Chapter 5

Discussing Socioscientific Controversies in Primary and Secondary Education: Potentials and Constraints in Science Lessons

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Additional information is available at the end of the chapter

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Abstract

This chapter presents the results of an investigation conducted with the objective of understanding the socioscientific controversies approach in science teaching from the perspective of curricular integration, against the background of the new social and environmental challenges currently faced by science education. The research was conducted as a case study, and the data presented here were collected using questionnaires and interviews and were analyzed using the discursive text analysis method. The approach is predominantly qualitative and descriptive. The results of these analyses indicate the potential of the socioscientific controversies approach combined with integrated projects, fostering debate between different subject areas in discussions of subjects that are considered controversial.

Keywords: socioscientific controversies, curricular integration, science education

1. Introduction

This chapter is intended to contribute to the academic debate around discussion of socioscientific controversies (SSCs) in science teaching from an integrative perspective.

This study of SSC is situated within the context of a century in which, according to Silva and Cicilini [1], we are witnessing scientific and technological achievements that have been predicted in the past, but more in a tone of science fiction than of reality. These developments have had impacts on society, communication media, and education. The traditional way that Biology is taught has undergone changes and new issues have emerged for discussion, both within schools and in other spheres of society. Social debate is definitively attracted by problems related to the promises, challenges, and controversies of subjects related to life sciences and technology.

Within this context, Schramm [2] has claimed that we are witnessing a Biological Revolution, some examples of which are already part of citizens' lives, such as in vitro fertilization and implantation of embryos; cloning; the medicines produced by application of biotechnological knowledge; treatments for cancer, for AIDS, and for other pathologies; modification of plants and animals by manipulating and reprogramming their genes; and the fight against the major endemic diseases, hunger, and so on.

As part of this veritable revolution, new scientific capabilities have been acquired, such as, for example, treatment of the genetic information of living beings. This Biological Revolution has not only made it possible to describe and understand life but has also enabled its modification, resulting from a new form of applied knowledge that has resulted from an alliance between the technical sciences of language and the technical sciences of biology [2].

Galvão and Reis [3] argue that nowadays the objective is to integrate scientific knowledge into the students' world, in order to help them understand the objects and events which they encounter every day, attempting to increase their interest in science and scientific activities and to encourage their involvement in processes of discussion and evaluation of socioscientific issues.

These authors state that it is the responsibility of the school and, consequently, the teacher to provide opportunities for discussion of the socioscientific issues that are increasingly part of everyday life. Schools must foster a scientific education that problematizes scientific developments, because, in addition to being necessary, it is an indispensable social duty to present students with science that is more up-to-date, historical, social, critical, and human.

Galvão and Reis [3] also point out that the teacher's role includes encouraging students to research and select reliable sources of information; contrast different points of view; seek the knowledge needed to understand a given issue; familiarize themselves with the practices, techniques, and theories of scientists, so that they can be related to their daily lives; to discuss the subjects; to study the benefits they can offer and the harm they can cause; and to critically assess and express opinions on socioscientific issues.

Therefore, the classroom should become a venue for discussion, where the students can participate actively, expressing their interest in and knowledge about the widest variety of subjects, which can be dealt with not merely in relation to scientific knowledge but also in terms of their social meaning and impact. This experience can be accomplished in a variety of different ways and should involve the points of view of distinct social groups, thereby providing a platform for discussion of the constraints on and potentials of participation in socioscientific controversies.

Within the scope of science teaching, the space occupied by this debate has been growing as a result of certain issues that have already attracted the interest of teachers and their students, such as cloning and assisted reproductive techniques. There appears to be the space and opportunity, and even a need, to design a form of science education that is able to, effectively, foster in-depth discussion of these issues. Working from the objectives of school-based education in the sciences, we should be developing scientific literacy, in other words, providing training in the sciences that "[…] provides the tools that make it possible to better understand the society in which we live" [4],[1] to enable students to take decisions consciously.

This chapter is derived from a doctoral thesis, and its overall objective is "to present the constraints on and potentials of the socioscientific controversies approach, by means of a case study of use of the integrated project teaching method in Science lessons."

2. Socioscientific controversies in science teaching

We live in a world in which new scientific discoveries and technologies are directly connected with our lives, interfering at greater or lesser intensities in our everyday society. On this basis, Delizoicov and Auler [5] refute the assumption that scientific enterprises and their agenda are neutral, pointing out that the questions that science asks, the phenomena that are selected for investigation and the problems chosen for solution, the research avenues opened and, as a consequence, the advances achieved in one or another field are all directly linked to the values of a specific spatiotemporal context and to the demands located within it.

We live in a society in which the technology clearly impacts on everyday affairs. This is why we must prepare our students to build the skills to evaluate and intervene intelligently in technological and scientific activities. In the current context, this role falls to science teachers.

The use of socioscientific controversies (SSCs) for teaching science and technology is increasingly emphasized in curricula and in research into science teaching. Certain elements of the science, technology, and society movement [6–8] refer to these subjects as socioscientific issues, which are an expression of the application of this movement's assumptions in the classroom. It is therefore more important to educate the population to take a position with relation to the scientific and technological revolution than it is to instruct and inform it.

2.1. Socioscientific controversies (SSCs)

In attempt to situate the reader, it is worthwhile to start by discussing what is meant by SSC, basing the discussion on the literature. The terms "controversial subjects," "scientific dilemmas," "socioscientific controversies," "socioscientific issues," and "contentious subjects" are all used to designate elements in common.

According to Rudduck [9], an issue is defined as controversial if it divides people and involves value-judgments that prevent it from being settled solely on the basis of analysis of evidence or by experiment. A controversy cannot be settled by an appeal to facts, empirical data, or experience alone, because it involves both facts and issues of values.

[1]This and all subsequent quotations from work published in languages other than English have been translated by the author.

According to Nelkin [10, 11], scientific controversies can be caused by: (a) the social, moral, or religious implications of a scientific theory or practice (e.g., issues related to cloning and genetic modification of living beings); (b) social tensions between individual rights and social objectives, political priorities and environmental values, economic interests, and health-related concerns that result from the application of technology; (c) by use of public financial resources for major scientific and technological projects to the detriment of other projects, such as, for example, for social ends. These controversies can also be referred to as socioscientific issues, that is, social issues provoked by scientific and technological developments.

Ramsey [12] defined three criteria for selection of controversial socioscientific subjects: (i) whether there are differences of opinion in relation to them; (ii) whether the subject has social significance; and (iii) whether the subject, to some extent, is related to science and technology.

According to Para Reis [13], controversial socioscientific issues (CSIs) are social issues with a considerable scientific and technological dimension, such as, for example, manipulation of the genomes of living beings, in vitro fertilization, and cloning; release into the atmosphere of substances with effects on public health, on the greenhouse effect, and on destruction of the ozone layer; use of hormones and antibiotics in animal production; environmental and public health issues.

Pérez and Carvalho [14] state that CSIs encompass debates, controversies, or subjects directly related to scientific and/or technological knowledge that have a major impact on society. According to Abd-El-Khalick [15], these issues are markedly different from the exercises or "problems" that appear at the ends of chapters of the text books used in the classroom. Such exercises are generally defined and cover multidisciplinary aspects that are very often loaded with ethical, esthetic, ecological, moral, educational, cultural, and religious values.

These authors argue that the characteristics generally observed in socioscientific issues are: (a) knowledge of a scientific nature; (b) formation of opinions and choosing between options; (c) frequent appearances in the news media; (d) local scope; (e) analysis in terms of cost versus benefit and of values; (f) awareness of sustainability; (g) permeation by ethical and moral rationales; (h) permeated by understanding of risks; and (i) normally, part of people's everyday lives.

We can see that even the definition of a controversy is a controversial issue. According to Velho and Velho [16], some authors consider a controversy to be a discussion between two parties about a particular subject in which their beliefs and arguments are at stake, which is a view that places controversy on a more cognitive or psychological plane. I therefore believe that controversies cannot be separated from a wider cultural context and are, therefore, social phenomena that are historically determined.

Faced with such a diversity of definitions, I have chosen to use the term "socioscientific controversies" and have adopted the following criteria for selection of the articles that make up our corpus for analysis:

(i) controversies that are provoked by the social impacts of scientific and technological innovations and divide both the scientific community and society in general;

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(ii) that which allows discussion between two or more involved parties on a given controversy, in which their beliefs and arguments are at stake;

(iii) whether, in relation to the controversy being discussed, people are divided because this reflection involves value-judgments that prevent it from being settled solely on the basis of analysis of evidence or by experiment.

2.2. Socioscientific controversies in Brazil

The proposal of working with the SSC in the classroom is relatively new and has received little publicity. For Brazil, searching with the dates 2001 to 2014, a total of 44 publications were identified in online periodicals dealing with science teaching, which suggested this type of approach [17]. Some studies list the educational potentials that discussing SSC in the classroom can leverage, not only for learning curricula content but also for learning about processes of a scientific and technological nature and for students' cognitive, social, political, moral, and ethical development [3, 13, 18–23].

Reis [13] conducted a series of studies investigating the educational impact of conflict and controversy in the classroom, finding that their use resulted in motivation, research, and interchange of information. Reassessment of individual positions, supportive relationships between the students, and appreciation of content and of the learning experience enabled development of logical and moral reasoning skills and a deeper understanding of the important aspects of the nature of science.

Reis and Galvão [19] believe that use of socioscientific issues can be important for the establishment of a link between the scientific culture (in which the scientific community participate) and science teaching.

Ramos and Silva [20] claim that discussion of controversial subjects allows students to acquire knowledge about the type of reasoning that motivates governments, scientists, and protest movements, and also a more realistic understanding of scientific and technological development, within its social and political context, and of its impact on the general public or on specific communities. They state that it is the school's and, therefore, the teacher's responsibility to create opportunities for discussion of controversial subjects, which are an ever growing part of daily life. Schools should provide science education that informs students of scientific developments since, in addition to being necessary, it is an indispensable social duty to provide them with science that is up-to-date, historical, social, critical, and human.

Galvão and Reis [3] add that it is the science teacher's job to encourage students to: research and select reliable sources of information; contrast different points of views with each other; search for necessary knowledge; familiarize themselves with scientists' practices, techniques, and theories, creating opportunities to relate this knowledge to their daily lives; debate the subjects; determine the benefits and harm that could result; and critically assess and form an opinion on controversial issues.

Vieira and Bazzo [21] state that discussing controversial socioscientific situations can offer students a more realistic image of science, whereas not including them in science teaching contributes to transmission of distorted ideas that often describe science as non-controversial, neutral, and disinterested.

Zuin and Freitas [22] describe how socioscientific controversies are not resolved by analysis of evidence such as empirical data. They state that we must pay special attention to considerations of ethics, morals, and values with relation to social elements and to conceptual, methodological, and technological elements related to science. Within this perspective, learning opportunities provided by teaching based on discussion of socioscientific problems have shown great potential for construction of a more realistic view of scientific development and for promotion of responsible citizenship.

Forgiarini and Auler [23] claim that another of the characteristics of controversial subjects is that they are given prominence in the press, on television, and in films, which may relate them to stereotypical ideas of science and technology and of the activity of scientists. It is accepted that both schools and the media can contribute to construction of misleading conceptions with relation to scientific and technological endeavors.

Forgiarini and Auler [23] also state that controversial subjects are still studied little in the classroom and highlight the reasons that lead many teachers to avoid them. According to Reis [13], one of the factors behind this absence could be: "[…] concerns about a possible failure of control during discussions, since there may not be correct answers, rather a diversity of value judgments" [13]. He recommends that the teacher should maintain a neutral position, that of a mediator, with relation to discussion of these subjects, in order to avoid revealing personal positions that the students might assume are correct. He states that the teacher's neutrality is of fundamental importance, because the students must be given the right to form their own opinions, and, therefore, the teacher should opt for neutrality during these discussions.

In addition to contribution to demystification of misleading ideas with relation to scientific endeavor, discussion of socioscientific controversies can also motivate students to express their opinions, to learn to construct arguments, and to take well-founded decisions with respect to scientific and technological development and its implications for society.

Reis also raises the suggestion that by using socioscientific controversies in science teaching, we can cover a range of different curricular content. This process can be conducted in an interdisciplinary manner, in the form of a collaborative effort involving teachers from several different subjects (general science, history, geography, chemistry, physics, and biology, among others).

2.3. Constraints on and potentials of socioscientific controversies in Brazil

A study conducted by Duso [17] identified work that focused on socioscientific controversies published from 2001 to 2014 in Brazilian periodicals dealing with science, available on-line, and indexed with the terms "controversial subjects," "contentious subjects," "socioscientific controversies," "contemporary subjects," or "socioscientific issues" in their subtitles, titles, abstracts, or keywords. The study located 44 papers published in the journals selected.

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The authors of these articles pointed out the difficulties faced by teachers who, in general, do not have the skills to manage and direct classroom discussions nor the knowledge needed for discussion of socioscientific issues with relation to the nature of science and the sociological, political, ethical, and economic elements of the subjects being discussed. Additionally, they also deal with the difficulties involved in assessing activities involving discussion of socioscientific controversies and/or the pressure exerted by national assessment systems that do not place value on this type of discussion, creating barriers to effective adoption of this approach.

One of the major problems of teaching, highlighted by Shulman [24], Carr and Kemmis [25], and Tardif [26], has been the lack of individual and collective systematization of teachers' experiences, which has resulted in a real absence of history and practice, without which it is difficult to conduct an analysis of its principles. This is why Lee Shulman's studies are important, because they follow teachers at different levels of education and constitute a considerable number of cases, in which their reasoning and actions while in service were recorded.

Shulman's contributions with relation to teacher's knowledge of their subjects' content are of interest in teacher training, because I consider that this knowledge helps to construct teachers' autonomy. Nevertheless, it is important to point out that achieving autonomy is not limited to teachers knowing their subjects' content, which is still in the personal dimension of a teacher's professional development, since it is also necessary to cultivate the social dimension, because teachers' autonomy is an especially collective process and not only an individual process.

Content is no longer discussed, it is simply replicated and derived. In contrast, training is a concept that must be problematized and reformulated, working from the concepts and the objectives of science teaching.

According to Fourez [27], there are divergent positions on the utility of training in epistemology, history of science, and interdisciplinary approaches, because of the complex situations or the fundamental questions provoked by scientific models. The collective dimensions of scientific work should be fostered, organizing interdisciplinary working groups and facilitating interaction between different groups of teachers from different subject areas and the scientific community.

Along the same lines, Forgiarini and Auler [23] state that teacher training that is excessively fragmented and disconnected from the social context exacerbates the extent to which the true situation is different from the ideal. They point out that the great majority of teachers suffer from knowledge gaps, from a lack of information related to controversial subjects, because controversial socioscientific issues are considerably different from the types of problems that are generally dealt with in science lessons.

However, in some of the articles analyzed, while the importance of collective working is highlighted, teachers from subjects in the humanities are not considered to have so many obligations with relation to the circumstances of controversies related to scientific subjects. The most excessive criticisms are leveled at biology teachers, possibly because of the specificity of the curricula content linked with this science.

Levinson [18] considers that science and humanities teachers have complementary strengths and weaknesses. While teachers from humanities subjects are more at home with controversy, Science teachers have greater knowledge of scientific concepts. Collaboration has useful contributions to make, but, unfortunately, the teachers from these different spheres rarely work in cooperation.

If collaboration between teachers can be fostered, the classroom can become a forum for discussions in which the students participate actively, demonstrating their interests and knowledge about the most varied range of subjects, which can be dealt with not only with regard to scientific knowledge but also in relation to their social significance and impact. This will give them the opportunity to experiment in a variety of forms or from different perspectives with the points of view of different social groups, which in turn makes dialogue over the limitations to and possibilities for debates about controversial socioscientific subjects possible.

I understand that it is not feasible to work with controversial subjects by exclusively drawing on subject knowledge. Contributions are needed from multiple fields of knowledge. This is why cooperative work is extremely necessary, so that all participants can make contributions from their own area of expertise to analyze the many different dimensions involved.

It is also indispensable to conduct in-depth studies with relation to controversial subjects, in order to avoid simplification of complex issues, and it is necessary to engage in coherent epistemological reflection on science and technology, acknowledging the impossibility of obtaining answers to all questions exclusively on the basis of technical and scientific knowledge [19], choosing working methods that are appropriate to the objectives that discussion of controversial issues in the classroom is intended to achieve.

2.4. The project teaching method as an option for integrated teaching practices

The project teaching method was pioneered by John Dewey and Kilpatrick in Chicago at the start of the twentieth century with the objective of resignifying the school environment to make it more open to real life. This approach was taken up and championed by Freinet, in France, in the 1920s and 1930s.

Kilpatrick believed that the foundation of all education is guided and decided activity. In other words, all school activities could be conducted in the form of projects, with no need for special organization.

In turn, Freinet [28] did not explicitly propose using this method, but did vehemently argue in favor of the idea of work as a vital function of each and every individual. This is the school of work that becomes the school of life, and each will become the other.

Jolibert and colleagues were influenced by Freinet's ideas and constructed a proposal based on working with projects. They proposed organizing work on the basis of principles such as the collaborative life, students' appropriation of their own school lives, and organization of teaching into projects. Jolibert [29] believed that the project teaching method allows school life to be founded on the real, open to multiple relationships with the exterior, and in which the students take an active part in their own learning.

This concept is founded on a globalizing and interdisciplinary view of organization of schools' curricular content. Within this proposal, it is possible to combine study of significant contemporary problems by groups of students and teachers with the content of school subjects, respecting their interests and their requirements and taking students' concepts, hypotheses, and knowledge as a starting point.

There are many different approaches to working with projects, following different methodological paths. The approach that is advocated in this text is the result of certain reflections on and experiments with implementation of integrated projects in a secondary school.

Working with the project teaching method proposes changes in the teacher's role, which becomes that of a guide and a researcher who both challenges and learns. The objective is to foster in the students an understanding of the problems investigated, going beyond the information provided and recognizing the different versions of a fact, proposing explanations and hypotheses and engaging in dialogue on different points of view.

Secondary education is possibly the most appropriate time to work with interdisciplinary projects, since it is a period during which young people are going through a process of transition between childhood and adulthood and is therefore a stage in which they are defining their future roles in society. As Hernández [30] puts it, "[…] the school culture takes on a function of remaking and renaming the world and of teaching students to interpret the changeable meanings with which people in different cultures and historical periods give meaning to reality."

When working with integrated projects, the activities are organized on the basis of students' experiences, motivations, expectations, and interests, and it is assumed that working groups will be formed that enrich through meaningful collaboration. The subject matter is not predetermined, because it is the result of an open process, and is explored in relation to the students' everyday lives, so that they gain a cognitive, emotional, and relational understanding of the phenomena of the world that surrounds them.

2.5. The constraints on and the potentials of the project teaching method

According to Santomé [31], certain constraints are because of a lack of adequate planning, of work in small groups, and a lack of motivation for work that is not appropriately remunerated. Compounding these elements is the prejudice against using projects because of ignorance of their meaning and lack of professional preparedness.

We should take into account the way teachers are trained by specific subject area. According to Schor [32], as a result of the specialization of scientific knowledge, certain problems emerge that demand a collaborative approach, that is, it is necessary that specialists work together collectively. We cannot expect that subject teachers will engage in integrated work if it does not fit in with their specialties. A lack of experience during training, both initial qualification and ongoing education, with an integrative curriculum approach can create constraints.

However, according to some authors, what is reported is that working with project teaching method is a challenge for teachers, since this dynamic implies that they must take on the roles of teachers, researchers, and mediators, leaving aside their roles as transmitters of knowledge to become mediators of learning, encouraging the formation of autonomous students, capable of acting and interacting in the world in which they live. The project teaching methodology, with activities conducted within the project, leads to considerable changes in students' behavior, interest, and motivation with relation to learning the subject.

One of the potentials of using integrated projects is the students' involvement in the process of construction of knowledge and of seeking solutions to problematic situations, in addition to positive changes in relation to day-to-day attitudes and greater motivation and involvement in the learning process.

Although it is difficult for teachers to achieve a good balance between the elements of the triad "subject matter," "activities," and "assessment" in the classroom, students are able to demonstrate and re-elaborate earlier concepts, which I consider to be of great importance in the construction of knowledge.

Beane [33] sees curricular integration as a concept that is concerned with the possibilities for personal and social integration through a curriculum that is organized around significant problems and questions, identified in a collaborative manner by the teachers and students, irrespective of the demarcations that separate subjects.

However, difficulties are encountered, especially with relation to the issue of bringing the humanities closer to the sciences. In the majority of cases, integration between these different groups of subjects proves to be a practical problem that is difficult to solve. The difficulty lies in establishing a set of common repertoires that will enable dialogue.

In view of the above, the SSC approach can be considered an ideal way to achieve curricular integration in teaching, since all of the different subject areas will get the opportunity to contribute a great deal of subject matter to the discussion.

3. Methodology

In order to understand the SSC approach using the project teaching method, I observed the planning of some of these projects in real teaching situations, thereby delineating their limits and possibilities in this area.

The SSC approach used in combination with integrated projects was observed in a private school that provides both Secondary and Technical Vocational education and is located in the state of Rio Grande do Sul, Brazil.

Data were collected by administering questionnaires containing open-ended questions to the 42 teachers with the objective of obtaining information on the conception that these teachers had of SSC, and of their constraints and potentials for teaching. This questionnaire was also designed to provide an understanding of teachers' concepts with regard to organization and application of projects conducted in the school and the constraints and potentials for using them in teaching. Fourteen teachers completed the questionnaires.

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After collecting the teachers' responses to the questionnaire, it was necessary to conduct unstructured interviews [34] with the objective of probing in greater depth the research participants' thoughts with relation to use of SSC and the way the projects are organized at the school.

These interviews were conducted with the school's Principal, the Vice-principal responsible for teaching and three teachers, one from each subject area (languages, humanities, and sciences), selected using the criterion of longest time teaching at the school.

The data collected were analyzed using Discursive Text Analysis [35]. This analytical resource was used to systematize information from the questionnaires and to construct an interpretation of the subject in question from the point of view of the research participants. This analysis, which is coherent with the qualitative approach chosen, facilitates comprehension of the phenomenon investigated with no intention of generalizing or explaining it.

During this analysis, the questionnaires were read and organized into units and assigned to a system of categories that provide the basis for construction of descriptive texts (metatexts) that would be used to interpret the phenomenon studied.

In order to organize these units, a labeling system was adopted in which units from questionnaires were marked with a "Q" and those from teachers with a "T." The units were numbered from 1 to 14 to represent the respondents, with no relationship between the number and the respondent. Finally, units were also labeled with the number of the questionnaire item, separated from the number of the respondent by an underscore character (_).

Next, the interviews were transcribed but were not categorized, rather they were used as a basis for in-depth discussion of the constraints and potentials identified in the data from the questionnaires. Data from the questionnaires and the interviews were combined to construct a metatext. To identify the teachers interviewed, I used the same numbers as for the questionnaires, adding the letter "I" to indicate interview data. The Principal is identified with the label "Prin," and the Vice-principal responsible for teaching is identified with the label "VPT."

4. The constraints on and potentials of projects in the school

The principal constraint, mentioned both by the Vice-principal for teaching and by the teachers, was the time allotted by the school for planning projects, as can be observed in the following extract: "[…] we should have more time for discussion" (IT14). This time could be apportioned during the school's teachers' meetings, since this is an activity that goes beyond the teachers' normal classroom activity. The same constraint was also identified by the Principal.

> *[…] the obstacles to them having more time to plan are administrative, teachers should nowadays have "teacher's time" and be paid for it, teachers do it on their own time, just like they grade tests, they do it as part of their jobs, but if we look at it properly, it would be more time for planning than, including paid time, perhaps more meetings. (IPrin)*

Another constraint, highlighted by the Vice-principal, is related to teachers who also work for other educational institutions: "[…] also considering the teachers' working hours, considering their involvement, sometimes, with more than one institution, well this caused some difficulties" (IVPT). This constraint, compounded by the lack of time, means that the teacher also needs to make more time available outside of the school.

> *It's obvious that there are certain barriers to this approach, but it demands that the teachers make themselves available beyond their involvement with the school. It requires teachers to talk to their peers both inside and outside of the school environment. (IVPT)*

However, despite the existence of these constraints, it is clear, in what was said by the history teacher, for example, that: "[…] we integrate and I loved meeting up to plan and grade the projects and we grew together with others who have different points of view, because we also have to negotiate" (IT4). This situation of integration and discussion of the debate encourages reflection within the group that is already working with projects.

It should not be forgotten that there is turnover among the school's teaching staff, that is, new teachers are contracted who had not taken part in the discussions about the projects. Therefore, new teaching concepts should be expected and also that teachers will be contracted who do not have this understanding of what working with projects is or how it is done.

> *Obviously, some people were not disposed, obviously they could not continue to work here because they were unable to work within this system. This is perfectly understandable, without detracting from, without considering that there is any lack of merit in these teachers' professional activity. They have to be respected, within their own concepts of education. (IVPT)*

In addition to the constraints reported above, issues related to paperwork and training also stand out in the interviews, such as, for example, personal issues, as illustrated in the following excerpt from the interview with the Portuguese language teacher: "I think that today the barriers are, on my part, overly optimistic expectations with relation to the presentation of projects; I always expect much more than the students produce" (IT13).

This constraint related to the expectations of a languages teacher was not observed in the transcripts from the humanities teacher. Here it is clear that when they are working with projects, the students tend to become more involved in the teamwork dynamic, which provides openings for exchange of ideas, which are sometimes different from the teacher's ideas.

> *[…] when we do an integrated project, we automatically involve the students and the students integrate and the students get a feel for the school, they work within a different perspective in which evidently the subjects don't matter, but they do matter, you know? But there is a type of socialization, of knowledge between all of the teachers, and with the students, and it becomes clear that many things, for example, what it means to work in a team; I think that the students take this experience away with them, because they end up, respect for human beings, because they are discussed, they're not imposed, so I have to accept that, very often, it's not how I think, so it is an exercise in democracy. (IT14)*

As the Vice-principal pointed out, when the theme is based on subjects that are more significant to the students, there is an observable increase in their involvement in the project.

> *[…] the advantages are obvious, to the extent that the students were involved in executing these projects, and they became more relevant each time, as we managed to focus on subjects that were significant to the students, as well. So, to the extent that we improved or perfected these subjects, the students' involvement with this is huge, in relation to this. (IVPT)*

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We can also see that the projects approach employed at the school enabled greater integration not only among the students but also between them and the teachers. This multiple integration is superior to pure memorization of curricula content with little meaning and depends upon a dialogue between different points of view. The result is an amplified view of the world and makes it possible to "[…] form a critical and creative person, at one with their times, who can collaborate in construction of a better society, you know? You see lots of all of this in the integrated projects, you see it in action, they have thousands of ideas" (IPrin). The teacher (IT13) confirms this:

> *[…] they (the students) have a much richer view of the world, […] a completely different reality, including to me, because I was also unaware, so you realize that we live in a much larger world, with those we live with. (IT13)*

We can see, in the interviews with the management team and with the teachers, that they have a number of different conceptions with relation to the nature of the projects that are run at this school, their planning, and the possible ways of implementing them. Their expectations are primarily linked to issues with the time available for planning and discussion with groups of teachers and are associated with a lack of teachers' meetings at the school.

Therefore, analyzing the interviews with my interlocutors, I was able to identify the many constraints that could make use of projects impossible, and I was also able to reflect on other spaces in the school dynamic where it would be opportune to expand this discussion.

5. The SSC approach in the school

Within this universe of reflection about integrated projects and their relationship with the school, I consider that it is opportune to discuss SSC and consider the possible contributions that this approach can make to enhance the project teaching method.

Socioscientific controversies emerge from the social impacts of scientific and technological innovations that cause controversy in both the scientific community and society in general. I talked to the management team and to the teachers, attempting to understand the concepts that underpin their points of view with respect to SSC.

During the years that the school used projects, there were times when controversial subjects were covered, but this was not explicit. Approaching and dealing with SSC in the school context can encourage discussion of different points of view on the same subject and contribute to students' and teachers' moral development and to building their argument skills and can also contribute to an improved understanding of the scientific process as a whole.

5.1. The constraints on and potentials of SSC

The responses to the questionnaire and my conversations with the interviewees brought up certain constraints that are unfavorable to adoption of the SSC approach. Among these constraints, I highlight "Curricular planning and time" and also "Insecurity with discussion of the subject." It will be noted that the time available and the space dedicated by the school to discussion between teachers once more figure as constraints, because, as one teacher pointed out, it is important "[…] that we discuss this among the teachers, isn't it? And everyone thinks along the same lines, you know? I think it's a good idea for us to approach it as a group […]" (IT14) to plan the project. This particular excerpt underscores the concern that all the teachers should think along the same lines with relation to the controversy to be dealt with. For this reason, this constraint can be linked to insecurity with discussion, with epistemological reflection, and with the treatment needed for use in projects.

> *[…] there are people who are in favor and people who are against, but that's it, the maturity, that the teacher's nakedness to, to be able to reach closure in each of these subjects, without giving his own opinion, agreeing or disagreeing, but then it is the adult's point of view, that has to end it. (IT13)*

The same teacher (T13) refers to the issue of neutrality in the discussion process "[…] because if the teacher also more or less sits on the fence, then he doesn't know and then the student realizes this, particularly adolescents, they will realize this […]" (IT13), thereby creating an obstacle to mediation of the subject being discussed.

> *[…] the teacher has to be very adult and take this position, of an adult, he can't give an opinion that he agrees, disagrees, I accept, don't accept, that's not it, he has to play the role of someone who is mature for power, provide a compass, you know? I think that's the teacher's job. (IT13)*

Other constraints are related to "teaching materials and supporting materials," as seen in an excerpt from another teacher: "These controversies, sometimes, are not covered in the teaching materials" (I14). This element is also highlighted in articles and by researchers [13, 21, 23] who use the SSC approach.

Another of the constraints that was cited was "assessment," and there were no comments specifically related to learning during the interviews. I therefore conclude that this may be related to insecurity with dealing with the subject, since, when assessing a discussion of controversial subjects, the teacher cannot only consider one point of view to be correct.

When asked about the potentials of using the SSC approach in lessons, the teachers considered that they provide motivation for the students to seek information on current issues. Taking into consideration the concepts involved in dealing with controversies, one teacher (T1) answered a questionnaire item as follows: "I think that this approach is always motivating and provoking, because it drives me to seek more information and greater precision with relation to the concepts covered" (QT1_5).

Other teachers stated that the controversies approach promotes better understanding of reality; as follows: "[…] it helps with development of critical reasoning and position-taking, helping students to think like a citizen and see beyond appearances[…]" (QT3_5), providing "[…] awareness of the facts and changes that are a part of learning […]" (QT4_5) and, therefore, "[…] gives significance to the students' reality" (QT14_5). A different point of view on potentials is revealed in another teacher's response: "It is important since they are who will continue scientific and technological develoxpment and presenting them with these controversies is a way of making them reflect so that in the future we can achieve better solutions than the current ones" (QT10_5).

My understanding is that including SSC among the subjects of the projects run at the school is relevant, since it provides an opportunity to discuss controversial subjects in society. Nevertheless, this challenge should be accepted in an integrated manner across the curriculum and within organization of the subjects and not delegated to just one subject department, because of the complexity of the subjects involved and their didactic organization. The school's Vice-principal responsible for teaching argues along the same lines:

> *Nowadays, I don't think it is conceivable any longer to analyze any controversy from the point of view of just one subject. I think it would be almost impossible. Perhaps, in my view, it is almost impossible, or such an analysis would be very prejudiced, or it would not be sufficiently enriched to even merit analysis of its results because of the bias introduced by the concepts of a specific subject. (IVPT)*

This perspective is shared by teachers from the different subjects themselves.

> *[…] that is exactly what the project is for, we identify certain issues which, after the curiosity, the asking of questions, these specific issues will be discussed with each student in the classroom, so perhaps, in Sociology they will discuss (one angle), and in History another, and in Geography they'll discuss another, I think it's more or less like that. (IT14)*

These contributions from the management team and the subject teachers show that some of the constraints are related both to planning the projects and to the way that SSCs are approached. Time is one of the most important elements to be considered in this context, followed by the challenge of directing discussions when there are differing positions on a given subject. Divergent points of view can arise among the group of teachers who are planning and organizing the project as well as among the students during lessons.

Despite these constraints, we can see that implementation of this approach in a school that is already methodologically committed to a perspective that values curricular integration appear to be appropriate and could potentialize this integration even further. The school understands that current issues that cause controversies should be dealt with through projects in several different subject areas, rather than be focused on just one branch of knowledge. In this chapter, I defend the claim that the SSC approach can potentialize this integration, not only by bringing the subjects together but also by encouraging wider curricular integration.

6. Some considerations

It is our belief that it is not enough to rely on traditional subject-based teaching alone, in which information considered relevant is provided by the teacher, with content isolated from its context. Rather, it is necessary to use methodologies that enable the integration of concepts across different subjects to be perceived in a clear and objective manner, taking advantage of the experiences provided by the environment of which the students are part, combined with an approach using socioscientific controversies to provide opportunities for discussions that are not restricted to scientific knowledge.

However, I have also shown some of the limitations of this type of activity, many related to planning its use within the daily routine of the school, describing a series of factors that are impediments to its effective implementation. These factors are linked to issues from a range of different domains, including of a political, emotional, and structural nature, in addition to elements related to training and qualifications. However, these limitations could be resolved if the teaching staff involved in a collective project were able to discuss strategies to overcome them. It is clear that some factors are not easy to resolve and, in some cases, are under the control of the school's Principal and Vice-principal, such as allocating space and time for more effective discussions to take place, in addition to more adequate remuneration for the teachers.

The analyses of questionnaires and interview transcripts enabled us to identify the principal factors that interfere with using controversial subjects in the classroom. One of these aspects is emphasis on memorization and the little attention given to aspects related to the process of construction of scientific knowledge or to the epistemological aspects of science. This is strongly linked to teachers' initial training, where the emphasis is on depositing the subject content learnt, passing it on to the students so they are instrumentalized to pass external assessment exams and university entrance exams, ignoring the context and the reality of society.

Another factor is the teachers' lack of experience and, consequently, the students' lack of experience with discussions in the classroom, which means they do not have the necessary skills for this type of activity. Of particular importance is a lack of knowledge about how to design and manage classroom discussion activities, obviously in relation to controversial subjects. Although they did use a space for, for example, simulation of a jury, the teachers had concerns with relation to mediating these activities. This insecurity, related to a lack of experience, demonstrates the extent to which theory and practice are separated in the classroom. Both initial training and ongoing education explore the importance of group activities and of discussion, but teachers do not have experience with these activities, making it less likely that they will employ them.

Other constraints are related to the large quantity of curricular content in science subjects; the teachers' concepts of science teaching and the socioscientific issues approach; and a lack of educational resources. These teachers end up opting for direct presentation as teaching strategy and concern themselves with transmission of knowledge, filling their lessons with fragmented elements from the curriculum, when they could be utilizing aspects of knowledge production and the epistemology of science, with the result that they create an idea of science as pre-established content that the students must master.

It is our understanding that using the SSC approach within the sciences alone will not achieve integration between the different subjects. Along the same lines, taking this approach to teaching the humanities or languages, in isolation, will also fail to achieve this success. The project teaching method is one means of bringing these subjects together, because it works, organizes, and teaches in a way that is collective and integrative, making the social dynamics of working groups explicit and providing opportunities for integration.

In addition to integration, which is fostered by the project teaching method, we need to go further, by planning projects with the SSC approach, since, in order to develop citizenship, we cannot limit ourselves to discussion but must provide opportunities for the students to act on their discussions, that is, enable them to go beyond the school walls and into society, motivating them to exercise their citizenship.

Analysis of the teachers' responses showed that, in general, the staff are open to new ways of working, including the strategy proposed, involving use of socioscientific controversies in an

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integrative manner. Many of them pointed out that they already include different ways of working in their practices, albeit in an isolated manner, which reveals a fresh view on their conceptualizations of teaching, students, and education. Working from the constraints on and potentials of discussion of socioscientific controversies within an integrative approach, I believe that we need to rethink the way that initial teacher training and ongoing education are constituted. It is important to help them to internalize the educational relevance of this type of educational experience and to develop the teaching knowledge necessary to implement it in the classroom setting.

I believe that the constraints and potentials raised by the teachers with relation to this type of practice in the school are potentialized by explanation of the contradictions between what is possible and what limits effective use. From this perspective, it is possible to understand what the “constraints” are and how they operate and how, sometimes, they can be overcome. Taking them as a basis, it is necessary to undertake planned actions to ensure that this type of discussion is included as part of teachers’ training, going beyond identification of limiting factors, in the direction of achieving better knowledge of and interaction with reality.

When faced with difficulties, teachers should attempt to evaluate the reasons behind the success or failure of the approach adopted. It is likely that they will not be inherent to the methodology proposed but to the way it has been conceived and managed. Particular attention must be paid to the subject and structure of the task, to the composition of groups, and to the social skills that are needed to complete the activities that follow.

Another concern related to using discussion of socioscientific controversies in an integrative model is that this approach could tend to be transformed into just another teaching resource for convincing students that scientific knowledge, because it is different, has greater validity than other types, or that it is the only knowledge that should be taken into account for decision-making. I believe that this can often lead to discussion of controversies being seen as an instrument exclusively for learning scientific knowledge, reducing a debate that could be much wider-ranging, because scientific discourse is seen as an instrument for understanding human controversies.

Teaching with Integrated Projects, allied to the SSC approach, can enable an expansion of horizons and lead to perception of the implications for understanding the reality of the curricular content of each of the subjects. In addition to this advantage, the practice can help students and teachers to perceive the importance of an integrative view of knowledge, stimulating them to advance beyond education bound by the domains of the content of a single subject. This study appears to show that the project teaching strategy is a promising way to transform the student-student, student-teacher, and teacher-teacher relationships in the classroom.

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Chapter 7

Software for Simulation of Static Switch Controllers

Marius-Daniel Marcu, Popescu Florin Gabriel and
Niculescu Titu

Additional information is available at the end of the chapter

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Abstract

In the power supply systems, static converters are increasingly used to feed every kind of consumers. Static converters are used widely in electric drive systems for the change in voltage and/or frequency power of electric machines. The authors realized a Windows software application to simulate the static converter function which is used for better understanding of the students. This software is realized like an independent application helping with Visual Basic software package.

Keywords: static switch converters, software development, Visual Basic, operating regime simulation

1. Introduction

The development of industrial automation leads by default also to the improvement of electrical drive systems as more than these systems represent the most spread conversion type of the electrical energy in the mechanical energy.

Hereby, by an adequate command given by a controller into a close circuit, the static converters adjust the output electrical energy parameters, to the necessity demand by an electrical motor.

The static switch controllers are converters where the exit size has the same form with the entry size. By changing the control angle of the converter thyristor is obtained a variation of the effective/average value of the output voltage [2, 3].

2. AC switch controllers

2.1. Single-phase AC switch controllers

In the case of these static converters, the control angle α of the thyristor is defined as the angle determined from the time of zero crossing of the voltage up to input in conduction of the thyristor [2, 5].

The AC switch controllers are AC to AC static converters. The converter output voltage is chopped so that the RMS value of AC output voltage is modified with change of the switching period of the power semiconductors.

Figure 1 shows a single-phase AC switch controller scheme and the voltage waveforms. The switching angle α can be modified between 0 and π. If the switching angle is $\alpha = 0$, the output voltage is $u_s = u_{smax}$ [3].

The instantaneous value of output current is given by Eqs. (1–3) [2, 5]:

- For resistive load:

$$i = \begin{cases} \frac{U_m}{R}\sin\omega\cdot t & \text{for} \quad \omega\cdot t\in[\alpha,\pi]\cup[\pi+\alpha,2\pi] \\ 0 & \text{for} \quad \omega\cdot t\in[0,\alpha]\cup[\pi,\pi+\alpha] \end{cases} \tag{1}$$

- For inductive load:

$$i = \begin{cases} U_m\left[\sin\left(\omega\cdot t-\frac{\pi}{2}\right)-\sin\left(\alpha-\frac{\pi}{2}\right)\right] \\ \quad for \quad \omega\cdot t\in[\alpha,2\pi-\alpha]\cup[\pi+\alpha,3\pi-\alpha] \\ \quad 0 \quad for \quad \omega\cdot t\in[0,\alpha]\cup[2\pi-\alpha,2\pi] \end{cases} \tag{2}$$

- For resistive-inductive load:

$$i = \frac{U_m}{\sqrt{R^2-(\omega\cdot L)^2}}\left[\sin(\omega\cdot t-\varphi)-e^{-\frac{R}{\omega\cdot L}}(\omega\cdot t-\alpha)\sin(\alpha-\varphi)\right] \tag{3}$$

The output current average value can be determined with Eqs. (4) and (5):

- For resistive load:

$$I_{med} = \frac{I_m}{2\pi}(1+\cos\alpha) \quad \alpha\in[0,\pi] \tag{4}$$

- For inductive load:

$$I_{med} = \frac{2I_m}{2\pi}[\sin\alpha+(\pi-\alpha)\cos\alpha] \quad \alpha\in\left[\frac{\pi}{2},\pi\right] \tag{5}$$

These values are useful for dimensioning of power semiconductor devices of the switch controllers.

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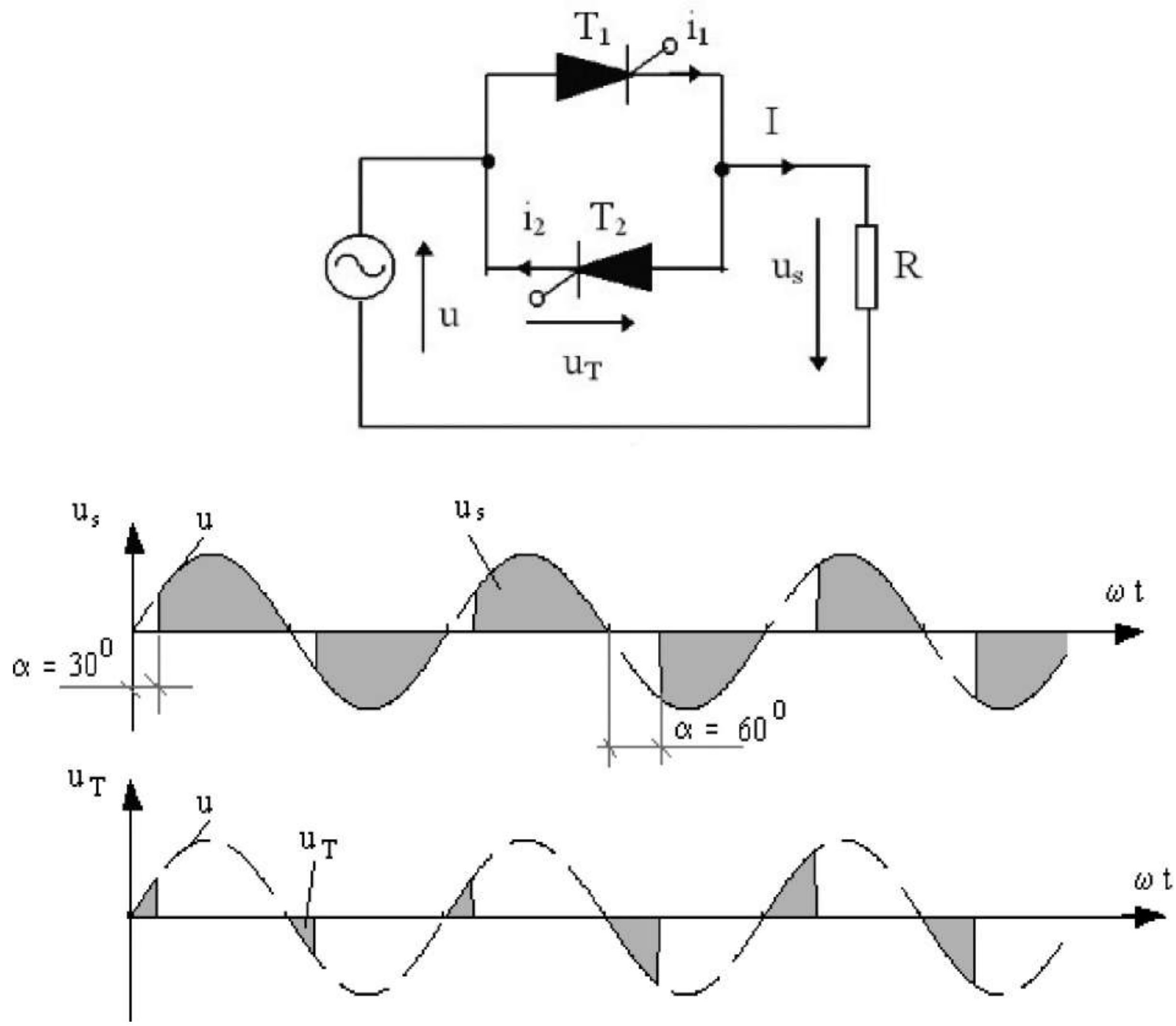

Figure 1. Single-phase AC switch controller electric scheme and the voltage waveforms.

The RMS output current is given by Eqs. (6) and (7) [2]:

- For resistive load:

$$I_{ef} = I_m \sqrt{\frac{1}{\pi}\left[\frac{1}{2}(\pi - \alpha) + \frac{1}{4}\sin 2\alpha\right]} \tag{6}$$

- For inductive load:

$$I_{ef} = I_m \sqrt{\frac{8}{\pi}\left[(\pi - \alpha)\left(\cos^2\alpha + \frac{1}{2}\right) + \frac{3}{4}\sin^2\alpha\right]} \tag{7}$$

Figure 2 presents the output current waveforms of the AC switch controller in the case of using different kinds of loads, and for different values of the switching angle α [5, 8].

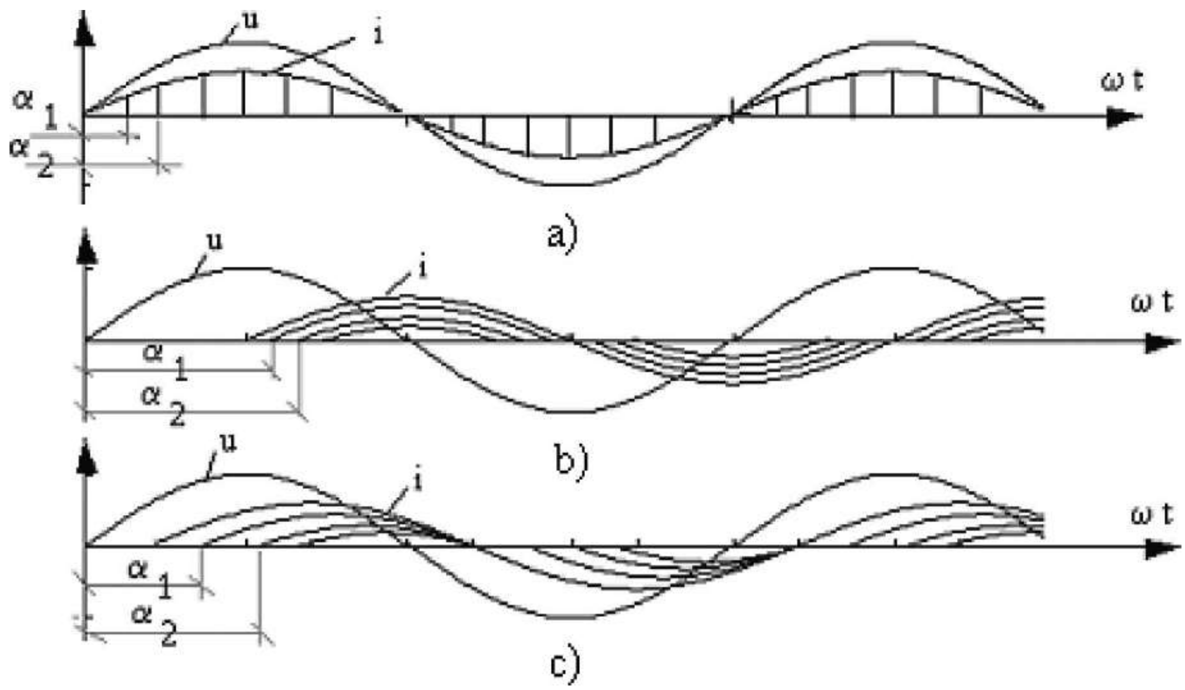

Figure 2. Current waveforms for a resistive load (a), inductive load (b), and a resistive-inductive one (c).

The AC switch controllers can be designed using only one thyristor. **Figure 3** presents the basic schemes and the output waveforms of these AC switch controller types.

2.2. Three-phase AC switch controllers

The three-phase AC switch controllers are designed using three single-phase AC switch controllers (k_R, k_S, k_T), one for each phase (**Figure 4**). The switching angle for each of the single-phase AC switch controllers is the same, but they must be phase angle with 2π/3 [3].

By changing the control angle, α, of the thyristors from each phase, changes the power absorbed by load between the maximum value and zero. Order the thyristors is performed using of the control device grid (DC), which must ensure a phase shift of the control pulses of 2π/3 between the phases [2, 5].

Variation the ignition angle of the voltages and of the currents depends on the load nature.

The voltage waveforms are determined from the vector diagram shown in **Figure 5**.

So, the voltage U_{KR} on a single-phase of R phase is zero on the period while one of two thyristors leads. The length of time while the thyristors are blocked, the load neutral point moves from 0 to 0′ and the voltage thyristor will be 3/2 U_R corresponding phasor $U_{0'\mathbf{R}}$. The voltage values are as follows:

- single-phase AC switch controller voltage is given by Eq. (8):

$$u_{kR} = \begin{cases} \frac{3}{2}u_R & \text{if} \quad k_R - \text{switch} - \text{off} \\ 0 & \text{if} \quad k_R - \text{switch} - \text{on} \end{cases} \tag{8}$$

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output line-to-line voltage is fit Eq. (9):

$$u'_{RS} = \begin{cases} u_{RS} & \text{if} \quad k_R, k_S - \text{switch} - \text{on} \\ -\dfrac{1}{2}u_{ST} & \text{if} \quad k_R - \text{switch} - \text{off} \\ -\dfrac{1}{2}u_{TR} & \text{if} \quad k_S - \text{switch} - \text{off} \end{cases} \tag{9}$$

output phase voltage (depending of the single phase switch converters which are in conduction) is given by Eq. (10):

$$u'_{R} = \begin{cases} 0 & \text{if} \quad k_R - \text{switch} - \text{off} \\ u_R & \text{if} \quad k_R, k_S, k_T - \text{switch} - on \\ \dfrac{1}{2}u_{RS} & \text{if} \quad k_T - \text{switch} - \text{off} \\ -\dfrac{1}{2}u_{TR} & \text{if} \quad k_S - \text{switch} - \text{off} \end{cases} \tag{10}$$

Figure 6 presents the voltage waveforms for a resistive load of an AC switch controller.

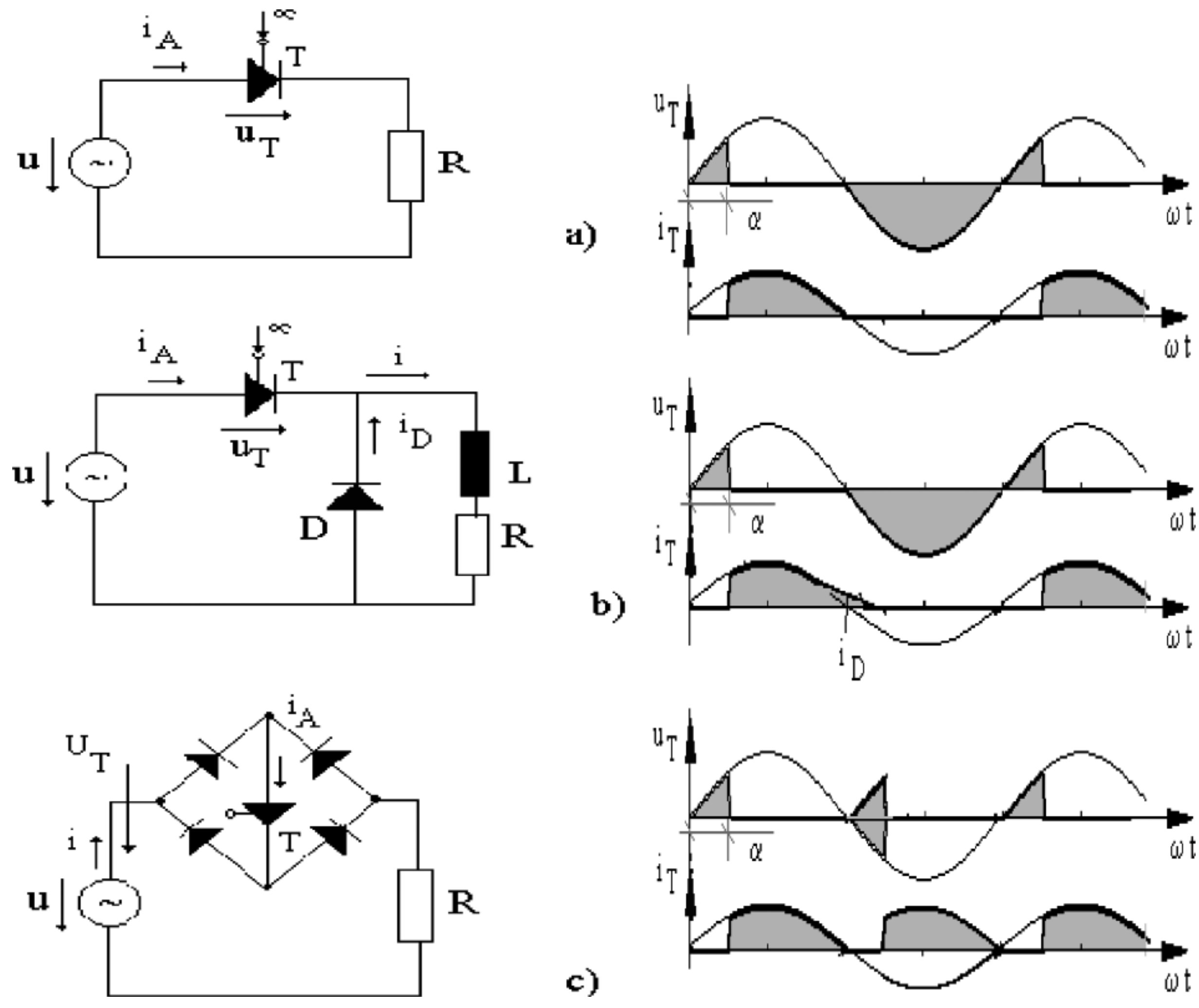

Figure 3. Basic schemes and output waveforms of different AC switch controllers: a) with one thyristor, b) with one thyristor and a diode, c) with one thyristor in a diode bridge.

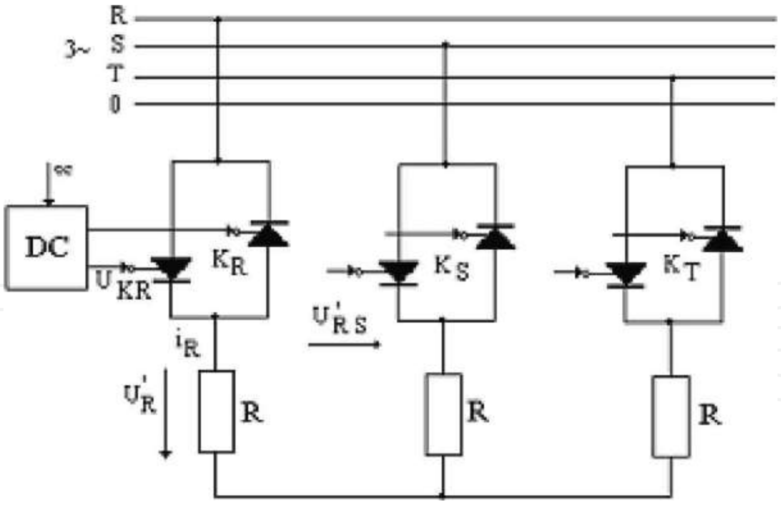

Figure 4. Three-phase AC switch controllers electric scheme.

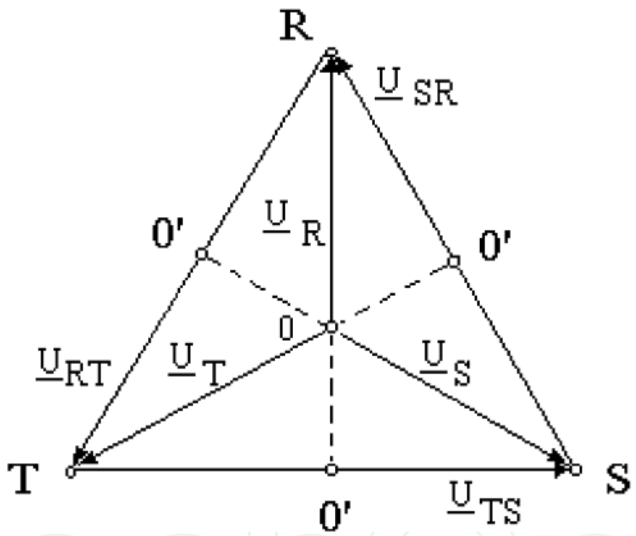

Figure 5. Vector diagram.

Because the load is resistive, the current waveform through the load is the same as the voltage phase raised on another scale.

In the case of an inductive load, the voltage waveforms are obtained similarly like in case of resistive load, but the thyristor ignition angle (α) is between ϕ and π, where φ is the delay angle between voltage and current due to the load. The current and voltage waveforms for an inductive are present in **Figure 7** [2, 3, 5].

If the three-phase AC switch controller supplies AC motors, the supply system must have the possibility to change the phase sequence to obtain a reversible drive system.

Figure 8 presents two schemes of AC switch controllers for reversible AC drive systems.

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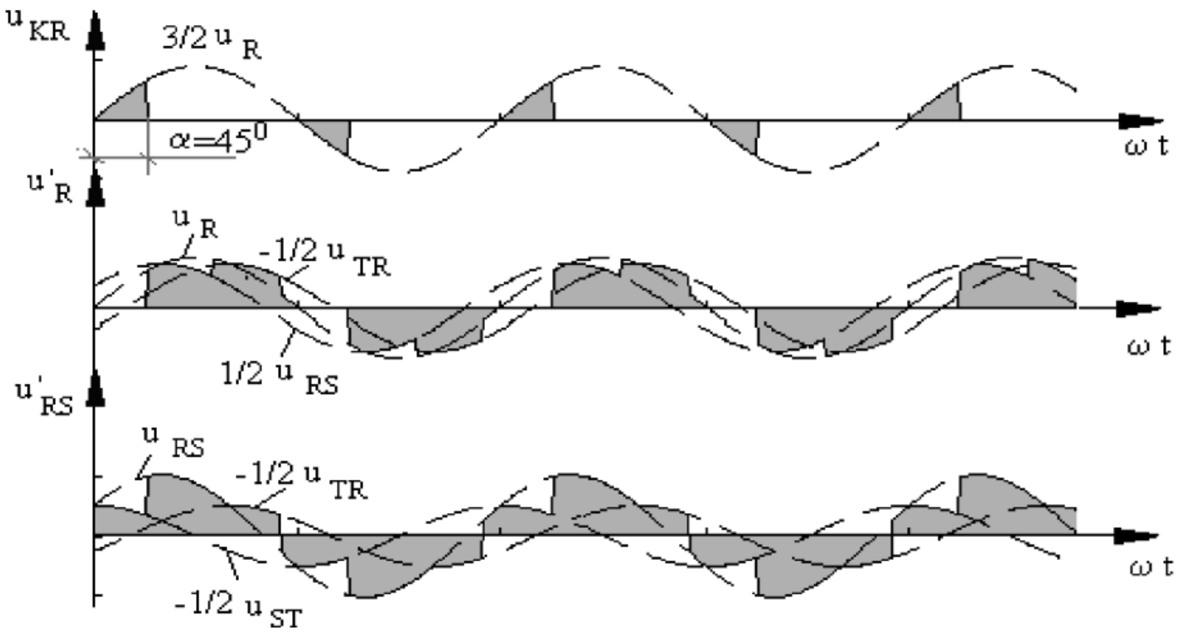

Figure 6. Voltage waveforms for a resistive load.

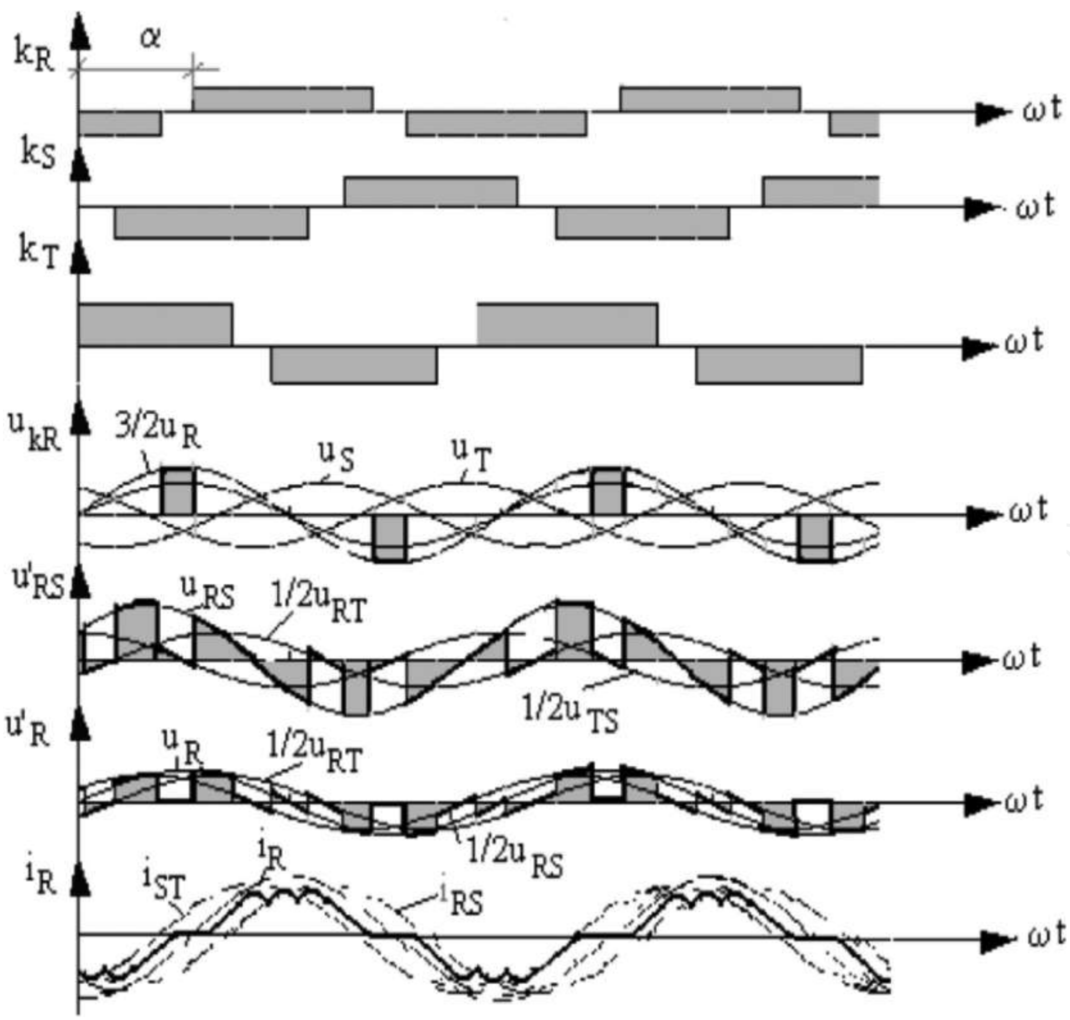

Figure 7. Current and voltage waveforms for an inductive load.

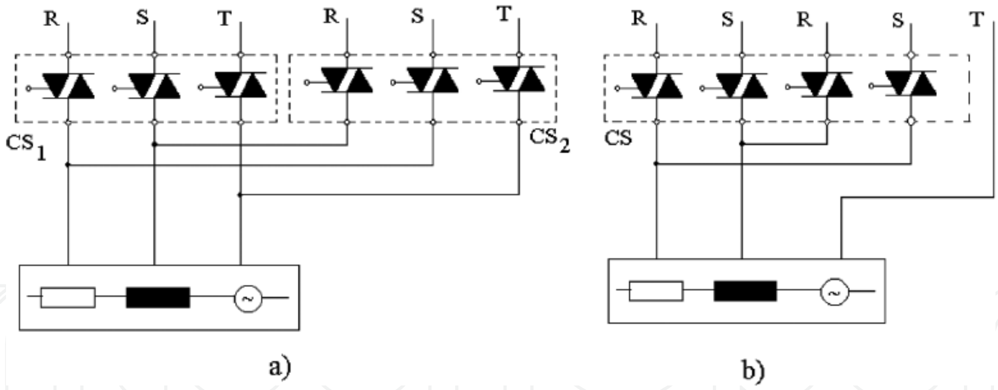

Figure 8. Reversible AC switch controllers: a) Symmetrical scheme, b) Non-symmetrical scheme.

3. Simulation of AC static switch controllers

The simulation of static switch function is realized like a Windows independent application helping with Visual Basic's software package [1, 4, 5]:

- It launches the simulation software.
- It opens the main simulation window of the switch controllers.
- In the main window, the user can choose the simulation type to be run with some radio buttons. The window also contains two buttons, one to continue the simulation (Continua) and the other to exit the application (Iesire) (**Figure 9**).
- It can choose the single-phase AC switch controller simulation, three-phase AC, or the chopper simulation using radio buttons.

Press the button for the continuation of simulation (Continua).

It opens the simulation window of the single-phase AC switch controller (**Figure 10**).

The simulation window containing three main parts [4]:

- A part that contains simulation scheme.
- Another part is dedicated to information area.
- The third part is the area where is dynamically getting up the waveforms characteristic to the switch controller analyzed.
- According to the manner of the scheme, choose the type of the single-phase AC switch controller, which can be with two thyristors, with one thyristor, or with one thyristor in diagonal of a diode bridge (**Figure 11**) [5].

In the laboratory classes, students choose the type of the switch controller, making different simulations to understand the principle of operation in each case. During the simulation, besides information in the text, the teacher explains what happens in each case.

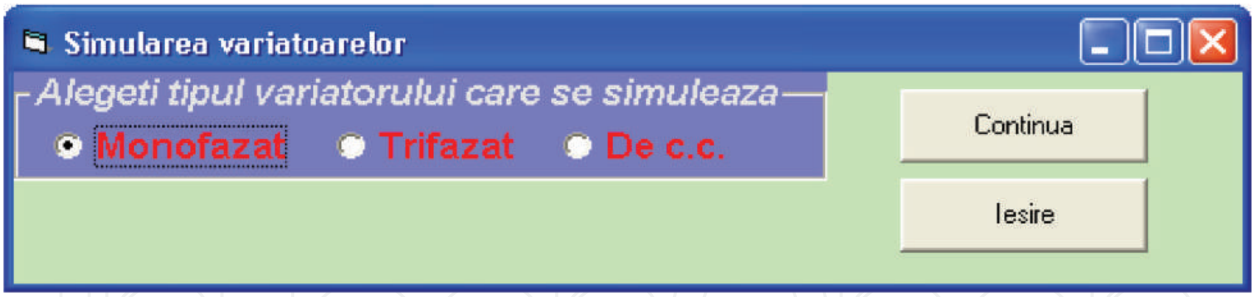

Figure 9. The main simulation window of the switch controllers.

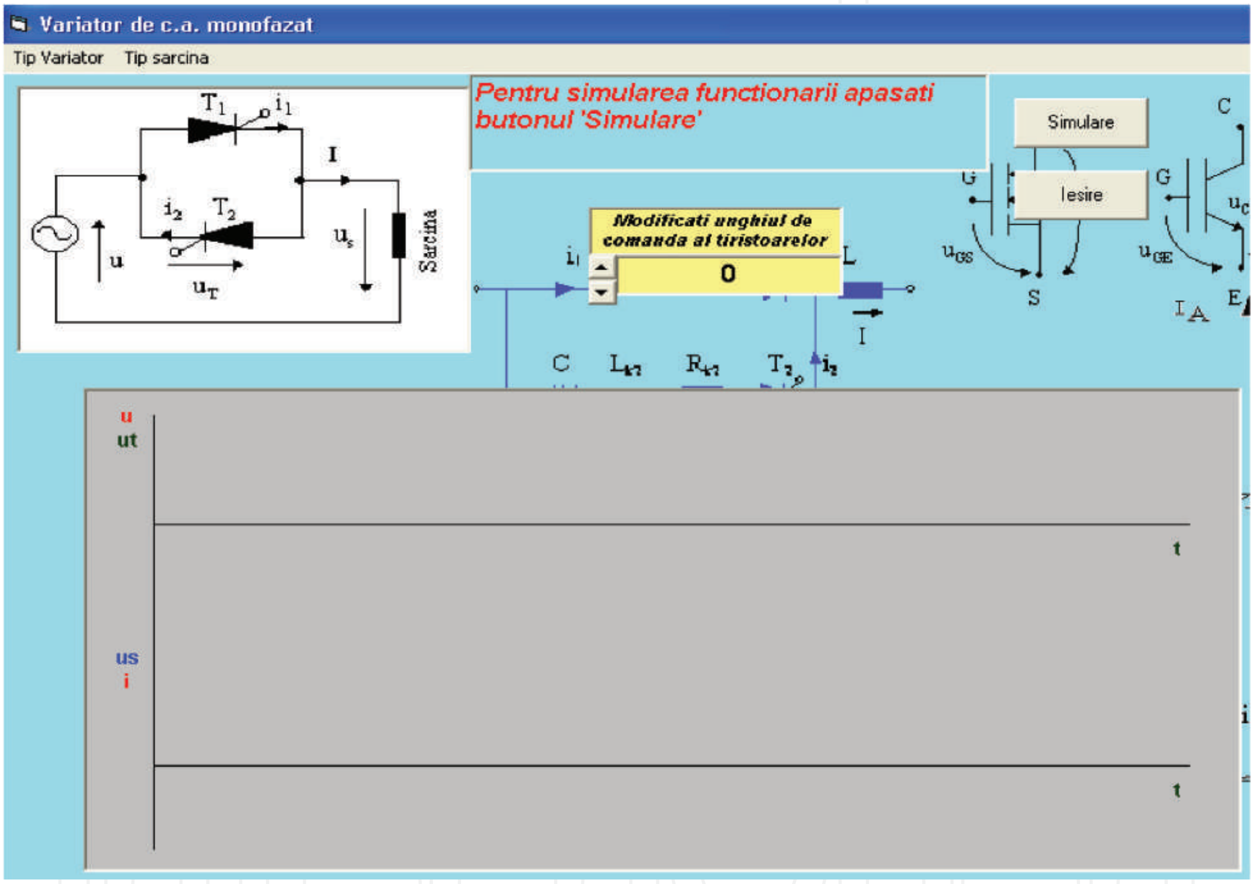

Figure 10. The simulation window of the single-phase AC switch controller.

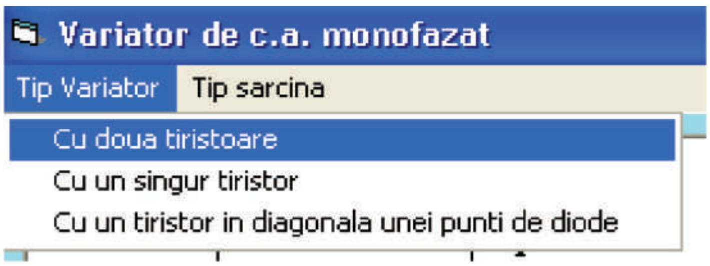

Figure 11. Choosing the single-phase AC switch controller type.

- It chooses the single-phase AC switch controller type (e.g., single-phase AC switch controller with two thyristors) (**Figure 12**).
- It chooses the load type which can be resistive, inductive, or resistive-inductive (**Figure 13**) [7].

The range of variation of the single-phase converter phase angle and the current variation depends on the type of load. To observe the differences in the different tasks, in laboratory classes are being analyzed converter function with resistive, inductive, or resistive-inductive loads, and is being drawn conclusions about the current variation. During the simulation, the students change the command angle to observe the modification of the RMS voltage and current.

- The command angle may be modified using up/down arrows, being shown their values. Along the simulation, it modified the command angle of the switch controller, in order to evidence the way of voltage modification, or the current through load (**Figure 14**).

Notes

It may choose any load type in combination with any switch controller types.

The command angle of the thyristors may vary between 90° and 180°, in the case choosing an inductive load (**Figure 15**).

In the case of choosing a resistive-inductive load, the command angle of the thyristors depends on the value that we want to establish by introducing a delay angle, changing the command angle of the thyristors being made from that value in up (**Figure 16**) [5].

In all three cases, if the command angle changes below or above the permissible values, the program alerts the user by an error message (**Figure 17**).

- It launches in running the single-phase AC switch controllers with two thyristors, with the control button (Simulare), which is then converted to the simulation stop button (Stop), which is located on the top right (**Figure 18**).
- During the simulation, the scheme dynamically changes its color, the sides what are in conduction at a time (**Figure 19**).
- It will follow the area in which text information about the function mode of the single-phase AC switch controllers are presented (semiconductor elements that are in conduction, semiconductor elements direct polarized, etc.) (**Figure 20**).
- Is watching the area in which is rises dynamically the characteristic waveforms of the single-phase AC switch controllers **Figure 21**.
- It is observed that by changing the command angle α between zero and π, the current by resistive load varies between maximum value U/R and zero. In the case of inductive load, because the current by load is a lag behind with $\pi/2$, the command angle can be varied by interval $[\pi/2, \pi]$, and in the case of resistive-inductive, the command angle varies between ϕ and π.

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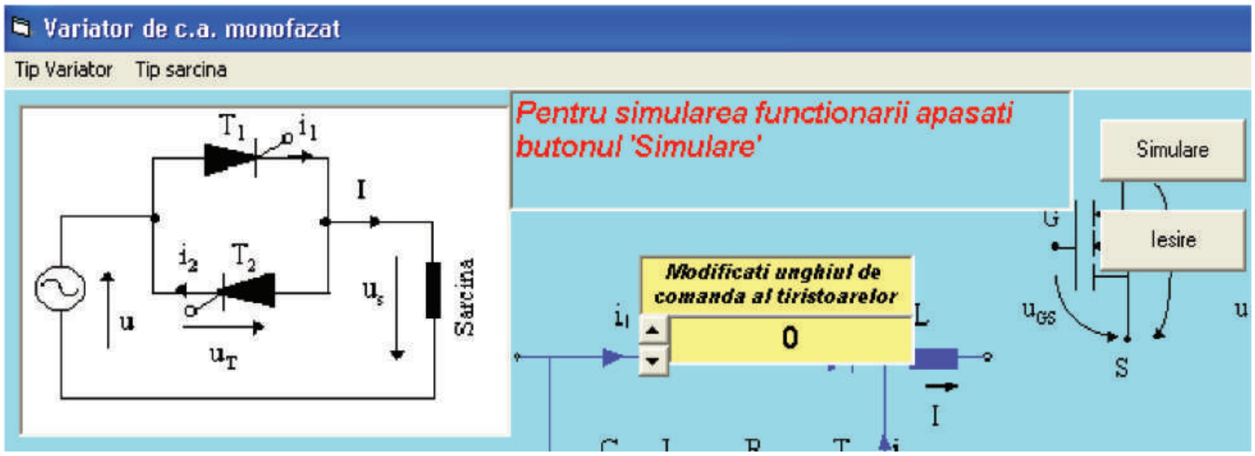

Figure 12. The single-phase AC switch controller window.

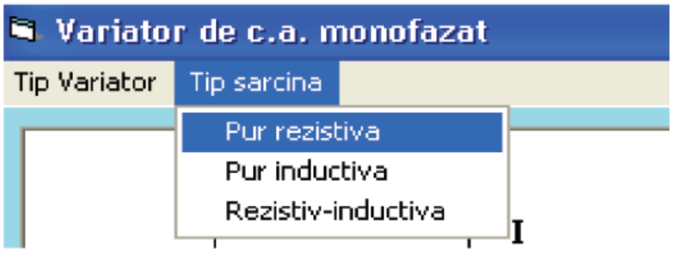

Figure 13. Choosing the load type.

Figure 14. Changing command angle in case of single phase switch controller.

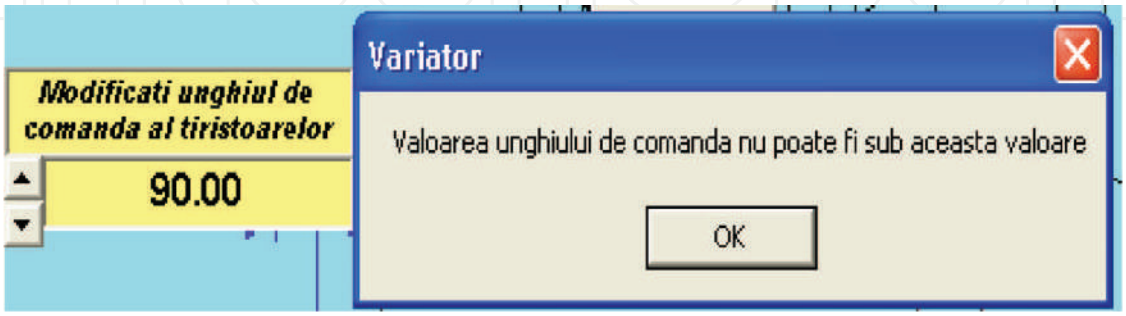

Figure 15. The error message in the case an inductive load.

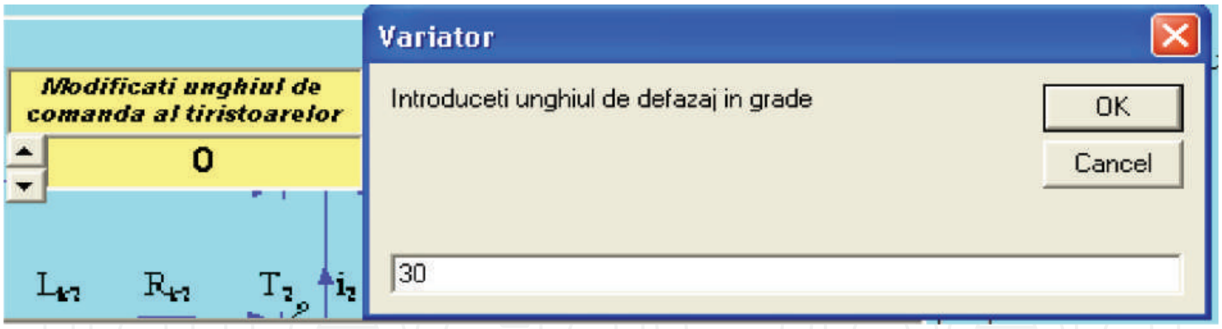

Figure 16. The changing of command angle in the case resistive-inductive load.

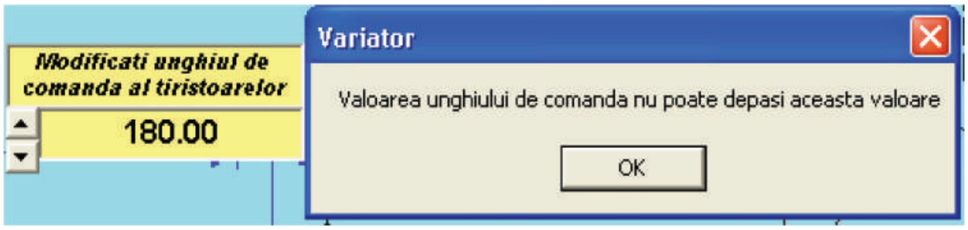

Figure 17. The error message.

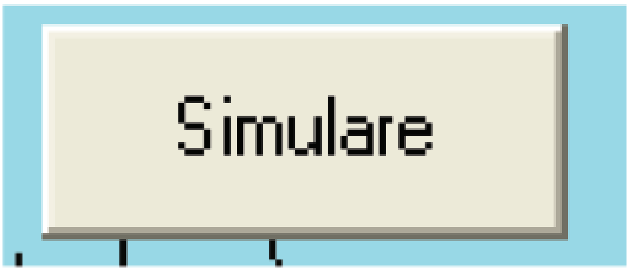

Figure 18. The control button (Simulare) in case of single phase switch controller.

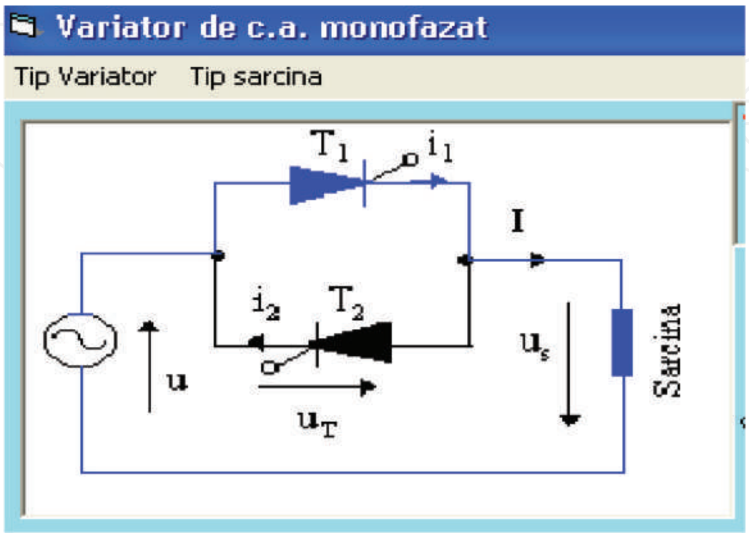

Figure 19. Simulation scheme in case of single phase switch controller.

Figure 20. The information area of text type in case of single phase switch controller.

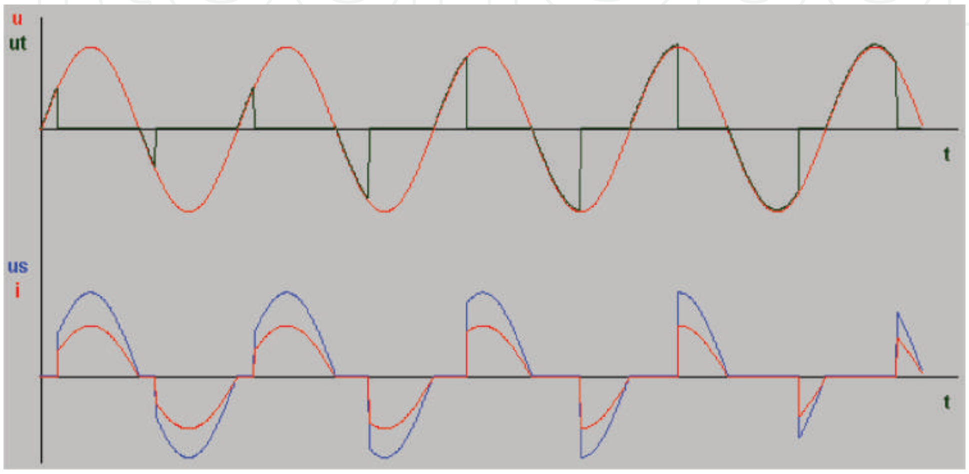

Figure 21. The waveforms area for the single-phase AC switch controllers with resistive load.

For the three-phase AC switch controller, simulation is opening the window as shown in **Figure 22**.

And to the three-phase AC switch controller, the simulation windows are three main part formats from the first part which contains simulation scheme, the second part is dedicated to information area, and the third part is the area where is dynamically getting up the waveforms characteristic to the switch controller analyzed [5].

- Choose the type of the three-phase AC switch controller, which can be with two thyristors on phase, with one thyristor and one diode on the phase (**Figure 23**).
- The command angle may be modified using up/down arrows, being shown their values. Along the simulation, it modified the command angle of the three-phase AC switch controller with two thyristors on the phase, in order to evidence the way of voltage modification, or the current through load (**Figure 24**).
- It launches in running the single-phase AC switch controllers with two thyristors, with the control button (Simulare), which is then converted to the simulation stop button (Stop), which is located on the top right (**Figure 25**).
- During the simulation, the scheme dynamically changes its color, the sides what are in conduction at a time (**Figure 26**) [6].

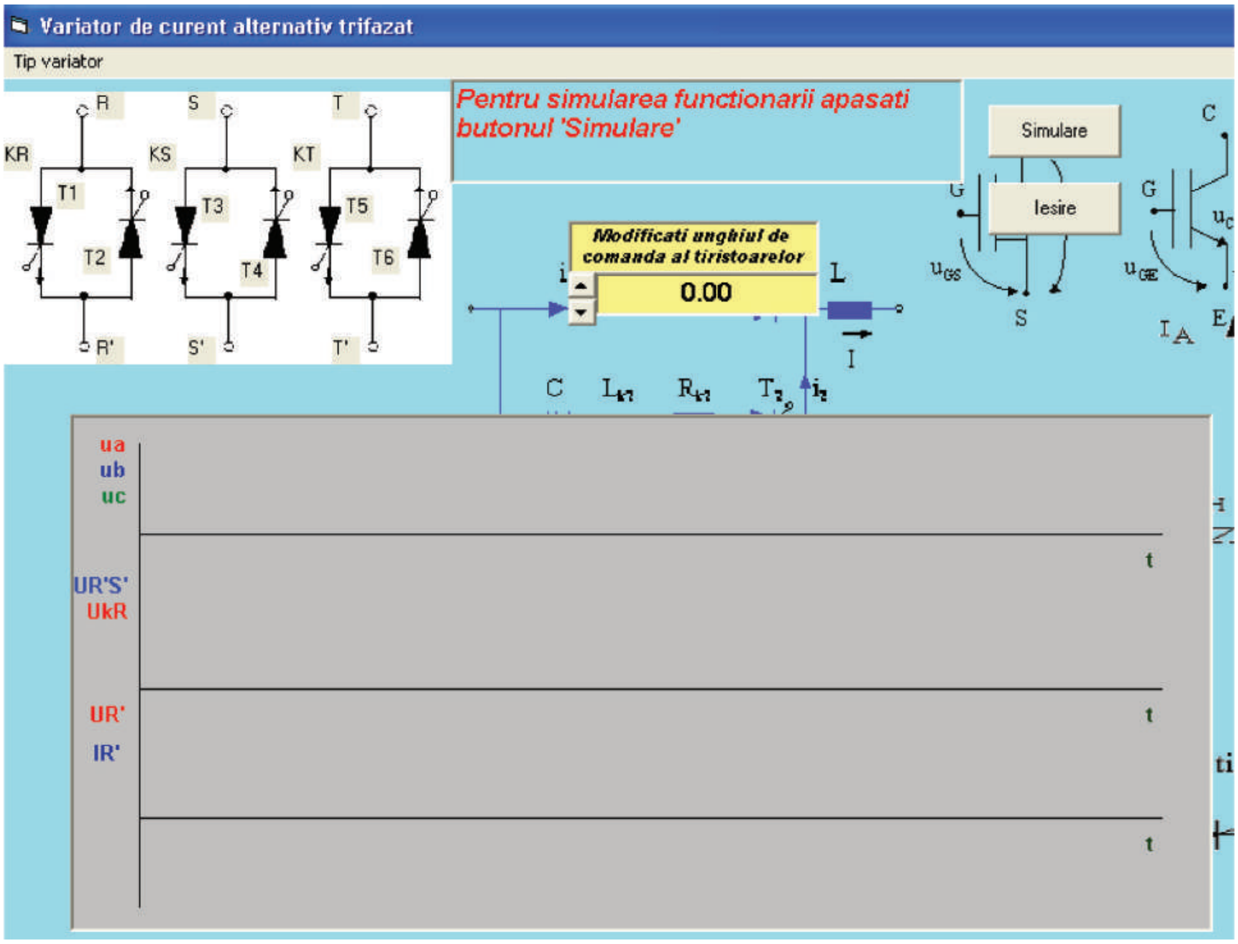

Figure 22. The simulation windows of the three-phase AC switch controller.

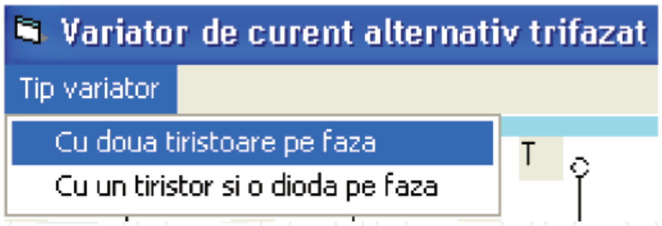

Figure 23. Choosing the three-phase AC switch controller type.

Figure 24. Changing command angle in case of thre-phase switch controller.

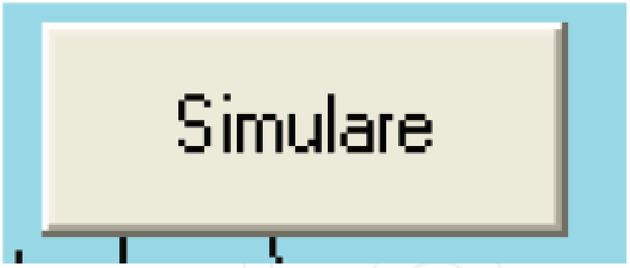

Figure 25. The control button (Simulare) in case of thre-phase switch controller.

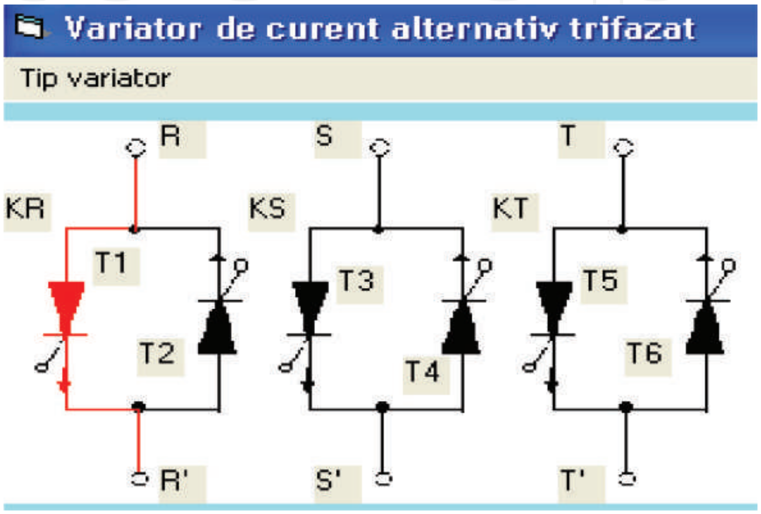

Figure 26. Simulation scheme in case of thre-phase switch controller.

- It will follow the area in which text information about the function mode of the three-phase AC switch controllers are presented (semiconductor elements that are in conduction, semiconductor elements direct polarized, etc.) (**Figure 27**).
- Is watching the area in which is rises dynamically the characteristic waveforms of the three-phase AC switch controllers (**Figure 28**).

The simulation of three-phase switch controller is made for different types of load and by changing the angle of the semiconductor elements. Based on information from the simulation, the students made a report on the functioning in different cases, which is then analyzed together with the teacher, being clarified with aspects of the operating principle.

Figure 27. The information area of text type in case of thre-phase switch controller.

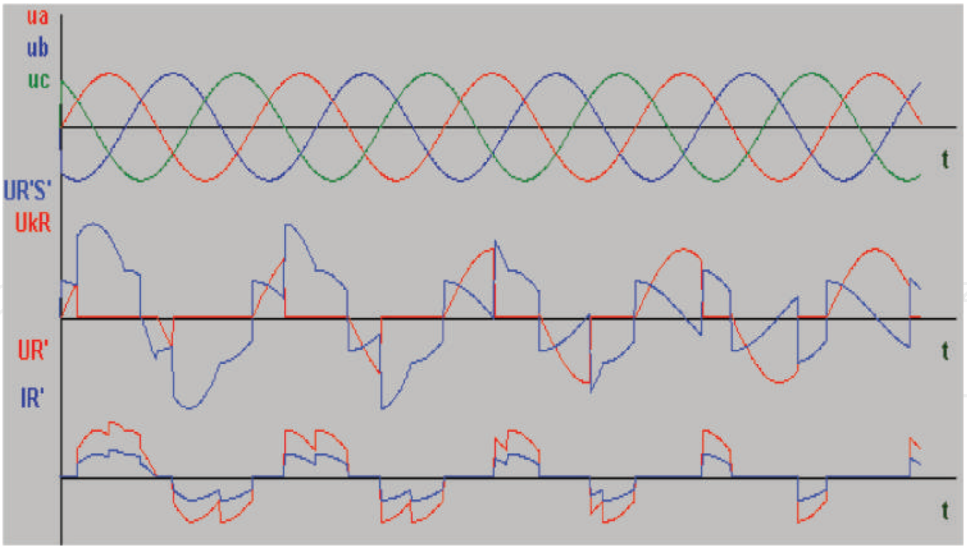

Figure 28. The waveforms area for the three-phase AC switch controllers with resistive load.

- In the resistive load case, the angle ignition variation to the thyristors is comprised between zero and π, the thyristors of K_R being in conduction on period $\alpha \div \pi$, for the positive semi-alternate and $\pi + \alpha \div 2\pi$ for the negative alternate.
- At the end of simulation is pressed the button (Iesire) for application exit, after that is being able to choose, from the main simulation window, another simulation to run (**Figure 29**).

Figure 29. The button for application exit (Iesire).

4. Conclusions

In electrical devices, the AC switch controller is used for asynchronous motor speed change by changing the supply voltage and to the asynchronous motor startup by varying the voltage between zero and nominal value.

These types of static converters are used to control the voltage applied to the stator windings of a cage induction motor or to modify the effective rotor resistance of a wound induction motor. In first case, the converter is connected in series with the stator windings, and in second case in parallel with a resistance.

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Using an AC switch controller is the simplest way to control the speed of AC drive systems. However, this method has some disadvantages such as low input power factor, decreasing efficiency with lower speeds, increasing losses of a drive system if the converter used modifies the effective rotor resistance.

The simulation scheme dynamically changes its color, the sides what are in conduction at a time. In the simulation window, there is a text area where information about the function mode of the converter, the semiconductor elements direct polarized or which are in conduction at that moment are displayed. The window contains also an area with buttons for changing the command angle.

Some of the simulation windows contain a pull-down menu button used to change some parameters or to choose different types of loads. All windows contain two command buttons, one for starting up the simulation (Simulare), which is transformed in button for stop the simulation (Stop) and a button to exit of the window (Iesire).

This documentation describes a Windows application, useful for understanding the functioning of the static variators, converters, and typing to cover all the needed aspects. This application has a teaching purpose, being useful for the students studying static converters.

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Chapter 8

Computer Science Education and Interdisciplinarity

Cristina-Maria Dabu

Additional information is available at the end of the chapter

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Abstract

The world today is characterized through three major elements in the scientific field: the development of classical sciences, the increasingly evolution in the field of computer science and, as result, the emergence of a large number of new border sciences or interdisciplinary and transdisciplinary sciences. In the formation of future specialists, computer science education cannot ignore the reality of a society in which research and technological progress are based primarily on interdisciplinarity and transdisciplinarity. Throughout this chapter, we will analyze the way in which all these elements are evolving in a very closely interdependency one of each other: the evolution of computer science accelerates the development of classical sciences, and the development of classical sciences and computer science generates the emergence and progress of new border sciences and how the educational curricula in computer sciences have to be adapted to this trend. We will present and analyze the ways in which computer science education can be performed in an interdisciplinary and/or transdisciplinary manner at all educational levels. In the same time, we will emphasize the reasons why it is necessary to teach computer science in an interdisciplinary and/or transdisciplinary way and the benefits that teaching strategy brings in the training of future specialists.

Keywords: computer science, education, interdisciplinarity, transdisciplinarity, barriers, emergent science, curricula, creativity, research, skills, development

1. Introduction

The world today is characterized through three major elements in the scientific field: the development of classical sciences, the increasingly evolution in the field of computer science and, as result, the emergence of a large number of new border sciences or interdisciplinary and transdisciplinary sciences.

Interdisciplinary and transdisciplinary research has emerged as a result of the complexity of the world that surrounds us and as a result of the fact that in all fields of scientific research, the complexity of the studied phenomena transcends the borders of a single science.

Another cause that determined the apparition of transdisciplinarity and interdisciplinarity is that the most important discoveries in scientific fields such as life sciences, aerospace sciences, biophysics and other sciences are emerging at the interface between two or more scientific fields.

Even though it is obvious that transdisciplinary and interdisciplinary research leads to spectacular results and that without interdisciplinary and transdisicplinary research current science does not have how to evolve; however, they have been identified a number of barriers that slows interdisciplinary and transdisciplinary approach in scientific research.

A study regarding interdisciplinarity in sciences, conducted by the Academy of Finland [1], highlights a number of barriers of different nature that occur in communication processes and interactions within teams working in interdisciplinary research projects, generating tensions, conflicts or delays in the completion of those projects.

These barriers can be classified into:

- Structural
- Knowledge
- Cultural
- Epistemological
- Methodological
- Psychological
- Reception

We will briefly introduce what each of these barriers represents. A thorough analysis of them is available in Ref. [1].

Structural barriers are related to the organizational structure of the institution or institutions where interdisciplinary research activity occurs: the hierarchy and decision systems, organizational rules, financing sources, influencing how it is carried out the research activity.

Knowledge barriers are generated by the gap of knowledge that specialists in a particular scientific field they have compared to other scientific fields involved in an interdisciplinary research project.

Cultural barriers occur because of problems related to the language used in communication within teams working in multidisciplinary research projects. Each scientific field is characterized by its own specialized terminology, the used terms may sometimes be the same, but in a greater or lesser measure, different in their meanings. As a result, confusion and misunderstandings can arise in the communication on the project, because different terms are used to refer to the same concepts, or similar terms have different meanings from one scientific field to another.

Epistemological barriers are generated by the vision that various scientific fields have regarding the world and by the way in which the various phenomena are perceived in terms of importance by each scientific field separately. It was also found that epistemological barriers depend on the way in which the various scientific fields have evolved over the time.

Methodological barriers are result of the fact that each scientific field is characterized by its own research methodologies in designing, conducting and reporting research.

Psychological barriers arise due to the fact that each scientific researcher involved in an interdisciplinary project is intellectually and emotionally attached to the scientific field to which he/her belongs and in which he/her has invested intellect, time and labor. In addition, the migration of scientific researchers from a research field in a multidisciplinary team, in which they have to interact with other researchers from other scientific fields, characterized by their own culture, especially in the early stage can generate negative emotions.

Reception barriers are specific to those interdisciplinary research project phases in which, in various forms (reports, publications, presentations, applications for funding), the results of interdisciplinary research activity are disclosed to the layman public (appraisers, financiers, civil society), and there are attempts to assess the interdisciplinarity in the project.

We found that similar barriers can also be identified in the case of transdisciplinary scientific research.

The study [1] identifies two main reasons of these barriers:

- The fact that theories and methods belonging to different disciplines are very difficult to integrate in a new common perspective.
- Scientific disciplines are conventions socially constructed that have their own institutional and ideological structures [1].

The Report of the MASIS Expert Group "Challenging Futures of Science in Society—Emerging trends and cutting-edge issues" [2] brings into discussion new concepts regarding science:

- Recontextualization of science
- Strategic research and strategic science
- Governance of scientific institutions
- Reflexive science
- Innovation-oriented research
- Industrialized science
- Structural and cultural transformations regarding science.

Through the concepts introduced and explained in the document, the report highlights new approaches regarding the evolution and philosophy of science. These approaches are generated both by the development sciences (classic sciences and new emerged sciences) and by the complexity of the world we live.

Considering the direction of evolution in scientific research, in order to prepare future professionals who can successfully face the challenges of sciences, education systems must adapt at all levels of education to the interdisciplinary and transdisciplinary trends in scientific research.

Moreover, one of the main objectives of the educational system should be eliminating the barriers identified in interdisciplinary and transdisciplinary research, in order to accelerate the progress of sciences and technology and through them, as result, to accelerate the progress of entire society.

The removal or mitigation of cultural, methodological or knowledge barriers that occur in interdisciplinary and transdisciplinary research can be achieved only through interdisciplinary and transdisciplinary orientation in teaching-learning activities, such that current students, future professionals, will develop from early stage during the years of study those skills that will make them competitive in an interdisciplinary or transdisciplinary scientific research activity.

The report emphasizes the absolute necessity for students to be familiarized with various fields of computer science during their schooling. In order to be an effective approach in favor of students, with long-term beneficial effect on the training of future specialists, familiarizing students with various areas of computer science should be done according on their own leaning skills and interests.

Thus, the discipline computer science should be studied in an interdisciplinary way, correlated with other scientific field (or fields), which constitute the subject of interest for every student.

In the same sense, in another important document, the report of the joint Informatics Europe & ACM Europe Working Group on Informatics Education, we have identified the following objectives concerning computer science education in Europe [3]:

1. Generalization of education in computer literacy and computer science (informatics) at all educational levels.
2. Creating a Europe based on an Informational Society and an informational economy.
3. Introducing digital literacy and computer science in the curriculum for all European countries.
4. Enhancement of The students training in computer science (informatics) so as to make Europe a major player in Information Technology.

The two bodies have developed the following recommendations for educational systems across Europe regarding computer science education [3]:

1. "All students should benefit from education in digital literacy, starting from an early age and mastering the basic concepts by age 12. Digital literacy education should emphasize not only skills, but also the principles and practices of using them effectively and ethically."

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2. “All students should benefit from education in informatics as an independent scientific subject, studied both for its intrinsic intellectual and educational value and for its applications to other disciplines”.
3. “A large-scale teacher training program should urgently be started. To bootstrap the process in the short term, creative solutions should be developed involving school teachers paired with experts from academia and industry”.
4. “The definition of informatics curricula should rely on the considerable body of existing work on the topic and specific recommendations of the present report” [3].

As it will be seen in the next chapters, the Romanian educational system integrated in the curricula at all educational levels, computer science education and computer literacy education, correlated with other disciplines included in the school curricula.

2. Computer science in actual science

In the contemporary society, the role of computer science has become and is becoming more and more important in all scientific fields: medicine, pharmacy, economics, education, sociology, physics, chemistry, biochemistry, anthropology, aerospace and others.

The evolution of computer science provides to other scientific research fields powerful instruments for research: high capacity computational systems, able to manage huge databases, powerful and sophisticated calculus algorithms for data analysis and data mining and dedicated software for computer-assisted modeling and simulation. At the same time are being built increasingly sophisticated measuring devices based on highly specialized sensors and biosensors, that incorporate dedicated software packages for automatic processing of collected data. Fall into this category devices used in the study of outer space, devices for measuring biological parameters in medicine, biotechnology, marine research and other similar devices used in physics, chemistry and others.

All these specialized devices, dedicated for gathering and automatic processing of large amounts of data on the one hand, have led to spectacular developments in various scientific fields like medicine, pharmacy, physics, biophysics, chemistry, biochemistry and others, and on the other hand, they have led to the emergence of new sciences, such as exo-oceanography, exo-biology, computing sociology, computing anthropology, computing ecology, computing toxicology and others.

The huge amount of data collected in all scientific fields using specialized devices allow the possibility to use these data in order to elaborate specific prognosis (population health prognosis, population movement prognosis, meteorological and exo-meteorological prognosis, environment evolution prognosis and others). As a result, in almost all fields of research are extensively used experimental models and simulations. This relatively new approach, belonging to the past 25–30 years, has made simulation and modeling to be considered an <<emerging “third leg” of Scientific Investigation>> [4].

Computer science is an extremely abstract, intellectually challenging field, because programming technologies operate with very abstract and codified representations for the surrounding reality. For this reason, especially in the initial stages, interdisciplinary and transdisciplinary research projects involving computer science are faced with certain difficulties, especially concerning the transposition into an abstract representation specific to computer science, the experimental reality belonging to a different scientific field.

These difficulties occurring in research activities constitute another reason for teaching computer science discipline, at all levels of education, in an interdisciplinary manner. Through teaching computer science in an interdisciplinary and transdisciplinary manner, on one hand the future specialist in computer science will have early formed the necessary skills to conduct a dialogue with specialists belonging to other scientific fields, and on the other hand, for specialists from different scientific fields (physics, chemistry, biochemistry, medicine), computer science will no longer be a stranger and abstract area.

Another important issue is that in the era of Big Data, characterized by huge databases in all fields of science (medicine, genetics, sociology, anthropology) collected through most various channels, one of the most challenging scientific work is to identify patterns and consistent elements of knowledge in large databases.

Big Data technology development determined that currently some of of the most increasingly used computing applications and algorithms, used today by researchers in most fields of science, are those dedicated for Data Mining.

In the scientific literature, it is defined the activity of Knowledge Discovery in Databases (KDD) as “the process of identifying valid, novel, potentially useful and ultimately understandable patterns in data” [5]. The most powerful tool used for Knowledge Discovery in Databases, Data Mining represents “a collection of methods of data analysis coming from different fields of computer science, artificial intelligence and statistics” [5].

Taking into account that, as we noted above, computer science is deeply involved in all current sciences, it is considered that “interdisciplinary computer science is becoming the norm” [6].

They are science or scientific results, which could not exist in the absence of computer science. An example of this is the genomic sequencing, a remarkably successful genetics result, which would not be achieved in the absence of tools provided by computer science [6].

In other sciences, like the aerospace sciences or exo-meteorology, they could not exist as scientific fields itself in the absence of computer science, because both in the collection of scientific data and in the processing thereof are being used computer systems and devices coordinated by computer systems (space probes, spatial robots, artificial satellites).

3. Science evolution and emergence

How we have mentioned above, the development of computer science has an huge impact upon the evolution of other science fields (chemistry, biochemistry, physics) and the emergence of new sciences such as Computational Social Science, Synthetic Biology, Quantum

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Biology, Exo-meteorology, Exo-oceanography, Cliodynamics, Computational Anthropology, Computational Toxicology, Computational Ecology and others.

This is due primarily to the fact that knowledge itself has an interdisciplinary character, and the human brain is trained to process permanently information coming from different scientific areas, and to make extremely rapid correlations between the newly acquired elements of knowledge and the oldest already stored elements of knowledge, belonging to other scientific fields.

Secondly, the extremely rapid evolution of computer science field, as noted in the previous chapters, has provided to the various scientific fields devices and applications able to collect, store and process huge amounts of information. As a result, the amount of scientific knowledge in all areas has grown exponentially and has become much more complex.

Explaining the phenomena based on vast amounts of information collected by devices made available by means of computer science, required the gradual emergence of new interdisciplinary or transdisciplinary scientific fields, some of them impossible to exist in the absence of computer science, and each of them having its own research methodologies, scientific terminology and their own areas of interdisciplinary knowledge.

We will present in the following some such new scientific fields, emerged at the intersection between computer science and other fields of scientific research.

3.1. Computational Anthropology

Computational Anthropology is emerging from a multitude of sciences: Computer Science, Anthropology, Sociology and Geographic Information Science.

The main objective of this new emerged science is the study how patterns of human behavior change over time and space [7].

The scientists in Computational Anthropology are analyzing data collected from social networks and geolocation systems in order to provide new insights regarding the nature of human society [7].

In the last decade, the increasing availability of big data generated by mobile phones and location-based applications has triggered a revolution in the understanding of human mobility patterns. Using specific algorithms for data mining, simulation and prognosis, one can be identified patterns regarding travel around the world, and very important for the health systems from all countries, one can be made forecasts on the spread of diseases and epidemics [7].

In the scientists in Computational Anthropology opinion, “there is considerable interest in looking more closely at human mobility patterns to see just how well it can be predicted and how these predictions might be used in everything from disease control and city planning to traffic forecasting and location-based advertising” [7].

3.2. Computational Ecology

Computational Ecology is another new emerged sciences, based on computer science and ecology.

Computational Ecology is using numerical models and computer simulations in researches regarding dynamics of populations and systems. There are studied tendencies and specificities for a better understanding and prognosis in areas such as fisheries, forestry, agriculture, climate change and evolutionary ecology [8].

Ecosystems are living systems that are formed and evolves in years, decades, hundreds or thousands of years. Consequently, experiments in the classical conception of scientific experiment in order to understand the dynamics and evolution of ecosystems are difficult or even impossible to carry out.

Computing Ecology through powerful research tools provided by mathematical models and computer aided simulations, software systems able to analyze large amounts of data gathered in situ, enables understanding of phenomena and processes occurring and enables elaborating predictions regarding the evolution of ecosystems.

This newly emerged science is of great importance in the heavily industrialized contemporary society, where the ecological disasters caused by various agents have become very common.

3.3. Computational Toxicology

Computational Toxicology is another new emerged science, correlated with computational ecology and environmental protection.

It was officially mentioned for the first time in September 2009 when the National Research Council Committee on Use of Emerging Science for Environmental Health Decisions held a public meetings titled "Computational Toxicology: From Data to Analyses to Applications" [9].

Computational Toxicology offers the opportunity to study and forecast, based on mathematical models and computer-aided simulation, the harmful effects that various toxic pollutants or sources may have on the environment, humans and animals.

The new emerged science brings substantial scientific contribution in a field in which experimental research are extremely harmful for the environment and humans. For this reason, experiments have to be replaced with computer-assisted simulations based on mathematical models, without danger for humans, animals and environment.

3.4. Exo-Meteorology

Exo-meteorology is a new emerged scientific and research field which is studying the meteorological phenomena that take place on other planets existing our solar system [10].

Field of research could not exist in the absence of computer science. Computerized systems are needed both in the collection and storage of data, as well as for their processing and interpretation and for the elaboration of forecasts.

Forecasts elaborated by this newly emerging science are important in planning space missions [11].

4. Computer science education in curricula

As we have seen in the previous chapters, in the context of actual science and society evolution, the goal of computer science education is to prepare actual students, future specialists, to work and think at the intersection between computer science and other scientific fields.

Considering that the in almost all scientific fields are used computer-assisted modeling and simulations, it is essential for future researchers to be familiar with algorithmic thinking and computer science. In addition, the barriers that arise during interdisciplinary and transdisicplinary research activities, mentioned in previous chapters, represent another important reason for approaching an interdisciplinary manner in teaching computer science, using examples and applications from other disciplines or from the world around us.

In the Romanian educational system, at all levels of education, curricula contain computer science education with multiple goals:

- To familiarize the student as computer user as future specialist in a particular scientific branch.
- Development of specific algorithmic thinking skills, useful for a future specialist in any scientific field.
- Development of programming skills for creating dedicated software systems in other scientific fields (biology, chemistry, physics).

In order to attain these objectives in teaching computer science, in the Romanian education, one has been made remarkable progress in the last 17 years, both in terms of technical endowment and in terms of improving the school curricula:

- Schools, high schools and universities were equipped with computer networks, connected to the internet.
- One was developed educational software packages for almost all subjects in the curricula.
- One has been made available for students' online platforms for training in computer science for Olympiads in informatics and other informatics competitions.
- One has been developed support materials and training programs for teachers.
- Many programs or projects aimed to promote new technologies in education and supporting computer-assisted learning (eLearning).

The Romanian education curricula take into consideration more categories of competencies:

- European key competencies
- Competencies established by the Romanian Education Law

At the fifth grade level, the European key competencies that need to be developed throughout the course information and communication technology are:

- Digital competences
- Mathematical competence and basic competences in science and technology [12].

Consistent with these European key competencies, the competencies established by the Education Law in Romania are as follows:

- Digital skills to use information technology as a tool for learning and knowledge
- Basic skills in mathematics, science and technology
- Social and civic competences
- Competence of learning to learn [12].

To ensure the interdisciplinary study of computer science, the curriculum recommends: "For the good development classes and curriculum implementation, to correlate is recommended teaching activities of other subjects studied the content" [12].

The main topics of the computer science curricula (Computer Literacy) at the fifth grade are:

- Basic computer hardware
- Windows
- Paint
- Microsoft Word
- Powerpoint

At high school level, the curricula provide differentiated study of computer science, according to the high school profile:

- Humanities
- Real (science)
- Computer science
- Arts and crafts

In Romania, the school curricula for computer science education provide both teaching hours and laboratory hours.

For high school, profile humanities, computer science education, consist in Computer Literacy (general) and Desktop Publishing.

On the other hand, for high school profiles real (science) and computer science, there are hours of algorithms, computer literacy, computer programming course in C++ or Pascal and laboratory courses.

During the programming courses (C++ or Pascal), there are taught concepts like:

- Data types and variables
- Operators
- Simple instructions

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- Control structures
- Pointers
- Functions
- Lists, stacks and queues
- Algorithms for searching and sorting

During the laboratory courses, students develop their own computer programs applying concepts learned in the classroom.

Involving students during the laboratory classes in interdisciplinary projects like:

- Software system for the study of geography
- Software system for the study of foreign languages with computer
- System Software for the modeling of some physical phenomena
- Software system for studying cell division
- Software system for mathematics study
- Software system for chemistry study

stimulates the development of interdisciplinary skills of the students.

Working organized in teams on projects such as those mentioned above, students are challenged to develop their critical thinking, analytical skills and abilities:

- They must know and implement concepts learned during the hours of Computer Science.
- They need to know at a sufficiently high level concepts belonging to the scientific fields for which they develop the software system.
- They must select which concepts will be introduced in the software system they build.
- They have to organize logically and easily accessible the informations within the software system.

The students have to analyze and determine what information from the selected scientific field that will take in the information system (theoretical concepts, exercises, tests for assessing knowledge).

They should consider how they will present the information in the software system in order to be easily accessible for the final user.

Students have to design and implement interfaces between the user and the computer system, students must show creativity and develop their creativity, and they have to know concepts regarding ergonomics of man-machine interfaces.

They design and implement computer-assisted exercises, quizzes and tests and evaluation algorithms for the verification of the acquired knowledge.

Through these projects, students are challenged to research and development of interdisciplinary and transdisciplinary knowledge of various fields merging computer science and other school disciplines, depending on the project and on students own preferences.

In addition, the teamwork activity forces them to develop their communication skills, collegiality, adaptability and other skills needed for teamwork, skills required also as future professionals who will need to integrate into a team of interdisciplinary and/or transdisciplinary research.

Under this manner, teaching computer science is done in an interdisciplinary and transdisciplinary way, which encourages students not only to study strictly the discipline of computer science but also encourages them to expand their knowledge in other scientific fields in order to develop their software projects during the laboratory hours.

Another extremely challenging exercise for students, which we use in teaching the chapter regarding computer structure (computer hardware), is to identify the various components of a computer in other devices that run based on computer programs and computational systems:

- Devices to monitoring patients in hospitals
- Fuel pump from gas stations
- Washing machine
- Mobile phones
- Other similar systems

Students are encouraged to identify for each case what would be the input unit, the output unit, whether the device is equipped with external memory or not and what would be their role and what would be the role of command and control unit. Such students are encouraged to think about a computer device in the context of another domain (medical, telecommunication, oil and appliances), helping them to develop their interdisciplinary and transdisciplinary thinking ability.

We have used these methods for teaching computer science in many schools throughout time and every time which have given very good results. Students have very good results informatics Olympiads and competitions, and some of them, who have followed careers in computer science, have integrated very well on the job.

At academic level, interdisciplinarity and transdisciplinarity of computer science education are reflected in the large offer of masters or doctoral programs and academic courses that universities offer their students on various interdisciplinary or transdisciplinary areas:

- Computational Biology,
- Computational Biochemistry
- Computational Bioengineering
- Computational Geometry

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- Computational Linguistics
- Computational Physics
- Computational Ecology
- Computational Economics and others.

All these <<computational X>> [13] programs and courses at academic level are in close correlation with the new emerging scientific and research fields, in order to train specialists for the respective fields.

In addition, these interdisciplinary programs or courses, based on computer science, contribute significantly to removing some of the barriers involved in interdisciplinary research, we have mentioned in the previous chapters. Students trained in two or more different scientific fields, as future professionals working on interdisciplinary or transdisciplinary research projects could more easily overcome with the difficulties raised by cultural barriers, methodological barriers or knowledge barriers.

5. Conclusions

Without exhausting the subject, throughout chapter, we have presented that the reasons that have lead to interdisciplinary and transdisciplinary research and the barriers that appear in interdisciplinary and transdisciplinary research activity.

Our society is in constant evolution, scientific and technical and educational program must follow this evolution in order to prepare future specialists to the standards required by the society.

Evolution of computer science has a major impact in the development of science, not only by the contribution to getting some spectacular scientific results already established in areas of science but also by contributing to the emergence of new scientific fields. There have been summarized in this regard several new emerged scientific fields whose research activities have major impact in human society: Computational Ecology, Computational Toxicology, Computational Anthropology.

Education in the field of computer science can be done both as a self-contained discipline, but more important is the study of computer science in an interdisciplinary manner.

Teaching computer science in interdisciplinary and/or transdisciplinary manner, by engaging students in interdisciplinary projects or offering them interdisciplinary and/or transdisciplinary courses and specialization programs, as we have shown in the chapter, will help them to develop a series of skills needed for future interdisciplinary scientific research.

Also engaging students during computer science hours to identify ways, in which computer systems are used in the management of various processes in the world around us, contribute to help the students to develop specific skills regarding analysis and identification of systems.

Systems analysis and identification are concepts belonging to systems theory and are currently applied in most fields of scientific research. They are used for many years in scientific research concepts such as biochemical systems, biological systems, ecological systems and others.

All these concepts are interdisciplinary concepts which correlate computer science and systems theory with other scientific fields and are crucial especially in computer aided modeling and simulation. It is therefore important that during the classes of computer science, students become familiar from early stages with systemic thinking, which is essential in building software applications dedicated to other scientific fields.

Interdisciplinary and transdisciplinary approach stimulates scientific curiosity, an essential feature for a future scientific researcher. Scientific curiosity is typical of human nature, which always, from the ancient times, sought to understand and explain phenomena that occur in the natural world and modern education systems should aim to encourage and develop this scientific curiosity.

School systems from everywhere, through educational curricula content and through educational strategies, should stimulate and develop scientific curiosity of students in light of forming future specialists.

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Electric Machines: Tool in MATLAB

Rabih Rammal and Mohamad Arnaout

Additional information is available at the end of the chapter

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Abstract

This chapter presents an educational modeling and parametric study of specific types of transformers, generators, and motors used in power system. Equivalent circuit models are presented and basic equations are developed. Through tests and operating conditions, essential parameters for each presented machine are extracted. Graphical user interface (GUI) on MATLAB software is used to study and analyze each element. GUI allows better comprehension and clearer vision to analyze the performance of each electric machine, thus, a complementary educational tool. In addition, GUI permits optimal collaborative learning situations when linked with the theoretical expansion and, thus, is a teaching process that forges the connection between traditional subjects and science education.

Keywords: MATLAB, GUI, educational tool, science education, electric machines, ferromagnetic material, transformers, DC machines, induction machines

1. Introduction

There are several ways to generate electricity which are burning fossil fuels, converting water into steam, and using the steam to spin a turbine that is connected to an electric generator. In hydroelectric power plants, generators are turned by water and via wind in wind turbines. In all cases, the electricity generated at these facilities flows across the transmission and distribution system to where it is needed to meet customer demand in cities and rural areas. The electric system is an interconnected network for generating, transmitting, and delivering electricity to consumers [1].

The conventional view of studying electric machines concentrates on concepts. The graphical user interface provides direct contact with the content, provokes curiosity, and implements the science education through scientific knowledge based on facts, laws, theories, and models. The integration of this new structure improves science comprehension and helps students to learn better and more efficiently.

The study of an efficient power system starts with understanding the behavior of each component that develops this system. Electric machines used in power systems (generators, motors, and transformers) will be examined through analytical expressions and computer simulation. The importance of simulation is that these components could be studied before it is manufactured; thus, the consequences of changing dimensions and parameters can be assessed.

This simulation will be implemented in an educational tool, going from the basic operation principles, through developing models and equations toward the solution. The graphical user interface of MATLAB allows the students to study and analyze the effect of each parameter in order to understand its electric behavior with respect to its electric model.

This chapter will discuss the implementation of ferromagnetic core using graphical user interface taking into consideration the effects of air gap and fringing of a ferromagnetic core. Then, a detailed study of output power and losses with voltage regulation and efficiency of a single- and three-phase transformer will be established. In addition, a special survey will be accomplished concerning the types of DC motors and generators. Finally, this chapter will be concluded by providing an adequate research on the induction machines including their parametric study, and it will be achieved by a general conclusion of this work.

This chapter presents learning situations going from the theoretical expansion to the graphical interpretation. It is a teaching methodology toward the science education.

2. Ferromagnetic core

Magnetic fields are the essential means by which energy is converted from one form to another in motors, generators, and transformers. The most important class of the magnetic materials is the ferromagnetic materials such as iron, cobalt, nickel, and manganese [2].

There are four basic principles which describe how magnetic fields are used [2]:

1. A wire produces a magnetic field in the area around it when current passes through it.
2. A change in magnetic field, by mutual inductance, induces a voltage in the coil of wire: this is the principle of transformer action.
3. In the presence of a magnetic field, a current-carrying wire has a force induced on it: this is the principle of motor action.
4. In the presence of a magnetic field, a moving wire has a voltage induced in it: this is the principle of generator action.

2.1. The magnetic field

The magnetic field is produced by induced current in Ampere's law:

$$\oint H.dl = I_{net} \tag{1}$$

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where I_{net} produces magnetic field intensity and H and dl are the length integration along a path. If the core is produced from ferromagnetic material (**Figure 1**), then all the magnetic field produced within the core will remain inside the core. Therefore, the path of integration dl in the Ampere's law is the mean path length l_c [2].

The current passing in the path of the integration I_{net} is NI since the coil of the wire divides the path of integration into N times when the current passes through it:

$$H.l = NI \Rightarrow H = \frac{NI}{l} \tag{2}$$

The magnetic field intensity H is the effort in which a current is applying to establishment of a magnetic field. Strength of the magnetic field depends on the material of core. There is a relationship between the magnetic field intensity, the material magnetic permeability μ, and the magnetic flux produced within the material as shown in Eq. (3):

$$B = \mu H \tag{3}$$

The permeability of free space is called μ_0 and equal to $4\pi \times 10^{-7}$ H/m, and the relative permeability is the permeability of any other material compared to the free space permeability:

$$\mu_r = \frac{\mu}{\mu_0} \tag{4}$$

In the core (**Figure 1**), the magnitude of the flux density is given by

$$B = \mu H = \mu \frac{NI}{l} \tag{5}$$

Therefore, the total flux in a given area is expressed in Eq. (6). This equation reduced if the flux density vector is perpendicular to any plane of area, and if the flux density is constant throughout the area, then to

$$\int_A \phi = B.dA \Rightarrow \phi = B.A = \mu HA = \mu \frac{NI}{l} A \tag{6}$$

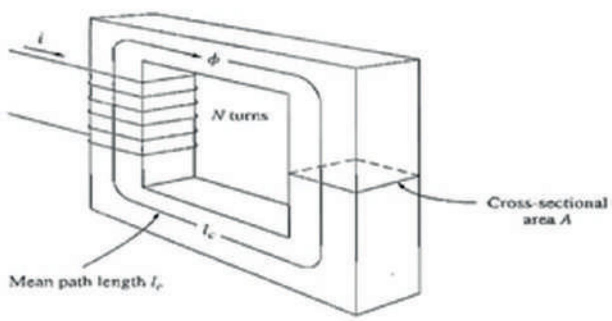

Figure 1. Ferromagnetic core.

2.2. Magnetic circuits

Magnetic flux is produced when the current in a coil of wire is wrapped around a core. This is similar to a voltage in an electric circuit producing a current flow. Thus, a "magnetic circuit" is defined by equations that are similar to that of an electric circuit. In the design of electric machines and transformers, the magnetic circuit model is used to simplify the complex design process [2].

The voltage or electromotive force drives the current flow in the electric circuit. The magnetomotive force of the magnetic circuit is denoted by where is the magnetomotive force in ampere-turns. In the magnetic circuit, the applied magnetomotive force causes flux (ϕ) to be produced (**Figure 2**).

The relationship that governs the magnetomotive force and flux is given by

$$\mathfrak{F} = NI = \phi\mathfrak{R} \tag{7}$$

The permeance of a magnetic circuit is the reciprocal of its reluctance. Therefore, the relation between magnetomotive force and flux can be expressed as

$$\phi = \mathfrak{F}P \Rightarrow \phi = \mathfrak{F}\frac{1}{\mathfrak{R}} \tag{8}$$

It is easier to work with the permeance of a magnetic field than with its reluctance.

The resulting flux and reluctance of a core are shown in Eqs. (9) and (10), respectively:

$$\phi = \mathfrak{F}\frac{\mu A}{l} \tag{9}$$

$$\mathfrak{R} = \frac{l}{\mu A} \tag{10}$$

The equivalent reluctance of a number of reluctances in series is just the sum of the individual reluctances:

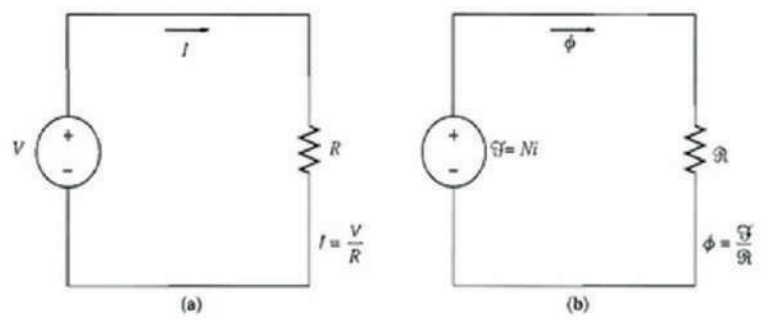

Figure 2. (a) A simple electric circuit. (b) The magnetic circuit analogue to a transformer core.

$$\mathfrak{R}_{eq} = \mathfrak{R}_1 + \mathfrak{R}_2 + \mathfrak{R}_3 + \ldots.. \quad (11)$$

The equivalent reluctance of a number of reluctances in parallel is just the sum of the individual reluctances:

$$\mathfrak{R}_{eq} = \frac{1}{\mathfrak{R}_1} + \frac{1}{\mathfrak{R}_2} + \frac{1}{\mathfrak{R}_3} + \ldots.. \quad (12)$$

The reluctance of each leg of a ferromagnetic core is

$$\mathfrak{R}_x = \frac{l_x}{\mu_r \mu_0 A_x} {}^{A.t}/_{wb} \quad (13)$$

The air-gap reluctance at leg X is

$$\mathfrak{R}_{xa} = \frac{l_{xa}}{\mu_0 A_{xa}} {}^{A.t}/_{wb} \quad (14)$$

The total flux of the ferromagnetic core is

$$\phi_{TOT} = \frac{\mathfrak{F}}{\mathfrak{R}_{eq}} wb \quad (15)$$

2.3. Implement in MATLAB GUI

When implementing in MATLAB, the user will add certain input which will then be calculated, and the result will be displayed. Below is a block diagram of the system.

The user fills the number of regions with availability of air gap indicating which leg is available and the details for core type such as relative permeability of the material and number of turns with the current (**Figure 3**). The results of the calculated parameters such as total flux and total reluctance and magnetomotive force of ferromagnetic core are displayed (**Figure 4**).

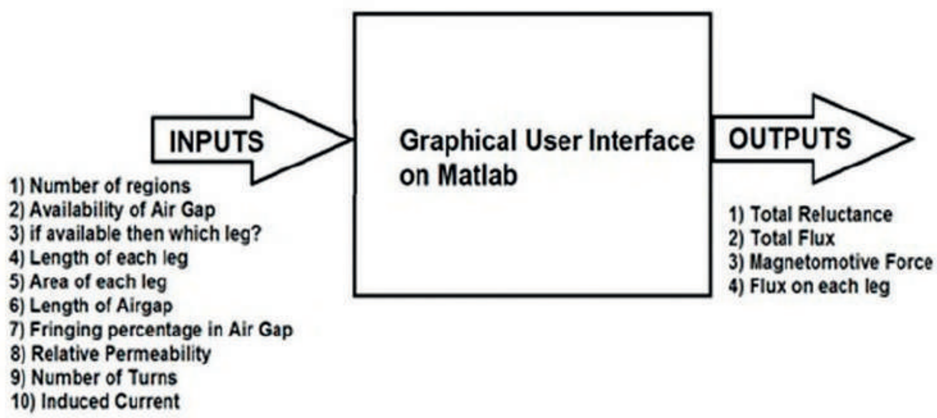

Figure 3. Ferromagnetic core GUI block diagram.

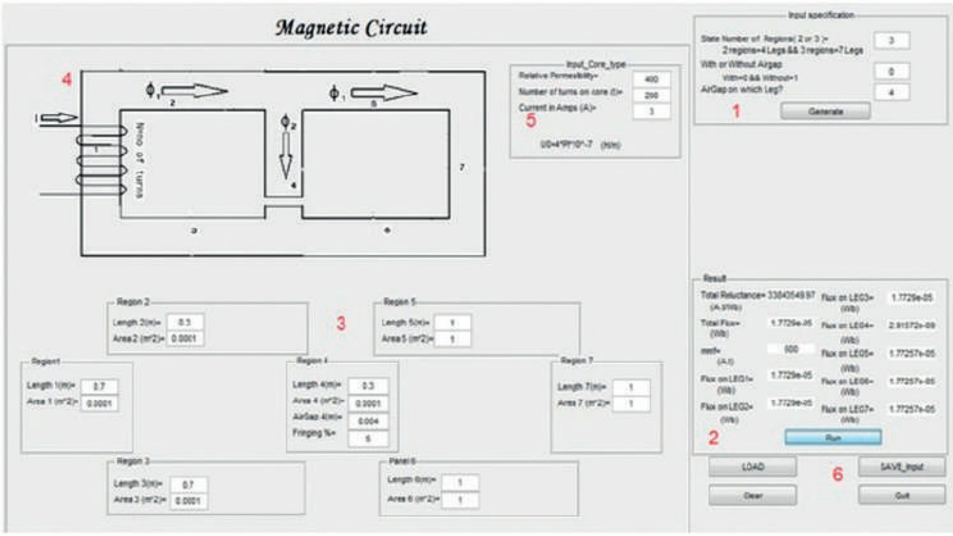

Figure 4. Graphical user interface for ferromagnetic core.

Also, the user should add the parameters of the ferromagnetic core such as length, area, air gap, and fringing percentage of each leg of the core; the ferromagnetic core is displayed after entering the inputs. Push buttons are added to load, save data, clear, and quit.

3. Single- and three-phase transformer

3.1. Introduction

Transformer allows developing different voltage levels across the system for the most cost-effective price. Transformer functioning principle is based on the idea that energy can be transferred by means of magnetic induction from one winding at the primary side to another winding at the secondary side. This is done by varying the magnetic field produced by alternating current [2, 3].

In this section, graphical user interface (GUI) on MATLAB software will be used to calculate the circuit parameters, efficiency, and voltage regulation of single-phase and three-phase ac transformer. The MATLAB results have been verified and compared with manual calculation in order to ensure they are correct and reliable.

Using GUI in electrical simulation, the instructor/teacher could show the effect of variation for different parameters and then permit to analyze and conclude without the need of manual solving.

3.2. Single-phase transformer model

A single-phase transformer consists of one primary winding and one secondary winding. The exact equivalent circuit with its parameter is shown in the figure below [4].

The parameters of this transformer are as follows (**Figure 5**):

Primary side:

a. Primary voltage terminal (V_P)

b. Primary current (I_P)

c. Primary resistance (R_P)

d. Primary leakage reactance (X_P)

e. Core resistance (R_C)

f. Magnetize in reactance (X_M)

g. Number of turns (N_P)

Secondary side:

a. Secondary voltage terminal (V_S)

b. Secondary current (I_S)

c. Secondary resistance (R_S)

d. Secondary leakage reactance (X_S)

e. Number of turns (N_S)

These parameters can be calculated by open-circuit test and short-circuit test procedure.

3.3. Transformer test

Two tests are applied on the transformer in order to determine its parameters: short-circuit and open-circuit tests [2].

The results permit to determine the equivalent circuit of the transformer, its voltage regulation, as well as its efficiency.

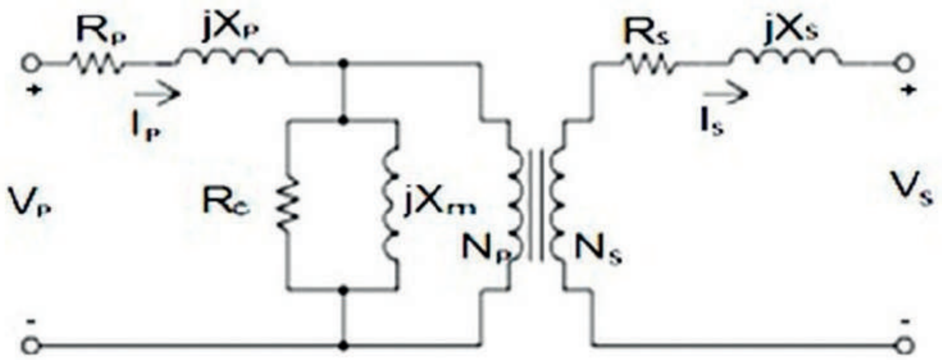

Figure 5. Exact model of transformer.

3.3.1. Short-circuit test

A voltmeter, ammeter, and wattmeter are connected in the HV side of the transformer. Then, the voltage at rated frequency is applied to that HV side using a variable ratio autotransformer. We will then short circuit the LV side of the transformer. Keep increasing the applied voltage, slowly, till reaching the rated current of the HV side (ammeter reading).

Once the rated current is reached on the HV side, the readings extracted on all three instruments, voltmeter, ammeter, and wattmeter, are recorded. The full-load current equivalent corresponds to the ammeter reading.

The transformer core losses could be neglected in this test. In fact, the voltage applied during the short-circuit test on the transformer is very small when compared to the rated voltage of the transformer.

The copper losses in the transformer could be read on the wattmeter. In fact, the wattmeter indicates the input power during the short-circuit test, when the voltmeter is showing the short-circuit voltage V_{SC}. At this time, no output power will appear (short circuited), the core losses are neglected due to the low applied voltage, and, thus, the copper losses in the transformer correspond to the input power.

The extracted values, when the test is accomplished on the transformer's HV side, are referred to the HV side. We can also refer these values to the LV side dividing by the squared turn ratio of the transformer.

Let us consider that the wattmeter reading is P_{SC}:

$$P_{SC} = R_e I^2 \tag{16}$$

If Z_e is the equivalent impedance of the transformer, then

$$R_e = \frac{V_{SC}}{I_L} \tag{17}$$

Therefore, if the equivalent reactance of transformer is X_e, then

$$X_e^2 = Z_e^2 - R_e^2 \tag{18}$$

Power factor of the current and angle of power factor are shown below:

$$PF = \cos\theta = \frac{P_{SC}}{V_{SC} I_{SC}} \Rightarrow \theta = \cos^{-1}\frac{P_{SC}}{V_{SC} I_{SC}} \tag{19}$$

3.3.2. Open-circuit test

The open-circuit test consists of connecting an ammeter, a voltmeter, and a wattmeter to the LV side of the transformer. At rated frequency, a voltage is applied to the LV side using a variable ratio autotransformer.

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Increasing this applied voltage until the LV side rated voltage is reached (using the voltmeter readings). The HV side of the transformer is kept open. Now, the three readings, voltage, current, and power, are recorded.

The recorded current is the no-load current I_e. It has a small value when compared to the transformer's rated current, and, thus, we can neglect the voltage drop due to this electric current. The recorded voltage V is now equal to the transformer's secondary induced voltage.

The wattmeter indicates the input power, which corresponds to the core and copper losses in the transformer, since no output power will appear (open circuit). Copper losses could be neglected since the no-load current is very small compared to the full-load current, and, thus, the core losses in the transformer are considered equal to the wattmeter reading, P_o:

$$P_o = \frac{V_1^2}{R_m} \tag{20}$$

where R_m is the transformer's shunt branch resistance.

If Z_m is the shunt branch impedance of the transformer, then

$$Z_m = \frac{V_1}{I_e} \tag{21}$$

Therefore, if shunt branch reactance of transformer is X_m, then

$$\left(1/X_m\right)^2 = \left(1/Z_m\right)^2 - \left(1/R_m\right)^2 \tag{22}$$

The test is applied on the LV side of the transformer, so the calculated values are referred to the LV side. We could calculate the referred HV side values by multiplying these values with the squared turn's ratio of the transformer. The open-circuit test on transformer is used to determine the parameters of the shunt branch of the equivalent circuit of transformer:

$$PF = \cos\theta = \frac{P_{OC}}{V_{OC} I_{OC}} \Rightarrow \theta = \cos^{-1}\frac{P_{OC}}{V_{OC} I_{OC}} \tag{23}$$

The excitation admittance is therefore

$$Y_E = \frac{I_{OC}}{V_{OC}} \angle -\theta_{OC} \tag{24}$$

The equivalent series impedance is therefore

$$Z_{SE} = \frac{V_{SC}}{I_{SC}} \angle\theta_{SC} \tag{25}$$

The voltage regulation is

$$VR = \frac{V_P/a - V_{s,fl}}{V_{s,fl}} \times 100\% \quad (26)$$

And the efficiency is

$$\eta = \frac{P_{out}}{P_{in}} \times 100\% \quad (27)$$

3.4. Three-phase transformer

A three-phase transformer is made of three transformers that are either separated or combined in one core. The primary side and secondary side of any given three-phase transformer can be connected independently in either delta (Δ) or wye (Y) [2].

3.5. Implementation on GUI MATLAB

The user will enter certain values into the GUI interface, and then the result will be displayed with respect to this flow chart (**Figure 6**).

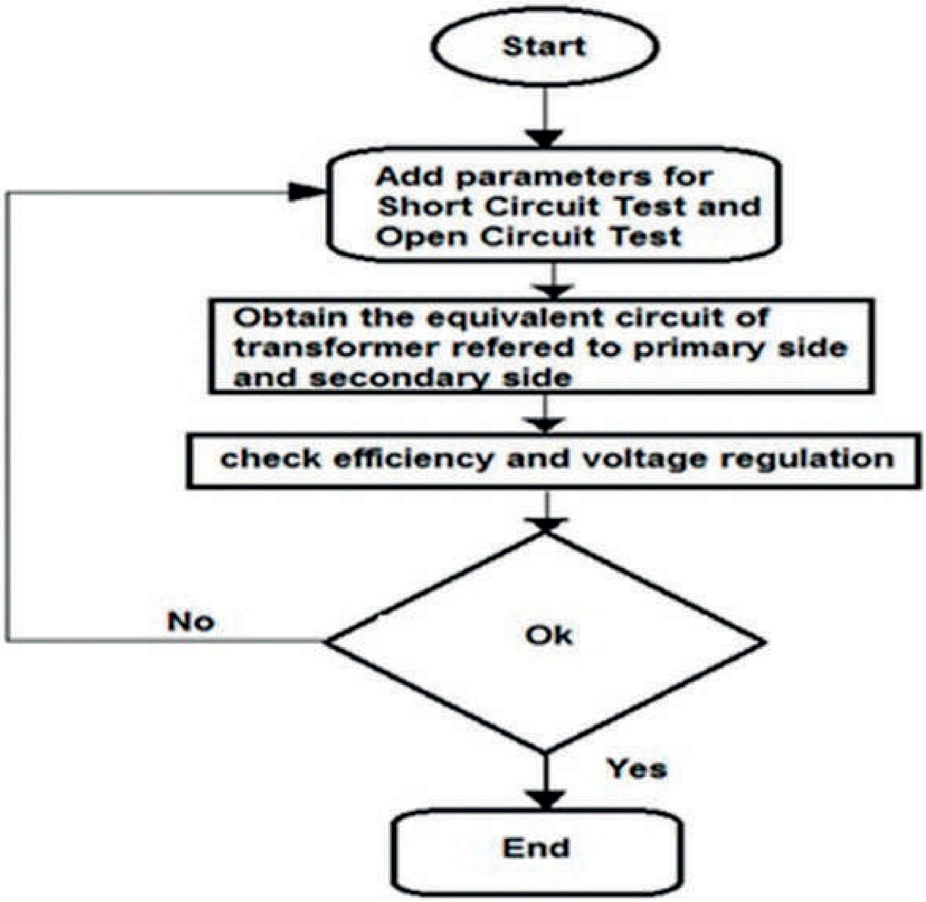

Figure 6. Flow chart for GUI.

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The graphical user interface for single-phase transformer is shown in **Figure 7**.

The user will add the inputs which are values of short-circuit test and open-circuit test. And then, choose between leading and lagging load. The results of the equivalent circuits referred to primary and secondary side are displayed after adding the parameter and clicking on to calculate the equivalent circuit, and the equivalent circuit of the transformer referred to the primary side and secondary side are displayed with their parameter.

The user may also choose the type of core of the transformer whether circular or rectangular in shape (**Figure 8**).

Push buttons were used to load and save data as well as to display the performance of the transformer (**Figure 9**).

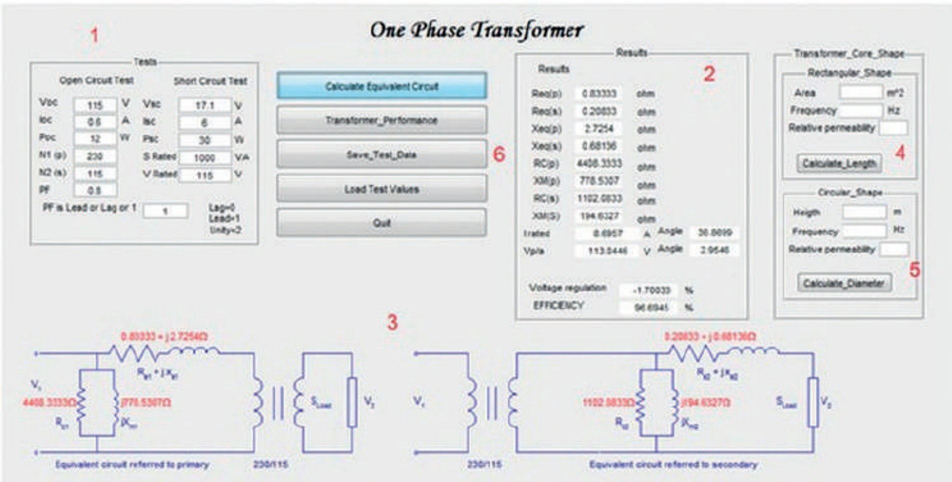

Figure 7. Graphical user interface for single-phase transformer.

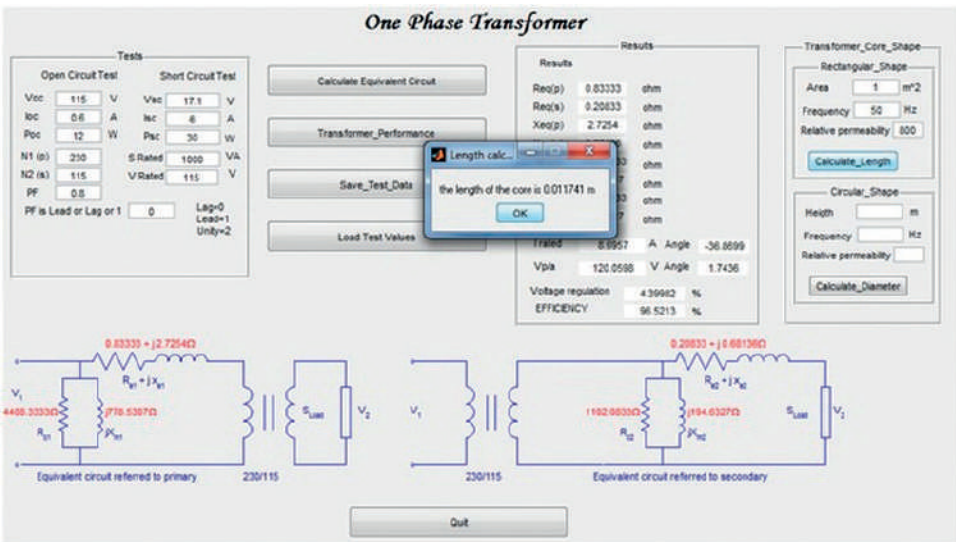

Figure 8. Transformer core shape calculated.

The graphical user interface for three-phase transformer is shown in **Figure 10**.

Here, the user has to choose the type of connection. An example of calculation is shown in **Figure 11**.

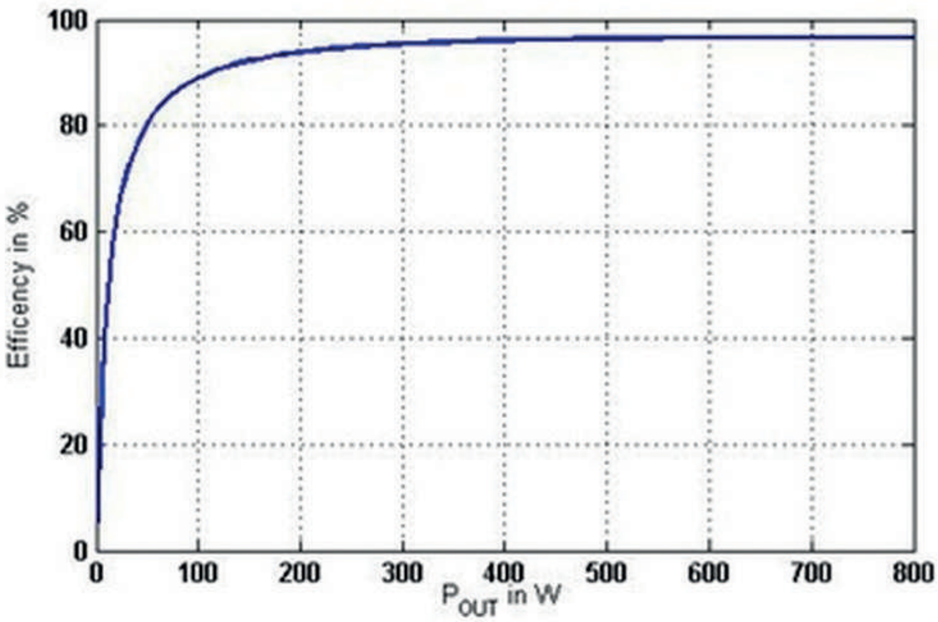

Figure 9. Single-phase transformer performance.

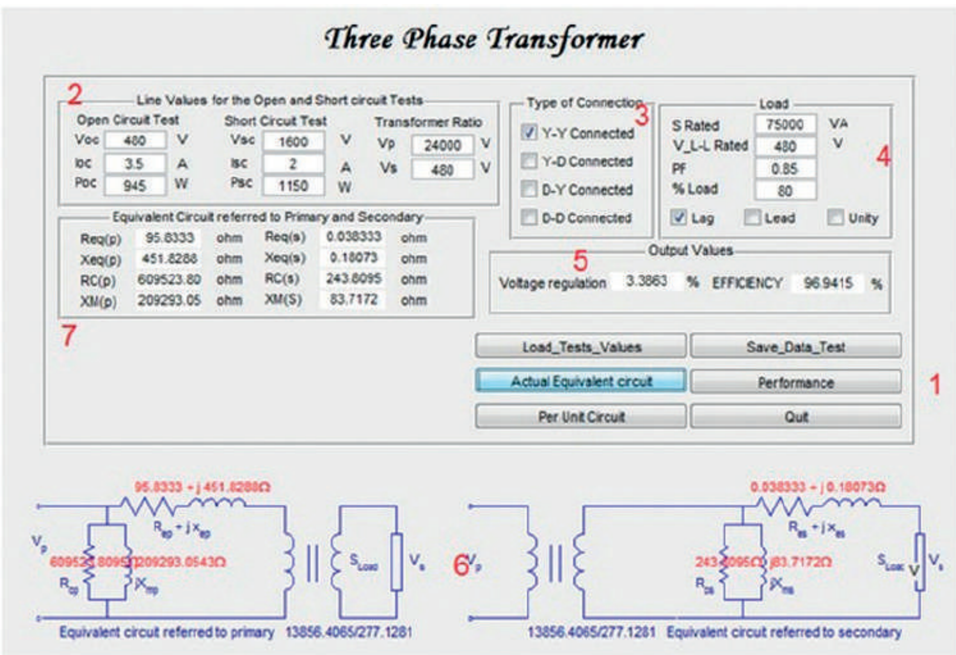

Figure 10. Graphical user interface for three-phase transformer.

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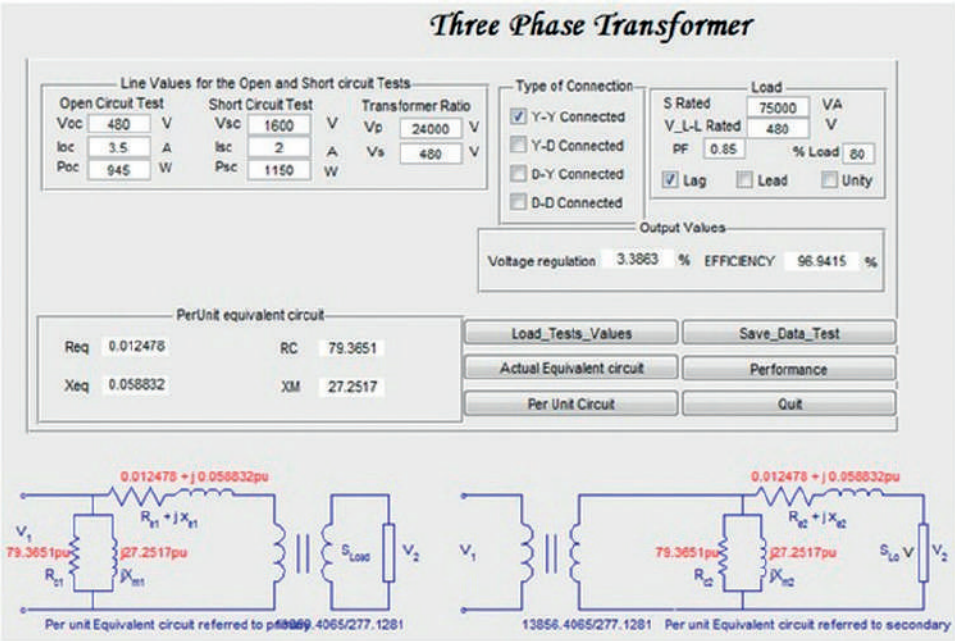

Figure 11. Per unit equivalent circuit of three-phase transformer.

4. DC machines

4.1. Introduction

This chapter discusses the types of DC machines with implementation of graphical user interface and plotting the torque speed characteristics and terminal characteristic for each DC machine [5].

In DC machines, the armature or loops of the rotor can be connected in many ways to the segments of the commutators. The rotor output voltage and the number of parallel current paths are affected by these several ways of connection [2, 5].

In any given machine, the voltage induced in E_A depends on three factors:

i. The flux ϕ in the machine

ii. The speed ω_m of the rotor of the machine

iii. A constant K that depends on the construction of the machine

The voltage of the real machine armature is given by

$$E_A = \frac{ZP}{2\pi a}\phi\omega_m = \frac{ZP}{2\pi a}\phi\frac{2\pi}{60}n_m \quad (28)$$

In any DC machine, the torque depends on three factors:

i. The flux ϕ in the machine

ii. The armature current I_A of the machine

iii. A constant K that depends on the construction of the machine

The torque on the armature of a real machine is

$$T_{ind} = \frac{ZP}{2\pi a}\phi I_A \tag{29}$$

4.2. DC motors and DC generators

DC machines can be used as DC motors or DC generators. The difference between the motor and generator is the power flow direction. The equivalent circuit of DC motors and DC generators is similar to each other, but the direction of the current flow of the DC motors is opposite to the direction in DC generators [2].

In a DC machine, the induced voltage is directly proportional to the flux and the speed of rotation of the machine. The magnetomotive field force is produced by field current, which in turn produces flux along with its magnetization curve.

As long as the field current is proportional to the magnetomotive field force and the induced voltage is proportional to the produced flux, it is usual to present the magnetization curve as a plot of E_A-induced voltage with respect to the current of the field for a constant speed ω_0.

4.2.1. Types of DC motors

a. **Separately excited DC motor**: is a DC motor where the field circuit is supplied by a separate voltage supply.

b. **Shunt DC motor:** is a DC motor whose field circuit gets its power directly across the armature terminals of the motor.

c. **Series DC motor:** is a DC motor where the field windings consist of few turns that are connected in series with the armature circuit.

d. **Compounded DC motor:** is a motor that consists of both a shunt and a series field. It consists of two types: cumulative and differential compounded DC motor.

   In cumulative compounded motor, the current flows into the dots of both field coils. The resulting magnetomotive forces add to produce a larger total magnetomotive force.

   In differential compounded motor, the current flows into the dot on one of the field coils and out of the dot of the other field coil, the resulting magnetomotive forces subtract.

4.2.2. Types of DC generators

a. **Separately excited generator:** a separate power source, independent of the generator, supplies the field flux to the DC generator.

b. **Shunt generator:** the field circuit is connected directly to the generator terminals in order to produce the field flux to the DC generator.

c. **Series generator**: the field circuit is connected in series with the generator armature to produce the field flux to the DC generator.

d. **Cumulatively compounded generator:** is a DC generator in which both the shunt and the series fields are available, and their effects are added.

e. **Differentially compounded generator:** is a DC generator in which both the shunt and the series fields are available, but their effects are subtracted.

4.3. Implementation on GUI MATLAB

A graphical user interface is implemented for DC machine with types of generators and motors. The first GUI will obtain the armature resistance for any DC machine (**Figure 12**).

The user will determine the type of winding and enter the inputs which are pole number. Coil numbers and turn numbers with the plex and resistance per turn then calculate results. The armature resistance (RA) is expressed by

$$RA = \frac{\text{Turns} \times \frac{\text{coils}}{\text{current path}} \times (\text{resistance per turn})}{\text{current path}} \tag{30}$$

The results will be displayed with armature resistance included. This value will be installed in the other part of the graphical user interface for DC generators and DC motors.

The graphical user interface for the types of DC generators and DC motors is shown in **Figure 13**.

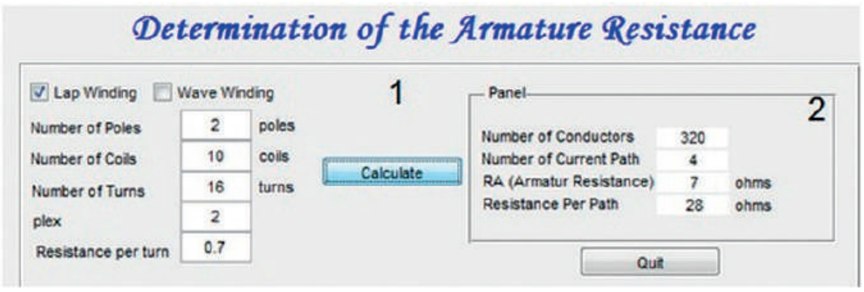

Figure 12. GUI to determine the armature resistance of DC machines.

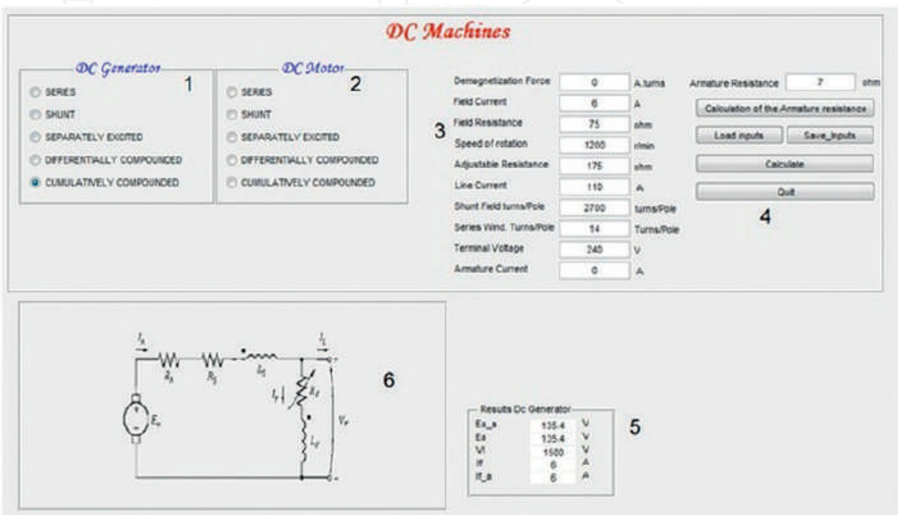

Figure 13. Graphical user interface for the types of DC motors and DC generators.

The user will choose the type of DC generator/motor and enter the corresponding parameters. Push buttons are available to load and save the data, calculate the armature resistance, and quit the program. Results will be displayed with the terminal characteristic and torque speed characteristics (**Figures 14** and **15**).

The equivalent circuit of the type of motor or generator will be displayed after calculating the result.

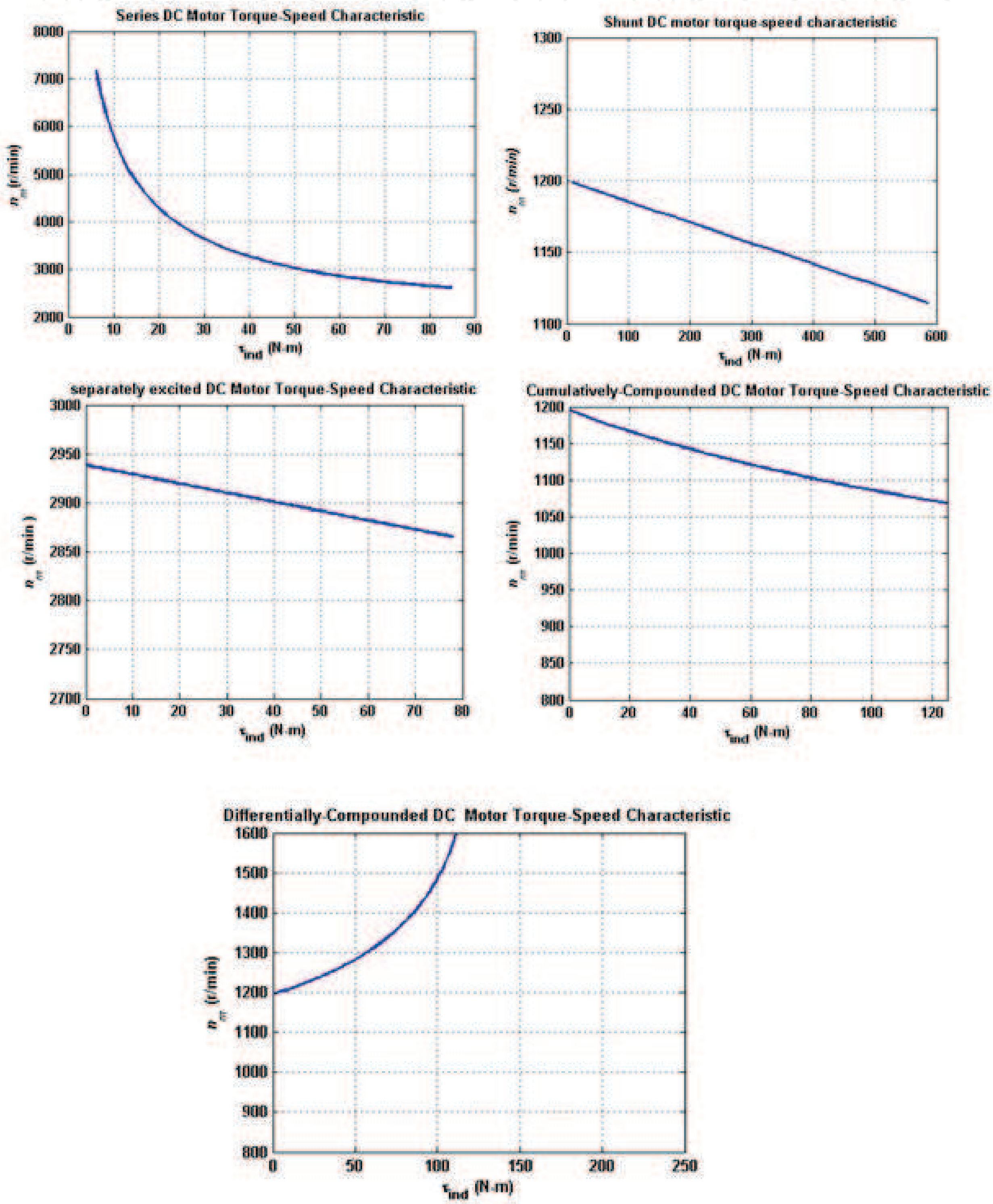

Figure 14. DC motor terminal characteristics.

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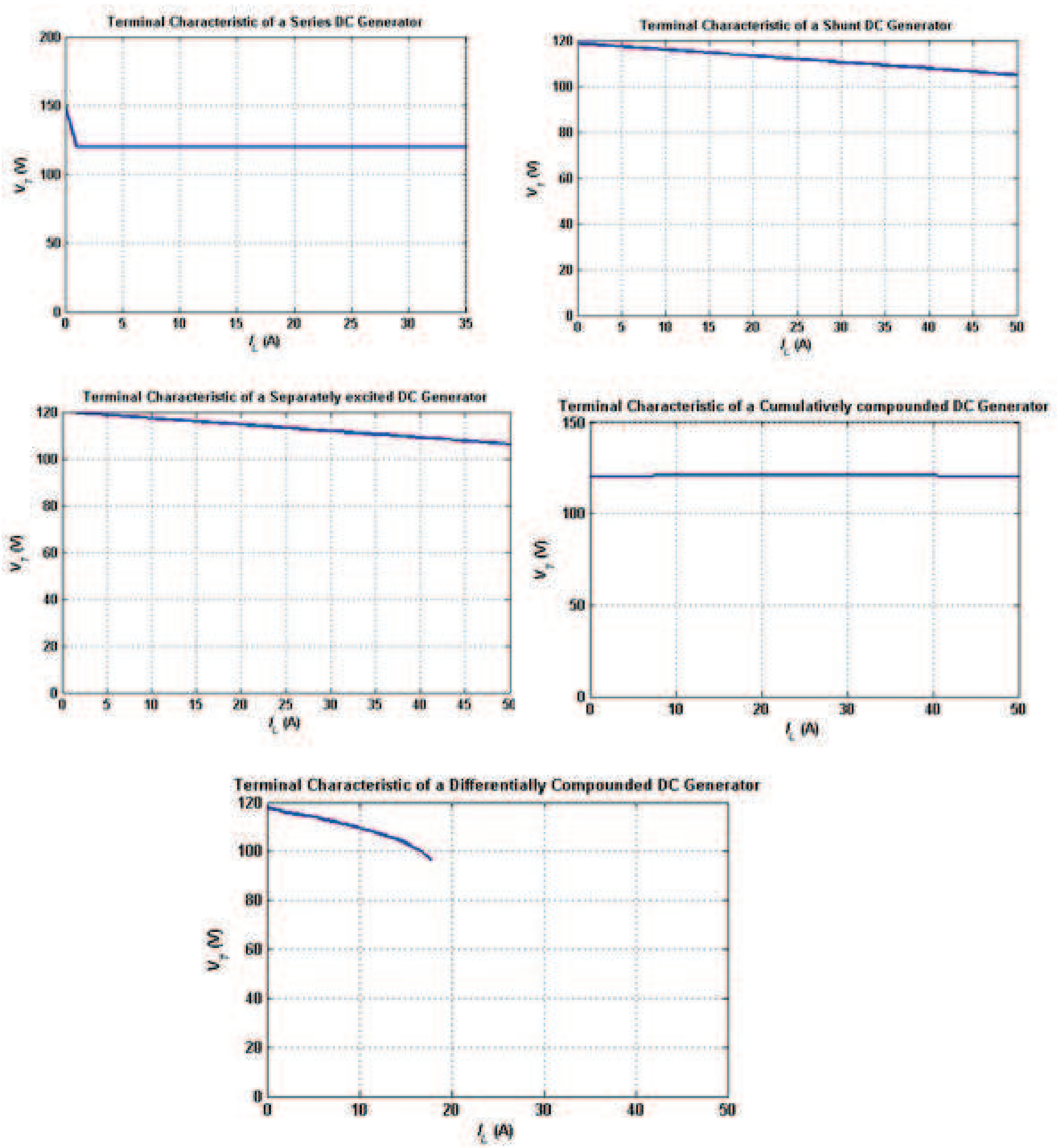

Figure 15. DC generator terminal characteristics.

5. Induction machines

5.1. Induction motors and induction generators

An induction machine is a machine with only a continuous set of amortisseur windings. They are induction machine because the voltage of the rotor is induced in the rotor winding instead of being physically connected with wires. To run the machine, it does not require a DC field current. Induction machines can be used as either generators or motors. Induction machines are not used as generators except in some special applications due to their disadvantages. Therefore, induction machines are most of the time referred to as induction motors [2].

After applying a three-phase voltage to the stator, current flows into the stator which produces magnetic field that rotates in a counterclockwise direction. The rotation speed of the magnetic field is expressed by

$$n_{sys} = \frac{120 f_{se}}{P} \tag{31}$$

The relative motion of magnetic field and rotor is defined with two terms, which are

a. Slip speed: It is the synchronous speed minus rotor speed.

b. Slip: It is the relative speed expressed as ratio of slip speed to synchronous speed in a percentage basis.

$$n_{slip} = n_{sync} - n_m \tag{32}$$

$$s = \frac{n_{slip}}{n_{sync}} \times 100\% \Rightarrow s = \frac{n_{sync} - n_m}{n_{sync}} \times 100\% \tag{33}$$

Note that the rotor turns at $s = 0$, whereas at $s = 1$, the rotor is stationary.

5.2. The equivalent circuit of an induction motor

The equivalent circuit of an induction motor is similar to that of the transformer, with a difference between the magnetization curve of the transformer and induction machine (**Figures 16** and **17**).

5.3. Implementation on GUI MATLAB

A graphical user interface is implemented on MATLAB for induction machines (**Figure 18**).

The user has to enter details related to the induction machine:

1. In this part the user can calculate and display the result of induction machine torque characteristics (**Figure 19**).
2. Single- and double-cage rotor characteristic (**Figure 20**).

As we noticed, the double-cage design, when compared to the single-cage rotor, has a high starting torque with smaller maximum torque and a slightly higher slip in the normal operating range.

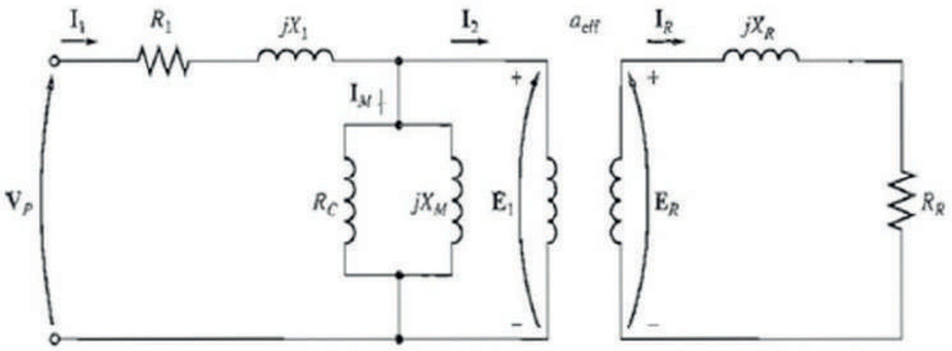

Figure 16. The transformer model of an induction motor, with rotor and stator connected by an ideal transformer of turn ratio a_{eff}.

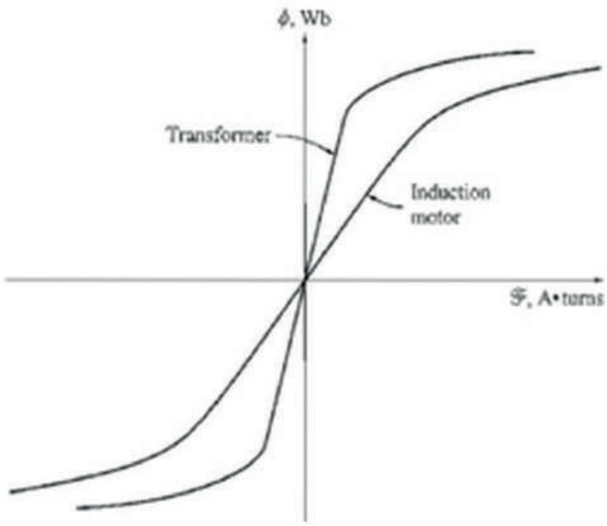

Figure 17. The magnetization curve of an induction motor compared to that of a transformer.

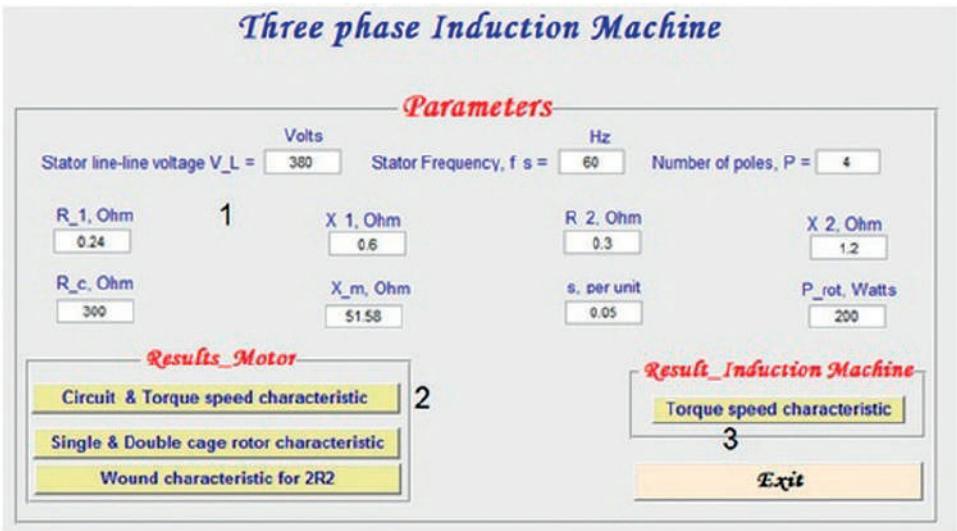

Figure 18. Graphical user interface for three-phase induction machine.

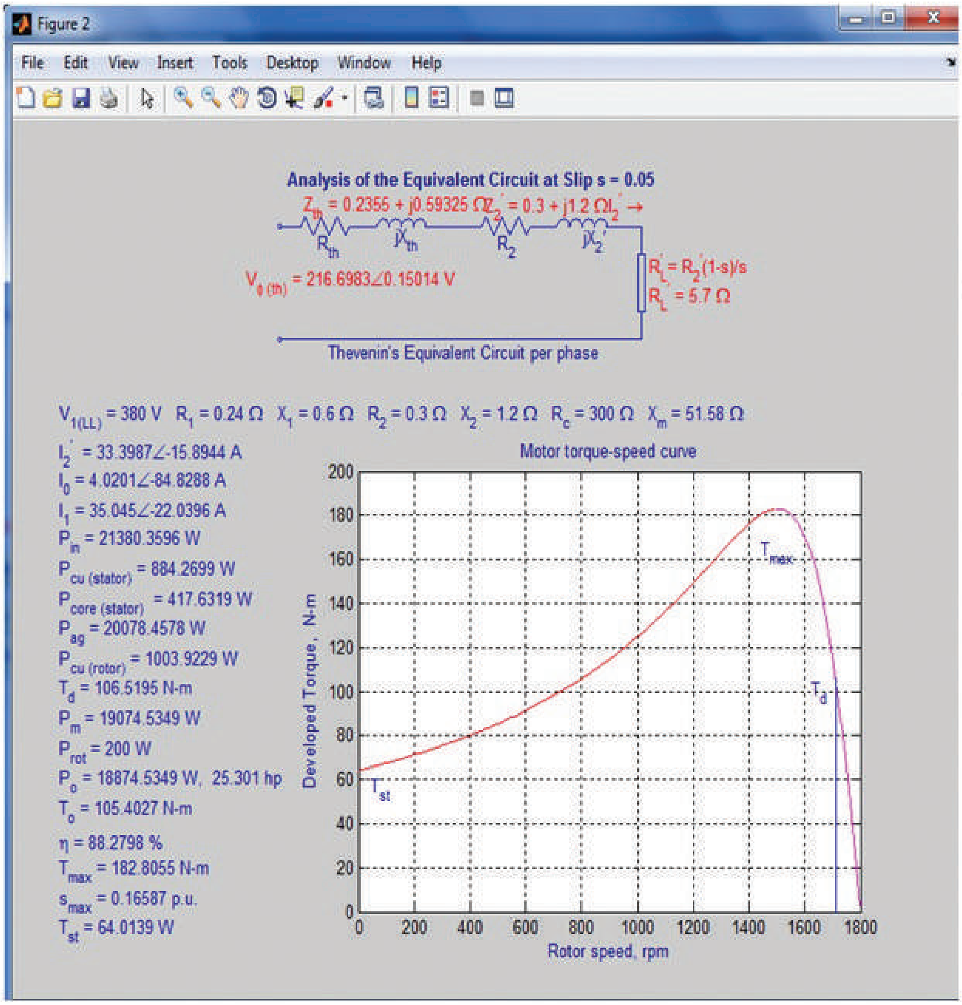

Figure 19. Equivalent circuit and torque speed characteristic.

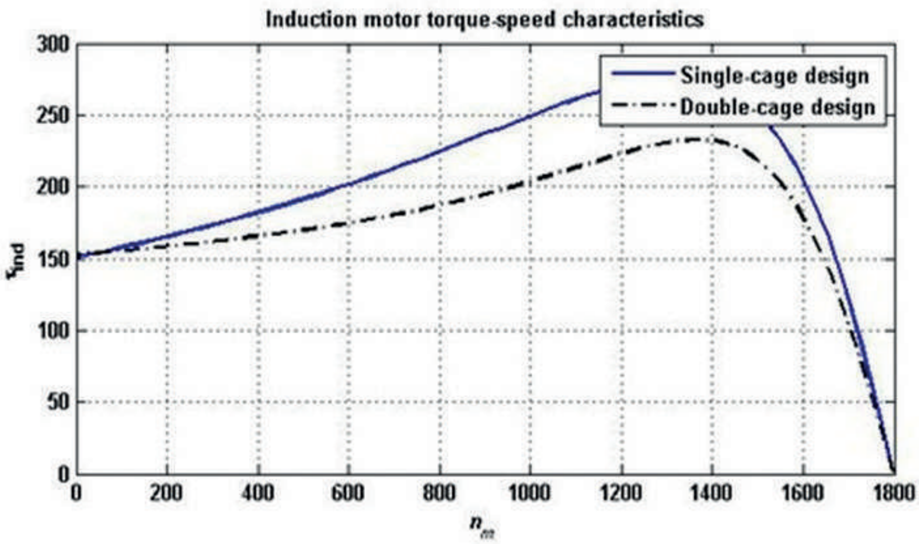

Figure 20. Single- and double-cage rotor characteristic.

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6. Conclusion

Ferromagnetic materials were discussed and implemented with respect to its magnetic model in graphical user interface using MATLAB.

Single-phase and three-phase transformers were discussed with implementation of transformer model in GUI on MATLAB. We also checked the parameter referred to secondary and primary side with the effect of load of the transformer.

DC machines were discussed with implementation of different types of DC motors, obtaining the plots of torque speed characteristic. Different types of DC generators were also implemented on GUI, and the terminal characteristics were also obtained.

Induction machines were examined through implementation of the parameters of induction motor in the GUI on MATLAB, obtaining the torque speed characteristics and the terminal characteristics.

Implementing an educational model on GUI MATLAB for the ferromagnetic core, single- and three-phase transformer, DC machines, and induction machines allows the students to study and analyze the effect of each parameter in order to understand its electric behavior with respect to its electric model.

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Chapter 9

Electric Machines: Tool in MATLAB

Rabih Rammal and Mohamad Arnaout

Additional information is available at the end of the chapter

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Abstract

This chapter presents an educational modeling and parametric study of specific types of transformers, generators, and motors used in power system. Equivalent circuit models are presented and basic equations are developed. Through tests and operating conditions, essential parameters for each presented machine are extracted. Graphical user interface (GUI) on MATLAB software is used to study and analyze each element. GUI allows better comprehension and clearer vision to analyze the performance of each electric machine, thus, a complementary educational tool. In addition, GUI permits optimal collaborative learning situations when linked with the theoretical expansion and, thus, is a teaching process that forges the connection between traditional subjects and science education.

Keywords: MATLAB, GUI, educational tool, science education, electric machines, ferromagnetic material, transformers, DC machines, induction machines

1. Introduction

There are several ways to generate electricity which are burning fossil fuels, converting water into steam, and using the steam to spin a turbine that is connected to an electric generator. In hydroelectric power plants, generators are turned by water and via wind in wind turbines. In all cases, the electricity generated at these facilities flows across the transmission and distribution system to where it is needed to meet customer demand in cities and rural areas. The electric system is an interconnected network for generating, transmitting, and delivering electricity to consumers [1].

The conventional view of studying electric machines concentrates on concepts. The graphical user interface provides direct contact with the content, provokes curiosity, and implements the science education through scientific knowledge based on facts, laws, theories, and models. The integration of this new structure improves science comprehension and helps students to learn better and more efficiently.

The study of an efficient power system starts with understanding the behavior of each component that develops this system. Electric machines used in power systems (generators, motors, and transformers) will be examined through analytical expressions and computer simulation. The importance of simulation is that these components could be studied before it is manufactured; thus, the consequences of changing dimensions and parameters can be assessed.

This simulation will be implemented in an educational tool, going from the basic operation principles, through developing models and equations toward the solution. The graphical user interface of MATLAB allows the students to study and analyze the effect of each parameter in order to understand its electric behavior with respect to its electric model.

This chapter will discuss the implementation of ferromagnetic core using graphical user interface taking into consideration the effects of air gap and fringing of a ferromagnetic core. Then, a detailed study of output power and losses with voltage regulation and efficiency of a single- and three-phase transformer will be established. In addition, a special survey will be accomplished concerning the types of DC motors and generators. Finally, this chapter will be concluded by providing an adequate research on the induction machines including their parametric study, and it will be achieved by a general conclusion of this work.

This chapter presents learning situations going from the theoretical expansion to the graphical interpretation. It is a teaching methodology toward the science education.

2. Ferromagnetic core

Magnetic fields are the essential means by which energy is converted from one form to another in motors, generators, and transformers. The most important class of the magnetic materials is the ferromagnetic materials such as iron, cobalt, nickel, and manganese [2].

There are four basic principles which describe how magnetic fields are used [2]:

1. A wire produces a magnetic field in the area around it when current passes through it.
2. A change in magnetic field, by mutual inductance, induces a voltage in the coil of wire: this is the principle of transformer action.
3. In the presence of a magnetic field, a current-carrying wire has a force induced on it: this is the principle of motor action.
4. In the presence of a magnetic field, a moving wire has a voltage induced in it: this is the principle of generator action.

2.1. The magnetic field

The magnetic field is produced by induced current in Ampere's law:

$$\oint H.dl = I_{net} \quad (1)$$

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where I_{net} produces magnetic field intensity and H and dl are the length integration along a path. If the core is produced from ferromagnetic material (**Figure 1**), then all the magnetic field produced within the core will remain inside the core. Therefore, the path of integration dl in the Ampere's law is the mean path length l_c [2].

The current passing in the path of the integration I_{net} is NI since the coil of the wire divides the path of integration into N times when the current passes through it:

$$H.l = NI \Rightarrow H = \frac{NI}{l} \tag{2}$$

The magnetic field intensity H is the effort in which a current is applying to establishment of a magnetic field. Strength of the magnetic field depends on the material of core. There is a relationship between the magnetic field intensity, the material magnetic permeability μ, and the magnetic flux produced within the material as shown in Eq. (3):

$$B = \mu H \tag{3}$$

The permeability of free space is called μ_0 and equal to $4\pi \times 10^{-7}$ H/m, and the relative permeability is the permeability of any other material compared to the free space permeability:

$$\mu_r = \frac{\mu}{\mu_0} \tag{4}$$

In the core (**Figure 1**), the magnitude of the flux density is given by

$$B = \mu H = \mu \frac{NI}{l} \tag{5}$$

Therefore, the total flux in a given area is expressed in Eq. (6). This equation reduced if the flux density vector is perpendicular to any plane of area, and if the flux density is constant throughout the area, then to

$$\int_A \phi = B.dA \Rightarrow \phi = B.A = \mu HA = \mu \frac{NI}{l} A \tag{6}$$

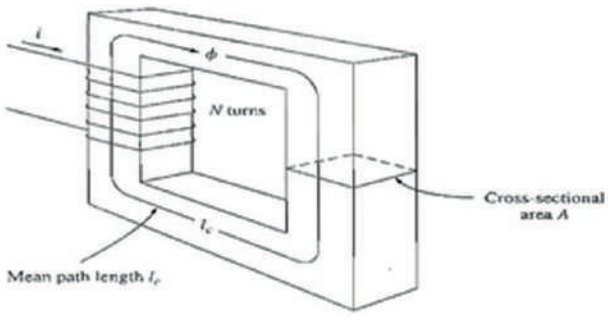

Figure 1. Ferromagnetic core.

2.2. Magnetic circuits

Magnetic flux is produced when the current in a coil of wire is wrapped around a core. This is similar to a voltage in an electric circuit producing a current flow. Thus, a "magnetic circuit" is defined by equations that are similar to that of an electric circuit. In the design of electric machines and transformers, the magnetic circuit model is used to simplify the complex design process [2].

The voltage or electromotive force drives the current flow in the electric circuit. The magnetomotive force of the magnetic circuit is denoted by where is the magnetomotive force in ampere-turns. In the magnetic circuit, the applied magnetomotive force causes flux (ϕ) to be produced (**Figure 2**).

The relationship that governs the magnetomotive force and flux is given by

$$\mathfrak{I} = NI = \phi\mathfrak{R} \tag{7}$$

The permeance of a magnetic circuit is the reciprocal of its reluctance. Therefore, the relation between magnetomotive force and flux can be expressed as

$$\phi = \mathfrak{I}P \Rightarrow \phi = \mathfrak{I}\frac{1}{\mathfrak{R}} \tag{8}$$

It is easier to work with the permeance of a magnetic field than with its reluctance.

The resulting flux and reluctance of a core are shown in Eqs. (9) and (10), respectively:

$$\phi = \mathfrak{I}\frac{\mu A}{l} \tag{9}$$

$$\mathfrak{R} = \frac{l}{\mu A} \tag{10}$$

The equivalent reluctance of a number of reluctances in series is just the sum of the individual reluctances:

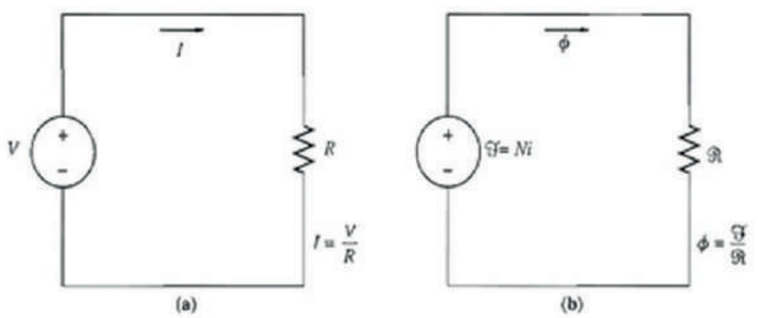

Figure 2. (a) A simple electric circuit. (b) The magnetic circuit analogue to a transformer core.

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$$\mathfrak{R}_{eq} = \mathfrak{R}_1 + \mathfrak{R}_2 + \mathfrak{R}_3 + \ldots.. \quad (11)$$

The equivalent reluctance of a number of reluctances in parallel is just the sum of the individual reluctances:

$$\mathfrak{R}_{eq} = \frac{1}{\mathfrak{R}_1} + \frac{1}{\mathfrak{R}_2} + \frac{1}{\mathfrak{R}_3} + \ldots.. \quad (12)$$

The reluctance of each leg of a ferromagnetic core is

$$\mathfrak{R}_x = \frac{l_x}{\mu_r \mu_0 A_x} \, {}^{A.t}\!/_{wb} \quad (13)$$

The air-gap reluctance at leg X is

$$\mathfrak{R}_{xa} = \frac{l_{xa}}{\mu_0 A_{xa}} \, {}^{A.t}\!/_{wb} \quad (14)$$

The total flux of the ferromagnetic core is

$$\phi_{TOT} = \frac{\mathfrak{J}}{\mathfrak{R}_{eq}} \, wb \quad (15)$$

2.3. Implement in MATLAB GUI

When implementing in MATLAB, the user will add certain input which will then be calculated, and the result will be displayed. Below is a block diagram of the system.

The user fills the number of regions with availability of air gap indicating which leg is available and the details for core type such as relative permeability of the material and number of turns with the current (**Figure 3**). The results of the calculated parameters such as total flux and total reluctance and magnetomotive force of ferromagnetic core are displayed (**Figure 4**).

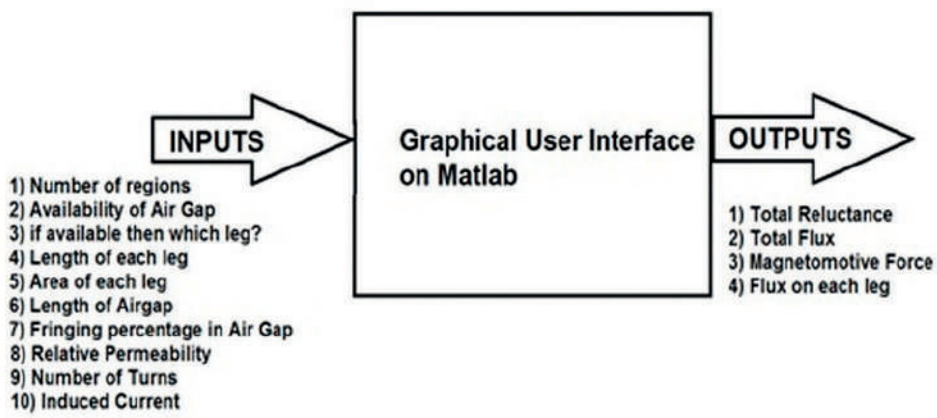

Figure 3. Ferromagnetic core GUI block diagram.

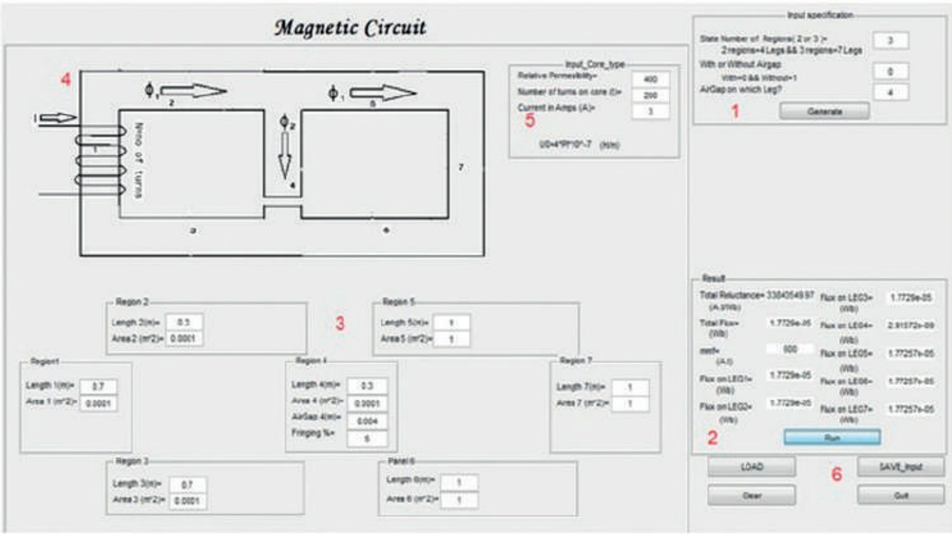

Figure 4. Graphical user interface for ferromagnetic core.

Also, the user should add the parameters of the ferromagnetic core such as length, area, air gap, and fringing percentage of each leg of the core; the ferromagnetic core is displayed after entering the inputs. Push buttons are added to load, save data, clear, and quit.

3. Single- and three-phase transformer

3.1. Introduction

Transformer allows developing different voltage levels across the system for the most cost-effective price. Transformer functioning principle is based on the idea that energy can be transferred by means of magnetic induction from one winding at the primary side to another winding at the secondary side. This is done by varying the magnetic field produced by alternating current [2, 3].

In this section, graphical user interface (GUI) on MATLAB software will be used to calculate the circuit parameters, efficiency, and voltage regulation of single-phase and three-phase ac transformer. The MATLAB results have been verified and compared with manual calculation in order to ensure they are correct and reliable.

Using GUI in electrical simulation, the instructor/teacher could show the effect of variation for different parameters and then permit to analyze and conclude without the need of manual solving.

3.2. Single-phase transformer model

A single-phase transformer consists of one primary winding and one secondary winding. The exact equivalent circuit with its parameter is shown in the figure below [4].

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The parameters of this transformer are as follows (**Figure 5**):

Primary side:

a. Primary voltage terminal (V_P)

b. Primary current (I_P)

c. Primary resistance (R_P)

d. Primary leakage reactance (X_P)

e. Core resistance (R_C)

f. Magnetize in reactance (X_M)

g. Number of turns (N_P)

Secondary side:

- **a.** Secondary voltage terminal (V_S)
- **b.** Secondary current (I_S)
- **c.** Secondary resistance (R_S)
- **d.** Secondary leakage reactance (X_S)
- **e.** Number of turns (N_S)

These parameters can be calculated by open-circuit test and short-circuit test procedure.

3.3. Transformer test

Two tests are applied on the transformer in order to determine its parameters: short-circuit and open-circuit tests [2].

The results permit to determine the equivalent circuit of the transformer, its voltage regulation, as well as its efficiency.

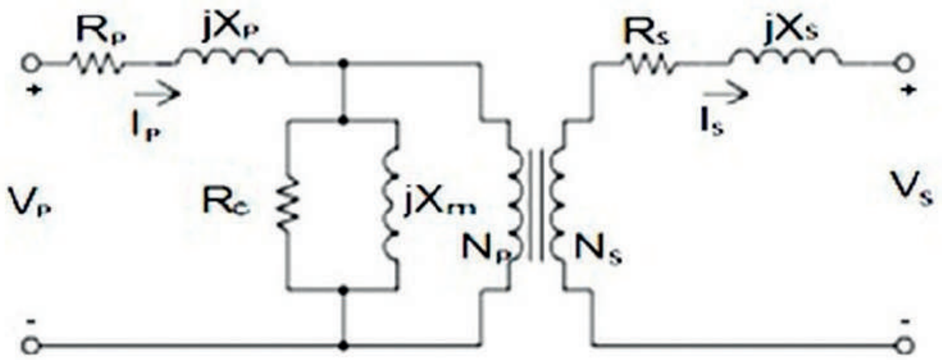

Figure 5. Exact model of transformer.

3.3.1. Short-circuit test

A voltmeter, ammeter, and wattmeter are connected in the HV side of the transformer. Then, the voltage at rated frequency is applied to that HV side using a variable ratio autotransformer. We will then short circuit the LV side of the transformer. Keep increasing the applied voltage, slowly, till reaching the rated current of the HV side (ammeter reading).

Once the rated current is reached on the HV side, the readings extracted on all three instruments, voltmeter, ammeter, and wattmeter, are recorded. The full-load current equivalent corresponds to the ammeter reading.

The transformer core losses could be neglected in this test. In fact, the voltage applied during the short-circuit test on the transformer is very small when compared to the rated voltage of the transformer.

The copper losses in the transformer could be read on the wattmeter. In fact, the wattmeter indicates the input power during the short-circuit test, when the voltmeter is showing the short-circuit voltage V_{SC}. At this time, no output power will appear (short circuited), the core losses are neglected due to the low applied voltage, and, thus, the copper losses in the transformer correspond to the input power.

The extracted values, when the test is accomplished on the transformer's HV side, are referred to the HV side. We can also refer these values to the LV side dividing by the squared turn ratio of the transformer.

Let us consider that the wattmeter reading is P_{SC}:

$$P_{SC} = R_e I^2 \tag{16}$$

If Z_e is the equivalent impedance of the transformer, then

$$R_e = \frac{V_{SC}}{I_L} \tag{17}$$

Therefore, if the equivalent reactance of transformer is X_e, then

$$X_e^2 = Z_e^2 - R_e^2 \tag{18}$$

Power factor of the current and angle of power factor are shown below:

$$PF = \cos\theta = \frac{P_{SC}}{V_{SC} I_{SC}} \Rightarrow \theta = \cos^{-1} \frac{P_{SC}}{V_{SC} I_{SC}} \tag{19}$$

3.3.2. Open-circuit test

The open-circuit test consists of connecting an ammeter, a voltmeter, and a wattmeter to the LV side of the transformer. At rated frequency, a voltage is applied to the LV side using a variable ratio autotransformer.

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Increasing this applied voltage until the LV side rated voltage is reached (using the voltmeter readings). The HV side of the transformer is kept open. Now, the three readings, voltage, current, and power, are recorded.

The recorded current is the no-load current I_e. It has a small value when compared to the transformer's rated current, and, thus, we can neglect the voltage drop due to this electric current. The recorded voltage V is now equal to the transformer's secondary induced voltage.

The wattmeter indicates the input power, which corresponds to the core and copper losses in the transformer, since no output power will appear (open circuit). Copper losses could be neglected since the no-load current is very small compared to the full-load current, and, thus, the core losses in the transformer are considered equal to the wattmeter reading, P_o:

$$P_o = \frac{V_1^2}{R_m} \tag{20}$$

where R_m is the transformer's shunt branch resistance.

If Z_m is the shunt branch impedance of the transformer, then

$$Z_m = \frac{V_1}{I_e} \tag{21}$$

Therefore, if shunt branch reactance of transformer is X_m, then

$$\left(1/X_m\right)^2 = \left(1/Z_m\right)^2 - \left(1/R_m\right)^2 \tag{22}$$

The test is applied on the LV side of the transformer, so the calculated values are referred to the LV side. We could calculate the referred HV side values by multiplying these values with the squared turn's ratio of the transformer. The open-circuit test on transformer is used to determine the parameters of the shunt branch of the equivalent circuit of transformer:

$$PF = \cos\theta = \frac{P_{OC}}{V_{OC} I_{OC}} \Rightarrow \theta = \cos^{-1}\frac{P_{OC}}{V_{OC} I_{OC}} \tag{23}$$

The excitation admittance is therefore

$$Y_E = \frac{I_{OC}}{V_{OC}} \angle -\theta_{OC} \tag{24}$$

The equivalent series impedance is therefore

$$Z_{SE} = \frac{V_{SC}}{I_{SC}} \angle \theta_{SC} \tag{25}$$

The voltage regulation is

$$VR = \frac{V_P/a - V_{s,fl}}{V_{s,fl}} \times 100\% \tag{26}$$

And the efficiency is

$$\eta = \frac{P_{out}}{P_{in}} \times 100\% \tag{27}$$

3.4. Three-phase transformer

A three-phase transformer is made of three transformers that are either separated or combined in one core. The primary side and secondary side of any given three-phase transformer can be connected independently in either delta (Δ) or wye (Y) [2].

3.5. Implementation on GUI MATLAB

The user will enter certain values into the GUI interface, and then the result will be displayed with respect to this flow chart (**Figure 6**).

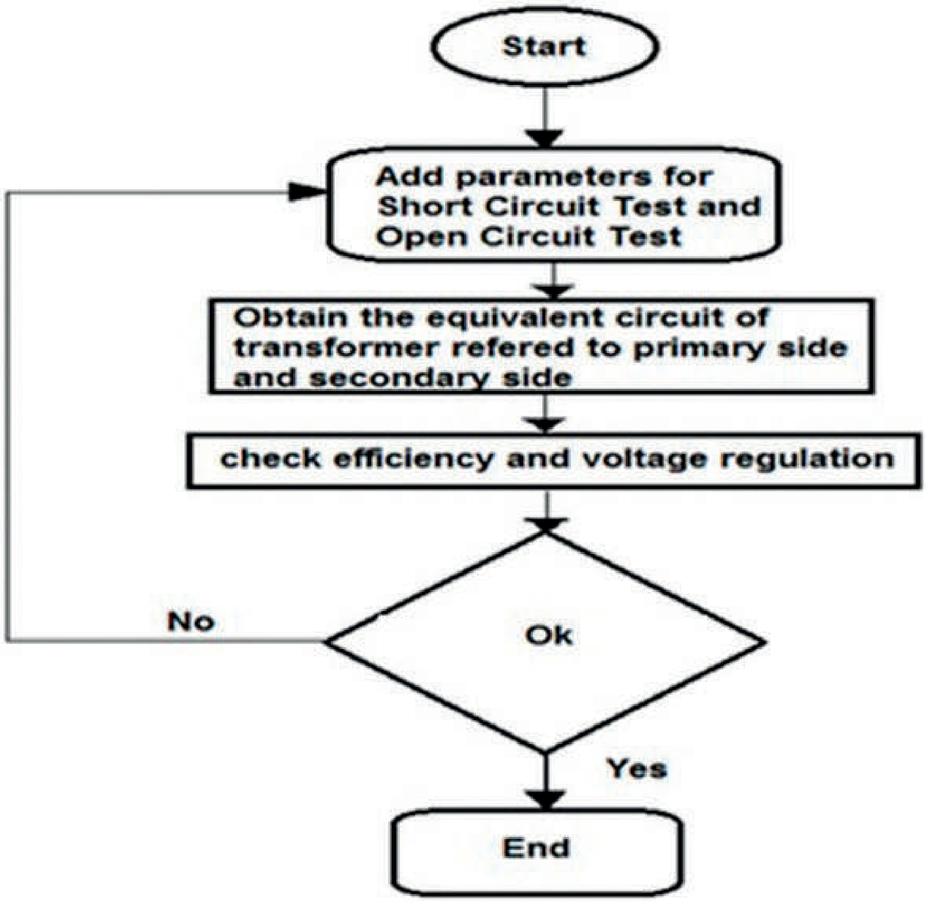

Figure 6. Flow chart for GUI.

The graphical user interface for single-phase transformer is shown in **Figure 7**.

The user will add the inputs which are values of short-circuit test and open-circuit test. And then, choose between leading and lagging load. The results of the equivalent circuits referred to primary and secondary side are displayed after adding the parameter and clicking on to calculate the equivalent circuit, and the equivalent circuit of the transformer referred to the primary side and secondary side are displayed with their parameter.

The user may also choose the type of core of the transformer whether circular or rectangular in shape (**Figure 8**).

Push buttons were used to load and save data as well as to display the performance of the transformer (**Figure 9**).

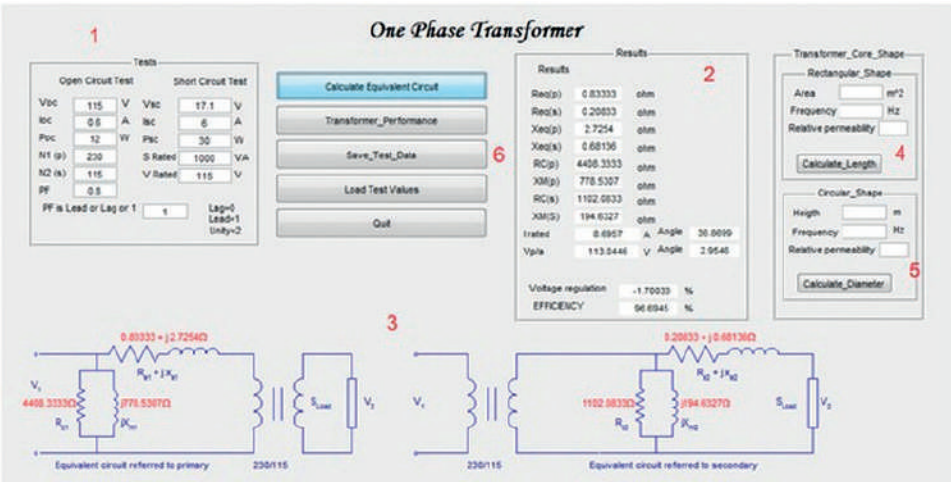

Figure 7. Graphical user interface for single-phase transformer.

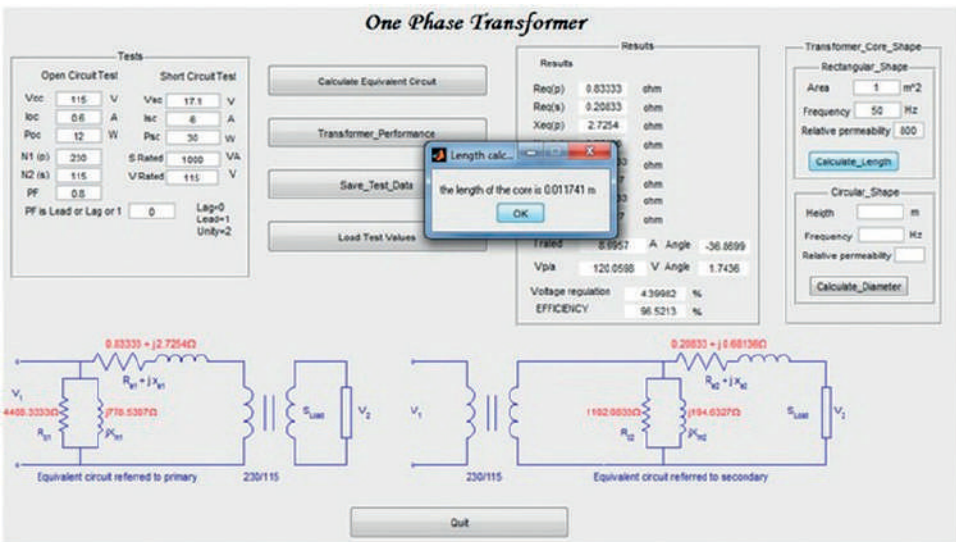

Figure 8. Transformer core shape calculated.

The graphical user interface for three-phase transformer is shown in **Figure 10**.

Here, the user has to choose the type of connection. An example of calculation is shown in **Figure 11**.

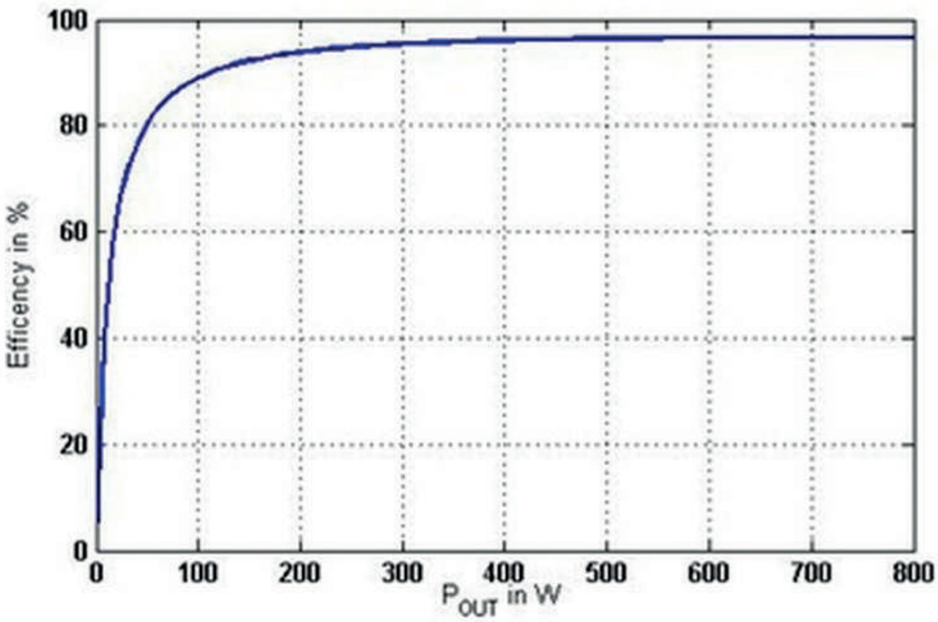

Figure 9. Single-phase transformer performance.

Figure 10. Graphical user interface for three-phase transformer.

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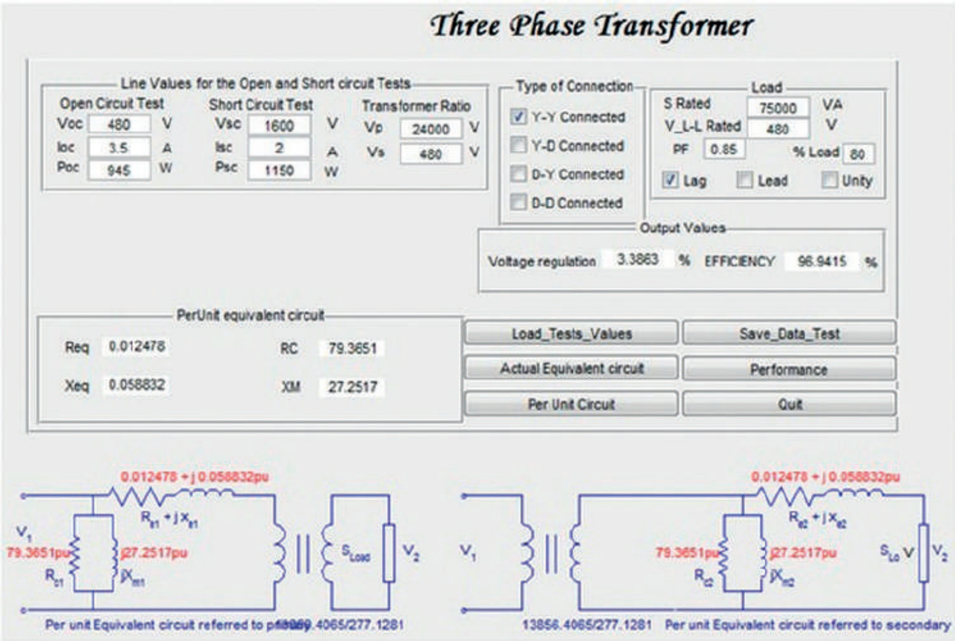

Figure 11. Per unit equivalent circuit of three-phase transformer.

4. DC machines

4.1. Introduction

This chapter discusses the types of DC machines with implementation of graphical user interface and plotting the torque speed characteristics and terminal characteristic for each DC machine [5].

In DC machines, the armature or loops of the rotor can be connected in many ways to the segments of the commutators. The rotor output voltage and the number of parallel current paths are affected by these several ways of connection [2, 5].

In any given machine, the voltage induced in E_A depends on three factors:

i. The flux ϕ in the machine

ii. The speed ω_m of the rotor of the machine

iii. A constant K that depends on the construction of the machine

The voltage of the real machine armature is given by

$$E_A = \frac{ZP}{2\pi a}\phi\omega_m = \frac{ZP}{2\pi a}\phi\frac{2\pi}{60}n_m \tag{28}$$

In any DC machine, the torque depends on three factors:

i. The flux ϕ in the machine

ii. The armature current I_A of the machine

iii. A constant K that depends on the construction of the machine

The torque on the armature of a real machine is

$$T_{ind} = \frac{ZP}{2\pi a}\phi I_A \tag{29}$$

4.2. DC motors and DC generators

DC machines can be used as DC motors or DC generators. The difference between the motor and generator is the power flow direction. The equivalent circuit of DC motors and DC generators is similar to each other, but the direction of the current flow of the DC motors is opposite to the direction in DC generators [2].

In a DC machine, the induced voltage is directly proportional to the flux and the speed of rotation of the machine. The magnetomotive field force is produced by field current, which in turn produces flux along with its magnetization curve.

As long as the field current is proportional to the magnetomotive field force and the induced voltage is proportional to the produced flux, it is usual to present the magnetization curve as a plot of E_A-induced voltage with respect to the current of the field for a constant speed ω_0.

4.2.1. Types of DC motors

a. **Separately excited DC motor**: is a DC motor where the field circuit is supplied by a separate voltage supply.

b. **Shunt DC motor:** is a DC motor whose field circuit gets its power directly across the armature terminals of the motor.

c. **Series DC motor:** is a DC motor where the field windings consist of few turns that are connected in series with the armature circuit.

d. **Compounded DC motor:** is a motor that consists of both a shunt and a series field. It consists of two types: cumulative and differential compounded DC motor.

   In cumulative compounded motor, the current flows into the dots of both field coils. The resulting magnetomotive forces add to produce a larger total magnetomotive force.

   In differential compounded motor, the current flows into the dot on one of the field coils and out of the dot of the other field coil, the resulting magnetomotive forces subtract.

4.2.2. Types of DC generators

a. **Separately excited generator:** a separate power source, independent of the generator, supplies the field flux to the DC generator.

b. **Shunt generator:** the field circuit is connected directly to the generator terminals in order to produce the field flux to the DC generator.

c. **Series generator**: the field circuit is connected in series with the generator armature to produce the field flux to the DC generator.

d. **Cumulatively compounded generator:** is a DC generator in which both the shunt and the series fields are available, and their effects are added.

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e. **Differentially compounded generator:** is a DC generator in which both the shunt and the series fields are available, but their effects are subtracted.

4.3. Implementation on GUI MATLAB

A graphical user interface is implemented for DC machine with types of generators and motors. The first GUI will obtain the armature resistance for any DC machine (**Figure 12**).

The user will determine the type of winding and enter the inputs which are pole number. Coil numbers and turn numbers with the plex and resistance per turn then calculate results. The armature resistance (RA) is expressed by

$$RA = \frac{\text{Turns} \times \frac{\text{coils}}{\text{current path}} \times (\text{resistance per turn})}{\text{current path}} \tag{30}$$

The results will be displayed with armature resistance included. This value will be installed in the other part of the graphical user interface for DC generators and DC motors.

The graphical user interface for the types of DC generators and DC motors is shown in **Figure 13**.

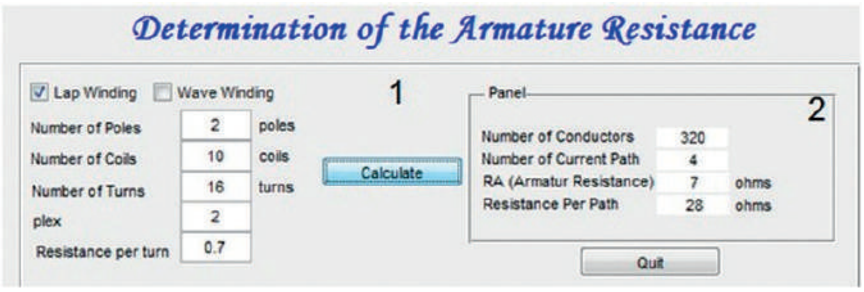

Figure 12. GUI to determine the armature resistance of DC machines.

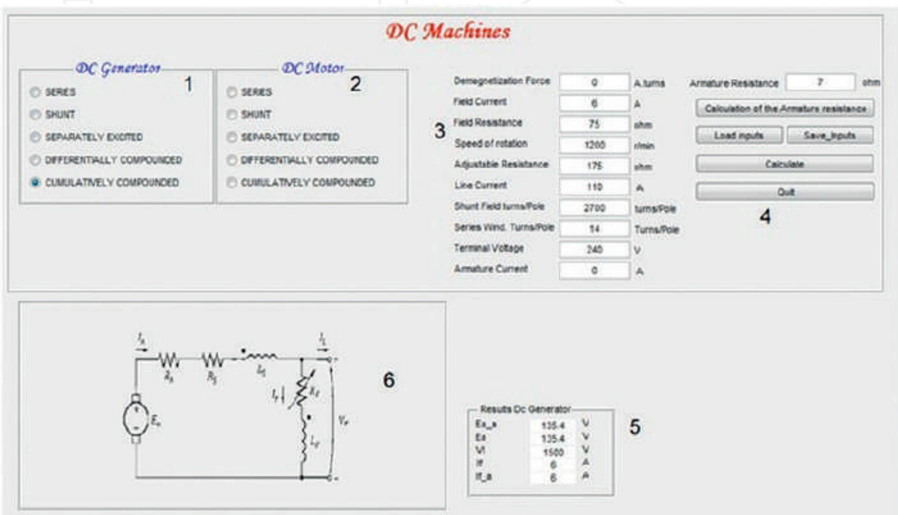

Figure 13. Graphical user interface for the types of DC motors and DC generators.

The user will choose the type of DC generator/motor and enter the corresponding parameters. Push buttons are available to load and save the data, calculate the armature resistance, and quit the program. Results will be displayed with the terminal characteristic and torque speed characteristics (**Figures 14** and **15**).

The equivalent circuit of the type of motor or generator will be displayed after calculating the result.

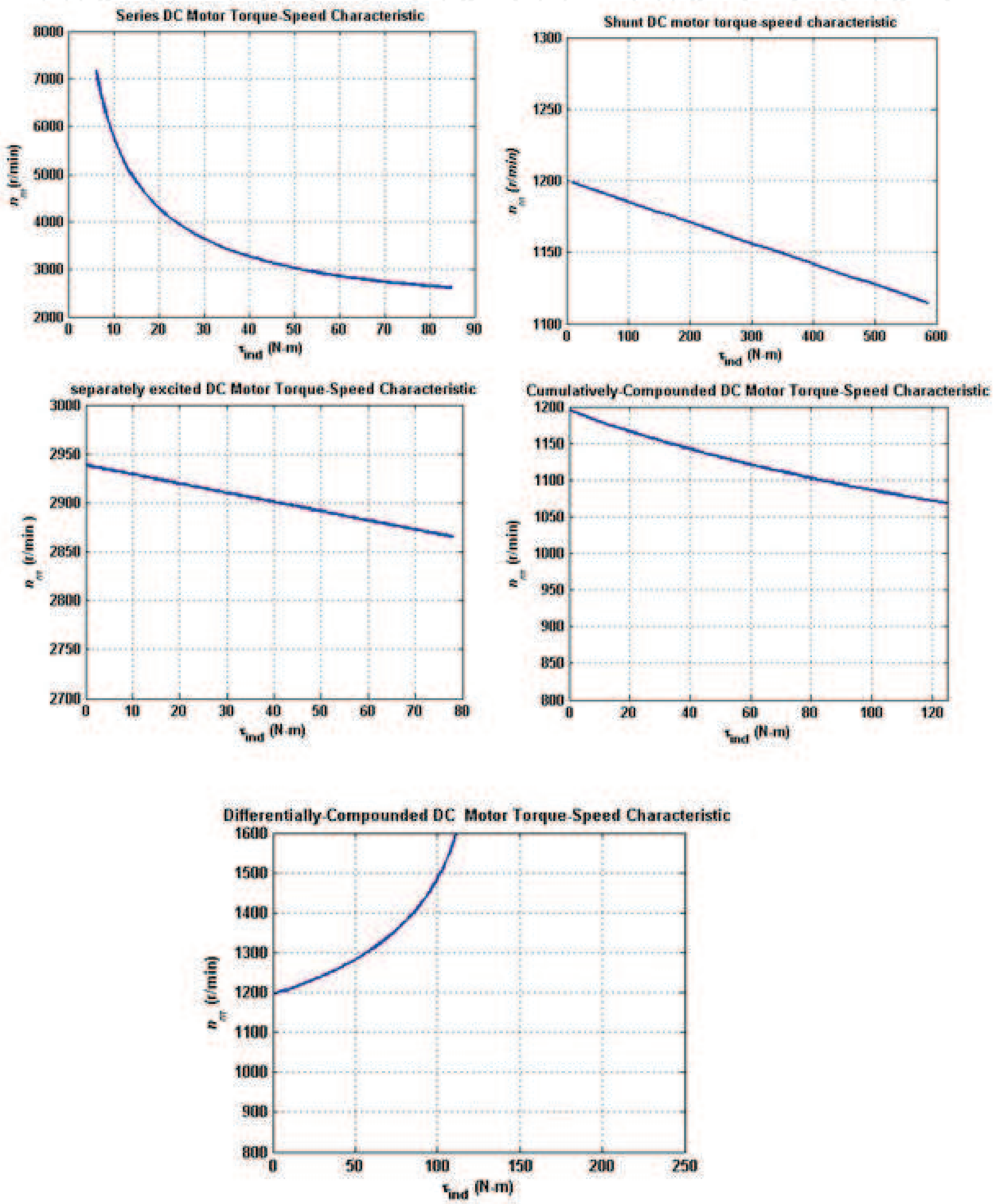

Figure 14. DC motor terminal characteristics.

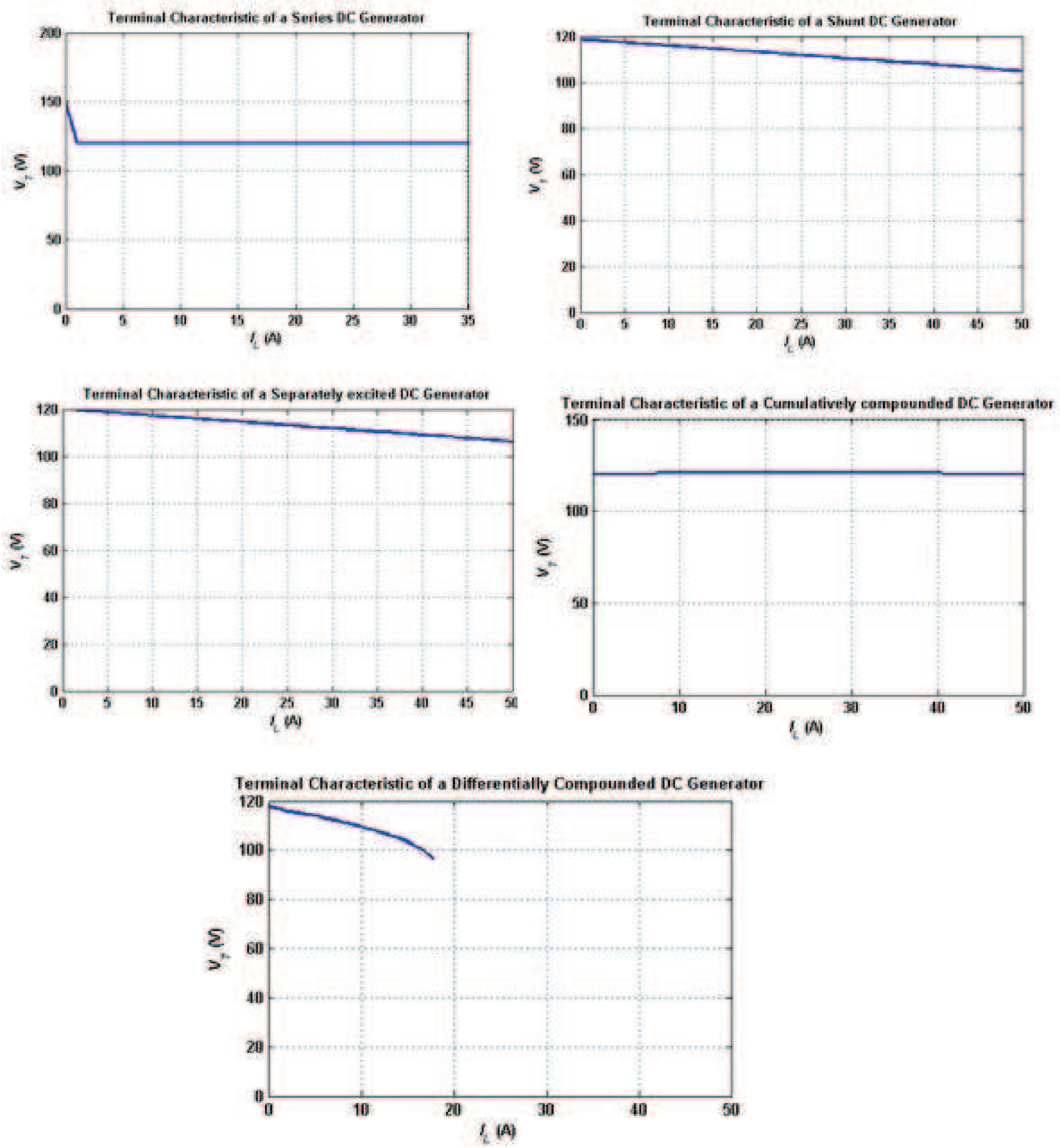

Figure 15. DC generator terminal characteristics.

5. Induction machines

5.1. Induction motors and induction generators

An induction machine is a machine with only a continuous set of amortisseur windings. They are induction machine because the voltage of the rotor is induced in the rotor winding instead of being physically connected with wires. To run the machine, it does not require a DC field current. Induction machines can be used as either generators or motors. Induction machines are not used as generators except in some special applications due to their disadvantages. Therefore, induction machines are most of the time referred to as induction motors [2].

After applying a three-phase voltage to the stator, current flows into the stator which produces magnetic field that rotates in a counterclockwise direction. The rotation speed of the magnetic field is expressed by

$$n_{sys} = \frac{120 f_{se}}{P} \tag{31}$$

The relative motion of magnetic field and rotor is defined with two terms, which are

a. **Slip speed:** It is the synchronous speed minus rotor speed.

b. **Slip:** It is the relative speed expressed as ratio of slip speed to synchronous speed in a percentage basis.

$$n_{slip} = n_{sync} - n_m \tag{32}$$

$$s = \frac{n_{slip}}{n_{sync}} \times 100\% \Rightarrow s = \frac{n_{sync} - n_m}{n_{sync}} \times 100\% \tag{33}$$

Note that the rotor turns at $s = 0$, whereas at $s = 1$, the rotor is stationary.

5.2. The equivalent circuit of an induction motor

The equivalent circuit of an induction motor is similar to that of the transformer, with a difference between the magnetization curve of the transformer and induction machine (**Figures 16** and **17**).

5.3. Implementation on GUI MATLAB

A graphical user interface is implemented on MATLAB for induction machines (**Figure 18**).

The user has to enter details related to the induction machine:

1. In this part the user can calculate and display the result of induction machine torque characteristics (**Figure 19**).

2. Single- and double-cage rotor characteristic (**Figure 20**).

As we noticed, the double-cage design, when compared to the single-cage rotor, has a high starting torque with smaller maximum torque and a slightly higher slip in the normal operating range.

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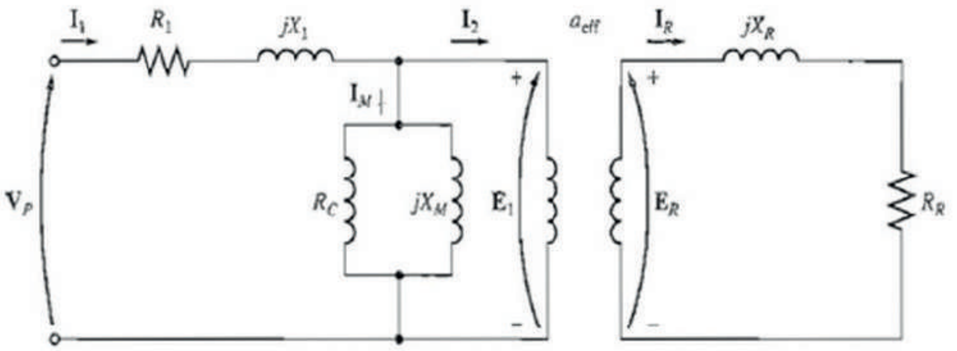

Figure 16. The transformer model of an induction motor, with rotor and stator connected by an ideal transformer of turn ratio a_{eff}.

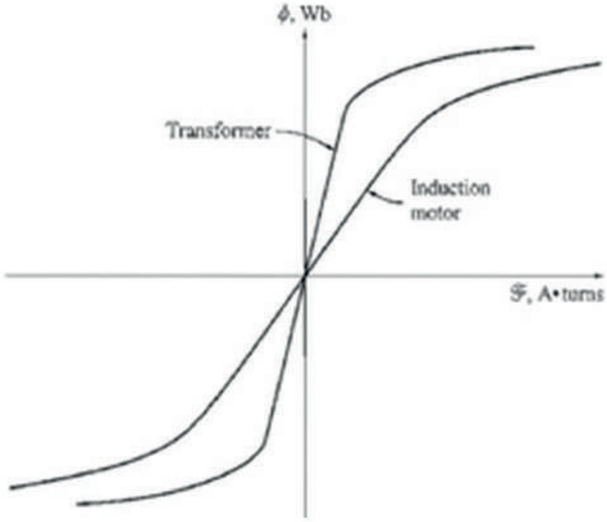

Figure 17. The magnetization curve of an induction motor compared to that of a transformer.

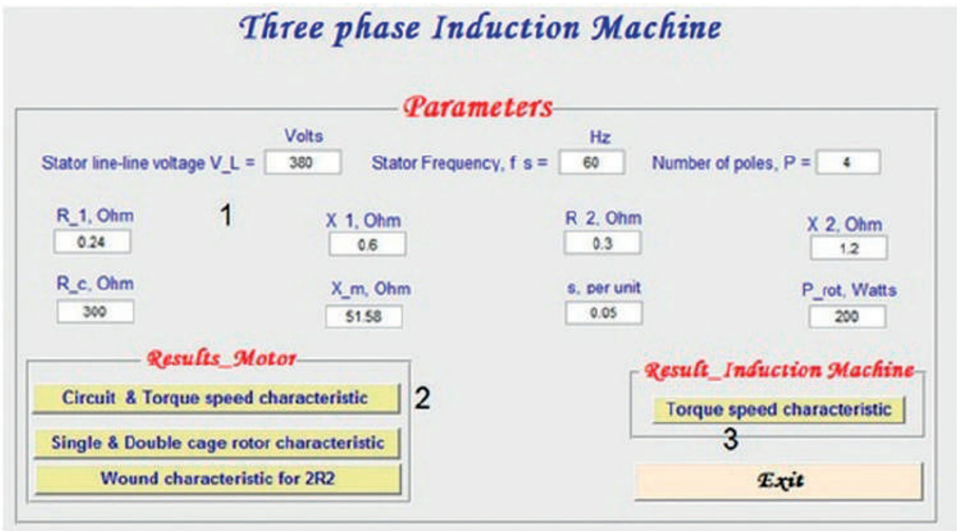

Figure 18. Graphical user interface for three-phase induction machine.

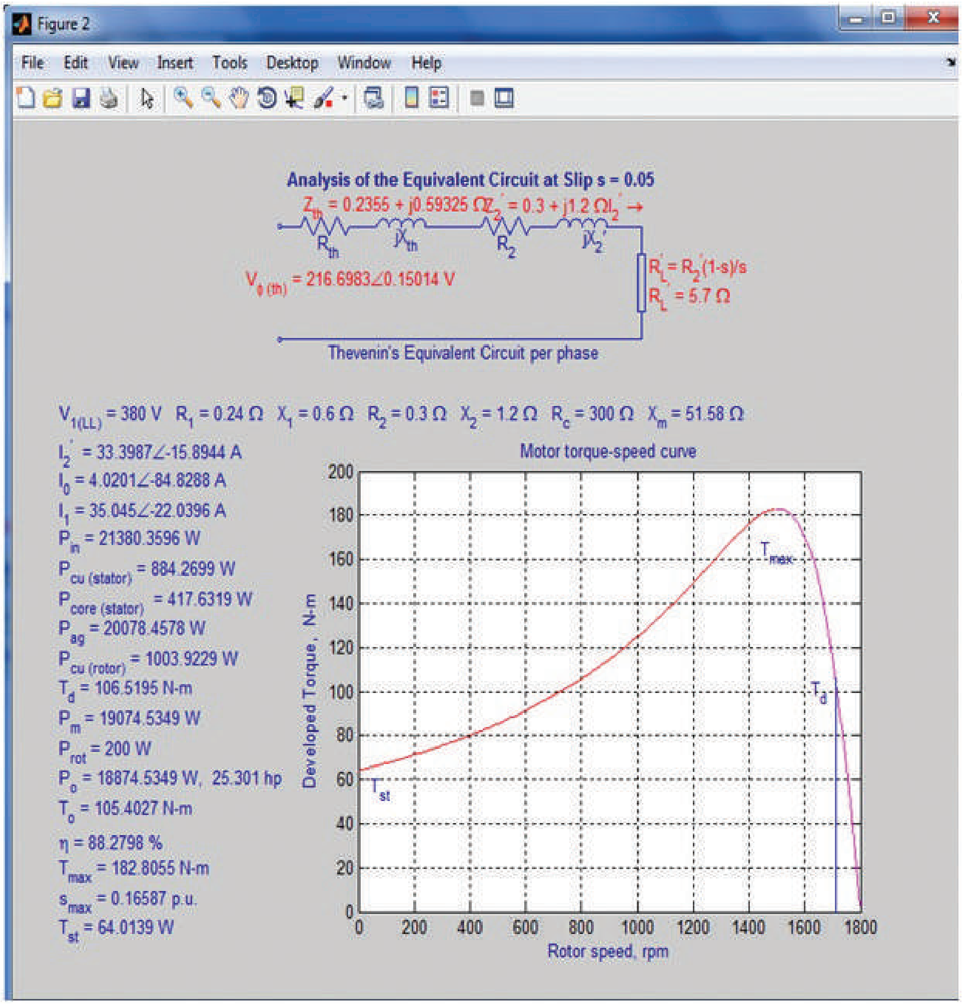

Figure 19. Equivalent circuit and torque speed characteristic.

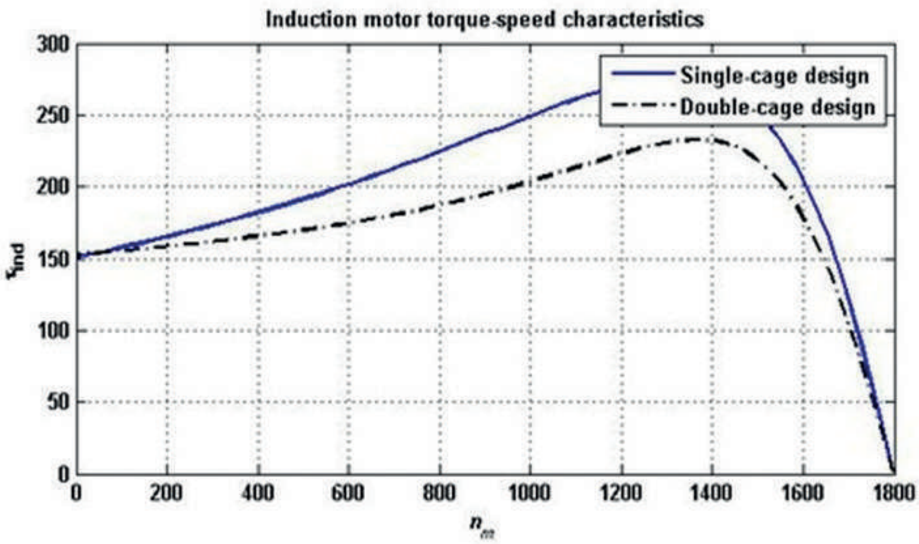

Figure 20. Single- and double-cage rotor characteristic.

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6. Conclusion

Ferromagnetic materials were discussed and implemented with respect to its magnetic model in graphical user interface using MATLAB.

Single-phase and three-phase transformers were discussed with implementation of transformer model in GUI on MATLAB. We also checked the parameter referred to secondary and primary side with the effect of load of the transformer.

DC machines were discussed with implementation of different types of DC motors, obtaining the plots of torque speed characteristic. Different types of DC generators were also implemented on GUI, and the terminal characteristics were also obtained.

Induction machines were examined through implementation of the parameters of induction motor in the GUI on MATLAB, obtaining the torque speed characteristics and the terminal characteristics.

Implementing an educational model on GUI MATLAB for the ferromagnetic core, single- and three-phase transformer, DC machines, and induction machines allows the students to study and analyze the effect of each parameter in order to understand its electric behavior with respect to its electric model.

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