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Implementation of UPQC for Voltage Sag Mitigation

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***Abstract* - The proliferation of power electronic based equipment has produced a significant impact on the quality of electrical power supply. The modern day equipments are highly sensitive to deviation from ideal sinusoidal voltages. Conventional power quality enhancement equipments are providing to be in adequate. A very promising solution for supply voltage imperfection is UPQC (Unified Power Quality Conditioner). Unified power quality conditioners (UPQCs) allow the mitigation of voltage and current disturbances that could affect sensitive electrical loads while compensating the load reactive power. In this Paper We deal with implementation of left shunt configuration UPQC for voltage sag mitigation. The solution is proved using MATLAB 7.5.**

Index Terms**—**Custom power device, FACTS, DVR, STATCOM, Series Injection, Shunt Injection, Power Quality.

1. OVERVIEW OF POWER QUALITY PROBLEMS

Any problem manifested in voltage, current or frequency deviation that results in failure of customer equipment is known as power quality problem.

Low power quality affects electricity consumer in many ways. The lack of quality can cause loss of production, damage to equipment and human health. Therefore it is obvious to maintain high standards of power quality.

The major types of power quality problems are,

- Voltage Sag
- Voltage swell
- Interruption
- Distortion and
- Harmonics.

A. Interruption:

An Interruption occurs when the supply voltage or load current decreases to less than 0.1 pu for a period of time that is not exceeding 1 min. Interruptions can be the result of power system faults, equipment failures and control malfunction. Instantaneous re-closing generally will limit the temporary fault to less than 30 cycles.

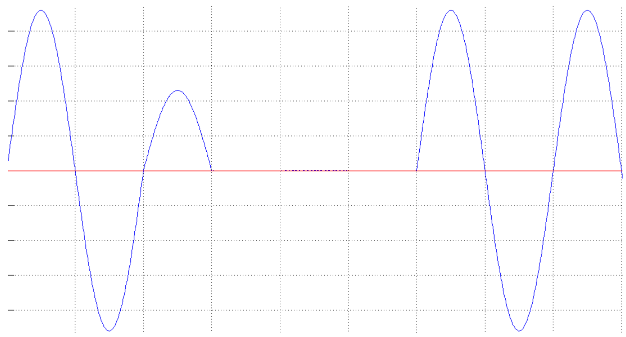

Figure 1 Interruption.

B. Voltage Sags

A sag is decrease in voltage between 0.1 and 0.9 pu at the power frequency for duration from 0.5 cycle to 1min. Voltage sags are usually associated with system faults but can also cause by energisation of heavy loads at starting of large motors.

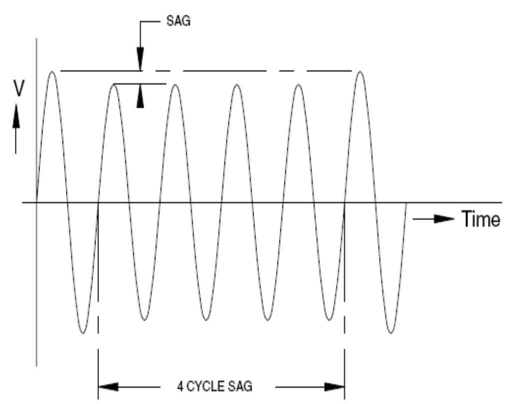

Figure 2 Voltage Sag

C. Swells

A swell is increase in voltage between 1.1 and 1.8 pu at power frequency for duration from 0.5cycle to 1min. The severity of voltage swell during a fault condition is a function of fault location, system impedance and grounding.

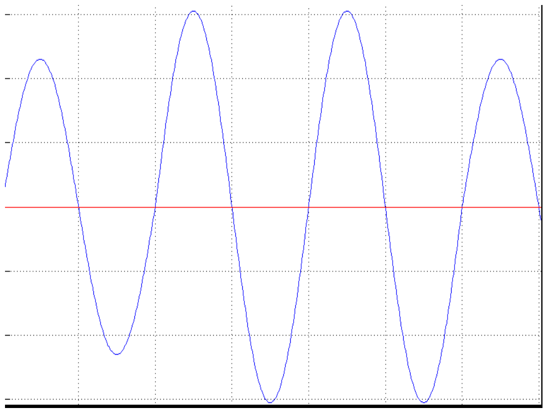

Figure 3 Voltage Swell

D. Waveform Distortion

It is defined as the steady state deviation from an ideal sine wave of power frequency principally characterized by the spectral content of the deviation.

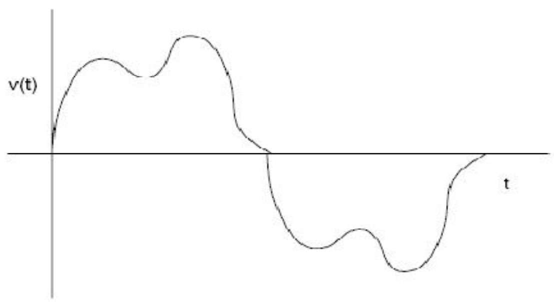

Figure 4 Distorted Waveform

E. Harmonics

Harmonics are sinusoidal voltages or current having frequency that are integer multiples of the fundamental frequency.

2. FACTS DEVICES

The practical operating capacity of a transmission line is much less than the installed capacity this leads to non-optimal operation of the power system. Facts concepts help in using the real capacity of a transmission system without adding any new lines.The new generation FACTS devices are,

- STATCOM
- SSSC
- UPFC
- UPQC

A. Static Synchronous Compensator (STATCOM):

Static synchronous compensator is applied in shunt transmission lines and can adjust the required reactive power dynamically and within the limits of capability of converter.

B. Static synchronous series compensator (SSSC)

Static synchronous series compensator is installed in series and injects the voltage with controlled magnitude and angle.

C. Unified power flow controller (UPFC):

UPFC is one of the unique equipment in facts which is used in series and shunt on transmission line.UPFC consists of two VSC and a DC link .This DC link may be a capacitor or any kind of DC source. One converter operate in shunt and other in series.

The UPFC installed at load centre is called as UPQC.

3. UPQC CIRCUIT AND OPERATION

Various UPQC configurations are,

- Right Shunt Configuration
- Left Shunt Configuration

The proposed system under investigation consists of Left Shunt Configuration of UPQC.

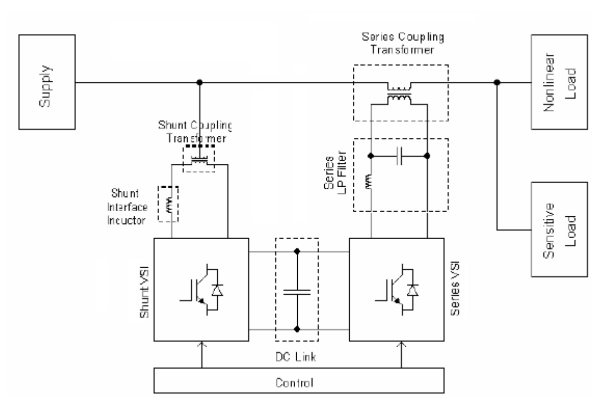

Figure 5 UPQC Block Diagram

The block diagram consists of STATCOM and SSSC to form a UPQC. The Shunt element consisting of shunt coupling transformer, shunt interface inductor and shunt VSI constitutes Statcom. The Series coupling transformer, series LPF filter, series VSI constitutes SSSC. The converters of shunt and series components are made up of IGBT or GTO because we need to control the turning off of the devices.

The SSSC injects the compensating voltage into the line and the STATCOM is responsible for maintaining the voltage of DC Source.At normal operation the power flows from the line to DC source through the shunt converter and DC source is charged. When Sag occurs at line, the desired voltage is fed into the line through the series converter. By varying the current carried through the shunt and series filters the compensating voltage is injected into the system. Current carried by the filters are controlled by controlling the impedance of thefilteing circuit. This can be achieved by varying the firing angle of converters.

Various modes of operation of UPQC are,

- Direct Voltage injection mode.
- Bus Voltage control mode.
- Phase angle Regulation mode.

4. MATLAB CIRCUIT

A. Over all Circuit

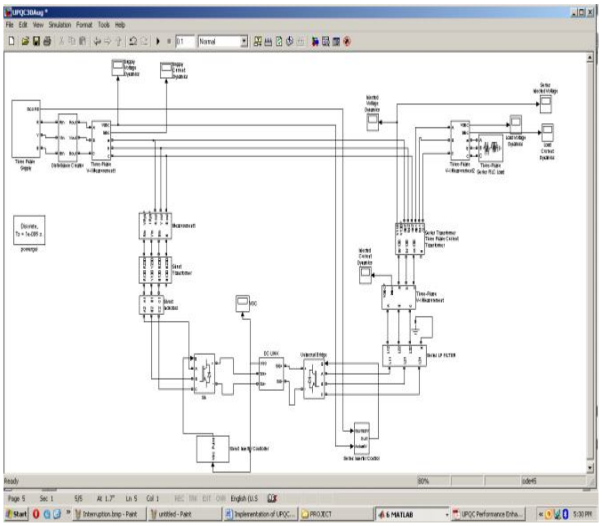

Figure 6 UPQC Implemented in Matlab 7.5

A three phase Voltage Supply of 325V peak amplitude is used. The disturbance creator injects a negative voltage of 92.5V to simulate the voltage sag that may occur in a power system due to any increase in load or occurrence of fault. The Shunt inverter is implemented by using shunt transformer, shunt inductor and universal bridge. The Shunt transformer is a three phase Y-Y transformer made of three single phase transformers. The shunt inductor avoids the harmonic current to be injected into the DC Link. The universal bridge consists of a greatz circuit to convert ac to dc voltage. The bridge consists of six IGBTs. The IGBTs are used as the converter can be used as both rectifier and inverter. The DC link consists of a capacitor and smoothing reactor to avoid ripples. The Series converter is implemented using universal bridge, series LPF, Shunt transformer. The Shunt Transformer is made up of three single phase transformers. The control signals of the two universal bridges are generated by various controllers.

B. Shunt Inverter Controller:

The Shunt Inverter can be controlled by,

- Tracking the shunt converter reference current
- Tracking the supply current
- Tracking the DC voltage.

We use DC voltage tracking as this technique is not complex and will give us the clear understanding of Shunt inverter function.

The error signal given to the PWM generator is V_{dc}-V_{dcref}. The reference voltage is chosen as 400V.

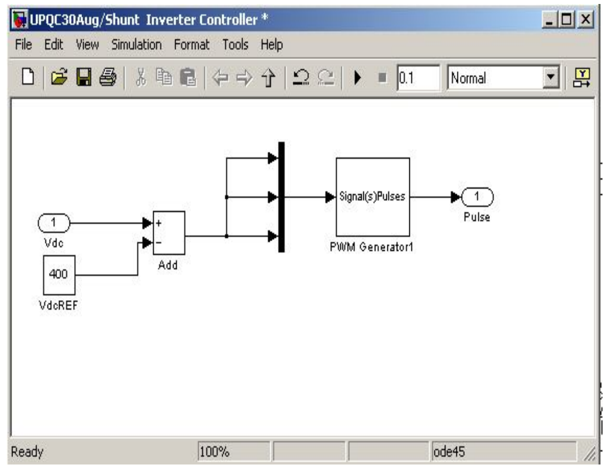

Figure 7 Shunt Inverter Controller.

C. Series Inverter Controller:

The series component of UPQC is controlled to inject the appropriate voltage between the point of common coupling (PCC) and load, such that the load voltages become balanced, distortion free and have the desired magnitude. Theoretically the injected voltages can be of any arbitrary magnitude and angle. However, the power flow and device rating are important issues that have to be considered when determining the magnitude and the angle of the injected voltage . Two UPQC terms are defined in depending on the angle of the injected voltage: UPQC-Q and UPQC-P. In the first case (UPQC-Q) the injected voltage is maintained 90o in advance with respect to the supply current, so that the series compensator consumes no active power in steady state. In second case (UPQC-P) the injected voltage is in phase with both the supply voltage and current, so that the series compensator consumes only the active power, which is delivered by the shunt compensator through the dc link.

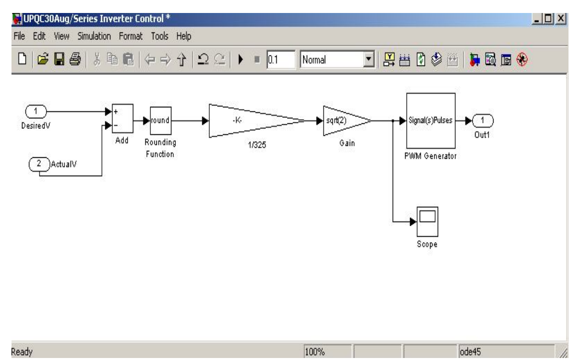

Figure 8 Series Inverter Controller.

The error signal is $(V_{desired}-V_{actual})(1.414/325)$.

5. OUTPUT WAVEFORMS AND DISCUSSION.

The voltage sag can be created by injecting negative voltage in the circuit or increase in load. Sag of 30% is created by injecting negative voltage. UPQC is connected in the circuit. UPQC is connected at point between supply terminal and load(i.e Load Centre and Load). Following voltages and current are recorded in order to justify the operation.

- Supply Voltage
- Injected Voltage
- Load Voltage

Here the series voltage injection takes place at the point of common coupling (PCC). PCC is the point where UPQC is connected.

The supply voltage is given by,

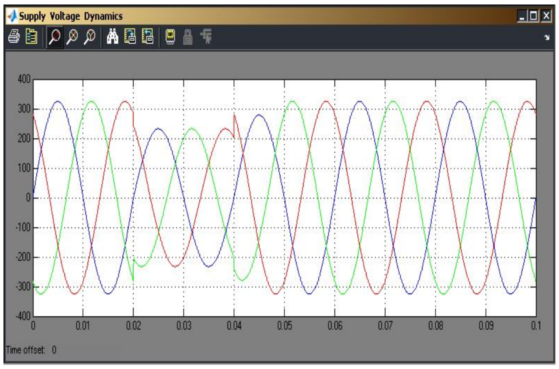

Figure 9 Supply Voltage

The above picture shows the supply voltage has sag from 0.02 to 0.04 seconds. At normal condition peak value of voltage is 325 V. During occurrence of sag is 227.5 V. The Supply voltage is reduced by 97.5 V.

The injected voltage is given as,

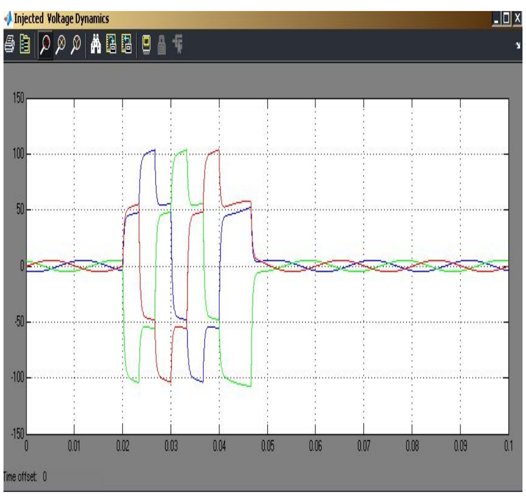

Figure 10 Injected Voltage

Here we can see that the voltage of required magnitude of 97.5 volt is injected in to the system during the time 0.02-0.04. During normal voltage there is almost zero voltage is injected into the system. Compensating is injected only during occurrence of sag.

The load voltage is given by,

Figure 11 Load Voltage

The load voltage is sum of injected and supply voltage. Thus there is no sag in the load Voltage. At normal operating condition the supply voltage is 325 V and injected voltage is almost zero. At time of occurrence of sag the supply voltage peak value is 227.5 and injected voltage is approximately 92.5 V. This makes the Voltage at the load terminal is 325 V. Thus the voltage is maintained within limits ensuring presise operation of the terminal equipment.

6. CONCLUSION

The UPQC to eliminate the Voltage Sag is implemented using the basic control strategy which gives clear understanding of UPQC operation. The same strategy can be expanded to tackle all kind of power quality problems. The fine tuning of the controllers have to be done in future so as to accommodate all power quality and protection issues.

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