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The Brazilian experience with hydrokinetic turbines

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Abstract

In Brazil since the 80th several studies and pilot projects have been executed to use the kinetic energy in water flows to generate electricity for remote communities without access to the services of electricity utilities. These experiences resulted in several new techniques, concepts and products that gave birth to new research projects and proposals that revisited this form of conversion of such type of renewable energy. The first initiatives were developed to implement pico hydropower plants to attend remote communities, inaugurating the first generation of hydrokinetic turbines. With the maturation and consolidation of the technology, new concepts and implementation methods focused on the up scaling of the production were designed, as well as new strategies to popularize and make the technology and production available. Nowadays a trend is noticed to use the hydrokinetic technology not only for pico hydropower, but also for larger hydropower plants, aiming at the conversion of kinetic energy present in large rivers, tidal flows and ocean streams. This paper describes the evolution of the hydrokinetic technology and the initiatives undertaken to make it available for rural electrification in Brazil during the last two decades. It also proposes to discuss the trends of hydrokinetic conversion for on grid electricity generation and its integration into the electricity sector.

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1. Main text

The term hydrokinetic turbines (or water current hydroturbines) is used for the hydraulic machines that convert the kinetic energy of river or marine currents to mechanical or electrical power. The use of kinetic energy of rivers can be considered one of the first methods invented to transform natural forces into mechanical work. Since then those simple waterwheels of the past turned in to hydrokinetic turbines.

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There are several reviews on hydrokinetic turbines that analyze the overall state of the art of this technology [1],[2],[3].

The evolution process of the hydrokinetic technology can be compared with the evolution of wind technology as done by Baker [4], who states that all the improvements within wind engineering have taken place within specific socio-political and intellectual contexts. Although Baker analyses the wind technology development in a broader and longer context, his separation of traditional, empirical, establishment/growth and modern periods can be instrumental also for hydrokinetic technology evolution.

So we can identify a traditional period where hydrokinetic energy in rivers was mainly used for specific applications such as water rods or water wheels to pump water or in mills. In this period there were no conditions to convert the mechanical power into electricity or other means to transport energy for other applications. Until nowadays these traditional applications still are used in the rural areas and are very site specific.

The empirical period is characterized with the use of hydrokinetic conversion to generate electricity and arises with the need to attend localized demand in rural sites where there is no access to grid electricity. This demand started when the rural areas became more dependent on the new intermediary energy products, such as diesel, gasoline, LPG and electricity that surged in the context of urbanization and industrial revolution. The logistics difficulties of attending these rural areas and the possibility to use local available natural resources were the main driving forces of this empirical period.

Nowadays the evolution of hydrokinetic technology can be classified as a growth period with technological innovation, scientific research and development and the elaboration of public policies to insert this technology within the rural electrification programs. These off grid generation applications were followed in the last decades by a new period with the development of large hydrokinetic systems, oriented to produce electricity for on-grid applications in rivers or sea, and use the same technological approach as large scale wind power.

2. Empirical period in Brazil

In the empirical period one of the first experiences with hydrokinetic turbines was carried out by Hardwood [2] who designed an underwater wheel at the National Institute of Amazonian Research (INPA) in 1985. Harwood tested several concepts on hydrokinetic turbines in the large Amazonian rivers and was a precursor on the use of floaters and inclined axes to fix the turbines. The main problems that Harwood faced in these early times were detritus, anchoring and other typical problems of the Amazon, such as seasonality and large differences between the dry and rainy season [3]. Another phase of empirical development on hydrokinetic turbines was in the Northeast of Brazil, in a region with a large deficit on rural electrification.

In 1991 the first well succeeded experience with hydrokinetic energy was developed by researchers of the University of Brasilia with an axial turbine with several innovations [5]. The turbine was installed in a region with a very constant river flow with little difference in water level in the dry and rainy season that permitted the use of a very simple anchoring or fixing mechanism. This so called first generation turbine, worked more then a decade and several improvements of its initial design were tested on site. The use of a suction tube and stator with direction blades were tested and registered in patent by the University of Brasília [6].

After 2000 several other turbines were designed with the obtained improvements and were installed in the Brazilian hinterland. The concept of these turbines is known as the second generation of hydrokinetic turbines developed by the University of Brasilia. The turbines were artisan build and designed to attend specific rural electrification projects with installed capacity from 300W until 2000W. Most of the turbines were specially designed for the steady flow rivers of Central Brazil who have maximal differences in water level of less than a meter, tough permitting the construction of anchoring systems at the riverside. Figure 1 shows some hydrokinetic turbines installed in the Central Brazil hinterland.

Figure 1. Hydrokinetic turbines installed in the central Brazil hinterland.

The success of this technology triggered diverse research projects to adapt it for other regions with other hydrological characteristics. The Amazon has a great potential for hydropower, but its rivers are not so well defined as in the Central Brazilian highlands.

The first initiatives to customize the technology for the Amazon and its characteristics were experimented in 2004 [7]. The anchoring system needed to be improved due to the big differences between water level in the rainy and dry season. The floating structure introduced by Harwood [8] was improved and several units were tested in the Amazon as shown in figure 2.

Figure 2. Anchoring and floating system for hydrokinetic turbines.

Most of the innovations implemented were result of empirical research to overcome the challenge to deal with anchoring systems, ducting, debris protection and simplified maintenance. Other initiatives over the world had the same challenges [9]. The study on the effectiveness of the duct over the turbine is also well covered in literature [10].

Although it was shown that hydrokinetic turbines were an option for decentralized generation, no significant initiatives were undertaken to implement this technology within rural electrification programs. Scale up of production was a problem as these second-generation hydrokinetic turbines were artisan made and there were no special rural electrification programs for funding. All initiatives were financed through research funds and were implemented as pilot project. There were no options within the rural electrification programs to finance the acquisition and installation of Pico hydropower installation with hydrokinetic turbines.

3. Growth period

The technological evolution of hydrokinetic entered in a dynamic growth period with several researches being conducted within the Academy due to increasing demands for rural electrification with decentralized electricity generation with renewable energy.

In 2003 the Brazilian government launched a National Electrification Project named Light for All (LfA) with a goal of attending 2 million households through grid extension and other forms of electrification in five years. Nowadays the grid extension approach reached its limit and the remaining communities without electrification are the remotest and most difficult to be attended by conventional grid extension.

Decentralized generation therefore can be an option for these communities and there was a need to access the technical and economical feasibility of this kind of option. The Light for All program included in its roll of technological options, among others, hydrokinetic technology.

But one of the main problems with decentralized generation is the up scaling of production and its use within the Electricity Distribution Companies (EDC) or utilities companies.

In order to solve the scale up of the production scheme, a new generation of hydrokinetic turbines was designed with funding of one of the mayor Brazilian electricity Generation Company. This third generation turbine had to be manufactured with modern production techniques and materials that permit production cost reduction through up scaling of production.

The design of the rotor and turbines body was optimized in order to increase its performance [11]. The new layout of machine is based in a conception of the diffuser enhancement axial turbines, and a complete and general study has been developed to optimize a high performance and low cost manufacturing. The idea underneath this conception is a standardized turbine that can attend a wide range of applications and production processes that facilitate up scaling and production in large scale. The main application of this kind of hydraulic turbine is related to the supply of electrical energy for remote communities in the Brazilian Amazon. Figure 3 shows the third generation hydrokinetic turbine.

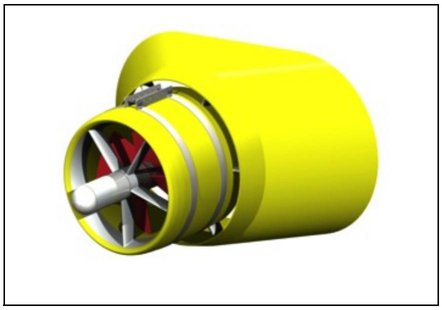

Figure 3. Third generation hydrokinetic turbines

This third generation hydrokinetic turbines was patented in 2008. Although the technological viability of these turbines has been shown, it is still a challenge to use this technology within the electricity utilities services.

In 2004 the Brazilian electricity sector established the legal option for the utilities services to offer decentralized electricity generation as service to attend remote consumers. This option was introduced primarily to permit the use of photovoltaic (PV) technology. One of the advantages of PV technology is that it does not have specific geographic limitation, as occurs with hydrokinetic turbines. So in theory, up scaling would not be such a problem. But experience shows that, even PV generation is not so easy to introduce as a service option within the electricity sector. This is due to the fact that the electricity sector has a culture of working with large grids and scales of operation that can be a barrier to the implementation of thousands of small-decentralized generation units with a high degree of dispersion and with little ability to pay for energy services.

This reinforces the necessity to introduce new or alternative ways to implement rural electrification with decentralized electricity generation. It needs a paradigm change by treating these initiatives as local development initiatives and not solely as rural electrification [12].

4. Conclusion

Nowadays a trend is noticed to use the hydrokinetic technology not only for pico hydropower, but also for larger hydropower plants, aiming at the conversion of kinetic energy present in large rivers and tidal or ocean flows. Worldwide novel schemes of mooring, floating and anchoring system are being tested [13]. In Brazil, research is being carried out to use the remaining kinetic energy downstream large hydropower plants. This research project will permit the development of innovative technological solutions and hardware to implement hydrokinetic turbines within mini hydropower plants. The first hydrokinetic turbine with a diameter of more then 10 meters and a potential within the range of hundreds of kW is being developed by a pool of Brazilian Universities for the downstream flow of the Tucurui hydropower plant in the Brazilian Amazon.

It can be expected that the technological evolution of larger hydrokinetic turbine will follow the same trends noted in wind turbine technology. In the last decades there was significant growth of wind turbine size and development of technology to interconnect these power plants to the grid. The up scaling of hydrokinetic turbines will lead to the technological development of new construction and anchoring techniques and also novel schemes for grid interconnection. The implementation of these turbines downstream large hydropower plants, will give the basis for the further technological development for tidal flows and ocean streams hydrokinetic turbines.

But as mentioned before, the evolution is bounded to specific socio-political and intellectual contexts. The technology for implementing decentralized pico hydropower with hydrokinetic turbine has been matured over the last decades, but its wide use within society depends now on socio-political conditions. As for larger hydrokinetic turbines, it can be expected that it will follow the same trends as in wind energy.

4. Copyright

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Biography

Rudi Henri van Els holds an undergraduate and master’s degree in Electrical Engineering and since 1996 is working with the implementation and installation of hydrokinetic turbines in Brazil. Since his PhD research concluded in 2008, his mayor research is on the sustainability of decentralized electricity generation in the Amazonian interior.