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Enhancement of Power Quality based on Unified Power Quality Conditioner (UPQC)

K.S.Srikanth, Shaik. Musthak Ahmed, Y.Srinivasa Rao

Abstract*— Majority of the distributed generations from renewable energy sources are connected to the grid through power electronic interface, which introduce additional harmonics in the distribution systems. Research is being carried out to integrate active filtering that is the combination of series and shunt with specific interface such that a common power quality (PQ) platform could be achieved. For generalized solution, a unified power quality conditioner (UPQC) could be the most comprehensive PQ protecting device for sensitive non-linear loads, which require quality input supply. Also, load current harmonic isolation needs to be ensured for maintaining the quality of the supply current. The present paper describes a review for UPQC, for enhancing PQ of sensitive non-linear loads. Based on voltage compensation strategy, the control scheme has been designed, which are termed as UPQC. As the power circuit configuration of UPQC remains same for the model, with modification of control scheme only, the utility of UPQC can be optimized depending upon the application requirement. This paper presents a review on the UPQC to improve the electric power quality at distribution levels.

***Index Terms*— Active power filter (APF), harmonic compensation, power quality, reactive power compensation, unified power quality conditioner (UPQC), voltage sag and swell compensation.**

I. INTRODUCTION

Distributed generation (DG) systems have both advantages and disadvantages in relation to grid power quality (PQ). They can increase the efficiency of systems by local power generation. More reliable and uninterrupted power can be provided to customers, with energy cost savings. World wide DG penetration in the grid is on the rising. Deregulation of electricity market may contribute to rising penetration level of DG from renewable energy sources (wind, solar, biomass, etc.) in the near future [4]. From the perspective of environmental protection,DG from renewable energy sources is of great importance, as they minimize harmful emissions. As most of the DG systems are interfaced to the grid through power electronic interface, hence injection of additional higher frequency harmonics in the system is obvious. Therefore, additional grid integration problems are equally worrying from electrical pollution point of view if not attended properly. Furthermore, variable wind speed, variation in solar and tidal power, etc., are uncontrollable parameters which are bound to affect the generated power quality. Research is being carried out to integrate active filtering i.e., series and shunt active filters options into the integrating power electronic converters themselves [2,5], but they need to be case specific. From the perspective of sensitive non-linear loads in the distribution system, a common platform of PQ needs to be ensured; as PQ varies due to various types of sources of generation. Hence, suitable power conditioning interfaces are recommended for sensitive non-linear loads. These type of loads primarily include production industries (like automotive plants, paper mills, chemical and pharmaceutical industries, semiconductor manufacturing plants, etc.), and critical service providers like medical centres, airports, broadcasting centres, etc. Typical grid integration problems associate with voltage and frequency compatibility and requirement of active and reactive power. A power conditioning equipment can act as an interface between the grid and sensitive loads, so that the load can remain insensitive to the variation of power quality from the utility. Unified power quality conditioner (UPQC) happens to be the most comprehensive power conditioning equipment that can mitigate both voltage and current quality problems [6,7]. Functionally UPQC is a combination of series and shunt active filter, for maintaining desired quality of both the incoming voltage and current. But its coordinated control gives it unique feature in terms of shared responsibility and reduced VA rating as compared to individual dynamic voltage restorer (DVR) [8,11] or active power filter (APF) [6,9,11]. The control scheme described in this paper have current control strategy, based on hysteresis current control. The series voltage compensation can be performed in a number of ways, which are non unique. The insight gained could be useful for design of control strategy of UPQC for various applications.

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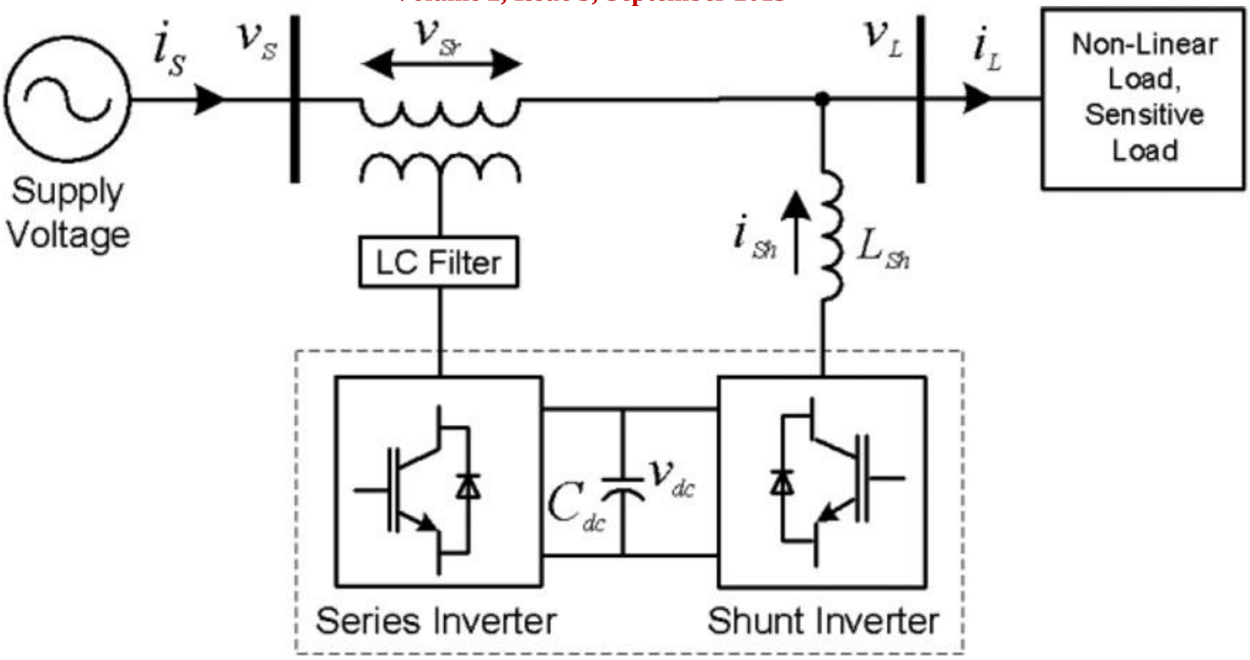

Fig 1: UPQC General block diagram representation.

II. UPQC TOPOLOGY AND POWER FLOW STRATEGY

A UPQC consists of voltage source inverters connected in cascade as shown in Fig. 1. Inverter 1 (Series Inverter SE) is connected in series with the incoming utility supply through a low pass filter and a voltage injecting transformer. Inverter 2 (Shunt Inverter SH) is connected in parallel with the sensitive load, whose power quality needs to be strictly maintained. The main purpose of SH is to provide required VAR support to the load, and to suppress the load current harmonics from flowing towards the utility and it is operated in current controlled mode. SE is responsible for compensating the deficiency in voltage quality of the incoming supply, such that the load end voltage remains insensitive to the variation of utility supply. The UPQC discussed in this paper have same power circuit configuration. But as the control strategies are different in SE, the individual loading of SH and SE varies and the overall rating of the UPQC differs, which is the thrust of this paper and is explained in the subsequent sections. The UPQC also has a few other important components that are essential for interfacing of the same. (Series Inverter SEI) is connected in series with the incoming utility supply through a low pass filter and a voltage injecting transformer. Inverter 2 (Shunt Inverter SH) is connected in parallel with the sensitive load, whose power quality needs to be strictly maintained. The main purpose of SH is to provide required VAR support to the load, and to suppress the load current harmonics from flowing towards the utility and it is operated in current controlled mode. SE is responsible for compensating the deficiency in voltage quality of the incoming supply, such that the load end voltage remains insensitive to the variation of utility supply. The SE needs to be connected to the supply side through a series injection transformer and a low pass filter (LPF), to eliminate the high switching frequency ripple of the inverter. The filter may inject some phase shift, which could be load dependent, but suitable feedback control is to be designed to dynamically adjust the shift, which is described in the control section. The active power flow through the UPQC originates from the utility, as it is the only source of active power. But the reactive power and load harmonic currents are shared between the SH and loads primarily. Therefore, SH provides harmonic isolation to the utility. SE may also share some VAR depending upon the control, described further in the subsequent section.

III. POWER QUALITY PROBLEMS

Power quality is very important term that embraces all aspects associated with amplitude, phase and frequency of the voltage and current waveform existing in a power circuit. Any problem manifested in voltage, current or frequency deviation that results in failure of the customer equipment is known as power quality problem. The increasing number of power electronics based equipment has produced a significant impact on the quality of

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electric power supply. Low quality power affects electricity consumers in many ways. The lack of quality power can cause loss of production, damage of equipment or appliances, increased power losses, interference with communication lines and so forth. Therefore, it is obvious to maintain high standards of power quality [3]. The major types of power quality problems are: Interruption, Voltage-sag, Voltage-swell, Distortion, and Harmonics.

A. Interruption

An interruption is defined (Fig 2) as complete loss of supply voltage or load current. Interruptions can be the result of power system faults, equipment failures, and control malfunction. There are three types of interruptions which are characterized by their duration:

1. The momentary interruption is defined as the complete loss of supply voltage or load current having a duration between 0.5 cycles & 3 sec.
2. The temporary interruption is the complete loss lasting between 3 seconds and 1 minute,
3. The long term interruption is an interruption which has a duration of more than 1 minute.

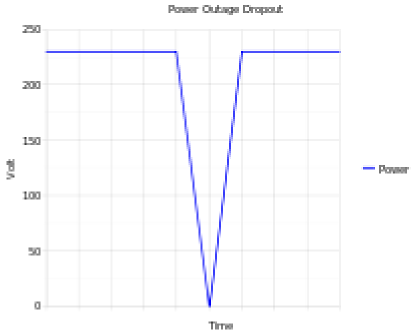

Fig 2 : Power Interruption

B. Voltage Sags

Voltage sags (dips) are short-duration reductions in rms voltage caused by short-duration increases of the current. The most common causes of the over currents leading to voltage sags are motor starting, transformer energizing and faults. A sag is decrease in voltage at the power frequency for duration from 0.5 cycle to 1min. Voltage sags are usually associated with system faults but can also caused by energisation of heavy loads at starting of large motors (Fig 3).

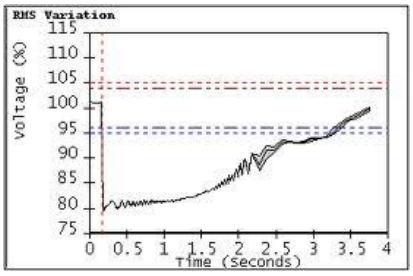

Fig 3: Voltage Sag

C. Voltage Swells

Voltage swell is an rms increase in the ac voltage, at the power frequency, for duration from a half cycle to a few seconds. As shown in Fig 4.,Voltage can rise above normal level for several cycles to seconds. Voltage swells will normally cause damage to lighting, motor and electronic loads and will also cause shutdown to equipment. The severity of voltage swell during a fault condition is a function of fault location, system impedance and grounding.

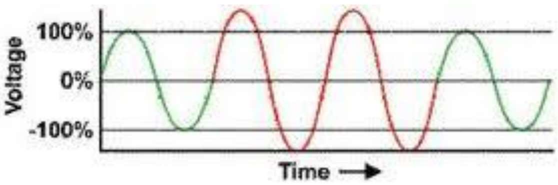

Fig 4: Voltage Swells

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D. Waveform Distortion

Voltage or current waveforms assume non sinusoidal shape called distorted wave as shown in Fig 5. When a waveform is identical from one cycle to the next, it can be represented as a sum of pure sine waves in which the frequency of each sinusoid is an integer multiple of the fundamental frequency of the distorted wave.

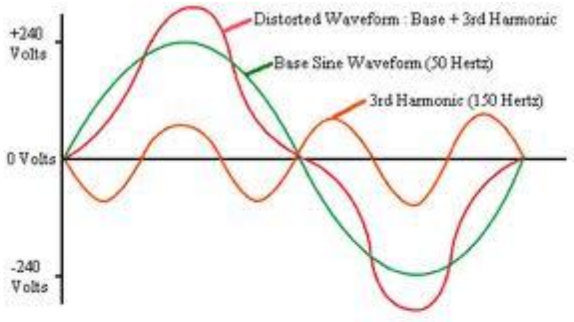

Fig 5 : Waveform Distortion

E. Harmonics

Harmonics are sinusoidal voltages or current having frequency that are integer multiples of the fundamental frequency. Here, 3rd harmonics is seen in the figure 6.

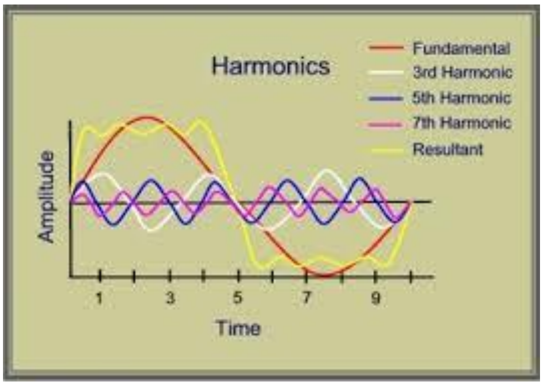

Fig 6: Harmonics

IV. CONTROL STRATEGY OF UPQC

Control strategy play very important role in system's performance. The control strategy of UPQC may be implemented in three stages:

i. Voltage and current signals are sensed

ii. Compensating commands in terms of voltage and current levels are derived

iii.The gating signals for semiconductor switches of UPQC are generated using PWM, hysteresis or fuzzy logic based control techniques

In the first stage voltage signals are sensed using power transformer or voltage sensor and current signals are sensed using current transformer or current sensor [7].

In second stage derivation of compensating commands are mainly based on two types of domain Methods: (1) Frequency domain methods (2) Time domain method.

Frequency domain methods: which is based on the Fast Fourier Transform (FFT) of distorted voltage or current signals to extract compensating commands. This FFT are not popular because of large computation, time and delay. Control methods of UPQC in time-domain are based on instantaneous derivation of compensating commands in form of either voltage or current signals. There are mainly two widely used time domain control techniques of UPQC are:

• The instantaneous active and reactive power or p-q theory, and

• Synchronous reference frame method or d-q theory.

In *p-q* theory instantaneous active and reactive powers are computed, while, the *d-q* theory deals

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With the current independent of the supply voltage. Both methods transforms voltages and currents from abc frame to stationary reference frame (p-q theory) or synchronously rotating frame (d-q theory) to separate the fundamental and harmonic quantities [8]. In third stage the gating signals for semiconductor switches of UPQC based on derive compensating commands in terms of voltage or current. Then, these compensating commands are given to PWM, hysteresis or fuzzy logic based control techniques.

V. CONCLUSION

The power quality problems in distribution systems are not new but customer awareness of these problems increased recently. It is very difficult to maintain electric power quality at acceptable limits. One modern and very promising solution that deals with both load current and supply voltage imperfections is the Unified Power Quality Conditioner (UPQC). This paper presented review on the UPQC to enhance the electric power quality at distribution level. The UPQC is able to compensate supply voltage power quality issues such as, sags, swells, unbalance, flicker, harmonics, and for load current power quality problems such as, harmonics, unbalance, reactive current and neutral current. In this paper several UPQC configurations have been discussed. Among all these configurations, UPQC - DG could be the most interesting topology for a renewable energy based power system.

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