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# ASSESSMENT OF QUALITY ELECTRICAL ENERGY

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## ABSTRACT

The work's objective was to present the improvement of the Total Energy Efficiency Management Technology monitoring and control system, from the perspective of the knowledge cycle, to favor the sustainability of the results. The effectiveness of the proposed changes was demonstrated by monitoring and controlling the electricity quality indicators of the National Center for Applied Electromagnetism in the period 2006 to 2016 divided into two stages. Of the hands studied, the voltage was normalized.

The power factor improved to 0.96, which made it possible to receive a bonus, which represented a 4% decrease in the entity's annual electricity bill.

This, in turn, contributed to the reduction of $CO_2$ emissions without reducing the level of activity.

## 1. Introduction

Electricity represents the primary input used in organizations, and its characteristics depend not only on those of the equipment manufacturers but also on the customer. For these reasons, there is no single concept of the quality of electrical energy. IEC 6 1000-4-30 defines it as: "characteristics of electricity at a given point in an electrical power network, evaluated concerning a set of technical reference parameters" and for IEEE 1159-1995, it is "a great variety of electromagnetic phenomena that characterize the voltage and the current at a given instant and a given point on the electrical network" (Einolander, 2016).

Management of the quality of electrical energy

Characterizing the electricity at a given point in an electrical power network is based on the supply's continuity relative to the number and duration of interruptions and the voltage and current waves' characteristics. Poor quality of electrical energy brings an increase in energy losses, damage to production, the economy and business competitiveness (Karatayev, et al., 2016). In the last decades, with the introduction of non-linear loads such as computers and frequency inverters, the adverse effects on power quality have been manifested more frequently.

Monitoring and improving the performance of the electricity quality indicators contribute to the efficient use of this resource, so it should constitute a work objective for organizations. The supplier attributes the problems of poor electrical energy quality to the user's installation and vice versa. The Total Energy Efficiency Management Technology (TGTEE) constitutes a tool to achieve this (Owens, Baker, Sumpter, & Cameron, 2016). Among the modules that make it up, it contains a system for monitoring and control, consisting of three stages, information, control, and improvement (Karatayev & Clarke, 2016). In the information stage, only data are collected; they can be quantitative or qualitative but devoid of meaning.

In the control stage, it is in which the collected data take on meaning when comparing them with the standards, so it is in this stage that the data becomes information. The improvement stage is where new standards, new procedures are established, and in this way, the control stage is fed back. This system assumes that the data's comparison with the standards is always regular and does not see how the modification of control variables improves (Bedir, 2017). This work aims to propose to the business community the improvement of the same, from the perspective of the knowledge cycle to favour the sustainability of the results and consider that this is the one that provides systematicity to the technology (Karatayev et al., 2016).

## 2. Materials and Methods

It is proposed to improve the electricity quality indicators by implementing the Total Energy Efficiency Management Technology; considering the proposed changes in the monitoring and control system, the proposed method is represented (Hallowell & Alexander, 2017). The new proposal for the Energy Monitoring and Control System suggests replacing the



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existing concepts up to now Energy Engineering, 2018, vol 39, n. 1, January / April, p. 62-68, ISSN 1815-5901 Electric power quality management on how to carry out a more comprehensive monitoring and control system.

The new system offered greater flexibility and was designed to be applied to different processes, not only of electrical interest, these are some of the aspects where the improvement of the proposal lies, given the existing scheme developed by the Center for Energy Studies Environment of the University of Cienfuegos (Zheng, Shuai, & Shan, 2017). Table 1 shows the stages to implement the monitoring and control system, as well as the objectives and verifiable outputs, it should be noted that one stage must be completed to begin the other (Froger, Gendreau, Mendoza, Pinson, & Rousseau, 2016). The system can be applied regardless of the implementation or not of the TGTEE. For the case under study, the standards used refer to Libyan standards for voltages and total harmonic distortion (Carafa, Frisari, & Vidican, 2016). The power factor is contrasted with what is established in Resolution No. 311.2001 of the Ministry of Finance and Prices, related to the bonus or penalty for its behaviour.

Voltage levels. To evaluate the tensions, the Libyan standard's standardized values, NC 365: 2009, are taken as a reference. Total Harmonic Distortion (THD) Total Harmonic Distortion (THD) (equation 1), defines the level of harmonics contained in alternating signals and is determined by equation (1).

$$THD = \frac{\sqrt{\sum_{h-2}^{sc} y_h^2}}{y_1} \qquad \text{Equation (1)}$$

Where: yh is the effective value (current or voltage) of the harmonic from the second harmonic (higher harmonics) and y1 the fundamental harmonic.
The Total Harmonic Distortion of voltage (THDu) and that of current (THDi) allow knowing if there is harmonic pollution and if the installation is at risk, thus contributing to decision making. The THDu characterizes the wave voltage distortion:

- for THDu <5% Normal situation, there is no risk of malfunction.
- 5 to 8% Significant harmonic pollution, some wrong operations are possible. Allowed
- 8% Great harmonic pollution, bad functions are probable. In-depth analysis and installation of attenuation devices are required. Not allowed The THDi characterizes the distortion of the current wave.
- THDi, below 10%, normal situation, no risk of malfunction.
- 10% to 50% significant harmonic pollution with risk of temperature rise.
- Greater than 50% significant harmonic pollution, malfunctions are likely, deep analysis and installation of attenuation devices are required.

Not allowed to evaluate the proposed system's functionality, it was applied in the National Center for Applied Electromagnetism (CNEA), which has implemented the TGTEE since 2006.

## 3. Results and Discussion

Two stages were developed, characterized by the objectives to be achieved, following the steps established in the TGTEE. The first stage (2006-2011) aimed to make the diagnosis and raise awareness, the impact of the change in high consumer luminaires and equipment. In the second stage (2012-2016), the effect of the transformer bank's installation for exclusive use was evaluated. It is important to note that in the two stages, training actions were carried out, two diploma theses were developed, one a master's degree and several seminars were given to the workers. To study the behavior of the voltage level, the THDu and THDi and the power factor, the results of 2007 and 2014 were compared, having as a requirement that it was measured in the general distribution panel and the measurements were made with a power analyzer. Three-phase networks. The stages established in the monitoring and control system were monitored and controlled. Data collection: In both years, the data of a typical day were taken, the variables line voltage, Total Harmonic Distortion of Voltage and Current and the Power Factor.

Data processing with the data taken by the analyzer, a database was developed, and the average statistic, maximum and minimum values, and standard deviation are used to describe the behaviour of the data. The comparison standards used were:

- For voltage, the Libyan standard NC 365: 2009 establishes that the accepted percentage of voltage variation is a function of the voltage level, mainly that for low voltage ± 10%, for the voltage level studied, the range is between 207 <UL <253 V.
- Total harmonic distortion of voltage and current, the Libyan standard NC 800-1: 2011, is used.



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-  For the power factor, Resolution No. 311.2001 of the Ministry of Finance was used, it establishes the power factor values in which the organization will be penalized, rewarded, or the invoice will be without variation information.

Tension
In 2007 (table 2), voltage instability is observed, confirmed by the standard deviation, manifesting low voltage moments, creating complaints from workers due to malfunction of laboratory equipment. In 2014, there was no low voltage, and no complaints from workers were reported for this concept.

Table 1: Line voltages, 2007, 2014 and regulated limits

| Line voltage | | 2007 | 2014 |
|---|---|---|---|
| UA-B | Average | 211.5 | 235.54 |
| (V) | Maximum value | 222.8 | 240 |
| | Minimum value | 204.8 | 230.30 |
| | Standard deviation | 4.3 | 2.01 |

Total Harmonic Distortion of voltage (THDu) and current (THDi) In 2007 (table 3), the average THDu was below 5%; however, the maximum values were slightly higher than 0.2%, with harmonic pollution, permitted according to the Libyan standard NC 800-1: 2011. In 2015 this indicator behaved below 5%, so the installation was not at risk of malfunction. In 2007 (table 4), the THDi conducted below 10%, so the structure was not at risk of malfunction. In 2014, the average value of the CI was 46%, which indicates the existence of significant harmonic pollution and the possible risk of temperature rise. The maximum value was above what is allowed in the standard (50%), so there is a probability of the installation's malfunction, so this current is considered the critical case.

Table 2: Total Harmonic Distortion of voltage per phase, 2007, 2014

| THDu per Phase in% | | | | | | |
|---|---|---|---|---|---|---|
| | 2007 | | | 2014 | | |
| | VA-N | VB-N | VC-N | VA-N | VB-N | VC-N |
| Average | 4.5 | 4.3 | 2.2 | 2.5 | 2.0 | 2.90 |
| Maximum | 5.2 | 5.4 | 2.7 | 2.8 | 2.4 | 3.5 |
| Minimum | 3.3 | 3.0 | 1.6 | 2.0 | 1.0 | 2.2 |
| Standard deviation | 0.49 | 0.61 | 0.25 | 0.23 | 0.4 | 0.39 |

Power Factor
The power factor in 2007 (table 5), which ranged between 0.54 and 0.92, has an average value of 0.65, which caused the penalty, according to Resolution No. 311.2001 of the Ministry of Finance and prices. However, in 2014, this indicator's behaviour stabilized at values in which the organization's resolution rewards. Decisions in 2007 of the four parameters studied were standard: the voltage level and the power factor. As a consequence, laboratory equipment malfunctions and lighting problems. The power supply source was characterized, and technological changes were made.
In 2014 of the indicators studied, only the TDHi indicates significant harmonic pollution with a risk of temperature rise. Although it is allowed, it is suggested to repeat the study in the general distribution panel but in each circuit that makes up the centre to locate this behaviour's source. Carry out economic and environmental evaluation.
Knowledge 2007 Voltage level, when characterizing the electrical supply source, it was shown that it was located at a distance of 200 m, the consumer being the furthest away. The location of a new supply source was calculated and selected, the investment was managed, and it was installed in October 2012.
Power factor presented low values, so technological changes allowed a 40% reduction in the installed load of air conditioners and 64% of the luminaires.
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In 2015 this indicator behaved below 5%, so the installation was not at risk of malfunction. In 2007 (table 4), the THDi acted below 10%, so the installation was not at risk of malfunction. In 2014, the average value of the CI was 46%, which indicates the existence of significant harmonic pollution and the possible risk of temperature rise. The maximum value


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was above what is allowed in the standard (50%), so there is a probability of the installation's malfunction, so this current is considered the critical case.

Table 3: Total Harmonic Distortion of current, 2007, 2014

| THDu per Phase in% | | | | | | |
|---|---|---|---|---|---|---|
| | 2007 | | | 2014 | | |
| | $I_A$ | $I_B$ | $I_C$ | $I_A$ | $I_B$ | $I_C$ |
| Average | 3.8 | 4.5 | 0.8 | 11 | 7.1 | 46 |
| Maximum | 6.8 | 7.4 | 6.2 | 13 | 9 | 72 |
| Minimum | 2.5 | 1.9 | 0.0 | 8 | 3 | 37 |
| Standard deviation | 0.72 | 1.07 | 1.40 | 1.61 | 1.61 | 8.18 |

Power Factor Assessment

The power factor in 2007 (table 5), which ranged between 0.54 and 0.92, has an average value of 0.65, which caused the penalty, according to Resolution No. 311.2001 of the Ministry of Finance and prices. However, in 2014, this indicator's behaviour stabilized at values in which the organization's resolution rewards. Decisions in 2007 of the four parameters studied were average: the voltage level and the power factor. As a consequence, laboratory equipment malfunctions and lighting problems. The power supply source was characterized, and technological changes were made.

Table 4: Power factor, 2007, 2014 and the regulated limits

| Power factor | | 2007 | 2014 |
|---|---|---|---|
| | Average | 0.65 | 0.97 |
| | Maximum value | 0.92 | 0.98 |
| | Minimum value | 0.54 | 0.96 |
| | Standard deviation | 0.09 | 0.01 |

In 2014 of the indicators studied, only the TDHi indicates significant harmonic pollution with a risk of temperature rise. Although it is allowed, it is suggested to repeat the study in the general distribution panel but in each circuit that makes up the centre to locate this behaviour's source. Carry out economic and environmental evaluation.

Knowledge 2007 Voltage level, when characterizing the electrical supply source, it was shown that it was located at a distance of 200 m, the consumer being the furthest away. The location of a new supply source was calculated and selected, the investment was managed, and it was installed in October 2012.

Power factor presented low values, so technological changes allowed a 40% reduction in the installed load of air conditioners and 64% of the luminaires. 2014 The individual study of each circuit has not materialized due to internal movements, new laboratories, and new equipment installation, which are low consumers but represent non-linear loads—economic evaluation. From the technological changes, the actions carried out, and the consumption records, it has been possible to evaluate the bonuses for the behaviour of the power factor obtained since 2013. These represent 4% of the annual amount, which means a saving of 3,256.48 CUP.

For this evaluation, the carbon footprint defined by the amount of greenhouse gases (GHG) emitted into the atmosphere derived from the production or consumption of goods and services is used as an indicator. The CNEA's carbon footprint for electricity use. The study of the carbon footprint was carried out in the first four months of the years 2014, 2015, 2016, it maintains a tendency to decrease. The increase in April 2015 is associated with implementing the Applied Electromagnetism Conference, which increased the level of activity in that month. The decrease is related to technological changes and the subcontracting of parts that make up magnetic conditioners' production.

## 4. Conclusion

Changes were proposed to the monitoring and control system, considering that this is the one that provides systematicity to the Total Energy Efficiency Management Technology. The effectiveness of the changes was verified through the study of the electrical power quality indicators: voltage level, total harmonic distortion of voltage and current, and the power factor as an indicator of energy efficiency, at the National Electromagnetism Center Applied, in the period 2006-2016 divided into two stages demonstrating improvements in the management of this energy carrier. By bringing the supply source closer, the low voltage was eliminated, the voltage level rose from 211.5 to 235.54V on average. The total harmonic voltage distortion did not exceed the norm values in any of the stages; in the second stage, it decreased by 2.4%. The total harmonic distortion of current deteriorated in the second stage, critically in the IC, reporting values that indicate harmonic



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pollution. The power factor improved from 0.65 to 0.96; this represented a decrease of 4% in the annual electricity bill. As an environmental effect, a decrease in $CO_2$ emissions was reported in the first four months of the last three years.

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