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A Comparative Study of the Performance of Mitigation Methods for Power Quality Problems

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Abstract

This paper focuses on various power quality issues and compares various mitigation methods based on their performance in resolving power quality issues. Power quality problems may lead to low efficiency, poor power factor and may reduce the life of equipment. To mitigate the power quality problems various methods have been employed in the recent times. A comparative study of Distribution Statcom, Dynamic Voltage Restorer and Unified Power Quality Conditioner has been done and results are obtained using MATLAB.

Introduction

It include all possible situations in which the waveforms of the supply voltage or load current deviate from the sinusoidal waveform at rated frequency with amplitude corresponding to the rated rms value for all three phases of a three-phase system. Power quality disturbance covers sudden, short duration deviation impulsive and oscillatory transients, voltage dips (or sags), short interruptions, as well as steady-state deviations, such as harmonics and flicker.

Some power quality problems occur within a strongly interconnected power network due to network switching. Non-linear loads cause other power quality problems. These non-linear loads also draw reactive power and harmonic currents along with active power from the mains. This may cost industry large amounts due to mainly dips and short interruptions. Fig 1 shows some of the most common problems encountered.

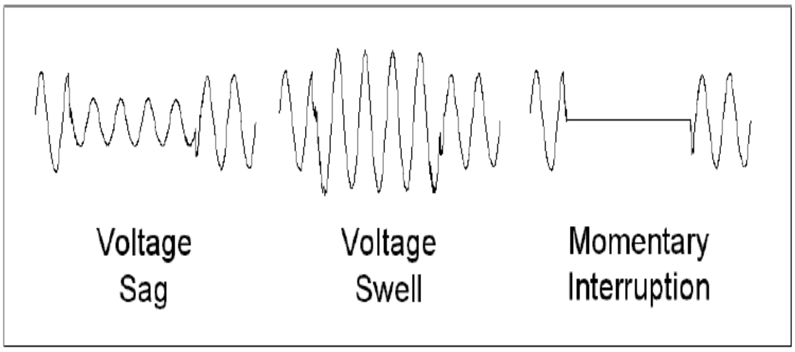

Figure 1

Power Quality Compensators:

Many solutions have been proposed to each of these power quality problems over the years. Passive filters consisting of a bank of tuned LC filters are widely used to suppress harmonics. But they have many shortcomings like fixed compensation, large size and weight. Hybrid compensating devices, combining converters, thyristor controlled reactors have been introduced to reduce the cost and improve efficiency. Developing converter-based compensators with more flexibility i.e. the ability to compensate for more than one power quality problem with a single converter based device, would make it a more economical solution. This paper is aimed to discuss such an economical solution to various power quality problems.

Distribution STATCOM

The D STATCOM is a three-phase and shunt connected power electronics based device. It is connected near the load at the distribution system. Fig.2 shows the topology of a 3-phase 3 wire D STATCOM.

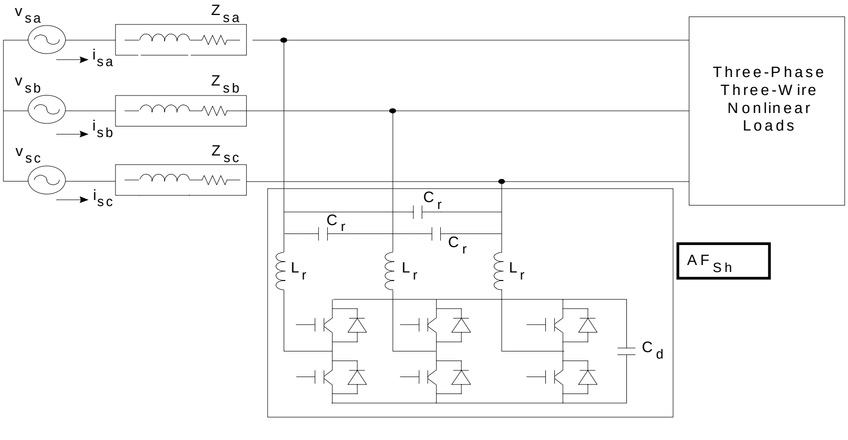

Figure 2

The basic electronic block of the D-STATCOM is the voltage-sourced inverter that converts an input dc voltage into three-phase output voltage at fundamental frequency. The voltage Vs, Vi is the effective supply and output voltage respectively of the D-STATCOM and δ is the power angle. The controller of the D-STATCOM is used to operate the inverter in such a way that the phase angle between the inverter voltage and the line voltage is dynamically adjusted so that the D STATCOM generates or absorbs the desired VAR at the point of connection. If Vi is equal to Vs, the reactive power is zero and the D STATCOM does not generate or absorb reactive power. When Vi is greater than Vs, the D STATCOM shows an inductive reactance connected at its terminals. The current flows through the transformer reactance from the D STATCOM to the ac system and the device generates capacitive reactive power. If Vs is greater than Vi, the D STATCOM shows the system as a capacitive reactance. Then the current flows from the ac system to the D STATCOM, resulting in device absorbing inductive power.

Fig.3 shows the results obtained from the simulation. From fig.3, it can be seen that load change at t=0.12s and voltage unbalance exists from t=0.18s to t=0.24s.During this period, D STATCOM responds well to give the system better ride through capability. The counterbalancing act of the D STATCOM maintained the Vpcc constant during the duration of the sag.

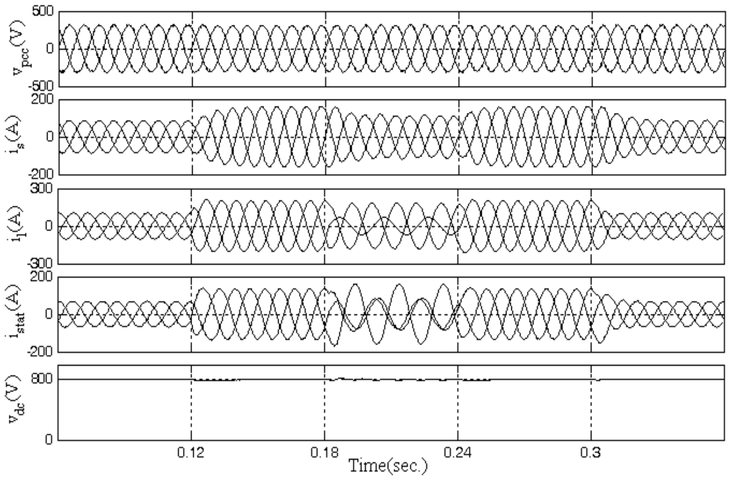

Figure 3

From the simulation results we can conclude that D STATC*OM* is a promising device and will be prominent feature in power system for mitigating power quality problems.

Dynamic Voltage Restorer

A DVR is a power electronics converter, which can protect sensitive loads from all supply side disturbances other than outages. It is connected in series with a distribution feeder and also is capable of generating or absorbing active power and reactive power. The basic principle of DVR is by inserting a voltage of required magnitude, the DVR can restore the load side voltage. Fig.4 shows topology of 3-phase 3-wire DVR. This topology lends itself more to voltage compensation such as power flow control, voltage unbalance, and dip compensation and voltage harmonics.

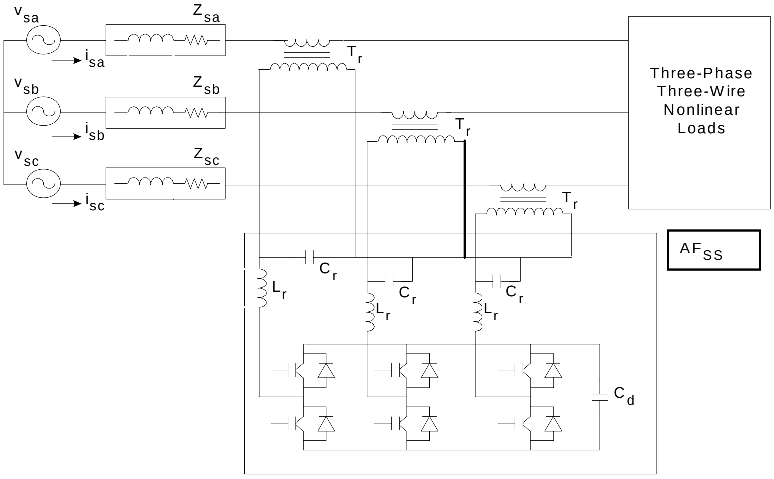

Figure 4

A simulation of performance of DVR during 20% sag is shows in fig.5. The operation of the series compensator under dip compensation. At 50 ms a dip of 20% was put on phase A. The magnitude of the injected voltage increased to keep the load voltage constant.

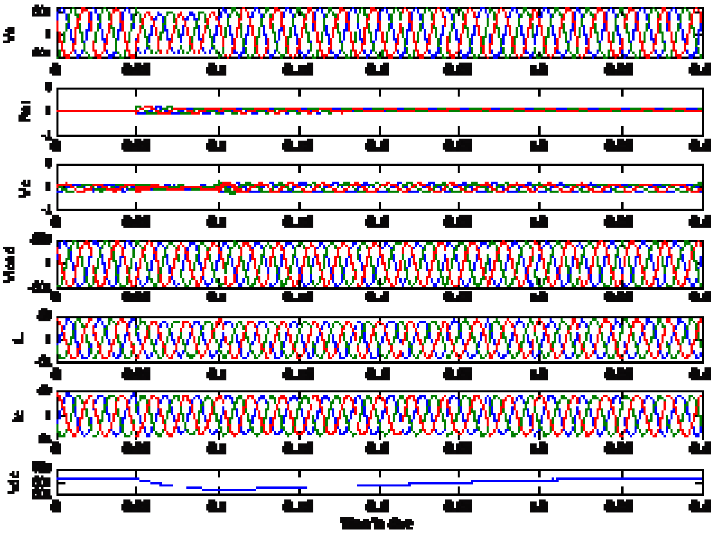

Figure 5

The maximum injected voltage is given by:

$$Vinj = \{(\%DIP/100)^{2} + THD^{2})\ Vs\}^{1/2}$$

The disadvantages of series compensation are that large fault current will flow through the device under line fault conditions. Harmonic distortion to the load voltage will be introduced by the PWM controller for the converter [6]. The protection being more complex than for the shunt device could be a reason for reluctance of the wide spread use of this topology.

Unified Power Quality Conditioner

The series shunt topology shown in the fig.6 combines the benefits of both topologies.

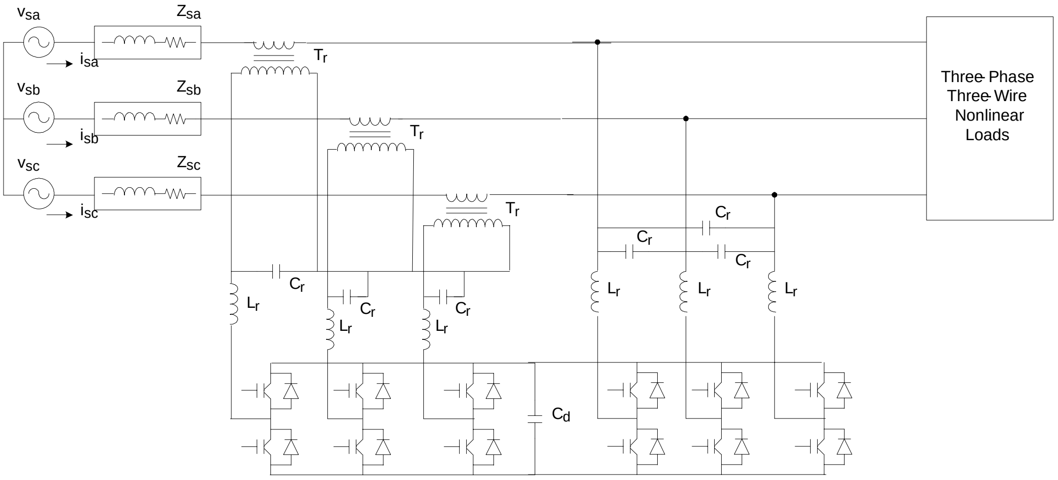

Figure 6

Depending on the type of load either the series or the shunt converter can be used to compensate for the load harmonics. It is also possible to compensate for the various power quality problems. The control of this device is more complex than in the other two topologies as well as the total cost of the device is much more due to two-converter system. The power rating of the two units will depend on the type of power quality solution required.

The UPQC consists of a shunt converter and series one connected by a dc capacitor with each other. Two types of the UPQC can be considered: one is a left-shunt UPQC and other is the right-shunt one. The difference between the two can be explained that shunt converter is connected at the utility side or at the load side. The UPQC can be utilized for both dynamic voltage restoration and fault current limitation in order to improve power quality [4]. The former is applied in a normal operation mode in order to compensate sudden voltage sag on the line. The voltage sag mainly originates due to system fault on the utility side. The latter is employed when a system fault occur at the load side.

Fig.7 shows simulation of the voltage sag by 50% at the utility side.

Before t=50ms to 150ms, one can see 50% voltage drop in the waveform of the terminal voltage Vt. In this case load voltage V_L can be well compensated as shown in the fig. This compensation is accomplished by inserted voltage Vs of the series converter. As a result, line current i_s does not show any disturbances. During sag, the dc link voltage E_d of the UPQC is well regulated as shown in fig. 7

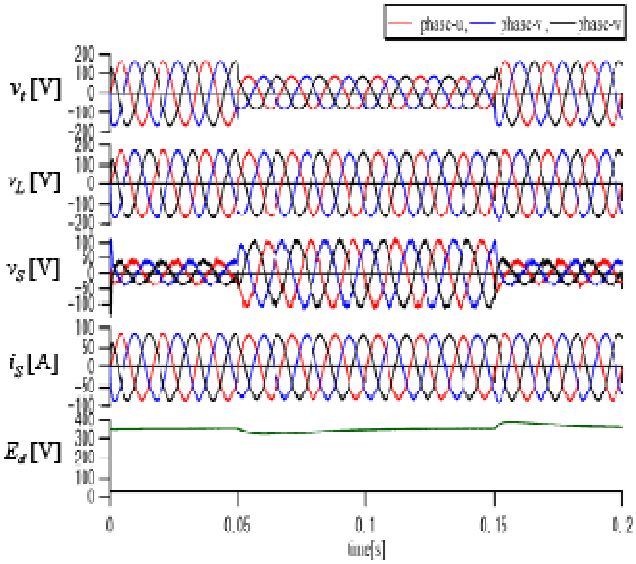

Figure 7

The main advantage of this topology is that it optimizes network current and load voltage parameters simultaneously. Using this combination it is possible to compensate for a variety of power quality and power flow problems. These include dips and sags, harmonic isolation, harmonic compensation, power factor improvement, voltage regulation.

Table 1 summarises the functions of the shunt, series and Unified series–shunt power quality compensators.

Table 1

PQ Function	DVR	DSTATCOM	UPQC
Dip/sag compensation	Yes	Limited	Yes
Harmonic isolation	Yes	No	Yes
Harmonic compensation	No	Yes	Yes
Power Factor correction	No	Yes	Yes
Power flow control	No	No	Yes

Conclusion

A unified approach to mitigate various power quality problems is described in this paper. Converter based power mitigation devices should be optimized for power rating, power losses and control performance. These converters can have payback times for several months to a few years.

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