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PV PLANTS FOR ALPINE HUTS: INSTALLATION AND OPERATING EXPERIENCE AT SEVEN ENEL PLANTS

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PV PLANTS FOR ALPINE HUTS: INSTALLATION AND OPERATING EXPERIENCE AT SEVEN ENEL PLANTS

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SUMMARY

The problem of supplying electric power to isolated users far from the electricity distribution grid is one of general interest. Such consumers are nowadays generally supplied with electricity produced by small diesel generator-sets, and only recently have photovoltaic arrays and wind-turbines offered an alternative to the internal combustion engine.
ENEL, as a State-owned electricity utility, is interested in the development of this particular application of renewable energy sources. Enlarging a low-voltage distribution network to connect consumers whose power requirements are extremely low (~ 1000 kWh/year) may, in certain conditions, be uneconomical, both for the utility, which has to absorb most of the expense involved in construction and maintenance, and for the consumer himself. The paper reports the design criteria, the tests and the problems encountered in electrifying seven alpine huts belonging to CAI.

1. THE "CASE SPARSE" (SCATTERED DWELLINGS) PROJECT

Small photovoltaic generators (with power of a few kW) are undergoing rapid technological change that is making them both more reliable and cheaper. However, before launching into industrial applications of this new source, ENEL deemed it advisable to conduct research on its potential production and reliability and - an extremely important point - on how far it was acceptable to the public and to users. The Scattered Dwellings Project is designed to find these things out. (1) (2)

Before trying out applications with private houses, the project provides for a phase of experiments involving consumers related to the interests of the general public, such as the Alpine shelters of the "Club Alpino Italiano".

These shelters are ideal for experimental work, and especially for demonstrating the use of PV conversion: their load demand is usually below 2000 kWh/year, they are used by the public, they are isolated, and the cost of wiring them to the electricity grid would, in many cases, be prohibitive. To date, 7 shelters have been electrified. (Table I)

2. DESCRIPTION OF PLAN

The plants have been supplied by Italian manufacturers according to ENEL's specifications, except for that of the Montanara shelter, which was entirely designed by ENEL. On-site assembly was carried out by ENEL departments that normally operate in the areas where the shelters are located.

Let us now take a look at some details of the equipment and its installation.

3. THE CONSUMER

In most cases, the units are 24 V d.c. (for lighting and refrigerators). In one case only (the Pacini shelter), the plant is 220 V a.c. In the latter case, because of the considerable distance between the building and the PV array, it was decided to convert the direct current generated by the modules to alternating current by means of a 24 V d.c./220 V a.c. inverter.

In this way, the power lost through transmission was greatly reduced. No-load inverter losses have been eliminated, since the inverter is connected up with a load-sensor.

Many of the shelters have been provided with small inverters, to enable staff to use appliances that normally have a.c. motors (slicers, drills, mixers, hair-dryers, etc.). Outside all the shelters, a special yellow light has been installed, to make it easier to spot the building at night or in fog.

4. BATTERIES

The Pacini shelter has Ni-Cd batteries, while all the others have low self-discharging Pb-lead acid batteries, made in Italy.

The decision to instal conventional Pb-acid batteries was taken after laboratory experiments to investigate the performance of these accumulators at low temperatures (down to -20°C). The test showed that, after a series of charging and discharging cycles at low temperature, conventional batteries keep up their initial performance. On the other hand the sealed batteries available on the market at the time of the experiments lost part of their initial capacity, which has been measured under standard conditions.

5. PHOTOVOLTAIC MODULES AND SUPPORT STRUCTURES

Mono- and semi-crystalline silicon modules, made in Italy, were used for the arrays. Particular care was taken over the siting of the latter, for both technical and aesthetic reasons. Installation on the roof, which is certainly preferable from the environmental point of view, was possible in two cases out of 7. (fig. 1)

6. REGULATION OF THE BATTERY CHARGE

The problem of optimal regulation of the battery charge in small photovoltaic plants remains an open question. A good regulator needs to offer a large number of advantages: - Reliability; - Simplicity of manufacture; - The ability to transfer energy from the photovoltaic array to the battery and towards the load with the maximum efficiency; - The ability to keep up battery capacity even during outages; - Low cost.

The regulators used in Alpine shelters are based on various structural principles, and the fundamental designs used are shown in fig. 2.

There are regulators in which the PV array is either completely connected or completely disconnected, or in which there is at least one level of partial utilization. A chopper, which was used in only one case, is certainly the most expensive, but is probably the one likely to ensure the longest battery life. All regulating systems use measurement of the battery's voltage for purposes of feed-back.

ENEL has decided to accept various types of regulator, in order to assess the efficiency of the various types available on the market. So far, there are no technical criteria that would justify the choice of one type rather than another. The choice generally depends on cost considerations, but the designer of PV installation must be very careful when special conditions occur.

Experimental work conducted by ENEL has shown that, in particular conditions (when the peak current of the photovoltaic array is about twice the I_{10} discharge current of the battery, and the daytime load demand is relatively low compared with peak current), the state of charge of the battery deteriorates as compared with the initial value, before finally settling down. The amount of the deterioration is dependent on the type of regulator used: the worst situation is found with a simple ON-OFF device. The situation improves if stepped regulators or a chopper are used.

7. EXPERIMENTAL RESULTS

All the plants are equipped with a system for measuring the amount of energy consumed. The meters are read periodically by shelter staff, who send the figures to ENEL. Table II shows some of the preliminary results.

8. PROBLEMS ENCOUNTERED

The technical problems encountered during the year 1986-87 were small ones, and the plants operated regularly.

However, it is worth mentioning the following points: - A relatively high fault rate in respect of inverters for fluorescent lamps (in some cases, up to 20%); - Oxidation on one of the terminal panels, resulting in interruption of the supply from a PV semi-array; - Penetration by snow of a battery-container, which led to temporary shut-down of the plant; - Faults in some of the electronic-cards of a charge regulator due to a lightning strike near the shelter; - Fault due to overvoltage in the load sensor of the inverter at the Pacini shelter; - Fault in an dedicated inverter; - Polarity inversion of a battery cell (during acceptance tests).

9. CONCLUSIONS

ENEL's experience has been successful, and it is to be hoped that CAI will consider the use of PV conversion for supplying electricity to mountain shelters in Italy. Certainly, the reaction of the public and of shelter staff has been enthusiastic. Undoubtedly, ENEL's Scattered Dwellings Project has greatly benefitted by this experience.

It is felt that the main question still outstanding is that of battery charge regulation or, more generally, that of the best way of coupling the battery to the photovoltaic array.

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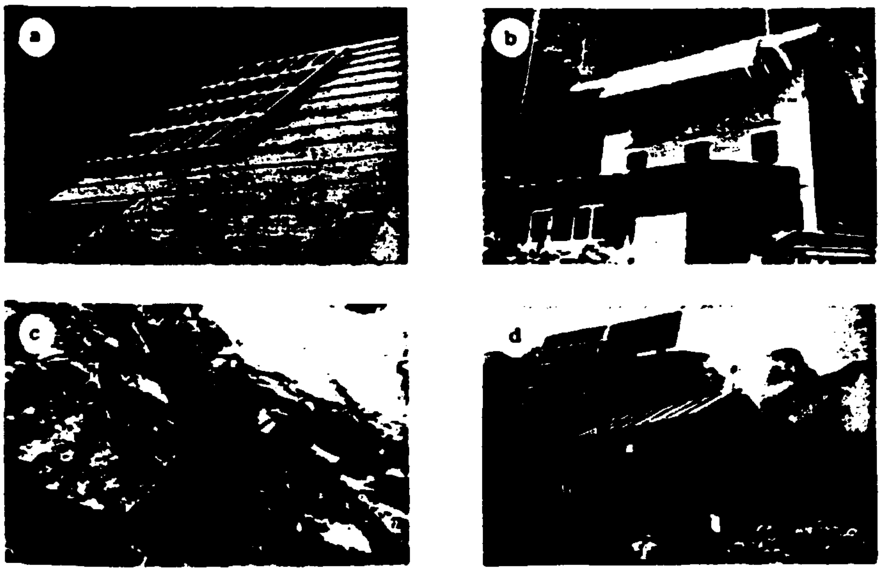


Fig. 1

a - Longoni hut
b - Montanaro resort
c - Mezzalama hut
d - Carlo Emilio resort
e - Battisti hut

TABLE I "CASE SPARSE" Project – Main features of the plants constructed by ENEL in the Alps and Apennines

Name, location and owner of the plant	Altitude (msl)	Latitude	PV ARRAY Peak power (kW)	N.° and size of the mod. (mm)	Type of cells	Tilt	E. ch. storage (kWh)	Six months' pv produc. 1/5 ÷ 30/10 (kWh)	Six months' pv produc. 1/11 ÷ 30/4 (kWh)
Mezzalama hut (AO) CAI Torino	3036	45,8°	0.35	10 (1300x350)	semicrystal.	adjustable	8.4	306	184
Carlo Emilio resort (SO) CAI Como	2140	46,2°	0.28	8 (1300x350)	semicrystal.	adjustable	6	245	147
Ponti hut (SO) CAI Milano	2550	46,2°	1.12	32 (1300x350)	semicrystal.	adjustable	24	981	580
Longoni hut (SO) CAI Seregno	2417	46,2°	0.9	24 (1041x405)	singlecrystal.	fixed 30°	26.4	728	428
Battisti hut (RE) CAI Reggio Emilia	1761	44,2°	0.7	20 (985x460)	semicrystal.	adjustable	12.6	640	401
Montanaro resort (PT) CAI Maresca	1567	44°	0.7	16 (1310x340)	singlecrystal.	fixed 60°	7.2	587	411
Pacini hut (PI) CAI Prato	1001	44°	0.8	20 (1067x445)	semicrystal.	adjustable	14	724	440
								Tilt = 30°	Tilt = 60°

TABLE II

HUT	DAILY PV PRODUCTION (SUMMER) (kWh / day)
Longoni	1.1
Battisti	1.32
Ponti	5.1
Montanaro	1.75
Pacini	2.9
Mezzalamo	*
Carlo Emilio	*

* Not yet available

CHARGE CONTROL DEVICES FOR STORAGE BATTERIES INSTALLED IN SMALL STAND-ALONE PV SYSTEMS

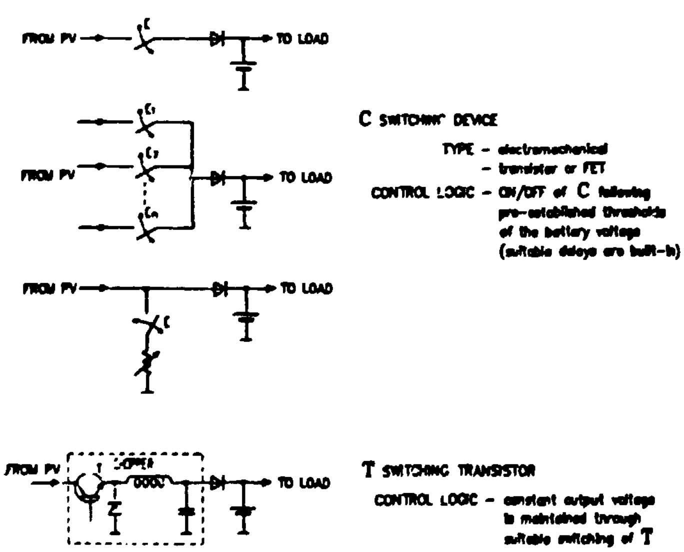
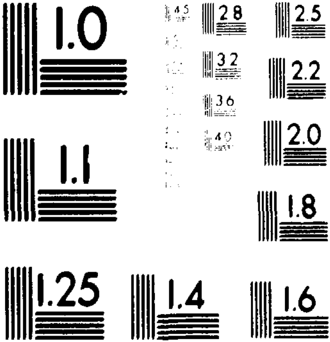


Fig. 2



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