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SOLAR PHOTOVOLTAICS FOR SUSTAINABLE RURAL ELECTRIFICATION IN DEVELOPING COUNTRIES; THE EXPERIENCES IN PERU

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Abstract - It is nowadays accepted that solar photovoltaics represents for many rural areas in developing countries the only real possibility to get in the foreseeable future sustainable electrification, and improve so the livelihood of millions of people. Despite the availability of a mature technology of PV, however, only few successful projects of rural PV electrification are reported. The high investment cost of PV is normally considered as the main barrier, together with related problems like financing. The failure of many PV projects in rural areas of developing countries indicates however that there are also other conditions for a sustainable PV rural electrification. The experience of Peru has shown that there are several conditions, apart from the necessary financing, to make PV projects in rural electrification sustainable. This includes technical conditions, like a good quality control of all the components of the PV systems (battery, charge controller, etc.), as well as management and social conditions. Of particular importance is the involvement of the user of the PV system. We report here the experiences with different PV projects in Peru, especially with a very successful project of PV electrification with 421 Solar Home Systems (SHS) in the region of Titikaka Lake, mainly on the Taquile island. We think that an essential reason of the sustainability of this project is the fact that the SHS have to be repaid (eventually subsidized) by their users, converting them finally in the owners of the systems.

1. INTRODUCTION

Nobody doubts that the availability of electric energy is today inherent to the quality of life and to modern civilization because of the facility to transport electricity and transform it efficiently in other forms of useful energy, like light or mechanical energy, and because of its imperative use in telecommunication and electronic equipment, like computers. But, whereas in developed countries practically everybody has electricity in his home, by far this is not the case in developing countries, where about 2 billions of people, mostly living in rural areas, still don't have access to electricity.

Rural electrification is in developing countries therefore a necessity in order to reach a sustainable development and to reduce the migration from the countryside to the towns, with all the negative consequences involved. Conventional rural electrification through connection to an electrical national grid is however very expensive. For example, further extension of the electric grid costs today in Peru on the average more then 1000 US$ per connection point, and this cost will increase significantly within the next years, because the population that still has to be connected to the grid is living in more and more remote and isolated regions. As an alternative, locally generated electricity has to be considered. As minihydro, or other local energy resources, are only at few places available, the local generation of electricity with Diesel generators, together with local grids, was during long time considered as the best alternative for rural electrification in remote areas of developing countries. However, the experience anywhere has shown that this is not a sustainable solution and, therefore, on the long run, is even more expensive then the connection to the national grid. A recent example in Peru is the electrification of the island community of Amantani, in Titicaca Lake, where six years ago one million of dollars were invested by the Peruvian Government in a local grid and a 250 kW Diesel generator, in order to give electricity to 600 families: since its inauguration in 1997 the system, designed to operate three hours daily (18:00 - 21:00 hours), was working only during some months: it didn't operate during 6 months because of the breakdown of a thermal circuit breaker and during most of the time it is standing still because the people are not willing to pay the fuel for a limited and deficient electricity supply (about $ 3 / month and family).

In the face of this situation and, in view of the development of a more and more mature photovoltaic technology and, last not least, an increasing awareness of the importance of ecological considerations, since the seventies solar photovoltaics is considered as an alternative for basic rural electrification in many developing countries, and even for a sustainable future for the whole mankind (IAE, 2002; Hamakawa, 2002 and Pearce, 2002). Several governments and international organizations, like GEF/UNDP or World Bank, have realized studies and executed photovoltaic rural electrification projects in developing countries and there exists a vast literature on this subjects (FAO, 2000; Chambouleyron, 1966).

As a result, it is nowadays accepted that solar photovoltaics represents for many rural areas in developing countries the only real possibility to get in the foreseeable future sustainable electrification, and improve so the livelihood of millions of people. Despite this awareness, only few successful projects of rural PV electrification are reported. The high investment cost of PV is normally considered as the main barrier, together with related problems like financing. However, there are also other conditions for a sustainable PV rural electrification (Marsh, 2003; World Bank, 2002).

2. PHOTOVOLTIC RURAL ELECTRIFICATION IN PERU

As in many developing countries, solar photovoltaics is particularly suited for rural electrification in Peru: on one side, about 25% of the 26 millions of Peruvians still don't have electricity in their houses, most of them living in rural areas, and eventually they will be without electricity in their houses even within ten or twenty years, because of the very high costs of a connection to the electrical national grid. On the other side, in most parts of the country exists a high availability of solar energy: the solar radiation is high and rather uniform during the year, with monthly means of 5-6 kWh/m^{2}day.

But, whereas in Mexico, a country that is 95% electrified, 40 000 Solar Home Systems (SHS) have been installed till 1996 with a national program (Huacuz and Agredano, 1998), in Argentine at that time a national program for PV rural electrification had started (CER, 1998), and in Brazil in recent years up to 6 MWp photovoltaics have been installed in rural electrification programs (about half for water pumping) (Zilles and Morante, 2000), in Peru till today only modest efforts were made with PV rural electrification.

The first PV rural electrification project in Peru was realized 1986 - 1988 in the southern Andean highland of the department of Puno with the technical cooperation of Germany (GTZ), introducing on a pre-commercial bases about 200 Solar Home Systems (SHS). A social and economical study showed that the rural population accepted very easily this new technology (there was no cultural rejection) and that the annual cost of a financed SHS is similar to the expenditures these people have for candles and kerosene for lighting, dry batteries for radios and, eventually, car batteries for b/w TV´s (these batteries have to be recharged in the nearest village where electricity is available). Despite these good results, the project discontinued, because the German cooperation left the country because of the Sendero Luminoso ("shining path") terrorism and because at that time a hyper inflation began in Peru (lasting till 1990), what made any financing scheme impossible.

The next PV rural electrification project started in Peru in 1995/7, when the Peruvian Ministry of Energy and Mines imported 1450 SHS. The Ministry considered and tried different schemes, but finally decided that most of these SHS were installed (till 1999) in rural homes in the Andes and the Amazon jungle, under the following organization and management scheme: the Government maintains the ownership of the SHS (a special state owned company was founded for this reason), each user, organized in a local "solar electrification committee", had to pay US$ 35 – 45 for the installation and US$ 5 – 8 monthly for maintenance costs (including eventual battery replacement). The idea was that these amounts should depend on a previous social evaluation of the community, but should be the same in a particular community. Each user signed a contract with the government company, in which was established that the SHS will be taken away if the user is 3 months late in his monthly payments. Only a short training for maintenance was given to the users during the installation of the SHS, and practically no post installation service was considered.

Information from different sources indicate that many of these SHS don't work today and that none of the users is paying the monthly maintenance costs.

3. THE TAQUILE PV PROYECT

In order to contribute to the elaboration and evaluation of a sustainable rural electrification scheme, the Renewable Energies Center of the National Engineering University in Lima (CER-UNI) proposed in 1995 to the Peruvian Ministry of Energy and Mines to execute a PV pilot project. CER-UNI got in 1996 from the Ministry US$ 100 000 for this project, with the compromise to install at least 75 SHS in a rural community without foreseeable connection to the national electric grid. After a preliminary survey, it was decided to develop the project in the rural insular community of Taquile in Titicaca Lake, on the Andean highland between Peru and Bolivia, at an altitude of 3810 m and a latitude of 16 degrees south. Taquile has a population of about 1500 people who live from agriculture, some fishing and beginning tourism.

Taquile island in Titicaca Lake; house with SHS

Each SHS consisted of a 50 W_p solar module, a 12 V, 100 Ah "solar" battery, a battery charge controller, 3 lamps with 11 W fluorescent tubes with 12 VDC electronic ballast, a connection box with fuses and a DC-DC converter (3 - 9 V DC, adjustable, in order to be able to connect radios, etc., working at these voltage), installation and 2 years post sale service. The best bid of a private company in 1996 resulted in a cost of each SHS of $ 850 (all components imported, paid cash, including about 40% taxes).

Essential characteristics of the project were:

- Strong involvement of the users in the project, particularly in their training for simple maintenance operations.
- Severe quality control of all the components of the SHS and its installation.
- Two years of post sale service.
- The beneficiaries (end users) had to buy their SHS, paying most part of the costs, but with facilities: during three years 5 quotes of US$ 150 each. (Most people, mainly in Lima, argued at that time that the peasants don't have the money to buy their SHS, and even if they pay their first down payment, they will not pay the following quotes).
- in order that the people of Taquile could see a PV system working, CER-UNI, in coordination with the authorities of Taquile, installed at the beginning of the project in the communal center free of cost a 400 W_p PV system for lighting and color TV (with satellite reception). The costs of maintenance are assumed by the community.

In 1996 one hundred contracts were signed with peasants in Taquile and 100 SHS were installed.

Today, these first 100 beneficiaries are already all owners (having paid 5 quotes of US$ 150 each). Only two beneficiaries stopped to pay their quotes (they could not) and the respective SHS were transferred to other people, without any money lost for the project. With the collection of this money, CER-UJNI created a revolving fund and additional 72 SHS were installed in 1998 in Taquile and the neighboring island of Uros and Soto.

Based on these achievements, in 1999 CER-UNI went a step further, trying to reduce the subsidies nearly to cero, taking a bank loan (US$ 100 000 at 10% yearly interest rate) and offering SHS at six yearly quotes of US$ 150 each, adding up to US$ 900. In few days 192 additional contracts were signed, even by people who three years earlier didn't want a SHS, arguing at that time that they wanted a "real" electrification, connecting the island with a cable to the shore.

In this opportunity CER-UNI made individual bids for the different components of the SHS and the installation and post sale service (modules, batteries, and so on). It was expected that in this way better qualities of each component could be achieved, what in reality then also happened. As the costs were also lower then expected, US$ 650 for each SHS, the systems could be sold, without a direct subsidy, again with 5 (instead of six, as offered) quotes of US$ 150, totaling US$ 750, and 249 SHS could be bought and sold to 249 beneficiaries. These SHS were installed at the end of 1999, after signing the corresponding contracts, in Taquile, in Huancho, a village near the shore of Titikaka lake and also in the neighboring island of Amantani. It is worthwhile to indicate in particular that many people of Amantani were interested in acquiring their SHS, under the conditions of the project, despite that they have a connection to the local grid, as mentioned before. The reduced number of SHS available permitted however to install at that moment only 52 SHS in Amantani.

Today, all these 421 SHS are operating well, 141 are already paid completely and there exists a huge acceptance of the photovoltaic technology in the Titicaca region and many families are interested to buy their own SHS under similar conditions as in this Taquile project. In an opinion poll made in Taquile about the requirements to improve the tourist services, solar electrification was named in the first place, ahead of other needs to improve the local infrastructure (sanitary installations of lodges, transportation, etc.)

In this context the "isla Suasi" project may also be named: Suasi is a small island in Titikaka Lake were a rural ecological "solar lodge" was build seven years ago (http://www.islasuasi.com). This is the first example in Peru of a "all solar" hotel, with solar cookers, solar water heaters and 2,2 kWp photovoltaics for illumination, water pumping, refrigeration, etc. (Horn, 2000)

Titikaka Lake with photographs from Taquile and Suasi Islands

4. CONCLUSIONS

In order to evaluate the possibilities of rural electrification with photovoltaic systems, and in order to identify the characteristics that a massive PV program has to have and what kind of barriers exist, CER-UNI had organized in 1998 a workshop on "Management and administration of projects of photovoltaic rural electrification projects". In this workshop different experiences of photovoltaic rural electrification in Argentine, Bolivia, Mexico and Peru had been presented

and the objectives of rural electrification had been discussed, as well as the essential attributes that a rural electrification program should have (CER- UNI, 1998). As discussed at this workshop, as well as from the continuous experiences with rural PV electrification projects in Peru, as in other Latin American countries, one can get the following conclusions:

a) A Solar Home System (SHS) of 50 W_p can produce 5-6 kWh of electricity per month and costs today in Peru less than US$ 1000, including the costs of installation, training of the users and post sale service (and including about 40 % of taxes), less then the average cost to connect a rural house to the national grid. As different studies have shown (Morante, Huaraco, Espinoza and Zilles (2001); Morante and Zilles, 2001), this amount of energy is sufficient to satisfy the needs of illumination and telecommunications (radio, TV) of a rural family and may be compared with 10 – 15 kWh per month consumed by rural families in Peru that have been connected to the public grid. Additionally, a SHS can be enlarged later on, according to the necessities and economical possibilities of its user.

b) There exists today a mature photovoltaic technology, that permits to satisfy the basic needs of electricity of the rural population, needs that are mainly for illumination and telecommunication (telephone, TV, radio). However, one has to select very carefully the components of the SHS, specially the battery, charge controller and lamps, because many of these parts available in the market are still of low quality. For this purpose the "Universal Technical Standard for Solar Home Systems" (Thermie, 1998) may be very useful, specially because it permits to evaluate a SHS in the field, requiring only simple instruments.

c) The possibilities, characteristics and limitations of the photovoltaic technology are still not well known in Peru, inclusively among professionals working in electrification. This represents a mayor barrier to a massive dissemination of photovoltaic rural electrification.

d) The photovoltaic technology is easily accepted by the rural population and, if known, people consider it useful and want to have it.

e) The costs for illumination with candles and kerosene lamps and batteries for radio and TV are to date for a big part of the rural population similar or higher than the costs (put on an annual bases) of a SHS, that satisfies much better these needs.

f) The beneficiary has to be motivated to acquire his SHS. Therefore he has to know previously the SHS, its benefits and its limitations.

g) The experience of Taquile (as well as of other places) has demonstrated that for a basic rural electrification it is best to install in each house individually and independently its own SHS, instead of installing a centralized photovoltaic system in a community.

h) Except few cases, the majority of the rural population of Peru doesn't have the economical capacity to pay cash for a SHS, but needs a credit scheme. For a wide sector of the Peruvian rural population one even needs some subsidy, at least an reduction or exoneration of the taxes. In this relation it may be remembered that the traditional rural electrification through grid extension is in Peru completely paid by the Government.

i) It is basically possible to make in Peru an electrification of remote rural regions with SHS within a free market economy where the user has to pay for the service he gets, but where the Government supports the financing of the SHS and pays the communal photovoltaic systems, like in schools or health posts.

Based on the exposed arguments, we consider that the Taquile project has demonstrated a real possibility to get a sustainable basic rural electrification with solar home systems.

We think that there are two essential ingredients for the success of this project: on one side, that the beneficiaries of the SHS are finally their owners, motivating them to maintain adequately their SHS and, on the other hand, that a severe quality control of the equipment and of the installation as well as a post sale assistance had been included (training, monitoring, replacement of defect equipment, etc.)

There are other schemes of management and organization for rural photovoltaic electrification projects, but all these other schemes have still to prove their sustainability. We think that the Taquile project has done it already. We think that it would be convenient if public institutions and authorities working in social projects would visit Taquile and get a direct impression of this project and check with the local population the arguments exposed in this article in favor of a rural electrification with SHS.

We consider it would be convenient to follow the model of Taquile, to improve it and reproduce it in other regions. In particular, it would be necessary to study the amount and the form of the necessary subsidize if one wants to reach practically the whole rural population. We suggest that the Government follows this scheme, assuming initially at least the costs of management and administration of the projects and the training of promoters and beneficiaries. (Unfortunately, at this moment, the Peruvian Government has decided that in a new SHS project in Peru, with the support of GEF/UNDP, 1000 SHS will be installed in communities in the jungle under a scheme where the people will have to pay monthly the service, without getting to be owners of the SHS.)

We are convinced that in this way one could reach within few years a real and sustainable electrification of extensive rural regions of Peru, with a limited cost to the Government and in the frame of an ecological sane development of rural regions of the country.

Finally we conclude that SHS are the best, and mostly the only alternative for the electrification of many remote rural areas, but there has to be governmental involvement, particularly to get the necessary financing

and eventual subsidize, and special care has to be given to different aspects, like the involvement of the users, a good post sale service and good quality of all the components of the SHS.

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