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Digital Learning: Modeling and Simulation of Three-Phase Short Circuit Fault Currents Using the Case Method for Strengthening MBKM Policy

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Abstract

This study discusses learning innovations in the field of electrical engineering for the study of short circuit analysis with real data using a computer program. Students work on projects from real data in the field. The proposed method is to design a short circuit analysis programming device based on Matlab GUI. The syntax and GUI media are validated by experts. So that the standard procedure is valid for students in working on projects in real cases. At the initial stage, small-scale trial data was conducted on 15 students as an experimental class with a GUI in learning. 15 students in another class as the control class. The test results show that the experimental class has better learning independence than the control class, which is indicated by the ability to solve real problems with better project report results. The results show that the role of the GUI in digitizing learning becomes a tool to help foster motivation and independence in electric power system analysis learning to support the MBKM policy of the Ministry of Education and Culture of the Republic of Indonesia in one aspect of the Main Performance Indicators that applies the case method in learning.

Keywords
digital simulation; short curcuit analysis; case methods; MBKM

I. Introduction

The skills of college graduates in using technology are the types of skills that are predicted to be needed by the business world and industry in the future. There are 10 types of skills, as reported by the World Economic Forum report (WEF, 2018), two of which are competence in the fields of technology and computer programming, and critical thinking skills. Important skills that need to be addressed by educators in implementing learning. Skills in the use of computer technology in enhancing the strengthening of competence and global competitiveness of Human Resources, especially in Indonesia.

The application of technology, especially computer simulations, is an important part in developing the quality of learning in the 21st century. Computer technology with software for simulation needs in learning is used to increase students' learning motivation in learning (Rahmaniar, 2019). Learning construction in increasing learning independence through learning practice experiments through computer simulations (Jordi, 2010). The world of education continues to innovate in improving the quality and quality of learning to face the challenges of learning in the era of technological disruption (Higgs, 2012). The role of technology can be effective in increasing the competence of students (Ghavifekr, 2015). Learning System Design is also called a linear and interactive procedure that demands accuracy and stability. Acting as a tool to control each other, all these stages must be completed. Improving the Learning Experience of Power System Protection Students using Computer-based Simulations and Practical Experiments, can improve the quality of student learning through observation of system performance (Farhad, 2014).

The process has the same meaning as the product, because trust in the product is based on the process. Planning to engineer the physical form that is formulated in a model. so that communication occurs between students and the study material being studied by paying attention to the rules of attention, perception, and capture power. Messages in the form of cues, or symbols that achieve changes in cognitive, affective and psychomotor behavior. Message design is related to various microstructures, such as: visualization materials, animations, simulations to be powerful tools in changing students' attitudes and learning behavior towards more optimal changes (Abbas, 2017). Simulation Product Design for Stability Electric Power System Using Power System Optimized Stabilizer and Control, designed using matlab software. This product was built to complement the simulation tool in the field of system stability learning for college students (Agus, 2017).

The Merdeka Belajar–Kampus Merdeka (MBKM) Policy is part of the efforts of the Indonesian Ministry of Education and Culture, aimed at encouraging students to be able to master various competencies as stated in minister of Education Regulation Number 3 of 2020 concerning National Higher Education Standards. In the MBKM Policy it is stated that the Merdeka Campus is expected to be the answer to these demands. In connection with the above, government policies or programs that will be or are being implemented or implemented in 2020, the problem of possible problems will occur. Problems will occur if the government rules or policies that are implemented or implemented are not as expected, in this case the Independent Learning Program Policy and the MBKM that are proclaimed are different from their implementation. The learning process in the MBMK one of the very essential manifestations of student centered learning. Learning in the MBKM provides challenges and opportunities for the development of creativity, capacity, personality, and student needs as well as developing independence in seeking and finding knowledge through realities and field dynamics such as ability requirements, real problems, social interaction, collaboration, self-management, performance demands, targets and achievements (Susetyo, 2020).

The MBKM policy is an effort to encourage the implementation of higher education to be more responsive to the needs of the world of work, as well as an effort to increase students' creativity in learning independently. Independent learning requires a pattern of critical thinking skills that are appropriate for adult learners. A recommended innovative learning model for critical thinking skills was tested. through purposive proportional random sampling using the Culture Fair Intelligence Test. Critical thinking data from slow learners and gifted students were collected using the Critical Thinking Scale. The results showed significant differences in the critical thinking of gifted students 'and slow students'; the former shows higher performance than the former last did it. The results of this study indicate that learning that must be applied in inclusive classes must apply innovative learning models that can accommodate differences in student abilities. This study recommends lecturers to apply a careful model that characterizes the use of critical thinking skills in improving student learning outcomes (Nurul, 2022).

The use of electrical energy continues to increase, along with the economic growth of a nation. Every year, power generation units continue to be added, transmission lines and substations are developed to meet the needs of electricity users in Indonesia. As stated by the Director General of Electricity at the Ministry of Energy and Mineral Resources of the Republic of Indonesia, that the plan for generation, transition and distribution networks, as well as electricity sales in an area in an effort to increase the production of electrical energy, in accordance with Government Regulation no. 25 of 2021 concerning the Implementation of the Energy and Mineral Resources Sector (RUPTL 2021-2030). This situation will have an impact on increasing the fault current in the electric power system. Fault is a condition in which the system experiences a relationship between one phase and another phase or system which causes a very large increase in fault current, which can cause damage to electrical equipment. Therefore, disturbance studies need to be carried out routinely by academics and practitioners in the field of electrical engineering (Daljeet Kaur, 2014). Study on Computer Based Learning Simulation (SCBL) for Short Circuit Multi Engine Power System Analysis. The related research builds a short circuit fault model of an electric power interconnection system with a bus impedance matrix model. The system modeling is done by observing the inline diagram, and the bus admittance matrix is designed through the reactance diagram, then the bus impedance matrix is modeled to determine the short-circuit impedance value (Maharani, 2017).

Research that examines the effectiveness of digital simulations to measure the use of digital media in learning in the field of vocational training techniques. To address the challenges and harness the opportunities offered by digital technologies during this crisis, participants shared a concern to recognize and protect digital rights in particular around the areas of privacy and inclusion (Hariati, 2021). This can be interpreted as internet users in Indonesia belongs to the category of digital natives group (Gunawan, 2020). The use of digital technology worldwide is increasing, especially since the COVID- 19 pandemic in early 2020 (Yugo, 2021). This observation uses a meta-evaluation technique. The use of digital simulations is beneficial for students in increasing learning creativity. The trial was applied in the field of technology and vocational training. Where the results obtained are known that Digital simulation is suitable for use in technical knowledge of procedures in vocational training. (Akrimullah, Giatman, et.al, 2020). This is in line with research conducted by Wiszniewsk (2018), practical experimental learning with the help of the electric LabVolt module using digital media. In the learning process in the field of electric power protection, students can visualize the error domain on the Over Current relay, simulate it using PSCAD / EMTDC software.

II. Research Methods

Symmetrical Short Circuit Analysis Model

Electrical power short-circuit faults caused by asymmetric three-phase short circuits, can cause hazards such as Damage to insulation, welding of conductors, fire and danger to life (Benoit, 2005). Short-circuit fault current is affected by the distance of the fault point, the closer the fault point to the source, the greater the short-circuit fault current at that point. The maximum and minimum short circuit currents result in a difference in the working time of the relay at each fault location, figure 1. Shows a model of a system experiencing symmetrical disturbances.

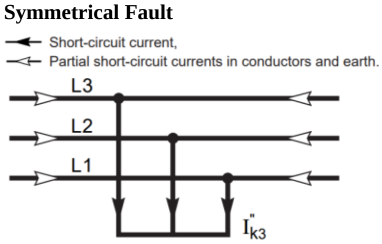

Figure 1. Symmetrical Fault Model

The system model concept for symmetric short circuit analysis and simulation is carried out by calculating the fault current at the point (bus) with a short circuit equivalent impedance (Z_{SC}) value. Figure 3 shows a reactance equivalent circuit of a power system. If there is a symmetrical fault on the k-bus Hadi (1999).

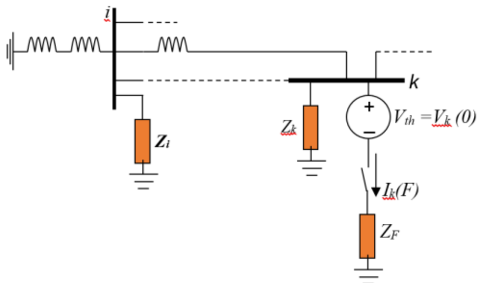

Figure 2*. Diagram of a Typical Power System Bus*

The fault current flowing at the k-bus point is called $I_k(F)$ with the short-circuit impedance value expressed in ZF. The voltage on the bus that is interrupted by thevenim equivalent circuit.

Matlab-assisted simulation tools are carried out to obtain the fault current of each channel of each bus. Symmetrical disturbance modeling is carried out with the following steps:

1. Observation of the inline diagram of the electric power system, the equivalent diagram in question is an inline diagram with equivalent reactance data. Multiple machines on each bus are represented by a single emf symbol.
2. Compile an inline diagram in the form of a reactance diagram. Inline diagrams depicted with data are only positive sequence diagrams (for symmetrical disturbances).
3. Determine the bus admittance matrix model through the data contained in the reactance diagram, and convert the bus admittance matrix model into the bus impedance matrix (ZBUS) with software.
4. Calculating the magnitude of the momentary current, the total fault current that occurs on the selected bus (bus k) with the short circuit fault current (I_F) formulation:

$$I_F = \frac{V_K}{Z_{KK}^1} \tag{1}$$

5. the fault current equation from bus-i to bus-j can be written as:

$$I_{ij}(F) = \frac{V_i(F) - V_j(F)}{z_{ij}} \tag{2}$$

The symmetrical fault analysis model is compiled in a program database, through the stages as shown in figure 3.

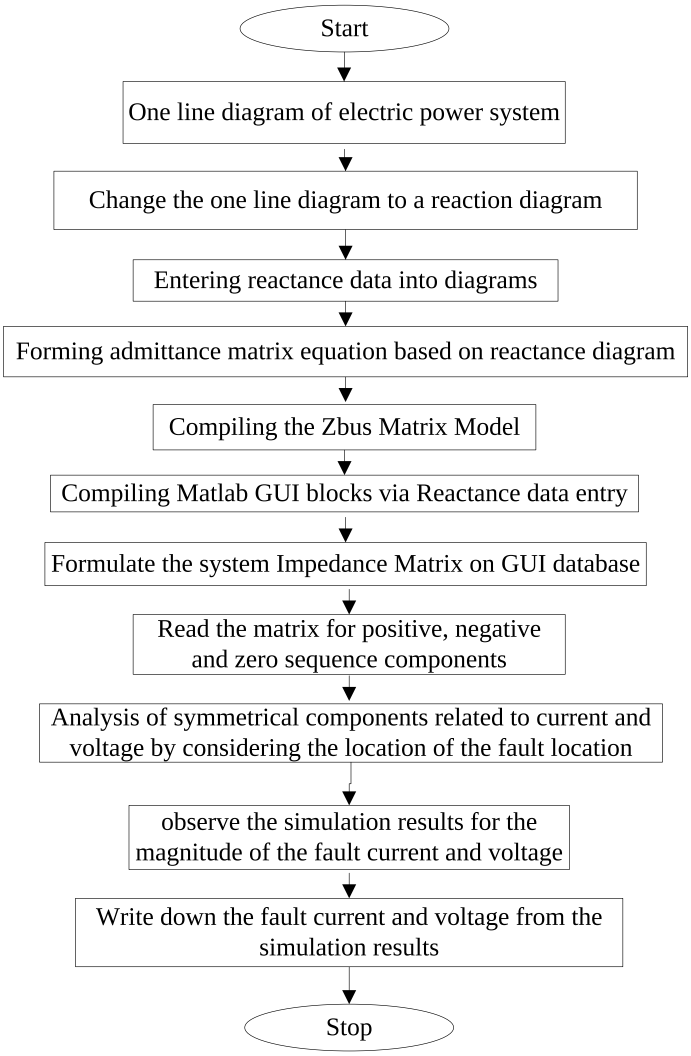

Figure 3. *Stages of preparing a GUI Program for Short Circuit Simulation*

Figure 3, shows the stages of designing a symmetrical short circuit simulation using the Matlab GUI program. The GUI system is built based on the Fault Analysis MATLAB Simulation literacy source by Josep M, (2013) modified, for the implementation of digital learning in electric power system analysis learning. The process starts from observing the inline diagram on the electric power system. Then compile a reactance diagram so that the admittance and bus impedance matrices can be modeled on the script m. In the matlab file there is a GUI Matlab source program. Next, perform data entry in the GUI and check the simulation results of the calculation of the power system short circuit fault. The programming design process is built with system reactance data input blocks from bus-i to bus-j arranged for data entry of positive sequence reactance, negative and zero sequence reactance, Base MVA and Base Voltage and determination of fault locations as shown in figure 4.

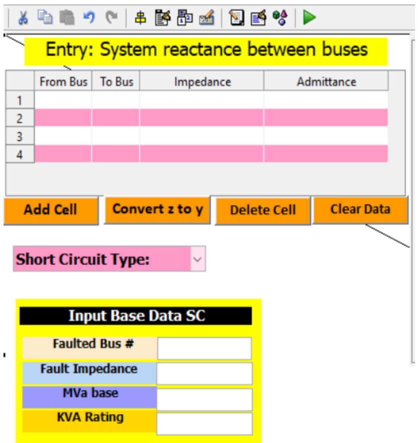

Figure 4. *Display Enter data in GUI Program*

Figure 5, shows the data input in the Program GUI. The input data is the reactance value of the electric power system with PU units. The data is based on observations of the real system reactance value or sourced from scientific articles.

The display of the GUI program used for learning symmetric short circuit analysis is shown in figure 6.

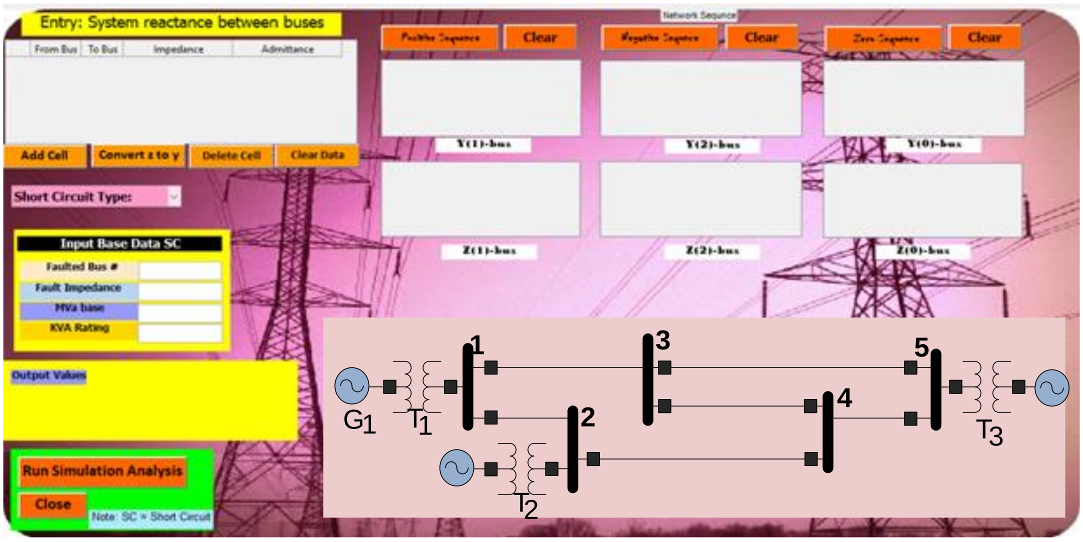

Figure 5*. The Display of the GUI Program Used for Learning Symmetric Short Circuit*

Figure 5, shows the GUI interface of the program used for symmetric short circuit analysis. On the left side of the figure, showing the data input between buses, adding a sell for the other bus reactance data netries. Conversion of x to z is a converter of reactance parameters per unit into impedance per unit. In the delete cell is the part where the cells that are not needed are removed. On the clear data button is to clear the simulation results for system impedance data. On the Short Ciscuit Types button, this is a button to select the type of short circuit fault to be calculated. Furthermore, on the SC database input, there are several commands to enter the fault location/location data, fault impedance, MVA base and KV rating. As supporting data for short circuit analysis. Run simulation analysis button, is a button to run GUI program. The results will be displayed on the left side of the GUI program. Here students will make careful observations in seeing the process or results of the short circuit simulation

III. Discussion

3.1 Sample Analysis

The data that is used as a trial analysis is sourced from the IEEE data sample. In this case, a 5 Bus system is tested with three generator units connected via T1, T2 and T3 to each transmission line, as shown in figure 6.

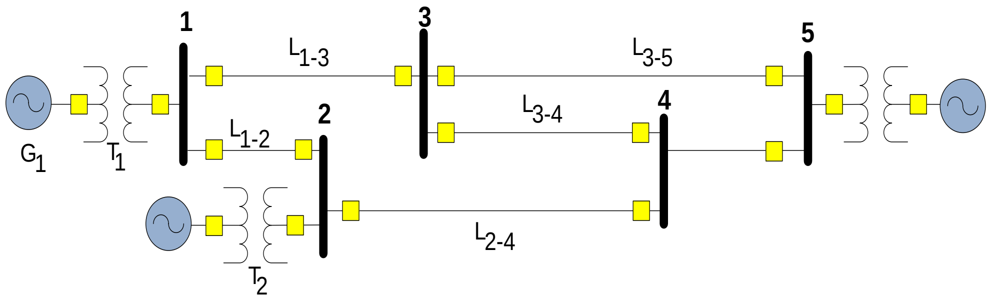

Figure 6*. One line Diagram 5-Bus Power System*

The reactance data and the voltage value as well as the MVA base are shown in table 1

Table 1. Electric power system: Bus Data (5 Bus)

Bus	V(Pu)	Δ(deg)	P_G	Q_G
1	1.06	0	232.9	-19.5
2	1.04	-5.01	40	36.92
3	1.01	-12.82	0	0
4	1.02	-10.60	0	0
5	1.02	-8.7	55	51.48

Transformer, transmission line and Generator data contained on buses 1, 2 and 5 and the lines connected between buses, shown in table 2.

Table 2. Transformer data and Transmission Line Data

<table>
<tr><th colspan="7">Transformer data</th></tr>
<tr><td rowspan="2">From Bus</td><td rowspan="2">To Bus</td><td colspan="2">Positive</td><td colspan="2">Zero</td><td rowspan="2">TAP</td></tr>
<tr><td>$R_{P.U.}$</td><td>$X_{P.U.}$</td><td>$R_{P.U.}$</td><td>$X_{P.U.}$</td></tr>
<tr><td>0</td><td>1</td><td>0.0006</td><td>0.56</td><td>0.0006</td><td>0.56</td><td>0.93</td></tr>
<tr><td>0</td><td>2</td><td>0.0006</td><td>0.45</td><td>0.0006</td><td>0.45</td><td>0.98</td></tr>
<tr><td>0</td><td>5</td><td>0.0006</td><td>0,56</td><td>0.0006</td><td>0,56</td><td>0.97</td></tr>
<tr><th colspan="7">Transmission Line Data</th></tr>
<tr><td>From Bus</td><td>To Bus</td><td>Positive Sequence (X_1)</td><td>Negative Sequence (X_2)</td><td colspan="3">Zero Sequence X_0</td></tr>
<tr><td>1</td><td>2</td><td>0.125</td><td>0.125</td><td colspan="3">0.331</td></tr>
<tr><td>1</td><td>3</td><td>0.150</td><td>0.150</td><td colspan="3">0.452</td></tr>
<tr><td>2</td><td>4</td><td>0.255</td><td>0.255</td><td colspan="3">0.514</td></tr>
<tr><td>3</td><td>4</td><td>0.142</td><td>0.142</td><td colspan="3">0.315</td></tr>
<tr><td>3</td><td>5</td><td>0.213</td><td>0.213</td><td colspan="3">0.298</td></tr>
<tr><td>4</td><td>5</td><td>0.130</td><td>0.130</td><td colspan="3">0.411</td></tr>
<tr><th colspan="7">Generator Data</th></tr>
</table>

From Bus	To Bus	Positive Sequence (X_1)	Negative Sequence (X_2)	Zero Sequence X_0
0	1	0.095	0.095	0.05
0	2	0.130	0.130	0.05
0	5	0.162	0.162	0.10

3.2 Simulation and Result

The simulation starts by entering data in the program GUI, sequentially as shown in the GUI data entry application figure 7.

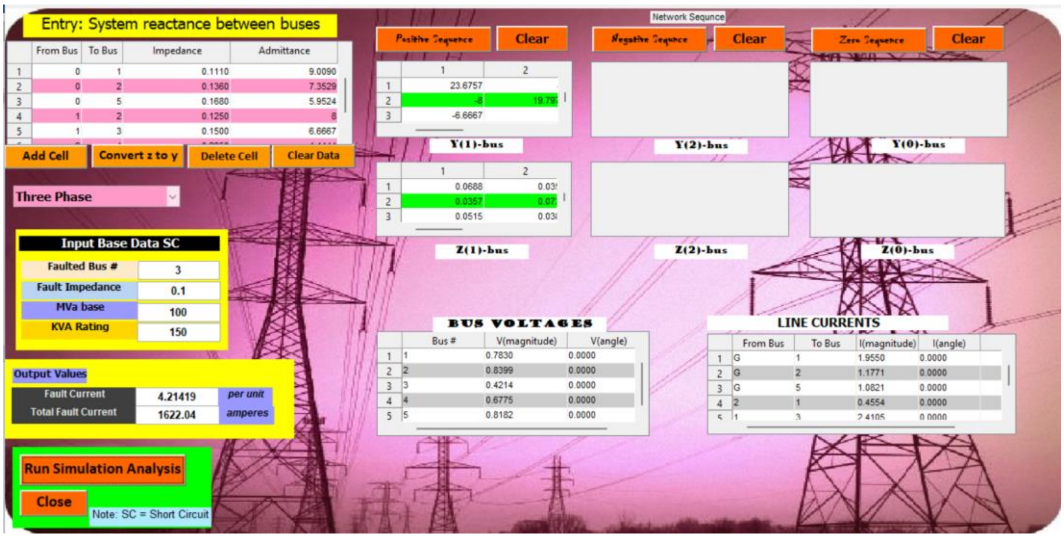

Figure 7. *SCC GUI Program*

From the simulation results using the GUI program, we get a picture of the magnitude of the 3-phase symmetrical fault current on bus 3 which is experiencing fault current. As shown in figure 8.

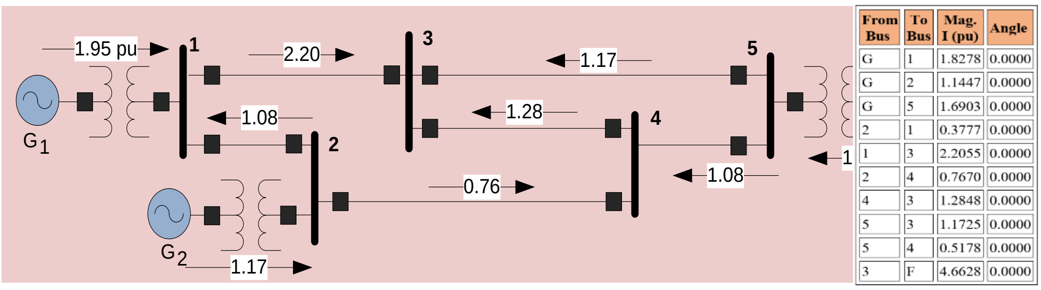

Figure 8. *Symmetrical Faults Result*

From the simulation results, it can be seen that the direction of the fault current if there is a fault on bus 3, respectively, namely: from the G_1, the Fault Current (I_F) is 1.95 pu. from G_2 the current is 1.17 pu. Mean while, from G_3 it is 1.08 pu. Fault current flows to the fault point, namely $I_{F\ (L1\text{-}3)}$ of 2.20 pu, $I_{F\ (L2\text{-}1)}$ 1.08 pu, $I_{F(L2\text{-}3)}$ 0.76 pu, $I_{F\ (L5\text{-}4)}$ 1.08 pu, $I_{F\ (L5\text{-}1)}$ 1.17 pu. so that the total current entering bus 3 is 4.66 pu. This means that the fault current on bus 3 has a value of 4.66 times greater than the nominal current. So this short-circuit current can damage the equipment if it is not quickly secured by protective equipment.

3.3 Short Circuit Simulation Trial in Small Class Training

The trial was carried out by applying training on understanding of symmetric short circuit analysis to 15 students who were taken randomly in the strata 1 electrical engineering class, through a training offer. The students involved consisted of 15 6th semester students who in carrying out learning activities for the power system analysis course and students in charge of the electrical power protection course. Learning treatment is given by providing the concept of symmetric short circuit analysis material, then students are given real field data based on data from scientific journals and data from the 14 Bus IEEE electric power system. students conduct guided investigative trials with the help of the program's GUI simulation tool. Lecturers as verifiers in checking student learning outcomes, who solve project-based learning problems. From the results of the trial, a measurement of the level of student learning success was carried out, by comparing the initial ability (before being treated with learning with the GUI Program) and the final ability through the post-test (after being treated with learning with the GUI Program. Through the analysis of effectiveness and practicality, test results were obtained as follows: shown in figure 9.

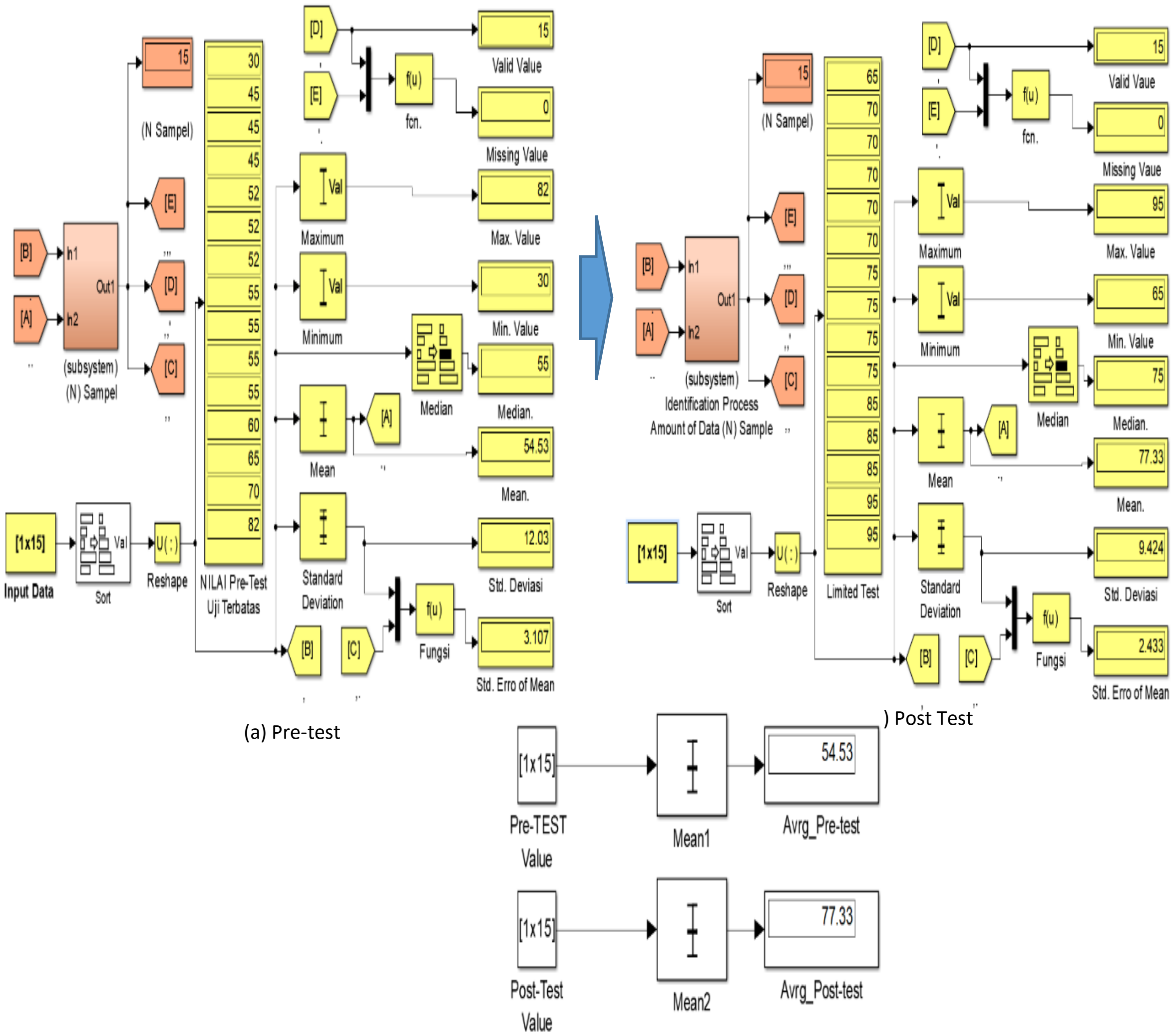

Figure 9. *The Effectiveness of Learning Using a GUI Simulation*

Measurement of effectiveness was carried out by testing before (pretest) and after being given treatment (post test) to 15 students participating in the training by using the comparison method against the average value, analyzed using simulation, obtained an average result of

77.33, an increase from the previous average value of 54.53. This shows that the use of simulation media in learning with digital learning concepts is effectively applied to adult students. he results of testing GUI products for learning are in line with research conducted by (Ismail, 2022), trials of implementing Augment Reality in experimental classes with culture-based Learning Model Problem Based Learning with Augmented Reality using parametric, that is t-test. To see the quality of student improvement mathematical communication skills taught through Learning model Problem Based Learning based on culture-assisted Augmented Reality Shows higher results.

IV. Conclusion

From analysis studies, simulations and measurements of GUI program trials in the field of electric power system learning, for symmetric short circuit analysis studies, it can be concluded

1. The GUI program is designed to solve learning problems in the field of analysis of short circuit analysis of electric power systems, in practical electrical power interconnection systems. Shown from the simulation results, the value of the short circuit fault current is 4.46 pu. The results are in accordance with theoretical studies that the magnitude of the symmetrical fault current can reach 3 to 6 times greater than the nominal current. Simulation results show the values are in that range. So it is concluded that the GUI SCC program can be used by students in project-based learning and independent learning
2. Testing using a comparison method with pretest and post test instruments to test the use of the GUI program in learning shows significant results, where the GUI Program can improve learning outcomes and independence and freedom in guided learning are more effective, this can create support in strengthening the program MBKM policy proclaimed by the government of the Republic of Indonesia through the Ministry of Education's Key Performance Indicators contained in the plan. medium term 2020-2024

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