TECHNOLOGICAL SOLUTIONS OF GENERATION DECENTRALIZED OF HYDROELECTRICITY FOR THOSE DEMANDS THAT CANNOT BE ATTENDED BY CONVENTIONAL ELECTRIC NET WITH CENTRALIZED GENERATION

Valdir Tesche Signoretti, vatesig@yahoo.com.br
Carlos Alberto Gurgel Veras, gurgel@unb.br
Rudi Henri Van Els, rudi@unb.br
Universidade de Brasília, Faculdade de Tecnologia, Departamento de Engenharia Mecânica, Campus Universitário Darcy Ribeiro
Asa Norte 70910-900 - Brasilia, DF - Brasil
Telefone: (61) 31075712 Fax: (61) 31075707

Abstract *A source of energy stable and reliable and of acceptable cost is a basic requisite for the development of a given region can give-if full. Access to energy is important basis of human existence, essential to the satisfaction of basic needs such as food, clothing, and housing and also of mobility and communication. However, the dependency world burning of fossil fuels for energy generation and supply of a demand constantly increasing, both in industrialized countries and those in development, already threatening the ecological stability of the Earth. At the same time, conflicts by distribution of the last reserves these resources non-renewable threaten significantly to civil society. Adding to the breakneck speed in which humanity consumes the energetic sources and the obvious devastation of nature has an unequal distribution in consumption and access to energy. Renewable sources and energy efficiency are viable and necessary, especially because they can be the key to reduce wastefulness and extend the access to energy. In this way, there is a significant influence on economic and social inclusion of population excluded, generating employment and income with costs local and global environmental reduced compared to traditional forms and unsustainable generation and use of energy. This work is a study involving issues related to rural electrification from hydroelectricity, especially related to those isolated communities of the Amazon region that are lacking this form of energy, presented a general review since the origins of hydroelectricity in Brazil, as well as a national panorama electric exclusion as well as a scenario Amazon's supply of electricity. Finally presenting-if the main technologies available for hydroelectric generation for these isolated communities.*

Keywords: *electric exclusion, electrification rural, hydroelectric generation to isolated communities*

1. GENERAL CONSIDERATIONS ON THE GENERATION OF ELECTRIC ENERGY

Generation of electric energy is the transformation of mechanical energy in electricity. may be a waterfall (hydroelectricity), steam produced by burning fuels (thermal energy), or the kinetic energy of wind. In this case, the electricity generators operating on the principle of induction electromagnetic, that is, a driver, as a yarn, moving-in a magnetic field, has a potential difference induced through their extremities (Hinrichs & Kleinbach, 2003).

The electricity can also be produced in processes of direct conversion, instead of the conventional mechanism of conversion of heat in movement and this in electricity. Examples of direct conversion of energy are the solar cells and fuel cells (Hinrichs & Kleinbach, 2003).

Although important for certain forms of generation, storage of electricity in large quantities is very expensive, so the reliability of the source of electricity must be achieved by producing the quantity and exact time (Gagnon Bélanger & Uchiyama, 2002).

2. HYDROELECTRICITY IN BRAZIL

Until the arrival of the royal family to Brazil, in 1808, the dominant energy resource was the firewood, the illumination in the few urban centers was done with fish oil, and in the other occupations it was done with tallow candles.

In 1879, D. Pedro II granted to Thomas Alva Edison the privilege to introduce in the Country, equipment and processes, of his invention destined to the use of the electricity in the public illumination. Thus was inaugurated at the Central Station of the Railroad D. Pedro II, now the Central Railway of Brazil, the first installation of permanent electric illumination that it was located in the part interns of the central station of the railroad Dom Pedro II (today Central of Brazil) (Eletrobrás, 2001).

In 1883, entered in operation the first hydroelectric plant in the country, located in Ribeirão of the Inferno affluent of the river Jequitinhonha, in the city of Diamantina.

In 1913, comes into operation Hydroelectric Delmiro Gouveia, the first in the Northeast and built to harness the potential of the Paulo Afonso waterfall on the river São Francisco, (Eletrobrás, 2001).

In 1954, came into operation the first large hydroelectric built in San Francisco river, Paulo Alfonso I Hydropower Plant, owned by CHESF. In the same year, began operating the Power Plant Piratininga, to fuel oil, the first large thermoelectric of the Brazil (Eletrobrás, 2001).

In 1963, started operating the hydroelectric of Furnas, Brazil's largest power plant at the time of its construction (Eletrobrás, 2001). With the entry of the military in power in 1964, aiming to turn Brazil into a "World Power" and pay the foreign debt, then it moved to deepen further the search for new energy sources. In this case, priority was given to new areas that could generate short-term electric energy sufficient to meet the demand of the sectors that government regarded as strategic to the country's development. In this context it was created the Program for Agricultural and Poles Agro minerals Amazon, Polamazônia and Development Program for Integrated Areas in the northeast, POLONORDESTE.

These two policies combined made possible in the Amazon, from the mid '70s, the construction of the Tucurui hydroelectric and ALBRÁS SA, and this power plant would have the purpose to generate and transmit electric energy to the chain of the mineral economy of Pará . This strategy of developing a more aggressive energy policy in the Amazon, UHE Tucuruí became then the most important new development in the Amazon, serving referential for the supply of heavy energy companies of the Project Great Carajás. In addition, the project of hydroelectric plant of Tucuruí may supply with efficiency the market of the region polarized by Belém and other cities of the interior of the State of Pará, beyond supplying energy to the Maranhão, to the installation of the ALUMAR, and supplying the Northeast Region, through the interconnection with the system of the CHESF (Bedin and Carvalho, 2005).

In 1973 was created ELETRONORTE responsible for the electricity sector in the North and in the same year as a result of the treaty signed between Brazil and Paraguay, regulating the construction and operation of hydroelectric plant on the Parana River, ITAIPU was created that entered in operation in 1984, being the largest hydroelectric plant in the world at the time with 12,600 MW of installed capacity, it also completed the first part of the interconnection system developed regions, allowing the transfer of energy in the Amazon basin to the Northeast. The same year also came into operation in Hydroelectric Tucuruí, of Eletronorte, the first hydroelectric plant of great capacity of the Amazonia in the Amazon (Eletrobrás, 2001).

In 1987, ELETRONORTE decided to build the hydroelectric plant of Balbina. In 1997, created the National Agency of Electric Energy - ANEEL, the regulator of the electricity sector (Eletrobrás, 2001).

In 2001, Brazil experienced its biggest energy crisis, boosted by extremely unfavorable hydrological conditions found in the Southeast and Northeast. According Bajay (2005), the Ministry of Mines and Energy has formed a working group - the WG 13 in the second half of 2003 to propose the necessary adjustments to the new institutional model of the Brazilian electric sector, at the time designed for the System Interconnected National (SIN), so that he could also be applied to systems electrically isolated from the country Resulting in two provisional measures submitted to Congress in December 2003.

The adjustments proposed by the WG 13 for the isolated systems were left out of provisional measures, and thus the SIN has not taken the north of the country, excluding the states of Amazonas, Roraima, Acre, Amapá and Rondônia, ie 3.4% of production capacity of the country's energy (ONS, 2010). Also according Bajay (2005), some isolated systems should be gradually connected to the National Interconnected System, while for others, this interconnection takes place only in the long term. In 2004, was created the Energy Research Company - EPE, competent to perform the studies necessary for planning the expansion of the electric system, the responsibility of the executive power, subordinate by the ministry of mines and energy.

Launched by the Brazilian federal government in 2007 in the Growth Acceleration Program (PAC), called the construction of the Madeira River hydroelectric complex, designed by the consortium formed between the state company Furnas and Odebrecht. This complex includes the building in the Brazilian Amazon, the hydroelectric plants Jirau and Santo Antonio, which together would total 6,450 MW of potency installed.

Although to be foreseen the construction of a transmission line energy of 2,450 km, estimated at R$ 10 billion required the distribution of energy to be generated by the plants for the more densely populated regions of Brazil (Riosvivos, 2010), in However it should be noted that this transmission line will not consider the riverside communities and more isolated settlements in the Amazon.

The way the isolated communities of the region are distributed, dispersed along the canal of rivers, makes the extension of energy distribution lines from centrals located in the municipalities will be discarded, in most cases, due mainly to the high costs that represent extensions of these lines and the difficulties of transposition of the geographic accidents that if interpose (large areas of forest, lakes, rivers, etc.).

Already in 2010, the most costly and controversial work of the PAC, Belo Monte, Pará, begins to leave the drawing board, after three decades of debate, with the concession of the previous license of IBAMA. Of ownership of her, the federal government tries to hold in April of this year's auction building's third largest hydroelectric plant in the world, estimated to cost up to $ 30 billion and expected to start generation in 2015. An optimistic perspective, before the problem ahead (Comerc, 2010).

The federal government contends that without the hydroelectric, need to activate the thermoelectric plants fueled by fossil fuels that contribute to increase air pollution.

This argument never convinced critics, which indicate that technical and social problems.

One would be the supposed economic infeasibility: Belo Monte would generate little energy most of the time, with decreasing amount of water in the driest period (Comerc, 2010).

According to the EPE (2006) Amazon has 41% of hydroelectric potential to be explored. In the Fig. (1) are presented the main hydroelectric enterprises of generation of energy in the region North foreseen in the PAC.

According to the executive secretary of the Ministry of Mines and Energy, Márcio Zimmermann 2011th are planned for construction of hydroelectric plants in the Tapajos Basin, Amazonas and Pará, that doesn't have great environmental impacts in areas of native forests, as the Amazonian. Which he calls "plant-platform," inspired by the production of petroleum offshore, this new concept is to build the plant and the closing of the forest around, not allowing the construction of cities, roads and other infrastructure that will causing deforestation in the region (MME, 2010).

In accordance with the forecast of the decennial plan of the Energy Research Company (EPE) between 2008 and 2017 will enter in operation 187 plants, being 79 hydroelectric and 108 thermoelectric, generating a total of 64 000 MW.

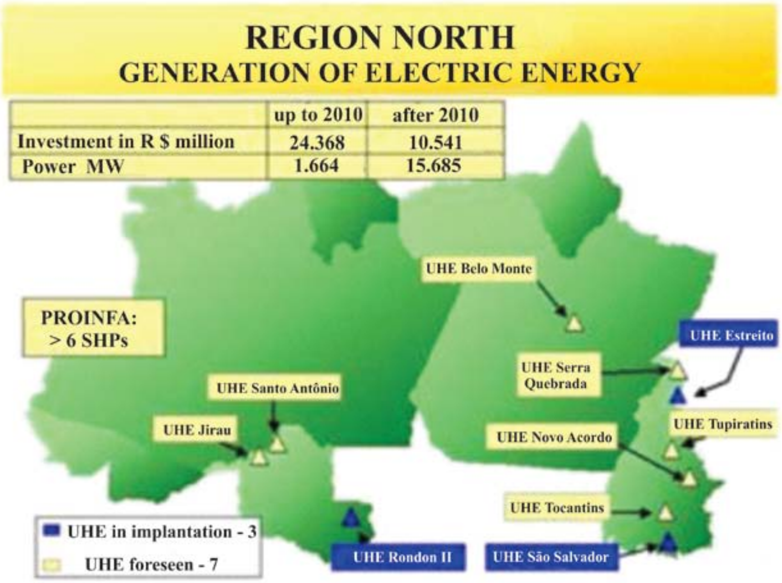


Figure (1) Enterprises of generation of electric energy in the Region foreseen North of Brazil in the Program of Acceleration of Growth - PAC. Source: (Brazil, 2010)

3. NATIONAL PANORAMA OF ELECTRIC EXCLUSION

One of the basic requirements for developing self-sustainable and human in a country is developing its rural areas, especially improving the quality of life of habitant. The underdevelopment of these regions has as one of the causes of the lack of electricity, which can meet the basic needs of human beings, including lighting, entertainment, education, health, water, communication and production needs: derived from agro-industrial operations, including pumping water for irrigation, processing of products, among others.

The conventional systems of electricity supply, developed primarily through the production units and distribution highly centralized, not always present themselves as the best option to meet the needs of the rural sector. This is due partly to the high dispersion of the rural populations and low energy demands, since the economic activities of these populations in general are much reduced. Difficult access to remote communities, the size of properties and low family income also contribute to that is technically and economically impracticable to provide electricity by extending the electricity grid. The cost of generating electricity for the rural sector, through conventional methods, is high because the transmission and distribution end up being more expensive than the proper generation.

Brazil, just like most countries, adopted an economic model that, by means of industrial production, eventually encourage rural migration and accelerated urbanization process. As a consequence of this model, the energy tends to be produced in "large blocks" and in a centralized manner, which does not meet the rural population (Sigaud 1994).

The challenge of the attendance in electric energy in Brazil is proportional to the confrontation of the high level of social and regional inaquality of the Country.

According to the 2000 census conducted by the IBGE, there were about two million rural households not served, representing 80% of total national electrical exclusion, or 10 million Brazilians live in rural areas without access to this public service. Figure (2) shows the panorama of electric exclusion in rural areas of the country in absolute terms, and Fig. (3) shows the panorama of electric exclusion in rural areas by states of the federation. The Fig. (4) shows the distribution of rural domiciles not served by the regions of Brazil.

As a general remark, we emphasize that the states of North, plus Piauí and Maranhão, have the lowest percentage of rural electrification (DOU, 2005).

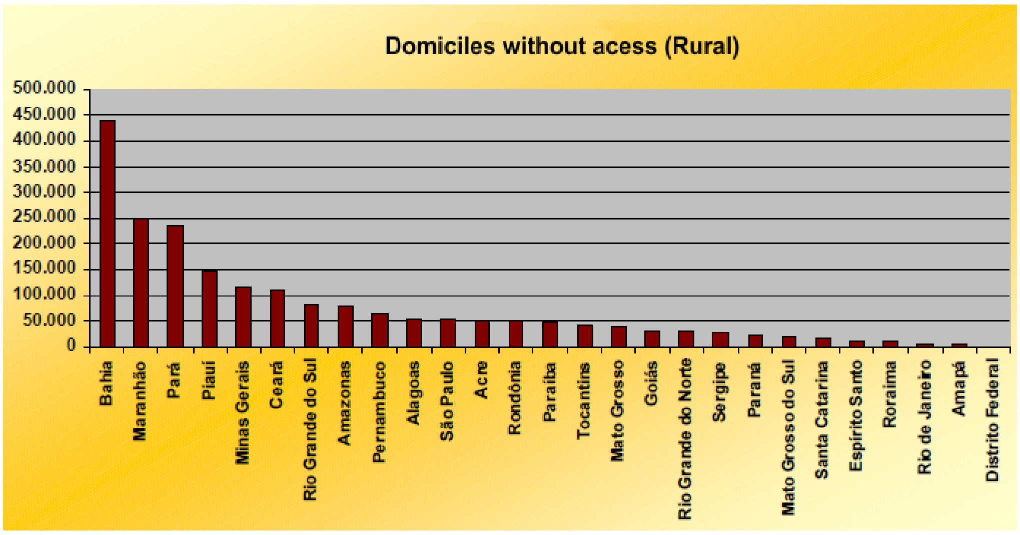


Figure (2) Panorama of electric exclusion in rural areas of the country in absolute terms
Source: (MME, 2010).

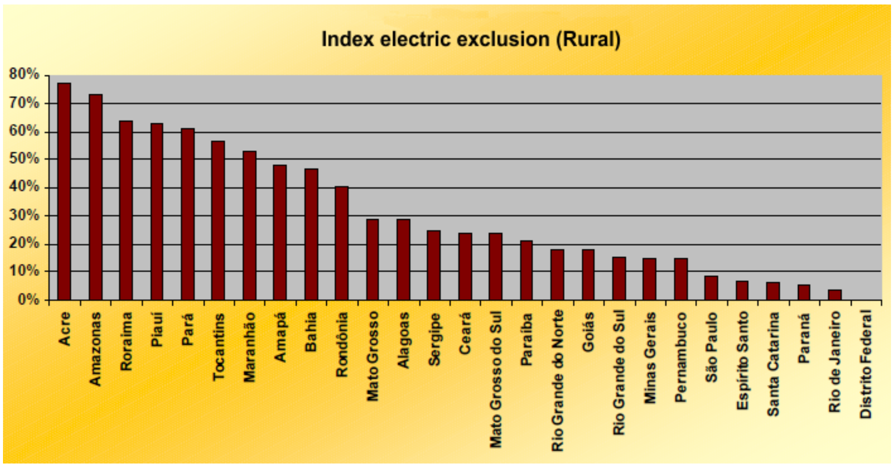


Figure (3): Panorama of electric exclusion in rural areas by states of the federation.
Source: (MME, 2010)

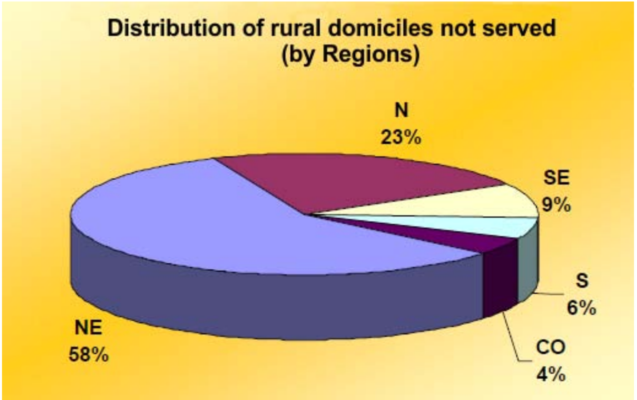


Figure (4): Distribution of rural domiciles not served by the regions of Brazil.
Source: (MME, 2010)

4. PRESENTATION OF THE AMAZON SCENERY SUPPLY OF ELECTRIC ENERGY

The electric service was first established in the city of Manaus in 1902, was the second city in Brazil to receive this service. It was produced energy in direct current to operate the tramway system and provide energy for lighting the city and the entire production from imported diesel oil (Cartaxo, 2000).

The power supply has as its basic pillars the generation and transport.

Transportation is composed of the processes of transmission and distribution of energy and its high importance in the case of Brazil, according to the hegemony of large hydroelectric plants that, in general, are located too far from major consuming centers.

The scenario of supply of electric energy in the state of Amazonas is characterized by several isolated thermal parks, small generating capacity. The locations of the interior are met by power stations operated by the concessionaire of the state (CEAM), these operate in her almost totality with derived of petroleum, in way many precarious times.

The fuel is subsidized by the government, making it competitive with other energy sources, with potential in the state.

The universalization of electricity to all rural households in Brazil has been promoted successfully by the Light for All Program (PLPT) of the Ministry of Mines and Energy (MME). This is a large enterprise, which has served approximately two million habitations (Di Lascio and Baker, 2009).

In the case of the Amazonian the difficulties are larger because of the great extension territorial, low demographic density, sparseness of the population, dense net hydrographic, countless flooded areas and forest compacts.

As these obstacles occur in different levels, the implantation of the PLpT initiated in the places where is viable the extension of distribution networks from existing systems. To the other part, that more than represents the half of the territory, generally the energy will come of isolated generation, whose sustainability requires that the primary energy is renewable. Face to these difficulties and aiming at the expansion of the covering for the areas that still had not been were not assisted the PLpT was extended up to 2010 (Di Lascio and Barreto, 2009).

For Valois *et al.* (2004) as regards the state of Amazonas, it is impossible to discuss the universalization unreflectingly in the distribution of development as unequally distributed in the region and in the local reality that cannot be analyzed from the same criteria with which discusses the reality of the rest of the country. And thinking in redistribute the development, sees-that the concept of universalization in the field of electricity not just illuminate all domicile of the interior and of the capital of the state. Is, too, distribute the consumption and the generation of a more equitable and that is saying that the priorities given to petroleum, gas and the large hydroelectric plants need to be reconsidered and redirected for the use of renewable sources and reduced social and environmental impact.

Second IBGE data compiled by Energy Research Company –EPE, in 2005, the number of domicile in rural areas north of the country which encompass the states of Rondônia, Acre, Amazonas, Roraima, Pará, Amapá and Tocantins were 27.3% .(EPE - PNE 2030). A comparative development of rural and urban population in the years 1990, 2000 and 2005 in the North region is presented in Table (1).

Table (1) - The evolution of the resident population (thousand habitants), second situation – Brazil and North Region, in 1990, 2000 and 2005.

Region/Year	1990			2000			2005		
	Urban	Rural	Total	Urban	Rural	Total	Urban	Rural	Total
North	**3.566,0**	**6.436,0**	**10.002,0**	**9.145,1**	**3.941,2**	**13.086,4**	**10.287,5**	**4.411,4**	**14.698,9**
Rondônia	383,8	743,5	1.127,3	894,8	501,0	1.395,8	983,8	550,8	1.534,6
Acre	160,0	256,7	416,7	382,7	193,5	576,2	438,2	221,6	659,9
Amazonas	1.073,7	1.023,9	2.097,6	2.134,4	714,4	2.848,8	2.429,1	813,1	3.242,2
Roraima	91,1	125,3	216,4	252,3	79,0	331,3	298,0	93,3	391,3
Pará	1.361,8	3.575,3	4.937,1	4.174,2	2.098,5	6.272,7	4.638,6	2.332,0	6.970,6
Amapá	189,4	99,0	288,4	435,5	53,7	489,2	529,3	65,2	594,6
Tocantins	306,1	612,2	918,3	871,4	301,1	1.172,4	970,4	335,3	1.305,7

Source: Adapted from EPE - National Energy Plan - (PNE) 2030

5. TECHNOLOGIES FOR GENERATION HYDROELECTRIC SMALL ISOLATED COMMUNITIES

In Brazil, hydroelectric energy was developed based on the creation of large hydroelectric power station. This strategy demanded high investments but brought great benefit as a cheap cost for energy. This low cost has been confirmed from the point of view purely economic, since there was no proper assessment of social and environmental impacts that the implementation of this model would (Centro da Memória da Eletricidade no Brasil, 2001).

According to Reis and Silveira (2000), these costs attractive and non-observance of social and environmental aspects has led to disinterest in the development of hydroelectric generation projects smaller as the SHP (small hydro power plants up to 30MW), micro and miniplant.

Today the situation has reversed. Greater awareness of social and environmental impacts and structural changes in the electricity sector (decentralization, privatization, new technologies for cost reduction etc.). Add to the effort to encourage the development of projects and smaller local plants.

In accordance with Tiago Filho and Duarte (2006), the use of renewable energy sources in units of small and medium size, serving mainly to consumers in isolated systems, was a major theme of studies and applied research in the mid-eighties until the reduction in petroleum prices, which discouraged its diffusion.

However, this thematic one has received new impulse with the development of technology with bigger recognition of its advantages regarding the promotion of sustainable development due to greater conscience of social and environmental impacts and structural changes in the electric sector (decentralization, privatization, new technologies aimed at reducing costs, etc..), that ally to the important changes in the legal aspects, currently consists in an area of great dynamism stimulating the development of projects of local plants and smaller.

Amongst the available technologies of generation hydroelectric plant for small communities include: hydrokinetic turbines, technology discussed in greater detail this work in terms of research has been conducted with this technology by the authors, Pico-hydro generator, Pumps As Turbines (PAT), Micro Hydropower Plant (μHP).

5.1 Hydrokinetics turbine

The use of the kinetic energy of the rivers to generate electricity an alternative is considered no conventional of hydroelectric uses. Its technology is an advance in relation to conventional hydroelectric plant with respect to environmental impacts, by the fact that dispenses the storage of energy potential in artificial lakes with the employment of dams and, consequently, does not interfere in the course of rivers.

That kinetic energy can be transformed in mechanical energy through a hydraulic turbine of the type hydrokinetic. One of the first equipment to make this conversion of energy was the water wheel which was already used in ancient civilizations and is still very frequent use applications for pumping water in rural areas. However, the water wheel has a much lower conversion efficiency of modern turbines hydrokinetic Els *et al.* (2005).

The hydrokinetic turbine operates through the kinetic energy resulting from the current of the water course, which is used to actuate the rotor. This type of turbine can be anchored in the river bottom or placed in balsa. To the extent that the water passes through the rotor machine produces a force, causing it to rotate. Thus, through a system of pulleys and belts, the generator is activated, producing energy, as is the operation of a common central. To develop a generation central with a hydrokinetic turbine, there is no need that the project has waterfalls and there is no need to build powerhouse, dam and ducts, as this type of turbine requires no waterfall. Therefore, this undertaking reduces the environmental impact to acceptable levels.

The modern hydrokinetic turbines can be classified in turbines axis vertical when the flow is perpendicular to the axis of transformation of the turbine, and in turbines of horizontal axis or axial, when the flow of water is aligned with the axis of mechanical conversion. Turbines of vertical axis are preferred when necessary take advantage of kinetic energy of a flow whose direction may change with time, for example, systems for the use of tidal flow. Darrieux (1931) and Gorlov (2000) describe some of these turbines Els *et al.* (2005).

The last two decades is that it is invested in the development of hydrokinetics technology. Harwood (1985) documented one of the first attempts, presenting a prototype for a horizontal axis turbine developed by National Research Institute of the Amazon (Inpa) in 1981 and called "cata-águas" in Portuguese. However, the first Brazilian experience successful was performed by researchers of the Department of Mechanical Engineering of the University of Brasilia, which have developed a turbine axial from studies initiated in 1990 ELS *et al*. (2003).

This experimental hydrokinetic turbine was installed in 1995 to support the operation of a medical center in the city of Correntina-BA. Their success resulted in the awarding of the project in 1997 by the Foundation for Research Support, the Federal District ELS *et al*. (2005). The turbine can be fixed in the margin of rivers in a structure of sustentation that allows to withdraw the turbine of water, thereby facilitating its maintenance and cleaning as well as to monitor the variation of the share of river. This first generation turbine as shown in Fig. (5), is in operation and has provided subsidies, improving and perfecting their design that resulted in the evolution of technology to a commercial model hydrokinetic turbine of the second generation, which incorporated several improvements on the hydrodynamics of the turbine and in the manufacturing process and is manufactured and marketed in Brasilia by the Company Hydrokinetic Engineering Ltda. ELS *et al*. (2004).

Figure (5) Hydrokinetics Turbines of the first generation in the city of Correntina - BA.
Source: Els *et al*. (2005)

The turbine of the second generation is composed of a stator at the entrance of the propeller which directs the water flow in the turbine in such a way to increase the attack angle of the blades of the propeller, optimizing the transformation of hydraulic energy. Another innovation is the use of a diffuser or suction tube at the outlet of the turbine and the use of cones in the center of the turbine to minimize the generating of turbulence in the water stream, as shown in Figure (6) which resulted in increasing the efficiency of the turbine.

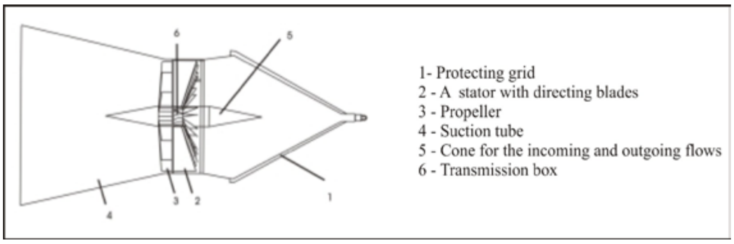


Figure (6) - Components of a hydrokinetic turbine of the second generation. Source: Els *et al*. (2005)

With the consolidation of the second generation of turbine as a commercial product and its subsequent transfer for industrialization, the department of Mechanical Engineering at UnB started a new research project to develop a third generation of turbines, using the CFD technique for improving the geometry of the diffuser and optimize performance of the turbine BRAZIL JUNIOR, *et al.* (2006).

Researchers at the Department of Mechanical Engineering at UnB currently have the technology to design turbines that can use water flux with speeds up to 2 m/s with the size of the propeller ranging from 0.60 to 2 meters in diameter, as well as turbines anchored under floating presented in Fig. (7) with diameters ranging from 1.5 to 2.8 m. for large rivers like the Amazon region with low water velocities ranging from 1 to 1.5 m/s.

Figure (7) - Hydrokinetic turbine under fluctuating. Source: Els *et al*. (2005)

The power generated by the hydrokinetic turbine depends on the projected area of the rotor of the turbine and the speed of water stream to the cubed, being calculated by equation (1) Els *et al.* (2005).

$$P = \frac{1}{2}(\rho k_b . A)\, v_0^3 \qquad (1)$$

Where P is the power generated by the turbine, K_b is the Betz coefficient (K_b = 16/27 or 59.2%), A is the rotor area (m^2), ρ is the fluid density (kg/m^3) and v_0 fluid velocity (m/s).

In another approach Gorban and Gorlov (2001) presents a new mathematical model to estimate the maximum efficiency of free flow turbines. Gorlov this approach shows that the maximum efficiency of a plain propeller is about 30%, well below the Betz coefficient of 59.2% Els *et al.* (2005). Table (2) shows the electrical power of hydrokinetic turbine in function of the speed of the river water and the diameter of the propeller, to an overall efficiency of 39% including mechanical and electrical losses.

Table (2) - Power hydrokinetic turbine

Water speed \ Propeller diameter	0,80 m	1,00 m	1,20 m	1,40 m	1,60 m	1,80 m	2,00 m
0,80 m/s	51	80	115	157	204	259	319
1,00 m/s	100	156	225	306	399	505	624
1,20 m/s	173	270	388	528	690	873	1078
1,40 m/s	274	428	616	839	1096	1387	1712
1,60 m/s	409	639	920	1252	1636	2070	2556
1,80 m/s	582	910	1310	1783	2329	2948	3639
2,00 m/s	799	1248	1797	2446	3195	4044	4992

Power in Watts

The cost of this equipment is directly related to the technology involved and the amount of material needed for its manufacture. However, the total cost of installation and assembly depend mainly on the ease of access, logistics and other costs of installation and can easily exceed the cost of purchasing the equipment.

All technologies for of use hydropower depend on the characteristics of the river that determines the technological options and the choice of site for installation of the project. In the case of hydrokinetic turbines, the essential factors are the speed and depth of river.

However, not only those physical factors that determine the choice of the site, but also the distance between the site and consumers. For when it comes to decentralized generation, is just the proximity to the natural resource that enables its installation.

5.2. Pico-hydro generator

The Pico-hydro generator shown in Figure (8), the result of a partnership CERPCH-National Center for Small Hydropower/Unifei with Cemig, was developed to serve small hydroelectric power station, up to 200 W. The equipment consists of a Turgo turbine, which turns a car alternator. This, in turn, activates a battery charger, producing energy (Tiago Filho and Duarte, 2006).

Figure (8) Pico-hydro generator Source: (Tiago Filho and Duarte, 2006).

5.3. Pumps as turbines

The design of pumps as turbines show in Figure (9) consists in selecting a pump to operate in reverse as a turbine, with power ratings below 50 kW.

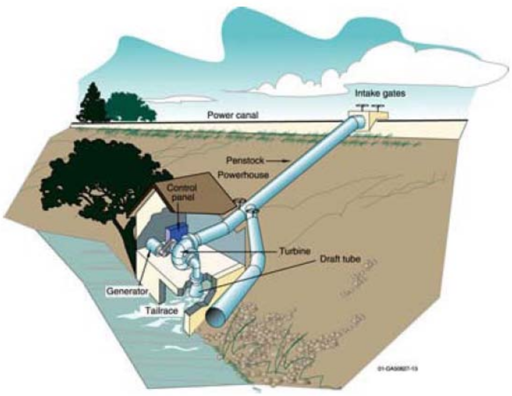
In Brazil, this study and has been developed at the Laboratory for hydro mechanical Small Central Hydroelectric (LHPCH - UNIFEI). This is an excellent alternative for the implantation of micro central hydroelectric to a lower cost.

Although the cost can represent only 30% the cost of a conventional turbine, the investment is around R$ 5,000.00 for a capacity of less than 3kW (Tiago Filho and Duarte, 2006).

Figure (9) Pumps as Turbines Source: (Tiago Filho and Duarte, 2006).

5.4. Micro hydropower plant

A Micro Hydropower Plant show in Figure (10) consists of devices that capture and carry river water to a powerhouse where energy transformation occurs in hydraulic electric energy through the use of a turbine-generator set. The water used is returned to the river when the process ends. The main components of one µCH are barrage, a structure capture, or a tubing of adduction, a canal of escape, floodgates, hydraulic Turbines, generators and electric protection equipment (Eletrobrás, 2010).



>Micro Hydropower Plant

Figure (10) Scheme of a Micro Hydropower Plant. Source (EERE, 2010)

The Micro Hydropower Plant are classified within the general concept of Small Hydroelectric Plants, identified according to quantities like potency up to 100kW, drop height less than 3m, flow rate of less than 2m³/s and maximum implantation of six months and are investments more expensive among those given by Viana *et al*. (2008) according to data presented in the Table (3).

Table (3) - Cost of implantation of small hydropower plants by region of the country

Region of Brazil	Micro central (até100 kW)	Mini central (de100 a 1000 kW)	Small central (de 1 a 10 MW)	Small central (de 10 a30 MW)
North	6.000	5.500	4.000	4.000
Northeast	5.500	4.800	3.500	3.500
Midwest	5.500	4.500	3.500	3.500
Southeast	3.000	3.000	2.800	3.000
South	3.000	3.000	2.800	2.800

These values were calculated for construction cost at R$/kW with dollar commercial $2.5280
Source: Viana *et al.* (2008)

6. REFERENCES

Bajay, S. V., 2005, "A Problemática do Fornecimento de Energia Elétrica Às Comunidades Isoladas Da Amazônia", T&C Amazônia, Ano III, Número 6, Janeiro, pp. 2-4.

Bedin, L.S., Carvalho, D.F., 2005, "Infra-Estrutura Energética e Desenvolvimento Setorial na Amazônia Legal Brasileira", T&C Amazônia, Ano III, Número 6, Janeiro, pp. 48-54.

Brasil.gov "Geração de Energia Elétrica Região Norte" disponível em http://www.brasil.gov.br/pac/investi-mentos/por-regioes/norte/geracao-de-energia-eletrica/view acessado em 14/03\2010

BRASIL JUNIOR, A.C.P., et al.,2006, A New Conception of Hydrokinetic Turbine for Isolated Communities in Amazon. In: Congresso Nacional de Engenharia Mecânica, Recife. Anais... CONEM, 2006.

Cartaxo, E. F., 2000, "Fornecimento de serviço de energia elétrica para comunidades isoladas da Amazônia: reflexões a partir de um estudo de caso", Tese de Doutorado, Universidade Estadual de Campinas, Faculdade de Engenharia Mecânica, Campinas-SP, Brasil.

Centro da Memória da Eletricidade no Brasil, 2001. "Energia elétrica no Brasil: breve histórico" Rio de janeiro.

Comerc Comercializadora - Comercialização de energia elétrica "A novela Belo Monte" disponível em http://www.comerc.com.br/web/page_com/noticias_dtl.asp?cod=14566 acessado em 10/2/2010

Di Lascio, M. A., Barreto, E. F., 2009, "Energia e desenvolvimento sustentável para a Amazônia rural brasileira: eletrificação de comunidades isoladas". Kaco Gráfica e Editora Ltda, Brasília,.

DOU – Diário Oficial da União : portaria 447 do MME seção1 de 05/01/2005.

Eletrobrás, 2001, "Energia Elétrica no Brasil: Breve Histórico (1880-2001)" Memória da Eletricidade.

Eletrobrás, 2010,"Projeto Ribeirinhas" disponível em http://www.eletrobras.com/EM_Programas_Ribeirinhas/sistemas.asp, acessado em 22/02/10.

ELS, Rudi Henri van. et al., 2003, Hydrokinetic turbine for isolated villages. Pch Notícias & Shp News, Itajubá-MG Brasil, v. 19, p.24-25.

ELS, Rudi Henri van; CAMPOS, C; SALOMON, L. R. B., 2004, Turbinas hidrocinéticas no Brasil. In: Primeiro seminário sobre atendimento energético de comunidades extrativistas - SAECX 2004, Brasília: Ministério de Minas e Energia e Programa das Nações Unidas para o Desenvolvimento.

Els, R.H.V., Campos, C.O. and Salomon, L.B.R.,2005, Turbinas Hidrocinéticas do Brasil, Projeto Turbina Hidrocinética da UnB, Brasília.

Empresa de pesquisas Energéticas - EPE PNE 2030 disponível em http://www.epe.gov.br/PNE/Forms/Empreen-dimento.aspx, acessado em 10/03/10

Energy Efficiency & Renewable Energy (EERE) U.S. Department Wind & Water Power Program disponível em http://www1.eere.energy.gov/windandhydro/hydro_plant_types.html acessado em 22/02/10.

Gagnon, L.; Belanger C.; Uchiyama, Y., 2001, Life-Cycle Assessment of Electricity Generation Options: The Status of Research in Year. Energy Policy. Nº 30, pg. 1267-1278. 2002.

Hinrichs, R.A.; Kleinbach, M., 2003, "Energia e Meio Ambiente". Pioneira Thomson. São Paulo.

Ministério das Minas e Energia (MME), "Brasil terá usinas-plataforma no Amazonas e Pará" disponível em http://www.mme.gov.br/ acessado em 13/03/10.

ONS - Operador Nacional do Sistema disponível em http://www.ons.org.br/conheca_sistema/o_que_e_sin.aspx acessado 01/03/2010

Reis, L. B. dos e Silveira, S. (orgs.), 2000, "Energia Elétrica para o Desenvolvimento Sustentável", Edusp, São Paulo.

Riosvivos.org "O maior tributário do Amazonas ameaçado - Hidrelétricas no rio Madeira" disponível em http://www.riosvivos.org.br/canal.php?c=536 acessado em 3/2/2010.

Sigaud, L., 1994, "Implicações Políticas e Sociais de Grandes Projetos Hidrelétricos Sobre as populações Indígenas e Camponesas. São Paulo: USP, Instituto de Estudos Avançados, Série Ciências Ambientais.

Tiago Filho, G.L., Duarte, E.R.B. C. de, 2006, "Uso do Micro-Crédito para Financiamento de Micros Empreendimentos Energéticos", An. 6. Enc. Energ. Meio Rural.

Valois C, Ilsa M. ; Cartaxo, E. F., 2004, "Universalização da Energia Elétrica: Uma Análise Política da Distribuição de Energia e da Sua Importância Sócio-ambiental para o Amazonas", Encontro de Energia no Meio Rural - An. 5. Enc. Energ. Meio Rural.

Viana, E.M.F., Martinez, C.B., Faria, M.T. C. de, 2008, "Implantação de mini centrais hidrelétricas como alternativa para a redução do custo de energia em sistemas de abastecimentos de água", SEREA 2008 VIII Seminário Ibero Americano, disponível em http://www.cph.eng.ufmg.br/nova/projetodoc/47.pdf acessado em 28/01/10.

7. RESPONSIBILITY NOTICE

The authors are the only responsible for the printed material included in this paper.