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Discussion on the Construction of Micro Hydropower Stations in China

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Abstract Through the demand analysis of emergency power supply construction, waterfall noise reduction treatment, and utilization of residual pressure resources, combined with water resources and industrial infrastructure conditions, this paper proposes the significance of micro hydropower station construction. However, micro hydropower stations face issues such as insufficient construction standardization, prominent safety hazards, lack of specialized standards, and the need for improved planning and design. Therefore, this paper analyzes and discusses the constraints and improvement summaries in the entire construction process of micro hydropower stations from aspects including guidance of standard formulation, rationality of planning and design, and innovation of new product applications.

Key words Micro hydropower station, Construction, Standard formulation, Planning and design, New product application

0 Introduction

Hydropower stations can be classified by installed capacity into large, medium, and small hydropower stations, with the conventional definition of small hydropower stations being those with an installed capacity of 50 MW or less. However, the capacity range of small hydropower stations is extensive with significant variations. In view of this, this paper defines hydropower stations with installed capacity below 500 kW as micro hydropower stations.

Although micro hydropower stations receive limited attention in China, they are playing an increasingly important role in production and daily life. On the one hand, remote mountainous areas in western China experience lagging economic development and weak infrastructure for people's livelihoods, frequently suffering from snow, ice, and rainstorm disasters with frequent network and power outages. As emergency power sources, micro hydropower stations can combine with small photovoltaic plants, small wind power stations, and energy storage facilities to form a new "source-grid-load-storage-supply" microgrid ecosystem. This system can quickly restore power supply during backbone power grid outages, especially during natural disasters, ensuring stability in production and daily life while maintaining smooth rescue communication. On the other hand, while numerous ecological landscape dams have been constructed in recent years to create water surface landscapes, waterfall noise in urban areas often disturbs residents, particularly at night. Micro hydropower stations can effectively resolve waterfall noise issues, enhance the social benefits of landscape dams, and serve as fish migration channels between upstream and downstream areas. Furthermore, residual pressure at the outlets of some water supply plants and wastewater treatment plants remains underutilized. Micro hydropower stations can harness this residual pressure for power generation, safely control outlet water pressure in supply pipelines, or reduce erosion impacts from wastewater plant effluent, increase power generation revenue, lower corporate operational costs, improve the proportion of clean energy supply, and facilitate the creation of green industrial parks.

Although there is extensive demand for micro hydropower station construction in China, there is insufficient standardization in construction practices and prominent safety hazard. Meanwhile, the promotion and application of new products face certain obstacles due to policy, funding, and scale limitations. Some research summaries on micro hydropower stations exist both domestically and internationally[1-3]. For instance, Reference[1] analyzed the characteristics and development of low and micro-head small-capacity hydraulic turbines as an example, while Reference[2] examined how to leverage small hydropower stations to promote rural electrification in mountainous areas.

In view of this, this paper focuses on discussing the constraints and improvement summaries regarding the construction significance, standard formulation, planning and design, and new product applications of micro hydropower.

1 Significance of construction

Hydropower is a vital civil water conservancy infrastructure and clean renewable energy source in China, having made significant contributions to societal development in its early stages. The Central Committee of the Communist Party of China and the State Council have consistently attached great importance to hydropower development, vigorously supporting and promoting rural electrification, ecological protection through hydropower fuel substitution, and hydropower emergency power supply construction. With continuous socio-economic development, the future priority lies in constructing eco-friendly hydropower projects.

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Remote mountainous areas in western China possess abundant water resources but lag in economic development, with substantial annual costs for the national grid to operate and maintain power supply facilities. Developing micro hydropower stations tailored to local conditions can meet emergency power demands, reduce grid pressure, increase local residents' income, and enhance public awareness of protecting power infrastructure. Simultaneously, they serve as critical components of the innovative "source-grid-load-storage-supply" microgrid ecosystem.

At the same time, as the number of urban landscape dam increases—some even adjacent to residential buildings—the hazards of waterflow noise cannot be overlooked, with frequent reports and complaints related to noise disturbances. Therefore, reconciling urban landscape water features with noise reduction requirements is a key consideration for future green urban development. Micro hydropower stations not only resolve waterflow noise issues but also fund dam maintenance through power generation revenue while creating fish migration channels.

Shennongjia Forestry District in Hubei Province, renowned as the "Water Tower of Central China", boasts abundant water resources, forest reserves, and eco-tourism attractions. As a distinctive mountainous region, the district features vast sparsely populated areas, crisscrossing mountain ranges, picturesque landscapes, numerous streams, and scattered unique homestays and villages. With its high altitude and prolonged snowy winters, the district faces significant grid supply pressure. Constructing micro hydropower stations near homestays and villages can substantially improve power supply reliability. Surrounded by cascading waterfalls or ecological dams, micro hydropower stations in these areas can mitigate nighttime waterflow noise while preserving waterfall landscapes during daytime non-generation periods. Additionally, integrating local tourism features with microgrid clean energy exhibition functions can enhance the quality of tourism resources. We conducted multiple field investigations in Shennongjia Forestry District, analyzing socio-economic conditions, ecological environments, and water resources, and submitted a feasibility study report on micro hydropower station development to the district government.

Some water supply plants experience high residual pressure at inlet pipe outlets, typically managed by pressure relief valves. This approach increases equipment maintenance requirements and operational costs. Replacing pressure relief valves with micro hydropower stations enables stable water pressure control, generates additional electricity revenue, and reduces operational costs.

The hydraulic head of wastewater treatment plant effluent is often underutilized. As a low-revenue public welfare project, constructing micro hydropower stations using this hydraulic head can diversify income streams and lower operational costs. Beyond abundant water resources, China's hydropower industry has advanced rapidly, with world-leading capabilities in design, construction, operation, equipment manufacturing, and R&D. Concurrently, the continuous advancement of intelligent control technologies provides a robust industrial foundation for integrated, unified, and intensive development of micro hydropower stations.

In summary, China's demand for micro hydropower station development is extensive and multifaceted. These projects integrate ecological, landscape, economic, and emergency power functions, delivering national and public benefits while effectively driving coordinated local economic, cultural, and social development.

2 Standard formulation

Micro hydropower stations feature small installed capacities, diverse powerhouse configurations, and varied equipment types. Both powerhouses and generating units can be constructed using multiple combinations.

Generating units are typically classified into conventional dry-type and submersible type. Conventional dry-type units allow water flow only through the runner passage without submerging other components, while submersible units can operate with the entire assembly submerged underwater.

Hydropower station configurations are generally categorized into conventional, integrated, and unitized gate types[4]. Conventional hydropower stations typically involve phased construction of structures and dry-type electromechanical equipment. Integrated hydropower stations usually integrate the station building shell, units, auxiliary equipment, control cabinets, shells, *etc.* into a complete set of devices. Some even integrate the water diversion channel and gates into the device, and hoist or assemble them as a whole on site. The units can be conventional dry or submersible; Integrated turnstiles usually combine submersible units, gates, hoists, *etc.* into a set of integrated turnstiles, which are lifted or assembled as a whole on site.

Powerhouse types include dry-type above-ground, dry-type underground, wet-type, and wet-type hydrogenerator pit configurations. Dry-type above-ground powerhouses incorporate both above-ground and below-ground structures with watertight interiors for dry equipment layout. Dry-type underground powerhouses feature solely subterranean watertight structures. Wet-type powerhouses utilize submersible units within floodable underground structures, while wet-type hydrogenerator pits employ partial underwater structures housing submersible units.

Current decentralized self-built micro hydropower stations exhibit random equipment layouts, posing significant regulatory challenges and safety risks. Unregulated water diversion practices lead to severe resource waste and potential river ecosystem damage. Some manufacturers demonstrate inadequate R&D capabilities, resulting in products with low efficiency, poor craftsmanship, and subpar quality. Lacking systematic planning and design guidance nationwide, most micro hydropower projects are initiated by individuals or group unfamiliar with hydropower industry standards, leading to functional deficiencies and prominent safety risks due to insufficient expertise in design, construction, and operation.

Moreover, the absence of dedicated national or industry standards forces practitioners to reference the *Design Code for*

Small Hydropower Stations[5], which inadequately addresses micro hydropower-specific requirements, particularly for wet-type powerhouses, integrated hydropower stations, integrated hydroelectric generator gates, submersible hydroelectric generator units.

In 2024, the implemented *Construction Code for Micro Hydropower Stations*[6], grounded in theoretical frameworks and practical experience from multiple projects, has established comprehensive regulatory requirements covering diverse structural forms and equipment for construction and operation management.

Therefore, the success of micro hydropower station construction fundamentally requires guiding principles and regulatory documents to standardize industry practices in planning, design, construction, production, and operational management.

3 Planning and design

Though compact in scale and simple in layout, micro hydropower stations must fulfill comprehensive safety requirements as fully functional structures, embodying the principle of "small yet complete". To prevent construction management failures, improper layout selection, functional deficiencies, or resource waste, experienced and qualified entities should conduct feasibility studies, followed by scientific planning and design, with final implementation adhering to design specifications.

(i) Development and construction should prioritize local governments or state-owned enterprises to directly benefit community economies and leverage projects as refinancing assets for other infrastructure. Case examples: In Shennongjia Forestry District (Hubei), State Grid spearheaded project initiation before transitioning operations to village collectives. Yuan'an County (Yichang) implemented village-led construction with municipal discipline inspection commission, transferring post-completion operations to communities. Dangyang City (Yichang) projects were developed by water authorities and investment companies, later transferred to state-owned hydropower enterprises.

Despite low returns hindering the participation of large corporations, local government initiatives have driven micro hydropower development to boost community incomes, consolidate poverty alleviation achievements, ensure operational safety, and optimize regional renewable energy portfolios.

(ii) It is necessary to conduct field surveys to collect hydrological, geological, meteorological, and socio-economic data, assessing resource availability and developmental impacts for techno-economic feasibility validation.

(iii) Local governments should streamline approvals through interdepartmental coordination mechanisms.

(iv) Based on the feasibility of hydropower station construction, the engineering layout and electromechanical equipment selection should be rationally determined through comprehensive consideration of various factors. Priority should be given to integrated or modular devices to optimize investment efficiency. Hydropower station buildings, whether designed for integral hoisting or modular assembly, should predominantly employ steel structures with simplified yet rational configurations that ensure both safety and stability. Concurrently, ecological flow discharge measures must be appropriately incorporated into the design. We should try to utilize the existing ecological dams for renovation and construction, while avoiding unfavorable geological areas as much as possible. Electromechanical equipment must adopt high-efficiency and low-consumption products, with the number of units minimized and their capacities aligned with standardized series specifications to reduce equipment development costs. Unit selection must be rationalized, particularly ensuring reliable sealing mechanisms for submersible generators. The terminal voltage of the generator should be between 400 V and 660 V depending on the type of generator. The stable output voltage regulated by the inverter is 400 V, which is connected to the user's power grid for fully automated operation. It can be monitored on both the handheld and computer terminals.

(v) Micro hydropower stations, characterized by small-scale installations and limited economic returns, require strict cost control over capital investments. Smart control technologies should be adopted to reduce operational costs while maximizing their input-output ratios.

The preceding analysis substantiates that planning and design serve as the critical enabler for successful micro hydropower project implementation. These phases can minimize adverse factors, apply high-quality products to practice, and improve and optimize them.

4 New product applications

Beyond conventional hydropower equipment, micro hydropower stations increasingly employ innovative technologies including submersible turbine-generator units, residual-pressure turbine units, hydraulic automatic control valves, self-regulating water diversion systems, integrated hydropower stations, integrated hydroelectric generator gates[6]. These technological innovations enable broader adoption of advanced equipment, laying the foundation for sustainable micro hydropower development.

Submersible turbine-generator units represent innovative hydraulic equipment operating in fully submerged conditions, demonstrating exceptional adaptability across diverse aquatic environments. Their deployment scenarios encompass downstream pipe outlet, weir hydraulic drop, and canal hydraulic drop. Installation configurations permit horizontal or vertical orientation, with implementation options including direct connection to pipelines, embedment within hydrogenerator pits, mounting on retaining walls, or integration with sluice gates to form gate-turbine complexes. Featuring tubular flow passages akin to borehole submersible pumps, these units integrate runners, shafts, submersible generators, bearings, and casings into single assemblies. Critical sealing systems protect generators from water ingress, demanding high-performance impermeability. Regarding the existing issues in the operation of submersible generator units, we propose various innovative technological solutions for sealing improvement and optimization in implemented cases. For instance, the integration of external positive-pressure air for anti-seepage purposes effectively prevents external water from infiltrating into the inner chamber of submersible generators through sealing structures. This solution has been practically implemented on-site with satisfactory outcomes. The advantages include a simple sealing structure and relatively effective sealing performance. However, the drawbacks involve the addition of an external air compressor system to maintain pressurized air supply, which requires continuous operation and incurs significant energy consumption. Moreover, any malfunction in this air supply system would expose the generator interior to water infiltration risks. Another proposed enhancement involves supplementing the existing sealing system with a magnetofluidic sealing structure at its rear section. As an unexplored technological innovation, this approach demonstrates notable merits including autonomous operation without supplementary equipment and enduring sealing performance, though it necessitates more intricate mechanical design implementations.

Submersible generators can be of asynchronous or permanent magnet type. Although permanent magnet submersible generators have a higher cost, they operate stably and efficiently. Most submersible generators utilize gas-pressurized internal chambers, which offer advantages such as lower construction costs, simplified structural design, and ease of maintenance. In contrast, water-filled, oil-filled, and hermetically sealed submersible motors impose stringent technical requirements for both internal and external anti-seepage treatment processes. These configurations result in significantly higher manufacturing costs, elevated maintenance expenses, and limited operational applicability under constrained environmental conditions. Submersible units demonstrate exceptional environmental adaptability, making them highly viable for widespread micro hydropower deployment.

Residual-pressure hydroelectric generator units are predominantly deployed in environments such as water supply plants, tailwater systems of wastewater treatment facilities, and cooling towers of chemical plants. These systems can be configured with either conventional units or submersible units, with structural configurations and installation modalities being adaptable to specific operational conditions for performance optimization.

Current submersible units lack integrated flow control mechanisms, relying on inefficient valve systems with high costs and low precision. Therefore, we have invented a novel pipeline-segment flow regulation device, currently undergoing patent review. The operational principle involves deploying the device at the turbine inlet side, utilizing the pipe casing as the structural support, with components including circumferentially arranged guide vanes, flow-guiding bodies, annular control mechanisms, and hydraulic lifting actuators. During rising inlet reservoir water levels, the guide vanes progressively rotate toward an open position, causing flow rates to incrementally increase to design capacity. During water level decline, the vanes rotate toward a closed position, resulting in continuous flow reduction until achieving zero-flow shutdown. This novel device effectively addresses uncontrollable flow issues in submersible turbine units. By replacing the hydraulic lifting mechanism with electro-hydraulic or fully electric control systems, its applicability extends to broader operational scenarios.

Integrated hydroelectric plants, particularly containerized hydropower stations, have demonstrated successful deployment with proven operational performance[7].

The integrated hydroelectric generator gate is an innovative product combining submersible turbines with steel gates, controlled by hoists for vertical positioning. During power generation, the unitized gate system drops; during maintenance or flood discharge, it elevates to a dedicated service platform. This system offers wide applicability and cost efficiency. It is especially suitable for scenarios such as hydraulic waterfall from ecological dams or channels or hydraulic drop from tail water of sewage treatment plants.

5 Conclusion

China's abundant water resources and perfect industrial base, coupled with growing demands for emergency power infrastructure, hydraulic drop noise mitigation, and residual-pressure utilization, underscore the strategic importance of micro hydropower development alongside the evolution of "source-grid-load-storage-supply" smart microgrid ecosystems.

As core components of micro hydropower systems, advanced electromechanical equipment drives continuous innovation through diversified technological solutions and R&D breakthroughs. Establishing national/industry standards is recommended to regulate construction practices, optimize design rationality, enhance manufacturing quality, and align with China's green ecological sustainability strategy.

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