Development of Power Management System for Electric Power Generation in Tanker Ship Based on Simulation

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***Abstract*—power management system (PMS) for electric power generation in ship especially on tanker ship keeps growing. The system has a function to control and monitor all generators in ship as the main electricity supplier for all electric equipments or installed load. The number of total load that supplied by generator depends on the frequency of the load itself which would be read in PMS as well. It help the operator to make a decision about how many generator should be operate whether in parralel or in a stand alone operation to fulfill the required power. Those loads should be grouped into essential and non-essential load. This groups affecting the performance of the generators, where it will covers the maximum load at 306.67 kw under the condition of all electric equipments are well operated while the cargo handling of tanker ship is on process. However, in the state of emergency while the non essential electrical equipments are being cut off trough PMS, the generator will only covers the the maximum load at 253.88 kw to fulfilling the same required power. In the extreme case (total efficiency of parralel operation at 70%), the generators would cover the total load at 306.6 kw by sparing the generate power of 52.72 kw.**

Keywords—essential load, generator, non essential load, power management, total load

I. INTRODUCTION

Maritime industry keeps evolve based on the market needs. These condition help the maritime professionals to develop some standard about an applied technology development on the ship. In order to meet the requirement on the ship, nowadays it needs a modern supporting system so the crew could work efficiently. One of the alternatives for making the crew work more efficient is by applying an automation system in the ship supporting system [1]. Those could help decrease the work of the crew. Those automation could be applied on all supporting system on the ships, especially on the electrical system [2].

Electrical system is divided into a few categories. First category is the main support system because most of the equipment that used in the system needs an electrical power in order to operate as its function [9]. Basically those equipment is controlled from a main controller or control panel in the engine control room [10]. Other than controlling function, the control panel also have a monitoring function.

Operational system of the control panel usually done manually by engine control room crew [3]. These work require a special monitoring on the electrical system, for example if there is a sudden increase of the current on one of its load, then the total load for starting will be increase as well.

Those addition load could resulted a blackout condition, and for restarting the generator it will need more operational cost.

To anticipate that, when the load is rising the crew needs to make a sudden decision to cut some installed load. Those cutting process is based on a priority from the computer. If those process is done automatically then it is named *power management system* (PMS) [4].

PMS for ship power plant is one of the system that have a function to control and monitor all the generator as main power source of all electrical equipment in the ship [5]. Electrical equipment in this case is called *load* and through the PMS the operational load will be grouped and will be prioritized based on the ability of the generator [6]. In a certain condition, these *load* needs to be cut immediately if needed so the generator won't have a *trip*.

II. METHOD

A. Data Collection

These are the main dimension and all electrical equipment that used in these research:

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TABLE 1.
ALL ELECTRICAL EQUIPMENT

No.	Equipment	Ʃ (Unit)	Power (kW)
	MACHINERY PART		
A.	**ENGINE SERVICE**		
1	HFO – MDO Transfer Pump (380 V: Δ : 3Ph; 50 Hz)	2	2.2
2	Separator + Feed Pump Pump (380 V: Δ : 3Ph; 50 Hz)	2	2.31
3	Fuel Feed Pump (380 V: Δ : 3Ph; 50 Hz)	2	2.31
4	HFO Circulating Pump (380 V: Δ : 3Ph; 50 Hz)	2	9.1
5	MDO Circulating Pump (380 V: Δ : 3Ph; 50 Hz)	1	7.5
6	Thermal Oil Boiler Circ. Pump (380 V: Δ : 3Ph; 50 Hz)	1	11.2
7	LO. Transfer Pump (380 V: Δ : 3Ph; 50 Hz)	2	2.2
8	LO Separator (380 V: Δ : 3Ph; 50 Hz)	2	5.5
9	LO Separator Feed Pump (380 V: Δ : 3Ph; 50 Hz)	2	0.75
10	Separator Preheater (380 V: Δ : 3Ph; 50 Hz)	2	12
11	LO Pump (Stand By) (380 V: Δ : 3Ph; 50 Hz)	2	2.7
12	Pre LO Pump (380 V: Δ : 3Ph; 50 Hz)	1	11
13	Air Compressor (380 V: Δ : 3Ph; 50 Hz)	2	1.7
14	SW Cooling Pump (380 V: Δ : 3Ph; 50 Hz)	2	15
15	Stand By Circulating Pump HT (380 V: Δ : 3Ph; 50 Hz)	1	18.5
16	Stand By Circulating Pump LT (380 V: Δ : 3Ph; 50 Hz)	1	8.5
17	Circulating Pump for Preheater (380 V: Δ : 3Ph; 50 Hz)	1	5.5
18	Circulating Pump for Evaporator (380 V: Δ : 3Ph; 50 Hz)	1	2.2
19	Drain Tank Pump (380 V: Δ : 3Ph; 50 Hz)	1	2.2
B.	**GENERAL SERVICE**		
1	Bilge Pump (380 V: Δ : 3Ph; 50 Hz)	1	7.5
2	Oily Water Pump (380 V: Δ : 3Ph; 50 Hz)	1	2
3	Oily Water Separator (380 V: Δ : 3Ph; 50 Hz)	1	2.5
4	Fire Pump (380 V: Δ : 3Ph; 50 Hz)	1	30
5	Ballast Pup (380 V: Δ : 3Ph; 50 Hz)	1	5
6	Ballast – Bilge Pump (380 V: Δ : 3Ph; 50 Hz)	1	5
7	Hydrophore FW (380 V: Δ : 3Ph; 50 Hz)	1	2.2
8	Hydrophore SW (380 V: Δ : 3Ph; 50 Hz)	1	2.2
9	Sewage Treatment Plant (380 V: Δ : 3Ph; 50 Hz)	1	1.5
C.	**HULL PART**		
1	Cargo Pump (380 V: Δ : 3Ph; 50 Hz)	2	75
2	Stripping Pump (380 V: Δ : 3Ph; 50 Hz)	1	4
3	Crane For Tanker (380 V: Δ : 3Ph; 50 Hz)	1	30
4	Crane for Provision (380 V: Δ : 3Ph; 50 Hz)	1	6
5	Fan for E/R (380 V: Δ : 3Ph; 50 Hz)	1	44.76
6	Accomdation Ladder Winch (220 V; 1 Ph; 50 Hz)	2	2.2
7	Steering Gear (380 V: Δ : 3Ph; 50 Hz)	1	5.5
8	Anchor Mooring Winch (380 V: Δ : 3Ph; 50 Hz)	2	40
9	Capstan (380 V: Δ : 3Ph; 50 Hz)	2	18

TABLE 2.
SHIP DATA

Ship Type = Product oil carrier	Main Generator:
Name of the Ship = MV. Pratiwi	Brand = Cummins
Type of Cargo = Diesel oil	Type = C220 D5e
Lpp = 84.03 m	Power = 146 kWe
Lwl = 86.55 m	Frequency = 50 Hz
B = 16.20 m	RPM = 1500 RPM
H = 7.50 m	
T = 5.873 m	
Cb = 0.744	
Endurance = 6 Days	
Service Speed = 11 knots	
Cargo tank cap. = 4961.74 m	

III. ANALYSIS AND RESULT

Based on those data, in order to estimate *load factor* from the generator the calculation on each of ship operation could be done. On those calculation, *load factor* of the generator is recommend to be more than 60% and less than 86%[4].

Those recommendation based on the most efficient from the operation of the generator, so the used power will be exactly match with the needed load.

TABLE 2.
ESTIMATION OF THE GENERATOR LOAD FACTOR

No.	Item	S*)	M*)	CH*)	P*)
1	MACHINERY PART				
	Cont. Load (kW)	127.5	1125.6	38.8	38.8
	Intern Load (kW)	37.86	35.76	27.87	27.87
2	HULL PART				
	Cont. Load (kW)	45.84	44.68	202.2	91.94
	Intern Load (kW)	0	0	31.71	31.71
3	ELECTRICAL PART				
	Cont. Load (kW)	28.79	28.79	23.89	23.54
	Intern Load (kW)	0.097	0.097	0.097	0.097
4	TOTAL POWER				
	Cont. Load (kW)	202.13	199.07	264.89	154.28
	Intern Load (kW)	38	35.86	59.68	59.68
5	Div Factor. (0.7 d)	26.6	25.1	41.78	41.78
6	Total Load (kW)	228.73	224.17	306.67	196.06
7	Ʃ Generator	2	2	3	2
8	Capacity (kW)	146	146	146	146
9	Avail. Power (kW)	292	292	438	292
10	Load Factor (LF)	0.783	0.768	0.7	0.671
11	Shore Conn (kW)			352.67	

Based on the calculation of *load factor* estimation, the highest needed power is on loading-unloading condition. These condition will be a basis to find the peak load that needs to be supplied by the generator. To anticipate system failure due to the load addition or generator failure, the equipment needs to be inspected and categorized into an equipment that needs to be turned on when the ship is operating.

These categorization of the electrical equipment is to find the essential and non essential equipment. The essential equipment is an electrical equipment that needs to be turn on to support the ship operation. Based on the ref. [6], type of the essential electrical system is divided into 4 group:

1. Engine service supporting system
2. Ventilation equipment – AC
3. Lighting equipment, and
4. Navigation & Communication equipment.

Total Load from those essential electrical equipment could be seen on Table 3. Other than those equipment, is the electrical equipment that called the non essential electrical equipment or the electrical equipment that could be cut off if it's needed or in an emergency condition.

TABLE 3.
TOTAL LOAD OF ESSENTIAL ELECTRICAL EQUIPMENT

No.	Item	S*)	M*)	CH*)	P*)
1	MACHINERY PART				
	Cont. Load (kW)	118.23	116.33	27.27	27.27
	Intern Load (kW)	9.05	9.05	1.16	1.16
2	HULL PART				
	Cont. Load (kW)	45.84	44.68	202.2	40
	Intern Load (kW)	0	0	0	0
3	ELECTRICAL PART				
	Cont. Load (kW)	28.43	28.43	23.53	23.53
	Intern Load (kW)	0.1	0.1	0.1	0.1
4	TOTAL POWER				
	Cont. Load (kW)	192.5	189.44	253	90.8
	Intern Load (kW)	9.15	9.15	1.26	1.26
5	Div Factor. (0.7 d)	6.41	6.41	0.88	0.88
6	Total Load (kW)	198.91	195.85	253.88	91.68
7	Ʃ Generator	2	2	2	1
8	Capacity (kW)	146	146	146	146
9	Avail. Power (kW)	292	292	292	146
10	Load Factor (LF)	0.681	0.671	0.869	0.628
11	Shore Conn (kW)			291.96	

Based on the load calculation on Table 2 and Table 3, the leftover power or *spare* could be done in order to determine lower limit of the power generator. Those lower limit is to find the minimum power of the generator. These lower limit of the power generator is an important thing because the generator is not always worked ideally. Those things is correlated with the efficiency of the generator that always goes down with the life time of the generator itself. Decrease of the generator efficiency will always influence the total load that could be handled by the generator. On Table.4 the scenario of the efficiency generator to the fixed load on the ships according to the lower limit is shown :

TABLE 4.
SCENARIO OF THE EFFICIENCY GENERATOR WITH ITS FIXED LOAD

No.	Item		S*)	M*)	CH*)	P*)
1	Total Load (kW)		228.73	224.17	306.67	196.06
2	Ƹ Generator		2	2	3	2
3	Capacity (kW)		146	146	146	146
4	Avail. Power (kW)		292	292	438	292
5	Avail. Power (kW)	Eff. 100% (kW)	292	292	438	292
		Spare Power (kW)	63.27	67.83	131.33	95.94
6	Avail. Power (kW)	Eff. 90% (kW)	262.8	262.8	394.2	262.8
		Spare Power (kW)	34.07	38.63	87.53	66.74
7	Avail. Power (kW)	Eff. 80% (kW)	233.6	233.6	315.36	233.6
		Spare Power (kW)	4.87	9.43	8.69	37.54
8	Avail. Power (kW)	Eff. 70% (kW)	204.4	204.4	306.6	204.4
		Spare Power (kW)	-24.33	-19.77	-0.07	8.34
9	Avail. Power (kW)	Eff. 60% (kW)	175.2	175.2	262.8	175.2
		Spare Power (kW)	-53.53	-48.97	-43.87	-20.86

TABLE 5.
POWER SPARE OF THE GENERATOR AFTER CUT OFF NON ESSENTIAL LOAD

No.	Item		S*)	M*)	CH*)	P*)
1	Total Load (kW)		198.91	195.85	253.88	91.68
2	Ƹ Generator		2	2	3	2
3	Capacity (kW)		146	146	146	146
4	Avail. Power (kW)		292	292	438	292
5	Avail. Power (kW)	Eff. 80% (kW)	233.6	233.6	315.36	233.6
		Spare Power (kW)	34.69	37.75	61.48	141.92
6	Avail. Power (kW)	Eff. 70% (kW)	204.4	204.4	306.6	204.4
		Spare Power (kW)	5.49	8.55	52.72	112.72
7	Avail. Power (kW)	Eff. 60% (kW)	175.2	175.2	262.8	175.2
		Spare Power (kW)	-23.71	-20.65	8.92	83.52

Based on those scenario, it is known that total power that generated from the generator could handle total load with the minimum efficiency of 80%, which mean that the lower limit from the generator is at least 80% from the specified power. When the generator is operating on the efficiency less than 80% from the specified powerthen there will be an additional load and it resulted on a trip generator and the whole system will be *black out*. To prevent these condition, the *power management system* (PMS) could be applied. There are various selection and choice on PMS when the power is less than 80%, one of those is to *cut off* non essential load or doing a parallel generator operation. By applying those action, ship will still be operated even though there will be a restriction on supplied power. Power *spare* because of those *cut off* is shown on Table. 5.

From the data on Table.5, it is shown that by cutting off the non essential load through PMS will be resulted on increasing the power spare generated from the generator. Those will avoid the whole system from the black out condition.

After all the calculation is done, the modeling and simulation will be conducted using a LabVIEW software. LabVIEW is one of the software that used for measuring and controlling the equipment based on programming from the figure or diagram. *Software* LabVIEW will be used to make a numerical analysis, modeling and simulating the data. These software have a several toolkit and module for analyze and designing the control system, signal processing, system identification, formula, simulation and many other things. In these research the LabVIEW that used is a LabVIEW 2013 version.

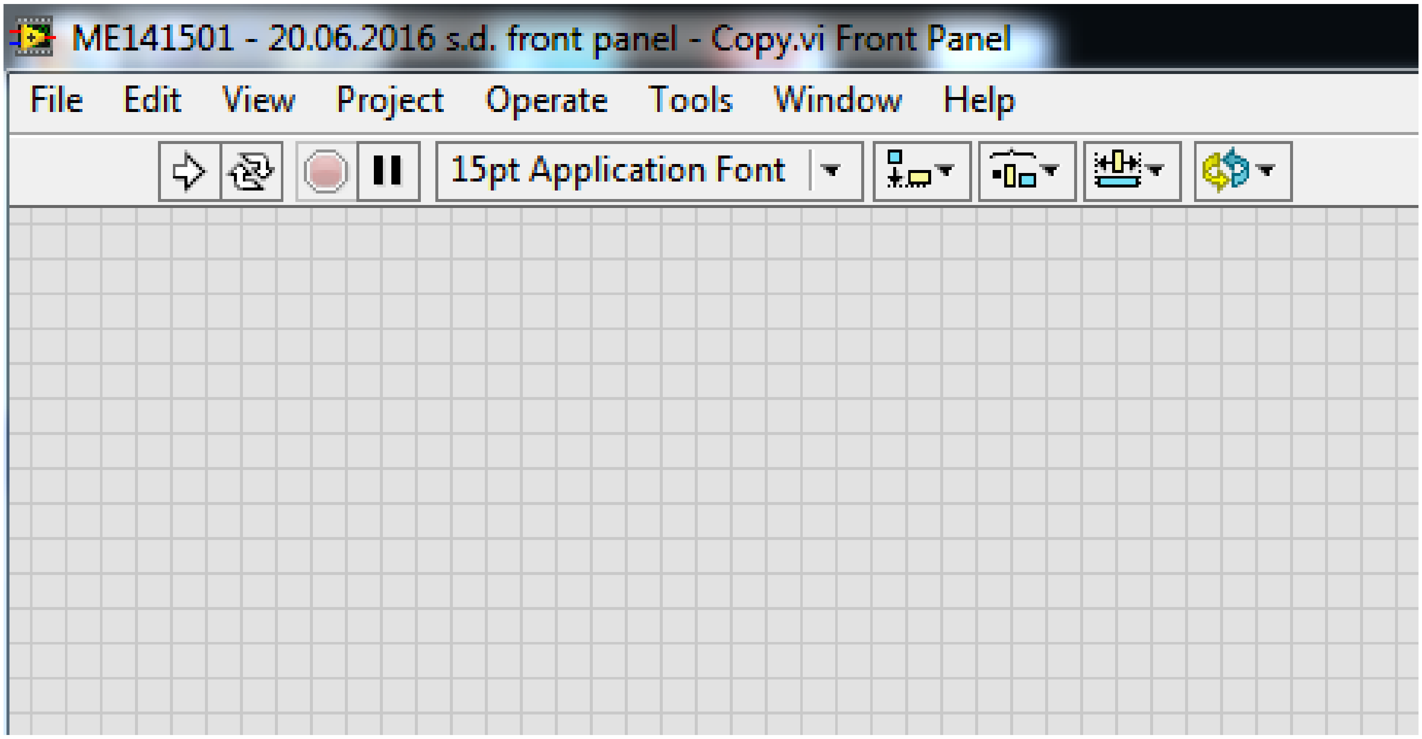


Figure. 1. Main Interface of *software* LabVIEW

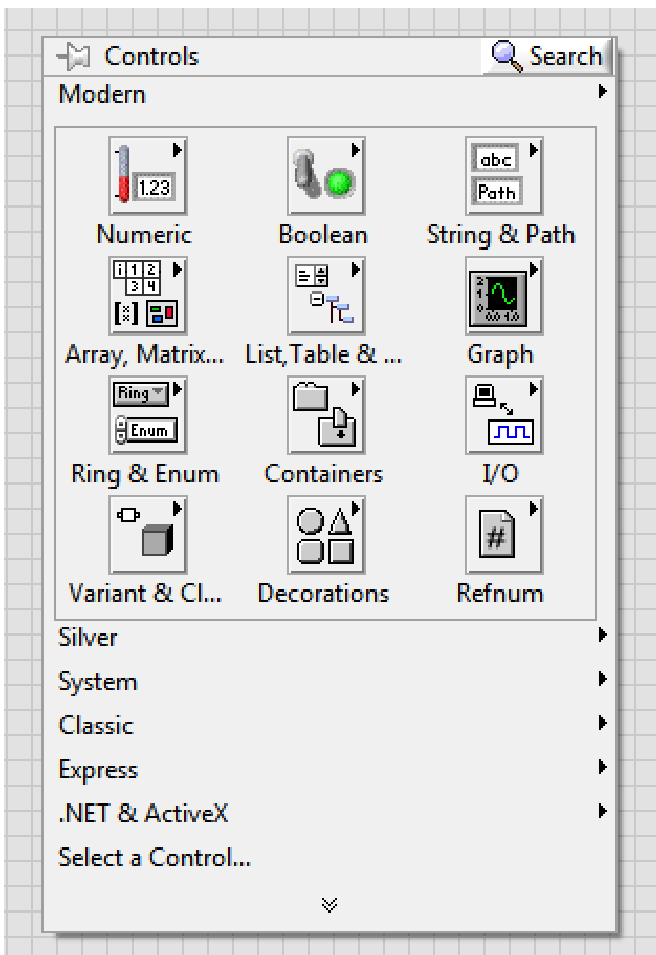


Figure. 2. Function on the *front panel*

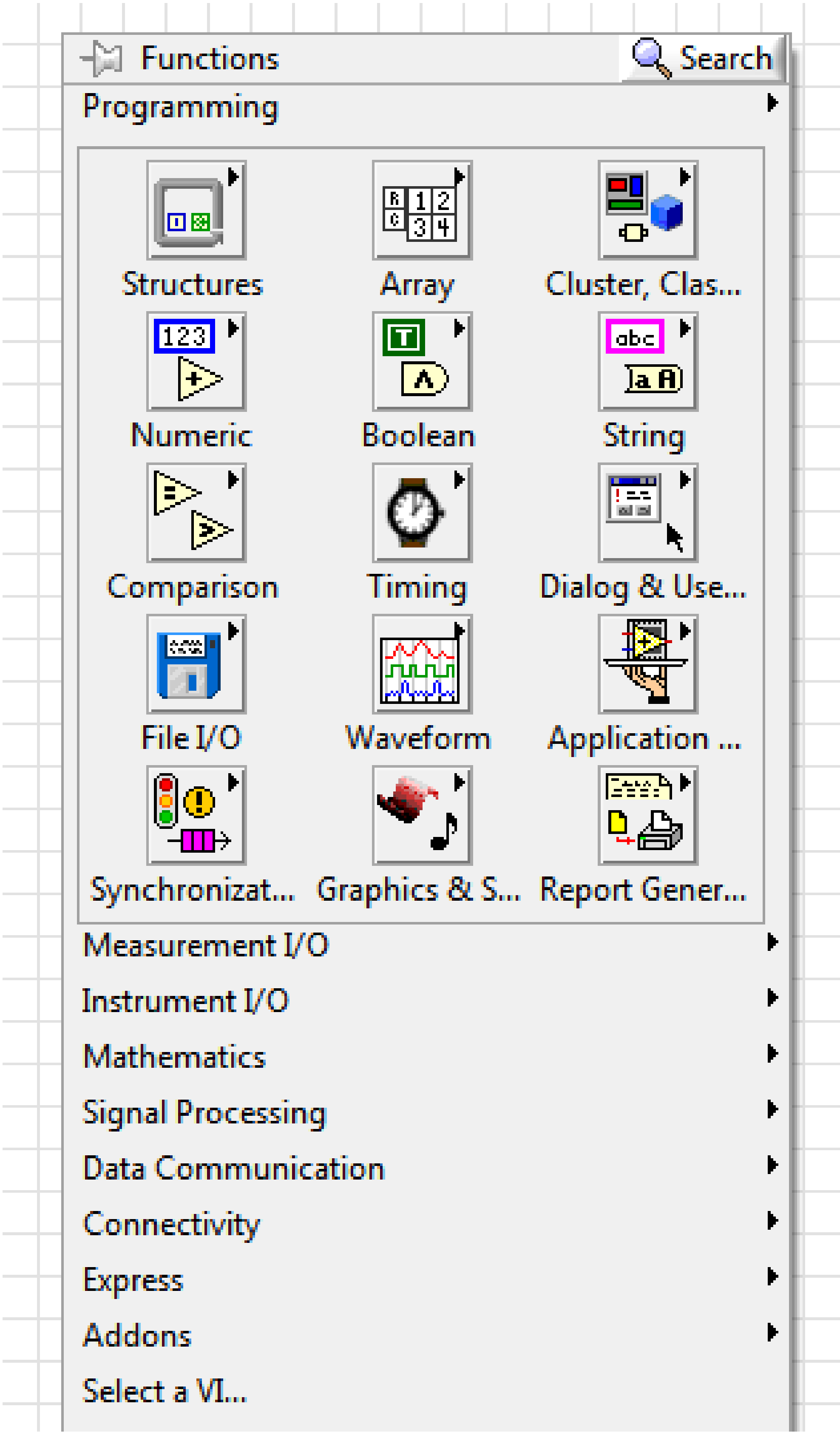


Figure. 3. Function on the *block diagram*

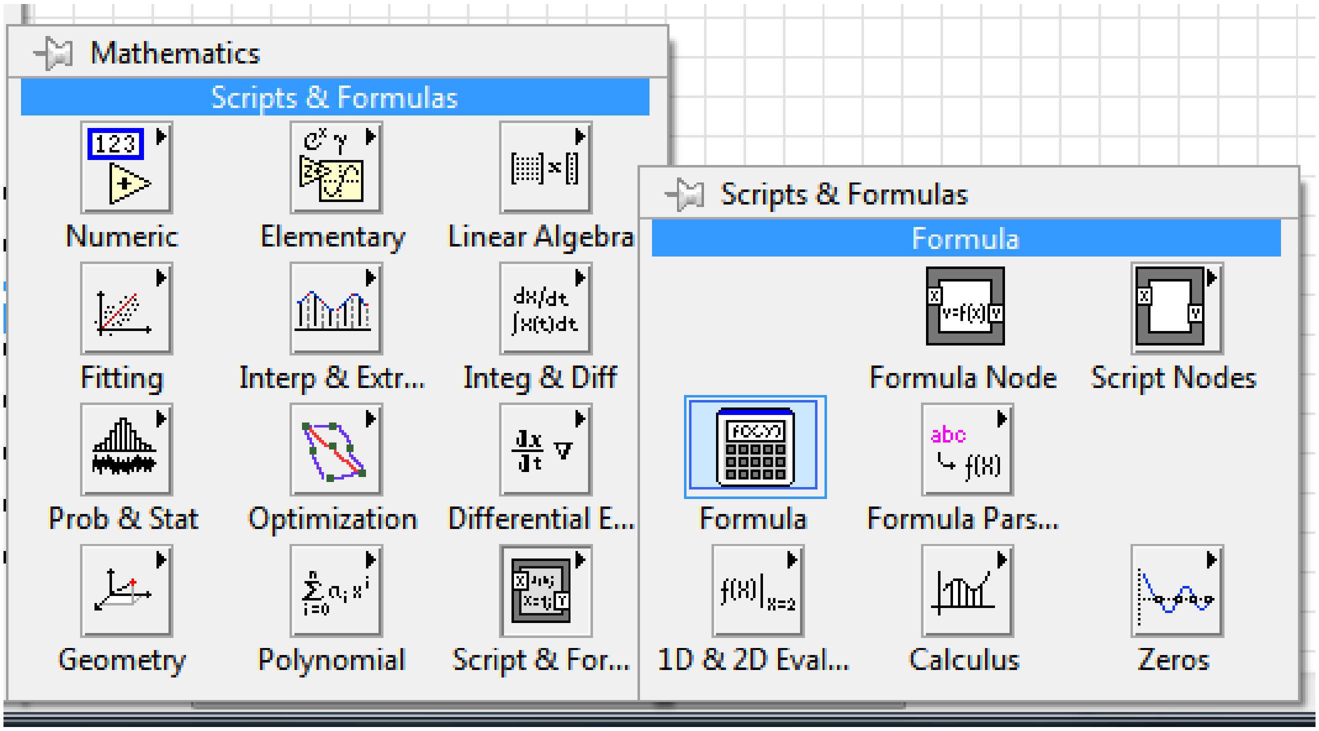


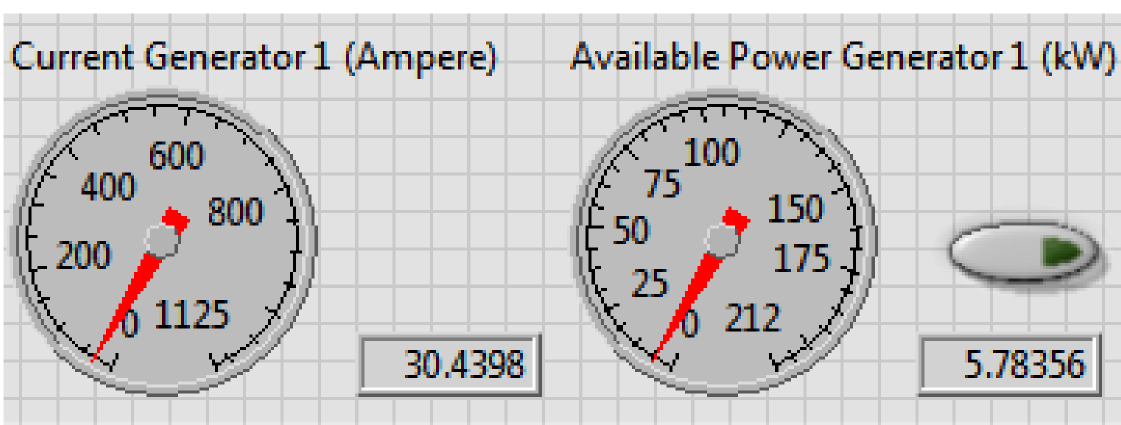
Figure. 4. Function of *scripts & formulas* on *block diagram*

Those figure is the menu and function that will be used on system modeling. All of those function will be used according to the data. Modeling of the power management system is based on fixed load from the ship generator in a several condition. Based on those, several scenario is made to simulate that in the software.

Modeling power management system is started by illustrating the load using *Boolean* function as *toggle switch* and lamp indicator. Load will be divided according to the *machinery part*, *hull part*, and *electrical part*.

All fixed load modeling result needs to be put so it could be seen on the *front panel*. Fixed Load is planned to be in operating condition, which means that in the front panel it needs to add the *sailing*, *manoeuvring*, *cargo handling*, and *at port* indicator along with the value of their load on each condition.

All load will be connected on the available generator based on the calculation. When the generator is turned on whether it is on single operation or parallel condition, the load will also be calculated and the lamp indicator will be turn on as well. Generator mode that could be seen on the front panel is the lamp indicator *off*, *stand by*, and *operate*. Generator illustration with its indicator on several operation mode.



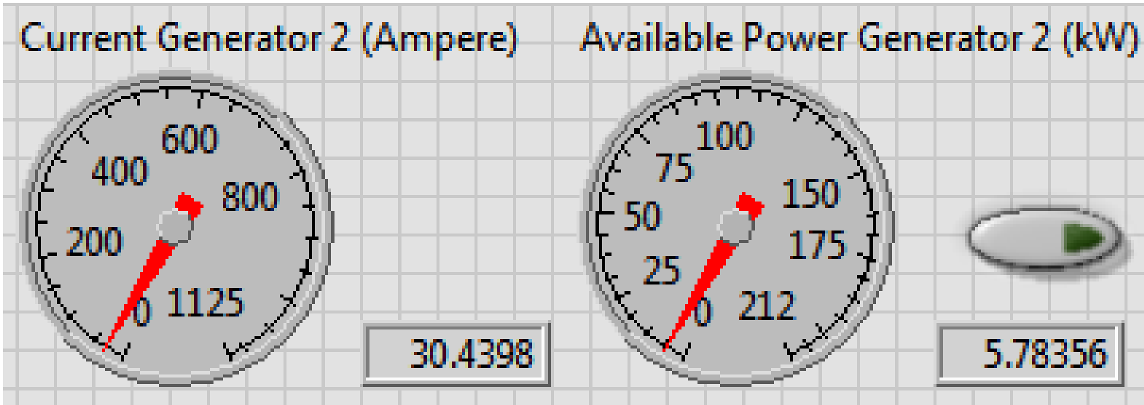


Figure. 5. Indicator on generator

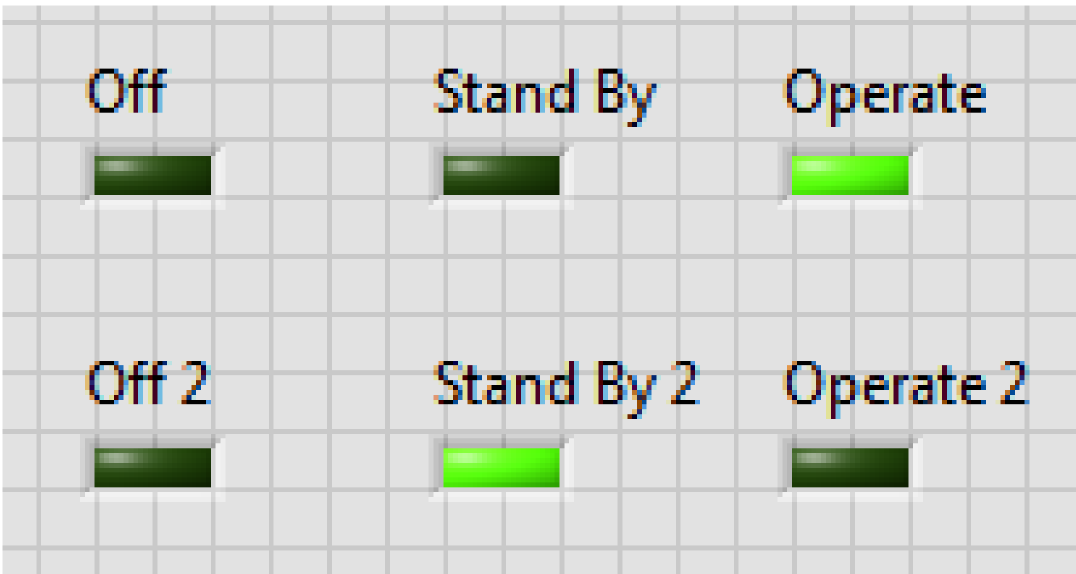


Figure. 6. Indicator on generator operation mode

Operation mode generator indicator

Indicator mode operasi generator is needed to make sure are the generator is ready to be used or not. This is important because generator cannot be operated instantly because of the *starting prime mover*. After *stand by* condition and load is turned on then the generator indicator will be shown an *operate* text. The block diagram that used to modeling current and total load on the generator is made using the formula function on Figure 7:

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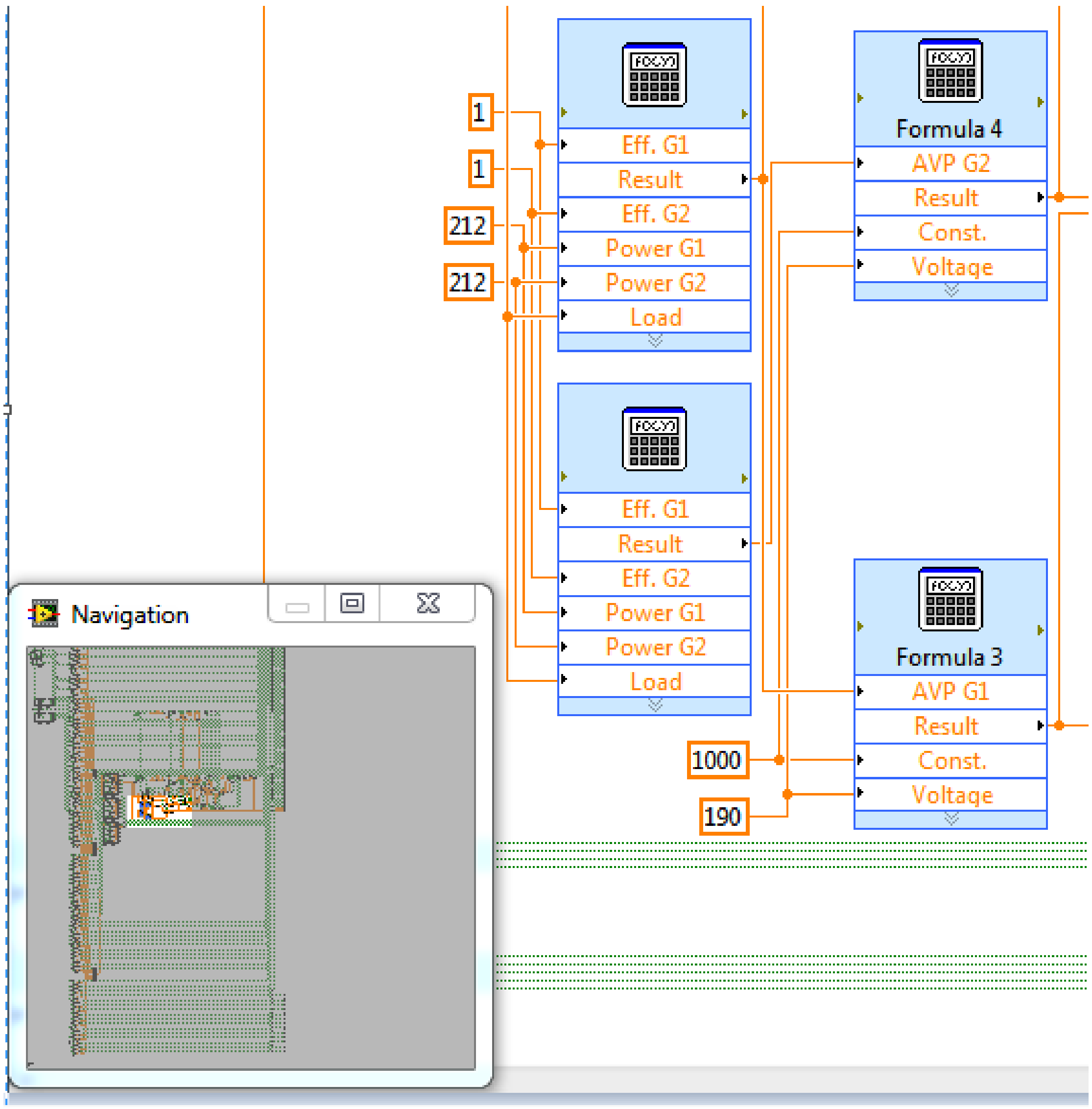

Figure. 7. Indicator current and total load on generator

After *front panel power management system* is made, the load scenario on generator could be done and *power management system* will be used as the *controling* and *monitoring function*.

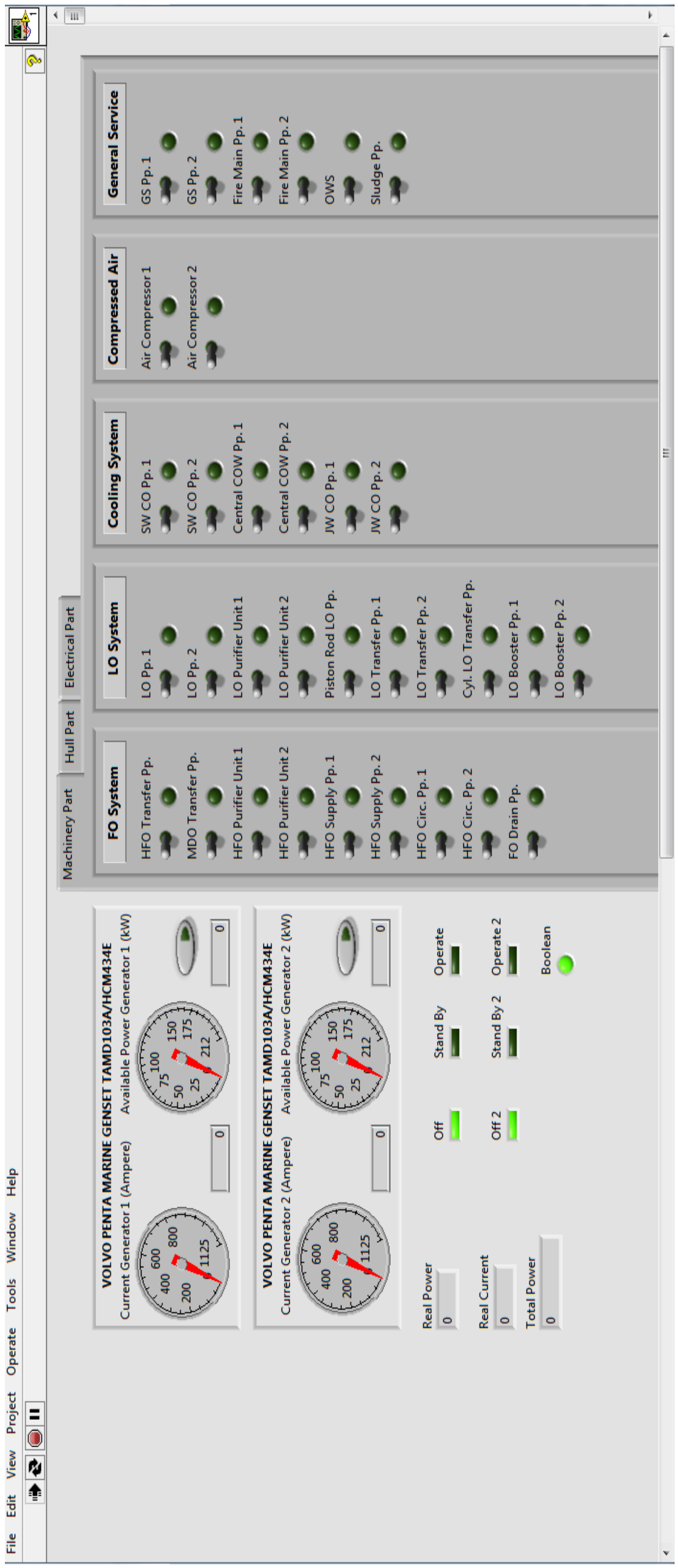

Figure. 8. *Front panel power management system*

III. CONCLUSION

After the analysis, calculation, modeling and simulation process, the conclusion from the simulation *power management system* using *software* LabVIEW menjadi are:

1. Grouping of electrical equipment based on the output generator could be done by selecting an essential and non essential electrical equipment from each tanker operation condition. The essential equipment are Engine service supporting system, Ventilation equipment – AC, Lighting equipment and Navigation & Communication equipment. While the non essential equipment on emergency condition needs to be able cut off immediately to keep the continuity of ship operation especially on *cargo handling* process. These group will affect the generator performance where, the peak load will be around 306.67 kW with all electrical equipment is operating to meet the demand of tanker loading-unloading. While on the emergency and cut off non essential load with a PMS, the generator only handled the load around 253.88 kW. On the extreme case (with total efficiency parallel operation is around 70%) generator could still handle the load around 306.6 kW with *spare* around 52.72 kW.
2. Development of PMS simulation on these research compared with another simulation on previous research are : *human machine interface* which is more *user friendly*, use of *switch* & important indicator for fixed load and generator is better and easier for the operator to make a sudden decision based on selected work scenario.
3. In these research, work scenario are addition/reduction of operating load, and decrease of efficiency from parallel generator operation. Action that needs to be taken when there are addition/reduction of operating load is the crew needs to look the total working load on the indicator. This is to optimize the work of generator, for example : based on those condition, should the generator make into parallel generator or not, are the non essential load needs to be cut off so the generator could work according to the load factor recommendation. If the efficiency of the generator is decrease then the crew needs to cut off non essential load and maintain the generator to increase life time of the generator. Those cut off is also to prevent the black out condition on ship tanker cargo handling or on load peak condition.

REFERENCES

[1] Buell, Charles, July. 2011. My electrical panel has no main breaker – is that a problem?, <URL: http://activerain.com/blogsview/2371182/my-electrical-panel-has-no-main-breaker---is-that-a-problem-

[2] Frozee, Jab, May. 2014. Main Switch Board (MSB) Safeties, Protection and Maintenance, <URL: http://marineengineeringonline.com/main-switch-board-msb-safeties-protection-and-maintenance/

[3] Kaushik, Mohit, July. 2013. What are the Main Safety Devices for Main Switch Board on Ship?, <URL: http://www.marineinsight.com/marine-electrical/what-are-the-main-safety-devices-for-main-switch-board-on-ship/

[4] Ma'arif, Firmansyah Putra Agung. 2011. Simulasi Paralel Generator Secara Otomatis pada Kapal STAR-50 BSBC 50,000 DWT dengan Menggunakan Pendekatan Software LabVIEW 8.5. *Tugas Akhir*. Institut Teknologi Sepuluh Nopember. Surabaya

[5] Markert, Matthias. 2013. Power Management Systems. Lecture Notes on Ship Automation. Hochschule Wismar. Germany

[6] Marshel S., Dyonisius. 2014. Perancangan Power Management System pada Kapal Penumpang. *Tugas Akhir*. Institut Teknologi Sepuluh Nopember. Surabaya

[7] Putra, Arya Kemal Pratama. 2012. Kajian Teknis Perencanaan Solar Cell untuk Wahana Bawah Laut Berpenggerak Motor Listrik Bertenaga Baterai. *Tugas Akhir*. Institut Teknologi Sepuluh Nopember. Surabaya

[8] Raand, Damir. 2008. Integrated Control of Marine Electrical Power Systems. *Thesis for The Degree of Philosophiae Doctor*. Norwegian University of Science and Technology. Norway

[9] I. R. Kusuma, S. Sarwito, and R. A. W. A. Irawati, "Analysis of Electric Propulsion Performance on Submersible with Motor DC, Supply Power 10260AH at Voltage 115VDC," Int. J. Mar. Eng. Innov. Res., vol. 1, no. 2, Mar. 2017.

[10] S. Sarwito, I. R. Kusuma, and B. H. Waramory, "Design of Automatic Transfer Switch ACOS with Human Machine Interface Monitoring System in Shipboard Application," Int. J. Mar. Eng. Innov. Res., vol. 1, no. 1, Dec. 2016.