Revista Iberoamericana para la Investigación y el Desarrollo Educativo
ISSN 2007 - 7467

Mejora del aprendizaje de la eficiencia eólica mediante el modelado del coeficiente de potencia en la Universidad Tecnológica de Altamira

Improvement of the Learning of Wind Efficiency by Modeling the Power Coefficient at Technological University of Altamira

Aprimoramento do aprendizado do eficiência eólica através da modelagem do coeficiente de potência na Universidade Tecnológica de Altamira

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Resumen

La presente investigación se llevó a cabo en la Universidad Tecnológica de Altamira en el Departamento de Energías Renovables, donde la parte medular y el compromiso de los docentes es incrementar el aprovechamiento académico de los alumnos; en este caso particular, en la materia de "Sistemas de conversión de energía eólica", y específicamente en un concepto fundamental de eficiencia energética que es el coeficiente de potencia en aerogeneradores. Para lograr este objetivo se recurrió a diversas investigaciones para presentar algunos modelos de representación del coeficiente de potencia y presentar sus gráficas asociadas a través del uso del *software* MATLAB. Entonces se establecieron los grupos de experimentación y control y se evaluó su desempeño académico en cuanto a la comprensión del concepto del coeficiente de potencia a través de los instrumentos de medición que fueron establecidos. Finalmente se analizaron los resultados obtenidos para emitir las conclusiones y recomendaciones pertinentes. El trabajo se efectuó durante el periodo enero-abril del 2018 y se espera que sirva como base para futuras investigaciones.

Palabras clave: aprendizaje, coeficiente de potencia, eficiencia, energía eólica.

Abstract

The present investigation was carried out in the Technological University of Altamira in the Department of Renewable Energies, where the core part and commitment of the teachers is to increase the academic achievement of the students; in this particular case in the field of Wind Energy Conversion Systems and specifically in a fundamental concept of energy efficiency that is the power coefficient in wind turbines. To achieve this objective, several investigations were used to present some power coefficient representation models and present their associated graphs through the use of MATLAB software. Then the experimental and control groups were established and their academic performance was evaluated in terms of understanding the power coefficient concept through the measurement instruments that were established. Finally, the results obtained were analyzed to issue the pertinent conclusions and recommendations. The work was carried out during the period January- April 2018 and is expected to serve as a basis for future research.

Keywords: learning, power coefficient, efficiency, wind energy.

Resumo

A presente investigação foi realizada na Universidade Tecnológica de Altamira no Departamento de Energias Renováveis, onde o núcleo e o comprometimento dos professores é aumentar o desempenho acadêmico dos alunos; neste caso particular, em matéria de Sistemas de Conversão de Energia Eólica e especificamente em um conceito fundamental de eficiência energética, que é o coeficiente de potência em turbinas eólicas. Para atingir este objetivo, várias investigações foram utilizadas para apresentar alguns modelos de representação de coeficiente de potência e apresentar seus gráficos associados através do uso do software MATLAB. Em seguida, os grupos de experimentação e controle foram estabelecidos e seu desempenho acadêmico foi avaliado em termos de compreensão do conceito de coeficiente de potência através dos instrumentos de medição que foram estabelecidos. Finalmente, os resultados obtidos foram analisados para emitir as conclusões

e recomendações pertinentes. O trabalho foi realizado durante o período de janeiro-abril de 2018 e espera-se que sirva de base para pesquisas futuras.

Palavras-chave: aprendizagem, coeficiente de potência, eficiência, energia eólica.

Fecha Recepción: Enero 2018 **Fecha Aceptación:** Junio 2018

Introduction

The problem that originates this research work in the career of Renewable Energy is the high failure rate in the subject of "Wind energy conversion systems" [SCEE] (Technological University of Altamira [UTA], 2018), where a concept Fundamental that serves as a basis for understanding many problems both theoretical and technological application is that of energy efficiency in wind turbines, technically known as the power factor (Cp). Likewise, students are expected to increase their academic performance through the use of educational technology such as laptops and programming software, simulation and modeling, just as MATLAB applied to various problems. This with the aim of framing a panorama that provides them with the appropriate conditions to respond appropriately when developing their cognitive skills based on the problems that arise.

The use of simulation software to stimulate learning has become a very effective method over time and especially in recent decades. More and more educators, universities, training centers and schools in general are leaning on software management with the purpose of improving the academic performance of their students and supporting them in the understanding of diverse concepts difficult to understand through traditional methods in the aulic space (Manrique, Gasca and Gómez, 2015). There are also jobs where educational games have been developed to stimulate learning in students (Liu, 2016).

In terms of programming and simulation of dynamic systems, MATLAB is undoubtedly one of the most used programs in the international academic world, and has

been used in various investigations as a catalyst for the stimulation of learning and the understanding of concepts (Moussavi y Fazly, 2010).

The UTA is part of a sector of higher education institutions in Mexico that is regulated by the General Coordination of Technological and Polytechnic Universities [CGUTyP] (2018), so it offers careers whose study programs include the management of computer, as well as technological specialty subjects that can exploit software resources to stimulate the learning of their students (UTA, 2018). From what has already been said, the research question that represents the guiding axis of this work is: How do the computer and programming software intervene to improve the academic achievement of UTA Renewable Energy students?

In this way the proposal of a problem is made with the purpose that the students are able to understand the core concept of the Cp, which is closely related to theoretical problems and technological application that derive, precisely, from it. When working with this concept, it is usually only approached from the theoretical point of view and the graphs associated with the different models are presented, without the student having to develop a full understanding of the energy efficiency phenomenon related to calculating the Cp. The proposal includes the development of the associated graphics through the programming of the known models through the use of MATLAB software.

Theoretical fundament

The methodology used by many teachers at various educational levels tends to synthesize a set of theoretical and deterministic constructs that encompass the characterization of concepts on a cognitive scale whose appreciation only allows to reach a primitive degree of understanding of the issues involved. This becomes clear when the individual faces problems that require a deeper understanding of the foundations of a line of knowledge that give him the ability to develop deeper tasks that have a positive impact on solving problems. (Chang, 2018).

Until the beginning of the 21st century, the traditional academic university space had undergone relatively insignificant changes on a global scale with reference to teaching and learning methodologies. At the time when an innovation in technology arose, the common

teacher made unconscious efforts to adapt it to its old paradigms. However, the proper use of computer technology and software for educational purposes have allowed in some way the development of individual and collective intelligence (Gash, 2015).

It is also worth mentioning the recognition of different intelligences in the individual, which have their own attributes and identity, although they are intertwined in an entity that allows to promote the global and harmonious development of the subject in the interaction with its environment, so that identifies and leads him to characterize the formation of ideas and thoughts that are translated into an entity that identifies with his reality (Gardner, 1993).

The development of methodologies that allow the development of diverse intelligences that are adequately supported by software aimed at strengthening and promoting the capabilities of the individual constitute a successful path through which it is possible to make a substantial difference in the construction of knowledge (Dolati & Tahiri, 2017).

Likewise, it is important to highlight the active participation, since evidence has been presented indicating that the complement of the theoretical classes with active learning strategies guide the individual to the capture of knowledge and the increase of knowledge through scientific and discovery processes, in such a way that this form of learning is positive and better with respect to the traditional purely theoretical methods. (Becker, Plumb y Revi, 2014).

On the other hand, in technical terms, energy efficiency has undoubtedly been an issue of great importance in the modern world, especially at this time when non-renewable resources are in a delicate situation (Manzano, Alcayde, Montoya, Zapata and Gil, 2013).

In many countries around the world, energy expectations are based on renewable sources and resources: solar, wind, thermal, oceanic and biomass, which are increasingly exploited using new and modern technologies (Chen and Lee, 2014; Tripathi, Tripathi , Mishra, Dubey and Baredar, 2016; Hussein, 2015).

In the case of the wind industry, its growth in recent years has been so great that by the end of 2017 it reached a total installed capacity of 539,123 GW according to the Global Wind Energy Council [GWEC] (2017).

For subjects such as SCEE, Cp is an element of great importance. Since its understanding, representation and estimation have been the subject of numerous investigations over the years due to the impact on wind energy that can be exploited. Even in the early 1920s, the German physicist Betz established a limit for Cp, known as the Betz limit, which has been under analysis for almost a century (Vennell, 2013, Farthing, 2013, Sen 2013). In addition, important advances have been made in wind energy technologies in recent years and several investigations on emerging technologies have already been published. (Yaramasu Wu, Sen, Kouro y Narimani , 2015; Mittal, Sandhu y Jain, 2010).

Methodology

The first step that was carried out in this work was the establishment of the experimentation and control groups, each one of which consisted of a total of 25 students from the Renewable Energies program. Then we proceeded to the identification of the appropriate characteristics of the teaching-learning method proposed, with the purpose of encouraging the understanding of concepts and foundations of energy efficiency.

These entities are constituted by a set of elements that imply the formation of knowledge based on the relationship that exists between theory and practice in an adequate environment, where the stimulation through the involvement of visualization, logic and critical analysis they constitute the starting point for the integral construction of knowledge (Chamorro, 2005).

All this resulted in the implementation of various representations of the Cp in wind energy conversion systems through the corresponding code of programming in MATLAB. The mechanism consists of the student identifying the typical structure of the polynomial models used for the representation of Cp in wind turbines, after carrying out the programming of the model using first the coefficients proposed by different authors and then modifying said values so that Analyze the changes in the behavior of the Cp curves.

The control group is limited to the study of the state of the art in terms of the typical representations of the Cp in wind turbines, while the experimental group also carries out the modeling of the Cp, its programming, manipulation, generation and analysis of the behavior

of the associated curves, which, in theory, allows you to develop a deeper level of understanding of the phenomenon.

The next step was to design an appropriate measuring instrument that would allow obtaining results that would reflect the academic performance of the students in terms of understanding the Cp concept as well as its relationship with the wind energy conversion systems.

Ultimately the instruments were applied to both groups just after viewing the contents in class and the results were measured. Another test was also applied without prior notice at the end of the course with the objective of measuring the retention of knowledge in the medium term. The tests consisted of two sections, one that focused exclusively on the assimilation of concepts and the other focused on solving SCEE problems.

The evaluation elements addressed by the reagents used within the assessment instruments are indicated in Table 1.

Tabla 1. Elementos evaluados por reactivo

Reactivo	Elemento evaluado
1-10	Asimilación y asociación de conceptos
11-20	Solución de problemas de SCEE

Fuente: Elaboración propia

Already in practical terms, the Cp in the SCEE matter is defined as the power (P) that extracts a turbine divided by the total power (P1) that affects the wind, as shown in (1).

$$C_p = \frac{P}{P_1} \quad (1)$$

On the other hand, the importance of this curve is that it allows to identify the point to extract the maximum power for a certain wind speed, which is associated with the angular speed of the wind turbine, which, in turn, can be modified through of an adequate control mechanism for that purpose. The problem is that this curve is not easy to obtain and also changes over time due to various factors of the environment and mechanical wear and electrical capacity of the system.

On the other hand, there are models that allow to approximate the curve of Cp. The students of the experimental group worked with the polynomial model shown in (2) and carried out its programming based on the coefficients proposed by different authors. In this model, λ represents the velocity relation, i is the iteration, n represents the degree of the polynomial, while ai is the i-th coefficient.

$$C_p(\lambda) = \sum_{i=0}^{n} a_i \lambda^i \qquad (2)$$

Table number 2 presents the coefficients proposed by four authors of diverse investigations, as well as a proposal made by the author of the present investigation. The polynomials programmed by the students in the MATLAB software range from the simplest, which is third grade, to one of seventh grade.

Tabla 2. Coeficientes del modelo polinomial de Cp propuestos por autores diversos

	a_0	a_1	a_2	a_3	a_4	a_5	a_6	a_7
Moussa, Bouallegue yKehedher (2014)	-0.0209	0.1063	-0.0048	-3.7e-5	0	0	0	0
Li, Ma, Xu y Zhang (2007)	0	0.0051	-0.0022	0.0052	-5.14e-4	-2.79e-5	4.63e-6	-1.33e-7
Carranza, Miranda, Ortega y Rodríguez (2014)	0.0344	-0.0864	0.1168	-0.0484	0.00832	-0.0005	0	0
Arifujjama, Iqbal y Quaicoe (2006)	0.11	-0.2	0.097	-0.012	0.00044	0	0	0
Propuesta propia	0.01	-0.0328	0.04926	-0.0067	2.39e-3	0	0	0

Fuente: Elaboración propia

In addition to this, Figure 1 shows part of the programming code used in MATLAB for the development of graphs associated with Cp, while Figure 2 shows the graphs generated and associated with the coefficients of Table 2.

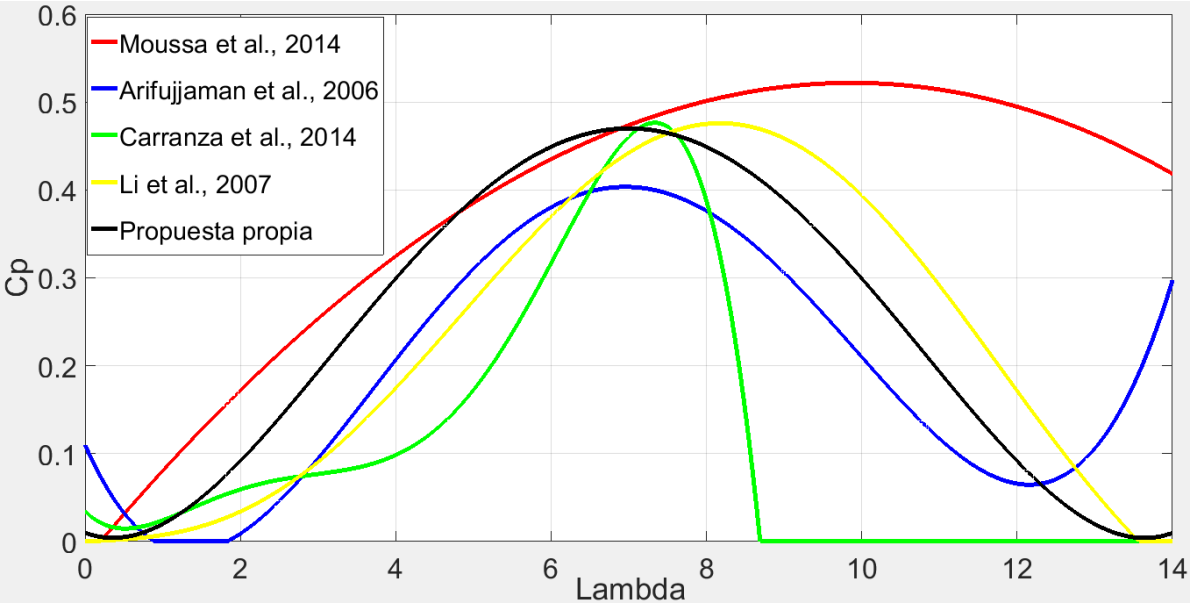
Revista Iberoamericana para la Investigación y el Desarrollo Educativo
ISSN 2007 - 7467

Figura 1. Código de programación utilizado para la generación de las curvas de Cp

```
clc, clear all
a=[-0.02086,0.1063,-0.004834,-0.000037,0,0,0,0;0.11,-0.2,0.097,-0.012,
    0.00044,0,0,0;0.0344,-0.0864,0.1168,-0.0484,0.00832,-0.00048,0,0;
    0,0.0051,-0.0022,0.0052,-5.1425e-4,-2.795e-5,4.6313e-6,-1.331e-7;
    0.01,-0.032802,0.049266,-0.0067033,0.0002394,0,0,0];
h=1e-4;lam_ini=0.000;lam_fin=14;lam=lam_ini:(lam_fin-lam_ini)*h:lam_fin;
pasos=length(lam);
%---------------Función polinomial---------------%
lam(1)=lam_ini;
for n=1:pasos
    lamx=lam(n);
    for i=1:5
        Cp(i,n)=a(i,1)+a(i,2)*lamx+a(i,3)*lamx^2+a(i,4)*lamx^3+
        a(i,5)*lamx^4+a(i,6)*lamx^5+a(i,7)*lamx^6+a(i,8)*lamx^7;
        if Cp(i,n)<0
          Cp(i,n)=0;
        end
    end
end
```

Fuente: Elaboración propia

Figura 2. Curvas de Cp generadas con el modelo polinomial por diversos autores



Fuente: Elaboración propia

In summary, the steps followed in the methodology were the following:

- Experimentation and control groups were formed, each of which consisted of a total of 25 Renewable Energy students
- The performance indicators that were the assimilation of concepts and the solution of SCEE problems were established.
- The teaching methodology of the experimentation group was designed, which involved the modeling of Cp, its programming, manipulation, generation and analysis of the behavior of the associated curves.
- The evaluation instruments of the established indicators were designed.
- The proposed teaching methodology was applied.
- The evaluation instruments were applied in the middle and at the end of the course.
- The results were obtained and its meaning was reflected.

Discussion

One of the most important aspects of the study is that it showed that the programming of the Cp curves forced the student to truly understand the structure of the most accepted representations of this concept. In addition, he aroused interest in students for the development of logic, syntax, order and visualization skills.

He also challenged the student to face other types of problems that encouraged his ability to translate and analyze polynomial models in a context of functional notation, establishing conjectures about his domain, limits, concavities and transitory evolution, motivating his ingenuity and creativity, and developing in this way competences and skills in him of great importance for his future professional activity.

Another important point is that it is essential to have the appropriate technology, as well as the appropriate equipment, laboratories and spaces so that an investigation of this type can be carried out successfully. To inform the corresponding authorities about the development and intention of the investigation is, of course, a recommendation that can not be missed.

Something that is worth emphasizing is that in this type of research you can not have total control of the groups, so it is not a real experiment, but rather a quasi-experiment, this is due to the plurality of students with what is counted, that is, because they are of different socioeconomic situation, culture, age, different physical conditions, motivations, values and family contexts, to name a few, which can generate a certain bias in the results.

On the other hand, this work can be applied in other institutions with their own students and thus increase the study population to obtain results that enrich the research, which is why other researchers are invited to use these tools and apply them in their own contexts.

Conclusions

After having carried out the present research, important results were obtained that show a general improvement in terms of the students who received the teaching methodology based on the use of MATLAB software to program and represent the Cp in wind energy conversion systems.

In relation to the first exam (short-term evaluation), the students of the experimental group presented a difference of 16 points in relation to those of the control group in the indicator of assimilation of concepts, while in the indicator of problem solving the difference was the largest of the whole experiment, standing at 23 units.

This makes us reflect that the clarity of the concepts allows to properly solve application problems; in contrast, the lack of clarity in the concepts clouds the understanding for the solution of problems, since, without having clear the bases, one starts from a wrong position.

Regarding the second exam (medium-term evaluation), contrary to what was expected, there was an improvement in both groups, but it was more significant in the control group. This is probably due to the fact that Cp concepts continued to be reinforced throughout the course; In addition, having obtained lower results in the first exam, they potentially had more opportunity to grow and improve the students in the control group.

It is clear that the results of assimilation of concepts both in the control group and in the experimentation group were always higher than those obtained in the solution of SCEE problems in the medium term. This is evident given that the solution of problems requires the use of concepts, which is why facilitating the teaching of them by the teacher is a matter of the utmost importance.

An important reflection in relation to the research results from a consequence of the teaching method applied to the students of the experimental group, who not only improved in SCEE, but also did it in subjects such as Programming Language and Mathematical Calculus. This fact is evidence that integral learning involves various aspects, such as the assimilation of concepts, their application, the analysis of the transient evolution of the phenomena through the use of appropriate technology and the reflection of the student in relation to the nucleus. of the studied phenomenon, it constitutes a catalyst that impels the student to improve their learning in other areas of knowledg.

Tabla 3. Tabla de resultados de las evaluaciones por grupo e indicador de desempeño

Grupo	**Indicadores de desempeño académico**			
	Asimilación de conceptos a corto plazo	Asimilación de conceptos a mediano plazo	Solución de problemas de SCEE a corto plazo	Solución de problemas de SCEE a mediano plazo
A (método tradicional)	75	80	60	65
B (método propuesto)	91	92	83	86

Fuente: Elaboración propia

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