Operation and management of batteries in photovoltaic power systems under development in Japan*

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Abstract

A review is given of the lead/acid battery types being used in photovoltaic power-generating systems under development by NEDO in Japan These systems find a wide variety of applications in remote areas

Introduction

The efficient utilization of various natural energy resources, such as solar energy, will reduce the consumption of fossil fuels and will moderate environmental pollution problems caused by CO_2 and NO_x emissions Unfortunately, the photovoltaic (PV) generation of electrical power depends largely on weather conditions, therefore providing an unstable supply Consequently, it is necessary to use storage batteries in PV systems

Since 1980, as part of the Sunshine Project, NEDO has been developing technology for PV power-generation systems by enhancing solar cell conversion efficiency and reducing the BOS costs Efforts have been aimed at achieving the earliest possible commercialization of PV power-generation systems

At present, the cost of PV power generation is several times higher than that produced by utilities Nevertheless, the price of PV power is expected to be reduced to the level of diesel generation in the near future, i e , ~ 100 ¥ kW h^{-1} As a result, current research is concentrating on the development of stand-alone PV systems for isolated islands and other remote areas.

NEDO survey of storage batteries in PV systems

A summary of the NEDO research and development projects on storage batteries with capacities of 10–1800 kW h is given in Tables 1–3. The work has been conducted on a wide variety of batteries with different construction

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TABLE 1

Battery storage component in stand-alone PV systems developed by NEDO

Application	PV (kW)	Period	Storage battery rated capacity (kW h)	DOD (%)	Model	Rate	Charge	Electrolyte diffuser	Remarks
Building lighting	32	'87–	112 (2 V×100×560 A h)[a]	70	SLB-600	High	Float	Own	Mini-hydro hybrid (2 kW)
Brackish water desa	65	'88–	230 (2 V×96×1200 A h)	70	SLB-1600	High	Float	Own	
Mountain lodge	70	'88–	128 (2 V×57×(420+700) A h)	75	SLB-600	High	Contrl	Own	Wind power hybrid (1 kW)
					SLB-1000	High	Contrl	Own	
Warning system	16	'89–	93 (2 V×93×500 A h)	65	SRE-500	High	Float	Non	
Marine farm	10	'85–'88	153 (2 V×64×1200 A h)	50	SLB-1200	Low	Float	Own	
Tunnel lighting	17	'86–'88	56 (2 V×100×280 A h)	65	SLB-400	High	Float	Own	
Broadcasting	36	'86–'88	360 (2 V×18×4 P×2500 A h)	80	SLB-2500	Low	Float	Own	
Desalination (RO)	30	'85–'88	87 (2 V×52×840 A h)	50	SLB-1200	High	Float	Non	
Remote island I	50	'84–'87	305 (2 V×136×1120 A h)	70	SLB-1600	High	Contrl	Own	Diesel hybrid (45 kW)
Greenhouse	300	'88–	500 (2 V×100×(2000+500) A h)	70	CSL-500	High	Float	Own	
					CSL-2000	High	Float	Own	
Woodman lodge	5	'85–'88	173 (2 V×96×3 P×300 A h)	50	CSL-300	High	Float	Non	Dendro hybrid (1 4 kW)
Mountain cottage	5	'84–'87	125 (2 V×52×1200 A h)	60	PS-1200TL	Low	Contrl	Non	Fuel cell hybrid (4 kW)
Swine farm	30	'85–'88	192 (2 V×96×1000 A h)	80	CS-1000	High	Float	Non	Methane hybrid (20 kW)
Desalination (ED)	25	'84–'88	115 (2 V×48×2 P×600 A h)	30	CS-600C	High	Float	Non	

[a]Cell voltage (V)×No of cells×No of parallel strings (P), if any,×cell capacity (A h)

TABLE 2

Battery-storage component in inter-connected normal PV systems developed by NEDO

Application	PV (kW)	Period	Storage battery rated capacity (kW h)	DOD (%)	Model	Rate	Charge	Electrolyte diffuser
Remote island II	200	'87–	610 (2 V×136×2 P×1120 A h)[a]	70	SLB-1600	High	Contrl	Own
Centralized	1800	'80–'89	1800 (2 V×190×9 P×526 A h)	50	CS-600	High	Contrl	Non
					CSL-600	High	Contrl.	Non
Dispersed system	25	'80–'86	400 (2 V×120×2 P×800 A h)	55	HS-800	High	Contrl	Non
Test I	2	'84–	16 (2 V×90×90 A h)	55	CS-90	High	Float	Non
Test II	3	'84–	24 (2 V×90×130 A h)	55	CS-130	High	Float	Non

[a]As for Table 1

TABLE 3

Battery storage component in inter-connected, non-reverse-power PV systems developed by NEDO

Application	PV (kW)	Period	Storage battery rated capacity (kW h)	DOD (%)	Model	Rate	Charge	Electrolyte diffuser	Remarks
Villa	2	'87–	17 (12 V×16×90 A h)	80	EB-90	High	Float	Non	
Multi-family house	20	'80–'84	114 (2 V×95×600 A h)	50	SF-600L	High	Float	Non	
Workshop	6	'80–'84	37 (2 V×110×170 A h)	50	SF-170L	High	Float	Non	PV/thermal concentrator
Residential house	3	'85–'89	38 (12 V×16×200 A h)	50	12CT-200	High	Float	Non	PV/thermal flat plate
					12CT-1000	High	Float	Non	
Residential system	3	'80–'84	14 (12 V×12×2 P×50 A h)	80	EB-50	High	Float	Non	
School	200	'80–'86	576 (2 V×120×2 P×1200 A h)	75	HS-1200E	High	Float	Non	
Factory	100	'80–'86	500 (2 V×100×2500 A h)		ES-2500E	High	Float	Non	

and operational techniques, performance characteristics, and maintenance procedures. The optimum capacity, design specifications, construction and operating methods have still to be established for the batteries.

A two-year survey program was commenced in 1990 to evaluate the performance of batteries already in operation and to determine battery specifications for future designs of PV power-generating systems.

Problems encountered with lead/acid batteries include:

(i) plate sulphation;

(ii) corrosion of the positive grid;

(iii) damage to separators;

(iv) breakage of containers, terminals, etc.

These problems are closely connected with internal factors (i.e., type and design of the battery, charging conditions, electrolyte density, grid alloy composition) and with external factors (i.e., number of cycles, depth-of-discharge, temperature, maintenance procedure, handling techniques). Laboratory tests are being undertaken to gather data on the failure modes of batteries.

Since most PV systems use batteries connected together in strings, non-uniform electrical conditions may occur between the individual units In extreme cases, it is possible that the batteries may become overcharged or over discharged. Therefore, the survey includes the collection of data on the voltage and current experienced by each battery in series/parallel configurations typically used in PV systems

To determine the relationship between utility duty and lead/acid battery failure, the following items are being examined:

- PV system specifications
- PV system operation results and maintenance techniques
- storage battery specifications
- storage battery performance
- methods for tear-down analysis of battery components
- storage battery modes of failure
- research activities and findings in countries outside Japan

Battery operation and management of a photovoltaic system

In order to research and develop a PV system giving a stable supply of power, even during rainy and cloudy periods, the battery capacity was set to 1.8 MW h. The rated battery voltage was based on 500 V d.c. inverter input, and consideration was given to a 680 V rising charge method and the 380 V falling charge method. The latter was selected on the basis of safety, controllability (particularly over a wide range of voltages) and economy. The specifications of the battery were as follows.

- type· tubular plate
- voltage: 380 V (190×2 V cells connected in series)
- capacity: 1800 kW h (*C*/10 rate)

- system configuration 200 kW h × 9 strings in parallel
- single-cell minimum capacity 526 A h
- energy efficiency 75% (minimum)
- operating conditions ambient temperature 15–45 °C, depth-of-discharge. 40–50%

The effective capacity was set at about 1 MW h, taking the battery capacity of 1.8 MW h into account, and the charge/discharge rate at 200 kW/5 h The charge/discharge method involved

- connection operation fixed power control (minimum power compensation, fixed maximum power control)
- independent operation fixed load voltage control
- restoration charge fixed current control
- equilization charging fixed current control

Concluding remarks

Many types of storage battery may be used in PV systems, depending on the application There is still a need, however, to improve the effectiveness of battery operation In Japan, research and development on PV systems includes work on both lead/acid batteries and alternatives such as redox-flow and nickel/hydrogen batteries