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Status of micro-hydrokinetic river technology in rural applications: A review of literature

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A B S T R A C T

Apparently, most hydrokinetic literatures mainly concentrate on large-scale technologies such as waves, tides and ocean current applications. This could be one of the reasons delaying the utilization of small-scale hydrokinetic river technology in rural areas. This paper therefore critically reviews the current status of micro-hydrokinetic river (MHR) technology for rural applications. Relevant research literatures based on developments, applications, design, operation as well as different MHR technologies involved in rural electrification projects have been reviewed. After conducting these reviews it has become clear that one of the key barriers hindering the employment of MHR technology in rural areas with access to flowing water is the lack of research demonstrating the technical, economic and environmental benefits of this technology compared to other rural electrification techniques. Studies that look towards the long-term perspective of techno-economic analysis inclusive of capital, maintenance and running costs computations need to be carried out promoting the interest in utilizing this technology. This paper will aid researchers to identify areas that need to improve as well as encourage public bodies to implement proper energy policies regarding the MHR technology usage in rural areas. It will also create awareness among site owners, investors, project developers and decision makers regarding the potential benefits of using this technology in rural areas especially in countries with little or no elevation.

Contents

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1. Introduction

The growth of climate change and electrical demand as well as rising diesel fuel prices are the key subjects encouraging the use of renewable technologies. Utilization of electrical energy plays an important role in economic growth and improvement of people's living standards. An ideal energy source should be renewable and should have minimal effect on environment [1]. It has been proved that one-third of the world's population does not have access to electricity, but does have access to moving water [2]. Majority of rural residents are very poor, with low living standards, limited education and little access to information. Despite the efforts in remote area electrification, progress and success rates remain low. Poor planning, lack of research and negligence are some of the factors contributing to the delay of rural electrification deployment [3].

To improve the living conditions of rural residents, provision of electricity is crucial. Small remote communities often require electricity supply for small loads such as lighting, refrigeration, communications etc. [4]. Solution towards rural electrification is made possible by means of basic approaches/techniques such as grid-extension, diesel generators or small-scale renewable energy systems. However, grid-extension to rural areas is considered uneconomical by many utility companies, due to the low consumption and poor load factors. This is certainly an unattractive supply option since most rural residents are poor and thus unable to finance electrical services [5].

Diesel-power generator (DG) has been the most popular option since it used to be the cheapest available option, particularly for low load applications [6]. It can be used in many remote settlements, either for a single user or as part of a local distribution network. In addition, it is safer, durable and also requires less maintenance. Nevertheless, DG approach continues to be more unsustainable for rural residents due to further increase of petroleum prices and difficulties in transporting the fuel to remote places.

Renewable technologies (biomass, wind, solar, hydro and geothermal) are offering clean and reliable energy to reduce greenhouse gas emission that lead to global warming while saving money and creating jobs. They provide a cost-effective source of electricity in rural areas where distances are large, populations are small, and demand for energy is low [7]. Small-scale renewable technology is a very good option for supplying electric power to isolated rural areas [8].

For remote areas situated in close proximity to flowing water, micro-hydro system is the most economical and reliable option for generating electric power [9]. It can compensate non-continuous availability of many renewable energy resources such as wind and solar. Among different renewable energy technologies, hydropower generation (large and small scale) holds prime position in terms of contribution to the world's electricity generation [9–12]. Large-scale hydropower stations are equipped with large dams and huge water storage reservoirs. As a result they received considerable criticism due to their negative environmental impact [10,11,13].

Small-scale hydropower is one of the most economical and environmentally friendly technologies to be considered for rural electrification projects. It can be a very good complement to a solar power system, as it produces electricity for 24 h a day as long as the running water is available. It is a much more concentrated energy resource than either wind or solar power [9]. It is often classified by the power generation potential as shown in Table 1 [8].

Table 1
Small-scale hydropower classification by power generation.

Classification	Size in kW
Small hydro	1000–30,000
Mini hydro	100–1000
Micro hydro	< 100

A conventional micro hydropower station essentially needs water to be diverted from the stream and brought to the turbines without losing the elevation/head. Compared to DG, conventional micro-hydro is characterized to have high initial capital cost and very low running costs [14]. However, the disadvantage of using conventional small-scale hydropower is that, in most cases it is obtained from run-of-river plants that lack the reservoir capacity to store water [9]. As a result, a backup electricity supply will be required due to seasonal variations resulting in severe reduction of firm output power, depending on the site hydrology [8,15].

Apart from conventional hydropower generation, hydrokinetic is a new category of hydropower energy that generates electricity by extracting kinetic energy of flowing water instead of potential energy of falling water. It shares lot of similarities with wind turbine systems in terms of the physical principles of operation, electrical hardware, and variable speed capability for optimal energy extraction [16]. But because water is almost 800 times denser than air, hence hydrokinetic turbines extract enough energy even at low speed [17–20]. It generates electricity without the need of building dams and other costly projects [21–24].

In addition, this technology is becoming more attractive among other renewable energy sources due to its high energy density, good predictability and minimal environmental impact [25–27]. Many remote villages and farms might be situated in close proximity to rivers with little or no elevation. In such cases it is impossible to use the conventional micro-hydro generation [28]. This simply depicts that there is theoretically huge number of potential sites available for hydrokinetic technology compared to the traditional hydropower generation [29].

This technology is still in the development stage and there is a lack of application especially in rural areas with reasonable water resources. It is hoped that the information presented in this paper can be useful for a better understanding of the benefits offered by this micro-hydrokinetic river (MHR) technology.

In order to aid with more development of this technology, it is of an urgent requirement to demonstrate its current status. Hence, through brief review of recent hydrokinetic river development studies for remote/rural electrification applications, this study aims to provide researchers/developers with more prioritized outlook of needed advancements. This paper will also be useful to site owners, investors, project developers and decision makers who are responsible for critical screening and approval of rural electrification programmes. It will facilitate permitting policies by regulatory agencies and promote project financing by financial institutions.

2. Hydrokinetic technology

Hydrokinetic energy is captured from waves, tides, ocean currents, the natural flow of water in rivers, or marine thermal gradients [1,30]. However, the scope of this paper is limited to applications in free-flowing rivers, since it is suitable for small-scale electricity generation [29,31]. Hydrokinetic or water current turbines, produce electricity directly from the flowing water in a river or a stream. The turbine blades would turn the generator and capture the energy of the water flow.

2.1. Operation principle

The amount of electricity that can be generated from this energy source is dependent on the volume and velocity of the