RESEARCH ARTICLE   OPEN ACCESS

Improvement of Power Quality by using PWM Converter Technique

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Abstract— The aim of this paper is to improve the power quality by using PWM converter technique of harmonics elimination. This paper gives a wide background of power quality in terms of its issues, definitions, causes and effects. Power quality is a term used to describe electric power that motivates electrical load and the loads ability to function properly with that electrical power. The different configuration PWM technique is used for harmonics reduction & improvement of fundamental peak voltage. In addition an exhaustive comparison of all configurations is made in term of FFT & dominating harmonics component. The PWM technique can be simply extended to allow harmonics minimization & harmonics Elimination.

Index Terms— Power Quality, Harmonics, PWM AC-AC Converter techniques.

I. INTRODUCTION

Power Quality is a terminology used to describe electric power that motivates an electrical load and the load's ability to function properly with that electric power. With the improper power, an electrical device (or load) may malfunction and fail prematurely or not operate at all. There are many path in which electric power can be of poor quality and many more causes of such poor quality power.

Power quality is a term that mean different to different people. Institute of Electrical and electrical engineers (IEEE) standard IEEE 1100 defines power quality "as the concept of powering and grounding sensitive electronic equipment in a manner suitable for the equipment". In a simpler words PQ is a set of electrical boundaries that allows a part of equipment to work in an intended manner without loss of performance or life expectancy [4].

Power quality is one of major concerns in the present era. It has become important, extremely, with the introduction of sophisticated devices, whose performance is very thoughtful to the quality of power supply. Power quality problem is occurs manifested as a non-standard voltage and current or frequency the results are failure with the end use equipment. One of the wide problems dealt here is the voltage sag.

Power quality issues and resulting problems are consequences of the highly use of solid state Switching devices, non-linear and power electronically switched loads, electronic type loads .The Advent and wide spread of high power semiconductor switches at utilization, distribution and Transmission lines have non sinusoidal currents [1]. The electronic type load causes voltage Distortions, harmonics and distortion. Power quality problems can cause system equipment mal Function, computer data loss and memory mal Function of the sensitive equipment such as computer, programmable logic devices [PLC] controls, and protection and relaying equipment [1]. Voltage sag and swell are most wide spread power quality issue affecting distribution systems, especially industries, where involved losses can reach very high values. Short and shallow voltage sag can produce dropout of a whole industry. In common, it is possible to consider voltage sag and swell as the origin of 10 to 90% power quality problems [2]. The main causes of voltage sag are faults and short circuit, lightning strokes, inrush currents and swell can occur due to a single line-to ground fault on the system, which can also result in a temporary voltage rise on the unfaulted phases [3].

II. TYPES OF POWER QUALITY PROBLEMS

Different people relate different problems using dissimilar terms and definition. Some power quality problems will be defined in this section.

A. Voltage sags (or dips)

Voltage sag is a short duration reduction in rms voltage. A decrease of the normal voltage level between 10 and 90% of the nominal rms voltage at the power frequency, for durations of 0.5 cycle to 1 minute.

I) Causes: Whenever a load end draws a heavy current suddenly. That's why it is associated with faults on the transmission or distribution network, faults in consumer's installation, sudden connection of heavy loads and start-up of large motors.

II) Consequences: Malfunction of microprocessor-based control systems (PCs, PLCs, etc), that may cause false tripping of contactors and electromechanical relay [4].

Fig.1. Voltage Sag

B. Long interruptions

Total interruption of electrical supply is in the duration of greater than 1 to 2 seconds.

I) Causes: Equipment failure in the power system network, storms and objects (trees, cars, etc) striking lines or poles, fire, human error, bad coordination or failure of protection devices.

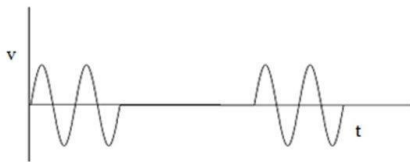*II) Consequences*: Stoppage of all equipment.

Fig.2. Long interruptions

C. Voltage spike

It is the very fast variation of the voltage for durations from a several microseconds to few milliseconds. These variations may reach thousands of volts, even in low voltage [4].

I) Causes: Lightning which is a natural cause, switching of lines or power factor correction capacitors, sudden removal of heavy loads.

II) Consequences: Damage of components (particularly electronic components) and of insulation materials, data processing errors, electromagnetic interference or information loss.
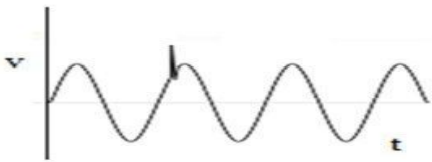

Fig.3. Voltage Spike

D. Voltage swell

It is the Momentary increase of the voltage, at the power frequency, outside the normal tolerances, with duration of more than one cycle and typically less than a few seconds.

I) Causes: Start/stop of heavy loads, badly dimensioned power sources, badly regulated transformers (mainly during off-peak hours).

II) Consequences: flickering of lighting and screens, data loss, stoppage or damage of sensitive equipment, if the voltage values are too high.
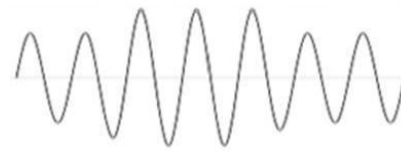

Fig.4. Voltage swell

E. Harmonic distortion

These are periodically distorted voltage or current waveform. The waveform corresponds to the sum of different sine-waves with different magnitude and phase, having frequencies that are multiples of power-system frequency.

I) Causes: Arc furnaces electric machines working above the magnetic saturation, welding machines, rectifiers, and DC brush motors. All non-linear loads, such as power electronics equipment including ASDs, switched mode power supplies, high efficiency lighting and data processing equipments.

II) Consequences: Probability of occurrence severe resonance increases, neutral overloading in 3-phase systems, overheating of all cables and equipment, loss of efficiency in electric machines, electromagnetic interference with communication systems, errors in measures when using average reading meters, nuisance tripping of thermal protections ,can induce visual flicker in arc lighting.
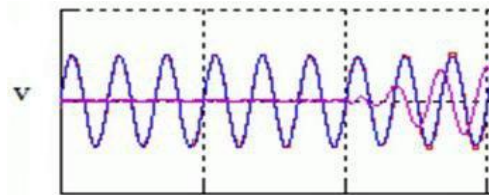

Fig.5. Harmonic distortion

F. Voltage fluctuation

It is a series of random voltage variations or systematic variations of voltage envelop but the variation does not exceeds the voltage ranges of 0.9 to 1.1 p.u. Oscillation of voltage value and amplitude modulated by a signal with frequency of 0 to 30 Hz.

I) Causes: Frequent start/stop of electric motors (for instance elevators), oscillating loads, arc furnaces.

II) Consequences: The most perceptible consequence is the flickering of lighting and screens, giving the impression of

unsteadiness of visual perception and the rest effects are similar to under voltages.
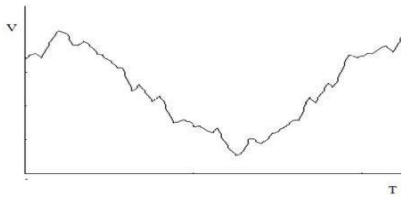

Fig.6. Voltage fluctuation

G. Noise

It is the Superimposing of high frequency unwanted signals on the waveform of the power-system frequency.
Causes: Electromagnetic interferences provoked by microwaves, television diffusion, and radiation due to welding machines, arc furnaces, and electronic equipment. Improper grounding may also be a cause.
Consequences: Disturbances on sensitive electronic equipment, usually not destructive. May cause some data related errors.

H. Voltage unbalance

A maximum voltage variation in a three-phase system in which three voltage magnitudes and the phase angle differences between them is not equal.
Causes: Incorrect distribution of all single-phase loads by the three phases of the system (this may be also due to a fault). Large single-phase loads (induction furnaces, traction loads)
Consequences: It mostly affects three-phase induction machines. Unbalanced systems imply the existence of a negative sequence that is harmful to all three phase loads. It has found that among all the PQ issues voltage sag and swell are the most occurring problems at the distribution end [1]-[2]-[3],as shown in fig.7.
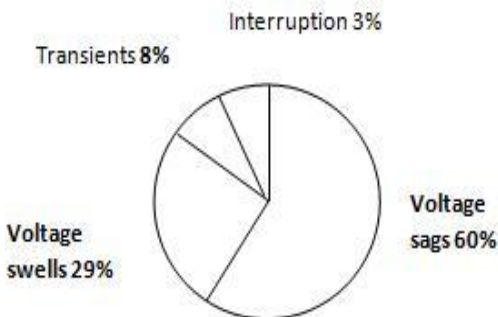

Fig.7. Showing the occurring percentage of various PQ issues

III. INTRODUCTION TO HARMONICS

Harmonics has been more of an issue nowadays due to the increased usage of non-linear loads which are the cause of harmonics. The non-linear loads here refer to loads which current is not proportional to the applied voltage. Fig 8 shows a comparison of linear and non-linear load voltage-current characteristics. It must be noted that different non-linear loads will have different voltage-current characteristics. Sometimes a slight increase voltage can cause the current to double.

Fig.8. Comparison of linear and non-linear VI characteristics

Any periodic, distorted waveform can be expressed as a sum of pure sine waves in which the frequency of each sinusoid is an integer multiple of the fundamental frequency (50Hz).
This multiple is called harmonics of the fundamental. Harmonics are normally analyzed up to the 40th multiple or component but the few odd, earlier harmonic components (3rd, 5th, 7th) are the ones that have significant effect on the system.

A Voltage and current Distortion

Non-linear loads are the sources of harmonic current causing distorted current waveforms. Voltage distortion is the result of distorted currents passing through the linear, series impedance of the power delivery system. Therefore, it is always the current distortion that results in voltage distortion. Nevertheless, it must be noted that loads have no control over the voltage distortion.
The same load in two different locations on the power system will result in two different voltage distortion values.

B. Even Harmonics

Even harmonics (2nd, 4th & 6th) are less likely to occur at levels detrimental to electrical system. This is because non-linear loads normally generate odd harmonics rather than even harmonics. Furthermore, when both the positive and negative half cycles of a waveform are similar in shape, the Fourier series contain only odd harmonics.

C. Odd Harmonics

Odd harmonics (3rd, 5th & 7th) are more common in power systems and are the ones which lead to severe consequences if they are not controlled. Each odd harmonic is associated with one of the sequence component (positive, negative or zero). The phase sequence is very important because it determines the effect of the harmonics on the operation of the electric equipment.

TABLE I: Harmonics and their corresponding sequence component

Harmonics	Sequence component
1	positive
3	zero
5	Negative
7	positive
9	zero
11	Negative
13	positive
15	zero
17	Negative
Etc	

D. Some other harmonics

Positive sequence harmonics (1st, 7th, 13th, and 19th) consist of three phasors, each equal in magnitude and are displaced from each by 120 degrees. They have the same phase sequence as phasors representing the nominal current of voltage. The presence of harmonic can accelerate a motor which may cause them to overwork.

Negative sequence harmonics (5th, 11th, and 17th) also consist of three phasors with equal magnitude and are separated from each other by a 120 degree phase displacement. Nevertheless, they have phase sequence opposite to phasors to phasors representing the nominal current of voltage, this negative direction of rotation of the motor causing it to decelerate.

Zero sequence harmonics (3th, 9th, and 15th) are the worst of the lot and are often referred to as triple harmonics. They consist of three phasors of equal magnitude but have zero phase displacement from each other, since they are in the same direction; they result in amplitude that is three times any of the phasors when combined in the neutral wire of an electrical system causing overheating.

IV. PWM CONVERTER TECHNIQUES

Because of advances in solid state power devices and Microprocessors, switching power converters are used in more and more modern motor drives to convert and deliver the required energy to the motor. The energy that a switching power converter delivers to a motor is controlled by Pulse Width Modulated (PWM) signals applied to the gates of the power transistors [7]. PWM signals are pulse trains with fixed frequency and magnitude and variable pulse width. There is one pulse of fixed magnitude in every PWM period. However, the width of the pulses changes from pulse to pulse according to a modulating signal. When a PWM signal is applied to the gate of a power transistor, it causes the turn on and turn off intervals of the transistor to change from one PWM period to another PWM period according to the same modulating signal. The frequency of a PWM signal must be much higher than that of the modulating signal, the fundamental frequency, such

that the energy delivered to the motor and its load depends mostly on the modulating signal.

IV. RESULTS

First, the fundamental voltage and its spectrum without harmonics have been found out by using MATLAB (as shown in Fig.9 and Fig.10). Secondly, the resultant voltage and its spectrum in presence of 7th harmonic have been determined by FFT analysis using MATLAB (as shown in Fig.11 and Fig. 12).
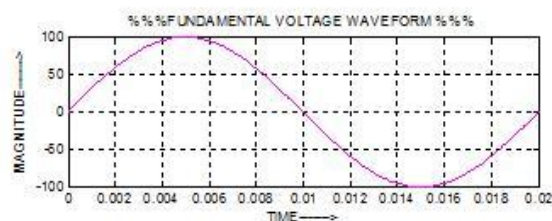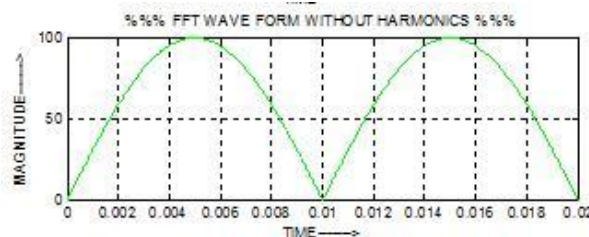

Fig.9. Fundamental Voltage Waveform
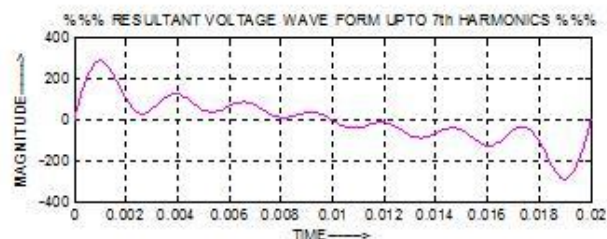

Fig.10. FFT waveform without harmonics

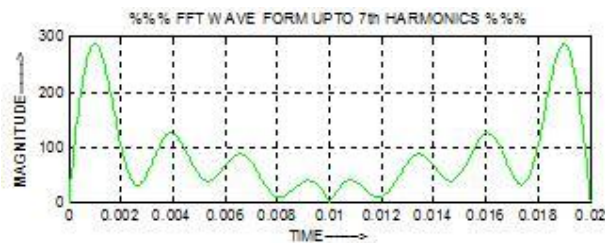Fig.11. Resultant waveform upto 7th harmonics

Fig.12. FFT waveform upto 7th harmonics

V. CONCLUSION

This paper gives a wide background of power quality in terms of its issues, definitions, causes, effects. Harmonic distortions levels in general are within limits in all areas except for one residential and one commercial area. In most areas, the 3rd and 5th harmonics are the highest suggesting heavy usage of computers and pulsed converters respectively. Specific power quality causes will be identified and its effect will be investigated. From there, the best and cost effective mitigation means can be proposed. This type of analysis will be more useful as the end result motivates the improvement of the power quality in that particular area. Some problems can also be improved, solved and mitigated by using some useful software tools.

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