The Implantation Of A PV Electric Energy Generation System At The Saint Peter And Saint Paul Islands

Marco Antonio Galdino*
Patrícia de Castro da Silva
CEPEL(1)

Marco Antônio Carvalho de Souza
SECIRM(2)

Abstract:

The Saint Peter and Saint Paul Islands are located at 0º55.00'N and 29º20.76"W, at a distance of *circa* 550M (Nautical Miles) NE from the City of Natal, RN (Northeast Region of Brazil), and comprises of many small islands and rocks of igneous plutonic origin.
In 1998, a first Scientific Station was built in order to receive researchers involved in several projects. The CEPEL, as responsible by the electrical energy supply to the Scientific Station; designed and installed a PV electric energy generation system which had a power of 3.6kWp. This system operated successfully for the last 10 years, suffering frequent maintenance.
In 2006, a new design for the Scientific Station has been started aiming to improve its resources and safety. The new PV system has a maximum power of 7.8kWp, and employs an updated technology (SMA, Germany). The equipment was integrated and submitted to intensive testing at facilities of CEPEL, and was installed and commissioned at the Islands in June 2008. Since the installation, the equipment has been operating as required, meeting the energy and water demand of the Station.
The present paper describes the many steps involved in the implantation of the PV system at the Scientific Station.

Keywords: Photovoltaics, PV systems, Solar Energy, Seawater Desalting, Reverse Osmosis, St. Peter and St. Paul Rocks

1. Introduction

The Saint Peter and Saint Paul Islands (ASPSP – Arquipélago de São Pedro e São Paulo), shown in figure I, are a part of the Brazilian territory located at 0º55.00'N and 29º20.76"W, at a distance of *circa* 550M (Nautical Miles) NE from the City of Natal, RN, Northeast Region of Brazil (see figure II). In the English Language maps it is normally referred to as St. Peter and St. Paul Rocks, and it is constituted of several plutonic islets and rocks.

figure I – Saint Peter and Saint Paul Islands

figure II – location of the Islands

[1] CEPEL – Electric Power Research Centre (Centro de Pesquisas de Energia Elétrica); Av. Horácio Macedo, 354; Ilha do Fundão, Cidade Universitária; CEP 21.941-911; Rio de Janeiro, RJ; Brasil; e-mail: marcoag@cepel.br, fax: 55-21-2280-3537
[2] SECIRM – Secretary of Brazilian Commission for the Sea Resources (Secretaria da Comissão Interministerial para os Recursos do Mar), Esplanada dos Ministérios, Bloco N, Anexo B, 3º Andar, CEP 70.055-900, Brasília, DF, Brasil

The Brazilian Commission for the Sea Resources (CIRM – Comissão Interministerial para os Recursos do Mar), formed by several Brazilian Federal Ministries and coordinated by the Brazilian Navy, created the Programa Arquipélago(3) – PROARQUIPÉLAGO (Programme for the ASPSP), aiming the permanent occupation of the Islands, as well as performing scientific research, since the Islands are an area of special interest for several branches of knowledge, like Marine Biology, Geology, Oceanography , etc.

In June, 1998, was built the first Scientific Station of the Saint Peter and Saint Paul Islands (ECASPSP – Estação Científica do Arquipélago de São Pedro e São Paulo), which objective is to lodge teams of 4 researchers working at the place.

The building was designed and built by the UFES (Federal University of the State of Espírito Santo, located in Vitória, ES), using concepts of bioclimatic architecture. CEPEL, which is the research centre of ELETROBRÁS (Brazilian Federal Electric Utilities Holding Company), was responsible for the electric energy supply for the Scientific Station, accomplished by a Photovoltaic (PV) System, as well as the supply of water, through a reverse osmosis (RO) seawater desalting system.

The PV systems are considered the only feasible option for the supply of electric energy to the Islands from renewables. The Wind Energy, although also available at the Islands, was ruled out due to environmental restrictions, since the Islands are a place of nidification of seabirds. Other options, like energy from sea waves or sea currents, are still far from practical application.

The experience of 10 years operating the Station shows that the environment is highly aggressive at the Islands, due to the presence of a salt mist, resulting in strong corrosion and causing failures in inverters, charge controllers and Diesel generators, as well as other electric and electronic equipment.

It was also noticed that the Scientific Station can suffer reduction of PV generation, lying between 10% and 30%, due to shadowing caused by the *guano* (excrements of seabirds) on the PV panel, and also due to the seabirds themselves lying on the panel.

It was also noticed that the first Station was built in a place subjected to wave impacts in times of rough sea.

The first Scientific Station operated satisfactorily during 10 years. However, in 2006 it was decided to design and build a new Station, involving the same institutions: the architectural project was made by UFES and the electric and hydraulic project by CEPEL. Serious damages in 2006, due to extremely rough sea, reinforced the necessity of building a new Station, in a new location.

2. Design of the PV System

The sizing of the PV system for the New Scientific Station of the St. Peter and St. Paul Islands considered the loads, and respective daily utilizations, presented in table I. The data of table I was estimated through real measurements or data sheets of similar equipment, since the equipment for the New Station was not yet available.

[3] www.mar.mil.br/secirm/psrm/psrm_arq.htm

table I – Loads of the New Scientific Station of the St. Peter and St. Paul Islands

loads	**qty**	**current (A)**	**h/day**	**comments**
lamps 20W	4	0.3	5	kitchen, communications, laboratory, room
lamps 15W	4	0.23	1	beds
lamps 20W	1	0.3	7	deck
lamps 15W	1	0.23	3	bathroom
lamps 20W	3	0.3	4	external
PC Computer	1	1.1	4	measurement in CEPEL
freezer	2	2.3	8	Bosch 230L vertical
refrigerator	1	2.1	10	Consul 325L 1 door
radio TX HF	1	3.4	0.5	ICOM IC-M802 (150W output)
radio RX HF	1	0.3	23.5	
radio TX VHF	1	0.7	1	ICOM IC-M602 (25W output)
radio RX VHF	1	0.15	23	
extra load	1	1.2	3	equipment of researcher
RO unit High Pressure pump	1	17.1	2.0	Seawater RO desalting unit, measurement in CEPEL
RO unit Low Pressure pump	1	8.21	2.0	
auxiliary pump ¼HP	1	8.21	0.5	seawater pump;
				total 18.6kVAh/day

Concerning table I, the following comments are necessary:

- The currents are those driven by the loads operating at 120Vac (the Station actually operates at 220Vac), either directly measured or extracted from technical specifications;
- The lighting of the New Station is based on compact fluorescent lamps;
- PC desktop computer, used in CEPEL;
- Communication equipment are maritime transceivers of the VHF and HF bands, operating in transmission (TX) and reception (RX) modes;
- RO desalting unit data of the brazilian manufacturer Perenne, tested in CEPEL in 2004 (equipment actually acquired from another manufacturer); corresponds to 36% of the energy consumption;
- refrigeration equipment (2 freezers and a refrigerator) from brazilian manufacturers, with Brazilian Label of Efficiency (Selo PROCEL de Eficiência); corresponds to 39% of the energy consumption.

The sizing was based in a simplified method, presented in the PV Engineering Manual of CEPEL (CEPEL/CRESESB, 1999), considering solar radiation data for Fernando de Noronha Islands, available at CEPEL's webpage SUNDATA program (www.cresesb.cepel.br). These other Brazilian Islands, circa 340 Nautical Miles far from the St. Peter and St. Paul Islands, are the nearest data available.

Table II shows data of global solar radiation at the horizontal plane (Gh), as well as the data converted to planes tilted 10 degrees, oriented in the North and South directions.

table II – global solar radiation data adopted for sizing – kWh/m^2.day monthly averages (Fernando de Noronha Islands)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Gh	5.64	5.33	5.19	4.72	5.33	4.83	5.31	5.50	5.86	6.28	6.36	6.06	5.53
10ºS	5.90	5.43	5.12	4.49	4.85	4.34	4.78	5.12	5.69	6.35	6.64	6.40	5.43
10ºN	5.21	5.09	5.12	4.82	5.66	5.20	5.70	5.72	5.87	6.03	5.89	5.54	5.49

Considering the yearly average incidence of solar radiation at S and N directions (~5.46kWh/m^2.day), a 7.8kWp PV panel was calculated. This 7.8kWp panel occupies entirely the roof of the Station, leaving, however, free area for personnel transit required for cleaning, maintenance, etc., so eliminating a problem of the First Station where this kind of work was difficult. The roof originally projected to the new Station had to be enlarged to accomplish with this.

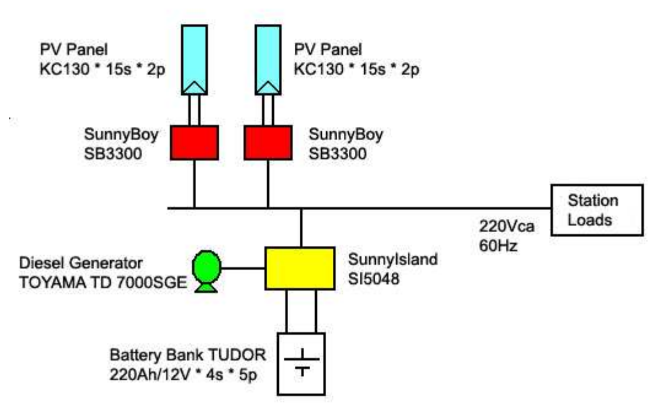

figure III – electric diagram of the PV system

The diagram of the system is presented in figure III. The system is based in SunnyBoy and SunnyIsland inverters manufactured by SMA[(4)] (Niestetal, Germany), with efficiency and reliability among the best in the market. The new Station, adopts an up-to-date technology, if compared to the older one, which was based in a conventional system with dc charge controllers and a single stand alone inverter.

The system uses 2 inverters SunnyBoy SB3300 and one inverter SunnyIsland SI5048, operating in parallel in a 220Vac bus.

It should be remembered that the SB3300 have the protection degree IP65 (totally watertight), and the SI5048, although being IP40, during installation were reinforced against penetration of moisture, thus assuring an excellent protection against the severe environmental salinity and corrosion of the Islands, one of the greatest worries with the system.

The *software* SunnyDesign, also from SMA, was used to verify the sizing and configuration of PV panel and inverters. However, the nearest solar data available in its database is for the SW Region of Brazil. Adopting these data the SunnyDesign calculates a generation of 8829kWh/year (4655kWh/year for the N face, and 4174kWh/year for the S face), corresponding to an annual daily average of 24.2kWh/day.

The sizing of the battery bank is not critical, since most of the load is diurnal, and there will be also available a Diesel Generator, with automatic start. The batteries are of the brazilian manufacturer TUDOR, since the imported batteries of the first Station were difficult to replace. It was specified a bank with 20 stationary/photovoltaic TUDOR 12TE220 (12V, 220Ah @ C_{20}), associated 4 in series and 5 in parallel (4s * 5p), reaching a total capacity of 1100Ah @ C_{20}, with a voltage of 48Vdc.

Concerning the sizing of the battery bank, the following considerations apply:

[4] SMA Tecnologie AG - www2.sma.de/em or www.sma-america.com

- It is estimated that 35% of the load is nocturnal, resulting in 16% daily discharge of the battery bank (in conditions of good insolation). According to the manufacturer data, this results in a lifespan of 8.8years for the bank;
- In conditions of bad insolation (cloudy days) the RO unit shall not be operated, reducing the daily load to 61% of the total load, resulting in 28% discharge of the battery bank. Again according to the manufacturer, the lifespan of the bank would be 3.8years;
- Since the inverter SunnyIsland is programmed to start the generator when the battery bank reaches a discharge of 50% of its capacity, the autonomy of the bank is approximately 2 days in the conditions specified in the above item.

The Diesel generator, from the brazilian manufacturer TOYAMA model TD 7000SGE, was chosen because is enclosed in a cabin, which results in less audio noise and improved protection against the environment. However, in the nominal power of 6kVA, there are not many options of generators with cabins, and none of them has the interface necessary to automatic operation with the inverter SI5048. Thus, it was necessary to adapt the original equipment using a PLC and switches, in order to allow the automatic operation, as well as totally manual operation, independent from the PV system.

3. Design of the Water Supply System

The water supply for the Station is limited, and by both saltwater (certain non potable uses, like washing, etc.) and freshwater, produced from the saltwater through a reverse osmosis desalting unit, similar to those used in ships. The water consumption is considered of 200L/day saltwater and 50L/day freshwater.

The hydraulic system of the Station is shown in figure IV, where the components are numbered and explained in the legend.

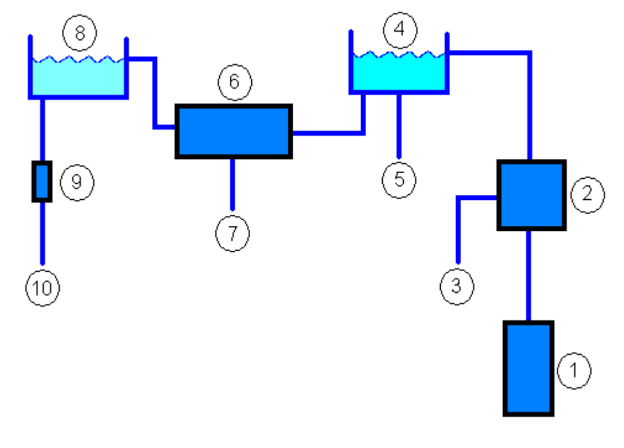

figure IV – hydraulic system of the Station

1. **Saltwater pump**, installed in a natural pool, fed by the waves and tides. A submersible pump DANCOR 3.2 SSR-07 (brazilian manufacturer), centrifugal with 7 impellers and ½ HP nominal power, normally used for water boreholes and totally in stainless steel, was used.
2. **Sand filter**, of the kind used in swimming pools, necessary for removing material suspended in water. The high flowrate DANCOR (brazilian manufacturer) DFR-15-7 filter was used in order to reduce friction loss;
3. **Return from sand filter flushing,** back to the ocean;
4. **Saltwater reservoir**, containing 1500L (3 x 500L), located 10m high with respect to the saltwater pump;
5. **Output of saltwater to the Station**;
6. **RO desalting unit**, and respective low pressure pump (DANCOR CP-4R, conventional centrifugal pump, totally in plastic ½ HP, brazilian manufacturer);
7. **Reject (brine) of the RO unit**, back to the ocean;
8. **Freshwater reservoir,** containing 1000L (2 x 500L);

9. **UV water sterilyzing unit;**
10. **Output of freshwater to the Station**.

Considering the Perenne RO unit, it would be necessary to pump 1090L/day of saltwater to produce 200L/day of freshwater, adding the consumption of 800L/day of saltwater for other purposes, results in a necessity of pumping 1890L/day of saltwater.

Considering the characteristic curve of the pump DANCOR 3.2 SSR-07, the hydraulic circuit of figure IV, the respective heights and the calculated friction losses, it will be necessary to pump saltwater for circa 28minutes daily, requiring 0.52kVAh/day. The RO unit must be on for 2hours and 5 minutes each day, in order to produce 200L of freshwater, requiring 6.23kVAh/day.

So, the total energy consumption of electric energy to supply water to the Station is of 6.75kVAh/day (already considered for the PV panel sizing).

4. Integration and Testing

All of the equipment acquired for the new Station was delivered in CEPEL, where the integration and testing of the system was performed. As the conditions of disembark (inflatable boats) and of work at the Islands are really hard, everything was prepared previously at CEPEL.

A replica of the roof of the Station, using the same metallic tiles, as well as a replica of the new Station´s power room, were built, what allowed to prepare the most of the wiring, the PV panel dc junction box, the ac box, fixtures, etc. The installation of the RO unit was also prepared.

The dc junction box encloses breakers, spark gaps and varistors for protection against lightning discharges. The ac box encloses breakers for the inverters, a transformer for the RO unit (needs 110Vac for the control circuit), and a transfer switch for manual operation of the Diesel generator.

The testing was performed using resistive loads, and the system showed to be able to drive the RO unit simultaneously to a 2.7kW load, or a 4kW load alone. The RO unit actually acquired from the manufacturer VMT – Village Marine Technologies (USA), was also tested at CEPEL and showed to consume 25% less energy than previously estimated.

An important part of the system integration and testing was the programming of the operational parameters of the SunnyIsland SI5048 inverter.

5. Conclusion

The real installation of the system at the St. Peter and St. Paul Islands occurred in the period from June, 12 to 27, 2008, in a 10-day stay at the place. Since the installation, the equipment has been operating as required, meeting the energy and water demand of the Station.

Reports received by CEPEL informed that there were verified problems with the Diesel generator and with the RO unit, but these did not impaired the habitability of the Station. However, the PV system is operating beautifully.

It is hoped that the system will be able to do so for the next 10 years, meeting the demand of energy and water of the Station.

6. References

CEPEL/CRESESB, 1999. PV Systems Engineering Manual, Rio de Janeiro, pp. 101-138.