Design of Protection Coordination for Overcurrent on Electrical System in Tanker Ship Plan using Electro Mechanical Trip Device

Indra Ranu Kusuma[1], Eddy Setyo Koenhardhono[2], Riantini Karmina[3]

***Abstract*—disturbance of power system in ship is unavoidable case that required a function from safety system to separate the affected parts of system. The disturbance in electrical system generally is a short-circuit current. It is affected when there are two conductors having lowest impedance in normal condition that have two different voltages thus causing an overcurrent. There is one of the device protection to prevent a disturbance like short circuit current, is circuit breaker. It opens the contact with component or system that disturbance using electromechanical trip device. The principal operating of trip device is using electric current flow in the circuit breaker and the magnet induces the tripping part to moving the contact from closed position to the opened position. The main discussion is to coordinate circuit breakers in four operating conditions of the ship's generator using software ETAP. The simulation of the result obtained value of short circuit in main bus one at sailing condition is 8.2 kA. Tripping time for the circuit breakers in sailing condition at one typical disturbance are 0.75 seconds for circuit breaker number 29; 0.83 seconds for circuit breaker number 37 and 1 second for circuit breaker number 28.**

Keywords—circuit breaker, disturbance, overcurrent protection, short-circuit.

I. INTRODUCTION

Disturbance in electrical system is an abnormal condition where it can be interrupted of continuity electricity service. Electrical system in the ship is one of the important elements that support operational activities. If the disturbance occurs, the ship could not operate optimally. Therefore, it is necessary a protection system to anticipating a disturbance in electrical distribution. Therefore, electricity supply for equipment could be met. Electrical system has important thing to prevent a disturbance and protection components or systems for electricity production.

Protection system is applied when a disturbance like short circuit or under voltage is happened. The most common failure in electrical system is the increase of current significantly [1-10]. As a result, protection about currents is applied in many of electrical system. One of the disturbance that caused by current is short circuit. Short circuit is a condition when the wires insulation of them is loose and they are touching in the circuit. The affected of short circuit is overcurrent. But overcurrent was not only affected by short circuit. It could be affected by overload in electrical system[11].

The application of protection system in the ship because of overcurrent is using circuit breaker and fuse. Circuit breaker is one of the protection devices to decide if the current flows in the system of the ability exceed and the circuit breaker was connecting again when the disturbance has overcome. The main subject of this paper is circuit breaker. Besides of choosing a circuit breaker as a device that used in protection system, there was also arrangement coordination of circuit breaker. And to determining when the time of contact in circuit breaker open. And also protect the area that has a disturbance.

Excessive current is referred to as overcurrent. An overcurrent may result from an overload, short circuit, or ground fault. Some circuit breakers provide only short circuit protection, but most circuit breakers provide protection against short circuits and overloads, and some circuit breakers provide protection against all three types of overcurrent [5, 9, 12].

A short circuit is a low resistance path for current created when bare conductors touch. When a short circuit occurs with voltage applied the decrease in resistance results in a short circuit current that can be thousands of times higher than normal operating current. The heat generated by this current will cause extensive damage to connected equipment and conductors unless current is interrupted immediately [11-14].

All circuit breakers perform the following functions. Sense when an overcurrent occurs. Measure the amount of overcurrent and act by tripping in a timely manner to prevent damage to the circuit breaker and the conductors it protects. In the following illustration, an AC motor is connected through a circuit breaker to a voltage source. When the circuit breaker is closed, a complete path for current exists between the voltage source and the motor allowing the motor to run. Opening the circuit breaker breaks the path of current flow and the motor stops. The circuit breaker automatically opens when it senses a fault. After the fault has been cleared, the breaker can be closed, allowing the motor to operate [10].

A trip device in circuit breaker does the timing of pickup in order to operate quickly and having high selectivity to feel and isolate a disturbance rounded the equipment. It must be prepared in order to prevent more current that flows in a motor or electrical circuit before the current can cause a rise in the temperature of that which impairs isolation, termination or around of conductors [5].

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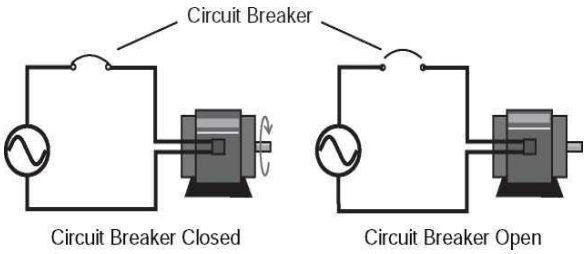

Figure. 1. How Circuit Breaker Works

The result of setting circuit breaker output is a current-time curve. Current-time curve is a curve that is used to indicate how quickly a breaker will disconnect a current that causes the disturbance. On the x-axis (the horizontal axis) shows the value of the nominal current for the breaker. On the y-axis (vertical axis) indicates the time in seconds. The timing of trip in circuit breaker are categorized in several types which are continues ampere, long time delay, short-time pickup, short time delay and instantaneous [7].

II. METHOD

Designing coordination protection of circuit breaker is the main disscusion for the paper. The Simulation of coordinate the circuit breaker was done by software ETAP. It could analysis of short circuit value in disturbance area and a coordinate protection is managed by trip device in circuit breaker.

The following are method for the paper from finding a literature review until the simulation using ETAP:

1. Finding the data and literature review.
   The data that used is from final design project. The datas is using an electric equipment in the ship and also lighting and generator calculation.
   A literature review for the paper is using reference from the paper from scientific journal, diktat, andbooks.
2. Making an online diagram.
   Online diagram is a circuit that using in software ETAP. Oneline diagram as a worksheet to doing all of the simulations (shortcircuit, coordinate of circuit breaker and current-time curve) in software ETAP.
3. Simulation of load flow analysis.
   A simulation is done to knowing a component that in overload condition and determining of circuit breaker rating.
4. Finding a value of short circuit.
   A value of short circuit obtained by making a few of failure condition at the bus using short circuit simulation on ETAP. The value going to be used as a current setting.
5. Coordination of circuit breaker.
   There are the spesification data for components in oneline diagram to coordinate a circuit breaker, generator, transformator and loads
   In the coordination circuit breaker, tripping times were based on all of the circuit breaker. The aim is to protect components or systems from the disturbance when more current flows to them. Time to minimize the affected areas because of any disturbance on equipment or other systems, the setting is based on of the short circuit happened on a bus with the disturbance. It is reference for circuit breaker setting.
6. Analyzing of time current curve.
   The function of the curve is to know the value of starting motor curve, generator, transformator and circuit breaker curve working. If there is a disturbance in another component, the circuit breaker could be minimize the disturbance of component that operating in normal condition.

III. RESULT AND DISCUSSION

A. The Value of Short Circuit

Based on the simulation of short circuit in software ETAP, the value of short circuit is obtained from four conditions in the ship which are sailing, maneuvering, cargo handling and at the port. The disturbance is located in main bus which connected to main generator and the values of short circuit from four conditions in the ship are compared.

Table 1**.** The value of short circuit

Fault : Main bus (1)

No.	Components	Short Circuit (kA)			
		Sailing	Maneuvering	Cargo handling	At port
1	Generator 1	1.81	1.81	1.81	1.81
2	Generator 2	1.81	1.81	1.81	1.81
3	Generator 3	1.81	1.81	1.81	1.81
4	Provision Crane	-	-	0.151	-
5	AC Central	0.273	0.273	0.276	0.276
6	Accommodation Ladder	-	-	-	0.075
7	Windlass 1	-	-	-	0.231
8	Windlass 2	-	-	-	0.231
9	Capstan 1	-	-	-	0.151
10	Capstan 2	-	-	-	0.151
11	Cargo Pump 1	-	-	0.727	-
12	Cargo Pump 2	-	-	0.727	-
13	Stripping Pump 1	-	-	0.132	-
14	Stripping Pump 2	-	-	0.132	-
15	Crane Cargo Hold	-	-	0.354	-
16	MDO Transfer Pump 1	0.03	0.03	-	-
17	MDO Transfer Pump 2	0.03	0.03	-	-
18	MDO Separator 1	0.103	0.103	-	-
19	MDO Separator 2	0.103	0.103	-	-
20	MDO Circulating Pump 1	0.029	0.029	0.029	0.029
21	MDO Circulating Pump 2	0.029	0.029	0.029	0.029
22	LO Transfer Pump	0.031	-	-	0.031
23	LO Separator Feed Pump	-	-	-	0.012
24	LO Separator	-	-	-	0.103
25	SW Cooling Pump 1	0.097	0.097	-	-
26	SW Cooling Pump 2	0.097	0.097	-	-
27	HT Standby Pump	-	-	-	-
28	LT Standby Pump	-	-	-	-
29	Circulating Pump	0.031	0.031	0.031	0.031
30	CO Transfer Pump	0.031	0.031	0.031	0.031
31	Bilge Pump	0.137	0.137	-	-
32	Fire Pump 1	0.183	0.183	-	-
33	Fire Pump 2	0.183	0.183	-	-
34	General Service Pump	-	-	0.137	-
35	Ballast Pump	-	-	0.137	-
36	Oily Bilge Pump	0.038	0.038	0.038	0.038
37	OWS	0.012	0.012	0.012	0.012
38	Air Compressor 1	-	-	-	0.032
39	Air Compressor 2	-	-	-	0.032
40	E/R Supply Fan 1	0.269	0.269	0.269	0.269
41	E/R Supply Fan 2	0.269	0.269	0.269	0.269
42	E/R Exhaust Fan 1	0.269	0.269	0.269	0.269
43	E/R Exhaust Fan 2	0.269	0.269	0.269	0.269
44	Emergency Fire Pump	0.072	0.072	0.051	0.051
45	Steering Gear	0.185	0.185	0.132	0.132
TOTAL		8.2	8.169	9.632	8.184

Based on the table 1, the value of short circuit in four conditions at the ship are 8.2 kA for sailing, 8.169 kA for maneuvering, 9.632 kA for cargo handling and the last 8.184 kA for at the port. The greatest value of short circuit is in cargo handling condition. And the smallest value of short circuit is in at the port condition. Based on the result of short circuit value, it's affected by the number of the equipment used and the power of electric equipment in each condition.

B. Coordinate of circuit breaker

There are three typical disturbances that representing the entire system protection and using them inorder that to coordinate the circuit breaker easily.

There are three typical disturbances at four operating conditions generator in the ship:

1. A disturbance in one of the deck in the ship.
2. A disturbance in transformer.
3. A disturbance in one of the emergency equipment.

The first arrangement in circuit breaker is determining the type of trip device in circuit breaker. For the paper is used electromechanical trip device. The second is writes the specification of circuit breaker (i.e. manufacture, model, minimum voltage). The third step chooses a value of current rating based on the result of simulation with load flow analysis. The final step is making a disruption using one of the three typical disturbances.

The next one is coordinate of circuit breaker in disturbance of typical one. Figure 3 shows when the sequences of circuit breakers open. The disturbance was affected in the one of sea water cooling pump. Therefore, the coordinate of circuit breaker have to be applied to minimize area that closes to the disturbance.

The first circuit breaker's contact opens, it is closes the disturbance area and there is an X circuit breaker. An X circuit breaker is opened the contact to prevent a short circuit that are coming from other components to the component which have been affected. The next circuit breaker would be opened is Y circuit breaker. It is connected circuit breaker X and circuit breaker Z. Circuit breaker Y is opened to shut off the short circuit from generator and other components and it is can be a backup when a X circuit breaker is failure. The last circuit breaker opened is Z. It is protect one of the main generators. Generators are having a greatest short circuit value when the disturbance was happened.

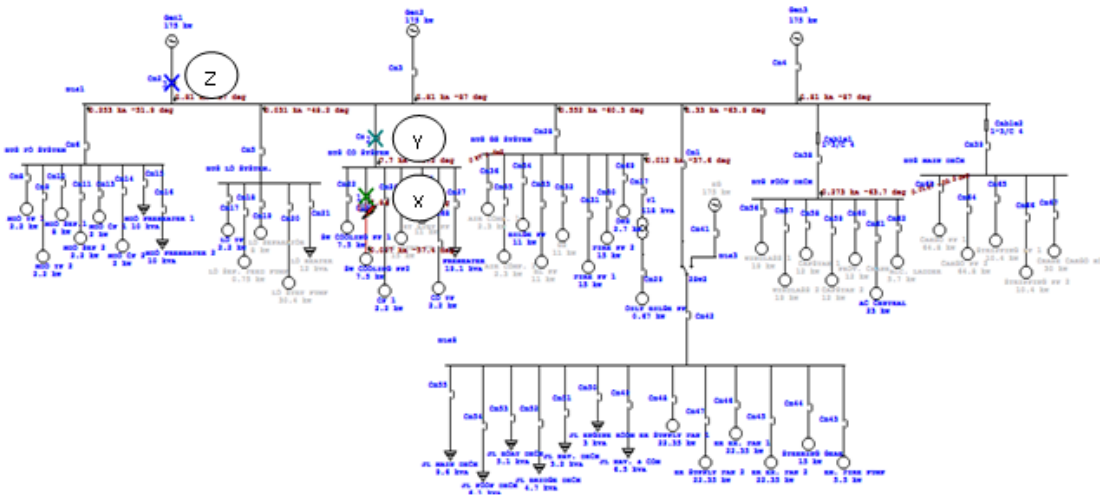

Figure. 2. The sequence of circuit breakers open

C. Time – current curve

Analysis the coordination of protection is using a working curve of the circuit breaker, motor starting curves and transformer or cables curve in a number of typical disturbances based on operating conditions in the ship. The simulation uses star protective device coordination. The curve was plotted and checked by the value of short circuit before. The next step is analyzing the curve to determine whether arrangement the equipment can be secured when the short circuit was coming

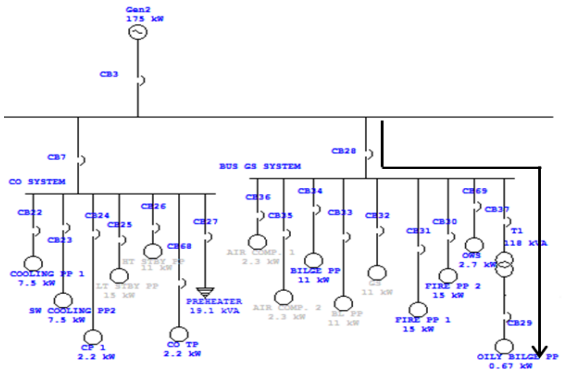

Figure. 3. Online Diagram in disturbance of typical one

In the following discussion, circuit breaker coordination analysis will be given for each the typical failures on the sailing and maneuvering conditions. Based on the typical disturbance in sailing condition which is consists of three circuit breakers. There are circuit breakers number 28, 29 and 37. The area that becomes a disturbance of short circuit current was found in oily bilge pump.

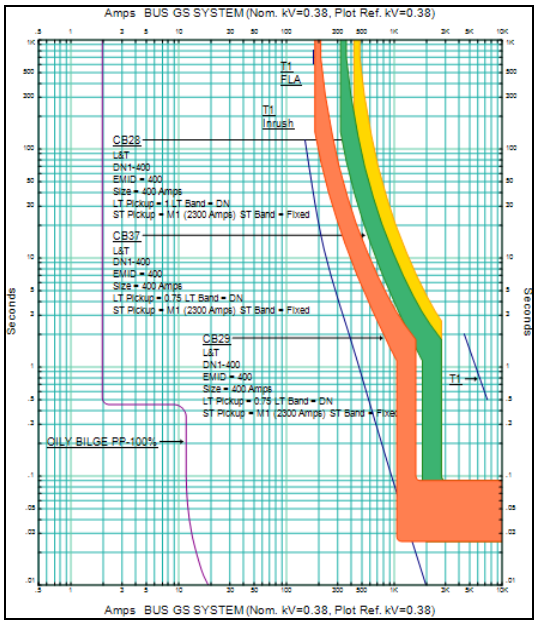

Figure. 4. Current-time curve in disturbance of typical one

The first circuit breaker protection is circuit breaker number 29. It has a function as a protection component to oily bilge pump in the event when the General Service (GS). Circuit breaker number 37 was under circuit breaker number 29. It serves as protection for transformer as well as a safety protection when circuit breaker 29 failed to protect the failures. The last circuit breaker is number 28. It connects to the one of main generator and the components under the General Service (GS) bus and also as a backup protection, if the others was failed to secure the underlying fault.

Based on the figure 7 shows when the oily bilge pump starts the curve is behind in the curve working of circuit breaker. Therefore if there was a high current caused by oily bilge pump starting, the current could be secured by circuit breakers. The Pickup times for each circuit breaker are circuit breaker 29 in 0.75 seconds, circuit breaker 37 in 0.83 seconds and the circuit breaker 28 in one second.

The Next is disturbance in typical two in sailing condition. There are three circuit breakers in this typical disturbance. There are circuit breakers number 3, 28 and 37. The area that becomes disturbance of short circuit current was found in transformer two windings.

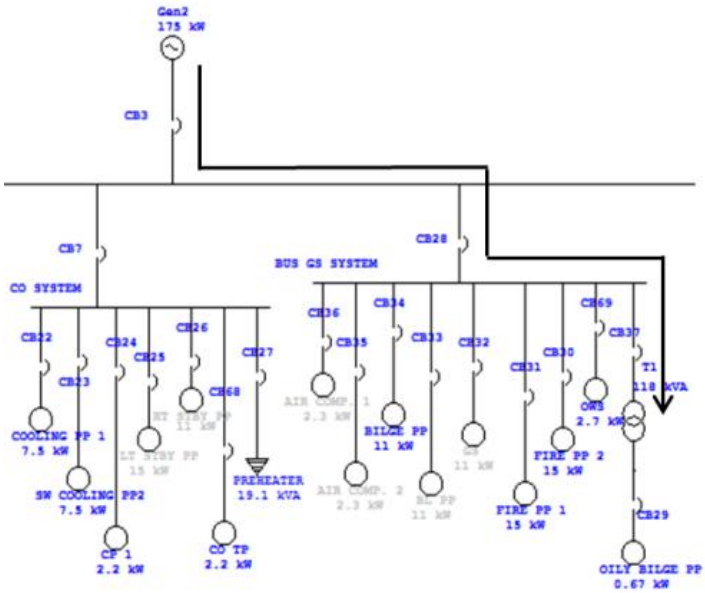

Figure. 5. Online Diagram in disturbance of typical two

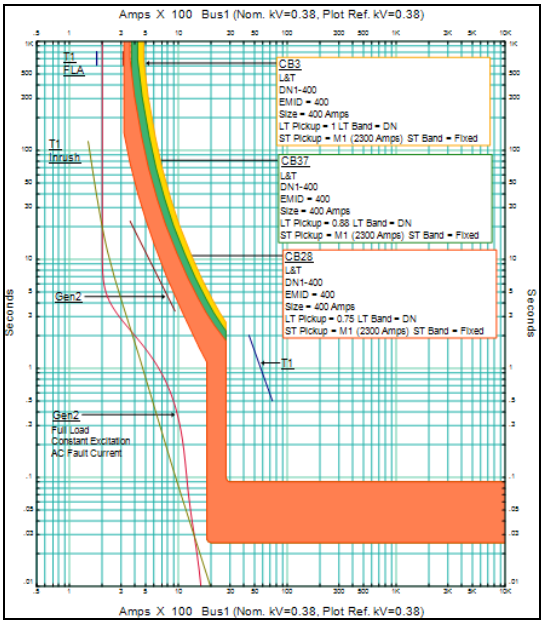

Figure. 6. Current-time curve in disturbance of typical two

The first circuit breaker is circuit breaker number 37. It serves as protection for transformer as well as a device protection when it is faults on the Bus General Service (GS) system. The above from circuit breaker 37 is circuit breaker number 28. It is connects the components in General Service (GS) bus to one of the main generators and as well as a device backup protector when the circuit breaker 37 failed to secure the disturbances. Circuit breaker number 3 is protects the main generators and also as a safety backup when the circuit breakers were failed.

Based on the figure 7 shows, the time-current curve of generator and transformer were cross. Therefore, transformer's curve in the condition of inrush intersecting with generator's curve in the 0.03 seconds, 1.7 seconds and 10.7 seconds.

Based on the figure 8 shows, the disturbance of typical three is in the maneuvering condition. Circuit breakers that protect the disturbance are circuit breaker number 2, 42 and 44. The area that becomes disturbance of short-circuit current was found in steering gear.

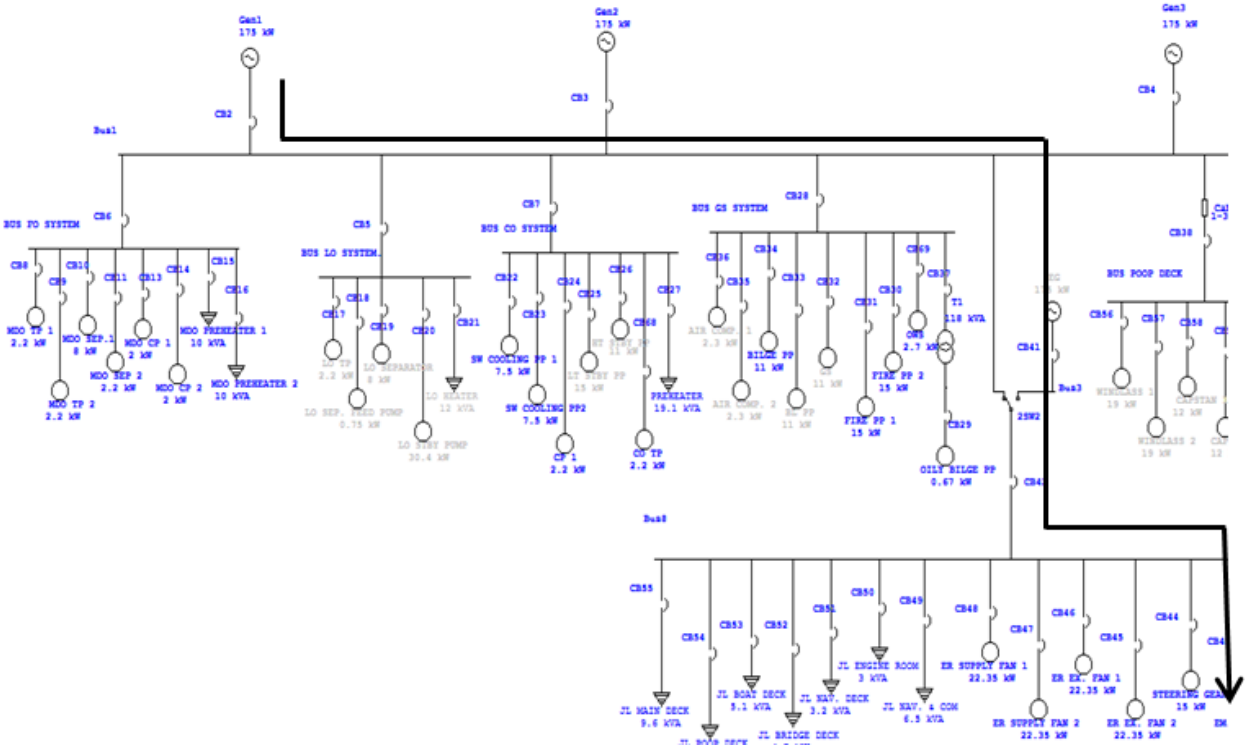

Figure. 7. Online Diagram in disturbance of typical three

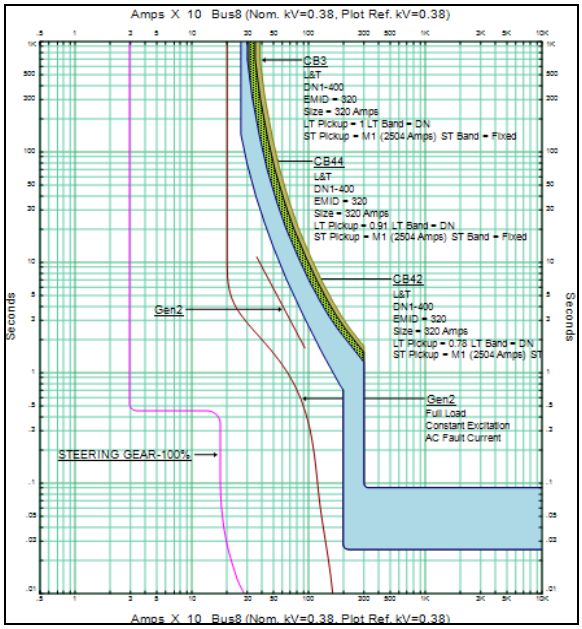

Figure. 8. Current-time curve in disturbance of typical three

The first circuit breaker in bus 42 has function to protect the components when the disturbance is coming. The components that protected are junction lightings in each decks, junction navigation and communication, supply fan motor, exhaust fan motor, emergency fire pump and steering gear. There is a circuit breaker under the circuit breaker 42 that is circuit breaker 44. It is serves as a protective component of the steering gear as well as a safety protection below when the circuit breaker 42 failed to secure the disturbances. The last circuit breaker that opens is circuit breaker 2. As a protective foil for the main generator and also as a safety fuse, if the circuit breaker failed to secure the underlying fault.

The result from simulation of the star protection device coordination is current-time curve in figure 9. Figure 9 shows when the motor steering gear is starting and the curve of steering gear is behind of the circuit breaker working curve. When the curve of steering gear is inrush current from the motor steering gear, it can still be attached by the third circuit breaker. Timing for the circuit breakers opening is 0.758 seconds for the circuit breaker 42; 0.91 seconds for circuit breakers 44 and 1.

IV. CONCLUSION

Implementation of coordination a circuit breaker is very useful to prevent the components or system in normal operation that was affected to components that has a disturbance like short circuit. And to minimize the components or system that has a disturbance in order to the effect of failure is not too dangerous.

Based on the result from short circuit simulation, the value of short circuit in four conditions in the ship, are 8.2 kA for sailing, 8.169 kA for maneuvering, 9.632 kA for cargo handling and the last 8.184 kA for at the port. The greatest and smallest value are affected by the number of components in the fourth of the condition is required during operation and the power needed for each electrical components.

From the next simulation is coordinating a circuit breaker. Load flow analysis is needed before coordinate the circuit breaker. It used to determine current rating in all of the circuit breakers. The sequence of circuit breakers opening are determining of the location of the disturbance, the connected which is between the disturbance area and the components that have greatest of short circuit value and also the last circuit breaker opens because the components is the biggest which is flowing the short circuit current. Generally the circuit breaker opening the last is the main component in electrical system (i.e. generator)

The simulation results with *Star-Protective Device Coordination*, it can be found for the motor starting curve behind the circuit breaker shows the starting time of the inrush current can still protect the motor during the motor start curve remains behind the working curve of the circuit breaker is closed.For components on time-current curve when the curves were intersection between other components to adjust the settings back in anticipation of the trip.When in the sailing condition, there is the intersection between the curves of generator and transformer in figure 5. From the results of plotting, the curve of transformer should be back to setting again.

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