Short Circuit Analysis on AHTS Ship Due To Use of Closed Circuit Electrical System

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Abstract. Dynamic Positioning (DP) enables a ship to automatically maintain a vessel's position and heading by using its own propellers and thrusters. The position can be kept optimally when the ship leans on the harbour with the assistance of the anchoring and mooring process. Under particular circumstances, when the ship is in the middle of the sea, both of the processes can’t be done optimally. To ensure the ship’s absolute position, the ship must have zero six degrees of motion: heave, sway, surge, roll, pitch and yaw, in which the vessel must be in absolute idle despite the wave effect. The DP is used to articulate wave force and against it by a work of mechanism and sensor in which prevents the ship’s standpoint deviates. The computer will proceed with the information, articulate a levelized thruster work, and avoid any degrees of motion from becoming non-zero. Ship equipped with this DP system generally uses split bus configuration in the electricity system, by allowing one load supplied by one independent generator to improve its reliability. However, this configuration condition had a deficiency. It is on efficiency aspect and high level of emission that caused by the power supply. With the closed bus power configuration system used in this electricity system, some generators are connected to power supply for the whole load through the main bus, when the system runs short circuit can happen. Some generator power supply pass through only one main bus with limited capacity, which can cause excessive current and burn the main bus. The heat from the main bus triggered a short circuit current.

1. Introduction
The ship maintains its position in the harbour with the help of anchor and robe on the anchoring and mooring process. Instead, both methods can't be done optimally when the ship is in the middle of the sea. There is forces from wind, wave and sea wave that can change the stable position that ship have to stay. Therefore, to overcomes those external forces that can change the ship position this dynamic positioning is used to predict where those forces work with sensor. Afterward, the computer will proceed with the information and continue to thruster or the pusher located in the back or front of the ship in order to against those forces. To maintain the ship position, the electric motor should work with loading which fluctuates significantly according to the weather when it operates. With those conditions, the dynamic positioning data will have a system failure, which will lose the power supply system's power.

The DP system ship generally uses split bus configuration, in which one load is supplied by one independent generator to improve its reliability. However, this configuration condition had a deficiency. It is on efficiently aspect and high level of emission that caused by the power supply.

With the closed bus power configuration system used in this electricity system, some generators are connected to power supply for the whole load through the main bus, when the system runs short circuit can happen. Some generator power supply pass through only one main bus with limited capacity, which can cause excessive current and burn the main bus. The heat from the main bus triggered a short circuit current.
According to the above-mentioned matter, that basis will be used to compile research about short circuit current on electricity system AHTS ship because of the use of thruster electric with matlab software simulation method.

2. Literature Review

2.1. AHTS Ship
AHTS (Anchor Handling Tug Supply) is a ship specially designed to support the operation of the offshore building system. This ship was designed to do offshore exploration work. This ship had a characteristic which has to operate in extreme environments. It has a small body of the ship, big main engines, double propeller system and some manoeuvre tools like a bow, thruster, stern thruster and azimuth thruster to maintain position in the middle of the sea. Therefore, the performance of this ship is highly considered when in the design process.

2.2. Dynamic Positioning
The main definition of dynamic positioning is a way to hold a ship into a relatively unchanged position with seabed reference, without using anchor instead using two or more propulsion which controls with instrumental input on the seabed, gyrocompass, with navigation satellite or any other way[1]. Figure 1 shows AHTS Pelangi Escort-2 Ship.

A ship with dynamic positioning (or DP) system maintains the relatives' position against the seabed. Advance technology, with many variates of positional sensor, propeller and pusher allow it to defend the natural power such as wind, wave and sea wave without an anchor.

The modern offshore industry will be not imagined without a dynamic position. DP is “possible Technology ” and connected with offshore oil and gas field’s development and operation. The dynamic positioning system of well-known control company, Kongsberg, now founded above supply ship, drilling rig, pipe and cable towing vessels, stone tugboat, tugboat, crane ship, sea hunter ship, cruise, floating hotel and cruise ship[2]. Figure 2 shows ship with dynamic positioning system

![Figure 1. AHTS Pelangi Escort-2 Ship](image-url)
2.3. Short Circuit

Short circuit disorders can be classified into symmetrical short circuit disorders and asymmetrical short circuit disorders. These disorders can be caused by overcurrent flow in the disturbing phase. Furthermore, this disorder also can be caused by voltage increase on a phase that has no interference. Almost every disorder that happens in the electric power system is asymmetrical.

The short circuit often causes overcurrent flow disorders on generators. At this moment, the generator has been made to survive against overcurrent flow, though it doesn't last long. Time delay settings of the protection should consider the surviving capability of the generator against short circuit conditions that happen in the generator [5].

As it’s known, when a short circuit happens, there are three current conditions or reactance that the generator had: subtransient, transient, and steady-state. Therefore, the current and time settings should consider those conditions. Figure 3 shows the different types of short-circuit interference.

Some short circuit current can happen in electrical installation. There are main characteristics this disorder had:

- Duration (self-extinguishing, transient, and steady-state)
- Sources: mechanical (broken off in one of the conductors, accidentally electrical contact between two conductors through external conductors, internal or atmospheric overload
- Insulation damage caused by heat, humidity, or corrosive environment
- Location: inside or outside the engine or electrical switchboard
- Phase to the ground (80% of failure)
- Phase to phase (15% of failure). This failure type is often classified as 3 phase failure[6]
- Three phases (only 5% of failure)
2.4. Matlab
Matlab is an abbreviation of Matrix Laboratory, which was firstly introduced by the University of New Mexico and the University of Stanford in 1970. Matlab can be farmed as a calculator with complete features. Matlab is like the scientific calculator, but with complete features, it can be used to program GUI-based applications and complete with a toolbox that can be used to solve science and engineering problems. Matlab provides assistance for users to find assistance provided easily with all facilities provided by Matlab. For example, help with how to start Matlab for the first time, programming tricks, creating two and 3-dimensional graphs, using data acquisition, processing, signalling, partial differential equation solving tools. In this study, the Matlab program was used for simulation by making coding programming. Simulation results are displayed in technical charts. The simulation graph is shown in 2D visualization, including plotting, chart format, and graphs in lines.

3. Result and Discussion

3.1. Manual Calculation
In this 3rd scenario, the configuration that is used is 2 of thruster generator and one diesel generator with two bow thruster load along with 60% of whole electricity load that installed in the ship. The loading variation bow thruster used in this simulation is 60%-75%, 100%-100%, and 110%-110%. This scenario is run with electricity sources on 2438 kVA, 415 kV. Table 1 shows value kVA, voltage, electric current flow scenario 3.
The value calculation impedance of every component scenario, the “E” bus is where the fault/interference happens. When it is decided the place where the fault happens, afterwards can be calculated how much the 3 phase short circuit current is the most significant short circuit current in this scenario. The value calculation impedance of every component included.

Table 2 shows several parameters used in the impedance value scenario 3 analysis. The impedance value used consist of thruster generator, bow thruster, diesel generator, and pump.

| Component                                      | R     | X     | Z = R + jX   |
|------------------------------------------------|-------|-------|--------------|
| Thruster generator 1                          | 0,005666 | 0,009444 | 0,005666 + j 0,009444 |
| \( X_g = \frac{5,483 \times (0,415 \times 10^3)^2}{100 \times 1 \times 10^6} \) |       |       |              |
| R/X=0,6, %PF = 0,8, R=3,29%                  |       |       |              |
| Thruster generator 2                          | 0,005666 | 0,009444 | 0,005666 + j 0,009444 |
| \( X_g = \frac{5,483 \times (0,415 \times 10^3)^2}{100 \times 1 \times 10^6} \) |       |       |              |
| R/X=0,6, %PF = 0,8, R=3,29%                  |       |       |              |
| Bow Thruster 1                                | 0,009629 | 0,024899 | 0,009629 + j 0,024899 |
| \( X_m = 7,44/746 \) x 415/(690,1 \times 100) \) |       |       |              |
| R/X=0,39, %PF= 92,22, R=2,88%                |       |       |              |
| Bow Thruster 2                                | 0,009629 | 0,024899 | 0,009629 + j 0,024899 |
| \( X_m = 7,44/746 \) x 415/(690,1 \times 100) \) |       |       |              |
| R/X=0,39, %PF= 92,22, R=2,88%                |       |       |              |
### Table 2. Impedance value scenario 3 (continued)

| Component                                | R           | X           | Z = R + jX    |
|------------------------------------------|-------------|-------------|---------------|
| Diesel generator 1                       | 0.012937    | 0.021561    | 0.012937 + j 0.021561 |
| F.W Pressure Pump                        | 32,28701    | 54,9149     | 32,28701 + j 54,9149 |
| S.W Pressure Pump                        | 32,28701    | 54,9149     | 32,28701 + j 54,9149 |
| B/T S.W Cooling Pump                     | 38,53217    | 64,99287    | 38,53217 + j 64,99287 |
| Misc. Vent Fan Load                      | 0,627941    | 1,371329    | 0,627941 + j 1,371329 |
| D.M Pwr pack 1/2                         | 0.121393    | 0.309001    | 0.121393 + j 0.309001 |
| D.M Pwr pack 2/2                         | 0.121393    | 0.309001    | 0.121393 + j 0.309001 |
| E.R Vent Fan 1                           | 1,536128    | 3,132427    | 1,536128 + j 3,132427 |
| Bilge Pump                               | 7,169552    | 13,22499    | 7,169552 + j 13,22499 |
| F.O Separator                            | 6,142833    | 11,43307    | 6,142833 + j 11,43307 |
| G.S/Fire Pump                            | 6,862345    | 12,69103    | 6,862345 + j 12,69103 |
| D.M Pwr Pack Pilot Motor                 | 2,691323    | 5,27755     | 2,691323 + j 5,27755 |
| CPP Hyd. Pack (P)                        | 2,74543     | 5,376545    | 2,74543 + j 5,376545 |
| Hyd. Pack, Karm Fork                     | 1,911293    | 3,836904    | 1,911293 + j 3,836904 |
| F.O TRF Pump                             | 38,53217    | 64,99287    | 38,53217 + j 64,99287 |
| S/G Room Vent.                           | 21,7366     | 37,71396    | 21,7366 + j 37,71396 |
| Sludge Pump                              | 47,27535    | 78,9504     | 47,27535 + j 78,9504 |
| Deck Crane                               | 1,940233    | 3,890295    | 1,940233 + j 3,890295 |
| Bilge Water Separator                    | 17,4548     | 30,63449    | 17,4548 + j 30,63449 |
| A.C Cooling Pump Starter                 | 1,332937    | 2,746137    | 1,332937 + j 2,746137 |
| CPP Hyd. Pack (S)                        | 2,74543     | 5,376545    | 2,74543 + j 5,376545 |

Selain nilai impedansi pada jaringan, pada proses analisa ini juga dibutuhkan parameter pembebanan sesuai dengan skenario aktualnya. Pembebanan ini meliputi pembebanan antara tiap cabang jaringan. Table shows 3. Impedance branch value scenario 3.
Table 3. Impedance branch value scenario 3

| Branch                      | R    | X    |
|-----------------------------|------|------|
| Branch 60% load             | 0,044564 | 0,106114 |
| Branch 60% load +DG1        | 0,010026 | 0,01792 |
| (Branch 60% load+DG1)+TG2   | 0,00362 | 0,006184 |
| (Branch 60% load+DG1)+TG2+TG1 | 0,002209 | 0,003737 |
| (Branch 60% load+DG1+TG2+TG1)+BT1+BT2 | 0,021467 | 0,053536 |
| Total                       | 0,021467 | 0,053536 |

The two parameters shown in table 2 and table 3 are then calculated by the equation below. The equation consists of calculating the resistance and impedance of the network to get the value of I"k3

\[
Z_{net} = \sqrt{R^2 + X^2}
\]

\[
I"k3 = \frac{(c Un)}{\sqrt{3} \times Z_{sc}}
\] with \(c = 1,1\) for 10% tolerance

\[
I"k3 = \frac{(1,1 \times 415)}{\sqrt{3} \times 0,057679071}
\]

\[
I"k3 = 4569,428607 \text{ A}
\]

\[
I"k3 = 4,569428607 \text{ kA}
\]

3.2. Simulation Result

According to Ismail Kasikci's research about the analysis of short circuit current on low voltage with IEC 60909 standard calculation, 3 phase short circuit current will happen when the creation of 3 phase short circuit current or maximal short circuit current is created 9 kA or 9.000 A [3].

For this 1st scenario, the value of 3 phase short circuit current on 110% bow thruster loading as the biggest value of this scenario is 7,741 A or 7.741 kA. This value is still under the standard of the occurrence of a low voltage short circuit. For the value short circuit current on bow thruster loading under 110%, Those are also still under standard of the occurrence 3 phase short circuit current on low voltage. Figure 5 shows 1st simulation scenario charts (2 generator thruster with load two bow thruster configuration)

![Figure 5](image_url)

Figure 5. 1st simulation scenario charts (2 generator thruster with load two bow thruster configuration)

In this 2nd scenario, the value of 3 phase short circuit current on 100% bow thruster loading as the biggest value of this scenario is 10,858 A. This value is above the occurrence short circuit low voltage
standard, which is 9.030 A. Even on the 74% bow thruster loading, the 3 phase short circuit current is reaching the highest standard, 9,030 or 9.03 kA. For the value of short circuit current under 74% bow thruster loading, everything is under the standards of the occurrence of 3 phase short circuit current low voltage. Figure 6 shows 2nd simulation scenario charts (1 generator thruster with two bow thruster load configurations)

![Graph](image)

**Figure 6.** 2nd simulation scenario charts (1 generator thruster with two bow thruster load configurations)

For this 3rd scenario, the value of 3 phase short circuit current on 110% bow thruster loading as the biggest value on this scenario is 4,989 A or 4.989 kA. Those values are still under the standard the occurrence of short circuit current low voltage, which 9,000 A or 9,0 kA. For the value of short circuit current under 110% bow thruster loading, everything is still under the standards of the occurrence of 3 phase short circuit current low voltage. Figure 7 shows 3rd simulation scenario charts (2 generators thruster dan one diesel generator with two bow thruster load along with 60% shipload configuration)

![Graph](image)

**Figure 7.** 3rd simulation scenario charts (2 generators thruster dan one diesel generator with two bow thruster load along with 60% shipload configuration)

Instead, in the 4th scenario, the value of 3 phase short circuit current on 110% bow thruster loading as the biggest value of this scenario is 8.150 A or 8,15 kA. Those values are still under the standard the occurrence of short circuit current low voltage, which is 9,000 A. For the short circuit current value
under 110% bow thruster loading, everything is standard for the occurrence of 3 phase short circuit current low voltage. Figure 8 shows 4th simulation scenario charts (2 generator thruster and two diesel generators with two bow thruster loads along with 60% shiploads configuration).

![Figure 8](image8.png)

**Figure 8.** 4th simulation scenario charts (2 generator thruster and two diesel generators with two bow thruster loads along with 60% shiploads configuration)

On this 5th scenario, the value of 3 phase short circuit current on 85% bow thruster loading as the biggest value of this scenario is 10.580 A atau 10.58 kA. Those value above the standards the occurrence of short circuit current low voltage which 9.000 A atau 9.0 kA. For the value of short circuit current under 75% bow thruster loading as the lowest variation of loading, the values that 3 phase short circuit current made already above standard the occurrence 3 phase short circuit current low voltage. Therefore, on this 5th scenario, whole variation loading on this scenario from 75%-85% had 3 phase short circuit interference/fault. Figure 9 shows 5th simulation scenario charts (1 generator thruster dan 2 diesel generator with 2 bow thruster load along with 60% ship load).

![Figure 9](image9.png)

**Figure 9.** 5th simulation scenario charts (1 generator thruster dan 2 diesel generator with 2 bow thruster load along with 60% ship load)
3.3. Overcome short circuit on AHTS ship

3.3.1. Operate the bow thruster on the scenario and loading variation under the standard of the occurrence of 3 phase short circuit current. For the second scenario, which the electricity system configuration that uses is one thruster generator with two bow thruster loads, the safe loading variation in running is variation loading <74%. On this 74% load, according to the simulation charts made in figure 19a, the 3 phase short circuit current value made is 9.03 kA. That value has exceeded the standard limit of the occurrence short circuit current, which 9 kA. For example, the operation of the 2nd scenario under 74% loading variation bow thruster, if the 2nd scenario has 60% loading variation, the 3 phase short circuit current made is only 7.95 kA. Certainly, this value is safe because of the standard. Instead, in the 2nd scenario run on 80% loading variation bow thruster, the 3 phase short circuit current that made are 9.549 kA, which the values passed the fault current standard.

In the 5th scenario, the electricity system configuration uses one generator thruster, two diesel generators with two bow thruster loads and 60% ship loading. The loading variation bow thruster that is safe to operate is under <62.5% (can be seen in Figure 23a). On 62.5% loading variation, according to the simulation charts that had been made, the 3 phase short circuit current values that made are 9.07 kA. That value has exceeded the standard limit of the occurrence 3 phase short circuit current, which is 9 kA[3]. For example, if the 5th scenario runs with 60% loading variation, the 3 phase short circuit current made is only 8.82 kA. Indeed, this value is safe because of the standard.

3.3.2. Insulation repair. On 3 phase short circuit current that happened in the electricity system, one of the reasons the fault often happened is the reduced performance of conductor wire insulators. When the conductor wire insulator had the thickness thinning or exfoliating because overwritten by objects, stretched, or animal bites, the performance is reduced even can cause the 2 of conductors connected, which made short circuit current. Therefore, the right choice of insulator should be adjusted to withstand the short circuit current that will happen. The thickness of the insulator conductor affects the insulator power that can penetrate by fault current on several values.

Suppose we have some short circuit current fault values “x”, then when choosing insulator and wire conductors should have the specification that can hold the fault current under >”x” value. Furthermore, the material type used on insulator production affected how much temperature that insulator can minimize the negative impact when the fault happened.

4. Conclusion

According to the simulation, 2nd scenario, and 5th scenario had 3 phase short circuit fault. On 2nd scenario, with 1 thruster generator and 2 bow thruster load configuration, short circuit current fault happened on 74% until 100% loading variation with 9.03 kA until 10.85 kA values of 3 phase short circuit current.

On the 5th scenario, with one thruster generator and two bow thruster loads with 60% shiploads, 3 phase short circuit current happened to start from 62.5% until 85% loading variation, with 3 phase short circuit current values on 9.023 kA until 10.58 kA.

To overcome the occurrence of 3 phase short circuit current on electricity operation AHTS ship can be done by operating 2nd and 5th scenario that known had loading variation with 3 phase short circuit current values over the standard of the occurrence 3 phase short circuit, on safe loading variation or had 3 phase short circuit current value under standard.

In 2nd scenario, it can be operated on <74% bow thruster loading variation. Instead, the 5th scenario can be performed on <62.5% bow thruster loading variation so the fault can be resisted.
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