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MODELLING AND SIMULATION OF SYMMETRICAL AND UNSYMMETRICAL FAULTS ON 14 BUS IEEE-POWER SYSTEMS

AGUS JUNAIDI[1], RAHMANIAR[2], RUDI SALMAN[3], JONI S. RAMBEY[4], ABD. HAMID K [5], BAHARUDDIN [6]

[1,3,4,5,6] Faculty of Engineering, Universitas Negeri Medan
[2] Department of Electrical Engineering Faculty of Engineering, Universitas Pembangunan Panca Budi
[1]agusjunaidi@unimed.ac.id, [2]rahmaniar@dosen.pancabudi.ac.id, [3]rudisalman@ unimed.ac.id,
[4]jonisyafrin079@gmail.com, [5]abdulhamid@ unimed.ac.id·,[6]baharuddin@ unimed.ac.id,

ABSTRACT

Short circuit disturbance in the electric power system, is the relationship between one voltage system and another directly connected system with a very small impedance. The direct connection results in the distribution of electric current at the fault point exceeding the nominal current. This situation has an impact on system instability, the system works in an unbalanced state and can damage equipment, if the disturbance is not neutralized (secured). The study of short circuit faults fundamentally consists of symmetrical faults and unsymmetrical faults (line to Ground Fault). In the simulation study, it is observed that three-phase symmetrical faults can be analyzed based on parametric data of the sub-switch reactance of the system, and one-phase asymmetrical faults to ground. Symmetrical fault analysis can be used as a reference in determining the breaker capacity, while for asymmetrical faults, L-G faults are implemented in determining the protection relay settings. The determination of the value of symmetrical and asymmetrical faults applies the analytical method of the Zbus model, carried out with system impedance data from the line diagram of the electric power system, then the system reactance data entry is carried out, then the symbolic notation of the connecting points is referred to as Bus. The number of buses will determine the number of orders of the bus impedance matrix (Z_{BUS}). This Z_{BUS} matrix becomes a reference in determining the value of short circuit impedance on each bus, by observing the diagonal of the Z_{BUS} matrix. Calculations using the Matlab software tool, to determine the amount of fault current for each bus. From the data of 14 BUS-IEEE Power Systems, a trial was carried out for the fundamental study of the largest analysis results on buses 2, and from the characteristics of the comparison results, it can be seen that the value of the symmetrical fault current is greater than that of the non-symmetrical fault.
Keywords: *Symmetrical, Short Circuit, 14 Bus, Power Systems*

1. INTRODUCTION

The growth of electricity users increases in line with customer growth every year, this situation ensures that electricity suppliers continue to increase the number of generators. Along with the increase in the number of generators, it certainly has an impact on the expansion of distribution access, as well as studies on system reliability through various studies including how to conduct a system reliability study with reliability index analysis using the System Average Interruption Duration Index and System Average Interruption Frequency Index models [1]. Various studies have been carried out in determining the reliability of the system through fault analysis and the manufacture of simulation products that are applied in learning, at the higher education level for the study of short-circuit faults and system reliability in the study of the stability of the electric power system [3]. The electric current that flows from the generator to the consumer sometimes experiences disturbances. Electrical current disturbances that occur in the electric power system are commonly referred to as short circuit disturbances.

There are generally 2 types of short circuit faults, namely symmetrical and asymmetrical faults. Symmetrical faults such as three-phase symmetrical faults, where a Asymmetric faults include single-phase to ground faults, dual faults, and dual to ground faults. Short circuit faults are caused by overloads and cause the current to increase and cause heat, so the safety cut off the current quickly so that the disturbance can under control. Mechanical short circuit faults can cause

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damage to the system as well as electronic equipment, and economically it can cause production and distribution activities to decrease or stop. The study of short circuit analysis is part of the fundamental study of the electricity system. A short circuit study of the electric power system was carried out to determine the parameters of short circuit disturbances in the study of the reliability and safety of electric power systems [4]. In electric power systems, short-circuit current studies are important, especially for planning, design and protection of electric power systems. The data obtained from this calculation will be used to determine the relay settings and breaker capacity.

The choice of circuit breaker for an electric power system depends not only on the current flowing in the circuit breaker in normal operation but also on the maximum current that it may flow over a period of time and on the current that it may have to disconnect at the line voltage where the breaker is placed. The short-circuit current can be calculated based on the following assumptions: prior to the occurrence of an unbalanced network condition, the speed of the generator does not change after a short circuit, the generator is assumed to work without load and overload, and the generator is connected to a large network, so that after the disturbance it is not affected by short circuit current. The models that can be used in the fundamental analysis of Symmetrical Short Circuit Calculation (Symmetrical SCC), by modeling the system impedance circuit formed in the bus impedance matrix equation [5].

From the literature sources described. it is necessary to carry out a practical investment and analysis, for the study of symmetrical and unsymmetrical short circuits. Aims to practically know the value of the short-circuit fault current using software or a simulation program

Symmetrical SCC

Symmetrical SCC is a short circuit analysis study for an electric power system experiencing a three-phase short circuit fault [6]. Symmetrical SCC can be analyzed by the equivalent electrical circuit analysis method, or by analysis by modeling using the bus impedance matrix. An overview description for the Symmetrical SCC event can be shown in Figure 1.

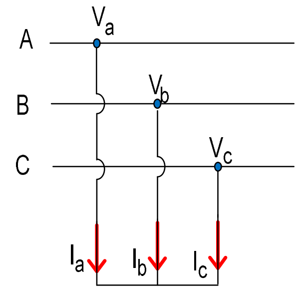

Figure 1: Diagram Symmetrical SCC

$$V_a = V_b = V_c = 0$$
$$V_{a1} = 1/3\,(V_a + a\,V_b + a^2\,V_c) = 0 \qquad (1)$$
$$V_{a2} = 1/3\,(V_a + a\,V_b + a^2\,V_c) = 0$$
$$V_{a0} = 0$$

From equation (1), it will be obtained:

$$V_{a1} = E_a - I_{a1} Z_1$$
$$V_{a2} = -\,I_{a2} Z_2$$
$$I_{a2} = 0 \qquad (2)$$
$$V_{a0} = -I_{a0} Z_0$$
$$I_{a0} = 0 \qquad (3)$$

From equations (2) and (3), it can be seen that for the Symmetrical SCC analysis only positive sequence reactance data is used, the reactance diagram can be shown in Figure 2.

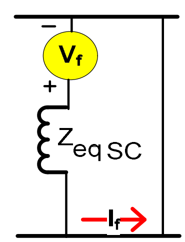

Figure 2: Positive Sequence Diagram of Symmetrical SCC

From figure 2, it can be stated the equation:

$$Ia_1 = \frac{Ea}{Z_1} \qquad (4)$$

Than, : $Ia = Ia_1 = \dfrac{Ea}{Z_1} = \dfrac{1{,}0 < 0^0}{Z_1}$

$Ib = a^2 Ia_1 = \dfrac{Ea}{Z_1} = \dfrac{1{,}0 < 240^0}{Z_1}$

$Ic = a^2 Ia_1 = \dfrac{Ea}{Z_1} = \dfrac{1{,}0 < 120^0}{Z_1}$

So the parameters of the short circuit current (I_f) for Symmetrical SCC can be expressed by the equation:

$$I_f = Ia_1 = \frac{Vf}{Z_1} \qquad (5)$$

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From equation (5) it can be seen that the three-phase short-circuit fault only takes into account the positive-sequence short-circuit impedance.

Un-Symmetrical Short Circuit Calculation-Single Line-To-Ground Fault (L-G)

The un-symmetrical fault modeled in this study is a single phase to ground fault (L-G). Schematically, an electric power system experiencing a single phase to ground fault is depicted in figure 3.

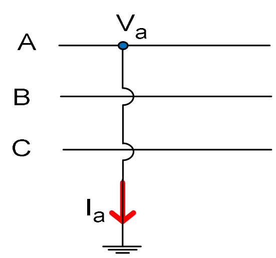

Figure 3: A single phase L-G fault

L-G short circuit is a disturbance that causes the voltage and current flowing in each phase to become unbalanced. The analysis of the L-G disturbance uses the L Fortesque method through the component analysis model of the sequence circuit, positive negative and zero. For L-G Fault expressed in figure 4.

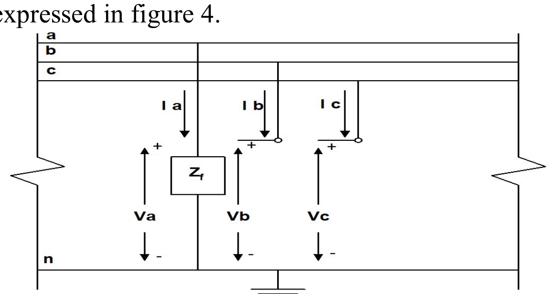

Figure 4: Model of the L-G Fault

Figure 4, is a diagram of the condition of the electric power system experiencing an L-G. disturbance. From figure 4 obtained the equation, $Ib = 0$; $Ic = 0$; $Va = 0$. The current for each positive, negative and zero sequence circuit is expressed in the equation

$$Ia_0 = Ia_1 = Ia_2 = Ia/3 \qquad (6)$$

So that during the L-G fault, the fault circuit is connected in series, Sequence network of L-G fault as shown in figure 5.

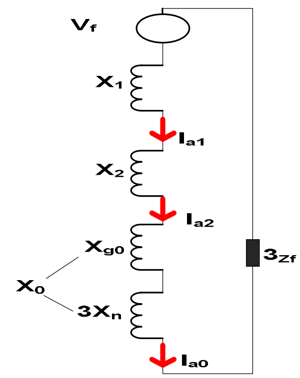

Figure 5: Sequence network of L-G fault.

From figure x, the sequence series shows the series circuit, $Ia_1 = Ia_2 = Ia_0$, and $Ea = Ia_1 (Z_1 + Z_2 + Z_0)$, so that the L-G fault equation, can be expressed by:

$$Ia_1 = \frac{Vf}{X_1 + X_2 + X_0} \qquad (7)$$

Z_{BUS}. Impedance Matrix Modelling

Symmetrical SCC analysis, can be determined using the bus impedance matrix model. The form of the bus impedance matrix is based on the reactance diagram obtained from the Ione-line diagram of the electric power system [8].

The form of Symmetrical SCC modeling can be determined based on inline diagrams and reactance diagrams. The real system in the electricity system is arranged in an inline diagram and with the sub-switch reactance data (x"), will be formed into a reactance diagram, as shown in figure 6.

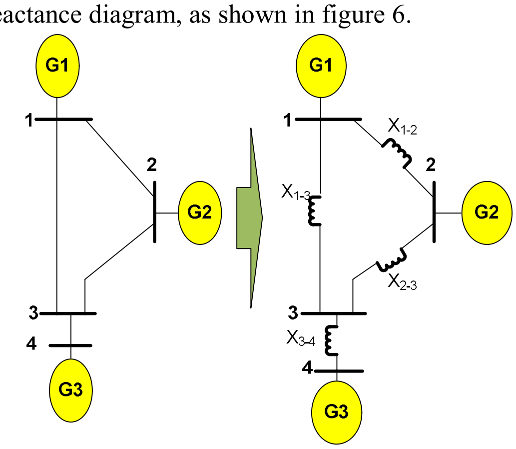

Figure 6: One Line diagram and Reactance Diagram

From the reactance diagram of Figure 3, it is represented by the emf and the series impedance connected to each bus is changed to the equivalent emf and the equivalent shunt admittance as shown in Figure 7.

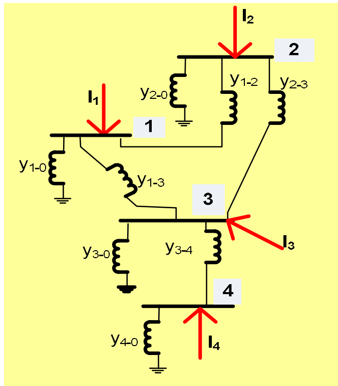

Figure 7: Equivalent Shunt Admittance

From figure 7, it can be written equation 8:

$$\begin{aligned} I_1 &= V_1\, y_{10} + (V_1 - V_2)\, y_{12} + (V_1 - V_3)\, y_{13} \\ I_2 &= V_2\, y_{20} + (V_2 - V_1)\, y_{12} + (V_2 - V_3)\, y_{23} \\ I_3 &= V_3 y_{30} + (V_3 - V_1)\, y_{13} + (V_3 - V_4)\, y_{34} + (V_3 - V_2)\, y_{23} \\ I_4 &= V_4\, y_{40} + (V_4 - V_3)\, y_{34} \end{aligned} \quad (8)$$

Equation 8, is simplified back to equation 9:

$$\begin{aligned} I_1 &= (y_{10} + y_{12} + y_{13})\, V_1 \; - y_{12}\, V_2 \; + y_{13}\, V_3 \; +0{,}0\, V_4 \\ I_2 &= \; - y_{13}\, V_1 \; (y_{20} + y_{12} + y_{13})\, V_2 \; + y_{23}\, V_3 \; +0{,}0\, V_4 \\ I_3 &= - y_{13}\, V_1 - y_{13}\, V_2 + (y_{30} + y_{12} + y_{23} + y_{34}) V_3 + y_{34}\, V_4 \\ I_4 &= 0{,}0 V_1 \; +0{,}0\, V_2 y_{34}\, V_3 + (y_{40} + y_{34})\, V_4 \end{aligned} \quad (9)$$

The equation of the diagonal element for the bus admittance matrix can be determined by the formula, in equation 10:

$$Y_{ii} = \sum_{j=0}^{m} y_{ij} \quad j \neq i \quad (10)$$

For the condition of the figure 7 then:

$$\begin{aligned} Y_{11} &= y_{10} + y_{12} + y_{13} \\ Y_{22} &= y_{20} + y_{12} + y_{23} \\ Y_{33} &= y_{30} + y_{12} + y_{23} + y_{34} \\ Y_{44} &= y_{40} + y_{34} \end{aligned} \quad (11)$$

The off diagonal element is the negative admittance between buses:

$$Y_{ij} = Y_{ji} = -y_{ij}$$

$$\begin{aligned} &Y_{12} = Y_{21} = -y_{12} \;\; ; \;\; Y_{13} = Y_{31} = -y_{13} \\ &Y_{32} = Y_{22} = -y_{22} \;\; ; \;\; Y_{34} = Y_{43} = -y_{34} \\ &Y_{14} = Y_{41} = 0 \;\; ; \;\; Y_{24} = Y_{42} = 0 \end{aligned} \quad (12)$$

So it can be written in matrix form, such as equation (13):

$$\begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ I_4 \end{bmatrix} = \begin{bmatrix} Y_{11} & Y_{12} & Y_{13} & Y_{14} \\ Y_{21} & Y_{22} & Y_{23} & Y_{24} \\ Y_{31} & Y_{32} & Y_{33} & Y_{34} \\ Y_{41} & Y_{42} & Y_{43} & Y_{44} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \\ V_4 \end{bmatrix} \quad (13)$$

Current on Bus:

$$I_{Bus} = Y_{BUS}\; V_{BUS}$$

$$I_{BUS} = \begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ I_4 \end{bmatrix}$$ is, Inflow to Bus

The voltage V bus, is

$$V_{BUS} = \begin{bmatrix} V_1 \\ V_2 \\ V_3 \\ V_4 \end{bmatrix}$$

The bus admittance matrix (Y_{BUS}) is expressed in equation 11

$$Y_{BUS} = \begin{bmatrix} Y_{11} & Y_{12} & Y_{13} & Y_{14} \\ Y_{21} & Y_{22} & Y_{23} & Y_{24} \\ Y_{31} & Y_{32} & Y_{33} & Y_{34} \\ Y_{41} & Y_{42} & Y_{43} & Y_{44} \end{bmatrix} \quad (14)$$

Equation (14) shows the Bus admittance circuit (Y_{BUS}) model connecting I (bus inrush current) and V (bus voltage) to ground. By doing an inverse Y_{BUS} matrix, a Bus Impedance matrix (Z_{BUS}) will be obtained, the result of which will be the parameter for determining the Symmetrical SCC value, by observing the diagonal of the Z_{BUS} matrix, written in equation 15:

$$Z_{BUS} = [\, Y_{BUS}\,]^{-1} = \begin{bmatrix} Z_{11} & Z_{12} & Z_{13} & Z_{14} \\ Z_{21} & Z_{22} & Y_{23} & Z_{24} \\ Z_{31} & Z_{32} & Z_{33} & Z_{34} \\ Z_{41} & Z_{42} & Z_{43} & Z_{44} \end{bmatrix} \quad (15)$$

Equation 15, shows the Z_{BUS} matrix. The diagonal element Z_{BUS} is Z equivalent SC for each Bus.

Systematic Analysis of Short Circuit Current Using Z_{BUS}

Figure 8, is an equivalent reactance diagram of an electric power system. It is illustrated that a fault occurs at the k-bus, the fault current flowing at the k-bus point is called I_k (F) with a fault impedance value of Z_F. From the thevenim equivalent circuit for the system that is experiencing a disturbance on

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the bus, it can be obtained the voltage on the bus that is disturbed by the equation,

$$V_{bus}(F) = V_{bus}(0) + \Delta V_{bus} \tag{16}$$

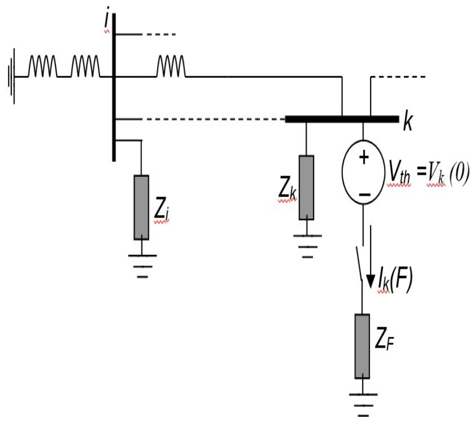

Figure 8: One Line Diagram of A Typical Power System Bus

The reduction of the network into the form of a reactance diagram as described in section 5, and the elaboration of formulation 16 becomes the basis for calculating the analysis of symmetrical short circuit faults. The current at each bus on the bus experiencing disturbance is expressed by:

$$\begin{bmatrix} 0 \\ \vdots \\ -Ik(F) \\ \vdots \\ 0 \end{bmatrix} = \begin{bmatrix} y_{11} & \cdots & y_{1k} & \cdots & y_{1n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ y_{k1} & \cdots & y_{kk} & \cdots & y_{kn} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ y_{n1} & \cdots & y_{n2} & \cdots & y_{nn} \end{bmatrix} \begin{bmatrix} \Delta V_1 \\ \vdots \\ \Delta V_k \\ \vdots \\ \Delta V_n \end{bmatrix} \tag{17}$$

for equation:

$$I_{bus}(F) = Y_{bus}\, \Delta V_{bus.} \tag{18}$$

The solution for Vbus is determined by the equation:

$$\Delta V_{bus} = Z_{bus}\, I_{bus}(F) \tag{19}$$

Z_{bus} is the bus impedance matrix obtained by inverse the bus admittance matrix ($Z_{bu}s = Y_{bus}^{-1}$).

Substituting equation (18) with equation (19) it will be obtained:

$$V_{bus}(F) = V_{bus}(0) + Z_{bus}\, I_{bus}(F). \tag{20}$$

The fault voltage on each bus can be expressed in the form of a matrix equation as follows:

$$\begin{bmatrix} V_1(F) \\ \vdots \\ V_k(F) \\ \vdots \\ V_n(F) \end{bmatrix} = \begin{bmatrix} V_1(0) \\ \vdots \\ V_k(0) \\ \vdots \\ V_n(0) \end{bmatrix} + \begin{bmatrix} Z_{11} & \cdots & Z_{1k} & \cdots & Z_{1n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ Z_{k1} & \cdots & Z_{kk} & \cdots & Z_{kn} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ Z_{n1} & \cdots & Z_{nk} & \cdots & Z_{nn} \end{bmatrix} \begin{bmatrix} 0 \\ \vdots \\ -I_k(F) \\ \vdots \\ 0 \end{bmatrix} \tag{21}$$

In equation (20) there is only one nonzero element in the current vector, the voltage at the fault point k is written in equation.

$$V_k(F) = V_k(0) - Z_{kk}\, I_k(F). \tag{21}$$

The voltage equation at the fault point k of thevenim equivalent circuit can be written:

$$V_k = Z_f\, I_k(F) \tag{22}$$

By substituting equations (21) and (22), we get the fault current equation at bus k:

$$I_k(F) = \frac{V_k(0)}{Z_{kk} + Z_f} \tag{23}$$

For fault currents at bus k, only the Z_{kk} element is required in the bus impedance matrix. The voltage on the i-th bus of the thevenim impedance circuit of the faulty bus can be written as:

$$V_i(F) = V_i(0) - Z_{ik}\, I_k(F) \tag{24}$$

Substituting equation (23) into equation (24), we get the fault current equation from bus-i to bus-j with the equation:

$$I_{ij}(F) = \frac{V_i(F) - V_j(F)}{z_{ij}} \tag{25}$$

Sample Case: Fundamental Concepts Z_{BUS} for Symmetrical Fault

The line diagram of the electric power system, 5 bus interconnection system with 2 generator units, with the reactance values in units per unit given in the figure 9.

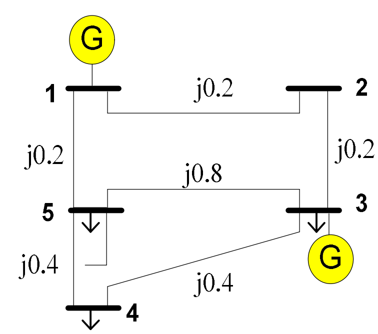

Figure 9:.One Line Diagram

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This one-line diagram is used as an example case to prove that by using the bus impedance matrix, short circuit analysis can be practically carried out by comparing the bus impedance matrix model with electrical circuit analysis. The calculation of Z is equivalent if it is assumed that a disturbance occurs on bus 4, it can be arranged in an equivalent diagram as figure 10:

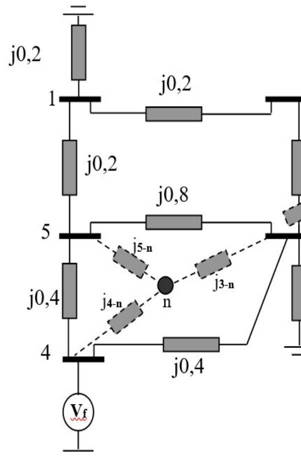

Figure 10: Equivalent Reactance Diagram 1 when bus 4 is faulty

Simplification of the equivalent circuit in Figure 7, is done by reducing the bus line connections 3, 4 and 5 which is a delta connection converted into a star connection to get the impedance value to the neutral point which can be calculated:

$Z_{3n} = \frac{(j0{,}4)(j0{,}8)}{j1{,}6} = j0{,}2$; $Z_{5n} = \frac{(j0{,}4)(j0{,}8)}{j1{,}6} = j0{,}2$,

and $Z_{4n} = \frac{(j0{,}4)(j0{,}4)}{j1{,}6} = j0{,}1$

After simplification, the equivalent circuit of figure 10 is changed to figure 11:

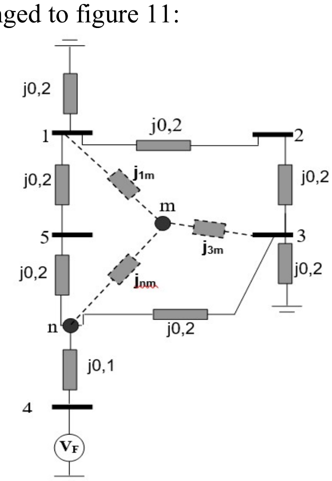

Figure 11: equivalent reactance diagram

The line connected on the bus 1, 3, n in Figure 11, is a delta connection so that it is converted into a star connection to get the impedance value to its neutral point with the following calculations and a simplified diagram as shown in Figure 11. The line connected on the bus 1, 3, n in a delta connection so that it is converted into a star connection to get the impedance value to its neutral point with the following calculations and a simplified diagram as shown in figure 12.

$$Z_{1N} = \frac{(j0{,}4)(j0{,}4)}{j1{,}0} = j0{,}16$$

$$Z_{3N} = \frac{(j0{,}4)(j0{,}2)}{j1{,}0} = j0{,}08$$

$$Z_{nN} = \frac{(j0{,}4)(j0{,}2)}{j1{,}0} = j0{,}08$$

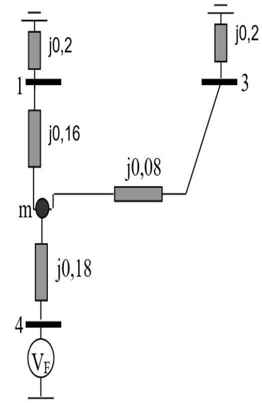

Figure 12: Equivalent Reactance Diagram.

The results of the calculation of the simplification of Figure 12 are as follows

$$Z_{44} = j0{,}18 + \frac{(j0{,}36)(j0{,}28)}{j0{,}36 + j0{,}28}$$

$$Z_{44} = j0{,}18 + j0{,}1575$$

$$Z_{44} = j0{,}3375$$

Equivalent circuit simplification diagram for short circuit conditions if it occurs on bus 4 (Z44) with a ZSC impedance value of j 0.3375 is shown in figure 13:

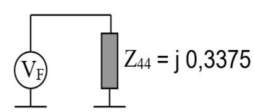

Figure 13: ZSC Equivalent Diagram when Bus 4 is Faulty

To create a Y_{BUS} matrix, it is necessary to determine the elements of the matrix with the equation , so that each element of the Y_{BUS} matrix can be obtained with the following calculations

$$Y_{11} = \frac{1}{0{,}2} + \frac{1}{0{,}2} + \frac{1}{0{,}2} = 15 \qquad Y_{22} = \frac{1}{0{,}2} + \frac{1}{0{,}2} = 10$$

$Y_{12} = -5$; $Y_{15} = -5$ $\qquad$ $Y_{21} = -5$;

$Y_{23} = -5$

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$Y_{13} = Y_{14} = 0$ $\quad Y_{24} = Y_{25} = 0$

$Y_{33} = \frac{1}{0{,}2} + \frac{1}{0{,}4} + \frac{1}{0{,}8} + \frac{1}{0{,}2} = 13{,}75$ $\quad Y_{32} = -5;$

$Y_{34} = -2{,}5;\ Y_{35} = -1{,}25 \quad Y_{31} = 0$

$Y_{44} = \frac{1}{0{,}4} + \frac{1}{0{,}4} = 5 \quad Y_{55} = \frac{1}{0{,}2} + \frac{1}{0{,}4} + \frac{1}{0{,}8} = 8{,}75$

$Y_{43} = -2{,}5;\ Y_{45} = -2{,}5 \quad Y_{51} = -5;\ Y_{53} = -1{,}25;$

$Y_{54} = -2{,}5$

$Y_{41} = Y_{42} = 0 \quad Y_{52} = 0$

Then from these bus elements a Y matrix is formed to become:

$$Y_{bus} = \begin{bmatrix} 15 & -5 & 0 & 0 & -5 \\ -5 & 10 & -5 & 0 & 0 \\ 0 & -5 & 13{,}75 & -2{,}5 & -1{,}25 \\ 0 & 0 & -2{,}5 & 5 & -2{,}5 \\ -5 & 0 & -1{,}25 & -2{,}5 & 8{,}75 \end{bmatrix}$$

With the Inverse process of the bus admittance matrix, the bus impedance matrix will be obtained as follows:

$$Z_{bus} = \begin{bmatrix} 0{,}1375 & 0{,}1 & 0{,}0625 & 0{,}0875 & 0{,}1125 \\ 0{,}1 & 0{,}2 & 0{,}1 & 0{,}1 & 0{,}1 \\ 0{,}0625 & 0{,}1 & 0{,}1375 & 0{,}1125 & 0{,}0875 \\ 0{,}0875 & 0{,}1 & 0{,}1125 & 0{,}3375 & 0{,}1625 \\ 0{,}1125 & 0{,}1 & 0{,}0875 & 0{,}1625 & 0{,}2375 \end{bmatrix}$$

From the results of the calculation of the two methods, it can be proven that the diagonal element of the Z_{BUS} matrix is the equivalent impedance parameter of thevenim short circuit which is used to determine the symmetrical short circuit fault parameters on each bus if it experiences a disturbance. The use of matlab program simulation helps to short circuit interconnection systems in a practical way

2. RESEARCH METHOD

Research Stages

Short circuit analysis and simulation of electric power system was carried out by calculating the fault current at the point (bus) with a short circuit equivalent impedance (Z_{BUS}) value. Matlab-assisted simulation is carried out to obtain the fault current of each channel if there is a disturbance on each disturbed bus. The steps for completing the analysis and simulation of short circuit system,include:

1. Describing an equivalent inline diagram of an electric power system, the equivalent diagram in question is an inline diagram with equivalent reactance data. Several machines on each bus are represented by a single emf symbol.
2. Change the inline diagram into a system Creactance diagram. Inline diagrams depicted with data are only positive sequence diagrams.
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 (Z_{BUS}) with the help of Matlab
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)
5. Perform analysis by simulation using the Matlab program.

The research design of Symmetrical SCC fundamental analysis, using the Z_{BUS} model, is arranged in stages, as shown in the flow diagram of figure 10:

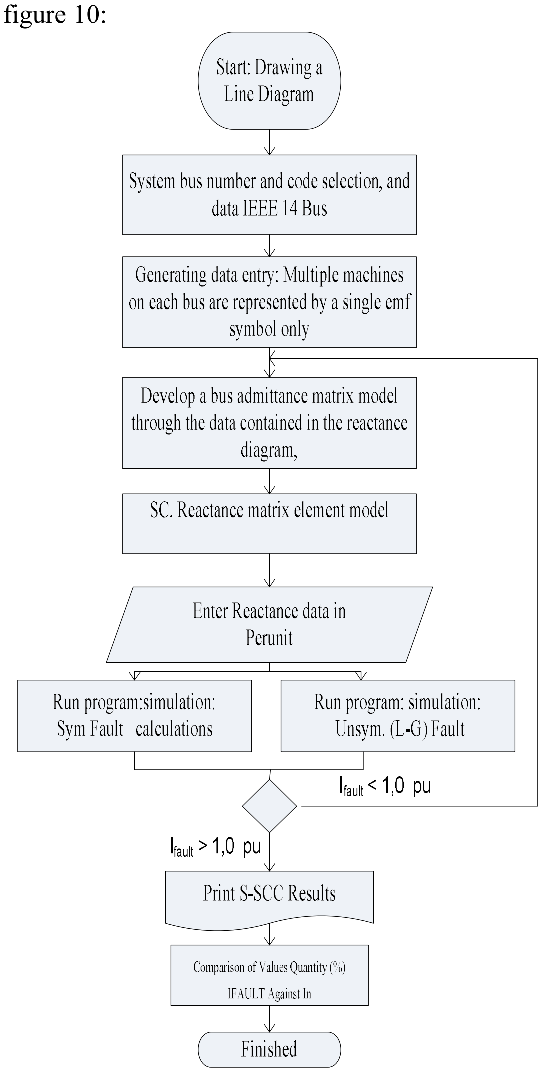

Figure 14: Stages of Symmetrical and Unsymmetrical SCC

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Figure 14 shows the research process of Symmetrical SCC analysis starting from observation of data from inline diagrams. until the percentage ratio of the Symmetrical SCC value in the system to the nominal current value is obtained. The comparison of results is used to determine the magnitude of the symmetrical short-circuit current, the value of which is used for the needs of the electric power security (protection) system, to anticipate equipment not being damaged due to a short circuit. Symmetrical SCC fault analysis can be used, one of which is to determine the breaker capacity or MVA Short Circuit which is often known as Short Circuit Capacity

The calculation of the Symmetrical SCC value is used with the help of Matlab software and a personal computer with equipment data shown in table 1.

Table 1: Equipment Specifications

Item	Spesifikasi
Software	Matlab R2014
Personal Computer (PC)	BIOS GL503GE.316, Procesor Intel ® i7-8750H CPU@2,20 GHz, Memory 8192MB RAM, Windows 10 Pro 64 Bit
Graphical user Interface	Matlab GUI used for symmetrical fault current calculation simulation

Data Collection And Analysis Techniques

In the study of determining the value of Symmetrical SCC, observations and literature studies were carried out to develop theories and observe data on electric power systems. Generating and line data obtained from the IEEE Power Systems 14-Bus power system. This data is used to obtain a symmetrical fault current in units per unit (PU). The ZBus model is used to determine the value of the symmetrical short circuit impedance. The diagonal element of the ZBUS matrix from the calculation simulation using Matlab is used as a reference for calculating the value of I_F.

3. RESULTS AND DISCUSSION

3.1. System Data

On line diagram, consisting of 14 BUS-IEEE electric power systems. The diagram shows the relationship between the generator units connected to the busbar through the interconnection network of the electric power system. In the short circuit fault study, using the sub-switch reactance data, other components such as resistance and ground capacitance of the transmission line can be neglected in the simulation. This assumption is taken based on the criteria for calculating a symmetrical short circuit that can ignore the two parameters. A online diagram of the IEEE 14 Bus system [8], is shown in figure 15.

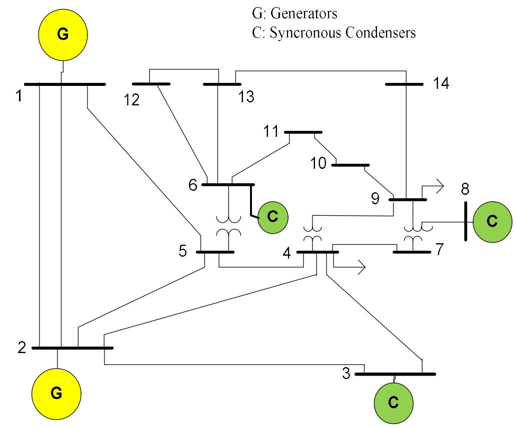

Figure 15: IEEE 14 Bus System

Figure 15, shows the IEEE 14 Bus System electric power system. The reactance data of the IEEE 14 bus system only uses positive sequence reactance, to examine the parameters of the Symmetrical SCC data analysis results. The system consists of 14 buses that are connected by connection between buses through channels. The IEEE 14 bus system data for generators, bus, transformers transmission lines and are given in the tables 2,3 and 4 respectively [9].

Table 1. Generator Data for Symmetrical SCC

From	Positive		Negative		Zero	
Bus	R p.u	X p.u.	R p.u.	X p.u.	R p.u.	X p.u.
1	0.001	0.007	0.001	0.007	0.001	0.007
2	0.002	0.011	0.002	0.011	0.002	0.01
3	0.007	0.130	0.006	0.22	0.006	0.1
6	0.002	0.162	0.002	0.22	0.002	0.1
8	0.001	0.095	0.001	0.20	0.001	0.1

Table 2. Bus Data

Bus	V(pu)	Δ(deg)	P_G	Q_G	P_L	Q_L
1	1.06	0	232.9	-19.5	0	0
2	1.045	-5.015	40	36.92	21.7	12.7
3	1.01	-12.821	0	20.69	94.2	19
4	1.0231	-10.601	0	0	47.8	-3.9
5	1.0262	-8.755	0	0	7.6	1.6
6	1.0697	-16.496	0	24	11.2	7.5
7	1.0526	-11.766	0	0	0	0
8	1.0823	-11.766	0	18.24	0	0
9	1.0548	-14.41	0	0	29.5	16.6
10	1.0504	-15.06	0	0	9	5.8
11	1.0569	-15.889	0	0	3.5	1.8
12	1.0543	-17.158	0	0	6.1	1.6
13	1.0503	-17.035	0	0	13.5	5.8
14	1.0348	-16.551	0	0	14.9	5

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Table 2. Transformer Data

From Bus	To Bus	Positive		Zero		TAP
		R p.u.	X p.u.	R p.u.	X p.u.	
5	6	$6e^{-4}$	0.556	$6e^{-4}$	0.556	0.93
4	7	0	0.048	0	0.048	0.98
4	9	0	0.556	$6e^{-4}$	0.556	0.97

Table 4. Transmission Line Data

From	To	R_p(p.u)	X_p(p.u)	FB-MVA	TB-MVA
Bus1	Bus2	0.0194	0.0592	1524	1524
Bus2	Bus3	0.0470	0.1980	1524	1524
Bus2	Bus4	0.0581	0.1763	1524	1524
Bus1	Bus5	0.0540	0.223	1524	1524
Bus2	Bus5	0.0570	0.1739	1524	1524
Bus3	Bus4	0.0670	0.1710	1524	1524
Bus4	Bus5	0.0136	0.0421	1524	1524
Bus7	Bus8	0	0.1762	229	229
Bus7	Bus9	0	0.1101	229	229
Bus9	Bus10	0.0318	0.0845	229	229
Bus6	Bus11	0.0950	0.1989	229	229
Bus6	Bus12	0.1229	0.2558	229	229
Bus6	Bus13	0.0662	0.1303	229	229
Bus9	Bus14	0.1271	0.2704	229	229
Bus10	Bus11	0.0821	0.1921	229	229
Bus12	Bus13	0.2210	0.1998	229	229
Bus13	Bus14	0.1710	0.3480	229	229

4. RESULTS DATA ANALYSIS

Analysis of Symmetrical and undsymmetrical SCC data using a bus impedance matrix model using matlab software. The calculation simulation uses the Interface (GUI) which is used to find the value of the Y_{BUS} and Z_{BUS} matrix and the SCC. The calculation simulation model interface is shown in Figure 16.

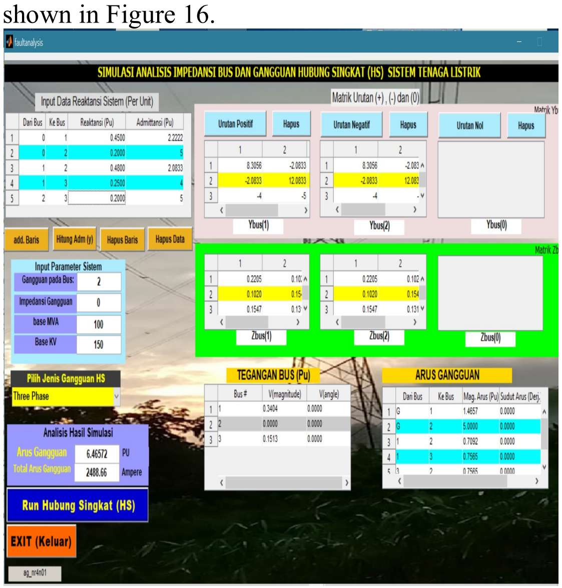

Figure 16: Short Circuit Calculation SCC - GUI display

The formation of the bus admittance matrix is expressed in the Y_{BUS} and Z_{BUS}. The results of the S-SSC analysis to determine the value of the bus impedance matrix (Z_{BUS}) for positif sequence, are given in the matrix results:

```
0.0000 + 0.0194i   0.0000 + 0.0203i   0.0000 + 0.0221i
0.0000 + 0.0272i   0.0000 + 0.0295i   0.0000 + 0.0342i
0.0000 + 0.0230i   0.0000 + 0.0257i   0.0000 + 0.0314i
0.0000 + 0.0561i   0.0000 + 0.0637i   0.0000 + 0.0793i
0.0000 + 0.0540i   0.0000 + 0.0556i   0.0000 + 0.0587i
0.0000 + 0.1331i   0.0000 + 0.1184i   0.0000 + 0.0882i
0.0000 + 0.0671i   0.0000 + 0.0784i   0.0000 + 0.1018i
0.0000 + 0.0501i   0.0000 + 0.0586i   0.0000 + 0.0760i
0.0000 + 0.0951i   0.0000 + 0.1130i   0.0000 + 0.1501i
0.0000 + 0.1060i   0.0000 + 0.1146i   0.0000 + 0.1324i
0.0000 + 0.1192i   0.0000 + 0.1165i   0.0000 + 0.1108i
0.0000 + 0.2607i   0.0000 + 0.1662i   0.0000 + 0.1143i
0.0000 + 0.1662i   0.0000 + 0.2135i   0.0000 + 0.1403i
0.0000 + 0.1143i   0.0000 + 0.1403i   0.0000 + 0.1938i
```

Matrix element 14 column 14, which is the value of the short-circuit impedance for the positive and negative sequences if the system has a fault on bus 14

For a zero impedance sequence, the impedance matrix is:

```
0.0000 + 0.0274i   0.0000 + 0.0281i   0.0000 + 0.0295i
0.0000 + 0.0325i   0.0000 + 0.0348i   0.0000 + 0.0394i
0.0000 + 0.0264i   0.0000 + 0.0296i   0.0000 + 0.0357i
0.0000 + 0.0611i   0.0000 + 0.0701i   0.0000 + 0.0874i
0.0000 + 0.0628i   0.0000 + 0.0629i   0.0000 + 0.0632i
0.0000 + 0.1158i   0.0000 + 0.1060i   0.0000 + 0.0872i
0.0000 + 0.0698i   0.0000 + 0.0839i   0.0000 + 0.1111i
0.0000 + 0.0419i   0.0000 + 0.0504i   0.0000 + 0.0667i
0.0000 + 0.1015i   0.0000 + 0.1236i   0.0000 + 0.1662i
0.0000 + 0.1054i   0.0000 + 0.1188i   0.0000 + 0.1445i
0.0000 + 0.1100i   0.0000 + 0.1132i   0.0000 + 0.1195i
0.0000 + 0.2903i   0.0000 + 0.1887i   0.0000 + 0.1441i
0.0000 + 0.1887i   0.0000 + 0.2453i   0.0000 + 0.1831i
0.0000 + 0.1441i   0.0000 + 0.1831i   0.0000 + 0.2581i
```

Matrix element 14 column 14, which is the short-circuit impedance value for the zero

Matlab software is used to simulate SCC calculations. Input data in matlab m.file to calculate admittance matrix value which is converted into impedance matrix. The diagonal element of the bus impedance matrix is the short-circuit equivalent impedance value, used in short-circuit analysis. The use of Matlab as a tool to simulate the magnitude of the value of the symmetrical and unsymetrical fault.

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The calculation of the off-diagonal elements of the Z bus matrix for positive, negative and zero sequences, is used in analyzing symmetrical faults and L-G asymmetrical faults. with a summary of the calculation simulation results, shown in table 5.

Tabel 5. Simulation of symmetrical Fault and L-G Fault

Bus	Z_{Seq} (1)	Z_{Seq} (2)	$Z_{Seq\ (0)}$	Sym. Fault	Unsym. Fault
1	0.128	0.128	0.166	7.763	7.07
2	0.098	0.098	0.127	10.13	9.22
3	0.130	0.130	0.163	7.66	7.0
4	0.122	0.122	0.168	8.16	7.25
5	0.148	0.148	0.173	6.72	6.37
6	0.147	0.147	0.130	6.76	7.04
7	0.134	0.134	0.206	7.44	6.31
8	0.149	0.149	0.194	6.68	6.08
9	0.160	0.163	0.206	6.10	5.61
10	0.292	0.292	0.381	3.41	3.08
11	0.304	0.304	0.405	3.28	2.95
12	0.260	0.260	0.2903	3.83	3.69
13	0.213	0.213	0.245	4.68	4.46
14	0.193	0.193	0.258	5.15	4.64

Symmetrical and asymmetrical fault current characteristics, the picture shows the variation of fault current above 1.0 per unit. there is the largest fault current value occurs on bus 1 and bus 2 reaching a disturbance value of 9.58 per unit. This significant symmetrical fault current is caused by the fault location being near the generator side and the short-circuit equivalent impedance value on the bus is small compared to other buses. so that the value of the symmetrical fault current is 10.13 pu, while for L-G fault it is 9.22 pu, on bus 2. Comparison between symmetrical fault and L-G fault, with characteristics as shown in Figure x.

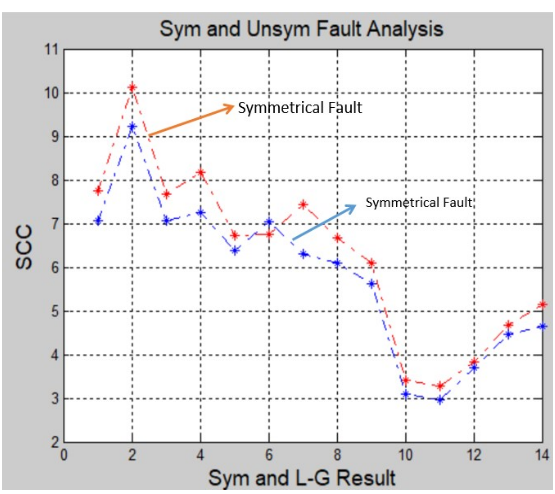

Figure 17. Comparison characteristics of Symmetrical Fault Current and L-G fault (pu)

Discussion

An electric power system does not always run ideally, because in reality there can be an abnormal condition (such as a disturbance or a short circuit). These abnormal conditions can endanger the system as a whole, so it is necessary to have a protection system that can minimize the effects of these abnormal conditions. The function of the protection system is to identify disturbances and separate the disturbed network parts from other parts that are still normal (undisturbed) and at the same time secure the normal parts from damage or greater loss. Disturbances in the electric power system can occur in generators, transmission networks and distribution networks. Wherever the disturbance occurs, the protection system must be able to identify and separate the parts that interrupted as soon as possible.

There are three very important studies in power systems, namely power flow studies, short circuit studies and stability studies. The three types of studies are interrelated and needs to be carried out periodically to ensure the continuity of generation and distribution as well as the best operation. Short circuit study is an analysis that studies the contribution of short circuit fault current which may flow at any branch in the system (in distribution networks, transmission, power transformers or from generators) during short-circuit faults that may occur in the electric power system. Short circuit as one of the disturbances in the electric power system that has transient characteristics that must be overcome by safety equipment. The occurrence of a short circuit causes a current surge with a magnitude higher than normal and the voltage in that place becomes very low. the modeling and simulation results show a short-circuit fault current value of 9.58 per unit which is far above the nominal current of 1.0 per unit this can cause damage to electrical power system equipment.

Short circuit analysis in the electrical system is an important discussion in efforts to maintain the reliability and security of the electric power system. Calculation of short circuit faults for power system planners to anticipate equipment damage due to fault current values that exceed nominal current values [10]. Circuit breaker protection is an important consideration in completing the short circuit analysis of the electric power system as an effort to maintain system reliability so that the equipment is protected to the maximum [11,12,13]. From the Symmetrical SCC data analysis shows that the value of the symmetrical fault current can reach a value of 9 times greater than the nominal

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current, for a 14 bus system condition with the system reactance data that has been analyzed. This research requires further development, applied in determining the reliability of the electric power system, especially in the province of North Sumatra, Indonesia, needs to be continued for research

5. CONCLUSION

From the results of the analysis of the Symmetrical SCC on the 14 Bus IEEE Powers systems, it can be concluded:

1. The smallest Z_{SCeq} value in the bus impedance matrix is on bus number 2, for symmetrical faults and asymmetrical faults of 0.128 and 0.166, respectively.
2. The maximum fault current occurs on bus 2 in one unit of 10.13 pu for symmetrical faults and 9.22 pu for asymmetrical faults
3. The Z_{BUS} model, which is built with reactance diagrams, can practically be solved by simulation analysis using Matlab software.
4. The asymmetric short-circuit fault current on average is smaller than the symmetrical fault current, judging from the comparative characteristics of the analysis results between the two faults.

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