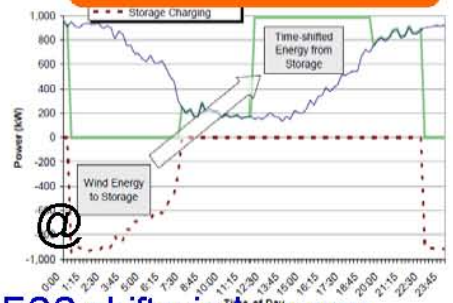
USCRC, May 19th 2011

Hybrid Energy Storage Module Technology Workshop

Power and productivity for a better world™

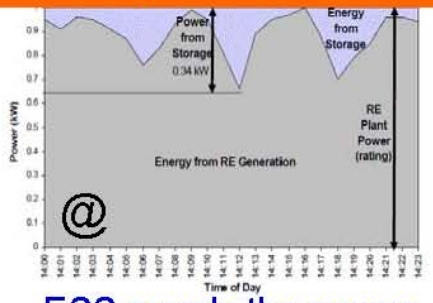
Wide applications of Energy Storage System (ESS)

Load shifting



ESS shift wind energy from night to peak hour

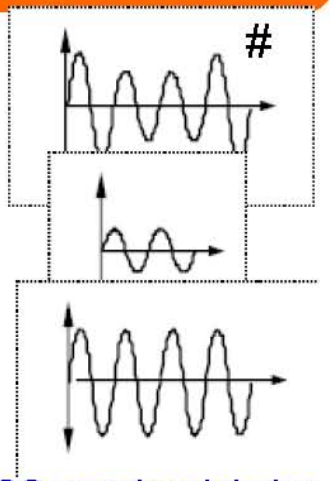
Peak power shaving



ESS supply the power during peak output

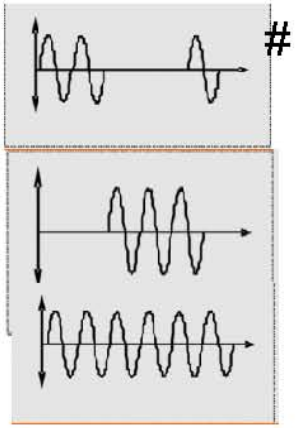
Source: SANDIA

Power Quality Improvement



ESS supply minimize the voltage sags

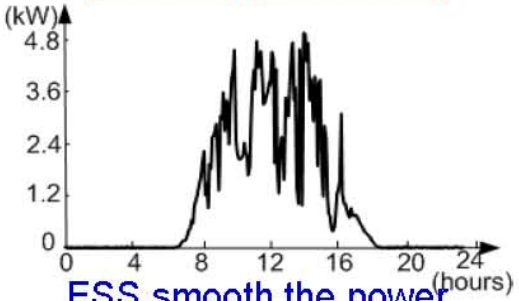
Uninterrupted Power Supply



ESS supply power when source fails

Energy Storage System (ESS)

Intermittency Mitigation



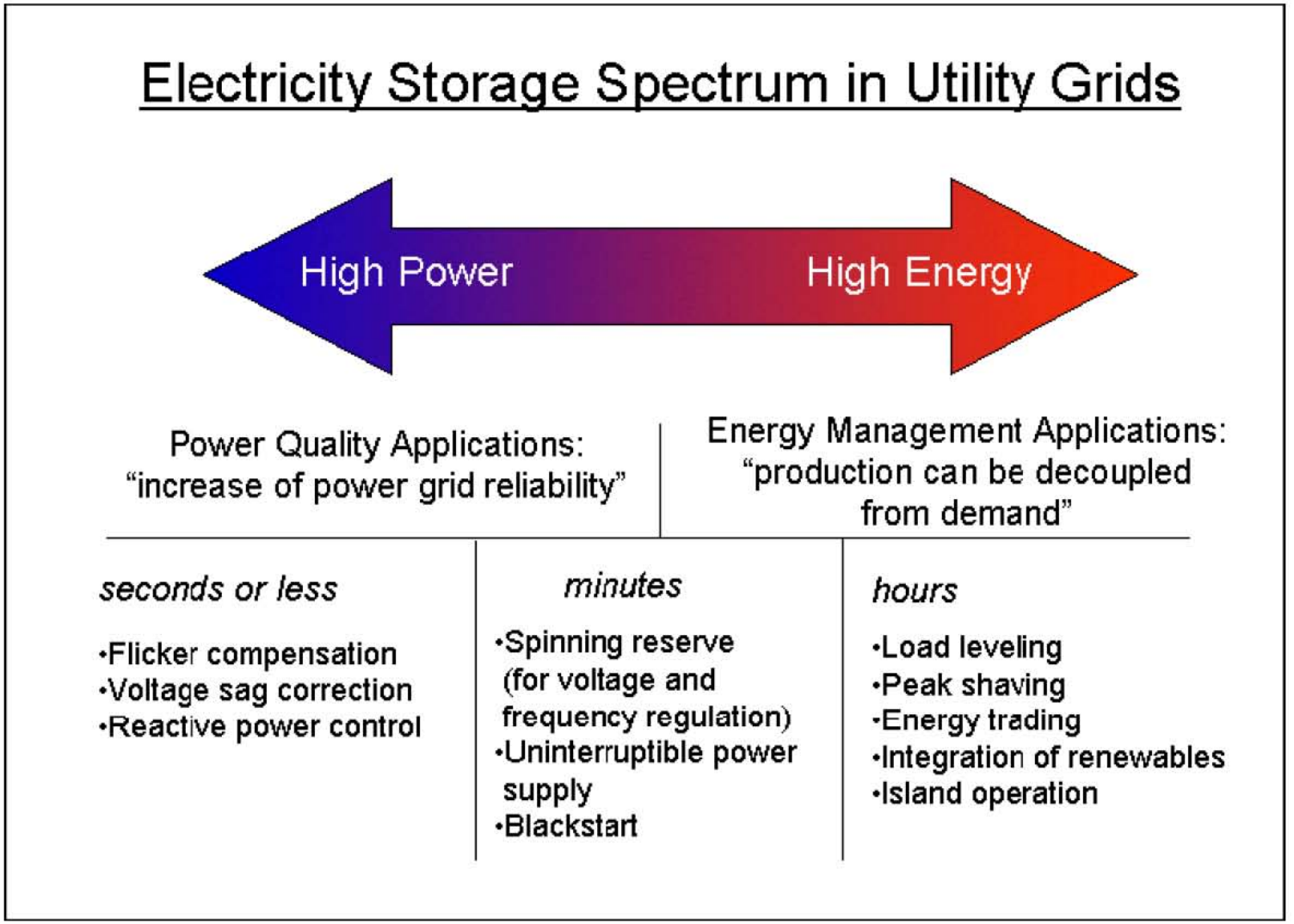
ESS smooth the power output from PV

Frequency regulation

ESS regulate frequency when wind is connected to grid

@Source: SANDIA
 # Source: ABB

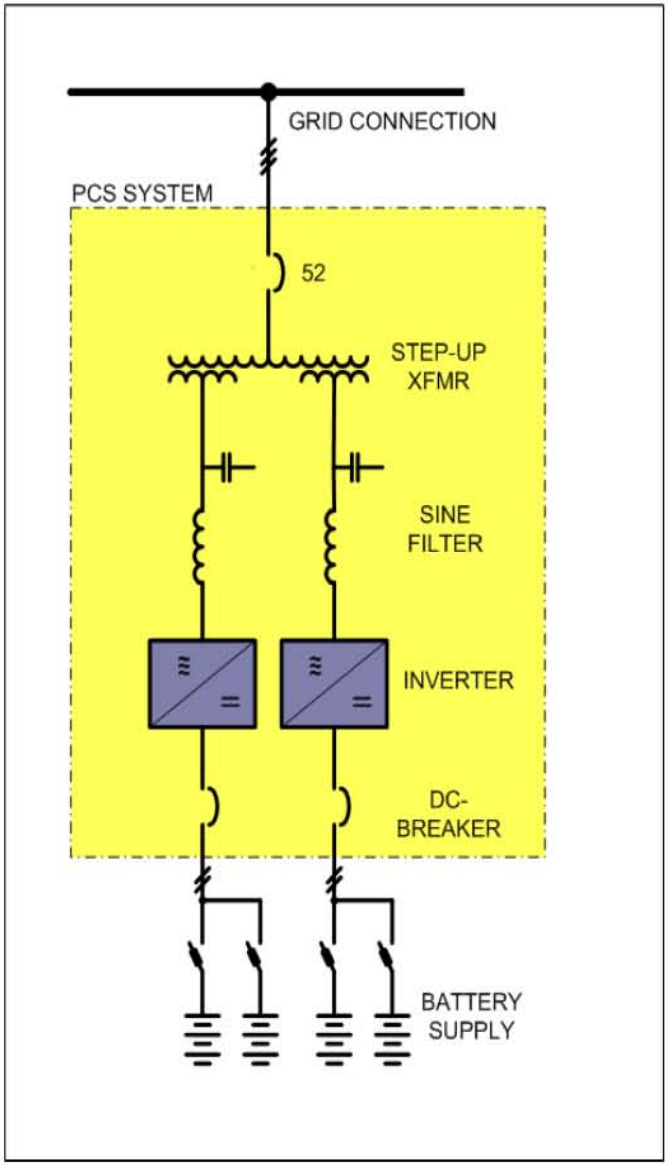
Storage Applications - Power vs Energy



BESS Layout

1MW / 6.5MWHr

BESS Design Components



- AC Grid Voltage
- Battery DC Voltage & Application
  - Battery Type
- PCS SYSTEM

BESS – ABB PCS Design Capabilities

Packaging

- Indoor or Outdoor
- Transformer internal/external to PCS container

Environmental Conditions

- Temperature
- Altitude
- Wind, dust, harshest environments

AC Grid and DC Battery voltages

Control and Operations

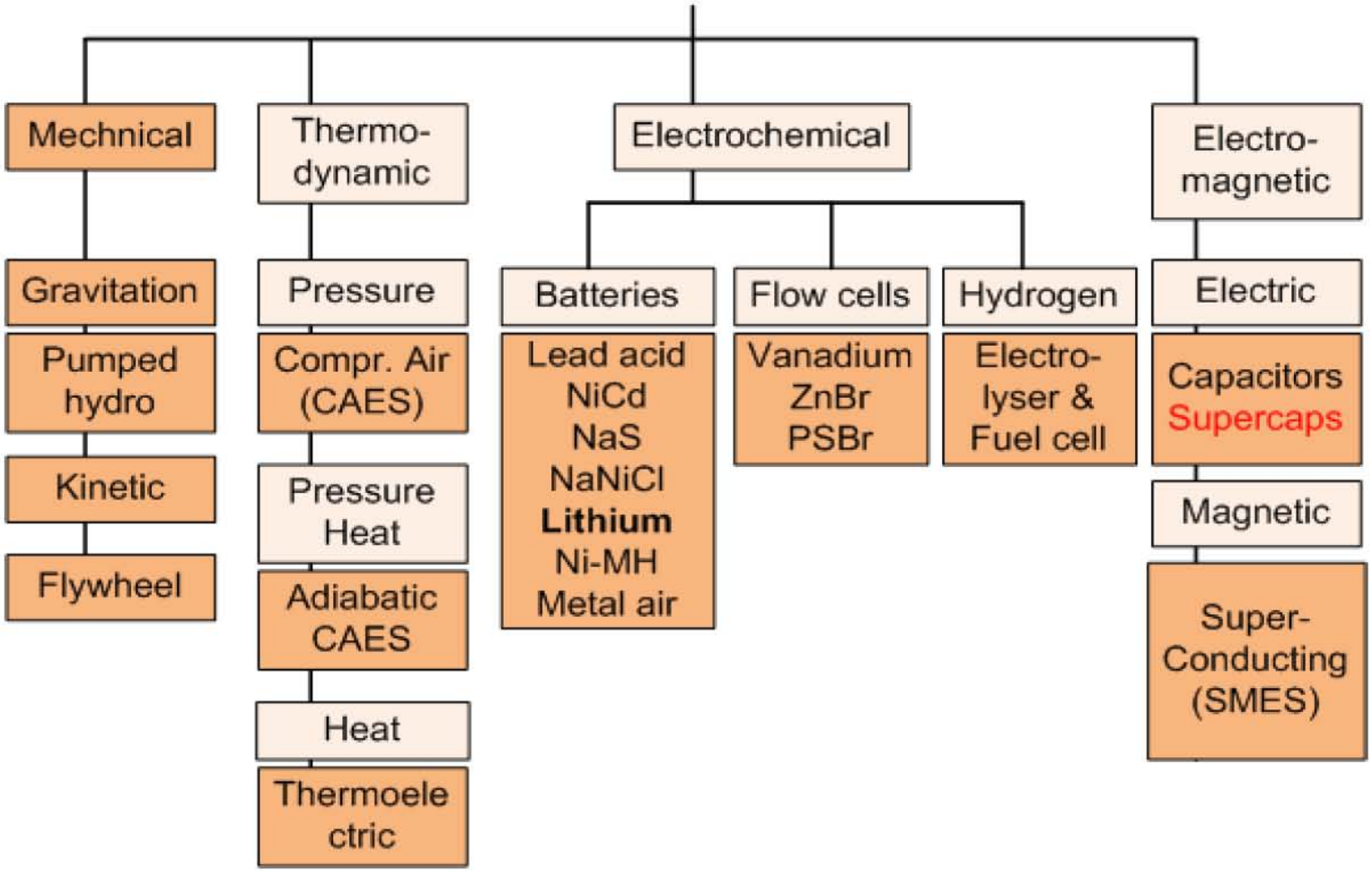
- BESS function, Statcom
- BMS interface
- EMS/SCADA interface
- Remote Diagnostics

Operation and Maintenance Support

PCS100 Inverter module

Power Conditioning System Package for BESS

Various types of energy storage

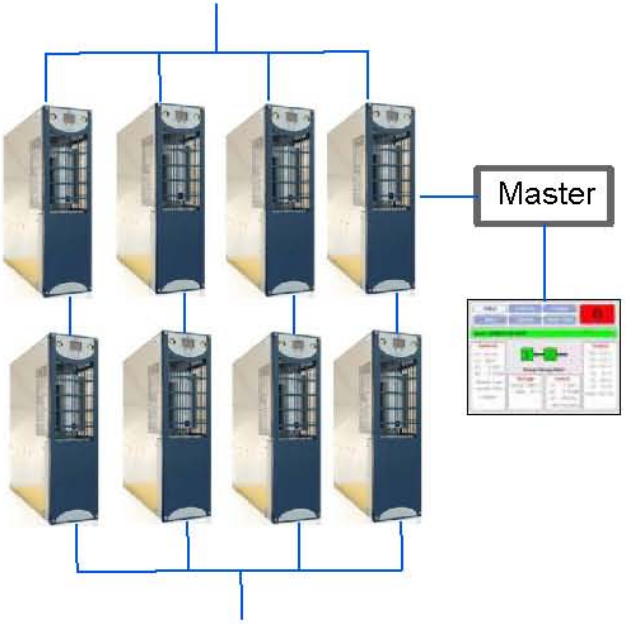


* Holger Hannemann, "*Innovative Solutions for grid stabilization and support*" , ABB Power Electronics Napier, 30 March 2010

Inverter Platforms
The Concept

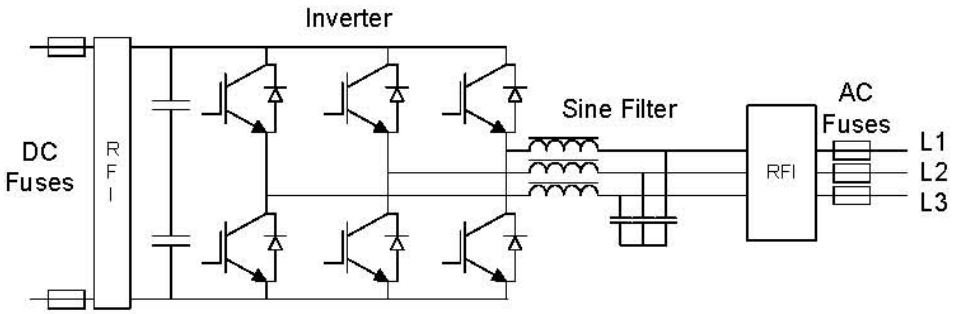
- Traditional high power converters are constructed as a single unit
- Topology is not as flexible
- Service is complex

- Modular structure
- Flexible sizing of converters by adding power modules
- Service is simple
- Highly reliable with redundancy

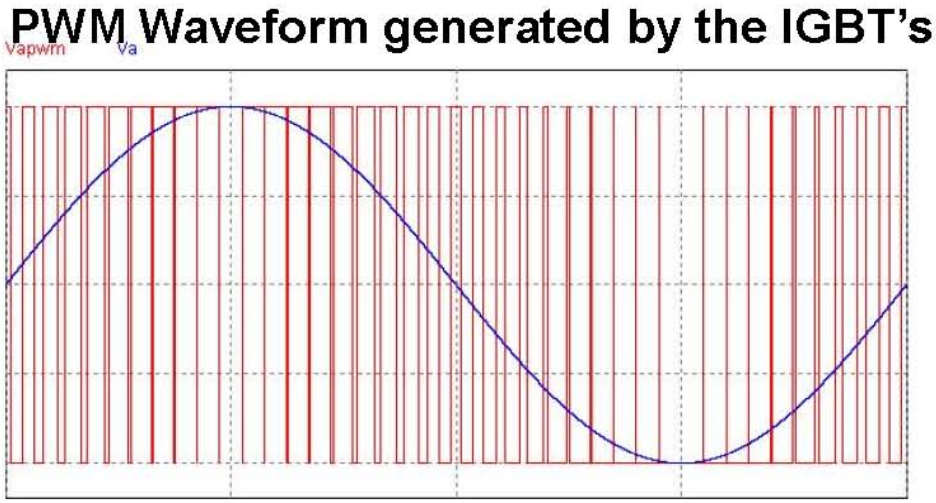


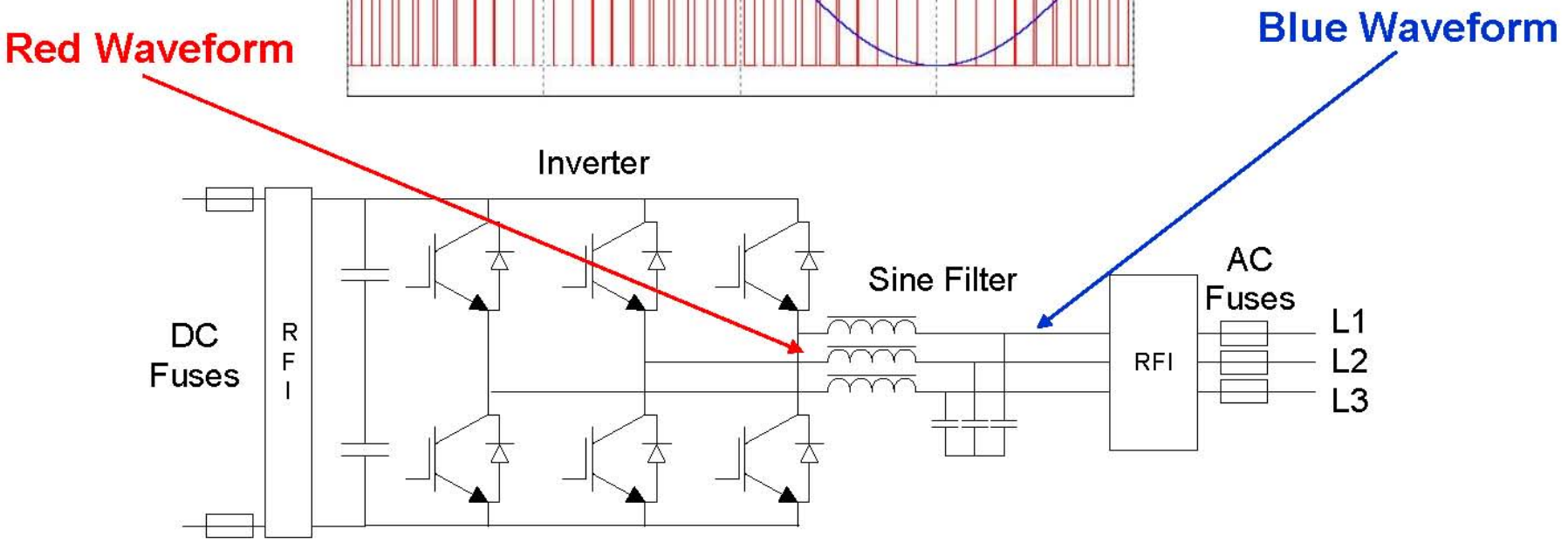
Inverter Technology

- IGBT Technology
- DC Voltage Range
- Forced Air, HVAC or Liquid Cooled
- Module kVA rating
- LCL Filter integrated or external
- Sized for temperature, altitude, overload and kVA ratings.



Inverter Waveforms
Sinusoidal PWM Modulation





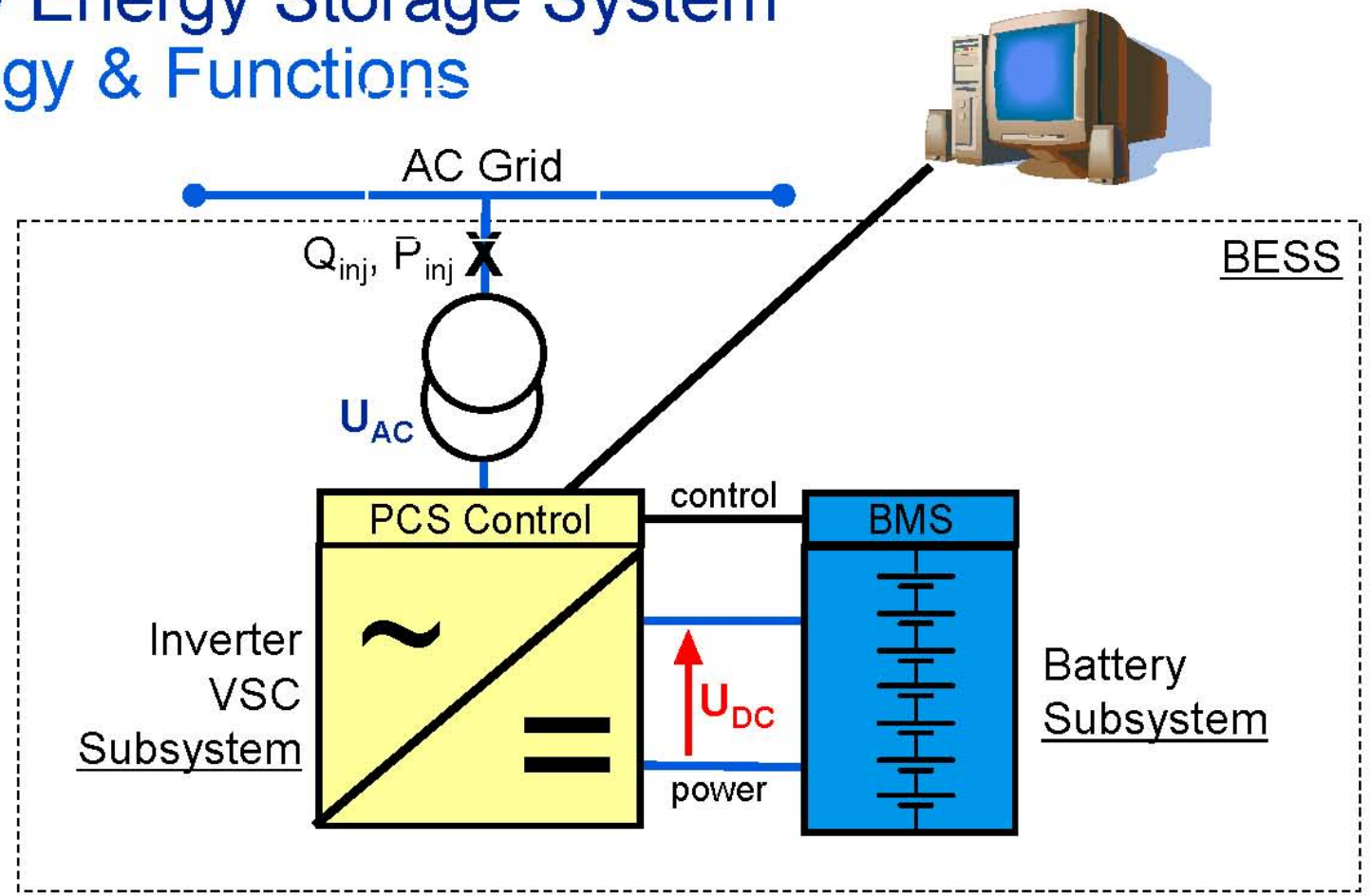
Hybrid Storage

- Optimized energy/power package as a whole
  - Storage mediums: Various types, which marriages make sense (system requirements, thermal compatibility, ambient conditions, costs), dimensioning, scheduling
  - Converters structures and interface: Right converter topologies (efficiency, reliability-parts count, costs), AC OR DC inputs but DC output, possible use in combination with renewables solar/wind
  - System performance: controllability and meeting energy/power delivery requirements, round trip efficiencies, faults handling
- Filling gaps from available storage mediums

Benefits with hybrid storage

- Batteries + supercaps /flywheels
  - Reduced batteries cost (weight, volume)
  - Extended batteries lifetime (deep charges/discharges and softer cycling rates)
  - Faster response
- Fuel cells + supercaps
  - ???
- Diesel + flywheels
  - Reduced emissions
  - Improved fuel efficiency

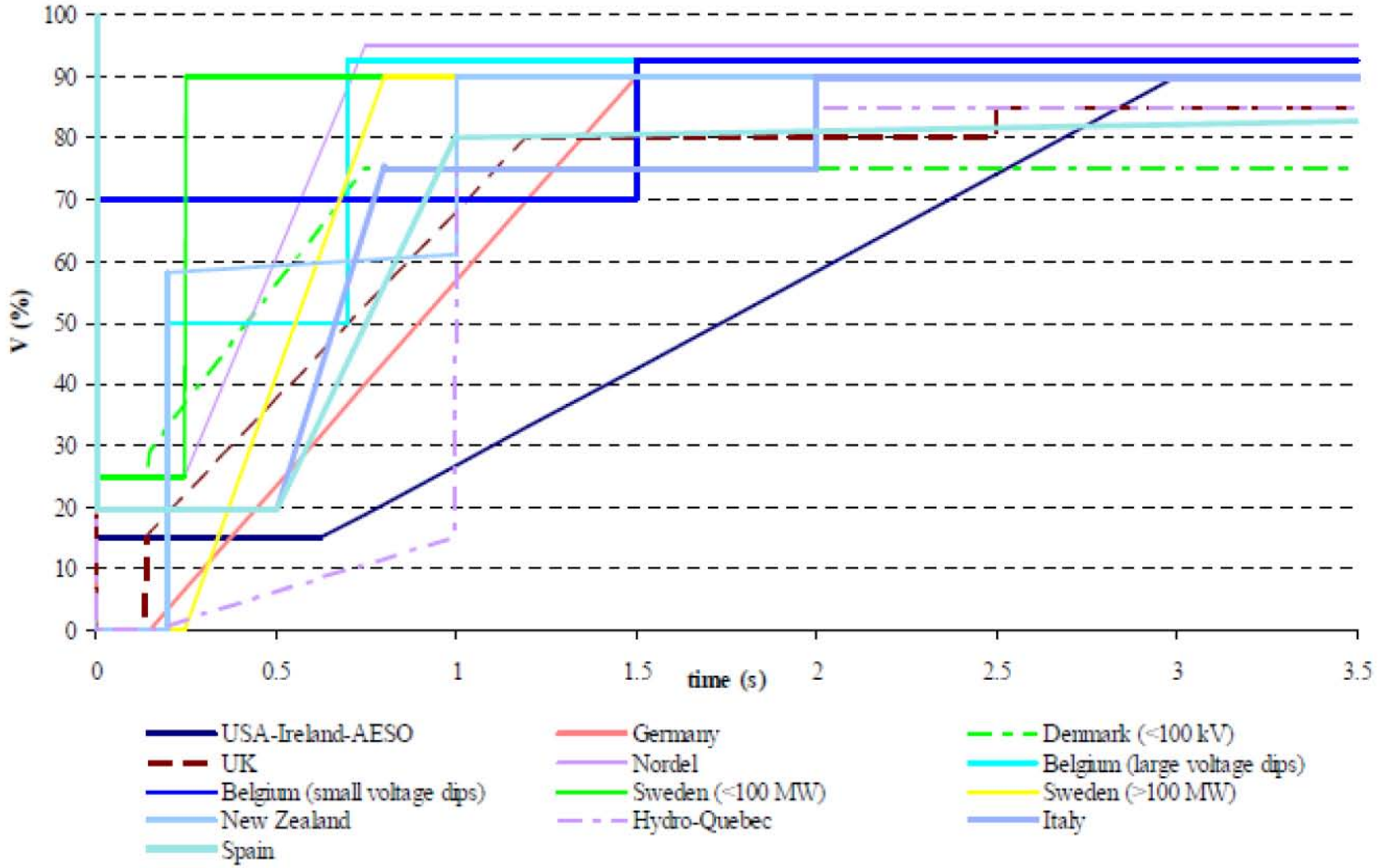
Battery Energy Storage System
Topology & Functions



Functions:

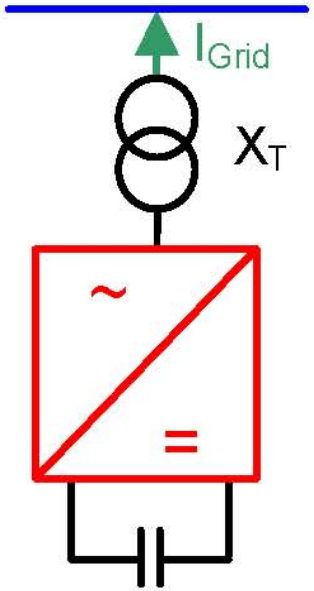
1. Voltage Control Operation: Reactive Power Q_{inj}
2. Frequency Control Operation: Real Power P_{inj}
3. Load Leveling / Peak Shaving Operation: Active Power
4. Black Start / Stand-alone Capability: Voltage and Frequency

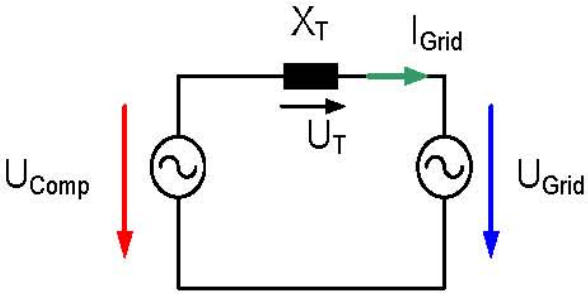
Low Voltage Ride Through – Grid Codes

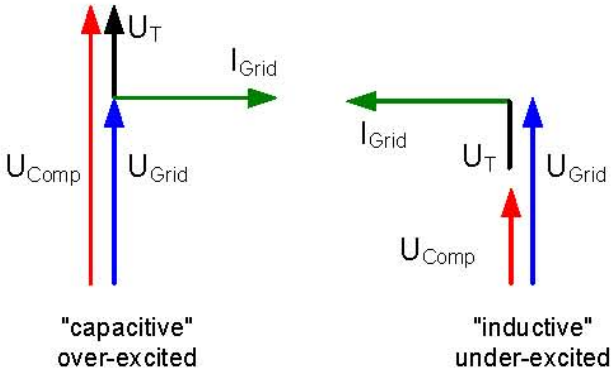


Grid Connect Interfaces
STATCOM: The concept

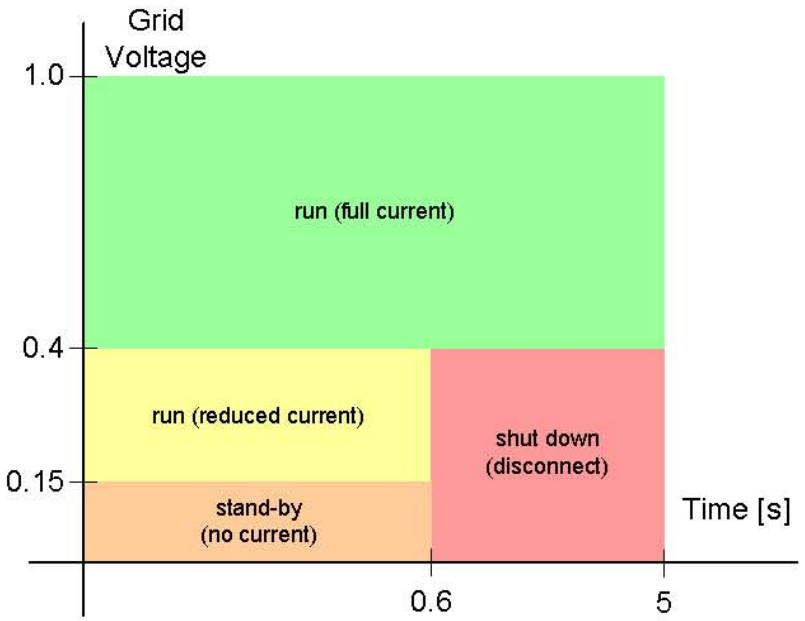
- Voltage source with variable voltage amplitude
- Transformer acts as inductance
- Shunt connected to the distribution (or transmission) grid



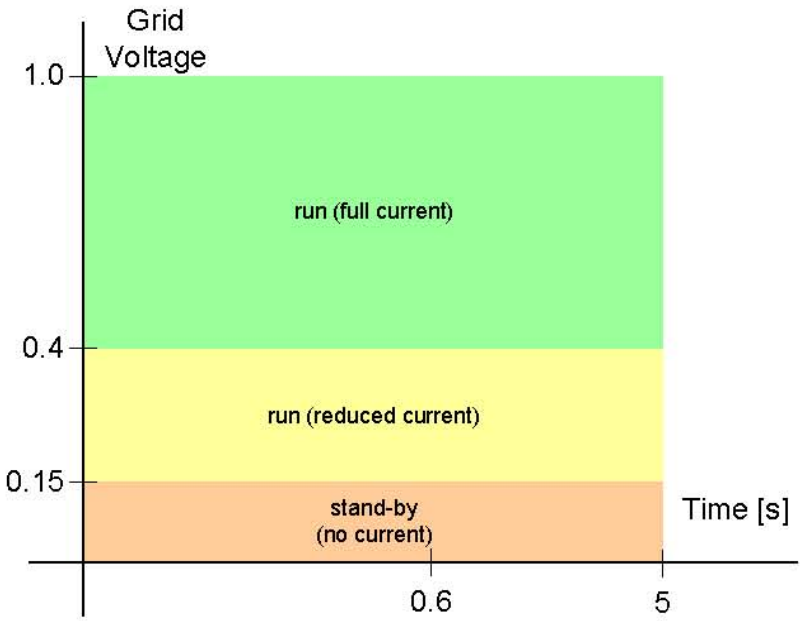




Low Voltage Ride Through capability

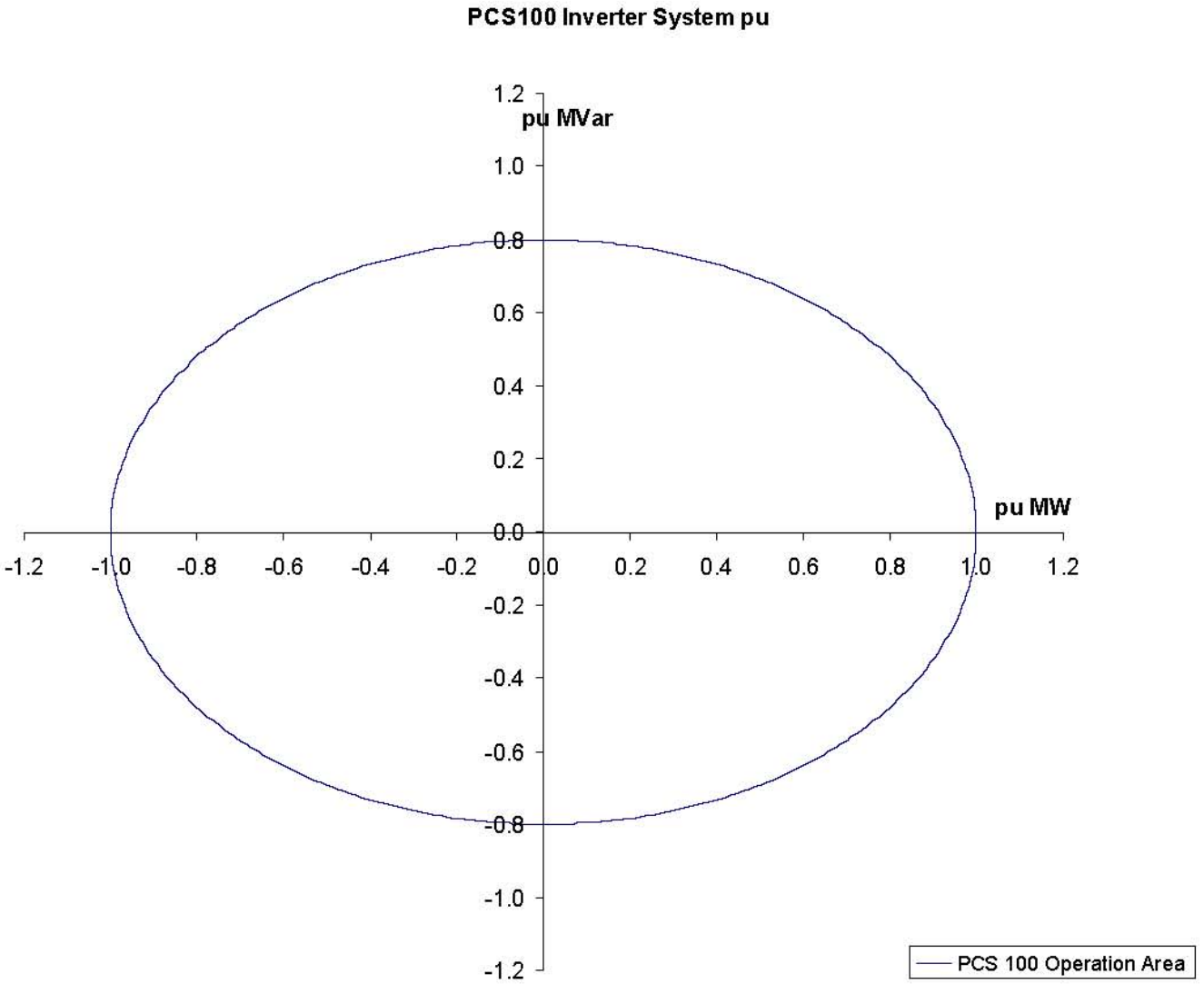


No UPS



With UPS

Inverter Operating Range



Grid Connect Interfaces
ESS inverter control modes

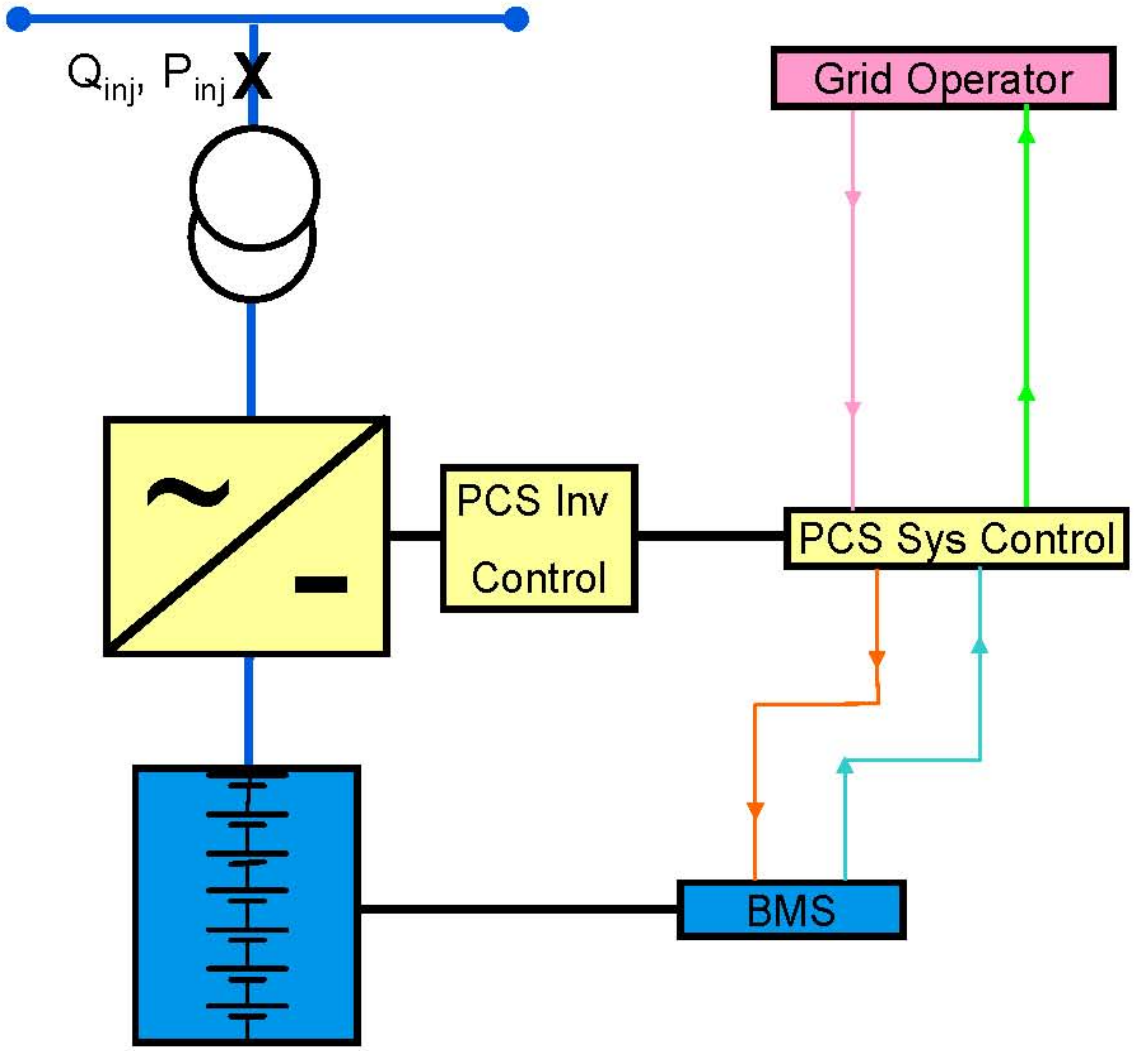
- **Generator Emulator Voltage Source Control**
  A unique feature of the PCS100 is its ability to provide power to the grid in the same manner as a regulator generator. This has many benefits for the grid;
  - Ability to source negative sequence current to correct grid unbalance
  - Stabilization of small grids through 'synthetic' inertia
- **High Speed Current Source Control**
  The PCS100 can also control power flow by controlling the current from the inverter. Direct current control provides a faster response to a power command.
  - Sinusoidal current regardless of grid voltage distortion
  - Minimizes DC ripple current
  - Fast response

Operating Modes

- Dynamic Power
- Voltage & Frequency Regulation
- Island

- Dynamic Power

BESS - Typical Open Loop Control Data



Grid Op to PCS

Start/Stop

P&Q Setpoints

+P=discharge

-P=charge

PCS to Grid Op

PCS Status

Actual P&Q, etc

Battery SOC

Battery Status

PCS to BMS

General Operating Status

BMS to PCS

DC Voltage

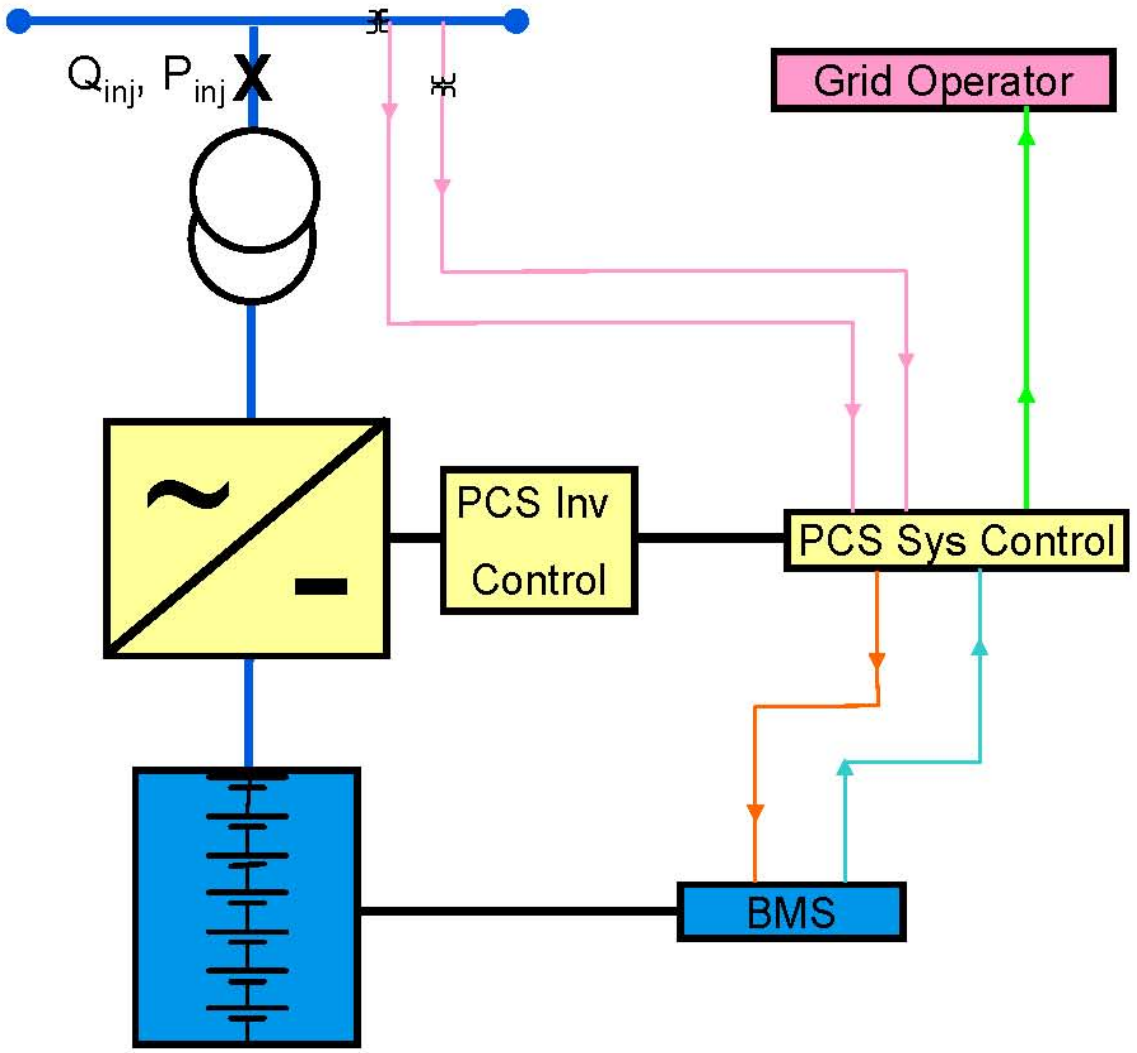
BMS/Battery Status

Charge current Limit

Discharge current limit

Battery SOC

BESS - Typical Dynamic Control Data



Grid PT/CT data to PCS to calculate

Start/Stop

P&Q Setpoints

+P=discharge

-P=charge

PCS to Grid Op

PCS Status

Actual P&Q, etc

Battery SOC

Battery Status

PCS to BMS

General Operating Status

BMS to PCS

DC Voltage

BMS/Battery Status

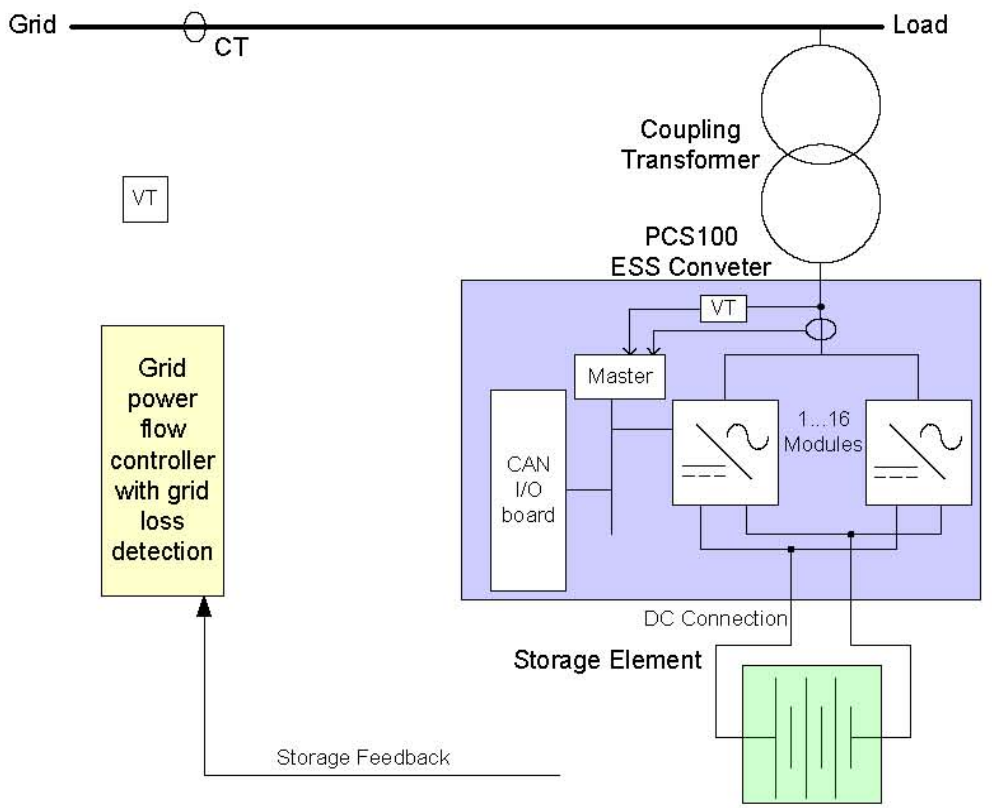
Charge current Limit

Discharge current limit

Battery SOC

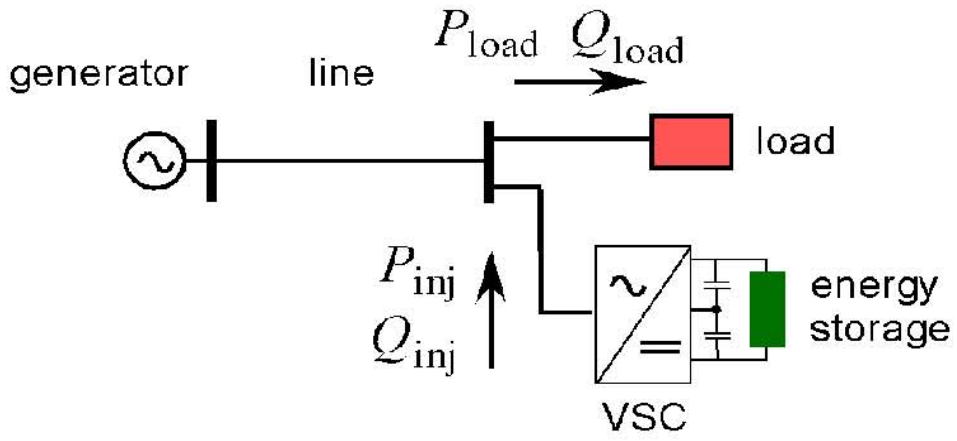
Grid Connect Interfaces

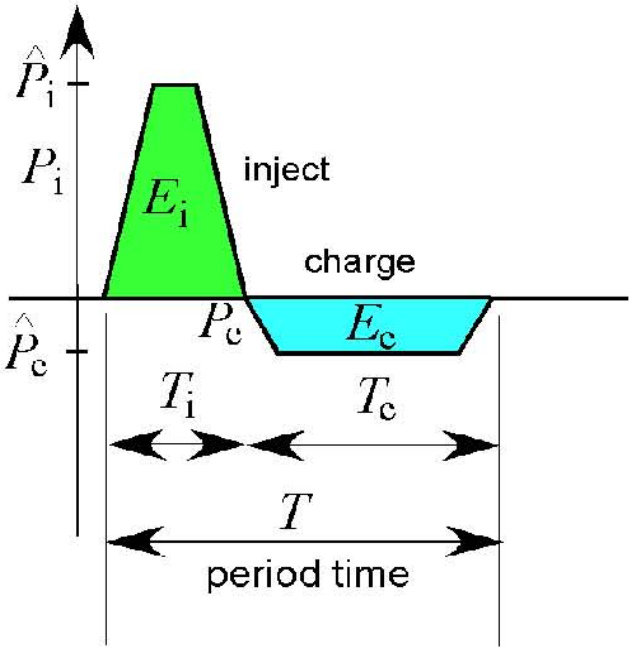
Energy Storage System (ESS), typical installations



- Typical End User or Utility application to perform load leveling with outage protection
- PCS100 has the ability to transfer from operating as a power flow controller to a fixed voltage and frequency (Island mode)
- Generator Emulation Mode (voltage source mode)

ABB FACTS: Dynamic Energy Storage (DynaPeaQ)

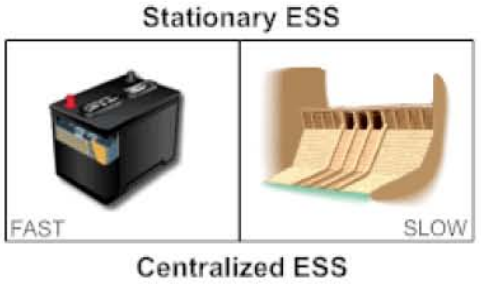




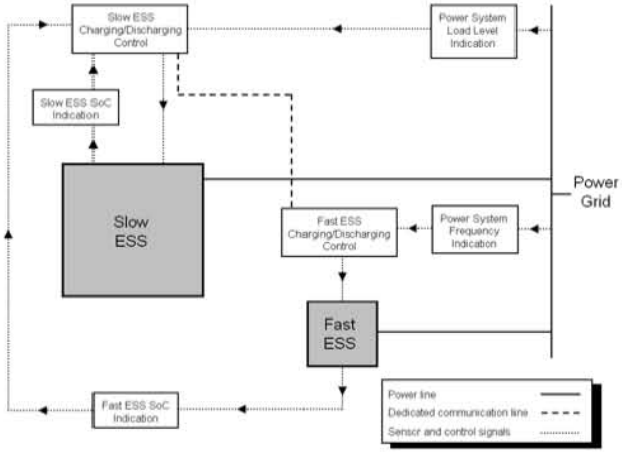
- Energy storage connected on DC-side of converter (SVC Light)
- Size depends on power level and duration
- Charge energy equal to load energy
- Focus on “dynamic”, manages:
  - High number charge and discharge cycles
  - High Power at medium duration
- Chosen high performance battery as energy storage

Hybrid-ESS
Design and control of hybrid energy storage system

- **Why (focus on technical reasons)**
  - ABB wants to grow in the area of BESS (PCS100, DynaPeaQ).
  - Today Li-Ion is expensive, thus a combination of Li-Ion and less expensive Lead-acid may reduce the BESS cost.
  - There is no universal ESS. In order to cover the whole spectrum of power and energy applications a combination of several ESS under central supervisory control is needed.



- **What (define the problem)**
  - Develop/collect models of different ESS (flywheels, batteries, PHS, TESS, etc.) suitable for dynamic and steady state power system analysis.
  - Propose several relevant configurations of Hybrid-ESS (cost, performance, etc.)
  - Develop and test control strategies for various applications taking into account interaction between different storage components, e.g. fast and slow (ABB CRCs has already started exploring this area, we have one patent application)
  - Generate new IDs



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