RECENT DEVELOPMENTS OF APPLYING SOLAR PHOTOVOLTAIC TECHNOLOGIES IN MALTA

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ABSTRACT: The paper presents an overview of some solar photovoltaic grid-tied installations in Malta, and gives a description of their purpose and date of commencement, besides other data.

A presentation of the Maltese past and present situations and the future prospects of solar photovoltaics is given. A brief comparison between the performance of existing grid-tied PV systems is made to demonstrate the good potential of generating electricity from the sun, thus making photovoltaics a future contributor to the energy mix in Malta.

Finally, some proposals are presented, which could be used by national legislative and statistical offices, in order to foster the wide-spread application of solar photovoltaics in a professional and orderly manner.

1. HISTORY OF SOLAR PHOTO-VOLTAICS IN MALTA

Until the year 1992, very little research or application of solar photovoltaic systems was carried out in Malta. Few enthusiasts had made use of solar photovoltaic modules to charge batteries on board of yachts or for lighting in farms but none of these individual efforts are officially documented.

Figure 1 shows a solar photovoltaic water pumping system that was installed in the early 1990's at the ex-Austrian Maltese Research Centre, Marsaxlokk. This centre now houses the Institute for Energy Technology, of the University of Malta.

A closer look at this system revealed that since the first day, some of the cells in these SIEMENS® M55 solar modules were damaged during installation. In a number of points the installers mistakenly drilled right through the supporting structure and the back surface of the modules. Although some corrosion had developed around the damaged areas, the solar system continues to power the d.c. water pump. The pump is being used to water the trees and at times supplies water to the Institute during water cuts and underground pipe damages.

Figure 1: A solar photovoltaic water pumping system, installed at the Institute for Energy Technology since 1985.

This shows that solar modules can withstand harsh treatment and the present guarantee of 25 years that manufacturing companies give on their silicon cell-based crystalline modules is justifiable. This set-up is probably the only solar water pumping system operating in Malta for the past seventeen years.

Other scattered projects were carried out such as the solar lights of *"l-Gharusa tal-Mosta"* Garden, some Maltacom solar telephone booths and five solar street lights at the Institute, as well as the Frisky Poultry Farm hybrid wind/PV lighting project in Mellieha. Some solar-powered light beacons may also be seen floating across the channel between Malta and Gozo.

Building and testing of solar cars is being carried out by the Department of Physics and the Department of Electrical Power and Control Engineering. The latter is also actively involved in research work on inverters.

Solar Power Ltd. was the first manufacturing facility for solar photovoltaic modules in Malta. Although some of the modules were sold locally, most of the company's production was exported to Mediterranean and North African countries. A stand-alone solar PV system was installed to provide power in an office at its premises in Qormi. Some streetlights were also fixed around the company's perimeter.

Other few companies have contacts with main module manufacturers and have at times imported some module brands such as Photowatt and Kyocera.

There are few homes around Malta and Gozo that are completely independent of the utility grid and produce their own electricity by using solar PV modules and small wind generators.

All of the above mentioned examples use batteries to store the energy for use during the night.

2. RECENT PHOTOVOLTAIC RESEARCH ACTIVITIES AT THE INSTITUTE

In order to facilitate the research work on photovoltaics and other solar-related applications, the Institute has invested in a complete solar and weather monitoring station. The Institute's programme of solar and weather monitoring started in 1992 and continues without interruption. It is worth noting that between 1972 and 1992, no solar radiation measurements were collected in Malta.

2a. Stand-alone PV System

Long-term research studies on *PV* solar energy applications in Malta started in July 1993, with the testing of a 1.2 kWp stand-alone *PV* system with battery storage, used for lighting purposes, as shown in Figure 2. The aim of this project was to evaluate the potential of using *PV* systems under the local weather conditions.

Figure 2: The first solar PV stand-alone system to be tested in Malta (1993-1995). A battery bank was placed underneath the modules and a battery charge control unit is seen to the left. Monitoring equipment was placed in the box to the right.

This system was installed on the roof of the Department of Chemistry at the University of Malta, Msida, and the stored electric energy was used to power 25 compact fluorescent lights spread around part of the roof's parameter. The system was dismantled at the end of the research period of two years.

The results of this study yielded a first-hand experience of the performance of solar modules in Malta as well as a set of equations that could be useful to design stand-alone systems that would reliably operate under local conditions. [1, 2, 3, 4].

2b. Grid-connected PV System

Since the utility's electric network covers almost every corner of the Maltese Islands, it is not practical to install stand-alone systems except in some rare cases. Also, since stand-alone systems have lower efficiencies and require higher capital and maintenance requirements, the Institute proceeded to test the performance of a 1.8 kWp grid-connected photovoltaic system.

This project installed the first grid-connected system that had the facility of producing solar-powered electricity to be used within the premises or exported to the electric utility, as shown in Figure 3.

Figure 3: The Institute's 1.8 kWp grid-tied solar photovoltaic system with the inverter shown to the right.

Enemalta Corporation had given its approval to operate the system and installed a number of meters in September 1996. During the past 6 years, a total of 10,000 kWh have been generated [5, 6, 7].

2c. Grid-connected Tracking PV System

In recent years, an increasing number of multi-level buildings are being built instead of older traditional two-storey terraced houses, due to space limitations, high land cost and greater demand for smaller dwellings. In turn, less roof area per household would be available for installing solar systems. Moreover, the older buildings that may be adjacent to these high-rise constructions would have less effective sunny areas on their roofs due to shading. In such cases, solar tracking may be attractive since it would maximize on the production of energy from solar radiation in a limited space. An added incentive would be the relatively cheap cost of the tracking system, as is the case today, when compared to a stationary system that would need more solar modules to produce an equivalent amount of output power.

The first project to study the performance of a tracking photovoltaic system in Malta was installed in June 2000. Figure 4 shows six BP-Solarex® modules placed on a single-axis tracking mechanism and connected to a state of the art SMA® SunnyBoy inverter. The tracking mechanism consists of a dc motor encapsulated in an aluminum pipe forming part of the structure and being driven by a bi-facial solar photovoltaic module, fixed at an angle of 75° relative to the PV array.

When the sun shines on one face of the pilot solar module, a potential difference is created and the motor rotates the tube towards the sun. When the modules face the sun, the bi-facial pilot solar module would be almost perpendicular to the solar beam and the potential difference between the two facades would not be sufficient to further rotate the solar array. As the sun moves in the sky, it will start shining on the other face of the pilot module and as the day goes by, the tracker closely follows the sun along its path. The full span of the tracker is about 120° from East to West [8].

Figure 4: A 360 Wp single-axis PV tracking system installed at the Institute for Energy Technology. The pilot module is seen attached to the lower part of the pole. A solar pyranometer is attached to the top to measure solar radiation. The inverter is placed in a metal box under the solar array.

Analysis of data and comparison to the performance of the tracking system to the stationary system is underway. A preliminary analysis showed that tracking could yield up to 67% higher output between spring and autumn, and could operate at higher efficiency. This implies that in order to produce a certain amount of electric energy, up to 40% less roof area would be needed for a tracking system [9].

Keeping in mind that the tracking system would have up to 1.66 times more final yield than a stationary system, one can easily conclude that for two systems with equal annual electrical energy outputs, the total capital investment would be about 20% lower for the tracking system that uses this type of tracking mechanism.

Within the confinements of the limited data available to date, it can be concluded that a 1.8 kWp stationary system operating in Malta would be equivalent to a 1.1 kWp tracking system. Future long-term analysis would produce more definite answers to such queries.

3. WIDESPREAD APPLICATIONS OF SOLAR PHOTOVOLTAICS IN MALTA

The aims of the Institute's programme of applied research reach their ultimate goals, when the results are applied to design, build and operate real-life systems around the Maltese Islands. During the past few months, several changes have contributed towards easing the way to allow Independent Power Producers (I.P.P.) to produce their own electricity. The Malta Resources Authority has taken over the responsibility of making legislations in the Energy Sector leaving Enemalta to concentrate more on the actual production of power.

3a. First Residential Solar PV Grid-Connected System in Malta

The first residential 1.5 kWp system was installed in May 2002 at Madliena, as shown in Figure 5. This solar PV system supplies about 25% of the electric requirements of the garden, mainly consumed by the pumps of the swimming pool.

The owner, who is also a member of the Executive Committee of the Malta Energy Efficiency and Renewable Energies Association (M.E.E.R.E.A.) [10], has set on converting the garden into an environmentally friendly haven by the use of solar water heating for the swimming pool and water ionisation rather than chlorination for keeping the water clean. Moreover, the garden completely depends on organic farming techniques and natural methods for controlling pests. The solar photovoltaic system has blended well in this environment since it was aesthetically placed along the drive.

Figure 5: The first 1.5 kWp privately owned residential solar photovoltaic grid-connected system installed in May 2002, Madliena, Malta.

3b. First Solar PV Grid-Tied System in an Industrial Establishment in Malta

The first industrial 3 kW PV system was installed at Baxter Ltd, in August 2002 as shown is Figure 6.

Figure 6: Malta's first and currently largest grid-tied solar PV system in an industrial area.

Baxter's Head of Maintenance and his team are also members of M.E.E.R.E.A.

In both cases, the Institute took leading roles in realizing these two projects from the moment of inception to commissioning. Monitoring and data analysis for both systems will be carried out for at least two years, according to the recommendation of the European Joint Research Centre – Ispra Establishment [11].

4. DATA COMPARISON FOR INSTALLED GRID-CONNECTED PV SYSTEMS

Different systems have varied lengths of data available depending on the date of installation. Several scientific papers have already been published regarding the detailed analysis of data as shown in the references to this paper. For the purpose of this work, data of the month of September 2002 will be presented, since it is the only month that all systems have data. These systems are described as follows:

- The Institute's 1.8 kWp stationary system (IET/1.8s). Data available since June 1996.
- The Institute's 0.36 kW tracking system (IET/0.36t). Data available since June 2001.
- The 1.5 kWp Mytton Lodge (Madliena) stationary system (MLM/1.5s). Data available since June 2002 and,
- The 3 kWp Baxter's stationary system (BXT/3s). Data available since September 2002.

Table 1 shows the angle of inclination of the modules *(α)* to the horizontal and the azimuth angle *(Φ)*, which is the angle between the true geographic South and the solar array, as well as the mean daily final yields *(Y_f)* for all systems during the month of September 2002.

The term final yield, "Y_f", is a ratio comparing the actual output power per kWp of nominal solar module power rating, at standard conditions of 25 °C and an irradiation of 1000 W/m². It is determined by the equation:

$$Y_f = \sum_{DAY} \frac{PV_{use}}{P_{nom}}$$

where PV_{use} is the useful energy output in kWh/day and P_{nom} is the nominal peak power output of the system as given by the manufacturer. The units for Y_f can therefore be stated as "kWh/kWp/day"

Table 1: The inclination angle and the azimuth of the solar PV array and the final yield for four different solar systems in Malta.

Type	IET 1.8s	IET 0.36t	MLM 1.5s	BXT 3s
α	36°	36°	30°	25°
Φ	0	0	S40W	0
Y_f	3.59	4.51	2.75	3.81

It is clear that the tracking system IET/0.36t has the highest yield of all systems, even for this month of September that was partly cloudy and sometimes rainy too.

The Mytton Lodge, Madliena MLM/1.5s solar system, delivered the lowest yield. There were three main reasons for this outcome. First, the system is not facing the true geographic South but had to be placed along the driveway, which was almost facing the Southwest. This area was the most favourable to install the solar system, as there were several large trees within the garden, that rendered other potential spots unattractive. Second, the modules were shaded from the East by a garage wall and from the West by a tall tree, which reduced the number of hours of direct sunshine on the modules by about one-quarter of the daytime. Third, the solar thermal system used for heating the pool, required a much larger area and therefore it took precedence and was placed in the most sunny area of the garden.

The Baxter BXT/3s solar system utilized the most efficient solar modules of all and had full exposition to solar radiation throughout the day. The lower angle of inclination serves to make the system less visible and compromises between spacing of the modules to avoid shading and the optimum inclination of 36°. It would be expected that this system will have a lower final yield in winter when compared to other systems such as that of the Institute IET/1.8s. However, one has to wait for more data to be available before jumping to conclusions. Finally, the IET/1.8s, which is the oldest of all four systems had a slightly lower output since it is inclined more to the horizontal.

5. INVERTER PERFORMANCE

Due to space limitations, it will not be possible to delve deeply into the performance of the inverters and their interaction with the grid. However, all inverters with the exception of that used in the older system IET/1.8s, monitor the grid's voltage, frequency and impedance change. Deviation of any of these three parameters from the acceptable limits would cause the inverter to switch down immediately. It would start up again only when all of the three parameters fall within safe operating values for at least sixty seconds.

Back in the 1980 and 1990's this problem of insensitivity of the inverter to variations in the grid's harmonics, caused the inverter to continue operating even when the grid was cut off. This is known as "islanding". Research in this field has made great strides and today tested and approved brands operate reliably all over the world.

Safety comes first and for that reason no solar system would be allowed to operate outside the safe range of values. However, it is worth noting that although some countries such as Germany require that all inverters are controlled by the above three parameters, other countries such as England do not impose the monitoring of the grid's impedance. However, all countries agree that inverters have to be controlled by both grid frequency and voltage. The grid's quality can also sometimes dictate what type of monitoring would best ensure the safety of solar systems.

6. THE FUTURE OF PHOTOVOLTAICS IN MALTA

In a paper that was presented during the 3rd Biennial Conference of the Malta Council for Science and Technology, "An Energy Policy for the Year 2000" [12], several proposals were made to encourage the widespread applications of solar applications.

With satisfaction one notices that some of these proposals have been recently brought into reality such as:

- Formation of a national body that would make and foster a national renewable energy plan. The Malta Resources Authority is now formed and has already published a Consultation Paper on the Development of a Strategy for the Exploitation of renewable Energy Sources for Electricity Generation [13].

- Exemption of *PV* modules and their related Balance of System components from the value added tax (VAT). Indeed, tax on solar systems has been reduced from 15% to 5%.

- Changing the energy legislation to allow grid interfacing of solar electric systems. This is being carried out now. Enemalta has also considered net metering, as a means of selling and buying of electricity from consumers. The new Enemalta's digital meters have facilitated this process.

The paper has also proposed other measures that would further accelerate the widespread application of solar systems, but these have not come into action. The most important points were as follows:

- Setting up of a national renewable energy plan. This entails the preparation and the implementation of a programme of initiatives that would be implemented within a specific period of time. It can also include the actual installation of renewable energy systems, promoting renewable energy projects through subsidies within a specific time frame and short as well as long-term planning for the implementation of these technologies.

- Ensuring that solar energy products, whether imported or locally manufactured, conform to the International standards for quality and safety, thus safeguarding the technology from bad reputation.

- Introducing carbon/pollution tax in the energy and petroleum sector and using this revenue to specifically subsidize pre-declared national programmes that would foster the installation of renewable energy systems in public and private venues.

- Offering of soft loans to citizens who wish to install such systems.

Such measures require the full support of government as well as the general public. As the environmental awareness increase, and possibly the price of oil too, it would become easier to implement such measures. However, one should not wait for too long because the present trend of decreasing prices of solar energy products might be reversed in the future.

It is essential that a statistical procedure be established now to keep the records of all installed solar grid-tied systems on the Maltese Islands. This would help in the future planning or upgrading of the grid's sub-stations and the proper management of supply and demand of electricity. Such a record could include the size of the system, the site address, and the type of installation besides others.

It is also necessary to further consolidate the application procedure for grid-connection. It is important that the requirements for any application be identified clearly and the process time taken to process an application be specified. This would encourage further installations of solar systems in Malta.

7. CONCLUSIONS

Photovoltaics has become a mature industry with a world total *PV* sales of 390 MWp (2001), which is more than six times as much as that of 1993 [14]. Some of the large oil companies are now among the largest manufacturers of solar modules. The bold programmes of the U.S.A., Japan and the E.U. to install rooftop solar systems would further help to reduce prices. The choice is in our hands whether to join in the parade towards a better environment today or wait for better times to come.

This paper has briefly described the situation of solar photovoltaics in Malta. The survey on the available solar applications and research in Malta was not intended to be exhaustive but it served to sufficiently indicate that there is still a lot to be done in this field. The research that was started at the Institute has now yielded practical results by the installation of the first two privately owned systems. The positive support that was given by the Malta Resources Authority and Enemalta Corporation augurs well for further implementation of such system in Malta.

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