Design and Intelligent Control of Hydrogen Fuel Cell Hybrid Ship

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Abstract: At present, with the continuous development of the world economy, people's demand for ships is also increasing. However, most of the existing ships use the traditional diesel engine power system, which makes the petrochemical energy consumption serious. At the same time, it also brought a large amount of exhaust gas pollution, oil pollution and noise pollution. Relevant information shows that the exhaust gas emitted by ships is also one of the main sources of PM2.5 in the air, resulting in increasingly serious air pollution. According to statistics, the global shipping industry's carbon dioxide emissions account for about 4% of global greenhouse gas emissions. The problem of ship pollution is very prominent today when it advocates cleanliness and greenness, which has also attracted the continuous attention of the regulators' policies. [1]

1. Introduction

Prior to this, the Ministry of Communications issued the "Implementation Plan for Ships and Ports' Pollution Prevention and Control Implementation Plan (2015-2020)", which worked out the timetable and road map for ship and port pollution control in the next five years. According to the plan, by 2020, sulfur oxides, nitrogen oxides, and particulate matter of ships in the Pearl River Delta, the Yangtze River Delta, and the Bohai Rim (Beijing-Tianjin-Hebei) waters will decrease significantly compared with 2015. At the same time, in accordance with the newly revised standards for the discharge of pollutants from ships, the existing ships will be rebuilt before the end of 2020, and if the reform still fails to meet the requirements, they will be eliminated within a time limit. From May 1st, the revised "Regulations on Environmental Management for the Prevention and Control of Pollution of Inland River Waters by Ships" will be formally implemented, providing new requirements for preventing and controlling atmospheric pollution from ships, and clarifying that the fuel used by ships should meet relevant national or local standards. Ships use clean energy. Not only domestically, with the urgent need for high energy consumption and strict control of carbon emissions in the world, a climax in the development of clean new energy will be set off. A large number of outstanding new energy companies will inevitably usher in the development of clean new energy in the near future.

In this context, in view of the current low energy utilization rate of marine diesel engines and large environmental pollution, this project takes inland river cruise ships as the research object, and uses fuel cells, batteries and super capacitors as the power source of ships to carry out the integration of ship power systems Design research and propose an intelligent energy management strategy based on fuzzy logic control to achieve the goals of no pollution, low energy consumption, fast response speed and long battery life.
2. Advancedness and advantages over traditional ships

(1) The hydrogen fuel cell is used as the main energy source to achieve zero pollution.

The reactants of hydrogen fuel cells are hydrogen and oxygen, and the emissions are only water, which can achieve zero emissions and is an ideal source of power for green ships. And high efficiency, not limited by Carnot cycle, the power conversion efficiency is 40% - 60%, if you consider the heat released by the battery, the efficiency can reach 85%. Reducing dependence on fossil energy is closely integrated with the theme of the energy conservation and emission reduction competition.

(2) With batteries and supercapacitors as auxiliary energy sources.

Fuel cells meeting peak power will greatly increase costs. If batteries and supercapacitors can be used for peak filling and valley reduction, the capacity of fuel cells can be reduced, thereby reducing costs. Supercapacitors have a very high power density, which can usually reach 0.5-10KW / kg, which is several tens of times that of ordinary batteries; and no heavy metals are required for production and production, so it is a more environmentally friendly energy storage element. The disadvantage of supercapacitors is that the energy density is relatively low, only 0.5-5Wh / kg. Based on the above characteristics, supercapacitors can be used as a supplement to the battery to bear the high-frequency part of the ship's load requirements.

(3) Intelligent control scheme using fuzzy logic theory.

Intelligent control scheme using fuzzy logic theory. Through fuzzy logic, not only can the power output of each power source be intelligently adjusted to achieve a reasonable distribution of energy. Compared with dividing a fixed interval according to the power value demand, the dynamic performance of each power source is more considered, and transient power pairs are avoided. Fuel cells and batteries. This solution further reflects the purpose of energy saving, improved fuel economy, and also ensures the reliability of the entire power system operation.

All in all, the new-type ships studied in this project have the advantages of less emissions, less pollution, and good fuel economy. Compared with traditional ships, the energy-saving and emission-reduction effects of the ships studied in this project are very obvious.

3. System design

(1) Ship power system design

First, calculate the ship's electrical load. According to the ship type, load and maximum design speed, the output power of the ship's propulsion motor (the motor energy utilization rate is 90%), the total power of other various electronic components in the ship, etc. Set aside 10% power margin and determine the total ship power based on the calculation results. Compare and analyze the advantages and disadvantages of DC and AC systems, and choose the appropriate system and voltage of the power system.

The second step is to determine the model of the fuel cell, lithium battery, super capacitor, unidirectional DC / DC, bidirectional DC / DC, main power distribution board, propulsion motor and its driving device.

1) Selection of fuel cell: In the ship's power system, the fuel cell bears most of the power requirements and is the source of power for ship operation. The electric energy output by the fuel cell
is supplied to the DC bus after the voltage is transformed by the unidirectional DC / DC voltage control unit, and the lithium battery and super capacitor can also be charged by bidirectional DC / DC. Therefore, its maximum power needs to be able to fully bear the power requirements of the entire ship, so the power of the fuel cell should not be less than the total power of the ship.

2) Selection of battery: The battery is an auxiliary power source, which mainly stores and releases energy. This project selected a lithium-ion battery with excellent charge and discharge performance. At the start of the fuel cell, the lithium-ion battery can supply power to provide the power required for heating the fuel cell system and the air compressor to solve the fuel cell startup defects. During the operation of the ship, when the total power demand of the ship decreases, the lithium-ion battery can absorb and store the surplus electricity in the system. When the demand power of the ship increases, the lithium-ion battery can respond faster and supply power to the system in a timely manner. When selecting the capacity of the lithium-ion battery, the extreme operating conditions of the system should be fully considered, and its power storage can be independently supplied to the entire ship to run at maximum power for one hour, and a safety margin of about 10% is reserved.

3) Selection of super capacitors: Super capacitors have the characteristics of high power density, fast charging and discharging. In marine power systems, supercapacitors can quickly respond to the ship's high-frequency changes in power requirements, undertake high-frequency, high-current charging and discharging, and maintain the stability of the DC bus voltage. During the operation of the ship, there may be cases where the drive motor suddenly stops driving or the ship's power demand is greatly reduced, which will cause a large instantaneous charging current and adversely affect the battery (reduction in battery life or battery thermal runaway and accidents). Therefore, the introduction of super capacitors in the hybrid power system in this project can effectively solve the above problems.

4) Selection of propulsion motor and its driving device: The propulsion motor adopts a DC asynchronous motor and is installed on the bottom of the ship.

(2) Power system design

There are no additional shore power sources for this project. All power sources, including start-up power, come from lithium batteries, super capacitors and fuel cells.

1) The fuel cell is used as the ship's main power source. It uses hydrogen fuel and is equipped with an automatic hydrogen / load control system. It can be remotely controlled through communication. At the same time, it is equipped with a DC / DC unidirectional isolated output module. And start-up power supply, equipped with bidirectional DC / DC module, with charging / electric energy absorption and discharge functions; supercapacitor as compensation power, equipped with bidirectional DC / DC module, with charging and discharging peak regulation functions;

2) The output of the fuel cell, super capacitor and lithium battery is short-circuit protected by fuses, remote control on-off control is realized by DC contactor, and power is supplied to the DC bus;

3) A set of DC adjustable electronic load is used to study and verify the stability of the energy management system in the case of power grid fluctuations; its input side uses fuses for short-circuit protection and DC contactors for remote control on and off;

4) The DC drive motor is selected as the main thruster of this project. The DC motor is controlled by a DC drive device, which can achieve stepless speed regulation through remote control; the power supply side is equipped with a fuse to achieve short-circuit protection, and the DC contactor to achieve remote on-off control.

(3) Design of energy management system

The purpose of this project is to design an energy management system that can reasonably distribute the output power between fuel cells and energy storage elements based on the real-time demand of the ship's load.

The construction of energy management strategies plays a vital role in the safe and economic operation of hybrid ships. Starting from the economy and safety of the ship, we build a hybrid ship energy management strategy based on intelligent control algorithms. This project requires the energy
management system to be able to reasonably distribute the power output between the fuel cell and the energy storage element according to the load demand. Its specific structure is:

1) Data acquisition: Collect power information, power grid information and propulsion information through data acquisition module and communication form. Through serial server, industrial computer establishes Ethernet network to realize data acquisition and control command output;

2) Logic control: The logic control of the energy management system is achieved through the industrial computer;

3) Operation and monitoring: In terms of monitoring, the host computer is equipped with a system monitoring and data display interface to monitor the ship's operating status in real time. The upper computer can control the movement of the hull through the control network. In terms of operation, it is equipped with a speed-adjusting handle and communicates with the DC drive system, which is used to complete the start and advance control of the system.

The system hardware architecture and equipment selection are performed according to high standards, and the bus form is reasonably allocated on the acquisition system network architecture according to different bus characteristics. RS485 and CAN communication are selected for the lower-level acquisition and long-distance transmission, and Ethernet communication is used for the higher-level data transmission. The equipment is selected for reliable and mature industrial-grade products.

The picture shows the overall block diagram of an energy management strategy. First, the load information of the ship, the state of charge of the battery and the super capacitor are collected as input signals of the energy management strategy, and the reference output power of the three power equipments is obtained through real-time calculation of the energy management strategy. Collect the voltage and current signals of the three devices respectively, calculate their actual output power, and compare with the reference output power obtained from the energy management strategy to obtain the deviation signal. The output of the DC / DC converter is controlled by PWM control.

4. Project innovation

(1) Marine hydrogen fuel cell hybrid power system

Based on the problems of heavy pollution, high energy consumption and poor endurance of electric propulsion ships in the traditional power system, the project designed a hybrid ship power system with integrated fuel cells, batteries, and supercapacitors. The characteristics of strong energy storage capacity and fast dynamic response of supercapacitors have innovated the energy structure of existing ships.

(2) Intelligent energy management control method

This project uses wavelet transform to decompose the ship's power demand signal into high-frequency signals and low-frequency signals in real time. Based on the current load characteristics of the ship and the dynamic characteristics of multiple power sources, fuzzy rule control is used to optimize the allocation of the ship's energy source, ensuring the ship Reliable and stable operation.

5. Conclusion

This project studies the design of hybrid ships based on fuzzy logic and intelligent energy management control strategies. It has strong generalization, wide adaptability, and high feasibility. It has stable and reliable characteristics and can be widely applied to inland river cruise ships, ferries, and small freight ships. The benefits of fuzzy logic control algorithms are not only in expressing rules that are difficult to accurately quantify, but also in saving power. Compared with traditional algorithms, it can make full use of the dynamic characteristics of each power source to optimize the power output of each power source, thereby reducing the waste of electrical energy and improving the stability of the power system. This design belongs to a pure green hybrid ship. If it can be applied to actual production and life, it will have a strong social effect on protecting the environment, saving energy and reducing emissions.
References
[1] Pintacsi, D., Bihari, P. (2013) Investigation of a low-grade industrial waste heat recovery system[P].
[2] Wang, Z., Liu, Y., Zhang, Z.K., (2016) Design and Simulation of Hydrothermal Module for 100kW Fuel Cell Power Generation System [J]. Eastern Electric Review, 30 (02): 1-6.
[3] PATELS. Utilization and development of marine energy [J]. Shanghai Electric Power, 2009 (1): 32-38.
[4] He, S.Q., Wei, X., Yu, A.B., (2014) Current Status and Prospects of Solar Energy Application on Ships [J]. Power World, (09): 42-44 + 41.
[5] Gao, Y., Liu, J. Zhang, J., (2016) Research on PLC-based Multi-data Acquisition Monitoring Alarm System [J]. Instrument Technology and Sensor, 2016 (05): 40-43.