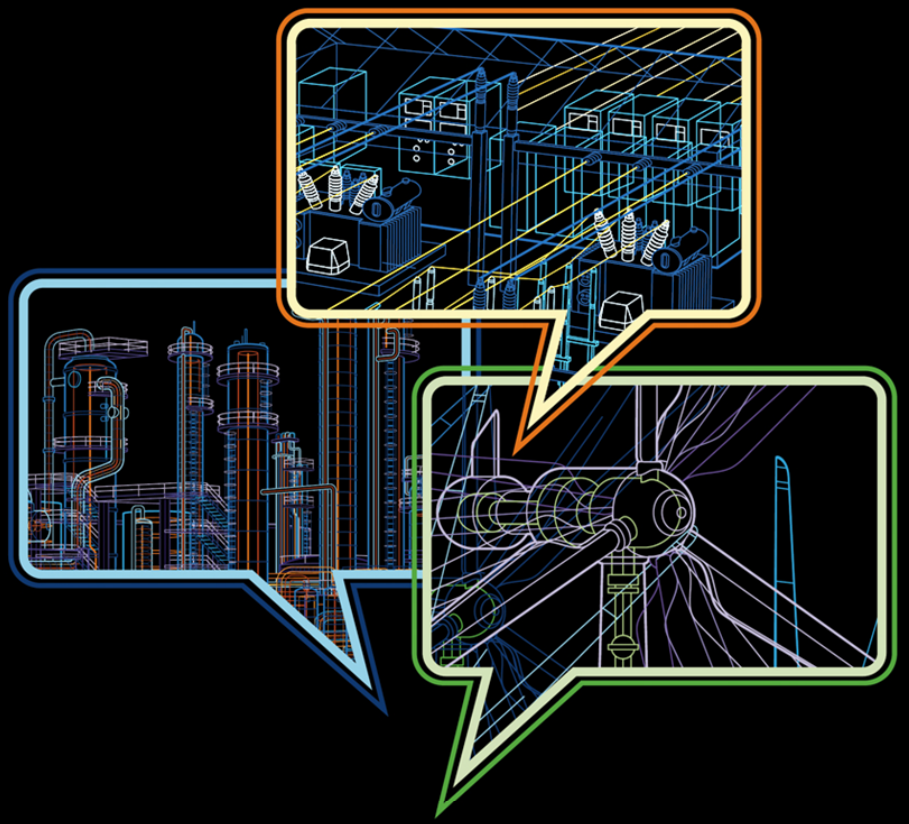


ABB Automation & Power World: April 18-21, 2011

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

Power and productivity for a better world™

WPS-145-1
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

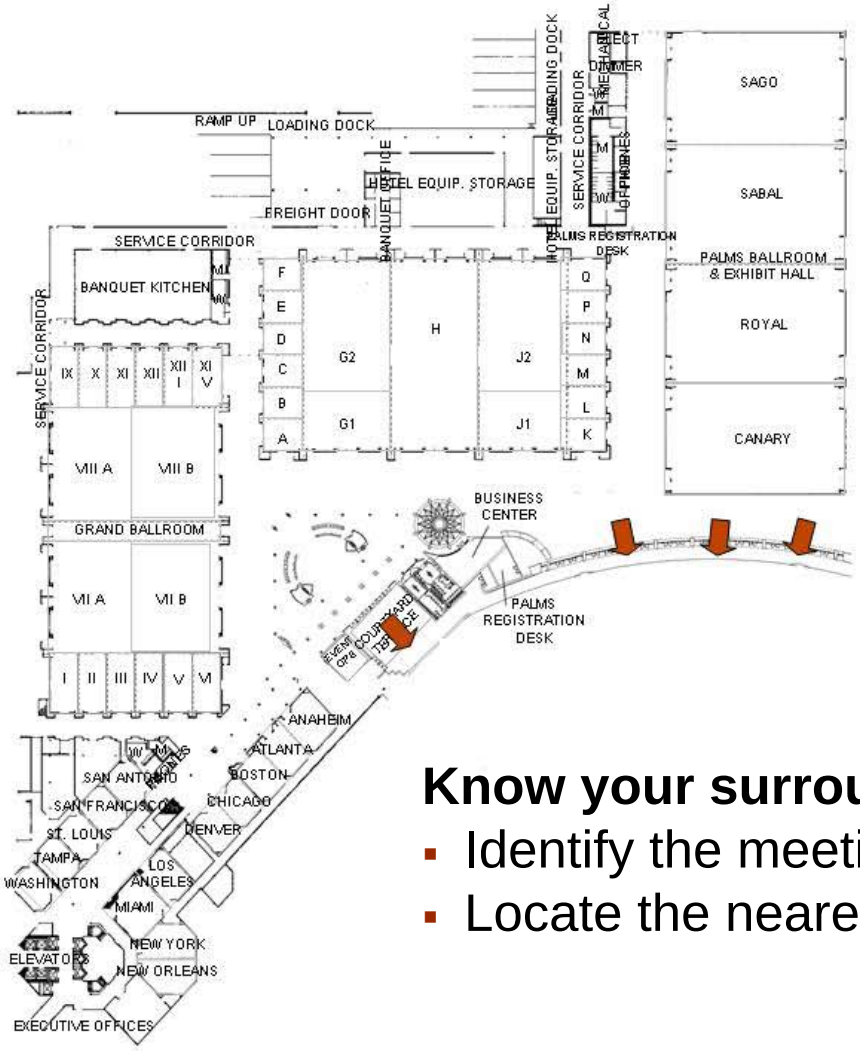
Co-presenter

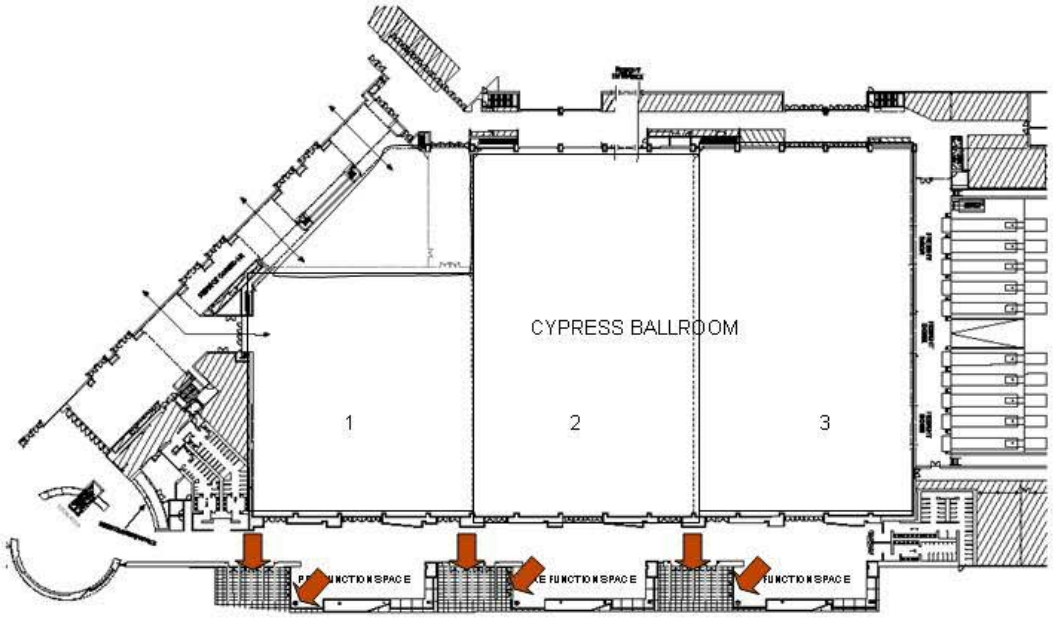
- Speaker name: Jim McDowall
- Speaker title: Business Development Manager
- Company: SAFT
- Location: North Haven, Connecticut

Your safety is important to us
Please be aware of these emergency procedures

- In the event of an emergency please dial ext. 55555 from any house phone. Do not dial 9-1-1.
- In the event of an alarm, please proceed carefully to the nearest exit. Emergency exits are clearly marked throughout the hotel and convention center.
- Use the stairwells to evacuate the building and do not attempt to use the elevators.
- Hotel associates will be located throughout the public space to assist in directing guests toward the closest exit.
- Any guest requiring assistance during an evacuation should dial “0” from any house phone and notify the operator of their location.
- Do not re-enter the building until advised by hotel personnel or an “all clear” announcement is made.

Your safety is important to us
Convention Center exits in case of an emergency





Know your surroundings:

- Identify the meeting room your workshop is being held in
- Locate the nearest exit

Agenda

- FACTS
- Energy storage applications
- DynaPeaQ overview
- Lithium-ion battery system
  - Lithium-ion basics
  - Safety
  - System design
- Summary

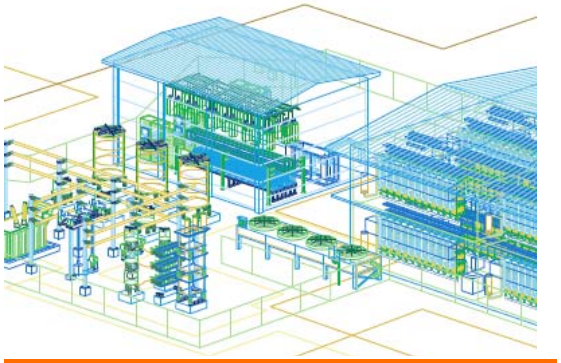
FACTS – Flexible AC Transmission Systems
Main products

Shunt Compensation

- SVC
- STATCOM (SVC Light)

Series Compensation

- SC - Fixed
- TCSC - Controllable



Energy Storage

- 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?




Generation

- Renewable capacity firming
- Capacity Firming and ramping
- Energy & Power applications

Transmission

- Ancillary services
- Frequency regulation
- High power applications

Distribution

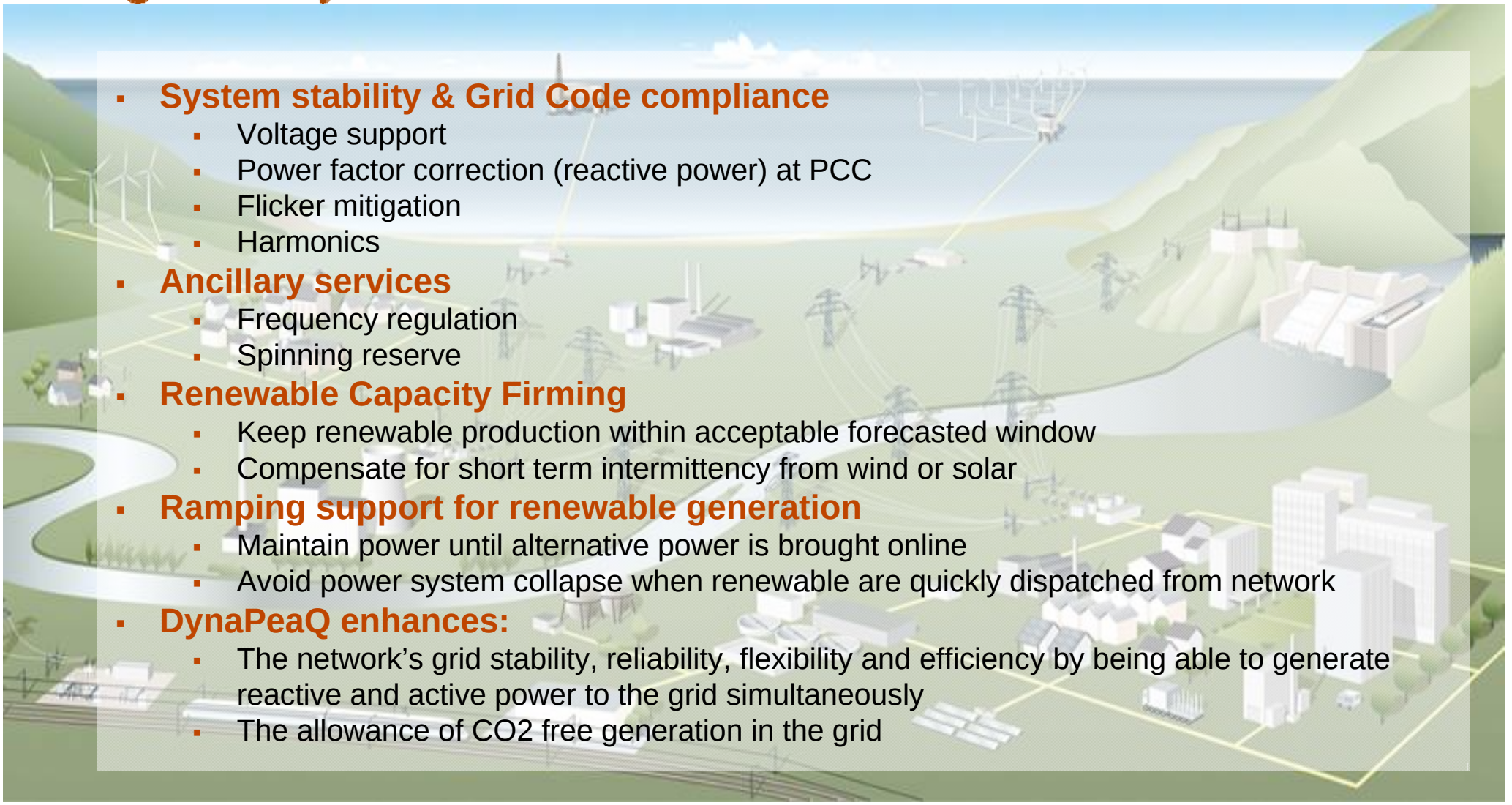
- Load management
- Peak shaving
- Energy and Power applications

Residential

- Time shifting
- Energy applications

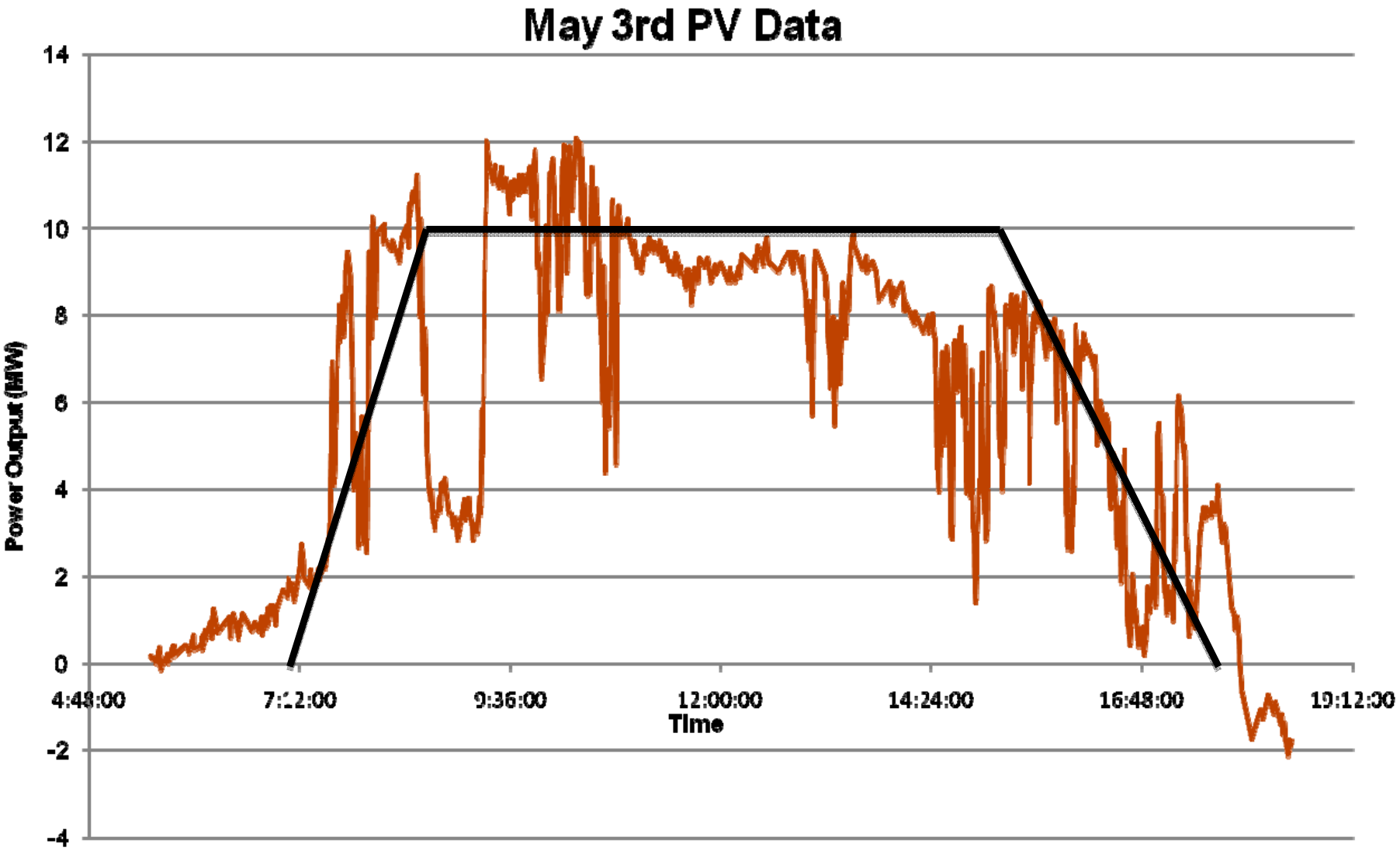
DynaPeaQ – ABB's large scale battery energy storage mainly suitable for transmission and renewable generation segment

Power Grid Challenge: Maintain grid stability when introducing ~~intermittent~~ variable generation
Usage of DynaPeaQ



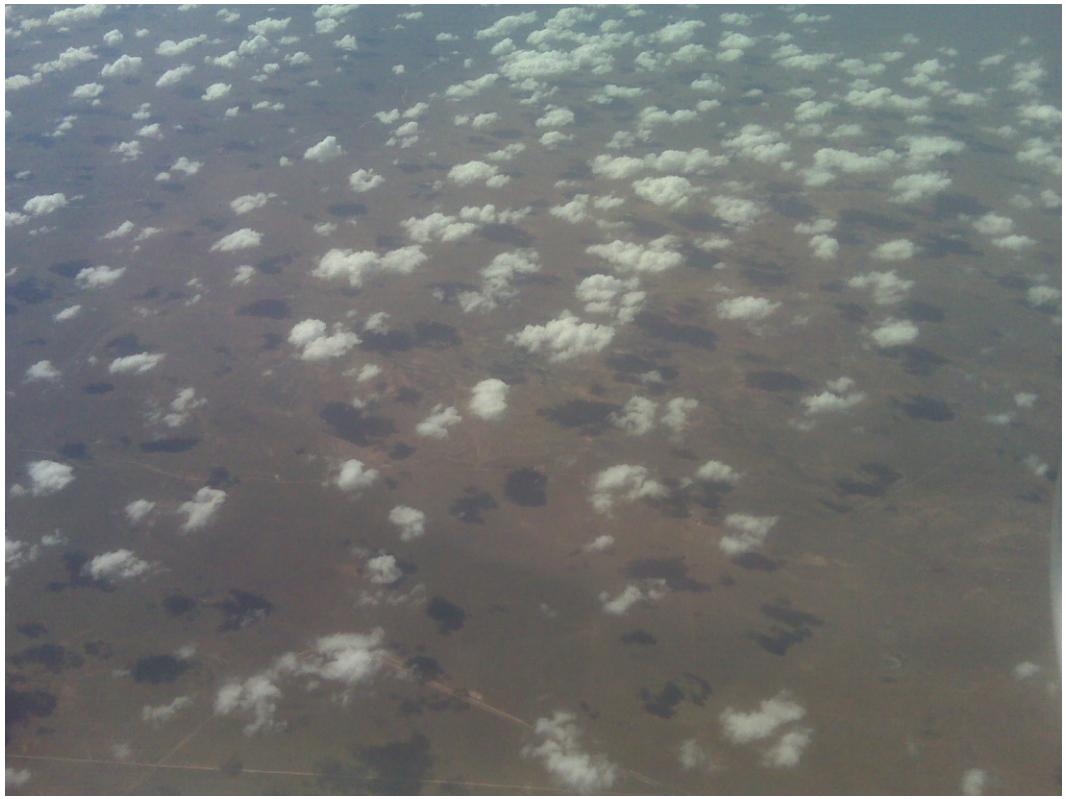
- **System stability & Grid Code compliance**
  - Voltage support
  - Power factor correction (reactive power) at PCC
  - Flicker mitigation
  - Harmonics
- **Ancillary services**
  - Frequency regulation
  - Spinning reserve
- **Renewable Capacity Firming**
  - Keep renewable production within acceptable 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)

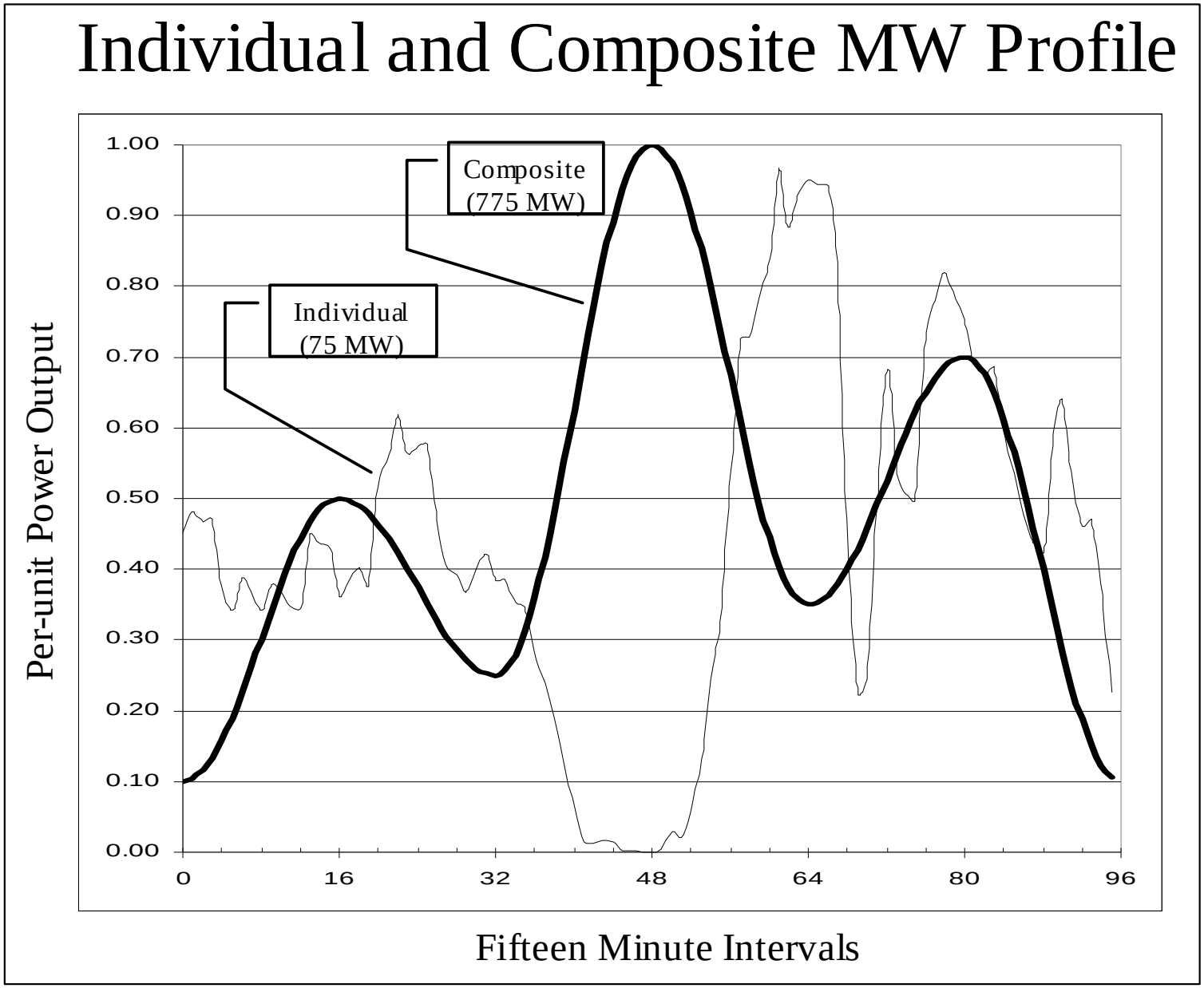


Additional macro considerations for PV

- 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)

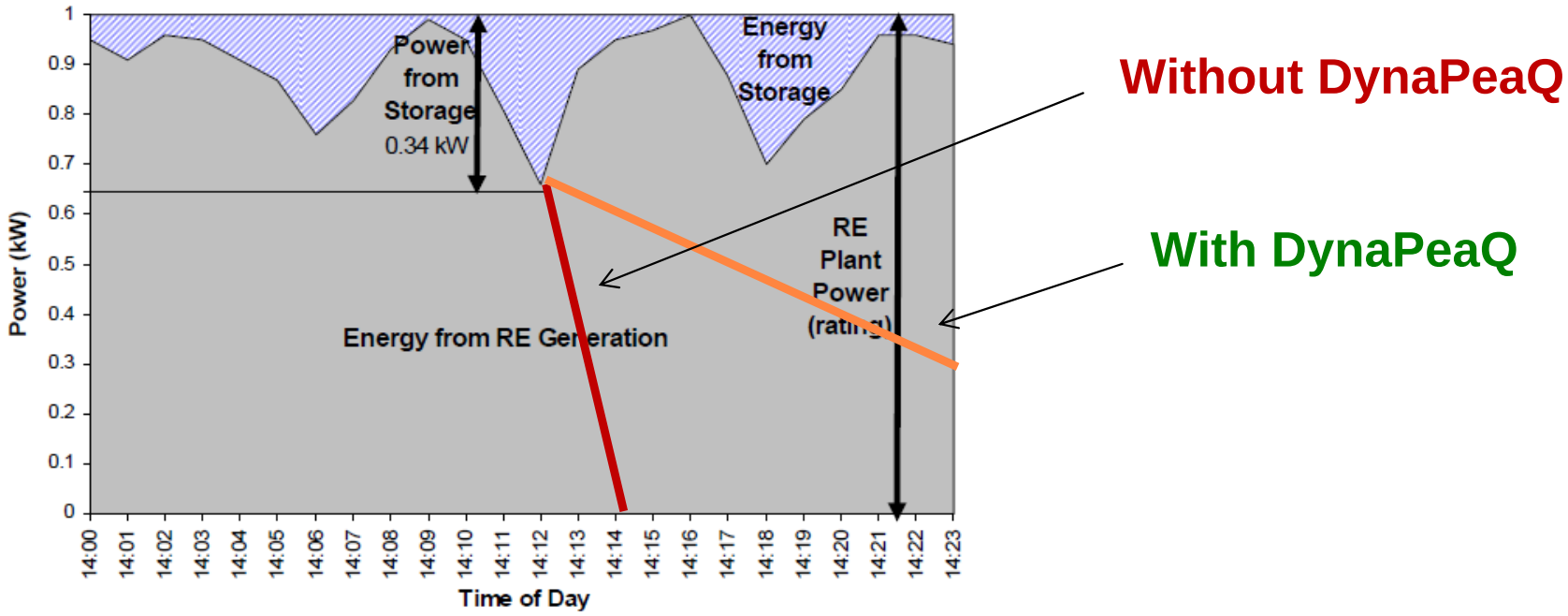


Regulation of voltage (reactive) and frequency (power)
Wind output example



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



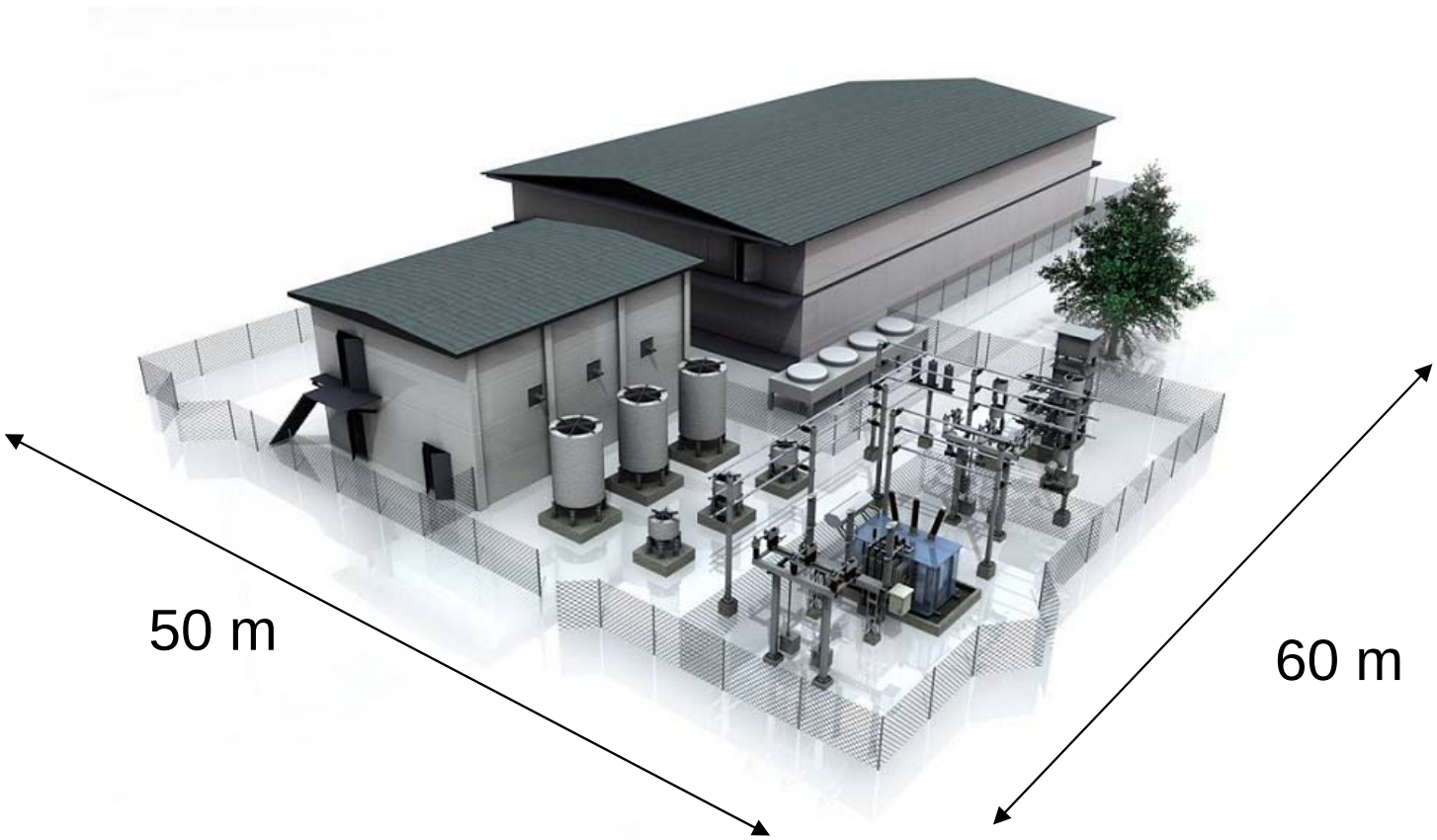
What to do with the active power in the batteries? Example of combinations of applications

- 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:

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

- 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

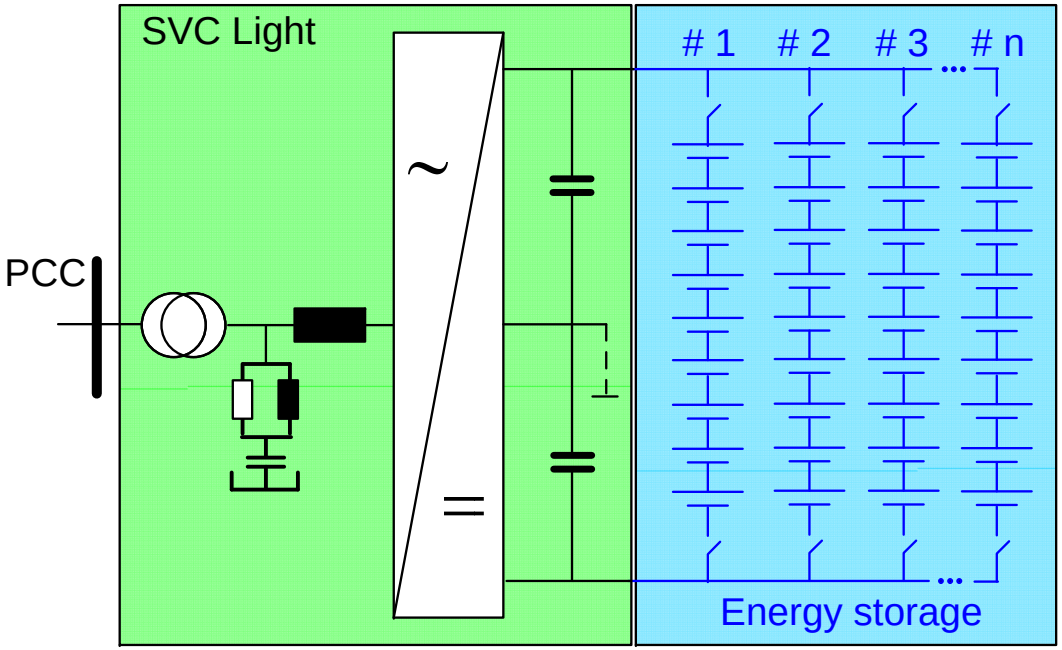
An SVC Light with Energy Storage is installed in the UK in close vicinity to a 2 MW wind farm connected to an 11 kV distribution grid.

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



Energy storage as add-on to SVC Light

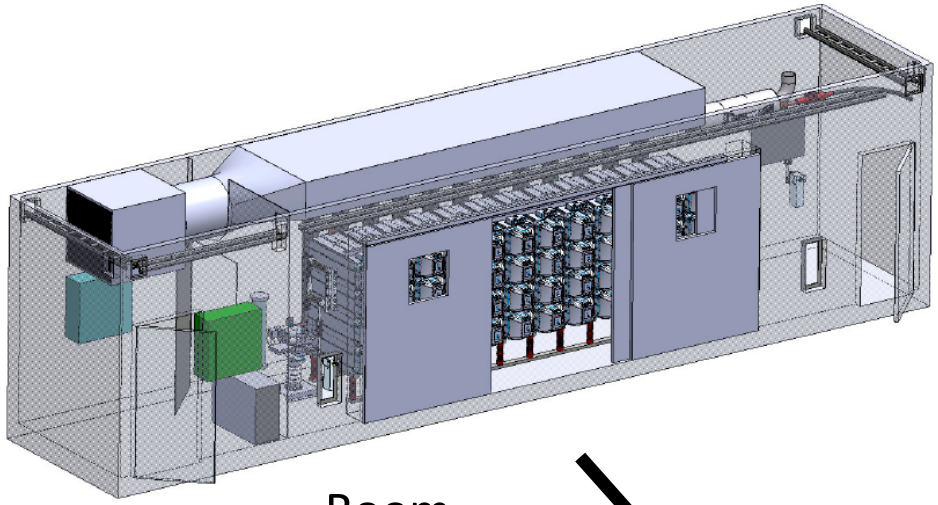
- Li-ion battery technology
- Operating at room temperature
- Calendar life time more than 15 years

- Charge / Discharge cycle life time
  3 kCycles @ 80 % DOD
  1 MCycles @3 % DOD
- High round-trip efficiency
- Scaleable modular system

DynaPeaQ - SVC Light with Energy Storage
Hierarchy of the battery solution

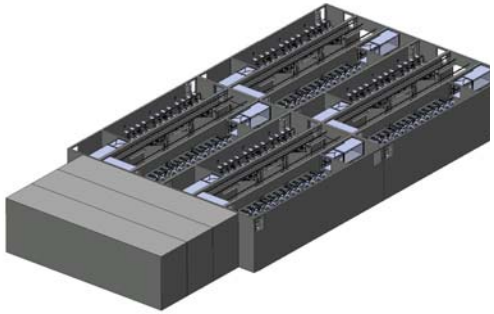
Cell

(3-4 V)



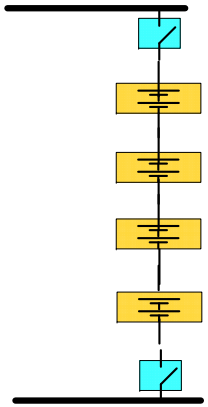
Room

(3 kV)



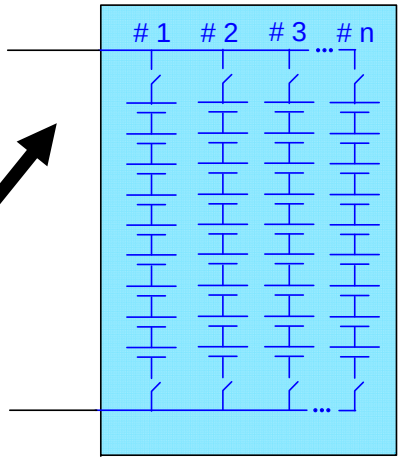
Module

(220 V)



String

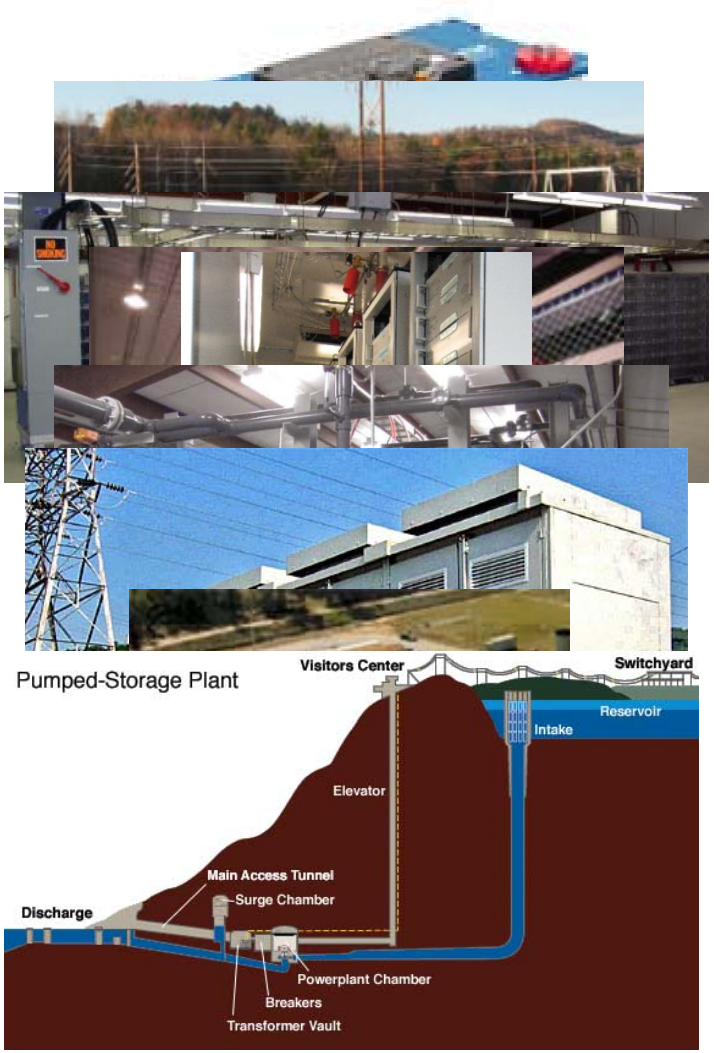
(up to +/- 40 kV)



Storage

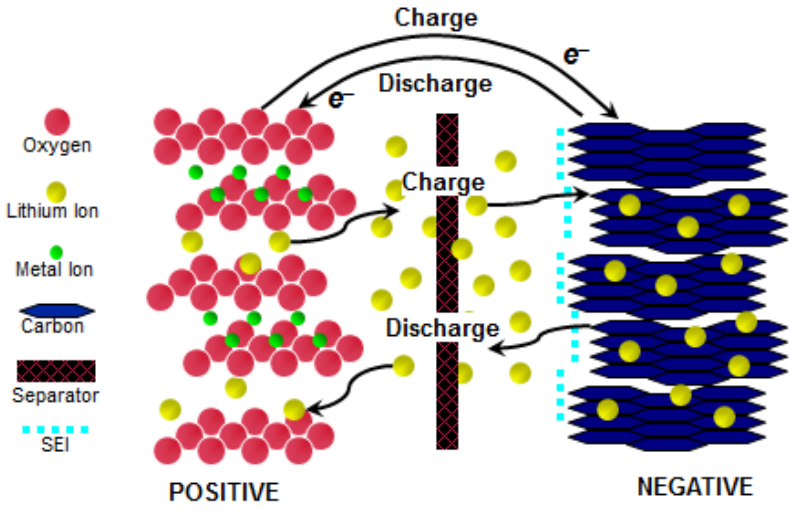
DynaPeaQ energy storage options
Why choose Li-ion?

Technology	Hours	Minutes	Seconds
EDLCs			●
Flywheels		◐	●
Lead-acid	◐	●	
Nickel-cadmium	◐	●	
Lithium-ion	◐	●	●
Flow batteries	●		
Sodium-sulfur	●		
Compressed air	●		
Pumped hydro	●		



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

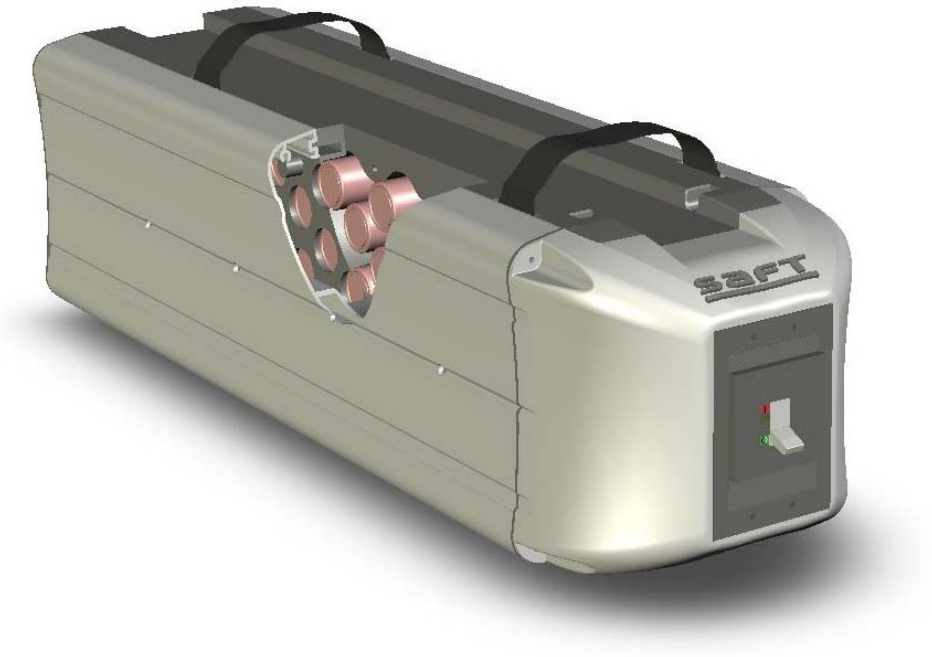
- NCA-graphite electrochemistry
- Cell options
  - Medium power – 15 to 60 minutes
  - High power – 5 to 15 minutes
- Safety in cell design
  - Cell vents
  - Current breakers
  - Ceramic-coated separators with shutdown effect

VL cell dimensions
- 222 mm H
- 54.3 mm D

Building the DynaPeaQ battery system
Module level

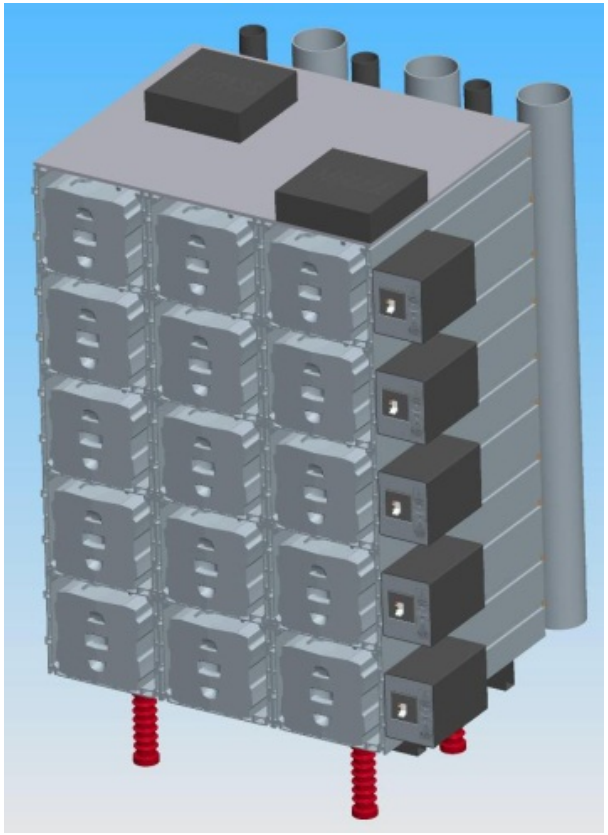
- 63 series-connected cells
- Electronics for monitoring and balancing
- Safety in module design
  - Cell spacing to prevent propagation
  - Venting space to channel released gas / smoke

High-power module
- 230 V
- 7 kWh
- 70 kW



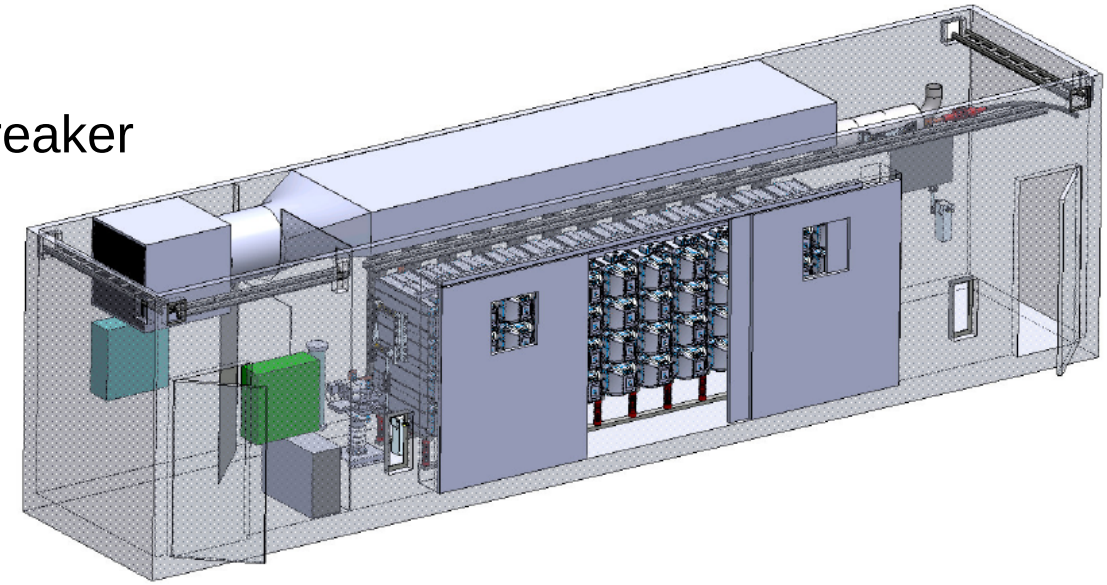
Building the DynaPeaQ battery system
Group level

- 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



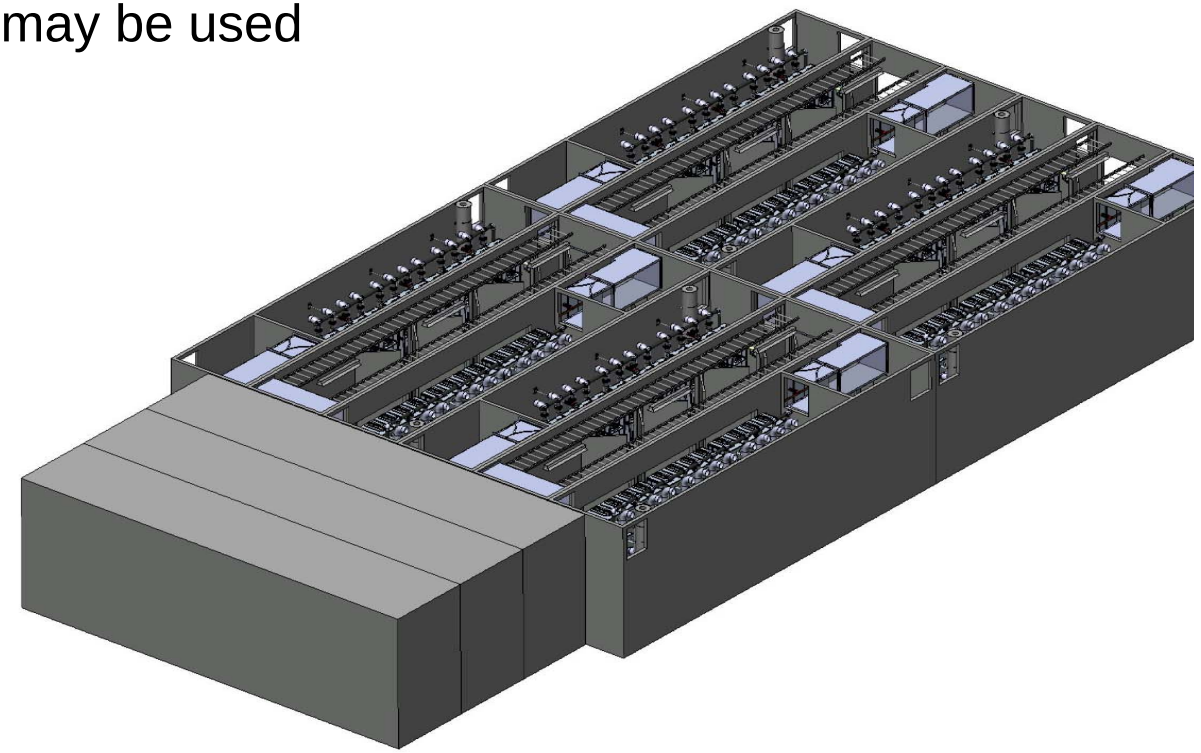
Building the DynaPeaQ battery system
Room level

- Four groups in series – 3 kV
- Distributed IGBT dc circuit breaker
- Air-handling system with heating / cooling
- Fire suppression
- Room bypass switches for servicing



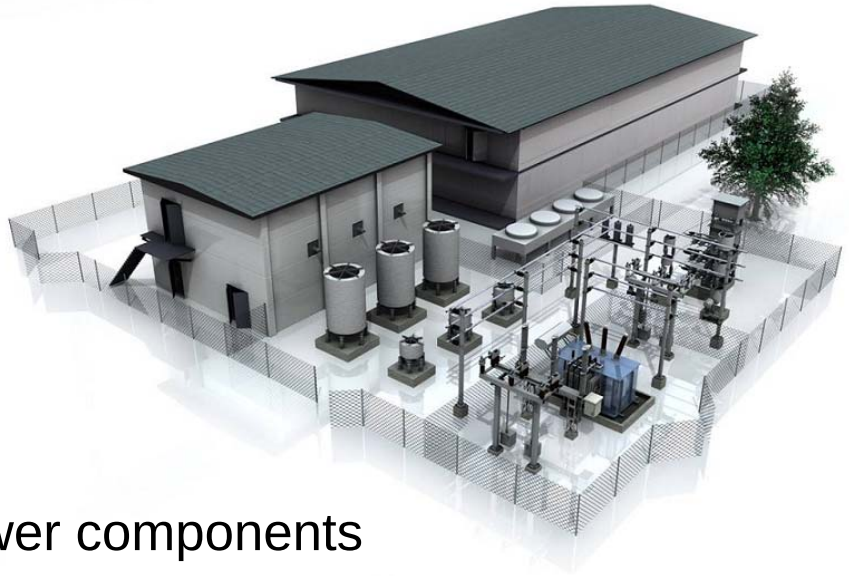
Building the DynaPeaQ battery system
Battery string level

- 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
Automation & Power World 2011

- Please be sure to complete the workshop evaluation
- Professional Development Hours (PDHs) and Continuing Education Credits (CEUs):
  - You will receive a link via e-mail to print certificates for all the workshops you have attended during Automation & Power World 2011.
  - BE SURE YOU HAVE YOUR BADGE SCANNED for each workshop you attend. If you do not have your badge scanned you will not be able to obtain PDHs or CEUs.

Power and productivity
for a better world™