

Diagnosis of the power quality in the welding warehouse of the company CIAUTO Cia. Ltda.

Diagnóstico de la calidad de energía en la nave de soldadura de la empresa CIAUTO Cia. Ltda.

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ABSTRACT

In this article a diagnosis of the power quality in the welding hall of the company CIAUTO Cía. Ltda. is carried out, following the Ecuadorian regulation No. ARCERNNR - 002/20. The electrical parameters are recorded with the FLUKE 435-II and analyzed according to the quality of the product and the consumer. The results reveal that the power factor is below 0.92, indicating inefficient use of electrical

energy. In the evaluation of the quality of the product, it is observed that the voltage remains within the established limits, although it decreases considerably during working hours, on the other hand, the Flicker does not meet the standard, also the individual harmonic distortion specifically in the fifth harmonic 20% of variables recorded exceed 5%, unlike the total harmonic voltage distortion (THD) that meets the regulation. Likewise, an analysis of the quality in relation to the consumer is performed, revealing alarming levels of current consumption that exceed the nominal levels of the 800 kVA transformer at 325 A, also 90% of individual current harmonics greatly exceed the limits and the total demand distortion (TDD) has records of harmonics up to 80.04%. Finally, it is determined that the power quality in the welding hall of CIAUTO Cía. Ltda. presents deficiencies in power factor, Flicker and harmonic distortion. These results highlight the need to take measures to improve energy efficiency and ensure power quality for both the product and the consumer.

KEYWORDS: electrical diagnostics, power quality, voltage, current, harmonics

RESUMEN

En este artículo se efectúa un diagnóstico de la calidad de energía en la nave de soldadura de la empresa CIAUTO Cía. Ltda., siguiendo la regulación ecuatoriana No. ARCERNR - 002/20. Los parámetros eléctricos se registran con el FLUKE 435-II y se analizan en función a la calidad del producto y al consumidor. Los resultados revelan que el factor de potencia se sitúa por debajo de 0.92, lo que indica una ineficiente utilización de la energía eléctrica. En la evaluación de la calidad del producto, se observa que el voltaje se mantiene en los límites establecidos, aunque disminuye considerablemente en el horario de trabajo, por otro lado, el flicker no cumple la norma, también la distorsión armónica individual específicamente en el quinto armónico el 20% de variables registradas superan el 5%, a diferencia de la distorsión armónica total de voltaje (THD) que cumple la regulación. Asimismo, se realiza un análisis de la calidad en relación al consumidor, revelando niveles alarmantes de consumo de corriente que superan los niveles nominales del transformador de 800 kVA en 325 A, también el 90% de armónicos de corriente individual exceden ampliamente los límites y la distorsión de demanda total (TDD) tiene registros de armónicos de hasta el 80.04%. Finalmente, se determina que la calidad de energía en la nave de soldadura de CIAUTO Cía. Ltda. presenta deficiencias en el factor de potencia, flicker y distorsión armónica. Estos resultados resaltan la necesidad de tomar medidas para mejorar la eficiencia energética y garantizar la calidad de energía tanto para el producto como el consumidor.

PALABRAS CLAVE: diagnóstico eléctrico, calidad de energía, voltaje, corriente, armónicos

Introduction

Electric power supply is widely used by a variety of industrial and domestic consumers around the world (Popa, 2022). In the last decade, Ecuador has experienced a significant increase in its population, which has driven the development of the Ecuadorian Electricity System. This system plays a crucial role in ensuring the supply of energy to meet an ever-growing demand (Abril et al., 2023). Power quality (PQ) analyzes the variety of electromagnetic phenomena in electrical networks, in a facility is affected by the presence of electrical disturbances that can affect the voltage, current or frequency that are generated in the power plants, distribution system or user facilities (Cai et al., 2019). The use of devices with non-linear loads such as: welding, furnaces, variable frequency drives (VFD), flexible AC transmission (FACTS) and power electronic converters are the main cause of disturbances in electric power systems (Khetarpal & Tripathi, 2020). Poor power quality causes incorrect operation of the loads, or even damage that generates interruptions in the manufacturing processes. It should be emphasized that the current equipment that makes up the electrical system are more sensitive to electrical variations, for this reason, it is necessary to perform periodic measurements of the PQ to reduce maintenance costs and extend the service time of the equipment (Ojo et al., 2019; Polo et al., 2017).

The researchers Campaña et al. (2023) state that the increase in demand in the different power electric systems (PES) has a negative impact on voltage stability, reliability and quality of power supply. While Vitaliy et al. (2019) determined statistical characteristics of the power quality indicators and distortion curves, Vizúete et al. (2019) analyzed the causes of low-quality voltage supply based on voltage parameters, harmonics, voltage flicker, average voltage and power factor. In the study, they determined that installing voltage regulators improved energy efficiency in the analyzed company. The investigation of Karmaker et al. (2019) stated that the large number of electric vehicles charging stations that are integrated into the electrical grid produce harmonics, voltage drop and increase and loss of power.

Power quality is determined based on the indicators evaluated at the point of delivery by the distribution company, such as: voltage level, fast voltage disturbance (Flicker), harmonic voltage distortion and voltage unbalance. On the other hand, it is important to highlight that end users can negatively affect the electrical network by not complying with the regulatory limits established for harmonic current distortion, which can alter the correct operation of the electrical system (Espín, 2022).

The quality of the power system supply is subject to different evaluation standards to verify amplitude and frequency variations (Martínez-Rodríguez et al., 2019). There are specialized institutions that establish different procedures for auditing electrical quality, such as: IEEE, IEC, EN-50160, EN-61000 (Martínez et al., 2022). In Ecuador, Regulation No. ARCERNNR - 002/20 establishes PQ indicators and limits, in addition to defining procedures for registration, measurement and evaluation, both for distribution utilities and users (Iñiguez-Morán et al., 2023).

1.1 Regulation ARCERNNR-002/20

Quality attributes focused on the product and the consumer, established in section 5.1.1 and 5.2 of the regulation ARCERNNR 002/20, are described. Product quality is determined by considering the voltage level, fast voltage disturbances (flicker) and harmonic voltage distortion. The quality of the consumer is evaluated by measuring the harmonic current distortion. The mathematical models related to the quality parameters are presented in equations 1, 2, 3, 4 and 5.

$$\Delta V_k = \frac{V_k - V_n}{V_n} \times 100 \text{ [%]} \quad (1)$$

$$P_{st} = \sqrt{0.0314P_{0.1} + 0.0525P_1 + 0.0657P_3 + 0.28P_{10} + 0.08P_{50}} \quad (2)$$

$$V_{h,k} = \sqrt{\frac{1}{200} \sum_{i=1}^{200} (V_{h,i})^2} \quad (3)$$

$$THD_k = \left[\frac{1}{V_{h,1}} \sqrt{\sum_{h=2}^{50} (V_{h,k})^2} \right] \times 100 \text{ [%]} \quad (4)$$

$$I_{h,k} = \sqrt{\frac{1}{200} \sum_{i=1}^{200} (I_{h,i})^2} \quad (5)$$

$$TDD_k = \left[\frac{1}{I_{h,1}} \sqrt{\sum_{h=2}^{50} (I_{h,k})^2} \right] \times 100 \text{ [%]} \quad (6)$$

Where: ΔV_k : supply voltage variation with respect to nominal voltage at point k ; P_{st} : short duration flicker severity index; $V_{(h,k)}$: voltage harmonic h at interval k of 10 minutes; THD_k : total harmonic voltage distortion; $I_{(h,k)}$: current harmonic h at point k every 10 minutes; TDD_k : total current harmonics (ARCERNNR, 2023).

In the case of low voltage, the following requirements are established to ensure product quality: the voltage must be within $\pm 8\%$ of the nominal voltage, the flicker must not exceed unity, the maximum allowable limit for individual harmonic voltage distortion is 5%, and the total harmonic voltage distortion must not exceed 8%.

On the other hand, in order to guarantee consumer quality, the corresponding limits are presented in *Table 1*. It is important to highlight that, in the case of even harmonics, a limit equivalent to 25% of the even value is established.

Table 1*Odd Current Harmonic Distortion*

<i>I</i>	$3 \leq h < 11$	$11 \leq h < 17$	$17 \leq h < 23$	$23 \leq h < 35$	TDD
<20	4.0	2.0	1.5	0.6	5.0
20<50	7.0	3.5	2.5	1.0	8.0
50<100	10.0	4.5	4.0	1.5	12.0
100<1000	12.0	5.5	5.0	2.0	15.0

To obtain accurate parameters and analyze the power quality properly, it is necessary to perform the measurement at the common point of coupling (PCC). The network analyzer used must comply with IEC 61000-4-7 or IEC-61000-4-30.

The measurement must be carried out for at least 7 consecutive days, using 10-minute sampling intervals. In order to comply with the established electrical quality parameters, 95% of the records collected during this sampling period must comply with the limits defined in this section.

1.2 Problem

In the vehicle assembly process at CIAUTO Cia. Ltda, the use of electrical equipment is common, which involves a consumption of electrical energy that has a direct impact on the quality of supply. The persistence of these electrical problems can cause uncontrolled consequences in the future, directly affecting production and causing permanent damage to the equipment.

In this context, the need arises to carry out a diagnosis of the electrical quality in the welding shop of the company CIAUTO Cia. Ltda, where Great Wall vehicle chassis are assembled by welding. Over the years, this brand has experienced an increase in sales, which has necessitated a greater demand for electrical energy to assemble more vehicles.

For the diagnosis of electrical quality, this article follows the guidelines established in the Ecuadorian Regulation No. ARCERNNR - 002/20. Also, the methodology used is described and the results of the measurements of various electrical parameters are presented, such as voltage level, flicker, voltage and current harmonic distortion, considering up to the thirtieth harmonic component. The objective is to verify the power quality in relation to both the product and the consumer in order to know the current situation of the different electrical variables in the welding area.

In addition, the active power supplied to the equipment installed in the welding hall and the power factor will be monitored to characterize the energy consumption. Finally, the detailed analysis of the results obtained and the conclusions reached in the framework of this research are presented.

Methodology

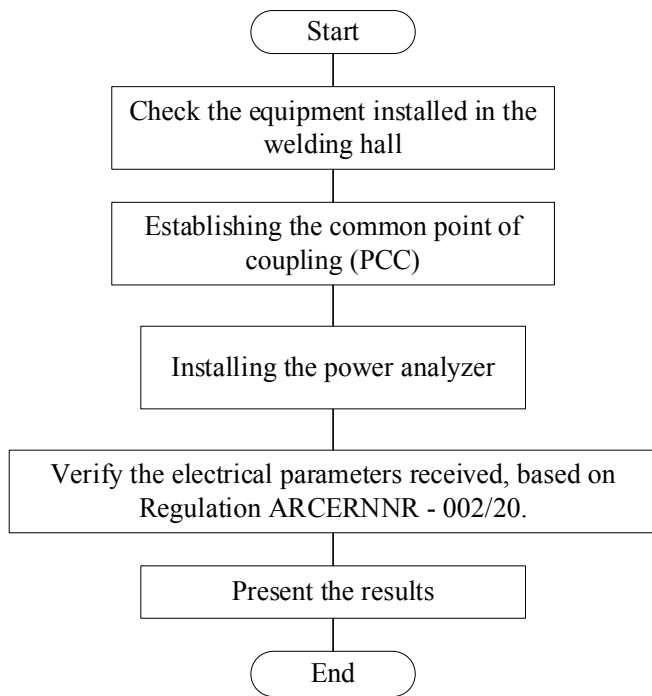
The study of power quality in the welding shop of CIAUTO Cía. Ltda. is carried out using the Work Breakdown Structure (WBS) methodology. This methodology allows breaking down projects into

individual parts, which facilitates their management, thus establishing the limits and scope of the project (Mañay et al., 2022).

The methodology is segmented into: direct observation of the low voltage system, identification of the loads installed in the welding hall, measurement and analysis of the power quality. *Figure 1* shows the procedure of the study carried out.

Figure 1

Power Quality Study Procedure



2.1. Description of the industry

CIAUTO Cia. Ltda. is an Ecuadorian company located in the city of Ambato, in the province of Tungurahua. In 2013, it began operations assembling Great Wall vehicles. It has body welding lines for SUVs, pickup trucks and pickup buckets (Ciauto, 2023). *Figure 2* shows the location of the company.

Figure 2

Location CIAUTO, "The City of the Car"



2.2 Welding hall

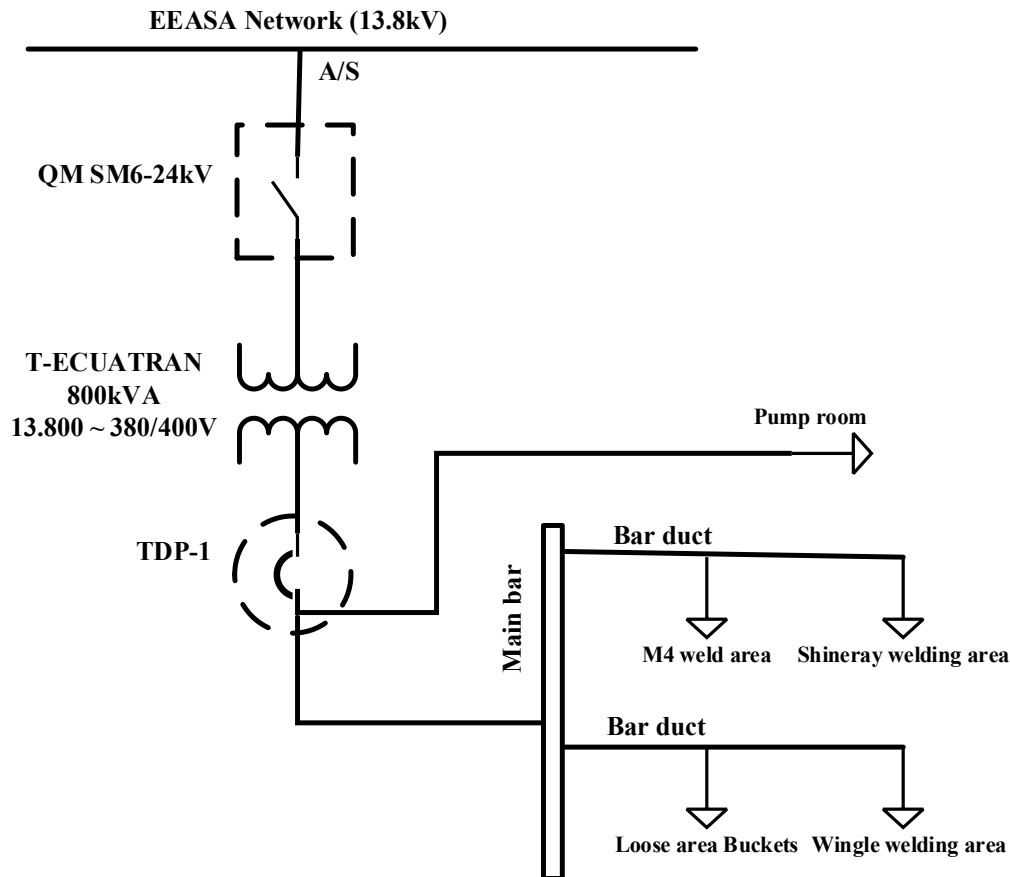
In the welding hall, the parts of the vehicles are joined by means of welding. In this hall, the installed equipment is identified and information is collected.

The electric power supply to the welding hall comes from the distribution company EEASA, through a medium voltage primary feeder of 60 Hz at 13800 V/33.36 A, which leads through the protection cell to the 800 kVA transformer that lowers the voltage level to 380 V and 1215.47 A on the secondary side.

A total of 87 units are installed in the welding hall, of which 99.82% of the installed load is composed of MIC welding (2 units), low frequency welding (40 units) and medium frequency welding (20 units), with an installed capacity of 12,844.8 kW and 16,056 kVA. The remaining percentage of the installed load (0.18%) is distributed among keyboards, water pumps and fans (Espín, 2022). *Figure 3* shows the single-line diagram of the welding area.

Figure 3

Simplified Single-Line Diagram



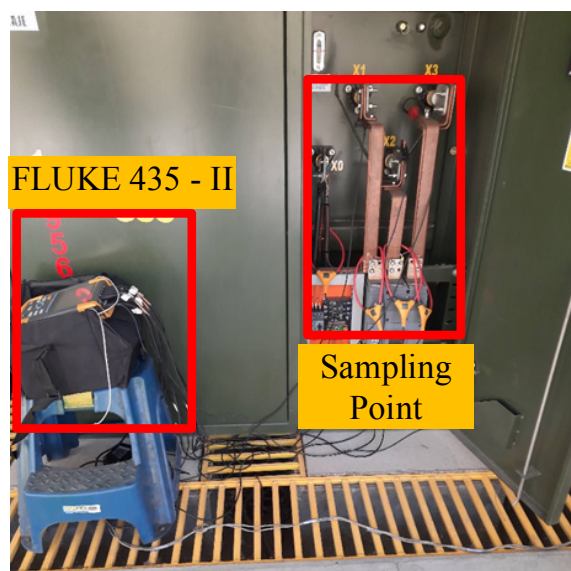
2.3 Measuring instrument

The FLUKE 435 category II analyzer is a tool used to measure various electrical disturbances that are essential for determining power quality. With the help of this analyzer, different samples of active power, power factor, voltage, flicker, current and harmonics are collected in the welding hall of the company CIAUTO Cia. Ltda. *Figure 4* shows the equipment in question.

Figure 4*FLUKE 435-II Quality Analyzer*

2.4 Arrangement of the power quality analyzer

Using the FLUKE 435 category II power quality analyzer as a support tool, electrical parameters were recorded to verify compliance with the operating limits established for power quality in the welding hall, in accordance with Regulation ARCERNR - 002/20. The analyzer was connected to the secondary side terminals of the 800 kVA transformer. Monitoring was conducted under steady-state conditions, at a sampling frequency of 10 minutes, over a 7-day period from October 3 to October 9, 2022. *Figure 5* shows the analyzer in operation.

Figure 5*FLUKE 435-II Analyzer in Operation*

Results

In this section, the results of nine factors recorded in the secondary of the 800 kVA transformer of lines 1, 2 and 3 are presented. The factors analyzed include active power, power factor, voltage, flicker, current and harmonics.

To verify compliance with energy quality standards, the ARCERNNR 002/20 regulation is applied, which establishes that at least 95% of the records in each phase must be within the admissible range. In this regard, a total of 607 data were collected to carry out the corresponding evaluations.

3.1. Characterization of electricity demand

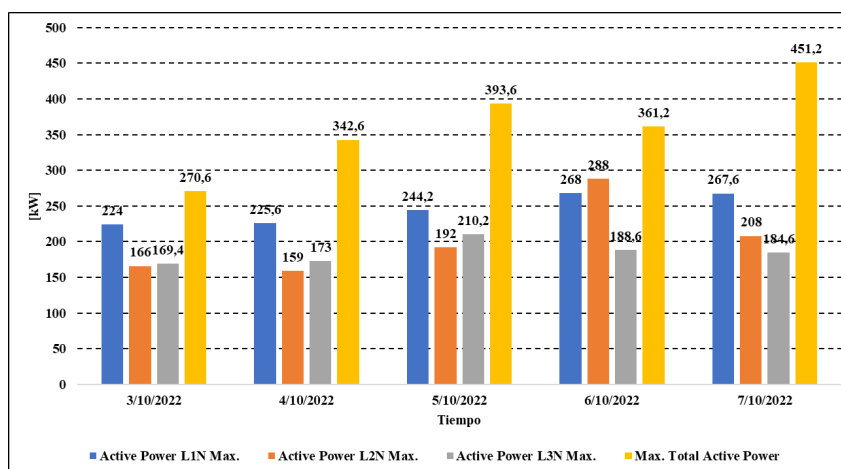
In order to evaluate the current energy demand in the welding hall of CIAUTO Cia. Ltda, a monitoring of the active power and power factor was carried out. First, the maximum demand of the company as a whole was verified, which was recorded at 770 kW.

Figure 6 shows the results of the maximum active power value for each line. Line 1 reaches a maximum of 268 kW, line 2 reaches 288 kW and line 3 with 210.2 kW. In addition, the total maximum consumption recorded is 451.2 kW.

Regarding the results presented, it should be noted that the maximum total power consumption was recorded on October 7, 2022. In addition, it is observed that line 1 is generally overloaded, with the exception of October 6, 2022, where an overload is detected on line 2.

Figure 6

Maximum Active Power



Power factor is a parameter that indicates how efficiently electrical energy is used to generate useful work (Saucedo & Taxis, 2008). A low power factor implies a loss of energy, which translates into an additional cost in the electric bill. Power quality regulations establish that the minimum

value for the power factor is 0.92 (Hernández, 2021). The results of the power factor studied are presented in *Table 2*.

Table 2

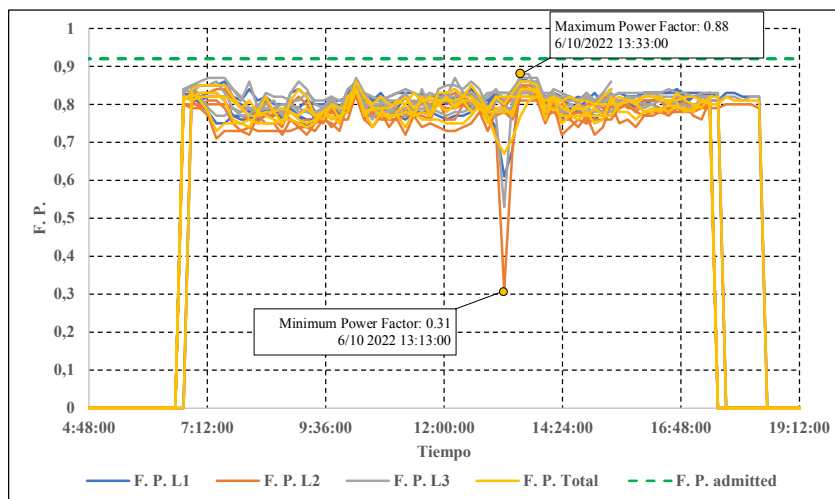
Power Factor Values

Variable analyzed	Maximum reading	Minimum reading
Power factor L1	0.87	0.61
Power factor L2	0.85	0.31
Power factor L3	0.88	0.53
Total power factor	0.86	0.67

It can be observed in *Figure 7*, that the power factor is under the limit of 0.92. The maximum total power factor obtained was 0.86 and a minimum value of 0.67. In addition, a worrying trend was identified on October 6, 2022 at 13:13, where minimum power factor values were recorded on line 1 (0.61), line 2 (0.31) and line 3 (0.53). In conclusion, it can be determined that the power factor is outside the allowed ranges established by the power quality regulation.

Figure 7

Power Factor Trend



3.2 Power quality as a function of the product

According to ARCERNR 002/20, product quality must comply with three main aspects: voltage level, flicker and harmonic voltage distortion.

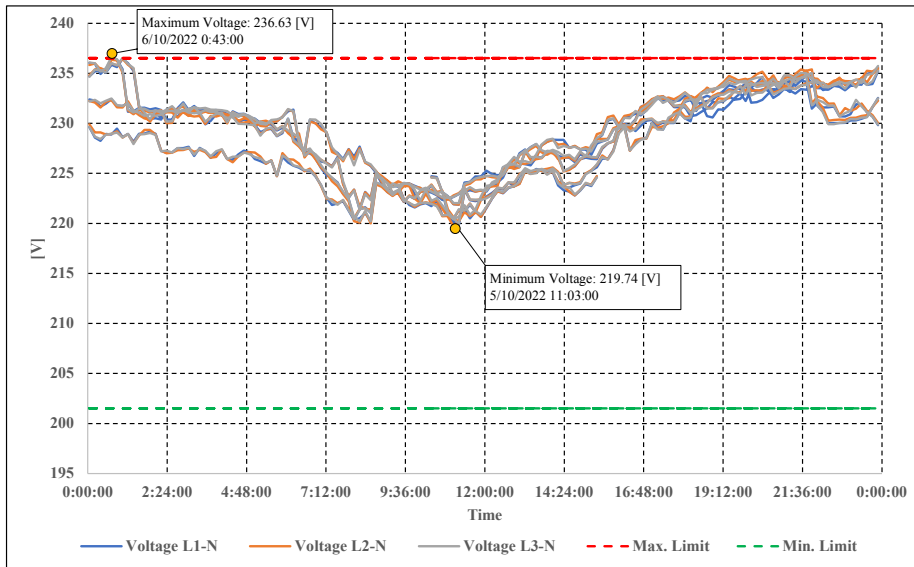
3.2.1. Voltage level

The welding vessel operates at voltage levels corresponding to the low voltage category, which implies that the supply voltage must not exceed $\pm 8\%$ of the nominal voltage.

The nominal voltage between line and neutral is 219 V. According to the regulation, the minimum allowed range is 201.52 V and the maximum range is 236.52 V. *Figure 8* shows a significant decrease in voltage during working hours. It is also concluded that voltage lines L1, L2 and L3 are within the minimum and maximum limits established by regulation ARCERNNR 002/20.

Figure 8

Line Voltage - Neutral



3.2.2. Rapid voltage disturbance (Flicker)

The power quality regulation ARCERNNR 002/20 establishes that the limit for Flicker at the measurement point should not exceed unity. The results of the study are presented in *Table 3*.

Table 3

Flicker Readings

Variable analyzed	Maximum reading	Minimum reading
Flicker L1	2,774	0,058
Flicker L2	3,5	0,06
Flicker L3	2,868	0,059

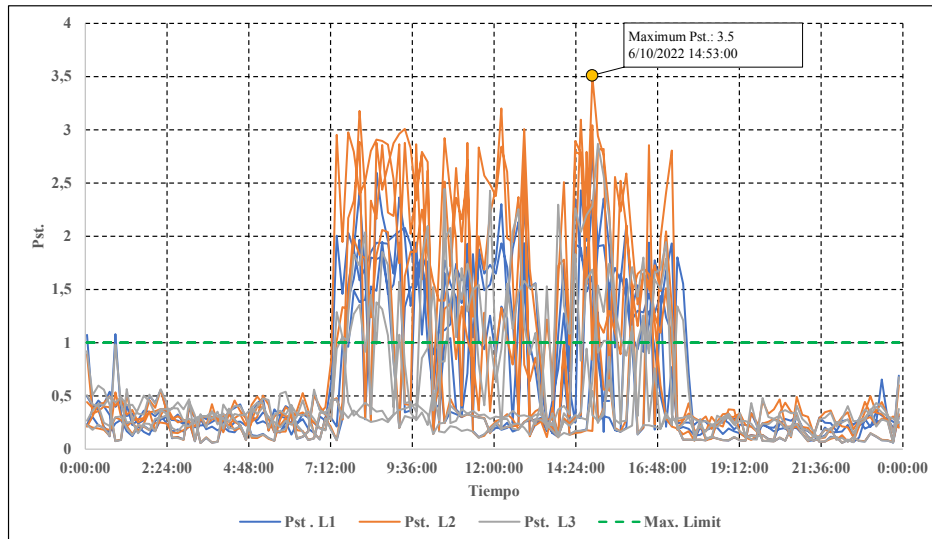
Figure 9 shows the trend of the Flicker readings, from which the following observations can be made:

In line 1, 2 and 3, it was observed that 25%, 27% and 17% of the measurements, respectively, are above unity.

In conclusion, although the largest number (>80%) of readings in lines 1, 2 and 3 are below unity, it does not comply with ARCERNNR 002/20 regulation, which states that at least 95% of the records must be below unity.

Figure 9

Flicker Trends



3.2.3. Harmonic voltage distortion

The ARCERNNR 002/20 regulation establishes that the maximum limit in low voltage for the individual harmonic distortion factor must not exceed 5%, while for the total harmonic voltage distortion factor (THD) it must not exceed 8%.

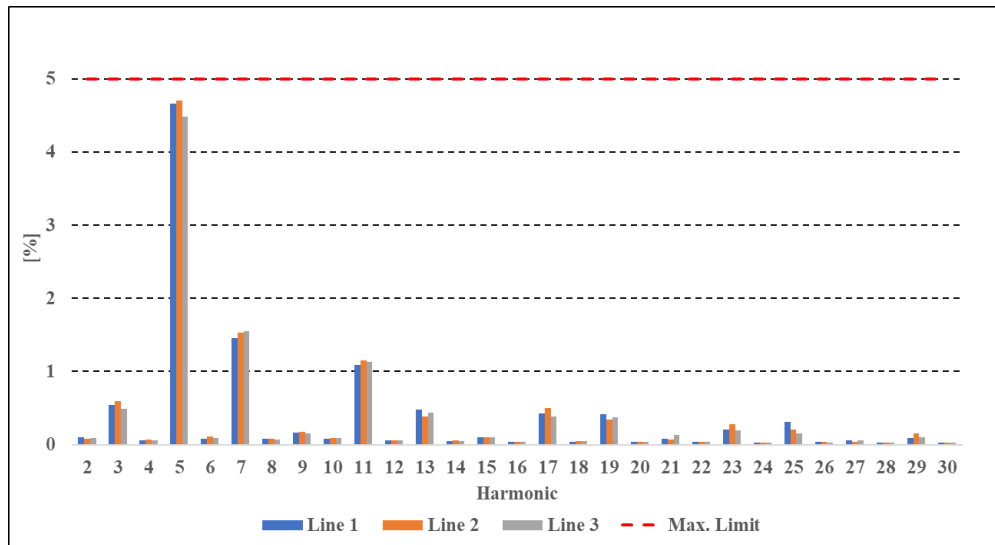
a) Individual harmonic voltage distortion

A comprehensive comparison was carried out using data obtained with the FLUKE 435-II analyzer. In this study, measurements were made up to harmonic 30. Most of the harmonics comply with the requirements established in the regulation, except for harmonic 5. In lines 1, 2 and 3, it was observed that 29%, 31% and 28% of the results, respectively, exceed the 5% limit established for harmonic 5.

Figure 10 shows a general representation of the individual harmonic distortion. Harmonic 5 is the most significant in the three lines analyzed with a value of 4.66% in line 1, while in line 2 it presents a value of 4.7% and in line 3 a value of 4.48% is observed.

Figure 10

Individual Harmonic Voltage Distortion

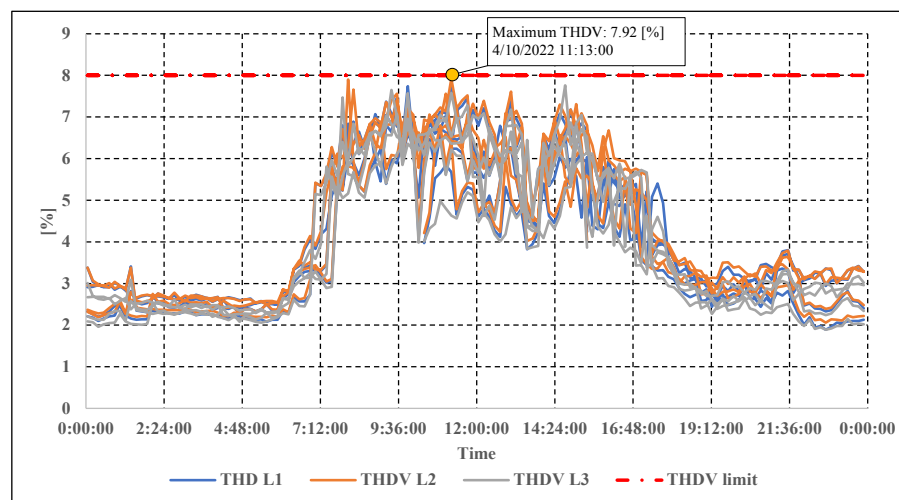


b) Total Harmonic Voltage Distortion (THDV)

The total harmonic distortion at low voltage should not exceed 8%. In *Figure 11* it can be observed that 100% of the analyzed data comply with the requirements established in the ARCERNNR 002/20 regulation. It is important to highlight that the maximum value of the total harmonic was recorded on October 4, 2022 at 11:13, reaching a percentage of 7.92%.

Figure 11

Total Harmonic Voltage Distortion



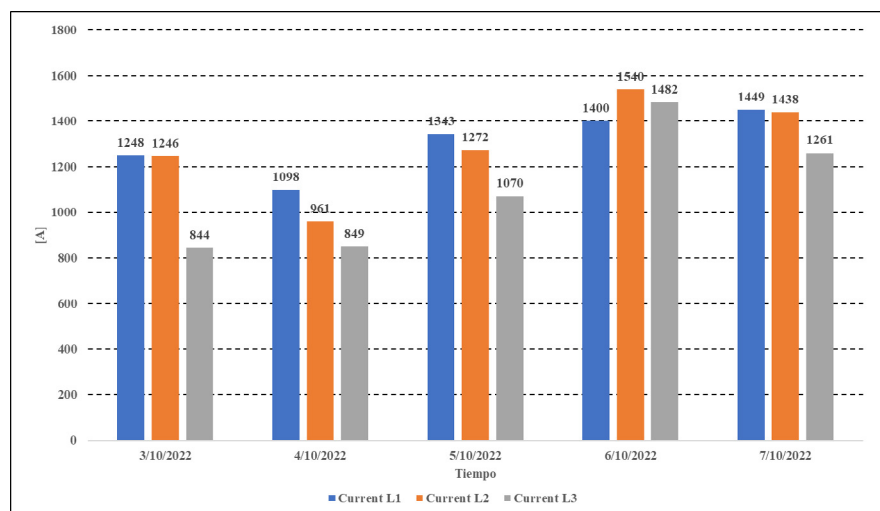
3.3. Energy quality according to the consumer

In this segment the line current in the welding hall is analyzed. It is important to note that the 800 kVA transformer has a rated current of 1215.47 A, while the busbars have a rated current of 1500 A. In Figure 12, it can be clearly seen that the electrical consumption on October 6, 2022 exceeded the established nominal limits. The current of line 1 exceeded by 185 A, the current of line 2 exceeded by 325 A, and line 3 registered an excess of 267 A with respect to the rated current of the transformer. In addition, it is important to note that the current of line 2 exceeded the rated current of the busbars by 40 A.

These results indicate a worrying situation regarding load capacity and measures must be taken to correct and avoid future electrical overloads in the welding hall.

Figure 12

Maximum Recorded Line Currents



3.3.1 Harmonic current distortion

In this part, the electrical quality in the welding hall is analyzed according to the consumer, the individual harmonic distortion and the total harmonic distortion of current up to harmonic 30 are evaluated.

In order to establish the limits of current harmonics, it is necessary to perform mathematical calculations according to IEEE519 (Jácome & Vargas, 2019). The fundamental parameter is the impedance of the 800 kVA transformer, which is found to be 3.7%. This impedance is used to determine the value of I_{L1} , which is equal to 27.027A.

To calculate the value of I_{L1} , the peak currents shown in Figure 12, in relation to the rated current of the transformer, were used. This revealed the following values: $I_{L1} = 1.19$, $I_{L2} = 1.26$ and $I_{L3} = 1.219$. Using these values, the ratio α was determined, which is calculated as I_{L1} divided by I_{rated} . The resulting values were $\alpha_{L1} = 22.71$, $\alpha_{L2} = 21.34$ and $\alpha_{L3} = 22.17$.

With the α results, the ratio $20 < 50$ arranged in Table 1 was identified, where the current harmonic limits are found. For individual harmonics in the range $3 \leq h < 11$, a maximum limit of 7% for odd harmonics and 1.75% for even harmonics is established. In the interval of $11 \leq h < 17$, the odd harmonics must comply with a limit of 3.5%, while the even harmonics have a limit of 0.75%. Likewise, in the interval of $17 \leq h < 23$, the odd harmonics have a limit of 2.5%, while the even ones must comply with a limit of 0.625%. Finally, in the interval of $23 \leq h < 35$, the odd harmonics have a limit of 1%, while the even ones must comply with a limit of 0.255%. In addition, a total harmonic current limit (TDD) of 8% is established.

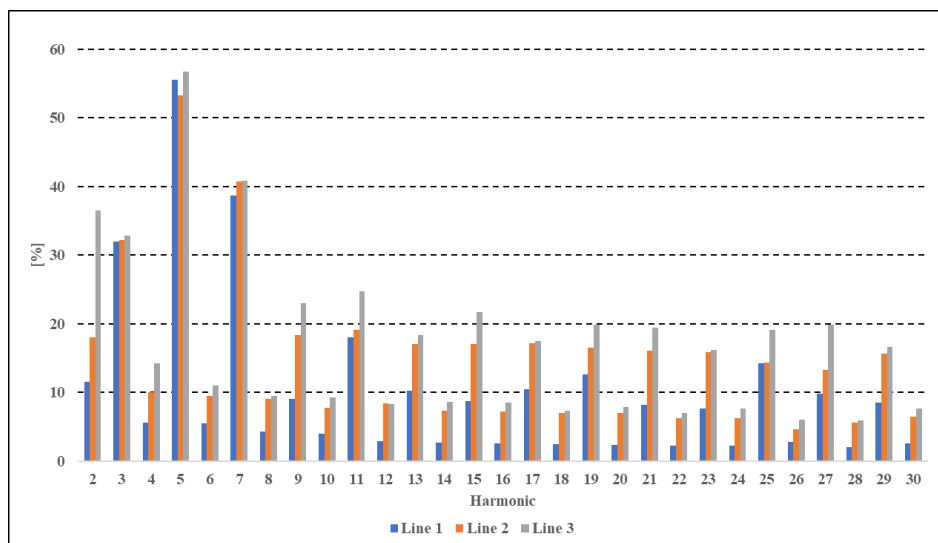
a) Individual harmonic current distortion

An exhaustive comparison was carried out using the data obtained with the FLUKE 435-II analyzer up to harmonic 30. After the comparison it was established that none of the harmonics complies with the limits established by the ARCERNNR 002/20 regulation, in all the analyzed cases 90% of the data exceed the normal limits.

Figure 13 shows a general representation of the individual harmonic distortion. Harmonic 5 stands out as the most significant harmonic in the three lines analyzed. In line 1, a value of 55.56% is recorded, while in line 2 it presents a value of 53.35%, and in line 3 a value of 56.77% is observed. In addition, 7 and 3 are identified as other important harmonics that disturb the electrical system under study. These findings indicate the need to take corrective measures to mitigate these harmonics and prevent the deterioration of the installations

Figure 13

Individual Current Harmonics



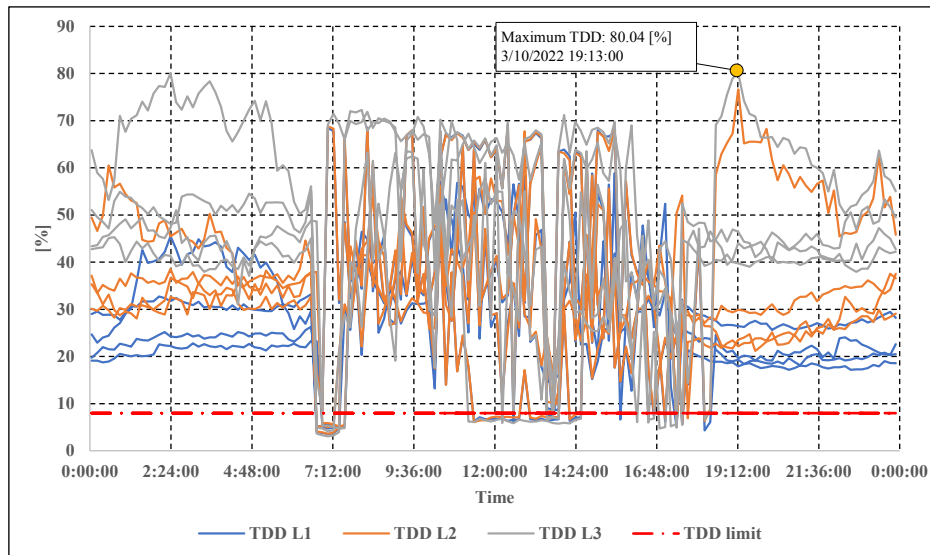
a) Total Demand Distortion (TDD)

The percentage of total harmonic current distortion must not exceed the limit of 8% established by regulation ARCERNNR 002/20. However, in Figure 14 it can be observed that in line 1, 93% of the

data exceeds this limit, in line 2 it reaches 94%, and in line 3 91% of the records are exceeded. It is important to highlight that the maximum value recorded for the total harmonic occurred on October 3, 2022 at 19:13, reaching a percentage of 80.04% in line 3. These results indicate a high presence of harmonic distortion in the electrical system, which requires actions to correct and reduce these levels, in compliance with established quality standards.

Figure 14

Total Harmonic Voltage Distortion



Conclusions

The total electricity demand of CIAUTO Cia. Ltda., oscillates around 770 kW. Of this value, the welding plant represents 58.5% of the demand, which is equivalent to a consumption of 451.2 kW.

Likewise, an analysis of consumption was carried out in the different lines L1, L2 and L3 with maximum peak records of 268 kW, 288 kW and 210.2 kW respectively. It is important to highlight that line 1 presented overloads in general, with the exception of October 6, 2022, when an overload was detected on line 2.

In relation to the power factor, a maximum value of 0.86 was obtained. It is worrisome to highlight an alarming trend recorded on October 6, 2022 at 13:13, where lines L1, L2 and L3 showed a power factor of 0.61, 0.31, and 0.53 respectively. These results clearly indicate that the power factor is below 0.92 established by the power quality regulation. Given this situation, it is imperative to take immediate and corrective measures to improve energy efficiency in order to avoid penalties and power supply problems.

As for power quality in terms of the product, aspects such as: voltage level, flicker and harmonic voltage distortion were evaluated. According to the ARCERNR 002/20 regulation, the admitted variation is 201.52 V to 236.52 V which is $\pm 8\%$ of the nominal voltage of 219 V between line and

neutral of the supply to the welding hall. During the working hours, a significant voltage decrease was observed. However, the voltage of L1, L2 and L3 remained within acceptable parameters and did not exceed $\pm 8\%$ of the nominal voltage.

When analyzing the Flicker at L1, L2 and L3, it was observed that 25%, 27% and 17% respectively of the measurements exceed unity. This indicates that it does not comply with the regulation that indicates that at least 95% of the records must be less than unity.

To analyze the individual harmonic distortion, it was taken up to harmonic 30, from which, except for harmonic 5, they comply with the ARCERNR 002/20 regulation. In harmonic 5, 29%, 31% and 28% in L1, L2 and L3 respectively exceed the 5% limit established in the regulation. While, the total harmonic voltage distortion (THD) 100% of the data comply with the regulation. It is important to highlight that the maximum THD value was recorded on October 4, 2022 at 11:13, reaching a percentage of 7.92%.

In relation to the power quality in relation to the consumer, the following were evaluated: consumption current, individual current distortion and total demand distortion (TDD). In relation to the consumption, the nominal current value of 1215.47 A of the 800 kVA transformer was exceeded. On October 6, 2022, the current consumption in L1, L2 and L3 exceeded the nominal value of the transformer by 185 A, 325 A, and 267 A respectively. In addition, it is important to note that the current of line 2 also exceeded the rated current of the busbars by 40 A. These results indicate a worrying situation in terms of load capacity and measures should be taken to correct and avoid future electrical overloads in the welding hall.

In the evaluation of the individual harmonic current distortion, harmonic 5 was the most severe in the three lines analyzed with a distortion of 55.56%, 53.35% and 56.77% respectively. In addition, harmonics 7 and 3 were identified as other important harmonics that disturb the electrical system under study. These findings indicate the need to take corrective measures to mitigate these harmonics.

In the total demand distortion (TDD), it was determined that in lines L1, L2 and L3 93%, 94% and 91% of the records exceeded the 8% limit set by regulation ARCERNR 002/20. It is important to highlight that the maximum TDD value recorded occurred on October 3, 2022 at 19:13, reaching a distortion of 80.04% on line 3. These results indicate a high presence of harmonic distortion in the electrical system, which requires actions to correct and reduce these levels.

In general, it is concluded that it is necessary to take measures to improve power factor, reduce flicker and control harmonic distortion. These improvements will contribute to ensure the power quality of the product and the consumer.

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