

REVIEW ON POWER QUALITY MITIGATION TECHNIQUES

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Abstract: Besides quantity, the quality of power is also equally important. Poor power quality decreases the efficiency and misoperation of electrical and electronic devices, this may result interrupted electrical power supply. Due to recent development of electronics and computer based automated and smart devices in every field e.g. medical, bank, industry, quality of power becomes more and more important as these devices require best power quality. Power quality mitigation becomes very important as we cannot avoid the nonlinear loadings and many more issues which is responsible for poor power quality. In this paper various power quality mitigation techniques are discussed such as Distribution Static Synchronous Compensator (DSTATCOM), Static VAR Compensator (SVC), Dynamic Voltage Restorer (DVR) and Unified Power Quality Compensator (UPQC) for the improvement of power quality in manufacturing industries. Recent developments in mitigation techniques are also discussed. Different techniques are explained in chronological order. Impacts of different techniques for different disturbances are also mentioned.

Index Terms: Dynamic Voltage Restorer (DVR), Unified Power Quality Conditioner (UPQC), Distribution Static Compensator (DSTATCOM), Transient Voltage Surge Suppressors (TVSS), Voltage Regulators, Uninterruptible Power Supply (UPS) Solid State Breaker, Static Current Limiter.

1. Introduction

Today's technological world completely depends on electricity; however the availability of electric sources is low. The deficiency of electricity becomes the breaking point for developing countries like India. Hence the electric utilities are finding a suitable solution for providing uninterruptable electricity [1]. Modern power systems are complex networks, where hundreds of generating stations and thousands of load centers are interconnected through long power transmission and distribution networks. The main concern of consumers is the quality and reliability of power supply at various load centers where they are located. Nowadays the requirement for power quality becomes more and more important to keep safety of the electrical devices and consumer satisfaction [2].

Power Quality is defined as power that enables the equipment to work properly. A power quality problem can be defined as any deviation of magnitude, frequency, or purity from the ideal sinusoidal voltage waveform. Good power quality is benefit to the operation of electrical equipment, but poor power quality will produce great harm to the power system [4]. It has been always difficult to maintain the quality of electric power so as to keep it within the acceptable limits. Mainly the use of power electronics devices that acts as the nonlinear load is responsible for the degradation in the poor power quality. Poor power quality results in various problems in the distribution systems like higher power losses, harmonics, sag and swells in the voltage, poor distortion and displacement factor [5]. There are different ways to enhance power quality problems in transmission and distribution systems.

To provide an active & flexible solution for power quality problems, various efforts have done from time to time. To increase the reliability of the distribution system and face the power disturbance problems, an advanced power electronics controller devices have launched over last decades. The evolution of power electronics controller devices has given to the birth of custom power devices [3].

The custom power devices are Dynamic Voltage Restorer (DVR), Unified Power Quality Conditioner (UPQC), Distribution Static Compensator (DSTATCOM), Transient Voltage Surge Suppressors (TVSS), Voltage Regulators, Uninterruptible Power Supply (UPS) Solid State Breaker, Static Current Limiter etc.

2. Custom power devices

Custom power is a strategy, which is intended principally to convene the requirement of industrial and commercial consumers. The concept of the custom power is tools of application of power electronics controller devices into power distribution system to supply a quality of power, demanded by the sensitive users.

These power electronics controller devices are also called custom power devices because through these valuable powers is applied to the customers. They have good performance at medium distribution levels and most are available as commercial products [3]. Some of custom power devices are described in this paper.

2.1 Transient Voltage Surge Suppressors (TVSS)

TVSS provides the simplest and least expensive way to condition power. These units clamp transient impulses (spikes) to a level that is safe for the electronic load. Employing an entire facility protection strategy will safeguard the electrical system against most transients. Multi-stage protection entails using TVSS at the service entrance, sub-panel at the point of use.

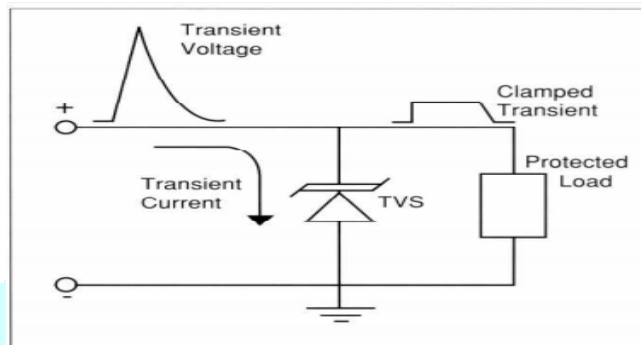


Fig.2.1 Transient Voltage Surge Suppressors

This co-ordination of devices provides the lowest possible let through voltage to the equipment. Transient voltage surge suppressors are used as interface between the power source and sensitive loads, so that the transient voltage is clamped by the TVSS before it reaches the load. TVSSs usually contain a component with a nonlinear resistance (a metal oxide Varistor or a Zener diode) that limits excessive line voltage and conduct any excess impulse energy to ground [7].

2.2 Uninterruptible Power Supply (UPS)

Uninterruptible Power Supply (UPS) is the most common solution for all types of RMS voltage variations (sags, swells, under voltage, overvoltage, and interruptions). A UPS uses stored energy in a battery to provide load power when the normal power supply falls outside a defined voltage range.



Fig. 2.2 Model of UPS

There are three major UPS topologies each providing different levels of protection:

- Off-Line UPS (also called Standby)
- Line-Interactive UPS
- True On-Line UPS

2.2.1 Off-Line UPS (also called Standby)

Low cost solution for small, less critical, stand-alone applications such as programmable logic controllers, personal computers and peripherals. Off-line UPS systems supply the load directly from the electrical utility with a limited conditioning. The unit provides

power to the load from the battery during sags, swells and power interruptions. They have some noise suppression through a filter/surge suppressor module.

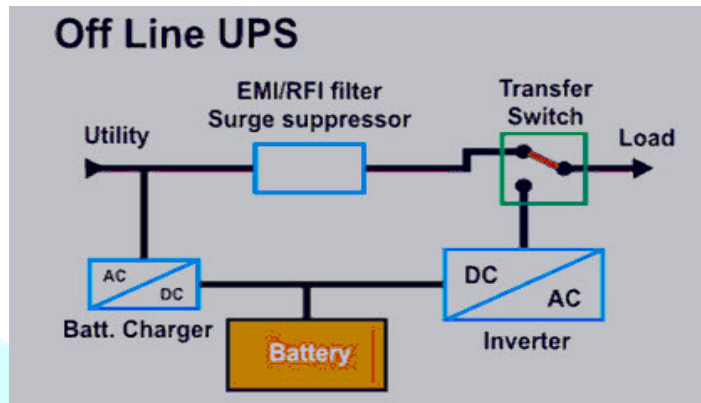


Fig.2.2.1 Block Diagram of Off-Line UPS

Advantages of off-line UPS are high efficiency, low cost and high reliability. The main disadvantage is that protection from high and low voltages is limited by the battery capacity. Other disadvantages are poor output voltage regulation and noticeable transfer time. To keep unit cost low, most off-line units utilize step-sine wave outputs when on battery power [7].

2.2.2 Line-Interactive UPS

Line-Interactive UPS provides highly effective power conditioning plus battery back-up. These units are ideal in areas where voltage fluctuations are frequent. The defining characteristic of line-interactive models is they can regulate output voltage without depleting the battery.

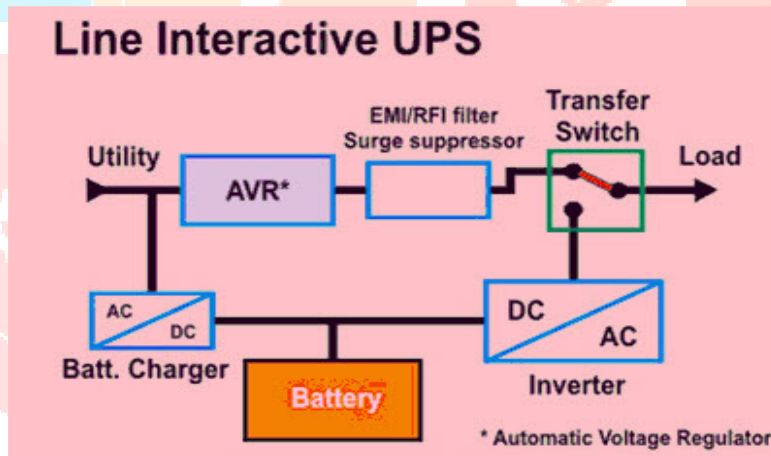


Fig. 2.2.2 Block Diagram of Line-Interactive UPS

Advantages are good voltage regulation and high efficiency. Disadvantages are noticeable transfer time and difficulty in comparing competing units. The output waveform can be either a sine wave or step-sine wave depending on the manufacturer and model [7].

2.2.3 True On-Line UPS

True On-Line UPS provides the highest level of power protection, conditioning and power availability. True on-line technology, also called double conversion is unique in that the power is converted from AC utility to DC for battery charging and to power the inverter. The DC is then converted back to AC to power the critical load.

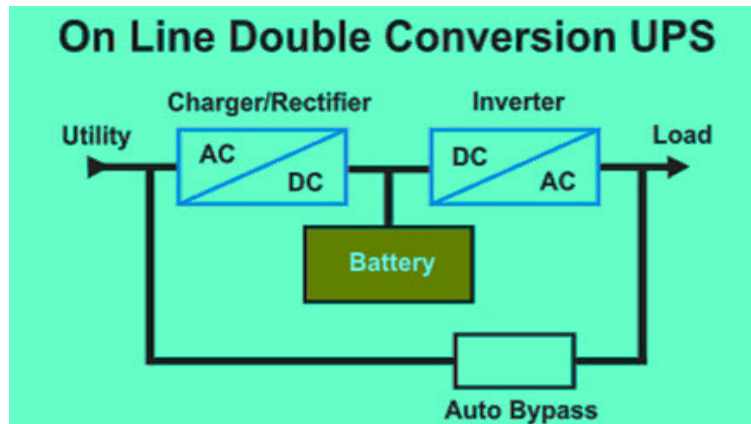


Fig. 2.2.3 Block Diagram of True On-Line UPS

Advantages of the online UPS include the elimination of any transfer time and superior protection from voltage fluctuations. Voltage regulation is achieved by continuously regenerating a clean sine wave. Disadvantages are lower efficiency and higher audible noise [7].

2.3 Voltage Regulators

Voltage regulators are normally installed where the input voltage fluctuates, but total loss of power is uncommon. There are three basic types of regulators:

- 2.3.1 Tap Changers:** Designed to adjust for varying input voltages by automatically transferring taps on a power transformer. The main advantage of tap changes over other voltage regulation technology is high efficiency. Other advantages are wide input range, high overload current capability and good noise isolation. Disadvantages are noise created when changing taps and no waveform correction.
- 2.3.2 Buck Boost:** Utilize similar technology to the tap changers except the transformer is not isolated. Advantages are the units withstand high in-rush currents and have high efficiency. Disadvantages are noise created when changing taps, poor noise isolation and no waveform correction.
- 2.3.3 Constant Voltage Transformer (CVT):** Also known as Ferro-resonant transformers. The CVT is a completely static regulator that maintains a nearly constant output voltage during large variations in input voltage. Advantages are superior noise isolation, very precise output voltage and current limiting for overload protection. The lack of moving parts mean the transformer requires little or no maintenance. Disadvantages are large size, audible noise and low efficiency [7].

2.4 Solid State Breaker

The solid state breaker is based on the GTO or thyristor switching technology. It is a high-speed switching device, applied to reduce the electrical fault and protect from large current in distribution system. It can be used in a single switch, static transfer switch, hybrid switch or a low level fault interrupter. The voltage and current rating of the breaker describes the requirement of no. of switching devices, cost and the losses of the breaker. It performs auto-reclosing function [3].

2.5 Static Current Limiter

It is a series connecting device that reduces fault current level by inserting series inductance in faulty path. It consists of a pair of GTO with snubber circuit and inductor [3].

2.6 Static Transfer Switch

Static Transfer Switch (STS) is used to protect sensitive load voltage sag or swell. It is composed of two parallel connected Thyristor or GTO blocks. Each block consists of three GTO or thyristor corresponding to the three phases of the system. The common configuration of STS in distribution system is shown in Figure.

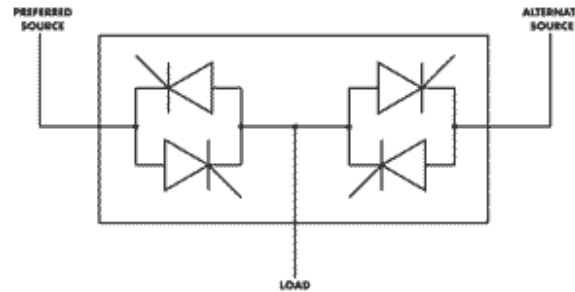


Fig.2.6 static transfer switch (STS)

As shown in the Fig STS are connected in the bus tie position and contain two pairs of anti-parallel thyristors to allow fast transfer of power from faulty feeder to an alternative feeder within the time scale of milliseconds. When fault occurs primary source affected, and then load is fed from alternating source through switch 2. The STS are effective devices to protect sensitive loads against power quality disturbance, to ensure rapid transfer between a faulty feeder and healthy feeder, a make-before break or break-before-make switching strategy is implemented in STS controller circuit to reduce negative switching impacts on load. Which means it supplied an uninterrupted power at distribution level to customers. The limitation of this switch is that, in high power application the load current leads the conducting losses. The conducting losses are in the range of 0.5 to 1% of the load power. A hybrid STS has been proposed in this switch a conservative circuit breaker is connected in shunt with thyristors or GTO's.

2.7 Distribution Static Compensator (DSTATCOM)

DSTATCOM is a Voltage source inverter (VSI) based static compensator device (STATCOM, FACTS controller) applied to maintain bus voltage sags at the required level by supplying or receiving of reactive power in the distribution system. It is connected in shunt with distribution feeder with the help of coupling transformer.

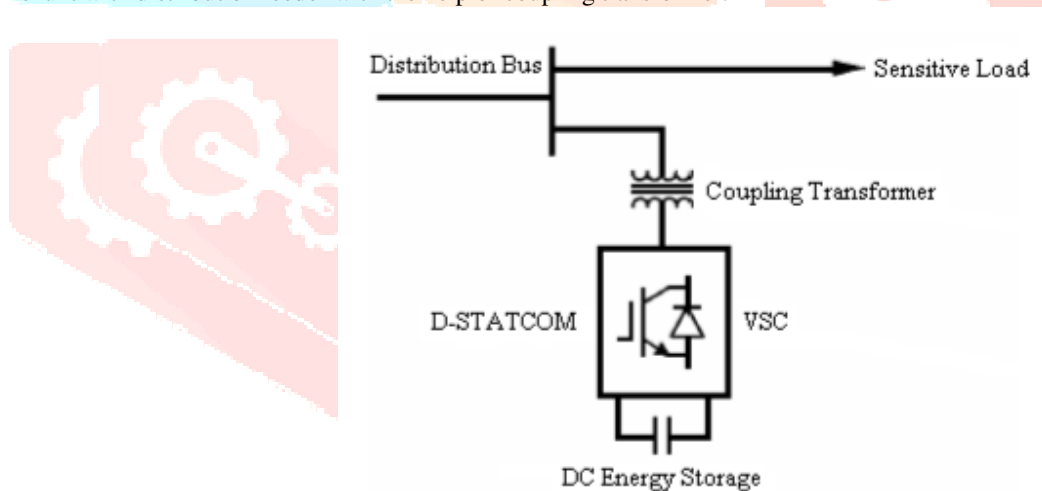


Fig. 2.7 single line diag. of DSTATCOM

The DSTATCOM consists of a VSI, dc energy storage device, an ac filter and coupling transformer. In the power circuit, VSI converts DC voltage into controllable ac voltage, synchronized by ac filter and connected to AC distribution line through coupling transformer. The DSTATCOM can also rely and absorbed active power, by using energy storage in sufficient amount. The operating principle of DSTATCOM that it continuously monitors the load voltages and currents, determines the amount of compensation required by distribution system for a variety of disturbances. In this scheme the active power flow is controlled by the angle between the ac system and VSI voltages, the reactive power flow is controlled by the difference between the magnitudes of these voltages. The DSTATCOM operates in both current and voltage control modes [3].

2.8 Static Series Compensator

Commercially, static series compensator is known as Dynamic Voltage Restorer (DVR). It is a high-speed switching power electronic controlling device. Also known as series voltage booster. DVR is a series connected custom power device, designed to inject a dynamically controlled voltage in magnitude and phase in to distribution line via coupling transformer to correct load voltage [3].

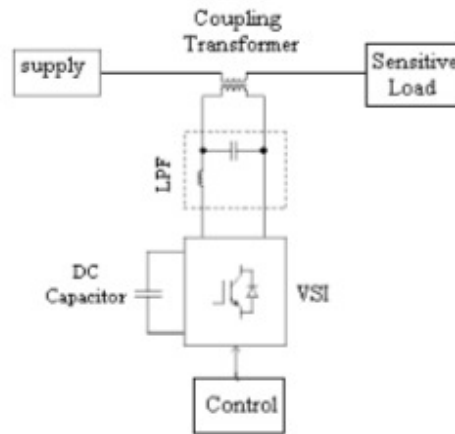


Fig. 2.8 Generalized block diag. of DVR

It consists of an energy storage device, a boost converter (dc to dc), voltage source inverter, ac filter and coupling transformer, connected in series. Here dc capacitor bank is used as energy storage device, which is interface by a boost converter. The boost converter regulates the voltage across the dc link capacitor that uses as a common voltage source for the inverters. The inverter generates a compensating voltage, which is inserted into distribution system through series matching transformer. In the case of voltage ir-regulation, the DVR controllers generate a reference voltage, and compare it with source voltage and inject synchronized voltage to maintain the load voltage constant. The energy storage devices provide the required power to synchronized injected voltage. The ac filter overcomes the effects on winding of coupling transformer and switching losses of control signal generating techniques for VSI.

Therefore DVR is supposing as an external voltage source of controlled amplitude, frequency, and phase angle. The aim of using DVR is to maintain the amplitude, and phase angle of fixed load voltage.

2.9 Unified Power Quality Conditioner (UPQC)

Basically UPQC (Unified Power Quality conditioner) is a equipment which is used for compensate for voltage distortion and voltage unbalance in a power system so that the voltage at load side is completely balance and sinusoidal & perfectly regulated and also it is used to compensate for load current harmonics so that the current at the source side is perfectly sinusoidal and free from distortions and harmonics. UPQC is a combination of a Shunt Active power filter and Series Active power filter. Here Shunt Active power filter (APF) is used to compensate for load current harmonics and make the source current completely sinusoidal and free from harmonics and distortions. Shunt APF is connected parallel to transmission line. Here Series APF is used to mitigate for voltage distortions and unbalance which is present in supply side and make the voltage at load side perfectly balanced, regulated and sinusoidal. Series APF is connected in series with transmission line [8].

Conclusion

Power quality maintenance is an important aspect in the economic operation of a system. Various power quality problems may lead to another undesirable problem. Proper mitigation devices can be used to maintain the level of power quality as desired.

An orthopaedic surgeon is unlikely to take any kind of action without taking an X-ray first. Similarly, in order to know the correct power quality mitigation actions to **take, proper measurement is required.** To “prescribe” a solution, the complete picture is required.

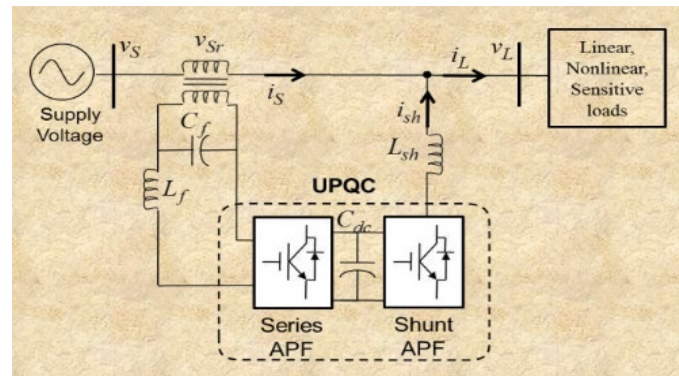


Fig. 2.9 Configuration of UPQC

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