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Smart Power Management System for Leisure-ship

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Abstract : *A leisure ship has a stand-alone type power system, and a generator is in use on this condition. But the generator cannot be operated in condition of leisure activity, ocean measurement and etc, because of environment and noise. Recently, renewable energy system is connected with power system of the leisure-ship for saving energy. The renewable energy system can not supply the stable power to leisure-ship because power generation changes according to weather condition. And most of the leisure ship is operated without methodical power management system. This study's purpose is to develop SPMS(Smart Power Management System) algorithm using the renewable energy (photovoltaic, wind power and etc.). The proposed algorithm is able to supply stable the power according to operation mode. Furthermore, the SPMS manages electric load (sailing and communication equipment, TV, fan, etc.) and reduces operating times of the generator. In this paper, the proposed algorithm is realized and executed by using LabVIEW. As a result, the hour for operating the generator is minimized.*

Key words : *Stand-alone type, Shaft Connected Generator, Renewable Energy, Leisure-Ship, SPMS (Smart Power Management System)*

1. Introduction

The generator of a leisure-ship can not be operated because of some reasons; noise, vibration, repair, maintenance and environmental problems. In addition, one of problems is the increased cost of fuel oil for the generator operation.

To solve this problem, the leisure-ship is being developed using the photovoltaic generation. The power from photovoltaic generation is used for charging a battery on most of leisure-ship. The battery is a supplement on ship power for general device, navigation and communication device. But photovoltaic generation has a problem on supplying the stable power because of power generation difference which is affected by weather condition. Also, sudden power cut-off problem is occurred in the absence of systematic power management system.

In this paper, the stable power will be supplied by using wind generation power. It is a supplement on the photovoltaic power generation when the solar radiation is insufficient. If the renewable energy power generation is sufficient, a power will be saved at the battery and supplied to the load through the inverter. Otherwise, the battery supplies a power to the load. And the load is controlled through the power management algorithm according to power condition. This power control algorithm is verified through the simulation program.

2. Power management & control system

2.1 Configuration of power system

Figure 1 is the power system configuration of the leisure-ship. The part of power supply consists of the photovoltaic generation, the wind generation, available shore power at the harbor.

This system has individual a MPPT (Maximum Power Point Tracking) controller to improve the efficiency of the photovoltaic & the wind generator. The power generation is send to a hybrid generation controller. The hybrid generation controller has four kinds of functions. One of the functions is to combine the photovoltaic and the wind power generation.

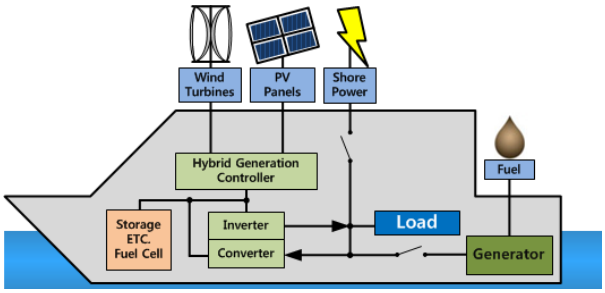

Fig. 1 Configuration of power system

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Note) This paper was presented on the subject of "SPMS based on Hybrid Generation System for Ocean Structure & Leisure-ship" in 2011 EU-Koera Conference on Science and Technology(OECD Conference Centre Paris, France, 21-23th July, 2011, pp.117)

Second is to charge the battery from the renewable energy power generation. Third is to send received power generation to the inverter. The last is to charge the battery from the generator or shore power [1].

The inverter and converter is the bi-directional controller, it supplies the power to load from the photovoltaic & the wind generation by converting DC power into AC power. Also, it charges the battery from the generator or shore power by converting AC power into DC power [2].

The elements which affect to output of the photovoltaic generation are solar radiation, temperature of solar panel surface, installation, etc. An output of the photovoltaic generation is formula 1 [3].

$$P = I_{ph} V_p - I_o V_p [\exp(\frac{q}{AKT} V_p) - 1] \quad (1)$$

I_{ph} : Cell current
V_p : PV output voltage
I_o : Saturation current
q : Charging quantum of electricity
K : Boltzman's constant
T : Cell temperature [K]
A : PN connection constant

The generated power will be increased when condition is on bigger radiation and lower temperature. But, the output of photovoltaic generation is different at the sea condition due to irregularly change the solar position. So, a generation efficiency will be decreased if the MPPT which is established as control method is used at the sea condition. Therefore, this system use MPPST (Maximum Power Point Searching Tracking) which is searching the maximum power point to increase generation efficiency.

The wind generator only can be used in mooring or anchoring because of resistance element in voyage. It is installed a vertical type generator which is enable to use in any direction of the wind.

Fig. 2 Example of leisure-ship and ocean structure

The capacity of installed generation is mainly comprised of the photovoltaic generation, and the wind generator supplement to it. The battery supply the power to leisure-ship when the photovoltaic and the wind generation are insufficient. So, it needs to the battery capacity selection.

The load is not continuous operation, it repeats start-stop operation. This characteristic operation load is shown formula 2.

$$P = \frac{Q}{T} \quad (2)$$

P : Maximum demand power [W]
Q : Use power [Wh]
T : Time [sec]

Formula 3 is the integrated power during a period.

$$P_a = \frac{\triangle Q}{\triangle t} \quad (3)$$

And, the total load power is able to obtain by integrated. Also, the system needs to know a spare power. The spare power is formula 4.

$$P_s = G_a - P_t \quad (4)$$

G_a : Average generation
P_t : Total average load

2.2 Smart Power Management System

A SPMS (Smart Power Management System) controls to the load by currently load & power calculation. The loads has a priority number according to importance and the power consumption, such as table.1. For example, TV and audio are cut off firstly because of bottom of the priority. The importance is able to change the order manually on the control program according to situation. Also, the SPMS arranged the loads automatically by importance & power consumption[4].

Table 1 Classification of electric load

Importance	Large Load	Medium Load	Small Load
High	7	8	9
Normal	4	5	6
Low	1	2	3

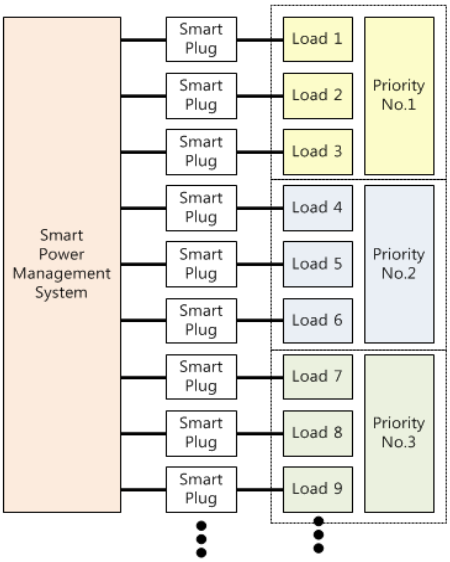

Fig. 3 Configuration of load control part

Figure 3 is configuration of load control part on the SPMS. Smart plug is connected to load individually, it is controlled power on/off and send measured the power consumption to SPMS. Also, it can on/off control by compare usable power with the load consumption before operation. A cut-off load will be operated automatically if has spare of power generation [5].

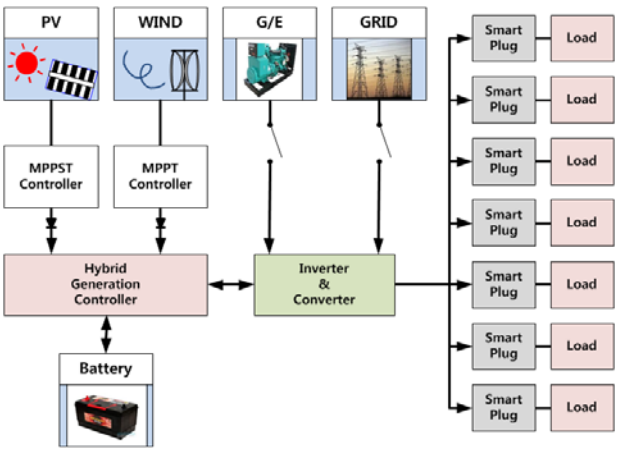

Fig. 4 System of power supply

Figure 4 is the system of power supply. It has four cases situation. First, the photovoltaic & the wind generation are higher than the total load consumption. In this case, SPMS supplies generated power to the load through the inverter and remaining power charge the battery. The generator isn't operation. The photovoltaic & the wind generation are lower than the total load. In this case, it supplements the power from the battery. Also, the generator isn't operation.

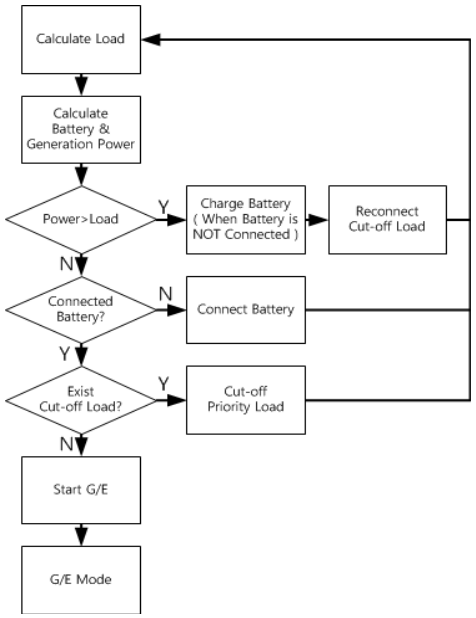

Fig. 5 The renewable energy generation mode

Figure 5 is power management algorithm at renewable energy generation mode. The loads are controlled through comparison of a power consumption with the photovoltaic and wind generation power. The battery will supply power for load if the photovoltaic & the wind generation are insufficient. Automatically the generator will operate if battery full discharged. In this case, the SPMS implements the algorithm of the generator operation mode.

Real-time capacity of the battery is able to obtain by measured current value at charge & discharge. Formula 5, 6 is battery SOC (State of Charge) [6].

$$SOC = SOC_i + \int i_c \eta \, dt - \int i_d \, dt - S(T) \tag{5}$$

$$SOC_i = \frac{V_1 - V_2}{1 + e^{\frac{V_b - V_n}{dV}}} + V_2 \tag{6}$$

SOC_i : Initial SOC of the battery
SOC : SOC of the battery
i_c : Charging current
i_d : Discharging current
η : Charging efficiency
$S(T)$: Self-discharging rate
V_1 : Discharging end voltage
V_2 : Charging end voltage
V_b : Terminal voltage
V_n : Normal voltage(SOC 50%)
dV : Gradient of the graph

Figure 6 is the battery use mode algorithm. In this case, the charged battery supplies the power to the load because the renewable energy has no power generation. In this mode, it controls the load by the battery power condition. And this algorithm is similar the renewable energy generation mode except comparison of the renewable energy power and the power consumption. Automatically the generator will operate if the battery is fully discharged.

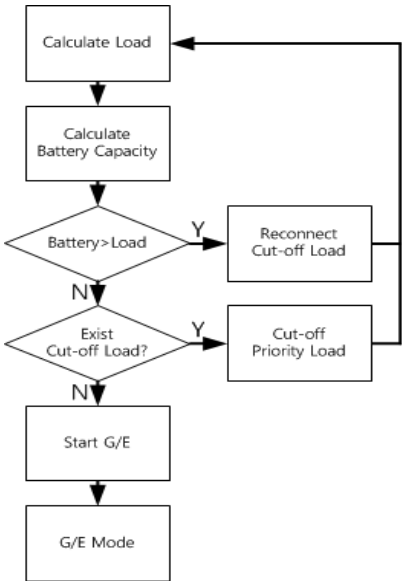

Fig. 6 The battery use mode

Figure 7 is the generator use mode or the shore power use mode algorithm. In this case, the SPMS does not control load, and it charges the battery because power is sufficient always. If the battery finishes charging, the generator will stop and the battery will supply power to the load. But, the shore power mode is supplied the power continuously to load regardless of the battery charging condition.

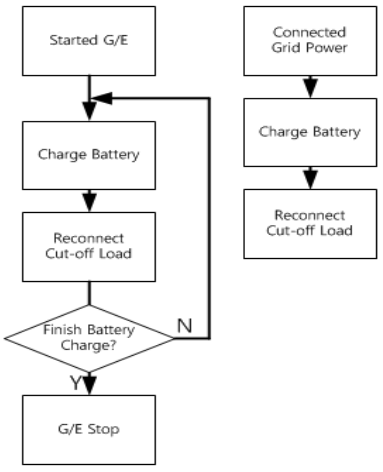

Fig. 7 The generator or the shore power use mode

2.3 Simulation

In this paper, the power management algorithm is verified by LabVIEW simulation. Table 2 is assumed loads.

The assumed loads has priority number according to importance. the low priority load will be cut off at first if the power is insufficient.

Table 2 Assumed the electric load

Cut-off Priority	Load [W]		
1	300	250	100
2	100	250	200
3	100	150	250
4	100	100	300
5	100	150	250
6	100	250	200
7	100	300	200
8	100	250	250
9	100	150	300

Figure 8 is the simulation result at assumed sunny & windy weather. X-axis and Y-axis is individually time [sec], power [W].

The total power is added the battery power and the renewable energy power when the renewable energy power is insufficient. And the battery is discharged due to using the battery power. But, the total power is only renewable energy power when the renewable energy power is high than the total load. In this case, the battery is charged. The power maintains without the load control because the power generation is sufficient.

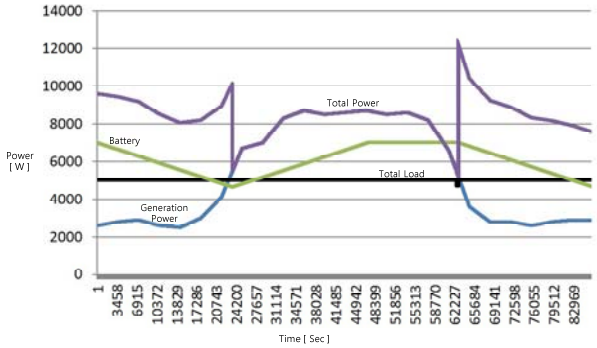

Fig. 8 Sunny & windy weather

Figure 9 is the simulation result at sunny & windless assumed weather. In this case, SPMS controls the load at sunset time because the wind generation power is low. the total load is decreased depending on the total power.

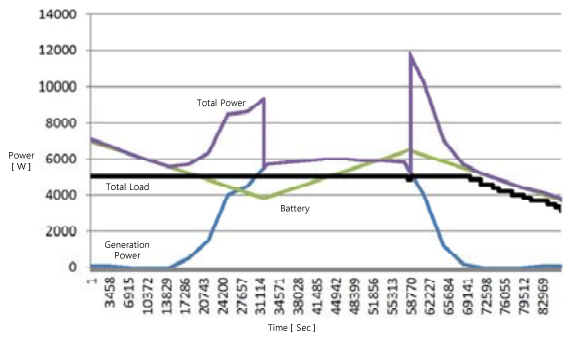

Fig. 9 Sunny & windless weather

4. Conclusion

The leisure-ship has problem on stable power supply due to character of a stand-alone power system. Also, the generator has problems on noise, vibration, repair, maintenance and environment. Recently, the leisure-ship is used the photovoltaic generation power system, but it has unstable power because the power generation of renewable energy is different depending on a weather condition.

The power system which is mentioned on this paper is consisted of the photovoltaic and the wind generation. Using the hybrid generation can supply stable power compared with only photovoltaic generation. And the battery's power is used to supplement the load when the power generation is insufficient. Also, the generator or shore power charges the battery through the bi-direction inverter and converter. A operation times of the generator is decreased by algorithm of priority load control for the SPMS. This power management algorithm is verified by LabVIEW simulation. As a result, the stable power supply and minimum operation time of generator are confirmed. And, the SPMS is able to use for ocean structure, for example, ocean buoy, ocean hotel, ocean city, ocean plant, and etc.

Acknowledgements

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