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INVESTIGATIONS ON POWER QUALITY IMPROVEMENT IN DISTRIBUTION LINES.

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Abstract:. *In power quality problems accurse many types of disturbance in voltage, current or frequency failure in distribution networks, sensitive industrial loads. A large number of single-phase linear and nonlinear loads may be supplied from three phase ac mains with neutral conductor. They cause excessive neutral current, harmonics and reactive power burden and unbalance. In a three phase system voltage sag by nature is three phase phenomena, which effect phase -to -phase voltages and phase-to-ground voltages or both. Voltage sag is the most important power quality problems faced by many industries and utilities. It contributes more than 80% of power quality (PQ) problems that exist in power systems. Voltage dips are one of the most happening power quality problems. The increased sensitivity of the vast majority of processes like (industrial, services and even residential) to PQ problems turns the availability of electric power with quality a crucial factor for competitiveness in every sector of activity. In this paper, various power quality issues are investigated in distribution lines to improve the power quality.*

Keywords: *Power quality, phase-phase voltages, voltage sag, voltage dip, sensitivity.*

I . INTRODUCTION

In recent years, Power engineers are increasingly concerned over the quality of the electrical power. Recently in modern industries, load equipment uses electronic controllers which are sensitive to poor voltage quality and will shut down if the supply voltage is excessive. Along with advancement in technology, the worldwide economy organization has evolved towards globalization and the profit margins of many activities tend to decrease. The increased sensitivity of the vast majority of processes like industrial, services and even residential to PQ problems turns the availability of electric power with quality a crucial factor for competitiveness in every sector of activity. Any electrical power system consists of wide range of electrical, electronic and power electronic equipment in commercial and industrial applications. The quality of the power is effected by many factors like harmonic contamination, arc in arc furnace, sag and swell due to the increment of non-linear loads such as large thyristor power converters, rectifiers, voltage and current flickering, arc in arc furnaces and switching of loads respectively which also affects the sensitive loads to be fed from the system The non-stop process industry and the information technology services are most significant area. Waveform distortion and voltage unbalance have become very important factors that essentially decrease the efficiency of both power supply systems and the consumers connected to them. Direct measurement in the network nodes is required in order to get valid information on these power quality indices. Many surveys have shown that most customer power quality problems originate within the customer facility. It is clear that monitoring is essential for both power suppliers and users to ensure optimal power system performance and effective energy management. Moreover, it provides information about power flow and demand and helps to identify the cause of power system disturbances. A measurement system was developed to gain knowledge about long-term power quality behavior within a studied distribution power system. The system was used to acquire the load data within the distribution system and, above all, to gather the practical information which was then used to compare it with the analytical considerations. Uncertainties have existed in power systems from the beginning of the power industry. Uncertainties from demand and generator availability have been studied in reliability assessment for decades. Among the sources of uncertainties, power system load plays an important role. Power system simulation is the most important tool guiding the operation and control of a power grid. The accuracy of the power system simulation relies heavily on the model reliability. Among all the components in a power system, the load model is one of the least well known elements.

II. ELECTROMAGNETIC PHENOMENA AND POWER QUALITY ISSUES.

The power quality problems are primarily due to electromagnetic disturbances which are broadly classified by IEC[International Electro technical Commission] as follows: Conducted low frequency phenomena, Radiated low frequency phenomena, Conducted high frequency phenomena, Radiated high frequency phenomena, Electrostatic discharge phenomena (ESD), Nuclear electromagnetic pulse (NEMP). A transient is that part of the change in a variable that disappears during transition from one steady state operating condition to the other. Transients are classified into two categories: Impulsive, Oscillatory. Impulsive transients can be due to (i) lightning discharge or (ii) switching due to opening and closing of circuit breakers. An impulsive transient has unidirectional (positive or negative) polarity and is

characterized by the rise and decay times. An oscillatory transient is a sudden non-power frequency change that is bi-directional (both positive and negative polarities). Depending on the frequency range, the oscillatory transients are classified as (i) high frequency (>500 kHz), (ii) medium frequency (5-500 kHz) and (iii) low frequency (<5 kHz). When rms (root mean square) deviations at power frequency last longer than one minute, they are called long duration voltage variations. They can be either over voltages (greater than 1.1 p.u.) or under voltages (less than 0.9 p.u.). Over voltages are usually the results of switching of a load or energizing a capacitor bank. Under voltages are the result of events which are the reverse of events that cause over voltages - switching in a load or switching off a capacitor bank. Short duration voltage variations are generally caused by (i) fault conditions (ii) energization of large loads such as induction motors. The voltage variations can be temporary voltage dips (sags) or voltage rises (swells) or a complete loss of voltage (interruptions). An interruption occurs when the supply voltage or load current decreases to less than 0.1 p.u. for a period of time not exceeding one minute. Interruptions can be due to either system faults, equipment failures or control malfunctions. A sag is a decrease of rms voltage to a value between 0.1 and 0.9 p.u. and lasting for duration between 0.5 cycle to 1 minute. Voltage sags are mainly due to system faults and last for durations ranging from 3 cycles to 30 cycles depending on the fault clearing time. A voltage swell is defined as an increase to between 1.1 and 1.8 p.u. in rms voltage at the power frequency for duration between 0.5 cycle to 1minute. Voltage imbalance can be defined using symmetrical components. The ratio of the negative sequence (or zero sequence) component to the positive sequence component is a measure of unbalance. The main sources of voltage unbalance are single phase loads on a three phase circuit resulting in load imbalance. Severe imbalance can be caused by single-phasing conditions. Waveform distortion is defined as a steady-state deviation from an ideal sine wave of power frequency. There are five types of waveform distortion: (a) DC offset, (b) Harmonics, (c) Inter harmonics, (d) Notching, (e) Noise. The presence of DC voltage or current in AC power systems is termed as DC offset. This can occur as the result of a geomagnetic disturbance or ground return operating mode in mono polar HVDC links. Nonlinear loads and power electronic controllers are the primary source of harmonics. Fourier analysis can be used to characterize harmonic distortion. Voltages or currents having frequency components that are not integer multiples of the supply frequency (50 or 60 Hz) are called inter harmonics. The main sources of inter harmonics are static frequency converters, cyclo converters and back to back HVDC links. Inter harmonics can affect power line carrier signaling and cause visual flicker in display devices such as cathode ray tubes (CRT). Notching is a periodic disturbance in the voltage waveform introduced by power converters when current is commutated from one phase to another (under normal operation). Since notching is a steady state phenomenon, it can be analyzed using Fourier series that gives the harmonic spectrum of the affected voltage. Waveform distortion and voltage unbalance have become very important factors that essentially decrease the efficiency of both power supply systems and the consumers connected to them. There are mitigation techniques for power quality problems in the distribution system and the group of devices is known by the generic name of custom power devices (CPDs). Faults due to lightning, is one of the most common causes to voltage dips on overhead lines. If the economical losses due to voltage dips are significant, mitigation actions can be profitable for the customer and even in some cases for the utility. Along with advancement in technology, the worldwide economy organization has evolved towards globalization
and the profit margins of many activities tend to decrease. The increased sensitivity of the vast majority of processes like (industrial, services and even residential) to PQ problems turns the availability of electric power with quality a crucial factor for competitiveness in every sector of activity. The nonstop process industry and the
information technology services are most significant area. As a result of disturbance, a huge amount of financial
losses may happen, with the consequent loss of productivity and competitiveness.

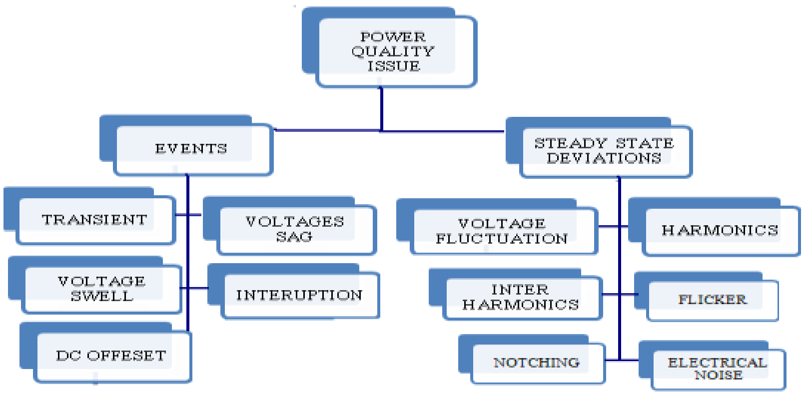

Fig: 1 Power quality issues.

III. GENERAL CONCEPT OF POWER MONITORING SYSTEM IN DISTRIBUTION NETWORKS.

Direct measurement in the network nodes is required in order to get valid information on the power quality indices. Many surveys have shown that most customer power quality problems originate within the customer facility. It is clear that monitoring is essential for both power suppliers and users to ensure optimal power system performance and effective energy management. Moreover, it provides information about power flow and demand and helps to identify the cause of power system disturbances. A measurement system was developed to gain knowledge about long-term power quality behavior within a studied distribution power system. The possibility to make long-term power quality surveys within the power system, additional modules were also developed and integrated in the structure of the monitoring system. A power resolution module can be used to perform power calculations at the cross-section of disturbing loads utilizing data exported in ASCII- format. Within the integrated graphical user interface (GUI) on-site presentation of the measurement results and their analysis can be performed as well.

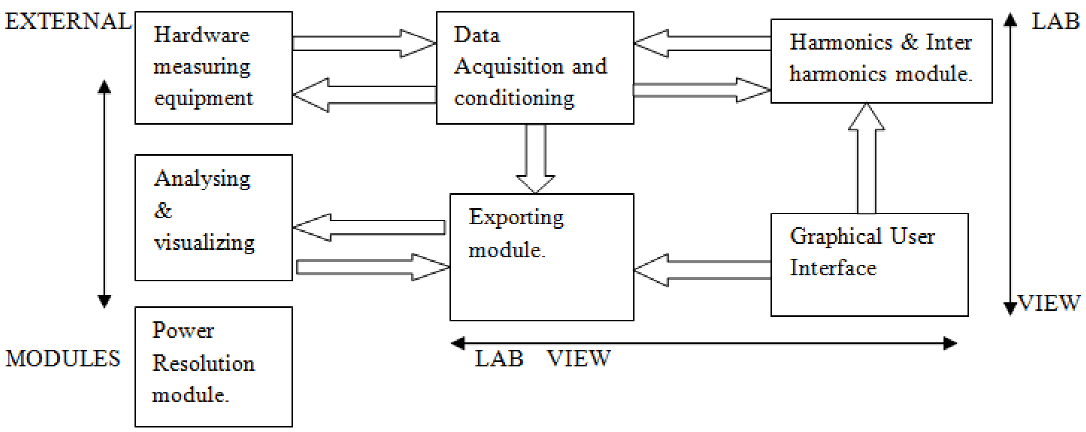

Fig: 2 Power Monitoring system

Such a structure enables one to observe and compare the trends of the PQ indices over a long period of time, and to also measure and analyze power quality problems that arise at the cross-section of disturbing loads or at the connection point of renewables. A synthesis of these types of information is possible within the monitoring system using an unified information exchange interface between the system components. The data acquisition and conditioning module covers a software interface that communicates with both hardware instruments used for long-term power quality monitoring and short term measurements at the cross-section between disturbing load and power supply respectively. The interface makes the conditioning of the acquired data in order to achieve a standardized output data format that is then utilized by other modules of the system. The data processing within the harm and inter harm modules of the monitoring system from is made according to norm guidelines utilizing the basic measures calculated using measurement data prepared in the appropriate way. The implemented algorithm utilizes theoretical background that defines the indices for harmonic and inters harmonic distortion. During construction of the monitoring system, the main methods of power resolution were chosen and implemented in the external evaluation module of the system to investigate the usefulness of each method in the scope of its practical implementation. The first method is that of Budeanu which was developed in the early 20 century and is still the best known and the most popular method in industry. The next one is that of Czarnecki which builds upon the work introduced by Fryze and the last one is that of the IEEE Working Group which was developed mainly with contributions done in the works of Filipski and Emmanuel. The three approaches are implemented in the algorithm of the external module of the power quality monitoring. The module consists of several MS Excel spreadsheets in which calculations are made automatically by the macros that are prepared to deal with the standardized data input that come from the exporting module.

IV: MEASUREMENT BASED EVALUATION OF POWER QUALITY IN DISTRIBUTION SYSTEMS UNDER BALANCED AND UNBALANCED SYSTEM CONDITIONS.

Harmonic studies are an important component of power system analysis and design. They are used to quantify the distortion in voltage and current waveforms at various points in a power system. In general there are three main tendencies in the modeling: studies in time domain, frequency domain, and harmonic domain that can be viewed as a restriction of frequency domain modeling to integer frequencies but with all non-linear interactions modeled. Time domain simulation consists of differential equations representing the dynamic behavior of the interconnected power system components. The calculations in time domain are used for simulations of transients and non-stationary disturbances in different time ranges. The resulting system of equations, generally non-linear, is solved using numerical integration. The derivation of harmonic information from time domain programs involves solving for the steady state and then applying the FFT. This requires considerable computation for relatively small systems. Frequency domain simulation in its simplest form provides a direct solution for the effect of specified individual harmonic injections throughout a linear system, without considering the harmonic interaction between the network and the non-linear components. The most commonly used model involves the use of single phase analysis, a single harmonic source and a direct solution. To achieve better accuracy harmonic domain analysis, also called iterative harmonic analysis, is often performed. The harmonic injection from each source will, in general, be a function of that from other sources and the actual system state. Accurate results can only be obtained iteratively solving non-linear equations that describe the steady state as a whole. The time domain simulation involving non-linear load behavior requires its mathematical description. The drawback is also the lack of power flow constraints, i.e. constant power specification at load buses at the fundamental frequency. The analysis in frequency domain can be built on the standard information including impedances of system elements and the characteristic (spectrum) of the current (or in some cases voltage) injected by non-linear loads bringing fast solutions and an overview, qualitative analysis of the system. In general, the problem of harmonic analysis can be cast mathematically as the solution of a network equation and a set of device equations at fundamental and harmonic frequencies. The network equation can be formulated in the form of a nodal admittance matrix or in a power flow equation form. In frequency domain there are two types of harmonic simulations: The first of these, the frequency scan, is the simplest and most commonly used technique for harmonic analysis. A scan calculates the frequency response characteristic at a particular bus or node. Frequency scan analysis is the best method for identifying resonance conditions. The second type harmonic distortion simulations use harmonic source characteristics of nonlinear loads to determine current and voltage distortion levels at various points in the system. Harmonic source characteristics are obtained from field measurements, other simulation programs, or a library of typical waveforms. Distortion simulations are useful for evaluating component duty and determining harmonic limit compliance. Good harmonic prediction requires clear understanding of three closely related topics that can be summarized as in Fig.

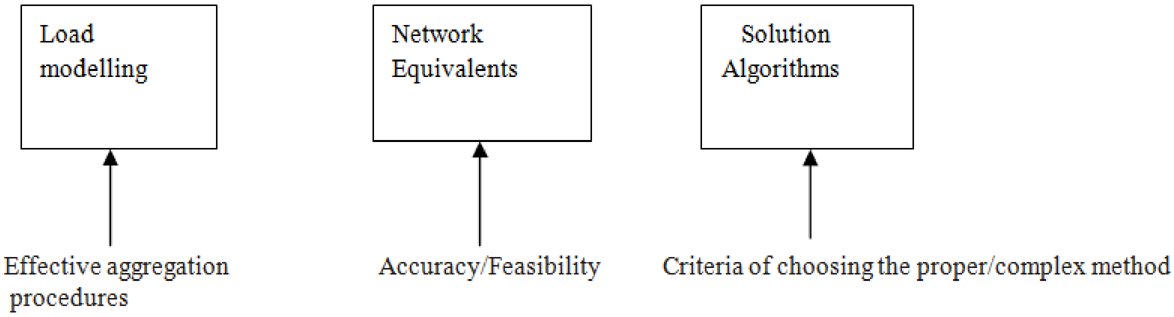

Fig 3. General concept of power system components modeling methodology

The first component is the non-linear load modeling with proper exactness and the choice of the right aggregate procedures for the linear load models. These tasks are in practice made difficult by insufficient information on the composition of the system loads and their dampening effect on the harmonic frequencies. The second component is the proper network equivalent, where one of the most important problems associated with developing a system model lies in the system should be modeled exactly. The best method for determining the appropriate system model is to start with a small, simple circuit that accurately represents the phenomena, and then add more of the system details to determine their impact on the solution result. The third component is the derivation of suitable solution techniques for the analysis to achieve a proper balance between complexity and accuracy for the study.

Device	Data needed
Overhead lines, cables	Phase and neutral conductor size, layout, length, or short circuit impedances; capacitance (when available)
Transformers	Turns ratio, connection diagram, short circuit impedance.
Capacitor banks	Voltage rating, VAR rating, configuration (wye, grounded wye, or delta)
Tuned filters	Tuned frequency, voltage rating, VAR rating, configuration in detail.

Table:1 Summary of typical data for a distribution system harmonic study

In general, by developing the power system model for harmonic and inter harmonic study a simplification will always occur. Very often the goal of the study is to determine the model complexity. Some factors affecting system simplification include model development and simulation time which is not a significant factor nowadays. The power system equipment modeling methods are well established, but the area of proper load modeling is still not satisfactorily arranged. Traditional modeling methodology that is based on a direct solution in frequency domain is not sufficient to represent major groups of non-linear loads in distribution system studies. The modeling does not include the interaction effect between the distribution system and the electronically controlled loads. Standard calculation programs concentrate on impedance calculations over the chosen frequency range and do not include the interactive phenomena, that the change of the supply harmonic voltage can have a big influence on the distortion currents drawing from the electronically controlled loads. It is, therefore, very important to improve the non-linear load modeling to include this important behaviour. It is appropriate to note that a large number of harmonic related problems encountered in practice need to be analyzed by a combination of the various methods to reach an improvement in the simulation exactness. This implies the usage of complex methods that combine the methods in a solution algorithm that is typical for the problem to be solved.

V: CONCLUSION

In the scope of this, hybrid-method for power quality investigations was developed that is intended for the analysis of electric power distribution systems with respect to harmonics and inter harmonics. The increasing application of electronically controlled devices in recent years not only affects the secure and reliable operation of the power system, but it also makes the maintenance of the customers' supply parameters standards more complicated. As a result, the distribution power system is exposed to the new operational conditions and self-generates interferences, which not only decrease the efficiency of the energy transport within it, but also badly affect its immunity. Distortion propagation depends on the system configuration, its actual state in the sense of load variation, and on the non-linear load characteristics. In the initial part, the subject of power quality and its interrelation to the field of electromagnetic compatibility was clarified with respect to the standards and regulations. Synthesizing this information a comprehensive classification of the power quality phenomena is analyzed. The concept of an appropriate measurement system for the evaluation of power quality in distribution systems is discussed. Also the improvement of the harmonic simulations can be achieved by including in the model an interaction effect that takes place between the non-linear, harmonic producing load - disturbance source and the network via its impedance - disturbance sink is presented.

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