International Journal of Electrical, Electronic and Communication Sciences
ISSN: 2517-9438
Vol:8, No:10, 2014

Power Quality Evaluation of Electrical Distribution Networks

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***Abstract*—**Researches and concerns in power quality gained significant momentum in the field of power electronics systems over the last two decades globally. This sudden increase in the number of concerns over power quality problems is a result of the huge increase in the use of non-linear loads. In this paper, power quality evaluation of some distribution networks at Misurata - Libya has been done using a power quality and energy analyzer (Fluke 437 Series II). The results of this evaluation are used to minimize the problems of power quality. The analysis shows the main power quality problems that exist and the level of awareness of power quality issues with the aim of generating a start point which can be used as guidelines for researchers and end users in the field of power systems.

***Keywords*—**Power Quality Disturbances, Power Quality Evaluation, Statistical Analysis.

I. Introduction

POWER quality has become a very important issue over the last decade. Various techniques have been applied for detecting different types of PQ disturbances encountered in power systems. Among them, the most widely used are the fast Fourier transform (FFT) and the short time Fourier transforms (STFT) [1]. Currently; wavelet and S-transform is used for detect PQ problems [2]-[3]. S-transform was found powerful algorithm in detection and classification in work of [4]. A large number of publications have been analyzed in this study to provide a comprehensive review of power quality surveys regarding the implementation of Power Quality Programs (PQPs) in the USA and Europe. However, recent studies shows that some countries like north of Africa and the Middle East are predicting to have a huge growth in power generation, transmission and distribution. This growth is not matched by similar growth in power quality awareness programs. This survey focuses mainly on the power quality issue in one of these fast growing North African countries (Libya) [5].

The rapid growth of the Libyan economy began in 1999, Therefore, since the early 1999, tackling power quality events has been a priority for Libyan distribution networks (LDNs). Thus, the increase in peak load was not as rapid as it is nowadays; it was 5,964 MW in 2011, and expected to increase to 18,417 MW by 2025. Moreover, the level of power delivered was not at its worst level, this is mainly because sensitive equipments were not yet introduced widely before 1999 [5].

II. Power Quality and Energy Analyzer

The Fluke 437 Series II 400Hz Power Quality and Energy Analyzer is designed specifically for the defense and avionics industries, Capable of measuring up to 400 Hz. According to IEEE 1159, 2009 [6], many standard PQs have been measured in this survey. Measurements have been done for different points of Misurata city electric distribution network:

1) Alogoshi 30/11kv substation.
2) Alskirat 30/11kv substation.
3) Alzarog 380/220V substation.
4) Al Nasim Dairy 11kv/380v substation.
5) Libyan Iron and steel company, 220kv substation.
6) Libyan Iron and steel company, 30kv substation.
7) Aljazira 30/11kv substation.
8) Alkaroba 30/11kv substation.

III. Survey Results

Results obtained from the survey indicate the current status of power quality condition in Misurata distribution network and the utility staff's point of view, indicating opinions of the level of power quality among both residential, agriculture, commercial and industrial users.

Some of the power quality disturbances have been found in this survey include: harmonics, short interruptions, long interruptions, voltage sags & swells, under voltage, over voltage, flicker & unbalance, transient & surge, low power factor and voltage collapse. These disturbances are considered in the statistical analysis. Only the 3^{th}, 5^{th} and 7^{th} harmonics are found at levels of several percent on distribution networks, but mostly not high presents. Fig. 1 shows the harmonics which was found in Algoshi 11KV substation.

Also in MV networks, the impact of the 5_{th} harmonic is significant, together with the 7_{th} harmonic. In several large MV systems both harmonic orders exceed 15% of the fundamental in the current wave. Taking into consideration that harmonics can circulate between the low, medium and high voltage levels, there is a risk that harmonic pollution in MV and even in HV networks could dangerously increase. Fig. 2 shows THD Factor in Alskirat 11KV Substation.

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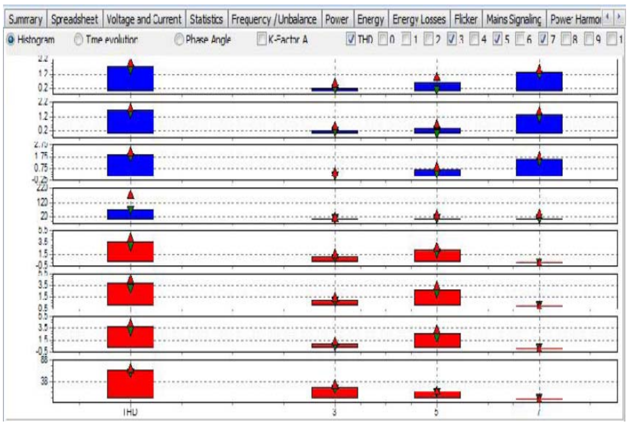

Fig. 1 Harmonics in Algoshi 11KV substation

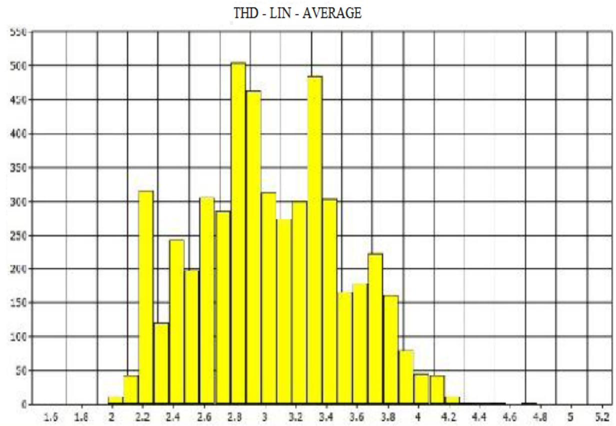

Fig. 2 THD Factor in Alskirat 11KV Substation

In some of the industrial points of the network, like in Al-Nasim Dairy the voltage level on electricity supply networks is subject to continuous variations (Flicker) under the influence of the frequent switching of electric motors which connected to the same bus bar of the lighting. Fig. 3 shows the flicker which was found in the main supplying board of the Al-Nasim Dairy. Measurement results show that flicker levels are generally well below the susceptibility level P_{st}= 0,7 which, however is exceeded occasionally.

Loads being connected to the network have a tendency of decreasing the voltage on the supply system, whereas the connection of generation units potentially increases the voltage. The voltage variation curve of Al-Nasim is shown in Fig. 4.

Due to heavy loads using large induction motors that are connected to this network, long Interruptions was found as one of the elements which causes PQDs. Also some of the main substation is only fed by one side of the transmission lines, which are driven far away from the generation plants.

Fig. 5 shows Dips and swells on a CBEMA (Computer Business Equipment Manufacturers Association) and ITIC (Information Technology Industry Council) plot classification table according to EN50160. On the CBEMA (blue) and ITIC (red), curve markers are plotted for each dip and swell. The height on the vertical axis shows the severity of the dip or swell relative to the nominal voltage. The horizontal position shows the duration of the dip or swell. These curves show an AC input voltage envelope which typically can be tolerated (no interruption in function) by most Information Technology Equipment (ITE).

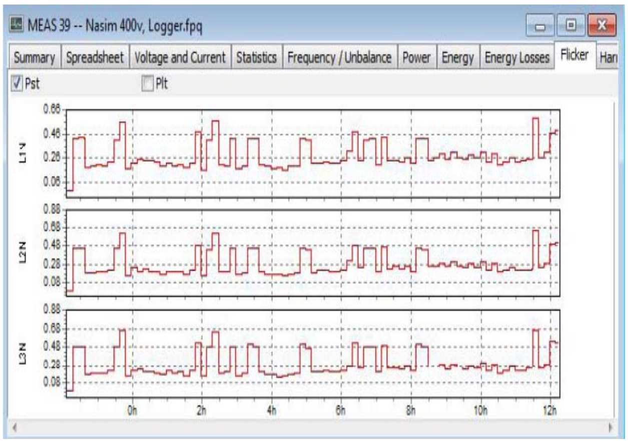

Fig. 3 Flicker level in Al-Nasim Dairy

Fig. 4 Voltage variation in Al-Nasim Dariy

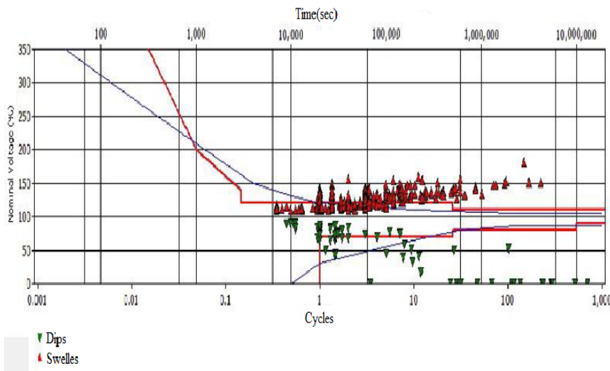

Fig. 5 Dips and swells in Alzarog 11KV Substation

Voltage /unbalance (%) in the Libyan Iron and Steel Company 220KV Bus bar is shown in Fig. 6. The method of calculation used is the ratio of positive-sequence symmetrical components divided by negative sequence components. This is the measurement method defined by the international standard IEC 61000-4-30. Unbalance is not available for all instruments. Generally the frequency was varying from 49.5 to 50.6Hz.

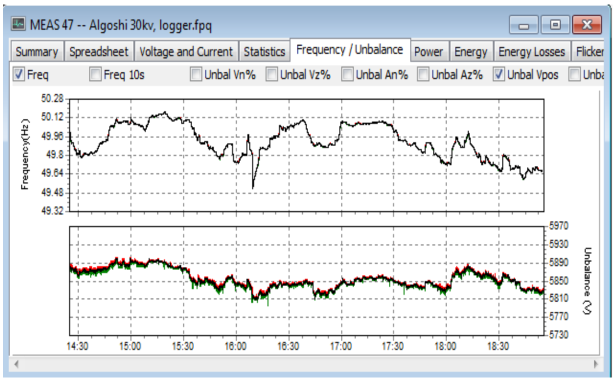

Fig. 6 Voltage /Unbalance (%) in LISCO 220KV Substation

The power factor, K-Factor, THD, Crest Factor, Unbalance, and Flicker of the eight substations is shown in Figs. 7-10.

Comparison of the K factor of the current gives an effect indication of the transformers frequency losses.

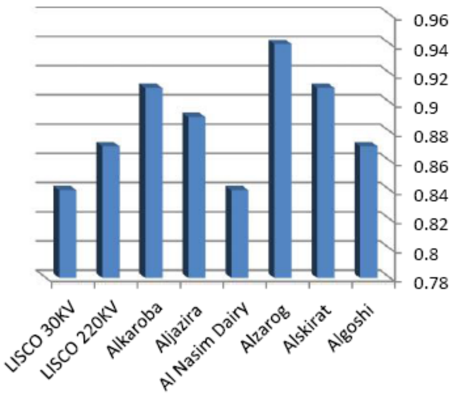

Fig. 7 Power Factor comparison

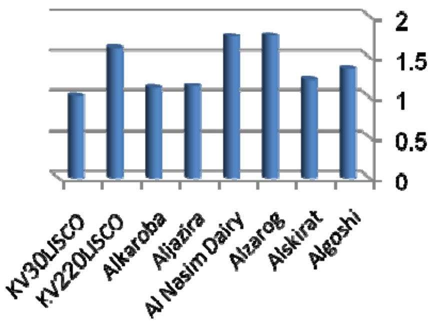

Fig. 8 K-Factor Comparison

Next figure is the comparison of total harmonic distortion factor for the current and the voltage for the eight different test locations.

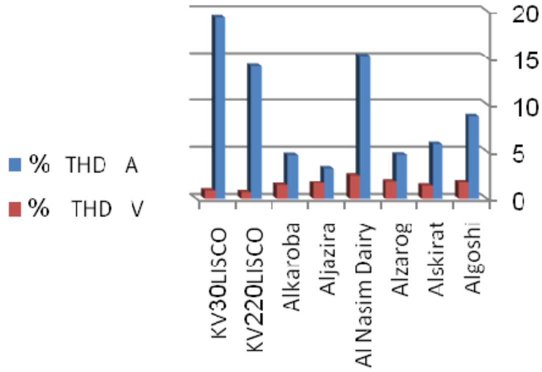

Fig. 9 THD Factor for the voltage and the current

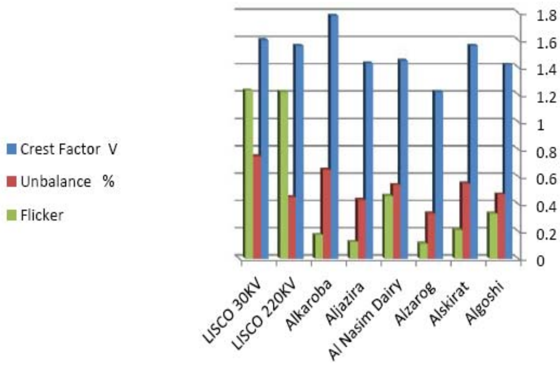

Fig. 10 Crest Factor V, Unbalance, Flicker comparison

The percentage of PQDs at the eight substations is shown in Fig. 11. The long interruption and low power factor have largest percentage among the eight substations.

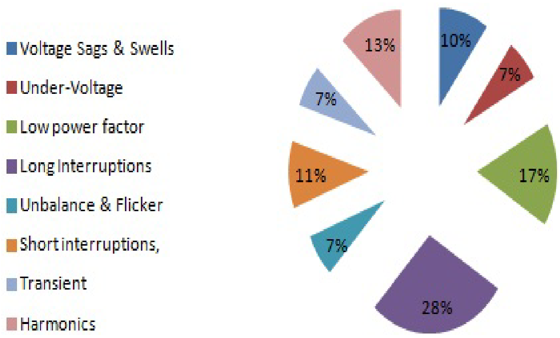

Fig. 11 PQ Disturbances %

Some general conclusions can be derived from the measurements, conducted under different network and load conditions. Of course strict statistical accuracy cannot be ascribed to these measurements or indeed to any similar measurements. To produce statistically accurate material would involve measurements at several thousands of carefully selected points over months. In relation to the limited amount of additional information that could be achieved, the financial and other resources needed for such measurement campaigns would be prohibitive.

From the survey results, it appears that, there are significantly power quality issues occurring due to lack of awareness. Network infrastructure was not at the level where the network could absorb the increases in demand due to population increases and requirements. Hence, it is one of the real reasons of causing PQDs in the network, which has not met and adapted to the growing demand and the increase in economic growth.

Customer categorization can be of assistance in resolving power quality disturbances if the network adopt it not only in urban areas, but also in rural areas, where many villages and remote areas with small populations suffering bad service of power quality.

On the other hand, the industrial, commercial, residential and agriculture sectors were found to be one of the biggest users causing PQDs. This has increased power quality problems, and the disturbances are generated constantly due to lack of awareness of the importance of it.

In addition, another cause of power quality problems is highlighted to be among the employees in head managers, engineers and technicians who were not aware of these issues to deal with its sources in increasing the problems. As a result of that both end users complaints and attitudes are raised and caused significant reactions by faulty connect to the distribution networks, which is impacted on the quality of electricity. Thus, both power quality guideline and datasets are required .This database is needed to record PQDs due to enormous use of new technology in electronic equipments, and in addition PQ framework is needed as guideline to increase the level of awareness, including management, employees and end users in order to implement PQ programs.

Among the responsibility of the network operator is to take all practical steps to ensure that its characteristics remain within such limits as are specified and to inform the consumer of the levels that can occur in normal conditions, and also to provide each consumer with such network information as may be necessary to enable him to use the supply without disturbance to others.

The most prominent cause of temporary overvoltages in LV networks is a break in the neutral conductor; in this case the maximum value is the phase-to-phase voltage of the system (i.e. 380 V in 230/380 V three-phase systems). Voltage dips are generally caused by faults occurring in the customers' installations or in the public distribution system. They are unpredictable, largely random events.

The levels of unbalance found at all network levels are generally below 2 % at all network levels which comply with EN 50160**.** Exceptions may occur in certain places. The disturbing action of loads that are connected to the electricity networks is a function of the current that they draw from or inject into the networks. The disturbing effect on other users, however, is a function of the voltage delivered to them. Voltage fluctuations and harmonics are two important examples. The conversion of the emitted disturbing current to the delivered disturbing voltage is a function of the impedances of the circuits through which the current flows– the network impedances.

The most common method is to reduce the system impedance by some form of network up rating e.g. installation of additional circuits or larger sized lines and cables. There are very rare cases of filters being installed on the public network to compensate for the general background level of harmonic distortion caused by equipment connected at low-voltage.

IV. Recommendation

Following points are different general needs and requirements in order to maintain and improve the distribution network which was clear through this survey.

1) Implementing a strategic plan for developing and enhancing the generation, transmission and the distribution which goes in parallel with the load growth.
2) Reduction of the generation of harmonic currents by increasing the pulse number of converters. If several sources are involved, connecting them through transformers with different phase shifts such that the vectorial summation of harmonic currents will have favorable diversity, installation of a filter at the bus with the disturbing source. A similar method is to install reactors in series with existing shunt capacitors so as to make the impedance inductive for the characteristic harmonics.
3) Disturbing loads and sensitive loads have to be supplied from different points to reduce the flicker level.
4) To avoid unbalance problems loads distribution on the phases has to be rearranged.
5) Installing Static VAR compensators and special transformers (reactors).
6) It has been clearly recognized that there is a need for consistency in making measurements of power quality parameters, and appropriate guidance should be provided to all utility and customer categories.
7) Enforcing the industrial and commercial customers to compensate their power factor and to install harmonic clearing and filtering technologies.
8) In most cases, making the end-use devices less sensitive to PQ disturbances is more cost effective than buying equipment to mitigate these problems.

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