Article **ECORFAN Journal**
June 2016 Vol.2 No. 2 22-32

Power factor correction for the efficient use of electrical energy, a success case at Universidad Tecnológica Emiliano Zapata del Estado de Morelos

SALINAS, Oscar†*, DÍAZ, María, PUIG, Jessica and CABALLERO, Alejandro

Universidad Tecnologica Emiliano Zapata del Estado de Morelo

Received February 29, 2016; Accepted June 2, 2016

Abstract

Fruits and vegetables are normally presented to consumers in batches. The homogeneity and appearance of these have significant effect on consumer decision. For this reason, the presentation of agricultural produce is manipulated at various stages from the field to the final consumer and is generally oriented towards the cleaning of the product and sorting by homogeneous categories.

The aim of this paper is to present the technique classification of oranges by vision, and to evaluate the efficiency of this technique regarding the color like quality attribute for detection of external blemishes. The segmentation procedure used, based on a Bayesian analysis, allowed to classify fruits according to their colors. The results obtained show that the quality of images to be analyzed has a great influence on the decision of the system. Blurred image increases the error of confusion in the classification, because the system will not be able to differentiate the color of good oranges with those that are rotten. For this reason it is very important to use a good quality camera providing images.

Bayesian classification, image processing, quality of fruit, segmentation

Citation: SALINAS, Oscar, DÍAZ, María, PUIG, Jessica and CABALLERO, Alejandro. Power factor correction for the efficient use of electrical energy, a success case at Universidad Tecnológica Emiliano Zapata del Estado de Morelos. ECORFAN Journal-Democratic Republic of Congo 2016, 2-2: 22-32

* Correspondence to Author (email: oscarsalinas@utez.edu.mx)
† Researcher contributing first author.

Introduction

Energy is that human beign use to have hot where is cold, do activities in an easy way, and to have ligth where is darkness for example. But having this energy available has a cost, some energy hs to be inverted to get the one human beign are going to use: gasoline, gas or electrical eneergy. This energy costs to the society and to the Earth planet, is why the sustanaible concept has a very important place in these days. Therefore, two issues are intimately related about social impact in the energy field: the competitiveness of the economy and the climate change.

Electrical Energy has transformeed the way human beigns live their lifes. The majoriety of human's beings activities, in urban communities are based on the use of electrical energy. The power energy commonly called as electricity, that human beign use at houses, building offices, and so on, is named in electrical engineering field as alternating current. Nikola Tesla was the electrical engineer who invented, or maybe discovered, this kind of current (Burgan, 2009). Actually Tesla faced a real war against in early 1880s, against Thomas Edison, both were embroiled in an epic battle now know as the War of the Currents (Burgan, 2009) (Smithsonian, 2015). Nikola Tesla fought for alternating current, (AC) and Thomas Edison for direct current (DC), and Tesla won the battle, sponsored by Geroge Westinghouse. Therefore the power energy people use at home, work, entertainment centers, and so on is Alternating Current (AC). Definitely the world would not be, as we know it today without the important contribution of Tesla, since the use of alternating current enables more efficient distribution of energy, from where it is generated to where it is consumed.

This would not be possible if DC is used instead of AC. Nevertheless conducting the energy from is generated to where is going to be used, implies a lot of interesting issue to have into account, and to deal with them.

There are a lot of losses in the complete process: generation, transmission, distribution and use, hence a managment energy procedure must be implemented in each one of them. The last one depends on the users, the other three to the energy company. Users are people to demand power energy to develop their activities related to work, home and entertainment. Under this specific scenario, losses or not an efficient use of energy is related to, Fig. 1.

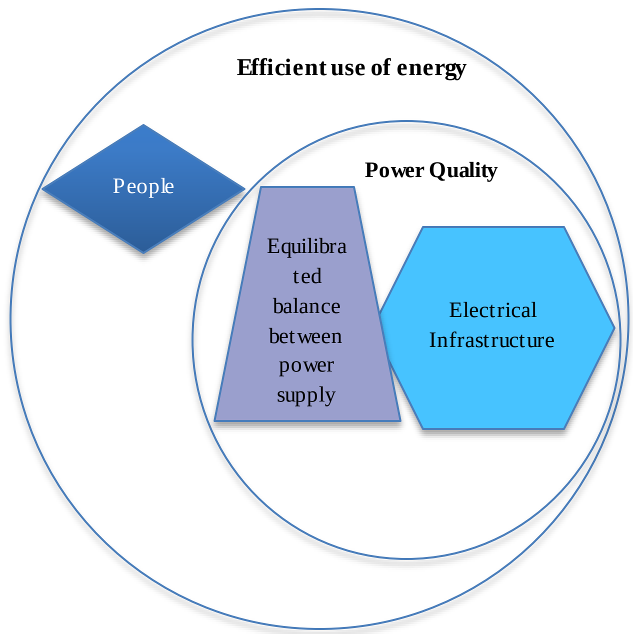


Figure 1 Factors about efficient use of electrical energy, from the users side

Is important to puntualize that there is a significant difference between energy saving and the efficient use of anergy (EUE), even tough they are intimately related. Efficient use of energy is one of the causes for saving energy is the consequence.

ISSN-On line: 2414-4924

In any kind of institutions implementing an energy management system in order to use electrical power efficiently, producing economic, social and environmental impact it is needed.

According to the National Commission for the efficient use of energy (CONUEE, acronym in Spanish), an energy management system is: “a methodology to achieve sustained and continuous improvement of energy performance in organizations in a cost effective manner” (CONUEE, 2012). Emphasising that the main factors of change are: operational control, adjusting controls, training and sensibliización, the same as have been mentioned in Fig. 1.

here is also the IEEE 739 – 1995 Standard:”IEEE recommended Practice for Energy Management in Industrial and Commercial Facilities” (Standards, 1995). Its purpose is to provide an engineering guide both for energy conservation and for use in electrical design. “The purpose of this recommended practice continues to be one of providing a standard design practice to assist engineers in evaluating electrical options from an energy standpoint. Hence, it is a recommended practice for energy management in design and operation of an electrical system” (Standards, 1995).

The essence of power quality, Fig 1., is the ability to accept power from the distribution bus for ultimate utilization, compatible with characteristics of loads. In commercial or industrial applications, this may involve a process that might entail a dynamic relationship to the AC voltage supply. AC voltage has the form of a sinoidal wave, Fig. 2.

However there are a lot of issues related with different topics that could or actually make distortions on this waverform.

Distortions in the waveform are a special issue to study and have direct and significative impact about the power quality (Cáceres, 2008). It is reported at the literature about experimental and analytics studies about the effect of the waveform distortions of voltage and current over the elements of the electrical grid (Situations, 1996) (Cáceres, 2008). Some of the factors that generate distortions are the electronic power equipments.

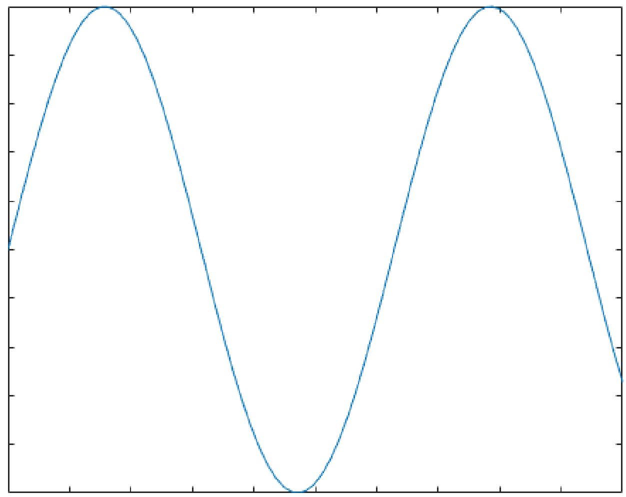


Figure 2 AC voltage and current waveform

It has been shown that they modify the sinusoidal nature of power electric signals. They cause an inefficient use of electrical energy; because they cause resonance problems, over voltage, the increase in losses due to they increase the distortion of current waveform (Magnago, Reineri, & Santiago, 2011; Magnago, Reineri, & Santiago, 2011). Between them employing power electronics, they merit special study, those with "socket" on a small part of the cycle of tension as the lamps called low consumption and those employing switched sources. This distortion could be provoked for an angle difference between voltage and current, since it produces power oscillation between the source and the load.

ISSN-On line: 2414-4924

June 2016 Vol.2 No. 2 22-32

One of the parameters to have an idea that how ideal is the interaction between power supply, internal grid and balance loads, distortions (called armonics) is the power factor (PF). PF is defined as the coefficient of active power suministred to the load (P), and the apparent power (S) (Fink & Beaty, 2013).

$$PF = \frac{P}{S} = \frac{V_0 I_0 + \sum_1^n V_n I_n cos\,\varphi_n}{\sqrt{\sum_1^n V_n^2}\sqrt{\sum_1^n I_n^2}} \qquad (1)$$

In general parameters used in electrical analisys are defined for sinusoidal conditions, therefore equation 1 most frequently is approximated to:

$$PF = \frac{P}{S} = \cos(\varphi) \qquad (2)$$

However is important to keep in mind and not dispase distortions to have a clearer picture of the electrical behavior (Cáceres, 2008). Since this work is about the initial analisys of the PF in the electrical grid of Universidad Tecnológica Emiliano Zapata del Estado de Morelos (UTEZ), and was based on the information on electrical parameters provided by the Federal Electricity Commission, both the receipt and the website. PF is interpreted as interpreted as measurement of performance power transmission, since it relates the usable power P with which it is necessary to provide S.

Under non-sinusoidal waveform some parameters could be misinterpreted, and some others can have no meaning at all. The most affected electrical parameters are apparent (S) and reactive power (Q), Fig. 3. P is what is the one used to be transformed into different types of energy, it is measured in W, represents the average value of the instantaneous power of a fixed period of time. Q is related with reactive loads in an electrical circuit in general.

It is supposed that them do not dissipate power, but they draw current and drop voltage, so they actually dissipate power in a certain way. Its measurement units are named Volt-Ampere-Reactive (VAR). Due to its reactive nature, Q can be compensated with inductive or capacitive devices.

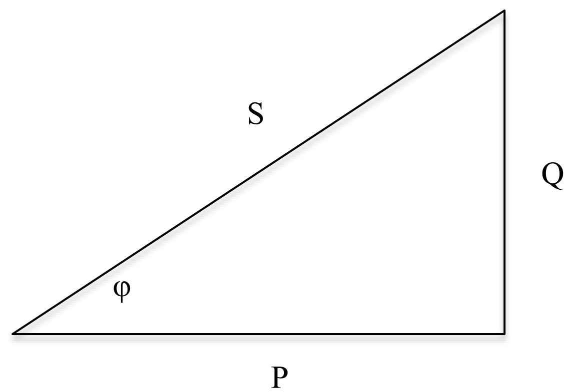


Figure 3 Mathematical relationships between different kinds of power

The mathematic expression for instant power of pure sinusoidal waveform is (Magnago, Reineri, & Santiago, 2011):

$$p(t) = Pcos[1 - \cos(2\omega t)] + Qsin(2\omega t) \qquad (3)$$

Where ω is the angular frequency, measured in radians. P is kown as the mean value of p(t):

$$P = VI\ cos(\varphi) \qquad (4)$$

And reactive power:

$$Q = VI\ sin(\varphi) \qquad (5)$$

The ideal value of Q is zero, because it means PF is equal to one. For example Q is the voltage drop in transmission lines. S is the geometric sum of Q and P, its measurement units are Volt-Ampere (VA). All of these defintions and mathematical equations are for sinusoidal signals. However not always they are sinusoidal, distortion has an important role.

ISSN-On line: 2414-4924

Values of PF close to 1, means there is a grid (source, transmission lines and loads) with quality, and the electrical energy is used in an efficient way. If PF tends to be one, this means that:

- Angle φ tends to zero.
- P and S powers are equal.
- Q tends to zero.

Even though power traditional power definitions are well described at the litherature and well known, just the active power concept has a clear physical meaning even for non-sinusoidal conditions. The other ones could be misunderstanding or intrepeted based on their mathematical formulation.

Hypothesis 1. Non-sinusoidal behavior of the electrical grid could provoke a not straight forward between power factor and reactive power.

Hypothesis 2. PF close to one is possible, even tough there are no inductive or capacitive devices installed to reduce reactive power.

People factor, is related with the culture, the habits, the way people adopted in a consciousness way the importance to use all resources in general in a moderated manner. Information Technologies (IT) are useful tools to divulgate information related with any topic to implement. IT can be used to develop a solid information structure in order to implement the culture of EUE:

- Videos (UTEZ, Universidad Tecnológica Emiliano Zapata del Estado de Morelos, 2015), (UTEZ D. , 2015).
- Applications for mobile devices (Del Pilar, Salinas, Velázquez, & Adan, 2015).
- Web page (UTEZ, Universidad Tecnológica Emiliano Zapata del Estado de Morelos, 2015).
- Electronic tools to calculate consume levels.

According with data reported by the New Buildings Institute, they indicates that plugs loads could be representing more than 50% of the electrical energy used in buildings with high efficiency systems (Menezes, Cripps, Buswell, & J. Wright, 2014). It is why is necessary to implement different mechanism to sow the culture of EUE in people, because they are the end users of electrical energy. For example, one survey revealed that less energy is consumed out-during working hours (44 %) than out-of-hours (56 %) (Masoso & L.J, 2010), because some people left equipment and lighting on at the end of day.

Methodology

The methodology was simple: basic and available data analisys, visual inspection, house keeping to electrical facilities.

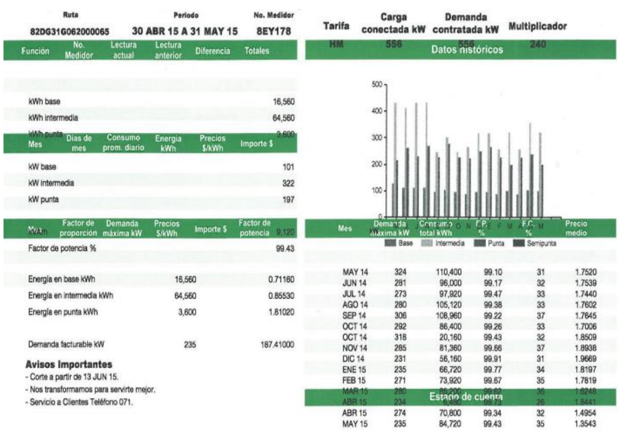
Basic of avalilable data

As a first step the payment receipt sent by the Federal Electricity Commission (CFE its acronym in Spanish) analyzed this as a research initiative rather than an institutional instruction. In the UTEZ, sustainable campus program implemented since 2012, and one of the axes of this is the theme of efficient use of electricity.

Following the research methodology suggested by Sampieri (Hernández, Fernández, & Baptista, 2006), one could say that the research question was: How is energy consumption on the campus of the UTEZ? To that based on these lines of work they were defined on how good or bad it was. There is some interesting and usefull information on the CFE payment receipt, Fig. 4., one of them is the PF.

ISSN-On line: 2414-4924

Other information is related to the type of rate, demand contracted, the connected load, the kilo-watt hours (kWh) consumed in different hourly rates. Besides technical information, economic information is showed; one of them is straight forward related with the PF, one called bonus. This bonus is applied to the institution if PF is equal or greater than 0.9, on the contrary if the PF is below of 0.9 an economic penalty applies. According to CFE PF is an indicator on the correct use of energy, is generally the amount of energy that has become work, which is in agreement with the description wrote above. According with this definition if PF is close to 1, it means all electrical energy consumed by the equipments has been converted in work.



Ruta	Periodo	No. Medidor
82DG31G062000065	30 ABR 15 A 31 MAY 15	8EY178

Tarifa	Carga conectada kW	Demanda contratada kW	Multiplicador
HM	556	556	240

Función	No. Medidor	Lectura actual	Lectura anterior	Diferencia	Totales
kWh base					16,560
kWh intermedia					64,560
kWh punta					3,600
kW base					101
kW intermedia					322
kW punta					197
kVArh					9,120
Factor de potencia %					99.43

Mes	Dias de mes	Consumo prom. diario	Energía kWh	Precios $/kWh	Importe $
Energía en base kWh			16,560	0.71160	
Energía en intermedia kWh			64,560	0.85530	
Energía en punta kWh			3,600	1.81020	

Mes	Factor de proporción	Demanda máxima kW	Precios $/kWh	Importe $	Factor de potencia
Demanda facturable kW		235	187.41000		

Avisos Importantes
- Corte a partir de 13 JUN 15.
- Nos transformamos para servirte mejor.
- Servicio a Clientes Teléfono 071.

Datos históricos

Mes	Demanda máxima kW	Consumo total kWh	F.P. %	F.C. %	Precio medio
MAY 14	324	110,400	99.10	31	1.7520
JUN 14	281	96,000	99.17	32	1.7539
JUL 14	273	97,920	99.47	33	1.7440
AGO 14	280	105,120	99.38	33	1.7602
SEP 14	306	108,960	99.22	37	1.7645
OCT 14	292	86,400	99.26	33	1.7006
OCT 14	318	20,160	99.43	32	1.8509
NOV 14	285	81,360	99.66	37	1.8938
DIC 14	231	56,160	99.91	31	1.9669
ENE 15	235	66,720	99.77	34	1.8197
FEB 15	271	73,920	99.67	35	1.7819
MAR 15	280	85,200	99.62	36	1.6248
ABR 15	234	6,480	99.73	26	1.8441
ABR 15	274	70,800	99.34	32	1.4954
MAY 15	235	84,720	99.43	35	1.3543

Base Intermedia Punta Semipunta

Estado de cuenta

Figure 4 View of part of CFE payment receipt

CFE calculates the bonus or penalization based on:

$$Bonus = \frac{1}{4}\left[1 - \frac{90}{PF}\right] * 100 \qquad (6)$$

$$Penalization = \frac{3}{5}\left[\frac{90}{PF} - 1\right] * 100 \qquad (7)$$

Equation (6) has a maximum applicable of 2.5 % of the total amount and equation (7) has 120 %.

So talking about money it is important to watch very close the PF, to have every month bonus instead of penalization. But also about technical point of view, because low PF means non-ideal behaviour of the grid and institution electrical grid could be facing problems like premature wear conductors, increased losses in conductors, overloading in transformes, higher power consumption, and distribution lines and increased brownouts.

Analysis of historic behaviour of electrical powers

The second step as part of data collection, contacted the FIDE (acronym in Spanish Trust for Electric Energy Saving), and the password was obtained to enter the website where the database historical of all electrical parameters and economic (Electricidad, 2010). And getting historical data, a variable behaviour of PF was found, Fig. 5.

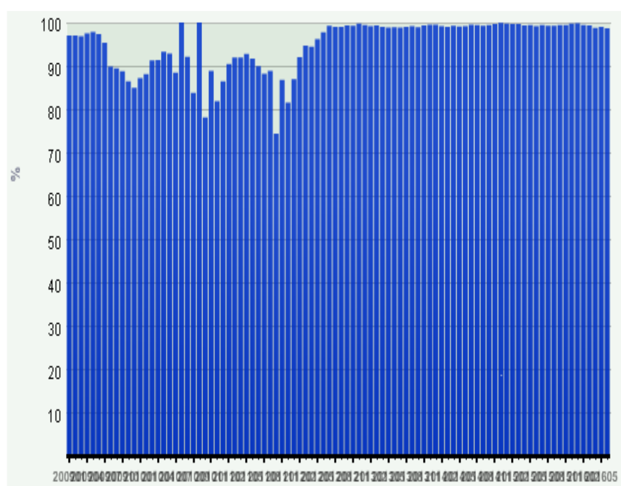


Figure 5 PF behaviour timeline

There is very clear variation on PF behaviour through the time. Before research was started the PF was variable, impredectible and lower than 90 %. There are two populations in the PF timeline, one before the variation and other after that, what can be observed better in a histogram graph, Fig. 6.

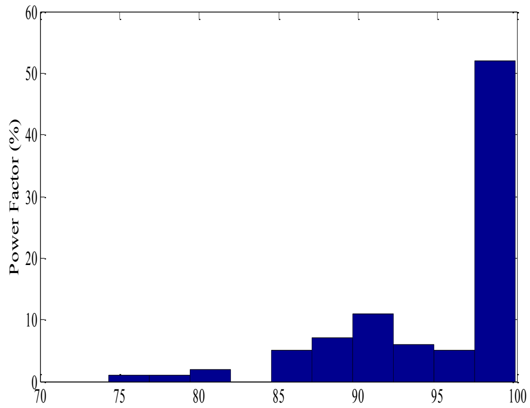


Figure 6 Two populations of PF data

Analizing Active (P) and Reactive (Q) powers, a different behaviour can be found, Fig. 7. Data distribution for P (kWh) has a more normal behaviour than Q (kVARh), Fig. 7. It means, in principle, that Q has a more variant and non controlled behaviour than P, and therefore S behaves in the same way, since Q, P and S are geometric related, Fig. 3:

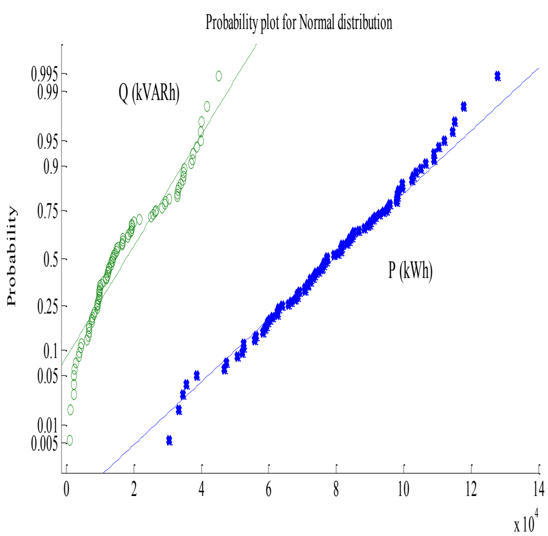


Figure 7 Normal distribution test for P and Q

$$S = \sqrt{P^2 + Q^2} \quad (8)$$

A correlation analisys between PF and P and Q was performed, Fig 8.

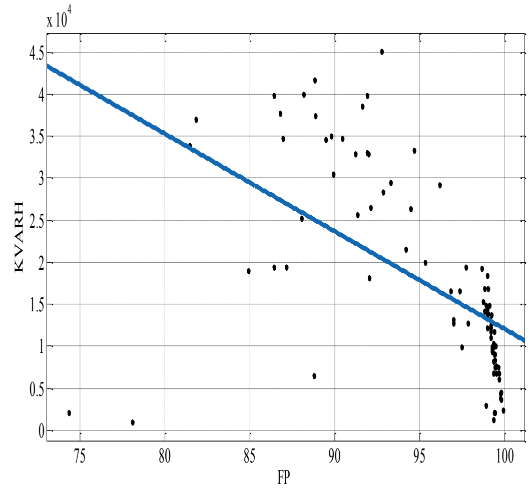


Figure 8 The higher the Q the lower the P

According with the graph Q vs P, a clear correlation can be stablished observing just the line, however due to the data dispertion the r-squared value is low, 0.3029. It means the linear model for the correlation analisys adjust poor for Q data. In the case of P vs. PF the r-squared is 0.1848, therefore statistically most significant dependency observed of PF from Q.

Visual inspection and house keeping

Next step was the visual inspection to the electrical facilities, focussed on electrical substations and ground systems.

About substations, was found some anomalies like high humidity, corrosion, insulators and damaged pipelines, mud, water, pipelines capless, Fig 9.

Article ECORFAN Journal
June 2016 Vol.2 No. 2 22-32

Figure 9 Damage in the electrical substations

Not just the corrective maintenance was performed but a redesign of the substation ventilation systems, drain added, was waterproofed, the ducts were fixed in a dry space, and grounded to prevent the passage and accumulation of water was added area.

About ground systems, if they existed but had not been given since the buildings maintenance, 10 or 15 years ago they were built. These systems were identified; it became a mapping of all ground systems campus, and started with redesign maintenance and in some cases, or scheduled.

In general the electrical infrastructure of the university was totally neglected, no inspections, no preventive maintenance, no attention to systems and even ground-ray.

And this is more than a matter of saving enegía is safety for personnel working in it. This has been corrected slowly, and has been getting favorable results.

One of them is the controlled or stable behaviour of FP after the house keeping work performed on the electrical substations and ground systems, as a start, Fig. 5.

Data distribution and correlation analisys, Fig. 10 was performed after that, r-squared raise to 0.6, however still some points far to the line, but the data dispertion is much closer than before, Fig. 8

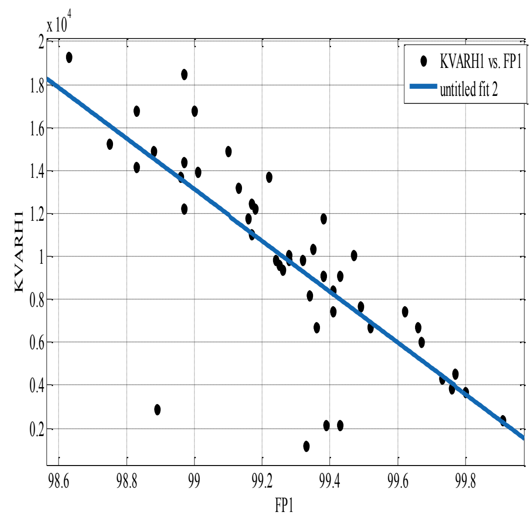


Figure 10 R-squared factor after house keeping

In Figure 11 can be observed that data distribution for Q is more normal after house keeping. Corrections for PF variable behaviour was performed at level of corrective maintenance of electrical facilities into the campus, installation of inductive or capacitive devices was not necessary so far.

ISSN-On line: 2414-4924

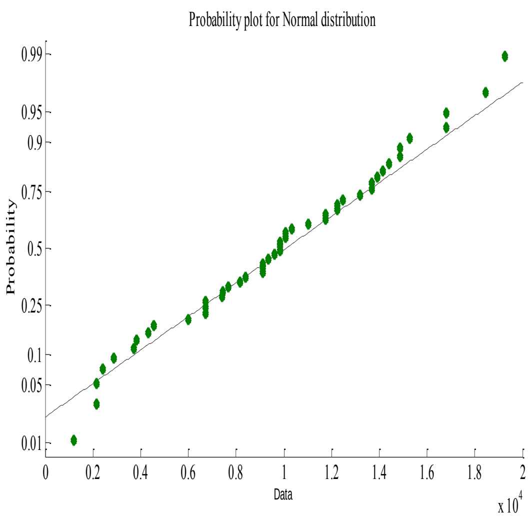


Figure 11 Normal distribution for Q after housekeeping

Results

The variation of the power factor was corrected significantly. It was possible to eliminate this unpredictable variation of this indicator parameter power quality. Corrective maintenance performed to ground systems and power substations had the desired impact. This success allowed a monitoring strategy programmed electrical infrastructure and a preventive maintenance program be designed.

After the previous analisys about public data of energy consumption into the campus, and a visual review of some facilities, a plan to go up the power factor was developed, oriented mainly to sistematize the maintenance of specific electrical facilities, like substations and ground systems.

It is necessary to supplement the analysis and actions implemented with technically formal, systematic measurement of the quality energy on campus, which includes harmonic measurement, measurement of the sinusoidal form of the power output, load balancing, consumption per building, etc.

An important institucional achievement was to have obtained the state prize for energy saving in 2015. This is not only a product of the work on the power factor but the actions were aimed at people in terms of the spread of culture of efficiency, the implementation of change programs luminaries, and technological developments to systematically control the power consumption.

Hypothesis 1. Non-sinusoidal behavior of the electrical grid could provoke a not straight forward between power factor and reactive power. This is the reason why the correlation analysis shows low r-squared values, even after the corrective maintenance.

Hypothesis 2. PF close to one is possible, even tough there are no inductive or capacitive devices installed to reduce reactive power. No one of them are been installed in the campus so far, and the PF has a stable behavior and it is higher than 0.98 level. Some recent energy quality measurements show electric harmonics, Fig. 12, and sinusoidal waveforms distortions, Fig. 13.

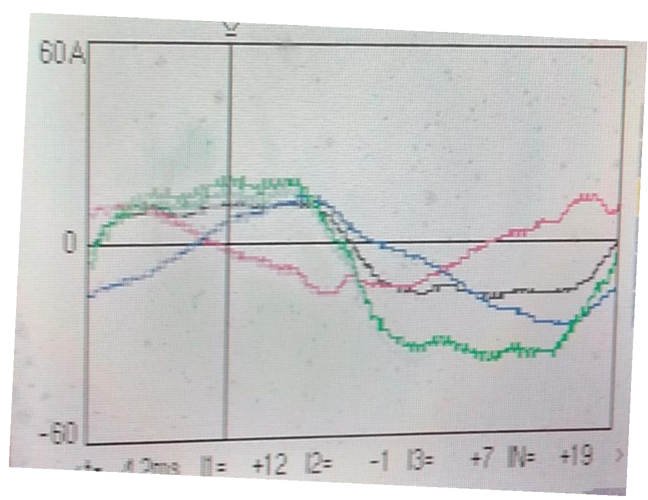


Figure 12 Presence of harmonics in all three electrical phases

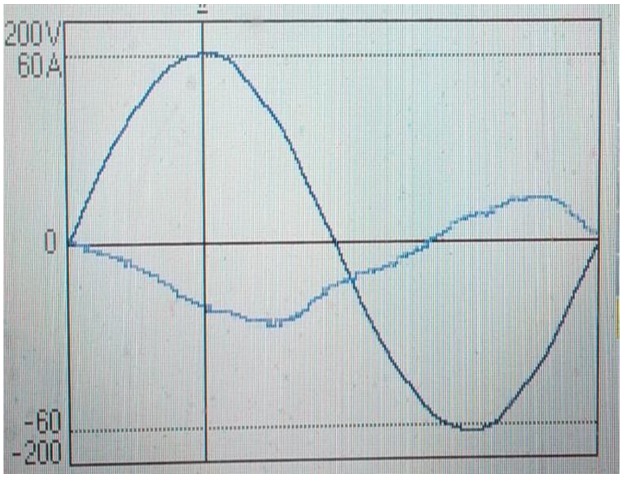


Figure 13 Waveform with some distortion of one fase

Quality energy measurements was not performed before because University has no the equipment, so an external company was hired. Why if there are electrical harmonics in the grid, and institution has no inductive or capacitive devices installed PF is high? There is no answer right now, but this is the future work to be done, to figure out what is happening in the grid.

Conclusions

Pay attention to the electrical parameters that are available on receipt of payment sent by the Federal Electricity Commission (CFE), it is an important starting point for an analysis to understand primary concepts of power quality, both in the process of delivery by CFE and consumption on campus.

Keep the power factor below 0.95, guaranteed to have a economical bonus by the federal electricity company (CFE), but does not guarantee a low level of reactive power, which in principle represent power quality.

Sometimes simple actions affect significant progress in achieving the objectives: schedule preventive maintenance of electrical installations, review of control systems for switching on and off of lamps, program requisitions improvement or repair of control systems on and off of the lights or air conditioners.

References

Burgan, M. (2009). Nikola Tesla, physicist, inventor, electrical engineering (First ed.). (C. P. Books, Ed.) Minneapolis, Minnesota, USA: Signature Lives.

Cáceres, R. (March de 2008). Factor de utilización de la potencia. IEEE Latin America Transactions, 6(1), 66-73.

CONUEE. (12 de Mayo de 2012). Comisión Nacional para el Uso Eficiente de la Energía. Recuperado el 10 de Enero de 2014, de Secretaría de Energía.

Del Pilar, M., Salinas, O., Velázquez, E., & Adan, E. (Diciembre de 2015). Diseño y elaboraciñon de material didáctico multimedia como apoyo el aprendizaje de habilidades matemáticas por y para estudiantes de ingeniería en T.I. Revista de Docencia e Investigación Educativa, 119-126.

Electricidad, C. F. (12 de January de 2010). CFEctiva Empresarial . Recuperado el 05 de February de 2014, de CFEctiva Empresarial : http://cfectiva.cfe.gob.mx/cfectiva/bibliotecas/datos_grales.php

Fink, D., & Beaty, W. (2013). Standard Handbook for Electrical Engineers. New York: Mc Graw-Hill.

Hernández, R., Fernández, C., & Baptista, P. (2006). Metodología de la investigación. México: Mc Graw Hill.

ISSN-On line: 2414-4924

Magnago, F., Reineri, C., & Santiago, L. (2011). Power Quality Measurement Under Non-Sinusoidal Condition. En Z. Ahmed, M. Canteli, & B. Ramesh, Power Quality Monitoring, Analysis and Enhancement (págs. 37-60). Croatia: Intech.

Masoso, Q., & L.J, G. (February de 2010). A monitoring study of 5 office buildings by Masoso et al. revealed that more energy was being used out-of-hours (56%) than during working hours (44%), largely due to occupants leaving lighting and equipment on at the end of the day . Energy and buildings, 42(2), 173-177.

Menezes, A., Cripps, A., Buswell, R., & J. Wright, D. B. (2014). Estimating the energy consumption and power demand of small power equipment in office buildings. Energy and Buildings, 75, 199-209.

Situations, I. W. (Enero de 1996). Practical definitions for Power in Nonsinusoidal Waveforms an Unbalanced loads: a discussion . IEEE Transactions on Power Delivery , 11(1), 79-101.

Smithsonian. (30 de January de 2015). Smithsonian.com. Recuperado el 30 de January de 2015, de www.smithsonianmag.com: http://www.smithsonianmag.com/history/edison-vs-westinghouse-a-shocking-rivalry-102146036/?no-ist

Standards, I. (01 de January de 1995). IEEE Standards Association. Recuperado el 12 de January de 2014, de IEEE Standards Association: https://standards.ieee.org/findstds/standard/739-1995.html

UTEZ. (09 de Junio de 2015). Universidad Tecnológica Emiliano Zapata del Estado de Morelos. Recuperado el 10 de Junio de 2015, de Canal de youtube de la UTEZ.

UTEZ. (20 de August de 2015). Universidad Tecnológica Emiliano Zapata del Estado de Morelos. Recuperado el 21 de August de 2015, de UTEZ_USEE: http://www.utez.edu.mx/USEE/

UTEZ, D. (09 de Junio de 2015). Universidad Tecnológica Emiliano Zapata del Estado de Morelos. Recuperado el 10 de Junio de 2015, de Canal de youtube de la UTEZ: https://www.youtube.com/watch?v=qO5r0at2v8o

ISSN-On line: 2414-4924