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Electric Power System Design and Analysis for Drilling Rigs

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Abstract : As electricity has been used in ship's propulsion, it is necessary to increase the system voltage and current for the electrical distribution system. So it is required to improve the system safety and efficiency, the power stability, the efficiency of the generation through various analysis of ship's electric power system. In this paper, the electrical service reliability of the power distribution system of semi submersible drilling rigs has been analysed and discussed using ETAP.

Key words : Electric propulsion ship, ETAP (Electrical Transient Analyzer Program), Drilling rig

1. Introduction

The interest of the off-shore plants in the deepwater drilling has been rising up because of the increase of oil price and the exhaustion of offshore oil and gas throughout the world. Now that it costs much more than hundreds of billion dollars, even trillions of dollars, to design and build one, these types of huge marine facilities require high-quality reliability, durability and safety with technology-intensive basis.

In the case of Semi Submersible Drill Rigs (SSDR) that are being used in most of the deepwater drilling operations, Korean major shipyards have excellent construction technology to occupy more than 60% of the whole shipbuilding orders received. SSDRs can move by thrusters with Dynamic Positioning System (DP), and has equipped a drilling packages like pumps, pipes and drills. It also has living quarter for crew on board. The electrical distribution system of Drilling Rigs is quite similar to typical redundancy system of electric propulsion ships made for transportation. However it is required the electrical distribution system of 2 to 4 split bus or more because of the severe marine environment, the hazards of fire and explosion, 24-hours operation, the standards and regulations related to oil and gas drilling. In this paper, to verify the stability of designed power system, the power system of SSDRs is modeled at first and load flow is analysed on each operational mode. On the basis of the analysis the voltage variation in the distribution feeder is discussed.

2. The Structure of SSDRs

The basic structure of SSDRs is mostly divided into three parts. It can control the movement and positioning of the plant using 4-8 thrusters located at the both ends of pontoons under water. And

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drilling packages in the middle of the upper deck has digging and drilling outfits. It also has a living quarter for workers.

Contrary to industrial power system on land, off-shore plant's electric power system has different aspects of electrically stand-alone system, frequent starting and stopping of large consumers such as thrusters and drilling rig, voltage sensitivity due to the faults, harmonic distortion derived from the rectifier, inverter and variable speed drive.

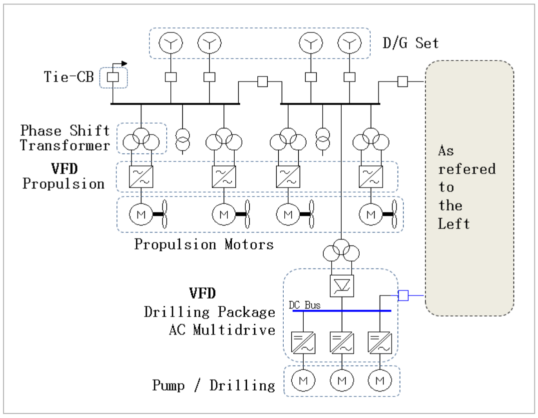

Figure 1: Typical electrical power system for semi submersibles

The distance is shorter between the power and the load in the off-shore plant and it is a concentrated load that flows a large current in a short time. The systematic capacitance caused by the cross section of the thicker power cable is growing bigger. So it should be considered switching voltages and insulation break of the electric system.

The electrical power distribution system in SSDRs (**Figure 1**) is generally composed of a 4-split high voltage buses and has 2 thrusters per one HV bus. An entire system's fail can be prevented by distributed generators and thrusters on 4-split buses in an accident.

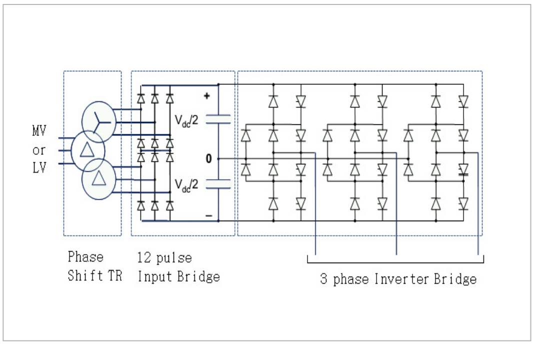

Figure 2: 12-pulse Variable Frequency Drive

2.1 Modeling of Electrical Power system

The modeling of electrical power system is based on operation mode(**Table 1**) and load profile(**Table 2**).

Table 1: Operation mode

Type	Transit + 1/2 DP	Drilling + 1/2 DP	Drilling + 3/4 DP	Back Reaming + 3/4 DP
Total Load	19790	27636	35780	34806
Generator	34668	34668	46224	46224
No. of Gen.	6	6	8	8
% Load	57	80	77	75
* DP : Dynamic Positioning, unit : kVA				

The generator capacity is calculated by considering the expecting maximum load of operation mode, design life of the off-shore plant and future load.

Table 2: Load profile(unit : KVA)

Type	Transit + 1/2 DP	Drilling + 1/2 DP	Drilling + 3/4 DP	Back Reaming + 3/4DP
Service Load	6222	8818	8818	9044
Drilling Load	0	5250	5250	4050
Thruster	13568	13568	21712	21712

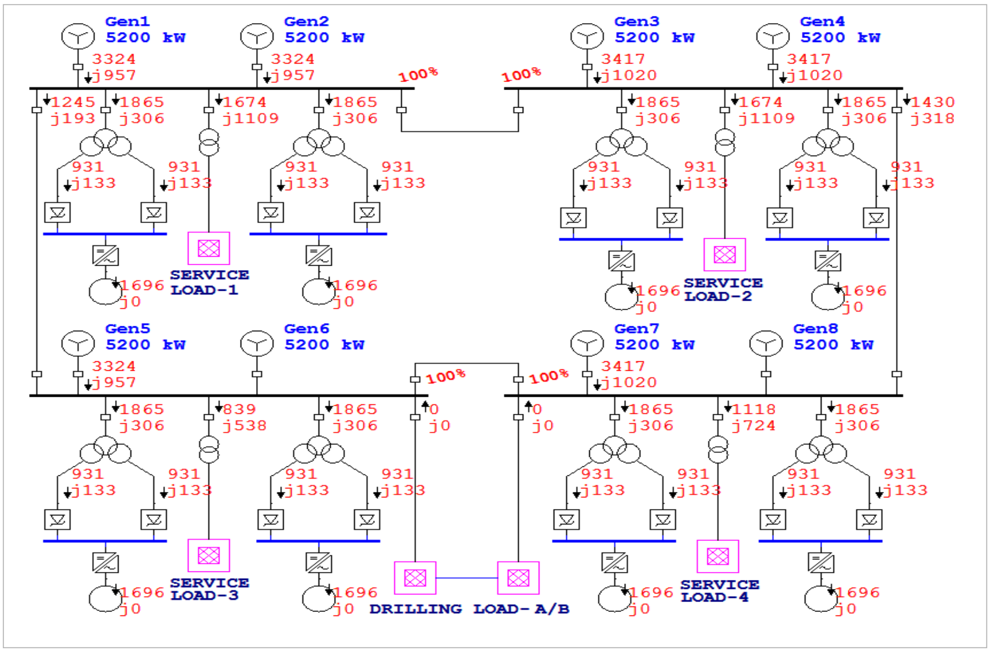

Figure 3: Load flow analysis result of minimum load

The load profile is shown in **Table 2** and the diagram of electrical power system in **Figure 3**. The load composition ratio based on its maximum value is 25.1% of service load, 60.3% of propulsion load, 14.6% of drilling load respectively. As a result it has 22% margin in generating capacity with the total load of 78%.

3. Load Flow Analysis

3.1 Minimum load flow analysis

In transition mode, a generator has a 57% loading of its rated kVA which is composed of minimum propulsion load and service load.

Table 3: The result of minimum load flow analysis

Type	Result	Remarks
Load	3294.5 kVA	57%
Generator	5778 kVA	43% margin
Voltage drop	674 Vac	97.7%

The generator has 5778 kVA generating capacity and the load flow moves from the generator to load nomally. In addition, the voltage drop of service feeder is allowable within 97.7% of rated voltage 690V. The analysis result of load flow in minimum load running is shown in **Figure 3**.

3.2 Maximum load flow analysis

The maximum load occurs when the drilling packages and DP thruster load should be operated at the sametime.

Operating in maximum load, 4449.1 kVA is loaded and it makes all 8 generators running. There is still 23% extra margin in the generating capacity, which can be used in the worst situation. **Table 4** shows the load and generator margin and voltage drop of feeders.

Drilling TR provides an redundancy and one transformer will take all the drilling loads in emergency.

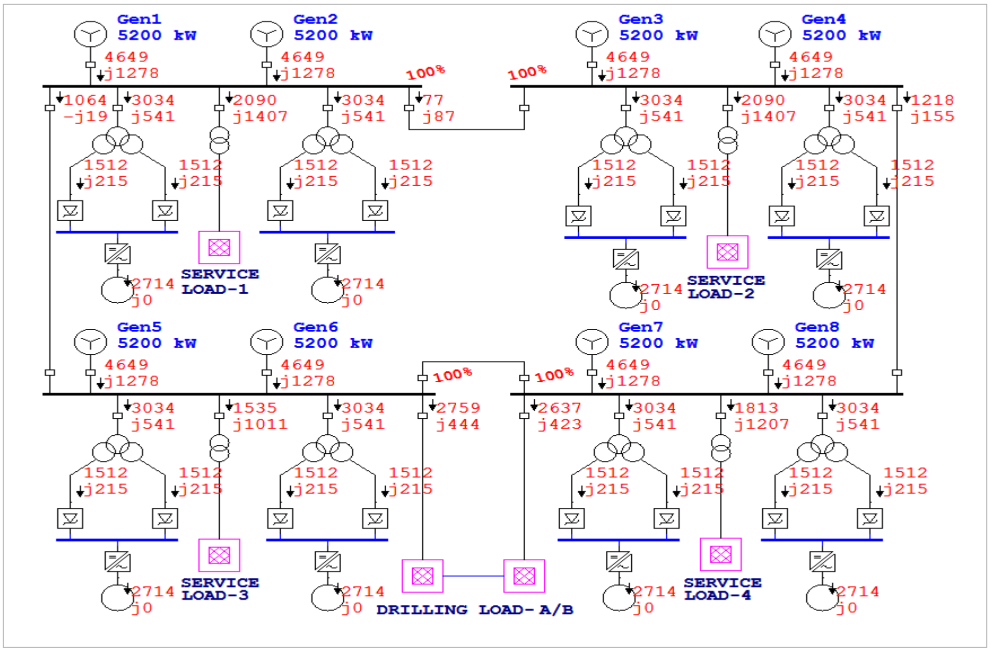

Figure 4: Load flow analysis result of maximum load

Table 4: The result of maximum load flow analysis

Type	Result	Remarks
Load	4449.1 kVA	77%
Generator	5778 kVA	23% margin
Voltage drop	669.9 Vac	97.1%

Table 5: Electrical Equipment's load profile

Type	Load(%)	Margin(%)
Service TR	55.7 ~ 76.4	25.6
Drill TR	46.6 ~ 44.5	53.4
Propulsion TR	81.1	18.9
Generator	77	23

The feeder voltage drop of low voltage service load is 97.1% within the permissible limit.

The running load of the propulsion transformer is 81.1%, which has about 19% margin to the full load and the service TR also has an appropriate load margin of 25.6%. It has enough margin and is allowable level of voltage drop under the maximum load condition in electric power system, consequently, the designed electrical power system is acceptable. **Table 5** shows the load and margin in percent by the electrical equipment

And the specification of equipment is shown in **Table 6**. It can be operated with the higher efficiency and will be operating at high power factor due to the 12-pulse rectifiers, VFDs (Variable Frequency Drive) and 3-winding phase shift transformers to drive a propulsion motor.

Table 6: Electrical Equipment's specifications

Type	Specification
Generator	5778kVA 11kV P.F=0.9 8poles 900rpm
VFD	4600kVA 690VAC
Charger	AC 690V/DC690V 1900kWDC I_n= 2754A
Transformer	1. Propulsion TR 3800/1600/1600kVA %Z=8 11/0.69/0.69kV 2. Service TR 11/0.69kV 3300kVA
Propulsion Motor	3200kW 690V 10poles 720rpm Efficiency = 94.3%

3.3 Short circuit analysis

The high voltage bus feeder of a drilling rig is sectionized in 4 buses and these buses are connected in open-ring topology.

Table 7: Condition for Short circuit analysis

Type	Condition	Remarks
Standard	ANSI C37.010-1999	related class rules
Prefault Voltage	100% Nominal kV	11kV
Contribution level	1	level
Motor Contribution	Based on Motor status	exclude VFD

Depending on the operation mode, it could be configured in a various ways, for example, the isolated operation mode that each bus is seperated electrically to the others.

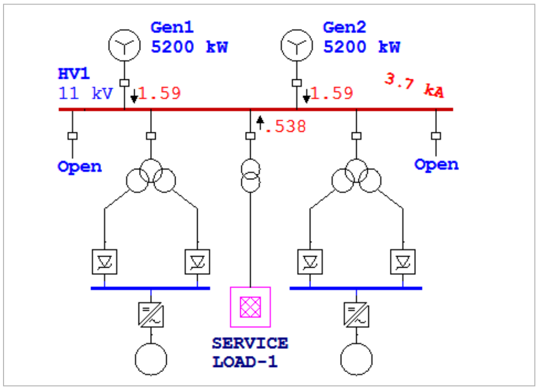

Figure 5: HV1 fault current

The fault current of a bus that is connected with the others will be much greater than the fault current of a bus which is isolated electrically from the others. So the rating of the bus and Tie-CB must be considered the short-circuit current of the entire electrical power system respectively.

The conditions to analyze the short-circuit current are shown in **Table 8** and the short-circuit analysis results of the isolated high-voltage bus feeder HV1 are also shown in **Table 8** and **Figure 5**.

Table 8: Short circuit current of Feeder HV1

Type	1/2 Cycle	1.5~4 Cycle
Generator	3.188	3.188
Service load	0.538	0.238
Total	3.705	3.414
(unit : kA Symm.rms)		

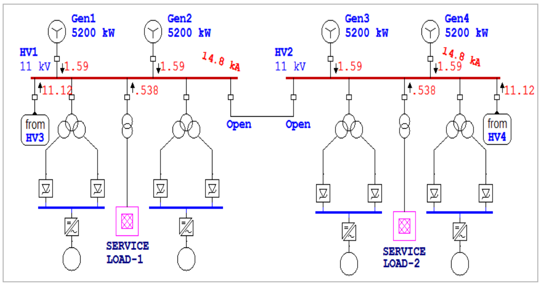

Figure 6: Total fault current of all HV buses

The total amount of short-circuit current of generators and service load is 3.705 (kA Symm. rms) in the first 1/2 Cycle. As shown in the Table 8, it is certain that the short-circuit current by service load is decreased gradually in the 1.5~4 Cycle.

Besides the fault current through the Tie-CB is 11.12kA in associated operation mode. It is large enough current that is compared with the fault current of HV1 bus in isolated operation mode. As shown in **Table 9** and **Figure 6**, the high voltage bus rating should be considered 14.8kA for the total fault current of all 4 HV buses.

Table 9: Total fault current of all HV buses

Type	1/2 Cycle	1.5~4 Cycle
Generator	3.188	3.188
Service load	0.538	0.238
HV3 bus	11.116	10.242
Total	14.822	13.656
(unit : kA Symm.rms)		

4. Conclusion

In this paper, the electrical power system of drilling rigs has been discussed with 2 operation mode which has the minimum and maximum system load. Load flow analysis, voltage drop and short-circuit current analysis have also been performed.

The voltage drop of high voltage and low voltage bus is within the permission limit at minimum and maximum load. And the load flow analysis shows the resonable result with appropriate load distribution. The capacity of generators and transformers is enough to feed the maximum load and has an acceptable margin for future load and emergency load.

There are some more difficulties in design and engineering of the off-shore plants electric power system because it is required more severe and strict conditions.

It will be necessary to study and research on harmonic analysis, load analysis and transient characteristics due to start/stop action between generators and loads, in the future.

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