WPS-145-1
DynaPeaQ: SVC Light with lithium ion battery energy storage
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DynaPeaQ: SVC Light with lithium ion battery energy storage

- Speaker name: Eric John
- Speaker title: Director, Marketing and Sales, FACTS North America
- Company: ABB Inc.
- Location: Raleigh, North Carolina

Co-presenter
- Speaker name: Jim McDowall
- Speaker title: Business Development Manager
- Company: SAFT
- Location: North Haven, Connecticut
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Agenda

- FACTS
- Energy storage applications
- DynaPeaQ overview
- Lithium-ion battery system
  - Lithium-ion basics
  - Safety
  - System design
- Summary
FACTS – Flexible AC Transmission Systems

Main products

- SVC
- STATCOM (SVC Light)
- SC - Fixed
- TCSC - Controllable
- DynaPeaQ – SVC Light with integrated energy storage

SC’s since 50’s and SVC’s since 70’s & approx 700 FACTS installations world-wide

……..FACTS are well-proven technologies!
Energy Storage Value Chain
Where to apply and which applications?

DynaPeaQ – ABB’s large scale battery energy storage mainly suitable for transmission and renewable generation segment
Power Grid Challenge: Maintain grid stability when introducing intermittent variable generation

Usage of DynaPeaQ

- System stability & Grid Code compliance
  - Voltage support
  - Power factor correction (reactive power) at PCC
  - Flicker mitigation
  - Harmonics
- Ancillary services
  - Frequency regulation
  - Spinning reserve
- Renewable Capacity Firming
  - Keep renewable production within acceptable forecasted window
  - Compensate for short term intermittency from wind or solar
- Ramping support for renewable generation
  - Maintain power until alternative power is brought online
  - Avoid power system collapse when renewable are quickly dispatched from network
- DynaPeaQ enhances:
  - The network’s grid stability, reliability, flexibility and efficiency by being able to generate reactive and active power to the grid simultaneously
  - The allowance of CO2 free generation in the grid
Nevada 12 MW PV plant (north of Las Vegas)
Additional macro considerations for PV

- SunPower observed that 2/3 of summer days exhibit “partly cloudy conditions and “high variability”

- UWIG has developed an ad hoc group to address variability concerns related to PV

- Individual PV plants rated 200+ MW have applied for grid interconnections in Western US (AZ, CA, NV, NM)
Regulation of voltage (reactive) and frequency (power)
Wind output example

Individual and Composite MW Profile

Per-unit Power Output vs. Fifteen Minute Intervals

- Individual (75 MW)
- Composite (775 MW)
Ramping

Need for dispatchable generation

- Sudden changes in wind/sun conditions – could lead to that an entire wind/PV park is disconnected to the grid, which could have severe impact on the power system
- Need for dispatchable power sources whose output can change rapidly => DynaPeaQ to play a role
- Use DynaPeaQ to bridge the time needed to start up other generation
What to do with the active power in the batteries? Example of combinations of applications

- Combining applications is a key to improving economics – battery system with revenue streams from different markets simultaneously.
- The key is to find the applications with the best revenues and to size the battery accordingly!
- With a 12.5 MWh sized battery DynaPeaQ can achieve:

<table>
<thead>
<tr>
<th>Option</th>
<th>Battery size</th>
<th>Amount of frequency regulation output</th>
<th>Amount of spinning reserve output</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>12.5 MWh</td>
<td>+/-10 MW (i.e. 20 MW)</td>
<td>5 MW (1 hr spinning)</td>
</tr>
<tr>
<td>2</td>
<td>12.5 MWh</td>
<td>+/-10 MW (i.e. 20 MW)</td>
<td>10 MW (15 min spinning)</td>
</tr>
<tr>
<td>3</td>
<td>12.5 MWh</td>
<td>Zero (Only spinning)</td>
<td>37 MW (15 min spinning)</td>
</tr>
</tbody>
</table>

- The application and duty cycle will have huge impact on the life of the batteries.
  - Frequent use and deep charges and discharges will wear the battery out faster.
  - Option 1 & 2 lifetime of around 10 years & option 3 lifetime around 20 years.
  - Li-Ion costs are expected to decline over time with production economies.
DynaPeaQ - SVC Light with Energy Storage.

Typical layout

Typical layout for 30 MW during 15 minutes +/- 30 Mvar continuously
DynaPeaQ® pilot project

An SVC Light with Energy Storage is installed in the UK in close vicinity to a 2 MW wind farm connected to an 11 kV distribution grid.

**Purpose:**
Gather operational experience with SVC Light with Energy Storage in joint operation with a wind farm.

**Project Details:**
- Energy Capacity: 200 kWh
- Real Power (P): 600 kW
- Reactive Power (Q): 600 kVAr
- SAFT Li-Ion batteries
- Commissioned 2010
DynaPeaQ® - SVC Light with energy storage

Typical single line diagram

- Li-ion battery technology
- Operating at room temperature
- Calendar life time more than 15 years

- Charge / Discharge cycle life time
  3 kCycles @ 80 % DOD
  1 MCycles @ 3 % DOD

- High round-trip efficiency
- Scaleable modular system

Energy storage as add-on to SVC Light
DynaPeaQ - SVC Light with Energy Storage

Hierarchy of the battery solution

- **Cell** (3-4 V)
- **Module** (220 V)
- **Room** (3 kV)
- **String** (up to +/- 40 kV)
- **Storage** (up to +/- 40 kV)
DynaPeaQ energy storage options
Why choose Li-ion?

<table>
<thead>
<tr>
<th>Technology</th>
<th>Hours</th>
<th>Minutes</th>
<th>Seconds</th>
</tr>
</thead>
<tbody>
<tr>
<td>EDLCs</td>
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<td>Flywheels</td>
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<td>Lead-acid</td>
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<tr>
<td>Nickel-cadmium</td>
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<tr>
<td>Lithium-ion</td>
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<td>Flow batteries</td>
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<td>Sodium-sulfur</td>
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<tr>
<td>Compressed air</td>
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<tr>
<td>Pumped hydro</td>
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</tbody>
</table>
Battery basics
What is Li-ion?

- Broad family of electrochemical systems based on lithium ions passing between electrodes
- Positive electrode (cathode) materials
  - Lithium cobalt oxide
  - Lithium nickel-cobalt-aluminum oxide (NCA)
  - Lithium nickel-manganese-cobalt oxide (NMC)
  - Lithium iron phosphate (LFP)
- Negative electrode (anode) materials
  - Carbon (graphite)
  - Lithium titanate (LTO)
- Many other materials both in production and in development
DynaPeaQ battery
Choice of Li-ion technology

- Requirements
  - Excellent calendar and cycle life
  - Range of power and energy options
  - Safe at system level
  - Future outlook
    - Production volume synergies
    - Downward cost curve
  - Saft NCA technology chosen
    - Demanding applications
    - EV synergies
    - Other technologies available in the future
DynaPeaQ battery system
Li-ion safety

- Public awareness of laptop battery recalls
- Four aspects to Li-ion safety
  - Cell level – electrochemistry & mechanical design
  - Module level – monitoring & mechanical design
  - Battery level – electronics & algorithms
  - System level – communications & control
- Using “safe” electrode materials does not guarantee system safety!

Google: Report of Investigation NRECA PHEV Fire.doc
Building the DynaPeaQ battery system

Cell level

- NCA-graphite electrochemistry
- Cell options
  - Medium power – 15 to 60 minutes
  - High power – 5 to 15 minutes
- Safety in cell design
  - Cell vents
  - Current breakers
  - Ceramic-coated separators with shutdown effect

VL cell dimensions
- 222 mm H
- 54.3 mm D
Building the DynaPeaQ battery system
Module level

- 63 series-connected cells
- Electronics for monitoring and balancing
- Safety in module design
  - Cell spacing to prevent propagation
  - Venting space to channel released gas / smoke

High-power module
- 230 V
- 7 kWh
- 70 kW
Building the DynaPeaQ battery system
Group level

- Modules in cassettes
  - 3 in series – 690 V
  - 3 to 5 in parallel
- Battery management system
  - Electronics and algorithms
  - Contactor and circuit breaker
- Communications with system controller
  - Diagnostic data
  - Alarm management
  - Watchdog signal
- Group bypass switches in case of module failure
Building the DynaPeaQ battery system
Room level

- Four groups in series – 3 kV
- Distributed IGBT dc circuit breaker
- Air-handling system with heating / cooling
- Fire suppression
- Room bypass switches for servicing
Building the DynaPeaQ battery system
Battery string level

- Up to 23 rooms in series – 69 kV nominal
- Multiple battery strings may be used
Summary

- Adds new dimension to traditional SVC Light solution
  - Active and reactive power combined
- Emerging market
  - Many players
  - Evolving regulations
- Importance of understanding applications
  - Correct sizing of active and reactive power components
- Safety was a key design feature at all levels
- ABB is set to be a major player in the energy storage market
Reminders
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- Please be sure to complete the workshop evaluation

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