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EFFECTIVENESS AND PRACTICALITY CAI BASED SIMULATION FOR LEARNING MEDIA OF SHORT CIRCUIT CURRENT

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ABSTRACT

The research will examine the manufacture of online practicum module products for the Power System Analysis (PSA) course. The PSA online module contains study material using a Real Problem Oriented (RPO)-based Computer-Assisted Instruction (CAI) model. The selection of research topics is based on 3 main problems. PSA learning is currently not available for PSA practicum modules. PSA courses, currently not equipped with online practicum modules as a basic need for students in learning during the Covid-19 pandemic, need to be realized, and Study materials on PSA have not been applied optimally in solving real problems. The online modules that were compiled were tested with instruments of effectiveness and practicality. Effectiveness test is carried out by applying module in small class training in two classes (experimental class and control class) with a difference in the value of the two classes. while for practicality modeled by testing the concept of aiken-v. To compose measurement simulations, a GUI is designed to study symmetrical and asymmetrical analysis on PSA. The simulation media is prepared to measure effectiveness and practicality. from the research results show that the GUI can solve the problem PSA analysis, and effectiveness and practicality simulation instruments designed to be valid as measuring instruments.

***Key Word**: Short Circuit, Graphical User Interface, PSA, Usymmetrical Fault, Symmetrical Fault*

1. INTRODUCTION

Conceptually, Computer Assisted Instruction (CAI) is a form of presenting learning materials and expertise or skills in computer-aided learning study units, helping students achieve competence in learning. CAI places computers as tools or learning media, where students can interact directly with computer systems that are intentionally designed and utilized by educators. Educators as facilitators in CAI learning and creativity in learning are wholly on the students (Student Center), because CAI applies a learning pattern with media to help students learn individually, ie as a whole from beginning to end using computer system tools [1,2]. Computer based learning is a learning program that is used in the learning process using computer software in the form of a computer program that contains learning content including titles, objectives, learning materials and learning evaluations. Utilization of computer based learning in delivering learning individually and directly to students interacting with subjects assisted by computer programs, has an influence on student learning outcomes. Information technology is an important part in the implementation of learning that requires it to be carried out online during the covid -19 pandemic as in the study of Implementation Of Religious Learning for Students With Special Education Needs Through Online Application, showing ICT as a very useful tool in learning activities [3].

CAI can function as an individual learning system and facilitate learning activities. CAI development must consider learning principles, learning system planning principles and individual learning principles, to increase interest in learning [4]. CAI can explore and learn without boundaries (Meka, 2020) in a study entitled Computer-Assisted Education (CAE) which examines the impact of CAE on students' academic success. Computer-assisted learning provides academics with a variety of teaching information and multimedia platforms to facilitate learning. CAE as a tool in facilitating students. As a tool, CAE media using a platform-based will grow the speed of learning independence for students, which is the goal in learning in the digital era [5].

The effect of the application of CAI on the academic achievement of students in the field of physics science studies. Testing CAI using a quasi-experimental pretest-posttest control group design followed by 157 students in the Philippines. The experimental group was taught using CAI while the control group was instructed to use conventional problem-based methods. The Mann-Whitney test with a significance level of 0.05 was used to compare the difference between the pretest scores of the control and experimental groups, the difference between the pretest and posttest scores of the control group and the experimental group, and the Z test with a significance level of 0.05 was used to compare the mean acquisition scores. the mean of both groups to determine the effect of CAI. The results of the study show that both CAI can be used as an alternative in good learning practices for students in the field of science [6]. CAI with the integration of ICT can actualize learning in the field of history in Africa, effective in improving learning outcomes [7]. A complex electric power system consists of many generators and is connected to a transmission network. The electric power system can be modeled mathematically to see the system's performance. as has been investigated in dynamic stability simulation trials with the Unified Power Flow Controller [8].

CAI It is widely believed that technology can have an important role in the production function of education. The results of Nicola Bianchi's research (2020), provide two main contributions about CAI in learning. First, the effect of computer-assisted learning can increase test scores in its implementation. Second, CAI as a medium in learning by utilizing technology can overcome the problem of rural-urban disparities in education. Students in rural schools are often disadvantaged because the quality of school inputs is very poor. The best educators tend to work in urban schools because of their more attractive geographic facilities and better career prospects. This disparity in school inputs is difficult to remove by simply offering subsidies for relocation to rural areas. The use of CAI to make education equal access to villages can be an alternative solution in overcoming the problem of education/learning gaps [9].

2. SHORT CIRCUIT CURRENT CONCEPT IN POWER SYSTEM ANALYSIS

A multi-machine power system means that the electrical energy services provided to consumers are supplied by many generators that are interconnected with each other through the electricity network. In the electrical system there are many kinds of interconnected generators to meet the needs of customers at different levels. A system with a multi-engine generating unit connected by a large number of buses with a large system interconnection, in system modeling has a more complicated level of complexity than a single engine system, this complexity is part of the research by making modeling in the form of a bus impedance matrix (Z_{BUS}) and compiled in a program using the Matlab graphical user interface (GUI) program. The system is built with a script program that contains simple system reactance and impedance data in completing the calculation of symmetrical short circuit faults. The electric power system is a unit starting from generation, distribution and load. An electric power system is said to be reliable if it can respond responsively to disturbances. One of the disturbances that occur in the electric power system is symmetrical interference. has been tested and simulated on a 14 bus IEEE electric power system, the value of symmetrical disturbances can be used for breaker capacity or can be referred to as MVA short circuit [10].

2.1. Symmetrical Component Theory

The short circuit current is analyzed to find out characteristics of the safety equipment required to be able to withstand and break the fault current. Stages in determine the various types of short circuit fault designed by modeling both in equivalent circuits and using matrix equations [11].

Analysis of short-circuit current based on the characteristics of the current-to-time function at the point of short-circuit fault. in accordance with the the value of the instantaneous voltage at the beginning of the short circuit, as shown in figure 1.

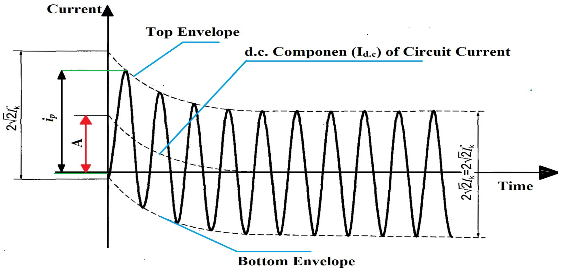


Figure 1. Characteristics of short-circuit current of short-circuit with constant a.c. components

From figure 1, it can be seen that, some disturbance parameters such as: I_k'' is initial symmetrical short circuit current, i_p is peak of short circuit current, I_k = steady state short circuit current,
$i_{d.c},$ is direct current component of short circuit current and A is initial value d.c. component $i_{d.c}$.

In most practical cases it is not necessary to determine the value of this short circuit. Depends on the application From the results of the analysis, these characteristics are interesting to study if you want to know the r.m.s. and the symmetric value of a.c. components as well peak value i, of the short circuit current after the short circuit occurs. The top value of i_p depending on the time constant of the decaying aperiodic component and the frequency f, i.e. at the R/X or X/R ratio of the short-circuit impedance Z_k, and is achieved if the short-circuit
The circuit starts at zero voltage. The i_p value also depends on the symmetrical ac component of short circuit current. In the case for meshed networks there are several direct current time constants to be considered. That's why it's impossible to provide an easy method for calculating i_p and $i_{d.c},$. A special method for calculating i, simply accuracy is given in figure 2.

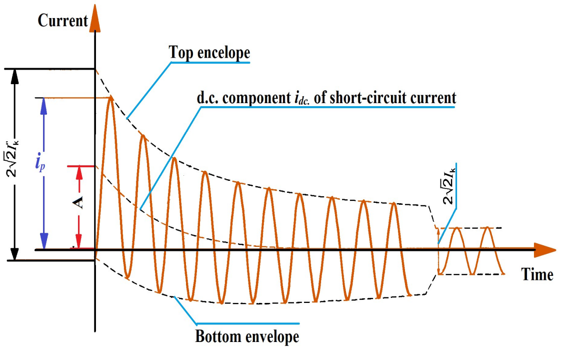


Figure 2. Short-circuit current of a near-to-generator short circuit with decaying a.c. component.

In the study of short-circuit analysis, the calculation of the maximum and minimum short-circuit currents is based on several simplifications and assumptions, which do not significantly affect the results of the short circuit analysis [12], including; (a). In the condition that during the fault there is no change in other types of short circuits. (b) During the short circuit duration, there is no configuration change in the network (c) The impedance of the transformer is referenced to the tap-changer in the main position. This is allowed, due to the impedance correction factor K_T for network transformers is introduced. (d) rc resistance is not taken into account / can be ignored. (e) All shunt line and inlet capacitances and non-rotating loads, except system zero sequence ones, are ignored.

Fortescue's work proves that an unbalanced system consisting of related n-phasors can be decomposed into n systems with balanced phasors called the symmetrical components of the original phasors. The three unbalanced phasors of a three-phase system can be broken down into three balanced phasors (Stevenson, 1999): (1). Positive sequence components consisting of three phasors of equal magnitude, separated from each other by 120 in phase, and having the same phase sequence as the original phasor. (2). Negative sequence components consisting of phasors which are large, separated from each other in phase by 120 , and have a phase order opposite to the original phasor. (3) a zero-sequence component consisting of three phasors of equal magnitude and with zero phase shift between one another.

The phase shift that occurs in the symmetrical components of voltage and current in a three-phase system, is described by the rotation vector of a phasor with 120^0. The product of two complex numbers is the product of the magnitude and the sum of the phase angles. If a complex number whose magnitude is one and whose angle is the resulting complex number is a phasor that is the same size as the original phasor but is out of phase by the angle. The notation a is usually used to denote the a-operator which causes a rotation of 120^0 in the anticlockwise direction, As shown in figure 3.

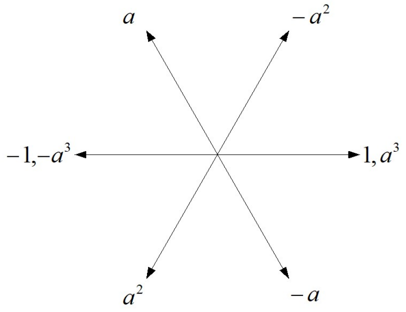


Figure 3. Diagram of the phasor-a operator.

This kind of operator is a complex number whose bearer is one and the angle is 120^0 and is defined by the formulation in equations 1 to 3:

$$a = 1 \angle 120° = -0.5 + j0.866 \quad (1)$$
$$a^2 = 1 \angle 240° = -0.5 - j0.866 \quad (2)$$
$$a^3 = 1 \angle 360° = 1 \angle 0° = 1 \quad (3)$$

The three unbalanced phasors into symmetry components are described in the form of a matrix, namely:

$V_{abc} = AV_{012}$ (4)
$V_{012} = A^{-1}\,V_{abc}$ (5)

The equations for each of the voltages in phases a, b and c in positive sequence, negative sequences and zero sequences, are represented by subscript 1, 2 and 3, respectively, are written in equations 6, 7 and 8:

$V_{b1} = a^2\,V_{a1}$ $V_{c1} = a\ V_{a1}$ (6)
$V_{b2} = a\,V_{a2}$ $V_{c2} = a^2\,V_{a2}$ (7)
$V_{b0} = V_{a0}$ $V_{c0} = V_{a0}$ (8)

The voltages in phases a, b and c are written in the equation:

$V_a = V_{a1} + V_{a2} + V_{a0}$ (9)
$V_b = a^2\,V_{a1} + a\,V_{a2} + V_{a0}$ (10)
$V_c = a\,V_{a1} + a^2\,V_{a2} + V_{a2}$ (11)

Arranged in Matrix A, it can be expressed by:

$$A = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \qquad (12)$$

From equation 12, the inverse matrix A value will be obtained:

$$A^{-1} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix} \qquad (13)$$

Voltage V_a, V_b and V_c in the form of a matrix equation can be written as:

$$\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} . \begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix} \qquad (14)$$

From equation (14), the voltages Va0 , Va1 and Va2 are expressed in equation 15.

$$\begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix} . \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} \qquad (15)$$

so that each equation can be described as:

$$\begin{aligned} V_{ao} &= \frac{1}{3}\left(V_a + V_b + V_c\right) \\ V_{a1} &= \frac{1}{3}\left(V_a + aV_b + a^2V_c\right) \\ V_{a2} &= \frac{1}{3}\left(V_a + a^2V_b + aV_c\right) \end{aligned} \qquad (16)$$

If required the components V_{bo}, V_{b1}, V_{b2}, V_{co}, V_{c1}, V_{c2} can be obtained from equation 16. The equation shows how to decompose three asymmetric phasors into symmetric ones. In the same way, we can write the equation for current instead of voltage:

$I_a = I_{a1} + I_{a2} + I_{ao}$ (17)
$I_b = a^2I_{a1} + a\,I_{a2} + I_{ao}$ (18)
$I_c = a\,I_{a1} + a^2\,I_{a2} + I_{ao}$ (19)
$I_{ao} = 1/3\,(I_a + I_b + I_c)$ (20)
$I_{a1} = 1/3\,(I_{a1} + a\,I_b + a^2I_c)$ (21)
$I_{a2} = 1/3\,(I_a + a^2\,I_b + aI_c)$ (22)

In a three-phase system the sum of the line currents is equal to the current In in the return path through neutral so:

$I_a+I_b+I_c=I_n$ (23)

By comparing equation (20), with equation (23) it will be obtained:

$I_n=3\ _{Ia0}$ (24)

if no path through the neutral of a three-phase system In is 0 and the line current contains no zero-charge component, a load with a delta connection does not provide a neutral path, and therefore the line current flowing into a delta-connected load does not contain a zero-sequence component.

3. Short Circuit Current Equation Model

3.1. Phase-to-earth fault

Simplification in the Model System Zero, positive and negative equivalent circuits are used in power systems. In the main simplification is basically not affect the accuracy of the results obtained, they consist of; (i) The shunt element in the transformer model is calculated, the magnetizing current and core losses are negligible. (ii) The shunt capacitance in the network model is neglected. (iii) The steady state circuit analysis technique is used. (iv). set the internal system voltage source $1\angle 0^0$. The basic considerations in solving the problem are generally depicted in Figure 1. In general, the terminal describes the external relationship of the fault simulation. Note that the positive sign is the phase quantity. Particularly important is the current flowing out of the system.

Asymmetrical faults cause unbalanced currents in the system, the component method is very useful in analysis to determine the currents and voltages in all parts of the system after the fault occurs.
Regardless of the type of disturbance that occurs at the generator terminals. One-phase to ground fault, in a system is when one of the conductors is connected to ground, as in the diagram of figure 4.

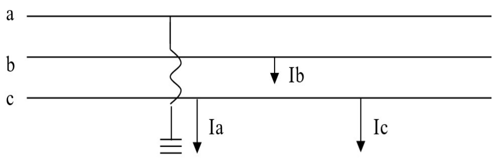


Figure 4. Phase-to-earth fault

Phase-to-earth fault from the figure 4, it is obtained for the equation for the condition:

$Ib = 0$ (25)
$Ic = 0$ (26)
$Va = 0$ (27)

By substituting equations (20), (21) and (22) the equations are in the condition where:
$I_b = 0$ dan $I_c = 0$, then;
$Ia_0 = 1/3 \ (Ia + Ib + Ic) = Ia/3$ (28)
$Ia_1 = 1/3 \ (Ia + a\, Ib + a^2 Ic) = Ia/3$ (29)
$Ia_2 = 1/3 \ (Ia + a^2 Ib + a\, Ic) = Ia/3$ (30)

From the equation above, to analyze it, three sequences are used, namely positive sequence, negative sequence and zero sequence which are connected in series, show in figure 5.

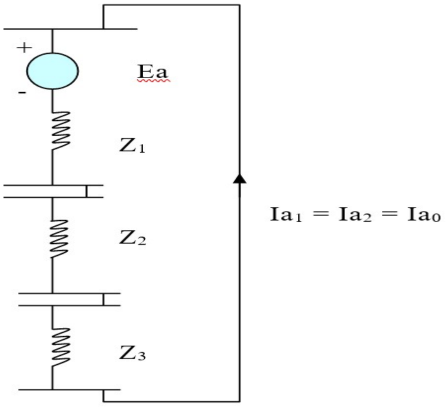


Figure 5. Connection diagram of Phase-to-earth fault

Figure 5, shows the relationship between positive, negative and zero sequence impedances for a single phase to ground short circuit fault condition. The three third-order components are faults connected in parallel, this condition is identified from the derivative of the equation which shows that the single-phase fault conditions to ground Z1, Z2 and Z3 are connected in series. From Equation:

$Va = Va_1 + Va_2 + Va_0$ (31)
$O = Va_1 + Va_2 + Va_0$ (32)
$Va_1 = -(Va_2 + Va_0)$ (33)

The general equation for the component voltage drop determined by the sequence network is:$Va_1 = Ea - Ia_1 \,.\, Z_1$ (34)

$Va_2 = -Ia_2 \,.\, Z_2$ (35)
$Va_0 = -Ia_0 \,.\, Z_0$ (36)
Than,
$Va_1 = -(Va_2 + Va_0)$ (37)
$Ea - Ia_1 \,.\, Z_1 = Ia_2 \,.\, Z_2 + Ia_0 + Z_0$
$Ea = Ia_1 \,.\, Z_1 + Ia_2 \,.\, Z_0 + Ia_0 \,.\, Z_0$

Where,

$Ia_1 = Ia_2 = Ia_0$

Than,

$Ea = Ia_1 \ (Z_1 + Z_2 + Z_0)$ (38)

$$Ia_1 = \frac{Ea}{Z_1 + Z_2 + Z_0} \quad (39)$$

From Equation aan : $Ia_1 = Ia_2 = Ia_0 = Ia/3$

Then the large fault current (I_f), for single phase ground fault:

$I_f = Ia = 3Ia_1$ (40)

For Phase-to-earth faults, the positive, negative and zero sequence sequences will be connected in series, as shown in figure 3.

3.2.Phase-to-phase short-circuit

Two-phase interference or interference between the lines of a system is when one conductor is connected to another conductor, show in figure 6.

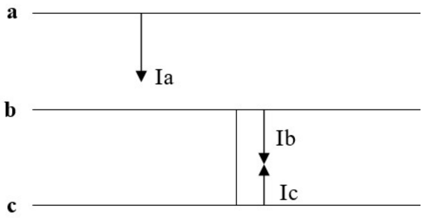


Figure 6. Short circuit diagram between phases

From the picture above, the following conditions are obtained: :

$Vb = Vc$
$Va = 0$
$Ib = -Ic$ (41)

By substituting equations 20, 21 and 22 the above equations are obtained:

$$Ia_0 = 1/3\ (Ia + Ib + Ic) = 0$$
$$Ia_1 = 1/3\ (Ia - Ib + a^2Ic)$$
$$= 1/3\ (0 - aIc + a^2Ic)$$
$$= \frac{-a + a^2\ Ic}{3} = j\ \frac{1{,}732\ Ic}{3}$$
$$Ia_2 = 1/3\ (0 - a^2\ Ic + aIc)$$
$$= \frac{-a + a\ Ic}{3} = \frac{-j\,1{,}732\ Ic}{3} \qquad (42)$$

therefore : $Ia_0 = 0$; $Ia_1 = Ia_2$

By equation 9, 10 dan 11 substituted with the above equation (Vb = Vc), will be obtained:

$$V_b = V_c$$
$$a^2Va_1 + aVa_2 + Va_0 = a\,Va_1 + a^2\,Va_2 + Va_0$$
$$a^2Va_1 - aVa_2 - Va_0 = a^2\,Va_1 - a\,Va_2\ \ Va_0$$
$$(a^2 - a)\,Va_1 = (a^2 - a)\,Va_2$$
$$V_{a1} = Va_2 \qquad (43)$$

From the above analysis, the analysis for two-phase faults is that only positive sequences and negative sequences are connected in parallel, show in figure 7.

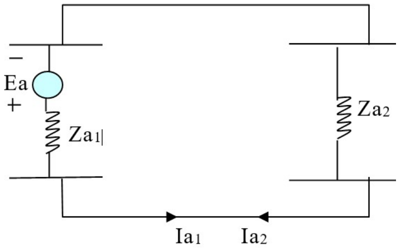


Figure 7. Sequence Sequence for Phase-to-phase short-circuit hase-to-phase short-circuit

From the equation: $Va_1 = Va_2$

$$Ea - Ia_1 Z_1 = -Ia_2 Z_2$$

Where, $Ia_1 = - Ia_2$

Than,

$$Ea - Ia_1 Z_1 = Ia_1 Z_2$$
$$Ea = \{(Ia_1)(Z_1)\}\ .\ Ia_1 Z_2$$
$$Ea = Ia_1 (Z_1 + Z_2)$$

Therefore:

$$Ia_1 = \frac{Ea}{Z_1 + Z_2} \qquad (44)$$

substitute equation 17, 18 dan 19 to the equation: Ia = 0 dan $Ia_1 = -Ia_2$, will be obtained:

$$I_a = I_{a1} + I_{a2} + I_{a0} = 0$$
$$I_b = a^2I_{a1} + a\,I_{a2} + I_{a0}$$
$$I_c = a\,I_{a1} + a^2I_{a2} + I_{a0}$$

The magnitude of the two-phase short circuit (I_F) is:

$$I_F = Ib = -Ic$$
$$I_F = -(a\,Ia_1 + a^2\,Ia_2 + Ia_0)$$
or, $I_F = Ib = a^2\,Ia_1 + a\,Ia_2 + Ia_0$

because $Ia_1 = -Ia_2$, than $I_f = a_2\,Ia_1 - a\,Ia_1 + 0$

$$I_F = a^2\,Ia_1 - a\,Ia_1 \qquad (45)$$

3.3. Phase-to-phase-to-earth short-circuit

Two-phase ground fault in a system is when two conductors are connected to ground or neutral wire, the diagram is as shown in figure 8.

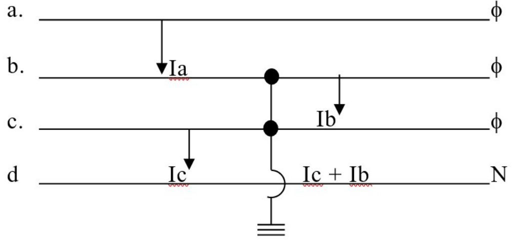


Figure 8. Phase-to-Phase-to-Earth short-circuit Diagram

From the figure 8, we get the equation of conditions,

Ia = 0 : Vb = ; Vc = 0

Substituting equations 16, to the equation of the above condition:

$$Va_0 = 1/3\ (Va + Vb + Vc) = \frac{Va}{3} \qquad (46)$$
$$Va_1 = 1/3\ (Va + a^2Vb + a^2Vc) = \frac{Va}{3} \qquad (47)$$
$$Va_2 = 1/3\ (Va + a^2Vb + a\,Vc) = \frac{Va}{3} \qquad (48)$$

Than,

$$Va_0 = Va_1 = Va_2 = \frac{Va}{3} \qquad (49)$$

From the above results, the analysis for a two-phase ground fault is positive sequence, negative sequence and zero sequence connected in paralel.

Positive order phase-a current (Ia_1) equation:

$$Ia_1 = \frac{Z_2 + Z_0}{Z_1\,Z_2 + Z_1\,Z_0 + Z_2\,Z_0}\ x\ Ea$$
$$Ia_1 = \frac{Z_2 + Z_0}{Z_1 + Z_2\,.\,Z_0\ /Z_2 + Z_0} \qquad (50)$$

From,

$$V_{a1} = Ea - Ia_1 Z_1$$
$$= Ea - \frac{Z_2 + Z_0}{Z_1 + Z_2\,.\,Z_0\ /Z_2 + Z_0}\ Z_1$$
$$= Ea - \left[1 - \frac{Z_{1\ 0}}{Z_1 + Z_2\,.\,Z_0\ /Z_2 + Z_0}\right]$$
$$= Ea - \left[\frac{Z_1 + Z_2\,.\,Z_0\ /Z_2 + Z_0}{Z_1 + Z_2\,.\,Z_0\ /Z_2 + Z_0} - \frac{Z_1}{Z_1 + Z_2\,.\,Z_0\ /Z_2 + Z_0}\right]$$
$$= Ea - \left[\frac{Z_1 + Z_2\,.\,Z_0\ /Z_2 + Z_0}{Z_1 + Z_2\,.\,Z_0\ /Z_2 + Z_0}\right]$$

$$= \text{Ea}\left[\frac{Z_1 + Z_2 \,.\, Z_0 \,/ Z_2 + Z_0}{Z_1 \dfrac{Z_2 + Z_0}{Z_2 + Z_0} + \dfrac{Z_2 + Z_0}{Z_2 + Z_0}}\right]$$

$$= \text{Ea}\ \frac{Z_2 \,.\, Z_0}{Z_1\,(Z_2 + Z_0) + Z_2 \,.\, Z_0}$$

$$V_{a1} = \text{Ea}\ \frac{Z_2 \,.\, Z_0}{Z_1\ Z_2 + Z_1\ Z_0 + Z_1\ Z_0}\ Ea \quad (51)$$

For conditions, $V\,a_1 = Va_2 = Va_0$

Than,:

$$Ia_2 = -\frac{Va_2}{Z_2} = -\frac{Va_1}{Z_2}$$

$$Ia_2 = \frac{Z_0}{Z_1\ Z_2 + Z_1\ Z_0 + Z_1\ Z_0}\ x\ Ea$$

$$Ia_2 = -\left[\frac{Z_0}{Z_w + Z_0}\right] Ia_1 \quad ;$$

$$\text{and, } Ia_0 = -\left[\frac{Va_0}{Z_0}\right] = -\frac{Va_1}{Z_0}$$

$$Ia_0 = \frac{Z_2}{Z_1\ Z_2 + Z_1\ Z_0 + Z_1\ Z_0}\ x\ Ea$$

$$Ia_0 = \left[\frac{Z_2}{Z_2 + Z_0}\right] x\ Ia_1 \quad (52)$$

Equation of short circuit current (I_F) two-phase fault to ground:

I_F = In = Ib + Ic

Where,, Ib $= a^2\ Ia_1 + a\ Ia_2 + Ia_0$ (53)

Ic $= a\ \ Ia_1 + a\ Ia^2 + Ia_0$ (54)

3.4. Three-phase short-circuit

Three-phase fault in a system is a balanced fault, the analysis can be done using symmetrical component analysis. The fault occurs because the three phases are interconnected. Schematic diagram for a three-phase fault, shown in figure 9.

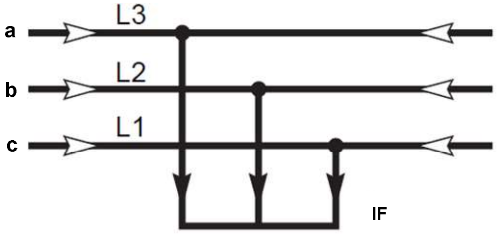


Figure 9. Schematic diagram for a three-phase fault,

Three-phase fault analysis is expressed by the following equations:

$Va = Vb = Vc = 0$ (55)

For positive-sequence a-phase conditions, negative-sequence a-phases and zero-sequence a-phases are written by the equation:

$Va_1 = 1/3\ (Va + a\ Vb + a^2\ Vc) = 0$ (56)

$Va_2 = 1/3\ (Va + a\ Vb + a^2\ Vc) = 0$ (57)

$Va_0 = 0$ (58)

From equation,

$Va_1 = Ea - Ia_1\ Z_1$ (59)

Than, $0 = Ea - Ia_1\ Z_1$

$$Ia_1 = \frac{Ea}{Z_1}; \quad (60)$$

$Va_2 = -\ Ia_2\ Z_2;\ Ia_2 = 0;\ Va_0 = -Ia_0\ Z_0;\ Ia_0 = 0.$ ……(3.36)

From this equation, it can be concluded that for three-phase faults, only positive sequence equivalent circuits are used, show in figure 10.

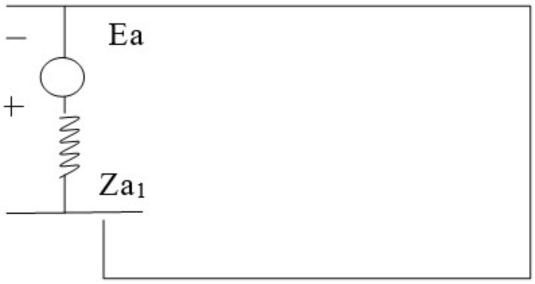


Figure 10. Positive Sequence Three phase fault ……………….(3.38)

The three-phase symmetrical fault condition equation is expressed in the equation

$$Ia = Ia_1 = \frac{Ea}{Z_1} = \frac{1{,}0 < 0^0}{Z_1} \quad (61)$$

$$Ib = a^2 Ia_1 = \frac{Ea}{Z_1} = \frac{1{,}0 < 240^0}{Z_1} \quad (62)$$

$$Ic = a^2 Ia_1 = \frac{Ea}{Z_1} = \frac{1{,}0 < 120^0}{Z_1} \quad (63)$$

So the short circuit current (I_F) for a three-phase fault is expressed in the equation:

$$I_F = Ia_1 = \frac{Ea}{Z_1} \quad (64)$$

Equation 64, shows that the short-circuit fault current, if it occurs at a certain point, is calculated using only positive sequence circuits, can be analyzed with ordinary electrical circuits or using the bus impedance matrix (Z_{BUS}) model [13].

4.RESEARCH METHODOLOGY.

4.1. Short Circuit Analysis Simulation Design.

The simulation design of symmetrical and asymmetrical short circuit analysis uses the stages as shown in figure 11.

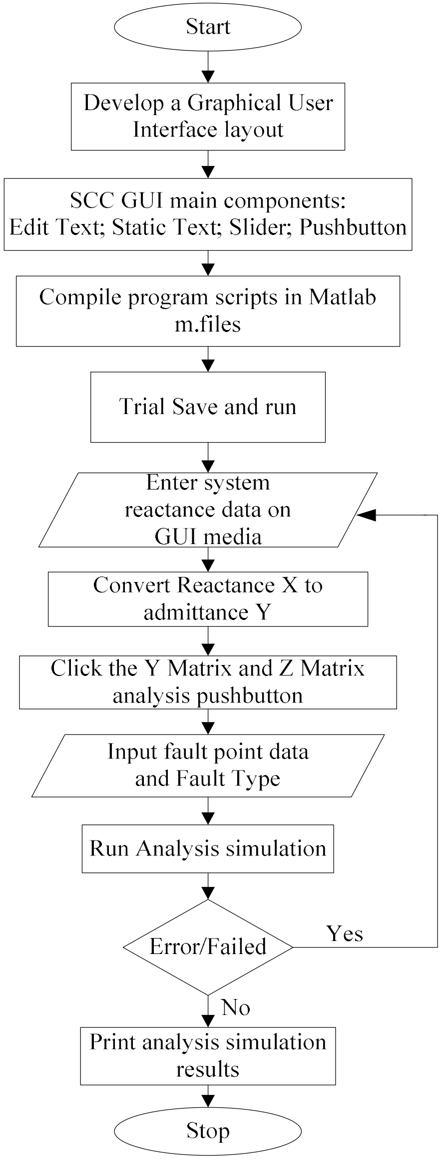


Figure 11. Stage of Compiling a Simulation GUI.

Figure 11, shows the construction of a short-circuit simulation GUI, starting from the GUI building blocks, with several tool components such as text editing, text statics, sliders and pushbottons. This component is the main medium in determining the script for the SCC GUI program in the matlab m.file. Next, compile the programming script on the matlab m.file based on the previous GUI functions. To see if the GUI functions are running well, a trial is carried out. The next step is to enter data, and press the X and Y modifier keys and convert to Y bus and Z Bus matrices. to determine the magnitude of the fault current based on the type and location of the fault. If you experience an error, check the input data in the previous stage, if there is no error, then the final step is to print the simulation results. This design refers to by Josep M, [13], modified, shown in figure 11.

4.1. Simulation program interface layout.

The simulation display of the three-phase short-circuit, single-phase to ground, inter-phase and two-phase ground fault calculation program, the structure is shown in figure 12.

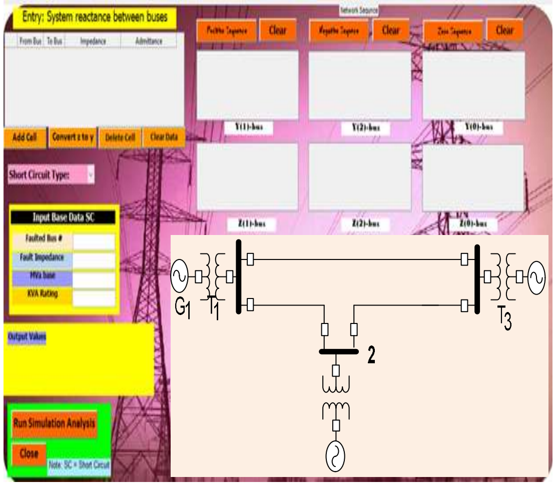


Figure 12. Simulation program interface layout

The display layout of the simulation program for calculating short circuit faults is shown in Figure 12. The input data in the program is the reactance value between lines entered in units per unit. The reactance value is based on data from the inline diagram of the electric power system. Next, a simulation of the calculation with the bus impedance matrix will be carried out. The selected disturbance is facilitated by an optional button for the type of disturbance, there is also input data for the magnitude of the fault impedance and the location of the fault point based on the selection of the location on the bus.

4.2. Simulation model to Measure Effectiveness.

The effectiveness test for the simulation media was analyzed to see the value of validity, missing value, mean, Std. Deviation, Std. Errors of Mean, Maximum and Minimum. Measurements were carried out with Simulink matlab, all parameters were observed from the simulation results The respective equation formulations are written in table 1

Table 1. Equation Formulation used in Modeling and Simulation for Effectiveness Test

Item	Formulation
Mean	$\mu = \frac{\sum X}{N}$
Std. Deviation	$y_j = \sigma_j = \sqrt{\frac{\sum_{i=1}^{M}\lvert u_{ij} - \mu_j\rvert^2}{M-1}}$ $1 \le j \le N$
Std. Error of Mean	*Standar error* $= \frac{\sigma}{\sqrt{N}}$
% k	$\% \text{k} = \frac{\bar{\bar{X}}\ Posttest - \bar{\bar{X}}\ Pretest}{\bar{\bar{X}}\ Posttest} x\ 100\ \%$ Keterangan: $\bar{\bar{X}}$ = *nilai rata-rata*
Gain-K	N-gain$=\frac{A-B}{C-B}x100$ Note: A= average post-test score B=mean pre-test score C= Maximum Score
Experimental Effectiveness	Experimental Effectiveness $= \frac{N-Gain\ experiment\ class}{N-Gain\ control\ class}$ Information.: a. If Ekp Effectiveness > 1 then the experimental class is more effective than the control class. b. If Effectiveness Ekp = 1 then there is no difference between the experimental class and the control class.

4.3. Practical Test of Using Simulation Media

Practical test of the simulation media developed in the implementation of the research with the data from the distribution of the instrument given to 10 students for a small-scale trial. Practicality test using the equation:

$$P = \frac{\sum f}{N} x\ 100\% \qquad (65)$$

Formula description:
P = Final Value
F = Total Score
N = Minimum Score

Equation 65, will be modeled in a media practicality measurement simulation, with a simulink model, such as figure 13.

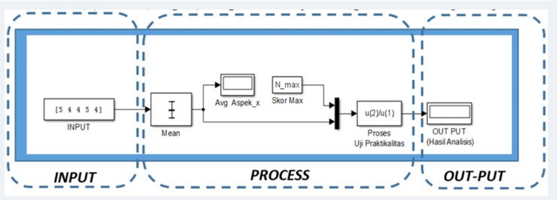


Figure 13. Practicality Measurement Simulation.

The range of the results of the media practicality test simulation with practicality assessment intervals is given in table 2.

Table 2. Classification of the level of practicality of research models and products

Value Range (%)	Category
$80 < P \le 100$	Very Practical
$60 < P \le 80$	Practical
$40 < P \le 60$	Practical enough
$20 < P \le 40$	Less Practical
$P \le 20$	Not Practical

5. RESULTS AND DISCUSSIONS

5.1. One Line Diagram

A system with a total of 11 buses 7 lines is drawn in a line diagram of an electric power system, shown in figure 14

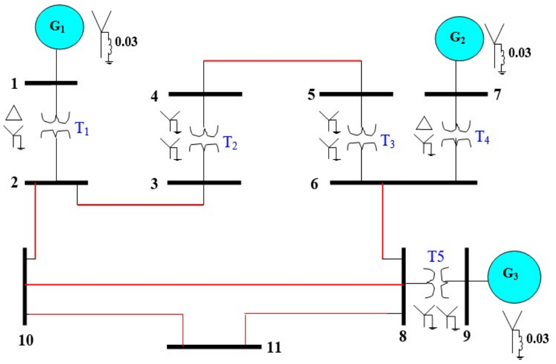


Figure 14. One Line Diagram-Power System

The data used in the simulation of short circuit analysis for each sequence reactance are given in table 3.

Table 3. Generator data

Item	Voltage Rating (KV)	X_1(Pu)	X_2(pu)	X_0(Pu)	X_n(Pu)
G_1	20	0,2	0.2	0.05	0.03
G_2	13.8	0.2	0.2	0.05	0.03
G_3	13.8	0.2	0.2	0.05	0.03

Data Transmission Line and Transformer (Table 4) . with MVA rating =100 MVA

Table 4. Data Transmission Line and Transformer

Item	Voltage Rating (KV)	X_1(Pu)	X_2(pu)	X_0(Pu)
T_1	20/150	0.05	0.05	0.05
T_2	20/150	0.05	0.05	0.05
T_3	20/150	0.05	0.05	0.05
T_4	13,8/150	0.05	0.05	0.05
T_5	20/150	0.05	0.05	0.05
$L_{2\text{-}3}$	150	0,10	0,10	0.30
$L_{4\text{-}5}$	150	0,10	0,10	0.30
$L_{6\text{-}8}$	150	0,10	0,10	0.30
$L_{8\text{-}11}$	150	0.40	0.40	0.09
$L_{8\text{-}10}$	150	0.40	0.40	0.09
$L_{2\text{-}11}$	150	0.40	0.40	0.09
$L_{10\text{-}11}$	150	0.40	0.40	0.09

5.2. Analysis Simulation Results

The results of the simulation analysis for each type of disturbance, with the assumption that if there is a disturbance on bus-8. The simulation is run using the Graphical User Interface, which has been built. From the simulation observations, the results are known as shown in table 5.

Tabel 5. Simulation results of various types of disturbances if they occur on Bus-8

Type of Fault	Fault Current (Pu)	Fault Current (IF) versus Nominal Current (Pu)
Three-phase short-circuit	6.38	638,7 %
Phase-to-phase-to-earth short-circuit	5.71	571,3 %
Phase-to-phase short-circuit	6.63	663,9 %
Phase-to-earth fault	3.83	383,9 %

Table 5 shows the results of short circuit fault analysis in various fault conditions. The results of this analysis are simulated by students when studying power system analysis. students are able to observe the results of short circuit disturbances based on the data provided in the case, namely a system consisting of 11 interconnected buses. During the media trial, an assessment of the learning outcomes was carried out through pre-test and post-test, with the level of learning effectiveness shown in figure 15.

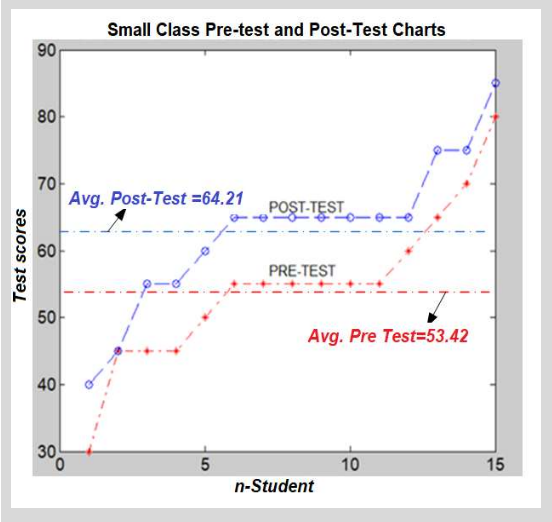
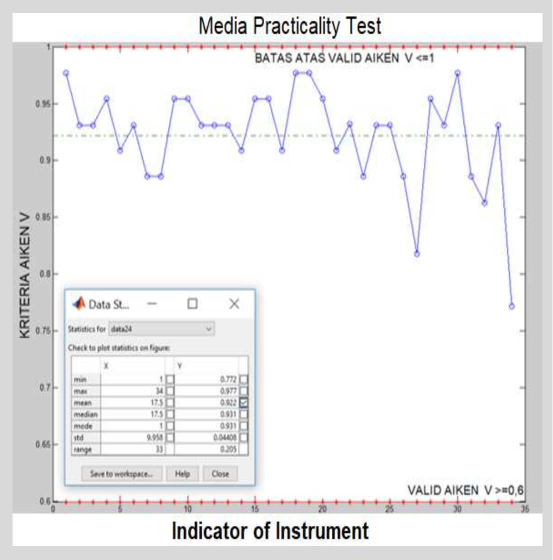


Figure 15. Effectiveness of learning outcomes

Figure 15, is the result of a plot of student learning scores, before and after using simulation tools. Learning independence is created and learning motivation is realized, identified from the average pretest result of 53.42 and the average learning outcome of the posttest test of 64.21

5.2. Practicality of the Media

Before conducting an assessment of the practicality of the media used by the user, validation was carried out on the instrument measuring the practicality of the media. The instrument was validated by an expert, and an analysis of the items of the instrument was carried out. From the analysis simulation results, it is known that the instrument is feasible to use to measure the practicality of the media, at the position of the average value of 92.2 as shown in figure 16. The items on the instrument indicators are valid to be used as measuring tools



Statistics for data24

Check to plot statistics on figure:

	X		Y	
min	1	☐	0.772	☐
max	34	☐	0.977	☐
mean	17.5	☐	0.922	☑
median	17.5	☐	0.931	☐
mode	1	☐	0.931	☐
std	9.958	☐	0.04408	☐
range	33		0.205	

Figure 16. The results of the instrument validation test plot

At the end of the research process, the media was tested by 27 respondents. There are 4 Aspects that are measured for the practicality of the media. Aspect 1 is related to the appearance of the media, Aspect 2 is easy to operate, aspect 3 is the color used in the media, aspect 4 is the command language contained in the media. of the four aspects are measured by distributing practicality instruments to users. with data analysis using simulation, to test the practicality can be seen in Figure 16. Practicality assessment by users is 83.7% for aspect 1, 88.89% for aspect 2, 91.11 for aspect 3 and 84.44 for aspect 4. All aspects are in the range, 80 < P 100, in the category very practical. So that this media is suitable for use by users in learning electric power system analysis, especially related to the study of short-circuit currents

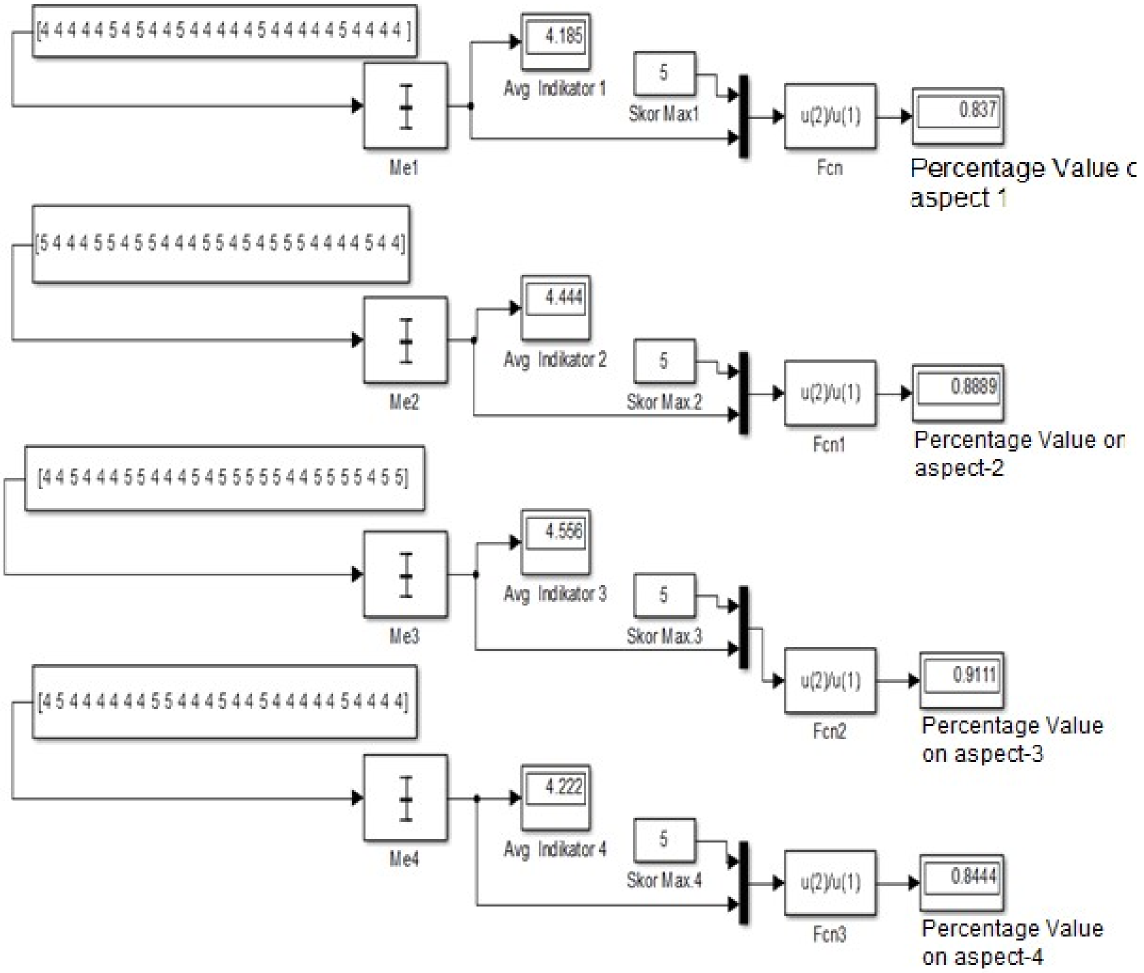


Figure 17. Simulation Of Media Practicality Measurement

6. CONCLUSIONS

From the results of the simulation analysis and testing of the simulation media, in learning short-circuit analysis for the study of short-circuit currents it can be concluded.

1. development of simulation media that has been tested for Practicality Validity and Effectiveness by using a strategy of using simulation tools. This media can help students do independent learning for the field of power system analysis, which requires the concepts of a case-solving-based scientific system model. Simulation media results in the effectiveness and practicality of learning in power system analysis courses
2. Simulation of short-circuit fault current, from 4 types of faults, it can be seen that the largest fault current is the phase-to-phase fault of 6.63 pu, or 663.9% of the nominal system current.
3. The use of simulation tools, in the form of a GUI program for short-circuit current analysis, is effective in improving learning outcomes, seen from the pretest test, the average student score is 53.42, and the post-test is 64.21. Learning aids in the form of media can improve student learning outcomes.
4. Measurement of the practicality of the simulation media, tested with the aiken v approach, shows that the practicality index is in the range of 80 < P 100, in the very practical category. The media that is built makes it easier for users to solve learning problems in the field of electric power systems.

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