ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 7, Issue 5, May 2018

Voltage Sag and Swell improvement by Unified Power Quality Conditioner (UPQC)

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ABSTRACT: Nowadays, the problem of voltage sags and Swells create a severe impact on sensitive loads in industries. Due to which load shedding and over voltages might occur. Several custom power devices can be used to overcome this problem.This paper describes UPQC principles for the effect of load VAR variation and voltage compensation methods during three-phase fault for balanced / unbalanced voltage sags and swells in a power system. UPQC consists of a nine switch power converter having two sets of output terminals in place of a twelve switch back to back converter with a combination of shunt active power filter and series active power filter. This converter features unity input power factor and more importantly, low manufacturing cost due to its reduced number of active switches. Simulation results carried out by MATLAB/Simulink to verify the performance of the proposedmethod.

KEYWORDS: Load Shedding, Over Voltage, Unified Power Quality Conditioner, Back to back converter, MATLAB

I.INTRODUCTION

In an industrial facility much of the electrical equipment requires high-quality electricity; it will not tolerate sags, swells, transients, or harmonics, and it certainly will not tolerate power outages, no matter how short-lived. Voltage support at a load can be achieved by reactive power injection at the load point of common coupling (PCC). Unified power quality conditioner can absorb active power or inject active power. A UPQC is a combination of shunt and series APFs, sharing a common dc link.

It is a versatile device that can compensate almost all power quality problems such as voltage harmonics, voltage unbalance, voltage flickers, voltage sags & swells, current harmonics, current unbalance, reactive current, etc. This paper is based on the steady state analysis of UPQC during voltage sag and swells on the system. The main objective of this article is to maintain the load bus voltage sinusoidal and at desired constant level in all operating conditions.

II.POWER QUALITY PARAMETERS

Voltage changes can range from small voltage fluctuations of short duration to a complete outage for an extended period of time.

The major types of power quality problems are,

- Voltage Sag
- Voltage swell
- Interruption
- Distortion
- 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.

DOI:10.15662/IJAREEIE.2018.0705061

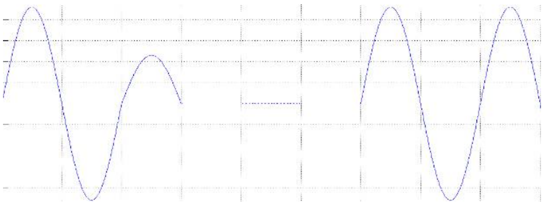


Figure 1 – Interruption

B. Voltage Sags

A sag is decrease in voltage between 0.1 and 0.9 p.u. 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.

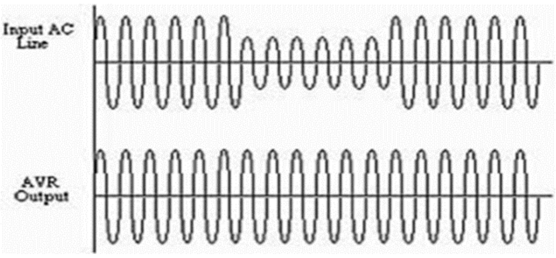


Figure 2 – Voltage Sags

C. Swells

A swell is increase in voltage between 1.1 and 1.8pu at power frequency for duration from 0.5cycle to1min. The severity of voltage swell during a fault condition is a function of fault location, system impedance and grounding.

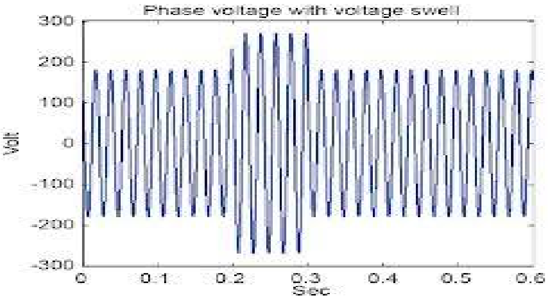


Figure 3 – Voltage Swells

D. Waveform Distortion

It is defined as the steady state deviation froman ideal sine wave of power frequency principallycharacterized by the spectral content of the deviation.

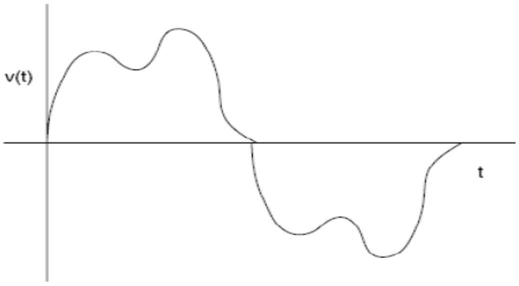


Figure 4 Waveform Distortion

E. Harmonics

Harmonics are sinusoidal voltages or currenthaving frequency that are integer multiples of thefundamental frequency.

III.FACTS DEVICES

The practical operating capacity of a transmissionline is much less than the installed capacity this leads to optimal operation of the power system. Factsconcepts help in using the real capacity of a transmission system without adding any new lines.

Thenew generation FACTS devices are,

- STATCOM
- SSSC
- UPFC
- UPQC

A. Static Synchronous Compensator(STATCOM):

Static synchronous compensator is applied in shunttransmission lines and can adjust the required reactivepower dynamically and within the limits of capabilityof converter.

B. Static Synchronous Series Compensator(SSSC)

Static synchronous series compensator is installedin series and injects the voltage with controlledmagnitude and angle.

C. Unified Power Flow Controller(UPFC):

UPFC is one of the unique equipment in factswhich is used in series and shunt on transmission line. UPFC consists of two VSC and a DC link. This DClink may be a capacitor or any kind of DC source. Oneconverter operates in shunt and other in series.

D. Unified Power Quality Controller (UPQC):

The UPQC, just as in a UPFC employs two voltage source inverters (VSIs) that connectedto a d.c. energy storage capacitor. One of these two VSIs isconnected in series with a.c. line while the other is connectedin shunt with the a.c. system.A UPQCthat combines the operations of a DistributionStatic Compensator (DSTATCOM)and DynamicVoltageRegulator (DVR)together.

The series and shunt-active filters are connected in a back-to-back configuration, in which the shunt converter is responsible for regulating the common DC-link voltage.

IV.DESIGN OF UPQC CONTROLLER

In series APF the Inverter injects a voltage in series with the line which feeds the polluting load through a transformer. The injected voltage will be mostly harmonic with a small amount of sinusoidal component which is in-phase with the

Current flowing in the line. The small sinusoidal in-phase component in the injected voltage results in the right amount of active power flow into the Inverter to compensate for the losses within the Series APF and to maintain the D.C side capacitor voltage constant. Obviously the D.C voltage control loop will decide the amount of this in-phase component. Seriesactive power Filter compensate current system distortion caused by nonlinear load by imposing a high impedance path to the harmonic current.

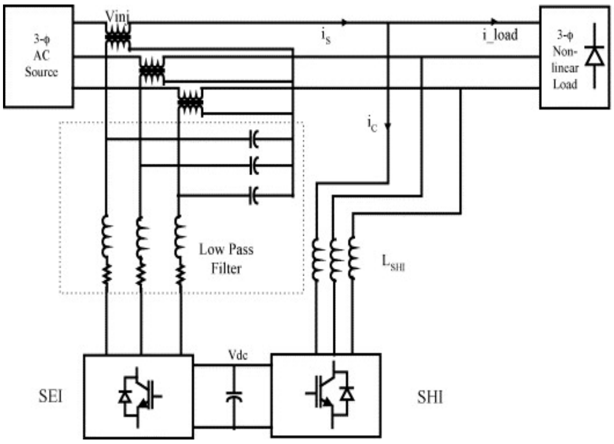


Figure 5 overall configuration and control of UPQC

V.SYSTEM CONFIGURATION

The nine switch converter is formed by tying three semiconductor switches per phase, giving a total of nine for all three phases. The nine switches are powered by a common dc link, which can either be a microsource or a capacitor depending on the system requirements. Like most reduced component topologies the nine-switch converter faces limitations imposed on its assumable switching states, unlike the fully decoupled back-to-back converter that uses 12 switches. Those allowable switching states can conveniently be found in Table I, from which,it is clear that the nine-switch converter can only connect its two output terminals per phase to either V_{dc} or 0V, or its upper terminal to the upper dc rail P and lower terminal to thelower dc rail N. the lastcombination of connecting its upper terminal to N and lower terminal to P is not realizable, hence constituting the first limitation faced by the nine switch converter.

That limitation is nonetheless not practically detrimental, and can be resolved by coordinating the two modulating references per phase, so that the reference for the upper terminal is always placed above that of the lower terminal.

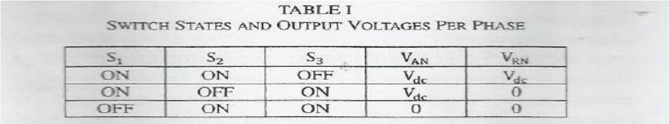


TABLE I
SWITCH STATES AND OUTPUT VOLTAGES PER PHASE

S_1	S_2	S_3	V_{AN}	V_{RN}
ON	ON	OFF	V_{dc}	V_{dc}
ON	OFF	ON	V_{dc}	0
OFF	ON	ON	0	0

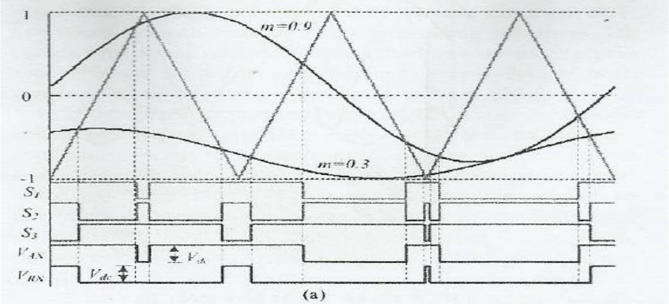


Figure 6(a) – Same frequency but different amplitude

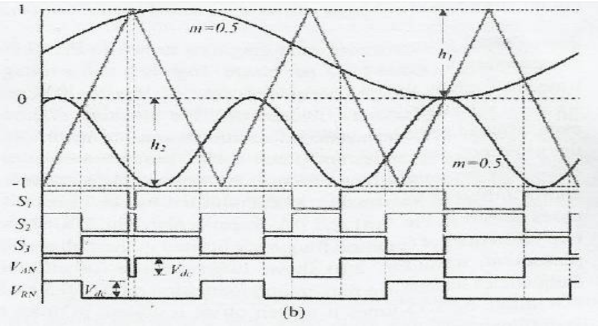


Figure 6(b) - Same amplitude different frequency

Imposing this basic rule of thumb on reference placement then results in those gating signals drawn in fig 5 for the three switches of S1, S2 and S3 per phase. Equations for producing them can also be stated as

$$S_1 = !S_1' = \begin{cases} \text{ON}, & \text{if upper reference is larger than carrier} \\ \text{OFF}, & \text{otherwise} \end{cases}$$

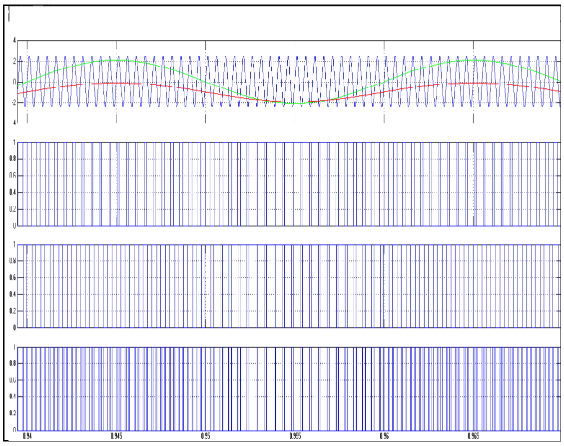
$$S_3 = !S_3' = \begin{cases} \text{ON}, & \text{if lower reference is smaller than carrier} \\ \text{OFF}, & \text{otherwise} \end{cases}$$

$$S_2 = S_1' \oplus S_3' \qquad (1)$$

Signal obtained from (1) when applied to nine switch converter, their output voltages are represented by V_{RN} and V_{AN} per phase. Together these voltage transitions show that the forbidden state of V_{AN} =0v and $V_{RN} = V_{dc}$ is effectively blocked off. The blocking is, however, attained at the incurrence of additional constraints limiting the reference amplitudes and phase shift. These limitations are especially prominent for references having sizable amplitudes and different frequencies.

VI.SIMULATION RESULTS

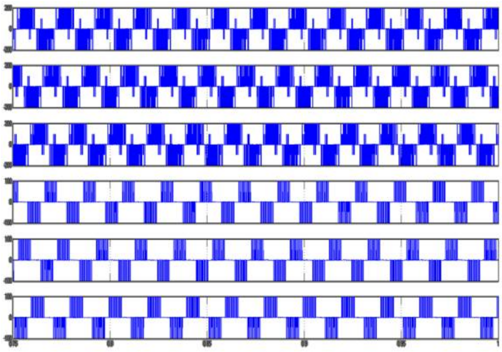
The pulses for IGBT are given through the pulse width modulation which is generated by comparing sine waves of same amplitude and different frequency as shown in figure 7.



X axis: Time (sec)
Y axis: Voltage(volts)

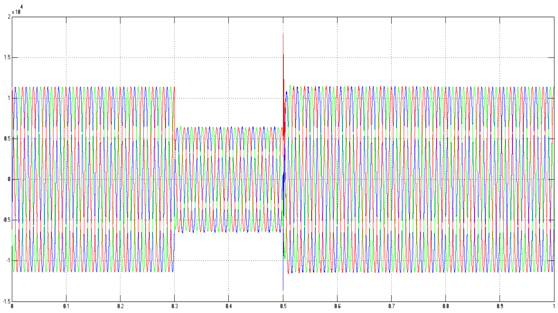
Figure 7 : PWM pulses signals for IGBT (Phase= zero degree)

The simulation of the nine switch conditioner has been shown in figure 8.



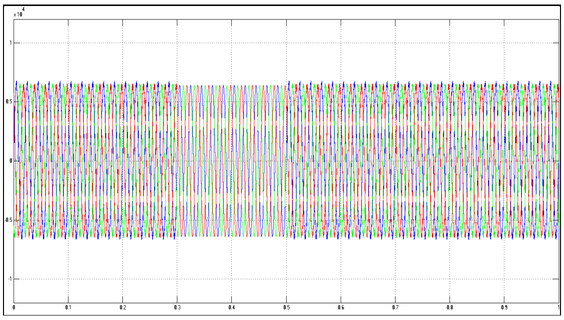
X axis: Time (sec)
Y axis: Voltage(volts)
Figure 8: Nine switch conditioner output

The simulation shows of three phase voltage sag . The simulation started with theSupply voltage 50% sagging as shown in Figure 9 .



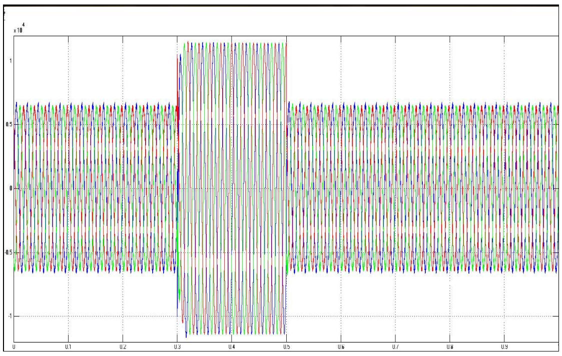
X axis: Time (sec)
Y axis: Voltage(volts)
Figure 9(a): Voltage sag simulated output

In Figure 9 also shows a 50% voltage saginitiated at 0.3 s and it is kept until 0.5s, with total voltage sag duration of 0.2s. Figures 10 show the voltage injected by the UPQC and the corresponding load voltage with compensation.



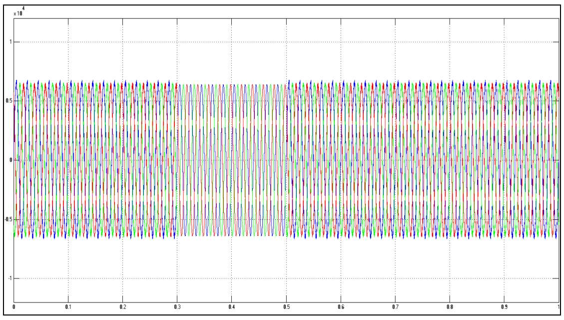
X axis: Time (sec)
Y axis: Voltage(volts)
Figure 9(b): sag compensated output

As a result of UPQC, the load voltage is kept at 1 pu. Through simulation the supply voltage with one phase voltage dropped down to 50%.The effectiveness of the UPQC under unbalanced conditions is shown in figure ,
The second simulation shows the UPQC performance during a voltage swell condition. The simulation started with the supply voltage swell is generated as shown in Figure 11.



X axis: Time (sec)
Y axis: Voltage(volts)
Figure 10(a): Voltage swell simulated output

As observed from this figure the amplitude of supply voltage is increased about 25% from its nominal voltage. As can be seen from the results, the load voltage is kept at the nominal value with the help of theUPQC. Similar to the case of voltage sag, the UPQC reactsquickly to inject the appropriate voltage component (negative voltage magnitude) to correct the supply voltage.



X axis: Time (sec)
Y axis: Voltage(volts)
Figure 10(b): Swell compensated output

VII.CONCLUSION

The modelling and simulation of a UPQC usingMATLAB/SIMULINK has been presented.The simulation shows that the UPQC performance is satisfactory in mitigating voltagesags/swells. From simulation results also show that the UPQCcompensates the sags/swells quickly and provides excellent voltage regulation. The UPQC handles bothbalanced and unbalanced situations without anydifficulties and injects the appropriate voltage component to correct rapidly any anomaly in the supply voltage to keep the load voltage balanced and constant at the nominal value.

SIMULATED VALUES:

Sag Voltage	6500 V
Compensated Voltage	6520 V
Swell Voltage	$1.14*10^4$ V
Compensated Voltage	6500 V
Output voltage of conditioner	400 V

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