EGAT'S EXPERIENCE WITH STORAGE BATTERIES FOR PHOTOVOLTAICS

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Introduction

A photovoltaic (PV) cell is an electronic device, without moving parts, capable of converting sunlight directly into electricity without pollution. The electricity generated by a PV is direct current (d.c.) and a rechargeable battery is required to store the derived energy for further usage when there is no sunshine, *e.g.*, at night. About 400 000 W of PV cells have already been installed in remote areas of Thailand (Table 1) and batteries are widely used as energy storage media. Usually, a 12 V 50 - 100 A h lead/acid automotive battery is supplied with a 40 W PV module. Thus, about 10 000 automotive batteries might have already been used for these PV applications.

TABLE 1

PV status in Thailand[a]

Application	Peak kilowatt (kW_p) installed										
	CU	EGAT	MH	ME	MI	MD	NEA	PEA	TOT	VH	MIS
Remote villages								60* + 60* + 30*			2
Telecommunications		6				10			90 - 100		30
Water pumping							10				5*
Primary school				15							2
Health care			1 - 2							5 - 7	3
Navigational aids		8									5
Miscellaneous lighting/TV, etc.	1 - 2	10		5	5 - 10		5				10
Hybrid/mains grid interface		27									
Total	1 - 2	51	1 - 2	20	5 - 10	10	15	150	90 - 100	5 - 7	57
Grand total	405 - 424										

[a]CU = Chulalongkorn University, EGAT = Electricity Generating Authority of Thailand, NEA = National Energy Administration, PEA = Provincial Electricity Authority, TOT = Telephone Organization of Thailand, MH = Ministry of Health, ME = Ministry of Education, MI = Ministry of Industry, MD = Ministry of Defense, VH = Volunteer Health Care Mission under the patronage of the King's mother, * = Donation from Japan.

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Due to economic constraints, thousands of remote-area communities in Thailand continue to remain without electricity, either supplied by diesel-driven generators or by extensions to the conventional grid. This situation exists despite the Government's ambitious rural electrification programme. There are, therefore, good marketing opportunities in Thailand for the PV and battery industries.

Present status of solar power in Thailand

The Electricity Generating Authority of Thailand (EGAT) is solely responsible for the generation and transmission of bulk power in Thailand. Solar power has been included in EGAT's alternative energy programme since the early 1970s. The purpose is to search for, and to encourage, new/alternative energy resources and related technologies to partially serve the ever-increasing demand for electricity.

EGAT's inventory of PV modules is presently about 50 000 W (Table 2). Applications range from navigation aids (up to 100 W) through remote survey camps and radio repeater stations (100 - 2000 W), to grid-connected demonstration plants (5000 and 20 000 W). In most installations, batteries are used to store energy. Until recently, all the batteries were of the lead/acid type obtained from a few different manufacturers (Table 3). The more expensive sealed (lead–calcium) batteries are used mainly for the navigation aids of high voltage transmission towers. The local-made automotive (lead–antimony) batteries are employed in small systems where periodic topping up of water is possible. The stationary batteries (low antimony, pure lead, lead–calcium) are used for larger systems of several thousand watt capacity. Performance data are collected from some installations for analysis and evaluation (see Figs. 1 - 3).

Results obtained from solar power systems

From observations during the past few years, it has been found that:

(i) most of the batteries used in PV navigation aids have service lives of around two years;

(ii) a number of the batteries in (i) failed to retain charge from the beginning and therefore had to be replaced;

(iii) most of the local-made* automotive batteries used in small PV systems have exhibited corrosion of the terminals, even after relatively short operating periods;

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*Although there are a number of automotive battery manufacturers in Thailand, EGAT as a state-owned enterprise is obliged to use only automotive batteries manufactured by the state-owned battery organization.

TABLE 2

PV status in EGAT

Activity	Region				
	Central	North	East	South	Total (kW)
Navigational aids	0.7	1	3.3	3	8
Telecommunications	2	2	2	—	6
Hybrid					
PV + wind	—	—	—	6	6
PV + hydroelectric		—	21	—	21
Miscellaneous	2	5	2	1	10
Grand total					51

Note: proportion of PV technology installed in EGAT: single-crystal silicon 49%, poly-crystal silicon 45%, ribbon silicon 4%, amorphous silicon 2%.

TABLE 3

PV battery inventory at EGAT

Trade name	Model	Capacity (A h)	Volt (V, nominal)	Type	Quantity
Delco	Delco 2000	105	12	sealed lead–calcium, automotive	28
Exide	COM-30H	90	12	lead–calcium, automotive	8
Viva	V6CR	100	6	lead/acid, automotive	48
GNB	Absolyte 12-5000	100	12	sealed lead–calcium, automotive	40
Varta	VB624	100	6	low-antimony, stationary	85
Oldham	TUS2	120	2	lead/acid, stationary	125
FB	PS200TL	100	2	lead–calcium, stationary	125
Chloride	2G225	225	2	pure lead positive, stationary	125
Power D		120	12	lead–antimony, automotive	100

(iv) burned or melted contacts have been found in some of the regulator relays that disconnect the load from the battery;

(v) most of the stationary batteries used in the larger PV systems are still functioning with no reports of any significant performance degradation, despite being subjected to a large number of charge/discharge cycles during the past few years (Figs. 1 - 3).

As a result of the above findings it appears that, first, the high ambient temperature of the tropical climate in Thailand, as well as the frequent charge/discharge cycling demanded by typical PV applications both serve to shorten the life expectancy of the batteries. In this regard, low-antimonial batteries should provide a better performance than lead–calcium types. Second, it is clear that many sealed batteries were left uncharged for too long a period — either before or after delivery to customers — and thus most of the ampere-hour capacity of the batteries was lost through sulphation of the plates. Third, it is possible that premature failure of the first few sealed

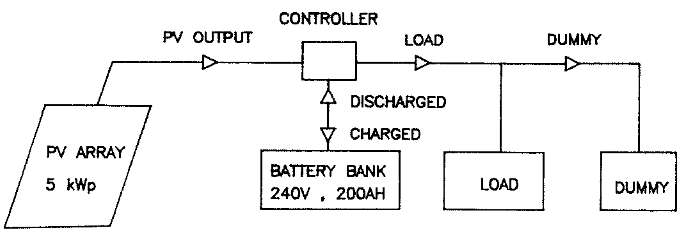

Fig. 1. Schematic of PV/battery system installed at Khuan Promthep, Phuket.

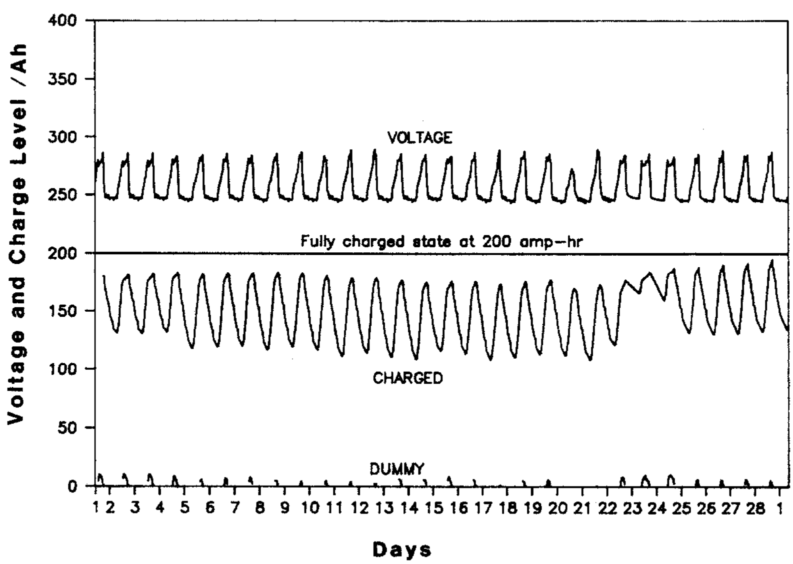

Fig. 2. Voltage and state-of-charge of batteries operating at Khuan Promthep test site during February 1989.

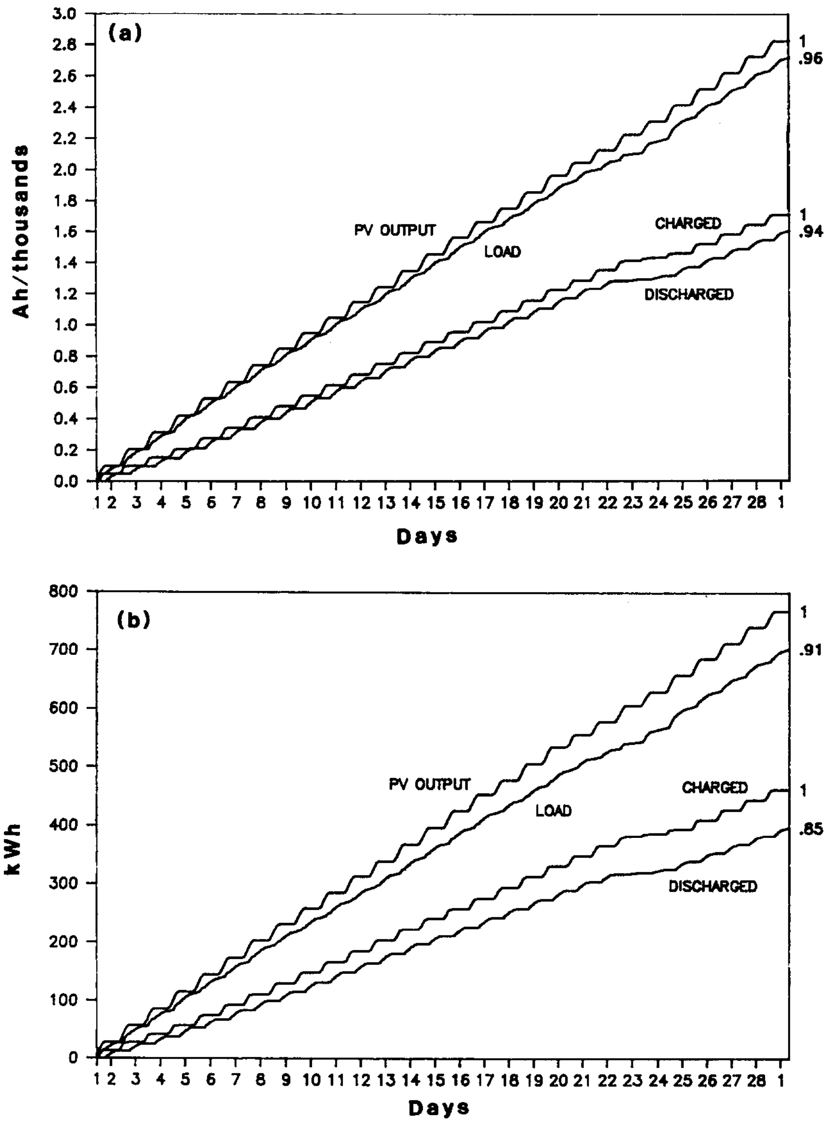

Fig. 3. Cumulative flows of (a) electricity and (b) energy in Khuan Promthep test site during February 1989.

batteries used in PV navigation aids was caused by improper setting of the charge/discharge regulators (*i.e.*, to give too high a charging voltage or too low a discharging voltage). Finally, leakage of electrolyte gave rise to corrosive reactions at the terminals of many local-made batteries and this, in turn, resulted in poor electrical contact with the PV modules so that some batteries were under-charged.

Conclusions

EGAT's experience with PV/battery power systems to date has resulted in the following conclusions.

1. A maintenance-free battery is required for remote-area power supplies. Possible candidates are a deep-discharging lead–calcium battery, a low-antimonial battery with extra electrolyte, or a nickel/cadmium battery. At present, the best choice for EGAT's PV applications is the low-antimony option.

2. Periodic inspection of the level and the specific gravity of the electrolyte are strongly recommended. In addition, scheduled cleaning of the battery terminals is necessary in order to prevent corrosive attack.

3. Scheduled boost charging is necessary for sealed batteries that have to be stored for long periods either before or after delivery to customers.

4. An under-voltage regulator is necessary to separate the load from the battery at a pre-determined battery voltage level; if over-discharged, the service life of batteries will be shortened. For a small system using less than 100 W of PV modules and a 50 to 100 A h battery, a high top-of-charge voltage will help to reduce electrolyte stratification. In these instances, an over-voltage regulator may not be required.

5. When using sophisticated electronic regulators, it is necessary to take precautions in environments where strong electromagnetic fields (*e.g.*, at, or around, high-voltage transmission towers) or frequent thunderstorms (during monsoon season) are to be expected.

6. The contacts in charge-regulator relays should be protected with arc suppressors in order to prolong their service lives. Of particular concern are the contacts that disconnect the load from the battery.

7. The high temperatures experienced in tropical climates may reduce considerably the service lives of batteries unless adequate ventilation is provided.