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A Review on UPQC Allocation to Improve Power Quality

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Abstract - *Flexible AC Transmission Systems (FACTS) devices are used to develop and improve the dynamic performance of the modern power system. The quality of the Electrical power is affected by many factors like the presence of harmonic, voltage swell and voltage sag due to switching of loads, current flickering etc. Unified Power Quality Conditioner (UPQC) is one of the FACTS devices that can provide controllable compensating voltage and current simultaneously.*

UPQC, which is composed of the DC/DC converter and the storage device connected to the DC link of UPQC, is proposed to balance the voltage.

***Key Words*: Harmonic, SPWM, Voltage sag, Voltage swell, UPQC.**

1.INTRODUCTION

There are many nonlinear loads in the distribution system due to which harmonic distortion occurs. The quality of the power gets affected by the loads like thyristor power convertors, arc furnace, etc. The current and voltage flickering occurs due to EAF. The sag and swell voltage quality issues occurs due to switching ON and OFF of loads. LC filters can solve this power quality issues but random variations in load current can't be solved by LC filters. Active filters may help in reducing flickers but those are very costly. They are also difficult to install on large scale. So for overcoming it, the UPQC can compensate the power quality issues in distribution system. UPQC is a combination of filters, series and shunt, connected through common DC link capacitor. UPQC can compensate power quality issues such as voltage sag, voltage swell, power unbalance, flickers, harmonics, and reactive power demand.

2. POWER QUALITY ISSUES

Power quality problem embodies deviation in voltage, current or frequency that culminates into a failure of equipment. Power quality problems often accompany loss of production, damage to appliances, higher power losses, communication interference and so on. It is, therefore, significant to establish and maintain higher standards of power quality. The frequently encountered problems related to power quality are voltage sags, voltage swells, interruption, harmonics and distortion.

2.1 Voltage Sags:

Voltage sag is defined as a decrease in voltage between 0.1 and 0.9 pu at a power frequency for duration from 0.5 cycle to 1 min. These problems are usually associated with system faults, but may also be caused due to the heavy loads.

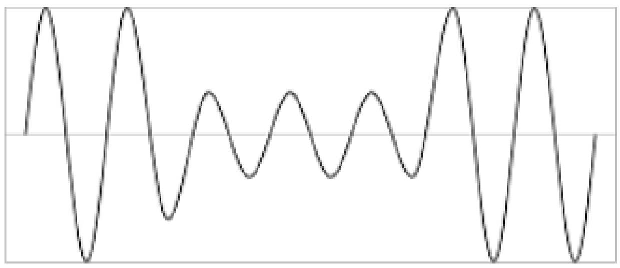

Fig . Voltage sag

2.2 Voltage Swells:

A swell is defined as an increase in voltage between 1.1 and 1.8 pu at power frequency for duration from 0.5 cycle to 1 min. These voltage swells during fault is a function of fault location, grounding and impedance of the system.

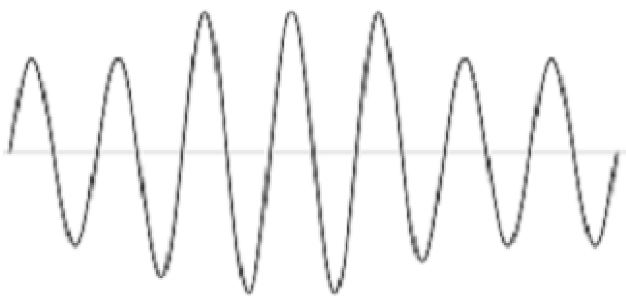

Fig 2. Voltage swell

2.3 Interruption:

Interruption in a power system is one of the major problems that occurs when the system or supply voltage or load current decreases to less than 0.1 pu for a period of time which is not more than 1 min. This can occur due to equipment failure, power system faults, etc.

Fig 3. Interruption

2.4 Harmonics:

Harmonics are defined as sinusoidal voltages and currents having frequency which are the integral multiples of the fundamental frequency.

2.5 Distortion:

Distortion is the deviation from an ideal sine wave of power frequency in steady state condition.

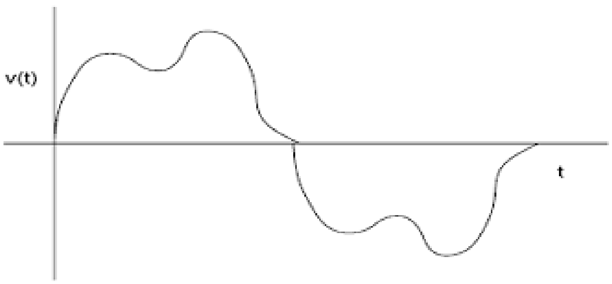

Fig 4. Distortion

3. BASIC CONFIGURATION OF UPQC

Unified Power Quality Controller (UPQC) consists of series and shunt active power filters (APF) that are connected back to back to the DC side and commonly sharing a DC capacitor. As shown in figure 5, the series active power filter of UPQC is primarily accountable for mitigating disturbances on the supply side namely; voltage sags, voltage swells, voltage flickers, voltage unbalance and harmonics. It injects voltage in series so as to maintain a desired level of load voltage which is balanced and free from distortion.

The shunt connected active power filter predominantly mitigates current quality problems namely poor power factor, harmonic currents and so on. It injects current into the system so as to maintain balanced sinusoidal currents in phase with the source voltage.

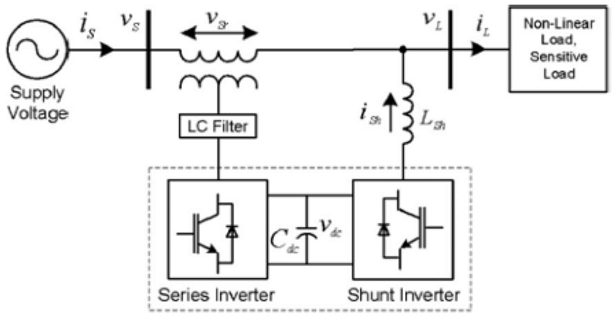

Fig 5. Basic configuration of UPQC

The three control approaches for UPQC to mitigate the voltage sag on the system are A) Active power control technique in which an in phase voltage is injected through the series inverter which is termed as UPQC-P, B) reactive power control technique in which quadrature voltage is injected which is famously termed as UPQC-Q, C) minimum VA loading technique in which a series voltage is injected at a certain angle, which is termed as a VAmin.

4. PROPOSED SCHEME OF UPQC

The first UPQC topology was introduced in 1998 by Fujita. Proposed configuration of UPQC is as shown in fig 5 which in additional to the basic configuration will have a DC/DC Converter and ultracapacitor to overcome the voltage interruption issues discussed above. In case of voltage interruption the ultracapacitor in the arrangement provides energy through the bidirectional converter to the DC link. In case of normal operation the ultracapacitor receives energy from the DC link through bidirectional converter.

The system operates at normal mode if the source voltage is held at 1.0pu. If the source voltage falls to a value in between 0.5 and 1.0 pu, voltage sag creeps into the system on the contrary, if the source voltage rises above 1.0pu, the system operates in voltage swell mode. The complete system interruption occurs if the value of source voltage drastically reduces below 0.5pu.

The DC/DC Converter operates either in charge or standby mode depending on the state of charge (SOC) of an ultracapacitor. The series inverter assumes the job of injecting the compensating voltage during voltage sag/swell condition to maintain constant voltage at load side. The DC/DC Converter operates at standby mode and the shunt inverter absorbs the current harmonics.

5. OPERATION STRATEGY

Some types of loads, like diode bridge rectifier or thyristor bridge rectifier, act as current source at point of common coupling while feeding an inductive load. An active power filter connected in shunt with the load effectively compensates it where as some other types of load like diode bridge with high dc link capacity filter are compensated by connecting APF in series with load. The series injected voltage follows a law such that sum of both the voltages is the sinusoidal voltage. Somehow, utility voltages are unbalanced and non-sinusoidal and an accurate choice of the magnitude and phase angle of the injected voltage can make them balance and sinusoidal. Thus the shunt connected active power filter acts like a current source injecting harmonic current and the series connected active power filter acts like a voltage source injecting a compensating voltage. The UPQC illustrated in above system involves several steps which are as follows:

1) Series APF control: Voltage sag, harmonic detection, reference voltage generation, voltage regulation and PWM gating signals generation.

2) Shunt APF control: Detection of harmonic current, generation of reference current, current regulation, voltage control of DC-link and PWM gating signals generation.

6. CURRENT AND VOLTAGE HARMONIC COMPENSATIONS

Due to nonlinear loads in the networks, voltage and current harmonics are introduced in the system. Harmonic currents are effectively compensated by shunt APF. Many control efforts have been developed to improve the harmonic compensation performance of the shunt APF. These control methods involves current measurements, harmonic detection, reference current generation, current control and DC link voltage control. Due to all these arrangement control scheme of shunt APF becomes very complex. It involves current controller and harmonic detector in addition but it has some drawbacks. Thus advanced control strategies for shunt APF has been developed to compensate current harmonics by using enhanced resonant controllers and without load current measurement and harmonic detector.

The supply currents are measured and controlled to be sinusoidal by an effective harmonic compensator which is developed based on PI and VPI controllers. The absence of load current measurement and harmonic detector not only simplifies the control scheme but also significantly improves the shunt APF performance.

7. VOLTAGE SAG AND SWELL COMPENSATION

The main purpose of the series APF in a UPQC is to inject a compensating voltage to maintain balanced and sinusoidal voltage at the load terminal and at the desired level irrespective of the supply voltage conditions.

The load voltage is deducted from the supply voltage and the voltage injected to the series APF.

$V_L(wt) = V_S(wt) + V_{Sr}(wt)$.

Where $V_L(wt)$ is load voltage, $V_S(wt)$ is supply voltage and $V_{Sr}(wt)$ is injected voltage of series APF.

8. VOLTAGE DISTORTION MITIGATION

Due to the presence of nonlinear loads, the voltage at the supply bus is generally not purely sinusoidal but distorted. This distorted voltage condition will affect sensitive loads connected at the load terminal, if not fully compensated. The UPQC is capable of isolating voltage harmonics on the supply side to improve the load voltage performance. The voltage controller, which is used to mitigate voltage harmonics are introduced.

The distorted voltages in a 3-phase system may contain negative phase sequence and harmonic components. To provide load reactive power compensation of the load harmonic and negative sequence currents, the shunt-APF acts as a controlled current source and its output components should include harmonic, reactive and negative-sequence components in order to compensate these quantities in the load current.

9. CONCLUSION

First, the adverse impacts of poor power quality of power distribution system are investigated and then several possible custom devices that can be deployed to tackle these issues are introduced, where the UPQC is the most advanced and powerful device for power quality improvement.

It is observed that Power Quality problem is a major issue in the distribution system. In the distribution system, UPQC has the ultimate capability of improving the power Quality. The proposed approach determines the optimal reactive power compensation. A new approach for mitigation voltage sag/swell is proposed here. When UPQC is operated at healthy operating condition, it substantially reduces the power loss and improves the node voltage. The UPQC is capable of injecting current in series compensation and injecting voltage in shunt compensation and thereby minimizing the system losses. The UPQC model is modified so as to obtain the reactive power compensation of the distribution system. Both Shunt active filter and Series active filter participate in reactive power compensation. In addition to the series and shunt compensation, the UPQC is equipped to eliminate the harmonics and render a sinusoidal nature to the voltage and current waveform. It is also particularly useful for mitigation of under voltages. An higher maximum load ability can be attained when the UPQC is located at specific location. The UPQC also reduces the maximum line current of the network.

The proposed advanced control strategies for the UPQC aim to improve the power quality of distributed power system. The control and performance of the proposed work are validated under various power quality problems such as current and voltage harmonic, voltage sag/swell, and voltage unbalance.

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