

Computer Assisted Teaching of Underground Power Cables (POWCABGUI) for Graduate Students

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Abstract: - This study presents a computer simulation program which was named POWCABGUI used to teach of underground power cables for graduate students who need to integrate modern teaching approaches with today's technology in order to reach and motivate. The graduate lecture includes different and complex analytic procedures based on the IEC 60287 standard. For this purpose, a Matlab Graphics User Interface (GUI) simulation program POWCABGUI was established to analyze the current carrying capacity (ampacity) of underground power cables under varies operation conditions. The students can compute and examine the rating of power cables, under different operating and install conditions and type-size of cables, simply and visually by using POWCABGUI. Thus, POWCABGUI allows the students to effectively learn the rating of underground power cables.

Key-Words: - Computer Assisted Education; Technical Education; Simulation Program; Educational Technologies.

1 Introduction

Today, the technology changes so rapidly and technical education is affected by this changing conspicuously. Simply presenting information to students does not guarantee that learning will take place. On the other hand, students are willing about the use of computer. For this reason, the computer and simulation programs play vital role in technical education to improve their learning.

Lecturers have used many learning strategies developed to provide effective learning such as Knowledge, Comprehension, Application, Analysis, Synthesis and Evaluation [1]. The analysis and synthesis are widely used in technical education particularly, electrical education and other fields. In learning process, the students have to make several solutions using variation of different parameters to create new ideas.

A study by Boyce is examined the role and impact of a range of computer technologies in accounting education, motivations and objectives for their introduction and use, and their potential impacts on the education of accounting students both positive and negative aspects [2]. In another study by Çepni et.al. is investigated the effects of a Computer-Assisted Instruction Material (CAIM) on student cognitive development, misconceptions and attitudes

[3]. They showed that using CAIM in teaching photosynthesis topic was very effective for students to reach comprehension and application levels of cognitive domain.

Computer simulations have efficient and effective way of teaching and learning complex systems. Garcia-Luque et al. was mentioned about simulations can incorporate special teaching and learning mechanisms to support the individual learner. In contrast to the real world, which is being simulated to various degrees of fidelity, the students using a simulator are able "to stop the world" and "step outside" of the simulated process to review and understand it better [4].

The necessities of Computer Aided Design (CAD) programs were explained very well by Garcia et al. Their results leave no room for doubt and show them that the students learn to use CAD while studying Geometry [5]. They also indicate that the specifically written CAD program was more effective than commercial program for CAD teaching.

As similar to mentioned above, commercial power cable programs may not meet educational abilities. For this reason, a specifically POWCABGUI program which is away from commercial concern was written by a team using IEC 60287 standard (**IEC 60287, 1995**). Personal abilities of the team: one of them is a lecturer of this

course, the other is the graduate student who was taken this course and the other is a computer education specialist. Hence, all the actor's demands have been taken into consider in teaching process of the course.

The purpose of this paper is primarily to present the POWCABGUI simulation program for the course students that learning will take place. The paper is structured as follows: Section 2 introduces the background of power cables ampacity on basis of IEC standard; Section 3 explains capabilities and structures of POWCABGUI with educational aspects; while Sections 4 and 5, respectively, present a case study and discussion in the evaluation of educational benefits of the program; Section 6 concludes the paper with a final discussion.

2 Background of the Course

The course has been executed in fall semester for graduate electrical students in Kocaeli University, Institute of Science. The aim of the course is to teach power transmission in underground cables. At the end of the course, students should be able to learn the following outcomes:

- Structure and design of underground power cables
- Ampacity calculation
- Thermal circuit model
- Install configuration
- Analysis of underground power cables under various operation conditions

Underground power cables are more expensive to install and maintain than overhead lines. The greater cost of underground installation reflects the high cost of materials, equipment, labor and time necessary to manufacture and install the cable. The large capital cost investment makes it necessary to use their full capacity. On the other hand, its conductor temperature limits ampacity of a power cable (i.e. maximum allowable temperature for XLPE insulated cables is 90 °C). Also the operating temperature adversely affects the useful working life of a cable. Excessive conductor temperature may irreversibly damage the cable insulation and jacket.

The first model proposed for calculating ampacity of underground cable by Neher-McGrath in 1957 (1). The Neher-McGrath Model has been widely accepted for over 50 years. Today, the greater majority of utilities and cable manufactures have been using the IEC-287 standard (2) based on the Neher-McGrath Model. This method employs a

lot of simplifications and has its limitations. Thus it cannot be used for the analysis of complex configurations.

2.1 Ampacity Calculation

The ampacity calculation of a power cable for steady state operation can be found by applying the analogy between electrical and thermal circuit shown in Figure 1, can be written in the following form:

$$\theta_c - \theta_a = w_c(T_1 + T_3 + T_4) + w_d\left(\frac{T_1}{2} + T_3 + T_4\right) + w_s(T_3 + T_4) \tag{1}$$

$$\Delta\theta = w_c \underbrace{(T_1 + (1 + \lambda_1)(T_3 + T_4))}_{T_A} + w_d \underbrace{\left(\frac{T_1}{2} + T_3 + T_4\right)}_{T_B} \tag{2}$$

$$I = \sqrt{\frac{\Delta\theta - w_d T_B}{T_A R_{ac}}} \tag{3}$$

Where,

- θ_c Maximum operating temperature °K
- θ_a Ambient temperature °K
- w_c Heat loss of conductor ($I^2.R_{ac}$) W/m
- w_d Dielectric losses W/m
- w_s Sheath loss ($w_c\lambda_1$) W/m
- λ_1 Sheath loss factor
- T_1, T_3, T_4 Thermal resistances of insulation, sheath and soil (°Km/W) respectively
- R_{ac} Ac resistance of conductor at temperature θ_c
- I The ampacity of cable Ampere (A)

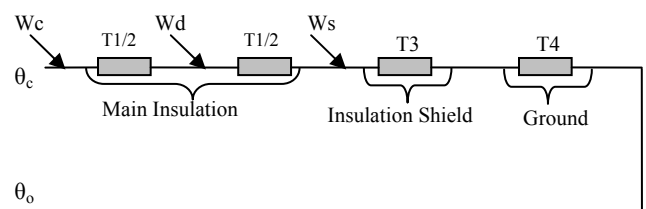


Fig. 1- Thermal circuit of a buried power cable

As shown in equation (3), the ampacity of a power cable depends on several parameters such as conductor- ambient temperatures, type of cable, cable structure and cable installation geometry. While Students study on power cables and its ampacity, the effects of all these parameters must be taken into consideration. Unsurprisingly, they can not easily

examined the effects of changed any parameters. Therefore, POWCABGUI can be met all these requirements as explained in the following section.

3 POWCABGUI Program

POWCABGUI program was prepared in MATLAB™ GUI program. As known, Guide is a program in Matlab for visually designing a GUI. As shown in Figure 2, Guide has two main parts; the first is a graphics window for designing visual components and the second is a Matlab source file for writing individual functions.

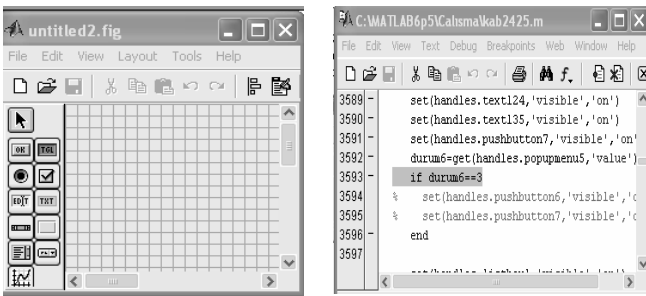


Fig. 2- Graphics and source files of the guide

parameters as shown in Figure 4. These are conductor type (copper, aluminum), insulation materials (XLPE, EPR, PE, PVC and PPL), cable type (single or three conductors in a cable, three phase single conductor), installation form (flat, three cables in trefoil, flat touching and single cable in trefoil) and installation condition (buried, buried in a bank with duct/sand). Each selection stage of the parameters is made automatically. If someone wants to learn any specific information about POWCABGUI program, can take any help by pressing HELP button.

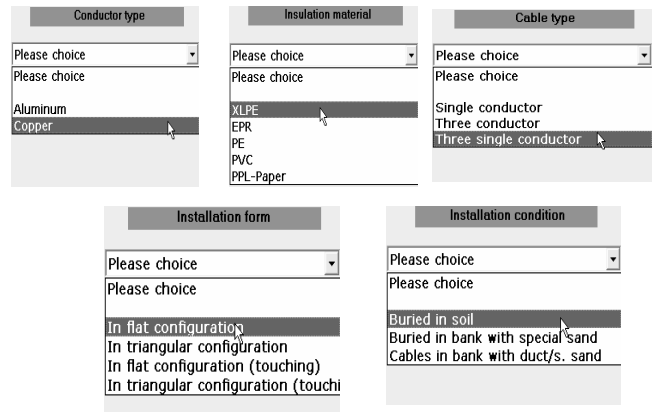


Fig.4- Five different stage of choosing the cable parameters

After selecting all these parameters, data such as system voltage and frequency parameters are inputted into related edit boxes as indicated in Figure 5. Data input windows has successive structure.

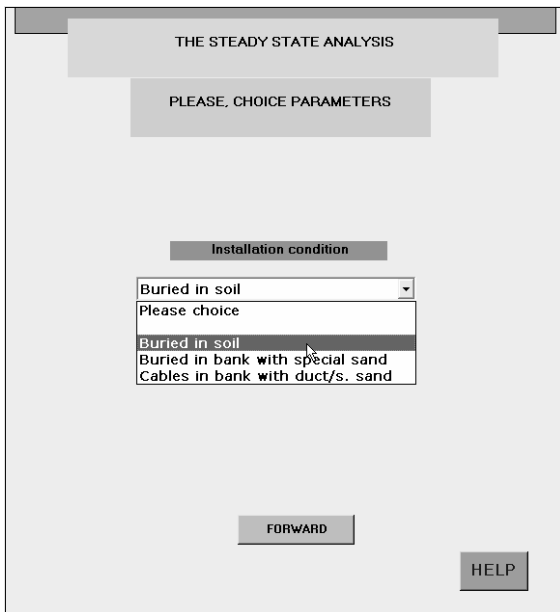


Fig. 3- Parameters choice tables

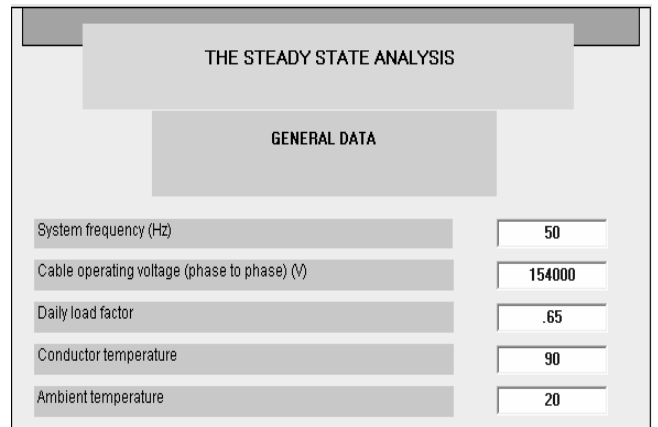


Fig.5- Input windows of parameter data

POWCABGUI can be analyzed any cable type with any parameters. The list boxes which are shown in Figure 4 come seriatim to the window which is shown in Figure 3. The first stage of the program consists of the five different choose

Under the data input windows, there are two buttons which are FORWARD and GOTO BEGINNING buttons. FORWARD button is used for inputting the successive data. Whereas, GOTO

BEGINNING button is used for changing the previous value of the input data.

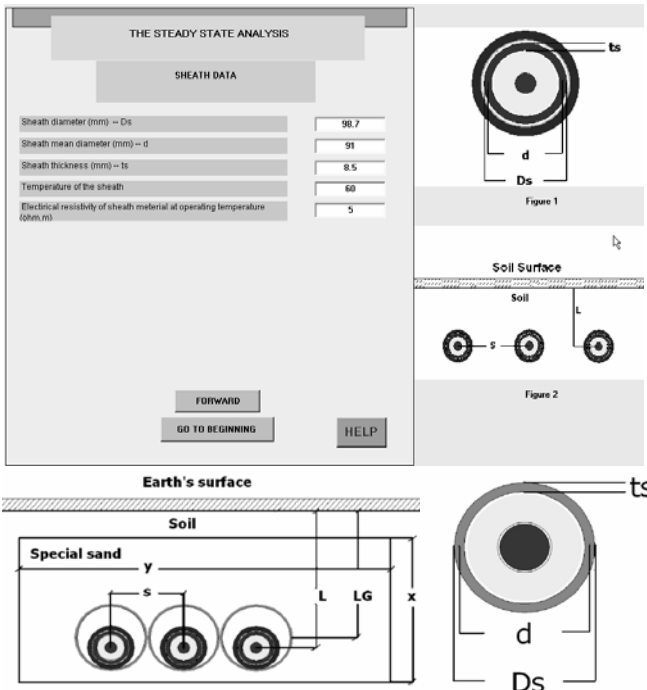


Fig.6- Visual auxiliary figures for calculation procedures

In addition, users can follow calculation procedures by visual auxiliary figures at nearby each form as seen in Figure 7. Hence, without supervisors; user friend characteristics of POWCABGUI program can direct students suitably to grasp analytic solutions in effective educational manner

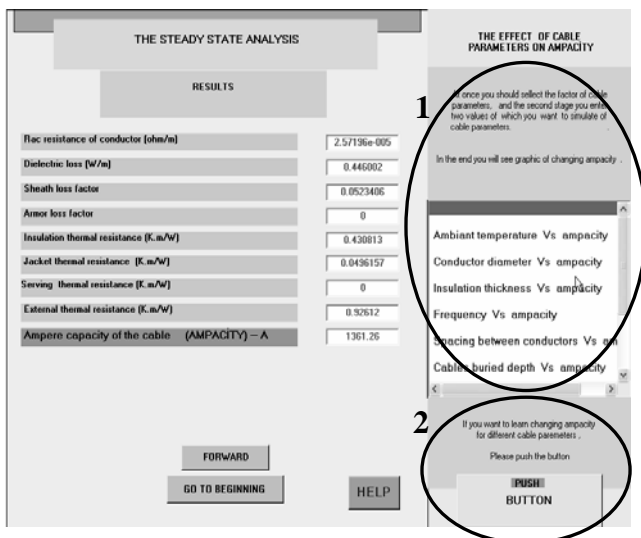


Fig.7- Obtained results of power cable ratings and analysis block

Finally, power cable ratings are computed according to the selected configuration and inputs by

POWCABGUI program. As shown in Figure 6, calculated ampacity and important parameters of the sample power cable are listed. There is a analysis block that is making two different kinds of analyses under the title of "THE EFFECT OF CABLE PARAMETERS ON AMPACITY" as shown in Figure 7 which is circled as 1 and 2 areas. The first kind of analysis graphically shows the effects of changing in range of parameters that are selected from Figure 8 on ampacity.

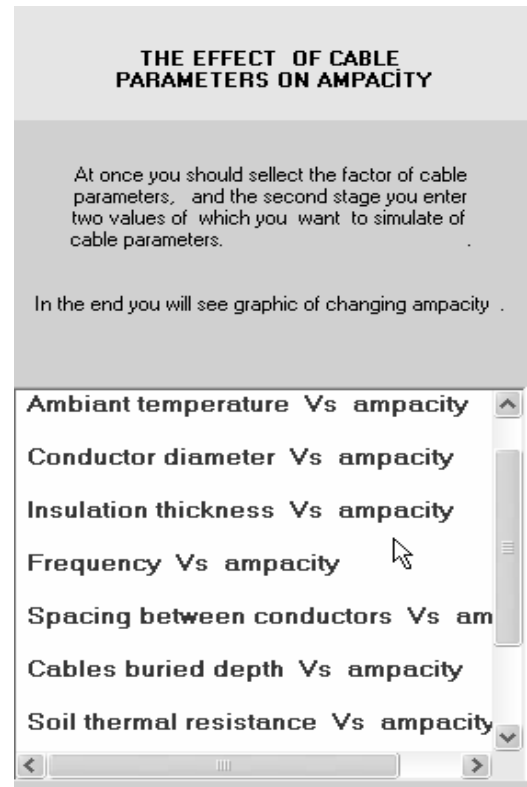


Fig.8- The choices of any parameters that are to be examined for the effects on ampacity

For this purpose, the following effects can be examined by selection of any parameters form list box as shown in Figure 8:

- Ambient temperature (°C)
- Diameter of conductor (mm)
- Insulation thickness (mm)
- Conductor
- Frequency (Hz)
- Spacing between conductors (mm)
- Cables buried depth (mm)
- Soil thermal resistance (Km/W)
- Cable active resistance (Ω)
- Conductor temperature (°C)

After that, user pushes the FORWARD button, A Steady State Analysis window opens in a new window as shown in Figure 9.

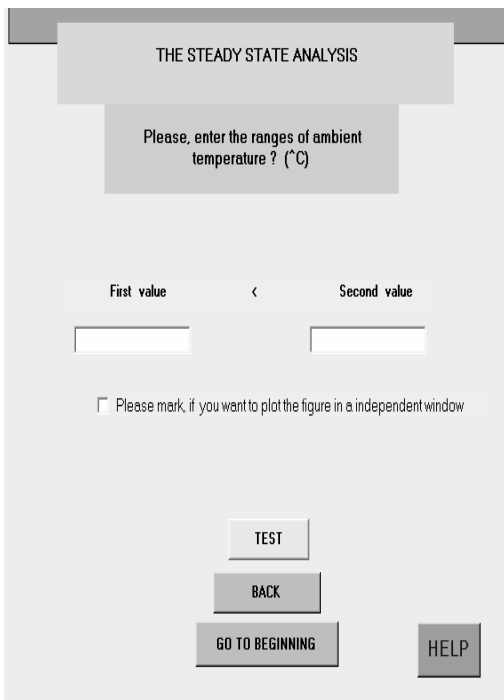


Fig.9- Steady State Analysis window

After the ranges of any parameters that are previously chosen are input in Figure 9, TEST button can be pressed for examining the effect of the related parameter on ampacity. For instance, the effect of the ambient temperature on ampacity is shown in Figure 10.

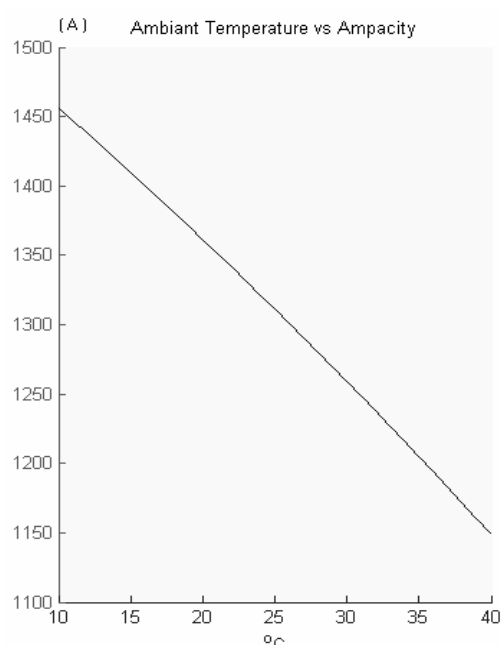


Fig.10- Graphics of the analysis result

The second kind of analysis is examining the effect of the type of the parameters on ampacity. If user pushes the PUSH button that is shown in Figure 11,

before FORWARD button, different cable parameters choices that will be examined the effects on the ampacity, appears in a new window as shown in Figure 12.

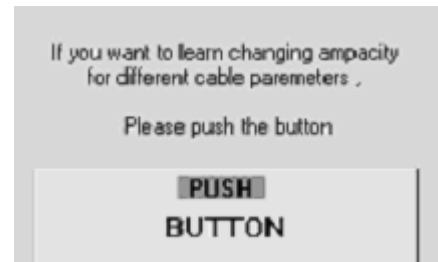


Fig.11- Push button for examining different type parameters

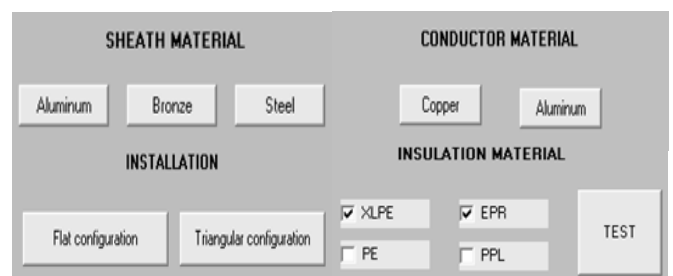


Fig.12- Different parameters selection window

According with previous data of the parameter before Figure 7, if user pushes one of the SHEATH MATERIAL or INSTALLATION group of buttons that are shown Figure 12, POWCABGUI program updates the general result table in the RESULTS window that is shown in Figure 7. Whereas, if user pushes both of the CONDUCTOR MATERIAL buttons, the program gives a graphical ampacity solutions of the copper and aluminum conductors on a single graphics as shown in Figure 13.

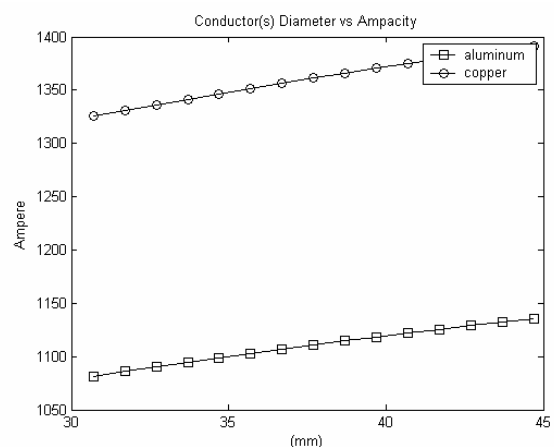


Fig.13- Graphics of the conductor type analysis result

If user pushes the TEST button after selects any INSULATION MATERIAL check boxes, such as XLPE and EPR, POWCABGUI program shows comparison graphics as shown in Figure 14.

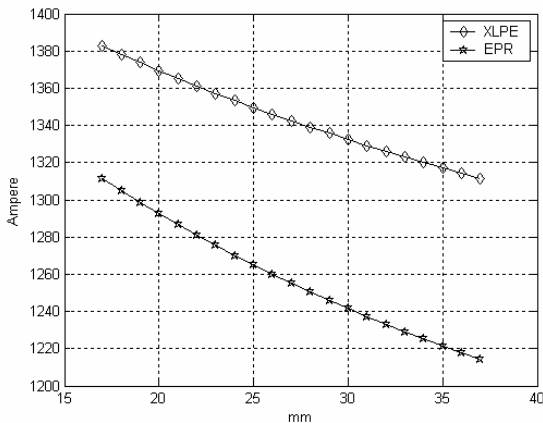


Fig.14- Graphics of the insulation type analysis result

3.1 Educational aspects and advantage

These kinds of analyses are required too much mathematical tasks. POWCABGUI program has a main aim to teach power cable subjects by saving time. For this reason POWCABGUI program has visual auxiliary figures and graphics which are plotted at the results of many calculations.

After required parameters are input, the program has ability to make successive repetition. Hence, user can make successive comparisons by changing one or more data. Always POWCABGUI save the values of any data that are previously input, during the simulation. Hence, when the user returns to the beginning of the program, he/she can see all data that are previously input and change any of them. While the user inputs any data, an auxiliary figure appears in the same window for easing the perception. Since the units are shown on the auxiliary figures, user can properly input the values of any parameters. Program can additionally simulate the effect of different cable parameters on ampacity by only changing any parameters from Figure 12 without changing other data that are previously input. This ability of the program gives superior for making easy simulation without considering previous data.

If we think that the POWCABGUI program is open source code, someone can easily improve the program for educational aspects. Since the program has been written in MATLAB®, the user can understand the codes with basic knowledge of MATLAB.

4 Conclusion

While POWCABGUI program is making complex procedures for calculating ampacity, it has a simple interface for users. In addition, the stages of the program follow meaningful and a sequential structure for easing the perception.

Even if user has not enough knowledge about power cables, POWCABGUI can be simply used with auxiliary figures such as Figure 6. Also user can make many experiments on the program. Hence users increase their knowledge to higher level. Especially, the result tables and comparative graphics which are calculated for different parameters and ranges of parameters, quicken the perceptions.

Today cost of professional programs is too high and these kinds of programs are constituted for industrial markets. So they have not any educational aspects for electrical engineers.

Therefore, POWCABGUI program has educational specialties and it is designed for the users to improve their abilities.

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