DEVELOPMENT OF A 100kW NAS BATTERY-BASED SYSTEM FOR COMBINED POWER QUALITY AND PEAK SHAVING APPLICATIONS

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1.Introduction

The demand for electricity in Japan has continued to increase, even during the past decade-long economic recession. Similarly, the demand for electricity between daytime hours of peak consumption and nighttime off-peak hours continues great difference. Energy storage potentially offers an attractive means for improving this imbalance between on-peak and off-peak demand for electricity, while avoiding the need to construct new electricity generation, transmission and distribution facilities.

The attributes of the Sodium Sulfur (NAS) Battery place it among the most promising energy storage technologies for such peak shaving applications. NAS Batteries have high energy density and long lives, plus they have been developed to the threshold of commercial deployment. Twenty NAS Battery Systems totaling about 16MW and 124MWh of capacity are under evaluation in Japan, mainly by the electric power companies. In addition, recent market assessments and laboratory tests indicate that NAS Batteries are well-suited to power quality applications, i.e., the mitigation of short duration disturbances in the electricity supply.

This paper describes the development of a Power Conversion System (PCS) to control active (or real) power for peak shaving and other functions, as well as reactive power to mitigate certain power disturbances. All of the control logic and pulse width modulation (PWM) functional calculations are performed by a single 16-bit, fixed-point digital signal processor (DSP). This system architecture enhances system integration at relatively low cost.

2. Power Conversion System Functions

The PCS is designed to function in two modes, corresponding to normal and faulted conditions. Under normal conditions, the PCS simultaneously accomplishes four functions: (1) active power control, such as for automated peak shaving, (2) voltage regulation, (3) phase voltage imbalance correction, and (4) active filtering of 5^{th} and 7^{th} harmonics. During faulted conditions, the system detects out-of-tolerance conditions in grid electricity and stops normal mode functions to supply active or reactive power as required to mitigate power disturbances such as voltage sags and frequency fluctuations.

Table 1. Normal Mode Functions

Function	Means
Active Power Control (e.g., automated peak shaving)	Active power control with load power feedback
Voltage regulation	Reactive power control
Voltage imbalance correction	Inverse current compensation
Active filtering(5^{th} and 7^{th})	5^{th} and 7^{th} harmonic current compensation

Table 2. Faulted Mode Functions

Function	Means	Fault Condition
Fluctuation Compensation	Active power output	Frequency drop
Sags Compensation	Reactive power output	Voltage drop

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3. Power Conversion System Specification

Specifications for the 100kVA PCS are shown in Table 3. The 16-bit, 20MHz, fixed-pointed DSP calculates all of the control signals for the IGBT driver unit.

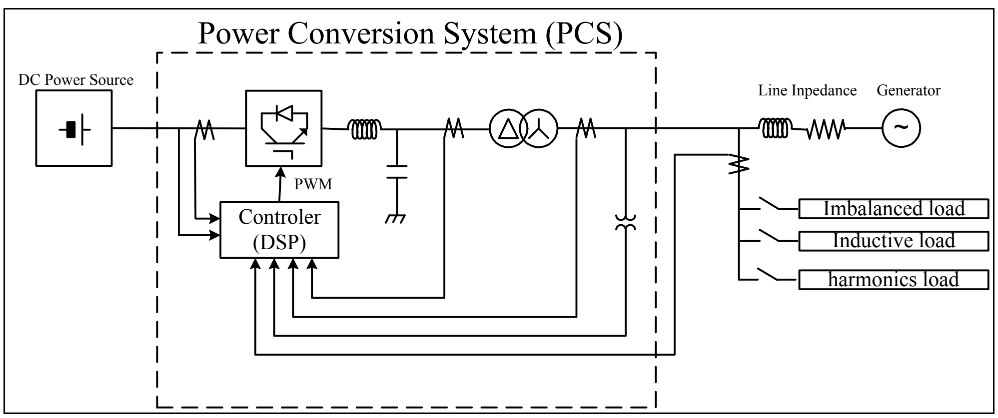
Table 3. PCS Specifications

Capacity	100KVA
Power Device	1200V, 1000A, IGBT
Power Conversion	Voltage source, self-commutated type
Modulation Method	PWM
Modulation Frequency	4.32kHz
DC voltage	120V

4. Results of Factory Tests

The PCS was tested in the test circuit shown in Figure 1 at factory of KYUSHU TRANSFORMER CO., LTD. The PCS is shunt connected through simulated line impedance to a 6.9kV generator. Inductive, imbalanced and harmonic loads are introduced to simulate normal and faulted operating conditions.

Figure 1. Factory test circuit of 100KVA PCS



Test results for normal operating conditions shown in Table 4 confirm that all four functions were simultaneously accomplished as designed. That is, under active power control of open circuit (0kW), 50kW discharging and 50kW charging conditions:

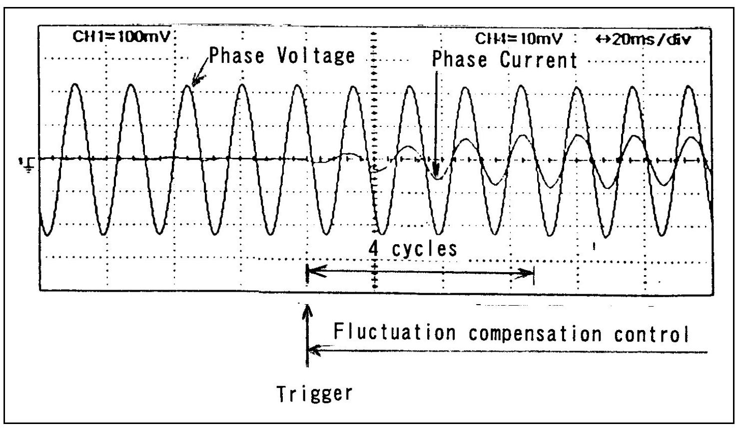
- Voltage imbalance is compensated from a maximum difference of 196V to differences of 39, 15 and 83V, respectively;
- The average voltage is regulated from 6451 to about 6610V; and
- Harmonic content is reduced by 20 to 30%.

Table 4. Normal Mode Operation

		Without Control	With Control		
			Open Circuit	50kW Discharge	50kW Charge
Phase $V_{U\text{-}V}$	(V)	6384	6603	6604	6611
Phase $V_{V\text{-}W}$	(V)	6580	6594	6611	6566
Phase $V_{W\text{-}U}$	(V)	6388	6633	6619	6649
Average	(V)	6451	6610	6611	6609
Max-Min	(V)	196	39	15	83
Harmonic Content	(%)	6.1	4.2	4.1	4.8

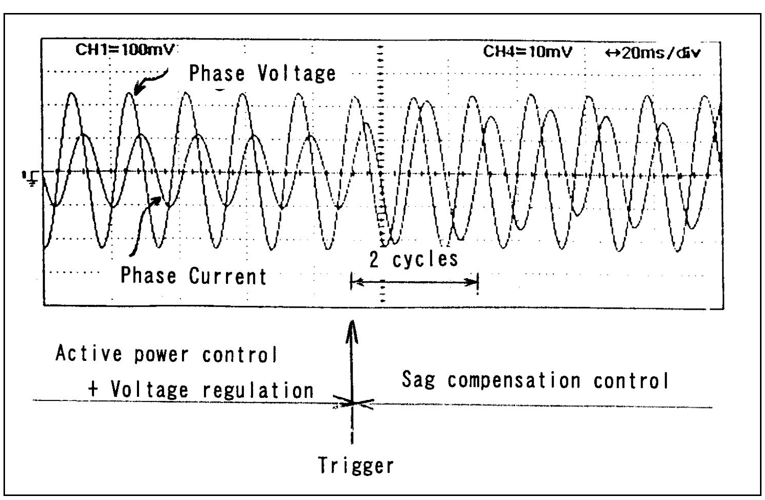
To verify PCS performance during faulted operating conditions, the response time to compensate for frequency fluctuations and voltage sags was tested. Figure 2 shows that active power introduced to compensate for grid frequency fluctuations is stable within 4 cycles from detection of the out-of-tolerance condition.

Figure 2. Active Power Response For Frequency Fluctuation Control



Similarly, Figure 3 shows that reactive power introduced to compensate for voltage sags is stable within 2 cycles from detection of the out-of-tolerance condition. In this case, normal mode functions cease at the point of fault detection.

Figure 3. Reactive Power Response For Voltage Sag Control



5. Integrated System Field Test At Imajuku Test Site

The PCS is now in operation at the Imajuku Test Site of Kyushu Electric Power Company. The PCS is connected to a 6.6kV power grid, and stored energy is supplied from two E50kW NAS Batteries connected in parallel. The performance of the system during normal and faulted mode conditions in the power network will be evaluated for several months.