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Journal of Innovative Engineering

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Presentation of Content

In the first article we present, *Basic operation of rotary potentiometer A, B, C and W*, by AGUIRRE-MANRÍQUEZ, Issac V., GARCÍA-GUZMÁN, Miguel Á., RAZÓN-GONZÁLEZ, Juan P. and CANO-LARA, Miroslava, with adscription in Instituto Tecnológico Superior de Irapuato, as the next article we present, *Design needs and creativity: strategic transitions towards innovation*, by MARTÍNEZ-ESPÍNOLA, Edgar Eliezer, BALDERRAMA-ARMENDÁRIZ, César Omar, ARIZA-AMPUDIA, Silvia Verónica and MORENO-TOLEDANO, Leonardo Andrés, with adscription in Universidad Autónoma de Ciudad Juárez, as the netx article we present, *Modeling of a control system for the boost-boost converter in photovoltaic applications*, by MÉNDEZ-DÍAZ, Juan Francisco, SÁNCHEZ-RUIZ, Francisco Javier, MUÑOZ-JARILLO, Carlos Rene, VEGA-LEBRUM, Carlos and ROSANO-ORTEGA, Genoveva, with adscription in Universidad Poular Autónoma del Estado de Puebla, as the next article we present, *Challenges for solar energy and its contribution to the fulfillment of SDG 7 in Oaxaca, Mexico*, by ACOSTA-MOYADO, Luz Dehni, with adscription in Instituto Tecnológico de Oaxaca.

Content

Article	Pag

Basic operation of rotary potentiometer A, B, C and W 1-5
AGUIRRE-MANRÍQUEZ, Issac V., GARCÍA-GUZMÁN, Miguel Á., RAZÓN-GONZÁLEZ, Juan P. and CANO-LARA, Miroslava
Instituto Tecnológico Superior de Irapuato

Design needs and creativity: strategic transitions towards innovation 6-12
MARTÍNEZ-ESPÍNOLA, Edgar Eliezer, BALDERRAMA-ARMENDÁRIZ, César Omar, ARIZA-AMPUDIA, Silvia Verónica and MORENO-TOLEDANO, Leonardo Andrés
Universidad Autónoma de Ciudad Juárez

Modeling of a control system for the boost-boost converter in photovoltaic applications 13-25
MÉNDEZ-DÍAZ, Juan Francisco, SÁNCHEZ-RUIZ, Francisco Javier, MUÑOZ-JARILLO, Carlos Rene, VEGA-LEBRUM, Carlos and ROSANO-ORTEGA, Genoveva
Universidad Poular Autónoma del Estado de Puebla

Challenges for solar energy and its contribution to the fulfillment of SDG 7 in Oaxaca, Mexico 26-32
ACOSTA-MOYADO, Luz Dehni
Instituto Tecnológico de Oaxaca

Article
Journal of Innovative Engineering
December 2022, Vol.6 No.19 1-5

Basic operation of rotary potentiometer A, B, C and W

Funcionamiento básico de potenciómetro rotativo A, B, C y W

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Abstract

Presents study of analytical, experimental, and numerical method corresponding a A50K logarithmic, B10K linear, C10K antilogarithm and W20K logarithmic-antilogarithm rotative variable resistances. The basic operation of each potentiometer according to the variation on the input voltage and the spin on degrees of 30° between each measurement is studied using Arduino, MATLAB and Proteus. The functioning of each potentiometer model is complemented with the adjustment of the experimental curve and its characteristic equation. Signal conditioning in a variable resistance is of very important to control and stabilize a basic application, for example the variation of input voltage, or a specific variable such as movement, speed, lighting, etc.

Resistances, Measurement, Stabilize

Resumen

Se presenta el estudio del método analítico, experimental y numérico en resistencias variables modelos A50K logarítmico, B10K lineal, C10K antilogarítmico y W20K logarítmico-antilogarítmico. Se estudia el funcionamiento básico de cada potenciómetro, dependiendo de la variación de voltaje de entrada a 5V y el giro en grados cada 30º entre medición empleando Arduino, MATLAB y Proteus. El correcto funcionamiento en cada modelo de potenciómetro se complementa con el ajuste de la curva experimental, así como su respectiva ecuación característica. El acondicionamiento de señal en una resistencia variable es de suma importancia para controlar y estabilizar una aplicacion básica, por ejemplo la variación de entrada de voltaje, o una variable específica como movimiento, velocidad, iluminación, etc.

Resistencias, Medición, Estabilizar

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Introduction

In basic electronics it is common to use both fixed and variable resistors. As they are simple transducers, they allow the implementation of low-cost electronic arrays avoiding the use of sophisticated modules. In this context, a potentiometer allows to vary its resistance to the passage of electric current, depending on the degree with which its knob is rotated, or how much the lever is slid [1]. For a potentiometer-type electronic component, there are four important elements: connector A and B, a fixed resistor linking these two, and a connector C called a cursor representing the knob that adjusts the resistance between the terminals as shown in Fig. 1a and 1b. The rotary potentiometer contains a resistive strip that is connected to terminals A and B, and a sliding contact that is connected to terminal C thus obtaining the total resistance [2]. Fig. 1c shows the European and American symbols for a variable resistance.

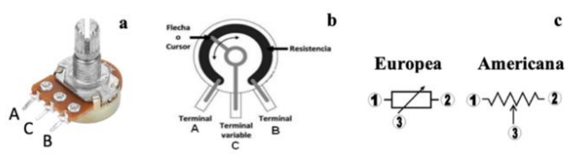

Figure 1 Rotary potentiometer a). Real device, b). Electronic design and c). Symbol.

To understand the main operation of a potentiometer, Ohm's law V=IR is used, which establishes the current intensity through the resistive element directly proportional to the potential difference applied and inversely proportional to the resistance it represents [3]. This law is useful to determine the behavior of the resistance generated by a rotating potentiometer in the arrangement of its degrees of rotation, approximately up to 300º. These degrees can be replaced by the use of percentage with which the potentiometer knob is turned, being a viable and correct alternative. Turning the potentiometer allows varying the amount of output voltage and likewise the resistance in Ohms of the model used [4]. Depending on the type of potentiometer will be the acquired behavior in the degrees of rotation and the % of voltage output. The sequence of Fig. 2 represents the behavior generated by a potentiometer type 2a. A-logarithmic, 2b. B-linear, 2c. C-antilogarithmic and 2d. W logarithmic-antilogarithmic.

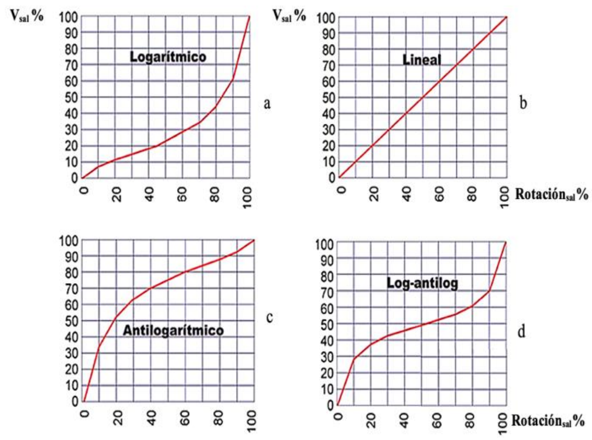

Figure 2 Response of rotary potentiometers: a). A logarithmic, b). B linear, c). C antilogarithmic and d). W logarithmic-antilogarithmic

Now, a potentiometer can be used in two different ways, being the first one as a voltage divider, where the input voltage is divided between each terminal according to the position of C, for example, when handling a 5V source and placing C just at its midpoint, we would have 2.5V between the terminal A and C and another 2.5V between the terminal C and B. And the second way, as a variable resistor, this can be measured by connecting terminal C with any other; C and A, for example, then, by moving the knob to the left end the resistance will be 0 and if it is moved to the opposite end its resistance will be the maximum allowed (without considering tolerances), in this way it is possible to say that, by moving the contact at C along the resistor, the level of the output electrical voltage will be adjusted [5]. The characterization of these devices for basic or complex applications requires the understanding of their response type and curve behavior.

Electronic systems that require variation of input resistance or voltage justify the use of this type of potentiometers, such as motion control, audio, speed, lighting, etc. However, each potentiometer is usually employed in more specific situations: the A-logarithmic is used as volume control in audio equipment since it easily simulates the auditory scale of the human ear [6]; the B-linear represents a practical option to automate processes where distance or position measurement is required [7]; the C-antilogarithmic is used as an operational amplifier in order to make precise adjustments in the signal adaptation of some sensors [8]; and finally the W-logarithmic-antilogarithmic is used in instrument pedals such as guitars to generate certain musical effects [9].

December 2022, Vol.6 No.19 1-5

In this work the experimental and numerical performance of the 4 types of potentiometers is presented. Obtaining the experimental values generates the characteristic equation and the graphical behavior in each potentiometer, which will be correctly adjusted using computational techniques.

Material and methodology

The material consists of four potentiometers: type A of 50KΩ, type B of 10KΩ, type C of 10KΩ and type W of 20KΩ, Arduino Uno board, Proteus and MATLAB. For the experimental case in Fig. 3, each potentiometer is shown with connector A at 5V from the Arduino board (red connection), connector C is sent to ground (black connection) and the output voltage variable is acquired at connector B (yellow connection). This last signal, being analog, is received by ports A1-A4 of the Arduino, monitored in real time and controlled by the angle of rotation of each potentiometer.

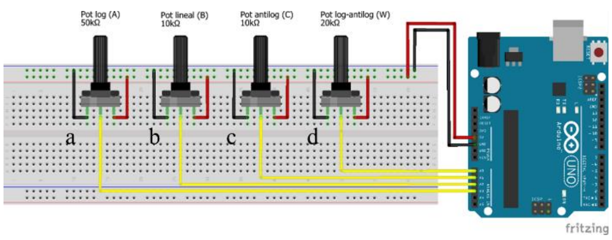

Figure 3 Connections of potentiometers A, B, C and W with the Arduino board

Fig. 4 shows the experimental arrangement for the resistive modules A, B, C and W with their respective degree indicator circle which is mounted on the threaded shaft. For the C-antilogarithmic potentiometer, a potentiometer B is used, which is modified in the Arduino code to acquire the desired behavior [10].

Fig. 5 shows the arrangement of the potentiometers in Proteus, where the Arduino Uno board, a virtual terminal, an oscilloscope, ohmmeter, voltage source and ground are used. For the logarithmic-antilogarithmic W potentiometer, the logarithmic and antilogarithmic potentiometer is used in parallel [11]. In each experimental and numerical case the total measurement swing is 300°.

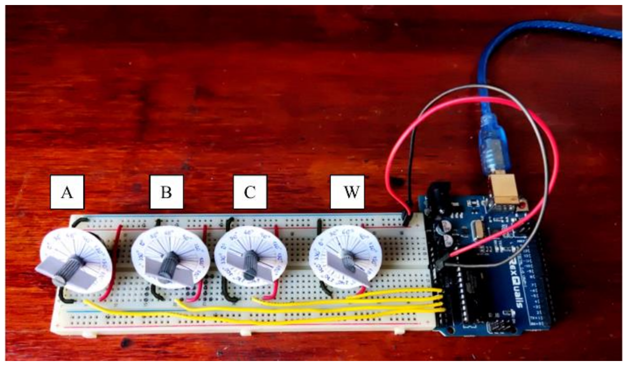

Figure 4 Experimental arrangement of potentiometers A, B, C and W with circle marked in degrees and Arduino board

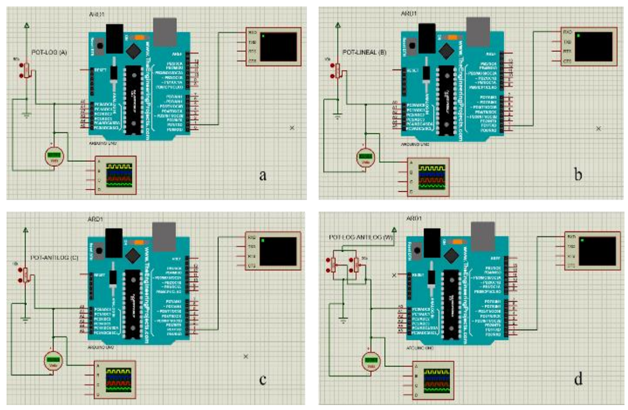

Figure 5 Proteus simulation of the potentiometers: a) Type A, b) Type B, c) Type C and d) Type W

Results

For each potentiometer Table 1 shows the experimental and numerical values of the voltage acquired with the rotation on each potentiometer in a range from 0 to 5V and 0° to 300° directly without signal adjustment. The analog signal acquired so far still represents an unstable signal, which can be adjusted in Matlab.

In particular, a B-linear potentiometer was experimentally used for the C-Anthyrhythmic potentiometer and programmatically adjusted with Eq. (1) and (2). The function map changes the range of values in the reading from 0 to 1023, finally obtaining a range from 1 to 10 with ten levels of 30°. The variable y1 is the reading in levels (1 to 10), y2 is the desired function for the path of those levels. The code in Arduino is adjusted with Eq. 2, likewise values are generated in the Proteus simulation.

$$y_1 = 10 * \frac{lectura-10}{10} + 10 \quad (1)$$

$$y_2 = \log(y_1) * 42.997 + 1 \quad (2)$$

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Angle [°]	Experimental				Simulation			
	Voltaje [V]							
	Pot. A	Pot. B	Pot. C	Pot. W	Pot. A	Pot. B	Pot. C	Pot. W
0	0	0	0	0	0	0	0	0
30	0.2	0.46	1.54	0.05	0.11	0.5	2.50	0.73
60	0.24	0.95	2.41	0.23	0.24	1	3.26	1.30
90	0.44	1.42	3.03	0.34	0.39	1.5	3.70	1.77
120	0.61	1.96	3.51	0.6	0.56	2	4.01	2.17
150	0.77	2.48	3.90	2.07	0.75	2.5	4.25	2.50
180	1.32	3.03	4.23	3.52	1	3	4.45	2.80
210	2.90	3.53	4.52	4.71	1.31	3.5	4.62	3.08
240	4.37	4.03	4.77	4.85	1.75	4	4.76	3.35
270	4.95	4.63	5	4.96	2.5	4.51	4.89	3.66
300	5	5	5	5	5	5	5	5

Table 1 Values without curve fitting acquired in each potentiometer by the experimental and numerical method

The values acquired in Table 1 are processed with the respective Polyfit function in Matlab. Table 2 shows the type of polynomial fit used in each potentiometer and its characteristic equation for the experimental and numerical case.

Potentiometer	Polynomial fit function	Equation
A	Logarithmic	3 and 4
B	Linear	5 and 6
C	Antilogarithmic	7 and 8
W	3rd degree and exponential	9 and 10

Table 2 Potentiometer type, polynomial function and its respective experimental and numerical equation

Potentiometer type A

$$y_{A.Exp} = 31(0.018447 + 2.8508 * \log x + 4.3) \quad (3)$$

$$y_{A.Sim} = 41(0.012173 + 2.2188 * \log x + 4.3) \quad (4)$$

Potentiometer type B

$$y_{B.Exp} = 0.01918x - 0.395 \quad (5)$$

$$y_{B.Sim} = 0.01601x - 0.0009091 \quad (6)$$

Potentiometer type C

$$y_{C.Exp} = (0.7328652 * \log x * 2.3) - 3.5 \quad (7)$$

$$y_{C.Sim} = (0.0020914 + 1.0495 * \log x) - 1 \quad (8)$$

Potentiometer type W

$$y_{W.Exp} = -1.158e^{-6}x^3 + 0.0005615x^2 - 0.05241x + 1.283 \quad (9)$$

$$y_{W.Sim} = 1.227e^{0.004429x} - 2.051e^{-0.03649x} \quad (10)$$

Table 3 presents the experimental and numerical values for each potentiometer with their respective polynomial fit. Fig. 6 shows the representative plots for the experimental case (a) A50K logarithmic, (b) B10K linear, (c) C10K antilogarithmic and (d) W20K logarithmic-antilogarithmic. The blue dots represent the experimental measurements and the red line represents the fit obtained in Matlab.

Angle [°]	EXPERIMENTAL				SIMULATION			
	Voltage [V]							
	Pot. A	Pot. B	Pot. C	Pot. W	Pot. A	Pot. B	Pot. C	Pot. W
0	0	0	0	0	0	0	0	0
30	0.06	0.17	1.59	0.18	0.11	0.48	2.54	0.71
60	0.24	0.75	2.62	0.09	0.25	0.96	3.26	1.37
90	0.43	1.38	3.23	0.27	0.39	1.44	3.68	1.75
120	0.61	2.02	3.66	1.07	0.56	1.92	3.98	2.06
150	0.80	2.55	4	2.14	0.75	2.4	4.21	2.37
180	1.47	3.15	4.26	3.28	0.97	2.88	4.40	2.72
210	2.76	3.73	4.49	4.31	1.31	3.36	4.56	3.10
240	4.56	4.27	4.69	5.03	1.75	3.84	4.69	3.55
270	4.94	4.85	4.87	5.27	2.5	4.33	4.82	4.05
300	5	5.04	4.87	4.82	4.98	4.8	4.92	4.63

Table 3 Values acquired in potentiometers after curve fitting, experimental and numerical case

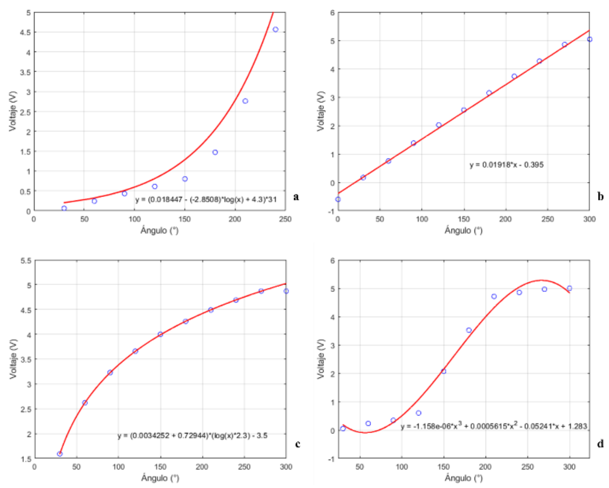

Figure 6 Curve fitting of experimental potentiometer behavior (a) A-logarithmic, (b) B-linear, (c) C-antilogarithmic and (d) W-logarithmic-antilogarithmic

For the numerical case Fig. 7 shows the response curves for (a) A50K logarithmic, (b) B10K linear, (c) C10K antilogarithmic and (d) W20K logarithmic-antilogarithmic.

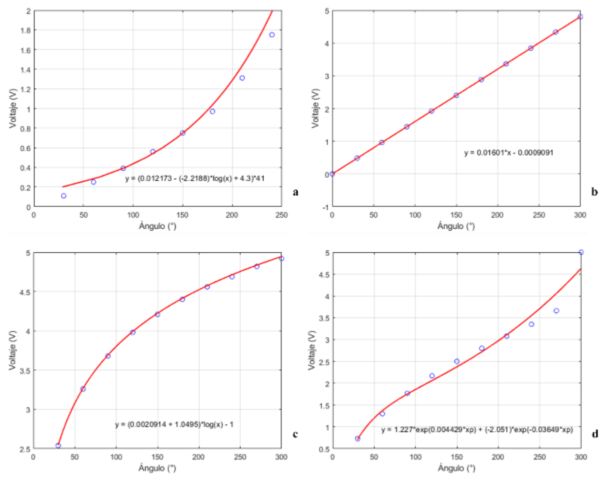

Figure 7 Curve fitting of potentiometer behavior in Proteus simulation: a) A-logarithmic, b) B-linear, c) C-antylogarithmic and d) W-logarithmic-antylogarithmic

The experimental and simulated values, as well as their respective curve fitting show the behavior generated by a basic rotary type potentiometer. It is observed that the polynomial adjustment is optimal to use it in the programming of the resistor, in this way a better control and quality in the signal will be achieved.

Acknowledgement

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Conclusions

It is relevant to identify the behavior of a variable resistor, using theoretical, experimental and numerical techniques. In practice, if the variable resistor requires a linear, logarithmic, antilogarithmic or logarithmic-antilogarithmic response, it is monitored in a multimeter or electronic software to control its rotation, voltage variation and resistance. Finally, it is recommended to make an adjustment to the potentiometer curve in use to improve the control signal of the electronic system.

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Design needs and creativity: strategic transitions towards innovation

Necesidades de diseño y creatividad: transiciones estratégicas hacia la innovación

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Abstract

Today identifying the user's need to design a product is somewhat confusing, on one hand, it is because some designers in Mexico do not carry out the design process based on the end user, on the other hand, terms with different meanings are generally used to refer to the needs, moreover, it is difficult to establish them and the result is perceived as conventional by those who will actually use the product. This article presents a proposal to design products that generate value for the end user based on the identification of their needs, through an organized process and with clear elements that facilitate the development of innovative proposals aimed at them. For this purpose, a documentary methodology was followed, the information collected was analyzed, the relationships between the concepts were established and the phases were identified, which we refer to as innovation transitions, in which the product can be innovated. We assume that, if a clear identification of the user's needs is made, the designer will be able to define the requirements to satisfy them in a disruptive way, as well as establish the design requirements and specify the attributes of the product, consequently, generate proposals mostly innovative.

Design needs, Needs identification, Innovation transitions

Resumen

Actualmente identificar la necesidad del usuario para diseñar un producto es algo confuso, por un lado, se debe a que algunos diseñadores en México no realizan el proceso proyectual con base en el usuario final, por el otro lado, generalmente se utilizan términos con significados diferentes para referirse a las necesidades, en consecuencia, es complicado establecerlas y el resultado es percibido como convencional por quien realmente utilizará el producto. Este artículo presenta una propuesta para diseñar productos que generen valor para el usuario final a partir de la identificación de sus necesidades, mediante un proceso organizado y con elementos claros que faciliten el desarrollo de propuestas innovadoras orientadas a él. Para este fin, se siguió una metodología documental, se analizó la información recopilada, se establecieron las relaciones entre los conceptos y se identificaron las fases, a las que nos referimos como transiciones de innovación, en las que se puede innovar el producto. Suponemos, que, si se hace una clara identificación de las necesidades del usuario, el diseñador será capaz de definir los requisitos para satisfacerlas de forma disruptiva, así como, establecer los requerimientos de diseño y especificar los atributos del producto, por consiguiente, generar propuestas mayormente innovadoras.

Necesidades de diseño, Identificación de necesidades, Transiciones de Innovación

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Introduction

It is clear the value that needs have for design, (Lecuona, Fernández, López, & Fernández, 2010; Baca & Roig, 2013), as well as the importance of the designer being able to identify those that are effective for the user (Asimow, 1962, p. 50), carrying out this process will result in increasing the chances of success of the project, since it will allow the development of a competitive product (Rodríguez, 2004). But, usually, the design process of some designers in Mexico does not start based on the user's needs, but from the definition of requirements, which, in this research, are understood as the way in which the solution is materialized to satisfy the needs. Consequently, by not establishing the needs adequately or by being ignored, the direction of the process will deviate from the objective, as well as the result and it is very likely that the design will fail (Seva, Duh, & Helander, 2007), therefore it is suggested to rely on different methods that will help to monitor the process, achieve compliance with objectives and document the actions in order to facilitate decision making (Ulrich & Eppinger, 2013).

In addition, the client is the one who will dictate the specifications of the project, so it is common to consider it as if it were the user, but, it should be clarified that those involved in the design project, the company, the client, the product, the user or the designer, each have their own needs (Lu, Feng, Zheng, & Tan, 2016). Therefore, it is paramount to know what needs the design will satisfy, otherwise, presumably, the result will not satisfy the user because the product was designed based on the customer.

Thus, identifying the user's needs in the design process is complex, "it is one of the most difficult parts of design" (Norman, 2013, p. 09), because, generally, the user does not know what his real need is. Then, designers got used to design what they are asked to design, which will not be precisely the most adequate because it will not satisfy the need, this lack of success will not be because of technical failures or a bad performance, but because the real needs of the users were not defined (Kirberg, 2005).

The origin of this situation is that this way of working leads to an automatic solution, i.e., the commonly used way to solve the problem is resorted to, which, probably, will result in something little or nothing innovative for the user, because no analysis of the problem was made, no reflection was made on what is really behind the user's or customer's request, i.e., the need that should be satisfied was not sought. For this reason, it is suggested that designers use methodological tools to design, so that it is easier for them to manage and organize all the information required during the process (Simón, 2009, p. 94).

To conclude, the objective of this article is to investigate through an analysis how to design innovative products from the process of identification of user needs, with the assumption that if a clear identification of user needs is made in the process of satisfying the need, by establishing the requirements, design requirements and product attributes, the designer will be able to generate more innovative proposals.

Theorists and design needs

To define need Vilchis (2014), starts from the Latin necesitatis, whose meaning is "necessarium constitutive quality that derives from necesse -that which does not cease, that which does not cease to be-". He mentions that "to understand a design need and its value, it is indispensable to take into account the contextual characteristics that affect the given object" (p. 51), he adds that needs are established by culture and civilization, so the value given to them, as well as their function, will depend on the context in which they arise. "The need is the result of some deficiency that when satisfied produces gratifying sensations, enjoyment, pleasure, well-being, relaxation, etcetera. Design satisfies needs that it concretizes through the use of objects and the configuration of meanings" (p.52), then, what is really of interest for design is the demand for a material or formal satisfaction.

The first stage of the methodology proposed by Morris Asimow (1962, p. 12) is the Feasibility Study that seeks to reach different solutions that will be useful for the design problem, the first step of this phase is to demonstrate if the original need, which was presumed to be valid, really exists and is valid or at least there is strong evidence that at least it exists latently. This original need is the starting point for this design process.

In the Diana Model developed by Oscar Olea and Carlos González Lobo, the designer must be able to discern five levels of response that characterize the specific field of design, two of which are related to the need. The first is the Functional, which corresponds to the relationship between the need and the form-function that satisfies it through use and the second is the Structural, which refers to the rigidity or durability of the object as a function of use, it relates the validity of the need with the permanence of the object in good condition (apud Vilchis 2014 p. 128).

For Gui Bonsiepe (1978) the project methodology begins with the structuring of the problem, where a situation that does not fit in the environment is sought and expressed in the form of an unsatisfied need, which will be evaluated "according to its compatibility with other needs, its priority with respect to other needs and according to the availability of resources (...) to establish whether the general formulation of a problem is at least justified" (p. 151).

In Bernd Löbach's method (1981, p. 140), phase one is the analysis of the problem, where the need is analyzed in order to establish "how many people would be interested in the solution of the problem in the form of an industrial product", which will allow companies to know the feasibility of developing the product and its success in the market.

Gillam Scott (1982) points out that "design is any creative action that fulfills its purpose (...) and creation satisfies human needs" (p. 1).

The research phase in Hans Gugelot's Methodology for the ULM School of Design, is where "you should find out as much as you can about the users (...) try to find the context in which the product will be used, and at the same time study its function and possible methods of production" (apud Simón 2009, p. 122).

Norman (2013, p. 20) establishes user-centered design as a philosophy based on the needs of users, with the goal of designing more usable products.

Victor Papanek (2014) points out that the function of design is "the way in which it fulfills its purpose" (p. 30) and proposes a diagram in which he shows the actions involved in what he calls "the functional complex" (p. 31) and the relationships between them. For Papanek, the real needs are economic, psychological, spiritual, technological and intellectual, on which design should focus, and he considers that they are regularly "more difficult and less profitable to satisfy than the carefully crafted and manipulated 'needs' that fashion and novelty inculcate" (p. 36).

Morris (2009) points out that a market-based design approach focuses on understanding what the main needs (or increasingly desires) of people are, "so that new or better products can be defined and created" (p.32).

It is necessary to work together with the user to identify their needs, therefore, to understand them, in order to develop design proposals that meet them; once these proposals are made, it is necessary to return to the original needs of the user and evaluate the design proposal from the user's point of view (Maldonado, Balderrama, Pedrozo, & García, 2019, p. 58), likewise, the authors highlight the importance of the user as a fundamental element to define the quality of a product, and on the other hand, they point out as the main factor in the failure of products, the fact that they were designed without considering the user's needs.

As we can see, there is a convergence in the importance of identifying the needs to design, as well as the benefit of doing it properly to achieve the correct development of the project and the importance of doing it from the initial phases.

To conclude, based on what has been stated in this section regarding the need, its definition and difference with respect to other concepts, as well as its importance for the design process, user needs will be considered in the following way in this research:

> - The user's need for the design is when a problematic of the person who will give use to a product is manifested with respect to a specific personal area and of its environment, which, the design must recognize and help to be satisfied -.

Study procedure

A documentary strategy was followed to gather information from the sources, analyze them and search for their relationships in order to organize the data collected for a reliable understanding of the subject. The search was carried out with the support of the Science Direct and Pro Quest databases, as well as the Google Scholar search engine, using the concepts 'needs', 'user needs' and 'design process'.

	Subject	Keywords	Combination		
t1	Definition of design process, method, methodology and technique	▪ Design Process ▪ Design Methodology ▪ Design Method ▪ Design Technique	————		
t2	Importance and advantages of requirements for design Consequences of omitting them	▪ Needs ▪ User Needs ▪ Design	Needs User Needs	+	Design
t3	Requirements as part of design processes, methodologies and methods	▪ Needs ▪ Design Process ▪ Design Methodology ▪ Design Method ▪ Design Technique	Needs	+	- Design Process - Design Methodology - Design Method - Design Technique
t4	Proposal of proprietary methods for needs identification	▪ Needs ▪ User Needs ▪ Design ▪ Design Method ▪ Design Technique	Needs	+	- Design Method - Design Method - Design Technique
			Needs User Needs	+	- Design Method - Design Method - Design Technique

Table 1 Search organization by subject
Source: Own elaboration

Table 1 shows the organization of the search organized by topics, for each of which key words were defined and, in some cases, combined to delimit the results. Afterwards, an elementary definition of the terms was sought, in order to subsequently look for how the need is defined from the design point of view.

The review made it possible to establish the differences and relationships between the concepts, which were organized to establish a process for satisfying the need. Based on the proposal of a diagram, the transitions where the greatest opportunity for innovation in the development of a product is produced were located.

Finally, a description of the transitions was made exemplifying their application and their moment of opportunity to generate products or elements of a product that contribute in the form of innovation.

Development

Once the documents were selected, firstly, the terms used to refer to needs were investigated. Table 2 shows these terms and the area of design where they are used, as well as the use of the term. The need is something that is impossible to avoid, lack or resist. A requirement is a necessary situation or condition for something.

On the other hand, a requirement is a request for a thing that is considered necessary.

Finally, the attribute is each of the qualities or properties of a being.

It has been considered to define these terms in order to establish their difference, since they are generally used indistinctly by some authors in the field of design to refer to requirements, as if they were synonyms, but they are not.

AREA	TERM	REFERENCE
Axiomatic Design	Attribute Requirement	Suh, 2001, p. 10
Industrial Design	Requirement	Rodríguez, 2000, p. 52
Quality Function Deployment (QFD) Methodology	Attribute Requirement What's	Yang & El-Haik, 2016, p. 179
Kano Model	Need Attribute Requirement	Brue, 2003, p. 127 Yang & El-Haik, 2016, p. 184

Table 2 Terms used to refer to needs in design
Source: Own elaboration

In addition to the fact that the concepts need, requirement, requirement and attribute are different, their place and time in the design process are also different, i.e., arranged in a linear way, as they are presented in the design process, we can observe that one follows the other, as in a process, consequently, they cannot occur in a synchronous way (See Figure 1).

As a consequence, they cannot occur in a synchronous manner (See Figure 1). Therefore, first the need must be known, which will allow the requirement to be defined, and this will give way to the establishment of the requirement, or requirements, ending with the generation of the attribute, as if they were prerequisites.

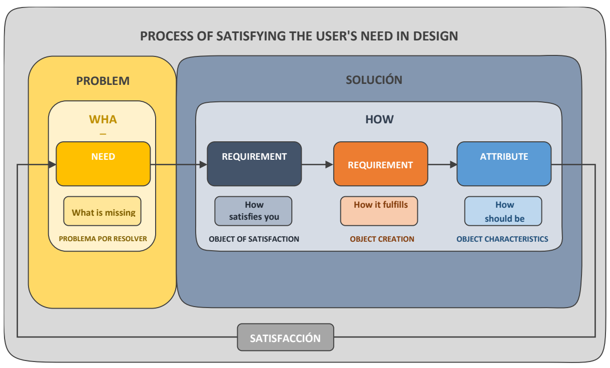

Figure 1 Process of satisfying user needs in design
Source: Own elaboration

To illustrate the above approach, the following examples are presented in Table 3. It is worth mentioning that only one requirement was considered in the responses to the needs as a measure of understanding of the approach, but it is known that a single need usually produces a series of requirements.

In these examples we can perceive the difference between the concepts, as well as the way in which each one fulfills its function in the process of satisfying the need. These examples show the conventional way or the way that is regularly used to satisfy the need, but it is here where you can take the step and generate an innovative proposal. By this, we mean that in the process of defining the requirement (Innovation Transition 1), which is the first step to start materializing the solution to the problem. By identifying the need, during a creative process, the designer is able to go beyond the conventional and devise an innovative way to solve the need to remain seated, by change the conventional response to the requirement, a chair, for a support suspended in the air by magnetism, for example.

DESIGN OF A DWELLING HOUSE				
NEED	REQUIREMENT	REQUIREMENT		ATTRIBUTE
Have a place in which to shelter and protect themselves from external agents such as the weather, wildlife, other people, etc.	Safe house	Resistant and safe materials		- Brick walls with concrete grating - Entrance grills, windows and metal doors
DESIGN OF A WORK CHAIR				
NEED	REQUIREMENT	REQUIREMENT		ATTRIBUTE
Working while sitting for prolonged periods of time	Comfortable chair	Ergonomics	Dimensions	- 17" x 25" backrest - Polyurethane
			Back morphology	- Flexible backrest - Polyurethane
			Support the weight	- Seat 20" x 20"
CELL PHONE DESIGN				
NEED	REQUIREMENT	REQUIREMENT		ATTRIBUTE
Immediate communication via phone call, text message and social networks	Smartphone	Of dimensions and weight that allow it to be carried and handled with ease		·Dimensions - 7" x 3" - Weight - 120 to 200 gr
		System capacity		- Operating system Android 11.0.0.0
		Storage capacity		- Storage capacity

Table 3 Exemplifications of the information flow exercise
Source: Own elaboration

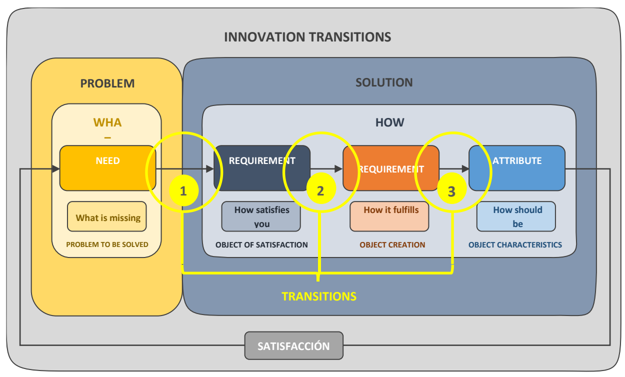

Figure 2 Transitions between stages of the need satisfaction process
Source: Own elaboration

In the step from the requirement to the requirement (Innovation Transition 2), there is another cycle of creativity where it is also possible to generate an innovation that meets the requirement, such as the process of creating this suspension support by magnetism, continuing with this example, or the mechanisms and technology necessary to achieve its operation. Then there is the step from requirements to product attributes (Innovation Transition 3), where it will be possible to innovate with the use of certain elements: materials, shapes, colors, joints, etc., not previously used. Figure 2 shows the transitions described here.

If we pay due attention to each of the transitions, then we have the possibility of breaking paradigms by responding from the design, as a way to satisfy real user needs posed through a problem. Then we can have as a result innovative elements within our product or a whole innovative product. It is important to clarify that the innovation will be under the user's perception, if all these proposals are focused on the detected need of the user, they have high probabilities of satisfying it, in addition, if they do it in an unconventional way and contribute value to the user, this will appreciate the innovation in the result.

Conclusions

It is already clear that the needs are an important part of the design process and that identifying them will be essential for the optimal development of this with results aimed at satisfying them, but, also now, we can highlight the importance of carrying out the process of identifying needs in an organized manner and being clear about the difference between the actors involved, that is, the difference between user and customer, to ensure that the needs with which it will be designed are those of the person who will use the resulting product. Also, understanding the stages of the process of identifying needs and what is established in each of them, to focus efforts correctly and ensuring that each stage goes according to the satisfaction of the need. Finally, we emphasize the importance of designing with the support of this process, because as shown, something as simple as ordering the elements of the process and clarifying the definition of each of them, can provide a better understanding of what is being done with the opportunity to generate innovative proposals, in some aspect of the product to be designed or in an integral way in the final product.

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Article

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Modeling of a control system for the boost-boost converter in photovoltaic applications

Modelado de un sistema de Control para el convertidor elevador-boost en aplicaciones fotovoltaicas

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Abstract

The boost-boost converter presents interesting characteristics for photovoltaic applications, due to the nature of the system where we can increase the voltage in an adequate and controlled way according to the load, in combination with an optimal control system we can obtain a better efficiency of a autonomous photovoltaic system, according to the above, this article deals with the low voltage photovoltaic application of an isolated system, using a boost-boost converter and a PI control system using two different solar panels, with the aim of showing that with a PI control we can obtain good efficiency of the two systems even with the presentation of disturbances as well as if a more robust control is implemented in photovoltaic applications, saving both operating cost and implementation time. The I-V characteristics similar to a non-linear source of the photovoltaic module, require the inclusion of linearization of the photovoltaic module and with this to be able to design the control of the system, the proper functioning of the designed control has been tested through mathematical modeling and simulation.

Autonomous, application, modeling

Resumen

El convertidor elevador-boost presenta características interesantes para aplicaciones fotovoltaicas, debido a la naturaleza del sistema donde podemos aumentar el voltaje de una manera adecuada y controlada de acuerdo a la carga, en combinación con un sistema de control optimo podemos obtener una mejor eficiencia de un sistema fotovoltaico autónomo, de acuerdo a lo anterior en este artículo se aborda la aplicación fotovoltaica en bajo voltaje de un sistema aislado, utilizando un convertidor elevador-boost y un sistema de control PI usando dos sistemas fotovoltaicos diferentes, con el objetivo de mostrar que con un control PI esencial podemos obtener buena eficiencia de los dos sistemas aun con presentación de perturbaciones al igual que si se implementara un control más robusto en aplicaciones fotovoltaicas ahorrando tanto costo de operación como tiempo en la implementación. Las características I-V similar a una fuente no lineal del módulo fotovoltaico, requieren la inclusión de linealización del módulo fotovoltaico y con esto poder diseñar el control del sistema, el buen funcionamiento del control diseñado ha sido probado mediante el modelado matemático y por simulación.

Autónomo, Aplicación, Modelado

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Introduction

In recent years, the demand for energy has increased continuously, with the main source being the indiscriminate use of fossil fuels. This constantly growing energy demand has generated an increase in greenhouse gases, causing severe damage to the environment, such as global warming and the worldwide problem of climate change. Thus, in the global energy context, renewable energies have emerged as a response to the social demand to reduce CO_2 emissions and other pollutants of direct action.

Photovoltaic systems are one of the most studied models for obtaining electricity from renewable sources. According to (Ram, et al., 2017), when using photovoltaic systems for energy production, one of their particularities is the fact that the electrical voltage generated by the photovoltaic panels has a non-linear relationship with irradiation in such a way that the maximum voltage generated does not represent the maximum power that the panel can deliver to an electrical load. Given this non-linearity, the maximum power that the PV panel can deliver is a function of the combination of voltage and current in the electrical load.

This non-linearity presented by the solar panels tries to be solved by determining an operating point or maximum power point (MPP) as long as it is under standard measurement conditions (STC), the STC according to the literature the solar panel must have a temperature of 25°C and an irradiation of 1000 W/m2 on the surface of the panel. The performance of the most promising PV technology should be regulated according to the MPP. The output of the PV system is affected by temperature, irradiation and partial shading conditions, these changes in environmental conditions limit the efficiency and power output of the panel and the measured output of the panel deviates from the desired set point. To improve the MPP there is the maximum power point tracker (MPPT) as it estimates and controls the MPP, the design of the MPPT system to achieve a regulated output is done by voltage converters and controllers to converge the MPP even under distribution conditions. There are different types of converters and controllers to optimise the efficiency of the PV panel using MPPT (Sharma & Jain, 2015).

According to Ebrahimi & Viki, (2015) DC-DC converters are widely used in renewable energy generation systems such as solar PV systems, wind systems and fuel cells in order to obtain correct power conversion as shown in figure (1).

Solar photovoltaic (PV) power generation system is used in grid-connected applications and stand-alone or islanded system (Saravanan & Ramesh Babu, (2017). In Alam & Hoque (2019) it is proposed that the most suitable power converter to solve the problem of low voltage levels obtained from PV panels, is the boost-boost converter; which raises and regulates the output voltage. The input of the boost converter acts as a current source due to the input inductor, which means that it has almost constant input current, which is favourable in PV systems. By interleaving boost converters, low ripple current is achieved in the input current, output voltage and high power conversion. This topology can be used for the interface connection between the low voltage of the PV array and a high input voltage of the battery bank or any DC load (Taghvaee, et al., 2013).

The boost-boost converter helps to increase the voltage level, improve stability and power factor. In some cases, the converter can also be used as a pre-regulator. It is clear that the DC-DC converters require an acceptable and efficient operation for the PV system to be effective and have the least possible energy losses, this also depends directly on the control used in the system and ensure the smooth operation of the system even with the presentation of disturbances.

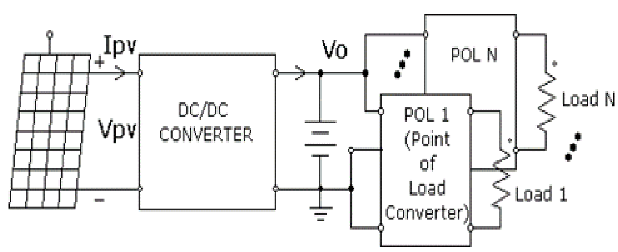

Figure 1 Photovoltaic system architecture with serial DC bus
Source: Méndez et al., 2014

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Another application of boost-boost converter is proposed in Dhople et al., 2009, where three boost converters are interleaved where superior current characteristics were found compared to the coupled converters. In Tian et al., 2016, they use an improved interleaved boost-boost circuit, concluding that this is the most suitable for PV using an MPPT algorithm, as it has greater advantages than the traditional interleaved boost converter (TIBC) and single boost converter (SBC) such as:

- Higher set-up ratio.

- More stable, accurate output voltage with less ripple.

- Lower switch voltages.

- It is useful to increase system efficiency and reduce energy losses.

But for the operating system to work properly, a control model needs to be developed to allow the system to operate properly. Among the control systems for photovoltaic applications with switched DC/DC converters are Proportional Integral Derivative (PID) and Proportional Integral (PI). According to Dwivedi & Saket (2017), in PV system the value of maximum power, current and peak voltage are increased by controlling the gain of the PID controller. In Rabiaa et al., (2019) a cascaded closed loop control using PI controller is proposed for DC-DC boost converter showing good performance in terms of rise time, disturbance rejection and steady state error. Furthermore, it is shown that the DC-DC boost converter has a strongly non-linear dynamic behaviour, so that the performance of any linear controller such as the PI controller can only be optimal as long as the system remains around a certain operating point, i.e. for photovoltaic applications, where solar panels are characterised by their non-linear structure, and if a PI or PID control is to be applied, which are controls characterised by using linearised models around an equilibrium point, the behaviour of the solar panels must be linearised by means of their basic equation. If this were not the case and it were desired to work with the non-linear structure, other control modes would have to be used, such as the sliding mode control used (Méndez, et al., 2014; Méndez, et al., 2015; Méndez, 2018 and Méndez, et al., 2019).

Therefore, this article presents the analysis of the boost-boost converter used in two photovoltaic systems, implementing a PI control system, with the aim of showing that with an essential control like this, widely used in various systems, we can obtain optimal control performance in the event that disturbances occur, as well as if a more robust control is implemented, reducing costs and operating times. In our application we can obtain the control of the input voltage V_PV of two different photovoltaic panels, taking into account the parasitic losses that occur in a real system, together with the non-linearity representative of the photovoltaic panels, and taking into consideration the linearisation of the models of both panels and working them around an equilibrium point, thus obtaining the maximum of their power even with perturbation, we obtain an optimal response of both systems. The analysis is performed with two different panels with powers of 85W and 100W, for the 85W panel was taken as a reference from the article Méndez et al., (2015), where they use the same panel.

The objective of this work can be listed as follows:

To present a general approach to derive in the transfer function of the boost-boost DC-DC converter and achieve system control in both solar panels.

Present a PI controller design approach for the input voltage of the PV panels to achieve a constant output voltage independent of the load variation.

Present the controller implementation using mathematical modelling and the control system to verify the results of each design.

To demonstrate that with a control system such as the PI it is possible to obtain satisfactory results in two types of solar panels with different powers, and that these respond appropriately in the event of disturbances in the system.

ISSN 2523-6873

Article
Journal of Innovative Engineering
December 2022, Vol.6 No.19 13-25

Theoretical analysis

Boost converter

The circuit diagram of the boost converter, as shown in figure (2), consists of an electronic switch that is controlled by a PWM signal. The inductor stores the energy coming from the source until the Ton period when the electronic switch is turned on. Meanwhile, when the diode is reverse biased it isolates the output of the circuit and the load current is supplied from the capacitor (Méndez, et al., 2014). When the electronic switch is off, the inductor is discharged and current flows through the diode. The output voltage is composed of the discharged voltage and the instantaneous panel voltage, so it is always higher than the input voltage. The switching on and off of the switch is controlled by the PWM signal (Bouchakour et al., 2015).

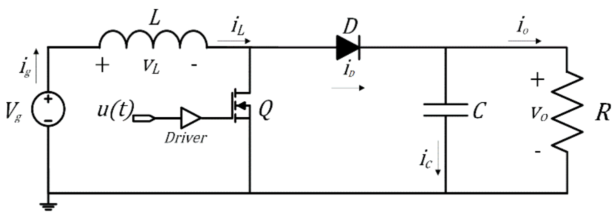

Figure 2 Boost converter schematic
Source: Mendez, 2018.

According to the above, for the research presented in this article, one of the elementary converters will be used, the boost converter, in combination with the solar panel and a battery which will have a linear behavior as shown in figure (3), applying a PI type control.

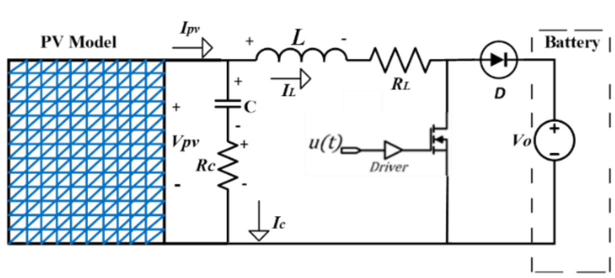

Figure 3 Behavior of a solar panel and its battery with a boost converter
Own source.

Photovoltaic panel analysis

Photovoltaic panels are non-linear systems, since as expressed in Leuchter, et al, (2012) there is a performance loss that is distributed non-linearly and parametrically (with solar irradiance and temperature) along the voltage axis of the panel, i.e. the direct application of the Shockley equation, I=Io*[e^((v/(n*Vt)))-1] in every panel does not give good modelling results, and the main reason is the existence of power losses that are spread along the voltage axis in a non-linear way.

In addition to these facts, the quality of the semiconductor material n is also variable and depending on the manufacturing process, the semiconductor material, the solar radiation and the temperature, the efficiency of the system depends a lot, so when you want to connect it with a DC/DC converter it is necessary first to linearise the photovoltaic panel and then linearise the converter, the technique to linearise the converter will be by means of state space analysis. For the analysis of the PV systems we use the parameters of the specification sheets of each of them, and the classical simplified model of the i-v relationship of the PV module (Méndez, et al., 2015).

$$i_{pv}=i_{sc}-I_R*e^{(a*v_{pv})} \quad (1)$$

The classical solar panel equation as shown in equation 1 is interpreted as follows: i_pves is the current supplied by the PV module, i_s is the short circuit current which depends on the irradiance, v_pv is the operating voltage of the module, I_R*e^a are parameters of the PV module which depend on multiple technological factors and temperature, as shown in figure (4a).

To linearise the system we represent it as shown in figure (4b), where the resistor will have the same current and voltage as the classical PV model as found in equation 2, always working at the maximum **power point of the MPPT panels.**

$$Rpv = \frac{Vmpp}{Ipv-Impp} \quad (2)$$

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Article

Journal of Innovative Engineering

December 2022, Vol.6 No.19 13-25

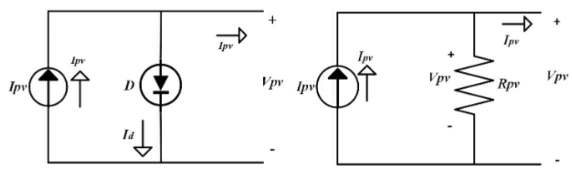

Figura 4a. **Figura 4b.**

Figure 4 Sample of a photovoltaic module with current and voltage variation
Source: Own elaboration

Based on the above, the linearised Norton model is used for the system analysis together with the boost converter as shown in figure (5), in order to perform the mathematical modelling, around the MPPT maximum power point as proposed by Hogan (2014). Circuits comprising arbitrarily complicated sets of voltage sources, current sources, resistors, capacitances and inductances can be represented by Norton equivalent circuits.

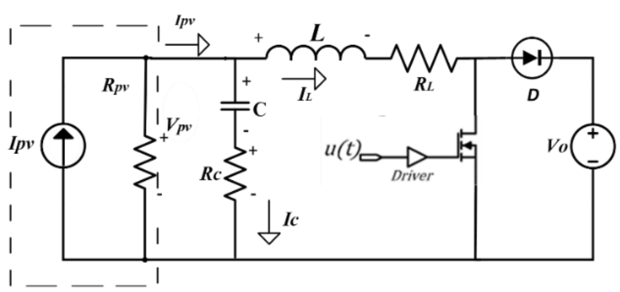

Figure 5 Norton model in a boost converter
Source: Own elaboration

A. Mathematical analysis

For the mathematical analysis of the system, the objective is to control the input voltage of the photovoltaic panel and produce the maximum power, based on the boost converter considering the losses in both the inductor and the capacitor by adding the series resistors in each of the devices.

For the analysis of the system we will perform it in its two operating points according to the boost converter as shown in figure (5).

To obtain the averaged system we analyse the boost-boost converter first in switched mode in its two operations obtaining the following equations:

$$\begin{cases} u = 1 \; en\ state\ on \\ u = 0 \; in\ state\ off \end{cases}$$

"$\boldsymbol{u = 1}$" Iinterval 1 (switch closed ON)

$$L\frac{dI_L}{dt} = V_C + I_C\ x\ R_C - I_L\ x\ R_L \quad (3)$$

$$C\frac{dV_C}{dt} = I_C = I_{PV} - I_L \quad (4)$$

"$\boldsymbol{u = 0}$" interval 2 (switch opened OFF)

$$L\frac{dI_L}{dt} = V_C + I_C\ x\ R_C - V_O - I_L\ x\ R_L \quad (5)$$

$$C\frac{dV_C}{dt} = I_C = I_{PV} - I_L \quad (6)$$

Taking into consideration that the current generated by the Norton model in figure (5) I_PV for the solar panel and the voltage of the same model V_PV are not equations of state as shown in equations (4) and (6) in the analysis of the interval when u=1 and u=0, these will have to be equated so that the current and voltage of the model are an equation of state, by equating these two variables with respect to the Norton model in figure (5) we are left with the following equations:

$$I_{PV} = I_{SC} - \frac{V_{PV}}{R_{PV}} \quad (7)$$

$$V_{PV} = V_C + I_C\ x\ R_C \quad (8)$$

Substituting equation (7) and (8) into (4) we obtain the following equation which is the same for both system states

$$C\frac{dV_C}{dt} = \frac{1}{R_{PV} + R_C}(I_{sc}\ x\ R_{PV} - I_L\ x\ R_{PV} - V_C) \quad (9)$$

By performing the relevant operations on equations (3) and (5) for the inductor and (9) for the capacitor in the boost converter, the averaged model looks as follows, where the equations are already a function of the system inputs:

$$L\frac{dI_L}{dt} = V_C + I_C\ x\ R_C - I_L\ x\ R_L - V_O\ x\ (1-d) \quad (10)$$

$$C\frac{dVc}{dt} = \frac{1}{R_{PV}+R_C}(I_{sc}\ x\ R_{PV} - I_L\ x\ R_{PV} - V_C) \quad (11)$$

For the steady state analysis, we again consider the Norton model of figure (5) where we analyse the following points according to the electrical structure of the PV system: taking into account that the average capacitor current is zero, we obtain that the inductor current will be equal to the PV panel current and the maximum power current, the same would be for the panel voltage which will be equal to the capacitor voltage and the maximum power voltage, thus obtaining the following equations (12 and 13).

ISSN 2523-6873

$$I_L = I_{PV} = I_{MPP} \quad (12)$$

$$V_C = V_{PV} = V_{MPP} \quad (13)$$

From the above we can also derive the duty cycle by equating equation (10) to zero and obtain the following equation (14).

$$D = 1 - \frac{V_{MPP} - I_{MPP} * R_L}{Vo} \quad (14)$$

Based on the averaged model, the equations of state and the steady state analysis, we can perform the mathematical modelling using state space analysis, this analysis is performed for both solar panels, where we define the state vectors x which are the inductor current I_L and the capacitor voltage V_C , the input vectors u, which are the duty cycle d the output voltage V_O together with the panel current I_PV and the control variable y which is the PV panel voltage V_PV as shown in the following equation.

$$x = \begin{bmatrix} I_L \\ V_C \end{bmatrix} \qquad u = \begin{bmatrix} d \\ V_O \\ I_{PV} \end{bmatrix} \quad y = [V_{PV}] \quad (15)$$

According to equations (10) and (11) to the vectors presented in (15), the matrix δ will give us the relationship that exists between the functions and the states, as follows:

$$\delta = \begin{bmatrix} \left(\frac{1}{L}\right) * \left(\frac{-R_{PV} * R_C}{R_{PV} + R_C}\right) - R_L & \left(\frac{1}{L}\right) * \left(1 - \frac{R_C}{R_{PV} + R_C}\right) \\ \left(\frac{1}{C}\right) * \left(\frac{-R_{PV}}{R_{PV} + R_C}\right) & \left(\frac{1}{C}\right) * \left(\frac{-1}{R_{PV} + R_C}\right) \end{bmatrix}$$

Taking equations (10) and (11) with respect to the input vectors $u = \begin{bmatrix} d \\ V_O \\ I_{PV} \end{bmatrix}$ For the matrix β which gives us the relationship between the function and the inputs we get:

$$\beta = \begin{bmatrix} \left(\frac{1}{L}\right) * V_O & \left(\frac{1}{L}\right) * (-1 - d) & \left(\frac{1}{L}\right) * \ R_C\left(\frac{R_{PV}}{R_{PV} + R_C}\right) \\ 0 & 0 & \left(\frac{1}{C}\right) * \ \left(\frac{R_{PV}}{R_{PV} + R_C}\right) \end{bmatrix}$$

For the matrix γ, having the variable to be controlled y=[V_PV] as a function of the states x=["(I_L@V_C)] we obtain :

$$\gamma = \begin{bmatrix} R_C\left(\frac{-R_{PV}}{R_{PV} + R_C}\right) & 1 - \frac{R_C}{R_{PV} + R_C} \end{bmatrix}$$

For matrix D having the variable to be controlled and $= [V_{PV}]$ en function of the inputs $u = \begin{bmatrix} d \\ V_O \\ I_{PV} \end{bmatrix}$ we obtain:

$$\varepsilon = \begin{bmatrix} 0 & 0 & R_C\left(\frac{R_{PV}}{R_{PV} + R_C}\right) \end{bmatrix}$$

As we can see the state space analysis shows us the complete behaviour of the system obtaining the transfer functions for both photovoltaic panels, these will be explained in the following section.

Comparison between Proportional, Proportional Integral and Proportional Integral Derivative Controls

As we know, in order to control a variable of a switched converter, it is necessary that the switched converters have a closed loop control system as shown in figure (6), where 4 components can be observed, 1) the main component which is the switched converter, 2) the block that calculates the error of the switching converter, 3) the block that calculates the error of the switching converter, 4) the block that calculates the error of the switching converter, and 5) the block that calculates the error of the switching converter, 2) the block that calculates the voltage error e(t) which is indispensable for the comparison of the system between those to be controlled, 3) the control component which mainly acts on the error by amplifying it and 4) the modulator which transforms the controller output into digital signals which are applied directly to the switches of the switched converter. Sometimes the modulator block is considered to be part of the controller block or the plant itself (Méndez, 2018).

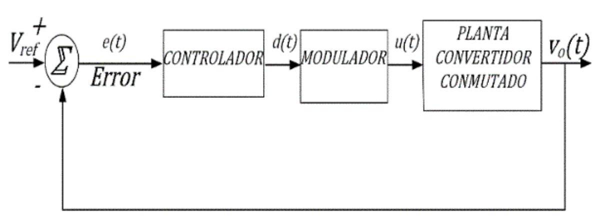

Figure 6 Control block diagram of a switched regulator.
Source: Méndez, 2018

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Based on the above for the control design and taking into consideration that we will have to control the input voltage of the solar panel according to the Norton model, we start with the comparison between the different control systems, explaining why the integral proportional control is the best suited to the needs of the photovoltaic system, for this according to the mathematical analysis previously explained in the previous section we first show the application of proportional control.

PROPORTIONAL CONTROL PANEL 85W.

Once the proportional control has been applied, we can see the following:

In figure (7) working in closed loop we can see that it is divided in three parts, the step response, the geometrical place of the roots and the Bode diagram: In the Bode diagram as can be seen when applying the proportional control the bandwidth never reaches the final value which is marked by the black line and is the value indicated by the control, in the geometric place of the roots we can observe according to the damping marked by the black lines that the closed loop poles also do not approach the damping indicated by the control system even changing the value of the proportional constant, and even though we see that the response over time reaches a certain stability, at start-up it tends to be oscillatory, so we conclude that proportional control is not a good option for implementation in our system.

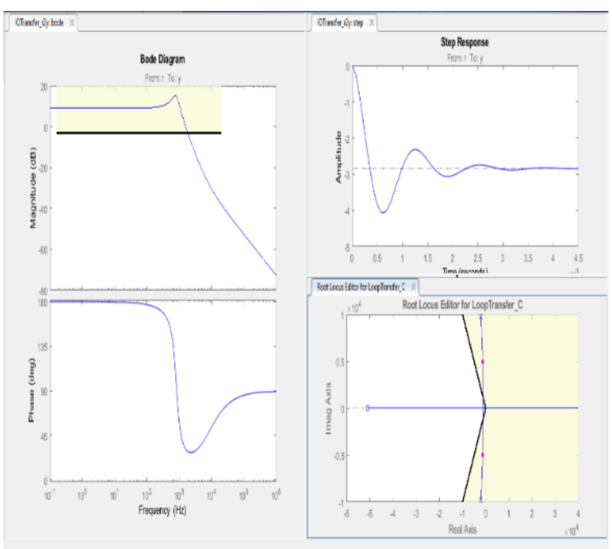

Figure 7 Application of Proportional Control.
Source: Own elaboration

Proportional integral derivative control panel 85w

When the proportional integral derivative control is applied, we can see the following: In the same way we analyse the system presented in figure (8), as we can appreciate in the Bode diagram the bandwidth does reach the value marked by the control line, but although it complies in this way graphically we can observe that the response is not optimal, in the geometric place of the roots we see that the closed loop poles are not close to the damping marked by the black lines, and the response in time as well as the proportional control finds certain stability but the response at the beginning of the system also presents certain oscillation.

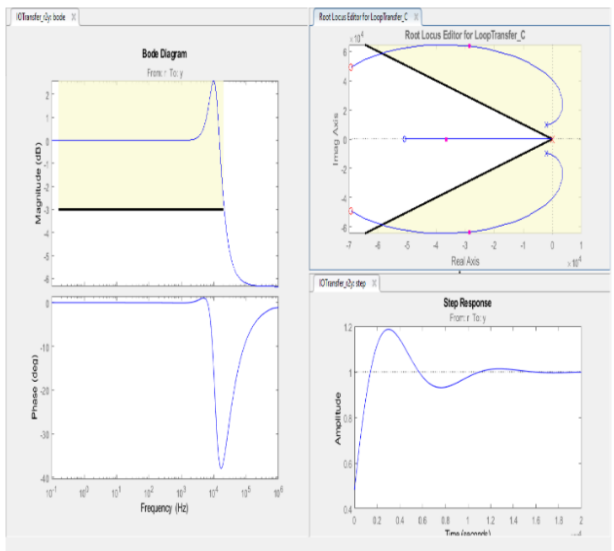

Figure 8 Application of Derivative Proportional Integral Control
Source: Own elaboration

Integral proportional control panel 85w

When the integral proportional control is applied, we can see the following: According to the figure (9) the same as the two previous controls it is shown in the Bode diagram the bandwidth where this if it arrives to the value marked by the control line, the same as the PID control but it can be observed that the response is optimal, in the geometric place of the roots we see that the poles of closed loop now if they are positioned directly in the lines of the damping marked by the control, and the response in time presents a stability and an optimal response for the control system, so we can conclude that the PI control compared to the other controls is the optimum in all operating conditions that marks the control system designed.

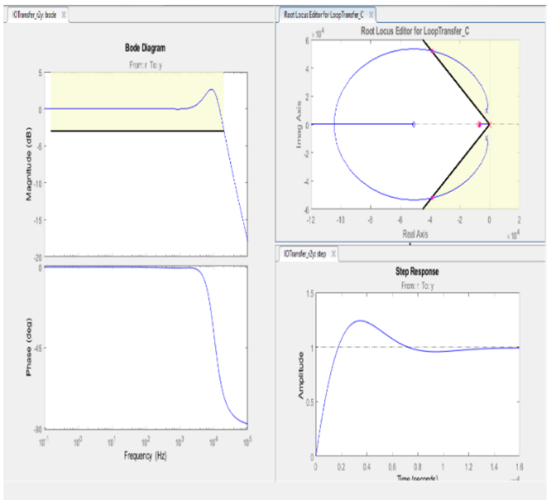

Figure 9 Application of Proportional Integral Control.
Source: Own elaboration

Proportional control panel 100

When proportional control is applied, the following can be seen:

In figure (10) the same as in the 85W panel working in closed loop: In the Bode diagram as it is observed when applying the proportional control the bandwidth never reaches the final value which is marked by the black line and is the value indicated by the control, in the geometric place of the roots we can observe according to the damping marked by the black lines that the closed loop poles also do not approach the damping indicated by the control system even changing the value of the proportional constant we do not have a significant approach, and even though we see that the response over time reaches a certain stability, at start-up it tends to be oscillatory, so we conclude that proportional control is not a good option for implementation in our system, very similar to the behaviour in the 85W panel.

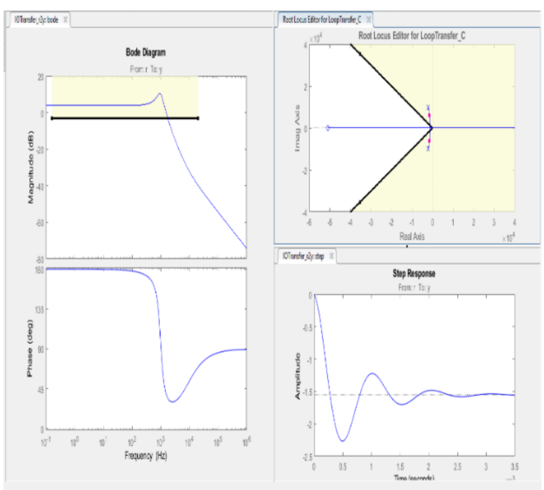

Figure 10 Application of Proportional Control 100W
Source: Own elaboration.

Proportional integral derivative control 100w panel

When the proportional integral derivative control is applied, we can see the following:

In the same way we analyse the system presented in figure (11), very similar to the behaviour of the 85W panel so we will summarise it a little, the Bode diagram the bandwidth does reach the value marked by the control line, but although it complies in this way graphically it can be seen that the response is not optimal, in the geometrical place of the roots, the closed loop poles are not close to the damping marked by the black lines, and the response in time as well as the proportional control finds some stability but the response at the beginning of the system also presents some oscillation.

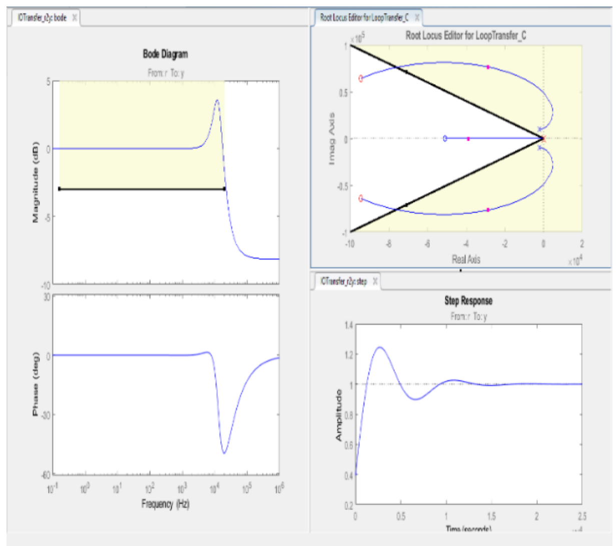

Figure 11 Application of Proportional Integral Derivative Proportional Control 100W
Source: Own elaboration.

Proportional integral control panel 100w

When the integral proportional control is applied, we can see the following:

ISSN 2523-6873

According to the figure (12) following the same thematic and observing that the control the behaviour of the control also is very similar to the panel of 85 W we can appreciate that in the diagram of Bode the bandwidth if it arrives to the value marked by the control line, the same as the PID control but it can be observed that the response is optimal, In the geometric location of the roots we can see that the closed-loop poles are now positioned directly on the damping lines marked by the control, and the response in time presents stability and an optimum response for the control system, so we can conclude that the proportional integral control is the most optimum for both panels as it meets the operating conditions required by the control system.

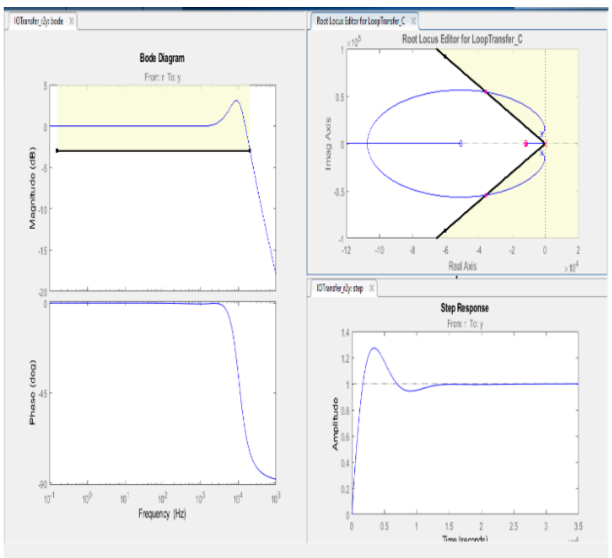

Figure 12 Application of Integral Proportional Control 100W
Source: Own elaboration

Application of the control systems

Based on Méndez, et al., (2015) for the analysis of the first panel we obtain the following technical characteristics; the photovoltaic panel is a module of 85 W, with nominal parameters at 25 ºC and 1 kW / m2 of: ISC = 5 A, Voc = 22.1 V, IMPP = 4.72 A, VMPP = 18 V. For the second panel which has the following technical characteristics; the 100 W photovoltaic panel has nominal parameters at 25 ºC and 1 kW / m2 of: ISC = 5.86 A, VOC = 22.3V, IMPP = 5.38 A, VMPP = 18.6 V. After the relevant analyses to obtain the boost converter parameters, the values for each of the components are as follows: L=75µH, RL=150mΩ, C=75µF, RC=196.3mΩ.

Obtaining the transfer functions by performing the previous analysis of the boost converter modelling and linearising around the operating point in both photovoltaic panels is as follows:

For the 85W panel

$$Gvd = \frac{-62641(s + 6.791 * 10^4)}{s^2 + 4817s + 1.776 * 10^8}$$

For 100W panel

$$Gvd = \frac{-62515(s + 6.791 * 10^4)}{s^2 + 4947s + 1.776 * 10^8}$$

As we can see both transfer functions are very similar, both show that the system is stable, but they present a negative gain, so the system could present some instability, because of this the control design becomes more complex, as it is left with a positive feedback. The control design now has to compensate or cancel the negative gain of the system, and thus have a stable system. By compensating the gain and as shown in the diagrams above from the comparison of the different controls we get the following transfer functions

For the 85w panel

$$Gcv = \frac{-1.6317s - 6773}{s}$$

Fort he 100w panel

$$Gcv = \frac{-1.7511s - 1.42 * 10^4}{s}$$

By obtaining the above transfer functions and with the control system applied, we observe that it is completely stable, which allows the objective of the control system to be achieved, which is to regulate the input voltage of the photovoltaic panel following a reference voltage, always looking for the point of maximum power. As shown in the following graphs, we start with the 85 W panel and then the 100 W panel.

As we can see in the figure (13) and (14) we can see that the panel operates in a suitable way, with which we verify that the linearization of the same one is the correct one since it is on the 18V that is the optimal voltage of operation of the panel according to its technical card in the same way that the current of the panel Ipv with a value of 4.72 A that is the optimal value of operation according to the technical card of the panel, and also we can observe that it is the equal to the current of the inductor, also fulfilling the analysis in stationary state IL.

For 85 W panel

Steady state analysis

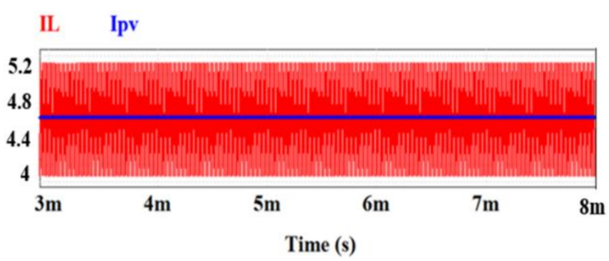

Figure 13 Steady state analysis
Source: Own elaboration

Implemented Control System

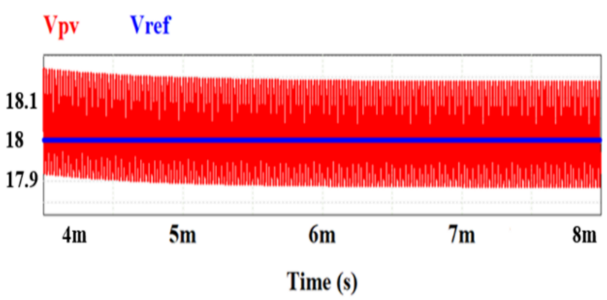

Figure 14 Panel voltage Vpv and reference voltage vref
Source: Own elaboration

In figure (14) we can see that the control operates properly since the panel voltage Vpv follows without problems the reference voltage Vref equal to 18V, always guaranteeing the maximum power point. Figure (15) shows a direct disturbance to the system simulating a partial shading in the solar panel of almost 70%, the control when presenting this disturbance, adapts almost immediately and responds again in an optimal way, where it is seen that the voltage Vpv of the solar panel after the disturbance follows without problems to the reference voltage Vref always over 18 V, taking into account that this is a fairly high disturbance the control continues to respond adequately.

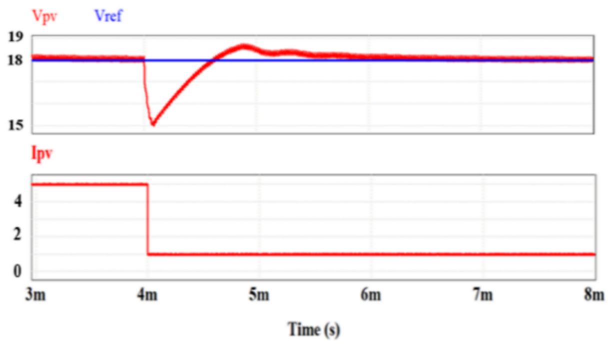

Figure 15 Disturbance present simulating partial shading
Source: Own elaboration

Figure 16 shows another disturbance which shows an increase in the battery voltage due to the load coming from the photovoltaic panel and as can be seen there is an increase in the output voltage Vo from 24V to 27V and again the solar panel voltage Vpv follows without any complication the reference voltage Vref always over 18V adapting quickly after the disturbance.

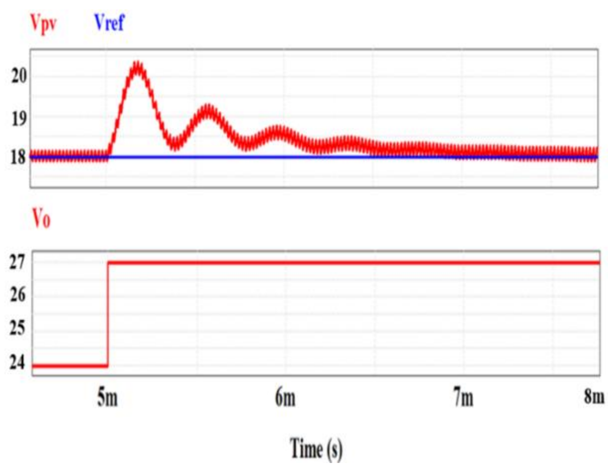

Figure 16 Second disturbance present in the battery.
Source: Own elaboration

In the same way that in the 85W solar panel we can see in the figure (17) and (18) now with the 100W solar panel, we can see that the panel operates in an adequate way, with which we also verify that the linearisation of the same is correct since it is over 18.6 V and the panel current Ipv is equal to the inductor current IL, also verifying the optimum analysis in steady state.

100W panel

Steady state analysis

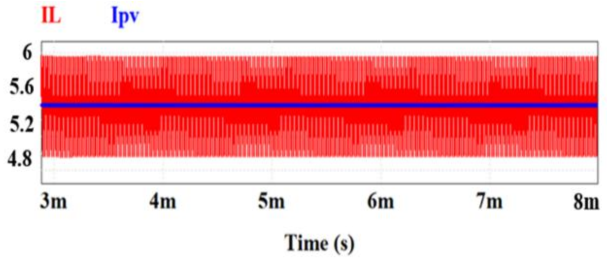

Figure 17. Steady state analysis
Source: Own elaboration

Implemented Control System

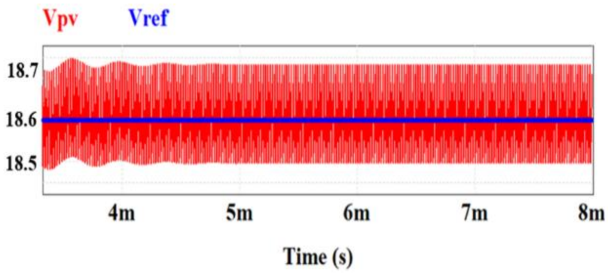

Figura 18 Panel Voltage Vpv and Reference Voltage Vref.
Source: Own elaboration

In the same way as in the previous panel in figure (18) we can see that the control operates properly as the panel voltage Vpv follows smoothly the reference voltage Vref now at 18.6V, always guaranteeing the maximum power point, and the stability of the system.

In figure (19) we repeat the same disturbance of the 85W panel causing a partial shading of the same magnitude now in the 100W panel, as we can observe the current Ipv drops its amperage suddenly and considerably, and the control continues to operate correctly, showing the good performance also for this panel.

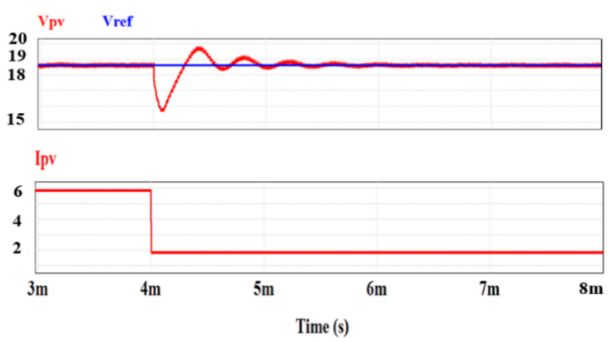

Figure 19 Disturbance present simulating partial shading
Source: Own elaboration

Following the same tests as for the 85W panel we now show the second disturbance in figure (20) of the 100W panel when the battery load is increased and we observe that the control is still operating correctly as the panel voltage Vpv is still smoothly at the reference voltage Vref now at 18.6V.

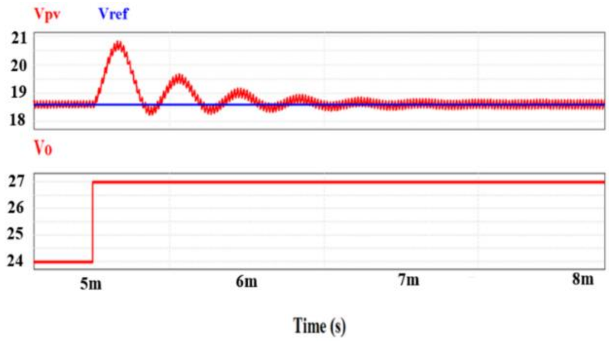

Figure 20 Second disturbance present in the battery
Source: Own elaboration

Conclusion

In conclusion, following the theoretical analysis and verifying with the simulations we can see that it is possible to regulate the input voltage of the two photovoltaic panels with the application of a PI controller, using the MATLAB tool for the design itself, therefore, we can also say that the use of this tool greatly facilitates the design of controllers for application in switched converters, and that it meets the objectives set for this research in an optimal way, It could also be observed that as mentioned in the introduction, implemented a conventional PI control we can have the same performance of a much more robust control, applied in photovoltaic systems, having as advantages the easy application, reduced operating time and reduced operating costs when the model is implemented physically, the following research work will be the application of the MPPT algorithm based on the method Perturb and Observe how in Méndez et al. , (2015) in the same way on both PV panels, and the physical implementation of the system.

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Challenges for solar energy and its contribution to the fulfillment of SDG 7 in Oaxaca, Mexico

Retos de la energía solar y su contribución al cumplimiento del ODS 7 en Oaxaca, México

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Abstract

This article is part of a doctoral research on solar energy in the state of Oaxaca. The aim of this paper is to identify the challenges for solar energy in the state by learning about the benefits, advantages and disadvantages from the experiences of those involved in the projects, in order to determine their contribution to the fulfilment of SDG 7 "affordable and clean energy". Semi-structured interviews were conducted with public servants and companies, and surveys were conducted with individuals and businesses to find out their perception of the use of solar energy technologies. The main results highlight that despite the great solar potential of Oaxaca, the two variables that represent the challenge for the use of this energy source is the lack of funding for projects and the lack of knowledge on the part of the people, however, there is a willingness of those involved to learn and accept proposals that allow them an energy transition that will contribute to the fulfilment of Goal 7 of the 2030 Agenda.

Solar energy, Perception, Contribution

Resumen

Este artículo forma parte de una investigación doctoral sobre la energía solar en el estado de Oaxaca. El objetivo del presente es, identificar los desafíos para la energía solar en el estado conociendo los beneficios, ventajas y desventajas a partir de las experiencias de los involucrados en los proyectos, para determinar su contribución en el cumplimiento del ODS 7 "energía asequible y no contaminante". Se aplicaron entrevistas semiestructuradas a servidores públicos y empresas, y encuestas a personas y comercios para conocer su percepción en el uso de tecnologías de aprovechamiento de energía solar. De los principales resultados destacan que a pesar del gran potencial solar con el que cuenta Oaxaca, las dos variables que representan el desafío para el uso de esta fuente de energía es la falta de financiamiento para proyectos y el poco conocimiento por parte de las personas, sin embargo, hay voluntad de los involucrados por aprender y aceptar propuestas que les permita una transición energética que permita contribuir al cumplimiento del objetivo 7 de la Agenda 2030.

Energía solar, Percepción, Contribución

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Introducción

This article is the result of the first stages of doctoral research on the incidence of solar energy projects in the sustainable development of the state of Oaxaca.

Derived from the observation, the concern arises to know the potential of this energy source and its contribution to the fulfillment of the Sustainable Development Goals, specifically number 7 "affordable and non-polluting energy" in the state, given that, At the national level, in the SEGOB report (2022) together with INEGI data, they show the percentage of participation of clean energies in the matrix of electricity generation (at the national level) in a graph, whose increase is clear from from 2019 (21.6%) to 2021 with 28.6%, although the National Voluntary Report (SE, 2021) says that 32.5% has already been reached; Of these energies, the one of interest is solar with a generation of 6.7%.

It should be noted that when talking about solar energy in most cases, reference is made to photovoltaic solar energy, which is one that takes advantage of direct solar radiation to transform it into electrical energy through panels. The data mentioned in the previous paragraph consider only this form of solar energy, however, it should not be reduced to this use, since there is a whole range of technologies that use the sun as a source for various tasks on different scales: domestic, commercial, public services and industry.

The contribution of this article focuses on the benefits, advantages and disadvantages of all forms of use of solar energy considering the experiences that users and those involved in the implementation of projects within Oaxaca have had.

In the following sections, solar energy is defined and the contexts at the national and state level are discussed, the objective of this article and the methodology to achieve it are mentioned, the results are presented, the thanks for being able to carry out this research and it is finalized. with the conclusions.

Solar energy

This form of energy could be classified into 4 forms of use (Rincón, 1999, p.15):

1. Passive solarization, which avoids energy consumption through bioclimatic constructions, or in agriculture with greenhouses (Bravo, González, González, 2018; Guzmán et al, 2021).

2. Use of collectors that heat fluids at low, medium and high temperatures whose applications range from heating water in homes for the bathroom and kitchen, heating, hot water for hotels, swimming pools and in the last decade refrigerators, to industrial processes where they are required. higher temperatures. Likewise, they can be plates on surfaces that heat the air within a system and help the drying and/or dehydration process (Vázquez et al, 1997; De Castel et al, 1999; Acosta, 2006; Esquivel et al, 2006; Guzmán et al, 2021).

3. The concentration of thermal energy in a single point to reach medium to high temperatures for different purposes such as cooking food in ovens and kitchens, to thermoelectric plants whose objective is to generate electricity from heating salts that melt and can move a turbine. In addition to using residual heat for industrial processes or cogeneration (Laborde, Williams, 2016; IEA, 2019).

4. The best known is to transform it into electricity directly through photovoltaic cells. In Mexico there are two options once the decision to acquire solar panels has been made, one is to interconnect to the National Electric System through the CFE Network and pay a much smaller difference in the bill than if the system had not been installed; the other is an isolated system that is generally installed in places where there is no access to the Network, both systems can be used in homes, businesses, industries, public and service buildings, but the isolated ones can be extended to public lighting, pumping or irrigation (CFE, 2008; Laborde, Williams, 2016; IEA, 2019).

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It is important to mention all the forms of use, since each one of them is so relevant within the social, environmental and economic impact that they have within the territories, which emphasizes the need to incorporate into colloquial language the breadth of applications that the concept implies. "solar energy".

Context of solar energy in Mexico

As mentioned in the introduction, the contribution of solar energy in the total generation of energy at the national level is barely 6.7%, although this only refers to photovoltaics, since other forms of use are not considered, this It could imply two things, one, there are not enough projects installed to significantly contribute to the substitution of fuels that contribute to global warming (fossils, firewood, LP gas, coal, etc.), only the percentage of private homes that have a solar heater is 3.2% according to INEGI data in 2015, being the only year where it is reported, which prevents the second implication, which is the lack of data collection,There is no record of all the solar energy projects that exist in the Mexican territory, which is why more efficient data collection and management is needed.

The results of the lack of this information translate to what Karina Cázares (2022) reports on the data gaps at the subnational level by SDG: “In the Mexican case, the largest data gaps at the subnational level are associated with SDG 7 (energy), SDG 12 (responsible production and consumption); SDG 13 (climate action); SDG 14 (life below water); SDG 15 (life and ecosystems on land).”; that is, there are not enough indicators to support compliance with the Objective of interest in this article, since there are only 2 national indicators but none at the state level.

Context of solar energy in Oaxaca

Within the same context, in the data reviewed in the first stage of doctoral research (Acosta, 2022), it is observed that Oaxaca has had the opportunity to contribute significantly to the fulfillment of objective number 7, thanks to the wind corridor in the Isthmus of Tehuantepec, despite its great potential due to the average annual radiation levels of 5.3 kWh/m^2, with a minimum of 4.4 in December and a maximum of 6 kWh/m^2 in May (Global Solar Atlas, 2020), the percentage of homes that use a solar heater is 0.6% (INEGI 2015), and those that have a solar panel is 0.4%; The large projects that are mentioned in the journalistic notes are reduced to 6, all of them involving photovoltaic energy at the household level, a soft drink company, two academic institutions that supply the energy demand of their campuses or laboratories and two solar parks in communities; There are only 4 academic publications that show the use in a desiccator for wood, disinfection of residual waters with sunlight, an economic technical study on flat solar collectors for rural areas and the same solar park of the University of the Mixteca (UTM) that It is mentioned in the journalistic notes, so there is not the same magnitude of potential in the number of projects that are taking advantage of this energy source.

In addition to these results, it is identified that in the maps of clusters of solar energy projects (PROMEXICO, 2016) Oaxaca is not contemplated and in the compliance report (SEGOB, 2022) of the SDGs objective number 7 is not even mentioned. . Even though in 2018 the Technical Work Committee and three Work, Economic Growth and Environmental Sustainability Committees were created (Government of Oaxaca, 2019) for being the state of Oaxaca, included in the Global Guide to Voluntary Local Reviews (GMRLV) of the organization United Cities and Local Governments and UN Habitat there are no results that can be consulted on the official page of the Government of Oaxaca, on the page of the Regional Observatory for Development Planning (CEPAL, 2022) or in any other means to find out about compliance of this specific objective.

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General objective

Identify the challenges for solar energy in the state, knowing the benefits, advantages and disadvantages based on the experiences of those involved in the projects, to determine their contribution to the fulfillment of SDG 7 "affordable and clean energy".

Applied methodology

This part of the research is of a qualitative nature because it knows the perception of the use of solar energy as a tool for sustainable development and exploratory because it is a first approach, the problem and the context of each locality were better understood.

The sample selection is described in the first part (Acosta, 2022), in which 14 municipalities were selected based on their radiation characteristics, percentage of homes with a solar system (heaters or photovoltaics), income, population level, number of projects. of solar energy and number of companies.

3 instruments were applied to know the perception of those involved in solar energy projects:

1. Semi-structured interviews with municipal and state authorities

2. Interviews with solar energy companies

3. Surveys of the population and commercial premises of goods or services

The data was homogenized for the qualitative analysis and the variables that people rate as advantages and disadvantages of their experience with solar energy are identified, in addition to the benefits that contribute to the fulfillment of SDG 7.

Results

The results are presented with respect to the responses obtained from each group:

1. Municipal and state authorities:

10 municipal authorities (councillors, ecology coordinators, director of health and ecology, and department heads) and 2 state authorities from the Ministry of Environment, Energy and Sustainable Development (SEMAEDESO) were interviewed.

When asked if there are solar energy projects implemented in the municipality, all respond that there are none or are unaware, except for the SEMAEDESO managers, who have the data on the projects with the highest investment, these are, the UTM park for its relevance and magnitude, in addition to the fact that it implied an investment from the federal level and with non-governmental organizations; some municipalities such as Santa María Atzompa who had the support of international organizations as part of the 10 municipalities integrated into the GMRLV to implement public lighting, pumping and irrigation systems; and in Oaxaca de Juárez there have also been public lighting projects, however many lights have already been stolen.

It is alluded that projects such as public lighting or solar parks have been carried out by federal or state authorities or private companies, but none have been at the request of the population. And that people are not interested in photovoltaic panels because there is very little energy consumption within homes that the investment is not profitable for them, especially because of the subsidy reflected in the CFE receipt. In addition, they emphasize that there is a lot of ignorance on the part of the population about solar systems and that their motivation to acquire this technology is economic, but not environmental.

An interesting response was that when asked for their opinion on solar energy, the majority mentioned positive concepts such as "alternative", "potential", "use", "it is necessary", plus one of the health and environment councilors mentioned Concern about the use of lithium "must take into account the production and impacts of solar cells, which should not be changed by extractivism."

Everyone speaks of a willingness and openness to receive training and knowledge on the subject that allows them to propose adequate systems for their municipalities, but that without financing the acquisition would not be possible.

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2. Interview with solar energy companies

6 solar energy companies located in Oaxaca de Juárez, Xoxocotlán and Miahuatlán de Porfirio Díaz were interviewed, 4 of them are small companies, even one is only the specialist that when it has projects it hires people outside its company to support it, and the others two are the largest companies, one of them is the only one that manufactures photovoltaic panels in the state.

100% have installed solar systems in private homes and in local or small companies, 66.7% in large companies, 33% have implemented a project requested by a local or state government and only one has collaborated with farmers. This allows them to have a reference on user experiences.

Only one of the companies claims to have more than 20 projects per year on average, the others range between 11 and 20 and 2 companies have between 5 and 10. Regardless of these amounts, 100% of the projects that all have installed are still running. Most are solar heaters and to a lesser extent photovoltaic.

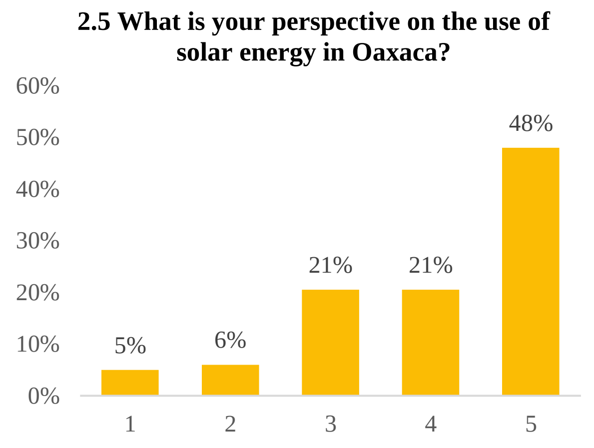
From their perspective, they consider that the main disadvantages and challenges that solar energy projects have is the lack of knowledge on the part of the users, since not all the population locates this technology or considers it very expensive, in addition to the fact that bad experiences by people who do not have adequate knowledge in the installation of systems and decide not to invest again.

Curiously, in the same way as the authorities, they mention the willingness and interest on the part of some sectors to promote this technology and they agree that without financing the use of this technology in the state cannot grow.

3. Surveys of the population and commercial premises of goods or services

A total of 200 responses were obtained, 187 from the general population and 13 from businesses.

With a Likert scale, their perspective regarding the use of solar energy in Oaxaca is qualified, being 1 "negative, 3 "indifferent" and 5 "positive, the results show that 48% (96 people) of the respondents consider it positive , 21% between indifferent and positive (41 people), another 21% are indifferent, 6% (12 people) are between negative and indifferent and the rest 5% (10 people) are negative (graph 1).



Graphic 1 Perspective of the use of solar energy in Oaxaca
Source: Own elaboration with response to question 2.5 of the surveys of the population and businesses

When asked to explain why they have given this weighting on the scale, they mention that in general their experience has been benefited by the use of energy, but that in the state the authorities are not interested in using this energy, some responded null because they did not they have been users of this technology so they feel unable to really rate it.

Of the main advantages that are observed with the use of solar energy according to the answers of the users are:

- in the social variable such as the improvement of the quality of life of the families and users who install it in their commercial premises, due to the significant economic savings, in addition to the fact that there is a feeling of well-being due to environmental awareness.

- the environmental variable such as not emitting greenhouse gases with the burning or use of any fuel.

- The economic variable due to the low return time of the investment.

One of the main disadvantages that people perceive is the high initial cost, that is, there is not adequate financing to acquire a system.

Conclusions

The main challenges facing the use of solar energy in Oaxaca are:

- The lack of initial resources to be able to acquire a system, either at the home or commercial level, or the lack of financing for municipalities that allows them to invest in solar technology appropriate to their contexts and energy needs.

- The little or limited information that is available on the use of solar energy, most users only believe that it refers to photovoltaic panels or solar heaters, when the full range of technologies that could be used has already been mentioned in this article. applying.

- The lack of regulations that promote the use of solar systems over other fuel systems that contribute to global warming.

It is then proposed that in order to meet objective 7 of the SDGs:

- Technologies that take advantage of solar energy should be promoted because their advantages are greater compared to their disadvantages, this implies regulations that benefit and encourage those users (homes, businesses, public services, industries, etc.) who decide to transition to this clean energy

- Municipal and state authorities must be trained to publicize the full range of possible projects with this type of energy and propose adequate systems for the energy needs within the localities.

- Financing networks are promoted by federal and state governments, in conjunction with international organizations and banking institutions or private companies, in order to guarantee the affordability of clean and non-polluting energy.

- Awareness campaigns on energy efficiency and solar energy aimed at the population and businesses in general are created. Workshops are given in the localities and those interested are trained so that learning is promoted and the use of technologies that take advantage of this energy source is encouraged.

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Abstract (In English, 150-200 words)

Objectives
Methodology
Contribution

Keywords (In English)

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Introduction

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General explanation of the subject and explain why it is important.

What is your added value with respect to other techniques?

Clearly focus each of its features

Clearly explain the problem to be solved and the central hypothesis.

Explanation of sections Article.

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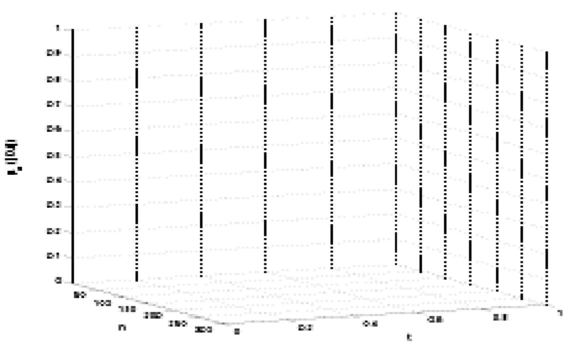

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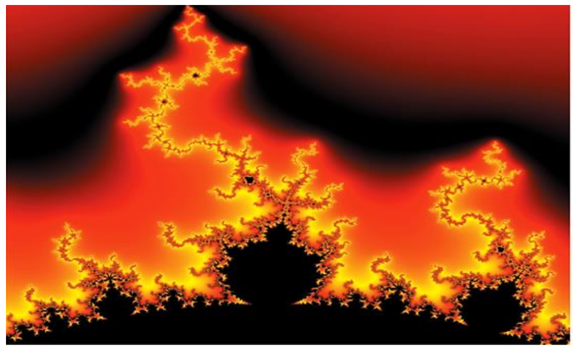

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