Lack of Energy in Isolated Communities: Micro and Small Hydropower Generators for Creeks and Rivers

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***Abstract*— Currently, there are millions of people who do not have electricity because they live in small towns or far from cities. In addition to distance, poverty is also a factor that affects access to energy and the lack of access to energy generates, in turn, more poverty. Fortunately, around the world there are many engineers creating solutions to this type of problem. The generation of electricity by hydroelectric dams is one of the most common methods to supply energy at electric grids and engineers have designed hydroelectric dams but in a small size: micro hydropower generators. They stand out for the quantity of power that they can generate, the different types in existence and their size, which makes it fit for creeks, rivers, and small flux of water. The principle of operation and some types of this device are presented in this paper with the intention to spread their existence. It is expected that this paper may inform the readers about the energy problem and its magnitude in people's quality of life, show the existence of reliable and friendly solutions with the environment, and provide the necessary information for them to do their share to help the global community.**

***Keywords:* hydroelectric energy, microturbine, sustainability**

***Resumen*— Actualmente, hay millones de personas que no tienen electricidad porque viven en pueblos pequeños o alejados de las ciudades. Además de la distancia, la pobreza también es un factor que afecta el acceso a la energía y la falta de acceso a la energía genera, a su vez, más pobreza. Afortunadamente, alrededor del mundo existen muchos ingenieros creando soluciones a este tipo de problemas. La generación de electricidad mediante represas hidroeléctricas es uno de los métodos más comunes para suministrar energía a las redes eléctricas, por lo que para este caso los ingenieros han diseñado represas hidroeléctricas, pero de menor tamaño: micro generadores hidroeléctricos. Éstos se destacan por la cantidad de energía que pueden generar, los diferentes tipos que existen y su tamaño, que se adapta a arroyos, ríos y pequeños flujos de agua. El principio de funcionamiento de estos dispositivos y algunos tipos de ellos se presentan en este artículo. Se espera que este artículo informe a los lectores sobre el problema energético y su magnitud en la calidad de vida en un gran grupo personas, mostrar la existencia de soluciones confiables y amigables con el medio ambiente, y brindar la información necesaria para que puedan contribuir a ayudar a la comunidad mundial.**

***Palabras clave*: energía hidroeléctrica , microturbina, sustentabilidad**

I. INTRODUCTION

Throughout the world, there are many people who reside in remote places and often suffer from problems that are rare in cities or towns. In most countries, the money and interests of the State are not enough to help these people, who are permanently deprived of basic services. One of these is the provision of access to the electric energy service since it can be the basis for other services.

Energy accessibility is a topic of great concern globally and it is explicitly stated in the United Nations' 2030 Sustainability Agenda through its Sustainable Development Goal (SDG) 7, "Affordable and clean energy"[1, p. 22]. This SDG is energy specific, and it focuses on ensuring access to energy for all without producing collateral issues such as contamination or environmental alteration.

Electric energy is highly used in the world, but its distribution and maintenance demand both money and work. Therefore, in communities and villages of developing countries, there is a lack of electric power accessibility, which might be the result of the government's impossibility or even disinterest beyond the regular budget deficit.

For many years, the use and generation of renewable energy has been studied and its benefits are now well known. Currently, there are several devices that can generate electric energy from natural resources such as solar energy, wind energy, biogas, and hydro-electric energy. The feasibility of use of every type of energy is related to its geographic zone and weather conditions. Particularly, in many places there are small water currents such as creeks whose hydropower is not harnessed. In this paper, the use and applications of small devices that are able to generate energy from creeks will be discussed.

In order to achieve the objective stated above, this paper is organized in three parts. First, the problem of the lack of power in isolated places will be presented, describing its causes and consequences as well. In the second part, the micro hydro power generator basic information will be shown, and its principle of operation will be explained. As well as this, a variety of types of these devices will be exemplified. Finally, the use of micro hydro-power devices and their benefits will be discussed. It is expected that this paper may inform the readers about the energy problem and its magnitude in people's quality of life, show the existence of reliable and friendly solutions with the environment, and provide the necessary information for them to do their share to help the global community.

II. PROBLEM DESCRIPTION: THE LACK OF ELECTRICITY AS A GLOBAL PROBLEM.

According to the United Nations (UN), in 2020 around the world there were approximately 759 million of people without electricity power service [2, p.14]. Moreover, according to [3] the developing countries are the most affected by lack of electricity, where Africa tops with 57 percent of the people without electricity total quantity, followed by Asia with 17 global percent, which are mostly the rural and isolated areas. In [Fig. 1, 4] the number of people that do not have electricity in rural areas globally is shown.

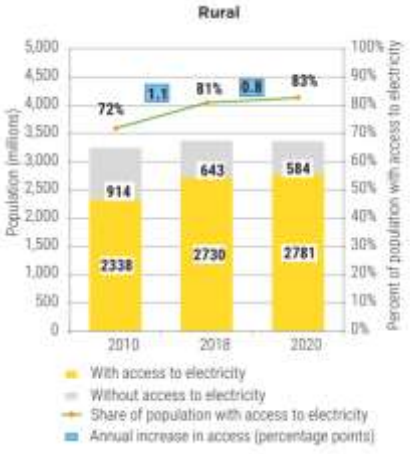

Fig. 1. Gains in electricity access in rural areas, 2010, 2018, and 2020 [4, p.33]

This paper will focus on the rural context, which suffers the lack of power due to its isolation and distance from urbanization. It is important to know why they suffer it since it is the key to understanding why the use of devices such as a hydropower generator is more advantageous.

The main factor that produces this problem is the high price of the high voltage distribution lines in these areas. Moreover, this is also connected with logistics costs, importation of material for current distribution lines construction and the economic inflation of the country, and the low levels of interest on the part of the government to help these people since they often see these people as the minority group. Also, [3] claims that 33 percent of rural areas in Asia do not have electricity, while in Africa the 86 percent suffer this [3]. Therefore, the number of affected people is very important and the consequences that they suffer are complex. In [Fig. 2, 5] the distribution of rural electricity access rate can be clearly seen.

Fig. 2 Global distribution of rural electricity access rate [5]

In relation to the specific consequences, there is research that assures that the impact of lack of electricity on poverty is high, since even if it is not the most important factor, it is known that access to electricity can give vulnerable communities better opportunities [6, section 2]. In addition, there exist data that affirm that the people in this situation use other methods to replace electricity, which are usually more expensive than regular electricity [7]. This is a very problematic issue with consequences on the environment since these alternative methods require deforestation to gather wood and to heat the households or the use of gasoline generators to produce electricity which at the same time generate a pollutant smoke fog that might severely damage people's health.

III. Problem Approach: The use of Micro Hydro-Power Generators.

Hydropower energy has been one of the most sustainable and reliable alternatives power sources and it has several advantages over most other sources generating electrical power. Hydropower generators are devices that generate energy from water flow. In terms of the devices size the definitions in [8] will be used, which offers a classification based on how much electrical energy a device can produce. For example, for hydro generators that produce less than 5 kW of electric power the prefix "Pico" is used, classifying the hydro generator as Pico-hydro generator.

The main differences between hydro generators with unequal size are the size of their components, initial costs, and the capacity to produce electricity. However, in this paper, the focus is on micro hydro generators because they are an advantageous way to harness energy in isolated communities.

Table. 1.

Hydro Power generators size concepts [8, p.5]

S/N	Classification	Rated Power	Consumer
1.	Large- hydro	>100 MW	usually feeding into a large electricity grid
2.	Medium-hydro	15 - 100 MW	usually feeding a grid
3.	Small-hydro	1 - 15 MW	usually feeding into a grid
4.	Mini-hydro	100 kW - 1MW	either stand alone schemes or more often feeding into the grid
5.	Micro-hydro	5kW -100 kW	usually provided power for a small community or rural industry in remote areas away from the grid
6.	Pico-hydro	< 5kW	

Micro-hydro generators are the ones that that can produce between 5 kW and 100kW as shown in [Table 1, 8]. This type of generator is very special given that they are the most accessible and sustainable solution to stop the lack of electricity in rural and isolated areas. Generally, between 5kW and 10kW are sufficient to supply a house so the use of small size devices that can give this electric power is the best option to supply small villages and farms that have access to water flow access.

All hydropower generators have the same operational principle although their size is different. In the next section, hydropower generators' operation is explained.

A. Principle of Operation

According to [8], the two essential components of a hydroelectric generator are the turbine, which is found in many different types, and the generator. In addition, these devices are composed of gearboxes or belt driven systems to obtain the necessary speed transmission between the turbine and the generator when the turbine rotation speed is not

enough for the generator as shown in [Fig 3, 9], a control mechanism to provide stable electric power, and electric transmission lines to deliver the power to its destination.

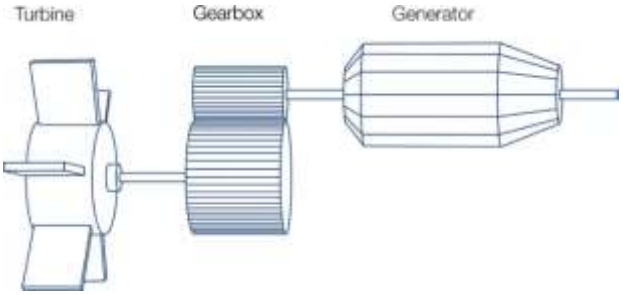

Fig. 3-Basic components of hydro-power generator [9]

To generate electricity, as shown in [Fig. 4, 10], the flow of water passes through the turbine blades that move the turbine in a circular motion. This flow is caused by the height, called the head, which is the vertical distance from which the waterfalls at the entrance of the turbine. In this way, hydraulic energy is transformed into mechanical energy at the same time that the generator transforms mechanical energy into electricity. It should be noted that the Micro Hydro Power generator just needs a low head according to [11].

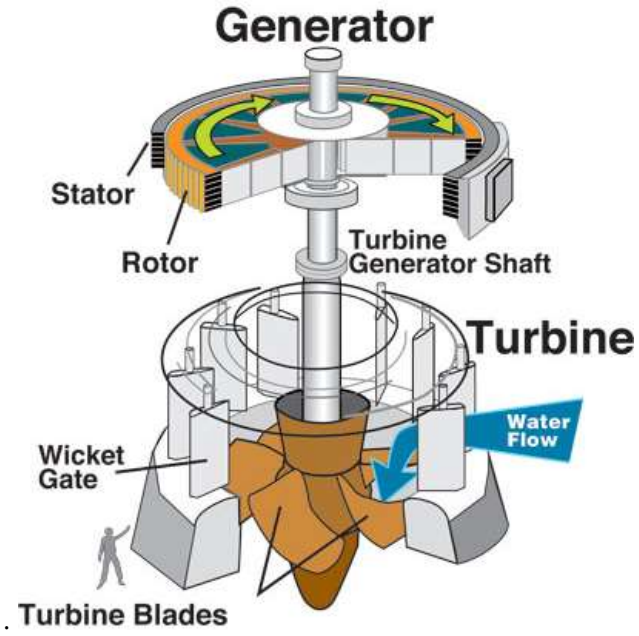

Fig. 4-Hydro-power generator operation principle [10]

In relation to micro-hydro power generators, there are many types of these. This characteristic is very important because it gives a higher versatility in the possible terrains to be used compared with others since each type of micro-hydro generator has their own dimensional properties. In the next section, a variety of micro-hydroelectric generator types used around the world are introduced.

B. Micro Hydro-Power generators Around the World.

In the different geographical zones around the Earth, there are many types of water currents such as streams, rivers, creeks, and other waterways. In order to harness the hydraulic energy of all types of water currents, engineers have developed different types of micro hydro-power generators.

1) *The Vortex Turbine:* The vortex turbine in accordance with [12] is inspired and powered by the natural phenomenon of a water vortex. Each vortex turbine has a capacity to generate between 15kW and 75 kW which makes it a very good option to supply a village.

Fig. 5- Picture of a vortex turbine generator [13]

The device feature that stands out the most is that the vortex turbine can operate even in any waterway that has low drops ranging from 1,5m-5m. The Belgian enterprise called Turbulent has been a pioneer in the application of these devices. In [Fig. 5, 13] there is a picture of one of Turbulent's past projects that resembles the ones built in Versailles, France with an electric power of 5 kW; Otepää, Estonia – 5,5kW; Bali, Indonesia – 13 kw; and others. Currently, Turbulent is working on bigger projects such as the installation of a Vortex turbine in Yilan, Taiwan with an electric power of 100 kW.

2) *Archimedean Screw Hydro Turbine:* The Archimedean Screw Hydro Turbine [14] is a relatively new device in the micro hydro power generators field. The capacity to generate between 5kW and 500kW, depending on its size, and the screw shape of its turbine make the device a very interesting concept of micro hydropower generator. In [Fig. 6, 15] it can see a simple illustration of Archimedean Screw Hydro Turbine can be seen.

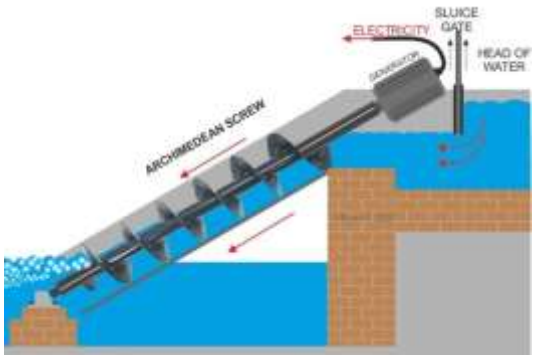

Fig. 6-Archimedan screw turbine generator illustration [15]

The Archimedean Screw hydro turbine has two important advantages: its operation life of 30 years and its debris tolerance, which is produced by the size of the screw flights. Although there is not much information about its application in rural or remote areas, it can be used, and it is a studied device. The application of the device in these places has been studied [16] and has been shown to be a viable and sustainable solution.

3) *Crossflow Turbine Generator:* Crossflow Turbine, based on [17], is a type of impulse generator which is called like that because it operates on the impulsive force created during the striking of the water flow on the turbine blades. According to [18], Crossflow Turbine can produce 100 kW easily. In [Fig. 7, 19] the illustration of a crossflow turbine is presented.

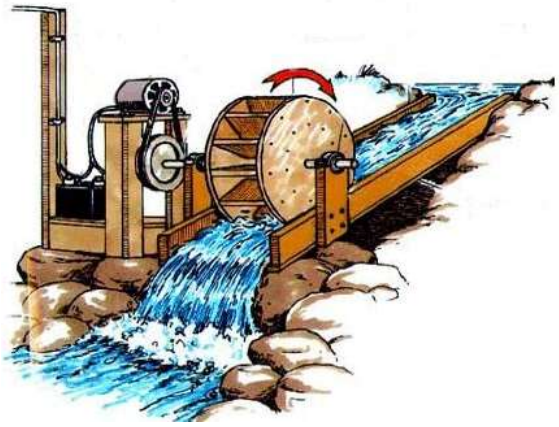

Fig. 7- Crossflow Turbine Illustration [19]

The most interesting characteristic of this device is that users may build it with recycled components and without technical difficulties. Therefore, this device becomes a very accessible and alternative solution to solve the lack of electricity in rural areas and isolated communities.

The devices showed in this section are the most popular types given that they have a good accessibility as well as great efficiency that rounds the 80%. However, there are more types of micro hydro-Power Generators with other turbines, such as Francis Turbine, Proplenne Turbine and Kaplan Turbine, which are not the focus of discussion in this work but that might be interesting for the readers to explore.

IV. ADVANTAGES AND DISADVANTAGES OF THE PROPOSED SYSTEMS

It is no coincidence that in this paper micro hydro generators were chosen to solve the lack of electricity in rural and isolated areas. There are several ways to get electricity from nature today, such as wind turbines, solar panels, biodigesters to obtain biogas, biomass, and others. However, in this case and due to several advantages enumerated in [20] the micro-hydro power generators are the best option to address the situation.

A. Advantages

There are several advantages to micro-hydro generator implementation such as:

1) Low head and flow required: 2 feet head, which is a little head, is sufficient for the device operation This is not possible to in bigger hydro power generators.
2) No reservoir needed: the device has been designed to take advantage of natural flow, so it is not necessary to have a reservoir of water.
3) Zero carbon-dioxide emission: No emission is produced during its operation.
4) Continuous operation and reliability: Unlike wind and solar power hydroelectric power is dependent on water flow variation which is much more predictable.
5) Comparatively low cost: Depending on the terrain characteristics and location, the costs of a micro-hydropower generator is between $USD1000 to $USD20000, while a solar panels system costs over $USD10000 and a wind turbine setup for a residential area cost between $USD5000 and $USD65000.
6) Higher efficiency: The micro-hydro generators have an efficiency that rounds between 70% to 90%.

The most interesting advantages have been shown. However, there are more advantages such as little impact on ecology, low running costs long useful life, buyback by the grids of the leftover or surplus energy and higher capacity factor of this device, which is expressed as a percentage and calculated by dividing the actual unit electricity output by the maximum possible output.

B. Disadvantages

Although the system presented above has many advantages, there are four main disadvantages of micro-hydro generators:

1) Location Suitability: Micro hydropower generators require specific conditions such as flow rate, water head, and distance from the power source to function effectively.
2) Expertise Required: Installation of micro-hydropower generators demands professional expertise due to complex evaluations required for its proper operation.
3) Limited Expansion Options: Unlike solar power, micro hydropower has limited potential for future expansion.
4) Seasonal Variability: Reduced water flow during summer months leads to lower power output.

In summary, if the user finds the correct place to install a micro-hydro system it is a system that brings more benefits than drawbacks. Also, it has been proven that the use of micro-hydro generators can be an indicated solution to solve the lack of electricity in remote areas.

V. CONCLUSION

It has been demonstrated that energy problems can be solved with sustainable devices such as micro hydropower generators. The people that lack energy can change their situation with one micro hydropower device, so it is very important to spread the existence of this technology. Nevertheless, other people that do not lack energy and have the sufficient resources can get this generator to save energy and reduce the carbon footprint. In the middle of a race to reduce the use of fossil fuels, engineers have the duty of creating increasingly efficient sustainable devices. Micropower generators are evidence of this work.

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The present manuscript is part of the research activities in the Inglés II lesson at Universidad Tecnológica Nacional, Facultad Regional Paraná. Students are asked to research into a topic so as to shed light on a topic of their interest within the National Academy of Engineering's Grand Challenges or the United Nations' Sustainable Development Goals frameworks. If sources have not been well paraphrased or credited, it might be due to students' developing intercultural communicative competence rather than a conscious intention to plagiarize a text. Should the reader have any questions regarding this work, please contact Graciela Yugdar Tófalo, Senior Lecturer, at gyugdar@frp.utn.edu.ar