Turkish Online Journal of Qualitative Inquiry (TOJQI)
Volume 12, Issue 7 July 2021: 13272 – 13279

A brief study on the impact of hydel micropower generation in the Indian energy sector.

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Abstract

Various technologies and aspects of hydel micropower generation and its viability are discussed in this article. As per Indian standards, Small hydropower plants (SHP) are hydropower facilities with a capacity of 25MW or less. The article is intended to provide the current scenario of the small hydro projects in India. The article is divided into five sections for better understanding, each emphasising the critical factors that affect the micropower generation from SHP in India. SHP, turbines for SHP, challenges in micropower generation (including the effect of Covid-19), and energy extraction from the dam's tailrace are discussed. The current research looks at the advancements and limitations of micropower generation in India and the prospect of more significant potential and applicability.

Keywords: *Micropower generation, Small hydropower (SHP), Cross flow turbines, Gorlov helical turbine, Covid-19.*

Introduction

India has the world's fourth-biggest coal deposits and is the world's largest source of electricity generation fuel. Coal meets two-thirds of India's electrical consumption. Even though the reserves are rapidly depleting, it is still possible to use them for an extended length of time. The environmental impact, on the other hand, is long-term. The Indian government has strengthened superior interconnectivity across the country and now seeks to improve the efficiency of the existing coal resource. Traditional energy sources are in a race against time, and renewable energy sources must be used to the fullest extent possible. Several national governments have recently announced their road map for net-zero carbon emissions. These decarbonization targets would necessitate larger-scale electrification of industries and transportation and energy generation from non-fossil fuel resources. Therefore, the production of a significant part of electricity from variable renewable energy sources becomes essential.

The construction of a single national power system powered by modern thermal and renewable systems has significantly improved current reforms by NITI Ayog (India's policy think tank).

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India's energy sector is undergoing a massive transition to a higher proportion of renewable energy, raising profound system integration and adaptability issues. Since 2000, the current government has successfully brought power to more than 700 million people, demonstrating its commitment to complete electrification. The Indian government has established short-term goals for renewable energy. By 2022, the country plans to install 175 GW of renewable energy, including 5 GW coming from small hydropower. At the United Nations Climate Summit in September 2019, India's Prime Minister proposed a new 450 GW of renewable energy capacity without specifying a deadline.

Given the major share of water on the planet's surface, hydropower holds immense among the renewable "clean" energy sources. The scope can be found as currents in enormous rivers and vast oceans and river creeks (Semerci & Yavuz, 2017)(Mehmood et al., 2012). Traditional turbines are well suited for low discharge-high head and high discharge-low head applications (Yuce & Muratoglu, 2015). They are, however, nearly obsolete in ultra-low head applications. The hydropower from tailrace water presents interesting prospects of micro hydropower generation which if implemented efficiently can enhance the existing rating of a power grid. Unfortunately, the hydropower capacity of such a scheme is often overlooked because it is deemed uneconomical.

In 2020, as per source wise estimate of energy in Energy Statistics Report, hydropower and nuclear power constituted only 13 percentage (as per Figure 1). India's total renewable energy reserve is estimated as 1096081 MW (mentioned in Table 1), of which the small hydropower constitutes only 1.8% (19749 MW). Building more dams is not an optimum solution for this problem as it leads to the destruction of forests, loss of wildlife, men –money and material.

Crossflow reaction turbines are currently being employed to harness energy from such systems. As the name implies, cross-flow turbines have a fluid flow perpendicular to the axis on which the turbine rotates. Due to their self-starting capabilities, the first turbine used for such a purpose was the Darrieus water turbine (Daniel & Nicklas, 2013), mainly from tidal sources. A self-starting water turbine can revolve in a set direction regardless of the direction of the tidal current, making them a favorite for low head applications. The article lays out a road plan for extracting hydel power using various micropower generating techniques. The current power generating status in India concerning hydropower will be discussed in detail. The article also mentions the possibility of dam-free power generation employing barriers with helical turbines. These barriers can provide low-head without interfering with fish movement through the turbines of the power plant. Turbines that can convert a high quantity of energy from moving fluid and those that can be used to generate micropower are given specific consideration.

Sl.no	Type of Energy	% distribution
1	Solar power potential	748990 MW (68.33%)
2	Wind power potential	302251 MW (27.58%)
3	SHP (small-hydro power) potential	19749 MW (1.80%)
4	Biomass power	17,536 MW (1.60%)
5	Bagasse-based cogeneration in sugar mills	5000 MW (0.46%)
6	Waste to energy	2554 MW (0.23%)

Table 1: Source wise estimated renewable energy potential in India as per Energy statistics report 2020

This article is based on research and analysis of recent scientific literature published in journals and conferences, data gathered from several Indian agencies (MNRE- Ministry of New and Renewable Energy), and books on hydropower development. After a thorough study of the literature, large and small hydropower are separated, and a detailed discussion of micro power generation in the context of short hydropower in India is offered. The article is structured into five sections, each of which highlights India's need for a micropower generation. They are: review of small hydropower in India, turbines for small hydro power plants, challenges in a micropower generation, energy extraction from dam's tailrace, and conclusion.

Review of small hydropower in India

Hydroelectric power was once India's primary source of renewable energy. In the late 1970s, hydropower alone accounted for around 40% of total electricity output. While hydropower output has increased significantly (as noted in figure 2), its percentage of total electricity production has decreased to approximately 10%. This is because most of the facility houses traditional turbines, which will develop ill effects over time, reducing the efficiency of turbines. The increasing power generation from wind, solar photovoltaic, and biofuels has kept the overall proportion of renewables consistent at around 16-17 per cent over the last decade. Hydroelectric power schemes are classified as large or small hydro projects based on their capacity. Small hydropower plants, which typically have capacities ranging from 10MW to 50MW, are identified by different capacity criteria in other nations. According to the Ministry of New and Renewable Energy's newest rules, a hydropower plant with a capacity of 25MW or less is defined as small hydropower, which is further divided into three segments: micro (100kW or less), mini (101kW-2MW), and small hydro (2-25MW)(Ministry of New and Renewable Energy, 2020). Hydropower was managed mainly by the Ministry of Power prior to 1989, with the help of State Electricity Boards. However, after 1989, the Ministry of New and Renewable Energy (MNRE) was given responsibility for plants with capacities of up to and below 3 MW. As a result, MNRE was given responsibility for 63 MW of total installed capacity of 3 MW and below hydro plants. The Department of Hydro and Renewable Energy (previously AHEC) of IIT (Indian Institute of Technology) Roorkee estimated a projected capacity of 21135.37 MW from 7135 possible locations for power generation in the country through small/micro hydro projects in its Small Hydro Database.

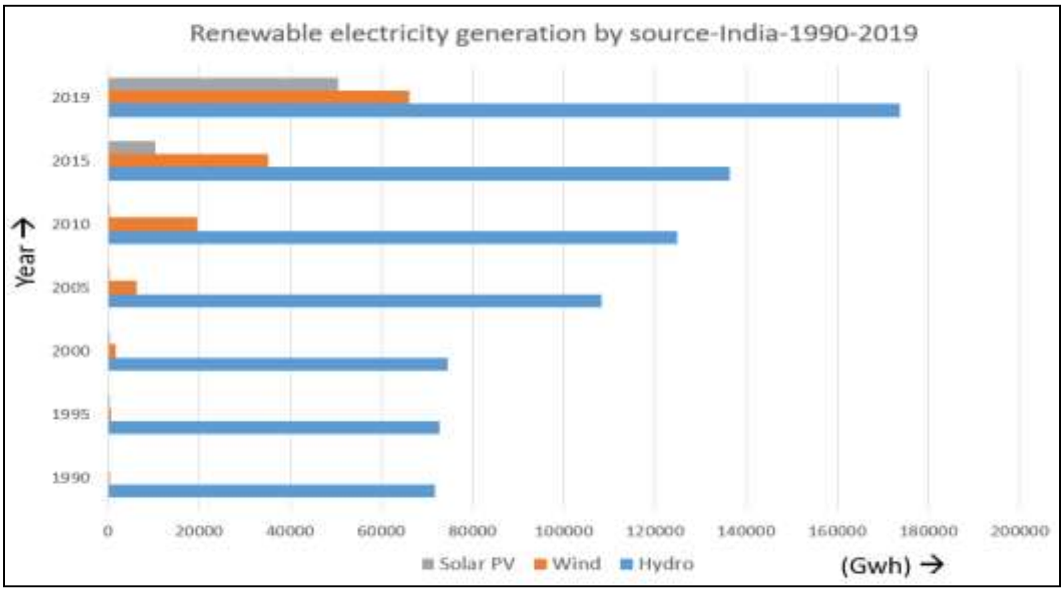

Figure 2: Renewable electricity generation by source (India) as per International Energy Agency report 2020

About half of this potential is represented by India's mountainous states, primarily Himachal Pradesh, Jammu & Kashmir, and Uttarakhand (as mentioned in table 2). Other states that could be considered are Karnataka, Chhattisgarh, Kerala, and Maharashtra. To encourage private investment, close interaction, programme monitoring, and analysis of the policy environment are given to these states. The Maniyar dam project in Kerala exemplifies private investment in small hydro projects. Smaller hydropower projects are less likely to confront the issues with larger hydropower projects, such as deforestation and displacement. These initiatives, along with the benefit of a micro hydel power system, can meet the energy needs of rural and inaccessible areas. Around 24 states in the country have policies that allow the private sector to participate in creating SHP systems. Micro-hydro turbines are appealing since they are less expensive and can be constructed domestically. Karnataka, Himachal Pradesh, and Maharashtra are the states with the most installed capacity. Small hydropower potential is abundant in India's north and northeastern regions; the northeast is known as the country's "Future Power House"(Doso & Gao, 2020).

Sl.No	State/Union Territory	Installed Capacity (MW)	Sl.No	State/Union Territory	Installed Capacity (MW)
1	Andhra Pradesh	162.11	16	Meghalaya	0
2	Arunachal Pradesh	131.1	17	Mizoram	32.53
3	Assam	34.11	18	Nagaland	30.67
4	Bihar	70.7	19	Odisha	64.62
5	Chhattisgarh	0	20	Punjab	173.55
6	Goa	0.05	21	Rajasthan	23.85
7	Gujarat	68.95	22	Sikkim	52.11
8	Haryana	73.5	23	Tamil Nadu	123.05
9	**Himachal Pradesh**	**911.51**	24	Telangana	90.87
10	Jharkhand	4.05	25	Tripura	16.01
11	**Karnataka**	**1280.73**	26	Uttar Pradesh	25.1
12	Kerala	222.02	27	Uttarakhand	0
13	Madhya Pradesh	95.91	28	West Bengal	98.5
14	Maharashtra	379.57	29	Jammu and Kashmir	180.48
15	Manipur	5.45	30	Delhi	0
			31	Anadman and Nicobar	5.25

Table 2: Installed Small hydro capacity in various states of India as per MNRE

The Indian government is pushing the rapid growth of SHP. In the fiscal year 2019–20, Twelve SHP projects were commissioned, six of which are in Himachal Pradesh and have a total capacity of 45.9 MW.(Doso & Gao, 2020)

Turbines for Small hydro power plant.

The potential energy of water is turned into mechanical energy in a turbine. The turbine configuration is separated into two types based on the head and flow. When the water turbine is located at a substantially high head, the impinging jet is made to descend on the impeller using the nozzle. Impulse turbines like Pelton and Turgo are utilised in medium and high head plants, whereas the crossflow turbine is employed in low and medium head plants. In most cases, the reaction turbine is submerged in water. This is used to convert the fluid's total energy (kinetic as well as pressure energy) into a usable form. Guide vanes and runner profiles are designed for optimum energy transfer in the flow. A typical example is the Francis turbine. Turbines for micro-hydro applications come in a variety of shapes and sizes. Because of its ease of design, installation, servicing, and maintenance, crossflow turbines are frequently recommended for the micro-hydro range. Despite the fact that the crossflow is designed for lower discharge, it can readily handle medium and higher heads. Such a trait is usually advantageous, as the discharge from perennial sources can change at any time. However, when compared to other conventional turbines, its efficiency is lower. Hydrokinetic turbines are kinetic energy transfer systems that extract energy from moving water. They don't generally need a casing and are completely exposed. In contrast to other traditional turbines, literature claims that in hydrokinetic turbines in the water, the need for a physical structure for the head can be omitted. However, the self-starting qualities and initial torque are crucial. There are several similarities between wind and water hydrokinetic turbines.

Class of Turbine	Type of Turbine	Minimum starting speed	No load output power
Gorlov Helical Turbine	Helical Darrieus cross flow axis	0.6 m/s	Up to 20 W
Water Current Turbine	Axis flow propeller	0.6 m/s	Up to 2000 W
DHV Turbine	Vertical axis Darrieus turbine	Min. 2 m/s	From 4600 W
MFP101a	Propeller turbine	Min. 3 m/s	Up to 30 W
ENTEC T15	Cross flow	More than 10m/s	From 29000 W

Table 3: Details of cross flow turbines used for SHP

To keep the turbine in place and protect it from shifting currents, a makeshift mechanism, usually, an exterior tubular framework to support the structure, is required. Pontoons could be used to anchor or hold it in place. A current of 0.5 m/s is known to start these turbines. Hydrokinetic turbines are classified as vertical axis or horizontal axis depending on the orientation of the shaft. They are further divided into two types: axial and cross flow. Some of the most common turbines used for SHP are mentioned in table 3.

Challenges in a micropower generation

The obstacles that micropower generation from small hydropower units faces as a growing alternative energy source are enormous. A single metric doesn't just determine any such technology's success. Instead, a slew of technical and non-technical concerns could cast doubt on its efficacy(Khan et al., 2008). This section presents a broad perspective on such underlying difficulties.

Geography

Perhaps the first and most important concern about micropower energy generation using SHP is if there are enough productive areas throughout India to collect energy in a cost-effective manner. What would constitute a "productive geography" if such sites were available? This needs a study of macro and micro scale site assessment, annual energy yield calculation, and river features analysis. Most researchers often rank accessibility to the site before the project implementation. An evaluation by site scoring should be performed to determine which site to move forward with. Site scoring is a complex screening procedure in which each site is evaluated separately and then compared using the same parameters. Each criterion is assigned a score, and each criterion or parameter is assigned a degree of importance or relevance to the project's progress. The site scoring parameters are as follows:

1.Ease of access: The team needs easy access to the site because they intend to conduct on-site testing once the prototype is built. The significance of this factor to the successful project is given a threshold value of 30%.

2.Flow Rate: For the marine turbine, an optimum flow rate of greater than 2m/s was specified. The significance of this parameter to the project's success is given a threshold value of 60%.

3.Flow Characteristic: The flow characteristic is important because the complexity of the marine current energy device is affected by the flow direction. It is essential to keep the design simple, so a unidirectional flow is preferable to a bidirectional or Omnidirectional flow. This parameter is assigned a threshold value of 10% in terms of significance to the project's progress.

A river's temporal and spatial flow parameters, as well as an examination of the river's depth, wide swath, transit, accessibility, and marine/ aquatic life, are all required. For river energy analysis, global river databases are not readily available. As a result, database analysis methods must be developed.(Khan et al., 2008)

Budgetary constraints

The price of power is the next big issue, and it is also the most critical factor impacting the accomplishment of most grid systems. The cost of construction, its operation, and maintenance always contribute to the total finance of the system. Standardization, adaptability, material costs engagement, and off-the-shelf component availability are all possible index subsets of the total budget. However, with the advent of 3D printing and related technologies, the cost spends on the turbine is drastically reduced. For instance, a Gorlov helical turbine used for a micro power generation would cost only 3 USD to be "printed", which previously cost around 100 USD.

Pandemic (Covid-19)

Pandemic was never a criterion that would be included in the challenges of power generation. However, Covid-19 has caused a breakdown of economies. Many projects were derailed, and spending had to be cut short. In June and July 2020, the contribution from large hydro (more than 25 MW) was 22% greater than that in 2019. This suggests that during these months, hydropower compensated for the reduced energy from wind power. Prime Minister Narendra Modi has asked Indians to turn out their lights for nine minutes at 9 p.m. on April 5 to show solidarity in the face of the Covid-19 pandemic. During the nationwide lights off event, hydro capacity was reduced by 66 per cent in just 25 minutes, demonstrating its flexibility.

Energy extraction from dam's tailrace

Hydropower potential can be found not only in big basins but also in massive oceans and rivers. Another potential topic is irrigation dam tail-race water. Because it is considered uneconomical to build new structures exclusively for power generation, the hydropower of such dams is mainly unused. Crossflow turbines are suitable for low head-high current applications; however, a modified form of crossflow turbines is required for properly extracting energy from a dam's tailrace, which is largely used for irrigation. Self-starting capability is another expected benefit of such turbines. Prof Gorlov, the inventor, was able to obtain 35 per cent efficiency using NACA0020 as the aerofoil profile of the blades. Complex geometric aerofoil constructions were challenging to manufacture earlier.(Jayaram & Bavanish, 2020) With improvements in additive manufacturing, such as 3-D printing, these problems are no longer an issue. According to the literature and tests, the most efficient configuration is a three-blade configuration, as seen in figure 3.

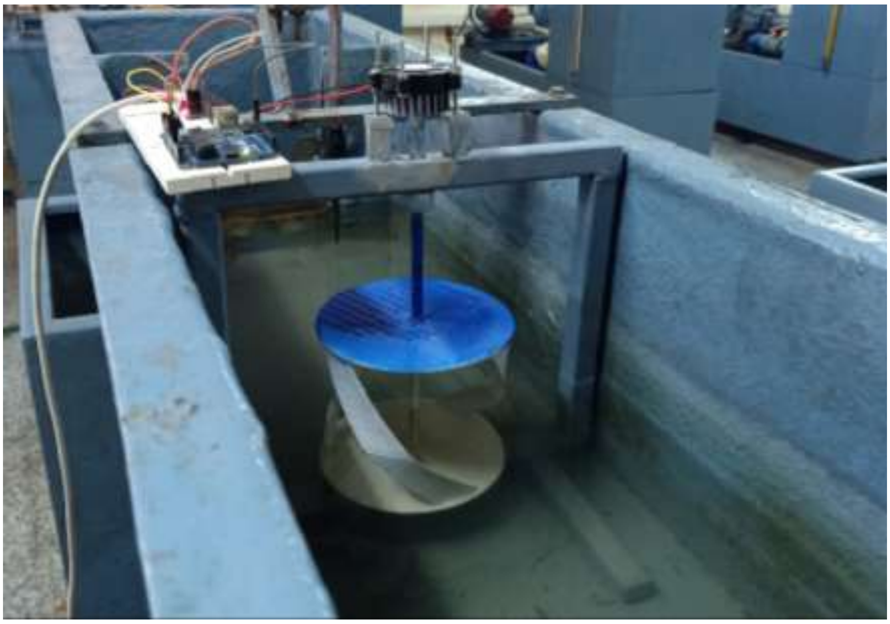

Fig.3: Gorlov Helical Turbine Installed in a horizontal channel (test bed).

Conclusion

The technology for micropower generation using SHP systems is most likely in its adolescence. According to several recent publications, such devices gradually make their way out of the laboratory and into the real world. The majority of the infrequent attempts in this field, however, have yielded favourable outcomes. Replicas with electric interfaces must be designed to show the effectiveness of a whole system. As the pandemic spread over the world, India was not immune to the virus's high infection rate, and the government was forced to enforce tight lockdown regulations. Because of the shutdown regulation, India's energy consumption fell drastically at the end of March 2020. However, once the regulation was relaxed, the energy consumption gradually began to recover. Over time, energy demand would increase. Building new dams is not the best solution for this problem because it results in the devastation of forests, the extinction of species, and the loss of men, money, and material. The article suggests methods to tap the existing energy from these dams with negligible investment to correct the scheme.

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