

TECHNICAL SOLUTION FOR POWER SUPPLY USING WIND, SOLAR, AND HYDROPOWER AT OFFSHORE WATER FACILITIES IN THE REMOTE RIVER SECTIONS OF THE THREE GORGES DAM AREA

Hui Sun, Qingyuan Fang, Zhijie Han, Hao Li, Zhiqi Li, He Jiang

*Three Gorges Navigation Authority, Yichang, Hubei, CN 443000
sunhuijob@163.com*

Keywords: THREE GORGES DAM AREA; WATER-BASED FACILITIES; POWER SUPPLY SYSTEM; TECHNICAL SOLUTION

Abstract

In response to the diverse navigation conditions of the Three Gorges hub section and the wide variety of wind, solar, and hydroelectric power generation equipment and utilization technologies available domestically and internationally, this study conducts a survey and evaluation of such technologies. It proposes an efficient and clean power supply solution for water-based facilities on mountain rivers (including tugboats and navigation beacon vessels) that utilizes a composite energy system combining wind, solar, and hydroelectric power. This approach effectively addresses the power supply challenges faced by these facilities in areas without shore power access, promotes energy conservation and emission reduction during operation, enhances power supply reliability, reduces staff workload, improves working conditions, and lowers operational costs.

1 Introduction

Currently, water facilities in mountainous regions with abundant water bodies predominantly rely on energy sources such as diesel generators and lead-acid batteries, which exhibit high resource consumption and significant environmental pollution risks. Therefore, adopting green energy for power supply in these aquatic facilities would contribute to pollution prevention, carbon reduction, and energy conservation. However, several challenges remain: First, high-power wind turbines are excessively bulky, and mature applications of wind power generation on water facilities are still rare; Second, compared to international progress, successful solar-powered boat applications in China's water facility sector are still in their infancy; Third, while foreign research on hydroelectric power generation has been advanced, it remains experimental. Domestically, apart from the conceptual proposal by Wang Yun and Fan Jun for a simplified hydroelectric power generation system, substantial research in this field is scarce^[1-3]. To enhance power supply reliability for mountain river water facilities, reduce operational labor intensity, improve working conditions, and lower maintenance costs, an optimal power supply solution is urgently needed. Building on existing limited research, this paper proposes an efficient and clean hybrid power supply approach utilizing three renewable energy technologies—wind, solar, and hydro—to serve remote river sections in mountainous areas.

2. Study on the Utilizable Wind, Solar, and Hydropower Models for Rivers in Mountainous Regions

2.1 Dockship for navigation in mountainous waters

River pontoon vessels in mountainous regions consume substantial amounts of electricity and require high peak operating currents from the power supply system. To meet their daily operational and living power demands, a considerable number of new energy generation units are necessary. These vessels typically anchor in open waters with gentle currents, offering ample deck space suitable for harvesting solar and wind energy, while the utilization rate of hydroelectric energy is relatively low. Therefore, the optimal energy application model for mountain river pontoon vessels is recommended as a hybrid wind-solar energy system^[4-5].

The design employs an integrated power generation model combining a single vessel-mounted wind power system, a solar photovoltaic system, and a horizontal-axis hydroelectric power generation unit. Given the limited power output capacity of the horizontal-axis hydroelectric unit, which offers limited practical value for pontoon vessels, the implementation plan may alternatively adopt only a combination of the photovoltaic system and multiple wind turbines. The power supply scheme for the pontoon composite energy system is shown in Figure 1.

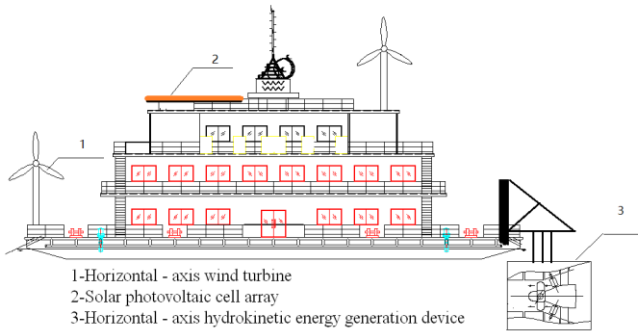


Fig. 1 Schematic diagram of the power supply scheme for the legboat composite energy system

2.2 Navigation beacon vessel for river sections in mountainous areas

Beacon vessels are typically equipped with low-power LED beacon lights, requiring only a minimal amount of new energy generation equipment to meet operational demands. Given the limited deck space on beacon vessels, wind energy installations are impractical, whereas solar and hydro energy can be utilized more conveniently^[7-8]. Statistical analysis of the power supply requirements for beacon vessels, combined with the need for high power supply reliability, demonstrates significant feasibility for adopting a combination of horizontal-axis hydroelectric generators, solar photovoltaic systems, and battery banks as the power supply solution (with dual redundancy configuration). The design scheme is shown in Figure 2.

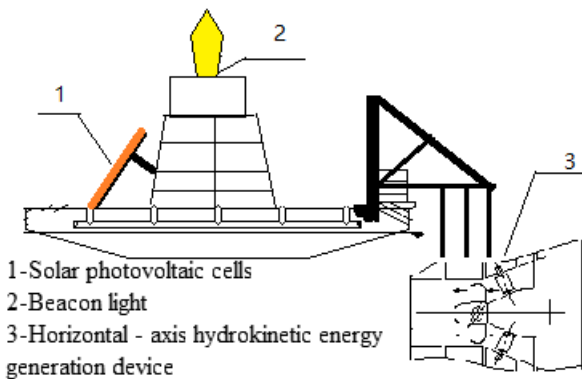


Fig. 2 Schematic diagram of the power supply scheme for the composite energy system of the navigation marker vessel

3. Research on the Application Methods of New Energy in River and Water Infrastructure in Mountainous Areas

3.1 Applications of solar power generation

To determine the number and location of solar photovoltaic panels, first calculate the total required power based on the electricity consumption of the water facility; then measure the available installation area for the panels and determine the effective installation area by considering the panel installation angle; finally, select the optimal number and installation locations for the solar photovoltaic panels after

comprehensively comparing various panel sizes and their power generation capacities.

3.2 Applications of wind power generation

For water-based facilities on mountain rivers, wind power generation applications can only be implemented in areas with stable wind energy conditions. The following principles should be observed during installation:

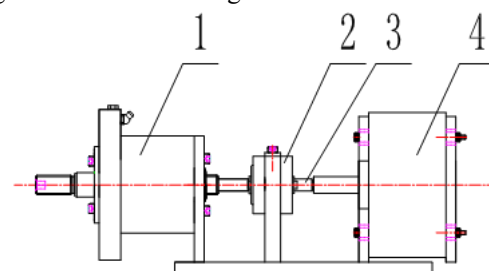
- (1) Wind turbines should be symmetrically arranged on the windward side of water-based structures to minimize wind-induced impacts on these facilities.
- (2) During installation, the highest point of the wind turbine must be lower than the highest point of the lightning rod on the water facility. Provided that the rotor blades do not contact the operational equipment of the water facility, at least 2.5 meters of clearance should be maintained beneath the blade tips to ensure personnel safety.
- (3) The electricity generated by wind turbines must undergo voltage stabilization before being supplied to the load.

3.3 Applications of water flow energy for power generation

The primary design efforts for these generators encompass three key aspects: the structural assembly design of the main body, the sealing design of the rotating shaft, and the water intake detection system.

(1) Structural Connection Design of Low-Flow Small-Scale Water Turbine Generators

The main structure of the low-flow-rate small water flow generator comprises a sealing device, a speed increaser, a connecting shaft, a generator, and a base bracket. Based on the actual dimensions of the sealing device, speed increaser, and generator, as well as the connection requirements, detailed designs for the connecting shaft and base bracket have been completed. The component layout and connection design are illustrated in Figure 3.



1-Sealing device 2-Growth rate
3-Connecting shaft 4-Generator

Fig. 3 Main structure of the small water flow generator

(2) Sealing Design for Low-Flow Rate Small Water Flow Generators

Low-flow-rate compact water flow generators must maintain watertightness during operation in water, with critical sealing points including the drive shaft seal, housing seal, and cable seal. Among these, the shaft seal, being a rotating seal, represents the most challenging and pivotal component in

design, whereas the housing seal and cable seal can employ established sealing technologies.

Currently, various sealing methods are employed for shaft seals, including mechanical seals, magnetic fluid seals, oil seals, and magnetically coupled transmission seals. The study compared the principles and installation methods of these sealing techniques, ultimately selecting an internal skeleton oil seal paired with an O-ring for the transmission shaft seal. The design of the transmission shaft seal is shown in Figure 4. Since designing and manufacturing the generator casing separately would incur high costs, the design was simplified. Based on the dimensions of the small hydroelectric generator and its components mounted on the base bracket, the main casing structure is fabricated by welding seamless steel pipes and reducers. A sealing rubber ring ensures a tight seal between the internal structure and the casing. The internal cable outlets on the generator casing utilize proven cable compression seal connectors.

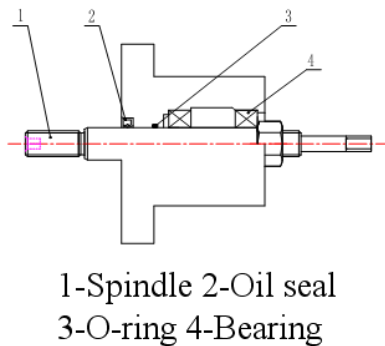


Fig. 4 Axis Seal Design Diagram

(3) Inlet Water Quality Detection Design

Various methods can be employed for water ingress detection. Currently, floating level switches are predominantly used for detecting water ingress in fixed submerged sealing components due to their low cost, ease of use, and high effectiveness. The design employs a stainless steel float-type level switch as the water ingress monitoring sensor. This type of switch requires no external power supply and directly outputs a dry contact signal, offering advantages such as compact size, simple installation, and long service life.

4 Research on the Overall Design of a Composite Power Supply System Integrating Wind, Solar, and Hydropower

To enhance power supply reliability for mountain river water facilities, reduce operational labor intensity, improve working conditions, and lower maintenance costs, an optimal power supply solution is urgently needed. Building on existing limited research, this paper proposes an efficient and clean hybrid power supply approach utilizing three renewable energy technologies—wind, solar, and hydro—to serve remote river sections in mountainous areas. This study aims to address the power supply challenges for river-based water facilities (raft boats) in mountainous regions lacking shore power during favorable meteorological conditions by utilizing renewable energy. It also seeks to enhance power

supply reliability when these facilities rely on a single power source. Based on the current structural design of renewable energy systems, the study proposes an integrated solution for a complementary renewable energy power supply system.

The hardware components of a hybrid power supply system integrating wind, solar, and hydro energy should include: renewable energy generation equipment (solar photovoltaic panels, wind turbines, hydroelectric generators), electrical control systems, safety monitoring systems, battery banks and their management systems, inverters, environmental monitoring sensors, and other related devices. For small water-based facilities such as navigation beacon boats, the system can be simplified accordingly. The overall system architecture is shown in Figure 5.

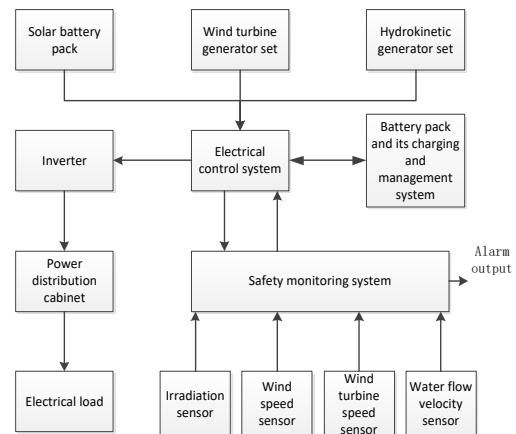


Fig. 5 Overall architecture diagram of the new energy power supply system

The overall design of the complementary new energy power supply system is as follows: Building upon the existing diesel engine power supply system of the bulk carrier, a complementary new energy power supply system has been developed, with its functional architecture shown in Figure 6.

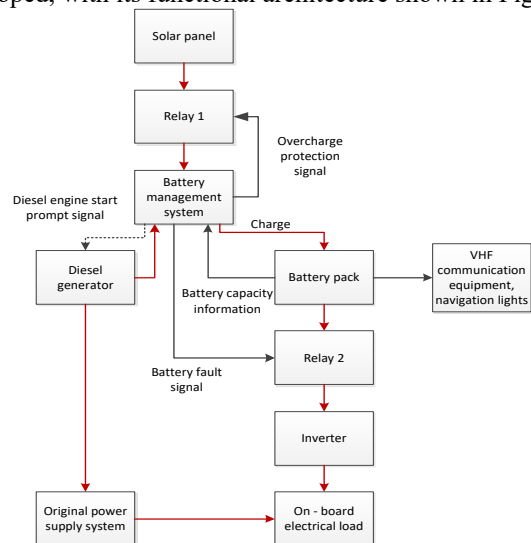


Fig. 6 Architecture diagram of the new energy complementary power supply system

The battery bank receives power from two sources: solar panels as the primary source and a diesel generator as a

backup. Under optimal sunlight conditions, the solar panels charge the battery bank; when sunlight is insufficient for the solar panels to meet the vessel's power demands, the diesel generator activates to supply power to the battery bank. In cases where certain renewable energy systems fail and cannot provide electricity, the diesel engine starts to supply power to the vessel's electrical loads^[9-10].

5 Overall Design Plan for the Security Monitoring System

- (1) Design Principles: High reliability, integration, scalability, low power consumption, and ease of operation.
- (2) Functional Design

The security monitoring system should possess the following functional categories, as shown in Figure 7.

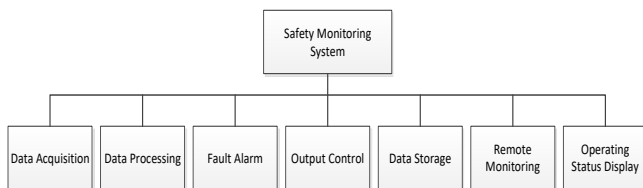


Fig. 7 Schematic diagram of the security monitoring system functions

The core unit of the safety monitoring system should integrate functions such as data acquisition, data processing, fault alarm, and output control, thereby reducing system design complexity while significantly enhancing reliability and scalability. The system must feature human-machine interaction capabilities, enabling operators to monitor equipment status through the interface and view fault alarms promptly when incidents occur. The interface should also store data and fault information, allowing analysis and evaluation of the hybrid power generation system using historical data.

System Functions: Wind power supply safety monitoring and protection; Solar power supply safety monitoring; Battery pack safety monitoring; Inverter safety monitoring and protection; Charger safety monitoring; Diesel generator startup alert; Power outage detection; Audio-visual alarm; Data storage; Human-machine interaction; Wireless remote monitoring.

(3) Security Monitoring System Design

The safety monitoring system employs a PLC-CPU as its data processing unit. It collects real-time sensor signals—including irradiance, wind speed, voltage, and current—through the PLC-I/O module, and gathers operational parameters from devices such as solar controllers via RS485. Based on predefined strategies, the system monitors its status and conducts safety assessments; upon detecting faults, it immediately issues fault alarms and safety control commands to prevent system damage or hazardous incidents. The PLC-CPU communicates with human-machine interface (HMI) devices over Ethernet, which display system parameters in real time and store relevant data. Additionally, the system

establishes data communication with shore-based networks through wireless remote communication modules and mobile wireless networks, enabling technicians to remotely monitor the operational status and fault information of the renewable energy power supply system. Its overall architecture is illustrated in Figure 8.

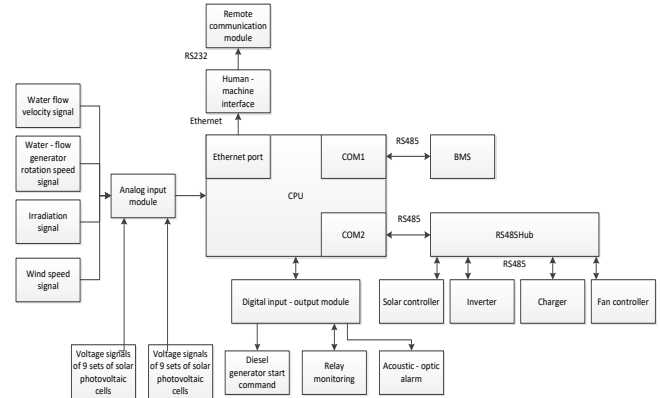


Fig. 8 Overall Structure of the Security Monitoring System

6 Conclusion

(1) Based on the navigation conditions of the Three Gorges Hub section, this study analyzes the utilization models of wind, solar, and hydro energy available in mountain rivers, explores application approaches for renewable energy on mountain rivers, and develops an integrated power supply system solution combining wind, solar, and hydro energy.

(2) By integrating existing renewable energy sources such as wind power, photovoltaic power, and hydroelectric power, a marine hybrid wind-solar-hydro power supply system has been developed. This system provides an efficient and clean power solution for water-based facilities in mountainous river areas (including tugboats and navigation aids).

(3) A hybrid renewable energy power supply system combining solar photovoltaic panels, wind turbines, and hydroelectric power generation has been piloted in the Three Gorges Dam area. Based on actual usage feedback, the system delivers stable output voltage with reliable equipment operation, saving nearly 10 tons of fuel consumption annually. Crew feedback indicates the system operates noiselessly, significantly enhancing their working and living conditions while achieving energy efficiency and emission reductions.

7 References

- [1] Zhong Yingkun, Qin Faming, Huang Jianming, et al: Research on the Feasibility of Photovoltaic Technology Applied to Maritime Barges in Chongqing. China Maritime Affairs, 2024, (7):53-55
- [2] Zhou Jialing: The First Photovoltaic Barge in Chongqing Connected to Grid for Power Generation. China Water Transport News, 2023-02-22(002)

- [3] Zhou Zilai: Design of Temporary Emergency Power Supply for Barges. *Marine Equipment & Materials Marketing*, 2021, 29(7):35-36
- [4] Kang Xiaoyong: Solar Power Supply System for Barges Based on Wireless Network Management[J]. *Marine Equipment & Materials Marketing*, 2021, 29(12):35-37
- [5] Wang Gang: Research on the Application of Shore Power Technology in the Three Gorges Dam Area of the Yangtze River. Master's Thesis.Hefei University of Technology, 2020
- [6] Chang Jia: Discussion on New Energy Application for Domestic Electricity of Waterborne Gas Stations[J]. *Oil Depot and Gas Station*, 2020, 29(6):23-27+5
- [7] Wang Shuirun: Electrical Analysis and Design of Catering Barges. Master's Thesis.Dalian University of Technology, 2018
- [8] Song Zhiqiang: Research on Solar Energy Application of Barges in Guizhou Area. Master's Thesis.Wuhan University of Technology, 2016
- [9] Ni Min: Research on Automatic Control System of Small Emergency Generators for Barges. *Mechanical and Electrical Equipment*, 2016, 33(2):23-26
- [10] Li Xiangrong: Development and Research on a Wind-Solar Hybrid Power Supply System for pontoon boats [J]. *Ship & Marine Engineering*, 2012,41(5):35 - 38