

# NEC Energy Solutions

## Energy Storage for Grid Stabilization in Electricity Grids with high Penetration of Renewable Energies



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# About NEC Corporation

NEC Corporation	
Head Office	7-1, Shiba 5-chome, Minato-ku Tokyo, Japan
Established	July 17, 1899
Representative Directors	Chairman of the Board <a href="#">Nobuhiro Endo</a> President and CEO <a href="#">Takashi Niino</a>
Capital	3.5 billion USD
Consolidated Net Sales	25.2 billion USD (Fiscal year ended Mar. 31 2016)
Business Domain	Public, Enterprise, Telecom Carrier, System Platform, Smart Energy
Employees	<b>NEC Corporation and Consolidated Subsidiaries</b> 98,726
Consolidated Subsidiaries	217



As of Mar 31 2016



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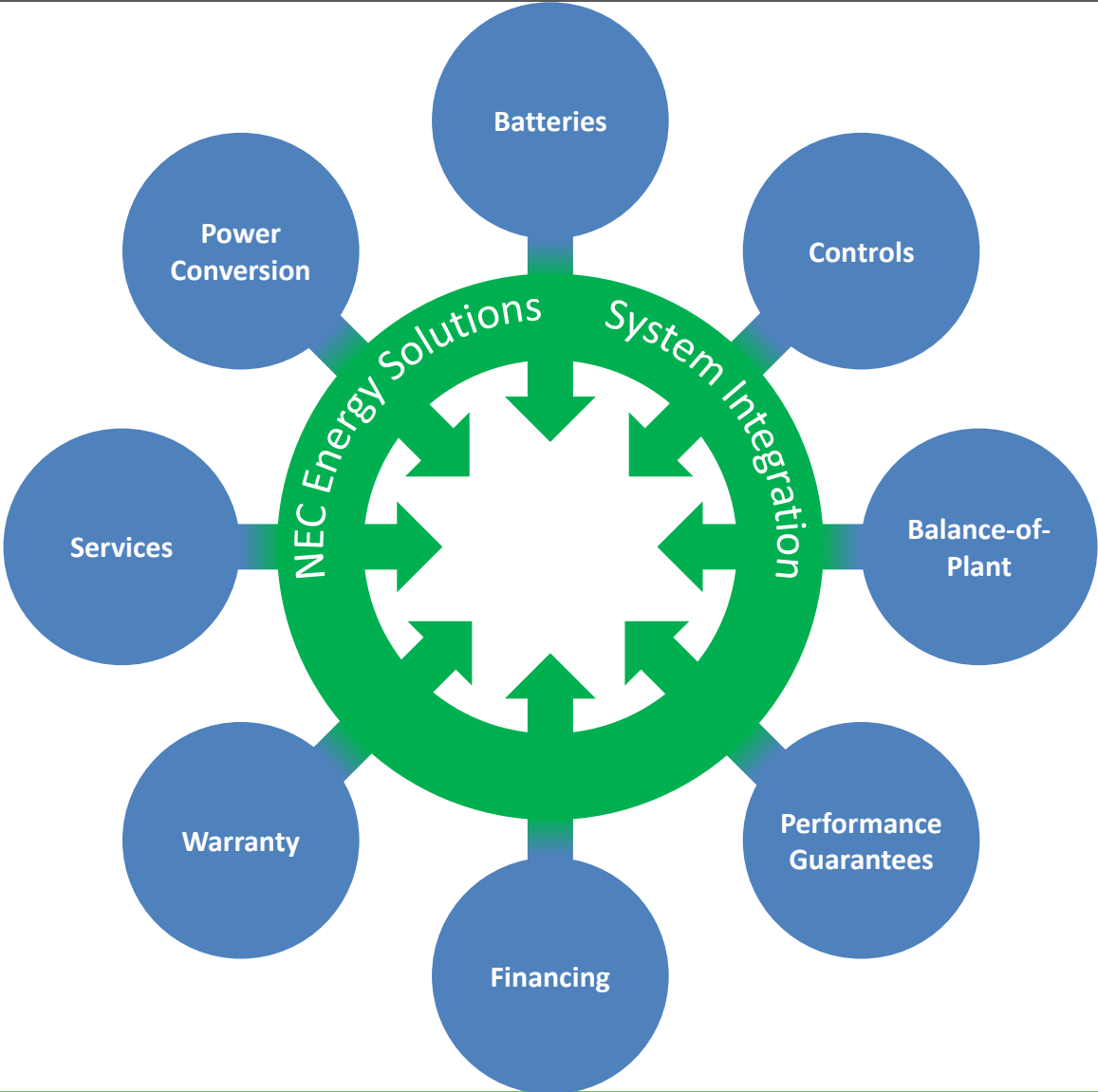
As of Mar 31 2016

# About NEC Energy Solutions

**NEC Energy Solutions is a full service, end-to-end turnkey energy storage solution and battery systems provider**

**Offering energy storage systems, technical and economic project analysis, installation and commissioning, operation, maintenance, equipment warranties, performance guarantees, and financing**

# Full Spectrum Energy Storage





# Energy Storage Products



**ALM® Battery Systems**  
12V to 48VDC  
0.6 kWh - 18 kWh



**Energy Storage Racks**  
700V to 1000VDC  
85 kWh to 112 kWh



**DSS® Distributed Storage Solution**  
100 kVA to 710 kVA  
85 kWh to 510 kWh



**GSS® Grid Storage Platform**  
800 kVA to hundreds of MVA  
1 MWh to hundreds of MWh

DC Energy Storage Systems

AC Energy Storage Systems

# DSS<sup>®</sup> Distributed Storage Solution

Fully integrated energy storage platform empowering commercial developers and utilities to deliver advanced energy services at the grid edge



## Distribution Scale

- 85-510 kWh energy; 100 -710 kW power

## Smart

- Same proven AEROS<sup>®</sup> controls platform as GSS<sup>®</sup> product line

## Simple

- To design-in, configure, install, operate, & maintain

## Compact

- Robust outdoor enclosures; high energy density

## Safe

- Tested and certified multi-layer system safety

## Cost effective

- In initial capex and long-term opex

# GSS<sup>®</sup> Grid Storage Solution

## Flexible power and energy options using standard components



### 53' Container

Configured for Maximum Power:	
Peak Power <sup>1</sup>	9.2 MW
Energy <sup>2</sup>	3.6 MWh
Configured for Maximum Energy:	
Peak Power <sup>1</sup>	1.6 MW
Energy <sup>2</sup>	5.1 MWh

### 40' Container

Configured for Maximum Power:	
Peak Power <sup>1</sup>	6.4 MW
Energy <sup>2</sup>	2.6 MWh
Configured for Maximum Energy:	
Peak Power <sup>1</sup>	1.6 MW
Energy <sup>2</sup>	3.5 MWh

### 20' Container

Configured for Maximum Power:	
Peak Power <sup>1</sup>	2.4 MW
Energy <sup>2</sup>	1.0 MWh
Configured for Maximum Energy:	
Peak Power <sup>1</sup>	800 kW
Energy <sup>2</sup>	1.4 MWh

1: At 480VAC output; 2: At peak power level shown



# The GSS<sup>®</sup> grid storage solution

## An Integrated System

- The GSS<sup>®</sup> grid storage solution is a fully integrated, turnkey, AC energy storage plant ready to interconnect to the grid
  - Configured-to-order from factory-assembled, standard modular components
  - Designed and manufactured by NEC Energy Solutions:
    - AEROS<sup>®</sup> controls, a complete energy storage command and controls software package
    - GBS<sup>®</sup> grid battery systems; energy storage with BMS and controls hardware in outdoor-rated enclosures (standard containerized, but custom enclosures possible)
  - Includes necessary equipment from third-parties, engineered to work with all NEC ES equipment
    - Power conversion hardware (inverters) from leading manufacturers around the world
    - Thermal management units (air conditioning or water chillers) for battery cooling

**Custom enclosure GSS<sup>®</sup> grid storage solution**

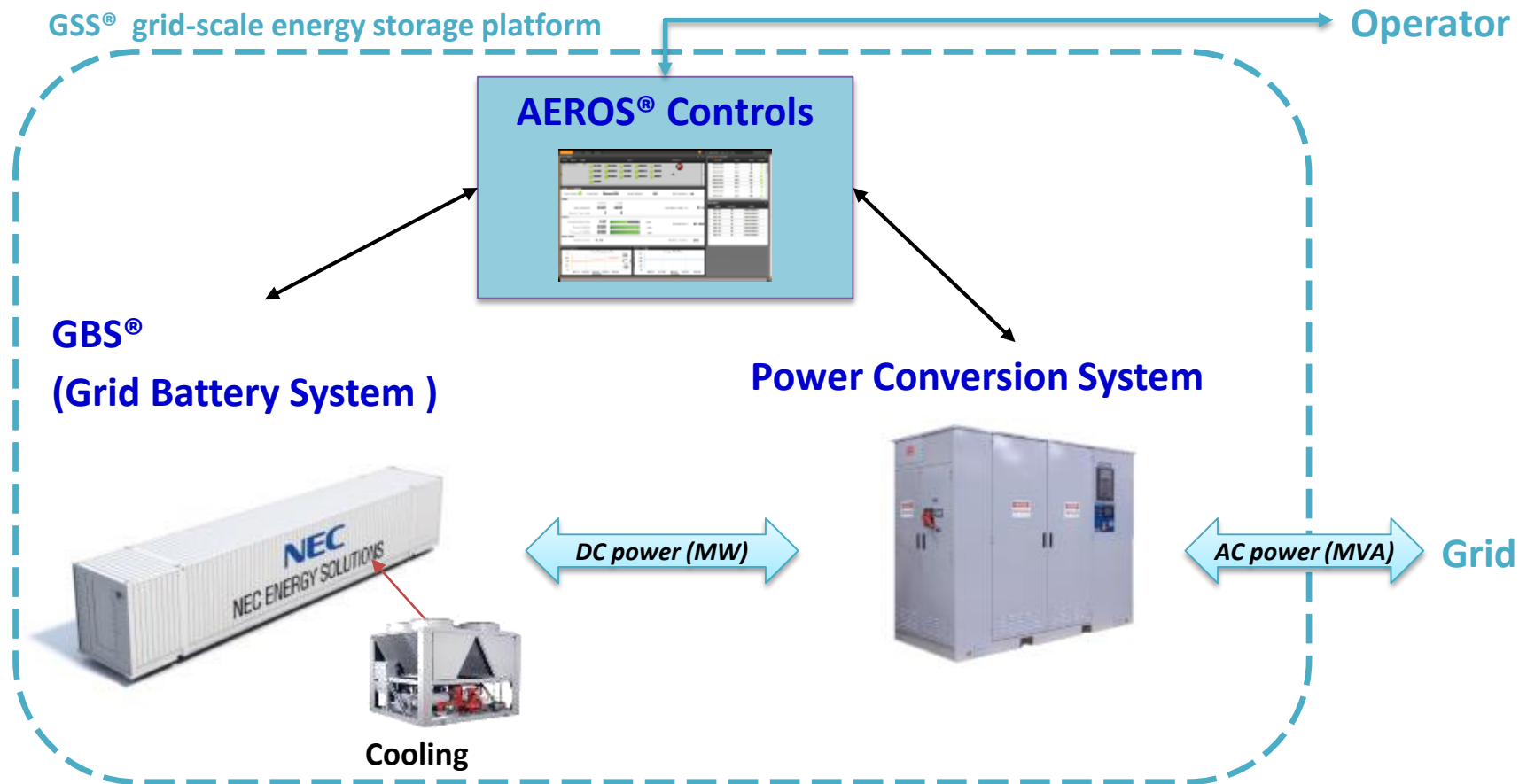


**Standard containerized GSS<sup>®</sup> grid storage solution**

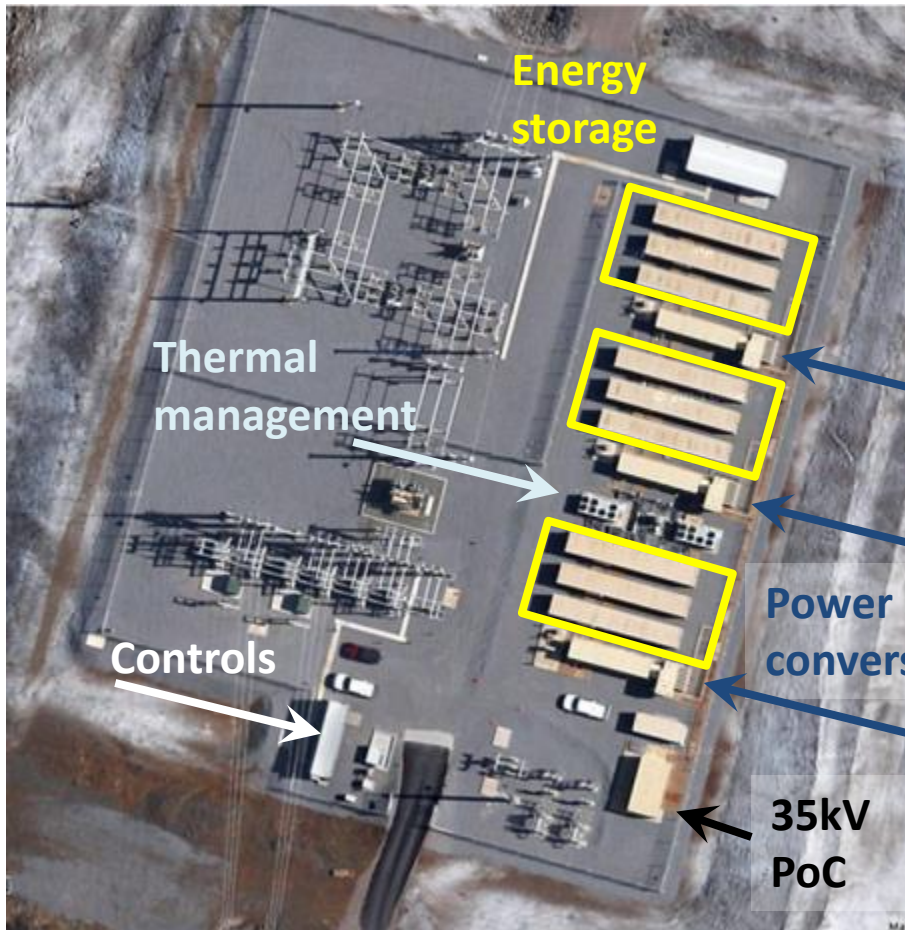


# GSS<sup>®</sup> grid-scale energy storage platform

## Three major functional components



# GSS® Project Example: Auwahi 11MW/4.3MWh install



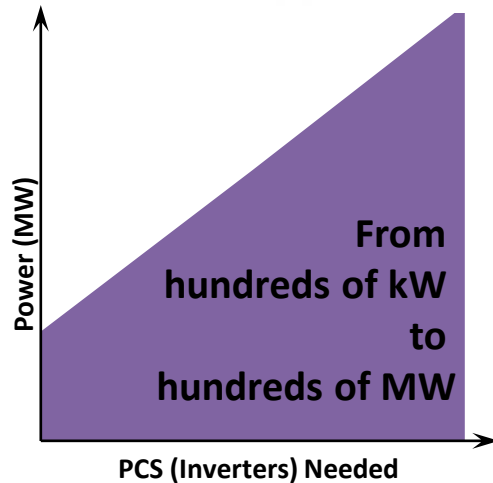
- What's included in a turnkey energy storage solution?
- Equipment
  - Everything required to interconnect to the grid and operate:
  - Energy storage
  - Thermal mgmt (as needed)
  - Power conversion
  - Controls
  - Transformers/switchgear (as needed)
- Service and Maintenance Programs
- Warrantees and Performance Guarantees
  - Equipment warrantees
  - Availability or uptime guarantee
  - Energy storage capacity guarantee
  - Power capacity guarantee
- What to expect? Example: Availability
  - EAF – Availability > 96%
    - \*EAF = Equiv. Availability Factor
      - $(\text{Available Power}/\text{Nameplate Power}) \times 100$
      - Incorporates Design and Performance



# Flexible Product Architecture

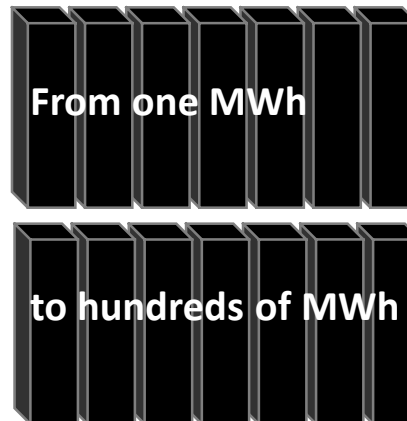
## Power

Choose Power Conversion Size



## Energy Storage

Choose Energy Storage Size



## Packaging

Package in containers



Or in custom enclosures



Or in buildings



# Applications

- **Renewable Integration**
- **Ancillary Services for Grid Stabilization**

# Why Energy Storage for the Grid?

## Preparing Grids For A Renewable Future

*Adding flexibility, efficiency, and reliability*

- Today's grids require more flexibility to address:
  - Increased renewable generation
  - Changing load patterns
  - Aging transmission and distribution network
- Energy storage in the grid is a powerful tool
  - Increase capacity utilization for generation, transmission, and distribution infrastructure





## Dynamic Energy Storage Solutions for a Smarter Grid

### Generation

- Frequency Regulation
- Frequency Response
- Renewable Integration
- Power Plant Hybridization

Improve plant efficiency and output, lower O&M costs, and decrease plant emissions, with no water consumption, no emissions of its own, and rapid deployment capability.



### Transmission

- Voltage Support
- Dynamic Line Rating Support
- Renewable Integration
- Upgrade Deferral

Increase grid reliability, increase asset efficiency and utilization, enable wind and solar, defer upgrades to transmission assets.



### Distribution

- Upgrade Deferral
- Community Energy Storage
- Microgrids

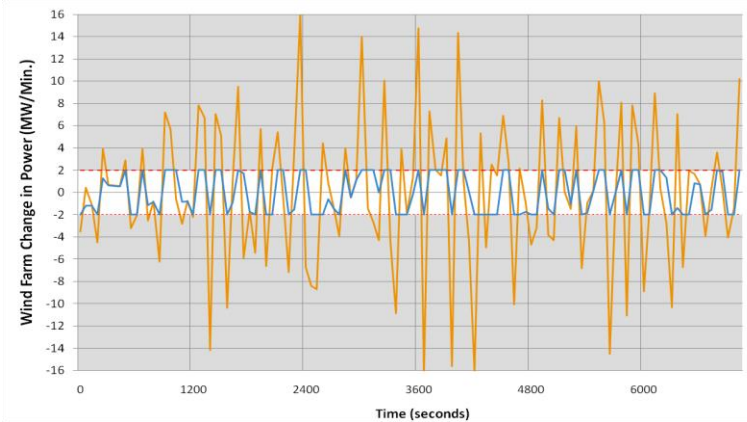
Improve power quality, increase asset efficiency and utilization, smart grid ready; aggregation and automation, defer upgrades and support distribution assets.



Providing benefits throughout the electricity supply chain

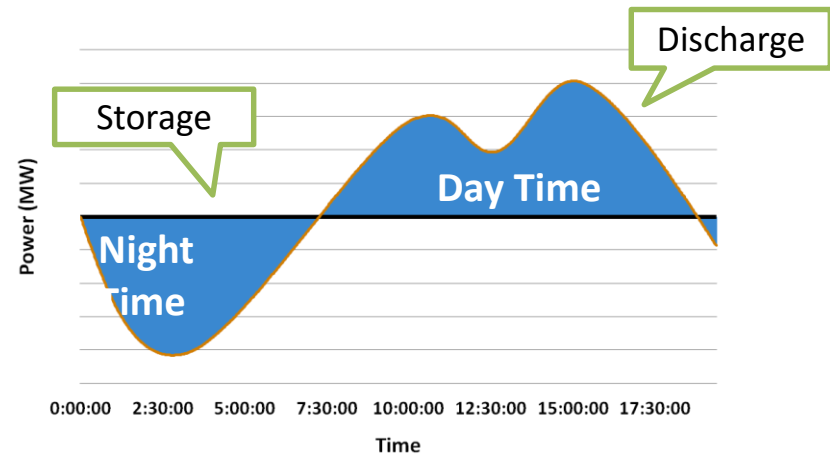
# Applications for Grid Storage

## High Power Applications:



- Frequency Regulation
- Primary Reserve
- Renewable Integration
  - Ramp Management
- **Requirements:**
  - High charge/discharge rates
  - Short duration (<1hr)
  - Many cycles (100's per day)
  - Continuous use

## High Energy Applications:



- Peak Load Shifting
- Renewable Integration
  - Firming, Shifting & Curtailment Recovery
- Arbitrage
- T&D Support
- **Requirements:**
  - Low charge/discharge rates
  - Long duration (1+ hrs)
  - 1-2 cycles per day

# Applications

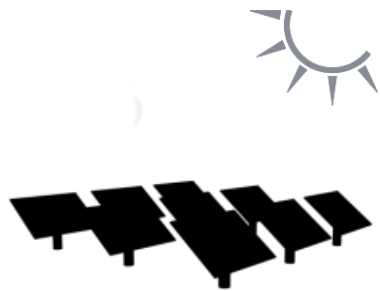
## ➤ Renewable Integration



# Renewable Capacity Firming

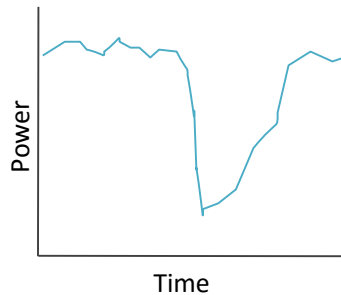
## Constant power output is desired

- Value Added by Energy Storage
  - How does energy storage work with non-firm renewable capacity?



PV solar farm

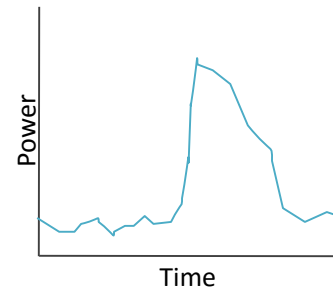
**Intermittent PV**



PV is intermittent – passing clouds cause power output to drop quickly. When the cloud departs, electricity begins flowing again.

**+**

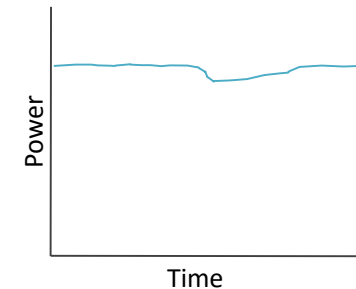
**Energy Storage**



Energy storage can fill in the valley with previously stored electricity.

**=**

**Firm Renewable Capacity**



The net result? Firm renewable capacity – consistent power output from a PV array even when clouds pass by!

# Renewable Curtailment Avoidance

## Transmission lines have a limited transport capacity

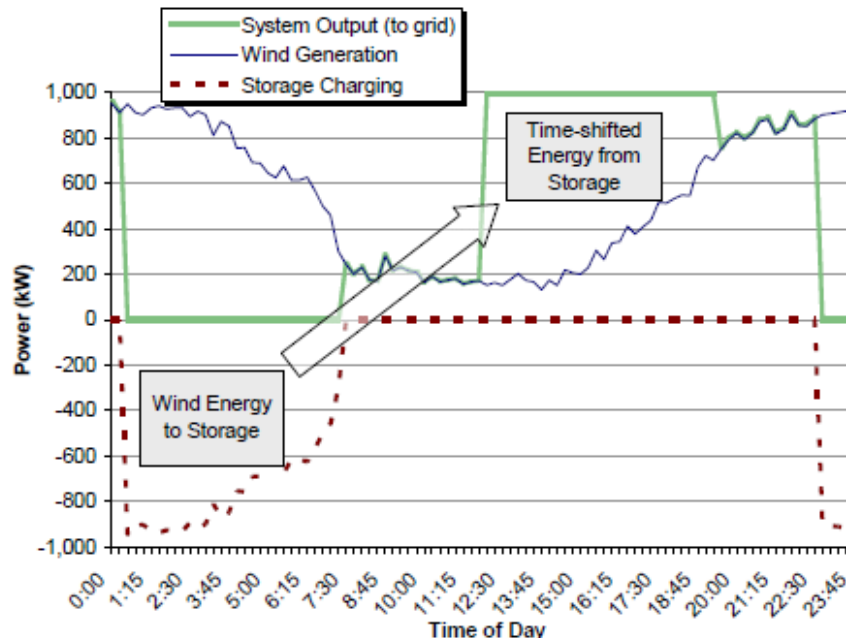
- Value Added by Energy Storage
  - Using energy storage to capture wind or solar energy under curtailment conditions gives the system operator more flexibility to manage oversupply or constrained transmission capacity and avoid negative power prices.
  - Avoiding curtailment can also increase the amount of energy generated by renewables, and increase the amount it can sell
  - Additionally, if renewable generation occurs at a time of negative pricing, storage could actually get paid to charge up!

# Renewable Time-Shifting

## Sell renewable electricity at peak time for a higher price

- Value Added by Energy Storage
  - Renewable energy time-shift can allow optimized revenue with energy storage charging during off-peak times, and discharging and selling the stored electricity during on-peak times.

An example is shown here for a wind with energy storage on a summer day. Wind generation is stronger at night, when energy's value is low, and is used to charge storage. About half of the energy used on-peak is from wind generation that actually gets generated off-peak. The result is firm, constant power for five hours, being sold at a higher price (on-peak time) as compared to a lower price (off-peak time).



Source: SANDIA Report SAND2010-0815, *Energy Storage for the Electricity Grid: Benefits and Market Potential Assessment Guide*, Jim Eyer & Garth Corey (February 2010)

### Did you know?

A commonly used term for time-shifting is "arbitrage". However, the strict definition of "arbitrage" is the simultaneous purchase and sale of identical commodities across two or more markets to benefit from a difference in pricing. Time-shifting is not the same since the "buy low sell high" mechanism occurs at two different times separated by several hours, and are not simultaneous.

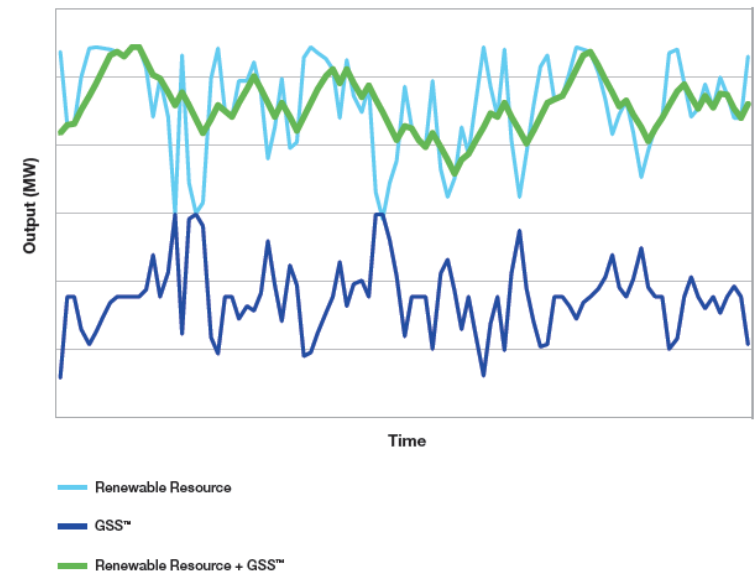


# Renewable Ramp Management

## Limit uncontrolled, rapid changes in generator output

- Problem
  - Renewable generation output is variable and can change rapidly. This rapid power ramp can cause instability on the grid.
- Value Added by Energy Storage
  - Renewable generation can limit up-ramps on its own, but typically cannot limit down-ramps. Energy storage can slow down the down-ramps to meet the limitations imposed by the system operator.

Renewable Resource with GSS™



Energy storage can charge when up-ramps are too steep, and discharge when down-ramps are too steep. Depending on the nature of the wind resource and the wind turbine equipment, relatively short durations of energy storage can mitigate large amounts of renewable generation. However, energy storage sizing is tricky – consult NECES for more details!

# Applications

## ➤ Ancillary Services for Grid Stabilization

# Ancillary Services from Energy Storage

## Grid electricity frequency must be maintained

- How does energy storage work in a frequency correction situation?

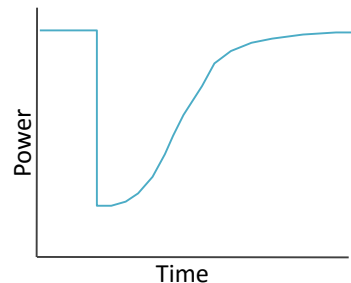
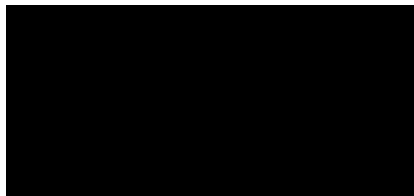
**Grid Disturbance**

**+**

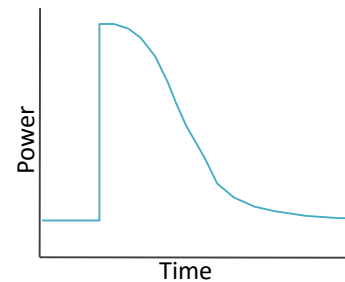
**Energy Storage**

**=**

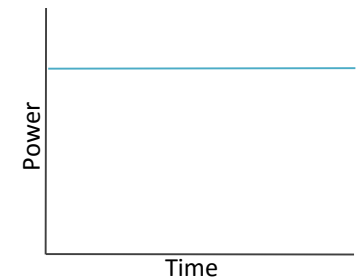
**Reliable Power**



Loss of generation or transmission can cause frequency to drop quickly – this disturbance must be contained and corrected.



Energy storage can provide a vertical ramp response to frequency deviation and also respond more consistently than traditional generators for better frequency containment.

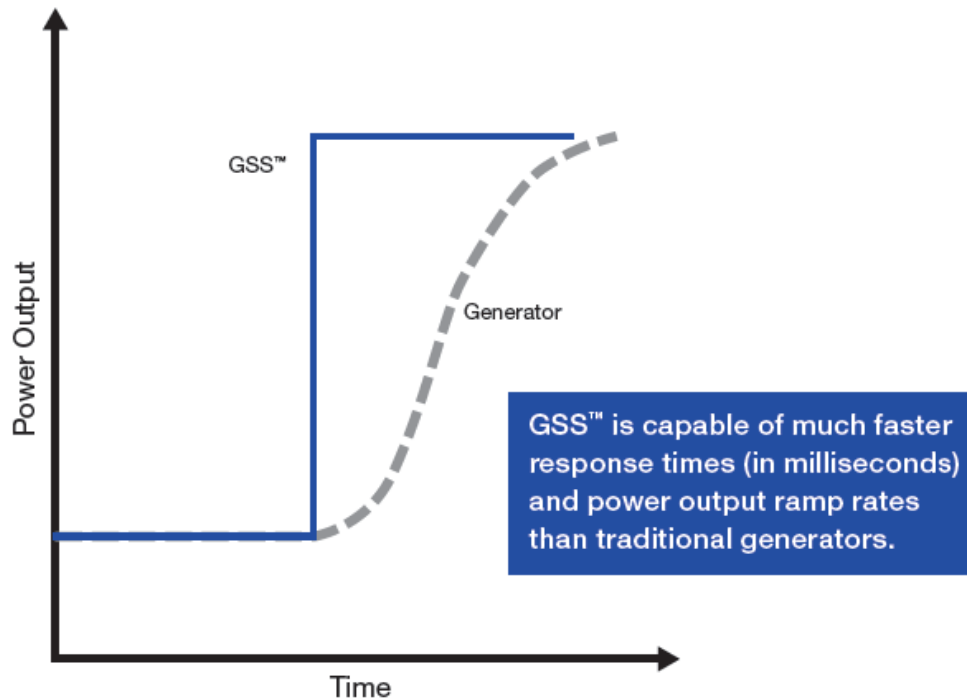


The result is more reliable power from better frequency response.



# Advantages of Energy Storage

## Ramping Capability



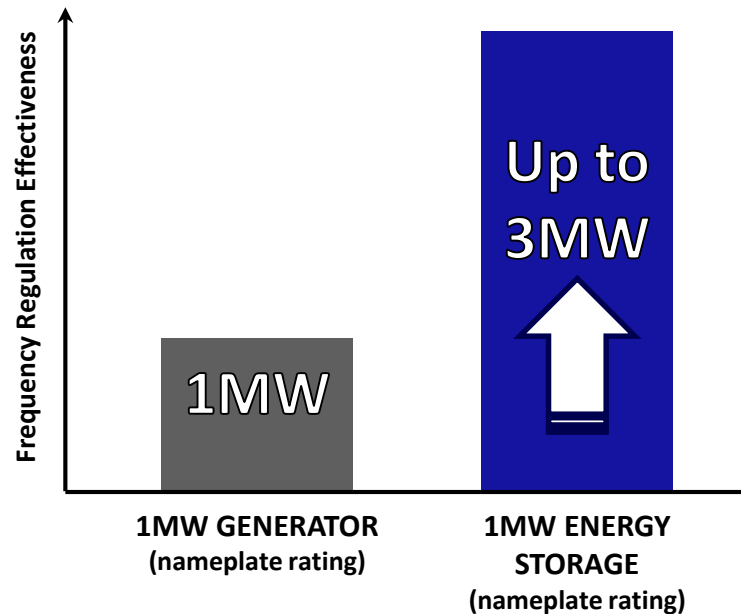
Note: The GSS® is NEC Energy’s Grid Storage Solution, which contains energy storage, power conversion to change AC electricity to DC and back, and a controls system to operate the entire GSS on the grid.

- Because of its **fast, almost instant response** it is more effective in providing ancillary services
- Can ramp up and down much **faster and easier** than traditional generators
  - Nearly “vertical” ramp rate, well under 1 second to full output
  - Generators can take several minutes to get to full output
  - No ramping wear-and-tear, unlike fossil fuel generators
- **No shutdown/startup costs**, unlike fossil fuel generators
  - Can operate at zero with no penalty

# Advantages of Energy Storage

## Fast precise resources more effective than slow imprecise resources

- With fast responding, precise, accurate frequency regulation (like that provided by energy storage, grid operators can procure LESS frequency regulation service than before!



### *Did you know?*

*PJM has reported that the total money spent on frequency regulation today is less than what it used to spend, based on its "pay-for-performance" reform (FERC Order 755) of the frequency regulation market in October 2012. It is well recognized that fast responding, accurate resources like energy storage are the most effective tool for frequency regulation.*

# Primary Frequency Control Operation

## Autonomous Response to Loss of Generation



CDEC-SING Fault Report No. 2777, June 3, 2011

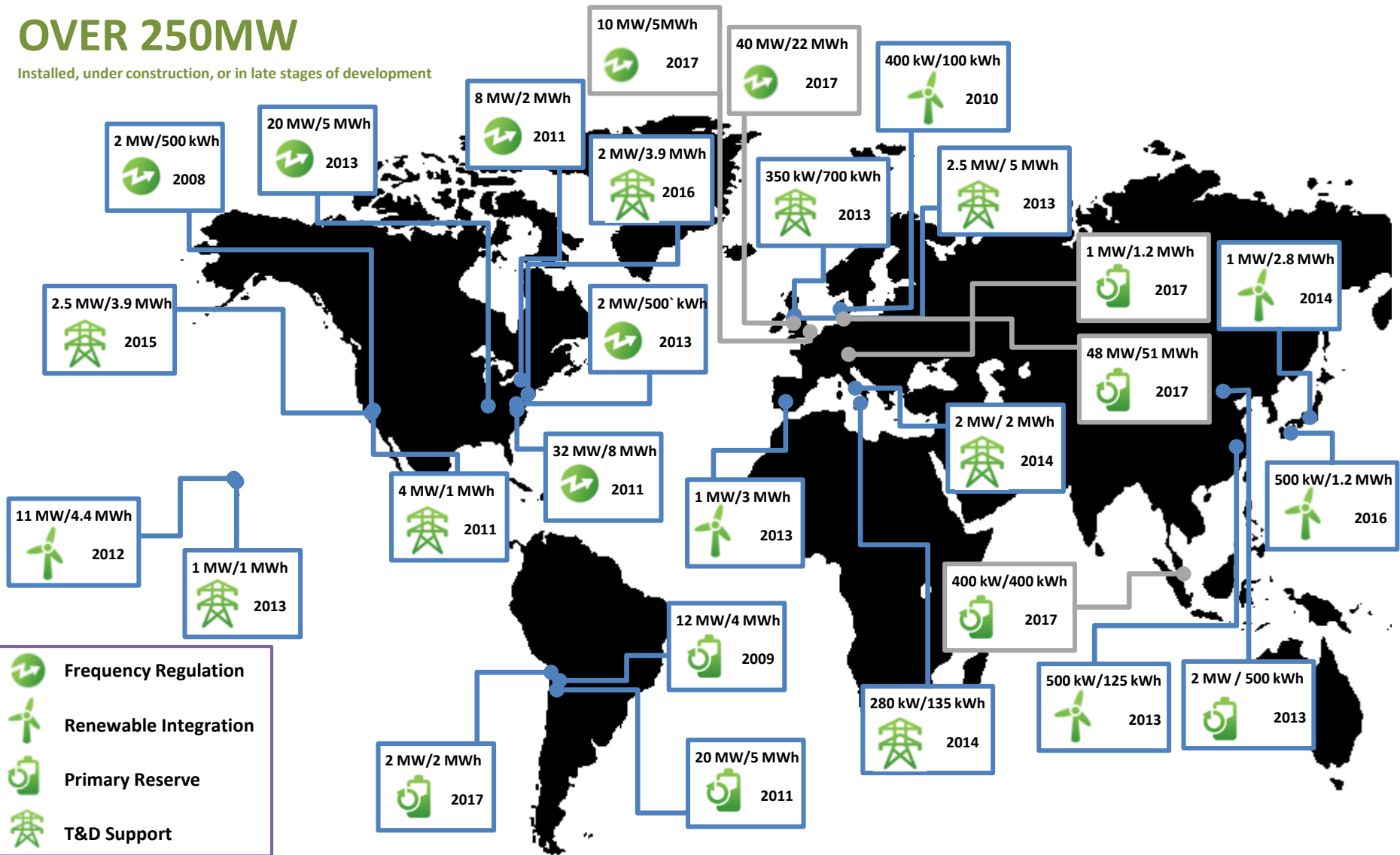
## Project Examples



# GSS® Grid Storage Solution Installations

## OVER 250MW

Installed, under construction, or in late stages of development



# Sterling Energy Storage Project

- Town of Sterling, Massachusetts
  - Sterling Municipal Light Dept
  - 3MW of PV in Sterling
  - Desired additional resiliency and better integration of existing PV
- Installed energy storage
  - 2MW, 3.9MWh  
GSS® grid storage solution
- Applications stacking
  - Frequency regulation
  - Energy arbitrage
  - Reduction in monthly network load
  - Reduction in capacity payments
- Multiple benefits
  - Provide power for Sterling Police and Dispatch Center during outages
  - Provides electricity cost savings to ratepayers
  - Firms the value of PV
  - Enables future microgrid capability





# Sterling, MA GSS<sup>®</sup> grid storage solution

- T&D Support Application
- 2 MW Power Capability
- 3.9 MWh Energy Capacity
- Battery container w/integrated cooling
- Power conversion system
- Operational December 2016

**2MW, 3.9MWh lithium ion energy storage system**

**Groundbreaking on Oct 12, equipment installation on Nov 14**

**First commercial operation on Dec 15**

# Energy Storage in Primary Reserve

Located at the Los Andes substation in the Atacama Desert in Northern Chile

12 MW lithium ion energy storage

Operational since 2009



“the Los Andes battery energy storage system is one of the best performing reserve units in Northern Chile”

-CDEC-SING, system operator in Northern Chile



# Energy Storage in PJM Frequency Regulation

- Located at the Laurel Mountain wind farm in Elkins, West Virginia
- 32 MW lithium ion energy storage
- Operational since 2011





# Energy Storage in Primary Reserve



- Located in Chile, South America 1,400km north of Santiago
- 20MW lithium ion energy storage facility
- Operational since 2011

# Energy Storage in Ramp Rate Management



**Located on Maui, Hawaii**

**11MW lithium ion energy storage working with a 21MW wind farm**

**Operational since December 2012**



# Energy Storage in Load Limiting/Peak Shaving



**Located in California distribution grid for improved power reliability**

**2.5MW lithium ion energy storage in custom enclosure**

**Operational since July 2015**

Photo Credit: Southern California Edison



# 4MW / 2MWh GSS<sup>®</sup> grid storage solution

## Peterborough, UK

- Renewable Integration
- Hybrid Fast Frequency Response
- Co-Located with Diesel Generation
- 1 Battery Container
- 2 Inverters
- Operational 2017



# 10MW/5MWh GSS<sup>®</sup> grid storage solution

## Cleator, UK

- Enhanced Frequency Response (EFR)
- 2 Battery Containers
- 6 Inverters
- Operational 2017





# 40MW/20MWh GSS<sup>®</sup> grid storage solution

## Glassenbury, UK

- Enhanced Frequency Response (EFR)
- 7 Battery Containers
- 19 Inverters
- Operational December 2017





# 48MW/51MWh GSS<sup>®</sup> grid storage solution

**Jardelund, Germany**  
Primary Control Reserves (PCR)



Building-based installation, battery room shown



**Thank you!**

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Energy in Latin America

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Las Condes

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