IEA Committee on Energy Research and Technology

Introduction, Operation Experiences, and Future Utilization of Stationary Batteries in Japan from the Viewpoint of User and Grid Operator

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東京電力

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Summary

1. Overview of Storage Battery
   - Necessity
   - Types and Characteristics

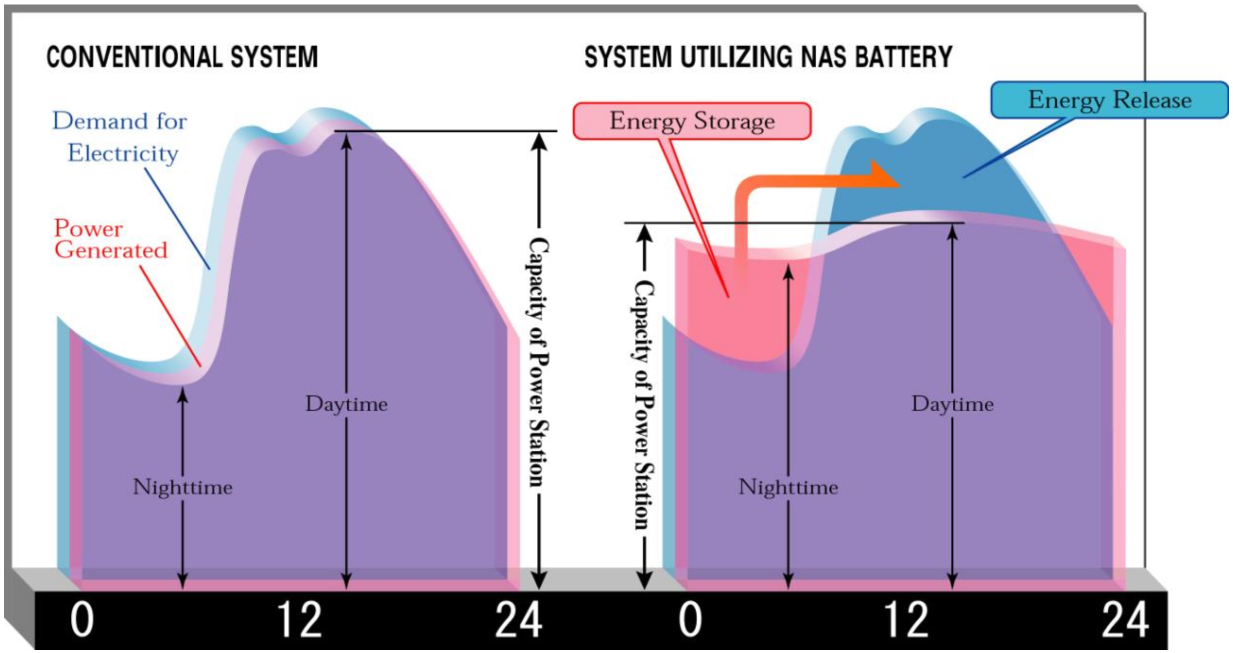
2. Experiences in Japan
   - Development and installation of NAS battery by TEPCO with the viewpoint of user and grid operator
   - Pre-existing use cases

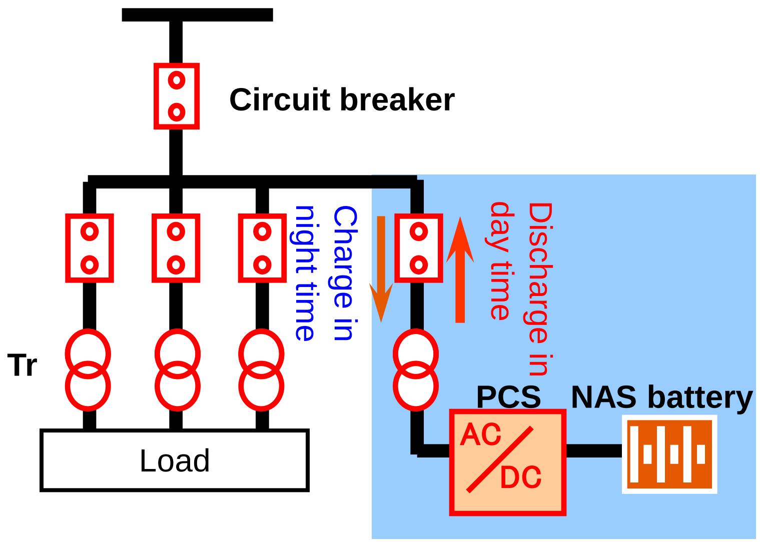
3. Future Utilization in Japan
   - Expectation as a countermeasure to integrate a huge amount of renewable energy
   - Current activities for future use case

Necessity of Storage Battery (1)

1. Load Leveling

- Demand Side: Reduce contract power and make use of inexpensive night time power supply.
- Supply Side: Efficient use of facilities and investment suppression on power system network.

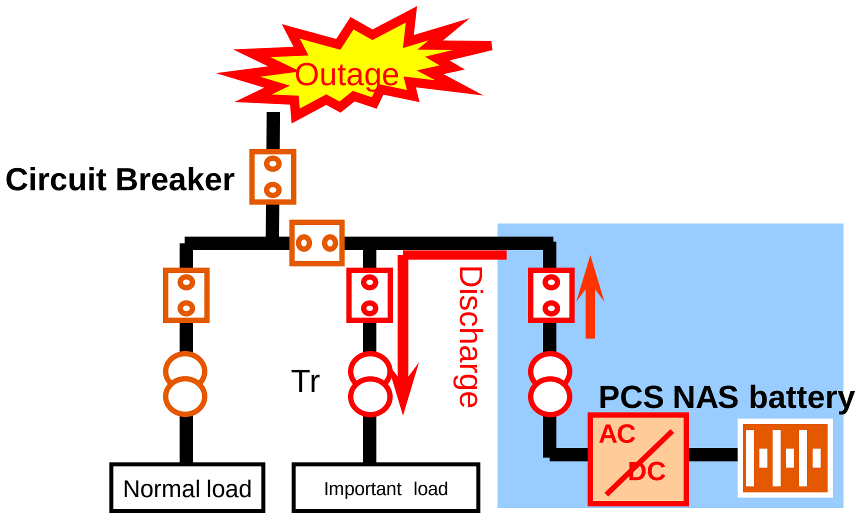




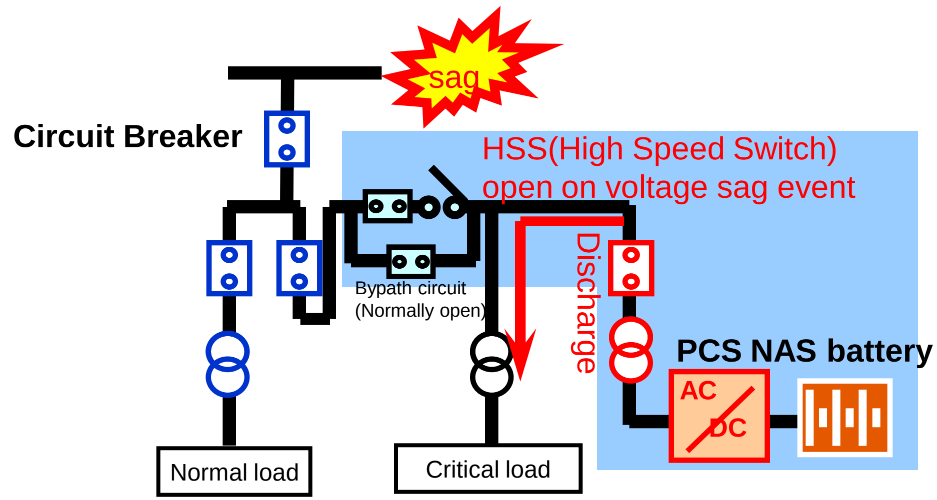
Necessity of Storage Battery (2)

2. Reliability & Power Quality Improvement

- Power supply on outage
- Save critical load from voltage sag



Power supply on outage



Save critical load from voltage sag

Necessity of Storage Battery (3)

3. Support for Integration of Renewable Energy Generation

- Absorb surplus power during light demand period
- Firm output from renewable energy generation
- Provide frequency control capability

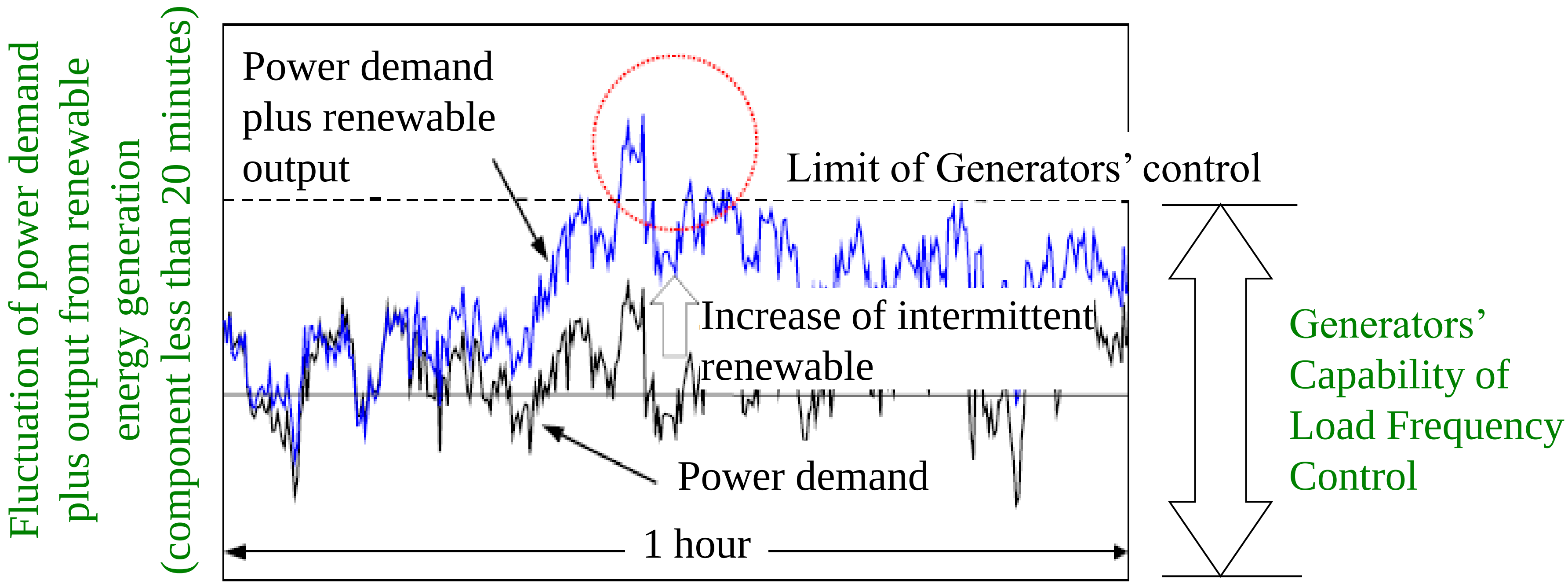


Image of insufficient frequency control capability

Types and Characteristics of Storage Batteries

Types	NAS	Redox Flow	Zn-Br	Lead-Acid
Active Material	Na, S	V^{2+}, V^{5+}	Zn, Br	PbO_2, Pb
Electrolyte	Beta-alumina	Vanadium suffate	ZnBr	Sulfuric acid
Energy Density	786 Wh/kg	100 Wh/kg	428 Wh/kg	167 Wh/kg
EMF	2.1V	1.4V	1.8V	2.1V
Operation Temperature	Around 300 degrees Celsius	Ambient	Ambient	Ambient
Accessory	Heater	Circulating Pump Chiller	Circulating Pump Chiller	None
Characteristics	• High energy density • No self-discharge • Fewer accessories	• Easy enlargement	• Simple structure • Easy mass production	• Matured technology

From the viewpoint of user and grid operator, TEPCO joined the development of NAS (Sodium Sulfur) battery which has several advantages;

- High energy density = more compact and light weight
- Fewer accessories = maintenance saving and fewer troubles
- No self-discharge = high efficiency realized by fewer loss of charged energy

History of NAS battery development

1960 1970 1980 1990 2000

- **FORD MOTOR Advanced the NAS-Principle (1967)**

Japan National Project

Electric Car Use *(1971-1976)*

Power Storage Use (NEDO*) *(1980-1990)*

TEPCO & NGK Joint Development *1984 -*

TEPCO: User & Grid Operator
NGK: Manufacturer

Beta-Alumina

Cell Development

System Development

Field Test (about 30MW)

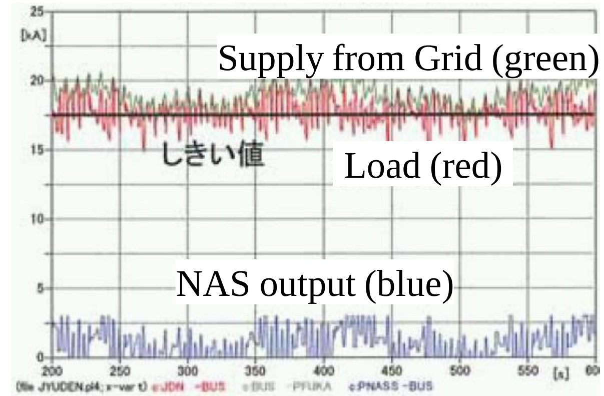
April 2002 TEPCO & NGK Launch Commercialization

*NEDO = New Energy and Industrial Technology Development Organization

Development from the Viewpoint of User and Grid Operator

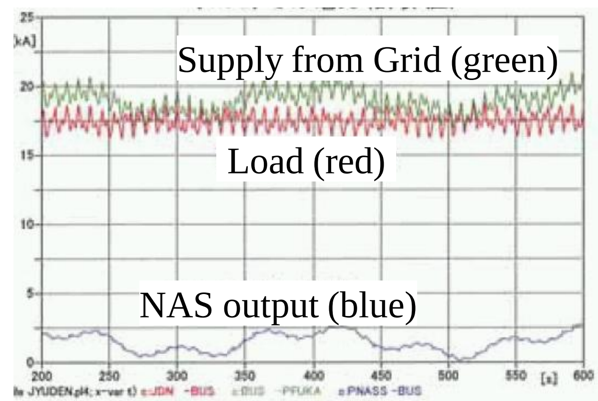
- In our installation and operation experiences, some lessons accumulated from studies and troubles were reflected in further development and improvement.
  - Ex1: Grid connection
    - ✓Voltage fluctuation, Harmonics, Load following
    - ✓Coordination with generators .etc
  - Ex2: Operation
    - ✓Influence on deterioration
    - ✓Control and protection scheme under cells failure
    - ✓Control avoiding depletion .etc
  - Ex3: Performance evaluation
    - ✓Evaluation of aged batteries .etc
  - Ex4: Safety evaluation
    - ✓Evaluation method and deregulation .etc

Ex. Connection with variable load



NAS battery is forced to continue start & shut-down due to load variability

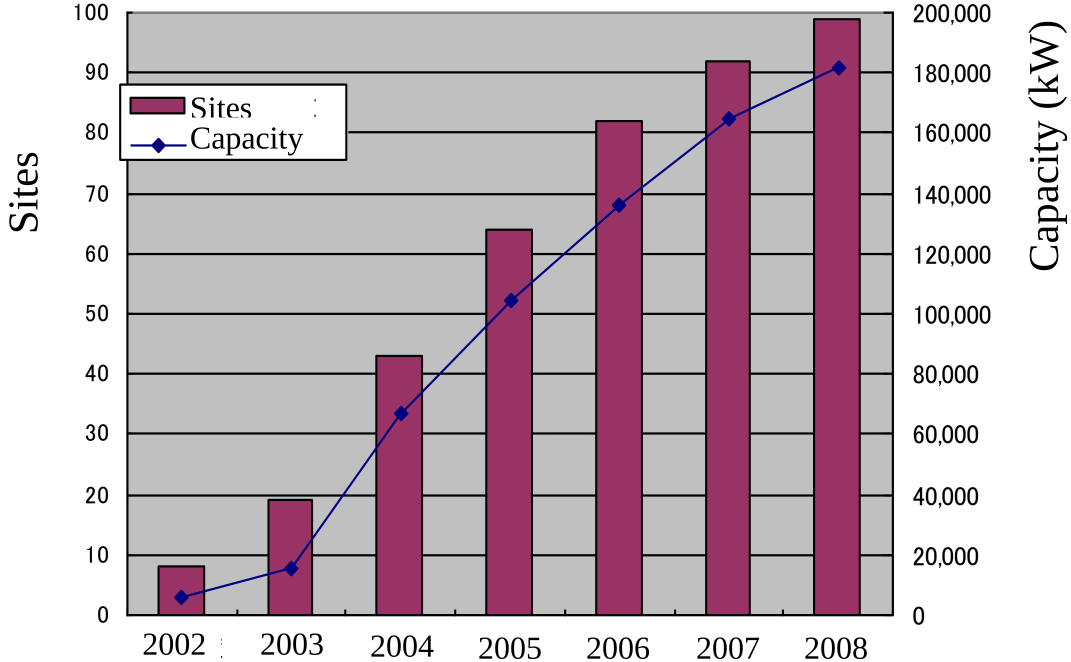
⇩ after adjustments



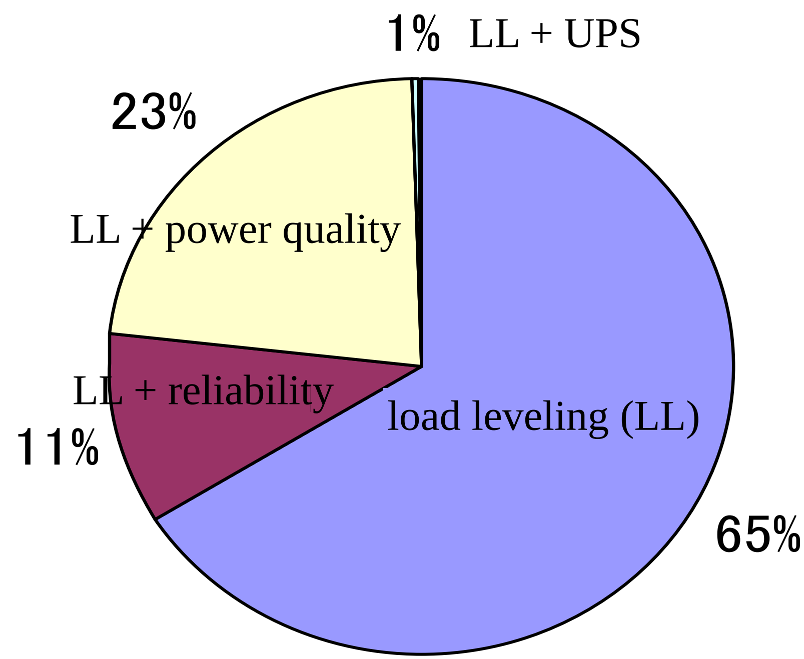
Installation Experiences

- Since TEPCO launched commercialization in 2002, we have been supporting installation by customers (lease from TEPCO) by providing know how from user's point of view.
- We offer one-stop service for customers; marketing & sales, system design (grid connection and operational pattern setting .etc), installation, and monitoring & maintenance.
- Installation data: 99 sites (96 at customer, 3 at S/S), 185MW

Installation (Sites and Capacity)



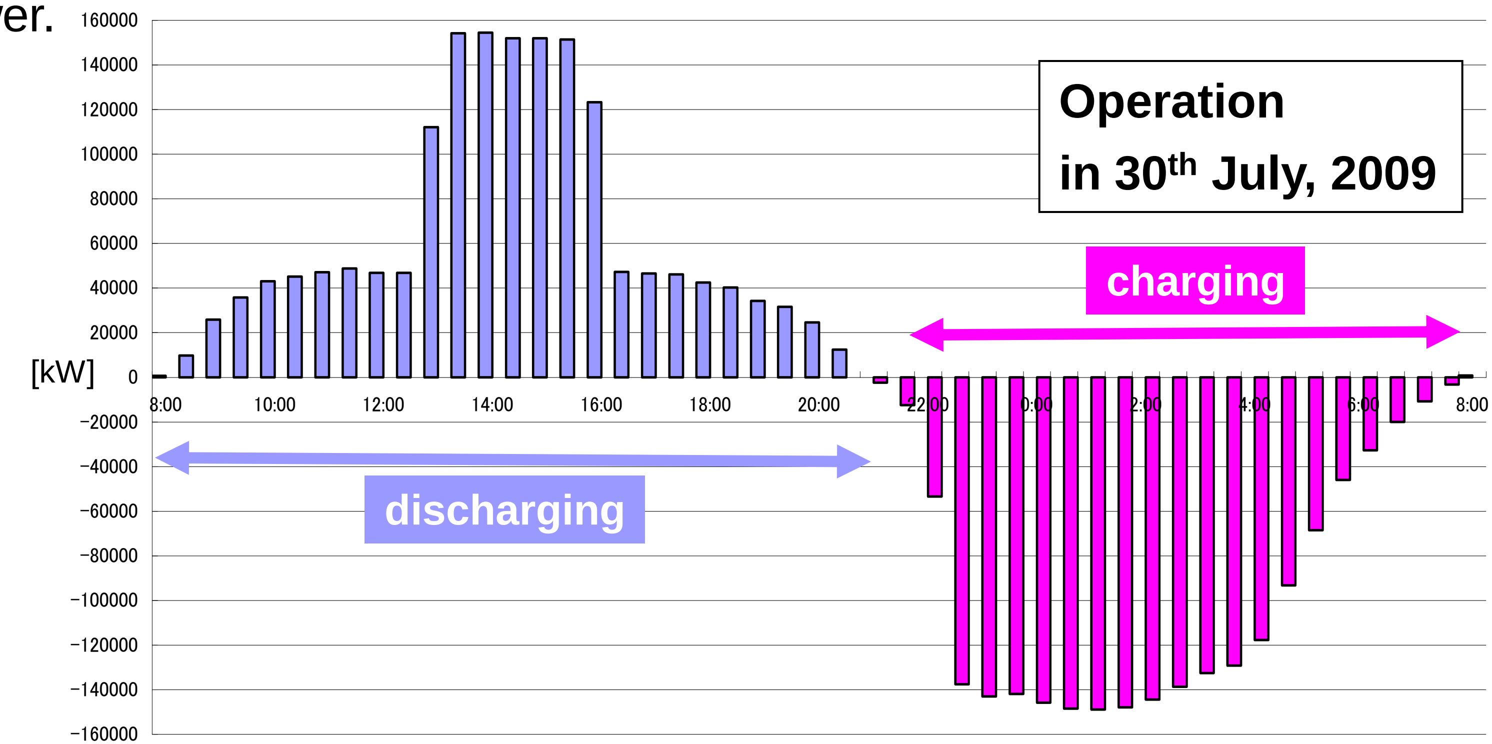
Use cases (by capacity)



Use Case 1: Load Leveling

Total charging & discharging results by all NAS batteries inside TEPCO's service area in 2009

- Contribution to peak shift by discharging nearly at their full power during summer peak hours (13 o'clock to 16 o'clock).
- Around 73% of annual capacity factor.
- The amount of annual discharged energy is much the same as that of 600MW pumped storage hydro power.

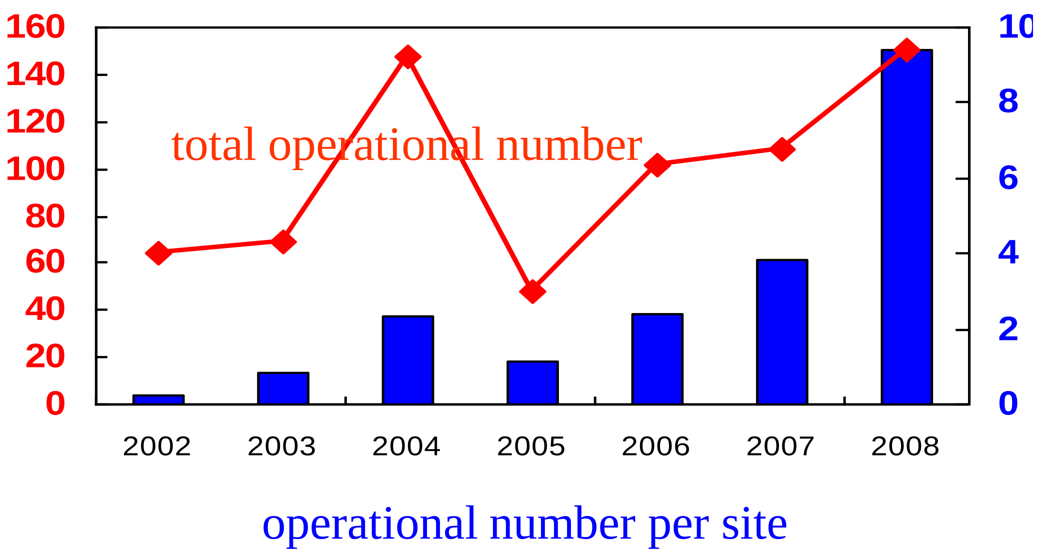


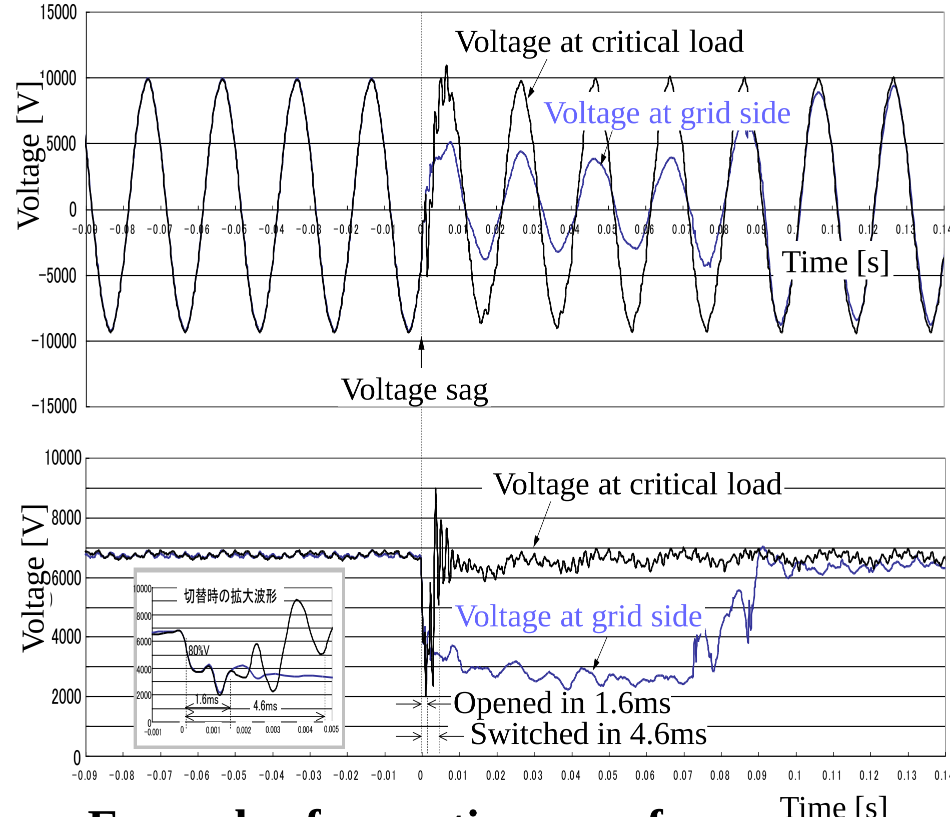
Use Case 2: Power Quality

Operational experiences of saving critical load from voltage sag

- Located at 12 sites and operated 342 times by September 2009.
- Operation is caused mainly in summer due to lightning, and finished within several mili-seconds.
- Highly evaluated by manufactures of semi-conductor and liquid crystal display, etc.

Annual operational number (2002 to 2008)

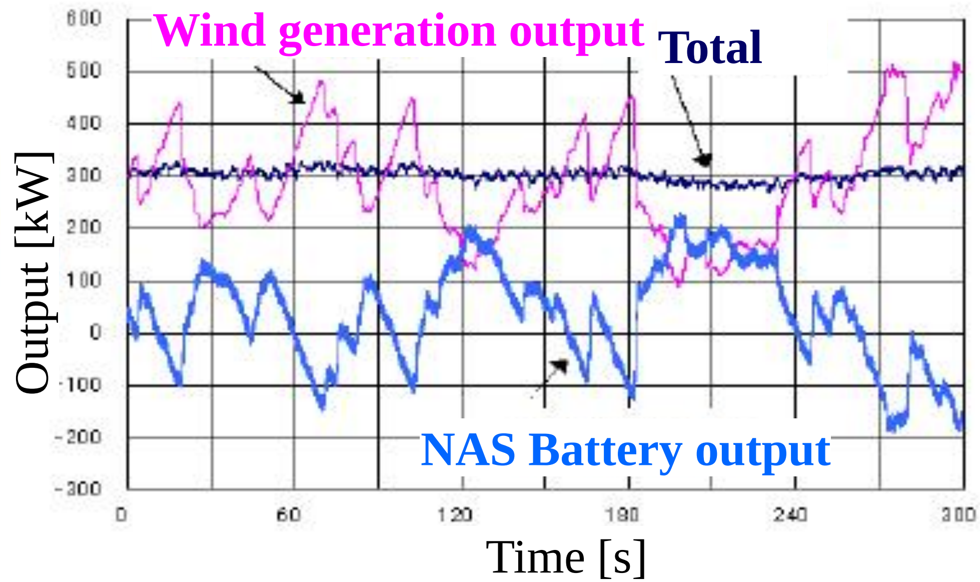


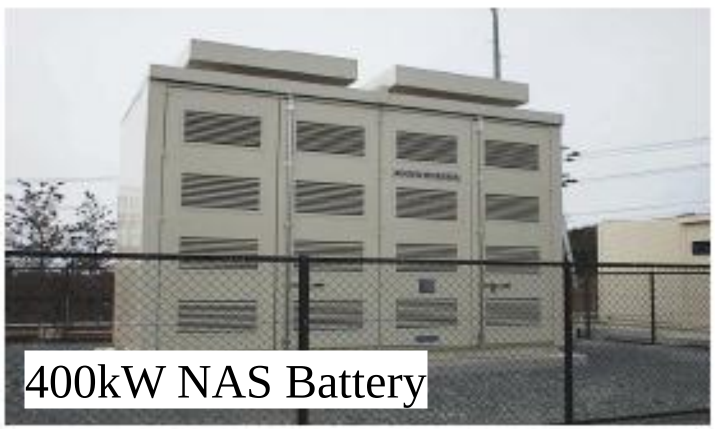


Example of operation waveform

Use Case 3: Renewable Energy Output Firming

500kW Wind Generation





400kW NAS Battery

Implemented in Hachijo-Island

<u>Field test of wind generation output firming with NAS battery (from Aug 2000 to Feb 2002)</u>

- Implemented by TEPCO with finance by NEDO
- Successfully firmed intermittent output

Next phase

Aomori: Wind (51MW) + NAS (34MW), launched in 2008

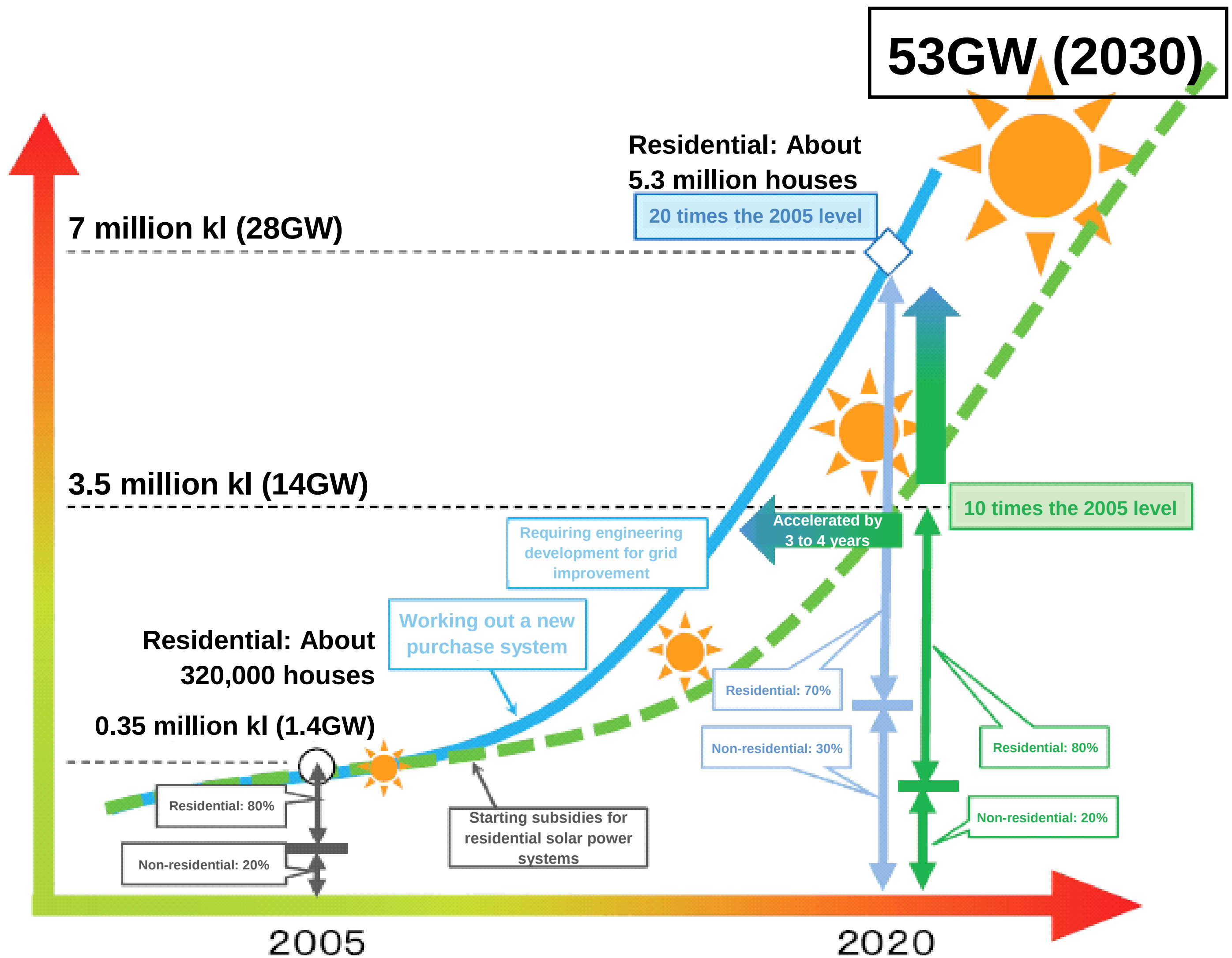
Hokkaido: Solar (4MW) + NAS (1.5MW), launched in 2009

Renewable Energy Installation Target in Japan

- Promoting R&D so that power system network can integrate a huge amount of PV (mainly residential).
  - 28GW by 2020, 20 times larger than in 2005
  - 53GW by 2030, 40 times larger than in 2005

- Three issues to be solved.
  1. Voltage rise in distribution network
  2. Surplus power
  3. Frequency fluctuation

- In Japan storage battery is expected to solve the 2nd and 3rd issue mentioned above.



Definition of Storage Battery Functions

■ Pre-existing and future use-cases can be classified in terms of functions.

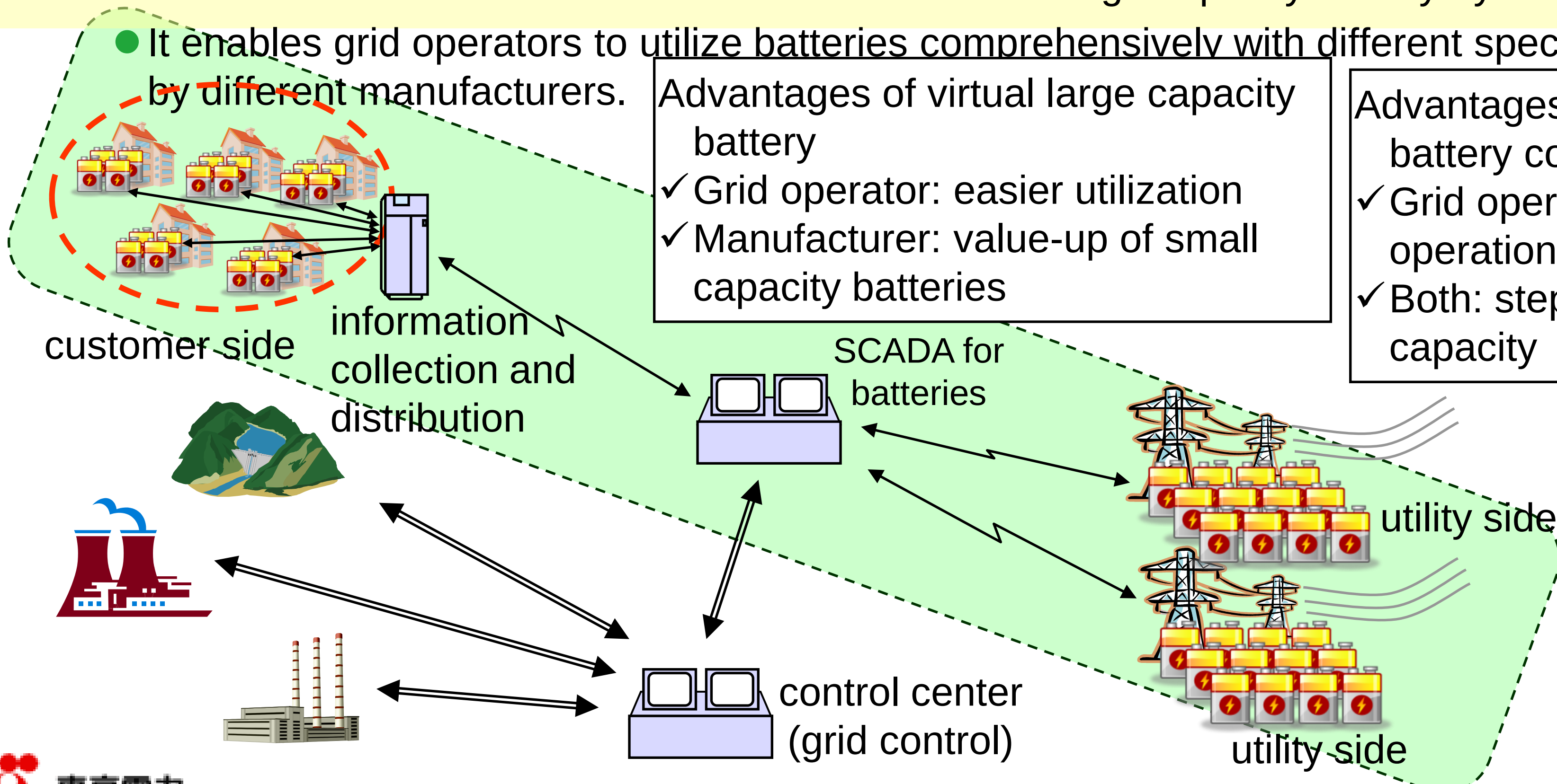
Associated with pre-existing use-cases (yellow) | Associated with future use-cases (pink)

Load Leveling (LL)	Setting of charging & discharging pattern
	Load following, Charging & discharging limiting
Emergency Power Supply Control (EPS)	Manual operation
	Automatic operation
Autonomous Grid Conscious Control (AGCC)	Firming output from intermittent RE
	Fault Ride Through [FRT]
	Emergency Power Pre Setter [EPPS]
	Autonomous frequency control (utilizing signals from its bus-bar)
	Autonomous voltage control (same as above)
Central Grid Conscious Control (CGCC)	Central frequency control (controlled by dispatching center)
	Scheduled operation (same as above)
	Central voltage control (linked with Distribution Automation System .etc)

Current Activities for Future Use Case

(1) Development and Demonstration of Integrated Control System

- Goal: System that enables grid operator to utilize batteries simply and efficiently, plus enables battery manufacturers to sell batteries easily.
  - Grid operator and battery manufacturers join development and demonstration cooperatively.
  - Distributed batteries can be dealt with like a virtual large capacity battery by being assembled.
  - It enables grid operators to utilize batteries comprehensively with different specifications provided by different manufacturers.



Advantages of virtual large capacity battery
✓Grid operator: easier utilization
✓Manufacturer: value-up of small capacity batteries

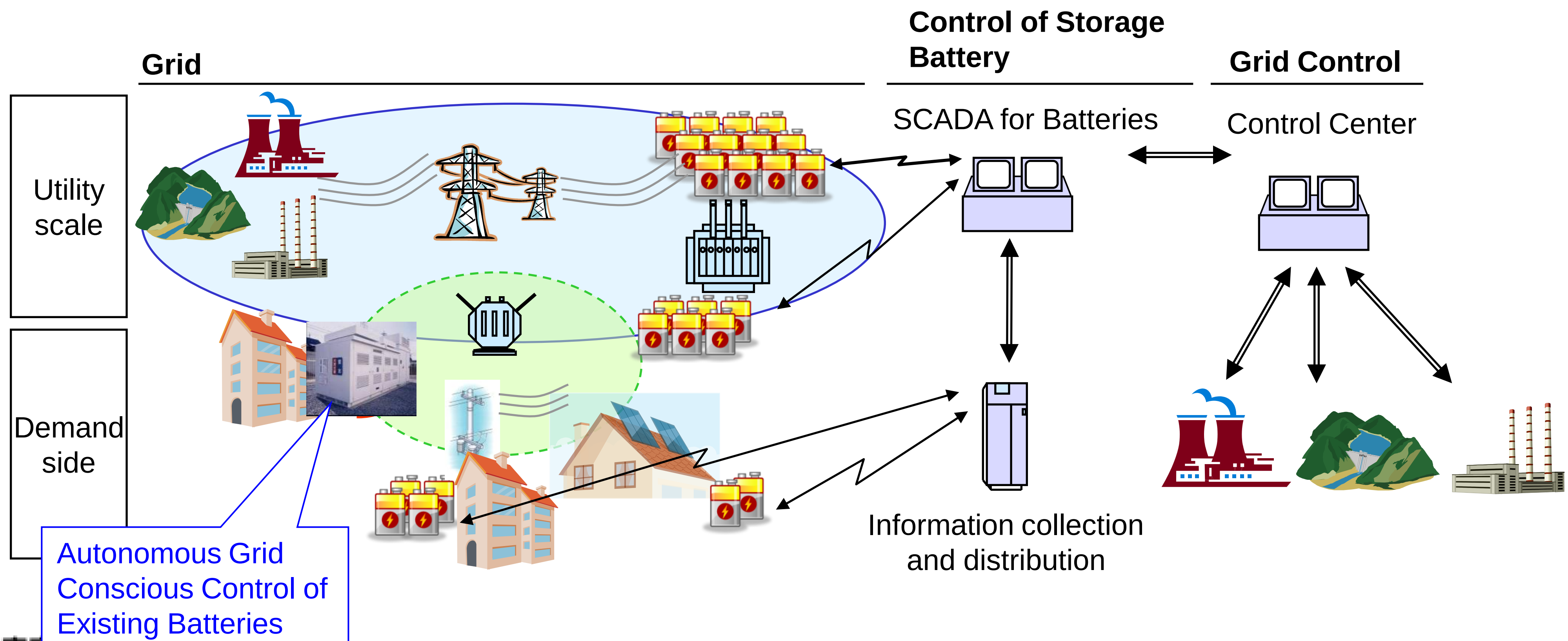
Advantages of comprehensive battery control
✓Grid operator: optimum operation for grid control
✓Both: step by step scale-up of capacity

Packaged development of Battery and Control System

Current Activities for Future Use Case

(2) Development and Demonstration of Autonomous Frequency Control

- Value-up of batteries by adding autonomous frequency control function compatible with load leveling.
  - Field tests will be implemented utilizing pre-existing NAS batteries installed for load leveling.
  - System that can be adopted to other types of batteries than NAS as well.



Thank you for your kind attention.

TOKYO ELECTRIC POWER COMPANY

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