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# Evaluation of energy consumption and power quality in oil mills using advanced smart meters

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**Abstract.**
One of the main industries in Spain and other Mediterranean countries are oil mills. Although the specific energy consumption of oil mills depends on the capacity and other characteristics, some studies have highlighted the high energy consumption of these industries. In the case of olive mills, previous studies have shown that energy consumption is mainly supported by electricity, with low contribution from gas, diesel or biomass. Considering the importance of reducing the electricity consumption in oil mills, it is necessary to analyse the power consumption in order to take actions focused to reduce the contracted power and the energy required in its operation. Moreover, since these industries may require stable power supply, it is appropriate to analyse the power quality in order to detect possible adverse effects derived from a poor power quality. This paper presents the analysis of data collected by the Circutor MYeBOX 1500 portable meter installed in an olive oil mill. It is shown how monitoring these facilities during several weeks can provide relevant information regarding the energy assessment and policies.

**Key words.** Energy consumption, power quality, meters, oil mills.

## 1. Introduction

Most of the energy assessment carried out in the literature focus primarily on the study of power consumption and the electricity billing by utilities, since their analysis can enable organizations to reduce their energy costs. However, it should be noted that, although the operation of production systems depends (in the first instance) on the power supply within adequate power levels, there are other aspects of great importance that are not usually the subject of detail in most professional energy studies as in power quality PQ). Therefore, in addition to supplying electricity, these organizations have a legal obligation to provide an adequate PQ, in order to guarantee the correct operation of the equipment connected to the distribution network (EN50160, Royal Decree 1955/2000, etc). Specifically, PQ refers to the need for the power supply to be within prescribed parameters and limits related to sine wave shapes and adequate voltage, current and frequency levels. However, in practice, the quality of the power supply does not conform exactly to the theoretical values, but rather presents certain deviations. When these deviations in voltage, current, or frequency exceed certain limits, they can lead to incorrect operation of the devices receiving the power supply, and even to their deterioration. Therefore, it is suitable to analyze the quality of the electrical supply of the installations, in order to detect possible deviations in the parameters contracted with the electricity distribution company, otherwise it would be necessary to take the necessary actions for their correction, in order to avoid the deterioration of the aforementioned devices.
In particular, this paper is focused in oil mills facilities, since the energy consumption in these industries is very high. In fact, some studies have shown that electrical energy represents from 75 to 83% of the total energy cost in olive oil mills, with costs oscillating between 13,8 €/ton and 21,6 €/ton [1]. In the case of sunflower oil mills, the cost, in terms of thermal power is, kWt per ton of oil: Electricity—132.5; heat – 779.1. [2].
The aim of this paper is: (a) to analyze the consumption patterns and the power quality of an oil mill using advanced smart meters, and (b) to establish proposals for the improvement of the facilities according to the analyzed data.

## 2. Methodology

The study is developed in several phases:

*A. Assessment of the characteristics of the oil mil facilities*
We analyze a medium-sized facility corresponding to the agro-industry sector with equipment and machinery operating with three-phase power supply. Given the cyclical characteristics of the olive harvesting and processing, the activity of this facility follows a seasonal pattern, with an important activity in the last months of autumn and during the winter, being lower in the rest of the year. From the point of view of the facility, it has a main electrical panel from which the electrical circuits corresponding to the low voltage installation are derived. This main electrical panel has been selected as the point where the measurements of the installation will be taken.

*B. Measuring equipment to be used*

The analyzed facility is supplied by a three-phase grid. It has industrial machinery with high power consumption, The power supply may operates under unbalanced condition, so disturbances can affect and produce PQ events, so it has been decided to use a high-precision professional PQ analyzer MYeBOX-1500 [3], manufactured by Circutor. It is a portable and highly configurable analyzer that performs the analysis of accessible electrical parameters, both on-site and remotely. MYeBOX® is a range of portable analyzers configurable from an app that performs the measurement, recording and analysis of electrical parameters in single-phase, two-phase or three-phase installations (with and without neutral). This model performs simultaneous measurement of leakage current, measurement of network quality parameters according to EN 50160 and recording of transients.

*C. Installation and measurement*

Smart energy meters can share information on energy usage and the state of power networks between utility companies and consumers in addition to detecting energy flows [4]. In our study, the power analyzer was installed using basic safety rules (safety gloves for low voltage installations, insulating safety helmet, safety shoes) to ensure their safety, and to correctly position the device. Figures 1 and 2 show the electrical panels in which the MYeBOX 1500 was installed. Taking into account the seasonality of oil mill activity, measurements were taken during six full weeks, from December 19th to January 30th. This is a period of maximum activity in the facilities where the interpretation and presentation of events that could be negative for the operation of the equipment installed is highly possible.

Figure 1. Electrical panels of the oil mill.


Figure 2. Installation of MYeBOX 1500 in the main electrical panel of the oil mill.

*D. Analysis of the collected data*

After the six weeks during which the network analyzer was taking measurements, we removed the meter, once it was verified that the necessary electrical variables had been correctly collected and that they were available for further processing. These data, once downloaded from the network analyzer, was then analysed on a computer equipment at the University of Almeria using the "PowerVision" software developed by Circutor [5].

## 3. Results

*A. Active power analysis*

Figure 3 shows the active power measured in the electric panel of the oil mil. This figure shows how peaks of more than 500 kW are reached within this period, while active power values close to zero are measured on the dates corresponding to the Christmas. On the other hand, relatively stable active power values are observed on the days of January, with slightly higher values on the first days of the month, which denotes a period of high electricity consumption in the installations.

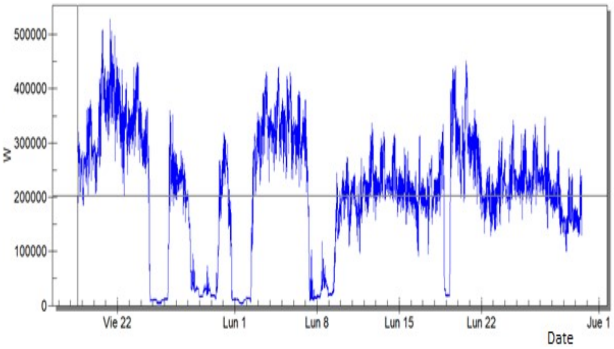


Figure 3. Active power measured in the electrical panel.

*B. Capacitive reactive power*

Figure 4 shows the capacitive reactive power recorded by the smart meter at the oil mill. This graph denotes that the reactive power exceeds 10 kVAR, with peaks of over 30 kVAR, being the high values recorded in the periods in which active power measured is also high.

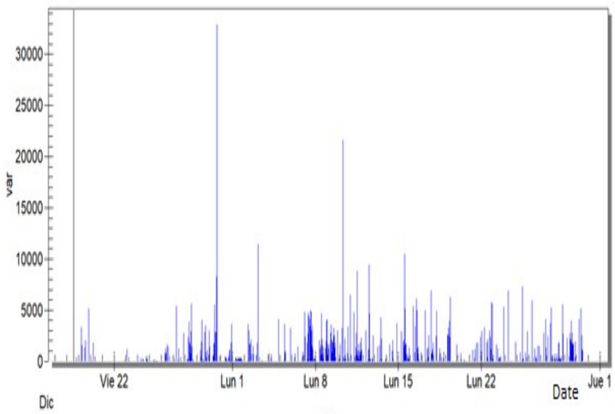


Figure 4. Capacitive reactive power measured in the electrical panel.

*C. Inductive reactive power*

Figure 5 shows the inductive reactive power recorded by the installed network analyser, according to which this reactive power exceeds 80 kVAR on numerous occasions, with peaks of up to 140 kVAR.

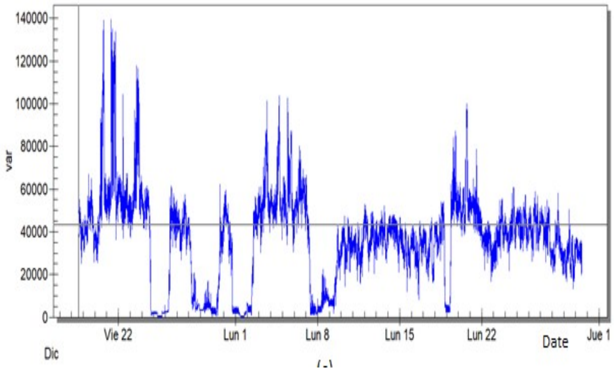


Figure 5. Inductive reactive power measured in the electrical panel.

*D. Power factor and phase angle*

The power factor expresses the ratio of the real power used in a circuit to the apparent power. In the event that an electrical installation has a low power factor, high losses can occur, and voltage drops, causing insufficient power supply to the loads and therefore this equipment will suffer a reduction in its power output. Closely related to the power factor is the phase angle (cos φ). It is referred to as the phase difference between the first harmonic in voltage and current. Thus, while the power factor defines the ratio existing between active power and apparent power, the cosine of phi expresses the angle of displacement existing between the current wave of a load and its voltage wave. Although the value of both concepts coincides in the case of purely linear loads, in the presence of non-linear loads such as switch-mode power supplies, variable speed drives, etc., a harmonic current component appears which means that there is no linear mathematical relationship between the current and the voltage, so the value of the cosine of phi differs from the power factor. For this reason, in the presence of non-linear loads, it is necessary to analyse both concepts, trying in any case to ensure that the cos φ is as close as possible to the unit value. Figure 6 shows how, during most of the measurement period, the value of cos φ oscillates between 0.98 and 1.00, although occasionally lower values are obtained.

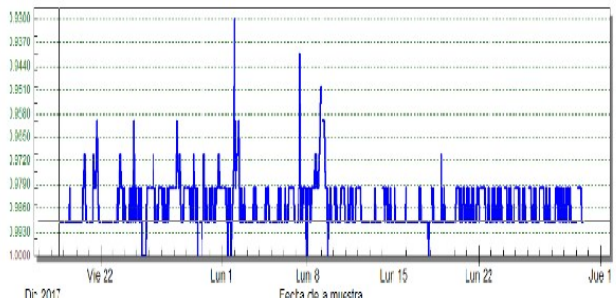


Figure 6. Cos(φ) measured in the electrical panel.

*E. Line voltage and voltage imbalance*

Figure 7 shows the voltage recorded by the Circutor meter. As it can be observed, the values are close to 400V, and the limit of ±7% is not exceeded during this period.

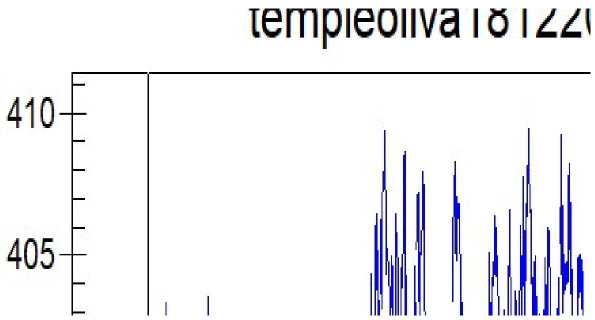


Figure 7. Line voltage measured in the electrical panel.

Figure 8 shows the voltage imbalance recorded by the Circutor meter. As it can be observed, there are some deviations, so that phase L3 usually has a slightly higher voltage than phase L2, and this in turn than phase L1. In any case, the differences are around 1V, as is to be expected since the daily averages do not provide relevant information in this respect. This figure shows the line voltages considering 15-minute averages, again showing that phase L3 has a slightly higher voltage than phases L1 and L2.

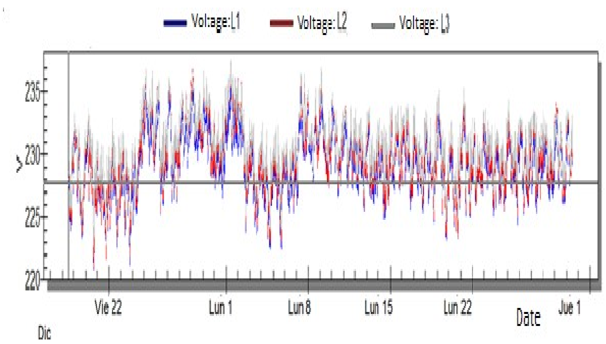


Figure 8. Voltage imbalance measured in the electrical panel.

*F. Frequency*

Finally, it is also analyzed the frequency values measured by the Circutor meter. The mains frequency should be 50 Hz under normal operating conditions. As long as generation and load remain balanced, this frequency should be kept constant. However, when anomalies occur between the generation capacity of the power system and the total load connected to the grid, frequency fluctuations may occur. If these fluctuations are of large magnitude, this can lead to failures in electric motors, problems in harmonic filters, etc. Figure 9 shows the frequency measurements in the olive mill, where it can be seen how the frequency values are very close to the nominal value of 50 Hz most of the time, only sporadically reaching maximum variations of 0.08 Hz (49.92 Hz) with respect to the nominal value. The UNE-EN 50160 standard states that, given the nominal frequency of the supply voltage of 50 Hz, under operating conditions, the value of the fundamental frequency must be within 50 Hz ± 1% for 95% of a week. Therefore, in terms of frequency, the values measured in this mill are within the range of acceptable electrical quality.

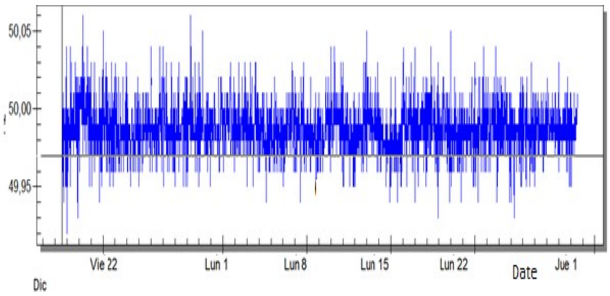


Figure 9. Frequency measured in the electrical panel.

*G. Harmonic distortion*

An important power quality issue to analyze is the harmonic distortion. Figure 10 shows how it is possible to determine the harmonics at any moment using Circutor meter. In this case, the most important harmonics are the fifth and the seventh ones.

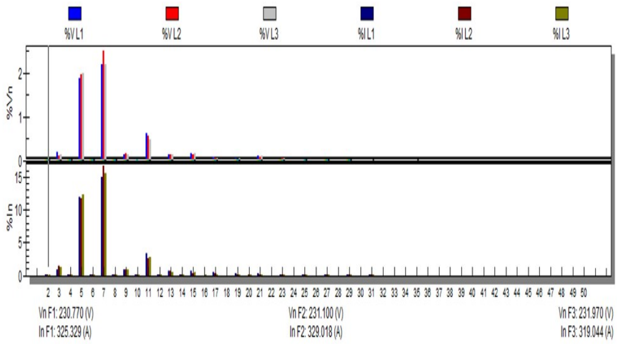


Figure 10. Voltage and current harmonics measured in the electrical panel.

Circutor meter also provides interesting information about the Total Harmonic Distortion (THD) values. As it is shown in Figure 11, voltage THD is lower than 4%. Values of L2 are slightly higher than those reported by L1 and L3.

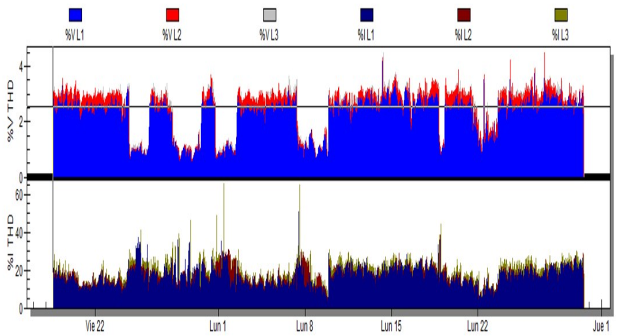


Figure 11. Total Harmonic Distortion (THD) measured in the electrical panel.

*H. CBEMA/ITIC*

Finally, Figure 12 shows the ITIC curve generated by Circutor MYeBOX 1500 which contains the events registered by this meter during these weeks. ITIC curve provides an AC voltage boundary that most equipment can tolerate without experiencing malfunctions or unexpected shutdowns. As it can be observed, most of the events included in the ITIC curve are located in the no damage region, but some of them are in the prohibited region, which denotes that a the electrical installation should be analyzed in detail.


Figure 12. ITIC curve generated by the Circutor meter.

## 4. Discussion

The analysis of the results obtained allows to propose some improvements that could be made to reduce consumption and to improve the power quality:

- Optimising working hours to reduce costs: This can be achieved in two ways. The first option is to reduce the excess power registered by the maximeter, which is associated with high-cost overruns. To eliminate this, consideration could be given to the possibility of balancing the work periods, so that they are not concentrated in the same time band. This can be done by reducing the number of electrical equipment in the installation that are in operation simultaneously. The second alternative is to reduce the activity in expensive time periods (expensive electricity time bands).
- Attenuation of the effects derived from the existence of harmonics: Taking into account the negative effects derived from the existence of harmonics, the possibility of using harmonic filters could be considered. Specifically, passive filters made up of inductances and capacitors installed in resonant circuits adjusted to the specific range of harmonics to be eliminated; active filters in parallel that, in addition to harmonics, can attenuate current unbalances; or hybrid filters that combine the advantages of passive filters and the active compensator.

## 5. Conclusions

When energy efficiency leads to lower usage, costs might be reduced. This is especially true if energy efficiency initiatives are widely implemented and on a big scale. This paper shows as it is possible to determine the power levels required by the operation of the industry and therefore to adjust the power contracted to this activity. Moreover, power quality measures can provide information about the possibility of introducing some strategies and devices in the daily operation.

The results obtained have allowed to obtain some suggestions of improvement, including the optimization of the working hours to reduce costs (this can be done by reducing the excess power or by reducing the production during expensive hours), and to attenuate the effects derived from the existence of harmonics using active harmonic filters.

These and other results provide suitable information about this oil mill, and the methodology can be extended to the analysis of other olive oil mills and also to sunflower [2] and palm [6] oil mills.

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