Design and Implementation of Mobile Integrated Off-grid Energy Storage Power Supply for Ship

Zhou Ling hui1,a, Liu Dan ya 2

1Wuhan Institute of Marine Electric Propulsion, Wuhan, China.
2Changjiang Wuhan Waterway Engineering Bureau, Wuhan, China
alu_yf.sy@gx.csg.cn
*Corresponding author’s e-mail: 116122474@qq.com

Abstract. This paper designs a Mobile Integrated Off-grid Energy Storage Power Supply for Ship (Power Bank for Ship). The power bank for ship is mainly used to provide power supply services for ships. It can supply power for daily loads of ships and can also be conveniently charged by the marine electric generator or the charging station onboard. The power bank for ship has the characteristics of high integration, intelligence, two-way power supply and charging. The successful development of this equipment provides new ideas for the realization of clean energy for ships in my country, and has a positive effect on the environmental protection of the Yangtze River and other inland river economic zones.

1. Introduction
With the continuous improvement of emission requirements in inland rivers, lakes, ports and other fields, some inland river and lake ecological protection areas, inland river ports, and shipping gates have higher emission requirements. Generally, ships will use mixed Power system to meet the requirements, but some ships that have already in operation are less economical to retrofit and due to ship structure and other issues, large-scale retrofitting cannot be carried out for that ships.

The mobile integrated off-grid energy storage power supply for ship (referred to as Power Bank for Ship) is mainly used to provide power supply services for ships docked at the anchorage in the heart of the river. The power bank for ship is powered by an energy storage system, it can provide power to ships through an inverter power supply to meet the daily electricity needs of ships. The system adopts an integrated design, which can realize power plug and charge, also can realize load plug and use. The power bank for ship is arranged in the charging station, and the charging station is equipped with a special charging device. The power bank for ship is fully charged by the charging station and placed in a centralized placement. The power bank for ship is transported by the service ship to provide or replace the power bank for ship.

2. The Design Of Power Bank for Ship
The power bank for ship can not only supply power for the daily load of the ship, but also directly supplement the electric energy on the shore or on the ship. It is mainly composed of an energy storage system, a two-way converter and a control system.

On the one hand, the power bank for ship has a charging function, the power bank for ship can be charged with 3AC/380V (shore power or generator set), the power bank for ship should have the protection function of the electrical system and the converter when charging.
On the other hand, the power bank for ship has a power supply function, which can supply power for 3AC/380V marine daily loads, with a maximum output capacity of 50kW, and has protection functions such as overload, short circuit, over temperature, and self-check. The amplitude, frequency, and harmonics of the output voltage of the power bank for ship must meet the corresponding requirements. According to the requirements of the CCS regulations on the working conditions of marine electrical equipment, the total harmonic distortion (THDv) of the output voltage of the power supply should be less than 5%. Voltage and frequency fluctuations meet the requirements of the following table:

At the same time, the control system of the power bank for ship controls the battery system and the converter, and has the following functions:

1. Human-machine monitoring function, which can dynamically monitor the operating status of lithium batteries and inverters on the human-machine interface, and modify the charging settings online;
2. Alarm function: Dynamic real-time fault alarm monitoring of lithium batteries and inverters, and corresponding processing of faults;
3. Page display: Including parameter page and alarm page, a small window of current alarm information pops up.

The main components are introduced below.

2.1. Energy storage system
Energy storage system mainly includes battery and battery management system. According to the current technical status and development trends, marine batteries mainly include lead-acid batteries, nickel-cadmium batteries, nickel-hydrogen batteries, and lithium-ion batteries[1]. The characteristics of various batteries are as follows:

- Lead-acid batteries: poor low-temperature performance, complete existing production and maintenance equipment, and high recycling rate;
- Nickel-cadmium batteries: complete production and maintenance equipment, poor high-temperature performance, difficult and expensive recycling, and harmful heavy metals;
- Ni-MH battery: The voltage characteristic is soft at high temperature, the self-discharge rate is high, the heat dissipation system is required, and the manufacturing cost is high [2];
- Lithium-ion battery: the cycle life is reduced at high temperature, overcharge and overdischarge are strictly prohibited, and the safety requirements are very high.

In practical applications, lead-acid batteries and lithium-ion batteries are the most widely used. Lead-acid batteries have lower specific energy and shorter service life, which are gradually being replaced by lithium-ion batteries in the marine field.

At present, marine lithium-ion batteries are mainly lithium iron phosphate batteries. The application of battery systems in large-capacity battery packs on ships should focus on improving safety, and there is no need to pursue high energy density too much. The power battery mainly includes lithium battery and battery management system (BMS). The battery system uses a single 90Ah battery cell and consists of 3 battery boxes and 1 high-voltage box. The specific parameters are as follows:

Each battery box is composed of 60 lithium iron phosphate 90Ah batteries in series, with a rated voltage of 192V and a rated energy of 20kWh. The battery box is designed with a fire protection module, which can play a flame retardant effect if the battery is thermally out of control.

The battery system includes a battery management system. The battery management system adopts a hierarchical structure. BMS can achieve the following functions: System power-on self-check function, charging, Discharging, temperature, current and other multiple protection functions, and managing the entire charge and discharge process, Battery pack total voltage, total current, temperature, single battery voltage and other measurement functions, battery pack and each single battery SOC and other functions, battery system related operating information storage and recording function, the whole system RS485 or CAN bus communication function.
2.2. Bidirectional converter
The bidirectional converter has two functions. On the one hand, it is used as a charging device for the energy storage system, and on the other hand, it is used as an inverter power source to supply power to the ship's daily load. When used as the charging device of the energy storage system, it is used as an active rectifier device to rectify the 3AC380V of shore power or generator set into direct current, and according to the requirements of the energy storage system, control the amplitude and current of the output voltage to charge the energy storage system. When used as an inverter power supply, the converter inverts the DC power into three-phase AC and then supplies power to the daily load through the isolation transformer. At this time, the power supply is of good quality and meets the requirements of the daily load on the ship. The inverter power supply can meet the requirements of the CCS specification for the power supply quality of daily loads, and has the protection functions of DC bus undervoltage, output short circuit, overload, overcurrent, and three-phase output imbalance.

In the three-phase inverter topology, the most widely used is the three-phase bridge inverter, as shown in Figure 1, the three-phase bridge inverter topology is composed of three phase arms, with advantages of simple topology and fewer power devices etc [3]. Due to the limitation of power module capacity, the inverter power supply composed of a single power module which has limited power. In order to increase the inverter power capacity, direct parallel connection of modules or parallel connection of inverter units can increase the output power of the whole machine and increase the input and output voltage levels.

If the inverter power supply is required to have grid-connected function, either L-type filter or LCL-type filter can be used. There is no resonance point in the L-type filter, so the control algorithm of the inverter power supply is relatively simple, but the filtering effect is relatively poor. Usually, a larger filter inductance is required to obtain low harmonic output current. If the short-circuit capacity of the AC grid is small, The inverter power supply using L-shaped filter inductor is easy to cause voltage distortion on the grid side [4]. The filtering effect of the LCL filter is relatively good, but because of the resonance point, it is relatively difficult to implement the control algorithm. For inverter power supplies that do not need to be connected to the grid, LC filters are usually used [4].

A model of bidirectional inverter was built in Matlab. The verification proved that the bidirectional inverter can meet the technical requirements. It can be used as an active rectifier device to charge the energy storage system, and it can also be used as a reverse. The variable power supply supplies power to the daily load.

2.3. Control System
The control system manages the switching of various modes of the power bank for ship, including the switching of charging mode, discharging mode, standby mode and the collection of various signal states.

Charging mode: at the charging station (on the dock or power supply barge), through 3AC380V alternating current charging;

Discharge mode: On the ship, supply power to the ship's 3AC380V daily load;

Standby mode: The power bank for ship is neither charging nor discharging, and it is in the middle of charging and discharging modes.
3. Implementation Of the Power bank for ship

![Figure 1 The implementation of the power bank for ship](image)

The power bank for ship has been successfully used on a certain type of inland river engineering ship. When the ship is in the navigable waiting area and waiting for the lock, the black smoke of the diesel generator is gone. At this time, the power bank for ship is used to supply power for the daily load of the ship. When the ship passes through the gate or sails out of the protected area, the diesel generator set can be turned on to supply power for daily loads, and at the same time, it can supplement power for the power bank for ship. It can also be charged by the shore electric. The promotion and application of the power bank for ship will significantly improve the environment in the Yangtze River and other inland river economic zones, especially for the protection of ecological protection areas in inland rivers or lakes, etc. It has good applicability in the field of new energy ships [5].

4. Conclusion

This paper designs a Mobile Integrated Off-grid Energy Storage Power Supply for Ship (Power Bank for Ship). The power bank for ship is mainly used to provide power supply services for ships. It can supply power for daily loads of ships and can also be conveniently charged by the marine electric generator or the charging station onboard. The power bank for ship has the characteristics of high integration, intelligence, two-way power supply and charging. The successful development of this equipment provides new ideas for the realization of clean energy for ships in my country, and has a positive effect on the environmental protection of the Yangtze River and other inland river economic zones.

References

[1] Zhu Bin. Technology and Application of High Power Batteries [J]. Marine Electric & Electronic Engineering, 2015,4:30-34.
[2] Mo Ke, Li-ion battery market size and expectations Advanced Materials Industry[J],2014,10,3-8
[3] Ye Ying. The Development of a Three-Phase PV Grid-Connected Inverter. China Shandong University Master’s Thesis, 2008.
[4] Wang YaoQiang , Grid Interfaced Inversion System with LCL Filter and its Control Strategy Adaptive to Complicated Grid Conditions. Harbin Institute of Technology, Dissertation for the Doctoral Degree in Engineering, 2013.
[5] Zhu Di, Wu Feiwen. On type of all-electric propulsion plan for suction hopper dredger. Ship & Boat, 2008, (5):36-41