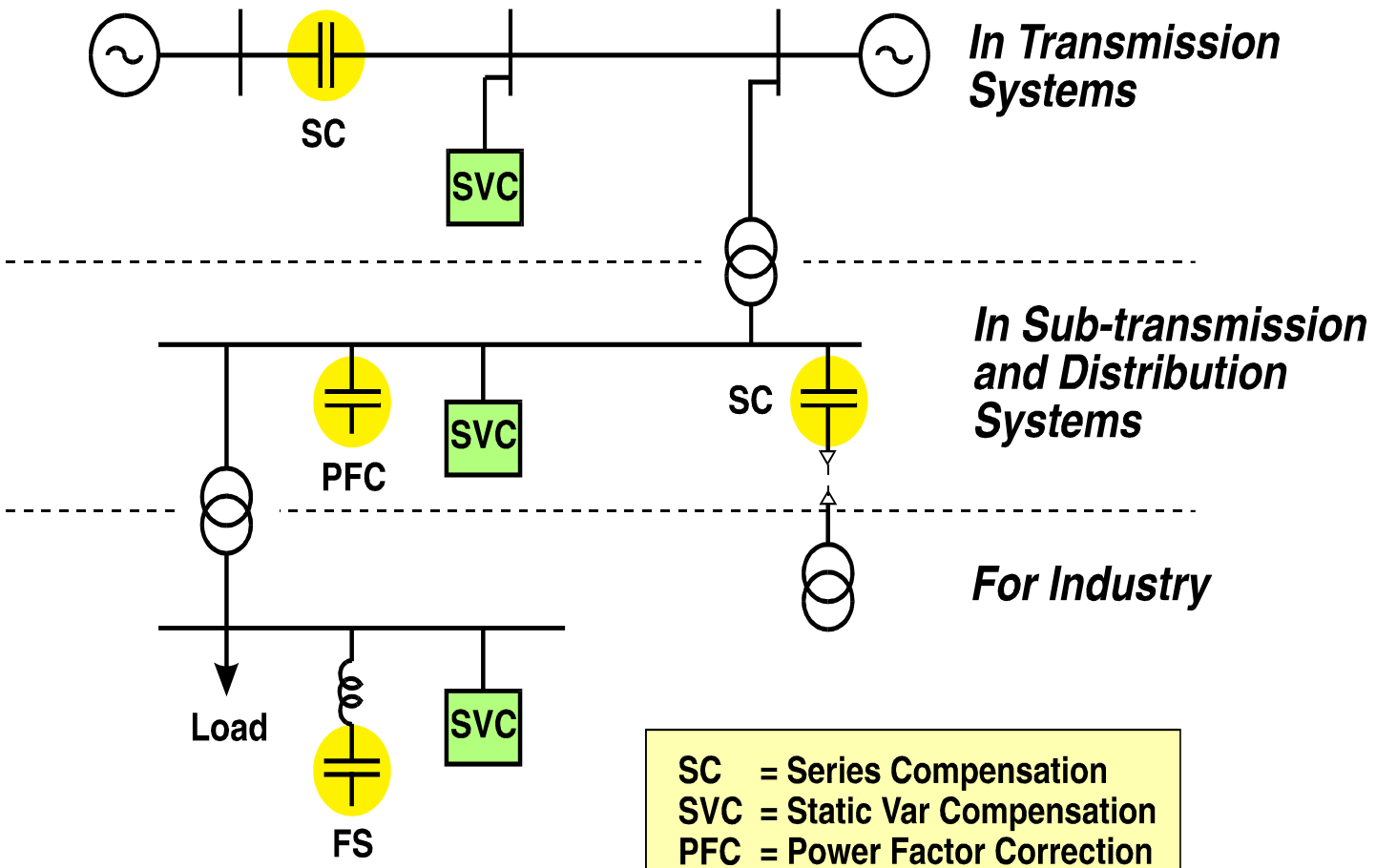
Christian PAYERL, Poznan, 20th May, 2009

ABB FACTS
Grid connection of Wind Farms

FACTS Applications
Flexible **AC** **T**ransmission **S**ystems



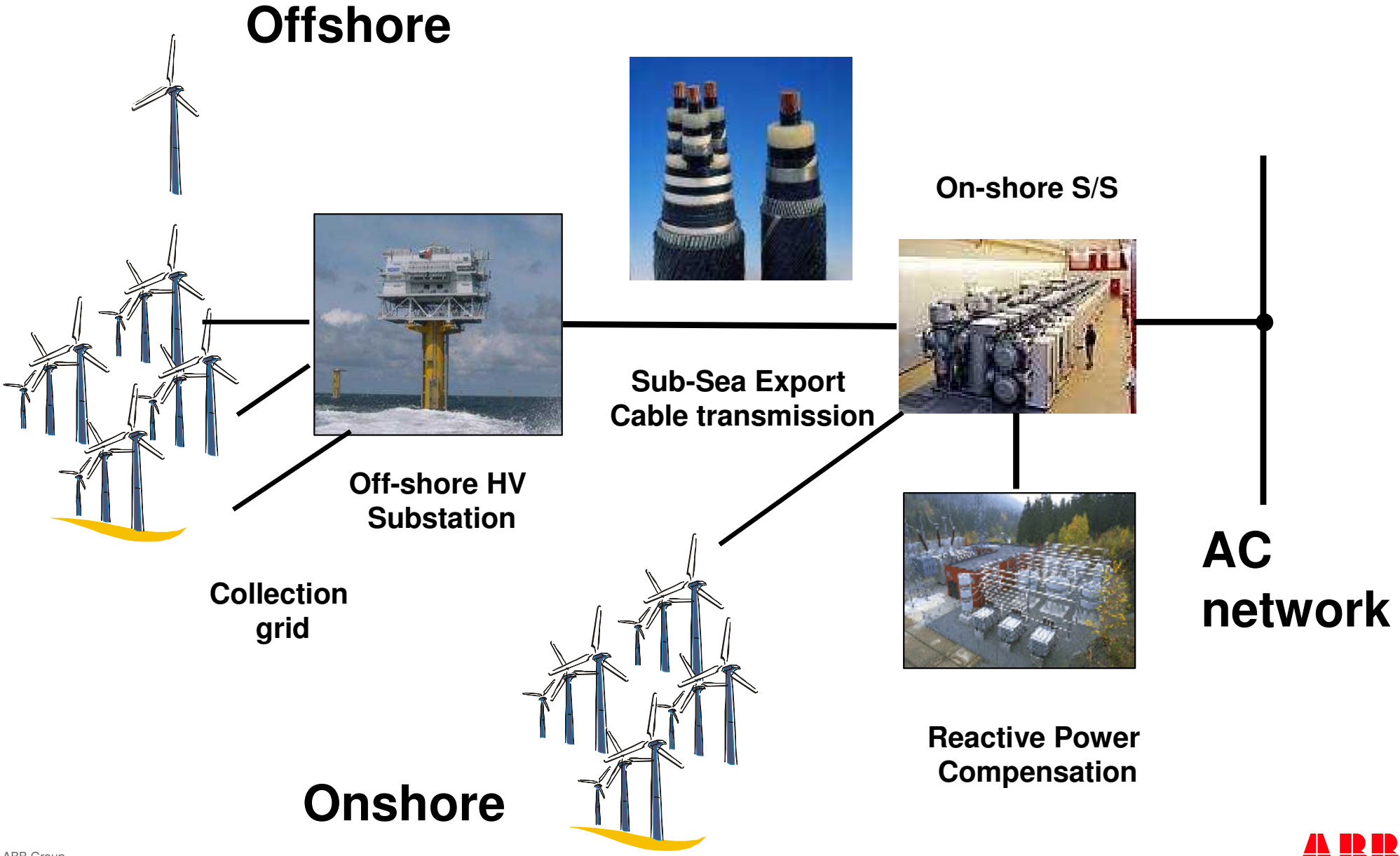
System Studies - Grid Codes

- Many markets are currently installing or discussing installing large amounts of renewable generation
- Of all the renewable energy sources, wind is currently the most viable technology
- In the past wind farms were generally small (ten's of MWs) and connected mainly to distribution systems
- Today most of the wind farms planned are +100 MWs and many are being connected to sub-transmission and transmission level

Why shall large wind plants NOT match the same demands as other large traditional power plants ?

- This prompts the need for systems analysis in the early stages of wind farm development to ensure proper integration into the transmission system

Grid Connection



Critical aspect, Grid compliance - wind power

General

- Reactive Power Balance
- Voltage Stability
- Frequency Control
- Fault Ride-Through
- Power flow

Other Advantages with an SVC at the GCP

General

- Voltage & Transient Stability
- Power Oscillation Damping
- Load Balancing
- Harmonic Mitigation
- “Flicker” Mitigation

Reactive power balance

Reactive Power Balance

- Generators giving local reactive power support are being retired, this disturbs reactive power balance.
- Load sensitivity regarding both fundamental frequency and harmonic voltages is increased. Customers are more sensitive to outages.
- Changed and often reversed power flow calls for studies and actions.

Possible FACTS Application

Reactive Power Balance

- An SVC at the Connection Point can be used to control the entire, or part of, the reactive power.
- An SVC at the Connection Point makes it possible to minimize the losses within the wind farm and mitigates the risk for over voltages.

Voltage Stability, Introduction

Historically, wind farms have been excluded from the demand that generating devices should contribute to voltage stability. They cannot, however, expect to enjoy this favorable treatment forever.

Many regulatory authorities adapt the requirement that the wind parks should be able to vary there reactive power output depending on the grid voltage level.

Possible FACTS Applications

Voltage Stability

- An centrally placed SVC stabilizes the grid.
- A solution with an SVC at PCC contribute to voltage stability independent of the active power production.

Frequency control

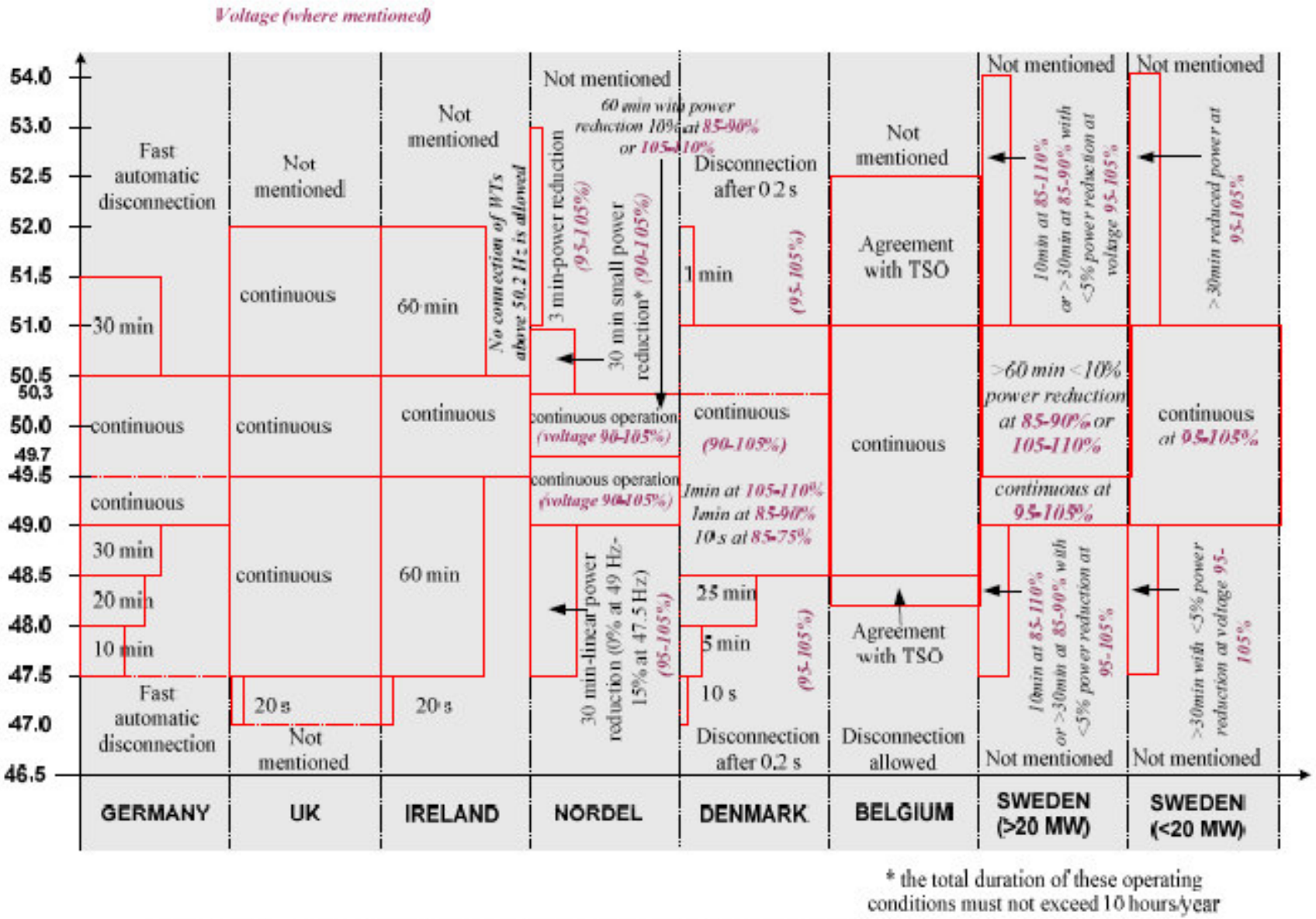
Frequency Control

As well as for the voltage stability,

new wind generation units are requested

to contribute to frequency stability.

Frequency control



* the total duration of these operating conditions must not exceed 10 hours/year

Figure 3. Overview of operating frequency limits imposed by grid codes.

Possible FACTS Applications

Frequency Control

- Active power needed.
- A FACTS device equipped with an energy storage is a possible solution.
- Clustering of smaller wind farms into larger production units makes it easier to apply solutions.

Fault ride through

Fault Ride-Through

- Minimum fault the system is required to survive.
  - Symmetric and asymmetric faults.
  - Depending on voltage level at Connection Point.
- Post fault behavior.
  - Minimum active power as compared to before event.
  - Reactive power and voltage control.

Advantages with an SVC at Connection Point

Fault Ride-Through

- **Fault Ride-Through is first and foremost a question for the Wind turbine generator manufacturers.**
- **An SVC can have a significant impact on the system after clearance of the fault.**

SVC Light Energy Storage

Latest development !

- **High voltage, high power, STATCOM / SVC Light® Energy Storage.**
- **The performance and functions of the SVC Light System are expanded by installing a high voltage, high power, Li-ion battery to the DC side of the converter.**
- **ABB are aiming for industry, distribution and transmission level energy storage applications. Especially the focus is on applications where the combined use of continuous reactive power control and short time active power support is needed.**
- **The new SVC Light Energy Storage System will be introduced to the market shortly. The first installation is undertaken in cooperation with a distribution company aiming at learning more about the usefulness of the system and technology.**
- **Development of the new SVC Light Energy Storage system started in 2003 and the Lithium Battery technology was selected in 2007.**

SVC Light Energy Storage

Grid connection of renewables

- **When connecting large wind farms to the power grid, these will typically be connected far away from the large generators in the system that provides for grid stability and base power production. Issues such as voltage control, grid stability during and after faults and frequency regulation are areas where the new SVC Light Energy Storage system will support the wind farm, and the combined function will to a large extent be similar to that of a large generator.**

Vattenfall: Photo by Hans Blomberg

SVC Light Energy Storage

Spinning reserve

- In a power grid a certain amount of power generation needs to be in service for back-up, emergency, use. This is typically referred to as spinning reserve. The amount differs from area to area, but in general an interconnected power system needs the same amount available as the largest unit in order to cope with a loss of the largest generation unit. The traditional solution is to run generators below maximum power in order to provide this capability. The environmental and economical aspects of this situation are that more than necessary generators are on-line. If dynamic (almost instantaneous) electrical power is available from sources such as the SVC Light Energy Storage the amount of generation on-line can be reduced. The system will support the grid continuously with reactive power and in case of loss of generation the system will push active power into the grid until new generation is on-line, typically within 20 minutes.

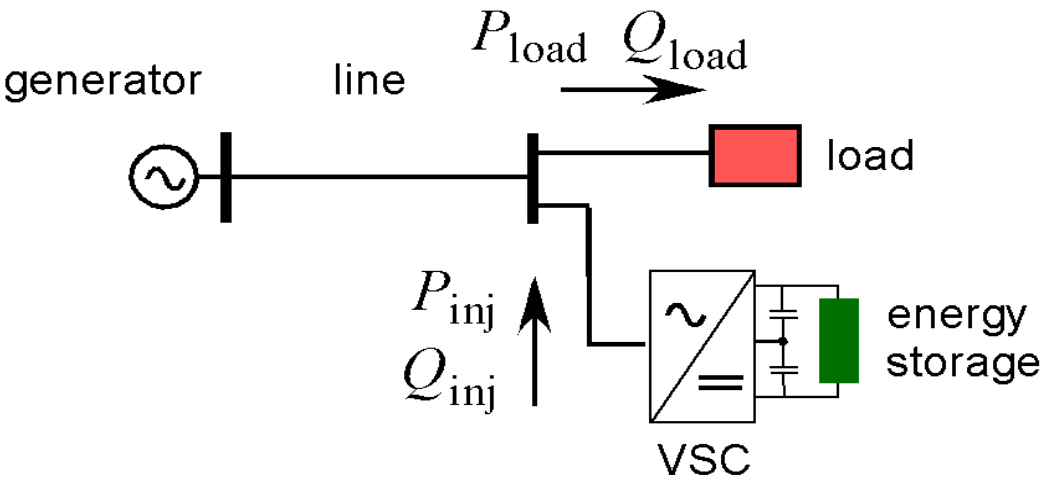
Vattenfall: Photo by Hans Blomberg

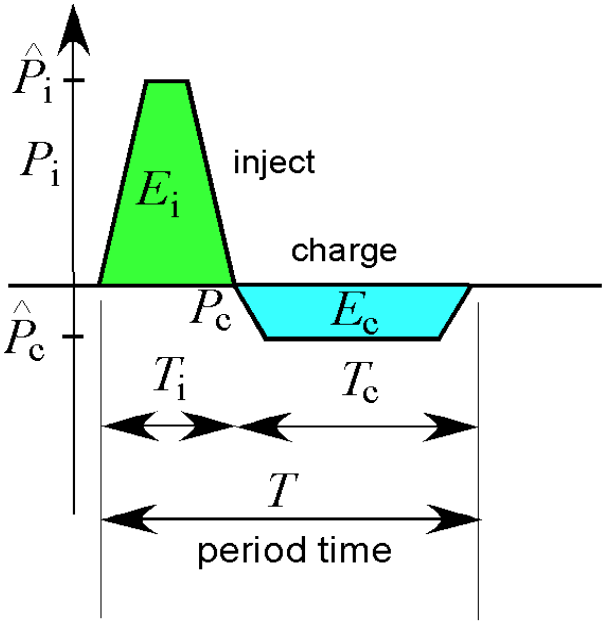
SVC Light Energy Storage

Emergency and Peak Power

- **In a distribution grid or at a sensitive load, an SVC typically provides for voltage control, filtering of harmonic and power quality improvements. By adding energy storage capacity to the SVC a range of new functions can be added. In cases where the local loading exceeds the grid capacity the SVC Light Energy Storage can support the load during a time, the length being dependent on the size of the battery, typically less than an hour. Further, in case of loss of power in the grid, a black-out, a sensitive load or distribution area can be fed by the SVC Light Energy Storage for the time until emergency generators are started.**

SVC Light Energy Storage



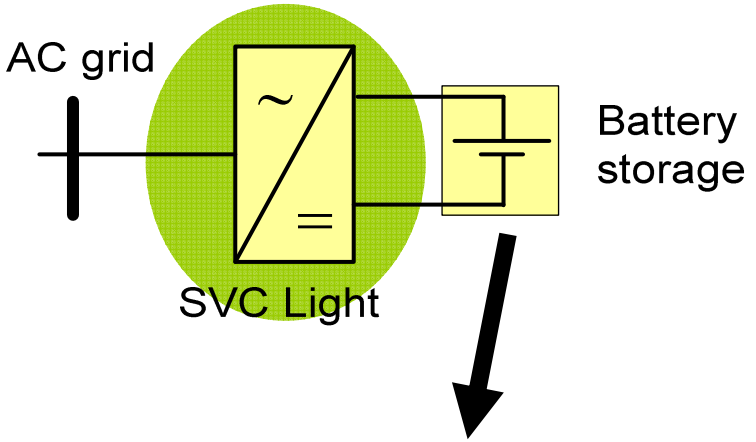


- Energy storage connected on DC-side of converter (SVC Light)
- Size depends on power level and duration
- Charge energy equal to load energy
- Focus on "**dynamic**", manages:
  - High number charge and discharge cycles
  - High Power at medium duration
- Chosen high performance battery as energy storage

SVC Light Energy Storage

- SVC Light
  - First project in 1999 for flicker mitigation of electric arc furnace
  - In total 12 project for both industry and utility applications
  - Power range up 164 Mvar, direct connected without transformer up to 35kV grid

- SVC Light Energy Storage
  - First project in 2009
  - Energy Company in UK
  - System Voltage 11 kV
  - Reactive Power:
    - 600 kVAr inductive
      600 kVAr capacitive
  - Active Power:
    - 200 kW during 1 hour
    - 600 kW (short time)



Picture of the new Li-ion battery after testing, October 2008

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