

NAS Battery Energy Storage System

34 MW (204 MWh)
NAS Battery System
Rokkasho in Japan
since 2008

October, 2013

NGK Corporate Profile



Company Name	: NGK INSULATORS, LTD.
Establishment	: May 5, 1919
Paid-in Capital	: Approx. 69.8 billion yen
Employees	: 12,400 (consolidated)
Head Office	: Nagoya, Japan
Main Office	: Tokyo
Sales Offices	: Sapporo, Sendai, Toyama, Osaka, Hiroshima, Takamatsu and Fukuoka
Plants & Laboratories	: Nagoya, Chita, Komaki
Overseas Branches	: U.S.A, Belgium, Poland, Australia, Indonesia, China, South Africa, etc.
Group Companies	: 55 companies
Three Product Lines	: Power Business (incl. NAS): Sales: 53,900 Million Yen Ceramic Products: Sales: 123,800 Million Yen Electronic Business: Sales: 61,700 Million Yen



NGK's NAS Storage - Overview



- **NGK NAS is the world's most widely chosen grid-scale battery**
 - Chosen by world's largest utilities in 3 continents (Asia, North America & Europe)
 - Multiple US deployments.
- **NGK's NAS is reliable, dependable and proven.**
 - Over 300 MW (1800 MWh) operating at over 170 projects.
 - Performance and reliability is field-proven
 - Performance specs are predictable and field proven
- **NGK's NAS is a complete, ready-to-deploy standard product - not a custom design**
 - Easy to specify, order, install
 - Easy to use and operate
 - Minimal maintenance.
 - Easiest to project finance. Lowest risk to shareholders if using balance sheet financing.
 - NGK has the production capacity to support bids larger than 50 MW

Development of the MW-Scale, Multi-Hour NAS Battery



NGK started R&D in 1984, took NAS commercial in 2002.

1967

1970

1980

1990

2000

Ford Motor found the principle

R&D in USA, Europe and Japan

1971-1976



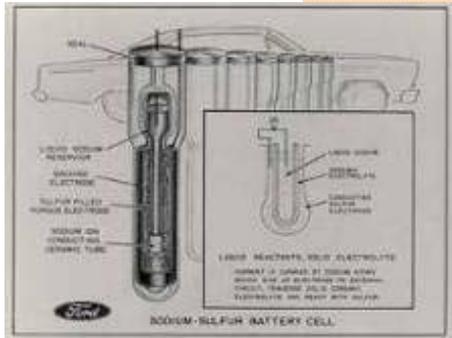
For EV Usage
Ministry Project

1980-1990

Development for Utility Usage
Moon Light Project (NEDO)

1991-1995

R&D for
Utilization



TEPCO – NGK

1984

Start Joint R&D

Element R&D

Technical injection from BBC
(now, ABB)



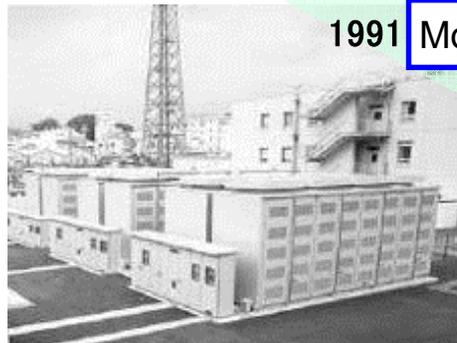
Larger Capacity of
Battery Cell/Module

1989

Cell Development

1991

Module/System Development



1997

Experiment/Evaluation

Experiment in Substation -> Industrial Consumers

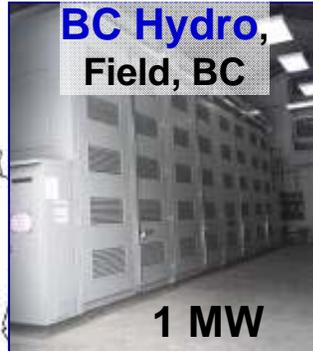
2002

Commercialization
World One Product

NAS Battery projects in North America



More than 20 MW of NAS Batteries have been installed in North America.



NAS Projects Deployed in Japan and Other Countries



Over 250 MW of NAS have been deployed in Japan since the mid-1990s.

Customer	Customer Type	Country	Location	Size (MW)	Application	Start of Operation
TEPCO (Tokyo Electric Power Co.)	Power Utility	Japan	Various locations around Tokyo (140 systems)	185	Load Leveling	1996 on
Other JP Utilities	Power, Water	Japan	Various locations	58	Mostly Load Leveling	2002 on
JWD (Japan Wind Development Co., Ltd.)	Wind Power Developer	Japan	Aomori, Japan	34	Wind Integration	Aug-08
ADWEA (Abu Dhabi Water & Electricity Authority)	Power Utility	UAE	Abu Dhabi	8	Load Leveling	Jan. 2010 (4MW), Jan. 2011 (4MW)
Yunicos	System Integrator	Germany	Berlin	1	Renewables Integration	July-09
Enercon	Wind Turbine Manufacturer	Germany	Emden, Lower Saxony	0.8	Wind Integration	Mar-11
EDF (Electricite de France)	Power Utility	France	Reunion Island	1	Load Leveling, Renewables Integration	Dec-09
BC Hydro	Power Utility	Canada	Field, B.C	1	Load Leveling, EPS	Mar-13

} **Japan**

Total: 288.8MW excluding US deployments

NAS Battery System

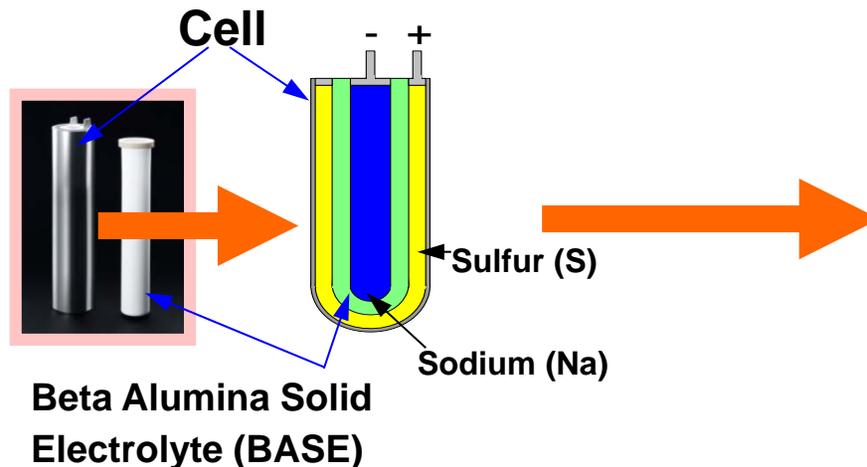
1 MW x 6 MWh standard battery system size

Each battery system has 20 modules,
each module is 50 kW AC

Each module is thermally insulated and has an operating
temperature range of 300 to 350 degrees C.
Internal heaters and normal operation maintain temperature.

Each module consists of internal cells that are
series-parallel connected and fused

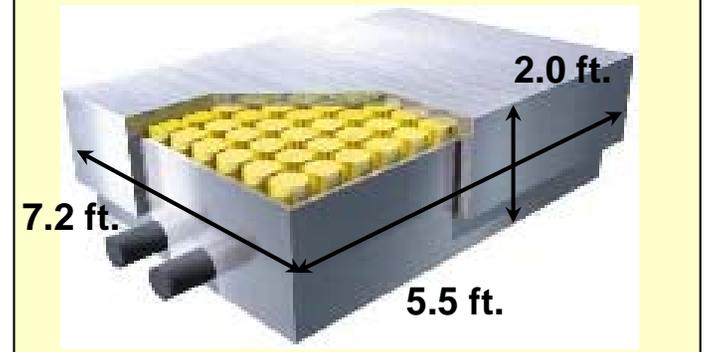
Large projects consist of multiple 1 MW systems



NAS Battery System



Battery Module (50kW)



Standard 1 MW, 6 MWh NAS Battery Installation



NOT TO SCALE

NGK Scope of Supply

Battery Enclosure
33.8 (W) x 7.6 (D) x 15.3 (H) - feet

Power Conversion System (PCS)

50kW NAS Battery modules
20 Sets

Battery module controllers
CNT-BOX & SSR-BOX
4 Sets

Control Cabinet
installed component
such as PLC, IPC, Display etc

Battery Management System

A network to tie PCS and NAS system to Ethernet/IP

PCS Manufacturer's
Scope of Supply

- Proven capability to deliver MW-scale, multi-hour stored energy for grid asset utilization, renewables integration and micro-grid support
- Long duration - 6 hours of storage
- 15-year calendar life and high cycle life – 4500 cycles (e.g., 300 discharge-charge cycles per year at rated energy capacity).
- High DC efficiency (~85%) (AC to AC over 75%)
- Insensitive to ambient temperature (-20 to +40C)
- No self discharge and no memory effect
- Prompt response – full power charge to discharge in 2 milliseconds
- Superior energy density – small footprint, ~1500 ft²/MW, 25 MW/Acre
- Easily sited outdoors and indoors; no emissions, noise or vibrations; relocatable if mission changes
- Remote operation and minimal planned maintenance, i.e., periodic inspection – no pumps, valves, heat exchangers, etc.
- Safety and reliability established by extensive testing and lessons learned
- Vendor strength – 20-year development program, NAS commercially available in Japan for over 10 years, marketed globally, 300 MW (1800 MWh) worldwide, over 170 projects.

NAS for ETT / AEP Transmission Support – Presidio, TX



Electric Transmission Texas (ETT) avoided remote transmission line upgrade

■ Background

- Presidio served by single 60-mile, 69 kV transmission ("T") line
- "T" line 50 years old, runs to border with Mexico at the end of US grid.
- Presidio subject to frequent lightning storms and power outages.

■ Solution

- 4 MW NAS installed to supply power during outages
- Due to prompt response, NAS addresses voltage fluctuations.
- NAS allows maintenance of the "T" line without service interruption.



Owner: ETT / AEP
System Size: 4 MW
Commissioned: April, 2010

PG&E enhancing “D” feeder reliability and demonstrating CAISO services

■ Background

- PG&E customers south of San Jose have demanding requirements for high reliability electrical service
- PG&E must also provide 30% of delivered energy from renewable resources by 2020 in accordance with CA RPS goals

■ Solution

- 4 MW NAS installed to enhance “D” line reliability, combined with
- Provision of ancillary services operated under CAISO’s Non-Generator Resource (NGR) market model.



Owner: PG&E
System Size: 4 MW
Commissioned: May, 2013

PG&E enhancing “D” feeder reliability, demonstrating multiple storage uses

■ Background

- PG&E customers proximate to intermittent PV and wind generation west of Sacramento need reliable electrical service
- PG&E seeking operational data on performance of storage in such locations

■ Solution

- 2 MW NAS installed to enhance “D” line reliability, combined with
- Stabilization of near-by PV generation and demo of future uses.



Owner: PG&E
System Size: 2 MW
Commissioned: December, 2012

NAS for SCE Island Support – Catalina Island, CA

SCE using NAS to solve an engine generator part-load emissions problem

- Background
 - The load on Catalina island is served by engine-driven generators and AQMD (Air Quality Managing District) restrictions on emissions required intervention
 - Catalina generators fail to meet emissions at load <80% rating

- Solution
 - 1 MW NAS installed to enhance reliability and serve load at < 80% generator rating
 - NAS charged from generators when demand is low.

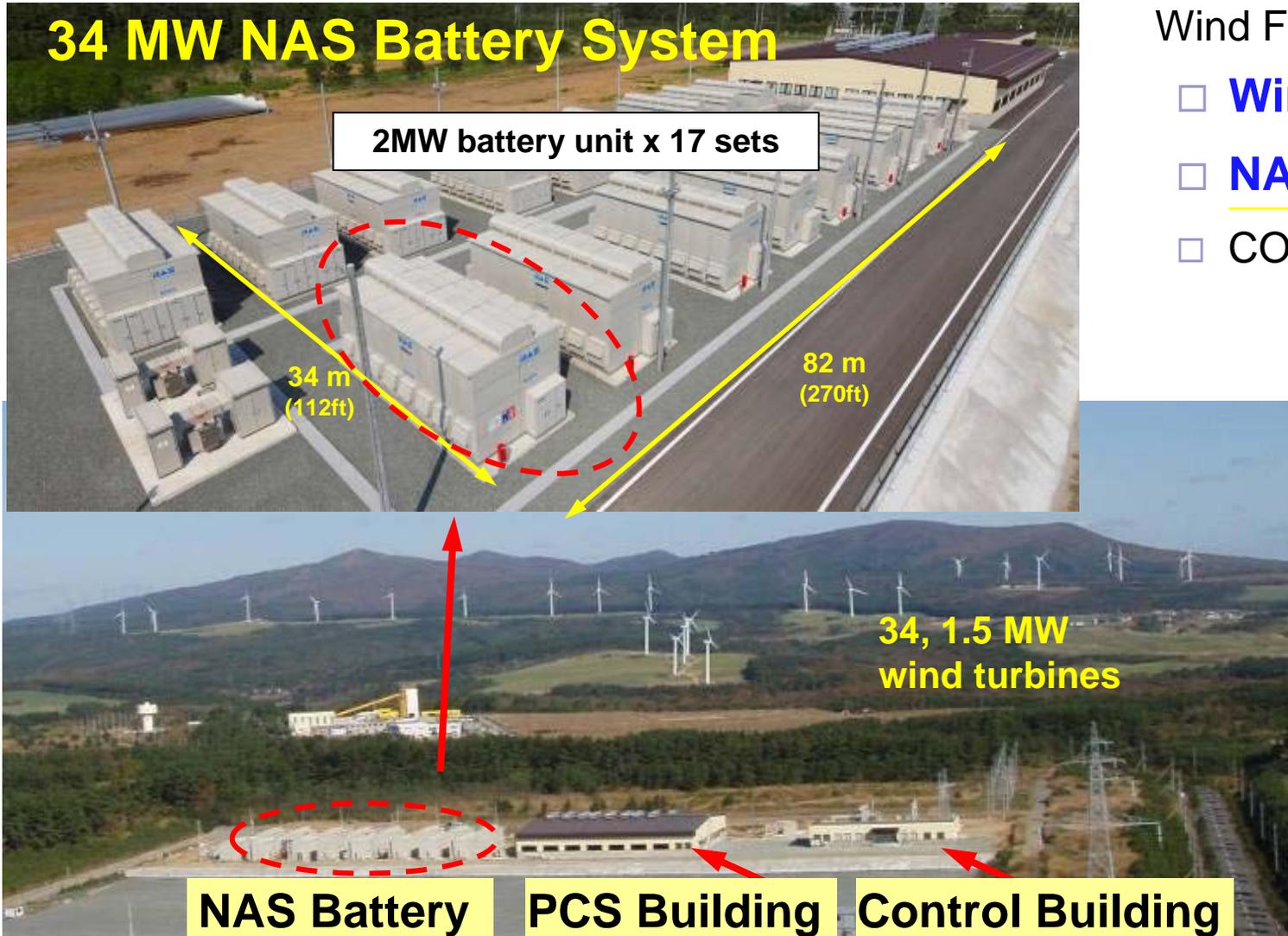


Owner: SCE
System Size: 1 MW
Commissioned: August, 2011



NAS for Wind Stabilization – Rokkasho, JP

Wind developer, JWD, using 34 MW of NAS to stabilize 51 MW of wind.



- JWD - Rokkasho Futamata Wind Farm

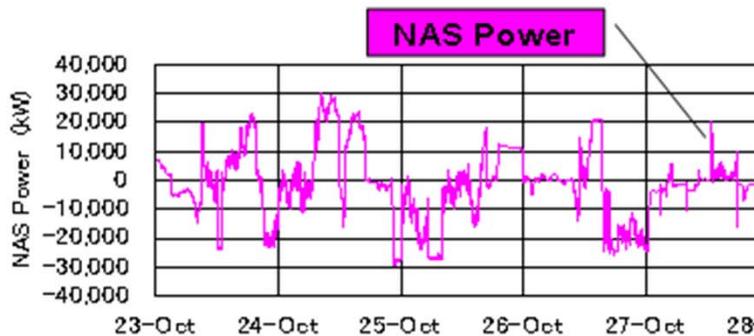
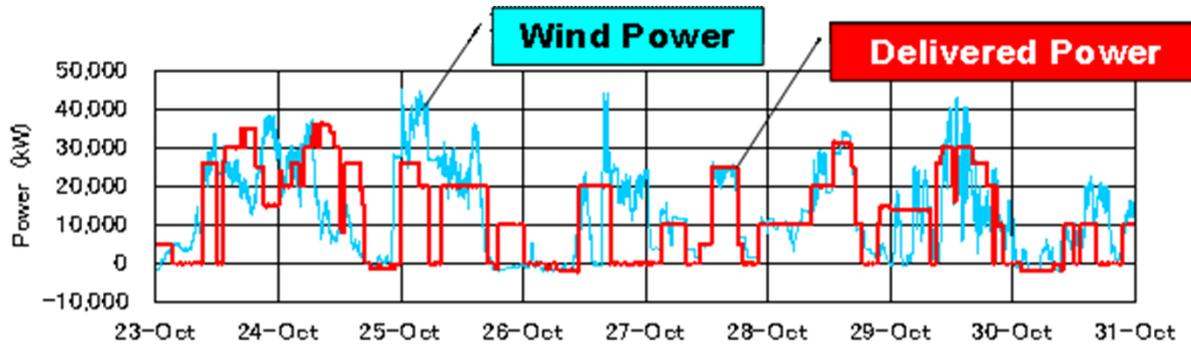
- Wind turbine: 51MW
- NAS battery: 34MW
- COD: August, 2008



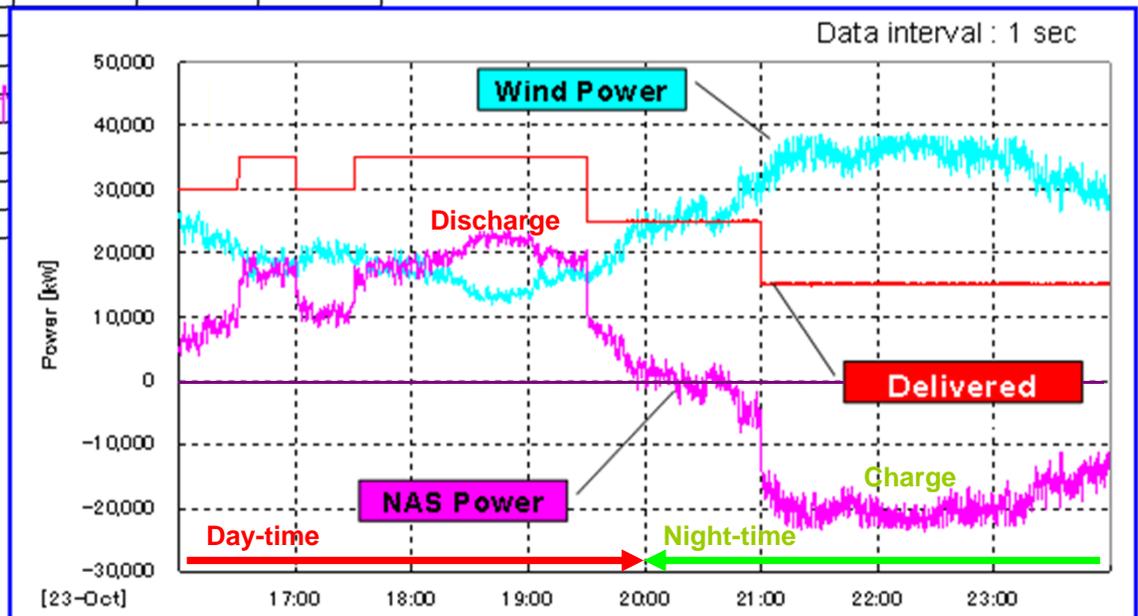
NAS Operating Profiles at Rokkasho Wind Farm



Wind generation is supplied at constant power to meet utility requirements.
(The system has been operating reliably for almost 5-years.)



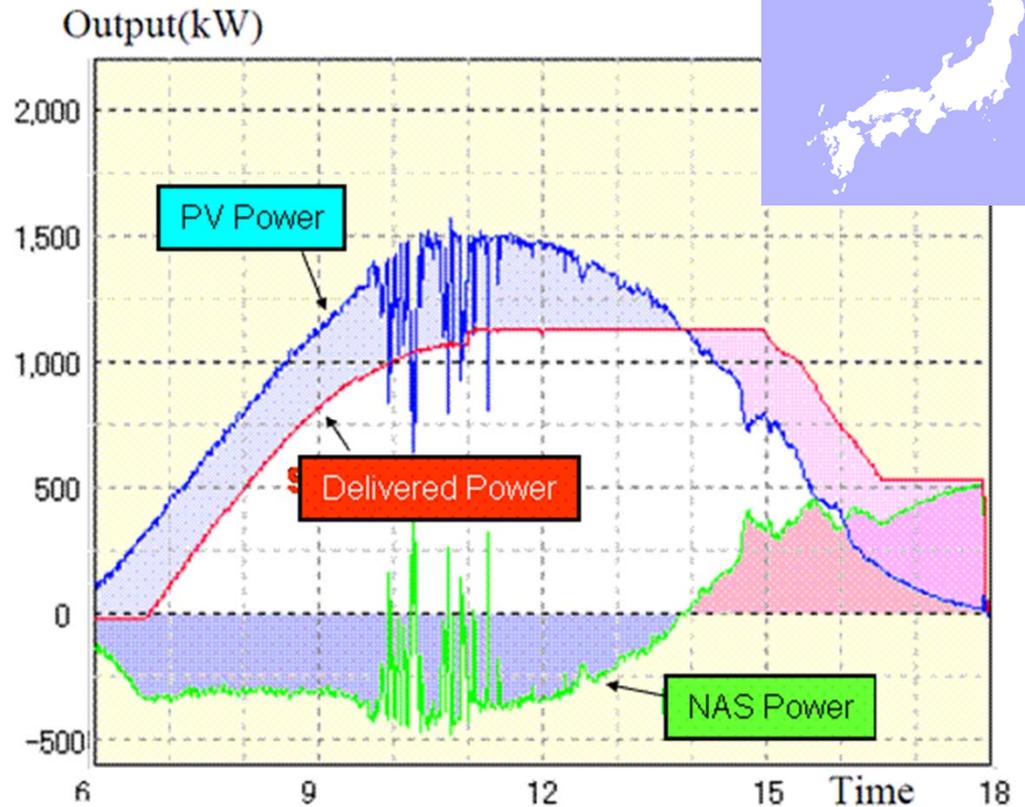
23Oct Excerpt



NAS for Solar Integration – Wakkanai, JP

1.5 MW NAS stabilizes 5 MW PV system.

(The system has been operating reliably for almost 5-years.)



Example of Operation pattern

Financed by NEDO
(New Energy and Industrial Technology Development Organization)

END



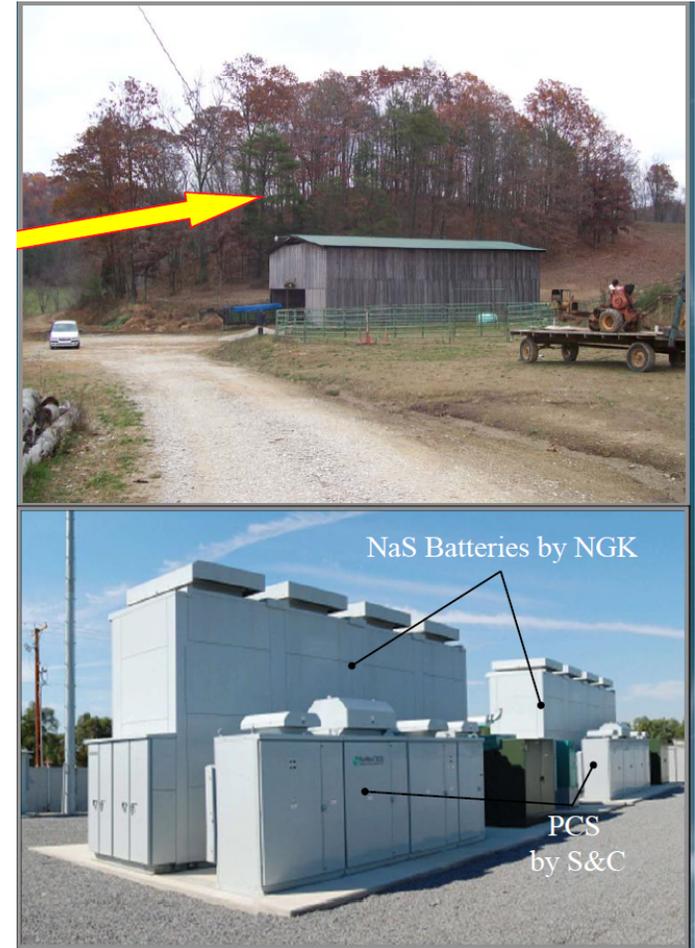
Spare



NAS for AEP Remote Feeder Support – WV, IN and OH

AEP using NAS to enhance reliability, improve service to rural customers

- Background – Milton, WV
 - Perennially a poor performing feeder
 - 35 mile, 34.5 kV radial with 2 MVA load at the end of the line
 - Most faults upstream of 2 MVA load
 - Nearest transmission is 8 miles distant
- Solution
 - 2 MW NAS installations with “islanding” capability to protect critical loads
 - Benefits included quick deployment and upgrade deferral
- Similar 2 MW NAS Installations
 - Bluffton, OH
 - Churubusco, IN



Owner: AEP
System Size: 3, 2 MW installations
Commissioned: 2008

Figures from “Energy Storage Applications Using NaS Technology for Islanding,” S&C Electric, ESA Conference, May 2008

NAS for AEP Substation Upgrade Deferral – 1st US Demo

AEP used NAS to defer substation upgrade in Charleston, WV

■ Background

- Aging “D” substation, overload reaching criticality
- 2-year delay to add second transformer

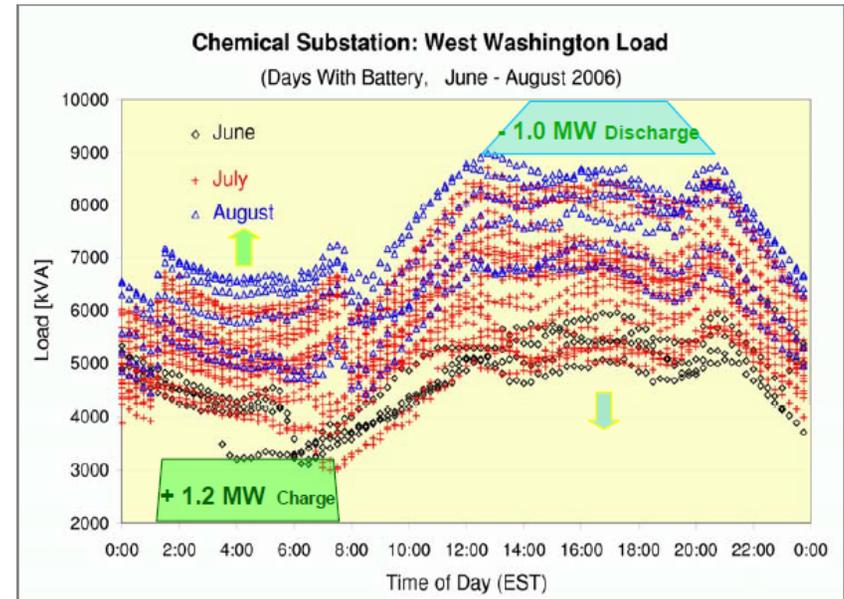
■ Solution

- 1 MW NAS installation deployed to “heat shave” transformers
- Benefits included quick deployment, capital deferral
- Demonstrated combined upgrade deferral (grid service) and energy arbitrage (market service).

Owner: AEP

System Size: 1 MW

Commissioned: 2006



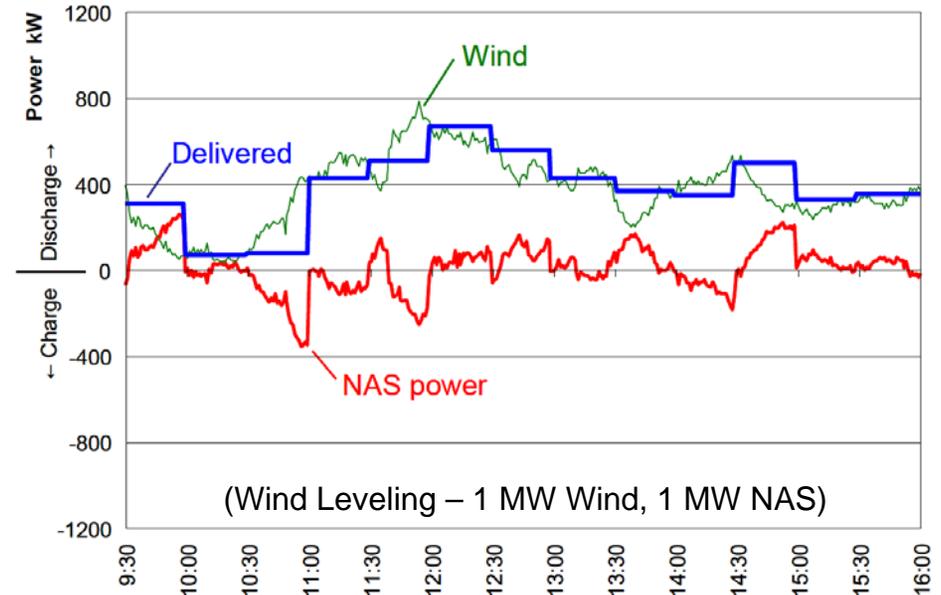
Figures from “Energy Storage Applications Using NaS Technology for Islanding,” S&C Electric, ESA Conference, May 2008

NAS for Xcel Energy Wind Integration Demo – Luverne, MN

Xcel using NAS to demo performance and benefits for wind integration.

- Xcel sought to:
 - Demo wind stabilization using stored energy
 - Assess economics of ancillary services in MISO markets
 - Deployed 1 MW NAS proximate to 11 MW wind farm

- Results – Demo'd capability to
 - Stabilize intermittent wind generation
 - Follow MISO AGC signal for frequency regulation



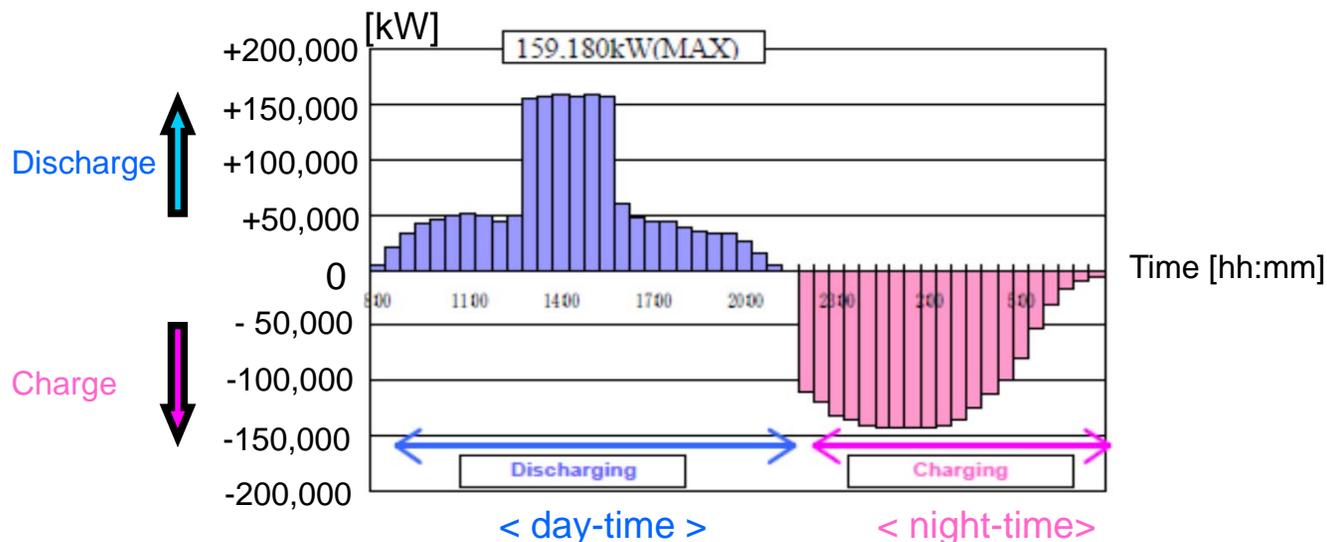
Owner: Xcel Energy
 System Size: 1 MW
 Commissioned: 2008

NAS for TEPCO Pumped Hydro Equivalent – Tokyo, JP



NAS within Tokyo provides equivalent of 160 MW pumped hydro.

- Background
 - Pumped hydro sites proximate to Tokyo already developed
 - Over past 20 years, TEPCO deployed over 200 MW of NAS proximate to load centers within the city
- Results
 - In 2008, TEPCO reported** that NAS provided equivalent of 160 MW, 200 MWh pumped hydro peak load reduction
 - Benefits included reduced peak load on T&D assets, enhanced reliability for users proximate to distributed NAS, off-peak load for utilization of generation

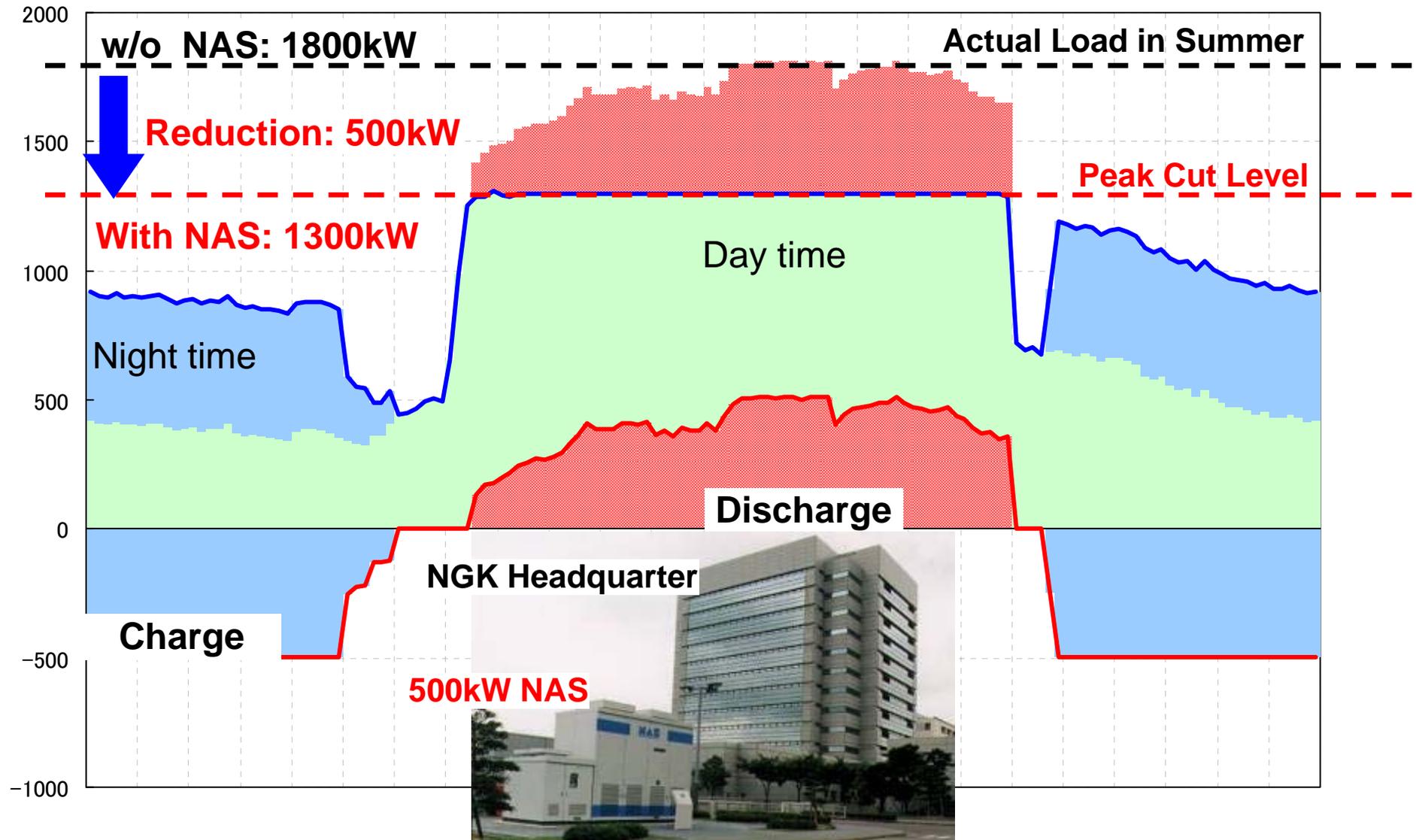


**CIGRE 2008 C6-302 The Sodium-Sulfur Battery for Utility-Scale Applications” by K. Tanaka, et al, TEPCO

NAS for Peak Shaving at NGK Headquarters – Nagoya, JP



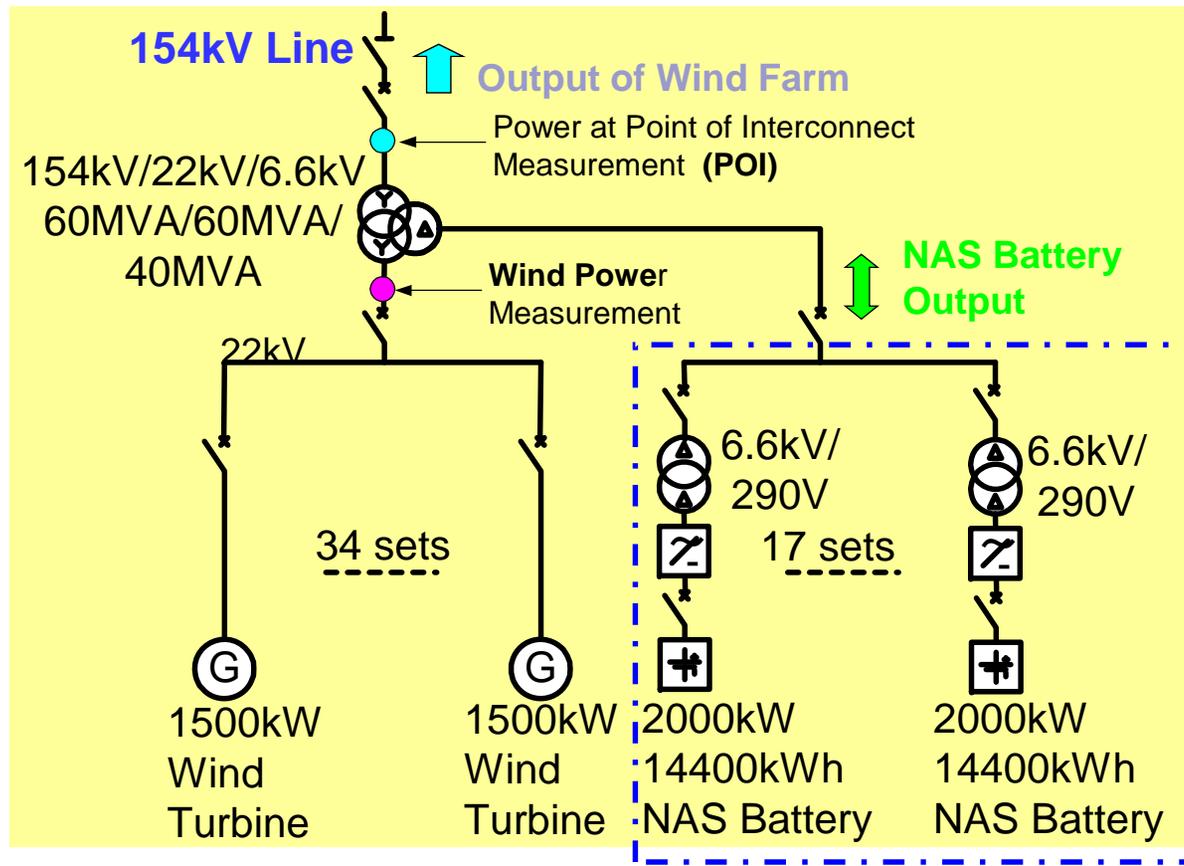
The oldest operating NAS battery installation is located at NGK Headquarters.



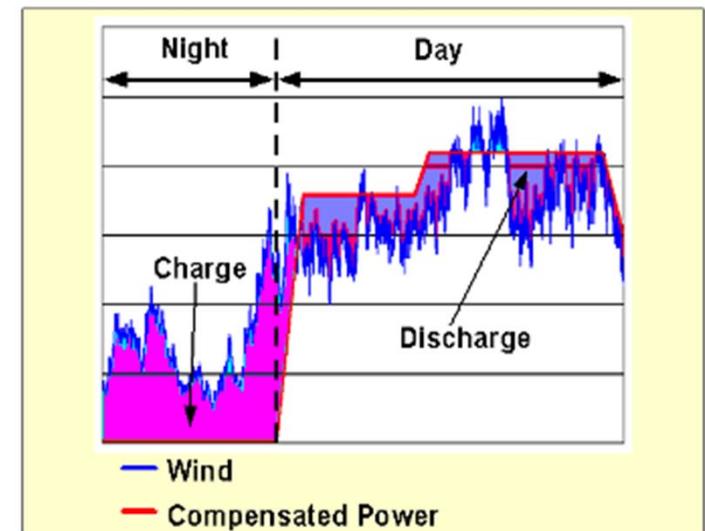
Power Control at Rokkasho Wind Farm

Wind and battery output are controlled to deliver constant power.
(within 2% of rated wind farm power)

One Line Diagram of Wind Farm

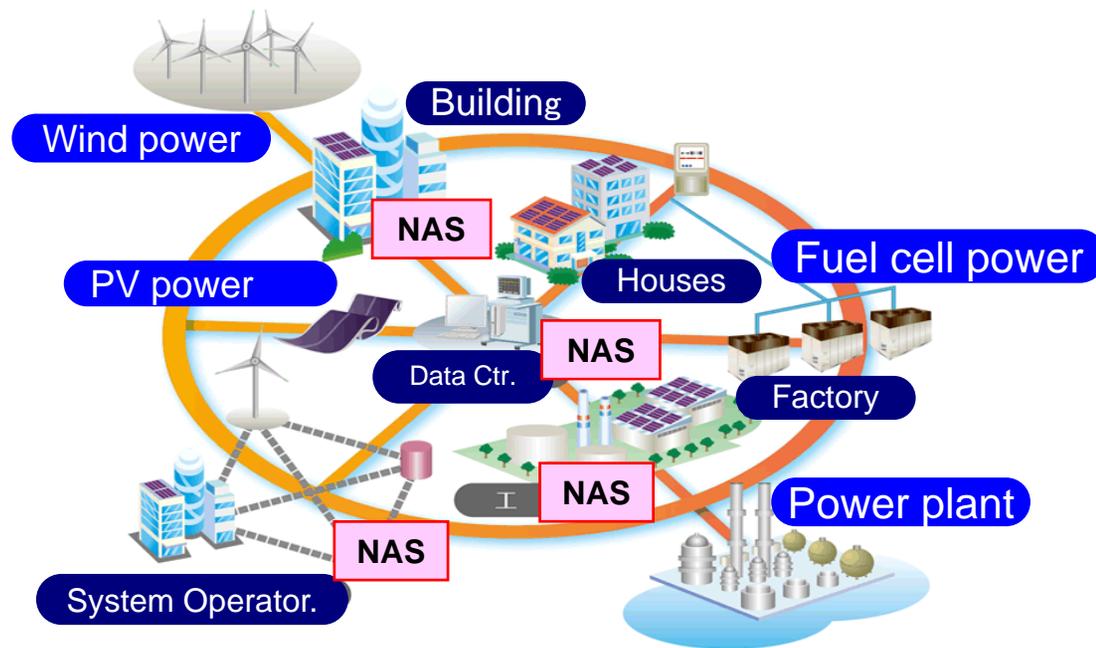


Concept of Constant Power Control & Energy Shift

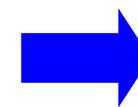


NAS for Island and Local Micro-Grid Applications – Concept

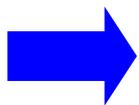
NAS can enable dispatchable power to be supplied from intermittent generation resources in island and local micro-grids.



Intermittent generation from renewable resources comes with power fluctuations and outages.



Power from NAS mitigates upsets



- Stable, reliable power supply within the micro-grid
- Efficient operation of thermal power plants (reduced fossil costs)

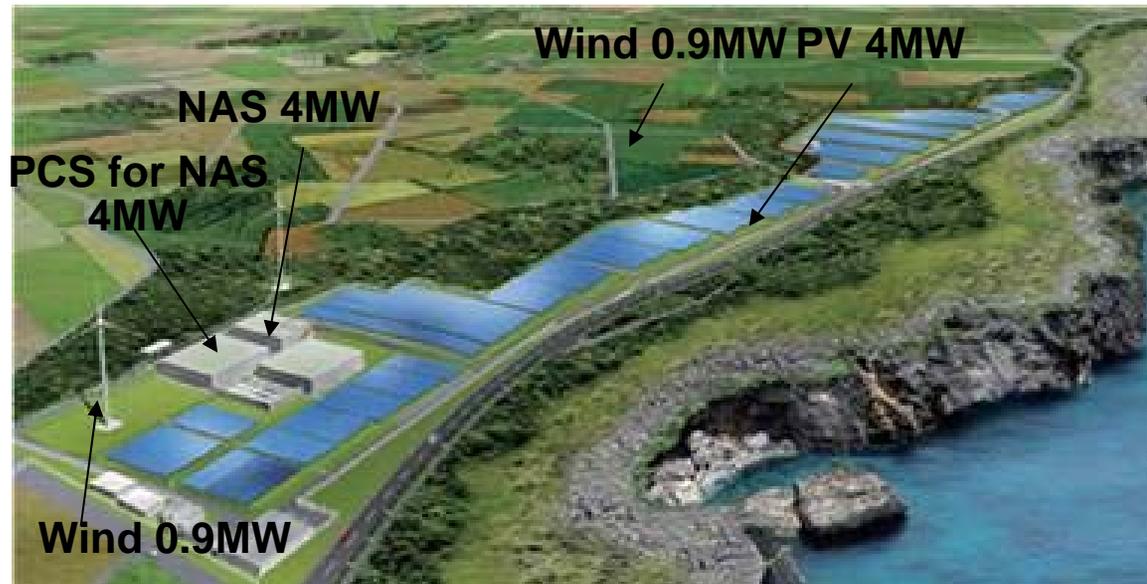
NAS for Miyakojima Island & Smart Grid Demo – Southern Japan



NAS and Li-Ion batteries are installed with PV and Wind generation.

(Demonstration tests are on going.)

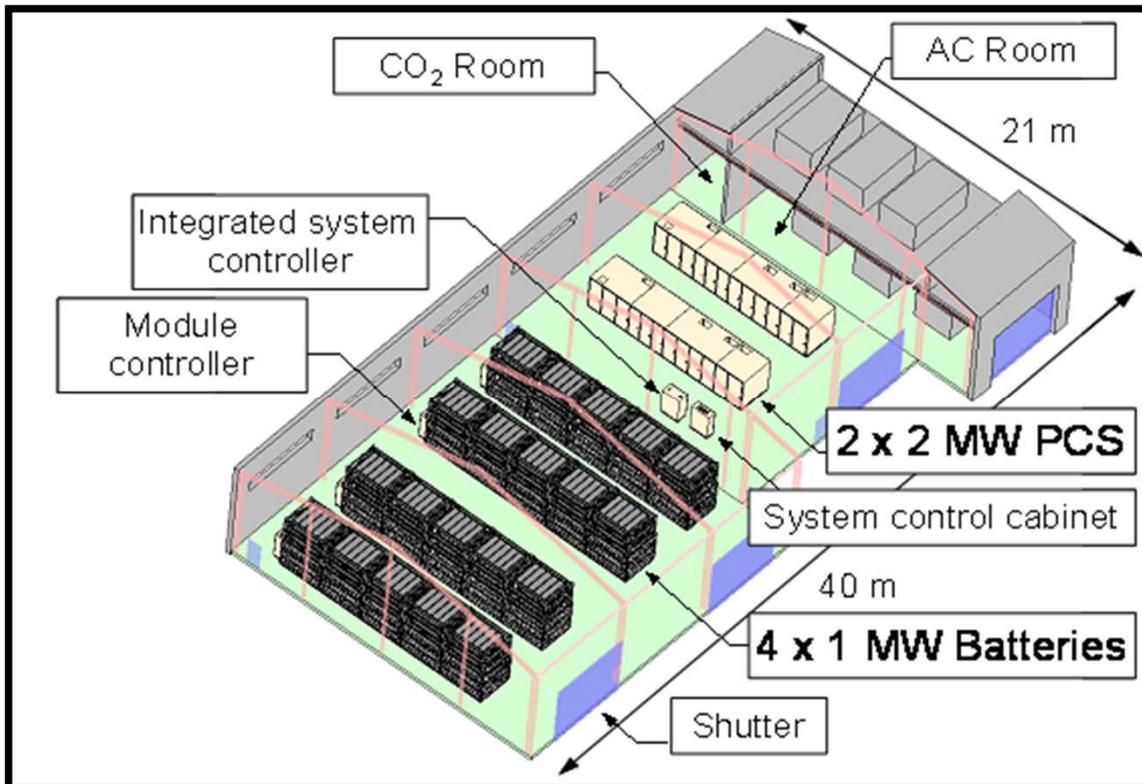
PV:	4MW (Area: 45,000m ²)
Wind:	4.2MW (0.9MW x 4units + 0.6MW x1 unit)
Batteries:	NAS battery 4MW (0.5MW x 8 units) Li-Ion battery 0.2MWh (8kWh x 25 units)
Thermal:	Diesel 61.5 MW + Gas-turbine 15 MW
COD:	October, 2010.



NAS for Large Scale Peak Cut Application in Abu Dhabi

8 MW of NAS are being used to level the load on GTs in Abu Dhabi.

- 8MW (2x4MW) / 48MWh
- Operated from end of 2009



4MW Battery Building



Battery room

NAS Battery projects in Europe

NAS Batteries are being used by European customers.

Berlin, Germany: 1MW NAS Battery for Younicos

NAS Battery in Micro Grid Testing Building



Yunicos Press Release (on 6 February, 2013)

In a joint pilot project, **Yunicos** and **Vattenfall** have commissioned the first large scale battery to be integrated in the European electricity **balancing market**.

Since the end of 2012, a 1 MW NAS battery based at the Younicos headquarters in Berlin successfully balances short-term fluctuations in the power grid. This is the first time a battery is employed in maintaining the frequency for the transmission system operator 50Hz Transmission GmbH.

Emden, Germany: 0.8MW NAS Battery for Enercon

Enercon's 6MW Wind Turbine with NAS Battery



Reunion Island, France: 1MW NAS for EDF



Indoor Type NAS Battery and PCS

NGK and Terna* reached agreement on supply of NAS batteries.

(*Italian Transmission System Operator (TSO) – May 2013 press release)

■ Background

- European nations have agreed to reach 20% of generation from renewable resources by 2020
- Stability of Italian grid challenged by 72% increase in solar and 34% increase in wind generation during 2012.

■ Solution

- Proceed with deployment of 35 MW of NAS for a price of 100m euros to support grid stabilization
- Plan future deployment of additional 35 MW of NAS

Owner: Terna

System Size: 35 to 70 MW

Ordered / Press Release: May, 2013