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ORIGINAL RESEARCH ARTICLE

Analysis of the energy management in the company irrigation elements for agriculture

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ABSTRACT

This paper analyzes the necessary linkage that must exist between the behavior of energy management in the industries destined to produce elements for agricultural productions, in this case, part of the components of irrigation systems for agriculture, important systems to ensure favorable results in the characteristic crops of each season of the year, whether or not they are short cycle. The behavior of the energetic expense is fundamentally analyzed, mainly of the electric system and the support energetic systems that determine the conformation of the productions destined for the irrigation systems. Proposals are made that can contribute to diminishing the production costs in the productive entity and that can contribute to a decrease in the cost of obtaining the agricultural product.

Keywords: system; energy; agricultural production; cost

1. Introduction

Energy is consumed in many ways in all areas of life, from the supply of vital resources such as water, oil, and gas to the lighting and heating of homes and the energy needed by industry and commerce[1]. Much of this energy is consumed in a useful way, but it does not always occur in this way, making it necessary to carry out actions that contribute to continuous improvement in this sense and in all productive processes. Therefore, the problem posed lies in how to reduce energy expenditure in the production process of irrigation elements for agriculture, a process that incorporates equipment with electricity consumption and that constitutes the social purpose of the Rufino Suarez Albo Base Business Unit, belonging to the Irrigation Elements Company of the Ministry of Industries.

The analysis is mainly aimed at assessing the behavior of the electrical system and its aggregates and their determining influence on the production costs for irrigation systems, taking into account the regulations in force for this type of study.

In 2011, the International Organization for Standardization (ISO) published the ISO 50 001 standard "Energy management systems—Requirements with guidance for use", whose purpose is to facilitate organizations in establishing the necessary systems and processes to improve their energy performance[2]. Although this regulation aims, in the long term, to increase energy efficiency by 20%, on the other hand, it

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does not establish absolute requirements in terms of energy behavior beyond the commitments of the organization's energy policy and its obligation to comply with legal or other requirements applicable to the case; therefore, other methodologies and tools are needed for the establishment, maintenance, and improvement of an energy management system (SGEn) as required by that standard, within which the Total Efficient Energy Management Technology (TGTEE) can be included[3].

Total Efficient Energy Management consists of a technology integrated by a package of procedures and technical-organizational tools that, when applied continuously with the philosophy and procedures of total quality management, allow the identification and use of all opportunities for savings, energy conservation, and reduction of energy costs for the company[4].

Understanding energy flows and balances is a basic element of achieving energy sustainability and is important for economic, ecological, and social reasons. Knowledge and quantification of the energy efficiency of food production systems should become a fundamental tool for the design of better agricultural management strategies and political decision-making. Therefore, it is a priority to incorporate the necessary methodological elements in order to design sustainable systems for food and energy production. This step will be a decisive element for the more efficient use of available energy sources, both biological and industrial[5].

The main objective of this work is to identify energy-saving opportunities in a metallurgical company producing irrigation system elements.

2. Methods

The study was carried out in the Rufino Suarez Albo Base Business Unit, belonging to the Empresa Elementos de Riego del Ministerio de Industrias located in the municipality of Guanabacoa, being a significant consumer of electric energy within the same. The productions of the entity are: windmills, irrigation machines, plastic articles, horizontal electric pumps, motor pumps, hoses, and irrigation systems. These productions have as main clients the Ministry of Agriculture and Tabacuba.

An analysis of the behavior of the energy carriers was carried out taking into account their consumption statistics using the tools of Total Efficient Energy Management Technology, including the first-order energy diagnosis[6].

Also called walk-through diagnosis. It consists of a visual inspection of the plant's energy facilities, observation of operating parameters, analysis of operating and maintenance records, as well as global statistical information on electricity, fuel, and water consumption and billing. This diagnosis provides a general overview of the energy status and a preliminary idea of the potential for energy and economic savings[4].

A Pareto diagram was made in order to identify the carrier that accounts for 80% of the total equivalent energy consumption (**Figure 1**).

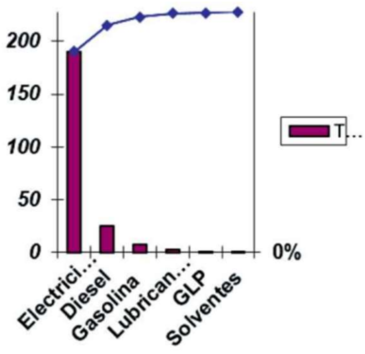

Figure 1. Pareto diagram-behavior of energy carriers.

The electric load curve for the year was drawn up taking as a reference the values for 2018, and it is observed that in the months of June, July, and August, consumption is higher, and the monthly planning of the electricity carrier was made on the basis of a linear behavior that introduces deviations in terms of the behavior of the carrier.

In Cuba, Total Efficient Energy Management Technology (TGEE) and the procedures for improving the processes involved in fuel consumption[7] have been designed to manage energy efficiency within organizations. Both respect the continuous improvement cycle Plan-Do-Check-Act, with techniques and tools coinciding between both methodologies; however, the TGEE has been more applied in the country but lacks energy planning in accordance with NC-ISO 50001:2011 2011[2].

For the preparation of the study, the Cuban Electrotechnical Code NC-800-2017-12, Resolution 152 of the Ministry of Energy and Mines 2018 and Resolution No. 116/2017 establishing the methodological indication containing the minimum technical-organizational requirements of the industrial maintenance system, and the NC 8995 S 008 illumination of indoor workplaces[8] were taken into account.

Conditions in the energy systems under study

The technical condition of the equipment was reviewed, and the inventory of existing equipment was reconciled with its technical availability, concluding that the machinery has a high degree of technological obsolescence, which implies that they are large consumers of electrical energy, which represents 80% of the entity's consumption structure.

The machines have electric motors, and therefore it is necessary to periodically perform the appropriate maintenance and tests on them. It must be fulfilled that:

The plans to be developed are:

Annual maintenance by specialties, mechanical, electrical, automatic, and constructive, in accordance with the maintenance cycles established according to running hours, actual working hours of the equipment, and manufacturers' specifications[7].

The electrical system needs maintenance and updating of its electrical mono-linear diagram to facilitate this activity. The equipment protections in the agricultural mechanization workshop are oversized, which conspires with the preservation of the equipment in the event of an electrical failure[9–11].

The lighting is not suitable for the visual task being performed considering that during the night shift natural lighting cannot be used, failing to comply with the provisions of Resolution 152 of 2018 of the ONURE-Ministry of Energy and Mines[12].

The characteristic load curve of the establishment was made considering the two working shifts of the entity to subsequently verify the correct application of Resolution 177 of 2014 of the Ministry of Finance and Prices (a resolution that establishes the payment rates of the non-residential sector)[13] through the analysis of the 2018 billing. From this analysis, it can be seen that the analysis should focus on the correct contracting of demand and the elimination of penalties for reactive energy consumption, both of which are contemplated in the current tariff system.

The Rufino Suarez Albo Business Unit was recently created, so it does not have historical consumption series that would allow it to establish a base period that would make it possible to prepare an analysis in accordance with the requirements shown below:

Determine the energy baseline and energy performance target line, and improve, design, or incorporate energy performance indicators. The baseline and target line are determined through linear dispersion analysis or alternative models. For this purpose, it is mandatory to take as reference data for more than 3 years when monthly information is available; however, when the information is daily, one year's data can be considered. To achieve this objective, the following tools are proposed:

- Scatter diagram
- Comparison of alternative models.
- Cumulative Sums Trend Chart (CUSUM).
- Consumption versus production index diagram[2].

In the course of the review of the existing energy statistics, the need to periodically reconcile the energy consumption with the finished production per assortment to quantify the production in process and the rejection in each concluded production is evident. The variety of assortments in the production has not allowed to establish a representative consumption index to perform the analysis by the linear regression method that allows to establish the correlation between the production and the consumption of electric energy. To achieve a representative indicator, there is the method of equivalent production.

For the execution of the equivalent production method in an entity (knowing the characteristics of the company in question and the different productive activities that are developed in it), it is necessary to process a large amount of information that must be obtained from the production department of the company, which has the technological chart of each of the machinery and the electricity consumption for each of the productive processes. Subsequently, the control variable, i.e., electricity, must be defined, and a base period must be set to regulate the products with the highest consumption and refer the remaining production processes to it.

Two basic indicators are used to evaluate changes in energy efficiency: energy intensity and specific energy consumption, or consumption index.

Energy intensity is defined, for a sector of a country's economy, as the energy consumption per unit of value added by that sector. At the national level, gross domestic product (GDP) is the sum of the value added by all economic sectors, and in this case, energy intensity for the national economy as a whole is the ratio of total energy consumption of all sectors to GDP.

For a company, energy intensity would be the ratio between total primary energy consumption and market output expressed in values.

Specific energy consumption, or consumption index, is defined as the amount of energy per unit of activity, measured in physical terms (products or services)[7].

Activities covering the production of irrigation systems are declared in the analyses in their entirety, e.g., "production of forage machines" and "production of irrigation systems," and consumption is not standardized by the component elements of both productions[11].

Taking into account the above, we can establish that, as a result of the preparation of the first-order energy diagnosis that covers all energy systems and equipment in their entirety.

Inspection plays an important role in detecting possible asset defects. An adequate inspection makes it possible to obtain information that will allow the diagnosis of the causes of failures and, thus, be in a better position to establish the strategies to be followed to eliminate them or minimize the occurrence of problems. On the other hand, this allows us to follow up and obtain criteria about defects that have already been detected, prolonging their useful life and contributing to avoiding the occurrence of accidents that could prevent injuries, loss of human lives, materials, economic, and environmental impacts[12].

The Prototipo Rufino Suárez workshop is fed by a Medium Voltage (MV) line at 13.8 kV by means of a bank of Y-Δ transformers of 167 kVA each. This voltage is transformed to obtain 110 and 220 V through the secondary that feeds two work bays, where most of the equipment is fed with 220 V while others are fed with 440 V by means of a step-up transformer from 220 to 440 V. Taking into account the above, the contracted tariff is M1-A.

From **Table 1**, it can be deduced that the average cost per kWh in this workshop is 0.25 cents, which is high, and there are possibilities to decrease this value by applying measures that lower the total cost, such as demand recontracting.

Table 1. Billing analysis, sample of analyzed values.

Date	Consumption (kWh/month)	Total amount (CUP)	Maximum contracted demand	Maximum recorded demand	fp (cos φ)
2/3/2018	5371	1627.29			0.92
2/6/2018	7958	1911.8			0.88
2/8/2018	10,046	2312.84			0.92
2/10/2018	8135	1993.59			0.87
2/12/2018	7454	1769.86			0.85

The maximum contracted demand, initially set by the company, is 60 kW. When inspecting the meter reading, it was observed that the average maximum demand is 33.6 kW. For this reason, it is convenient to recontract the demand to adapt it to the real maximum demand values, which would imply a significant saving in the company's annual electric billing expenses.

For this saving, a contracted demand of 40 kW is proposed.

For the savings calculation it was taken into account that the kW of maximum contracted demand at any time of the day is charged at 7 CUP/month (Equation (1)).

$$\text{Icf} = \text{Prsf} \cdot \text{Dc} \tag{1}$$

where Icf—Fixed charge amount; Prsf—Price for the contracted demand in the month; Dc—Maximum contracted demand.

Current contracted demand: Icf = 7 CUP⁄mes × 60 kW = 420 CUP/month

Proposed contracted demand: Icf = 7 CUP⁄month × 40kW = 280 CUP/month

Monthly savings = 420 CUP/month – 280 CUP/month = 140 CUP/month

Annual savings = 140 CUP/month × 12 months/year = 1680 CUP/year

Through this analysis, a favorable economic impact was obtained by reducing the costs of the fixed charge of the invoicing, which constitutes a decrease in the total expenses of the entity and therefore in the production cost of the elements produced for agriculture.

Penalty analysis

The supply of electric energy to services of any demand, in order to take into account the assurance and rational operation of the National Electric Energy System (SEN), is carried out with a power factor (cos φ) for the customer of 0.90 or higher, since lower values imply unnecessary reactive energy expenses through the SEN lines, causing energy losses.

Mathematical model to calculate the penalty (Equation (2)):

$$\text{Penalty} = \text{Normal Billing} - ((0.90 - \text{F. Pot.Actual})/\text{F.Actual.Pot.Actual}) \quad (2)$$

Mathematical model to calculate the bonus (Equation (3)):

$$\text{Bonus} = \text{Normal Billing} - ((0.92 - \text{F. Pot. Actual})/\text{F.Pot.Actual}) \quad (3)$$

3. Results and discussion

The power factor in the Rufino Suárez Prototype workshop had a low behavior throughout 2017 and part of 2018, averaging 0.87, except in the month of August, when it was above the average value of 0.92. Therefore, the possibility of evaluating the proposal to install a capacitor bank in this facility was reviewed. The investment was made after a feasibility study, and a 250 kV capacitor bank was acquired. This solution was provided by the National Company of Machines and Tools (Maquimotor), belonging to the Ministry of Industries. Currently, the entity averages 0.94, for which they receive a bonus from the Electrical Union. They are recovering the investment made in compliance with Article 27.1 of Resolution 152 of the ONURE 2017 Ministry of Energy and Mines.

It is necessary to consider the fields of activity of a company and of the Centers of Higher Education. Actually, the scopes of the companies and of the centers of higher education are different; the areas of action of the companies are framed in science, technology, and market; the scope of higher education is broader and includes its close link with society[14].

The updating of the monoline diagrams of the center was carried out with fifth-year students of the Electrical Engineering Faculty of CUJAE, thus completing technical information of great utility for the entity and linking the students with practical work in the Cuban industry following the regulations established for the preparation of the diagram. A proposal was made to change the input transformers for others of lower capacity because they were underloaded and contributed to physical (kWh) and economic losses. The transformer bank is 500 kVA, and the study proposed replacing it with a 75 kVA transformer.

The lighting levels of the workshops were also reviewed, taking into account that adequate lighting and sectionalization of electrical circuits constitute a potential for savings. For the analysis of this situation, the Dialux 4 software was used. 11 was used to propose an adequate lighting system that will allow a better working environment and therefore greater progress and quality in production. This software is based on the method of lumens according to Castilla et al.[15], It is proposed to replace existing lighting fixtures with LEDs, achieving an improvement in the working environment of the operators, mainly in the agricultural mechanization ship. The Cuban Lighting Standard ISO 8995/CIE S 008 was consulted in 2003 (published by ISO and CIE) NC ISO 8995/ CIE S 008:2003[8] and González et al.[14].

Economic valuation

From **Table 2**, it can be concluded that by implementing these proposals the cost per kWh in the Rufino Suarez Prototype workshop can be reduced from 0.25 to 0.21 cents, being a significant economic saving for the company, contributing to a good execution of the budget allocated for the payment of electric energy, which contributes to the reduction of the production costs of irrigation elements, the social purpose of the analyzed entity.

Table 2. Results of the proposals made.

Proposal	Physical savings (kWh)	Monthly savings (CUP)	Annual savings (CUP)
Demand recontracting to 40 kW		140.00	1680.00
Power factor compensation		63.15	757.80
Change of transformer bank to 75 kVA	227.51	52.32	627.84

4. Conclusions

Total and Efficient Energy Management Technology is applicable to all entities and its calculation tools, in addition to making it possible to evaluate the economic impacts on the cost of the final products that constitute the corporate purpose of each particular case.

In the entity that concerns us, it is necessary to apply all the necessary steps to implement this management system, even in the integrated management scheme, because it requires the involvement of all personnel, from managers to operators, all of whom are important participants in the scheme to achieve the desired result of efficient and quality production with the necessary expenditure of energy carriers.

Conflict of interest

The authors declare no conflict of interest.

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