Study of Power Quality Disturbance for Restructuring of Power Systems

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Abstract— **In recent years, the traditional power systems' structures have been changed, and the concern over power quality has increased due to the new generation of load equipments. This equipments has been fully automated electronically, so it can be highly sensitive to any power quality disturbances. Indeed, power quality disturbances may cause malfunctions in the equipment, which leads to higher production costs due to decreased production efficiency. Moreover, the electronic converters in these loads produce harmonic currents that increase current distortion. Eventually, the impact of electronic converters on power quality will be increased proportional to the converters lifetime; therefore, maintaining power quality levels above specific baselines will be an essential requirement in future decades.**

Index Terms— **production efficiency, power quality, harmonic currents.**

I. INTRODUCTION

Many of the loads installed in present-day power systems are harmonic current generators. Combined with the impedance of the electrical system, the loads also produce harmonic voltages. The nonlinear loads may be viewed as both harmonic current generators and harmonic voltage generators. Until 1970s, speed control of AC motors was primarily achieved using belts and pulleys.

Now, adjustable speed drives (ASDs) perform speed control functions very efficiently. ASDs are generators of large harmonic currents. Fluorescent lights uses less electrical energy for the same light output as incandescent lighting but produce substantial harmonic currents in the process. Due to increase of personal computer use it has resulted in harmonic current in commercial buildings. Harmonic distortion is no longer a phenomenon confined to industrial equipment and processes, where the first power quality concerns developed. Uninterruptible power supplies (UPSs), personal computers (PCs), and electronic and entertaining devices proliferate nowadays in commercial and residential installations. These special kinds of loads represent formidable sources of harmonic currents and they increase with the expanding use of video recorders, digital clocks, and other sensitive electronic equipment.

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II. BACKGROUND

The first demonstration of electric light in Calcutta was conducted on 24 July 1879 by P W Fleury & Co. On 7 January 1897, Kilburn & Co secured the Calcutta electric lighting licence as agents of the Indian Electric Co, which was registered in London on 15 January 1897. A month later, the company was renamed the Calcutta Electric Supply Corporation. The control of the company was transferred from London to Calcutta only in 1970.
Enthused by the success of electricity in Calcutta, power was thereafter introduced in Bombay. Mumbai saw electric lighting demonstration for the first time in 1882 at Crawford Market, and Bombay Electric Supply & Tramways Company (B.E.S.T.) set up a generating station in 1905 to provide electricity for the tramway. The first hydroelectric installation in India was installed near a tea estate at Sidrapong for the Darjeeling Municipality in 1897. The first electric train ran between Bombay's Victoria Terminus and Kurla along the Harbour Line, in 1925. In 1931, electrification of the meter gauge track between Madras Beach and Tambaram was started.

III. LITERATURE SURVEY

A new recursive algorithm for autoregressive (AR) spectral estimation was introduced by Marple (1980) based on the least squares solution for the AR parameters using forward and backward linear prediction. The algorithm had computational complexity proportional to the process order squared, comparable to that of the popular Burg algorithm. The computational efficiency was obtained by exploiting the structure of the least squares normal matrix equation, which may be decomposed into products of Toeplitz matrices.AR spectra generated by the new algorithm had improved performance over AR spectra generated by the Burg algorithm. These improvements include less bias in the frequency estimate of spectral components, reduced variance in frequency estimates over an ensemble of spectra, and absence of observed spectral line splitting.
Prony analysis by Hauer,et al.(1990),extends Fourier analysis by directly estimating the frequency, damping, strength, and relative phase of modal components present in a given signal. The ability to extract such information from transient stability program simulations and from large-scale system tests of disturbances would be quite valuable to power system engineers.
Moo et al.(1995)presents an enhanced measurement scheme on the harmonics in power system voltages and currents which was not limited to stationary waveforms, but can also estimate harmonics in waveforms with time-varying amplitudes.It starts with a review of the common techniques for harmonics measurement based on the Fast Fourier

transform (FFT).The major pitfalls in the common FFT application techniques are described and the concepts of a new scheme for reducing the picket-fence effect are introduced. The proposed scheme was based on Parseval's relation and the energy concept which defines a "group harmonic" identification algorithm for the estimation of the energy distribution in the harmonics of time-varying waveforms.

Prony's method has been proposed in order to improve the monitoring of electrical machines. Costa et al. (2005) showed that the method was efficient to track frequency deviations. The proposed method was advantageous over the method proposed in Costa et al. (2004) because the former does not rely on the previous knowledge of fundamental frequency. It has also been showed that the quantization can deeply affect the spectrum of the analyzed signals.

Feilat (2006) presents an efficient method for the detection of the instantaneous flicker level. The technique was based on extracting the magnitudes, frequencies, and phase angles of all frequency components of the voltage envelope using Prony analysis. By reconstructing the voltage waveform as linear combination of sinusoids, Hilbert transform can be applied to the predicted signal to develop the envelope of the voltage waveform.

Two cases of flicker with single low frequency and wide band frequency interharmonics are investigated using simulated voltage signals.

Costa et al.(2007)proposes a technique for harmonic analysis in electrical power systems. At the end, a frequency estimator, the Prony's method, has been matched to a Kalman filter. In the proposed technique, the sinusoid amplitudes of electrical power signals are estimated by the Kalman filter. The Kalman filter regressors are built up using the frequencies estimated by the Prony's method. The technique have been tested to both synthetical and experimental signals.

Many algorithms have been proposed for harmonic estimation in a power system. Most of them deal with this estimation as a totally nonlinear problem. Consequently, these methods either converge slowly, like GA algorithm or need accurate parameter adjustment to track dynamic and abrupt changes of harmonics amplitudes, like adaptive Kalman filter (KF). A novel hybrid approach, based on the decomposition of the problem into a linear and a nonlinear problem, was proposed by Joorabian et al. (2009),a linear estimator, i.e., Least Squares (LS), which is simple, fast and does not need any parameter tuning to follow harmonics amplitude changes, is used for amplitude estimation and an adaptive linear combiner called 'Adaline', which was very fast and very simple and was used to estimate phases of harmonics.

An improvement in convergence and processing time is achieved using this algorithm.The one-dimension frequency analysis based on DFT (Discrete FT) is sufficient in many cases in detecting power disturbances and evaluating power quality (PQ). The character of the signal, using time-frequency analyses are performed by Szmajda et al.(2010). The most common known time-frequency representations (TFR) are spectrogram (SPEC) and Gabor Transform (GT). However, the method has a relatively low time-frequency resolution. The other TFR: Discreet Dyadic Wavelet Transform (DDWT), Smoothed Pseudo Wigner-Ville Distribution (SPWVD) and new Gabor-Wigner Transform (GWT) are described. The main features of the transforms, on the basis of testing signals, was presented.

IV. POWER QUALITY

Many sources in the literature have addressed the importance of power quality; however, there is no single agreed definition for the term "power quality", and various sources have different and sometimes inconsistent definitions for it. "power quality" is sometimes used loosely to express different meanings: "supply reliability", "service quality", "voltage quality", and "current quality" . The multiple meanings of power quality are the result of defining power quality from different perspectives. Power quality, in generation, relates to the ability to generate electric power at a specific frequency, 50 or 60 Hz, with very little variation; while power quality in transmission can be referred to as the voltage quality. At the distribution level, power quality can be a combination of voltage quality and current quality. From the marketing point of view, electricity is a product and the power quality is the index of the product quality.

The Institute of Electrical and Electronics Engineers (IEEE) defines power quality in the IEEE standard 1159-1995 as: "power quality is the concept of powering and grounding sensitive equipment in a matter that is suitable to the operation of that equipment". This definition limits the term power quality to only sensitive equipment, and this definition narrows down the impact of harmonic currents to consider it as affecting only that equipment. The International Electro-technical Commission (IEC) states in IEC 61000-4-30 that "Characteristics of the electricity at a given point on an electrical system, evaluated against a set of reference technical parameters." The definition evaluate power quality as depending on its measurement and quantity from a power system point of view. Heydt, in Electric Power Quality (1994), defines power quality as "power quality is the measure, analysis, and improvement of bus voltage, usually a load bus voltage, to maintained that voltage to be a sinusoid at rated voltage and frequency." It is cleared that Heydt defined power quality from the utility's point of view; the definition confines the eaning of power quality only to voltage quality. Indeed, before deregulation took place, the electrical systems structure was vertical, and the electrical utility was the only entity taking care of power quality problems. The electrical utility can only control the voltage and the frequency; however, it has no control over the current that particular loads might draw. Thus, voltage quality problems were the focus at that time, or in other words, power quality problems were handled as voltage quality problems.

The increasing of nonlinear and sensitive loads in the distribution system causes noticeable current deviations that lead to power quality disturbances; therefore, power quality problems are no longer considered as only voltage quality problems. Dugan et al.define power quality problems in as "any power problem manifested in voltage, current, or frequency deviations that results in failure or disoperation of customer equipments." This definition covers the possible reasons that can cause power quality disturbances; however, power quality disturbances can result from more than one source. Because of the close relationship between voltage and current in any practical power system, any deviation in the current will affect the voltage and vice versa. Bollen defines power quality in his book Understanding Power Quality Problems as "power quality is the combination of voltage quality and current quality. Thus power quality is concerned with deviations of voltage and/or current from the ideal." So, any deviations of voltage or current from the ideal is a power quality disturbance.

It is hard to distinguish between voltage disturbances and current disturbances due to the close relationship between the two, and there is no common reference point that the disturbance can be seen from. For instance, starting a large induction motor leads to an over current; this is a current disturbance from the network perspective. However, the neighboring loads can suffer from a voltage dip, which is considered a voltage disturbance from another perspective. This action, starting an induction motor, leads to a disturbance that can be looked at from different perspectives: as a voltage disturbance from one point and a current disturbance from the other. The distinguishing complexity makes using the term "power quality disturbance" more preferable in general; however, the underlying cause of a disturbance is still either a voltage deviation or a current deviation.

However, the typical power quality disturbance classification is usually based on voltage magnitude and frequency variation for different time durations. The typical classification has been specified by many sources, such as IEEE and IEC. The classification of power quality disturbances can help in understanding power quality phenomena, and it is considered the base for monitoring and mitigating power quality problems.

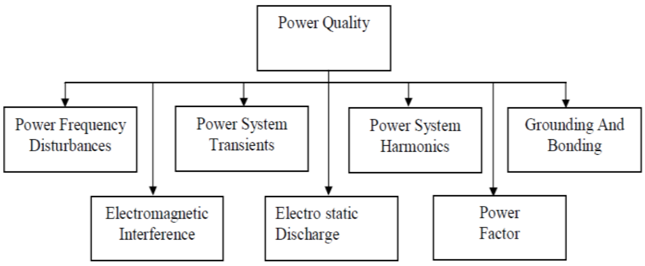

Fig. 1: Power quality concerns.

V. POWER QUALITY DISTURBANCES CLASSIFICATION

In order to be able to classify different types of power quality disturbances, the characteristics of each type must be known. In general, power quality disturbances are classified into two types: steady state and non-steady state. This classification is done in terms of the frequency components which appear in the voltage signals during the disturbance, the duration of the disturbance, and the typical voltage magnitude. These disturbances are mainly caused by :

- External factors to the power system: for example, lightning strikes cause impulsive transients of large magnitude.
- Switching actions in the system: a typical example is capacitor switching, which causes oscillatory transients.
- Faults which can be caused, for example, by lightning (on overhead lines) or insulation failure (in cables). Voltage dips and interruptions are disturbances related to faults.
- Loads which use power electronics and introduce harmonics to the network.

Waveform Distortion

- This is a steady-state deviation from an ideal sine wave of power frequency, principally characterized by the spectral content of the deviation. There are five types of waveform distortion:

- **DC Offset**
  DC Offset is defined as the presence of a DC voltage or current in an AC power system. This phenomenon can occur as the result of a geomagnetic disturbance or be due to the effect of half-wave rectification. Incandescent light bulb life extenders, for example, may consist of diodes that reduce the RMS voltage supplied to the light bulb by half-wave rectification. Direct current in alternating current networks can be detrimental due to an increase in transformer saturation, additional stressing of insulation, and other adverse effects.

- **Harmonics**

Harmonics are sinusoidal voltages or currents having frequencies that are integer multiples of the frequency at which the supply system is designed to operate. Harmonics combined with the fundamental voltage or current can produce waveform distortion. Harmonic distortion exists due to nonlinear characteristics of devices and loads on the power system. Voltage distortion results as these currents cause nonlinear voltage drops across the system impedance. Harmonic distortion is a growing concern for many customers and for the overall power system due to increasing application of power electronics equipment. Harmonic distortion levels can be found throughout the complete harmonic spectrum, with the magnitudes of each individual harmonic component varying inversely with their position in the spectrum. Furthermore, the phase angle of each component is unique unto itself. It is also common to use a single quantity, the total harmonic distortion (THD), as a measure of the magnitude of harmonic distortion.

- **Inter-harmonics**

Inter-harmonics are defined as voltages or currents having frequency components that are not multiples of the frequency at which the supply system is designed to operate. Interharmonics can be found in networks of all voltage classes. They can appear as discrete frequencies or as a wide-band spectrum. The main sources of inter-harmonic waveform distortion are static frequency converters, cyclo-converters, induction motors, and arcing devices.

VI. NOTCHING

Notching is a periodic voltage disturbance caused by the normal operation of power electronics devices when current is commutated from one phase to another. Voltage notching represents a special case that falls between transients and harmonic distortion. Three-phase converters that produce continuous DC current are the most common cause of voltage notching.

VII. NOISE

Noise is unwanted electrical signals with broadband spectral content lower than 200 kHz superimposed upon the power system voltage or current in phase conductors, or found on neutral conductors or signal lines. Noises in power systems can be caused by power electronics devices, control circuits, arcing equipments, loads with solid-state rectifiers, and switching power supplies. Noises problem are often exacerbated by improper grounding. The problem can be mitigated by using filters, isolation transformers, and certain line conditioners.

CONCLUSION

The restructuring of power systems raises the concerns over power quality problems resulting from harmonics distortion. Electrical power organizations have proposed some standards in order to protect their electrical power systems from the consequences of harmonics pollution. Due to the highly complex interconnected networks in the distribution systems, identifying the harmonics pollution can be achieved, The problem of precise estimation of fundamental harmonics frequency is very important used in power quality monitoring systems. Poor quality can be defined as any event related to the electrical network that results in a financial losses. For precision short time analysis of power waveform fluctuations the least square (LS) Prony's method can be used , which enables in estimation of fundamental harmonics frequency. The LS Prony's method is based on the representation of a signal as a linear combination of exponential functions.

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