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Software Development for Transformer Model Supporting Significant Learning Electrical Machines

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Abstract---*In the field of engineering, the execution of practices that allow students to contrast theoretical concepts with practical application is essential, allowing them to establish the relationship of physical variables and their effects on the system. These practices can currently be carried out using simulation systems, known as virtual laboratories, which rely on software that allows us to offer advantages over physical experimentation, and since this requires higher costs, access to equipment that is sometimes unavailable and risks, is one of the significant practices in the electrical engineering career, it is the one concerning the course of electrical machines and particularly the one directed to the design of transformers because the objective of this research focused on the development of a free application software that allows the students to carry out simulations for the design and testing of dry transformers and at the same time the analysis of their behavior, facilitating the comparison with the installed and commercially available transformers with an allowable error margins of less than 8%.*

Keywords---*dry transformers, electrical machines, laboratory practice, meaningful learning, virtual laboratories.*

I. INTRODUCTION

Within the engineering, career plays a key role, the development of practices that allow the student to contract theory with reality and therefore the assimilation of said knowledge (Arnt, 2010; Guerrero-Mosquera, Gómez, & Thomson, 2018),but often the use of practice equipment is risky, or even merits the use of very expensive equipment, which is often not available in universities (Domínguez, Fuertes, Reguera, González, & Ramón, 2010).The traditional scale model, for the representation of industrial systems and equipment used in university practices (Domínguez *et al.*, 2010; Gonzalez, Dunia-Amair, & Pérez-Rodríguez, 2017; Luengas, Guevara, & Sánchez, 2009; Pérez *et al.*, 2019), It is constantly evolving through the use of computer systems, which allow to simulate the behavior of different circuits, equipment and even complex processes, modeled from its design, operating scenarios, including its failures; facilitating the learning and interaction of students. Taking these simulation environments more and more to graphic environments of impressive resemblance to real processes.

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At present, various sectors use simulators, such are the cases of the sector: automotive, energy, aeronautics, electrical, among others; These systems use software for commercial use (Chorafas, Steinmann, & Barrera Ugalde, 1996; Makarova, Khabibullin, Belyaev, &Bogateeva, 2015), while in the field of education most of these developments tend to be carried out openly (Alfonsi & Pérez, 2009), trying to make it broad in scope, so they are often prepared by universities to make them available to their own teaching processes, adapting them to their purposes, needs and reducing costs (ChérrezVintimilla& Quevedo Sacoto, 2018; Medina, Saba, Silva, & de Guevara Durán, 2011; Potkonjak*et al*., 2016). In the academic field, this type of teaching methodology assisted by simulation systems, usually referred to as virtual laboratories, these teaching tools that support the teaching-learning process have multiple advantages, which have been recognized by UNESCO, for creating interactive and innovative scenarios, that facilitate strengthening the knowledge acquired (Grodotzki, Ortelt, &Tekkaya, 2018; Infante Jiménez, 2014; Sundari, 2019).

Virtual laboratories are not intended as a substitute for traditional laboratories, but if an excellent complement to the acquisition of practical knowledge, in this sense, they provide a set of advantages to traditional laboratories, which include: improvements in the accessibility and affordability to the knowledge of technologies (Martín-Gutiérrez, Mora, Añorbe-Díaz, & González-Marrero, 2017), it allows the iteration of practices without limitations of schedules, nor of number of repetition of events, selection of subject to experiment according to their needs, in addition to facilitating experimentation without fear of suffering, causing accidents or damage to equipment (Medina *et al.,* 2011; Prayoga&Rusli, 2019).

The realization of laboratory practices encompasses two simultaneous actions: it is taught to think and learn by doing it (Driver, 1988), which goes beyond the traditional teaching approach, based on transmission learning and machine learning (Henríquez, Azcarraga, & Coppola, 2012; Rinartha*et al.,* 2018), practical laboratory activities are important tools for the construction of their own knowledge by the student.The need to train students as learners of procedures and methods of a specific team or subject, is aimed at them being able to design, evaluate independently, independently and self-regulated,the construction of this knowledge (Yi Yang &Echempati, 2015), based on the information available in Information and Communication Technologies (ICT), and the current educational scheme, where the teacher is only the guide to knowledge (Manrique & Puente,1999); In this task, virtual laboratory practices, together with the theories of meaningful learning, are a dynamic tool (Infante Jiménez, 2014).

Meaningful learning occurs when the contents are related congruently and the student acts as a builder of new knowledge from previous knowledge, incorporating this new knowledge into its conceptual structure, to give them meaning (Manrique & Puente, 1999).In the programs of the Electrical Engineering degree, there are several subjects whose theoretical contents need to be contrasted with the realization of practices, in this sense, the course of electrical machines was selected because it is a core course for the race, which traditionally has a high index Difficulty in capturing the knowledge of the subject (Aquino Martínez & Valera Torres, 2012), within this subject, there are three thematic axes: transformers, direct current machines and alternating current machine (Sarmiento Muñoz, 2015; Shaikh &Shelke, 2019).Within the previous thematic axes, the issue of transformers is of particular importance, starting there the application of fundamental theories and concepts in the area of electromagnetism,

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fundamentals necessary to start the construction of knowledge in the area of electrical engineering (Sarmiento Muñoz, 2015).

The need to carry out transformer practices is based on the suitability of putting them in contact with an activity of the professional practice, with equipment of constant demand in the electric sector (Ramírez-Romero & Rivera-Rodríguez, 2017; Sarmiento Muñoz, 2015). The importance of this practice is that the student makes the design of the equipment, and understands its operation (through manipulation of the design variables), establishing different design conditions, where you can evaluate solutions according to the particular needs required and determine the effects of the design on its operation.Although there is software that has been designed to simulate the behavior of transformers, these are not specific to be used in the teaching-learning process, since they do not facilitate the student to configure their design variables, and contrast their effect with the operation of the transformer, displaying a limited set of options (Játiva, Maldonado, & Mena, 2019; Giler*et al.*, 2019).This development focuses on the design of software to support meaningful learning in electrical engineering students, mainly in the subject of transformers in the course of electrical machines.

II. MATERIALS AND METHODS

1. Carry

Toout the program, the methodology was followed in cascade or cycle of life, as the classical schemes put it (Castrillón, 2011; Costa, Loureiro, Reis, & Technology, 2009; Gamboa, 2018; Rivas, Corona, Gutiérrez, & Hernández, 2015; Rozo, 2014), the summary of the steps are shown in figure 1.

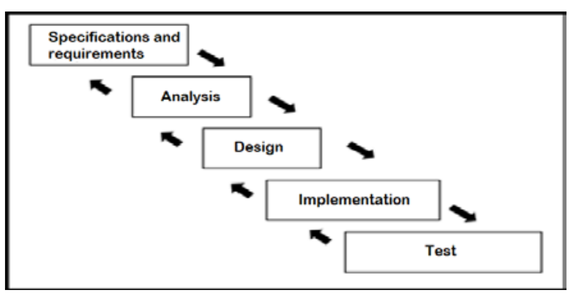

Figure 1. Partial scheme of the methodology Cascada or Life Cycle

The development of the design was based on the first subjects of the subject electric machines of the curricula of the electrical engineering career, dictated in various universities (Aquino Martínez & Valera Torres, 2012; Chacón, 2016; Játiva et al., 2019; Sarmiento Muñoz, 2015), the selection of the subject is based on the different fundamentals of concepts, which are then support for the construction of knowledge in the rest of the subject, which allows framing them within the significant learning of the area of electric machines.The fundamental axes of significant learning, on the subject of transformers, were limited to the following elements:

1. Characteristics of materials
2. Physical dimensions

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3. Concepts of electromagnetism
4. Concepts of electrical circuits
5. Concepts of magnetic circuits
6. Single-phase
7. transformers Equivalent circuit of transformers

Three (3) were developed for this purpose) Modules, comprising: Design, Analysis and Practice. These modules together cover the significant issues mentioned above.The design module was based on the selection of schemes and operating parameters, materials and construction methods. In the analysis module, the parametric changes of the equivalent circuit of a transformer were associated with the voltage and current relations of the same. Finally, the practice module shows how, from the tests of a transformer, the parameters of its respective equivalent circuit are found.The integration of these modules serves as a tool for the analysis and design of transformers, allowing students to consolidate the construction of knowledge and therefore significant learning(Xiu&Xeauyin, 2018).

2.Results

The software was designed to support significant learning in the experimentation of single-phase transformers dry, linking previous knowledge in electromagnetism, physics, mathematics, chemistry, algebra, electrical circuits, among other knowledge acquired in previous courses. The designed software is proposed for complementary use to the content of the subject, so that students have a first approach to the design process, and also to be able to compare the results of the designed calculations, previously manually, are corresponding to those obtained in the proposed simulator, called Transformers: Analysis, Design and Experimentation (TADE). Additionally, this tool can be used for the design of fractional power transformers (less than 1 kW), and can be very useful, as a first approximation, in the professional field. In the initial screen, you can select the three modules described above, as shown in figure 2, it is here that you select which module will be used according to the student's need.

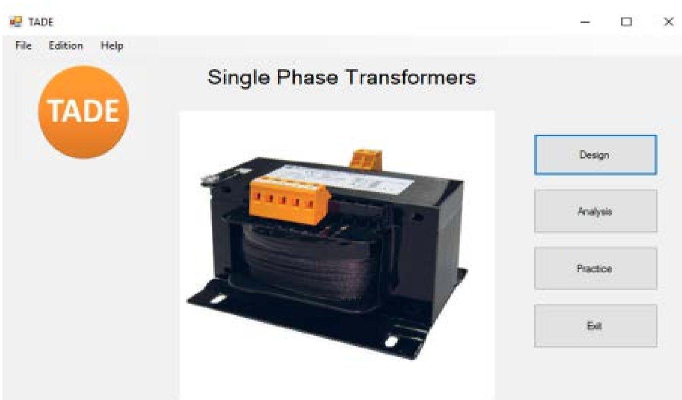

Figure 2.The initial screen of the TADE software

In the Design module, as shown in figures 3, the design parameters are specified and the type of core, winding characteristics are configured, and once the calculations have been made an estimate is presented of the

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losses and the performance of the proposed prototype, this is done to associate the design parameters of the transformer, with the proper operating variables, so you can establish connection criteria between the variables to be configured and their effects on the operation of the device.

Figure 3. Tade software design screen

This module was developed thinking that the student can carry out the validation of each of the variables, which must be entered for the design of a transformer, as shown in Figure 4, where you can change the parameters and types of construction elements, and see the results almost immediately.

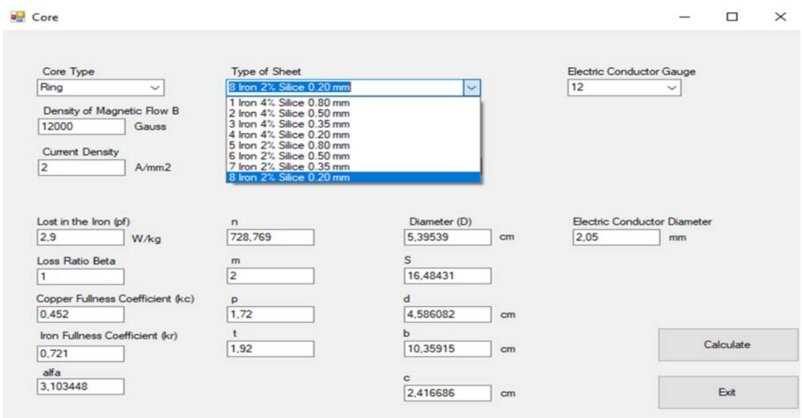

Figure 4. Transformer core design screen

When the design is completed, the student will be able, through the software, to issue a report where all the parameters inherent to it are presented, an example of this report is shown in Figure 5.

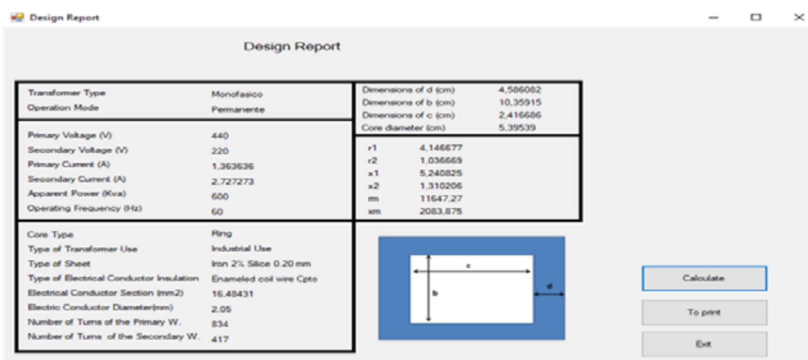

Figure 5. Report design transformer

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Oncedefined, a first version of the design, the student can select the analysis module, by which can perform the equivalent circuit of the transformer, with the parameters thrown by the design, and make operation studies for different power and load values, in addition to calculating the different voltages and currents of the model, as presented in figure 6, it can identify the electrical parameters of the equivalent circuits of the transformer, as well as the variables that show how it works.

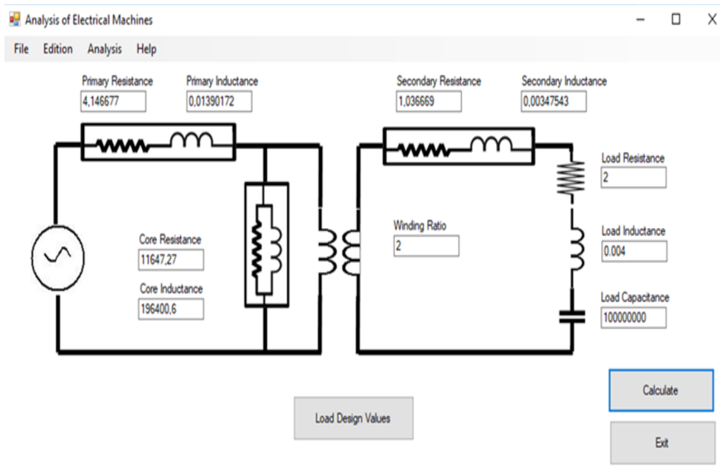

Figure 6. Equivalent circuit of the designed transformer

In the Graph window**,** the results show the shapes of the waves, in the permanent regime for 100 milliseconds or less, presenting the student with a direct association of the variable with the characteristics of the waves, and their respective offset, an example of this is shown in Figure 7.

Figure 7. Graphs of the variables of the equivalent circuit of the transformer

Subsequently, the student can check the regulation and performance levels of the designed transformer, according to the type of load and the selection of the parameters of the design itself, unequivocally verifying the appropriate selection of parameters and the correct taking of design criteria, adjusting to the results that are expected to be obtained, as shown in Figure 8.

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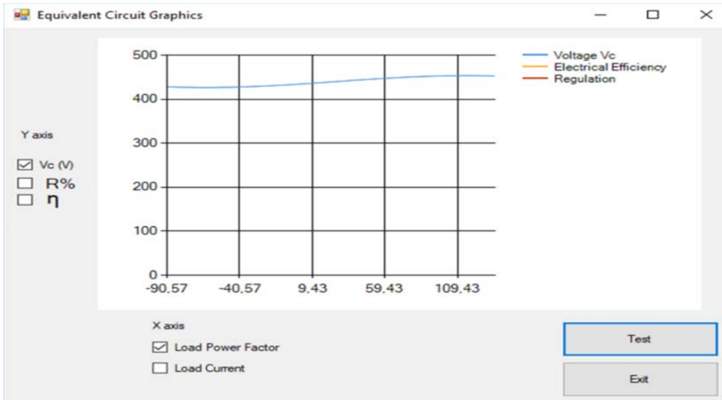

Figure 8. Characteristics graphs of operation of the transformer

By using the program, the student focuses all his attention Nation to the association of the fundamental concepts of electromagnetism and electric machines, in addition to the analysis of the changes in function of their constructive parameters, allowing the experience to familiarize the student with the operating principles of the electric machines, encouraging learning to be experienced significant and reinforcement of fundamental theories in the careers of electrical engineering, electronics, telecommunications, among others.

III. CONCLUSION

The software allows the design of single-phase transformers through the selection of physical and operating parameters, in addition to the choice of materials.The realization of electrical machine practices using software such as the one developed for TADE dry transformers, allows the student to make their own learning constructs, integrating the knowledge prior to the design task, with the variants that can be presented for this equipment, is facilitated the comparisonof the results obtained with the calculations performed manually, which constitutes a valuable tool for the significant learning of the electrical engineering career.This TADE designed software responds to the practical needs of the subject electric machines, in the field of dry transformers, covering from its conception modalities of practices in a single design, since its development focuses on: a) achieving the association of theoretical criteria In a practical application, b) manage to generate the association of the intervening physical variables and their effect on the system, c) relate the causes and the existing effect between the selection of a characteristic of the material,parameter and variable of the equipment, d) associate the effects of the design on the equipment, e) the comparison of the results obtained with the software, with those obtained through manual calculations or in the operations carried out with installed equipment.

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