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Multi-User Solar Hybrid Micro-Grid Technologies can Overcome Energy Poverty in Palestinian Villages

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Abstract

This paper presents a programme of rural electrification with PV hybrid micro-grids for remote villages in Palestine, dealing with all the issues as techno-economical, the creation of the legal framework and the operation and maintenance. The relevance of this programme is the high level of sustainability and the approach that integrates all the aspects (social, economic, technical) and involving local stakeholders as the community itself, the universities, the electrical utilities and the local authorities. Users generally get organized around the local committee which is in charge of the fee collection, the O&M, etc. The power plants have been monitored and hourly operational and performance data is available for the technical monitoring of the energy flows: solar radiation, PV generation, battery voltage, output energy, etc. Additionally, several social and economic assessments have demonstrated the immediacy of the benefits and the added value of the action.

Keywords: Techno-economic feasibility of energy systems; Rural electrification; Multi users solar Hybrid; Power generators

Introduction

Palestine has a number of remote small villages around 75 small communities that lack electricity and the probability of connecting them with the grid in the near future is very poor mainly due to financial and political situation [1,2]. The daily average of energy demands in these villages is very low and varies in the range of 0.5 to 2 kWh per household. The main electrical loads in these villages are represented in lighting, TV and small refrigerators in few houses. In some cases small diesel generators of power ranges from 3 to 5 kVA are used by different villagers to cover the power demands of their houses, the cost of one kWh generated from diesel generators are very high at a price between (US $ 0.6-1 per kWh). Usually the operation of these generators is limited, 3-4 hours on the night periods. The low voltage networks connecting these systems with the consumers are mostly unprofessionally laid out, which makes these networks dangerous and accompanied with high power losses. In addition, these small generators pollute strongly the environment, and are not reliable due to their frequent faults. The price of diesel fuel in Palestine is relatively high around US $ 1.4/L. Therefore, utilizing of such generators doesn't represent a durable effective solution [1].

Palestine has a high solar energy potential, where the daily average of solar radiation intensity on horizontal surface is 5.4 kWh/m^2, while the total annual sunshine hours amounts to about 3000 [1,3]. These figures are very encouraging to use PV generators for electrification of remote villages as it has been worldwide successfully used.

The PV electrification could be using the decentralized stand alone and centralized systems depending to the nature of the load and the distribution of houses.

Palestinian Energy Authority and Energy research Centre at An-Najah National University started implementation the program for electrification of small communities in West Bank by using mini grid solar PV hybrid systems [4,5], some of technical and social important issues from electrified rural villages in West Bank ,such as Emnazeil village, will be illustrated in this paper, which represent as a sample of Palestinian rural village had been electrified by multi-user solar hybrid system.

Solar Energy Potential in West Bank-Palestine

Since 2000 the Energy Research Centre (ERC) at An-Najah National University (ANNU) has carried out measurements on solar radiation intensity using modern meteorological stations equipped with automatic data loggers. Figure 1 illustrates a sample of measurements at different cities [3].

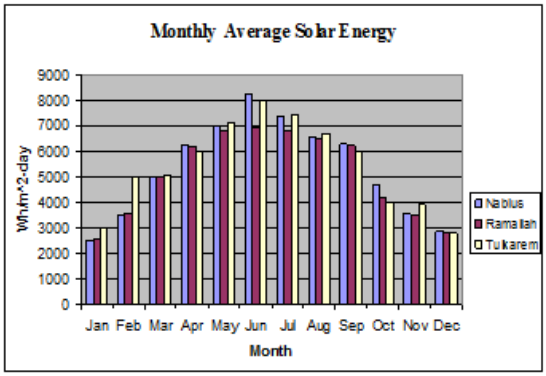

Figure 1: Solar radiation in different cities in Palestine.

Solar Electrification of Emnazel Village

The village of Emnazel is located in the Hebron district, south of Yatta. Its inhabitants working mainly in farming and cattle breeding. Their number amount to about 300 persons living in 45 houses. A school and a small clinic are available in Emnazel.

The village area is known with high solar energy potential, the daily average of solar radiation on horizontal surface was measured to 5.5 kWh/m^2/day.

During main summer months, high solar intensities exceeding 8 kWh/m^2/day has been measured. The lowest average intensity has been registered during January with a value of 3.2 kWh/m^2/day. The above briefed illustration had encouraged us to candidate this remote village to be a model for a solar electrification villages in Palestine.

The PV-power supply system

The distance between village and the nearest distribution electrical network of the 33 kV lines is 7.5 km. A micro grid, which is electrically isolated set of power generators that supplies all of the demand of a group of customers, in the village was implemented. The electrical load is mainly concentrated on the night period since the population work during the day in the agricultural fields and cattle breeding.

The main electrical loads in the village are: household appliances (lighting, TV, refrigerator, radio, washing machine and fan); street lighting not available in this village; school appliances (lighting, computer); clinic appliances (lighting, refrigerator and lab devices).

For electrification of this village, a micro-grid centralized PV solar system has been implemented. The system consist of two PV array, battery bank and power conditioner (charge regulator and inverter) to generate AC electricity which is distributed *via* a micro grid as illustrated in Figure 2.

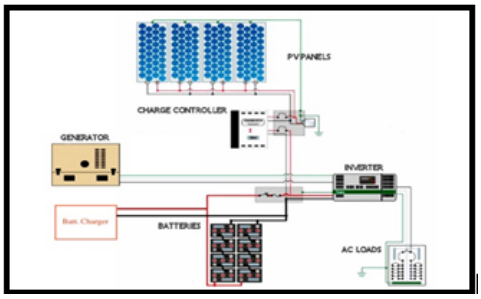

Figure 2: Components of PV power hybrid system of the remote village (Emnazel).

The project utilized a stand-alone PV modules with Capacity of 13 kW, installed charge controller and inverter as in Figure 3, the PV system connected as a hybrid system with existing 20 kW diesel generator.

Figure 3: Charge controller and inverter.

System reliability is enhanced by the Power Conditioning Rack, which controls all aspects of operation. This unit includes the charge regulator as well as converting direct to alternating current of mains quality (230 V-50 Hz). Operational performance parameters (state of charge, battery voltage, PV-current etc.) are recorded hourly.

Key meteorological data are also registered Figure 4. These data can be seen in real time on the unit's display, or analyzed remotely *via* modem- link.

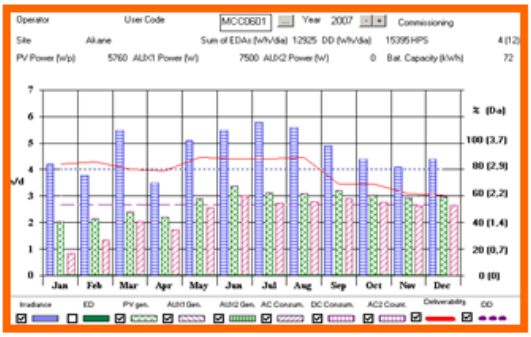

Figure 4: Performance data collection.

The Performance ratio of PV system shown in Figure 5.

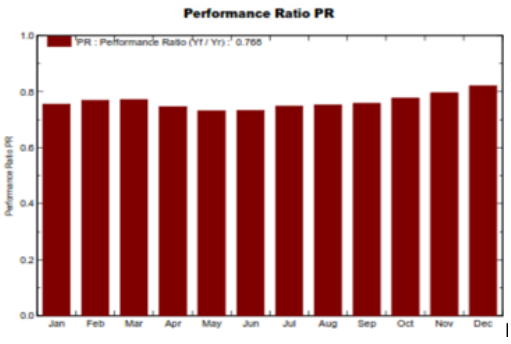

Figure 5: Performance ratio of PV system.

Each house is fitted with an energy-dispenser Figure 6, and meter which limits the amount of energy available for each user in accordance with their predetermined needs and the contracted tariff.

Figure 6: Energy dispenser meter.

The cost of annuity and the production cost of energy unit (kWh) of the PV-system , included the fixed and running charges is around (0.45-0.6 US$) per kWh [4] , and it means that in Palestine the cost of energy producing from PV systems are less than the costs related to the diesel generator systems.

The utilizing of PV-system is more economic feasible for electrification of remote villages of geographic, climate and load conditions similar to Emnazeil villages in Palestine. In addition the PV-system does not pollute the environment as the case of using diesel generator.

Elements for the long-term sustainability of a rural electrification projects "field experience"

Instead of importance the maintenance and technical issues for sustainability of rural electrification projects, although one of the elements that guarantees the long-term sustainability is also subject to the social, organizational and economical aspects of the community where the action takes place. Thus, it is necessary to count on a high-quality design and engineering, but it is also essential to establish a management model, a regulation for the electricity service and an economic structure; it is as well crucial for the success of such a project that the beneficiary community feels the project is theirs and that they are capable to decide on certain aspects [5,6].

A management model could be defined as the way in which the different actors involved in the electricity service organize for its maximum efficiency and sustainability. These actors, if we tried to establish a stereotype model, would be: the operator, the users and the maintenance technician. However, the models to be chosen are as varied as the communities and the countries where an electrification project can be implemented. The operator is the structure in charge of organizing and managing the electricity service, such as an association or committee, etc. and it has to be legally registered. Some of its main roles are to control the regular and on-time payment of tariff by users, and the preventive maintenance of the installation. Its relation with the users and the maintenance technician is based on a service contract [5].

The users are the family units having electricity in their homes. One of their obligations is to regularly pay the monthly tariff and to comply with the regulations established for the service. The tariff they pay depends on the capacity of each family to pay. Users are trained as to make an efficient and rational use of the energy in the household. The corrective (*vs.* preventive) maintenance technician is a contracted professional in charge of repairing potential failures of the system and of keeping it in optimal conditions. He is trained on the functioning of the microgrid with adequate workshops and technical materials and manuals.

In the community recently electrified of Emnazeil, the operator is a committee of 6 members chosen by the community, of which 2 are women. Amongst the roles of its members are: the coordination of women groups, collection of monthly tariffs, representation of users, administrative and budgetary control, and preventive maintenance of the system. This committee has been legally registered in the municipality of Yatta, in the Hebron region of the West Bank, Palestine.

The users in Emnazeil are 45 families and 3 communal services (school, mosque and clinic) enjoying a 24-hour quality electricity service. The project also includes streetlight. The families paid an initial investment of around 100 US$ and their monthly tariffs are of 0.12 US$ for 1000 Wh/day and 0.18 US$ for 1500 Wh/day. Each family/user has signed a binding contract with the committee establishing their tariff and the daily assured energy.

The electricity service in Emnazeil is subject to the regulations agreed and signed by the community. They include, amongst others, the rights and obligations of users; the roles of the committee, the technician and of Yatta Municipality; the conditions for being able to contract the service; the definition of the tariff structure and some sanctions to be applied in case, for example, of misuse of the installation or of outstanding payments.

As to the economic structure of the service, its goal is to guarantee the economic sustainability of a project. Thus, the fees paid by users stay in the community and are kept by the operator (normally in a bank account). The payment of fees is aimed at covering the expenses of Operation and Maintenance (O&M) of the system, that is, the cost of components, fuel, manpower, transport, spare parts, etc. This economic sustainability is highly dependent on the users' capacity and willingness to pay [6].

One very essential element for the long-term sustainability we are dealing with is the feeling of appropriation of the project by the community. Our experience has shown that the more informed the people are, the more involved. So, regular informative meetings are very necessary. Other key elements here are the local management of the service, which gives the community a sense of sovereignty (that is, they are non-dependent of the electricity company or of Israeli supply); a good training (on the rational use of energy, the individual energy control, …), which makes them feel more confident in the use of the service; and finally the empowerment of women, who at the end of the day are the ones managing the electricity use in the households.

One last essential step in the process of implementing a rural electrification project is the transference of the property of the assets/equipment from the promoters of the project to the operator of the service or corresponding authority/legal body, such as the Municipality of Yatta in the case of Emnazeil project. This transference is made effective through an official document stating, amongst others, the limitations on the future use of the assets (as for example the prohibition of selling…), the current and future ownership and guarantees and the inventory of the equipment.

Finally, let me mention some of the positive impacts the arrival of electricity has caused on the beneficiaries of Emnazeil, especially on women. On the one hand, on their daily life: they have more patience

with children because they do not have the stress of finishing work before it gets dark; the education of the young ones has improved as they can study at night; women have improved their health since they can use machines to make some of the hardest work (washing machine, butter maker).

The electricity has also had good effects on the development of the community. There is now more cohesion between the clans, they socialize more because they can invite people to their houses at night, their sense of sovereignty from Israel has increased, they feel more stable as a community because people is returning to the village, they also feel more safe to walk on the streets in the dark and, very important, they feel less isolated because Emnazeil is gaining importance in the area.

The perspectives for the future of this community thanks to electricity are quite optimistic according to the villagers: they see a better future for their children; they are thinking of starting new businesses or productive activities, they also see improvements in the services of the villages, such as the pavement of roads or the installation of a water system. All in all they see the permanence of their home: Emnazeil.

Economic Feasibility of Micro-Grid PV System instead of Diesel Generator

Economics is the basis of most engineering decisions so; this section presents an economic analysis of the proposed stand-alone PV system estimated by using the Simple Payback Period (SPBP). The calculation of SPBP describes (in present value terms) how long it takes the project to recover its initial investment. This method depends on annual saving from electricity instead of using diesel generator and the capital cost of PV system, and it can be calculated for Emnazeil installation as the following in Table 1.

Parameters	For Emnazeil Village
Yearly Energy output (Kwh)	21765
Average yearly bills from PV system (US$/family)	15$ x 12=180
Average yearly energy expenses before PV installation ($/family)	30 $ x 12=360
Yearly saving ($/family)	180
Yearly total saving $ from all families	45x180=8100
PV installation cost $	65000
S.P. B.P (year)=Investment or capital cost/saving per year	8 years

Table 1: Economic aspects.

Conclusions

General conclusion

The projects that have been implemented in Emnaziel village in West Bank operate successfully. The sustainability in term of technical and also economic issues is proven. The replication is feasible in most of the areas of the West Bank. The level of quality is very high providing a 24-hour qu ality electricity service and a very positive impact from the environmental, social and economic point of view. The possibility of using not only lamps for illuminating the households but also electrical appliances such as TV, radio or fridge allowed the villagers to, amongst others, extend study hours, be informed and communicate, and increase their potential for generating revenue and reducing chronic poverty.

Specific results

From the specific monitoring realized in the community of Emnazeil, the following conclusions could have been made:

The design and the configuration of the plant have been a success since there have never been general black outs and less than 50% have experienced interruption of the energy supply and the rate of incidences is very low.

The training regarding electricity dispenser is a critical point.

The degree of satisfaction is very high (more than 90%).

The activities at night have increased. 90% of the children can study at night (30% before) and more than 30% of the users can work after the sunset (0% before).

The electricity access modified the habits for basic needs and productive uses. Almost 80% of the dairy products are manufactured by machine now and almost 30% can have access to water through electric pump.

The most important positive issue is the light at night (90%) for safety and for general purposes.

Fees within user's willingness to pay. Collection very successful in part because of clear transaction mechanisms based on flat fees.

For 60% of the users the incomes have increased due to the electricity access.

The project has been a good school for local governance. During the first year the user's association has been capable to operate the service and to up keep the plant.

The relationship among the community is stronger.

The degree of satisfaction is high.

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