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Journal of Technological Operations

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Content of Presentation

In the first article we present *A review of some results of completely invariant components of meromorphic functions outside a small set*, by DOMÍNGUEZ-SOTO, Patricia & CANO-CORDERO, Laura Angelica, with adscription in the Benemérita Universidad Autónoma de Puebla, respectively, as second article we present *Characterization of the static contact angle of zinc oxide nanowires synthesized by hydrothermal method*, by CANO-LÓPEZ, Axel, MELO-MÁXIMO, Lizbeth, ESTRADA-MARTÍNEZ, Fortino Fabián and MELO-MÁXIMO, Dulce Viridiana, with secondment at Instituto Tecnológico de Tlalnepantla and Tecnológico de Estudios Superiores de Monterrey-Campus Estado de México, as third article we present *Interharmonic currents generated by soft starters in induction motors*, by GUDIÑO-OCHOA, Alberto, OCHOA-ORNELAS, Raquel and JALOMO-CUEVAS, Jaime, from the Instituto Tecnológico de Ciudad Guzmán, as fourth article we present *Monitoring system for photovoltaic cells*, by GALVAN-CALDERON, Carlos Daniel, CHÁVEZ-MARTÍNEZ, Marcos Javier, SANTIAGO-AMAYA, Jorge and LÓPEZ-GARCÍA, C., with assignment at the Tecnológico de Estudios Superiores de Chalco.

Content

Article **Journal of Technological Operations**
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A review of some results of completely invariant components of meromorphic functions outside a small set

Una revisión de algunos resultados sobre componentes completamente invariantes de funciones meromorfas afuera de un conjunto pequeño

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Abstract

We consider the class $\mathcal{K}$ of functions f that are meromorphic outside a compact countable set $B(f)$, which is the closure of isolated essential singularities of f. We give a review of some results of functions in class $\mathcal{K}$ related to completely invariant components of the Fatou set. We state some open problems and give some examples which support them.

Fatou and Julia sets, Meromorphic functions

Resumen

Consideramos funciones en la clase $\mathcal{K}$ que son meromorfas afuera de un conjunto compacto contable $B(f)$, el cual es la clausura de singularidades esenciales aisladas de f. Presentamos algunos resultados de funciones en la clase $\mathcal{K}$ relacionados con componentes completamente invariantes del conjunto de Fatou. Enunciamos algunos problemas abiertos y proporcionamos algunos ejemplos que los ilustran.

Fatou y conjuntos de Julia, Funciones meromórficas

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Introduction

Between 1990 and 1991 I.N Baker, J. Kotus, and Y. Lü produced four papers [2, 3, 4, 5] in which they investigated the dynamics of transcendental meromorphic functions.

A. Bolsch [9] and M. Herring [14] in their PhD thesis investigated the iteration of analytic functions outside some set $B(f)$ of essential singularities, the set $B(f)$ is in some sense small. Their study was a natural generalization of the Fatou-Julia theory.

In particular, Bolsch in [8, 9, 10], investigated the iteration of analytic functions outside a compact countable set which is the closure of isolated essential singularities. In this class infinity may not be an essential singularity. If the set $B(f)$ has at least one essential singularity, removing the case when we have always omitted poles, then the study of the dynamics of this kind of functions is different from either rational functions or transcendental entire functions. We can think this class as the smallest semi group with the composition operation, containing all transcendental meromorphic functions. We denote this class by $\mathcal{K}$ following the notation in [12].

In this article we study the functions in class $\mathcal{K}$ and give a short review, with some examples, related to completely invariant components for $f \in \mathcal{K}$. In Section 2 we define the class $\mathcal{K}$, the Fatou and Julia sets and some of its properties. Section 3 contains generalizations of some results of transcendental meromorphic functions to functions in class $\mathcal{K}$. Also, we state some open problems and Conjectures with examples which support them.

The class $\mathcal{K}$ and the Fatou and Julia sets

We consider the $\mathcal{K}$ class of functions investigated by Bolsch in [8, 9, 10], which is the set of functions f from $\hat{\mathbb{C}}\backslash B(f)$ onto $\hat{\mathbb{C}}$ such that f is not constant and meromorphic in $\hat{\mathbb{C}}\backslash B(f)$, where the set $B(f)$ is a compact countable set and it is the closure of the set of isolated essential singularities of f.

We assume that $B(f)$ has at least one element e such that $f^{-1}(e) = p$, where p is called a *preimage under* f. Some examples of functions in class $\mathcal{K}$ are the following.

(i) $\lambda e^{R(z)} + \mu(z)$, where $R(z)$ and $\mu(z)$ are either rational functions or transcendental meromorphic functions.

(ii) $f_{\lambda,\mu}(z) = \tan(\lambda \tan(\mu z))$, for $\lambda, \mu \in \mathbb{C}$.

(iii) Composition of functions in (i) or (ii).

Bolsch in [9] proved the following result.

Proposition 2.1 *If f, g are in class $\mathcal{K}$, then the composition $f \circ g$ is in class $\mathcal{K}$, where*

$$B(f \circ g) = B(g) \cup g^{-1}\big(B(f)\big)$$

For $n \in \mathbb{N}$, we denote

$$f^{-n}(B(f)) = \{z: f^n(z) = e \in B(f)\}$$

The following theorem follows from [8] and [14].

Theorem 2.2 *If $f \in \mathcal{K}$, then $f^n \in \mathcal{K}$ and for each $n \geq 1$ the natural boundary of f^n is the set*

$$B_n = B(f^n) = \bigcup_{j=0}^{n-1} f^{-j}(B(f)),$$

so that f^n is meromorphic function in the region

$$D_n = \hat{\mathbb{C}}\backslash B_n.$$

Further, the sets B_n are all compact and countable. Moreover, f^n cannot be continued meromorphically over any point of B_n.

The *singular values* of the inverse function f^{-1}, $f \in \mathcal{K}$, consist of algebraic branch points or critical values together with the asymptotic values along paths which tend to $e \in B_n$, $n \in \mathbb{N}$. We denote

$$SV_n(f) = \{\text{singularities of } f^{-n}, \quad n \in \mathbb{N}\},$$

where $SV_1(f) = \{\text{singularities of } f^{-1}\}$. By Theorem 7.12 in [14] we have:

$$f^{n-1}(SV_1(f)\backslash B_{n-1}) \subset SV_n(f) \quad \subset \bigcup_{j=0}^{n-1} f^{-j}(SV_1(f)\backslash B_j),$$

with $B_j = \{z: f^j$ is not meromorphic at $z\}$ and $B_0 = \emptyset$.

The set

$SV = \{w\,\hat{\mathbb{C}}: f^{-n}$ has a singularity at w,for $n \in \mathbb{N}\}$ is given by

$SV = \bigcup_{j=0}^{\infty} f^{-j}(SV_1(f)\backslash B_j)$.

Observation. $\overline{SV} = J(f)$.

Definition 2.3 *Let* $f \in \mathcal{K}$.

(i) When $p \in f^{-n}(\infty)$, for some $n \geq 2$, p is called a *n- pre-pole of* f. For $n = 1$, p is called a *pole.*

(ii) When $e \in B(f)$ and $p \in f^{-n}(e)$, for some $n \geq 1$, p is called a *n-preimage under* f (or pre-singularity of f).

Following the notation in [12], we denote the set of all pre-singularities and essential singularities by

$$B^{-}(f) = \bigcup_{j=0}^{\infty} f^{-j}\big(B(f)\big).$$

For functions in class $\mathcal{K}$ we shall give the following definitions:

(i) w is an *omitted value* of $f \in \mathcal{K}$ if for every $z \in \hat{\mathbb{C}}\backslash B(f)$ the equation $f(z) - w = 0$ has no solutions.

(ii) w is a *Picard exceptional* value of $f \in \mathcal{K}$ if the equation $f(z) - w = 0$ has only finitely many solutions.

(iii) $E(f)$ is the set of *Fatou exceptional values* of f, that is, points whose inverse orbit $O^{-}(z)$ is finite, where $O^{-}(z) = \{w: f^n(w) = z$ for some $n \in N\}$.

Observations. (i) If w is an omitted value of $f \in \mathcal{K}$, then w is a Picard exceptional value of $f \in \mathcal{K}$.

(ii) When $B(f) = \{\infty\}$ is the only essential singularity and there exists a non-omitted pole, we are dealing with transcendental meromorphic functions.

If $f \in \mathcal{K}$ and $n \in \mathbb{N}$ is the minimum such that z satisfies $f^n(z) = z$, the point z is called a *periodic fixed point of period* n. When $n = 1$ the point z is called a fixed point.

If z is a fixed point of period n, the set $\{z_1 = z, z_i = f(z_{i-1}), z_{n+1} = z_1; 2 \leq i \leq n, n \in \mathbb{N}\}$ is called the cycle at z.

If z is a fixed point of period n, the *eigenvalue or multiplier* of the cycle at z is defined and denoted by

$$\lambda(z) = \prod_{j=1}^{n} f'(z_i).$$

When any value z_i is the point at infinity $f'(z_i)$ is replace by the derivative of $1/f(1/z)$ at the origin.

The classification of a periodic point z_0 of period n of $f \in \mathcal{K}$ is given as follows:

(a) if $|\lambda(z_0)| = 0$, z_0 is called *super-attracting*;

(b) if $0 < |\lambda(z_0)| < 1$, z_0 is called *attracting*;

(c) if $|\lambda(z_0)| > 1$, z_0 is called *repelling*;

(d) if $|\lambda(z_0)| = 1$ and $(f^n)'(z_0)$ is a root of unit, z_0 is called *rationally indifferent*, in this case z_0 is also known as a *parabolic periodic point*;

(e) if $|\lambda(z_0)| = 1$ and $\lambda(z_0)$ is not a root of unit, z_0 is called *irrationally indifferent*.

The definitions of the Fatou and Julia sets are as follows.

The *Fatou set*, denoted by $F(f)$, is the maximal open set U, such that all f^n are analytic and forms a normal family in U in the sense of Montel.

The *Julia set*, denoted by $J(f)$, is the complement of the Fatou set, that is,

$$J(f) = \hat{\mathbb{C}}\backslash F(f).$$

Some basic properties of the Fatou and Julia set sare the folowing; see [9] for a proof.

(a) The Fatou set is open, so the Julia set is closed.

(b) The Julia set $J(f)$ is perfect.

(c) The set $F(f)$ is completely invariant, this means, it is forward invariant $f(F(f)) \subseteq F(f)$ and backward invariant $f^{-1}(F(f)) \subseteq F(f)$.

The set $J(f)$ is also completely invariant in the sense that $f(J(f) \backslash B(f)) \subseteq J(f)$ and $f^{-1}(J(f)) \subseteq J(f)$.

(d) For a positive integer p, $F(f^p) = F(f)$ and $J(f^p) = J(f)$.

(e) The Julia set $J(f)$ is the closure of the set of repelling periodic points of all periods of f.

(f) If U is an open set and $U \cap J(f) \neq \emptyset$, Then $\bigcap_n f^n(U)$ contains $\hat{\mathbb{C}}$ except for the omitted values.

For a function $f \in \mathcal{K}$ a Fatou component U can be either:

(a) *periodic* if $f^n(U) \subset U$, for some $n \geq 1$;

(b) *pre-periodic* if $f^m(U)$ is periodic for some integer $m \geq 0$ or

(c) *wandering* if U is neither periodic nor pre-periodic.

Consider $U_1 \subseteq F(f)$ a periodic component, we say that $\{U_i\}$, $1 \leq i \leq p$, is a *periodic cycle of period p* if $f(U_i) \subseteq U_{i+1}$, for all $1 \leq i \leq p-1$, and $f(U_p) \subseteq U_1$.

If U is a periodic component of the Fatou set of period n its classification is given similar to that for transcendental meromorphic functions, that is, U is either *an attracting component, a parabolic component, a Siegel disk, a Herman ring or a Baker domain*.

Invariant components of the Fatou set for $f \in \mathcal{K}$

In this section we will take $f \in \mathcal{K}$ and assume that $B(f)$ has at least one element with non empty pre-image, observe that with this assumption we are ruling out transcendental entire functions, since they cannot have poles and analytic functions in $\hat{\mathbb{C}} \backslash \{0, \infty\}$, while transcendental meromorphic functions are allowed. The following result is a corollary of Theorem 9.1.1 in [14] which applies to functions in class $\mathcal{K}$.

Theorem 3.1 *Let $f \in \mathcal{K}$. If U is a component of $F(f)$such that $B(f) \cap \partial U = \emptyset$, then $f: U \to f(U)$ is a finite branched cover.*

In holomorphic dynamics interesting problems are related to the connectivity of the Fatou components. We recall that a component U in the Fatou set is completely invariant if $f(U) \subset U$ and $f^{-1}(U) \subset U$. Concerning completely invariant components in the Fatou set Lemmas 4.1, 4.2 and 4.3 for transcendental meromorphic functions in [4] were generalized to a class of functions which contains the class $\mathcal{K}$ in [7] and [14]. The results for functions in class $\mathcal{K}$ are stated as follows.

Lemma 3.2 *Let $f \in \mathcal{K}$ and U be a completely invariant component of the Fatou set. Then $\partial U = J(f)$.*

Lemma 3.3 *Let $f \in \mathcal{K}$. If there are two or more completely invariant components in the Fatou set, then each one is simply connected.*

For a periodic component in the Fatou set, Bolsch in [9] improves Lemma 4.1 in [4] for invariant components.

Theorem 3.4 *If $f \in \mathcal{K}$ and U is a periodic component of the Fatou set, then U has connectivity 1, 2 or ∞.*

Lemmas 4.4 and 4.5 in [4] were generalized in [7] and [14] to a class of functions that contains the class $\mathcal{K}$, where the set of singular values SV is finite. We state the results for $f \in \mathcal{K}$.

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Theorem 3.5 *Suppose that $f \in \mathcal{K}$, the set $SV_1(f)$ is finite and the Fatou set has a simply connected completely invariant component U. If $e \in B(f)$, then e is accessible in U.*

Theorem 3.6 *If $f \in \mathcal{K}$ and the set $SV_1(f)$ is finite, then the Fatou set has at most two completely invariant component.*

Examples of functions in class $\mathcal{K}$ that satisfies Theorems 3.5 and 3.6 are the following:

(i) $f_\lambda(z) = \lambda \tan z$, for some $\lambda \in \mathbb{C}$, see [15] for details.

(ii) $f_{\lambda,\mu}(z) = \tan(\lambda \tan(\mu z))$, with some conditions in $\lambda, \mu \in \mathbb{C}$.

For function sin class $\mathcal{K}$, where the set $SV_1(f)$ is not finite, we can state the well known open problem for transcendental meromorphic functions to functions in class $\mathcal{K}$.

Problem 1. *Is it true that for $f \in \mathcal{K}$, the Fatou set has at most two completely invariant components?*

We do not know examples of function f in class $\mathcal{K}$ with $SV_1(f)$ not finite that satisfies Problem 1, so we state the following problem.

Problem 2. Is there $f \in \mathcal{K}$, where the set SV_1 is not finite, such that the Fatou set has two completely invariant components in the Fatou set?.

One can ask: Is there $f \in \mathcal{K}$ with at most one completely invariant component? For transcendental meromorphic functions with finite many poles it was proved by Domínguez in [11], but the proof is very close to that in [1], for transcendental entire functions, which unfortunately has a missing case. Thus the proof of Theorem F in [11] is not correct . Therefore, we state the following conjecture.

Conjecture 1. *If f is a transcendental meromorphic function with at most finitely many poles, then there is at most one completely invariant component.*

There are examples which support Conjecture 1.

Example 1. A transcendental meromorphic function which satisfies hypothesis of Conjecture 1 is $f_\lambda(z) = \lambda \sin z + \frac{\epsilon}{z-\pi}$, where $0 < \lambda < 1$ and $\epsilon > 0$ is sufficiently small. Observe that f_λ has just one non-omitted pole π and the set $SV_1(f_\lambda)$ is countable infinite. The Fatou set of f_λ is a completely invariant component which is unbounded and multiply connected; see [11] for details.

Could Conjecture 1 be generalized to functions in class $\mathcal{K}$ with at least two essential singularities? We claim that we can substitute the poles for pre-images. Thus we state the following conjecture.

Conjecture 2. *If $f \in K$ with at most finitely many pre-images, i.e., $f^{-1}(e_i)$ is non empty with $e_i \in B(f)$, then there is at most one completely invariant component.*

The claim above is given by the following example.

Example 2. Take the composition

$h(f) = f_\lambda(f_\lambda(z))$ with $f_\lambda(z) = \lambda \sin z + \frac{\epsilon}{z-\pi}$, we obtain:

$$h_\lambda(z) = \lambda \sin(\lambda \sin z + \frac{\epsilon}{z-\pi}) + \frac{\epsilon}{(\lambda \sin z + \frac{\epsilon}{z-\pi}) - \pi},$$

where the pole π has become an essential singularity with non-empty preimages and $\epsilon > 0$ sufficiently small. It is not difficult to verify that for $0 < \lambda < 1$ the dynamics of f_λ and h_λ are similar. Thus, h_λ has a completely invariant component in the Fatou set.

Continuing with general results of completely invariant components in the Fatou set for $f \in \mathcal{K}$ the following theorem was proved in [6] for another classes of functions, but the proof applies to functions in class $\mathcal{K}$.

Theorem 3.7 *Let $f \in \mathcal{K}$ and suppose that that there is an attracting fixed point whose Fatou component U contains all the singular values of f. Then $J(F)$ is totally disconnected*

Examples of functions which satisfies hypothesis of Theorem 3.7 are the following:

(i) $f_\lambda(z) = \lambda \tan z$, for some $\lambda \in \mathbb{C}$, see [15] for details.

(ii) $f_{\lambda,\mu}(z) = \lambda e^{\frac{1}{z^2+1}} + \mu$, for some $\lambda, \mu \in \mathbb{C}$, see [13] for details.

Observe that in Theorem 3.7 the Fatou set is just one completely invariant component which is multiply connected.

Another conjeture related to completely invariant components for functions in class $\mathcal{K}$ is the following.

Conjecture 3. *If $f \in \mathcal{K}$, the set $SV_1(f)$ is finite and the Fatou set is a completely invariant component, then every repelling periodic point is an accessible boundary point in the Fatou set.*

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Characterization of the static contact angle of zinc oxide nanowires synthesized by hydrothermal method

Caracterización del ángulo de contacto estático de nanocables de óxido de zinc sintetizados por método hidrotermal

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Abstract

The ability of a liquid to maintain contact with a solid is known as wetting, this is determined by the existence of a balance between the cohesive and adhesive forces. To study this property in materials it is required that the three phases of matter exist: liquid, solid and gas. The present work focuses its study on the characterization of the static contact angle that relates the cohesive and adhesive forces in the liquid-gas-solid system. Hexagonal zinc oxide nanowires were synthesized by the hydrothermal method on conductive glass substrates to which a zinc oxide seed was previously deposited by spin-coating and dip-coating. The results obtained show the change in the contact angles according to the growth of the nanostructures on the surface.

Static contact angle, Nanowires, Hydrothermal

Resumen

La capacidad de un líquido para mantener contacto con un sólido se conoce como humectación, está determinado por un equilibrio entre las fuerzas cohesivas y adhesivas. Para estudiar esta propiedad en los materiales se requiere que existan las tres fases de la materia: líquido, sólido y gas. El presente trabajo centra su estudio en la caracterización del ángulo de contacto estático, que relaciona las fuerzas cohesivas y adhesivas en el sistema líquido-gas-sólido. Se sintetizaron por el método hidrotermal nanocables hexagonales de óxido de zinc sobre sustratos de vidrio conductor a los que se les depositó previamente una semilla de óxido de zinc por spin-coating y dip-coating. Los resultados obtenidos muestran el cambio en los ángulos de contacto según el crecimiento de las nanoestructuras sobre la superficie.

Ángulo de contacto estático, Nanocables, Hidrotermal

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Introduction

Within nanotechnology, the shape, size and functionalisation of materials are topics of interest, as they have a significant impact on the properties of materials [1].

Zinc oxide is one of the materials with great potential for its applications in the development of permeable materials, transistors, sensors and UV laser diodes, thanks to its conductive, hydrophobic and hydrophilic properties [2].

Contact angle

The contact angle is used to quantify the wettability of solid surfaces. In an interacting system of a vapour, a solid and a liquid at a given pressure and temperature the angle should be in equilibrium reflecting the relative strength of the vapour, liquid and solid interactions [2].

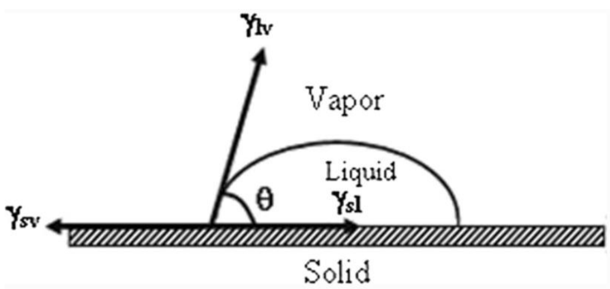

Figure 1 Schematic of contact angle and surface stresses

γLv	Vapour-liquid surface tension
γSv	Solid vapour surface tension
γSl	Solid-liquid surface tension

Table 1 shows the schematic of the relationship between surface stresses and contact angle (θ)

In the 20th century, Gibbs demonstrated the volumetric dependence of the contact angle by modifying the study carried out by Thomas Young in 1805, where he demonstrated the relationship between the contact angle and the surface tensions exerted on sessile droplets [3].
The relationship of surface tensions on flat surfaces proposes that there is a linear tension that limits the solid-liquid-gas phases and is explained by the following equation:

$$\cos(\theta) = \frac{\gamma_{sv} - \gamma_{sl}}{\gamma_{lv}} + \frac{k}{\gamma_{lv}}\frac{1}{a}$$

The above equation relates the linear stress (k) and the droplet radius (a) to the cosine contact angle taking into account the phase interface [3].

When the liquid droplet remains motionless on the solid surface the contact angle measured is the static (or sessile) angle, this is not the only stable type as there is a range of contact angles given by factors such as topography, chemical homogeneity and above all roughness [4].

The main contact angles are forward (measures liquid-solid cohesion) and backward (measures liquid-solid adhesion) since the difference between them generates the static angle which is defined by the angle hysteresis [4].

Contact angle hysteresis

Static contact angle measurements produce values depending on other parameters such as the way in which the liquid is deposited (velocity, angle, quantity) so hysteresis is used which encompasses the relationship between the dynamic angles (advance and retreat), it is analogous to the static friction term requiring a minimum amount of work to modify the contact line [5].

$$\theta = \theta_A - \theta_R$$

$\boldsymbol{\theta}$	Static angle
$\boldsymbol{\theta_A}$	Angle of advance
$\boldsymbol{\theta_R}$	Backward angle

Table 2

Relationship of roughness to the contact angle

Roughness plays a major role in the performance of the contact angle and wettability of the surfaces, since the more voids there are on the surface of the material, the more air pockets there are between it and the surface of the droplet. In relation to roughness, two phenomena are described: the first is the Wenzel effect, where the droplet homogeneously wets the grooves of the rough surface and the second known as Cassie-Baxter, where the droplet heterogeneously wets the surface of the material and stays above the grooves that encapsulate air [6] [7].

Methodology to be developed

By means of a chemical synthesis with zinc acetate and sodium chloride diluted in methanol, this mixture was kept under stirring for two hours at a temperature of approximately 60°C. Zinc oxide nanostructures were obtained and used as seeds on conductive glass substrates.

Seed deposition was carried out by spin-coating at a speed of 3,000 rpm for 40 seconds (3 samples) and by dip-coating by performing 20 dips at intervals of 5 seconds each (3 samples). Once the doped substrates were dried at room temperature, they were immersed in a solution of hexamethylenetetramine and zinc nitrate and baked for 2, 4 and 6 hours at a temperature of 90°C. At the end of this time, they were carefully washed with distilled water and left to dry at room temperature. Each sample was characterised for contact angle (seed and nanowires) and observed by scanning electron microscopy.

Results

The contact angles were measured by placing a drop of water on the surfaces. The first angle measured was that of the conductive glass without any modification, as can be seen in figure 2 without any modification the glass presents an angle of 63.064°.

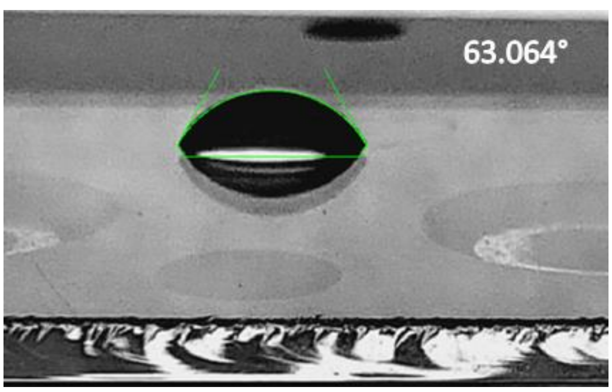

Figure 2 Contact angle of the conductive glass without modification

Since the parameters of the samples are the same before the synthesis of the nanowires, the contact angle was measured for Dip-coating and Spin-coating; as shown in figure 3, the seed deposition generates a change on the surface.

The contact angle decreased to 19.693° when the seed was deposited by the Dip-coating method, the same happened for the Spin-coating method, however, the decrease of the angle was not so drastic.

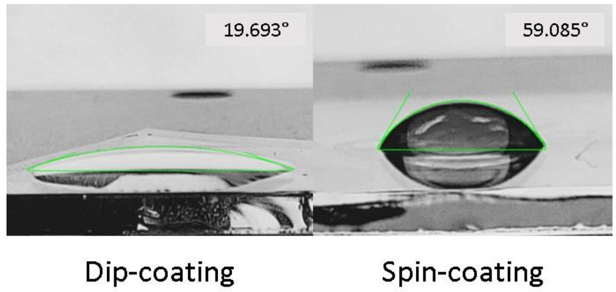

Figure 3 Contact angles of the seeds

EDS analysis was performed to validate the presence of zinc oxide on the surfaces, as shown in figure 4 by the characteristic peaks exist on the surface of the sample zinc and oxygen.

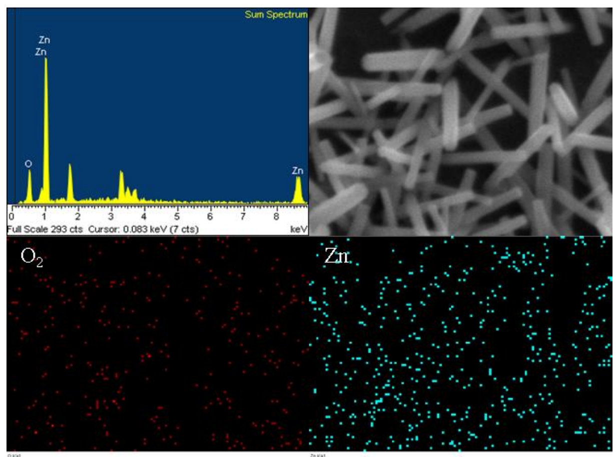

Figure 4 EDS of the surface of the zinc oxide nanowires

The characterisation of the contact angle of the dip-coated samples with the zinc oxide nanowires showed an unusual behaviour. As shown in figure 5, the first two hours increased the angle to 58.048°, but after two more hours the angle returned to a low angle, even smaller than with the seed. At the end of the experiment and after 6 hours of the hydrothermal method, the surface angle measured 46.490°, below the main angle (glass without modification) but exceeding the previous measurement.

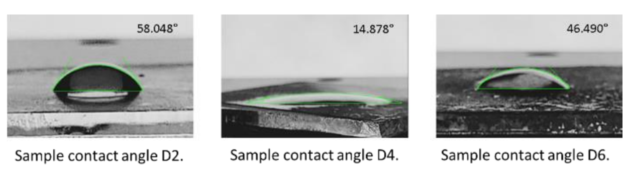

Figure 5 Contact angles of the dip-coated samples

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To observe the possible causes of the effect presented in the samples, they were characterised by scanning electron microscopy. In figure 6a, belonging to the two-hour sample, the presence of small structures forming "bushes" can be observed, these are attributed to the increase in the contact angle due to the air that could have been trapped between them; in figure 6b, the structures are observed 4 hours after the hydrothermal method, it is possible to identify more clearly the hexagonal and long structures that come from the seed deposited on the surface. These structures are characteristic of the most stable structure of zinc oxide: wurtzite, the arrangement of the nanowires in this image exhibits gaps between them, therefore, water can penetrate between the structures thus decreasing the contact angle. The structures in figure 6c are long and thin, with an interlocking arrangement where air can be encapsulated.

Figure 6 Scanning electron microscopy of the dip-coated samples

In the case of the spin-coating samples, the contact angle decreased a little, but remained in the same range after two hours of hydrothermal method, after 4 hours it increased reaching almost the main angle of the glass without modifications, however, after 6 hours the angle decreased again to 44.503°.

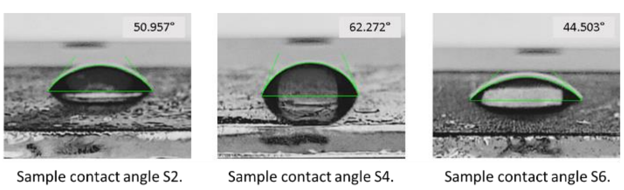

Figure 7 Contact angles of the spin-coated samples

As with the dip-coated sample, the three substrates were characterised by scanning electron microscopy. Figure 8a shows small accumulations of material on the surface which could be the bases of the nanowires; in figure 8b, hexagonal structures are observed growing vertically and forming a type of "grass", the growth of the structures after 6 hours can be seen in figure 8c, a "bush" of vertical nanowires is formed.

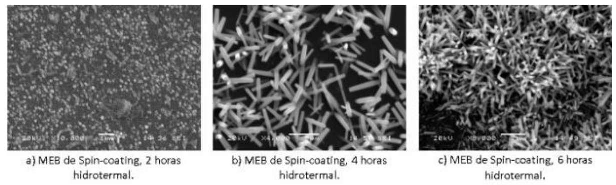

Figure 8 Scanning electron microscopy of the spin-coating samples

The decrease of the contact angle between the 4 and 6 hours samples could be due to the fact that, although these "bushes" are not sequential over the whole surface, they are located as if they were colonies, so the droplet could fall outside these structures decreasing the contact angle.

Acknowledgements

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Conclusions

The results obtained in the 6 samples show the growth of zinc oxide nanowires in relation to the time exposed to hydrothermal synthesis.

The samples with the seed deposited by dip-coating showed an accelerated growth since from the first two hours small linear structures were visible on the surface, which with the passage of time grew and intertwined.

The seed deposited by spin-coating maintained a progressive growth, after two hours the surface shows protrusions without any linear structure. After 4 hours of synthesis, hexagonal structures are observable, which adopt a bush-like shape after 6 hours.

The contact angles show varying values depending on the structures grown on the surface. Taking into account the description of hydrophobicity and hydrophilicity by the angles obtained on the surfaces not exceeding 90°, it is concluded that all the samples are hydrophilic.

Although the dynamic measurement of the droplets was not carried out, the static contact angle measurements show the behaviour between the growth of the zinc oxide nanowires and their contact angle.

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Interharmonic currents generated by soft starters in induction motors

Corrientes interarmónicas generadas por arrancadores suaves en motores de inducción

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Abstract

The presence of non-linear loads, as well as the use of induction motors cause the generation of harmonic pollution, which includes frequency components that are not multiples of the fundamental frequency referred to as interharmonics and subharmonics, causing disturbances in the network, being parameters of importance for the evaluation of power quality. Soft starters have shown electrical energy savings for induction motors; however, the present investigation shows a higher generation of interharmonics during starting. The method used for the time-frequency analysis is through the Wavelet Synchrosqueezing Transform, the measurements were made with non-invasive current sensors SCT-013. The results show that the current amplitudes during starting to depend on the load moment of inertia and the phase control according to the type of soft starter, being one of the main causes of interharmonic generation.

Interharmonics, Power quality, Induction motors

Resumen

La presencia de cargas no lineales, así como el uso de motores de inducción ocasionan la generación de contaminación armónica, donde se incluyen componentes de la frecuencia que no son múltiplos de la frecuencia fundamental referidos como interarmónicos y subarmónicos causando perturbaciones en la red, siendo parámetros de importancia para la evaluación de la calidad de energía. Los arrancadores suaves han demostrado un ahorro de energía eléctrica para motores de inducción, sin embargo, la presente investigación demuestra una mayor generación de interarmónicos durante el arranque. El método utilizado para el análisis tiempo-frecuencia es mediante la transformada Wavelet Synchrosqueezing, las mediciones se realizaron con sensores no invasivos de corriente SCT-013. Los resultados demuestran que las amplitudes de corrientes durante el arranque dependen del momento de inercia de carga y el control de fases según el tipo de arrancador suave, siendo una de las principales causas de generación de interarmónicos.

Interarmónicos, Calidad de energía, Motores de inducción

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Introduction

In the industrial sector, induction motors are considered a fundamental part for carrying out various processes (Liang & Ilochonwu, 2010). The use of electrical machines is very important, given that their respective performance is determined from their construction and those components that make it up, however, different conditions of this equipment could reduce the quality of energy, resulting in equipment failures and vibrations (Delgado-Arredondo et al., 2019).

It has been found that they cause certain harmful effects of disturbances such as interharmonics and subharmonics, components that are not integer multiples of the fundamental frequency, due to the speed fluctuations that they can present, torque pulsations, and additionally, network disturbances and premature damage to the equipment (Gnaciński et al., 2021).

These disturbances, in addition to causing the flicker effect (Testa et al., 2007), in induction motors tend to cause local saturation in the magnetic circuit, torque reduction, overheating and temperature in the windings (Gnaciński & Pepliński, 2014). The incorporation of renewable energy sources that include double conversion systems, including a DC link can generate harmonic disturbances, these can also occur at the inverter voltage output (De Rosa et al., 2005).

The main source of generation of interharmonics ranges from non-linear loads and such as frequency inverters, which have been used to control the speed of asynchronous machines, however, they generate a harmful effect on the network in addition to acoustic noise in the equipment (Gnaciński et al., 2019). Going deeper, this is mainly due to having a conversion stage based on a DC link, based on a conversion stage based on IGBT devices (Shen et al., 2016). Various investigations have shown that symmetrical subharmonic and interharmonic components, having the same magnitude, cause effects in voltage fluctuations, being some phase angles in the torque pulsations triggering certain undesirable vibrations which can cause damage to the machine and corresponding torque pulsations to the natural frequency of the first elastic mode (Gnaciński et al., 2022).

Soft starters

Soft starters are very common devices in the industrial sector and control the voltage applied to the motor using thyristor semiconductors (Riyaz et al., 2009), or better known as SCRs. The starting pair carries current in only one direction; therefore, an antiparallel arrangement is required for each phase. By reducing the voltage applied to the motor, its torque is reduced, mechanical wear and savings in electrical energy are achieved, one of its main advantages being less motor wear (Ferreira & Almeida, 2017). One drawback, however, is its reduced starting torque. Figure 1 shows the common architecture of these devices.

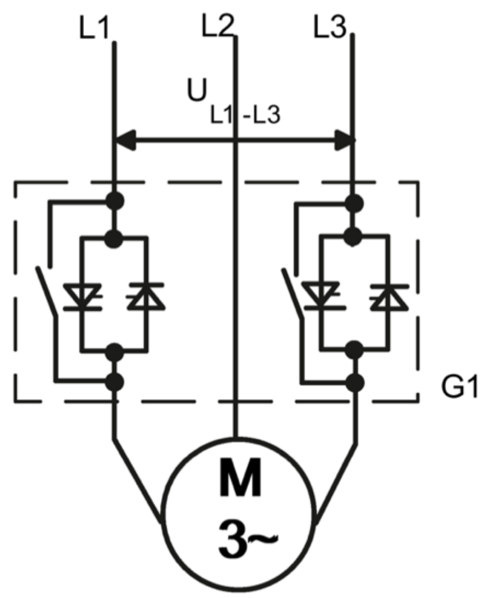

Figure 1 Soft starter with 2-phase control

The control by phase cutting is shown in Figure 2, it is observed that the control exerted by the electronic soft starter on the motor voltage also regulates the starting current consumed and the starting torque generated in the motor during the process. Therefore, unlike the frequency-controlled start and stop of a frequency converter, the frequency remains constant during this process and corresponds to the mains frequency.

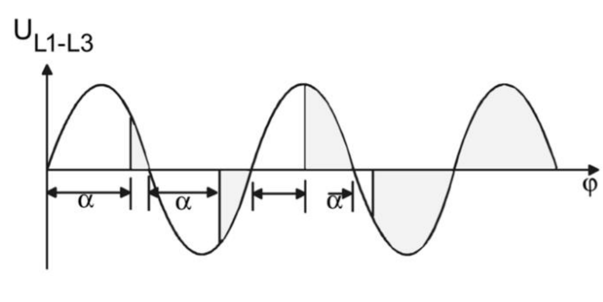

Figure 2 Phase clipping control

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It has been found that soft starters produce a wide range of frequency components, which could cause overvoltages, being the starting process one of the main conditions, depending on the number or configuration of the thyristors, there are leakage currents to earth. when controlling only two phases and a direct line to the motor (Meshcheryakov et al., 2017).

Load and moment of inertia of a motor

When starting and stopping a motor, the relationship that includes the inertia and load inertia of an induction motor affects the performance of the system (Andoh, 2007). The moment of inertia refers to the rotational inertia of a body, it is used to determine the motor torque necessary to achieve a desired speed within a given time.

During the starting of squirrel cage induction motors, the motor torque must exceed the mechanical load torque, the rotor inertia torque, mechanical load, and friction (Verucchi et al., 2005). The equation that describes these behaviors is the following:

$$\mathrm{T} = \mathrm{T}_L + \frac{d}{dt}([j + j_L] \cdot \omega) + B \cdot \omega \qquad (1)$$

Where T is the motor torque, $\mathrm{T}_L$the resistant torque of the mechanical load, j is the moment of inertia of the induction machine, j_L is the moment of inertia of the mechanical load, B the coefficient of friction and ω the angular velocity of the axis.

It has been shown that when there is also a mechanical load in induction motors, current interharmonics are generated in synchronous and asynchronous motors, which induces oscillations in the load torque (Li & Wang, 2014).

In other studies, the effect of the moment of inertia and certain speed-load characteristics were corroborated as the main cause of interharmonics, likewise depending on the type of load in the torque, therefore, fluctuations in the rotational speed are also generated, which could be suppressed for a large value of moment of inertia (Gnaciński et al., 2019).

Asynchronous inertia in motors has also revealed certain effects on the system response, being the sensitivity of the electromagnetic torque to slip, the sensitivity of the mechanical load torque to motor speed and their respective inertia (Chen et al., 2020).

Therefore, it is important to determine the main causes of interharmonic generation, even in devices commonly used for starting electrical machines, and to propose solutions to mitigate harmful effects that impair the evaluation of power quality, as well as affect the efficiency to electrical machines connected to the network.

Signal processing: wavelet synchrosqueezing

The Wavelet Synchrosqueezing Transform (SSWT) is a method for the analysis of signals in the time-frequency domain, it is based on the CWT, which has been useful for the analysis of signals with multicomponents or with non-stationary characteristics (Franco et al., 2012). It has shown to be useful for the detection of power quality disturbances, especially for each frequency component, which, compared to other methods (Chang et al., 2021), has anti-noise characteristics and better resolution, without presenting spectral leaks. The following equation expresses the sum of the added components:

$$s(t) = \sum^{k}{}_{k=1} \; A_k(t) cos\left(2\pi\phi_k(t)\right) \qquad (2)$$

Where $A_k(t)$corresponds to the amplitude of the signal, ϕ_k is the phase, the SSWT is based on the continuous Wavelet transform, it is defined as the following expression established by Daubechies et al. (2011):

$$s(b) = \Re e\left[C_{\psi}^{-1} \sum_k W_s(a_k, b) a_k^{-\frac{3}{2}} (\Delta a)_k\right] \qquad (3)$$

Methodology

For this study, two triphasic motors of the ABB and Siemens brands were considered respectively, the first corresponds to an induction motor ABB MBT ARM 71 A(48).

No. M97F-25924 coupled to a DC generator and tachometer, the second, a decoupled induction motor GP10-1LE22011AB214AA3 without torque load. The characteristics of these machines are presented in Table 1.

Motor	Rated Power	Poles	Rated Speed	Rated Voltage	Rated Current
ABB	0.75 kW	4	1610 RPM	220 Δ	1.0 A
GP10	0.746 kW	4	1750 RPM	220 Δ	3.2-3.0 A

Table 1 Parameters of the motors

The hypothesis proposed is that the relative moment of inertia of the load affects low power motors, the lower the inertia of the machine and a load at its torque is considered constant, the higher the production of components that are not multiples of the fundamental frequency, they will be reflected in the current of the motor and in the network. This analysis has not been addressed in previous research or studies, only those that determine that speed fluctuations have a direct relationship with interharmonics (Zhang et al., 2005).

The soft starter used to start each motor is from SIEMENS, model SIRIUS 3RW30. The connection is shown in Figure 3.

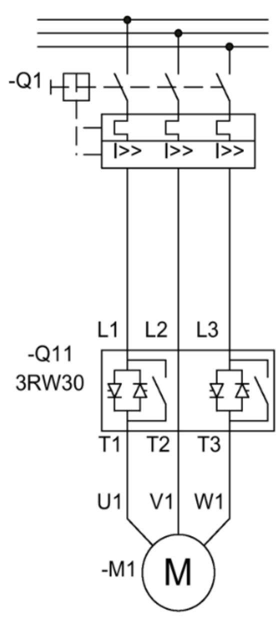

Figure 3 Siemens SIRIUS 3RW30 soft starter schematic

For the respective measurements and data acquisition, SCT-013 non-invasive current sensors were used to obtain the phase currents of the motors, previously calibrated. Data acquisition was by means of a National Instruments DAQ MyRio for data capture, the established sampling time was 500 Hz, this to avoid aliasing problems (Costa & Boudreaux-Bartels, 1999). Subsequently, the data obtained were imported into the Matlab workspace and subsequently the signal processing was applied with the SSWT. Figure 4 shows the established methodology.

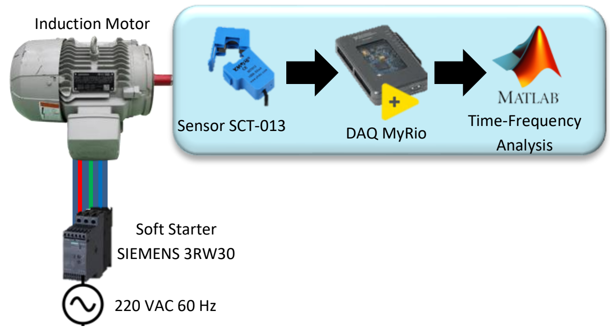

Figure 4 Signal measurement flowchart

The moment of inertia (j) of the motor coupled to the DC generator is 0.01, while the uncoupled motor is 0.1535. For the start of the coupled motor, a starting voltage of the motor was established at 40% to produce a lower start, with a ramp time of 10 seconds, since this influences the motor to reach its nominal speed in that time, if it is a very short time, high currents may appear, and the soft starter may be damaged. The waveform generated during startup for the coupled motor is shown in Figure 5, which presents non-stationary characteristics.

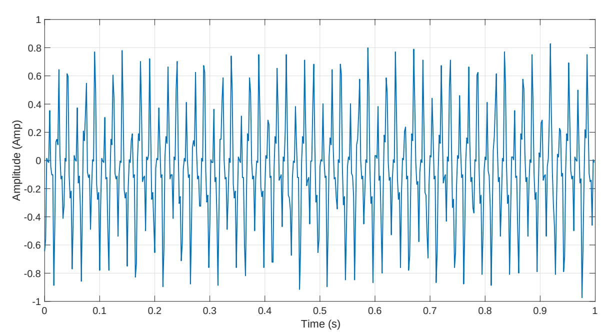

Figure 5 Coupled motor current waveform

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To have an analysis prior to processing with the SSWT, the FFT was applied to detect the most significant frequencies. Figure 6 shows notorious interharmonic content after the even harmonics of 101, 141, 157, 222 and 262 Hz, as well as the presence of 20 Hz subharmonics.

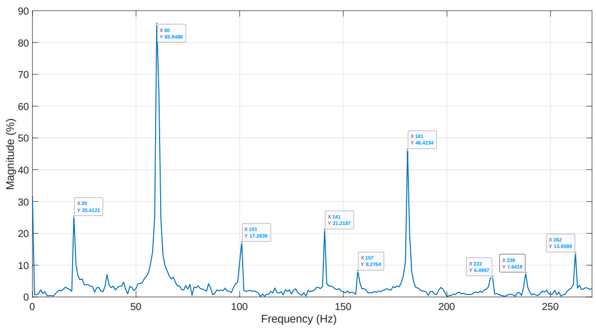

Figure 6 Spectrum with FFT of coupled motor signal

For the SIEMENS motor with no load in its torque, it presented the same non-stationary characteristics only in the first sample just after the start-up, the harmonic and interharmonic content being significant, since the speed was constant, the disturbances were reduced compared to the motor coupled to the torque. DC generator containing up to the fifth sample interharmonic content. Figure 7 corresponds to the signal generated when starting the motor.

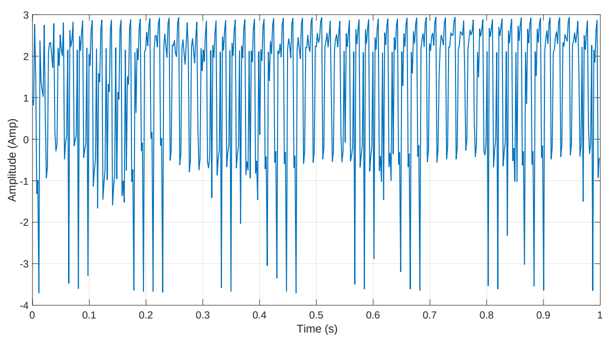

Figure 7 Decoupled motor current waveform

Figure 8 shows interharmonics that exist very close before and after the odd and even harmonics.

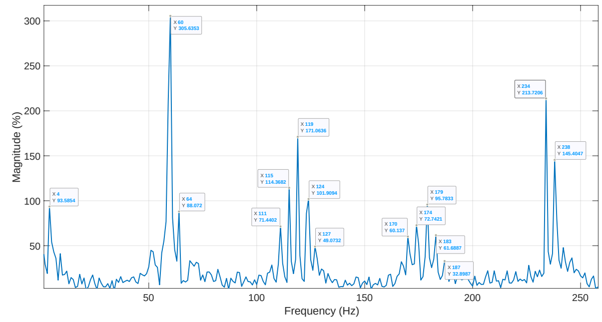

Figure 8 Spectrum with FFT of decoupled motor signal

Results

Once the measurements were obtained, the SSWT function was executed in Matlab, establishing 'bump' as the mother wavelet defined for the spectral analysis, with the sampling frequency defined according to the number of samples, in this case 500 Hz.

In the spectrogram of Figure 9, the presence of significant interharmonics is observed only in the first sample when the motor starts uncoupled, given that when it reaches its maximum speed there are no fluctuations in the nominal speed of the machine, therefore, there is no interharmonic contamination when the nominal speed is reached.

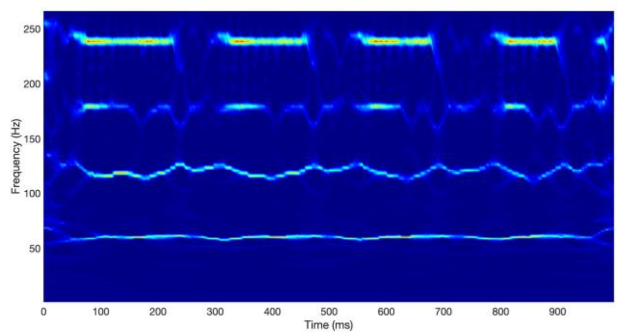

Figure 9 Decoupled motor SSWT spectrogram with interharmonic and subharmonic content

The time-frequency analysis for the motor coupled to the DC generator shows that during starting there is interharmonic and subharmonic content that can be harmful to other equipment connected to the network. The figure 10 shows the definition in which these harmonic disturbances oscillate, which suggests being motors of low power and with a lower moment of inertia, being more damaging than other induction motors with load to their torque, but a moment of inertia much older.

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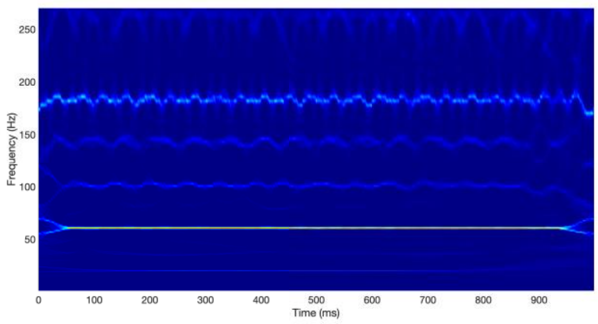

Figure 10 Spectrogram with SSWT of coupled motor with interharmonic and subharmonic content

Gratitude

Addressed to TecNM, Instituto Tecnológico de Ciudad Guzmán campus, for providing everything necessary for the development of this work. Thanks to the CONACYT National Quality Postgraduate Program for the financial support used in part to carry out the experiments.

Conclusions

The results obtained corroborate that induction motors with properties with a lower moment of inertia, with a constant load when started through soft starters that only contemplate two voltage lines for their control, foster interharmonic generation, which could be harmful to equipment connected to the network or other electrical machines. For an induction motor with no load, but with a lower moment of inertia, this phenomenon is still visible, so more research should be carried out in this regard and other types of starts in motors that present lower inertia characteristics of their own in their model and load. applied in torque.

In the case of soft starters, being devices commonly used in the industrial sector, it is important to review the effects that it would have on the quality of energy and efficiency of the machines if it is desired to establish a control strategy for its respective mitigation.

Likewise, time-frequency analysis carried out with the SSWT method guarantees better results for harmonic analysis in the presence of non-stationary signals and with oscillations that could make their visualization difficult.

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Monitoring system for photovoltaic cells

Sistema de monitoreo para celdas fotovoltaicas

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Abstract

Efficiency control in photovoltaic cells can establish whether or not such technology is feasible in certain sectors of industry. This fact can determine the partial or total change to these sustainable energies. For this reason, this paper proposes a wireless photovoltaic cell monitoring system, which can be integrated by an industrial communication network in order to establish a better efficiency of this type of technology. The system is based on a master-slave architecture and consists of two main communication devices, of which one of them (slave) registered voltage and resistance for monitoring solar power generation, while the second (master) collects the information to process such data. This system is compared with other devices in the resistance readings, in addition, through the proposed system the voltage drop of a photovoltaic cell during the day is identified.

Communication, Microcontroller, Measurement, Radio frequency, Monitoring

Resumen

El control de la eficiencia en celdas fotovoltaicas puede establecer si es viable o no dicha tecnología en ciertos sectores de la industria. Este hecho puede determinar el cambio parcial o total a estas energías sustentables. Por este motivo en el presente trabajo se propone un sistema de supervisión de celdas fotovoltaicas inalámbrico, que puede ser integrado por una red de comunicación industrial con la finalidad de establecer una mejor eficiencia de este tipo de tecnología. El sistema está basado en una arquitectura maestro-esclavo y consta de dos dispositivos de comunicación principales, del cual uno de ellos (esclavo) censa voltaje y resistencia para el monitoreo de la generación de energía solar, mientras que el segundo (maestro) recopila la información para procesar dichos datos. Se compara este sistema con otros dispositivos en las lecturas de resistencias, además, a través del sistema propuesto se identifica la caída de tención de una celda fotovoltaica durante el día.

Comunicación, Microcontrolador, Medición, Radio frecuencia, Monitoreo

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Introducción

There are various monitoring and control methods for supervising critical equipment in the industry (Chacon, 2001-2002) . One of the most relevant are automated systems (Pérez, 2015). The characteristic of these is based on remote monitoring of the production process. The way these systems communicate is defined by various communication protocols (Pardo, s/f). The most used are: PROFINET, PROFIBUS, AS-I, HART among others. These protocols are supported by the OSI model (Balchunas, 2014). This model consists of 7 layers: physical, link state, network, transport, session, presentation and application as shown in figure 1.

7	Application
6	Presentation
5	Session
4	Transport
3	Network
2	Data-link
1	Physical

Figure 1 Layers that make up the OSI model

The modernized control of any system today is based on the pyramid of automation (Pardo, s/f), this consists of 5 levels, the first refers to the field network. This section defines the devices needed to measure and execute any process in the factory. The second level establishes a control network, this layer manipulates the instruments for production, the third monitors layers 1 and 2 through SCADA and HMI systems. The fourth inspects the production of a factory in a general way, and in the last one statistical information is established for one or more production plants. Its main function of these systems is to optimize the processes of product generation. The development of this technology can be used in other areas such as energy, specifically in sustainable energies such as solar. This type of technology is subject to weather conditions, which limits the efficiency of it. Another restriction that these photovoltaic systems have is the loss of power due to their use (Cepeda, s/f).

These characteristics condition an in-depth study of the climatic conditions and uses that these devices have, so that through automation systems a better efficiency can be established in the generation of energy through sunlight. One of the most relevant studies on the monitoring of the conditions in which photovoltaic cells are found over time was carried out by Amira (Shahieda, 2020) where she proposes a system that monitors dust on solar panels, her system determines the thickness of it in photovoltaic cells. Another outstanding system in the last decade was proposed by Devi which proposes a system to monitor the solar energy delivered by solar panels through IOT technology, this system is based on Arduino technology and Rasberry equipment. However, these methodologies although they guarantee a constant monitoring of the conditions of a photovoltaic cell, there is still no communication network between panels for the monitoring of them as in which the automation pyramid is defined, therefore, these studies are limited to a single photovoltaic cell and not a network of the same, Consequently, the malfunction of each cell cannot be identified. For this reason, a wireless monitoring system is proposed to monitor the efficiency of a photovoltaic cell network and its correct operation.

Methodology

The operation of the system consists of five blocks as shown in figure 3. From these blocks two main aspects are derived. The first establishes the reading and transmission of information, Figure 2-A. While in the second it receives this information and processes it, figure 2-B. The first block performs voltage and current readings in accordance with Cat standards [8]. The second through a digital analog converter, transform the analog signals of the photovoltaic cells to digital, so that later in the third stage, by means of FSK modulation, the data is transmitted to the master reading equipment. The master system interprets the origin of the information, where it is determined what type of device sends it. The information from it is processed and stored in an Excel workbook (Microsoft, 2021) and displayed on an LCD display.

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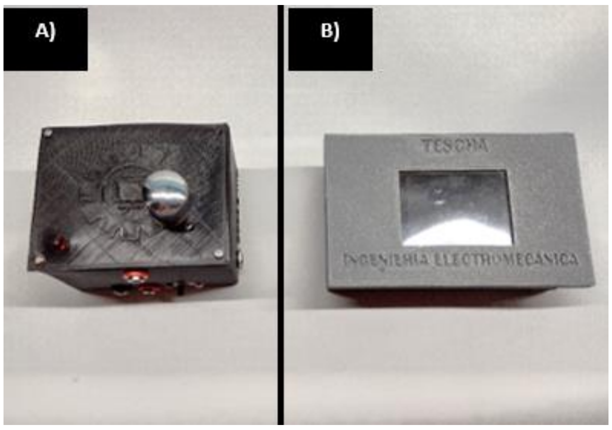

Figure 2 Wirelees multifuncional measuring device

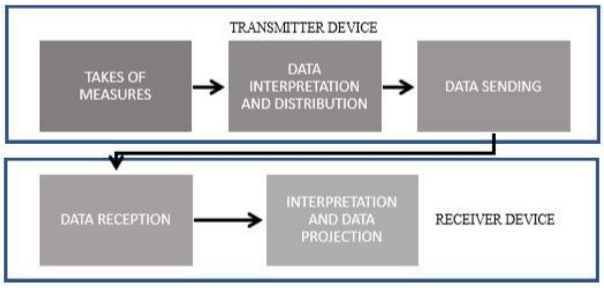

Figure 3 Operation wirelees muntifuncional device

To determine the correct operation of the system, electrical impedance and potential tests were performed, for the first stage the resistance of a copper wire was calculated by means of equation 1 (Boylestad, 2004), with a resistance factor (ρ) of $1.68_{x10^{-8}}$ Ω*m, , with 0.12 mm diameter (A) and 21.5m length (l) and resistivity readings were compared with different brands of multimeters, including: FLUKE 115 with accuracy of ±0.5% at a resolution of $1_{x10^{-1}}$ volts (FLUKE, s.f.) and TRUPER MUT-33 with accuracy of ±0.5% at a resolution of $100_{x10^{-3}}$ volts (TRUPER, s.f.). In addition, different measurements of commercial resistances were made with a resistivity error of ±5%

$$R = \frac{\rho l}{A} \quad (1)$$

In the second stage, the reading of electrical potentials of a solar cell was carried out at different times within the eastern zone of the state of Mexico, in the Tecnológico de Estudios Superiores de Chalco, in a period that includes from 01:00 pm to 05:30 pm at intervals of 15 min from the start time of the reading. Measurement readings were saved via Microsoft Data Streamer.

Results

Voltage readings which the measurements were, this is due to the decrease in sunlight in the course of the day.

Figure 4 System coupled to a photovoltaic cell

Time	Voltage (V)	Time	Voltage (V)	Time	Voltage (V)
01:00	20.86	02:45	20.43	04:30	19.14
01:00	20.86	02:45	20.43	04:30	19.14
01:15	20.96	03:00	20.48	04:45	18.93
01:15	20.91	03:00	20.48	04:45	18.98
01:30	20.86	03:15	20.48	05:00	19.03
01:30	20.86	03:15	20.48	05:00	19.03
01:45	20.86	03:30	20.05	05:15	18.87
01:45	20.86	03:30	20.05	05:15	18.87
02:00	20.75	03:45	19.78	05:30	18.44
02:00	20.75	03:45	19.78	05:30	18.44
02:15	20.59	04:00	19.73		
02:15	20.59	04:00	19.73		
02:30	20.59	04:15	19.57		
02:30	20.59	04:15	19.62		

Table 1 Record of electric potential in photovoltaic cell

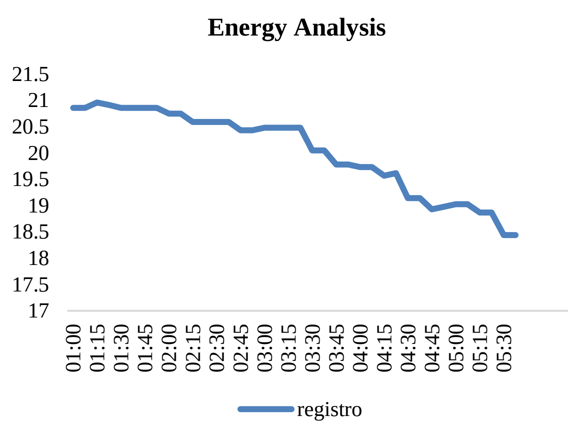

Figure 5 Energy analysis

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Resistance

The tests performed in which the resistance reading is taken are shown in Table 2. The values obtained by the system are in column four. The first row of the table refers to a wire whose resistance in calculation by equation 1, the remaining rows, are equivalent to commercial resistive values.

RESISTIVE VALUE (Ω)	TOLERANCE	RANK(Ω)	MEASURED VALUE DMMI(Ω)	MEASURED VALUE FLUKE 115(Ω)	MEASURED VALUE MUT-33(Ω)
31.93			32.4	31.3	31.2
56	±5%	[53.2-58.8]	51.39	55.5	55.1
100	±5%	[95-105]	100	98.6	97.7
156	±5%	[148.2-163.8]	150.73	154	152.5
180	±5%	[171-189]	173.11	176.8	175
220	±5%	[209-231]	213.52	217.1	215
400	±5%	[380-420]	391.84	393.8	390.0
460	±5%	[437-483]	467.62	469.5	465
680	±5%	[646-714]	690.91	685.0	680
820	±5%	[779-861]	810.62	812	804
1000	±5%	[950-1050]	974.90	976	968

Thanks

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Conclusions

The voltage data of the photovoltaic cell mark a decreasing trend that is equivalent to the amount of light perceived by the same cell, the values that stand out the most are between 20 to 21 volts, these values fall into the ranges in which the manufacturer indicates. In terms of the resistances measured in the proposed equipment, all readings are within the ranges established by the resistor factories, therefore, the reading error is less than 5%. Consequently, the system can continuously monitor a network of photovoltaic cells.

Discussion

Sustainable energy generation such as solar has been a compromising alternative due to the low costs that have been presented in recent decades (IRENA, 2020). However, the efficiency of these is still low. This largely refers to the separation of electrons in the semiconductor, which are only presented by high evoked frequencies in most cases by UV rays (Pacheco, 2018). This fact limits effective power generation to a time range of the day when sunlight can best be harnessed.

However, this range is conditioned by the climatic conditions and those of photovoltaic cells, this fact derives the importance of continuously measuring the amount of energy that enters a network of photovoltaic cells, so that with this the necessary means are obtained to better perform the efficiency in the generation of energy of this technology. An interesting study in which it could be highlighted through this proposed system, is to predict in certain seasons of the year, what type of inclination is optimal for a better efficiency of these devices, in addition to predicting automatically in which time intervals this equipment should be changed or have a certain maintenance. Another advantage to highlight in the proposed system are the timely establishments of failures in the system. This is because the system can be coupled with automated systems such as ERP (FAEDIS, s.f), dedicated to storing and reporting control parameters in production factories.

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Abstract (In English, 150-200 words)

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What is your added value with respect to other techniques?

Clearly focus each of its features

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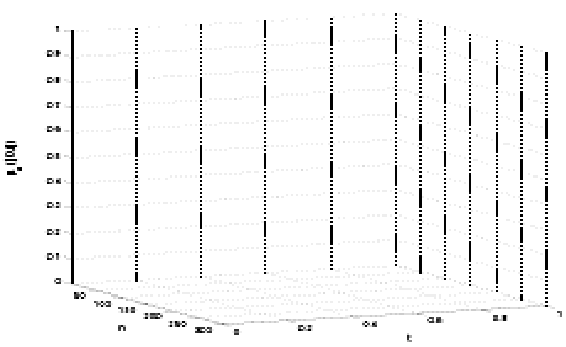

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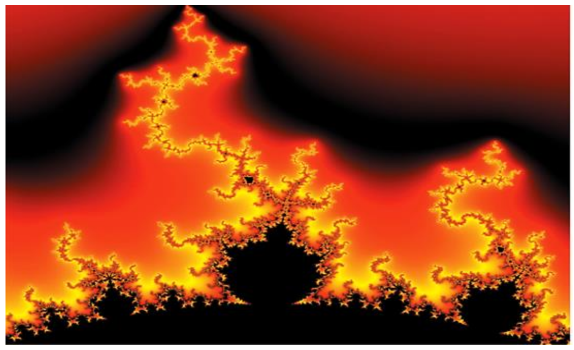

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$$Y_{ij} = \alpha + \sum_{h=1}^{r} \beta_h X_{hij} + u_j + e_{ij} \quad (1)$$

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Methodology

Develop give the meaning of the variables in linear writing and important is the comparison of the used criteria.

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Annexes

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