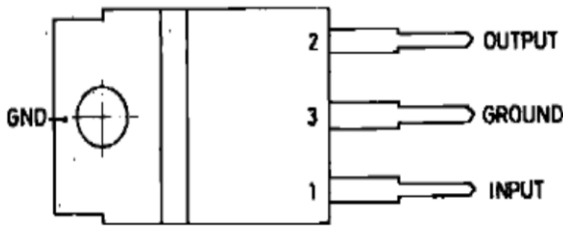


Fig -5.4: Regulator IC LM7805

The entire electronics component such transistor, IC's etc generally requires DC for their operation. So AC supply is then stepped down. Now this stepped down AC is converted to DC supply by rectification process. There may be some ripples coming out of Power supply circuit. The 12V supply given to the LM7805 regulator. Now as microcontroller, LCD module, relays and other certain ICs requires 5VDC supply for their operation we need a regulated uninterrupted 5VDC supply. This block involves production of 5V DC supply for whole circuit.

5.5 Zero Crossing Detectors

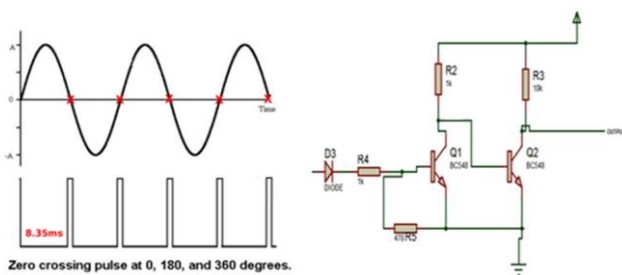


Fig -5.5: Output and circuit of zero crossing detectors

The regulated 5V is also used as biasing voltage for both transistors (Q₁ and Q₂) and the control section. A pulsating DC voltage is applied to the base of transistor Q₁ through diode D₃ and resistors R₄ and R₅. When the pulsating voltage goes to zero, the collector of transistor Q₁ goes high. This is used for detecting the pulse when the voltage is zero. Finally, the detected pulse from 'OUTPUT' is fed to the microcontroller of the control section.

5.6 LCD (Liquid Crystal Display)

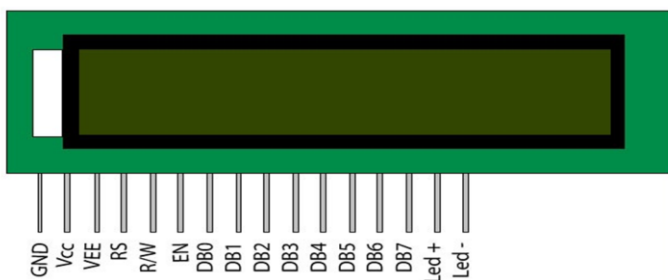


Fig -5.6: Liquid Crystal Display

A 16x2 LCD means it can display 16 characters per line and there are 2 such lines. In this LCD each character is displayed in 5x7 pixel matrix. This LCD has two registers, namely, Command and Data. The command register stores the command instructions given to the LCD. A command is an instruction given to LCD to do a predefined task like initializing it, clearing its screen, setting the cursor position, controlling display etc. The data register stores the data to be displayed on the LCD. The data is the ASCII value of the character to be displayed on the LCD.

5.7 Relay



Fig -5.7: Relay

A relay is an electrically operated switch. Many relays used are electromagnet, but others are also used, such as solid-state relays. Relays are used where it is necessary to control a circuit by a separate low-power signal, or where several circuits must be controlled by one signal. The first relays were used in long distance telegraph circuits as amplifiers: they repeated the signal coming in from one circuit and re-transmitted it on another circuit.

A type of relay that can handle the high power required to directly control an electric motor or other loads is called a contactor. Solid-state relays control power circuits with no moving parts, instead using a semiconductor device to perform switching. Relays with calibrated operating characteristics and sometimes multiple operating coils are used to protect electrical circuits from overload or faults; in modern electric power systems these functions are performed by digital instruments still called "protective relays".

Magnetic latching relays can have either single or dual coils. On a single coil device, the relay will operate in one direction when power is applied with one polarity, and will reset when the polarity is reversed. On a dual coil device, when polarized voltage is applied to the reset coil the contacts will transition. AC controlled magnetic latch relays have single coils that employ steering diodes to differentiate between operate and reset commands.

5.8 TRIAC

Symbol

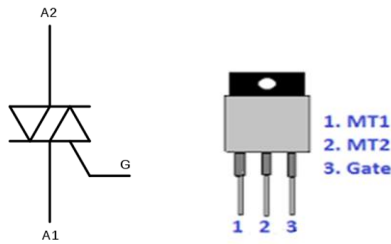


Fig -5.8: TRIAC

TRIAC, its formal name is bidirectional triode thyristor or bilateral triode thyristor. A thyristor is analogous to a relay. TRIACs are a subset of thyristors and are related to silicon controlled rectifiers (SCRs). TRIACs differ from SCRs in that they allow current flow in both directions, whereas an SCR can only conduct current in a single direction. Most TRIACs can be triggered by applying either a positive or negative voltage to the gate (an SCR requires a positive voltage). Once triggered, SCRs and TRIACs continue to conduct, even if the gate current ceases, until the main current drops below a certain level called the holding current.

5.9 Resistors

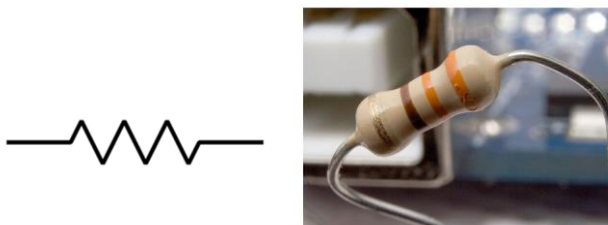


Fig -5.9: Resistor

A resistor is passive two-terminal electrical component that implements electrical resistance as a circuit element. In electronic circuits, resistors are used to reduce current flow, adjust signal levels, to divide voltages, bias active elements, and terminate transmission lines, among other uses. High-power resistors that can dissipate many watts of electrical power as heat may be used as part of motor controls, in power distribution systems, or as test loads for generators. Fixed resistors have resistances that only change slightly with temperature, time or operating voltage. Variable resistors can be used to adjust circuit elements (such as a volume control or a lamp dimmer), or as sensing devices for heat, light, humidity, force, or chemical activity.

5.10 Opto-couplers

Functional Block Diagram

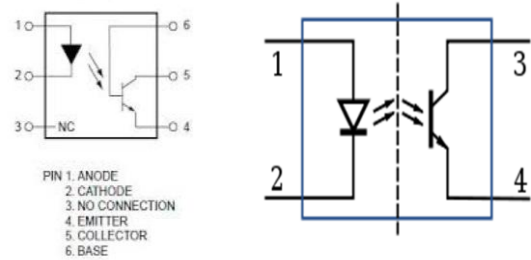


Fig -5.10: Circuit and pin diagram of opto-coupler

In electronics, an opto-isolator, also called an optocoupler, photocoupler, or optical isolator, is a component that transfers electrical signals between two isolated circuits by using light. Opto-isolators prevent high voltages from affecting the system receiving the signal. Commercially available opto-isolators withstand input-to-output voltages up to 10 kV and voltage transients with speeds up to 10 kV/μs. A common type of opto-isolator consists of an LED and a phototransistor in the same opaque package. Other types of source-sensor combinations include LED-photodiode, LED-LASCR and lamp-photoresistor pairs. An opto-isolator contains a source (emitter) of light, almost always a near infrared light-emitting diode (LED), that converts electrical input signal into light, a closed optical channel (also called dielectrical channel), and a photo sensor, which detects incoming light and either generates electric energy directly, or modulates electric current flowing from an external power supply. The sensor can be a photoresistor, a photodiode, a phototransistor, a silicon-controlled rectifier (SCR) or a TRIAC.

5.11 Capacitors

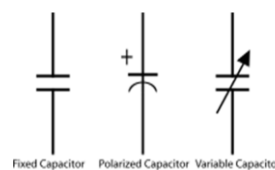


Fig -5.11: Capacitor

A capacitor is a passive two terminal electrical component that stores electrical energy in an electric field. The effect of a capacitor is known as capacitance. While capacitance exists between any two electrical conductors of a circuit in sufficiently close proximity, a capacitor is specifically designed to provide and enhance this effect for a variety of practical applications by consideration of size, shape, and positioning of closely spaced conductors, and the intervening dielectric material. A capacitor was therefore historically first known as an electric condenser.

The physical form and construction of practical capacitors vary widely and many capacitor types are in common use. Most capacitors contain at least two electrical conductors often in the form of metallic plates or surfaces separated by a dielectric medium. A conductor may be a foil, thin film, sintered bead of metal, or an electrolyte. The non-conducting dielectric acts to increase the capacitor's charge capacity. Materials commonly used as dielectrics include glass, ceramic, plastic film, paper, mica, and oxide layers. Capacitors are widely used as parts of electrical circuits in many common electrical devices.

6. COMPENSATION METHODS OF DVR

The type of the compensation technique mainly depends upon the specified factors such as DVR power ratings, various conditions of load, voltage sag type & swell. Some loads are non-linear towards phase angle jump and some are sensitive towards change in magnitude and others are tolerant to these. Therefore, the control strategies mainly depend upon the type of load characteristics; there are three different methods of DVR series voltage injection which are:

- (a) Pre-sag compensation
- (b) In-phase compensation
- (c) Voltage tolerance method with minimum energy injection

(A) Pre-Sag/Dip Compensation Method:

The pre-sag method detects the supply voltage continuously and if it detects any disturbances in supply voltage by micro-controller it will inject the difference voltage between the sag and pre-fault condition, so that the load voltage can be restored by back to the pre-fault condition. Compensation of voltage sags in both phase angle and amplitude. Non-linear loads would be achieved by pre-sag compensation method. In this technique the series injected real power cannot be controlled and it is calculated by external conditions such as the type of faults and load conditions. The voltage of DVR is given below:

$$VDVR = V \text{ pre fault} - V \text{ sag}$$

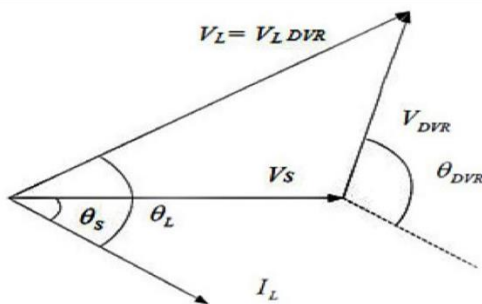


Fig -6.1.1: Phasor diagram of pre-sag/dip method

(B) In-Phase Compensation Method:

In this method the injected voltage is in phase with the supply side voltage regardless of the load current and pre-fault voltage. The phase angles of the pre-sag and load voltage are not similar but the vital criteria for power quality that is the constant magnitude of load voltage are fulfilled. The load voltage is given below:

$$|V_L| = |V \text{ pre-fault}|$$

One of the advantages of this technique is that the amplitude of DVR injection voltage is minimum for some voltage sag in comparison with different strategies. Practical application of this technique is in non-sensitive loads to phase angle jump.

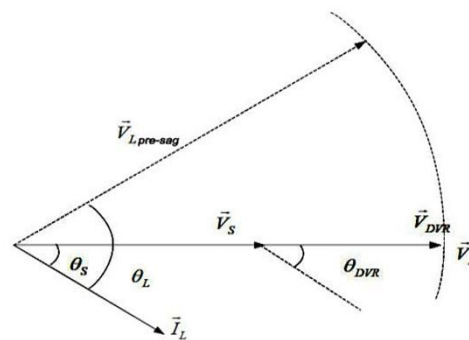


Fig -6.1.2: Phasor diagram of in phase method

(C) Voltage Tolerance Method with Minimum Energy Injection:

A small jump in phase angle and a small drop in voltage can be tolerated by the load itself. If the phase angle variations between 5% -10% of nominal state and voltage magnitude lies between 90%-110% of nominal state that will not disturb the operational features of loads. Both phase and magnitude are the control parameter for this method and can be achieved by small energy injection. In this technique, the magnitude and phase angle of corrected load voltage inside the area of load voltage tolerance are changed. The phase angle jump and voltage drop on load can be accepted by load itself. The delicacy of loads to voltage magnitude and phase angle jump is different.

7. PROPOSED CONTROL TECHNIQUE:

The control system of a DVR plays a vital role, with the operational requirements of fast response when voltage sag/swells are occur. When voltage sag or swells are detected, the DVR must react as fast as possible and should inject AC voltage to the grid. It can be implemented by using a Space Vector PWM control technique which is based on the voltage reference and instantaneous values of load voltage and supply. There are many basic rules of a controller in a DVR that is the detection of the voltage sag or swell occurrences in the system; generation of the trigger pulses of

PWM inverter, calculation of the compensating voltage and stop triggering pulses when the occurrence has passed. The dq method gives the information of the phase shift (q) and depth (d) of voltage sag with start and end time. The load voltage is converted to VD, VQ and V0 based on park transformation according equations (1), (2) & (3).

$$\vec{V}_d = \frac{2}{3} [V_a \cos \omega t + V_b \cos(\omega t - \frac{2\pi}{3}) + V_c \cos(\omega t - \frac{4\pi}{3})] \quad (1)$$

$$\vec{V}_q = \frac{2}{3} [V_a \sin \omega t + V_b \sin(\omega t - \frac{2\pi}{3}) + V_c \sin(\omega t - \frac{4\pi}{3})] \quad (2)$$

$$\vec{V}_0 = [V_a + V_b + V_c] / 3 \quad (3)$$

8. COMPONENTS WITH THEIR RATING:

Sr. No.	Component	Rating
1	PIC Microcontroller	32-Bit
2	Series Inverter	1kV
3	Thyristor	0.5kV
4	Capacitor Bank	300kVAR
5	Potential Transformer	230/5V
6	Zero Crossing Detector	5V
7	Opto-coupler	12V
8	Regulator IC	5V
9	Line Frequency	50Hz
10	Filter Inductance	7mH
11	Filter Capacitance	10µF

9. CONCLUSION

In this paper, hardware model of DVR is setup. The proposed method is used for identification of the voltage sag and is capable of mollification of the sag by keeping and maintaining the magnitude of load voltage at the voltage which is desired and THD within limits. The proposed method is very easy to understand and is reliable, has been used only for one switching per phase. Hence the system is easy, simple, but requires energy storage device as compared to commonly used DVR or STATCOM. The working performance of the proposed device is verified by theoretical results and is found to be satisfactory. This is the best control technique for non-linear loads which can't withstand for phase angle jumps is pre-sag compensation. For minimum voltage injection, in-phase injection compensation is the best. For minimum energy insertion by the DVR, phase advance compensation is best but requires more voltage injection.

REFERENCES

[1] N.G. Hingorani, "Introducing Custom Power", IEEE Spectrum, vol. 32, pp. 41-48, 1995.

[2] N. G. Hingor C. Sankaran, "Power Quality", CRC Press 2002.

[3] K.R. Padiyar, "Facts Controllers in power transmission and distribution" new age international (P) Ltd publishers, 2007.

[4] N.G. Hingorani, Flexible AC Transmission", IEEE Spectrum, vol. 30, pp. 40-44, 1993.

[5] Sanjay Haribhai Chaudhary, Mr. Gaurav gangil "Mitigation of voltage sag swe using Dynamic voltage restorer (DVR)" IOSR Journal of Electrical and Electronics Engineering.

[6] Mansour A. Mohamed. "New Adaptive Method for voltage sag and swell Detection" Global Advanced Research Journal of Engineering, Technology and Innovation February, 2013.

[7] Rosli Omar, Nasrun, Marizan Sulaman "Modelling and Simulation for voltage sags swells Mitigation using Dynamic Voltage Restorer" Journal of Theoretical and applied Information Technology.

[8] Guide for Application of Power Electronics for Power Quality Improvement on Distribution Systems Rated 1 kV to 38 kV, IEEE P1409 Distribution Custom Power Task Force, 2003

[9] Masoud Aliakbar Golkar. "Power Quality in Electric Networks: Monitoring and Standards" the second world engineering conference, pp. 137-141 July 2002.

[10] Michael D. Stump, Gerald J. Keane "The role of custom power products in enhancing power quality at industrial facilities", Energy Management and Power Delivery, vol. 2, pp. 507-517, International Conference 1998.

[11] D. Daniel Sabin, Senior Member, IEEE, and Ambra Sannino, IEEE "A Summary of the Draft IEEE P1409 Custom Power Application Guide" Transmission and Distribution Conference and Exposition, IEEE PES, vol. 3, pp. 931-936, 2003.

[12] C. Alvarez, J. Alamar, A. Domijan Jr., A. Montenegro, and Song, "An investigation toward new technologies and issues in power quality", in Proc. 9th Int. Conf. Harmon. Qual. Power, vol 2, pp. 444 449, 2000.

[13] Yash Pal, A. Swarup, Senior Member, IEEE, and Bhim Singh, Senior Member, IEEE "A Review of Compensating Type Custom Power Devices for Power Quality Improvement" IEEE Power India Conference, pp. 1-8, 2008.

- [14] A.A.D.R. Perera, D.M. Vilathgamuwa, S.S. Choi, "Voltage Sag Compensation with Energy Optimized Dynamic Voltage Restorer", IEEE Trans. on Power Del., Vol. 11, No. 3, pp. 928-936, July 2003.
- [15] V. Salehi, S. Kahrobaee, S. Afsharnia, "Power Flow Control and Power Quality Improvement of Wind Turbine Using Universal Custom Power Conditioner", IEEE Conference on Industrial Electronics, Vol. 4, pp. 1688-1892, July 2002.
- [16] B.H. Li, S.S. Choi, D.M. Vilathgamuwa, "Design Considerations on the Line-Side Filter Used in the Dynamic Voltage Restorer", IEE Proc. Gener. Transmission Distrib., Issue 1, Vol. 148, pp. 1-7, Jan. 2001.
- [17] H.P. Tiwari, Sunil Kumar Gupta, "DC Energy Storage Schemes for DVR Voltage Sag Mitigation System" International Journal of Computer Theory and Engineering, Vol. 2, No. 3, June, 2010.
- [18] Bingsen Wang, Giri Venkataramanan and Mahesh Illindala, "Operation and Control of a Dynamic voltage Restorer Using Transformer Coupled H-Bridge Converters", IEEE sactions on power electronics, vol. 21, pp. 1053-1061, July 2006.
- [19] R. Ibrahim. A A. Haidar, M. Zahim, "The effect of DvR location for enhancing voltage sags" Intelligent and Advanced systems (ICIAS), International Conference pp. 1-4, 2010.
- [20] S. S. Choi, H. Li, and D. D. Vilathgamuwa, "Dynamic Voltage Restoration with Minimum Energy Injection," IEEE Trans. Power Syst, vol. 15 pp. 51-57. Feb. 2000.
- [21] John Godsk Nielsen and Frede Blaabjerg "Control Strategies for Dynamic Voltage Restorer Compensating Voltage Sags with Phase Jump", Applied Power Electronics Conference and Exposition, IEEE, vol. 2, pp. 1267-1273, 2001.
- [22] M. H. Haque, "Compensation of Distribution System Voltage Sag by DVR and DSTATCOM", IEEE Porto Power Tech Conference, vol. 1, 2002.
- [23] D.N.Katole Research scholar: Department of Electrical Engg G.H.Raison College of engineering, India. "Analysis and Mitigation of Balanced Voltage sag with the Help of Energy Storage System" ICETET pp. 317-321, 2010.
- [24] H.P. Tiwari and Sunil Kumar Gupta "Dynamic Voltage Restorer against Voltage sag" International Journal of Innovation, Management and Technology vol. 1, no. 3 2010.
- [25] Francisco Jurado, Member, IEEE, and Manuel Valverde University of Jaen, "Fuzzy logic control of a dynamic voltage restorer IEEE-ISIE, vol. 2, pp. 1047-1052, 2004.
- [26] Paisan Boonchiaml, Nadarajah Mithulananthan, Rajamangala University of Technology Thanyaburi Thailand, "Detailed Analysis of Load Voltage Compensation for Dynamic Voltage Restorers TENCON, IEEE region 10 conference, pp. 14, 2006.