

GeoGebra Tool: Development of Applications for Electrical Machines and Drives Teaching Support*

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The paper reviews a set of developed GeoGebra applications designed to be used in several university courses related to Electrical Machines and Drives (EMD). The applications are developed to support students' learning of relatively complex physical phenomena in the field through remote and online learning. A detailed review of the possibilities of newly developed applications in the field of electrical engineering and various types of electrical machines is presented in the Part I of the research. The emphasis is placed on the advantages of the applications and procedures for making conclusions based on the software possibilities in terms of learning process improvement. The presented developed EMD GeoGebra applications, adapted for different e-equipment, are publicly available. The Part II of this research presents the evaluative research on the applicability and quality of the described set of applications. The students of electrical power engineering assessed the quality of the EMD GeoGebra applications as very important and useful tools for learning and mastering related courses. Finally, the usefulness and effectiveness of these applications are summarised in the conclusion of the paper.

Keywords: electrical machines; electrical drives; characteristics; GeoGebra; distance learning; educational software evaluation

1. Introduction

The world has recently faced a severe health crisis and pandemic caused by the SARS-CoV-2 virus which significantly changed the quality of life and ways of functioning in almost all everyday activities. The change in traditional living habits during the lockdowns has primarily influenced young people both by restricting their movement and socializing as well as through the system of primary and higher education [1]. In a very short period, educational institutions were forced to make a transition from traditional to distance learning, which was the only way to ensure the continuity of the educational process. Disruption in educational procedures and quick transition to online teaching methods and resources could significantly impede pupils and students' post-pandemic lives and professional engagement [2].

In order to enhance the quality of distant learning, various models and strategies for this rapid transition from traditional to distant, adaptive and flipped learning have been proposed [3–5]. A huge effort has been put into the development of remote teaching approaches and solutions, particularly in remote laboratory stations and networks [6]. Practical knowledge gained through work in traditional laboratories in many cases is irreplaceable for students of electrical engineering [7]. Having that in mind, remote, real-time connection with different

laboratory setups and emulators have been the focus of many researchers, dealing not only with the challenges related to remote access and streaming, but more important and complex issue of the safety of high-fidelity equipment and prevention of unauthorised and potentially hazardous user actions [8, 9].

The didactic challenges related to presenting and understanding complex processes and phenomena in the field of electrical engineering, such as rotational electromagnetic field [10], electric machine windings assembly [11], etc., emphasize the need for new online teaching aids and support, especially in terms of developing an interactive instructional technique. In the field of electrical machines there are several well-designed solutions which encompass different learning tools, combining computer simulation and numerical analysis and experimentally obtained numerical results towards a better understanding of the basic concepts of electrical machines together with straightening students' long-term memory and knowledge [12, 13].

Teaching the electro-mechanical characteristics of electrical machines, and their often complex, step-by-step development and analysis, under different operating regimes, require the appropriate software where students could interactively change corresponding machine parameters, power supply and other conditions, and subsequently observe the obtained results. GeoGebra as an online, open source, dynamic mathematics software tool that combines geometry, algebra, and calculus with

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attractive graphing possibility, seemed like an appropriate teaching support solution [14, 15] which could potentiate all of the previously stated. One of the important assumptions of the use of GeoGebra applications in engineering courses is that the activation of students' visual abilities and skills is necessary for the comprehension of theoretical and practical principles and processes [16].

In the field of Electrical machines, there are many GeoGebra applications developed by various authors. All of the applications in the field (over 160, Sept. 2023) can be found consolidated at [17]. In the last few years, having realized the great possibilities of this software package, Laboratory for Electrical Machines, Drives and Automatics (EMDA laboratory, Faculty of Technical Sciences Čačak – FTS Čačak, Serbia) has been designing, developing and using new applications based on GeoGebra in several engineering courses. The use of the developed GeoGebra applications within the courses of Electrical machines and Electrical drives in bachelor and master studies of Industrial Power Engineering resulted in increased students' interest and knowledge gain, which was also evident in higher marks on tests and final exams. The authors have developed almost 40 different GeoGebra Applications (GGA) in the field of power engineering, particularly Electrical Machines and Drives (EMD). These EMD GeoGebra applications are all open access and available to the students of FTS Čačak, as well as other external users interested in the field, through the EMPA laboratory web page [18]. Moreover, the EMD GeoGebra applications described in the paper, as such, are appropriate and ready for integration into the interactive electronic books [19]. These applications are suitable for use on a PC, tablet or smart phone, making this kind of learning simple, readily available and interesting to users.

This paper provides a detailed description some of the more than 30 developed EMD GeoGebra application, as a set of teaching support in the field of electrical machines and drives. The paper is organised as follows: after the introduction, sections II and III present the applications related to the fundamentals in electrical engineering and power transformers; section IV describes the application related to DC electrical machines, while the applications related to induction and synchronous machines are given in sections V and VI respectively. Several applications focused on special electrical machines are presented in section VII. The Part I of this extensive research ends with the appropriate conclusions given in section VIII, while the evaluation methodology, and comprehensive results of students' evaluation of these EMD GeoGebra applications, together with an

appropriate discussion and conclusions are given in [20].

Each GeoGebra application presented in this paper is followed by a short description and user manual. The background theory the developed applications is either well known in the field or it is supported by accompanying equations and literature displayed. All applications have the possibility of changing input parameters usually by using a slider or entering values in a numerical box. Developed applications are focused on the electric machine steady state regimes neglecting the influence of the dynamic which would exceed GeoGebra software potentials and purpose. Moreover, realised applications intend to help users (students) to master basic physical and operation principles in the process of engineering education providing swift calculations and conclusions derivation. When it comes to the graphs related to the characteristics of electrical machines, the application keeps the graph obtained by previously set parameters with the aim of comparing results and deriving appropriate conclusions in the process of learning.

2. Electrical Engineering Fundamentals

In order to adequately understand and master the principles of electrical machines, some of the electrical engineering fundamentals related to electromechanical energy conversion should be pointed out first. Active, reactive and apparent power and their mutual dependence on power factor are presented through the application whose print screen is shown in Fig. 1. The application is developed with the idea to bring students closer to the concept of active, reactive and apparent electric power and their relation to the shown instantaneous values of periodic voltage $u(t)$, current $i(t)$ and corresponding phase angle difference $\varphi(t)$ (power factor). All values of the three stated quantities can be changed by using a corresponding slider within the predefined scale. Also, while the graphs are being plotted each of can be hidden or shown by selecting an appropriate check box.

3. Power Transformers

Power transformers are one of the vital and most important elements in power systems used in transmitting electrical power between generators and distribution networks. In order to help students understand the graphical approach in the determination of voltage drop at the secondary circuit of the power transformer, an appropriate application is developed. The application for voltage drop calculation in power transformer by using the

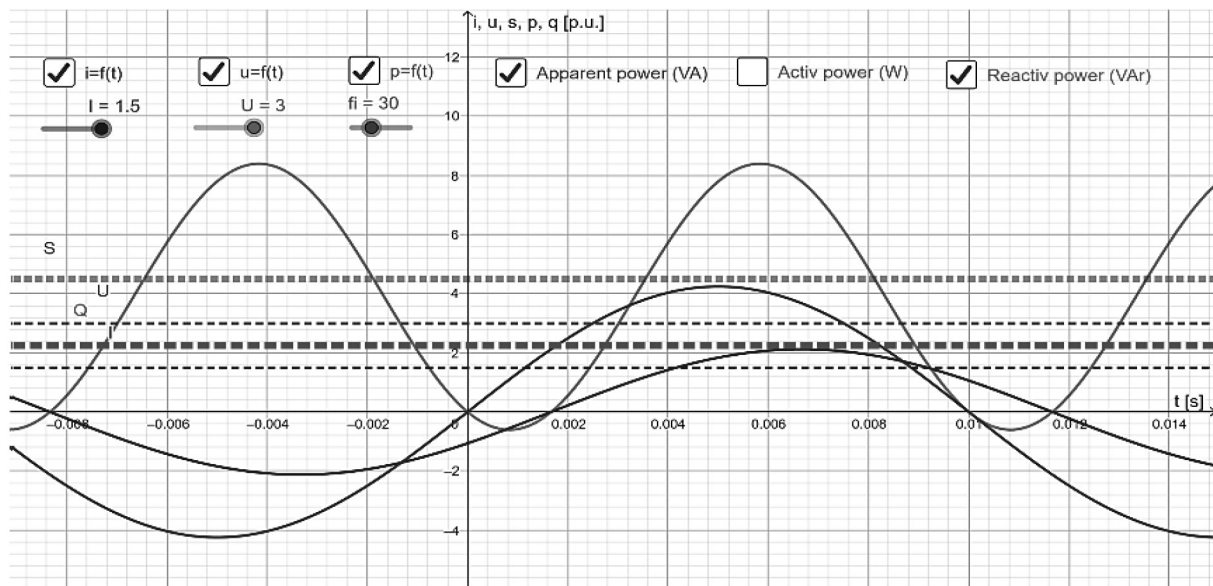


Fig. 1. Instantaneous and effective values of voltage $u(t)$, current $i(t)$, current phase angle $\varphi(t)$, active P , reactive Q and apparent power S (EF_C1).

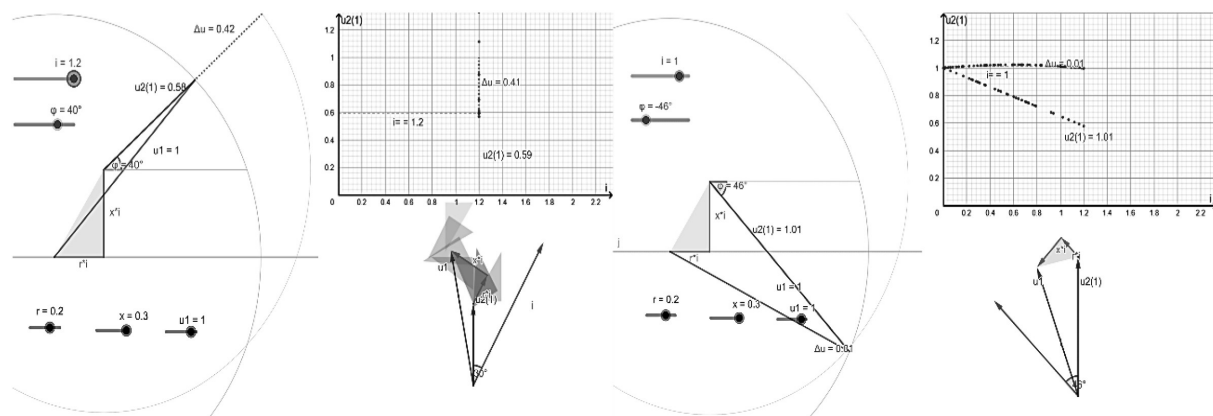


Fig. 2. Determination of voltage drop by using Kapp diagram (TR_C2).

Kapp diagram, shown in Fig. 2, allows the user to observe: a phasor diagram of a loaded power transformer, a modified overview of the phasor diagram (suitable for obtaining more obvious insight into the output voltage drop), and external characteristics of the transformer derived for different values of load current.

It is possible to set the relative values of primary voltage, resistance and reactance of the transformer, as well as the load current and its phase angle (power factor) by the corresponding sliders. By defining these input parameters, the user can subsequently observe the changes in the voltage drop of the transformer's secondary windings.

The graphically presented external characteristic ($u_{2(1)} = f(i)$) keeps the secondary voltage intensity overview for all previously set parameter values. The application allows the user to derive the following conclusions from the resulting graphs, depend-

ing on different load current values: a) voltage drop intensity during the inductive load, b) capacitive load value which will result in zero voltage drop. These two characteristic cases are shown in the graph at the up-right corner of Fig. 2.

4. DC Machines

This section focuses on the applications developed for the construction of appropriate characteristics of DC machines, both motors and generators. A special quality of these applications relates to the ability of characteristics' gradual construction, step by step, which allows the users (students) to master the principles of obtaining the resulting characteristics of the electrical machines more thoroughly in distance learning conditions. When it comes to electric motors, one of the most important characteristics is the torque vs speed characteristic. The

torque-speed characteristics of the DC motor with separate or parallel (shunt) excitation and the characteristics of the motor with series excitation are presented in the print screen images of the application shown in Fig. 3 and Fig. 4 respectively.

In both developed applications different torque-speed characteristics can be plotted and modified by changing the armature voltage, adding resistance in the armature circuit, or changing the machine field (field weakening). These applications are quite useful during the analysis of different ways to appropriately adjust the shape of the machine torque-speed characteristic and its corresponding characteristic points. Moreover, the applications help students better understand how the three stated well-known techniques (variation of arma-

ture voltage, added armature resistance and machine field weakening, which are studied within the course of Electrical drives) influence the resulting machine operating point depending on different machine loads. Analytical function $n = f(I)$, which corresponds to the currently displayed graph, is printed automatically and it changes simultaneously with the parameters that can be modified by appropriate sliders or by direct input. The motor load can be simulated by adjusting the armature current slider, by which the motor operation point (n , I) on the actual torque-speed characteristic is determined. Figs. 3 and 4 show four characteristics obtained by adding different armature resistance values with separate and series motor excitation respectively.

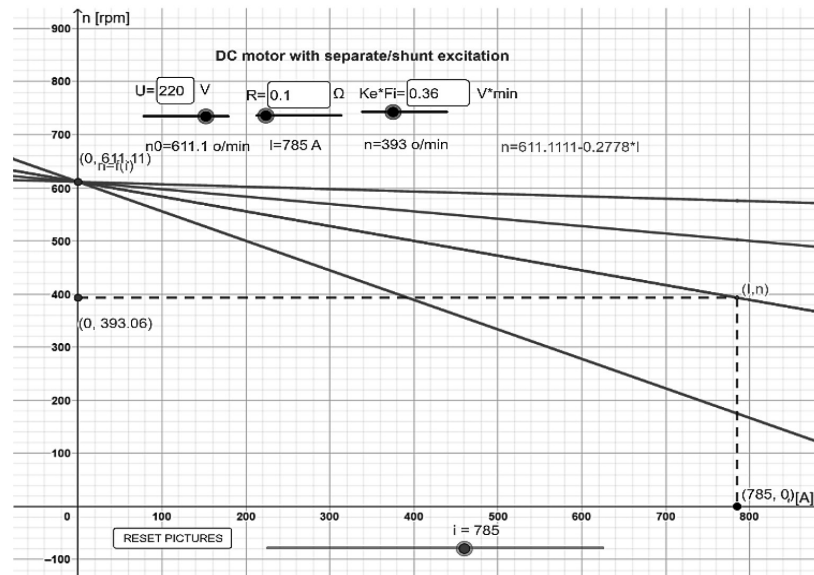


Fig. 3. Torque-speed characteristic of DC motor with separate/shunt excitation and 4 different added armature resistances (DCM_C11).

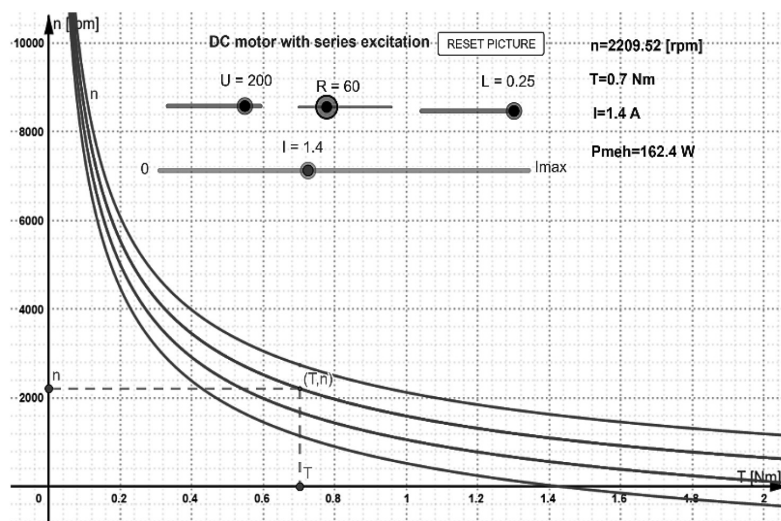


Fig. 4. Torque-speed characteristic of the DC motor with series excitation and 4 different added armature resistances (DCM_C12).

Another set of applications refers to the characteristics of DC generators as follows:

- The characteristics of a separately excited DC generator: load characteristic (Fig. 5), external characteristic (Fig. 6), regulation characteristic (Fig. 7) and short circuit characteristic (Fig. 8).
- The external characteristic of the DC generator with parallel (shunt) excitation (Fig. 9).
- The external characteristic of the DC generator with series excitation (Fig. 10).
- The external characteristic of the DC generator with compound (cumulative/differential) excitation (Fig. 11).

A unique feature of these characteristics is that they are graphically derived instead of being derived by the means of graphically represented mathematical relations. Namely, the resulting machine characteristics are plotted as a group of points determined by the currently set parameters of the machine. Although these characteristics are obtained during the laboratory work on the real setup, it is very important for students to know in advance what shape of the characteristic they should expect, the reasons why the graphs have such a shape, and which parameters they depend on and in what ways. Derived characteristics represent an excellent basis for understanding the characteristics of synchronous generators, which are far more common in real-life situations of electrical engineers and industry than DC generators.

The application presenting the load characteristic of the DC generator (Fig. 5) allows the user to define four parameters: generator speed n , armature resistance r_a , coefficient of magnetic armature reaction k , and armature current i_a . By moving the operation point position (electromotive force – EMF point) on the no-load curve, the resulting load characteristic is obtained as a “trail” consist-

ing of the resulting generator voltage points, calculated for different excitation currents and set values of the aforementioned four machine parameters within the defined range. Besides moving the EMF point by mouse, the appropriate characteristic can be plotted automatically by selecting the button “START Animation”. At any time, plotting can be stopped by selecting the “STOP Animation” button, and the values that define the current operation point of the generator can be read on the right side of the application, or directly from the graph. Fig. 5 shows two load characteristics obtained for the rated machine parameters with rated load, and generator load as twice as rated.

One of the important characteristics of the DC generators is the external characteristic, which represents the generator output voltage dependence u on the applied load current i , while the generator speed n and excitation current j remain constant. The graphic on the left side of Fig. 6 explains the procedure of characteristics graphical derivation, during which the characteristic triangle (whose sides are proportional to the load) plots the generator’s external characteristic. Plotting is enabled by changing the load current, during which the EMF point (corner) moves along the no-load curve, while the triangle corner which represents the generator output voltage moves vertically depending on the defined value of the generator excitation current. The resulting external characteristic (a set of red dots in the second quadrant) can be derived by using the load current slider or automatically by selecting the start or stop animation button. The right side of Fig. 6 shows the external characteristics for the following 3 sets of defined parameters: rated values, speed 20% higher than rated and with added resistance in the generator’s armature circuit $r_{add} = r_a$.

The regulation characteristic can be simply

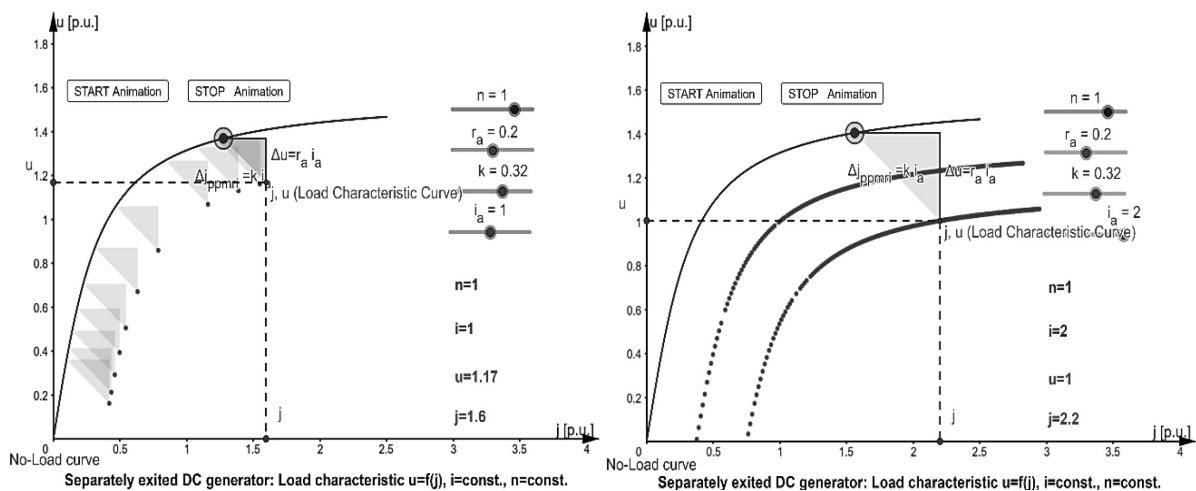


Fig. 5. Load characteristic of the separately excited DC generator $u=f(j)$ (DCM_C4).

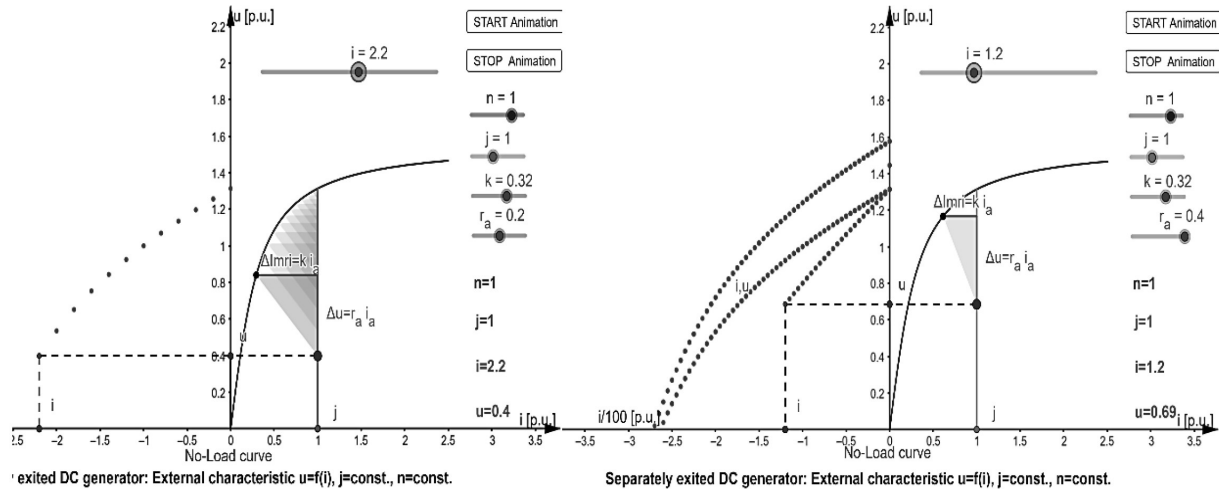


Fig. 6. External characteristic of the separately excited DC generator (DCM_C5).

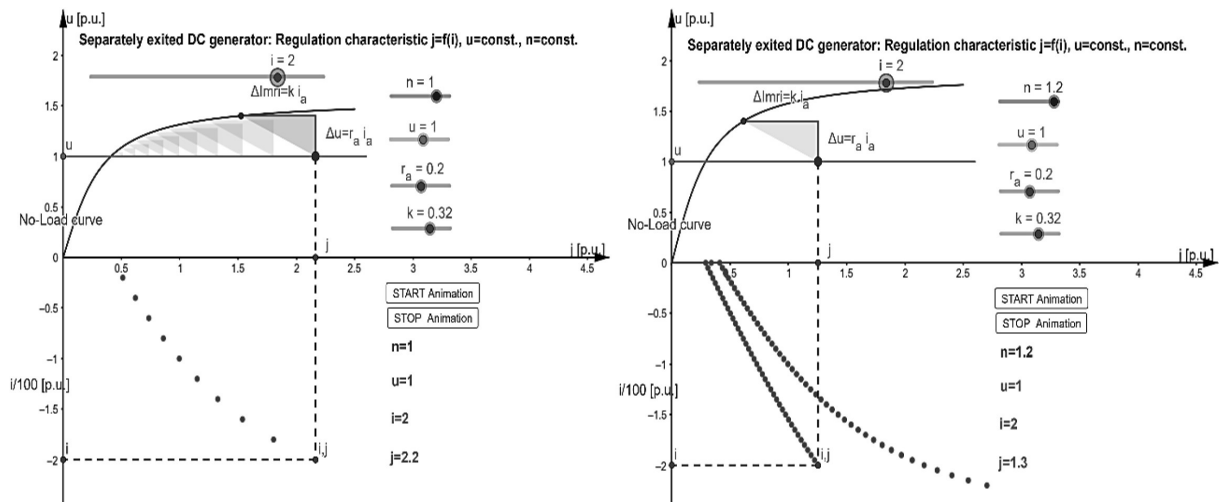


Fig. 7. Regulation characteristic of the separately excited DC generator (DCM_C6).

derived graphically by moving the characteristic triangle corner on the horizontal line which represents the constant voltage at generator output (left side of Fig. 7). Several characteristic triangles, one corner of which is moving on the no-load curve and another on the horizontal constant voltage line, should be constructed in order to plot the set of points defining the generator's regulation characteristic, $j = f(i)$. The load current value is calculated based on the size of the triangle, the sides of which are linearly proportional to the generator load. The right side of Fig. 7 shows two derived characteristics: the first one for the machine rated parameter values and the second one for the output voltage 20% greater than rated. In the second case, students can notice a significant rise in the excitation current caused by magnetic circuit saturation effect originating from the generator's voltage higher than rated.

The derived short circuit characteristic is shown

in Fig. 8. The same characteristic could be derived by using the previous application with the generator voltage set to zero. However, having in mind the importance of the short-circuit characteristic of the DC generator, a separate application is developed. By using this application, it can be understood that the machine is in the unsaturated state which is the reason for obtaining a straight line for the resulting characteristic.

The applications for other machine types (with parallel, series and compound excitation) are created as well. In these applications, it is possible to change the slope of the $u = f(j)$ characteristic by changing the additional resistance value of the field circuit, and see how it influences the resulting external characteristic of the DC generator. Fig. 9 shows the characteristics for two values of overall field circuit resistance: 100 p.u. and 150 p.u. These applications are useful for students in terms of noticing and understanding how the field (excita-

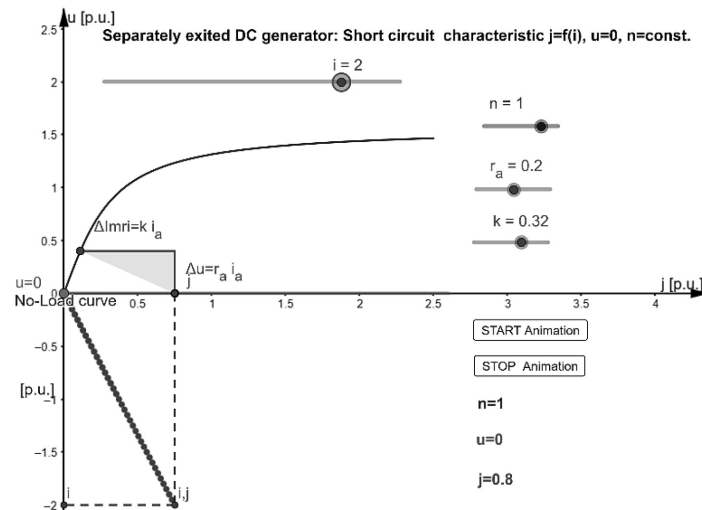


Fig. 8. Short circuit characteristic of the separately excited DC generator (DCM_C7).

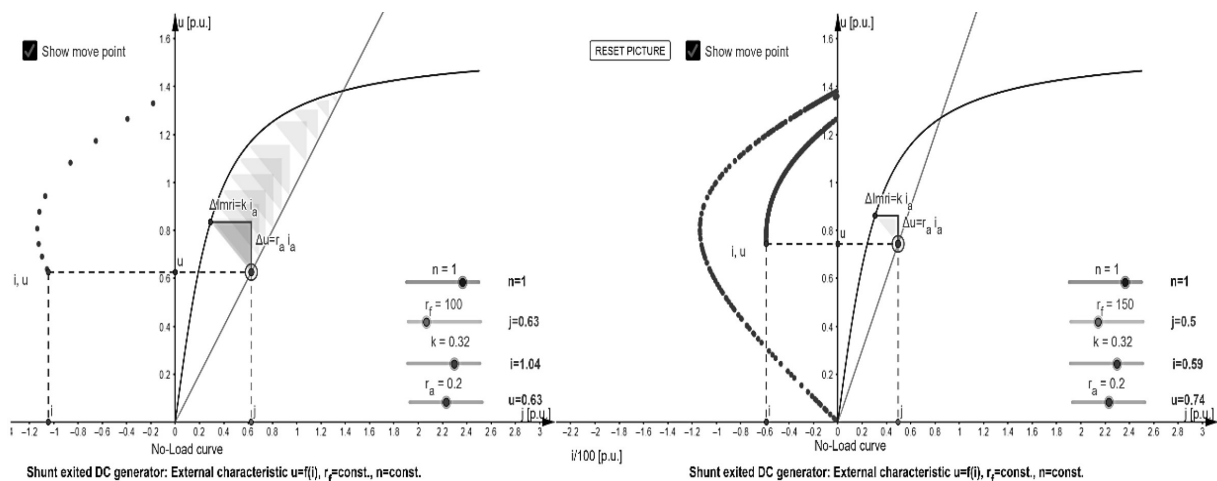


Fig. 9. External characteristic of the DC generator with parallel (shunt) excitation (DCM_C8).

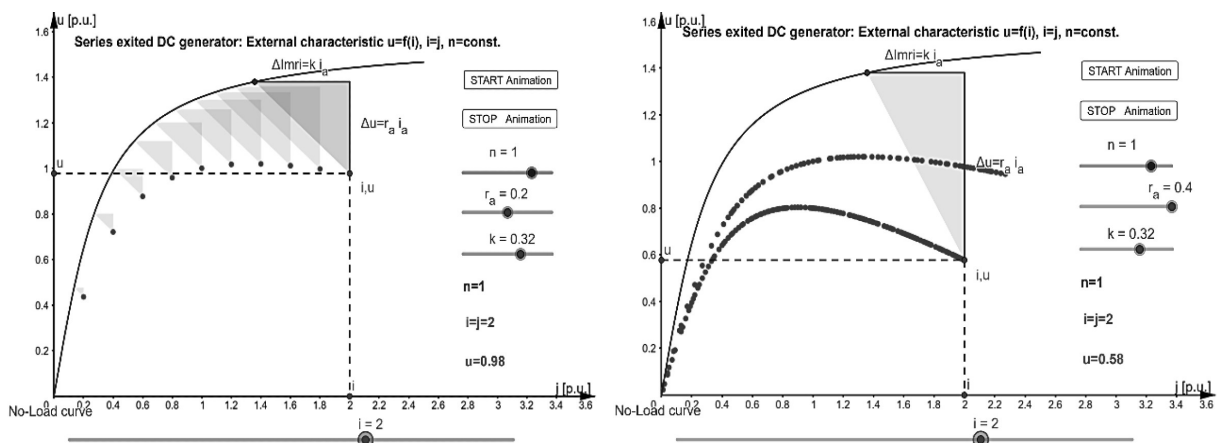


Fig. 10. External characteristic of the DC generator with series excitation (DCM_C9).

tion) circuit resistance and generator speed critical values are defined (maximum value of field circuit resistance R_f and minimum value of generator speed n_{\min}).

The external characteristic of the DC generator with series excitation is shown in Fig. 10. Since the load current is also the excitation current in this case, students can derive conclusions why this type

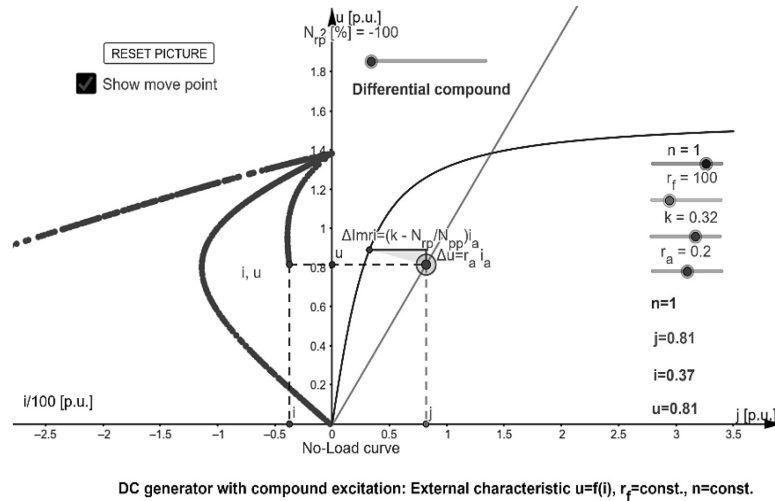


Fig. 11. External characteristic of the DC generator with compound (cumulative and differential) excitation (DCM_C10).

of machine is not suitable to operate in the generator regime (the voltage at the generator output greatly varies depending on the load – the higher the load the greater the voltage drop). The right side of Fig. 10 shows two derived characteristics: the first one obtained for the rated machine parameters, and the second one with the added resistance of $r_{add} = r_a$.

Differential and cumulative excitation regimes are possible for a DC generator with compound excitation (which can be under-excited, accurately excited and overexcited). All these excitation regimes are combined into the application shown in Fig. 11. By moving the excitation slider from the zero position to the left and right, the characteristics of differential (slider to the left) and cumulative (slider to the right) excitation can be obtained. The described regimes are defined by different slider colours and accompanying labels.

5. Induction Machines

Two applications have been created for induction machines (IM) in GeoGebra. In the first one, the

corresponding torque-speed characteristics of the IM are obtained for different values of the machine equivalent circuit parameters: RMS and frequency of the stator voltage, the number of pole pairs and the phase excitation sequence.

The application allows separate changes of the machine supply voltage and frequency values or change of these quantities maintaining the ratio U/f locked. This helps students to analyse the families of resulting characteristics obtained for a different set of the machine parameters with the changes of the supply voltage U and frequency f (Fig. 12). Having in mind the growing presence of frequency converters in electric motor drives nowadays, this application provides a very useful overview of the torque-speed characteristics of IM and the corresponding pull-out torque values within a wide range of stator frequencies (motor speed). Moreover, the torque diminishing effect at low speed (with $R_1 > 0$) can be examined and estimated depending on the defined stator resistance, as well as the appropriate stator voltage values enabling accurate RI compensation during the U/f machine control.

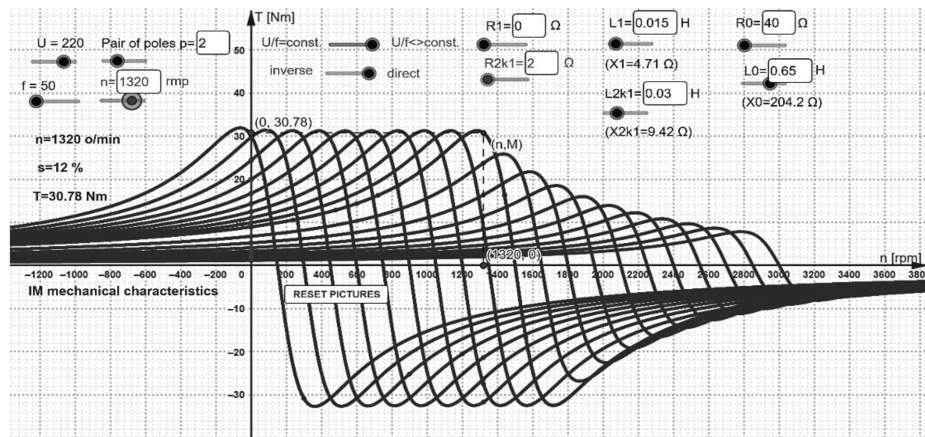


Fig. 12. Torque-speed characteristic of the induction machine (IM_C13).

The second application (Fig. 13) is related to the three-phase IM circle diagram construction with a detailed step-by-step procedure. The application represents the upgrade of the previously described application where the construction of the circle diagram is performed directly based on locked-rotor and no-load test results, rather than by using an IM equivalent scheme derived from the measured results. However, the application enables the overview and the results comparison of both mentioned approaches. The constructed circle diagram allows users to read the power loss components located in the stator and rotor of the IM. The results of the IM slip, during different machine operating regimes (motor, generator, braking), are available within the obtained results as well. A special quality of this application is the presentation of the step-by-step construction procedure of the IM circle diagram, with over 40 steps, enabling students a clear overview and tutorial on how it can be done manually.

6. Synchronous Machines

Several applications dedicated to the field of synchronous machines have been developed. The main idea was to help students cope with relatively complex learning material related to various diagram constructions in the field, and make it interesting and easier for them to understand during the unconventional working and learning conditions from home.

Vector diagrams of the synchronous generator and motor for both rotors' shapes (cylindrical and salient pole rotor) are presented through the applications referred as SM_28 – SM_31 [18]. The developed applications allow the control of relative values of the stator voltage u , angle φ , load current i , and relative values of the synchronous reactances x_s , x_d and x_q . The applications are helpful to students since they allow them to see how different types of synchronous machine phasor diagrams look like, how they differ, and how they depend on different machine parameters.

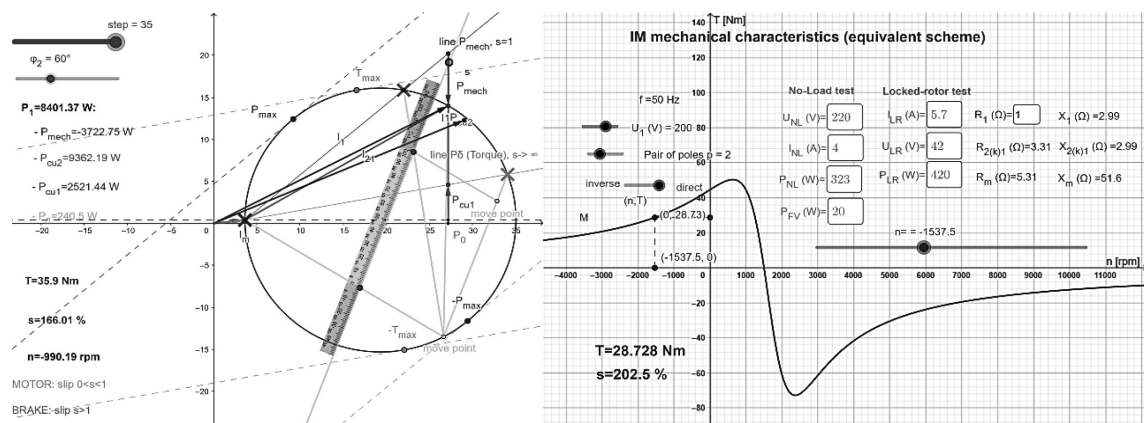


Fig. 13. Circle diagram of the induction machine (IM_C14).

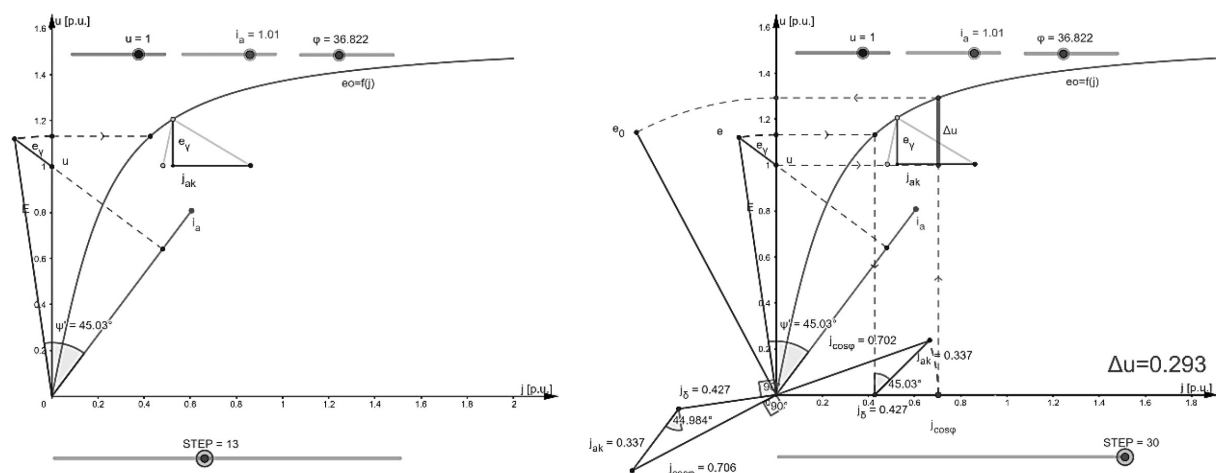


Fig. 14. Synchronous generator voltage drop determination by Potier triangle construction (SM_C22).

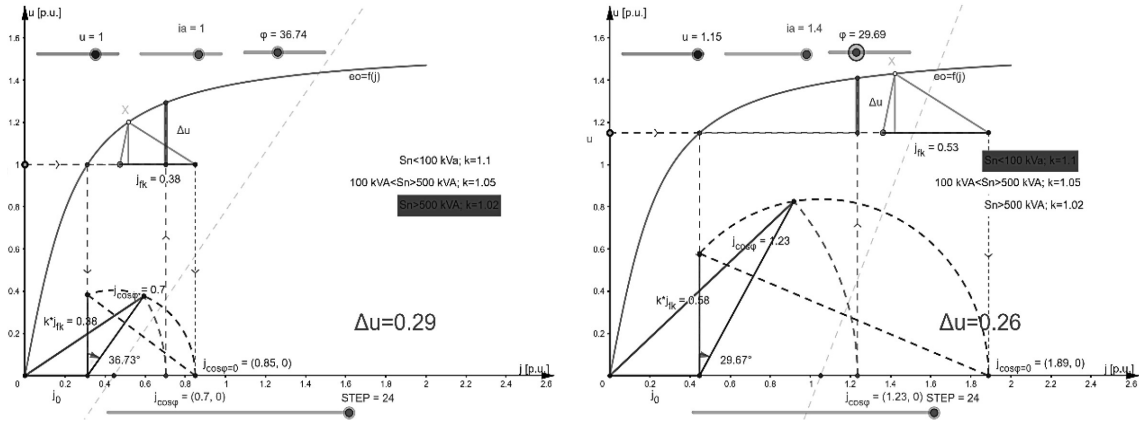


Fig. 15. Synchronous generator voltage drop determination by Swedish diagram for two different working regimes (SM_C23).

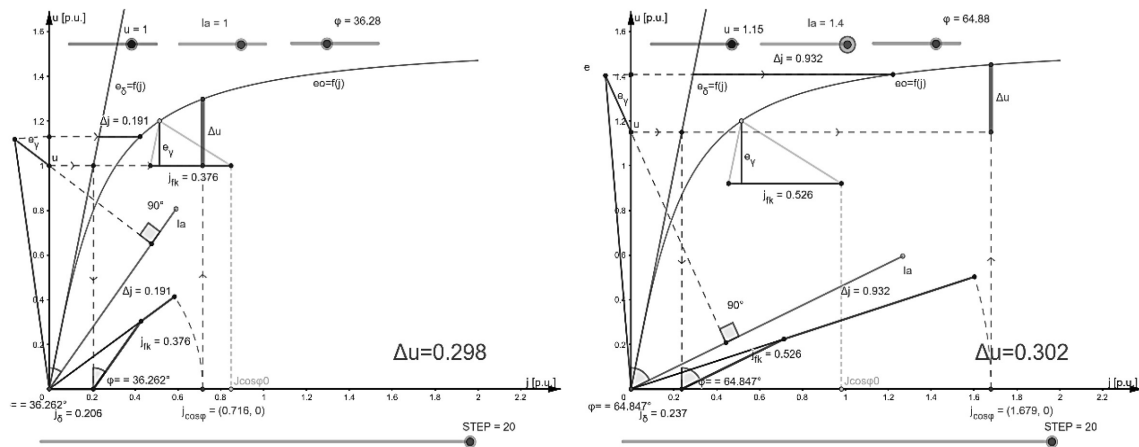


Fig. 16. Synchronous generator voltage drop determination by American diagram for two different working regimes (SM_C24).

The next three applications belong to the group dedicated to the determination of the synchronous generator voltage change using three well-known techniques: by Potier triangle (Fig. 14), Swedish (Fig. 15) and American diagram (Fig. 16) constructions according to the procedure given by [21]. All three diagrams are programmed to be constructed by the defined rules and standards. The applications provide step-by-step diagram constructions and allow subsequent comparison of the mutually obtained voltage drops, as well as the analysis of the results' dependence on various input parameters.

In order to fully comprehend the meaning of the synchronous generator PQ diagram, two applications have been developed, and they refer to the synchronous turbo generator – TG (Fig. 17) and synchronous hydrogenator – HG (Fig. 18). In both applications, the PQ working plane, and its limits where the operation point can be located during different operating conditions, can be marked and examined by setting the following machine parameters in relative units: power p_{\min} , p_{\max} , voltage u , angle φ_n , synchronous reactance (for TG) and x_d and x_q (for HG).

Depending on the defined load current and angle φ , the voltage phasor diagram and consequently the power phasor diagrams are constructed simultaneously (with derived values of active and reactive power), defining the operation point of the generator. The operation point must be located in the shaded area bordered by several operating limits as presented in Fig. 17 and Fig. 18, in order to have stable operation of the synchronous generator. The PQ diagram also provides well-known analytical expressions for the calculation of active and reactive power, that can be easily derived graphically based on the PQ diagram itself. If the operating point is located outside the defined limits, a warning of this unauthorized operating regime will be displayed.

The next three applications refer to different operating regimes of the synchronous generator. The first application (Fig. 19) shows the results of a three-phase short circuit synchronous generator failure according to [22, 23]. The application allows the definition of all resistance and reactance values of the machine on one hand, and voltage and generator speed as input parameters on the other hand. The obtained results are very useful for the

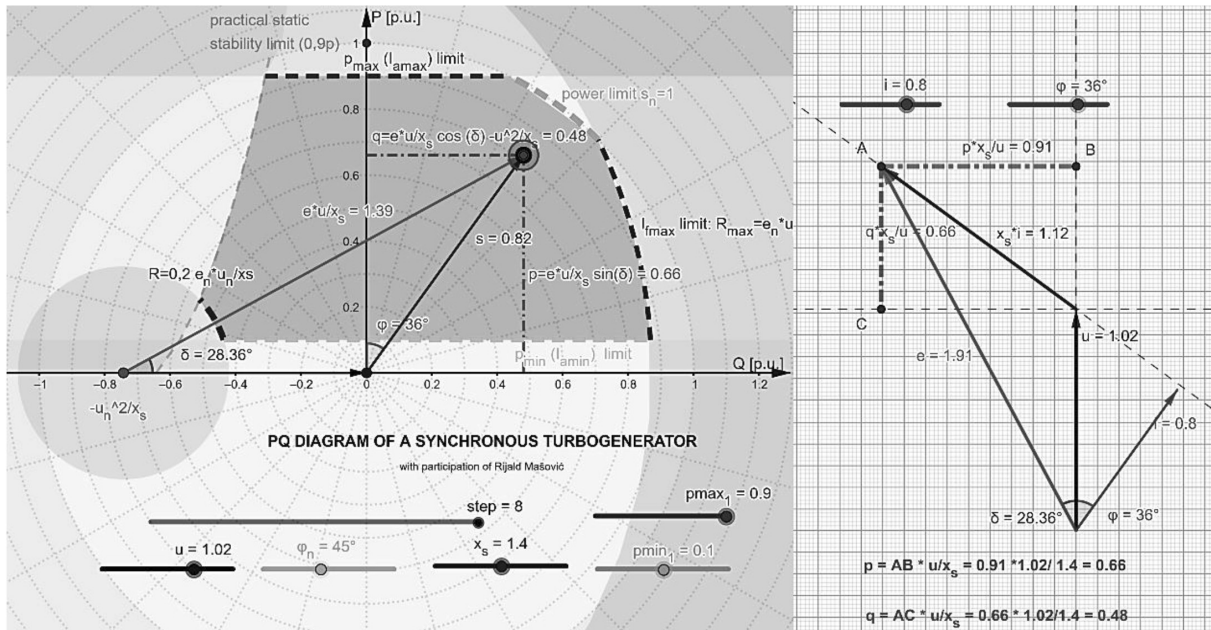


Fig. 17. Synchronous turbogenerator PQ diagram (SM_C19).

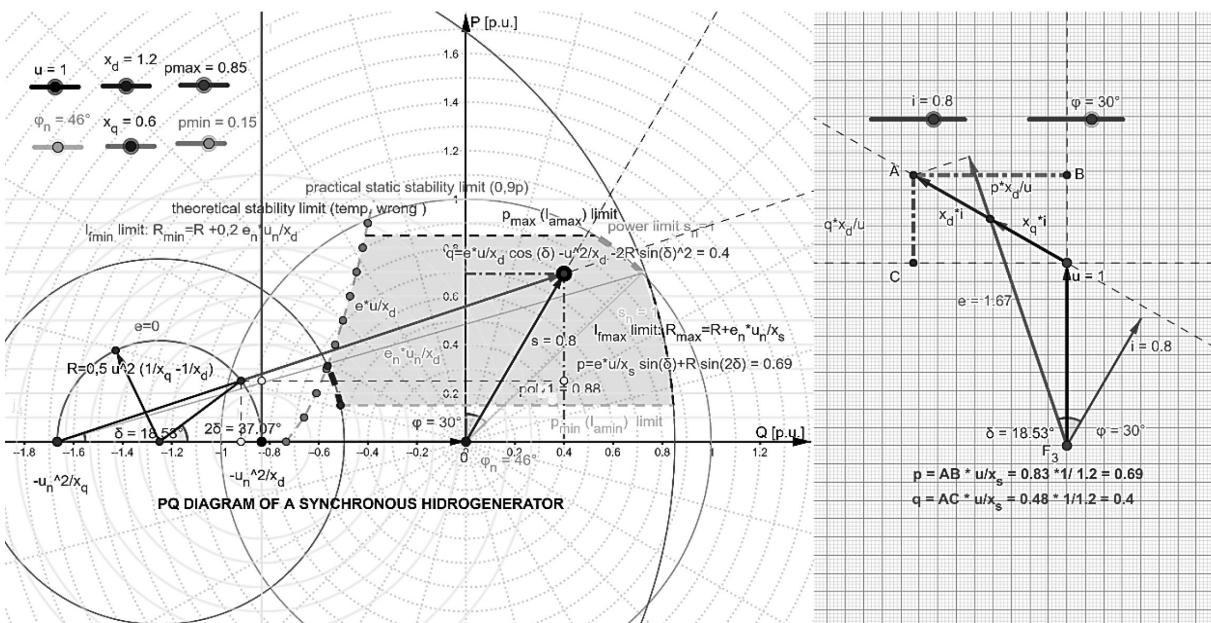


Fig. 18. Synchronous hydrogenator PQ diagram (SM_C20).

users since they depict 4 important short circuit current components (subtransient, transient, steady state and aperiodic component) of the synchronous generator. In this way, the user can analyse the shape and critical current values depending on the variation of machine parameters and other pre-fault conditions.

The second application (Fig. 20) depicts the graphical construction procedure of the synchronous machine armature vs field current graphs, better known as V curves. The application allows

the definition of the V curve as an associated group of points for a given setpoint of relative active power p , and in accordance with the defined power factor angle φ . A phasor diagram is also shown on the right, in which it is possible to change the value of generator voltage and synchronous reactance. The coordinate values corresponding to the excitation current and the load current are indicated on the graph in different colours.

The third application (Fig. 21) presents the components of the reluctant torque of the synchro-

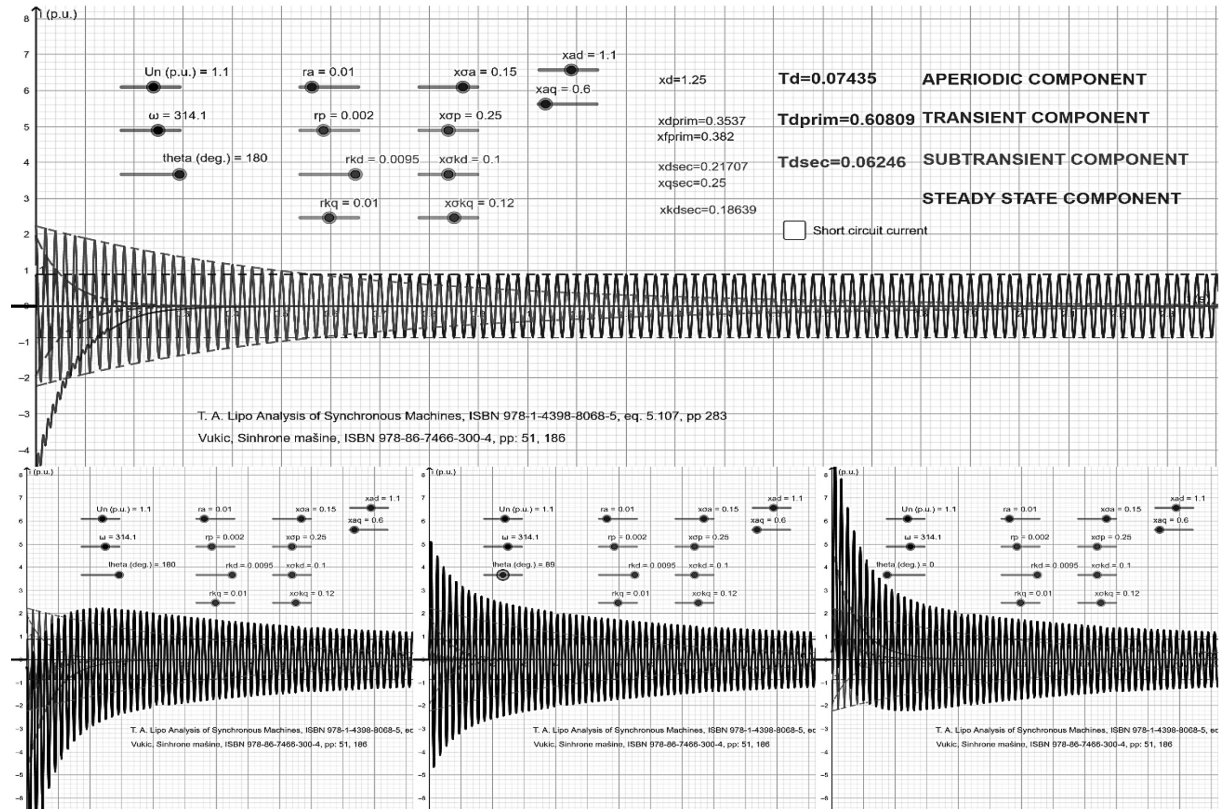


Fig. 19. Three phase short circuit failure of the synchronous generator (SM_C26).

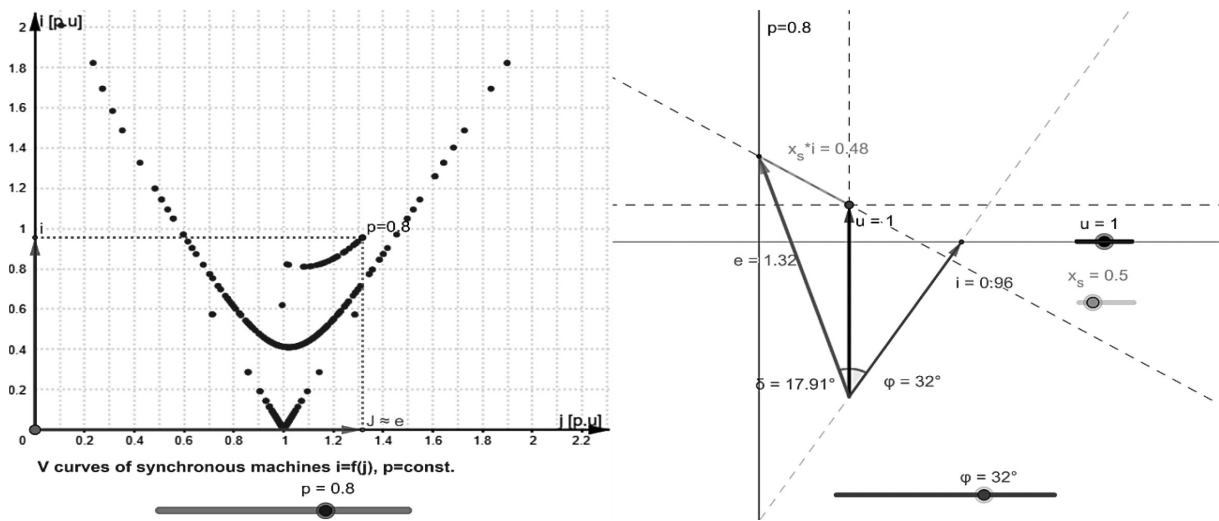


Fig. 20. V curves of the synchronous machine (SM_C25).

nous reluctance machine given by [24]. By changing the angular motor speed, it is possible to observe the case when the motor speed is equal to the circular frequency of the supply voltage (speed of rotation is equal to synchronous speed), during which the mean motor torque value defers from zero. For all other motor speeds, the mean value of all torque components (whose corresponding equations are shown on the left) have zero mean value.

7. Special Electrical Machines and Efficiency Curves

The area of special electrical machines is covered by two applications related to two different motor types: universal and single-phase induction motor.

The first application defines the torque-speed characteristic of the universal motor for defined values of supply voltage, frequency f , armature

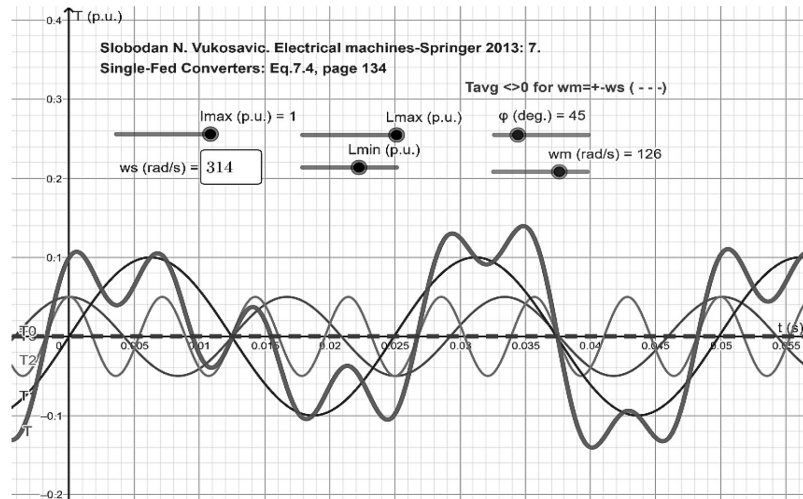


Fig. 21. Torque of the synchronous reluctant machine (SM_C3).

resistance R and inductivity L . The equivalent circuit and phasor diagrams are shown on the right together with the appropriate equations (Fig. 22). The definition of machine load current results in the operation point movement on the torque-speed characteristic, simultaneously redefining the corresponding phasor and circle diagram. It is interesting to analyse how the torque-speed characteristic changes with the supply frequency. If the frequency is reduced to zero the torque-speed characteristics of the DC motor with series excitation are obtained. For each specific value of the input parameters, the calculated values of the appropriate electromagnetic torque and the motor speed are shown. Several torque-speed characteristics obtained for different values of the supply voltage are depicted in Fig. 22.

The second application (Fig. 23) simulates the torque-speed characteristic of the single-phase and two-phase induction machine according to [25]. By

setting the parameters of main and auxiliary (starting) machine windings, the direct, inverse and resulting component of electromagnetic torque are displayed. The application allows the analysis of 4 characteristic cases:

- (1) only one (main) winding of the motor is connected to the single-phase power supply: the direct and inverse electromagnetic torque components are symmetrical, resulting in zero starting torque;
- (2) both the main and auxiliary windings are connected to a symmetrical two-phase power supply (with $\varphi = \pi/2$): the resulting torque is equal to the direct torque component, while the indirect torque component doesn't exist.
- (3) both the main and auxiliary windings are connected to the same single-phase power supply with the capacitor connected in an auxiliary phase circuit: the direct torque component is

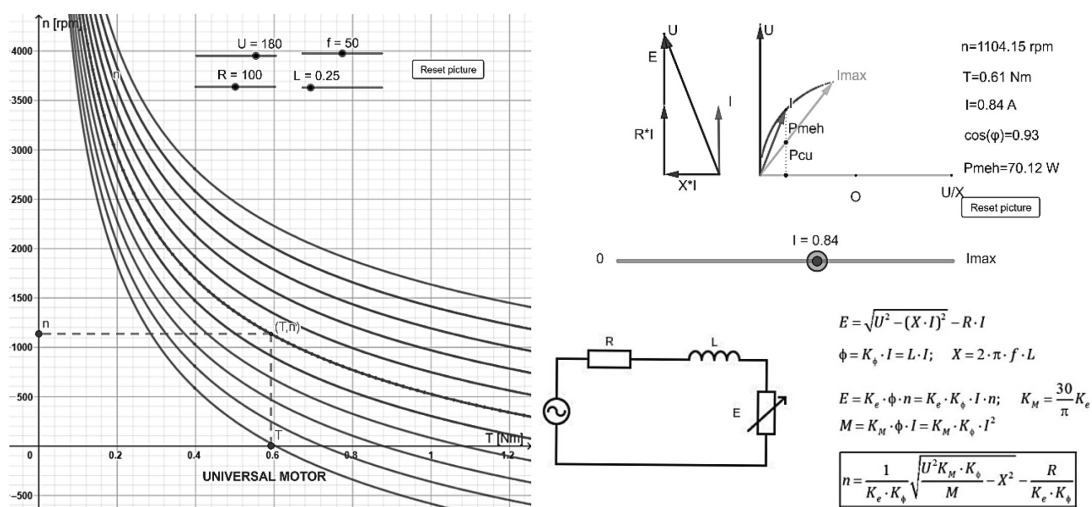


Fig. 22. Torque-speed characteristic of the universal motor (SPECM_C28).

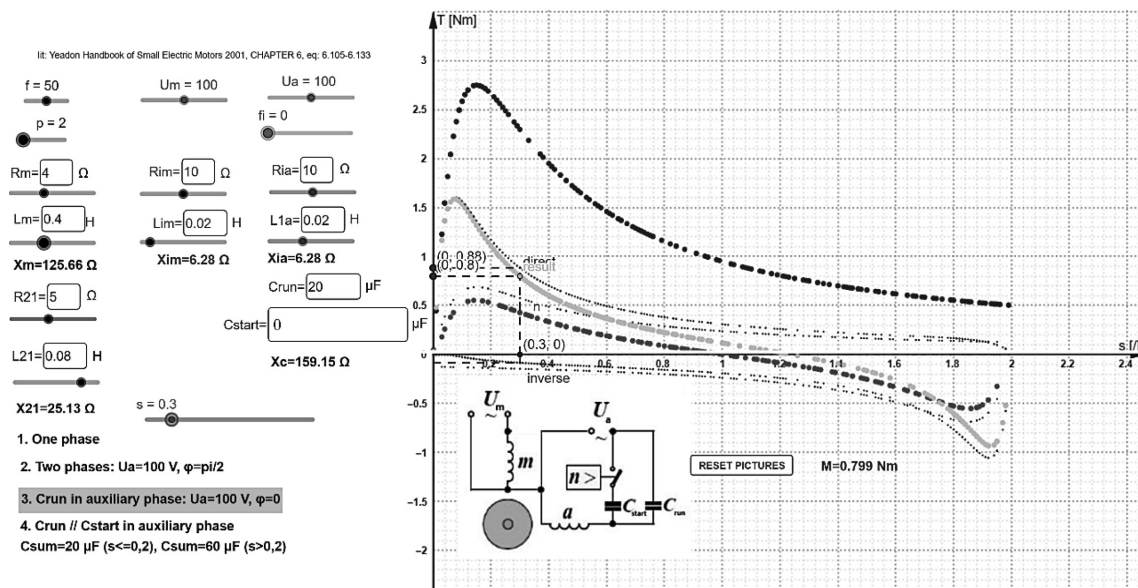


Fig. 23. Torque – speed characteristic of single-phase induction machine (SPECM_C27).

greater than the inverse component resulting in a positive starting torque;

- (4) both the operating and starting capacitors are connected to the auxiliary phase, whereby the starting capacitor is switched off at a certain speed of rotation (centrifugal switch simulation): two curves of the resulting torque-speed characteristic are obtained. The first, which corresponds to the period in which the motor begins to operate to the moment when the starting capacitor is switched off, and the second, which gives the appropriate torque-speed characteristic for the slip greater than 20%.

8. Conclusions

The two related articles (GeoGebra Tool: Development of Applications for Electrical Machines and Drives Teaching Support and The Efficacy of GeoGebra Tool in Enhancing Electrical Power Engineering Instruction [20]) are parts of the unique research approach to improving university instruction of electrical machines and drives. The Part I of the research presents a description of more than 30 applications in GeoGebra software, created at the EMDA laboratory (University of Kragujevac, Faculty of Technical Sciences in Čačak, Serbia) as a support in the process of engineering education

through several courses related to the field of electrical machines and drives.

The applications were developed to enhance students' understanding of important and usually complex phenomena in the field of electrical machines and drives in the frame of traditional or distant learning conditions. Guided by the step-by-step principle, the applications provide a complete overview of the process of deriving the complex characteristics of electrical machines and their understanding. The possibility of a simple setting of input parameters and the provision of dynamic graphic visualization effects is particularly emphasised, which significantly contribute to the understanding of electrical machines control principles, as well as corresponding stability and efficiency related issues.

The repository of the developed applications is provided for free use for those interested in the field, where all developed applications can be easily accessed and used by PC, smart phone, tablets and other modern IT devices which makes specific contribution of the presented work.

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