ISSN 2523-2517

Volume 5, Issue 15 — July — December — 2021

Journal Electrical Engineering

ECORFAN®

Journal Electrical Engineering, Volume 5, Number 15, July-December 2021, is a magazine published biannually by ECORFAN-Peru. La Raza Av. 1047 No. - Santa Ana, CuscoPeru. Postcode: 11500. WEB: www.ecorfan.org/republicofperu, revista@ecorfan.org. Editor in Chief: QUINTANILLA - CÓNDOR, Cerapio. PhD. ISSN: 2523-2517. Responsible for the last update of this issue of the ECORFAN Informatics Unit. ESCAMILLA-BOUCHÁN Imelda, LUNA-SOTO, Vladimir, updated December 30, 2021.

Journal Electrical Engineering

Definition of Journal

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Support the international scientific community in its written production Science, Technology and Innovation in the Field of Engineering and Technology, in Subdisciplines Electromagnetism, electrical distribution sources, electrical engineering innovation, signal amplification, electric motor design, material science in power plants, management and distribution of electrical energies.

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Knowledge Area

The works must be unpublished and refer to topics of Electromagnetism, electrical distribution sources, electrical engineering innovation, signal amplification, electric motor design, material science in power plants, management and distribution of electrical energies and other topics related to Engineering and Technology.

Presentation of the content

As the first article we present, *Automated system for electrical lighting control of a sports field*, by CHOQUE, Santos, GARRÓN, Danny, ZÁRATE, Víctor and COLQUE, Juan, with affiliation at the Universidad Mayor, Real y Pontificia de San Francisco Xavier de Chuquisaca, as the next article we present, *Proposal for analysis and improvement of the quality of electrical energy used at the Universidad Tecnológica del Sureste de Veracruz (UTSV), analysis period 2014-2015*, by RAMÍREZ, Francisco, GONZÁLES, Rafael, IGLESIAS, Pedro and ESTUDILLO, Víctor, as next article we present, *Statistical analysis of the wind speed in Mazatlán Sinaloa*, by GALÁN, Néstor, OROZCO, Eber, MEJIAS, Nildia and MELLADO, Carlos, as last article we present *Methods of material recycling and energy recovery from waste electrical and electronic equipment (WEEE),* by BAUTISTA-VARGAS, María Esther, CABRERA-CRUZ, René, GARCIA-NAVARRO, Josefina and GOMEZ-CARPIZO, Santiago, with affiliation at the Universidad Politécnica de Altamira.

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Automated system for electrical lighting control of a sports field

Sistema automatizado para el control de iluminación eléctrica de un campo deportivo

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DOI: 10.35429/JEE.2021.15.5.1.6 Received July 10, 2021; Accepted December 30, 2021

Abstract

The illumination gives sport facilities in the local means, at the moment they lack he/she gives a good level he/she gives illumination like likewise give an effective control he/she gives the time he/she gives demanded illumination, these inconveniences and other they take us to innovate the systems he/she gives illumination he/she gives sport facilities and other dedicated facilities to the entertainment I publish where require he/she gives a system he/she gives control for this installation, either illumination, air conditioning, lights give emergency, it alarms against fires, etc., these problems can be solved by the automation by means of PLC (programmable logical controller).

Automated system, Electric lighting, Control, Athletic field

Resumen

La iluminación de instalaciones deportivas en el medio local, actualmente carecen de un buen nivel de iluminación como así también de un control eficaz del tiempo de iluminación demandado, estos inconvenientes y otros nos llevan a innovar los sistemas de iluminación de instalaciones deportivas y otras instalaciones dedicadas al entretenimiento publico en donde requieren de un sistema de control para dicha instalación, ya sea iluminación, aire acondicionado, luces de emergencia, alarma contra incendios, etcétera, estos problemas pueden ser solucionados por la automatización mediante PLC (controlador lógico programable).

Sistema automatizado, Iluminación eléctrica, Control, Campo deportivo

Citation: CHOQUE, Santos, GARRÓN, Danny, ZÁRATE, Víctor and COLQUE, Juan. Automated system for electrical lighting control of a sports field. Journal Electrical Engineering. 2021. 5-15:1-6.

†Researcher contributing as first author.

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Introduction

When a lighting control project is carried out for a sports facility, the programme of needs of the facility must be considered. In general, in sports facilities that have already been built, the first thing to consider is the lack of a lighting control system for turning on and off these sports facilities, once they are rented, and on many occasions, it is also possible to note the non-existence of a circuit plan. In general, therefore, all sports centres and sports grounds in the city of Sucre, both private and public, control their electrical lighting manually.

This is why it should be taken into account that players, technical teams, spectators and audiovisual media need to be able to see precisely everything that is happening on the playing field in order to act correctly, as do the spectators, who need to be able to clearly appreciate the circumstances in which the game is taking place within a comfortable lighting environment, They must therefore be able to clearly see everything that is happening not only on the playing field or pitch but also in the immediate vicinity and surroundings, i.e. the lighting must also guide the spectators so that they can enter, leave and take their seats in complete safety; since spectator safety is one of the most important aspects of sports lighting.

The audiovisual media that cover the information of everything that happens in sports facilities also have specific requirements that must be verified to ensure the quality of the image in terms of colour reproduction, textures, i.e. the good quality of the images must be ensured both in the general shots and in the close-ups of players, referees and spectators.

In general, in the lighting of sports facilities, the following levels of lighting can be distinguished: recreational level (training, non-competitive activities and national competitions) and professional level (professional training, national and international competitions with the intervention of audio-visual media). It is in this sense that the present research project deals with the design and construction of an automated system for the control of electric lighting in a sports field and also that this system can also be applied to other spaces in public or private sports fields, or educational institutions to control the switching on and off of lighting in their environments (classrooms, laboratories, etc.).

Problem statement

Due to the student growth that in recent times has occurred in the city of Sucre, both at primary, secondary and even more at university level, is that it has seen the creation of different areas or public and private sports spaces.

A determining factor that sometimes makes it difficult to provide a good service to people who request the rental of these sports centres or spaces is that there is no control of the excess of time used by the players, which results in an excessive use of electric lighting.

This is due to the fact that there is no automatic control, as it is done manually, i.e. the person in charge has to remind people verbally telling them it is time, which can cause inconvenience for those who are playing and who have to leave immediately, but there is also inconvenience for those who are waiting to enter, as they have to wait until it is unoccupied, which causes certain inconveniences and difficulties among the applicants.

Therefore, the problem that has arisen is:

The non-existence of an automated system for the electrical lighting control of a sports field.

Objectives

General objective

To design an automated system for the electrical lighting control of a sports field.

Specific objectives

- Characterisation of electrical lighting systems for sports fields.
- Characterisation of sports fields in the city of Sucre.
- Describe the operation of the system.
- To build the system
- Tests of application to other spaces.

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Importance or justification

The research is necessary in view of the fact that there is currently no automated system for the automatic control of the electric lighting of the different sports fields.

On the other hand, it is considered that this project could not only be applied or executed to a sports field, but that the assembly of the electrical circuit and its operation could be applied to any sports space, in classrooms, computer laboratories or other environments of the academic units of San Francisco Xavier de Chuquisaca, or otherwise also to private homes among others; with which it would be possible to obtain a reuse of the model to be used in different spaces.

With regard to the economic factor, the cost of the project is not high, which is why it is applicable, also given that if we go to the aspect of control, it will reduce the cost of electrical energy that is wasted in the different sports spaces or other environments.

Therefore, this project is feasible because it is a proposal for the application of knowledge, abilities and practical skills related to electricity by a team of teachers and students of the electricity degree course.

Methodological development

Materials and Methodology

For the elaboration and execution of the present work, a work team and the necessary logistics will be required. Thus, the work team will be made up of 2 teachers (research and interaction teacher) and 2 students of the sixth semester of the Electricity course, under the supervision of a person in charge, who in this case is one of the teachers.

The materials used are mentioned below:

- 1Plc Easy-Soft Model 3.0
- 3 Single-phase Thermal Relays
- 3 Contactors
- 50 terminal blocks
- 3 5mm by 10mm Cable Cover Bars
- 1 Roll of Flexible Cable No. 14
- 7 Thermomagnetic Switches
- 3 Insulating Tapes of Different Colours
- 6 Reflector (150w)
- 1 Masquin
- 6 Push Buttons with Na and Nc
- 10 Signal Lights of different colour
- 1 Sheet of Pressed Cardboard 2.40m by 1.22m (For Scale Model)
- 1 Liter of Glue for Pressboard
- 150 Screws (1 inch long and 4mm Diameter)
- 1 Neutral Bar 2cm * 30cm
- 1 Square Tube Profile Bar (1cm2)
- 1 M of Bar (Rail, Rail, Tab)
- 1 Drill
- 1 Computer
- 1 Printer
- 1 Camera
- 1 Pc Screwdriver Set
- 1 set of pliers
- 1 Hammer
- 1 Digital Tester
- 1 Analog Tester
- 1 Pole Finder
- 1 Banner
- Desk Material
- Welding Arc
- 5 Pairs of Gloves

- Welding Gun
- Mechanic Lock
- 5 Protective Goggles
- 1 Grinder
- 1 Roll of Tin
- 1 Wear Disc
- Printer Ink

The methods used are:

- Documentary analysis, which will allow the study related to the control of lighting in sports facilities, both nationally and internationally, i.e. documents, publications, regulations that have to do with the topic addressed.

- Comparative study, which will allow us to study the different trends in the development and generalities of automated systems.

- Systematisation, which will enable us to organise the sports field.

To obtain information about the reality of the situation, a survey will be carried out to obtain data related to the subject in question.

Observation will also be used at different times during the research, as it will reveal different aspects of our object of study.

Results and discussion

Results obtained

The results of the project are expressed in the following tables where the following parameters that are necessary to carry out the construction in reality are calculated.

Parámetros de magnitud	nombre	Dato	Calculado
Superficie del terreno a iluminar	Metros 2		540 m2
Flujo luminoso total	lúmenes		450000 lm
Flujo luminoso del reflector	lúmenes	55000 lm	
Numero de luminarias	unidad		8 lamp.
Potencia total	vatios		3200 W

Table 1 Calculated data

The cross-section of the conductors to be used was divided into four sections for the corresponding reflectors and a general or main section, which is detailed in the following table.

Main section to section number four is tabulated from top to bottom accordingly.

Demanda Maxima Prevista (Kw)	Número De Fase Hilos	Conductores De Cobre Con Aislamiento Pvc				Canalizacion De Acometida Tubo Galvanizado	Aislado Tipo Rodillo	
		Fase		Neutro				
		AWG	mm^2	AWG	mm^2	Diametro Interno	0	L
3,2	1-2	12	3,3	12	3,3	3/4	1 3/4	11

Table 2

The cross-section of the conductors in the sections is:

Tramo	Sección del conductor	Equivalente AWG	Interruptor térmico de (amperios)
Primer tramo	1,86 mm^2	14	15
Segundo tramo	1,86 mm^2	14	15
Tercer tramo	1,39 mm^2	14	15
Cuarto tramo	1,39 mm^2	14	15

Table 3

After the calculations of the necessary parameters, the design of the automation circuit was continued with the corresponding software.

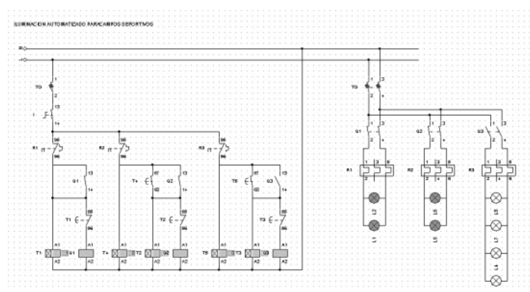

Figure 1 Circuit Design

Subsequently the circuit design was taken to the PLC language using the EASY-SOFT software, which is the language used by the PLC to carry out its connection.

Circuits designed in CADE SIMU and EASY SOFT

The circuits used for the time control process of the lights are divided into three with which the following reflectors are switched on: Q1 activates the reflectors 1-2, Q2 after a short time switches on the reflectors 3-4, and finally the contactor Q3 switches on the last four remaining reflectors 5-6 and 7-8, thus completing the total lighting of the environment. In the same way and in the same order they are automatically switched off.

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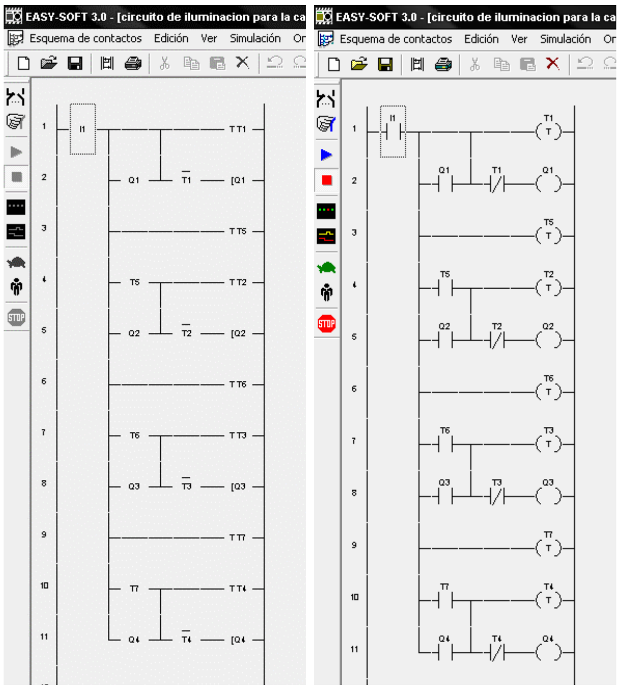

Device language ANSI/CSA language

Figure 2 Timing circuit for one hour

Timing circuit for two hours, figure 2, where only the timing time of the TTs varies in the following circuit and so the circuits are repetitive, varying only in the timing time of the TTs. These times are programmed before being installed and assembled in reality.

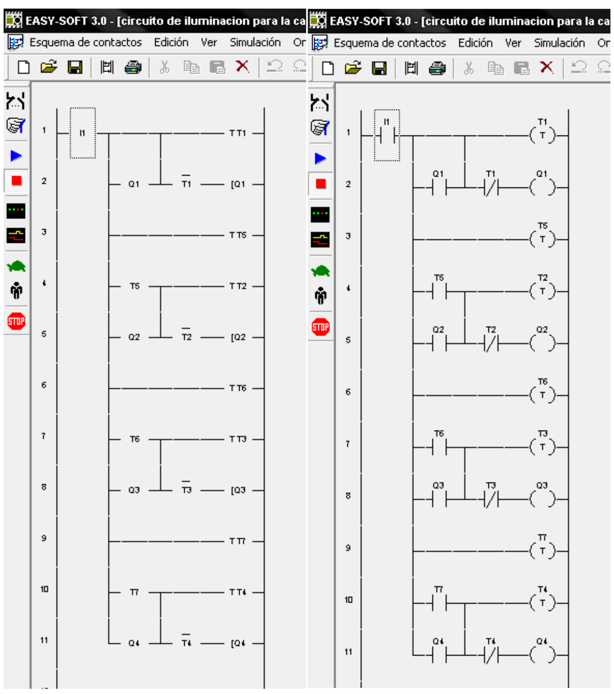

Figure 3 ANSI/CSA Language

The language or symbols that the program handles are the language of the device that the device works with and displays. While the ANSI/CSA standard is another type of symbology used by other PLCs, in our case we use the device symbology for the operation of the circuit.

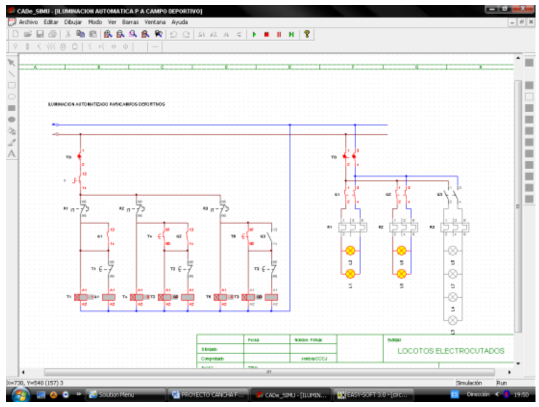

Figure 4 Simulation tests in CADe SIMU

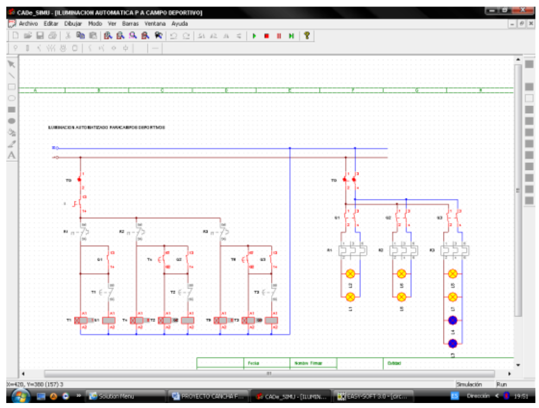

Figure 5 Simulation tests in EASY SOFT

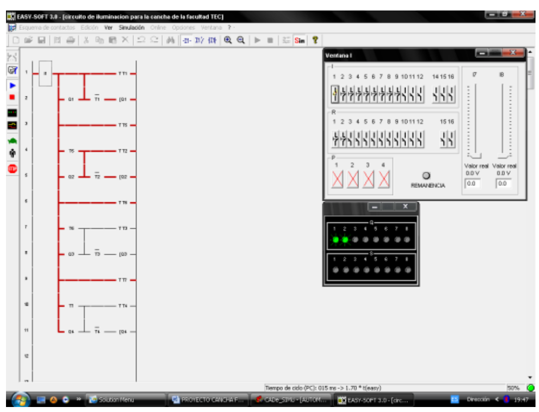

Figure 6

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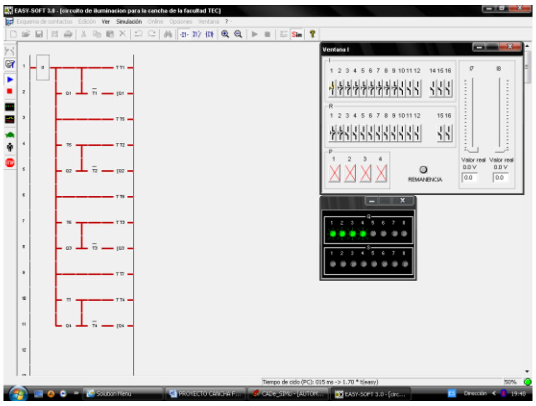

Figure 7

Discussion

In general, automatic lighting systems for sports fields do not exist in the local environment, although on the other hand, we can verify the existence of automatic lighting in public roads and parks, this type of automatic system has a limited application, switching lights on and off depending on the level of illumination of the solar spectrum, which makes it unfeasible in the application for the controlled lighting of a sports field.

An automatic lighting time control system is not only intended for sports fields, but also for other spaces such as: night-time education centres, university teaching centres, sports centres and others. In these public centres it is necessary to have lighting time control for an efficient organisation of the installation, and it could also reduce the demand for electrical energy of an installation and the cost paid for the kilowatt hours (kWh) used, and in some way help the environment.

The lighting control system gives us the great advantage of being able to control the lighting circuit from a single point by means of a computer or from the control panel itself, without the need to move around the installation to control and/or switch off the lights on.

Conclusions

Nowadays, needs go hand in hand with technology and technology meets human social needs. The computerised logic programmers better known as PLC are technological devices of wide application in automation processes.

The student-teaching team proposes and makes use of this technology to solve the lighting time control in a sports field, in order to provide a better organisation and/or administration of these recreational centres.

It is also worth mentioning that it does not estimate high costs, so its application will show real issues with practical solutions.

Acknowledgements

The researchers would like to thank the Dirección de Investigación Ciencia y Tecnología (DICYT) of the Universidad San Francisco Xavier de Chuquisaca for their support in the development of this work.

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ISSN: 2523-2517

Article **Journal Electrical Engineering**
December 2021, Vol.5 No.15 7-13

Proposal for analysis and improvement of the quality of electrical energy used at the Universidad Tecnologica del Sureste de Veracruz (UTSV), analysis period 2014-2015

Electrodomésticos de CA en una nanored doméstica de CD

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DOI: 10.35429/JEE.2021.15.5.7.13 Received July 15, 2021; Accepted December 30, 2021

Abstract

Today it is becoming more widespread use of electrical equipment and sensitive electronic and continually electricity demands increase so it is essential that the facilities are conducted with adherence to current regulations and have obtained adequate protection equipment equally reduce disturbances in the national grid and installation depending on the application, for which it is important to establish coordination between the utility, manufacturers of electrical and electronic equipment and the users themselves because in this case We are dealing with the educational sector, directly talking about a Universidad Tecnológica del Sureste de Veracruz (UTSV).

Energy, Quality, Economy, Methods, Consumption

Resumen

En la actualidad cada vez es más extendido el uso de equipo eléctrico y electrónico sensible y continuamente las demandas de energía eléctrica se incrementan por lo que es indispensable que las instalaciones se realicen con apego a la normatividad vigente y se cuente con equipos de protección adecuados de igual forma se reduzcan los disturbios en la red eléctrica nacional y de una instalación en función de su demanda, para lo cual es importante establecer una coordinación entre la compañía suministradora, los fabricantes de equipos eléctricos y electrónicos y su vez los usuarios mismos ya que en este caso tratamos con el sector educativo directamente hablando de la Universidad Tecnológica del Sureste de Veracruz (UTSV).

Energía, Calidad, Economía, Métodos, Consumo

Citation: RAMÍREZ, Francisco, GONZÁLES, Rafael, IGLESIAS, Pedro and ESTUDILLO, Víctor. Proposal for analysis and improvement of the quality of electrical energy used at the Universidad Tecnologica del Sureste de Veracruz (UTSV), analysis period 2014-2015. Journal Electrical Engineering. 2021. 5-15:7-13.

† Researcher contributing as first author.

Introduction

The purpose of this article is to provide information on transients and voltage disturbances that sometimes occur in power and low voltage circuits of this, the Universidad Tecnológica del Sureste de Veracruz (UTSV) while implementing actions that are committed to energy saving.

The transients and disturbances considered in the scope are limited to disturbances whose duration is less than half a cycle of the waveform as well as power interruptions that occur at undetermined times and that in turn hinder the continuity of teaching and administrative tasks. while the equipment inside the (UTSV) is not working.

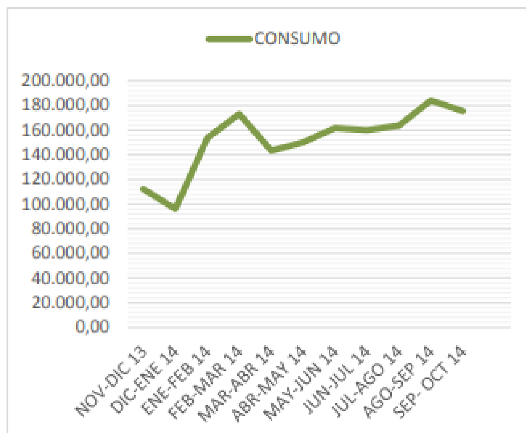
It is difficult to assign limit values to some of the characteristics of the transients because their effect and therefore their impact depends on the nature of the equipment subjected to these disturbances, since it can damage some, others it can temporarily modify its performance, or it does not cause any problems.

Based on the ―IEEE STD 1159-1995‖ ―Recommended Practices on Voltage Transients in Low-Voltage Alternating Current Power Circuits.

It is not sought to establish the performance parameters of protective equipment, but to present the guidelines on the application parameters of the same, as well as the corresponding actions to be implemented by the maintenance, administrative and teaching staff, as well as the awareness of energy saving in the Universidad Tecnológica del Sureste de Veracruz (UTSV).

Antecedent

Due to the rate structure of the sector, the medium voltage rate *(HM), which is the rate that is currently supplied by the (UTSV) and is the third most expensive in the country, not without first mentioning that due to deficiencies in electrical installations with Low quality presents a high consumption of energy causing a direct economic impact (graphic 1) for the educational institution in this case the Universidad Tecnológica del Sureste de Veracruz (UTSV) which has sophisticated equipment of laboratories and computer equipment itself that they need to operate in ideal conditions speaking in parameters of energy quality and for this purpose joint actions are being implemented between students, teaching staff and administrative staff of the institution to reduce the consumption of electrical energy, not without first mentioning that there are still harmful variables in each institution is the turn of the same that contribute to a poor quality of energy consumed.



Graphic 1 Approximate billing amount in the period 2013-2014 in the UTSV

We can define the quality of energy as the amount of energy that can be supplied to the equipment in an electrical installation with the appropriate characteristics in terms of defined variables such as (voltage, intensity, frequency, power, etc.).

These are necessary to maintain maximum efficiency in the equipment interconnected to the main supply network.

Therefore, variables and terms like:

- Transients.
- Flickers.
- Wave amplitude.
- Low voltage.
- Sudden over-voltage.
- Frequency.
- Harmonics.
- Power factor.

They are common to carry out a qualitative analysis of the conditions in which the institution operates, in this way the power factor is addressed first hand, which is a very strong conditioning factor that impacts the economic part of the institution, as shown in (graphic 2) in the lower part the (f.p) has remained stable at an average of 95.47% during the period from 2014 to the date analysed February 2015.

Noting thus and considering that currently the company C.F.E "FEDERAL ELECTRICITY COMMISSION". Considers optimum a power factor greater than 90%, it is concluded that this condition is satisfied in the institution.

Considerations

It is worth mentioning that the company C.F.E manages standards in the sense of penalties and bonuses, benefiting the institution in the last months of monitoring.

And like any project, you need to know what the benefit of power factor correction is. And indeed, it is:

- Reduction of electrical losses in the conductors.
- Reduction of voltage drop losses.
- Increased availability of transformers and distribution equipment commonly called “reliability”.
- Increase in the useful life of the installation.
- Reduction of the cost of service in the billing period.

According to C.F.E the behavior of the power factor, a penalty will be applied when the P.F. <90% and a bonus when the P.F. >90% using the following equations where:

$$B=\frac{1}{4}\left[1-\left(\frac{90}{F.P}\right)\right]*100$$

$$P=\frac{3}{5}\left[\left(\frac{90}{F.P}\right)-1\right]*100$$

B: bonus (-%)

P: Penalty (+%)

P.F.: power factor (%)

Condición de facturación.	% máximo aplicable.
BONIFICACION.	2.5
PENALIACION	120

Table 1

In such a way that in the UTSV it was possible to exceed the nominal value established by C.F.E as optimal, having an f.p = 95.47% average during the entire billing period from February 2014 to January 2015.

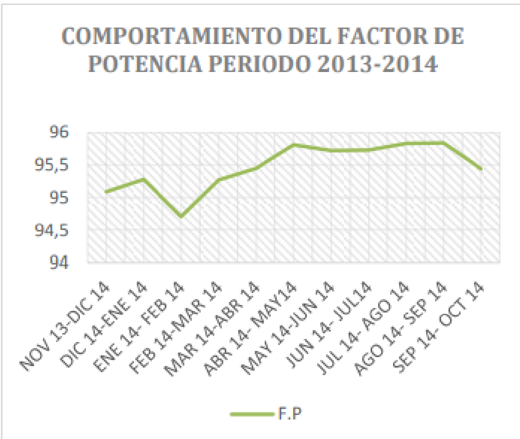
Result 1

Said benefit was obtained by the replacement of more efficient transformation equipment and load distribution in the distribution equipment internal to the institution, since initially there were voltage fluctuations and hot spots originated in the areas of poor conduction.

Figure 1 CT'S current transformers with weakened conductor and in poor conditions.

ISSN-2523-2517

Not so, it is considered that due to the main business of the educational institution, a slightly irrational use of electrical energy is detected, which seeks to implement actions with the students, teachers and administrative staff that reduce the time of use of the lights, equipment inviting to reduce the period of suspension of computer equipment until reaching the possibility of implementing proximity sensor equipment so that they act when students and staff are not in the classroom or cubicles.



Graphic 2 Power factor UTSV billing period 2013-2014

Conditions of the current electrical installations in the (UTSV)

Currently the facilities of the (UTSV) are in a general maintenance phase since the expansion of the infrastructure requires more load consumption, for this reason it is important to detect failures in time and determine the fluctuation rates of the load in order to ensure energy quality within the institution. (fig. 2).

Figure 2 Switching station of the (UTSV) with hardware recently replaced and under maintenance.

Figure 3 Set of switching substation and current transformers TC'S

Analysis of electrical infrastructure in the (UTSV)

The Technological University of the Southeast of Veracruz (UTSV) currently has equipment of different utility, especially in workshops, due to this situation (table 1) mentions the number of them, giving an estimate of the load installed in the institution based on the following: perform the following analysis:

EDIFICIOS	POTENCIA MAXIMA CONSIMIDA*
EDIFICIO DE DOCENCIA “A”	15.023KWH
EDIFICIO DE DOCENCIA “B”	13.00 KWH
BIBLIOTECA	4.2 KWH
TALLER DE METROLOGIA	1.5KWH
TALLER DE ELECTRICIDAD Y MECATRONICA	2.5 KWH
TALLERES DE INFORMATICA	3.5KWH
TOTAL (KWH)	39.723

Table 2 Average consumption of the institution by areas of greatest impact

Developing methodology

The parameters that make up the power quality are commonly governed by the relevant regulations for this case, the "IEEE STD 1100-1999", in such a way that the power quality analyzer will be used for the analysis of its operating conditions. mca: hioki 3197.

Which has the characteristic of performing the on-site analysis of the energy quality conditions, taking into account the current regulations and the possible basic conditions of operation in the installation through the entity that monitors the energy sector in this case C.F.E.

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Figure 4 Hioki 3197 power quality analyzer.

Mainly what is sought in the diagnostic analysis with the hioki 3197 equipment. It is:

- Qualitatively determine the installation of the main supply equipment and its grounding.

- Power quality upon arrival of the delivery team to assigned areas.

- Detection of current leaks and/or hot spots by means of thermography.

Result 2

Figure 5 Inspection and analysis of power quality - in situ with hikoi 3197 equipment

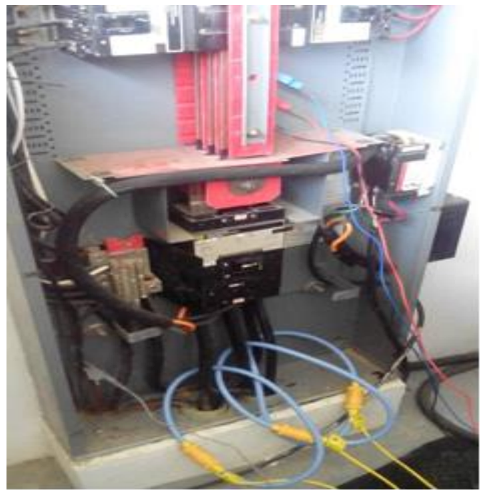

Figure 6 Current clam connections of the power quality analyser equipment

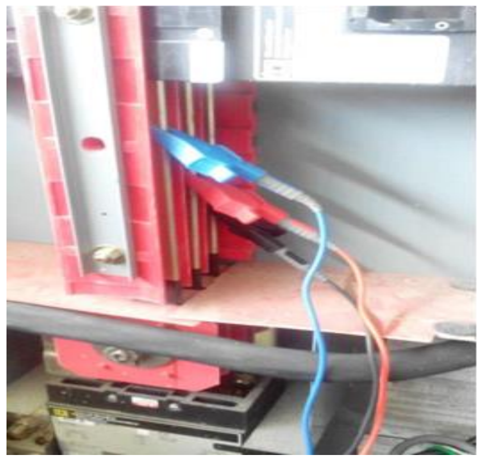

Figure 7 Connections for voltage detection of the power quality analyser equipment

The three points essentially mentioned above are considered to have a great impact on what is the utility of energy, functioning as main factors of large-scale and long-term electrical failures.

Therefore, it was detected that there is an overloaded power supply phase in the workshop area.

LINEA (V1)	VALOR VOLTAJE (VOLTS)	CORRIENTE (AMP)
V1	124.1	12.53

Table 3 Values obtained from the power quality analyser taken from the main distribution centre to laboratories.

As far as (figure 7) corresponds to the line The main distribution module which is illustrated in the figures shown above.

ISSN-2523-2517

Figure 8 Appreciable current unbalance in phase 2 (V2)

The procedure was to verify at that moment which was the largest load that was being consumed and in which workshop to detect the possible anomaly.

On the other hand, the participation of the university community, especially (teachers and administrative staff), is very important, since they are normally in continuous contact with teams that are employed on a day-to-day basis.

For this reason, there is a strong possibility of carrying out a preliminary investigation of the tests with the hioki 3197 analyser equipment. This calls for questions such as:

- Are there occasional flickers on the equipment?
- How and when does the problem occur?
- Many teams manifest the same problem?
- What time does the problem occur?
- Are there abnormal temperatures in the equipment?

For this purpose and in the same way, the topography of the electrical installation must be taken into account. Specifically to locate possible origins of the faults and also in which points the hioki 3197 power quality analyzer equipment has to be placed.

It is very important to take the parameters of the input energy from the supply company C.F.E, as well as the data plate of the arrival transformers from medium voltage to low voltage, types of connection to service, size of the conductors and date of the last electrical maintenance activities carried out on the equipment.

Acknowledgment

The present progress of research and improvement work is being carried out by the academic body in degree of "in consolidation" of the industrial area maintenance career of the Technological University of the Southeast of Veracruz (UTSV), which is in charge of Ing. Edgar Fidel Toledo Matus Rector of the maximum house of studies of the cd. From Nanchital de Lázaro Cárdeno, to whom we thank for their valuable and timely support for making this study possible, in addition to thanking the time and dedication of our fellow teachers and students who have participated in this improvement project.

Conclusions

The electrical equipment represents the main energy consumption in an electrical installation, regardless of the type of activity, for this reason it is of the utmost importance to minimize energy consumption or to use exactly each (kwh) in the task that is required.

What is planned to be done with this study is to create mainly a plan for saving energy and in the same way a new culture for saving it among the teaching staff, administrative staff and students in general.

From this, the reason for being able to reduce to the minimum the amount of energy that the university invoices month after month to the energy company becomes important, since this action indicates a not very encouraging situation, since the additional consumption not only generates more contamination, but also produces an excessive spending of money on concepts of billing and maintenance to the technological university of the southeast of Veracruz.

All this reflects that a complete culmination has not yet been reached in terms of correcting and mitigating excessive energy consumption, however, the group in which we work to reduce this problem will continue to work on the occasion of continuous improvement for the electrical installation. university in general.

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ISSN-2523-2517

Statistical analysis of the wind speed in Mazatlán Sinaloa

Análisis estadístico de la velocidad del viento en Mazatlán Sinaloa

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DOI: 10.35429/JEE.2021.15.5.14.19 Received July 20, 2021; Accepted December 30, 2021

Abstract

The wind speeds are analyzed in this article during the month of May in Mazatlan Sinaloa, Mexico. Starting from the first measurements obtained from the meteorological station installed at the Universidad Politécnica de Sinaloa. As measurements of wind speed were made at 10 m height, we want to know how the wind speeds are at 55 and 85 m, which are the hub heights of two different Enercon wind turbines. This study aims to determine the available wind resource and wind power density within the city at different heights. Contribution. The main contribution of this work is the management of statistical data to determine the wind resource available in the Mazatlan City.

Mean wind speed, Standard deviation, Wind power, Mean wind power density

Resumen

En este artículo se analizan las velocidades de viento presentes durante el mes de mayo en la ciudad de Mazatlán, Sinaloa, México. Partiendo de las primeras mediciones obtenidas de la estación meteorológica instalada en las instalaciones de la Universidad Politécnica de Sinaloa. Como las mediciones de la velocidad del viento se realizaron a 10 m de altura, se desea conocer las velocidades de viento que se tendrían a la altura de 55 y 85 m, que es la altura de dos bujes de aerogeneradores Enercon diferentes. Este estudio tiene como objetivo conocer el recurso eólico disponible y la densidad de potencia eólica al interior de la ciudad a diferentes alturas. Contribución. La contribución principal de este trabajo es el manejo de datos estadísticos para determinar el recurso eólico disponible en la ciudad de Mazatlán.

Velocidad media del viento, Desviación estándar, Potencia eólica, Densidad media de potencia eólica

Citation: GALÁN, Néstor, OROZCO, Eber, MEJIAS, Nildia and MELLADO, Carlos. Statistical analysis of the wind speed in Mazatlán Sinaloa. Journal Electrical Engineering. 2021. 5-15:14-19.

† Researcher contributing as first author.

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Introduction

Wind generation is currently the source of greatest use and growth among the other alternative sources of energy [1]. Wind energy has shown a certain superiority compared to traditional energy sources, which is why it is considered one of the most precious, clean, abundant, cheap, inexhaustible renewable energy sources that is also part of the environment [2].

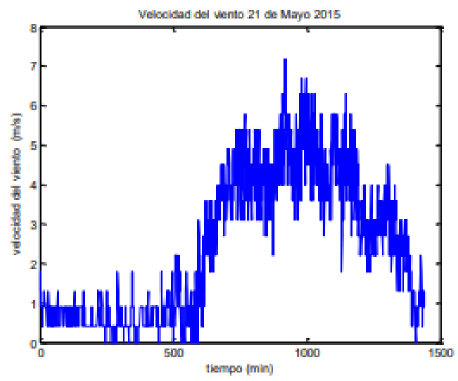
Wind energy is literally inexhaustible and abundant throughout the world, which can be used as a promising internal source of energy in several countries. More importantly, with the continuous development of new wind generation technologies, it has become a renewable energy source with the lowest generation prices [3].

Today, wind energy harvesting has been widely spread all over the world. In Mexico, there is an installed wind generation capacity of 1,677 MW in operation, 2,792 MW are about to come into operation soon and there is an estimated capacity of 1,594 MW of electricity generation in the process of construction. Foreseeing an installed wind generation capacity in the near future of 6,446 MW [4].

A weather station has recently been installed at the Polytechnic University of Sinaloa in order to obtain real data on the different natural resources in the area, which will help create a statistical database that will serve as a reference for the different projects and investigations that are being carried out. making the academic body of the Energy Engineering career from the solar and wind resource.

In this work, the wind speed measurements obtained during the month of May are analyzed. The values measured are with a sampling frequency of 1 min, and are averaged for one-hour wide intervals, with which a statistical treatment is performed defining the average (or stationary) speed and the standard deviation. Thus, laying the foundations for the evaluation of the wind resource of at least one year at different heights that is planned to be carried out at the University.

During the 24 hrs of sampling, a long period of calm winds has been observed, with only 8 hours of usable winds between 11:00 and 19:00 hrs (660 – 1,140 min), as shown in the graph. 1, it is for this reason that only this interval of hours will be taken for the evaluation of the wind resource.



Graphic 1 Wind speed May 21, 2015

The article begins by dealing with what is related to the statistical data process of the wind speed, continuing with the statistical numerical analysis that is carried out on the speed to determine the power density and the available wind power, mentioning the methodology developed and the results obtained, as well as the conclusions.

Statistical treatment of wind data

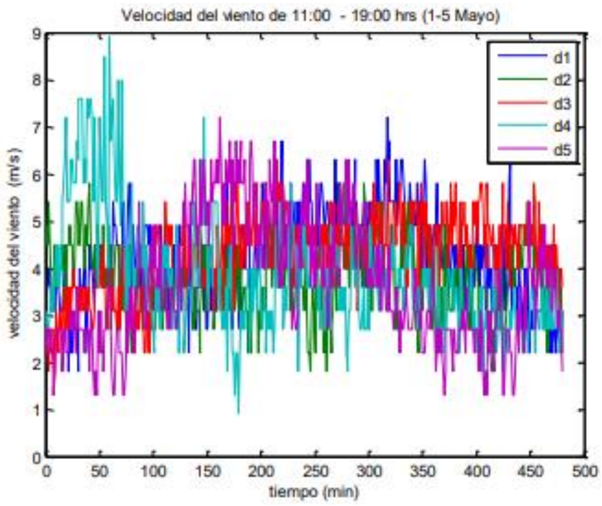
Several mathematical tools have been used for the analysis of wind speed data. Among these tools, the use of centralization parameters such as the arithmetic mean stands out:

Dispersion parameters such as standard or typical deviation for a set of N speed data:

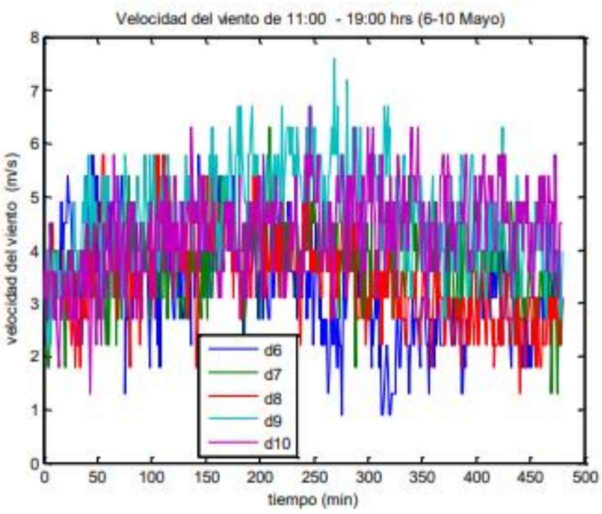
From where I saw is the speed shown in a minute.

These basic parameters will allow us to know the average speed and the standard deviation of the wind in intervals of one hour within the range of 11:00 – 19:00 hrs. of the month of May 2015, according to the data obtained with the meteorological station. The behavior of the wind speed in this month is shown in graphs from 2 to 7. To finally obtain the daily average values of the month.

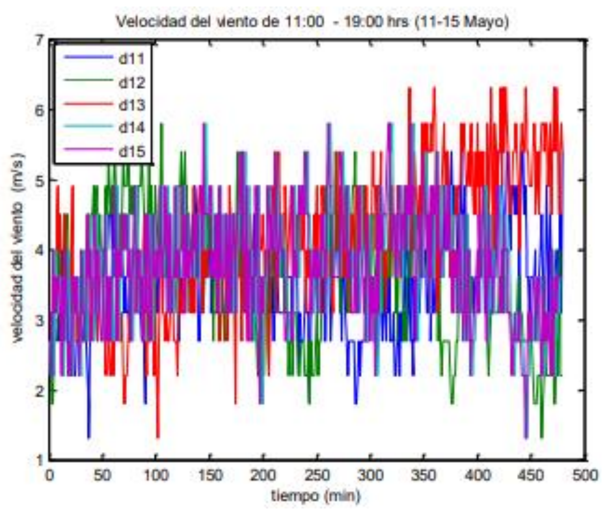
ISSN-2523-2517



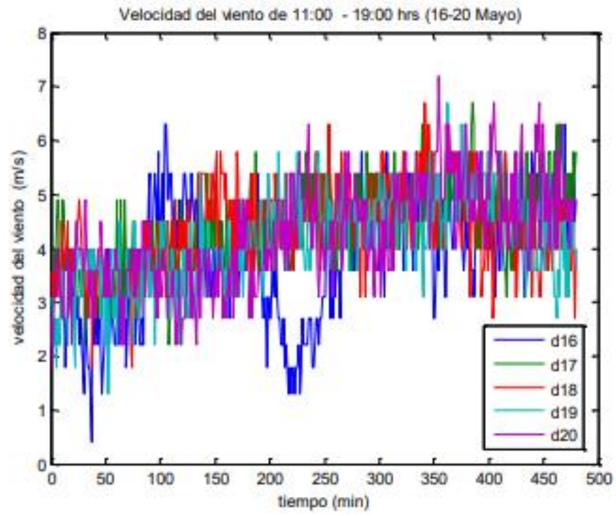
Graphic 2 Wind speed May 1-5



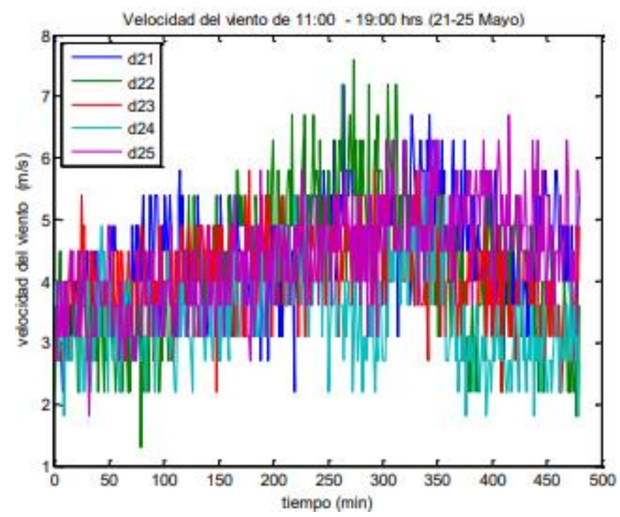
Graphic 3 Wind speed May 6-10



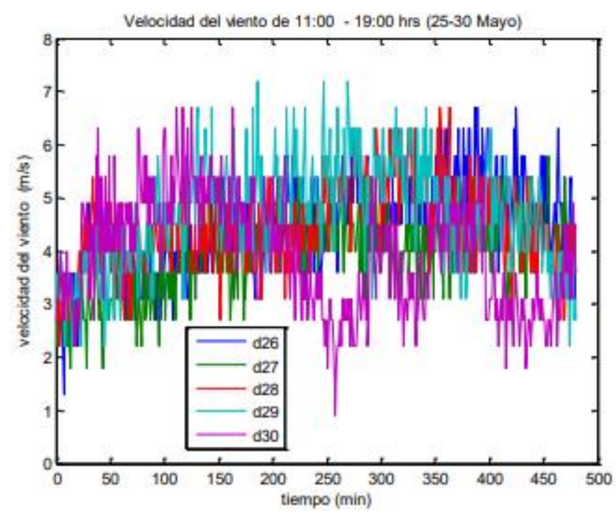
Graphic 4 Wind speed 11-15 May



Graphic 5 Wind speed May 16-20



Graphic 6 Wind speed 21-25 May



Graphic 7 Wind speed 25-30 May

Statistical wind analysis

In addition to the mean wind speed and standard deviation, the statistical analysis includes the mean wind power density and the available wind power.

ISSN-2523-2517

$$k = \left(\frac{\sigma}{\bar{v}}\right)^{-1.086}$$

These results of mean velocity and standard deviation will allow to estimate in a second work, the shape factor k,

$$c = \bar{v}\left(0.568 + \frac{0.433}{k}\right)^{-1/k}$$

and the scale factor c in (m/s) is,

From the Weibull Probability Density Function (PDF), which allows from the wind speed distribution to calculate its energy potential and the annual energy that a wind turbine can produce [5].

The WTP is expressed as:

The wind speed is measured at 10 m height (weather station location), so it is necessary to extrapolate the wind speed data to the hub height of the selected wind energy conversion system using the following power law expression:

Where, vw is the wind speed measured at height h,

$$f(v) = \frac{k}{c}\left(\frac{v}{c}\right)^{k-1} e^{-\left(\frac{v}{c}\right)^{k}}$$

v_W is the wind speed at the height h, vw of the hub, the factor α depends on the type of surface roughness and atmospheric stability [6]. Numerically α is in the range of 0.1-0.3, adopting for wind-settlement terrain the value of 1/7.

Máquina Eólica	Vo (m/s)	Vm (m/s)	Vn (m/s)	Pn (kW)	h (m)	Diámetro Rotor (m)
E-40-6.44	2.5	28	12	600	50	44
E-66-18.70	2.5	28	12	1800	98	70

Table 1 Technical data of two ENERCON wind turbines

Figure 1 ENERCON wind turbine

The technical data of the ENERCON wind turbine are shown in Figure 1. This type of wind turbine has been selected to determine the wind speed at the hub height, this height corresponds to the type of machine that is specified in Table 1. In this case the hub height is at 50 m and 98 m above ground level [7].

The average wind power density (PD) expressed in Watts/m^2, at the installation site is calculated as:

$$P_D = \frac{P_w}{A} = \frac{1}{2}\rho\bar{v}_w^3$$

With the available wind power Pw in Watts:

$$P_w = \frac{1}{2}\rho A\bar{v}_w^3$$

Of which A is the swept area of the wind turbine in m^2, ρ is the air density (1,225 kg/m^3).

Methodology to develop

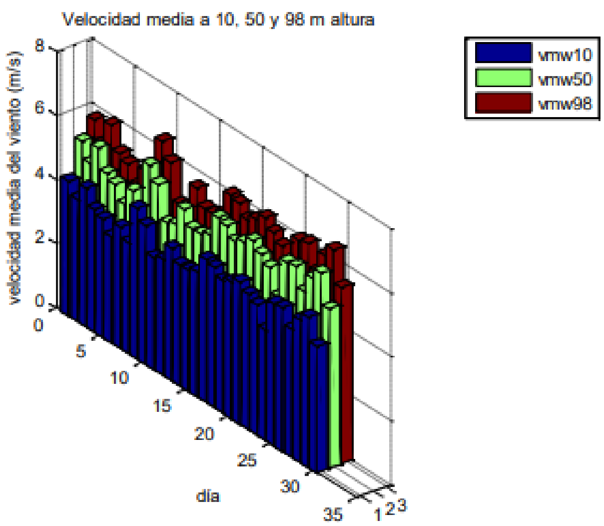
The daily mean wind speed and standard deviation are calculated based on measurements taken at 10 m height. These mean values are recalculated for 50 m and 98 m height.

ISSN-2523-2517

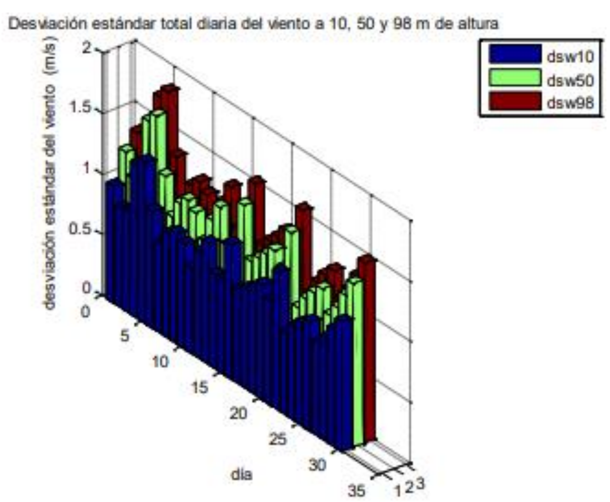
The average daily wind power density is obtained for the three proposed heights, 10, 50 and 98 meters. The swept area to determine the available wind power is obtained based on the diameters of the wind turbine rotors according to the hub height.

Results

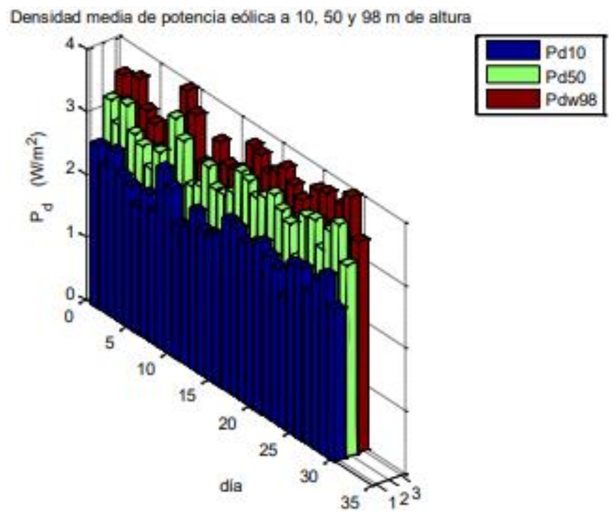
The results of mean wind speed, standard deviation, mean wind power density and available wind power in the city of Mazatlan Sinaloa, Mexico, at 10 m, 50 m and 98 m are presented in graphs 8 - 11.



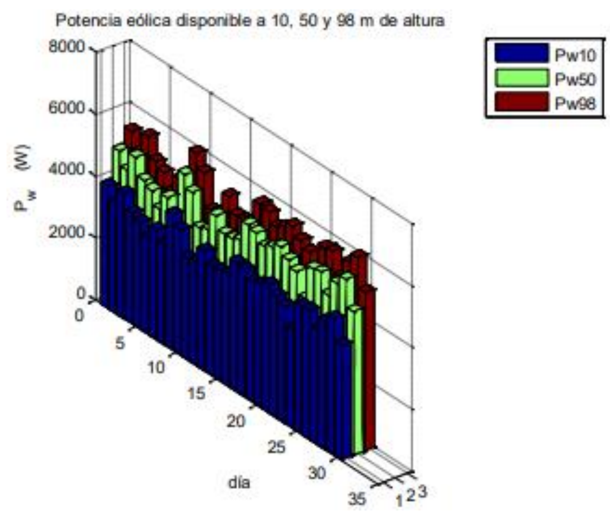
Graphic 8 Average wind speed



Graphic 9 Daily wind standard deviation



Graphic 10 Average Wind Power Density



Graphic 11 Available wind power

Conclusions

The average usable wind speed is above 90 m height, in the interior of the city of Mazatlan, which is a wind speed influenced by the roughness of the terrain and very different from the wind speed in front of the sea. There is an interval of four four hours a day where the wind is above average, which influences This has a direct influence on the calculation of the available wind power since it is raised to the cube of the wind speed.

This is only the beginning of the treatment of data obtained with the meteorological station, hoping that in the course of a year the first annual average can be obtained and thus determine the complete Weibull distribution in order to determine the true energy potential existing in the city of Mazatlan Sinaloa, Mexico.

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ISSN-2523-2517

Article **Journal Electrical Engineering**
December 2021, Vol.5 No.15 20-32

Methods of material recycling and energy recovery from waste electrical and electronic equipment (WEEE)

Métodos de reciclaje de materiales y obtención de energía a partir de los residuos de equipos eléctricos y electrónicos

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DOI: 10.35429/JEE.2021.15.5.20.32 Received Julyy 25, 2021; Accepted June 30, 2021

Abstract

Waste Electrical and Electronic Equipment (WEEE) currently have generated a great demand for research about the revaluation. The result has been economic sources from the recovery of these waste materials. In Mexico, 56% of states have at least one action for the collection and presentation of WEEE. The main methods for revaluation of WEEE are mechanical and manual. The aim of this study is to describe the different methods of material recovery and energy recovery from WEEE. Developing a descriptive study, using a matrix comparing the different treatment of WEEE. The results allow identifying the feasibility of alternative materials recycling and energy recovery of WEEE. The relevance of this research is to know the various options for recovering materials; new materials identify alternative energy generation, in order to reduce the risk of contamination.

Recycling of materials, Energy, Electronic waste, WEEE

Resumen

En la actualidad los Residuos de Equipos Eléctricos y Electrónicos (REEE), han generado una gran demanda de investigaciones a cerca de la revalorización. La consecuencia se la creación de fuentes económicas a partir de la recuperación de materiales de estos residuos. En México, el 56% de los estados cuentan con al menos una acción para el acopio y revalorización de REEE. Los principales métodos para la revalorización de los REEE son mecánicos y manuales. El objetivo del presente trabajo es la descripción de los diferentes métodos de recuperación de materiales y la obtención de energía a partir de los REEE. Desarrollando una investigación descriptiva, mediante una matriz comparativa de los diferentes tratamientos de los REEE. Los resultados obtenidos permitieron identificar la factibilidad de las alternativas de reciclaje de materiales y recuperación de energía de los REEE. La relevancia de esta investigación es el conocer las diversas alternativas de recuperación de materiales, identificar nuevos materiales de generación de energía alternativa, con el fin de reducir el riesgo de contaminación.

Reciclaje de materiales, energía, residuos electrónicos, REEE

Citation: BAUTISTA-VARGAS, María Esther, CABRERA-CRUZ, René, GARCIA-NAVARRO, Josefina and GOMEZ-CARPIZO, Santiago. Methods of material recycling and energy recovery from waste electrical and electronic equipment (WEEE). Journal Electrical Engineering. 2021. 5-15:20-32.

† Researcher contributing as first author.

Introduction

Currently, Waste Electrical and Electronic Equipment (WEEE) has generated a great demand for research into the revaluation of materials. This is a consequence of the dynamic generation scenario due to the unsustainable consumption of sophisticated electronic devices, which due to their demand are easy to acquire and have a programmed obsolescence (Cruz-Sotelo et al. 2013, Ojeda-Benitez et al. 2013,).

Obsolescence occurs when the device is old or provides the user with insufficient performance in its functions. Planned obsolescence arises when a product stop working in a time that benefits the producer, without the consumer losing confidence in the brand. This can be defined as -the consumer's desire to own something a little newer, a little sooner than necessary‖ (Tobar 2013).

The device when becoming a REEE must be handled properly as they are made up of a complex mixture of different materials. It consists of about 15-30% plastics, 40-50% ceramics and 20-30% metals. However, the composition depends on the age, origin and manufacturer of the equipment (Cui and Zhang 2008, Maurell-Lopez et al. 2011).

In Latin America and the Caribbean, countries such as Argentina, Colombia, Chile, Venezuela, Peru, Costa Rica, among others, are countries that, like Mexico, are part of the Regional Platform on PC e-waste in Latin America and the Caribbean (RELAC), which is an associative project implemented from Santiago de Chile, with the support of the International Development Research Centre of Canada, being an initiative to promote solutions for the prevention, management and handling of the final destination of WEEE (González 2007, Lindhqvist et al. 2008). These regulations imply, in some cases, from the manufacture and design of electronic equipment resulting in a sustainable manufacturing process, although its useful life is a function of the way it is used (Cruz-Sotelo et al. 2013).

In Table I, the useful life of some electronic devices is specified according to their weight, such data were estimated in 2007, although this item may vary due to the versatility of supply and demand, as well as technological advances; for example, a television of ten years ago is different from the current ones both in size and weight, as well as in the material and substances that make it up (Blaser and Schluep 2011, Borraz et al. 2011).

Equipo	*Peso (kg)*	*Vida Útil (años)*
Televisores	30	10
Computadoras de escritorio	25	5
Computadoras portátiles	11	5
Aparatos de Sonido	12	6
Teléfonos fijos	1.2	6
Teléfonos celulares	0.82	3

Table 1 Weight and lifetime of some electronic equipment

Due to the increase of these national and foreign economic investments, Mexico is committed to complying with laws that regulate this type of products, ratifying its obligations with the Basel and Stockholm conventions, as well as being part of the RELAC platform project and participating in the trade and environmental agreements of the Commission for Environmental Cooperation (CEC), it acquires the responsibility to continuously evaluate the health and environmental impacts that come from the manufacturing and disposal waste of electronic devices, in order to develop instruments for solutions (Silva 2013).

To this end, the National Institute of Ecology and Climate Change (INECC) and the Ministry of the Environment and Natural Resources Natural Resources (SEMARNAT) have elaborated diagnoses of WEEE generation in the country. country, which are:

Diagnosis on the generation of electronic waste in Mexico, 2006. The objective of this study was to generate information in order to know the state of the generation and management of electronic waste, constituting the generation inventory and its management modalities. The study is limited to six types of electronic equipment: televisions, personal computers (PCs) and laptops, sound devices, fixed telephones and mobile phones, describing the toxic substances they contain and the effects they produce.

The estimated amount of waste generated in 2006 was between 150 and 250 tones to be disposed of, which generated an indicator of 1.5 to 1.6 kg/year per capita per year. 1.6 kg/year per capita (Román 2007).

Regional diagnosis on the generation of electronic waste at the end of its useful life in the northeastern region of Mexico, 2008. It estimates the generation of e-waste, the risks associated with its disposal and proposes strategies for the mitigation of these risks in the states of Coahuila, Nuevo León and Tamaulipas. It is based on the Diagnosis on the Generation of Electronic Waste in Mexico and selects televisions, computers, stereos, home telephones and mobile phones as the main sources of electronic waste. The results of the estimated generation of e-waste disposed by state, extrapolating the results of the survey, are 20,835 tonnes in Nuevo León, 12,665 tonnes in Coahuila and 15,749 tonnes in Tamaulipas (Acevedo et al. 2008).

Regional diagnosis of e-waste in two northern border cities in two cities on Mexico's northern border: Tijuana and Ciudad Juarez of Mexico: Tijuana and Ciudad Juárez, 2009. Applying the same methodology designed in the first diagnosis in 2006, the study is based on two main cities, Tijuana and Ciudad Juárez, and on the application of surveys in statistically representative samples for both cities of 384 people in each. The results obtained for the northern border area were between 32,000 and 40,000 tonnes per year respectively (Román 2009).

Diagnosis of electronic waste generation in two cities on the northern border of Mexico: Tijuana and Ciudad Juárez, 2009. Applying the same methodology designed in the first diagnosis in 2006, the study is based on two main cities, Tijuana and Ciudad Juárez, and on the application of surveys in statistically representative samples for both cities of 384 people in each. The results obtained for the northern border area were between 32,000 and 40,000 tonnes per year respectively (Román 2009).

Diagnosis of e-waste generation in the Metropolitan Zone of the Valley of Mexico (ZMVM), 2010. In this study, it was estimated that the amount of electronic waste generated was 13,216,422 devices, equivalent to 112,490 tonnes. Of the total, 53% are discarded or stored because they are considered obsolete (by the user) and the remaining (47%) are reused (Meraz 2010).

Other studies that have been carried out at the national level were:

Evaluation of alternatives for the management of Special Handling Waste, 2007. This study contributed elements to the North American Regional Action Plan (PARAN) on dioxins, furans and hexachlorobenzene (Almada-Calvo 2007).

Life cycle analysis of electronic waste and management proposal in border cities of Coahuila, Nuevo León and Tamaulipas, 2012. In which the impact of e-waste on different natural resources such as water, soil and air is analysed under different scenarios such as the current management of low recycling and deposition in open dumps to an optimal scenario of controlled disposal in landfills (González 2012).

Basic Diagnosis for Integrated Waste Management, 2012. Its objective is to update information on waste management in Mexico up to 2012, to support the National Programme for the Prevention and Integrated Waste Management, as well as to provide elements for the formulation of objectives in the National Development Plan 2013-2018 (INECC-SEMARNAT 2013).

The above shows the growth of WEEE in Mexico, with televisions, computers and audio equipment having a considerable impact. However, there are inconsistencies in the generation indicators due to the versatility of the WEEE design and the problems in obtaining information from the generating sources. Table II shows the WEEE generation trend in Mexico.

Año	*Generación (toneladas)*	*Generación (kg/año per cápita)*	*Fuente*
2006	150 y 250	1.5 a 1.6	Román 2007, Gavilán-García 2007, González 2007.
2010	307, 220	2.7 a 2.5	Ojeda-Benítez et al. 2013a, Benitez et al. 2010, Gavilán-García, 2007.
2012	1,032.74	8.9	STEP 2014, Frey 2012.

Table 2 WEEE generation trends in Mexico

According to the National Programme for the Prevention and Integral Management of Waste (PNPGIR) 2009-2012, they estimate an annual generation of between 150,000 and 180,000 tonnes of WEEE (Román 2007). They report at least 411 ton/day of WEEE generation; specifying the difficulty of developing information about the management and disposal of WEEE (SEMARNAT 2008).

The main problem is that the toxic materials and substances contained in WEEE are grouped into Polychromated Organic Compounds known as Brominated Flame Retardants (BFR), Heavy Metals and other compounds generated by improper management such as dioxins and furans (Chen et al. 2011, Noel et al. 2013).

Poor disposal has created informal economic sources due to the amount of metals that can be recovered and traded. These economic sources from the recovery of materials from these wastes have evolved, as have the material recovery processes. Denmark, the Netherlands and Norway have since 1999 taken action to minimise their environmental impact with regard to WEEE.

Countries such as Belgium, Sweden and Switzerland have integrated the management of WEEE into their laws since 2002. In Spain, the recycling of electronic equipment began in 2003, with the legal framework regulating electronic waste, known as -tecnobasura‖ (Sáez 2005). One of the metals recovered from WEEE is Copper (Cu). In Spain, its demand has been increasing since 2004, with the most important source of recycled copper coming from products at the end of their functional life (Sáez 2005).

Because of the revaluation of these materials, the volumes of waste to be disposed of at Final Disposal Sites (FDS) are lower, causing collection and disposal costs to decrease (Li et al. 2012, Martínez 2013). The revaluation of a WEEE is 95% of its totality, the remaining 5% of its materials are those that have a negative impact, causing adverse effects on the health of the population and the environment, due to the toxic substances present such as mercury, lead, selenium, bromine and cadmium, among others (Zhang et al. 2012, Labunska et al. 2013).

Mexico is in transition with respect to WEEE. Fifty-six percent of the Mexican states have already taken at least one action to manage WEEE, which allows setting areas of opportunity for the development of specific WEEE management plans (Bautista-Vargas et al. 2014).

In Mexico, the reported formal recycling capacity is 10% of total generation, while non-formal recycling ranges from 10-20%. In other words, there is 70% of WEEE whose final destination is uncertain (Román, 2007).

As mentioned above, the characteristics of the WEEE components are based on toxic materials if they are not disposed of properly, but they are potentially revalued. This is why it is necessary to determine the composition of the materials, their recycling alternatives and energy recovery. Knowing how to recover materials and their revaluation provides an alternative to minimise these impacts. There are few companies in Mexico that carry out WEEE recycling activities, so these are areas of opportunity for the generation of new materials, ecological design and revaluation of materials from WEEE.

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WEEE compounds

Halogenated Organic Substances such as Polyvinyl Chloride (PVC) and BFRs, such as Polybrominated Biphenyls (PBBs), Polybrominated Biphenyl Ethers (PBDEs) and Tetrabrominated Bisphenol A (TBBPA), which are highly toxic, are used as additives to plastics in TV circuit boards, plastic monitor and TV housings, plastics and circuit boards in Personal Computer (PC) keyboard and mouse, PC plastic cabinet, PC motherboard, PC microprocessor bonding paste, PC memory, video game equipment plastics, video game microprocessor, VCR circuit boards, VCR microcontrollers, VCR housings, among others. (Gavilán-García et al. 2009, Niu et al. 2012). Such toxicity and persistence raises concerns about environmental and public health impacts (Chi et al. 2011, Gaidajis et al. 2011).

Metals such as Cadmium (Cd), Lead (Pb), Mercury (Hg), Chromium (Cr) and Nickel (Ni) are present in batteries, solder, electronic circuits, in Cathode Ray Tubes (CRT) which are part of the kinescopes of televisions and computer monitors. Lead oxide is used in CRT glass, lamps and fluorescent tubes. Copper (Cu), Gold (Au), Aluminium (Al), Iridium (Ir), among other metals are present in mobile phones. Printed circuit boards contain heavy metals such as Antimony (Sb), Au, Silver (Ag), Cr, Zinc (Zn), Pb, Tin (Sn) and Cu (Román, 2007, Chancerel et al. 2009, Chancerel 2010, Kalantzi and Siskos 2011).

However, there are countries that have transformed their economy to recycling WEEE, such as Ghana, India and China, which receive around 70% of all exported WEEE, as do Pakistan, Vietnam, the Philippines, Malaysia and Nigeria. The techniques they use are very rudimentary, leaving them exposed to highly toxic compounds emitted during dismantling and recycling activities (Kong et al. 2012).

Informal reuse actions are precarious, ranging from burning cables, hammering screens and monitors, where Pb is released from the glass of the CRTs and exposed to the environment and people, electronic cards bathed in acids and other chemicals used to recover valuable metals, as well as contaminated waste materials that are disposed of in an improvised manner (Niu et al. 2012).

Currently, the reuse of materials from WEEE is an economic opportunity that stimulates the revaluation of waste as 90% of the materials can be recovered and recycled.

Of the materials used in electronic devices that can be recycled, 50% is iron and steel, 20% is plastic, 13% is other metals including precious metals and 5% is glass. Approximately 95% of a computer can be recycled in its entirety, ranging from the hard disk and memory to the motherboard and its gold and silver wiring. From mobile phones up to 92.5 % can be recovered, from which precious metals such as silver, gold, palladium, 14 % of other metals such as copper and 80 % of other materials and elements (glass, tin, indium, cobalt and plastic) can be extracted. In both equipment there is 5% of non-recyclable material such as lead, selenium, bromine and other heavy metals, which are considered Hazardous Waste (HW) (Chancerel 2010, Buchert et. al. 2012).

WEEE material recovery process

Various processes are used for materials recovery, Figure 1 shows the percentage composition of e-waste. As well as the different material recovery processes that are used for each part that makes up a WEEE. A WEEE contains 0.8% of hazardous materials such as batteries, components with Mercury, among others, which there are specialised managers in the handling of this type of Hazardous Waste (HW). 99.2% of the WEEE is made up of plastics and mixed plastics (20%), glass (13.4%), printed circuit boards and cables (5.7%) and ferrous and non-ferrous metals (60.1%). There are two main trends in the disassembly process of electrical and electronic equipment: Manual and Mechanical.

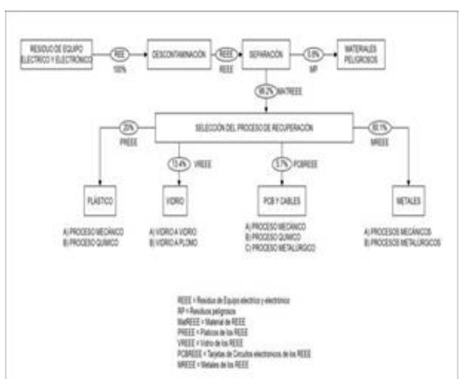

Figure 1 Composition of WEEE and recovery processes

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Manual Process

Manual dismantling is common in WEEE recycling plants. They use flexible tools, planning in advance the most efficient way to dismantle a piece of equipment so that it takes less effort and time. However, it is labour intensive and requires a high degree of training resulting in a costly process. One of the main affecting factors is the design of the equipment that facilitates or hinders disassembly (Cui and Forssberg 2003, Almada-Calvo 2007, Tobar 2013).

Process time is critical to the economic viability of recycling and therefore a dismantling-friendly design is key to making the process cost-effective. This has led engineers and designers to look for new electronic product designs to simplify disassembly.

One proposal is to avoid the use of screws, to make manual dismantling easier, or the use of clear dismantling instructions engraved on the surface of the equipment for the operator to use (Campbell and Hasan 2003, Rios et al. 2003, Williams 2006).

Mechanical Process

The initiation of this disassembly process is due to the disadvantages of the manual process, which has led to the development of automated technologies for these processes. One of the obstacles to this process is the diversity of electrical and electronic products which require flexible and intelligent disassembly processes. One of the alternatives is the use of robots with cameras, which can perform simple disassembly operations, whether destructive or non-destructive. By means of artificial intelligence and robots with force sensors, arms and grippers to handle equipment with different characteristics. However, these technologies have not been applied, so manual disassembly is still the most commonly used method (Van Kuren 2002, Cui and Zhang 2008).

Separation of materials

The separation of materials is carried out after disassembly, where there are a number of materials that need to be further processed. These materials can be a mixture of plastics, glass and metals or pure streams of materials.

In the case of pure streams of metals, plastics and glass, these are melted down and reincorporated into the life cycle of the materials. Components that are mixtures of plastics, ceramics, semiconductors and metals can be subjected to different separation processes in order to be reused as raw materials.

In which sub-processes are used to obtain these components, which are: Grinding, screening, magnetic separation, thermal conductivity separation and density separation.

Plastics Recovery

It is carried out by three different methods:

a) Mechanical recovery.

The aim of which is to obtain raw material to close the material cycle. An important problem for this type of recycling is the content of paints and coatings, because if they are not removed before recycling, the quality of the product can be affected.

b) Chemical recovery.

This aims to recover the main chemical components to be used in other applications. Such recovery can be of two types: (1) recovery of monomers by depolymerisation or (2) conversion of the plastic to pure carbon, so that it can be used in metallurgical processes as a reducing agent.

c) Energy recovery in incinerators.

Plastics have a higher calorific value than coal. According to the United States Geological Survey (USGS), one tonne of plastic can replace 1.3 tonnes of coal. Incineration of these plastics is a fairly common practice, in 2002, Switzerland and Denmark incinerated 70% of the plastic from electronic waste and in 2003 Europe recovered the heat energy from 23% by weight of all discarded plastics.

Recycling for glass

There are two recycling methods for glass from Cathode Ray Tubes (CRT), which are:

a) Glass to glass.

This consists of reusing the glass from the CRT for the construction of more CRTs. In this method it is necessary to completely separate the glass from the other electronic components, plastics and metals. Normally, after disassembly, it is subjected to grinding to obtain a uniform and pure glass mixture. The mixture is then melted and molded into the new CRT.

b) Lead glass.

In this method, glass from CRTs is used as raw material for the manufacture of lead. The aim is to recover the lead, while the glass is lost in the process. As in the previous process, the CRT is separated from the other components, however in this process the purity of the glass is not relevant, it is subjected to grinding and then used directly in the lead smelter. The glass serves as a fluxing agent, which helps to lower the melting point and density, making the process more efficient. In the production of primary lead, silicon dioxide is used as a flux. Compared to both processes, the Glass to Lead method is more cost efficient, as the process is more automated. However, it detracts from the value of the CRT glass, as it is only used as a raw material for lead.

PCB recycling processes

Printed circuit boards (PCBs) are the main component of almost all electronic devices. They are found in almost all electronic equipment and expire at the same or faster rate than the equipment itself. PCBs are basically composed of organic matter, metals and ceramics. The organic matter consists of paper, plastics and flame retardants. The metals are mostly copper, iron and aluminium, and to a lesser extent valuable metals such as platinum, gold, silver and gallium and toxic metals such as chromium VI, lead and mercury. The ceramics are silicon dioxide and aluminium dioxide (Hong-Chao et al 2006, Li et al 2007, Cui and Zhang 2008, Zheng et al 2009). The recycling processes for PCBs are as follows:

a) Mechanical process.

This consists of shredding the boards as finely and homogeneously as possible, so that the metal, ceramic and plastic parts that were originally glued together are separated. Different methods can be used to separate metallic and non-metallic particles. The difference in densities, or the difference in electrical properties can be exploited (Peng et al. 2004).

b) Chemical processes.

Sulphuric acid is used to solubilise copper and other metals. The cards are soaked for several hours in the hot acid and then the cards are removed, which no longer have any metals attached to them. Then, either by an electrochemical process or another chemical reaction, the copper is precipitated and sold. This technology is used to directly recover the metals without sending them to smelters.

The major drawback of this process is that it uses acids that have to be treated to avoid the release of heavy metals into the environment.

c) Metallurgical process.

This process directly uses the cards to be used in copper smelters. It takes direct advantage of the metal content, however strict control of emissions is needed, as the polymers and flame retardants present when burned can produce toxic substances such as dioxins and furans (Zhang and Cui 2008, Maurell-Lopez et al. 2011).

Methodology

As mentioned above, a descriptive investigation was carried out in the present work, using a comparative matrix of the different WEEE treatments.

The Comparative Matrix tool focused on the criteria that manage each alternative for the recovery of materials, contrasting with the environmental and technical aspects of WEEE management. The development stages consisted of:

- Description of the materials containing WEEE identifying the approaches on which it is based and the specific parameters in reuse.

- Selection of treatment alternatives and material recovery criteria.

- Elaboration of a double-entry Comparative Matrix showing the information in a summarised and concentrated form on the characteristics of the material recovery treatments.

- Analyse the results by correlating the aspects obtained, identifying the relevant aspects.

Results

On analysing the recycling processes, the following descriptive and comparative matrix of the WEEE material and energy recovery processes was obtained. Table 3 shows a summary of the material recovery processes and their relevant characteristics. It can be seen that the processes for the recovery of plastics, metals and glass are the main materials to be processed and reincorporated into the life cycle. Energy recovery from WEEE comes mainly from plastics which have a calorific energy generation of 23% by weight and from PCBs which need electrochemical processes for metal recovery.

The recycling of PCBs requires three processes which are pre-treatment, physical recycling and chemical recycling. All these processes are reduced to physical and chemical methods and it appears that there are no modern technologies available to replace both methods effectively (Hadi et al. 2015).

Parte de REEE	Tipo de proceso	Características relevantes	Recuperación		Observaciones
			Material	Energía	
1	Manual	Herramientas flexibles, se requiere mucha mano de obra y un grado elevado de capacitación	Plástico, vidrio, partes electróni cas.	No	Afecta es el diseño del equipo que facilita u obstaculiza el desarmado.
	Mecánico	Tecnologías automatizadas, uso de robots con cámaras. inteligencia artificial y robots con sensores de fuerza, brazos y pinzas	Plástico, vidrio, partes electróni cas.	No	La diversidad de los productos eléctricos y electrónicos los cuales requieren procesos flexibles e inteligentes de desensambla do
2	Corrientes puras	Metales, plásticos y vidrio	Metales, plasticos y vidrio	No	Fundidos y reincorporad os al ciclo de vida de los materiales
	Componente s que son mezclas	Plásticos, cerámicas, semiconductores y metales	Metales	Si	Molienda, cribado, separación magnética, separación por conductivida d térmica y separación por densidad
3	Mecánico	Materia prima para cerrar el ciclo de materiales	Plástico	No	Problema para este tipo de reciclaje, es el contenido de pinturas y recubrimient os
	Química	Recuperar los componentes químicos principales	Plástico	No	Recuperació n de monómeros por despolimeriz ación y Conversión del plástico a carbón puro
	Energética en incinerador	plásticos tienen un poder calorífico mayor al del carbón	no	Si	La energía calorífica del 23% en peso de todos los plásticos desechados

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					plásticos y metales
	Vidrio a Plomo	Vidrio proveniente de los TRC como materia prima para la fabricación de plomo	Plomo	No	Es la recuperación del plomo, mientras que el vidrio se pierde en el proceso.
	Mecánico	Triturar las tarjetas de la manera más fina y homogénea	Partes metálicas, cerámicas y plásticas	No	Aprovechar la diferencia de densidades, o la diferencia de propiedades eléctricas, para la separacion de metales
5	Química	Ácido sulfúrico para solubilizar el cobre y otros metales, por medio de un proceso electroquímico u otra reacción química	Metales	No	Inconveniente de este proceso es que se utilizan ácidos que tienen que ser tratados para evitar la liberación de metales pesados al medio ambiente.
	Metalúrgico	Proceso utiliza directamente las tarjetas para ser usadas en fundiciones de cobre	Cobre	No	Necesita un control estricto de las emisiones, ya que pueden producir sustancias tóxicas como las dioxinas y furanos

Table 3 Description and comparative matrix of WEEE material and energy recovery processes

Among the treatments for PCBs, they contain environmental and human health risk factors, as they produce air, water and soil contamination.

Rapid cryogenic treatment of PCBs minimises the impact of PCB treatment. Another treatment is pyrolysis, which can be considered as an alternative method of recycling PCB waste, because the organic materials are decomposed into low molecular weight products in liquid and gas phases (Khanna et al. 2014, Hadi et al. 2015).

Published results of this type of treatment process for PCBs indicate that the metals contained in the WEEE have a catalytic role for the vapour gasification of plastic components that can improve the hydrogen production performance in the vapour gasification of WEEE as well as nickel dust (Salbidegoitia et al. 2015). However, metals oxidise at high temperature decreasing their catalytic power. To carry out an efficient gasification process, e-waste must be mixed with metal powder recovered from the same e-waste and gasified with water vapour at low temperature around 823K (Zhang et al. 2012, Salbidegoitia et al. 2015).

One of the WEEE recycling processes is the use of steam gasification to obtain clean hydrogen.

Another alternative is to carry out hydrogen production by pyrolysis and steam gasification. Both techniques produce hydrogen, however steam gasification is the more viable option for H2 production from e-waste as it produces more moles of H2 than pyrolysis. However, steam gasification has a disadvantage that it produces a considerable amount of CO2 and this could cause an environmental impact because CO2 is a gaseous pollutant (Zhang et al. 2012).

Conclusions

This research has presented a descriptive and comparative analysis of the different treatment processes for the recovery of matter and energy from WEEE.

The results obtained allowed to identify the feasibility of alternatives for material recycling and energy recovery from WEEE. Identifying the type of revalorisation of each part of the WEEE. Plastics and PCBs are sources for energy production. The feasibility of the processes depends on the degree of contamination arising from the process.

In Mexico there are few companies that carry out WEEE recycling activities, only 56% of the states have collection and recycling activities, so these are areas of opportunity for the generation of new materials and eco-design from WEEE. Similarly, formalising this type of process will reduce informal recycling and the environmental and health impacts that it entails.

The relevance of this research is to know the different alternatives of material recovery, to identify new materials for alternative energy generation, in order to reduce the risk of contamination.

There is an important tendency to continue with research into new recycling processes and the generation of clean energy from WEEE. These results also allow us to advance in the knowledge of WEEE treatment.

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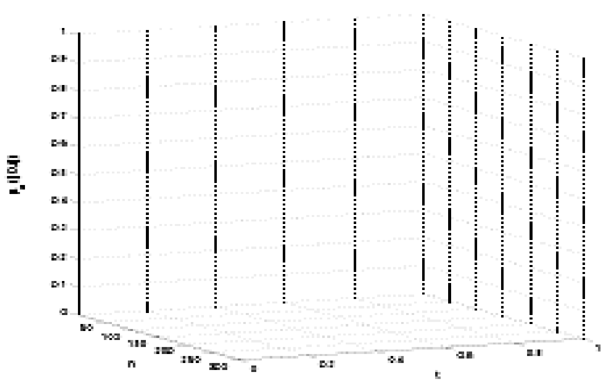

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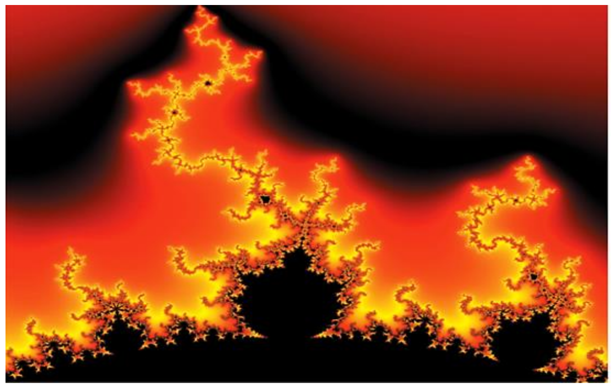

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