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PROPOSAL OF A MICROTURBINE FOR GENERATION OF ELECTRIC ENERGY IN ISOLATED AMAZONIAN COMMUNITIES

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Abstract. *In Brazil, the Legal Amazon region represents around 59 % of the national territory, however, its large territorial dimension reconciled with a low demographic density and negligible government assistance slow down the local development growth, having electrical energy unavailability as an aggravating factor in large part of its formation. Accordingly, the present paper aims to present a hydraulic micro turbine to be installed on a floating platform, as one of possible solutions, to attend isolated Amazonian communities, using recycled raw materials or reused components. After social, scientific and environmental data entry, in order to evaluate the energetic needs from local communities, the investigation found that generating 2.0 kW of power energy is possible to supply small villages. Therefore it hoped that, with the development of this study that is it possible to reduce the electric energy requirements for isolated communities, especially, in the Amazon riverside communities.*

Keywords: *Amazon, isolated communities, micro floating turbine.*

1. INTRODUCTION

The legal Amazon region represents around 67 % of all tropical forest in the world, having the biggest watershed of the planet. It is estimated that this basin has a potential energy greater than 100.00 GW having an even larger share in the production of electric energy in Brazil "stored" through large projects such as hydroelectric plants and Tucuruí and Belo Monte, or through small hydro and / or microturbines distributed by its area.

Even with continental dimensions, in the Amazon region, there are several groups of persons who with difficulty will have service of electric energy, either by a little demand of his communities, for the service logistics of electric energy, or still for the great distances of the urbane centers. These groups of people have one thing in common, they all live near rivers, streams, or creeks. In the Amazon region these groups are called of riversides.

By analyzing the characteristics of several Amazon regions, it's not difficult to realize that the kinetic energy, of the passage of the flow of the water on the inside of a device, can be turned into mechanical energy, through the movement of a rotor. This rotor can be tied to a creator (electric alternator), who turns the mechanical energy into electric energy.

Great undertakings use of the retention of water for the increase of the potential energy and consequent increase of the kinetic energy, however, the damming to of this water produces a great impact socio-environmental in the region, due to the necessity of clearing the forest and of withdrawing persons and animals, of the flooded areas.

However, it is possible to happen the captivation of water in small quantities, using the philosophical one suggested by Sousa (2009), what is the use of micro central hydroelectric, known how to run of river, in other words, unless there is the need of damming for great volumes of water, and with the application of hydraulic turbines of small transport, and that they are located near of the consumer centers, with distances less of ten kilometers, conformable it recommends the manual of small hydroelectric central offices of the Eletrobrás (1983).

The feature of several Amazonian rivers that all it has great and little slope, in other words, the hydraulic turbines when they are being used in this region, it has to attend these characteristics. Analyzing the Brazilian market it is noticed that there are not many types of hydraulic turbines of small transport that pay attention to these peculiarities.

Therefore in this study, which is in process of patents, intends to present another, among many solutions to service small energy demands, with the application of hydraulic microturbines, aiming to produce a quantity of electric sufficient energy to pay attention to isolated communities, like loads less than 5.0 kW, since it is the case of the riverside communities, of the communitarian centers, of the rural schools, churches, etc.

This solution contributes to the reduction of environmental impacts in the region, with the development of the locations; generating jobs and income, as it does not require water impoundment and there will be no interference in the flow of rivers in the microturbine are installed. This form of energy generation is located near the consumer units, reducing spending on large networks distribution, maintenance and loss.

2. ENERGY

Brazil is the sixth largest economy in the world, taking as principal fountains of generation of resources the industry, the agriculture and the commerce. The Brazilian economical growth is based on the generation and distribution of electricity to several sectors, which is a very important factor for the development of the nation, both in the economic context, and improving the population's quality of life.

The distribution of electricity is made from a large mesh wiring, of high and low voltage, covering most of the major national centers, see Fig. 1. However large territorial extensions are left aside due to large cost wiring maintenance, for little financial return. According to the Mines and Energy Ministry (MME), there are approximately 500.000 not attended residences in the Amazon region, and that at least 300,000 will not be able to be attended by the extension of the electric net. These numbers illustrate the enormous challenge that the Amazon region must do to meet their consumers.

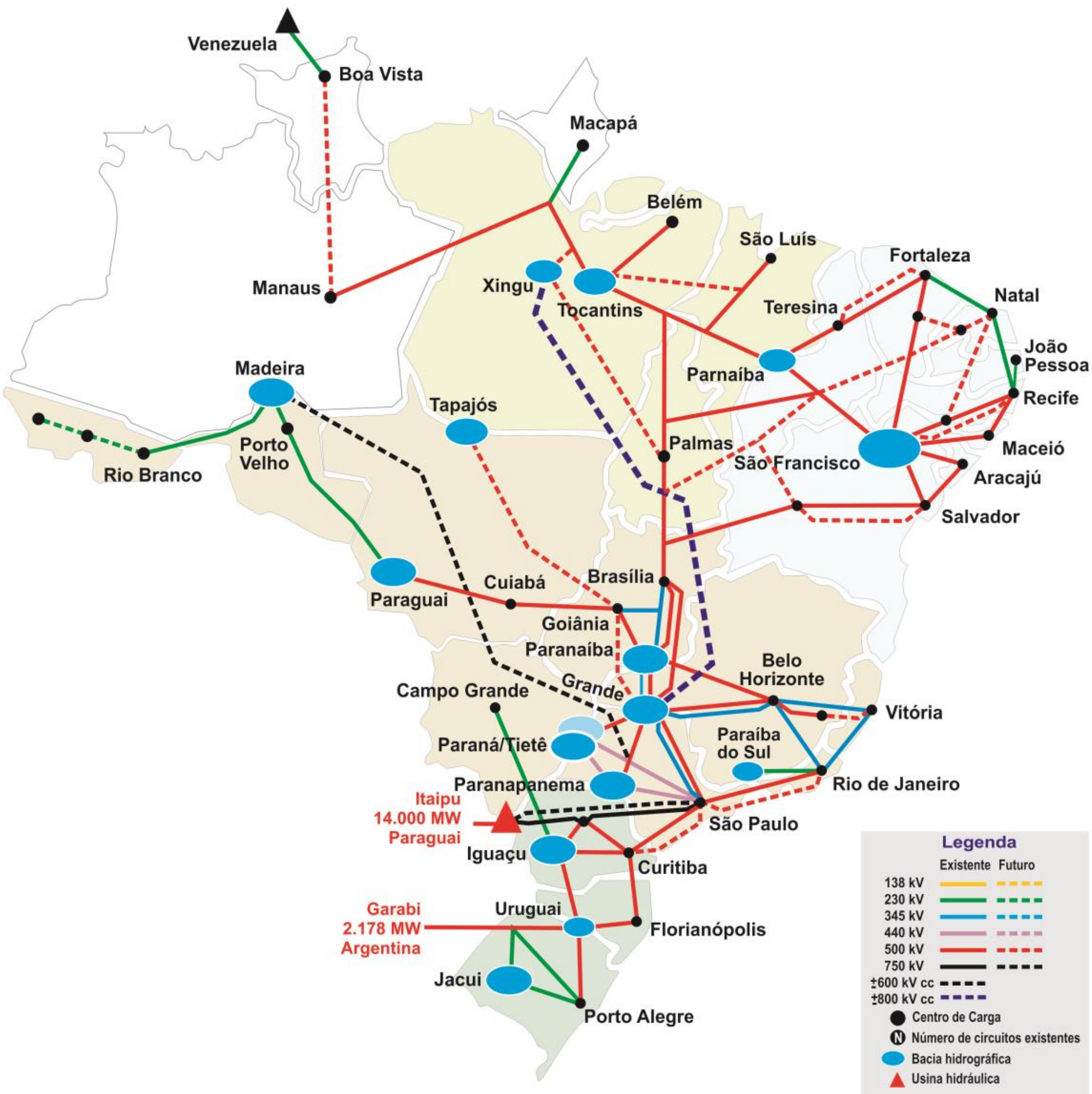

Figure 1. Electro integration Map – 2014. Source: MME.

The lack of electricity often is the cause of underdevelopment of a region, discouraging commerce and local industry, depriving the population of a better quality of life, besides the basic public services such as health, education, sanitation, between others. The Human Development Index (HDI) in these isolated regions, compared to the southern region of Brazil, Fig. 2, it can be clearly observed the difference between them, and so the regions not served by mains have a lower evolutionary capacity in the technological, social and economic areas.

The riverside communities are a traditional people who live near rivers and have artisanal fishing as the main survival activity. Cultivating small clearings for own consumption and may also practice extractive activities.

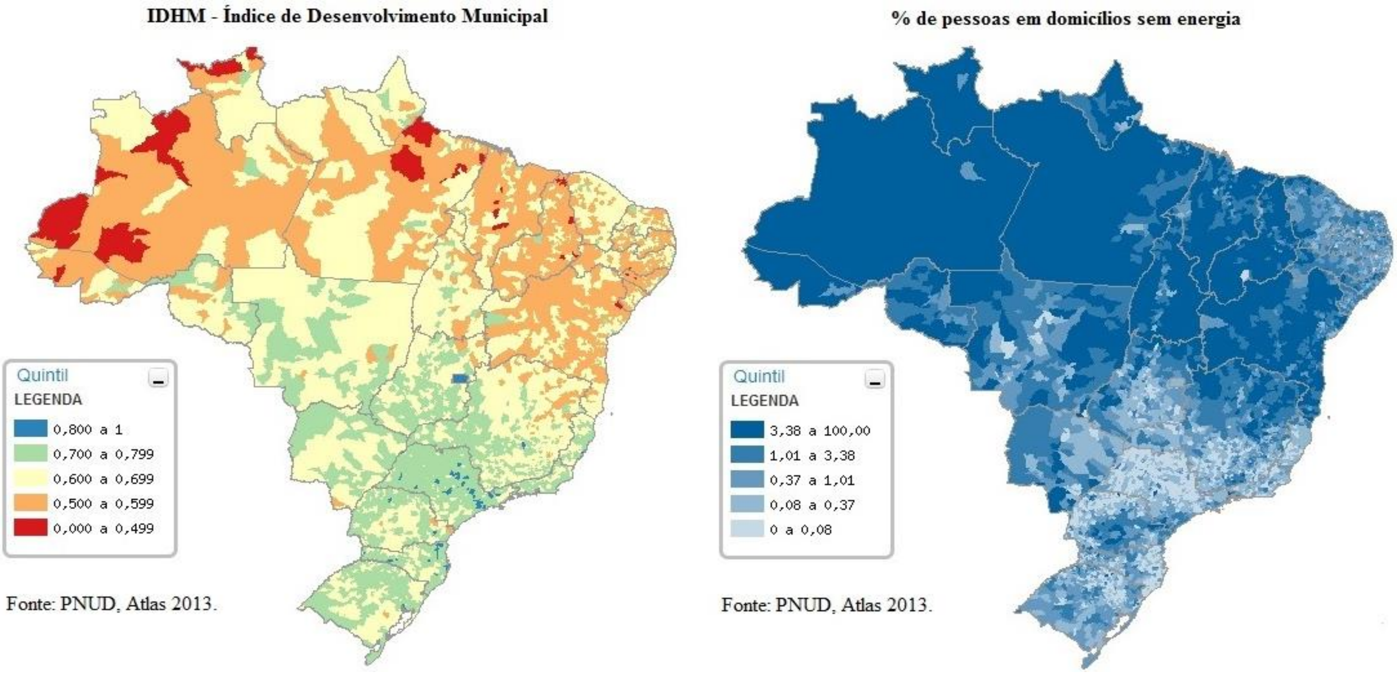

Figure 2. Relation between HDI and the index of the lack of electricity service. Source: PNUD - Atlas 2013.

Communities not served by the national grid distribution network are commonly known as isolated systems. They require unique solutions of the measures applied to large energy needs, such as in large cities and industry.

According to surveys conducted in the state of Pará, the average load an Amazon family with five people in a house with four compartments is around 80 kWh/month. This amount of energy is enough for six points of light, a television antenna satellite and a refrigerator. So at the Fig. 3 shows a typical house of a riverside family Amazon.

Figure 3. Typical Amazonian riverside house.

On average, the riversiders live with distances of fifty to two hundred meters, usually in wetlands over mangroves. This low population density, coupled with the conditions of access hinders the expansion of the power grid and makes it impossible for the service to these communities.

Distributed energy generation, with the application of micro hydropower plants, becomes more efficient in locations isolated system due to the ability to meet only the power needs of each community on time. Thus distributing the generation has a lower environmental impact due to: the need for small or no wetland for its implementation, reducing deforestation and preserving local biodiversity; lower socio-cultural impact, because you do not need that whole communities moving from his native land; and economical because it is located close to the consumer, a wiring and control equipment are more compact, hence cheaper.

The local Governments have as an alternative to generate power in remote locations is the system of monthly installments of diesel distributed among communities. However, when they exceed their quota, the residents assume the additional costs, bringing the average cost for above average rate charged by the concessionaires.

According to Athayde et al (2001), within the Federal Government, are considered three important inserts in isolated communities to meet the energy exclusion, held in recent decades: The first stage begins around the year 1990 with the implementation of several projects of technological research, characterized by the introduction of technologies of unconventional generation by research centers and universities in the region, which such wind, solar and hydraulic; The second phase starts in 2002 with the establishment of alternative systems promoted by the federal public power; The third time, in 2004, with universal access and use of electricity through the Program "Luz para todos".

As an incentive to expand the supply of electricity, in addition to private investment in the sector, it has pursued the develop alternative generation sources. In April 2002, it was established by Law number. 10438 / 2002, PROINFA, subsequently as amended by Law number 10762 / 2003, with the objective of to promote the share of renewable energies in power generation destined to supply the SIN (Electricity System National Grid). All the energy of PROINFA was hired by Eletrobras. Therefore utilities in each region are obliged to meet consumers of these communities, and the onus is for the state. Article 15 of the Law introduces the possibility of universalization be accomplished through the use of alternative energy sources such as wind, biomass and small hydroelectric plants:

> Art. 15 - In order to universalize electricity utility, Aneel can promote bids for the granting of public electricity service permissions in areas already granted whose contracts do not contain an exclusivity clause.
>
> § 3 - The licensee will be contracted to provide public service of electricity using conventional form of distribution, can simultaneously also provide the service through "association or contracting with technology holders agents or authorization holders for solar, wind , biomass and small hydro. "

Another form of alternative energy supply expansion is the incorporation of cogeneration systems to electrical systems, as supply grows through the efficient use of fuels that meet the production lines. It is noteworthy that cogeneration plants are not used only in industry but also in the fields of trade and services. Cogeneration is the simultaneous production of thermal energy and electricity from the use of a conventional fuel (natural gas, fuel oil, diesel and coal) or some type of industrial waste (wood chips, sugar cane bagasse). Can be cited as attractive points of this type of enterprise: efficiency gains in certain cases, increased power quality, spread of distributed generation, autos-sufficiency of supply and reduce environmental impacts.

3. PROPOSAL TURBINE

As mentioned earlier, the characteristics necessary for a hydraulic microturbine can be located nearby of riverside communities in the Amazon, must meet the following conditions: working with low head or gaps (less than 2.0 meters), operate with high flow rates and speeds rivers (from 0.6 to 3.6 m/s), to provide for small-generated power (between 1.0 to 5.0 kW), which are the majority of the characteristics of the communities found in the Amazon region.

The small free-flow turbines, moved by the passage of water flow by a rotor aerodynamically designed, are implementing alternative in remote areas in the Amazon, both for its easy construction, as for its low maintenance and modular practice facility. The use of these types of equipment is sustainable forms of electricity generation due to its low environmental impact and little interference in the ecosystem of the region.

The turbine presented in this work, which is in process of patents, has a rotor system similar to that of a Michell-Banki turbine (cross flow), having nozzle for direct the water that will pass through the interior of the rotor and a diffuser which has the purpose of directing the water out of the turbine so as to prevent backflow of water into the hydraulic turbine.

In Fig. 4 is a schematic view of the possible idealized hydraulic turbine, with its intake system and water outlet, in addition to the air outlet system, located at the top for relief system.

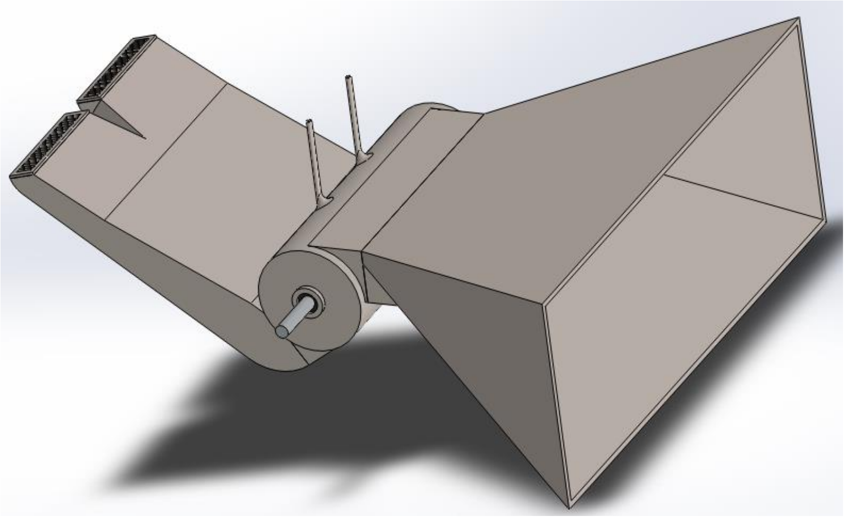

Figure 4. Schematic project of the proposed turbine.

Although you can't be better demonstrated the idea presented due to the confidentiality of law related to the patent protection of this project, the basic idea is that this will be turbine can generate power from both sides of the rotor, this because, should seek to use a symmetrical system formed by two flywheels, a speed reducer and an electric alternator, both coupled to the turbine rotors.

The turbine proposal will be coupled to a floating system, so it is always in a range of correct operation, meaning that the diffuser inlet is always at a level below the waterline. This fluctuation should be made from handcrafted concepts used in the Amazon region, where homes, restaurants, and other enterprises are installed in floats mounted on rivers with the use of PET bottles, united in large quantities, forming a floating floor, as the examples shown in Fig. 5 and Fig. 6.

Figure 5. Floating Hotel on PET bottles. Source: andoexperimentando.com.br/manaus-capital-verde.

Figure 6. Floating system. Source: epocanegocios.globo.com/

In the fluctuation's case of the turbine, the bottles were grouped and attached to the structure, located on the bottom and sides. This flotation system is functional, because they can adapt to various levels as to increase or decrease, just fill or dry the bottles, Evening turbine as needed.

4. METHODOLOGY

The properties of the hydraulic turbine proposal is presented from the classic equation, where hydraulic power - P_h systems is equivalent may be calculated visor Eq. (1) and shaft power by Eq. (2).

$$P_h = \rho \cdot g \cdot Q \cdot H \quad (1)$$

$$P_e = \eta \cdot \rho \cdot g \cdot Q \cdot H \quad (2)$$

Where ρ is density of water (kg/m), g is the acceleration of gravity (m/s²), Q is the water flow (m³/s) and H is height of drop relative to a reference point (m), and η is the turbine efficiency (%). As in the case turbine is free flowing, which slope does not occur, then it used Bernoulli's Theorem, making the transformation of the H, presented in Eq. (3).

$$H = \frac{V^2}{2 \cdot g} \quad (3)$$

Where V is the velocity of the water jet that focuses on the blade (m/s). The torque (τ) is represented, from Eq. (4), where ω is the rotor angular velocity (rad/s) and is represented by Eq. (4).

$$\tau = P_h \cdot \omega^{-1} \quad (4)$$

$$\omega = 2 \cdot \pi \cdot n \quad (5)$$

Where n is the rotation of the rotor, described as Eq. (5), taking the maximum linear velocity as the distance r being the line of action to the mass centroid of the rotor blade.

$$n = \frac{V}{4 \cdot \pi \cdot r} \quad (6)$$

From this equation computational algorithms have been developed in order to plot graphs of the rotor, causing variations in the length of the blade and the speed of water flow, and performance, through the aid of *Matlab*® software, the analysis was made later of results and discussions about it.

The blade chose for this project is *GOE 652 Air Flow*, because their format and their characteristics are well fit in the project proposal, as can be seen in Fig. 7. The profile and schematic drawings of the proposed turbine were made *SolidWorks*® with the aid of software.

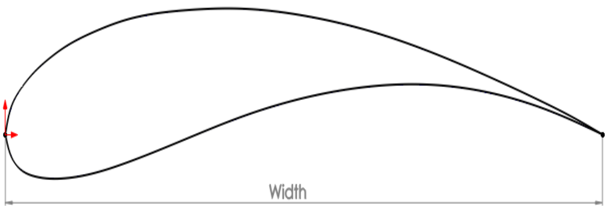

Figure 7. The GOE 652 *Air Flow* profile drawing

Figure 8. Profile GOE 652 Air Flow printed.

The turbine rotor blades will be built using a 3D printer of Mechanical Engineering Laboratory – LABEM, at Institute of Technology – ITEC – UFPA. Hydrodynamic tests will be performed in the river near the UFPA.

5. RESULTS

The power chart in relation to the nozzle width variation can be seen in Fig. 9, where it checks the growth of the hydraulic power according to the increase in surface area, this being directly connected to the width of the nozzle, since the length is one meter, generating no influence on calculations.

In Fig. 9, shows the influence of speed in the system, so as from the speed of 1.0 m/s hydraulic power increases rapidly, arriving in certain configurations to generate 2.0 kW, amount of electricity sufficient to meet the needs of small communities, schools, community centers and health centers located far from urban centers and with no access to other means of electricity.

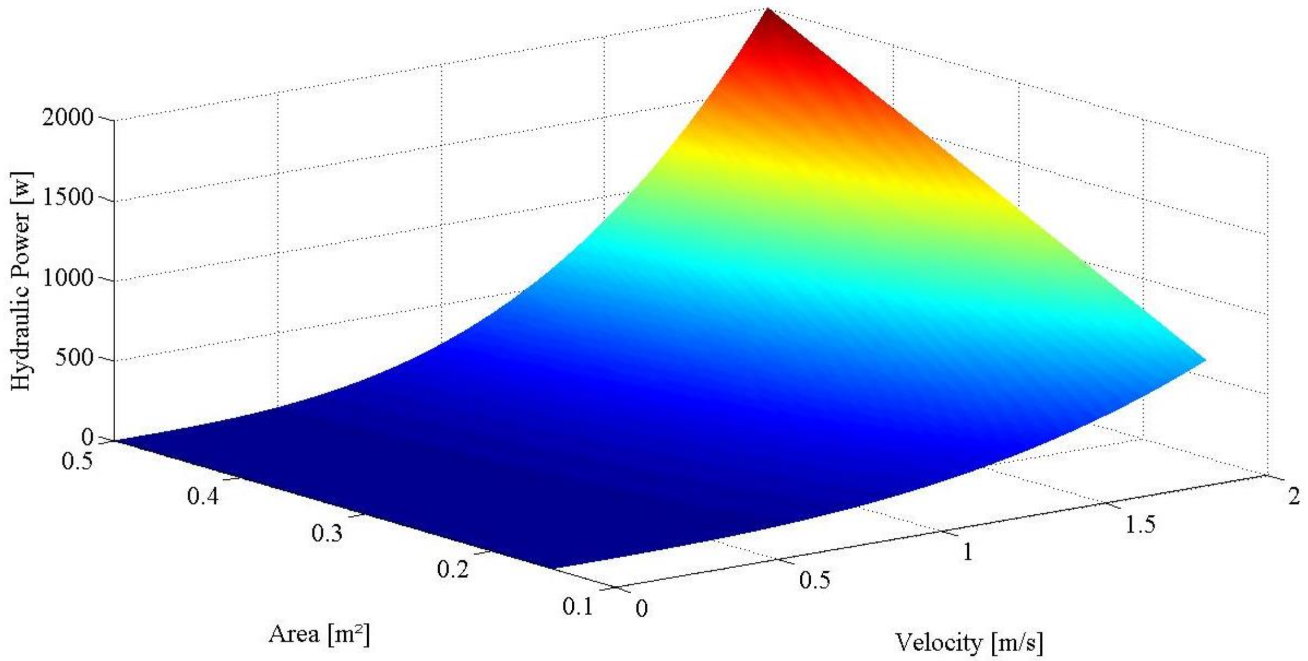

Figure 9. Hydraulic power varying speed and area of the blade.

In Fig. 10, the generated torque is displayed that reaches significant results, as this factor is necessary for the entire turbine to enter and remain in operation, and if the torque does not exceed the moment of rotor mass inertia, together with couplings and bearings, the turbine will not operate.

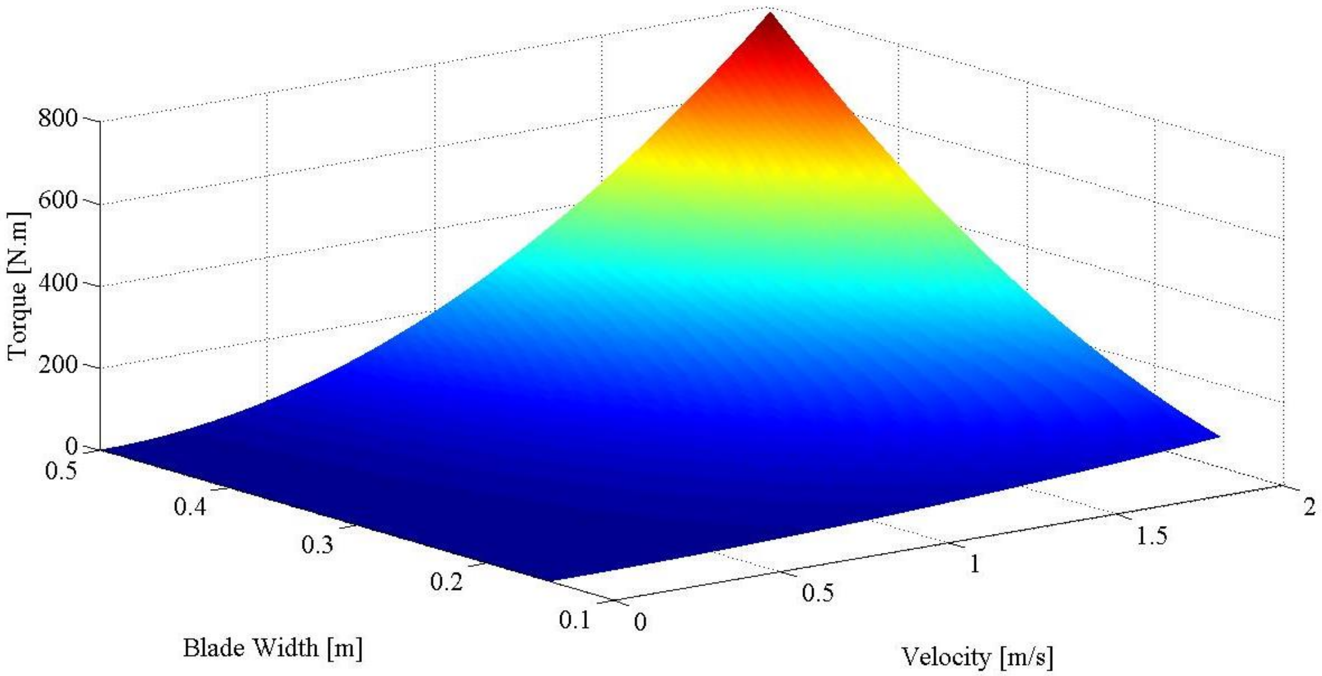

Figure 10. Graph torque varying the speed and the width of the blade.

In Fig. 11 displays the rotation system that behaves inversely proportional to the graphs shown in Fig.10, where the increased width of the blade directly interfere with the increased the torque. In the case of the rotation, when the width of the blade is small, the rotor is more compact therefore has a smaller mass moment of inertia and a greater ease to start rotating.

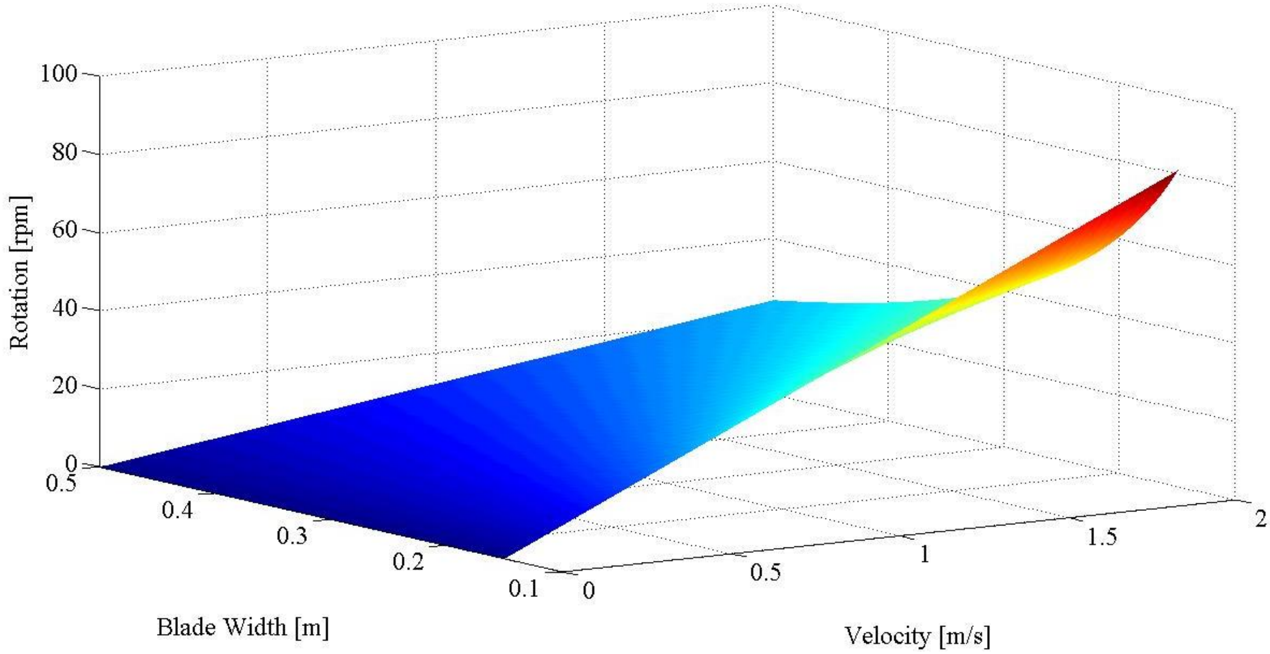

Figure 11. Graph rotation as the change the velocity and the blade width.

In Fig. 12 it analyzed the axis of power, establishing the speed of the jet that focuses on the shovel in 2m/s and varying the width of the nozzle and possible system yields, thereby having an overview of the power that can actually turn out to be generated the proposed system, with different dimensions.

When considering a maximum yield of a Michell-Banki turbine principle Where did the turbine proposal, the same is 85%, and thus analyzing the Fig.11, the axis of power amounts to approximately 1.7 kW, energy electric enough to meet the locations proposed in this work.

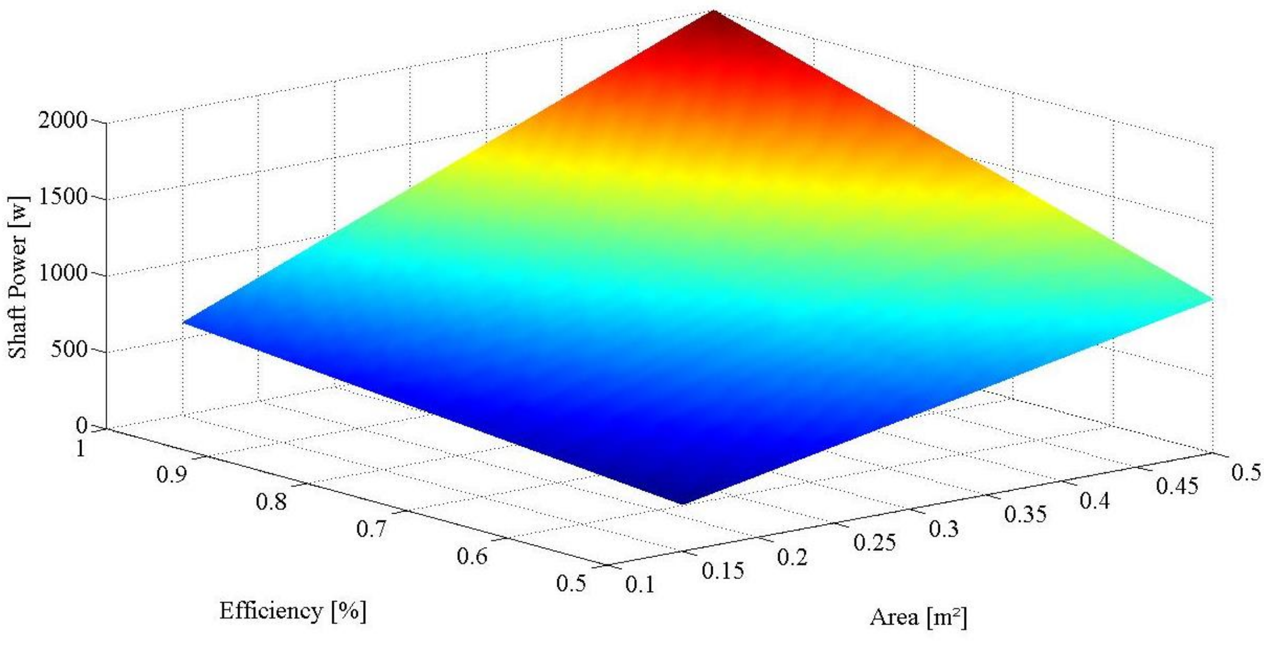

Figure 12. Graph axis power varying yield bands and the width of the blade.

6. CONCLUSION

The Amazon region has a large territory and has a lot of mineral resources and a large biodiversity, however, a lots of people migrate to the cities, seeking better conditions in their lives. Projects such as the proposed are present as an alternative to preserving people in their localities because these projects can provide improved living conditions, and gains great importance to improving income and quality of life of this population and therefore an improvement in the development the region.

The purpose of this microturbine becomes valid due to its great application potential in many rivers, lakes and streams in the Amazon region, causing lower environmental impact and bringing improvement in the quality of life of a population forgotten by the government. It is noteworthy that this is a preliminary work, and many other calculations and analysis should be made to the turbine has its real application.

The power generation is enough to supply small home communities, since the turbine shaft comes to have a power of approximately 1.7 kW, and may be greater as the coupling gearbox and the increase of the rotor or number Rotor cells, since in this work was done with only two calculations of the rotor cells, are increased if the number of cells of the rotors, higher powers may be achieved.

7. ACKNOWLEDGEMENTS

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