Comparison of voltage drop in AC and DC shipboard electrical power distribution systems: A case study of 17,500 DWT tanker vessel

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Abstract. The recent emergence of power electronics equipment raises the possibility of implementation of DC shipboard electrical distribution systems. Several investigations on the effectiveness of DC shipboard electrical power distribution systems have proven that it is more profitable than AC distribution systems both in technical and economical aspect. However, known investigations are still limited to the system in ship with electric propulsion, which the consumption of electric power is enormous. The current study investigates the technical performance of both distribution systems in a non-electric propulsion ship, especially in the aspect of power losses. Both of the original AC distribution systems in a 17,500 DWT tanker ship and its equal DC distribution systems are modelled in a computer simulation program. The electric power flow simulation for both models are performed with the data of electric load during operating conditions, to compare the power losses in the distribution systems. The results show that the DC distribution systems has fewer drop voltage than its AC counterpart.

1. Introduction

Oil tanker is a ship used to transport liquids from one place to another. The use of tankers today has become very common and very easy to find anywhere. Tankers are distinguished based on the cargo carried in them, whether crude oil, product oil, or chemical. In order to support activities related to tankers, both when sailing and when loading and unloading, various components are needed. The use of each of these components requires a large amount of electricity. As the electricity in the ship is provided by diesel-powered generator, the efficient use of electricity is required. One of the possible methods to increase the efficiency of electrical system in ship is by reconfigure the distribution systems [1].

In the distribution of electricity, the distribution system is an important part of distributing electrical energy to consumers. Electrical energy produced by conventional generators requires a transmission and distribution system so that electric power can meet the needs of the load. The distribution system is tasked with dividing electric power to several load centers through substations and connecting substations [2].

There are two methods that have been proven to increase the efficiency of the electrical system on ships, namely reconfiguration from a radial alternating current (AC) distribution system to a zonal AC system [3,4], or replacing the electricity distribution system from an AC system to a direct current
The use of an AC electrical distribution system has become a common thing used in on-board power systems on ships. At present the field of power electronics has progressed with the introduction of a DC (Direct Current) electricity distribution system in several activities on board. Several activities have started to be used on merchant ships. However, the use of the DC distribution system has not been widely used on commercial vessels.

The use of AC electricity has several advantages and disadvantages, one of the drawbacks is that it has a frequency so that it will produce a higher impedance (Z) value than DC electricity. The impedance value in AC electricity consists of several aspects other than the resistance value (R) which has a reactance value which is influenced by the magnitude of the inductance (L) and capacitance (C) values [9]. The reactance value will only appear on AC power because the reactance value is strongly influenced by the frequency value (f) owned by AC power [10].

In order to reduce the impedance value of the electrical distribution system on the ship, it is necessary to reconfigure the electricity distribution system on the tanker from AC to DC. With the reconfiguration of the system from AC to DC, the impedance value of the system will decrease because there is only resistance (R). As a result of the impedance value dropping, the value of the voltage drop and power loss will also decrease.

2. Method

2.1. Collecting vessel data
Collecting primary data from the research object of the final project, especially in the case of power flow studies and voltage drop analysis as a result of reconfiguring the AC to DC distribution system on this simulation-based tanker, some of the data obtained, including data on electrical equipment specifications on tanker vessel and data of single-line diagram of the ship.

2.2. Modeling AC distribution system
At this stage, after obtaining accurate data related to the single-line diagram on the tanker, the AC single-line diagram data will be modeled on a simulation software application. However, later it will be changed to a DC distribution system based on an AC circuit that has been made by adding the necessary components in DC electricity distribution. The generator section of the single line diagram is shown in Figure 1.

2.3. Modeling DC distribution system
At this stage, changes are made to the single-line diagram of the tanker electricity distribution system from initially using an AC distribution system to a DC distribution system by adding converter components such as inverters and rectifiers, both AC distribution systems. The generator section of the single line diagram is shown in Figure 2.
2.4. Simulation and data analysis

In the simulation stage, a single-line diagram of the tanker's electrical system will be run on simulation software using an AC distribution system which will be compared with a DC distribution system related to the power flow and voltage drop.

At this stage, after the data for each simulation is recorded, then the simulation data is matched or validated with the applicable rules or standards (IEEE and IEC standards). In addition, if the simulated electrical system does not meet the requirements, improvement efforts will be made which will also be discussed at this stage. At this stage, a comparison is also made between the simulation results on the AC distribution system and on the DC distribution systems.

3. Results and discussion

In this section, it will be explained related to the study of power flow and analysis of the voltage drop on the electricity distribution system on tankers. The process of working on this final project is carried out in various steps, starting with searching for data related to tankers that will be used in this research process. Followed by making a single line diagram using simulation software on the AC distribution system according to the available data, there are no changes related to the specifications of the components in the distribution system.

When the single line diagram modeling has been completed, it will be continued with a power flow simulation or load flow to determine the active, reactive, and voltage drops for each bus or every device in the system.

Based on the results of the power flow simulation per condition that has been carried out, then recap all the existing voltage drop values that are read in the system in the simulation software. The simulation is carried out in 4 conditions, namely, sailing, leaving-arriving, at port, cargo loading-unloading. Among them, loading unloading requires the greatest power. Data retrieval from the simulation results is carried out on each bus that has been modeled in the simulation software and presented in Table 1.

Figure 2. Single line diagram of DC system
Table 1. Drop voltage on loading-unloading condition

| No | Bus Group                                      | V  | Vd-Bus AC | Vd-Bus DC |
|----|-----------------------------------------------|----|-----------|-----------|
| 1  | Floor No. 1                                   | 450| 0.23%     | 0.02%     |
| 2  | Vacuum Pump                                    | 450| 0.64%     | 0.10%     |
| 3  | No. 1 DB E/R DB Purifier (MSB 450 V No. 1)    | 450| -         | -         |
| 4  | E/R 2nd Deck No. 1                            | 450| 0.11%     | 0.00%     |
| 5  | Sewage Treatment PLan                         | 450| 0.12%     | 0.02%     |
| 6  | No. 2 DB E/R DB Workshop (MSB 450 V No. 1)    | 450| 0.15%     | 0.68%     |
| 7  | E/R 3rd Deck No. 1                            | 450| 0.12%     | 0.02%     |
| 8  | Fresh Water Hyd.                              | 450| 0.75%     | 0.74%     |
| 9  | GSP 1                                         | 450| 0.11%     | 0.02%     |
| 10 | Incenator                                     | 450| -         | -         |
| 11 | Accomodation Vent. Fan                        | 450| 0.49%     | 0.31%     |
| 12 | Upper Deck No. 1                              | 450| 0.11%     | 0.00%     |
| 13 | Hyd. Control Valve                            | 450| 0.49%     | 0.54%     |
| 14 | Air Condition Plant                           | 450| 0.36%     | 0.21%     |
| 15 | Provision Crane                                | 450| 0.34%     | 0.08%     |

Based on the simulation results above, it can be seen that the voltage drop value for each bus still meets the IEC standard, which is +/- 5%. However, some components also have a fairly large voltage drop when compared to others, namely the load on certain buses, especially those that use 220V voltage. On some buses also do not have a voltage drop value because in the loading-unloading condition there is no device that operates like the Incenator. The value of the voltage drop on each bus has decreased when compared to the AC distribution system. The decrease occurs because the DC distribution system does not have a frequency value so that it does not cause a resistance value that causes the voltage drop to drop.

4. Conclusion

As a result of reconfiguring the AC power distribution system into DC the value of the voltage drop for each bus in the distribution system becomes smaller and the value of the voltage drop always has a value below the standard specified by IEC 5%. The drop in voltage drop is influenced by changes in the distribution system from AC to DC, because also the DC distribution system does not have a frequency value so that it can reduce the value of the voltage drop in the distribution system. Based on this research, some suggestions are given which can later support further research related to this research. If there is research that will discuss the reconfiguration of the distribution system, it should be tried using other simulation software. Preferably in the process of selecting electronic components, it should be based on the actual specifications on the market, bus grouping as much as possible is done with load groups that are on the same floor or floor.

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