PHOTOVOLTAIC IN LIBYA APPLICATIONS, AND EVALUATION

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ABSTRACT: The photovoltaic conversion of sun energy is well established in many countries. The objective of this technology in terrestrial applications is to obtain electricity from the sun that is cost competitive and has advantages on other energy sources, in the seventies photovoltaic systems was used as a stand-alone in remote areas, but it is now widely used in grid connected systems .

Libya is one of the developing countries in which photovoltaic system was first put into work in 1976 to supply electricity for a cathodic protection station. Since then; the use of photovoltaic systems is widely used in size and applications as stand alone systems.

The total peak power installed in Libya was developed from less than 20 KWp by the end of the seventies to about 1.5 MWp by the year 2005 . all systems being stand alone and no grid connected system has been established, no photovoltaic system components industry has been established yet in Libya which opened the door to many manufacturing companies to take part in the installation of these mentioned systems .

This paper presents a survey on photovoltaic systems, its applications in Libya, which were installed, by the end of 2005, and it provides a comprehensive review of applications, experience on rural electrifications, social impacts, and future prospects of photovoltaic in Libya.

Keywords**:** 1-Stand alone PV systems: 2- Applications and loads: 3- Performance

1 INTRODUCTION

Libya is an oil exporting country located in the middle of North Africa, with 6 million inhabitants distributed over an area of 1,750,000 Km^2. The daily average of solar radiation on a horizontal plane is 7.1 $kwh/m^2/day$ in the coastal region, and 8.1 $kwh/m^2/day$ in the southern region, with a sun duration of more than 3500 hours per year [1].

The national electric grid consists of a high voltage network of about 12,000 km, a medium voltage network of about 12,500 km and 7,000 km of low voltage network. The installed capacity is 5600 MW with a peak Load of 3650 MW, for the year 2002[2]. In spite of that; there are many villages and remote areas located far away from these networks. Economically these areas cannot be connected to the grid, owing to its small population, and the small amount of energy required, in the past these facts dictate the use of diesel generators as a source of power supply. Libya is one of countries which got involved in using diesel generators to electrify some of the villages in the seventies and eighties, though there are other areas where diesel generators cannot be used as it is not easy to either reach it or to make regular transportation of fuel [3]. These reasons open the door to look into some other sources like renewable energy, moreover renewable energy provides clean and reliable energy sources which

can be used in many applications in remote areas (electricity, water pumping,…etc.) .The use of renewable energies have been introduced in a wide applications due to its convenience use and being economically attractive in many applications, the most potential renewable energy sources are solar energy, and wind energy.

There are four options for electric power generation in remote and isolated areas, namely electric network, diesel generators, wind energy, and photovoltaic systems. The electric network may not be available at the place needed beside in developing countries the electricity from the national grid in remote areas is subjected to frequent interruptions without notice. There are two factors which effecting the use of electricity from the general network the population, and the distance from the nearest high line voltage, depending on these two factors the use of the network may or may not be an option to electrify a remote area [4].

The use of wind energy to electrify remote areas will not be a reliable source as wind energy is not a continues supply, beside the use of wind source need maintenance personal, so this option will not be a reliable power supply in remote areas for developing countries.

The diesel generators option has been used in many countries as a power supply for rural areas but it was found that it is not suitable for remote areas, as it needs maintenance, skilled personal which are not available for low population areas, the high running cost and low reliability made this option not preferable for the developing countries.

Photovoltaic conversion which is the direct conversion of solar energy to electricity may be the most reliable source for rural electrification for the developing countries. The PV systems utilization, which considered as a new technology for developing countries has some obstacles.
The photovoltaic conversion as an electric power supply has been started in Libya in 1976 where a PV system was installed to supply a cathodic protection station to protect the oil pipe line connecting Dahra oil field with Sedra Port. Projects in the field of communication were started in 1980 where a PV system was used to supply energy to a microwave repeater station near Zella. Projects in the field of water pumping was started 1983 where a PV pumping system was used to pump water for irrigation at El-Agailat. The use of PV systems for rural electrification was started for street lighting and then used in remote villages. The role of PV application was grown in size and type of application.

2 PHOTOVOLTAIC APPLICATIONS IN LIBYA

There are four main types of PV applications in Libya PV application in Communication, PV systems in Cathodic protection, rural electrification and water pumping.

2.1 PV Systems for Libyan Microwave Communication Networks

The Libyan Microwave communication networks consist of more than 500 repeater stations. Only 9 remote stations were running by photovoltaic systems till the end of 1997 with a total peak power of 10.5 KWp.

Remote stations in the eighties were running by diesel generators alone while stations near by general electric grid powered by grid as the main supply and diesel generators as a backup. The diesel generators are subject to replacement and in some cases generators has to be changed after one year or two years of work due to lack of maintenance. Figure 1, shows a picture of generators, which has been put out of work in one of the stations.

Figure 1. A picture of generators which has been put out of work in one of the station

Nine stations were powered by photovoltaic systems at the beginning of 1980; four of these stations are still running after 26 years of work, the batteries which are of open type batteries were replaced three times with an average life time of eight years.
In the other hand the stations running with diesel generators have experienced a lot of communication stops due to lack of maintenance, theft of fuel and engine parts, and in one case one of the stations [Zalaf station] has been out of work for 17 days in the year 1997 [5].
It was the success of the PV systems technically and economically that pushes the changing of all possible diesel stations to PV stations in the Libyan communication networks. The total number of stations running by PV in the field of communications exceeding 80 stations; the increase in the number of PV stations counter a decrease of the number of stations running on diesel is shown in Figure 2 [6].

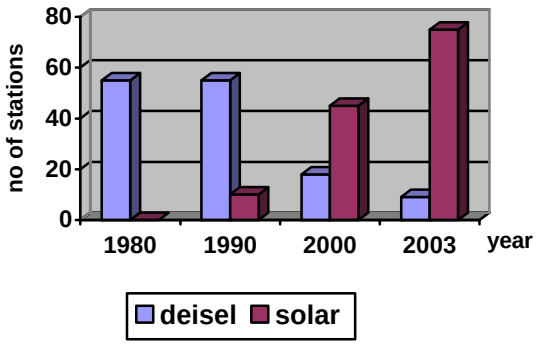

Figure 2. PV and diesel stations in the communication network

The total installed photovoltaic peak power installed by the end of the year 2005 is around 420 KWp. Figure 3, showing the accumulated installed photovoltaic systems in the communication networks in the period 1980-2005 [7].

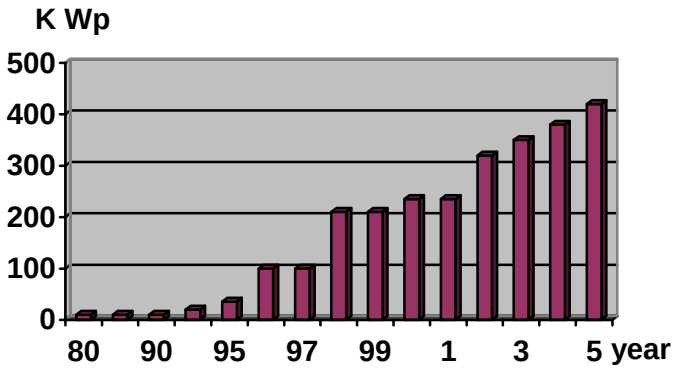

Figure 3. The accumulated installed PV peak power in the period 1980-2005

2.2 PV in Cathodic protection

In a previous studies, Ibrahim M. Ibrahim [2] it was shown that the cost of one KWh to supply a daily load of 15 KWh for a cathodic protection (CP) station is 1.4 $ for a load which is located 5 Km from the 11 KV electric grid, in another study conducted by Hibal A. to supply a daily CP load of 7.5 KWh it was found that it will break even with a PV systems at a distance of 1.2 Km from the 11 KV electric grid [8].

The CP stations are usually far away from electric grid; A conclusion out of this indicate that it is not feasible to use this type of source for this type of applications when a CP (15 KWh/day) station located more than 2 Km from 11 KV transmission line.

PV systems can be used as a power source for CP units in this case the PV size can be defined to suite best the load, which can be placed at any place to generate the required energy using the direct conversion of solar energy, this is an advantage which can not be implemented in the conventional types of generators. It is due to the problems of maintenance for diesel generators, running cost, vandalism, fuel supply, the availability of the electric grid, and the difficulty of running high line voltage any where, it was decided that the option of using PV system in the CP units will be more practical *[4,5]*.

A feasibility study was conducted to compare the energy cost for the three possible ways of powering CP stations, Figure 4 shows the cost of KWh versus distance for electric, grid, power supplies [8].

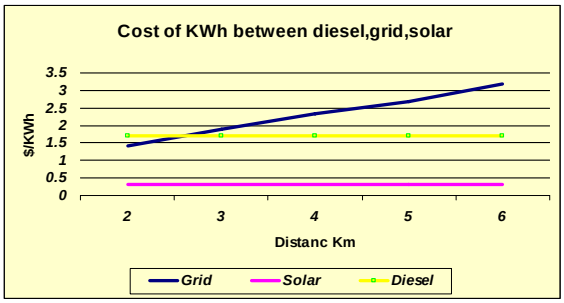

Figure 2 Cost of KWh versus distance

From the cost comparison, it can be shown that the PV systems are the most economical choice; the choice will be more acceptable when considering real operations which include sources failure.

The first system in this field was put into work in 1976 , the accumulated total power of PV systems in this field is second to PV systems in communications , the total PV systems in this field is around 300 system by the end of 2005, with a total installed PV systems of 540 KWp.

PV technology is considered to be a relatively new in developing countries; the problem we are facing not dealing with the technology rather how other people dealing with it. We are experiencing some vandalisms issues, the problem is breaking the modules either by direct throwing stones on the module surfaces, or when shooting birds setting on the PV array.

To solve this problem one of the petroleum companies (AGOCO) made a new look for PV generator, a galvanized steel grid designed to be constructed over the array with enough distance to allow enough sun light to reach the array and prevent stone from reaching the modules. The galvanized grid of 3cmX3cm was placed about 10 cm above the array. We measured the decrease in power which we found to be 9% in its worst case. This solve the problem completely and no more modules has been broken in the station which is protected by the galvanized grid [9].

2.3 RURAL ELECTRIFICATION WITH PV SYSTEMS

Problems facing the electrification of all regions in any country are low population, and being away from the electric networks. It is so expensive to extend high line voltage through desert to electrify few hundred inhabitants. In low population countries electricity is only available in the cities and no electric network is used to power its rural areas, where as powering rural areas are not easy or available. The electric network in low population countries may not be available within a reaching distance of the needed places.

The question which rises, it is when we can call an area is an isolated or remote area? The answer to this depends on population and distance from general grid network.

For a village of 200 inhabitants located 15 Km away from a low voltage distribution point (11 KV), Based on the average consumption per person for these type of areas in Libya (1000 Kwh/y), then 200 inhabitants will consume 200 MWh/y. The break even cost per KWh will be 0.2 LD (Libyan Dinar = 0.75 $), which is 10 times the Libyan tariff. In [4] a rural area was

defined as an area in which 200 inhabitants living, and located 5 Km or more away from the low voltage network. [4].

It is very costly to extend local electric network to the places of remote areas. Thus it will be more practical to use other possible sources of energy, which will be either diesel generators or renewable sources

The Libyan national plane to electrify rural areas consists of electrifying scattered houses, villages, and water pumping. The PV supply systems for ten villages was introduced as a project to electrify remote areas [4].some of these villages are

a- Mrair Gabis village as an example of scattered houses
b- Swaihat village as an example of scattered houses
c- Intlat village as an example of scattered houses
d- Beer al-Merhan village as an example of scattered houses
e- Wadi Marsit village as an example of a village having diesel generator
f- Intlat village

The installation of photovoltaic systems started in the middle of 2003 . The total number of systems to be installed by GECOL is 340 with total capacity of 220 kwp, while that which will be installed by Center of Solar Energy Studies (CSES) and Saharian Center is 150 systems with a total power of 125 KWp , the applications are as follow:

- 380 system for isolated house
- 30 systems for police station.
- 100 systems for street lighting.

The total peak power of 345 K Wp.

2.4 PV systems for Water pumping

Water pumping was considered as one of the best PV applications to pump water for human and live stoke in rural places. The water pumping project consists of installing of 35 PV systems with a total peak power of 96 K Wp. The total estimated peak power for this application is 110 KWp. Table 2 showing the total installed capacity as PV.

Table :2

Applications	**Number of systems**	**Total power [KWp]**
Communication	**100**	**420**
Cathodic protection	**300**	**540**
Rural Electrification	**510**	**345**
Water pumping	**40**	**110**
Total		**1415**

3 EXPERIENCE GAINED

3.1 experience from PV systems in communications

From the data collected concerning the PV systems performance in the local environment, PV systems proved to be highly reliable and cost effective. Experience gained and remarks that were drawn from the past experience of PV systems are as follows [10].

1. No spare parts had been used for PV systems which are installed 26 years ago.
2. No failure has been registered for the systems installed 26 years ago.
3. Very low cost or no running cost for most of the PV systems.
4. Batteries have been changed after about ten years from installation.
5. We have noticed change of module glass color; this is due to high temperature and ultraviolet.
6. The remote monitoring of the solar system will be the way for monitoring of the system.
7. Vandalism in the PV systems consists of breaking the modules either by direct hit by stones or going after birds.
8. Lack of knowledge; People in developing countries should be made aware of the PV systems through increased their understanding and appreciation of this technology.
9. Batteries are the only problem that engineers are facing in dealing with PV system in CP units.
10. Closed batteries proved to be more economically justified.

3.2 Experience from PV systems in rural electrification protection

The use of PV systems becomes more visible, and a greater attention was given to its use for developing remote areas in low population countries, therefore the PV systems will be the way to electrify rural areas.

As a first step in the direction of using PV systems, it is essential that people be made aware of the technology through increasing the understanding of the processes and the fundamental principles on which it is based. The following are some remarks which has been noticed from the projects which installed in the year 2003.

1. People in this villages in spite of being not knowledgeable with the technology yet they are dealing with the systems with care.
2. In spite that PV systems does not have energy meters to disconnect the load when the energy drawn by the house holder more than designed , non of the systems went over discharge.
3. The PV systems which are installed in all villages are working without any system failure.
4. The average production energy for systems of 1.2 KWP is 6 KWh/day.
5. The a.c option of electricity was the best choice.
6. The closed type batteries option was the best choice for the rural areas people.
7. More and more remote areas people asking for PV system.
8. The people in the villages started to have night gatherings.
9. The people start to watch TV and using refrigerator.
10. The PV systems performance at the local environment proved to be highly reliable and cost competitive.

11. Children should be aware of the PV systems through their schools.
12. Repeated visits should be done to inshore the correct use of the PV systems.
13. All systems have been installed by local engineering and technicians.

4 SOCIAL IMPACTS OF PV SYSTEMS

Since this technology is considered as relatively new; we are experiencing a lot of social changes; among these; the settlement of Bedouins in some locations started even before starting the installation of the PV systems, we are expecting that some small industries will be started. The availability of power supply will give a good chance to involve the populations of such remote areas in increasing their knowledge and be familiar with the modern society daily life.

The existence of electrical power supply motivates the population to use more appliances like TV sets, refrigerators that are normally in use in grid connected areas. As a result we have noticed load increase in some houses which exceed the maximum capacity of the PV supply systems.

We also noticed due to the availability of electrical energy some population start to move back to these remote areas resulting in adding new houses and loads that area not planned.
It is expected that the increase in population will drop the family income and this may drive some family members to move to other places looking for new jobs. The reception of TV programs may change the way of family life resulting in low productivity.

We have not experience any vandalism, and the only problem is reported in one of the system in which the inverter stopped due over load which may be considered to be due to the equipment itself.

5 FUTURE PROSPECTS OF PV IN LIBYA

There is a great potential to use PV systems and other renewable energy sources in Libya, the following are some of the projects planed for.

5.1 Desalination pilot project powered from renewable energy sources :

General Electricity Company of Libya GECOL is planning to install of pilot plant for Sea Water Reverse Osmosis desalination powered from Renewable Energy Sources . The nominal production of the plant will be 300 m^3/d for the supply of a village with potable water. Both wind energy conversion and photovoltaic (PV) power generation will be integrated into a grid connected power supply for a Reverse Osmosis (RO) desalination plant with power recovery.

5.2 One MW PV pilot plant in Libya

GECOL is now planning a PV project of 1 MW capacity grid connected system . The site of the plant is already decided .

This pilot PV project is intended to accommodate know-how on PV technology and on the operation, maintenance and management of a large PV system, in preparation for larger - scale installations in the future . The consulting firm is already selected employed to prepare detailed design of the pilot plant, to produce a tender specifications for selecting the supplier and to supervise the project implementation.

5.3 Water pumping Systems

A plane was made to install around 100 PV systems to pump water for irrigation of date trees in the desert of Libya.

5.4 PV industry

No industry yet has been installed, though a plane was set to get into modules assembly line.

6 CONCLUSIONS

The use of a stand-alone PV power supply in the field of communications, cathodic protection, rural electrification, and water pumping was established and a very high reliability was recorded. No or very low running cost of PV solar energy made it more and more acceptable from economic point of view beside technical , and power availability in comparison with diesel generators. The total installed peak power capacity of PV systems is reaching 1.5 MW.

PV power supply systems for supplying electrical energy to remote and isolated areas are justified based on economical and technical reasons. It is also recommended to add more PV systems to feed all inhabitance that suffer from shortage or lack of electrical supply. Some kind of industry for the production and manufacturing of solar cells and other PV system components should start to cover the expected increase of PV systems applications. The feasibility study on the sample of remote villages to identify the size, type and mode of applying PV systems was based on the real local social and environmental conditions. Future evaluation should take place to verify the previously estimated parameters. Finally, can concluded the following:

1. There is a good potential of PV systems which can be used in different applications.
2. Photovoltaic systems for supplying electrical energy to remote areas are justified based on economical and technical reasons.
3. Social changes have been noticed in the villages which have been electrified.

7 REFERENCES

[1] I. M. Saleh Ibrahim, The forth Arab International Solar Energy Conference, Amman, Jordan, 1993.

[2] General Electric Company of Libya (GECOL) annual report 2004.

[3] I. M. Saleh Ibrahim, and etal, Comparative Study in Supplying Electrical Energy to Small Remote Loads in Libya, Renewable Energy Journal, Volume 14 NO. 1-4, 135, May-August 1998.

[4] I. M. Saleh Ibrahim, and etal, Planes of General Electrical Company of Libya for the electrification of rural areas in Libya , Symposium on renewable energies in hot regions , Hoon, Libya , October 2002.(in Arabic)

[5] I. M. Saleh Ibrahim, M. A. EKhlat, M. A. Mousa, I. M. Molokhia, The role of photovoltaic in the development of Libyan rural and remote areas. The fourteenth European Photovoltaic Solar Energy Conference, Barcelona 1997.

[6] I. M. Saleh Ibrahim, Khalifa ,Behamed , The role of using PV system in changing the infra structure of power generation in Libyan Communication network the second engineering conference , Benghazi Libya 2003.

[7] Performance of a stand alone PV systems used in Telecommunication Network in Libya, 19th European Photovoltaic Solar Energy Conference, taking place from 7-11 June 2004 in Paris, France.

[8] Hibal A m M. Sc. Thesis m EE department Al-Fateh University , Libya 2003.

[9] Experiences with Photovoltaic systems used for cathodic protection in Arabian Gulf Oil Company, 19th European Photovoltaic Solar Energy Conference, taking place from 7-11 June 2004 in Paris, France.

[10] I. M. Saleh Ibrahim, Khalifa ,Behamed, Experiences with Photovoltaic systems for telecommunication in Libya,the eighth Arab solar energy conference , Bahreen 2004.

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