Colegio Nacional Galápagos

Puerto Ayora, Santa Cruz Island, Galápagos, Ecuador.

Photovoltaic System

Installed during 1998 in accordance with the "*Convenio para Implementar Sistemas Fotovoltaicos en los Colegios Alejandro Humboldt y Nacional Galapagos*" (agreement to implement photovoltaic systems in the Alejandro Humbolt and Nacional Galapagos schools) signed by the Ecuatorian Ministry of Education, the Instituto Ecuatoriano de Electrificación (INECEL) and the representative of UNESCO in Ecuador.
The project was financed by the British government through UNESCO, the Global Environment Facility (GEF) and United Nations Development Program (UNDP)*
The systems began operating in October 1998.

1: System Description

a. Photovoltaic Panels:

Brand: BP Solar
Model: BP585
Power: 85 W max (18 Vp – 4.72 A) 22.03 V open circuit
Number of panels: 40 Note: The frame has space for 42 panels.
Connection: 13 sets connected in parallel. Each set has 3 panels connected in series. There is one panel not in use.

b. Batteries:

Brand: BP Solar.
Model: Powerblocs
Voltage: 2 V
Capacity: 900 AH/100
Number of Batteries: 24

c. Charge Controller:

Brand: Trama Tecno Ambiental, Barcelona, España.
Model: TApS C-8648 (Centralita)
Current: 48 V system – 70 A

d. Inverter:

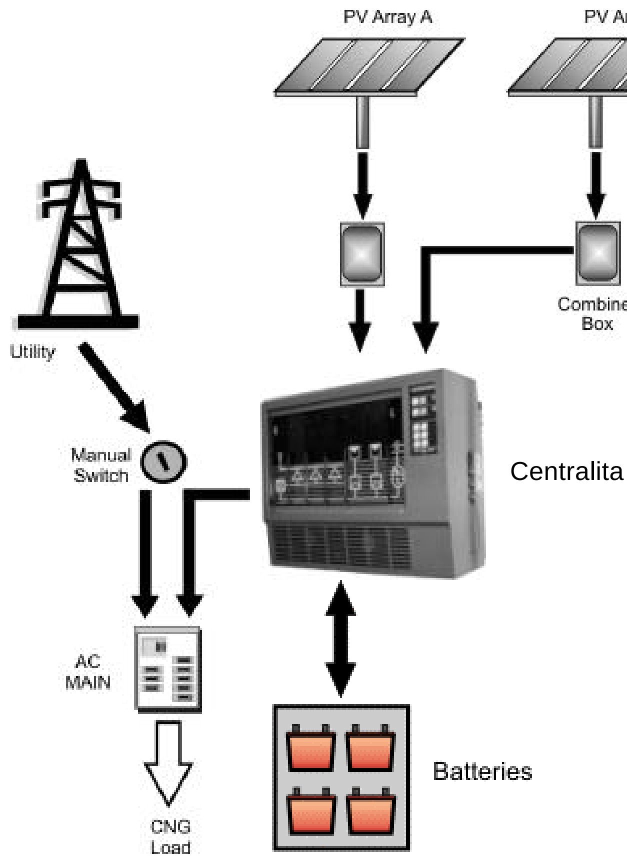
Brand: Trama Tecno Ambiental, Barcelona, España.
Model: TApS C-8648 (Centralita)
Power: 3 modules, 1.1 KW each.

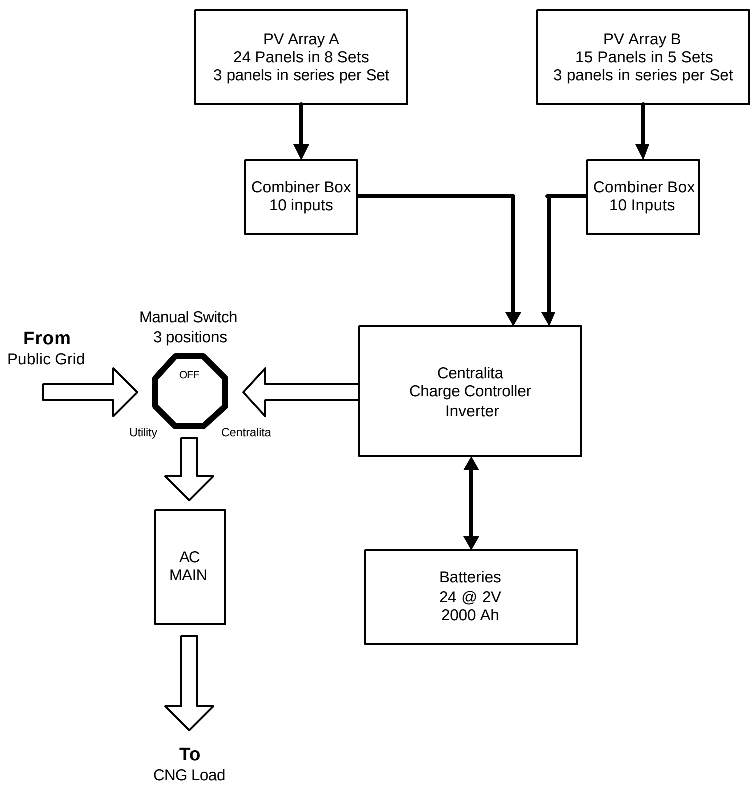
e. Battery Charger:

Brand: Trama Tecno Ambiental, Barcelona, España.
Model: ?
Power: ?

* I have a copy of the original agreement signed in Quito in April 1998

f. System Diagram (current configuration):





2: Preliminary Assessment

a. **Photovoltaic Panels:** Visual inspection of the panels indicates that the body of each one is in good shape. No fractures on the glass or on the back. No apparent separations between the aluminum frame, the plastic body and the glass cover. The attached connector boxes in the back plane are slightly aged; however, I didn't see an easy way to replace them. The electrical connectors in those boxes do not have a convenient design, I noted one cable disconnected and one burned at the tip. The main frame to support all PV panels is a solid steel structure. No signs of significant rusting. The frame supports 42 panels. There are 40 panels installed. One of those panels is not in use.

b. **Batteries:** There was not enough time to carefully evaluate the electrical performance and condition of the batteries. The nominal voltage of each battery is 2 V and the measurement of this parameter -between 1.91 to 1.98 V- indicated the state of charge of the batteries was low. The density of the electrolyte showed a charged value though. All terminals were covered with lead-sulfate. Some of the batteries have severely corroded terminals.

c. **Charge Controller & Inverter (Centralita):** Equipment installed by Trama Tecno Ambiental (Spain) for the INECEL/UNESCO project in 1998. This equipment integrates a charge controller and a modular inverter in a single unit. The control panel display had a fuse burned that I replaced. Even though the display was operational, I am not familiar with the equipment and I was not able to fully interpret the messages, or there is the possibility that it was not responding properly. The first test I made was to charge the batteries during the day (cloudy day) with no load. Apparently the charge controller was functioning with no problem, however, the display was not indicating the status of the process. At night I turned on the inverters with no load and the equipment showed an erratic behavior: sometimes the inverters stayed on and sometimes the Centralita would shut them down. I noticed a strange sound (like a click) in the batteries when I turned the system on. I didn't have an adequate instrument to measure the current in some points to try to find out what was happening. That night I was not able to connect the load to test the system. Next day I tested the system with and without load. Apparently it worked fine but the test was performed with an unknown load and for some minutes only.

d. **Battery Charger:** Power switch broken. Equipment disconnected from the system.

e. **Wiring:** The cables that interconnect the PV panels in series need to be checked. The same applies to the cables that combine in parallel the sets of PV's connected in series. In my preliminary inspection I found one cable disconnected and one with the tip burned. The quality of the connections can be improved. Some cables will need to be replaced with new cable depending on the state of the insulator, but I believe that most of the cable can be reused.

To deliver power to the control/conversion equipment there are 2 cables, each cable has two conductors. The length of each one is approximately 20 meters. The gauge of each cable is 6 AWG, 600 V. The gauge of this cable is adequate for the distance, ampacity and current they are used for. It is necessary to check the grounding for the PV system and power equipment.

f. **DC Power Switches & Breakers:** Non existent. I installed a temporary and rudimentary solution to disconnect the PV panels from the system, and the batteries from the system.
The Centralita system doesn't have an automatic AC transfer relay. There is a manual switch to select AC power from the PV system (Centralita) or from the public grid, to the load.

g. **PV system load (AC):** The AC generated by the PV system is delivered to a switch box in the nearby building. There is not a central panel for the electrical system at the building. The electrical installation is disorganized from that point on. That building houses two computer labs in the upper floor and two large rooms –apparently empty- at the ground level. I was told that several electrical failures have occurred in the past which have damaged 3 computers. I can't be sure what the cause of those failures is although I see 3 possibilities so far: Malfunction of the inverter, peaks on the public network, or improper electrical installation in the building.

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Appendix A

Wire Sizing Chart

This chart works for any voltage or voltage drop, American (AWG) or metric (mm2) sizing. It applies to typical DC circuits and to some simple AC circuits (single-phase AC with resistive loads, not motor loads, power factor = 1.0, line reactance negligible).

1: Calculate the Voltage Drop Index:

$$VDI = \frac{I \times d}{V \times V_d} \times 3.28$$

Where

- VDI = Voltage Drop Index (a reference number based on resistance of wire)
- d = Length of the wire in meters (one way)
- V = Voltage across the wire
- V_d = Voltage drop selected as a percentage (use 3 for 3%)

2: According to the VDI value calculated, determine the appropriate wire size to use. Amps must not exceed the AMPACITY indicated for the wire size.

Wire Size	Area mm2	COPPER		ALUMINUM	
AWG		VDI	Ampacity	VDI	Ampacity
16	1.31	1	10	Not Recommended	
14	2.08	2	15		
12	3.31	3	20		
10	5.26	5	30		
8	8.37	8	55		
6	13.3	12	75		
4	21.1	20	95		
2	33.6	31	130	20	100
0	53.5	49	170	31	132
00	67.4	62	195	39	150
000	85.0	78	225	49	175
0000	107	99	260	62	205

Metric Size by cross-sectional area:	COPPER: (VDI x 1.1 = mm2)	ALUMINUM: (VDI x 1.7 = mm2)
Available Sizes: 1 1.5 2.5 4 6 10 16 25 35 50 70 95 120 mm2		

NOTES: AWG=American Wire Gauge. Ampacity is based on the National Electrical Code (USA) for 30 degrees C (85 degrees F) ambient air temperature, for no more than three insulated conductors in raceway in free air of cable types AC, NM, NMC and SE; and conductor insulation types TA, TBS, SA, AVB, SIS, RHH, THHN and XHHW. For other conditions, refer to National Electric Code or an engineering handbook.

3: For fast reference you can also use the following table. It is a table for 48 V systems with a 5% voltage drop. The distances in the table include the NEC requirement for current over sizing of 25%.

Amps	AWG										
	#14	#12	#10	#8	#6	#4	#2	1/0	2/0	3/0	
1	15	103	160	411							
2	51	80	126	205	324						
4	22	40	62	103	162						
6	17	27	40	68	108	172					
8	13	19	33	51	81	132					**length**
10	10	16	26	41	65	103	164				**in**
15	6	10	16	27	43	68	109	176			**meters**
20		8	13	22	33	51	82	132	165	209	
25			10	16	26	41	66	105	132	167	
30			8	13	22	34	55	88	109	139	
40				10	16	26	41	66	82	104	
50				8	13	20	33	52	66	83	