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Variable Priority Number Control of SPMS for Leisure Ship

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Abstract: The power system of leisure ship has a character of stand-alone type, so it continuously checks the usable power. Especially, the leisure ship using renewable energy needs to adjust the power consumption of loads according to the usable power. Also, the important loads of leisure ship are different by operation mode. However, current power management system doesnot consider such character. This paper studied load management system of the SPMS(Smart Power Management System) and composed using the smart plug. The SPMS controls the loads depending on a user’s pattern and character through variable priority number control. This control algorithm was verified through simulation of assumed user and situation using LabVIEW.

Key words: Renewable Energy, SPMS (Smart Power Management System), Priority, Leisure Ship, Smart Plug, Operation Set Time

1. Introduction

The power system of leisure ship has a character of stand-alone type, so stable power supply is important for the leisure ship. Recently, the leisure ship is developed using photovoltaic generation due to the environmental and vibration issues. However, the photovoltaic generation is an unstable power source as the power generation fluctuates dramatically by the weather conditions as demonstrated in Figure 1. Figure 1 illustrates photovoltaic generation output at the ocean. The generation output is sometimes decreased in spite of sunny weather conditions[1]. To settle this issue, the leisure ship use the hybrid generation that combines photovoltaic and wind power generation, and it uses battery back-up system shown in Figure 2. However, such power system has inefficiencies in costs and installation capacities. Thus, it is occurred that usable power is insufficient than the total power consumption of loads. In this case, the leisure ship needs the power management system that can control the loads suitably according to the situation. Furthermore, this system will be able to manage the loads according to operation mode and user.

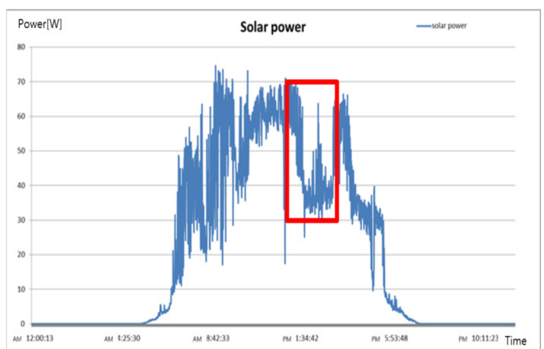

Figure 1: Graph of photovoltaic output at ocean.

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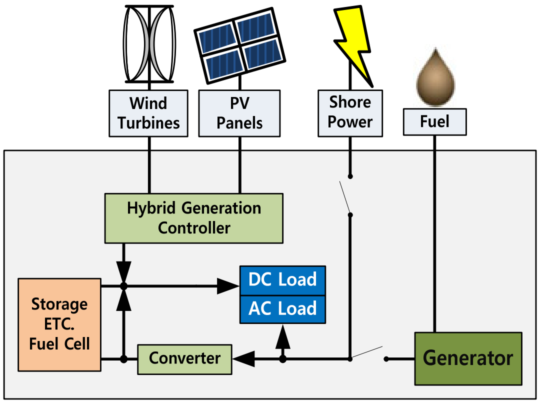

Figure 2: Configuration of power system.

2. Smart Power Management System

2.1 Leisure-Ship's Operation Mode

The leisure ship has three kinds of operation mode such as navigation mode, port and harbor mode and leisure activity and keeping area mode. The use of power and load is individually different depends on operation mode. Especially, the generator cannot be used at the harbor and anchoring mode because of environment, noise and vibration factors. In this mode, the power source is a renewable energy. Also, the harbor mode can use the shore power system (grid power). The navigation mode can use the generator. In this mode, the power source is a hybrid power that combined the generator and the renewable energy. Therefore, the usable power of this mode will be sufficient if the generator is operating.

However, the harbor and anchoring mode needs a load control system when usable power is insufficient. And the loads have a priority number for a cut-off. The load's priority number is determined by the importance. The important loads of navigation mode are navigation & communication equipment such as navigation light, GPS and radio system. The leisure equipment & home appliance is an important load in the harbor & anchoring mode.

2.2 Smart Power Management System

The SPMS (Smart Power Management System) is an integrated management system for the leisure ship. It consists of power system, load control system and measurement system. The power system controls generation equipment which is a controller of renewable energy system and a generator by operation mode. The load control system manages power consumption according to the condition of power generation. The measurement system receives the sensor's data, for example in/outdoor temperature, power consumption and usable power[2].

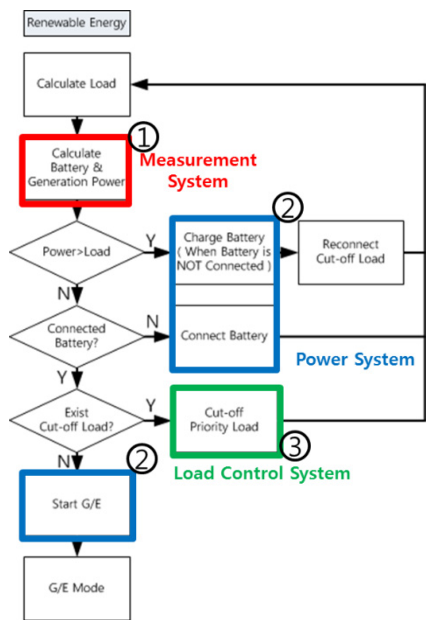

Figure 3: Example of SPMS control algorithm.

Figure 3 is an example of the SPMS control algorithm. No. 1 box and No. 2 box are individually measurement system and power system. The No. 3 box is a load control system. Firstly, the SPMS compares present power generation and total power consumption of load. If the power generation is less than the total power consumption, a battery will be connected for power supplementation. The SPMS calculates a real-time capacity of the battery and compares with the total power consumption after battery was connected. The real-time capacity of the battery is able to obtain by measured current data at discharge & charge[3]. If the usable power is less than the total power consumption, the SPMS will control the total power consumption.

The total power consumption can be decreased by load cut-off using a smart plug[4]. The smart plug has three kinds of functions. It measures the power consumption of a load and controls power on/off. Lastly, it communicateswith the SPMS. The smart plug is connecting a load with the load control system individually like Figure 4. However, the load's concept can extend a group of loads.

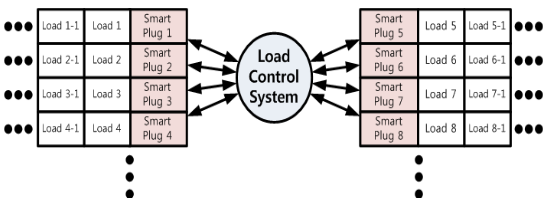

Figure 4: Configuration of smart plug.

Further, most loads of leisure ship are not operated continuously, because types of loads are different and most loads are home appliance or leisure equipment. It operates start-stop repeatedly. Therefore, if the SPMS controls loads suitably, it will reduce not only peak power but also installation capacity of the power system through load control.

2.3 Fixed Priority Number Control

The loads have priority number for cut-off according to its importance such as preference trip system of a merchant vessel, but priority number is fixed manually regardless of operation condition. Figure 5 is a concept of fixed priority number control. The loads had been received priority number, andit keeps priority number intact until the load cut-off. This control is unsuitable in a case that importance of loads is different according to operation mode such as a leisure ship. For example, navigation and communication device is important load at navigation mode, but it is not important load at port and harbor mode. In this case, leisure activity equipment and home appliance is important load.

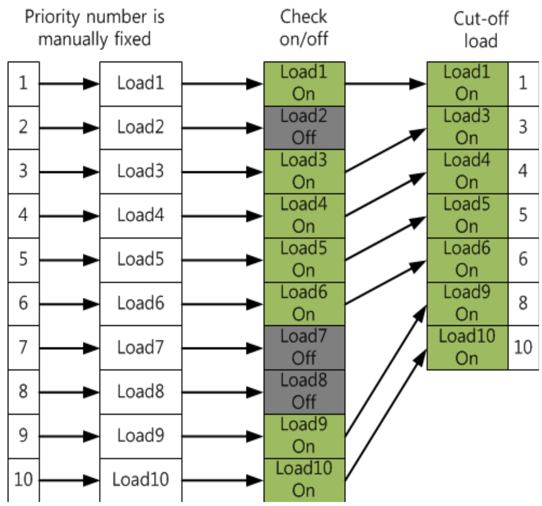

Figure 5: Fixed priority number control.

The leisure ship has the loads of home appliance. For this reason, the SPMS has to check user's pattern, habits and preference loads. However, the priority number of fixed priority number control is unchanged according to these conditions, thus user feels inconvenient. For example, a user is using a computer but it will be stopping the operation when usable power is insufficient because it has low priority number. The user in this situation will feel inconvenient.

2.4 Variable Priority Number Control

The SPMS controls the loads of leisure equipment and home appliance at leisure activity and harbor and port mode depending on usable power, especially renewable energy use mode. Figure 6 is a variable priority number control algorithm. The load has several preconditions. These preconditions have to meet for operation. For example, the precondition of a light system is motion sensor and the precondition of an air-conditioner is setting temperature. And the load has two kinds of mode. In auto mode, the loads can operate only when it meets the preconditions. However, in manual mode, the loads can operate regardless of the preconditions. An unnecessary load is not operated already before the SPMS control in auto mode.

Also, the load has operation set time that is average of operation time from power-on to power-off. It is updated whenever the load is stoppedand is saved at the SPMS. Therefore, as time goes by, the SPMS become more suitable for the user. The SPMS uses these operation set time data to obtain the user's pattern, and use to avoid cut-off power during the operating load. The operation set time can be formulated as the formula 1.

$$A_{OST} = \frac{A_{OT1} + A_{OT2} + ... + A_{OTn}}{n} \quad (1)$$

A_{OST} = OperationSetTime[sec]

A_{OT} = Operation Time [sec]

n = Operation number of times

The loads are classified as four cases of sequence demonstrated in Figure 5. Firstly, the algorithm arranged the operating loads and checks auto and manual mode, and it check the preconditions of load secondly. If the load met the preconditions in the manual mode it will receive level 1, and otherwise, level 2 will be received. Such level is a group which comprises the same importance load. Thirdly, the algorithm checks that elapsed operation time of load is less than the operation set time. If it was within the operation set time, this load will receive level 3. Lastly, the remaining loads are received level 4. Then the loads in level are rearranged by rated capacity power of loads. The load control system sends the selected priority number to the SPMS in order to use the load cut-off when the usable power is insufficient. The selected priority number is again sent to the first sequence, and the priority number is changed continuously. Through the variable priority number control, the priority number will be changed more suitably for the user.

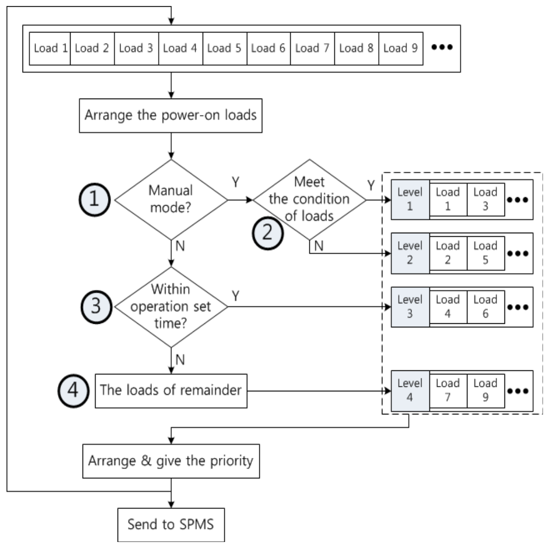

Figure 6: Variable priority number control.

2.5 Installation Capacity of Power System

Most loads repeatedly operate on-off, and they cannot operate continuously. Thus, such nature of load is considered to design an installation capacity of power system. If the SPMS can cut off the unnecessary loads by control algorithm without the user's interventions, the installation capacity will be reduced than the previous one. In other words, the SPMS controls the power and arranges the operating time to avoid peak power. Such reference set point for load control is mainly usable power, but it can change manually or automatically by program to save the electric power at port & harbor mode.

3. Simulation

The variable priority number control was simulated for verifying the algorithm, and the assumed loads and users A, B and C was made by LabVIEW. Table 1 shows ten different types of assumed loads and three types of assumed user. The individual user has a character that is preferentially used load. The preference loads of user A, B and C individually are TV, air-conditioner, and computer, main light, and charge and ETC, main light. Also, this simulation was assumed that all loads meet the preconditions and operate during twelve hours without power cut-off. Through the simulation, it was confirmed that the priority number was changed by the user's pattern.

Table 1: Assumed loads and users.

Load		Operation set hour		
		User A	User B	User C
Load 1 (Mainlight)	40W	4	8	6
Load 2 (TV)	150W	10	1	2
Load 3 (Computer)	100W	1	10	5
Load 4 (Charger&ETC.)	33W	3	1	10
Load 5 (Kitchenequipment)	1000W	1	3	90min
Load 6 (Waterheater)	800W	30min	50min	40min
Load 7 (Heater, Air-conditioner)	900W	7	2	4
Load 8 (Fridge)	200W	24	24	24
Load 9 (Bedroomlight)	20W	2	4	1
Load 10 (Aux.light)	80W	1	90min	3
User Preference		TV	Computer	Charger & ETC
		Heater, Air-conditioner	Main Light	Main Light

Figure 7: The front panel of simulation program.

Figure 7 is front panel of the simulation program LabVIEW. The operation set time was set by manual entry for simulation. The current priority number and the score are demonstrated through graphs and table below.

Figure 8, 9 and 10 are the priority number variation of users A, B and C during 12 hours. Y-axis is priority number and X-axis is time [sec]. The No.1 priority number is high important load, and the No.10 priority number is low important load. The priority number was changed according to operation set time of loads. In the case of user A, the priority number of TV and air-conditioner rose gradually during 10 hours and 7 hours. And its priority number declined sharply after 7 hours and 10 hours. This is because elapsed operation time was longer than the operation set time. The case of user B was changed similarly. However, the priority number of main light and computer was kept highly because of preference load. The priority number of main light was higher than computer during 8 hours, because the power consumption of main light was smaller than computer. The case of user C also was changed similarly. The main light and charger and etc had high priority number during 6 hours and 10 hours.

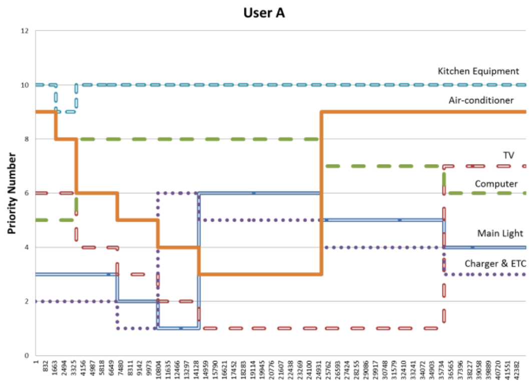

Figure 8: Variation priority number of user A during 12 hours.

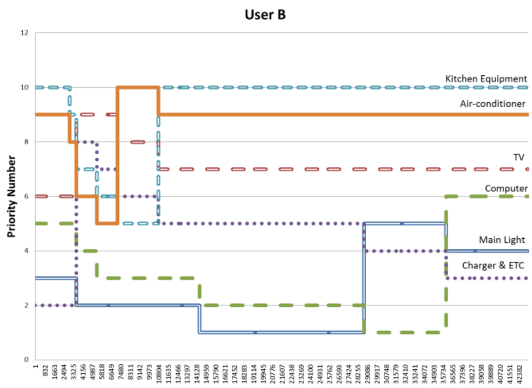

Figure 9: Variation priority number of user B during 12 hours.

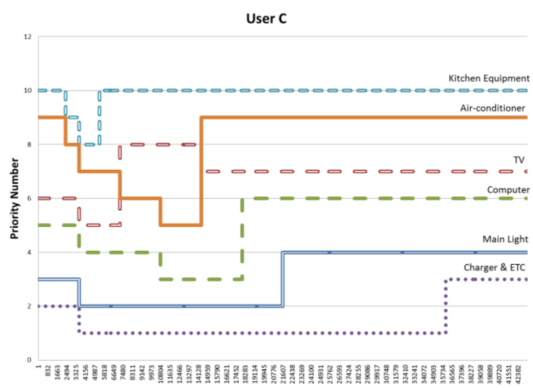

Figure 10: Variation priority number of user C during 12 hours.

The priority number was the same at 12 hours because the elapsed operation time of all loads was passed by operation set time. If loads were operated on-off, the priority number is different at 12 hours.

Table 2: The priority number of load at 6 hours and the score of load during 12 hours

Priority No.	User A	User B	User C
1	Load 2 (TV)	Load 1 (Mainlight)	Load 4 (Charger&ETC.)
Score	(5820)	(6060)	(6900)
2	Load 8 (Fridge)	Load 3 (Computer)	Load 1 (Mainlight)
Score	(5940)	(5730)	(5800)
3	Load 7 (Heater&Aircond)	Load 8 (Fridge)	Load 8 (Fridge)
Score	(3270)	(5670)	(5680)
4	Load 9 (Bedroomlight)	Load 9 (Bedroomlight)	Load 9 (Bedroomlight)
Score	(5640)	(6120)	(5070)
5	Load 4 (Charger&ETC.)	Load 4 (Charger&ETC.)	Load 10 (Aux.light)
Score	(5280)	(4650)	(4440)
6	Load 1 (Mainlight)	Load 10 (Aux.light)	Load 3 (Computer)
Score	(4920)	(3810)	(4260)
7	Load 10 (Aux.light)	Load 2 (TV)	Load 2 (TV)
Score	(3480)	(2760)	(2740)
8	Load 3 (Computer)	Load 6 (Waterheater)	Load 6 (Waterheater)
Score	(2760)	(1960)	(1910)
9	Load 6 (Waterheater)	Load 7 (Heater&Aircond)	Load 7 (Heater&Aircond)
Score	(1740)	(1600)	(2000)
10	Load 5 (Kitchenequipment)	Load 5 (Kitchenequipment)	Load 5 (Kitchenequipment)
Score	(750)	(1240)	(800)

Table 2 is the priority number of the loads at 6 hours. Through the table 2, it is again confirmed that the priority number was changed by the user's pattern. Especially, such change was well knowable at 6 hours. Furthermore, the loads were scored every 1 minute during 12 hours for checking user's pattern. The score was from 1 point to 10 point according to the priority number. High priority number 1 was scored 10 point, and low priority number 10 was scored 1 point. Total score was 39600 point as shown in formula 2, and each load divided up the score.

$$\text{Total Score} = 55\text{point} \times 12\text{ hours} \times 60\text{min} \quad (2)$$
$$\text{Load } 1 = P_{m1} + P_{m2} + P_{m3} + \cdots + P_{m720}$$
$$\text{Load } 2 = P_{m1} + P_{m2} + P_{m3} + \cdots + P_{m720}$$
$$\text{Load } 3 = P_{m1} + P_{m2} + P_{m3} + \cdots + P_{m720}$$
$$\vdots$$
$$\text{Load } 10 = P_{m1} + P_{m2} + P_{m3} + \cdots + P_{m720}$$
$$P_m = \text{Point every minute}$$

The load that kept high priority number continuously was scored high point such as TV of user A. Otherwise, the load that kept low priority number continuous was scored low point such as kitchen equipment of user C. In case of fridge, it normally operates without power-off during 24 hours. Therefore the fridge kept the high point continuously. Through these the score, it was confirmed again that the priority number varies depending on the user.

When the usable power is insufficient than total power consumption of loads, the SPMS will control the loads. In case of user A, firstly kitchen equipment will be cut off and TV will be cut off lastly. Therefore, the TV which is mainly operated by user A isnot cut-off at least when the usable power is insufficient.

4. Conclusion

The power system of leisure ship has a character of stand-alone type, so it continuously checks the usable power. Especially, the leisure ship using renewable energy needs to adjust the power consumption of loads according to the usable power. Also, important loads of leisure ship are different by operation mode. The leisure ship has three types of operation mode such as navigation mode, port and harbor mode and leisure activity & keeping area mode.

But current power management system doesn’t consider such character. This paper studied load management system of the SPMS and composed using the smart plug. The SPMS controls the loads depending on a user pattern and character through variable priority number control in harbor, port mode and leisure activity mode. The SPMS can eliminate the peak power through unnecessary load control. Also, it is expected that the installation capacity of generation system is reduced by load control system.

This control algorithm was verified through simulation of assumed user and situation using LabVIEW. Also, it was confirmed that the priority number changed according to loads operation time.

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