Photovoltaic System For Electrical Power Generation In Remote Rural Areas Of The Brazilian Amazon

Celia Salama Andrade, Ph.D. Candidate, Energy Planning Program – COPPE/UFRJ
Cidade Universitária, Centro de Tecnologia, Bloco C, sala 211, Ilha do Fundão, CEP: 21945-970, Rio de Janeiro - RJ – Brasil, Tel.: 55-21-9634--6237, Fax: 55-21-2562 8258, csalama@ppe.ufrj.br

1. Electric Power And The Amazon Isolated Communities

The model of power supply applied in Brazil in the last decades priorized the hydroelectrical generation from big undertakings and the transmission of large blocks of energy. In terms of installed capacity of power generation, the hydroelectrical plants cover almost 80% of the production. Such model made it possible to reach an electric power supply rate over 90% in Brazil, with huge discrepancies between the urban and rural areas and within the many areas of the country, "copying" the unevenness noticed in the Index of Distribution of Human Development in Brazil.

The electric power supply to the Brazilian Isolated Systems is mostly made through thermoelectrical plants and with great number of small generating unities run on diesel, which causes fuel waste, due to worn out pieces and low efficiency, with fuel provided from Fuel Consumption Account - CCC.[I] One liter of diesel transported to generate electric power in the Amazon may mean spending up to 2 liters of fuel.

The Isolated Systems supply an area of 45% of the brazilian territory and about 3% of the national population, i.e., 1,6 million of consumer unities.
The lack of electric power is a common thing in the communities supplied by isolated systems, the power quality is low and many systems are not assisted 24 hours a day.

[I] The Fuel Consumption Account – CCC was created in 1973 to finance the costs of fossil fuel electric power generation in the Isolated Systems. Its extinction is predicted to 2022.

The CCC mechanism, at the same time that makes it feasible the assistance of isolated communities, slows down the competitiveness of renewable sources for the supply of electric power in the area.

For 2008, it is estimated 256 Isolated Systems of the North Area which correspond to 1.107 thermoelectric generating unities, with power of 3.002 MW, from petrol derivates, with cost to be covered by the CCC estimated in R$ 3 billions (GTON, 2008).

2. Rural Electric Power Supply In The Brazilian Context

In rural areas, the challenge to supply electricity must take into account some essential characteristics as:

- Rural areas present high space dispersion, i.e., low demographic density, sometimes lower than 1 inhab/km^2, comparing to urban areas, which means difficulties concerning logistics, time, transport expenses and access and communication services.
- These areas are not integrated with the formal economy, which makes it difficult to diffuse the goods and services in and outside the communities.
- The lowest levels of the Human Development Index are recorded in the rural areas of countries in development, where one can notice the reduced presence of public services, such as lack of clean water, sanitation, health service, education and electric power supply. Such scenario contributes to the poverty and absence of jobs, food resources, housing, and others. As a result, in these places it is found the highest levels of child mortality, reduced lifespan and the highest rates of illiteracy (Rosa et al, 2006).
- Rural population, especially in Brazil, disposes of little or no monetary profit, making it difficult to promote electric power supply.
- Even with the possibility of power supply access, due to the low income of the isolated rural communities, the level of electric power consumption is very low, at least in the short run, making the viability of electric power supply projects of the utilities difficult, due to the uncertainty of profitability of the investments (Obermayer, 2005).
- High maintenance cost for the utilities made worse by the long distances to be reached.

Given the social scenario in the rural areas, the only option for the countryside man is to move to the urban centers, forced to live in slums, in poor conditions of housing and survival.

It is important to point out that the guarantee of access to electric power is considered an essential condition to fulfill the rural people’s basic demands. However, it does not represent *per se* the conditions for the rural area social and economical development, once many other social debts are yet to be solved (Rosa, 2006).

In the context of the structuring process of the public policies towards the guarantee of accessibility to electric power in Brazil, it has been recently released some programs aiming at the rural power supply in Brazil: The State and Municipal Power Supply Development Program – *PRODEEM*; The Rural Power Supply National Program – *Luz no Campo* and The Globalization of Electric Power Supply Access and Use National Program – *Luz para Todos*.

2.1 State And Municipal Power Supply Development - *Prodeem*

PRODEEM was created in 1994 to assist the rural communities that are not connected to the power supply distribution system, by using the decentralizing generation system from renewable energy sources, supplying schools, health centers and other community facilities.

The technologies considered by *PRODEEM* include the photovoltaic solar power, eolic power, small hydroelectric plants, biofuel and biodigestors. However, it was the photovoltaic technology that stood out in the Program. Between 1996 and 2002 about 5,2 kWp in photovoltaic solar power were installed, distributed in more than 8.700 systems.

A number of managing problems in the Program has been accumulated and many systems were lost, due to lack of preparation, capacity and organization from the communities to access, operate, maintain and be responsible for the equipments, basically due to the decision centralization, without the beneficiary communities being involved.

2.2 Rural Power Supply National Progam – *Luz No Campo*

Luz no Campo was created in December 1999, to raise the level of power supply in the countryside, as a way to establish the basic conditions to the expansion of field activities and to contribute to the social and economical development of the countryside.

The Program has been focused in the expansion of the distribution system and between the year 2000 and 2003 about 630.000 connections were made.

2.3 Globalization of Electric Power Supply Access and Use National Program – *Luz para Todos*

Luz para Todos, created by the Federal Government in 2003, to supply, until the year 2010, with electric power, all the rural homes and establishments in the Country, providing electric power to 12 million brazilians in more than two million homes, yet unattended, budgeted in R$ 12,7 billions. Besides, the program aims at promoting improvement in services to the benefited population, intensifying the rhythm of assistance and diminishing the tariff impact by allocating the subvention resources and the financed ones. In this Program, the low income consumer receives the electric power initial kit without any expenses. *Luz para Todos* has been presenting relative success in the expansion of rural electric power services, focusing on the priority for the amount of connections and yet with a very low participation of the renewable sources and without an actual perspective of sustainable development of the population.

Since the beginning of the Program until September, 5th 2008, 8.463.000 people have been benefiting from the *Luz para Todos* in all the brazilian states.

From 2003 to September 2008, it is estimated that *Luz para Todos* generated 250 thousand jobs directly and indirectly, used 600 thousand transformers, 3,9 million poles and 750 thousand km of electric wiring.

More recently, for the globalization of isolated communities, the priorities are mini solar power plants and mini grids, directing the systems into three compact lamp bulbs, 200 - liter fridge, *20'' TV* per home, a collective water pump, a Gesac aerial for digital inclusion and two computers per community with billing through measuring pre-paid card like.

Other alternatives are: generation through diesel, biofuel or natural gas thermoelectrical plants, mini hydroelectrical plants, hydrokinetic turbo devices and grid expansion using the *ecological grid* concept with posts from the forest and low cost options that do not harm the ecosystem.

3. Electric Power Supply And Renewable Sources In Amazon

In the Amazon area there is a diversity of environmentally sustainable renewable primary sources of power and a biodiversity singular in the Planet. Plenty of solar energy all year through, winds in some seashore areas, water flow courses and falls. Biomass is seen as potential generating source of renewable power for the area through different technological routes and vegetables. The possibility of using the photovoltaic solar energy, hybrid systems: diesel/eolic, diesel/solar photovoltaic and other possibilities must be analyzed for the Amazon. The area presents high hydroelectric potential, but its lands are not favorable, taking it to the possibility of usage through mini hydroelectric centers or hydrokinetic turbo devices that are moved by the speed of the river.

The big question for the Brazilian Amazon is how to generate electricity, utilizing natural resources and at the same time promoting the Amazon's socio-economic growth in a sustainable way.

4. ANEEL Resolution # 083 Of September 20th, 2004

ANEEL Resolution # 083 of September 20th, 2004 establishes the supply proceedings and conditions through the Individual Generation Systems with Intermittent Sources– SIGFI[II].

The initial proposal was to exclusively regulate the home photovoltaic systems, but due to the similarities to other sources it has been spread to other technologies called *flow energy sources,* which cannot be stocked like eolic and solar energy.

The main motivation of the Resolution was to fulfill the needs of the *Luz para Todos*.

5. Autonomous Photovoltaic System

The Photovoltaic Solar System generates electric power directly from solar energy, differently from the thermosolar systems where the solar energy produces steam that moves a thermal plant that generates electric power.

Due to the stochastic nature of the solar radiation on the surface of the Earth, it is made convenient to base solar resources estimates and predictions on solar metric information rose through long periods of time.

In June 2001 it was published the *Atlas Solarimétrico do Brasil*[III] which provides a solar metric database for the country that organizes, classifies and standardizes the data measured and published by different authors and institutions throughout the last decades along with new solar radiation isoline maps.

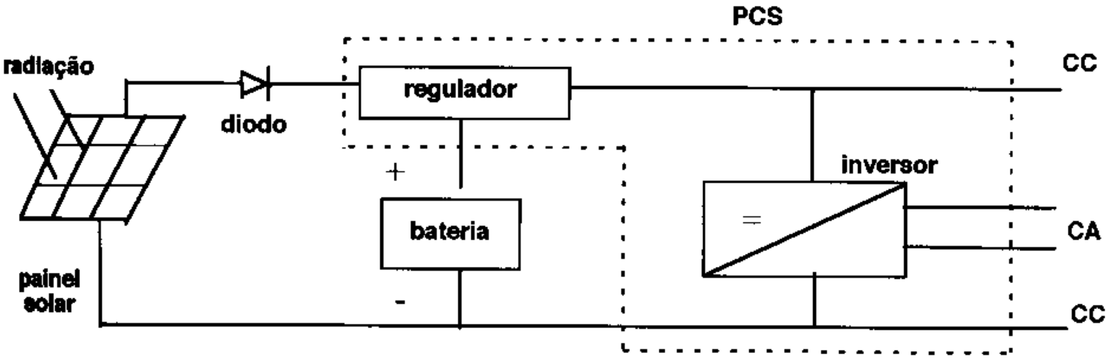
In great atmospheric conditions, i.e., clear sky, the maximum of light observed at midday in a place at sea level is of 1 kW/m^2.

A photovoltaic system for electric power production consists of a group of modules of photovoltaic panels and other relatively conventional equipments that change or store electric power so that it can be used by the consumer.

[II]SIGFI – Sistema Individual de Geração de Energia Elétrica com Fonte Intermitente, is constituted basically of a generation system, an accumulation system and a conditioning system. The SIGFI 13 Class corresponds to a guaranteed monthly availability of 13 kWh, according to Resolution ANEEL Nº. 083 of September 20th, 2004.

[III] The Data Base is the result of Photovoltaic Solar Energy Work Group, coordinated by CEPEL – Centro de Pesquisas de Energia Elétrica/ELETROBRÁS and constituted by companies of the electric power industry, research groups, universities and photovoltaic equipment manufacturers or representatives.

The main constituents of this system are: group of photovoltaic modules, tension regulator, electric power storage system, and direct current/alternating current converter, according to the exemplified scheme below (Reis, 2003).



PCS = subsistema condicionador de potência (*power conditioning subsystem*);
CC = corrente contínua;
CA = corrente alternada.

The module is the generating device (solar panel) itself and consists of a group of interlinked and connected photovoltaic cells.

Different materials and types of structure are used in the production of photovoltaic cells. These days silicon is the most important material, once for a long time we have been aware of its technological function and the raw material that originates it.

The electric power storage system is constituted of electrochemical batteries.

The power conditioning subsystem, generally known as PCS (*Power Conditioning Subsystem*), allows the interlink of the source of electric power generated by the modules as direct current with a charge or a power system in alternating current. The PCS is composed of different devices, in general, physically connected. Their functions are:

- To control the connection-disconnection and the operation spot of the photovoltaic arrangement;
- To protect the system;
- To control the conversion of direct current into alternating current;
- The most important component of the PCS is the converter, which must convert the generated power into alternating current.

The power generated in a photovoltaic system with the configuration shown depends on the solar radiation at the time and is directly related to the solar panel area. The batteries regulate the power and therefore raise the capacity factor of the system.

6. Configurations Of Photovoltaic Systems

The individual photovoltaic systems can adopt 3 configurations:

- Supply exclusively in direct current
- Supply in direct current and alternating current ("hybrid" system)
- Supply exclusively in alternating current

The Assistance exclusively in direct current, besides being widely spread to low power systems, is a configuration that shows limitations as for the use of conventional final equipments.

The systems that adopt the “hybrid” configuration consist of a line in direct current for lighting and a converter *DC*/*AC* to supply small charges of traditional equipments in the market in alternating current. This way, the converter is not operated when the charge is exclusively for lighting final use. This configuration shows as advantage the possibility of supplying the lighting requirements even in cases of converter failure. However, the disadvantages are:

- The complexity of managing the installation in case of supply interruption of charges in *AC*, characterizing then *a partial interruption*, situation which is not regulated in the globalization context
- Installation costs associated with each *DC*/*AC* line
- Quality, Access and lamp prices for the *DC* and *AC*.

So, the configuration exclusively in alternating current *vis-à-vis* the other options, has been defended in the globalization context due to the facilities in terms of wiring (smaller diameters) as well as in relation to access to electric equipments, both of control and final use. Besides, the entry standards would be those established in cases of net expansion. The bad side on the configuration is exactly in relation to the converter, when it operates in partial conditions of charge. This component shows a failure incidence yet to be resolved.

This last alternative is also seen as the only one to maintain the equity among all consumers in the country, with a standard similar to those supplied through grid and that allows higher facility in transition to supply via conventional power grid.

The specification of the type of system adopted by ANEEL Resolution 083, due to its special features, is associated with the amount of energy intended to offer the consumers, reason by which it is made essential to establish minimal supply standards (power and energy).

The definition of the system size is a matter to be associated with the amount of energy, in kWh/month, intended to offer.

To great part of the brazilian geography, a 50Wp system will not be able to offer more than 3,5 kWh/ month, i.e., just enough to supply energy for some low power fluorescent lamps to work and a radio, four hours a day. While a 300 Wp system can offer about 20 kWh/ month, providing more flexibility to the consumer in relation to usage, number of lamps and use of electric/electronic equipment. No matter the size, the functioning of both systems is identical.

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