STUDENT RESEARCH MINOR PROJECT

PRODUCTION OF ELECTRICITY BY SOLAR PANELS , ITS CONSTRUCTION & WORKING

By

III Bsc Students

Under the guidence of

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WGD.AP

June-2022

DECLARATION

I hereby declare that the work describe in this student Minor Research Project has been carried out entirely by B.SC Students in the Department of Physics Sri Y N College Narsapur and further that it has not been submitted earlier either wholly or in part to any University or Institution .

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CERTIFICATE

This student Minor Reasearch Project described in this Project has been carried out by 3rd Bsc students under the guidance of Department of physics . I certify that it is a bonafied work .The work is original and has not been submitted for any other institution .

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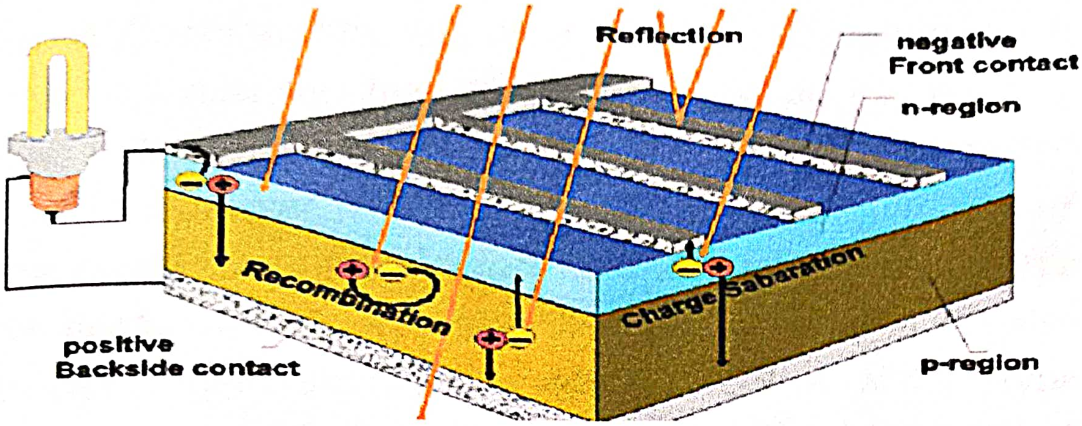
CONTENTS-

Solar power

Solar power is the conversion of renewable energy from sunlight into electricity, either directly using photovoltaics (PV), indirectly using concentrated solar power, or a combination. Photovoltaic cells convert light into an electric current using the photovoltaic effect.[1] Concentrated solar power systems use lenses or mirrors and solar tracking systems to focus a large area of sunlight to a hot spot, often to drive a steam turbine.

Solar Cell: Working Principle & Construction (Diagrams Included)

Oc



What is a Solar Cell?

A **solar cell** (also known as a photovoltaic cell or PV cell) is defined as an electrical device that converts light energy into electrical energy through the photovoltaic effect. A solar cell is basically a p-n junction diode. Solar cells are a form of photoelectric cell, defined as a device whose electrical characteristics – such as current, voltage, or resistance – vary when exposed to light.

Individual solar cells can be combined to form modules commonly known as solar panels. The common single junction silicon solar cell can produce a maximum open-circuit voltage of approximately 0.5 to 0.6 volts. By itself this isn't much – but remember these solar cells are tiny. When combined into a large solar panel, considerable amounts of renewable energy can be generated.

Construction of Solar Cell

A solar cell is basically a junction diode, although its construction it is little bit different from conventional p-n junction diodes. A very thin layer of p-type semiconductor is grown on a relatively thicker n-type semiconductor. We then apply a few finer electrodes on the top of the p-type semiconductor layer.

These electrodes do not obstruct light to reach the thin p-type layer. Just below the p-type layer there is a p-n junction. We also provide a current collecting electrode at the bottom of the n-type layer. We encapsulate the entire assembly by thin glass to protect the **solar cell** from any mechanical shock.

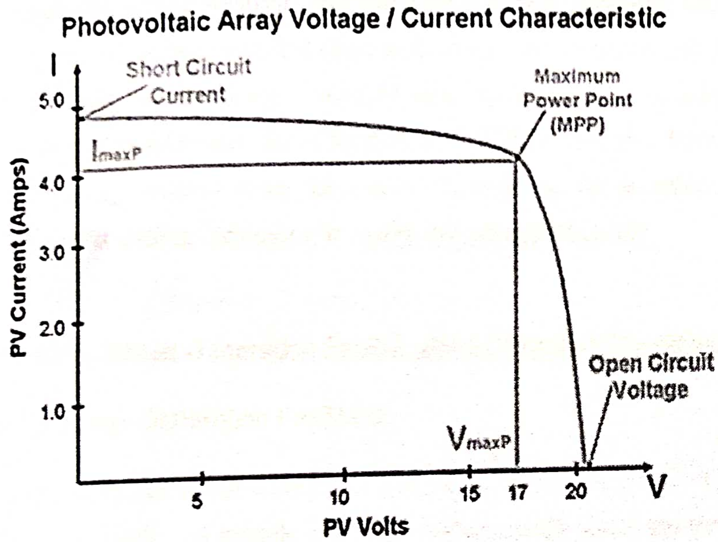
Working Principle of Solar Cell

When light reaches the p-n junction, the light photons can easily enter in the junction, through very thin p-type layer. The light energy, in the form of photons, supplies sufficient energy to the junction to create a number of electron-hole pairs. The incident light breaks the thermal equilibrium condition of the junction. The free electrons in the depletion region can quickly come to the n-type side of the junction.

Similarly, the holes in the depletion can quickly come to the p-type side of the junction. Once, the newly created free electrons come to the n-type side, cannot further cross the junction because of barrier potential of the junction.

Similarly, the newly created holes once come to the p-type side cannot further cross the junction became of same barrier potential of the junction. As the concentration of electrons becomes higher in one side, i.e. n-type side of the junction and concentration of holes becomes more in another side, i.e. the p-type side of the junction, the p-n junction will behave like a small battery cell. A voltage is set up which is known as photo voltage. If we connect a small load across the junction, there will be a tiny current flowing through it.

V-I Characteristics of a Photovoltaic Cell



Materials Used in Solar Cell

The materials which are used for this purpose must have band gap close to 1.5ev. Commonly used materials are-

1. Silicon.
2. GaAs.
3. CdTe.
4. $CuInSe_2$

Criteria for Materials to be Used in Solar Cell

1. Must have band gap from 1ev to 1.8ev.
2. It must have high optical absorption.
3. It must have high electrical conductivity.

8. Solar Power Generation

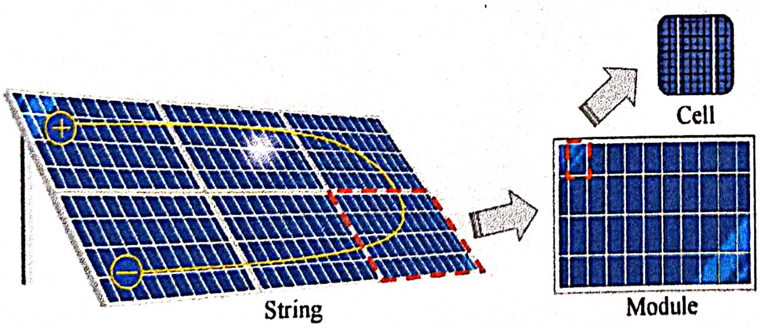
Concerning solar power generation equipment in Cabo Verde, two mega solar power plants were constructed and went into operation in 2010 on Santiago Island and Sal Island respectively utilizing funds from the Government of Portugal. These plants have rated output of 4.28MW and 2.14MW respectively, making them smaller than wind power plants. Since Cabo Verde has hardly any rainfall, even though solar radiation conditions are good, sands and dry soil carried by strong winds off the continent cause the solar panels to become covered in dust; moreover, because the absence of rainfall means that no rain washing effect can be anticipated, generating capacity deteriorates.

Equipment has been installed close to the coast, and corrosion and degradation caused by salt damage can be seen here and there. Because repair costs are not adequately secured, equipment failures tend to be left unaddressed for a long time. SCADA systems have been introduced to monitor the equipment, however, since these aren't functioning due to server failure, they are not utilized for gauging operating conditions or conducting maintenance, etc.

8.1 Solar Power Generation Facilities and Operating Conditions

8.1.1 Power Generation Facilities

First, an outline of the solar power generation systems is given. Figure 8.1-1shows the composition of solar panels. A module comprises multiple cells, which are the basic elements, connected over a panel and protected by glass and so on. Normally, it is such modules that constitute products. Modules are further joined together in series arrangements known as strings. The string voltage is the power generation system DC voltage, and DC current of a certain capacity from strings connected in parallel is inputted to an inverter, where it is converted to AC power and outputted.



Source: JICA Study Team

Figure 8.1-1 Composition of Solar Panels

Based on the above contents, Table 8.1-1 and Table 8.1-2 show lists of the equipment at the two mega solar power plants in Cabo Verde. The manufacturer in both cases is Marifer Solar Co. of Portugal.

Table 8.1-1 Outline of Mega Solar Power Plant Equipment (solar panels)

Island	Modules						Output Power		PV panel inclination (°)
	Manufacturer	Model	Peak power (Wp)	Number	Cell		Peak power (MWp)	Rated power (MW)	
					Type	Efficiency			
Santiago	Martifer Solar	MTS 230P	230	10,944	Polycrystalline Si	14.3%	4.44	4.28	15
		MTS 225P	225	8,568	Polycrystalline Si	14.0%			
Sal	Martifer Solar	MTS 225P	225	9,912	Polycrystalline Si	14.0%	2.23	2.14	15

Source: JICA Study Team based on Information from Electra

Table 8.1-2 Outline of Mega Solar Power Plant Equipment (inverters, transformers)

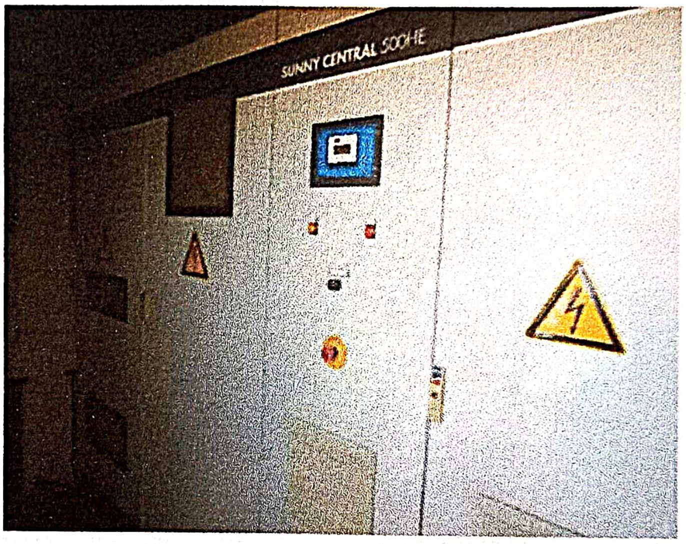
Island	Inverter						Transformer		
	Manufacturer	Model	Nominal AC output (kW)	Power factor	Efficiency	Number	Capacity (kVA)	Voltage	Number
Santiago	SMA Solar Technology AG	SC 500HE	500	0.95	98.4%	1	630	315V/20kV	1
		SC 630HE	630	0.95	98.4%	6	630	315V/20kV	6
Sal	SMA Solar Technology AG	SC 250HE	250	0.95	98.4%	1	500	270V/20kV	1
		SC 630HE	630	0.95	98.4%	3	630	315V/20kV	3

Source: JICA Study Team based on Information from Electra

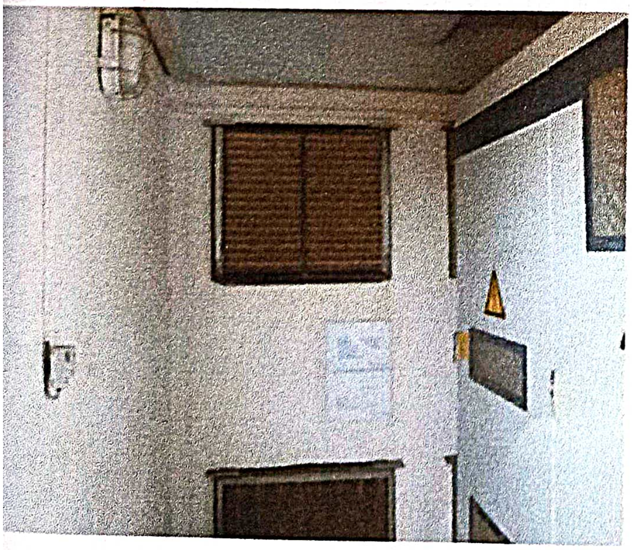
(a) Entire view

(b) Power source connection panel hut (PS)

(c) Inverter, transformer hut PT)

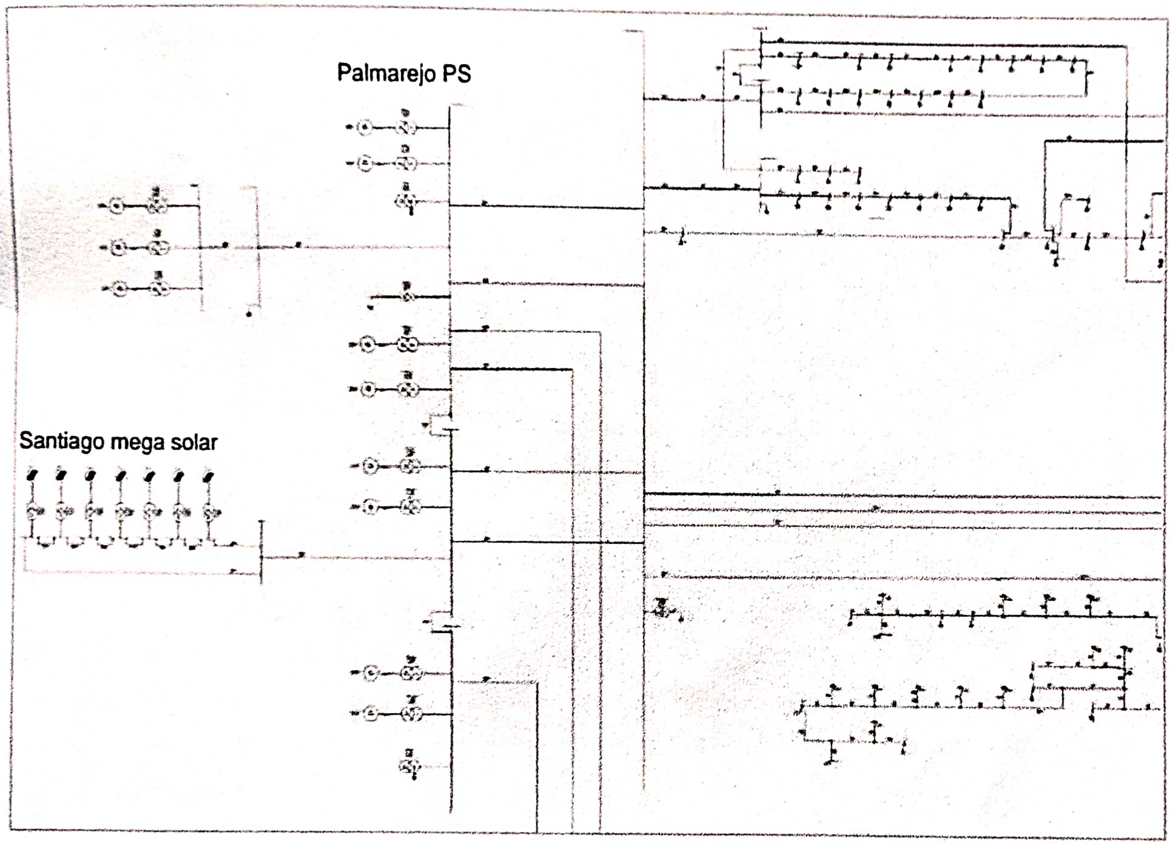


(d) Inverter panel



(e) PT external air suction inlet

(f) PT exhaust vent



Source: Electra

8.1.2 O&M (Power Generation Performance)

(1) Santiago Island

Figure 8.1-8 shows photographs of weather data observation equipment in a mega solar system. The data measured by such equipment, i.e. solar radiation, wind velocity, air temperature, rainfall, and also solar power generation data regarding voltage, current and frequency, are stored in a SCADA system. However, in Santiago mega solar, due to failure of the current server, it was not possible to acquire current and past data. Even so, since the solar power generation is directly connected to Palmarejo Power Station, where it is possible to grasp the solar power generation output in real time, the daily operating report records the amount of generated electrical energy based on the hourly output and routine watt hour meter readings.

Figure 8.1-8 Weather Data Observation Equipment (Santiago)

Table 8.1-3 shows the amount of generated energy at Santiago mega solar in 2015 based on the daily operation reports. The lower row of the table shows the equipment capacity factor. The annual equipment capacity factor is 10.7%, which is lower than the general equipment capacity factor in Japan of 12~14%. Looking at the monthly figures, the equipment capacity factor dips greatly between July and November.

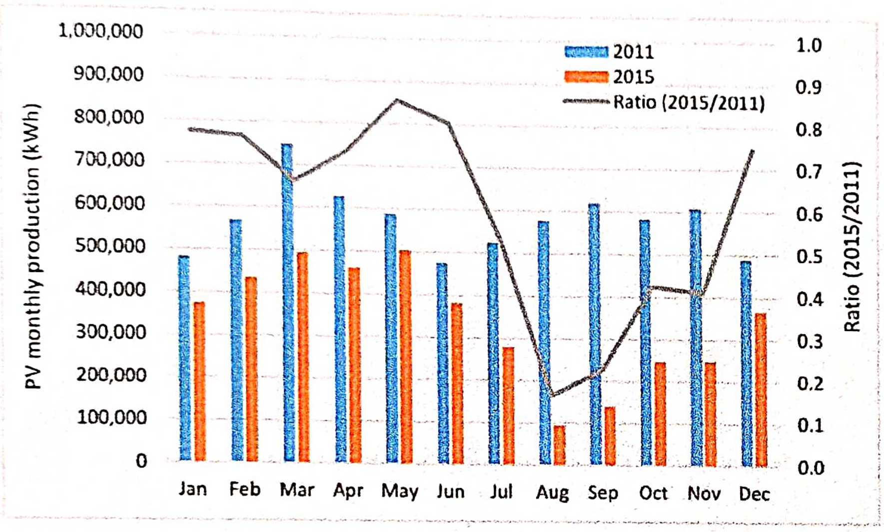
Table 8.1-3 Monthly Solar Power Generated Energy (Santiago, 2015)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Production (kWh)	373,601	434,733	494,132	460,819	503,852	382,056	279,851	95,268	140,232	247,869	249,207	365,867	4,027,487
Capacity facter	11.7%	15.1%	15.5%	15.0%	15.8%	12.4%	8.8%	3.0%	4.6%	7.8%	8.1%	11.5%	10.7%

Source: JICA Study Team based on Information from Electra

Figure 8.1-9 shows a graph giving a comparison with the past amount of generated energy. In 2015, compared with 2011, which was the next year following the start of operation, the amount of generated energy declined greatly between July and November. It is thought that generation during this period was impacted by a lot of cloud cover as well as major equipment failure, etc., although this cannot be confirmed at the present time. Concerning the period from December to June, the amount of generated energy was roughly 20% lower in 2015 than it was in 2011. It is guessed that this was due to reduced generating efficiency caused by degradation of the cells over time as well as partial equipment failure and so on.

The annual equipment capacity factor for 2011 was 18.4%, which was fairly high compared even to the aforementioned equipment capacity factor in Japan, and this is thought to demonstrate the good quality of sunlight conditions in Cabo Verde.



Source: JICA Study Team based on Information from

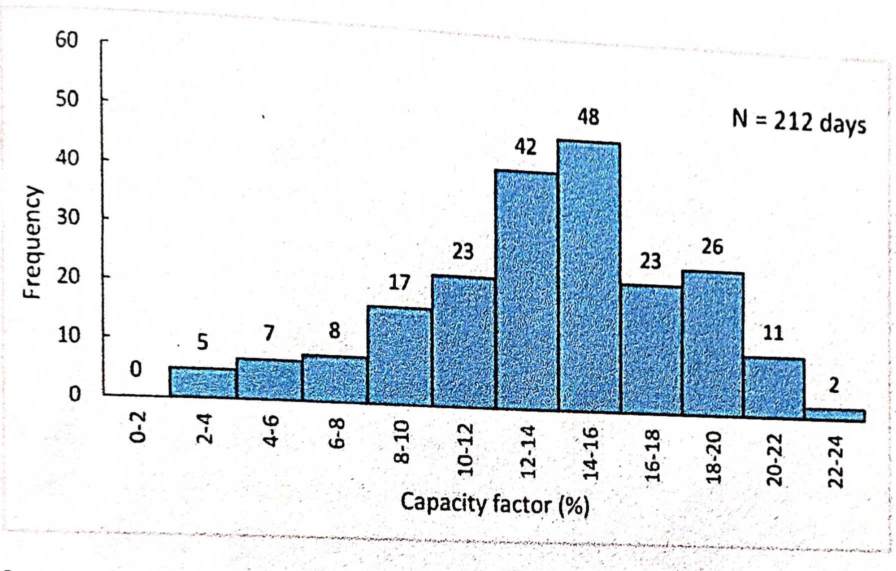
2011 data: Information Collection and Confirmation Survey Report in the Cabo Verde Climate Change Countermeasures Sector, JICA, August 2012

2015 data: Electra

Figure 8.1-9 Monthly Solar Power Generated Energy (Santiago 2011, 2015)

Figure 8.1-10 and Figure 8.1-11 respectively show the daily amount of solar generated energy and peak power output throughout 2015.

energy over seven months not including the period from July to November, when generated energy declined for some reason or other. The equipment capacity factor over this period was 13.8%.



Source: JICA Study Team based on Information from Electra

Figure 8.1-12 Histogram of Equipment Capacity Factor in Solar Power Generation (Santiago)

Since the local climate has little rainfall, there are few days when the generated energy and equipment capacity factor are low, so the overall power generation performance is stable.

Concerning the peak power shown in Figure 8.1-11, since the figure for March 16 is thought to be the result of mistaken entry in the daily report, if this is omitted, the peak power is 3,467 kW on February 2 and the ratio with respect to the module rated output of 4,440 kW is 78.1%. Generally speaking, compared to the rated output of the solar power modules, since output on the inverter AC side is said to decline to around 70~80% due to the actual values under the aforementioned normal conditions of use and conversion loss in the inverter and so on, this figure is generally assumed to be valid output.

(1) Santiago Island

Power transformation equipment undergoes preventive maintenance six times per year. Specifically, this comprises internal cleaning of the PT, PS, inverters and transformers; moreover, tightening and so on is implemented on the transformers, frame joints and inverters two times per year. Concerning the solar panels, if sufficient budget can be acquired, cleaning is implemented a maximum of four times between February and June at an annual cost of CVE 660,000. In 2014 and 2015, a repair budget of approximately CVE 770,0000 was secured, however, this wasn't enough to acquire all the necessary materials due to the need for consumable parts and maintenance.

A problem with equipment means that decline in the insulation resistance of solar power generation equipment at times of rainfall leads to persistent occurrence of the PID phenomenon described later, burning of connectors (MC4 connectors) between modules (this occurs with high frequency during the rainy season) and power loss due to inverter tripping. Concerning the burning of MC4 connectors, the dust and water resistance performance that is stipulated in the IEC's (International Electrotechnical Commission's) IEC144 and IEC529 standards has been addressed through replacing IP65 connectors with IP68 connectors, which offer greater water resistance.

Concerning detection of system abnormalities, SCADA was used to check the condition of fuses installed along each string as well as measure voltage, etc., however, now that this system is broken, maintenance staff members check for abnormalities and measure values using measuring instruments in the junction box (Figure 8.1-18).

Initially 50 replacement modules were provided, and 12 of these have already been used due to failures. Moreover, the ventilation fans in the PT and PS huts have also broken down.

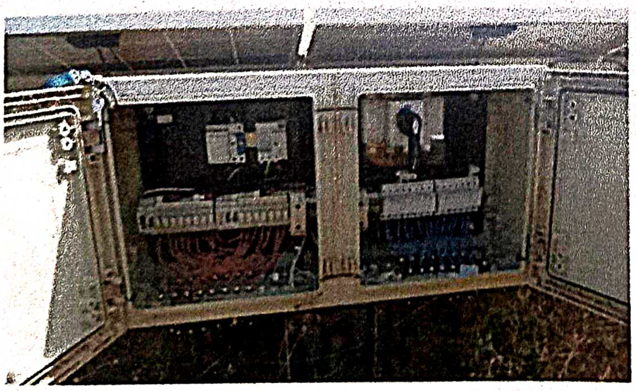
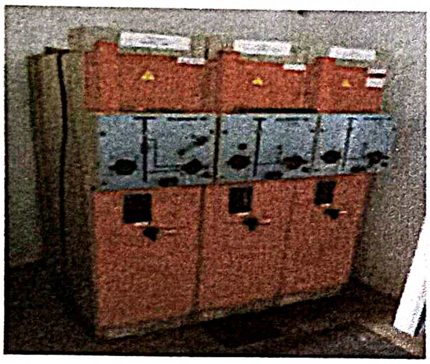
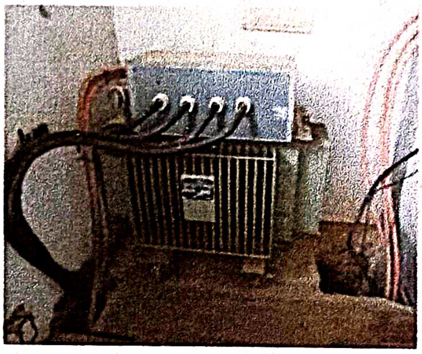


Figure 8.1-18 Junction Box (Santiago)

20kV switchgear (left: by EFACEC, center: by ALSTOM) and transformer (back right)



6kV switchgear (by ALSTOM)
(two feeders)



House transformer: 250kVA (by GONELLA)
(20kV/400V)

Figure 9.1-27 Nova Sintra SS

Figure 9.1-28 Decommissioned wind turbine facility

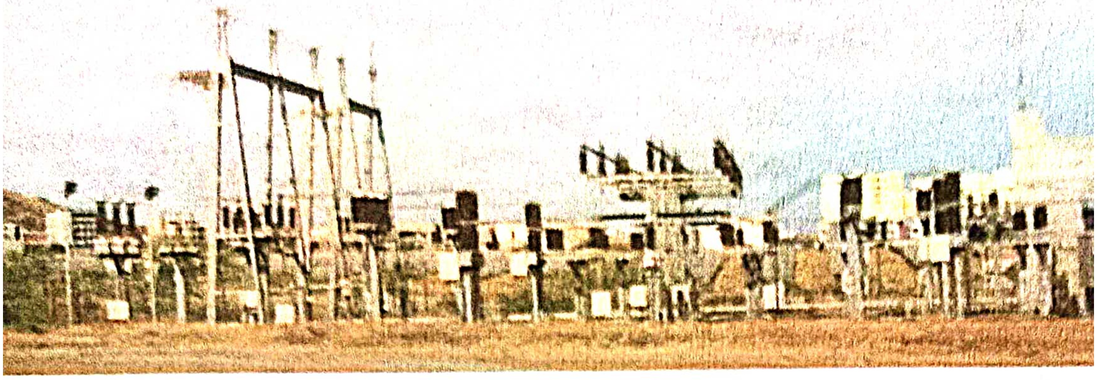
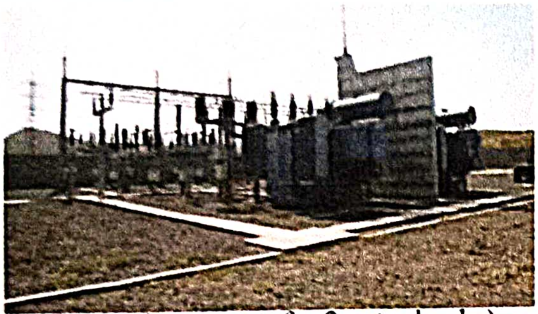


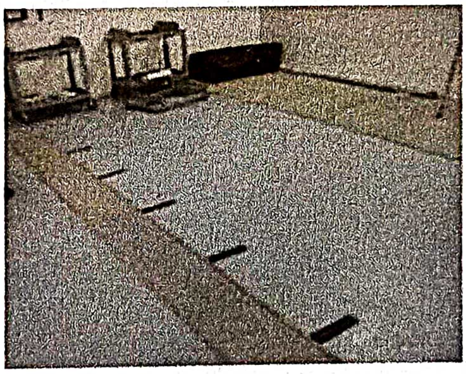
Figure 9.1-19 Palmarejo SS



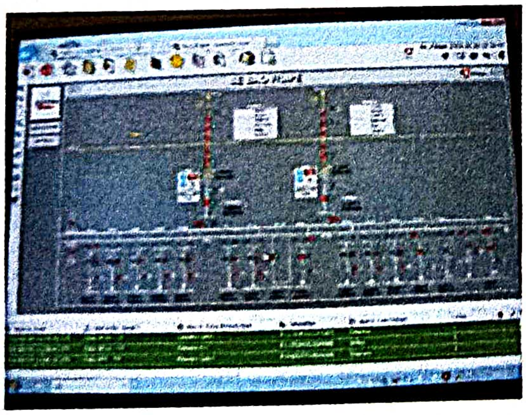
SS premises (space for 2 extra banks)

Transformer nameplate (made in Portugal)

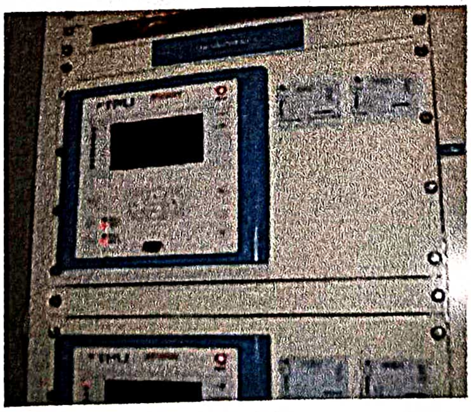
20kV Switchgear



Space for extra 20kV switchgears



Monitoring and control screen



SCADA

Figure 9.1-20 São Filipe