RESERVOIR SOLUTIONS

Flexible, modular Energy Storage Solutions unlocking value across the electricity network
TODAY’S ENVIRONMENT

The electricity industry is facing new challenges that have not been seen for the past 100 years. As consumers become active power producers who demand clean, reliable, and affordable power, the transforming grid needs innovative technical solutions that can unlock new business models and revenue streams.

78% of the 9000GW+ of new generation forecast to be built by 2040 will be RENEWABLE

TOTAL ENERGY STORAGE SOFTWARE REVENUE TO HIT $3.3 BILLION BY 2025

Sources:
- Bloomberg - New Energy Outlook Report
- Navigant Research - Energy Storage Software Report
- Navigant Research - Global DER Deployment Forecast
This change to energy generation and consumption is being driven by three powerful trends: the arrival of increasingly affordable distributed power technologies, decarbonization of the world’s electricity network through the introduction of more renewable energy sources, and the emergence of digital technologies.

### Decarbonization
The rapid deployment of low-carbon technologies such as wind and solar is making it increasingly difficult to forecast variable generation, creating challenges around grid stability, congestion and market volatility.

### Digitization
A rise in the number of connected devices and smart sensors enables fast decision-making on dynamic and nodal prices, while intelligent control systems and internet-enabled software optimize power plants and the grid.

### Decentralization
The growing penetration of distributed energy resources, including renewables and storage, is creating more “prosumers” (end users who are active in the power system), greatly increasing distribution grid complexity.

**INTEGRATING INTERMITTENT RENEWABLES INTO AN AGING GRID REQUIRES FLEXIBLE AND RESILIENT TECHNOLOGIES, ABLE TO RAMP QUICKLY AND DYNAMICALLY ADJUST TO REAL-TIME GRID SIGNALS**
WHY ENERGY STORAGE?

A battery energy storage solution offers new application flexibility and unlocks new business value across the energy value chain, from conventional power generation, transmission & distribution, and renewable power, to industrial and commercial sectors. Energy storage supports diverse applications including firming renewable production, stabilizing the electrical grid, controlling energy flow, optimizing asset operation and creating new revenue by delivering:

### Active Power Services
- Frequency regulation
- Frequency response
- Peak shaving/firming
- Remote power commands
- Ramp rate control
- Curtailment avoidance
- Scheduled dispatch/shifting
- Scheduled power commands
- State of charge management
- Islanding
- Black start

### Reactive Power Services
- Voltage control
- Voltage droop
- Power factor control
- VAR control

$103B INVESTMENT IN ENERGY STORAGE PROJECTS BY 2030

Outcomes achieved with GE’S RESERVOIR SOLUTION

- **ENABLE UP TO 50% MORE SOLAR ENERGY SALES** WITH ENHANCED PV TO INVERTER LOADING RATIO
- **UP TO 50% REDUCED CONSTRUCTION TIME** WITH FACTORY BUILT & TESTED SOLUTION
UNLOCKING NEW BUSINESS VALUE WITH GE’S RESERVOIR ENERGY STORAGE SOLUTION

- Improve Financial Performance
  Monetize assets through new revenue streams, increased asset utilization, improved yield, and reduced operating costs.

- Increase Renewables Integration
  Improve integration and maximize utilization of the energy generated from photovoltaics (PV) and wind turbines.

- Optimize Electrical Grid
  Defer upgrades, relieve congestion, control voltage, provide reserves and ancillary services, and improve reliability with backup power and black start functionality.

- Reduce Energy Costs
  Commercial and industrial end users can mitigate demand charges, optimize differential (Time of Day) energy prices, and benefit from additional onsite PV generation.

- Develop Microgrids
  Create a new and more flexible grid by locally integrating renewable generation and smart devices with energy storage and real-time communication.

- UP TO 15% EXTENDED BATTERY LIFE UTILIZING PROPRIETARY BLADE PROTECTION UNITS

- IMPROVE SAFETY BY REDUCING FAULT CURRENT BY UP TO 5X

GE’S RESERVOIR IS A FLEXIBLE ASSET THAT HELPS ENABLE GRID OPTIMIZATION
GE APPROACH

GE’s broad portfolio of Reservoir Solutions can be tailored to your operational needs, enabling efficient, cost-effective storage distribution and utilization of energy where and when it’s needed most. Our expert systems and applications teams utilize specialized techno-economic tools to help optimize the lifetime economics of a project. Our approach results in an investment grade business case that provides the basis of project planning and financing.

GE’s System Approach

System Design Process & Optimization

Once the project scope, business objectives and services are established, GE’s technical experts will define the energy sources, equipment and services required. Using advanced system planning and optimization tools, GE will deliver a tailored solution to meet the desired objectives.

GE INPUTS

CUSTOMER INPUTS

GE OPTIMIZATION TOOL
GE SOLUTION

GE’s Reservoir is a flexible, compact energy storage solution for AC or DC coupled systems. The Reservoir solution combines GE’s advanced technologies and expertise in plant controls, power electronics, battery management systems and electrical balance of plant – all backed by GE’s performance guarantees.

POWER CONVERSION
- Inverters are a bidirectional system converting AC to DC for battery charge and DC to AC for discharge
- 4 quadrant operation
- High efficiency

BATTERY MANAGEMENT
- Battery Protection Unit
- Long life Li-ion battery
- Integrated lockable disconnect
- Active string balancing
- Factory tested
- Field replacement

PURPOSE BUILT ENCLOSURES
- Ships with batteries installed
- Enhanced cooling and insulation
- Built in redundancy for 25 years of life
- Fast and flexible installation

RESERVOIR CONTROL UNIT
- Advanced functionalities to monitor batteries and help optimize asset operations
- Based on GE Mark™ Vle
FLEXIBLE SYSTEM DELIVERY

The solution can be delivered as Engineered Equipment Package (EEP), Engineering, Procurement, and Construction (EPC) turnkey solution or lease and financing arrangement.

**MV TRANSFORMER**
- Connects to any MV network up to 66kV through a step-up transformer
- Dry or oil-type transformer designed for both outdoor or e-house indoor environment

**MV SWITCHGEAR**
- MV switchgear and LV auxiliaries integrated into an ISO container for easy site installation

**CONSULTING & SERVICES**
- Technical and economic feasibility studies
- Network analysis
- Project management & design
- Real-time optimization services
- Long term service contracts
- Performance guarantees

**SOFTWARE SUITE**
- Asset performance management
- Fleet management
- Dispatch optimization

World’s First Hybrid Electric Gas Turbine, 10 MW/4.3 MWh Energy Storage Solution
RESERVOIR STORAGE UNITS

The Reservoir Storage unit is a modular high density solution that is factory built and tested to reduce project risk, shorten timelines and cut installation costs. The Reservoir Storage unit is built with GE’s Battery Blade design to achieve an industry leading energy density and minimized footprint. GE’s proprietary Blade Protection Unit actively balances the safety, life and performance of each Battery Blade, extending battery life by up to 15% and reduce fault currents by up to 5X. The modular system has multiple installation and cabling options including pad or pier and is configured to minimize operation and maintenance (O&M) expenses over the life of the project with all weather capabilities and high efficiency cooling system.

**ELECTRICAL INTEGRATION**
- DC disconnect, service rated
- Auxiliary power equipment
- Optional combiner package for DC coupled PV
- Bottom and front entry cable option

**ENCLOSURE**
- High density configuration with reduced footprint
- All weather capabilities
- High efficiency cooling
- Long service life

**BATTERY BLADE UNIT**
- Integrated protection unit
- Serviceable with integrated lockable disconnect device
- Digital twin technology for lifecycle management
- 1500V class with less cable, fuses and switches
- Tier 1 Li-Ion cells for highest cycle life

**BLADE PROTECTION UNIT (BPU)**
- Active string regulation to extend life by up to 15%
- Reduce fault currents by up to 5X to improve safety
- Intelligent DC bus enables direct PV integration
- Enables safe replacement of individual battery modules
- Reduces NFPA PPE levels from HRC4 to HRC2

Large Energy Reservoir, 20' Package, 1.2 MW / 4 MWh*

*Final Specifications subject to change
SYSTEM CONFIGURATIONS

The Reservoir Solution can be designed in a power or energy configuration depending on the required application. In an energy configuration, the batteries are used to inject a steady amount of power into the grid for an extended period of time. In a power configuration, the batteries are used to inject a large amount of power into the grid over a short period of time. The configuration of power or energy is determined by the ratio of inverters to batteries.

Modular and Scalable Solution

MORE POWER
Additional inverters are added to achieve desired power level.

MORE ENERGY
Additional reservoir storage units are added to achieve desired energy output.

GE’S DC COUPLED RESERVOIR SOLUTION ENABLES ENHANCED PV TO INVERTER LOADING RATIO RESULTING IN UP TO 50% INCREASE IN ANNUAL SOLAR ENERGY SALES PER SITE
## TYPICAL RESERVOIR APPLICATIONS

### Standalone Applications

<table>
<thead>
<tr>
<th>Application</th>
<th>Generation</th>
<th>Transmission</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>POWER</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Voltage Regulation</td>
<td></td>
<td></td>
<td>✓</td>
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<tr>
<td>Compensate anomalies or disturbances (e.g., voltage magnitude, harmonics, etc.) by sending reactive energy into system.</td>
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<td></td>
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<tr>
<td>Frequency Response</td>
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<td>☑</td>
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<tr>
<td>Provide fast regulation of grid frequency to balance supply and demand.</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Frequency Regulation</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Provide regulation of grid frequency to balance supply and demand based on signals sent by the grid operator.</td>
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</tr>
<tr>
<td>Renewable Integration</td>
<td></td>
<td></td>
<td>✓</td>
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<tr>
<td>Balance the local excesses or deficits of renewable generation caused by rapid weather fluctuations.</td>
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<tr>
<td>Black Start</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Energize part of the generation asset without outside assistance after a blackout.</td>
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<td></td>
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<tr>
<td>Back-Up</td>
<td></td>
<td></td>
<td>✓</td>
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<tr>
<td>Store energy to maintain service continuity and grid resilience in the event of an outage.</td>
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<tr>
<td>Peak Management</td>
<td></td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Reduce grid capacity needs during peak periods with local storage.</td>
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<td></td>
<td></td>
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<tr>
<td>Shifting</td>
<td>✓</td>
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<tr>
<td>Buy or produce electricity at low price (off-peak) to store and sell at peak price.</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Capacity</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Store renewable energy production for peak and base load consumption.</td>
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</tr>
</tbody>
</table>
### Integrated Hybrid Solution Applications

<table>
<thead>
<tr>
<th>POWER</th>
<th>Solar</th>
<th>Wind</th>
<th>Thermal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Synthetic Inertia</td>
<td></td>
<td></td>
<td>✔</td>
</tr>
<tr>
<td>Compensate losses of grid inertia caused by high renewable penetration.</td>
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</tr>
<tr>
<td>Frequency Regulation</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Provide fast regulation of grid frequency to balance supply and demand.</td>
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<tr>
<td>Firming</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
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<tr>
<td>Prevent undesirable short-duration effects from rapid fluctuations in solar generation due to intermittency and weather conditions.</td>
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<tr>
<td>Improved Operations</td>
<td>✔</td>
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<td>✔</td>
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<tr>
<td>Help optimize generation fleet operations and costs.</td>
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<tr>
<td>Contingency Reserve</td>
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<td>✔</td>
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<tr>
<td>Provide fast ramp-rate to meet grid requirement for online dispatch within a short delay of operating reserve.</td>
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<tr>
<td>Curtailment Avoidance</td>
<td>✔</td>
<td>✔</td>
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</tr>
<tr>
<td>Avoid output curtailment at certain times, preventing loss of energy production.</td>
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</tr>
<tr>
<td>Dispatchable</td>
<td>✔</td>
<td>✔</td>
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<tr>
<td>Control solar generation at request of power grid operators or according to market needs.</td>
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</table>
**KEY COMPONENTS**

**Reservoir Control Unit (RCU)**
GE’s integrated Reservoir Control Unit is a supervisory control and data acquisition system for energy storage plants.

At the heart of the system is GE’s field proven Mark™ Vle control system used to monitor and control gas turbines, wind and solar energy fleets.

**Reservoir Storage Unit**
GE utilizes proven Li-Ion technology for battery storage solutions; each solution is tailored based on the customer’s application. GE’s battery solution exceeds industry standards for protecting against common industrial battery failure and reduces environmental impact with restricted use of substances controlled by US EPA, Global REACH and RoHS regulations.

**Inverters**
GE’s inverters are designed specifically for dynamic operation and high performance lithium ion batteries.

Built with enhanced technology including integral ground fault detector/interrupter low voltage, zero voltage and high voltage ride through capability (LVRT, ZVRT, HVRT).

**Modular & Scalable**
**AC or DC-Coupled Systems**
**Performance Guarantee**
High Performance Transformers
GE provides comprehensive portfolio of HV and MV transformers. Each transformer is made for performance, efficiency and immunity to withstand electronic noise.

Purpose Built Enclosures
GE’s enclosures are prefabricated with redundant HVAC and optional fire suppression systems, and provide the following benefits:

- Low maintenance, configured with enhanced cooling and insulation with built-in redundancy for 25 years of life.
- Easy transportation, minimal installation effort on site and better battery insulation

Electrical Balance of Plant
GE offers a comprehensive portfolio of high voltage and medium voltage substation equipment and technical expertise to ensure efficient and reliable interconnection of power generation.

FROM ADVANCED TECHNOLOGIES AND PLANT CONTROLS TO BATTERY MANAGEMENT SYSTEMS, GE DELIVERS COMPREHENSIVE STORAGE SOLUTIONS
RESERVOIR SOFTWARE SUITE

The reservoir software suite includes edge to cloud infrastructure that’s scalable, adaptable and easy to use. The software suite includes:

- **FLEET MANAGEMENT**: Fleet aggregation software designed for asset monitoring, alerts, trends and forecasting.
- **COMPONENT LIFE ANALYTICS**: Manages battery life based on history and expected future use profiles to minimize downtime and unplanned outages.
- **DISPATCH OPTIMIZATION**: Charges and discharges batteries based on equipment status and market conditions to maximize customer outcomes.
Reservoir Services

GE’s service agreements are customized based on the customers’ requirements and can lower operating costs and mitigate operational and financial risks. GE’s services include:

**Planned Maintenance**
Routinely service equipment and keep the energy storage system online, resulting in superior fleet performance.

**Unplanned Maintenance**
Monitor, troubleshoot and inspect equipment, boosting uptime and lifecycle production.

**Parts Plans**
Provide full range of offerings to support preferred levels of service. Our forecasting capability, driven by fleet-wide parts consumption data configuration and management knowledge, can even help to predict what you may need.

**Remote Operations Center**
Provides continuous monitoring and diagnostics services 24 hours a day, 365 days a year. An on-site SCADA system enables continuous tracking of key operating parameters and detects abnormal conditions. GE technicians can then troubleshoot or reset the equipment remotely, in real-time.

**Performance Guarantee**
The specific performance criteria and duration of the performance guarantee will vary depending on your application, economic incentives, and requirements. Performance guarantees are only available to customers who maintain a contractual services agreement with GE and include:

- **Availability Guarantee**
  This guarantees that the battery energy storage solution will be available to charge or discharge electric energy at the nameplate power output and at the agreed-upon percentage of time.

- **Capacity Guarantee**
  The amount of energy that the battery is able to extract from and discharge to the grid can be guaranteed.

- **Custom Metric Guarantee**
  Some owners have unique measurements or metrics, such as the PJM fast response frequency regulation score. In such cases, GE works with you to assess the risks involved and define a guarantee structure that aligns the interests of both parties throughout the life of the asset.
SERVING GLOBAL CUSTOMERS WITH LOCAL EXPERTISE

GE is globally recognized for designing and delivering customized energy storage solutions for diverse applications. With regionally located technical experts, our teams work directly with customers during the lifetime of the project. To date GE has more than 207 MWh of energy storage in operation or in construction globally.

126 MWh in North America

Services

52+ SERVICE AND REPAIR CENTERS
17 TECHNICAL INSTITUTES
10 years of storage experience

20 year performance guarantee

1st Hybrid EGT storage + gas turbine peaker in operation

Black Start first proven emergency start of CCGT

40+ Countries providing comprehensive consulting & services

53 MWh in Europe

21 MWh in Asia

7 MWh in Africa
This project will relieve pressure on the host country’s energy system and provide flexibility when it is most needed to deliver a more balanced, secure energy system and help reduce consumer energy cost. The focus is on building long term commercially sustainable battery storage systems that are not reliant on subsidies and incentives.

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“We have a history of working with GE in thermal and wind, and we are pleased to continue our long-standing collaboration into the evolving world of energy storage. GE brings a strong technical solution, along with performance guarantees.”
**CUSTOMER**  PUBLIC POWER UTILITY

**CHALLENGE**  
Addressing local grid reliability concerns

**GE SOLUTION**  
10MW / 4.3MWh BESS, integrated controls

This project consists of two 10 MW of battery energy storage systems, each paired with GE’s proven 50 MW LM6000 aeroderivative gas turbines, capable of providing instantaneous response during a spinning reserve event.

**APPLICATION**  
Hybrid - Thermal (EGT)  
Spinning reserve

**LOCATION**  
Southern California (US)

**STATUS**  
In operation

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**CUSTOMER**  DISTRIBUTION NETWORK OPERATOR

**CHALLENGE**  
Local grid reliability

**GE SOLUTION**  
1MW / 560 kWh BESS, EMS

Smart-solar energy demonstration project. First application of large storage integrated at microgrid level, combined with a solar PV farm.

**APPLICATION**  
Standalone - Distribution  
Load shifting, frequency & voltage regulation

**LOCATION**  
Nice, France

**STATUS**  
In operation
## CUSTOMER APPLICATIONS

### CUSTOMER: ENERGY STORAGE ASSET DEVELOPER

**Challange:** Balance long duration voltage and frequency irregularities

**GE Solution:** 7MW / 7MWh BESS

“GE worked with us to create a fully integrated energy storage solution that helps meet the growing needs of the local transmission system. The project utilizes reliable GE equipment and products ranging from enclosures through the point of utility interconnection — a strategy that is cost-efficient, simplifies system warranties and guarantees, and provides a financeable solution to our customers.”

**Application:** Standalone - Transmission
- Voltage control, reactive power support, frequency regulation, ramp rate control, peak shaving, load shifting

**Location:** Ontario, Canada

**Status:** In operation

### CUSTOMER: LARGE INDUSTRIAL COMPANY

**Challenge:** Grid support; pilot program

**GE Solution:** 2MW / 2MWh BESS

This project will repurpose their facility in order to develop a large scale storage park. The goal of the storage park is to further develop know-how on large scale storage. In the first stage, 6 MW of li-ion battery energy storage systems will be installed to deliver primary frequency regulation for the Transmission System Operator as a first application.
The project is part of a larger initiative to test battery storage in real conditions for the purpose of frequency regulation, stabilizing the grid and preventing blackouts.

**CUSTOMER** PUBLIC POWER UTILITY

**CHALLENGE**
Providing grid stability & smoothing renewable output

**APPLICATION**
Standalone - Transmission
Emergency power / black start capability, distribution management system integration, ramp rate control, frequency response, spinning reserve

**LOCATION**
Southern California (US)

**STATUS**
In operation

Located in California, which has some of the most aggressive renewable portfolio requirements in the US, this 33MW / 20MWh battery system complements the integration of renewable resources, such as solar and wind, by adding stability and improving power quality.

**CUSTOMER** UTILITY

**CHALLENGE**
Local grid reliability

**APPLICATION**
Standalone - Transmission
Frequency regulation

**LOCATION**
France

**STATUS**
In operation

The project is part of a larger initiative to test battery storage in real conditions for the purpose of frequency regulation, stabilizing the grid and preventing blackouts.
For more information about GE’s Energy Storage Solutions visit www.GEPower.com/EnergyStorage