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Research Original Article

Analysis of calculating the fault current on the generator In Power System

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Abstract
Short circuit fault current in the electric power system is one of the problems that can threaten the reliability and safety of system operations. This disturbance, which occurs due to direct contact between phases or between phases and ground, produces significant currents and can damage network equipment if not handled with adequate protection. This study aims to analyze and calculate short circuit fault currents in the electric power system using MATLAB and Simulink software . In this study, the electric power system model is simulated with various types of disturbances, namely three- phase , two -phase , and single -phase to ground disturbances , to determine the system response and the magnitude of the current that occurs. Power system parameter data such as voltage, component impedance, and load conditions are used as input in the modeling. The " Three-Phase" block Fault " in Simulink is used to implement a fault at a specific point in the system. The simulation results show that the magnitude of the fault current varies depending on the type of fault and the line impedance. With this analysis, system designers can determine the appropriate protection equipment, such as circuit breakers and relays , to prevent damage and maintain the stability of system operation. This study demonstrates the effectiveness of MATLAB as a simulation tool in power system fault analysis, providing practical and accurate solutions in fault current calculations.
Keywords: Short Circuit Current, Electric Power System, MATLAB and Simulink

Introduction
Electric generators are important components in electric power systems that function to produce electrical energy through the conversion of mechanical energy [1]. However, in its operation, generators are not free from various types of disturbances, such as single- phase to ground, two -phase , two -phase to ground, and three- phase disturbances. These disturbances can affect system stability and cause damage to equipment, which has an impact on the continuity of electricity supply and operational safety [2]. Proper handling of these disturbances is very important to maintain the reliability and efficiency of the electric power system. To understand and overcome these disturbances, simulation using MATLAB software provides an effective solution in analyzing system behavior under various disturbance conditions. Thus, this study focuses on modeling and analyzing various types of disturbances in generators using MATLAB, to provide an in-depth understanding and appropriate mitigation strategies in dealing with these disturbances [3], [4].

Literature Review
A. Generator

A generator is a device that functions to convert mechanical energy into electrical energy. The basic principle of its operation is based on the law of electromagnetic induction discovered by Michael Faraday, namely that changes in magnetic flux in a closed circuit will produce an electric current. In generators, mechanical energy is usually generated by primary energy sources such as steam turbines, water turbines, gas turbines, or diesel engines, which are then converted into electrical energy through the process of electromagnetic induction [5], [6].

The generator structure generally consists of two main components: the stator and the rotor. The stator is the stationary part and usually contains coils where electric current is generated. The rotor is the rotating part and is equipped with a magnetic field, which can come from a permanent magnet or an electromagnet. As the rotor rotates, the magnetic field cuts the coils in the stator, generating electric current in the coils.

B. Generator working principle

The working principle of the generator is based on Faraday's law of electromagnetic induction, which states that an electric current can be generated in a conductor when there is a change in magnetic flux. In a generator, this principle is applied by moving a magnetic field so that it cuts the coil or conductor inside the generator, which then produces an electric current.

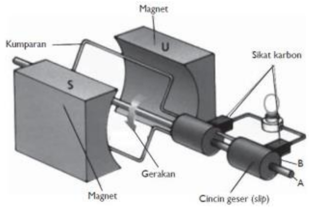

Figure 1. generator working principle

Following are the main steps in the working principle of a generator:

a) Rotor Rotation

The rotor, the moving part of the generator, is rotated by an external source of mechanical energy, such as a water turbine, wind turbine, diesel engine, or steam turbine. This energy source determines the strength and frequency of the electricity produced [7], [8].

b) Electromagnetic Induction

As the rotor rotates, the magnetic field produced by the rotor cuts the coils in the stator (the stationary part of the generator). Because this magnetic field changes continuously as the rotor rotates, the magnetic flux through the coils also changes, producing an electric voltage in the coils. stator.

c) Formation of Electric Current

The electrical voltage formed in the stator coil flows as an electric current. If the stator coil is connected to a load or electrical network, the electric current will flow out and can be used for various electrical needs.

d) Output Frequency and Voltage

The rotor rotation speed and the number of magnetic poles on the rotor determine the frequency of the electricity produced, while the number of coil turns affects the generator's output voltage. In power plants, generator frequencies are generally kept stable according to standards, such as 50 Hz or 60 Hz , depending on the country [9].

C. Fault current

Fault current in a generator is an electric current that occurs due to abnormal conditions or disturbances that affect the electric power system in which the generator operates. This condition triggers a current flow that is greater than normal, which can damage generator components and even pose a risk of fire or permanent damage. Fault currents usually occur when there is an unwanted shortcut in the circuit or when a component in the generator or system fails [10].

Some factors that can cause fault currents in generators include:

a) Short Circuit Circuit)

A short circuit is a condition in which a path connecting two points with a large voltage difference is directly connected without a load intermediary. This causes a large current to flow through the path, exceeding the normal capacity of the component and causing excessive heat that can damage the generator [11].

b) Isolation Failure

The insulation surrounding a generator wire or component serves to prevent current from flowing out of its proper path. When this insulation is damaged, current can leak to the ground or to other components, creating fault currents that can cause damage to the generator and related equipment.

c) Component Failure

Each component of the generator, such as the coil, rotor, or stator, has a certain endurance limit. If any of these components are damaged due to factors such as overload or wear, a breakdown can occur, allowing a larger current to flow uncontrollably [12].

d) External Conditions

External factors, such as lightning, high humidity, or foreign objects entering the generator, can also trigger fault currents. Lightning, for example, can cause voltage spikes that result in large fault currents, damaging equipment and generator components.

D. Types of fault currents in generators

The types of current disturbances that frequently occur in generators include:

a) Single Phase to Ground Fault (Single Line -to - Ground Fault)

Occurs when one phase is connected to the ground . This is the most common type of fault, especially in systems with a neutral point connected to the ground. The form of a single- phase short circuit is as follows.

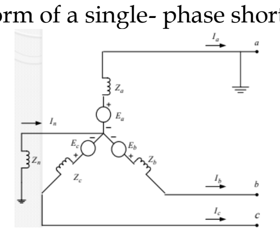

Figure 2. Single phase ground fault

From the image above, there is a short circuit between phase a and the ground where during the disturbance the values of I_b, I_c, $V_a = 0$. To calculate the fault current you can use the equation below .

$$Ia1 = \frac{Ea}{Z0 + Z1 + Z2}$$

b) Two Phase Fault (Line- to -Line Fault)

Occurs when two phases are connected without going through a load, causing very high currents between the two phases . This disturbance can cause excessive heat that can damage the generator and surrounding equipment. The form of the short circuit is as follows.

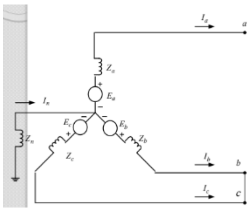

Figure 3. two- phase fault

From the image above, there is a short circuit between phase b and phase c, during the disturbance the value of $I_a = 0$, $I_b = -I_c$, $V_b = V_c$. To calculate the fault current , you can use the equation below .

$$I = -j\sqrt{3Ia1}$$

c) Two Phase to Ground Fault (Double Line -to - Ground Fault)

Occurs when two phases are connected to the ground simultaneously . This disturbance can cause very large currents and serious damage if not handled immediately. The form of a two- phase to ground fault circuit is as follows [13].

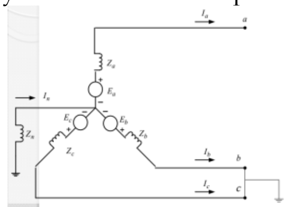

Figure 4. two- phase ground fault

From the image above, there is a short circuit between phases b and c to the ground, during the disturbance the values of I_a, V_b, $V_c = 0$. To calculate the disturbance current , you can use the equation below .

$$I_{f\,(LL\text{-}G)} = I_b + I_c$$

d) Three-Phase Fault Fault)

This fault occurs when all three phases are connected directly or through ground , which causes the largest fault current compared to other types of faults. Three- phase faults are rare but very dangerous for equipment and the power grid [14].

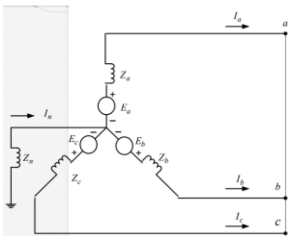

Figure 5. three- phase fault

From the image above, a short circuit occurs between phases a, b and c, during the disturbance the value of $I_a + I_b + I_c = 0$, $V_b = V_a$ and $V_c = V_a$. To calculate the fault current, you can use the equation below .

$$I f\,(LLL) = I_a = I_{a0} + I_{a1} + I_{a2} = I_{a1}$$

Materials & Methods

The research materials consist of software and system parameter data used in the short circuit fault current analysis simulation, namely:

a. Simulink Software : MATLAB is used as the main tool for modeling, simulating, and calculating fault currents. Simulink provides specific components for modeling electric power systems, including three- phase voltage sources , transmission lines, transformers, loads, and fault blocks . block) to simulate various types of disturbances [15].

b. Power System Toolbox : An add-on package in MATLAB that provides various components and functions for modeling electric power systems. This toolbox allows power flow calculations and power system disturbance simulations [16].
c. Power System Parameter Data: System parameters used in the simulation model include:
   - System Voltage: The nominal voltage of the electrical power source, generally expressed in kilovolts (kV).
   - Component Impedance: The impedance of transmission lines, transformers, and generators, which can be calculated or obtained from the technical specifications of each component.
   - Load: Load data includes the amount of real power (kW) and reactive power (kVar) required by the system.

This research method involves modeling the electric power system, adding disturbances, and analyzing simulation results using MATLAB and Simulink [17].

The flow diagram for the process of determining the magnitude of the fault current in the generator follows the diagram below.

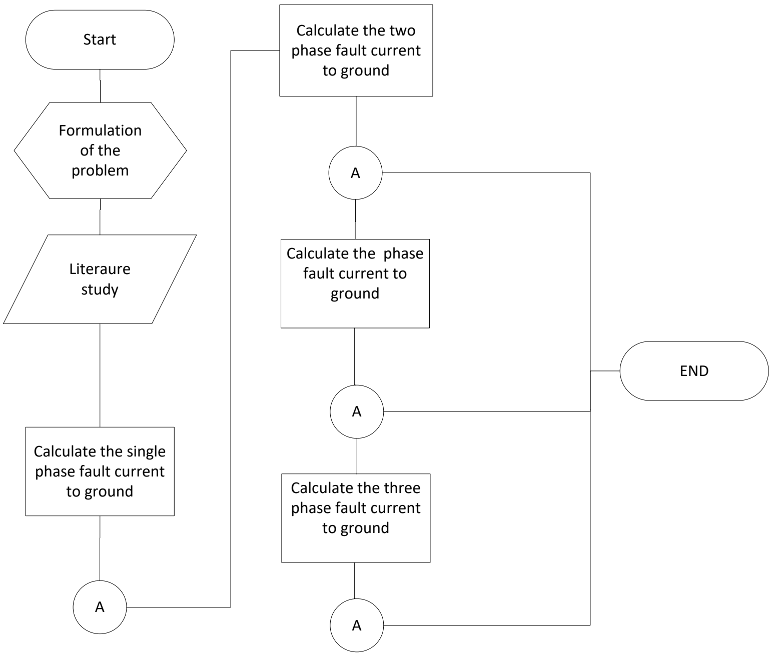

Figure 6. flowchart

Results and Discussion

A. Determining the impedance value on the generator

In the generator there are three types of impedance, namely Z0, Z1, Z2.
For example, generator A has the following impedance data.
Z0 = 0.1; % Zero- sequence impedance
Z1 = 0.2; % Positive- sequence impedance
Z2 = 0.15; % Negative impedance- sequence

B. Determining the value of single phase fault current

Phase to ground fault is a condition where one of the generator phases is directly connected to the ground. The current generated by this fault can be related using the formula:

$$Ia1 = \frac{Ea}{Z0 + Z1 + Z2}$$

Information:
Ia1 = Initiation current or current generated at a particular part of the system (A).
Ea = Source voltage or voltage at the starting point in the system (V).
Z0, Z1, Z2 = Impedance or resistance in each part of the system path (Ω).
Calculation of current value for single ground fault using the equation :

$$Ia1 = \frac{Ea}{Z0+Z1+Z2}$$

$$Ia1 = \frac{1.0}{0.1+0.2+0.15}$$

$$Ia1 = \frac{1.0}{0.45}$$

$$Ia1 = 2.22\ pu$$

The form of the fault current plot is as follows:

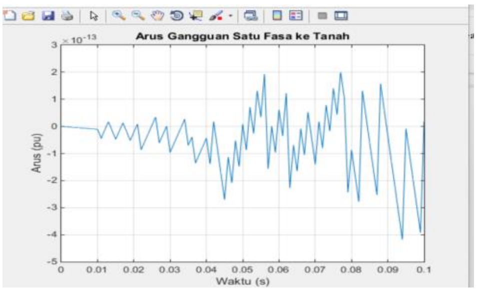

Figure 6. plot of single phase ground fault current

C. Determining two- phase fault current

Phase faults occur when two phases touch each other, for example between phases B and C. The current for this fault can be calculated using the following formula:

I = -j√3Ia1

Where Ia1 is the current calculated from a single phase ground fault.

From the previous calculation results, we already have the values:

Ia1 = 2.22 pu

The value √3is approximately 1.732. So, substitute this value into the formula:

I = -j× 1.732 × 2.22

Perform the following calculations:

$I = -j \times 1.732 \times 2.22$

$= -j \times 3.845$

Current two phase fault is

$I = -3.845j\ pu$

So, for two phase fault , the current generated is $-3.845\ pu$ with an angle of -90 degrees.

The form of the fault current plot is as follows:

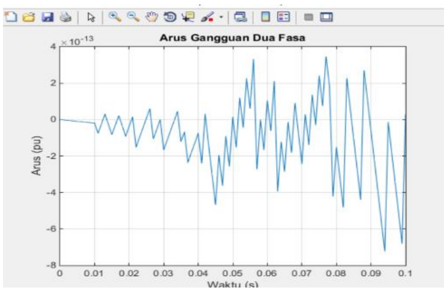

Figure 7. plots two- phase fault currents

D. Determining two- phase ground fault current

Phase to ground fault occurs when two phases (e.g. phase B and C) are directly connected to ground. For this condition, the fault current can be calculated using the equation:

If (LL-G) = Ib + Ic

Information :

phase fault current

Ib = current in phase b

Ic = current in phase c

From the two- phase fault calculation , we have:

I = -3.845i

So, the current in phase B (Ib) and phase C (Ic) is

Ib = I/2

Ib = (-3.845i)/2

Ib = 1.9225j Pu

With the current in phase c, namely Ib = Ic

Ic = I/2

Ib = (-3.845i)/2

Ib = -1.9225j Pu

The form of the two- phase ground fault current plot is as follows.

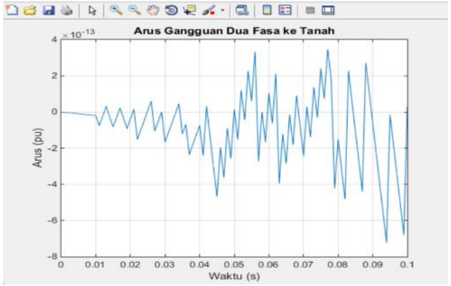

Figure 7. plots two- phase fault currents

E. phase fault current on a generator

This disturbance occurs when all three phases experience a short circuit to each other or to the ground simultaneously [18]. In this condition, only the positive- sequence component is calculated , then

If(LLL) = Ia = Ia1

Information:

phase fault conditions (LLL), namely when the three phases experience a short circuit or short circuit with each other.

Ia : A symbol that is also used to indicate the current on a particular phase that is experiencing a fault.

Ia1 : Positive sequence current component for three- phase fault conditions , namely the current generated in symmetrical conditions in the power system.

Where Ia1 is the result of the calculation of a single phase to ground fault.
Using the value of single phase to ground fault of Ia1 = 2.22 pu

Since only positive - sequence components contribute to a three- phase fault , the three- phase fault current is also equal to the value of Ia1:

If(LLL) = Ia = Ia1
If(LLL) = 2.22pu

Then the three- phase fault to ground is If(LLL) = 2.22pu
The form of the three- phase fault current plot is as follows.

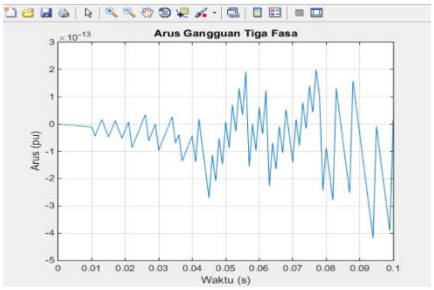

Figure 8. plot of three- phase fault current

When a short circuit current disturbance occurs, the rotor angle (δ) can change rapidly due to the torque imbalance between the mechanical torque of the prime mover (e.g. turbine) and the electromagnetic torque generated by the fault current [19]. If the system is stable, the rotor angle change remains controlled and oscillates back towards stability. However, in unstable conditions, the rotor angle continues to increase until significant instability occurs, as seen in the graph with the red line [20]. The shape of the graph is as follows

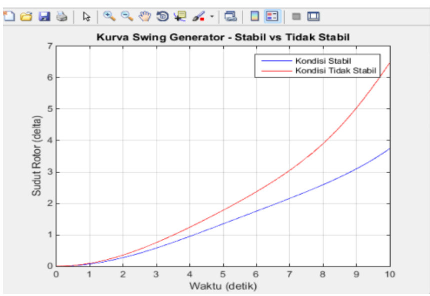

Figure 9. stable vs unstable conditions

Conclusions

From the description and explanation of the results and discussion, the following conclusions can be drawn.

1. The magnitude of the fault current that occurs in each type of fault:
   Phase fault current in the generator is 2.22 pu
   Phase fault current in the generator is -3.845 j pu
   Phase to ground fault current in the generator is -1.9225 j Pu
   Phase fault current in the generator is 2.22 pu
2. In terms of stability, it can be explained that the system is unstable when a fault occurs, because the swing curve is seen

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