RECENT SODIUM SULFUR BATTERY APPLICATIONS IN JAPAN

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1 ABSTRACT

The sodium-sulfur (NAS) battery has been under development by Tokyo Electric Power Company (TEPCO) and NGK insulators, Ltd., since 1984. Its long term reliability and high performance have been confirmed in more than twenty demonstration projects dating from 1992. This report summarizes the most recent advancements in NAS battery development and deployment, including early investigation of power quality and emergency DC power applications

2 NAS BATTERY DEVELOPMENT

At the 1998 ESA Fall Meeting, NGK described the evolution of NAS cells from 160Ah (T4.1), to 248Ah (T4.2), and then to 632Ah (T5) cell capacity, as well as the results of tests and demonstrations (Reference 1). The focus of development activities was on daily load-leveling (or peak-shaving) applications for about 8 hours. Since then, long-term tests and demonstrations have continued, and results are very good. For example, as shown in Figure 1, the rates of degradation of NAS T4.1 cell capacity and energy over 5000 cycles are very low.

Meanwhile, additional emphasis has been placed on refinement of the NAS T5 cells and battery modules for power quality applications, which require pulses of power for periods from 5 to 15 minutes. Initial results of tests for such applications were reported in the Fall of 1999 (Reference 2).

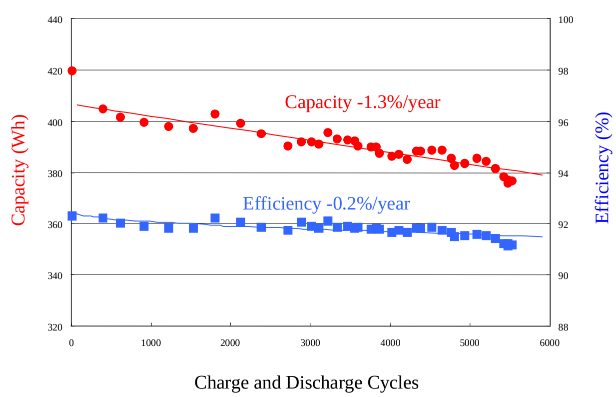


Figure 1 Performance Stability of T4.1 Cells

Module specifications for these applications are summarized in Table 1. The most prominent difference between Type 1 (load-leveling) and Type 2 (power quality) design is the increased number of cells placed in series. This enables fewer modules to used to achieve battery terminal voltages needed for commercial power quality applications. The 50kW Type 2 module uses 320 cells in series for commercial (e.g., 480Vac) applications, and the 12.5kW Type 2 module uses 72 cells in series for lower voltage applications.

Table 1. NAS Module Specifications

	50kW Module		12.5kW Module
	TYPE 1	**TYPE 2**	**TYPE 2**
Application	Load-Leveling or Peak-Saving	Power Quality or Spinning Reserve	Power Quality or Spinning Reserve
Nominal Output DC Power, kW	52.1	52.1	13.4
Average Discharge Voltage, Vdc	59.7	597	132
Energy, kWh	375	375	80.4
NAS T5 Cell Connections S – series P – parallel	[8Sx10P]x4S	320S	72S
Size WxDxH, Millimeters (inches)	2170x1690x640 (85x67x25)		680x1400x640 (27x55x25)
Weight, Kilograms (pounds)	3400 (7496)	3400 (7496)	750 (1653)
High Power, % nominal	NA	500	500

The pulse power capability of Type 2 NAS battery modules, nominally rated for a 7.2 hour discharge (i.e., 100%) is illustrated in Figure 2 for durations ranging from 5 minuets to 10 hours. Pulse durations of 500% for 30 seconds are sufficient to address more than 95% of

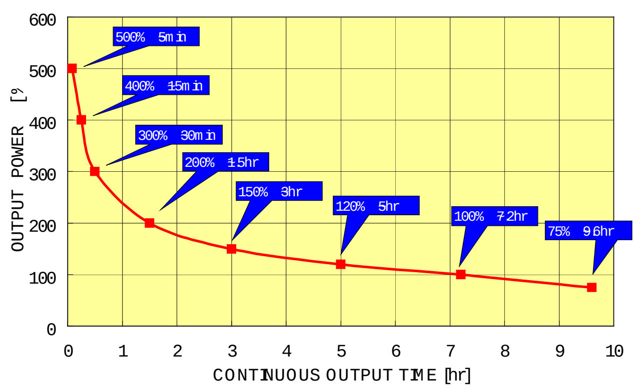


Figure 2 Pulse Power vs Duration Capability

power quality events and provide transition to backup generation. In addition, at 400% rate power, NAS can sustain a 15-minute pulse which is sufficient time to start and synchronize primary generation assets, i.e., this application is functionally equivalent to spinning reserve. With proper thermal management, NAS power quality and peak shaving applications can be combined under some conditions. NGK limits the operating temperature range to 290 and 360C to ensure highly reliable performance and achieving design life.

Other dynamic response characteristics important for power quality applications include transient response and charge/discharge reversal. Figure 3 illustrates that response from zero to 500% demand occurs in less than 1 millisecond, and Figure 4 shows that transition from a charging to discharging state remains continuous under cyclic loading. These attributes are also important to such as applications as stabilization of wind and solar power generation.

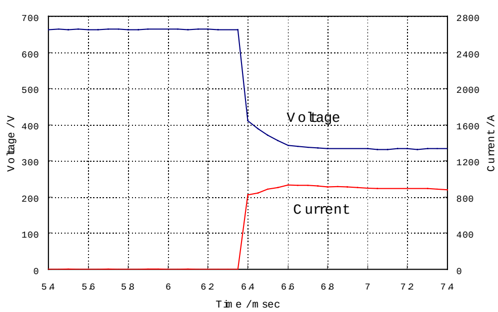


Figure 3 Response to 500% Transient

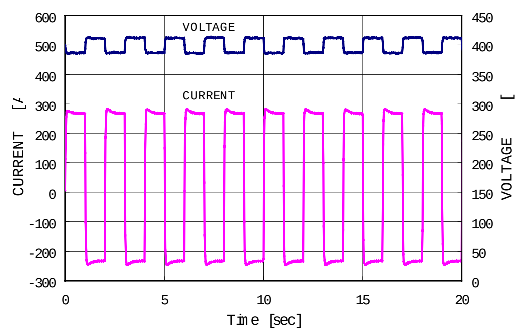


Figure 4 Response to Cyclic Charge/Discharge

For all applications, experience has shown that the need for field maintenance should be avoided whenever possible, and this remains an important design goal. The NAS battery is completely sealed, and thermal management is accomplished with internal electric heaters and natural air convection to maintain the operating temperature range without forced cooling via fans or pumps. As a result, the NGK design is essentially maintenance free, with only routine inspection and cleaning required to ensure adequate air flow. No other scheduled maintenance is required.

3 NAS BATTERY DEMONSTRATIONS

Demonstration of Type 1 modules using NAS T5 cells for load-leveling and peak-shaving applications has been in-progress since March 1999. Recently deployed projects, and projects in the planning stage, are described below. Plans for demonstrating Type 2 modules are under development for several power quality (and combined power quality and peak shaving) applications. In the interim, the dynamic attributes of NAS batteries are being demonstrated in a wind energy stabilization project described below.

3.1 Load-Leveling & Peak Shaving Demonstrations

Two, 2MW NAS battery systems for load-leveling applications were installed this year at TEPCO's Tsunashima and Shinagawa substations. Specifications for these installations are summarized in Table 2. Each installation is configured in 2 parallel trains of 20 modules in series with a power conversion system. A photograph of the battery system and the site arrangement for the Shinagawa substation are shown in Figures 5 and 6, respectively. The NAS battery's high energy density (compact size) was an important factor in accommodating the inner city space constraints imposed by both sites.

Table 2 2MW NAS Battery System Specifications

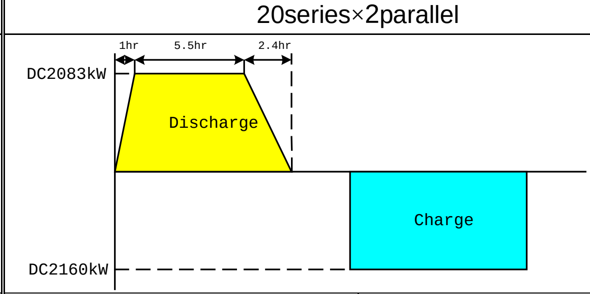
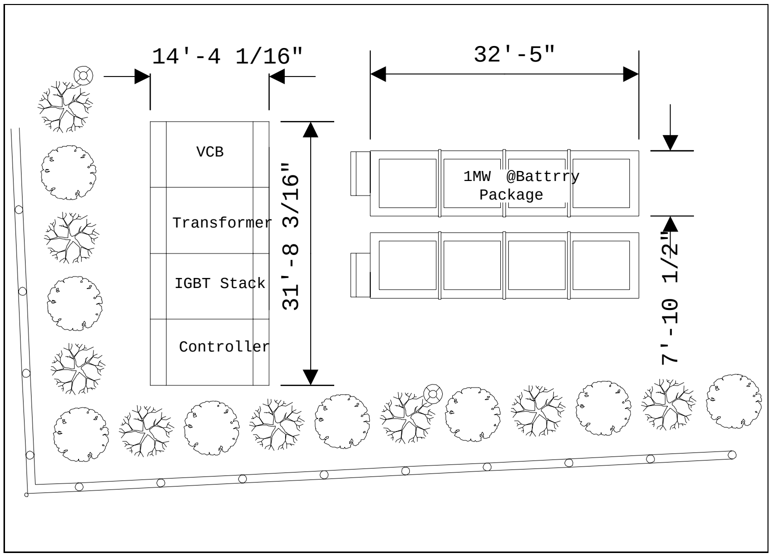
	Tsunashima Substation	**Shinagawa Substation**
Nominal Output DC Power, kW	2083	
Average Discharge Voltage, Vdc	1165	
Energy, kWh	15,000	
Module Type	50kW Module (TYPE 1)	
Module Connections	20series×2parallel	
Load-Leveling Operating Profile		
Start Date	November 27, 2000	March 28, 2001
DC Efficiency, %	81.2	80.7

Figure 3 .
2MW NAS Battery System

Figure 4. Layout of
2MW NAS Battery System
at Shinigawa Substation



In addition to utility load-leveling applications, customer peak-shaving applications are cost effective in Japan, and generally require smaller systems. Several 250kW NAS battery peak shaving systems will be installed at water treatment plants this year. As illustrated in Figure 7, the electric load for these installations has both morning and evening peaks each day, plus low demand during the middle of the day when the load on the utility system is highest. Stored energy (red) will displace peak energy (dark blue) and enable estimated cost savings of ¥10,350,000 (~83,000USD). Furthermore, emergency power capability (e.g., UPS functions) from on-site stored energy and power conversion will ensure high reliability and add value to the NAS battery installations.

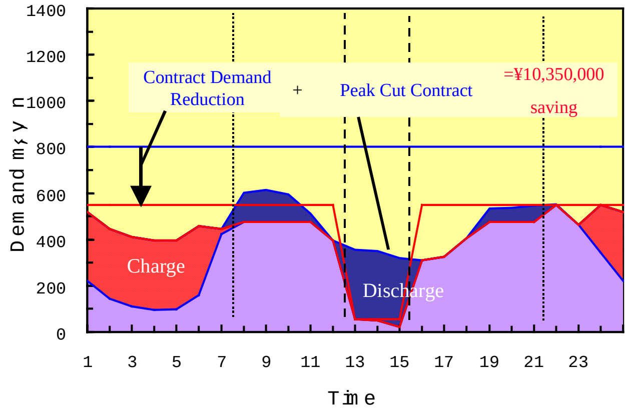


Figure 5 250kW NAS Battery Systems at Water Treatment Plants

3.2 Dynamic Response Demonstrations

The dynamic response characteristics of NAS batteries are being demonstrated in a NEDO[*1] sponsored program on wind generation. In March of this year, a 400kW NAS battery energy storage was integrated with a 500kW wind generator to stabilize both short and long term fluctuations. Results of this arrangement over a 3-minute period are shown in Figure 8. Power from NAS batteries (blue) ranging from about +200kW (discharging) to -200kW (charging) is stored or injected at high frequency such that net output is constant within a band of about 30kW.

The NAS battery system can provide 400kW charge or discharge power for stabilization, except at full charge and full discharge. To maintain an acceptable range of power for stabilization, the system state-of-charge is managed to ensure margin for accepting or injecting power, as illustrated in Figure 9.

[*1] New Energy and Industrial Technology Development Organization

Project participants are TEPCO, NGK and HESCO[*2]. The installation is located on Hachijo Island, about 290km southeast of Tokyo.

Figure 8. NAS Stabilized Wind Generation

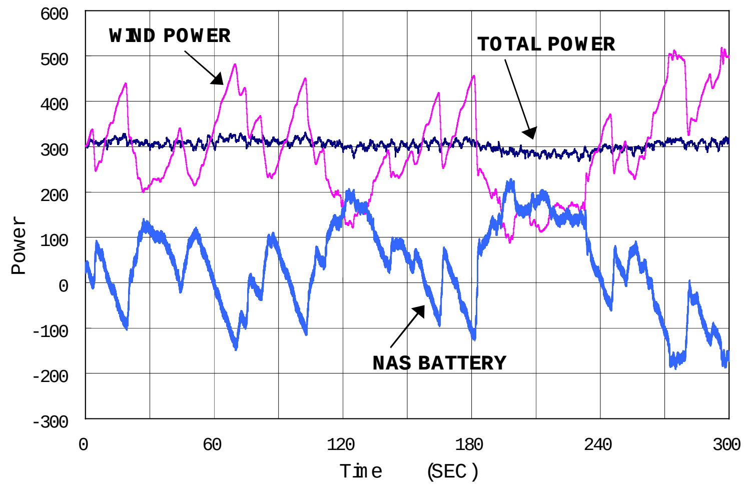
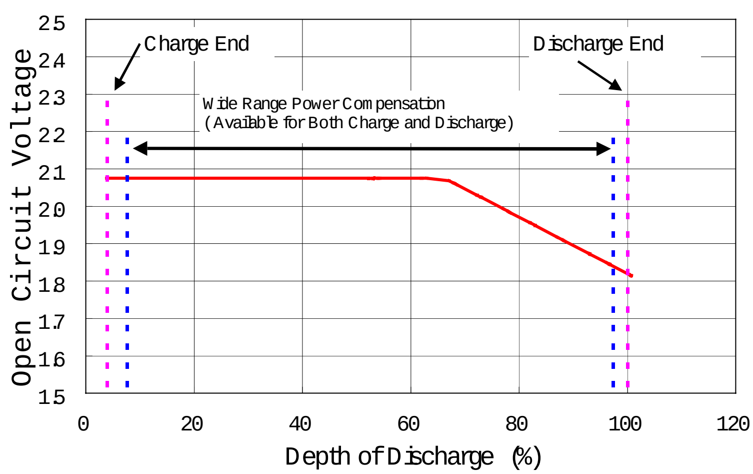


Figure 9. NAS Charge Control for Wind Stabilization



[*2] Hitachi Engineering & Services, Co., Ltd.

3.3 Other NAS Demonstrations

The development of NAS batteries has been focused on utility load-leveling and commercial power quality applications. However, NAS technology is also well-suited as a source of DC emergency power, and the recent rapid growth in information technology (e.g., communications and computers) has created a premium market for highly reliable backup power. Specific attributes that make NAS batteries an attractive option for this market include:

- High energy density, efficient space utilization
- Minimal required maintenance
- Insensitivity to temperature
- No self-discharge
- 15-year life

Figure 10 shows the simplicity of a NAS battery-based emergency DC power source. Since there is no self discharge, float charging is unncessary, and a simple diode prevents over charge.

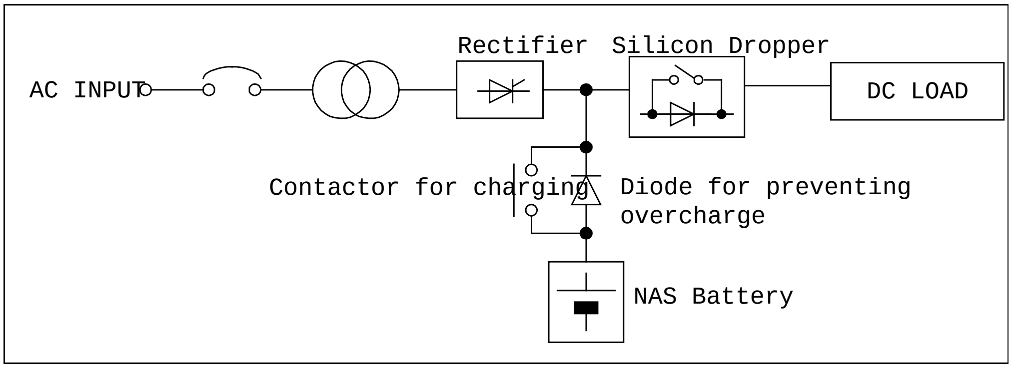


Figure 10. NAS Battery System for Emergency DC Power

4 REFERENCES

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2. Development of Compact Sodium-Sulfur Batteries, 6th International Conference on Batteries for Utility Energy Storage, September 1999, by T. Oshima and H. Abe, Sodium Sulfur Battery Division, NGK Insulators, Nagoya, Japan.