Commercial Deployment Of The NAS Battery In Japan

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In April 2002, TEPCO launched direct sale of NAS battery systems to its customers, and 16 systems have already been commissioned as of the end of September 2003. An overview of the NAS battery system commercial deployment through TEPCO and two actual systems are presented in this paper. TEPCO also has installed NAS battery systems at its substations for load leveling. NAS battery system installations at TEPCO substations are also presented and benefits compared with DSM programs are explained.

1. INTRODUCTION

In April 2002, TEPCO launched the direct sales, including system design, installation, commissioning, maintenance and operation, of the NAS battery system to their commercial and industrial customers. The purpose is to satisfy the requests from customers wishing to have extremely reliable power supply. In parallel, NGK, the co-developer of the NAS battery, committed to commercial-scale NAS battery production facilities. Figure 1 shows NGK's new NAS battery assembly plant whose annual production capacity is 65MW/520MWh. This plant started its operation this past April, providing reduced NAS battery production costs and prices, which encourage Japanese customers to install the NAS battery system.

Figure 1 – NAS battery commercial-scale production factory

2. Overview of NAS battery system commercial deployment

As of the end of September, commercial NAS battery systems deployed through TEPCO are operating at 16 sites with an accumulated capacity exceeding 15MW/90MWh. The commercial systems are listed in Table 1.

Table 1 – Commercial NAS Battery Systems Deployed Through TEPCO

Customer Type	Function	Capacity	Customer Type	Function	Capacity
Car Manufacturer	LL	1,500kW	Amusement Park	LL+EPS	1,000kW
Pharmacy	LL+UPS	250kW	Semiconductor Factory	LL+UPS	1,000kW (3,000kW)*
Shopping Center	LL	750kW	Waterworks	LL+UPS	300kW
Shopping Center	LL	1,000kW	University	LL	1,000kW
Shopping Center	LL	1,000kW	Waterworks	LL+UPS+EPS	400kW
Shopping Center	LL	1,000kW	Printer Supply Material	LL+UPS	200KW
Hospital	LL+UPS	250kW	Chemical Processing	LL+UPS	2,000KW
Waterworks	LL	200kW	Food Processing	LL+UPS	500kW (1,500kW)*

Note : 3 times of rated power is supplied for UPS function.

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LL = Load Leveling; UPS = Uninterruptible Power Supply; EPS = Emergency Power Supply

Figure 2 depicts how many commercial NAS battery systems have been commissioned in each quarter. From 1st quarter 2003, NGK started operation of the commercial-scale NAS production line and the price of the NAS battery has been decreased. This helps TEPCO NAS battery business expansion and TEPCO plans to supply around 30MW of NAS battery systems to its customers in 2003. Figure 3 illustrates the distribution of NAS battery system functions for the existing commercial systems.

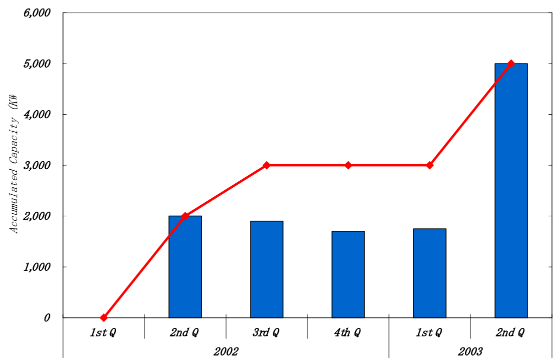

Figure 2 – Evolution of NAS battery system sales

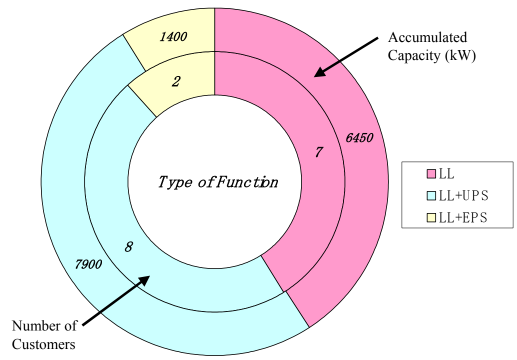

Figure 3 – Distribution of NAS system functions

By making use of the NAS battery's large energy capacity, high efficiency and long durability, all the customers are using the NAS battery system for load leveling which reduces their cost of electricity. Since the annual load factor of TEPCO's power system is relatively low, for example 56.2% in 2002, load leveling at a customer site is useful for the improvement of the utilization of TEPCO's overall generation and T&D facilities. In accordance with the increase of NAS battery system installations, customers recognize the high reliability of NAS battery system and many of them adopt the NAS battery system for Power Quality support as well. Now more than half of the customers also apply the NAS battery system for uninterruptible power supply or emergency power supply.

3. Examples of NAS battery systems at customer sites

We present two NAS battery systems installed at customer sites. Figure 4 shows the NAS battery system installed at the new semi-conductor technology center of Fujitsu, a world famous IT & communications solution company. Fujitsu had experienced several voltage sags and power supply interruptions during the technology center's construction period and anticipated potential enormous economical damages caused by such power quality problems. To decrease the possibility of power supply interruption, insulators with lightning arrestors were installed at each transmission line tower and an automatic switching device, which detects power supply interruptions on the power supplying line and switches to the other standby supply line, were installed. To solve voltage sag problems, Fujitsu evaluated many solutions including the lead acid battery, capacitors, flywheel, fuel cell, other advanced battery and the NAS battery. Fujitsu evaluated these options from the viewpoint of initial cost, operation & maintenance cost, impact on the environment and system reliability. As a result, Fujitsu appreciated the NAS battery system's superior features, including its daily load leveling capability, and selected the NAS battery system.

This NAS battery system consists of 20 of the 50kW NAS battery modules and supplies 1000kW during 7 hours for daily load leveling. By making use of the NAS battery pulse power capability, this system can secure up to 3000kW of critical load when voltage sags occur. As for the system design, we adopted the line interactive Stand-by Power Supply (SPS) topology instead of the double conversion topology. Though this SPS topology decreases the power flow loss during normal operation, the voltage at the load side is distorted until the establishment of power supply from NAS battery system. To avoid any influence of this voltage distortion, we studied the immunity of the critical load in cooperation with Fujitsu and defined the duration of over 11% voltage sag as not more than 20ms. From its commission on July 2002, there have been 5 such voltage sags. The NAS battery system functioned properly for all of the voltage sag events and Fujitsu suffered no damages. An example of voltage waveform during voltage sag is shown in Figure 5. While the voltage sag at grid side continued for 80ms, the NAS battery system responded immediately and the duration of voltage distortion at load side was only 2ms.

The other example is the NAS battery system installed underground of an amusement park, Tokyo Dome City LaQua, located in the heart of Tokyo Metropolitan area. This NAS battery system operates for load leveling and for emergency power supply, which does not require a prompt response power conversion system (PCS). A photo of the NAS battery and PCS is presented in Figure 6. This system provides backup power for selected loads, including sprinklers, fire detection and extinguishing devices, exhaust fans, emergency elevators and emergency lights. Ten percent of the NAS battery capacity, namely 720kWh, is always reserved for this purpose.

Figure 4 – NAS battery system for LL and UPS

Figure 6 – NAS battery system for LL and EPS

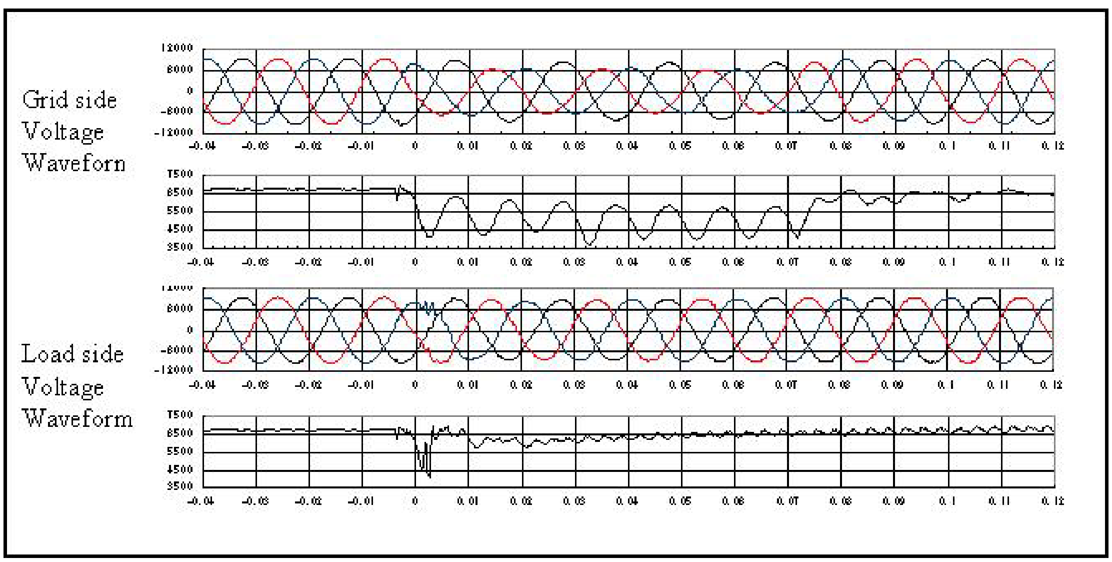

Figure 5 – Voltage waveform during voltage sag

4. NAS battery system at TEPCO substations

TEPCO also installs the NAS battery system at its substations. Through earlier demonstration projects, rated at 6MW and 48MWh, at Tsunashima substation and Ohito substation, we established the reliability of NAS battery systems for such applications. TEPCO selected a 2MW system as the standard unit for utility substation applications and executed system design standardization. Demonstration of the first 2MW standard system was achieved at Shinagawa substation in 2003, as shown in Figure 7 with two 1MW, back-to-back enclosures.

Now, TEPCO operates a 1MW practical NAS battery system at Chichibu substation and plans to install 2 standard size systems this fiscal year. The principal purpose of these installations is to defer T&D facility upgrades. In Japan, as in other advanced countries, electrical demand growth has declined and is unforeseen in some cases. Hence, the electric utility would like to avoid the risk of large investment such as the construction of new transmission lines. Accordingly, modular and relocatable capacity upgrades using the NAS battery are attractive.

Figure 7 – 2MW NAS system at Shinagawa S/S

Figure 8 – 1MW NAS system at Chichibu S/S

5. Comparison of electric energy storage and demand side management

To cope with peak demand growth, electric utilities have many options, such as new generation plant construction, enhancement of interconnection with neighboring grids, purchase surplus power from off-grid generators, demand side management (DSM) programs and load leveling by electric energy storage facilities. While most of the options are the approaches from supply side, DSM and load leveling are the solutions from demand side. DSM is an approach where demand responds to actual prices and is curtailed by price escalation. Since DSM seems to require no additional equipment, it looks like an ideal solution. Though the electricity tariff structure can be thought of as a type of DSM, we will address the more direct load control type DSM programs in this paper.

Compared with other commodities, electricity has several unique characteristics; first is the requirement of exact balancing between supply and demand at every instant, second is the necessity of the long period for supply side enforcement and third is low elasticity of demand. These characteristics are constraints for power system planning and operation. From the perspective of electric power system planning and operation, we would like to indicate the advantages and disadvantages of electric energy storage solution in comparison with DSM programs.

(1) Response reliability

In daily power system operation, power system operators dispatch generation facilities in accordance with present demand and demand forecast. Generally speaking, imbalance between generation and demand within 1 minute is adjusted by self-output control of generators with Automatic Generation Control (AGC), and imbalance within several 10s of minutes is controlled by output control of generators in response to Load Following Control (LFC) signal from power system operator. Imbalance of longer term is adjusted by Economic Dispatch Control (EDC), and by pre-defined generator schedule operation. Since most of the DSM programs are based on the customers' voluntary action, the power system operator is anxious about how much demand will be curtailed by the DSM program. This uncertainty is also applied to power flow and some vacant capacity of transmission and distribution facilities must be assured. When DSM programs are widely adopted, power system operators shall take into account total amount and distribution of curtailed load by DSM programs. Even if statistical data are correctly accumulated and estimation is executed carefully, the forecasted value has some uncertainty and power system operators shall prepare other resources for backup. In contrast, electric energy storage systems with appropriate control settings function almost perfectly, so power system operators can count on the amount of curtailed load by electric energy storage.

(2) Response speed
Another advantage of electric energy storage is its response speed. When a power system operator requests reduction of demand through DSM programs, the request must be sent in advance for the customer to take necessary measures to curtail loads. This time lag disturbs usage of DSM program for emergency situation such as sudden trip of an important generation or unexpected rapid demand growth often caused by hot weather. On the contrary, electric energy storage system reacts very quickly, for example typical response time of battery energy storage system is less than 1 second. This feature makes it possible to use battery energy storage system for regulation control and/or spinning reserve.

(3) Planning Certainty
The other superiority of electric energy storage is the planning certainty. Since the DSM program needs neither land acquisition nor construction work, it can be implemented in a relatively short period, which enables the use of the DSM program for an immediate need such as peak demand reduction in the next summer. In the meanwhile, demand forecast in the near future is concrete, so power system planners need to build up a firm supply plan and wish to know how much load can be curtailed through the DSM program with high accuracy. But it is not easy to predict how an existing DSM program works in the next summer and it is even more difficult to know how many customers will participate in a new DSM program. This uncertainty forces the power system operator to underestimate the effect of DSM program and obliges the procurement of more conventional generation. Except for pumped storage hydro plant and large CAES plant, electric energy storage system can be installed in relatively short time period. Most of battery energy storage systems with modular structure, which can be thought of as distributed energy resources, can start operation within 1 year from planning. Further, taking into account the necessity of the troublesome rule making process for DSM programs, electric energy storage is a more assured, reliable and flexible measure for system planning.

(4) Implementation Cost
One problem of electric energy storage is its implementation cost. Since relevant electric energy storage systems, other than pumped storage hydro plants, are pre-commercial or market entry stage, its prices are not mature. On the other hand, DSM programs need no large equipment installation and would appear to be the least cost solution. But when an "effective" DSM program is deployed to many customers, large expenses are necessary for advertisement, communication systems between power system operation center and each customer, demand control apparatus and so forth. The best way is to realize price reductions of electric energy storage systems as soon as possible. The history and forecast of the NAS battery system prices are presented in Figure 9. Its mass production has already started and we expect further price reductions via volume production expansion.

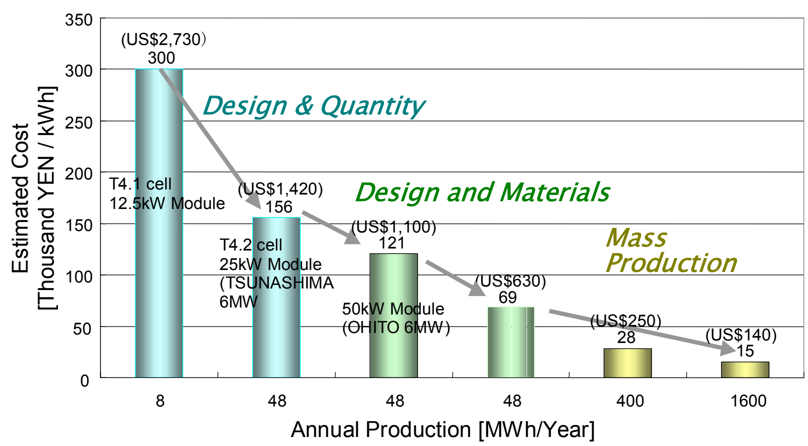

Figure 9 – History and future NAS battery system price

(5) Energy efficiency
The other challenge of electric energy storage is its energy loss though charge and discharge cycles. DSM programs only curtail or shift peak demand and don't induce energy loss that is inevitable for electric energy storage. Since average generation efficiency increases and transmission losses decrease when demand is shifted from peak hours to off-peak hours, load leveling by electric energy storage with high efficiency may contribute to the efficient energy use. We have tried to improve the efficiency of NAS battery system for a long period, and the actual efficiency of NAS battery system for load leveling is superior to that of typical pumped storage hydro plant. The NAS battery system efficiency also depends on system design and operation pattern, so we will continue to figure out optimum design and operation procedures.

6. Conclusions
In a deregulated electricity market, the investment on peak generators can be unattractive. For example, the PJM State of the Market Report 2002 says, "Analysis of 2002 net revenues suggests that the fixed costs of a marginal unit were not fully covered." Based on PJM market design, revenue of generators mainly consists of energy payment, capacity payment and ancillary services payment. A bid from a generation facility owner to an energy market shall be based on its marginal cost, so a peak power generator which tends to have relatively high marginal cost will be awarded for shorter hours in a year and hence obtains small revenue from this energy market. As for the capacity payment, it is almost equally distributed to all the generators being available during summer peak hours. So total revenue for a peak generator is much smaller than that for a base load generator and may not be enough to cover its initial cost. This market structure discourages investment to power generators that is indispensable for efficient and reliable power supply.

But the customers' benefits from peak power supply addition and/or peak demand reduction are enormous. When an energy price is decided by auction, the energy price during peak time can be reduced by load leveling and the accumulated electricity price reduction enjoyed by the overall customer is enormous. This mechanism is illustrated in Figure 10. We believe that load leveling by battery energy storage system will play an important role in the future. To realize more rational power system with efficient use of electric energy storage, we would like to validate all the benefits from electric energy storage and distribute such information to related entities.

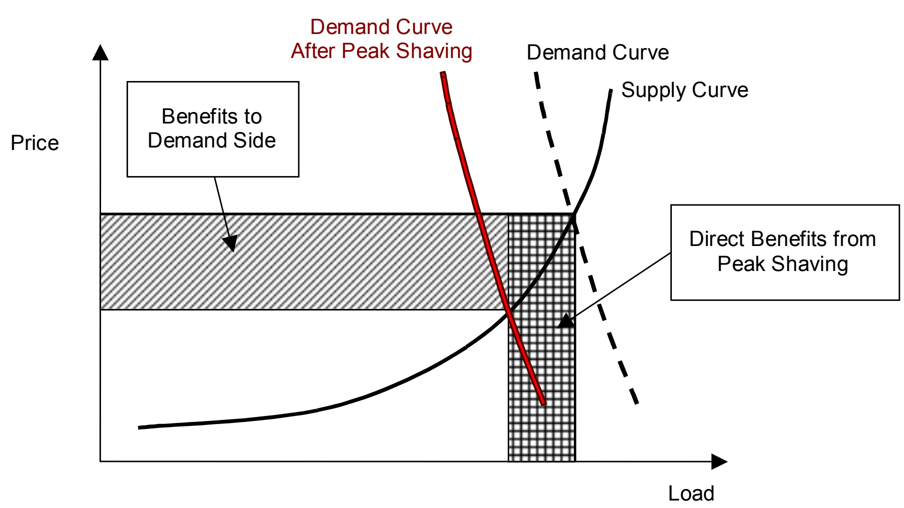

Figure 10: Value of Peak Shaving

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