Dr Fahd Hashiesh, Head of power Consulting, October 2016

The Grid System

Challenges & Mitigations

Contents:

- ABB & Bio
- The Balance Equation
- Changes in the Power Market
- New Challenges
- Mitigation Methods

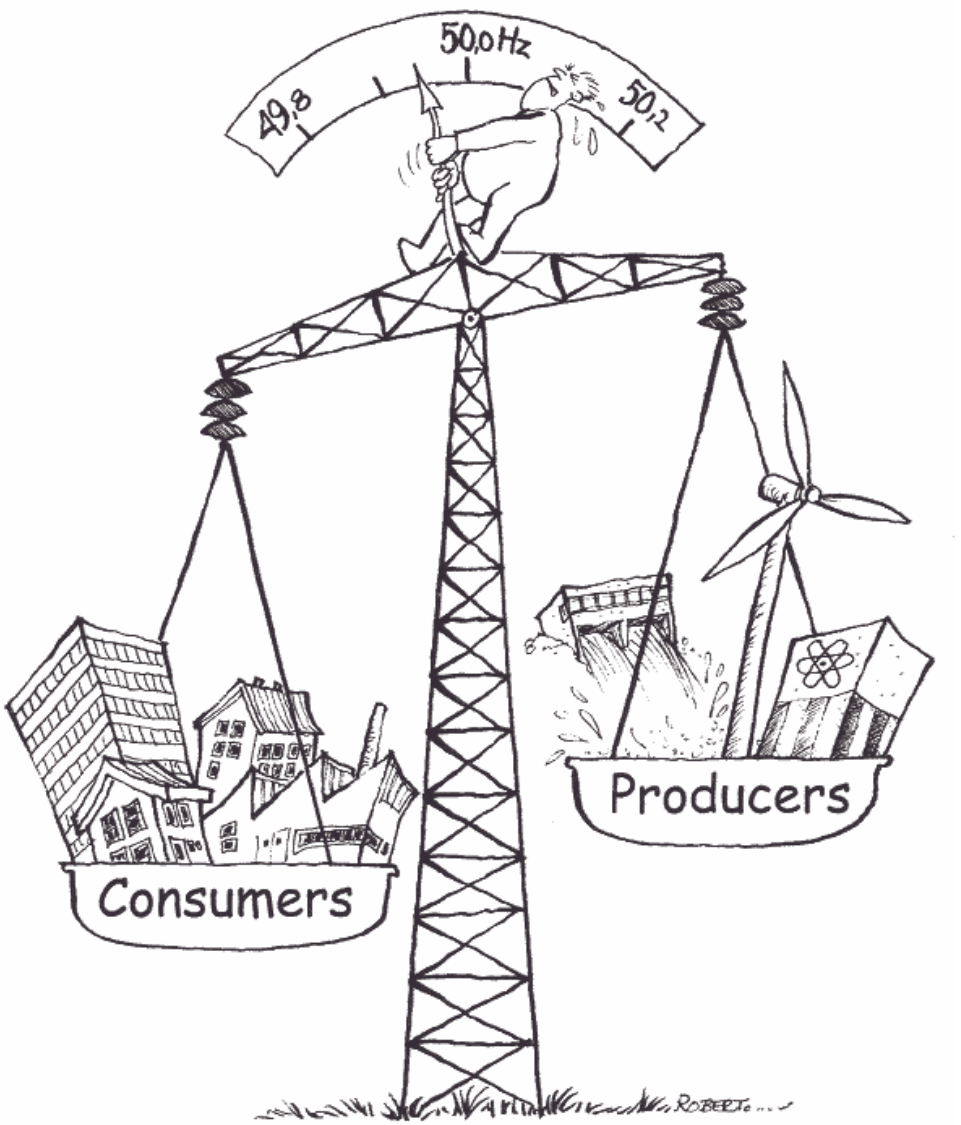
Fahd Hashiesh, PhD, CEng, FIET, SMIEEE

- More than 20 years of Power Systems experience
- Hub Manager UK, ME & Africa (Power Consulting)
- Global Business Development Manager (Power Consulting)
- Previous:
  - Head of Technology (ABB Power Systems)
  - Substations Design Team Leader (ABB)
- Research Interest:
  - Wide Area Monitoring, Protection and Control
  - System dynamics
  - Powerline commu
  - Substations' techr

rests:

- Fishing

The Balance Equation



Changes in the Power Market

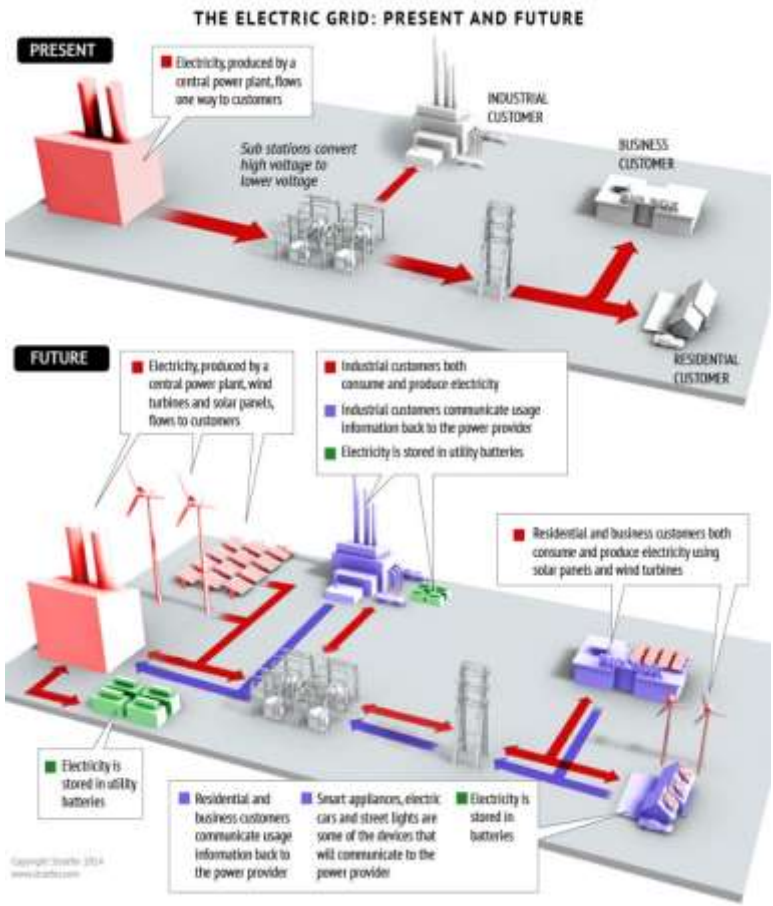
- Increased use of renewable production
- More consumption points (i.e. Electrical Vehicles)
- Transmission monopoly challenged
- Reduced implementation times
- Reformation of regulations
- Globalization - increased cross boarder investment
- Increased electricity trading
- Increased urbanization
- Increased demand on power quality

Increased competitiveness of electricity

Grid Complicity is Accelerating the Change

Implications

- Managing multi-directional power flow.
- Need to store energy.
- Increasing need for power quality & reliability.
- Need for more interconnected grids



What happened in 4th November, 2015
£2.4m to keep the system running

Cordi O'Hara says National Grid is looking to industry to help curb consumption

The grid said it spent **£2.4m** that day to keep the system running — "in line with a normal winter's day" — and that the high prices paid at the peak did not last long.

with one company receiving emergency payments of **£2,500** per megawatt hour compared with the going rate of about **£60**.

Source: financial times

Shifting the demand by two hours
£1bn of savings

The UK could save about £1bn and thousands of tonnes of carbon emissions by paying people to use electricity at different times, according to a study using government figures.

Source: financial times

From China to Germany
Ultra-High Voltage

China looks to export surplus energy to Germany

A dam construction site in China

China's proposed investments in long-distance, ultra-high voltage (UHV) power transmission lines will pave the way for power exports as far as Germany, the head of the national power grid said on Tuesday as he launched an initiative for cross-border power connections.

Source: financial times

Cyber Attack Ukraine

Stage 1 Intrusion:

At least six months prior to power cut - operator workstations infiltrated.

Stage 2 Attack:

December 23rd 2015 all circuit breakers were opened in (at least):

23 x 35kV Substations

7 1x 10kV Substations

Stage 3 Attack Amplification:

UPS power supplies were disabled in Utility Control Center – Control Room Dark

Firmware downloaded to Serial/Ethernet communication devices taking them out of service.

Telephony denial of service attack on call center.

Operator Workstation Hard Disks were erased.

SANS/ICS-Cert Report: https://ics.sans.org/media/E-ISAC_SANS_Ukraine_DUC_5.pdf

Wind Energy

Turbine Blade Convoy Passing through Edenfield, UK (Wikipedia)

Wind Energy

Wind Energy

Wind Energy

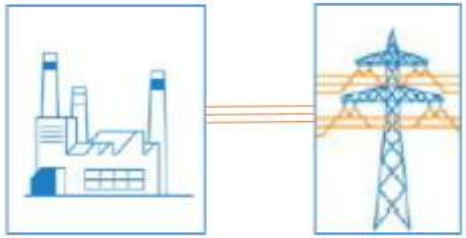
Offshore Wind

Source: ABB

Power Consulting

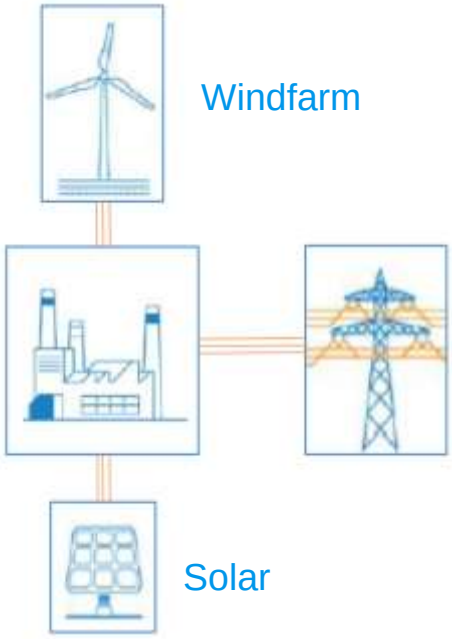
Generation Expansion: Increase in Short Circuit levels

Before



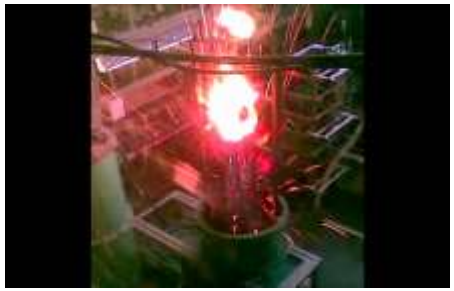
Industry Grid

After



New Generation is added

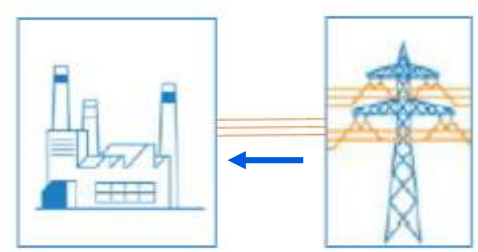
Impact



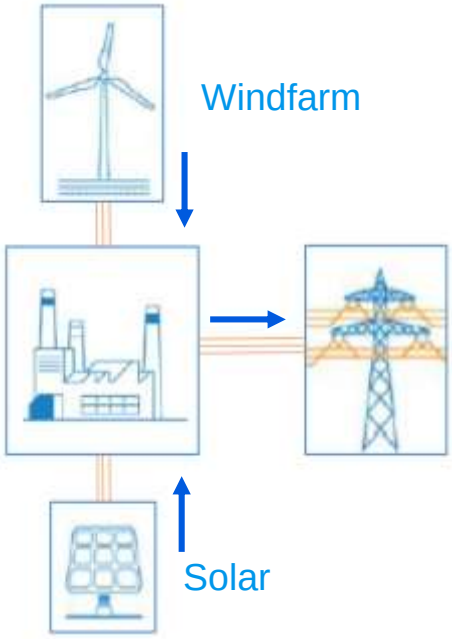
Increase in short circuit levels leads to busbar damage

Power Consulting
Generation Expansion: Equipment Overloading

Before

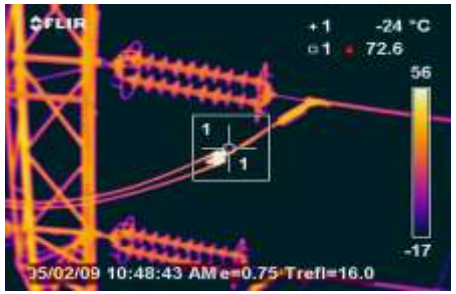


After



Power flow changes.

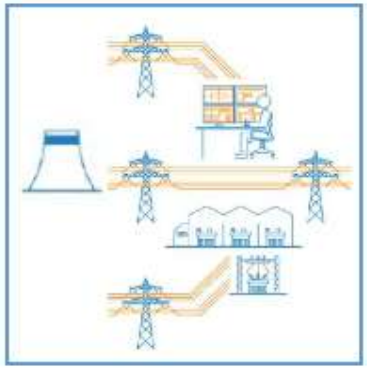
Impact



Overloading of equipment. Fatal damage and final out of service of the electric system.

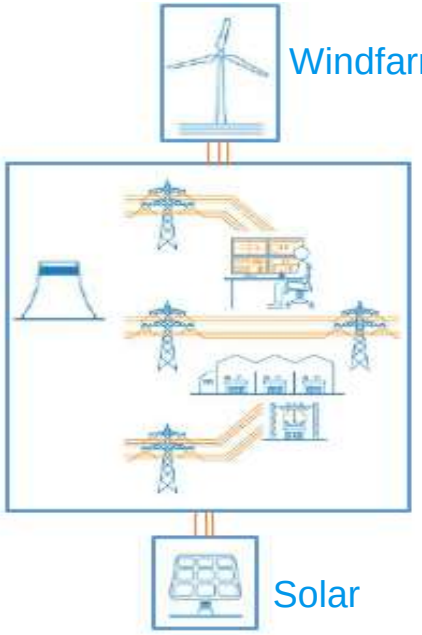
Power Consulting
Grid Impact Due to Renewable Integration

Before



Conventional Grid

After



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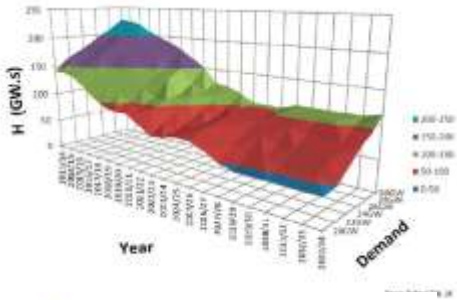
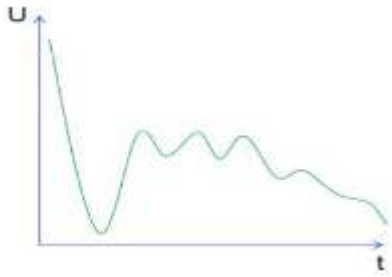
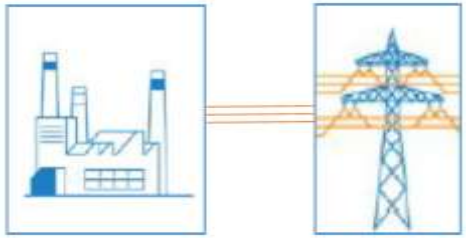




System Inertia Issues, LVRT, HVRT and Power Quality issues

Power Consulting
Harmonics

Before

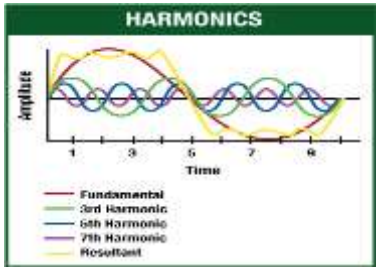


Industry Grid

After

New loads like VFD's, furnace, rolling mills added

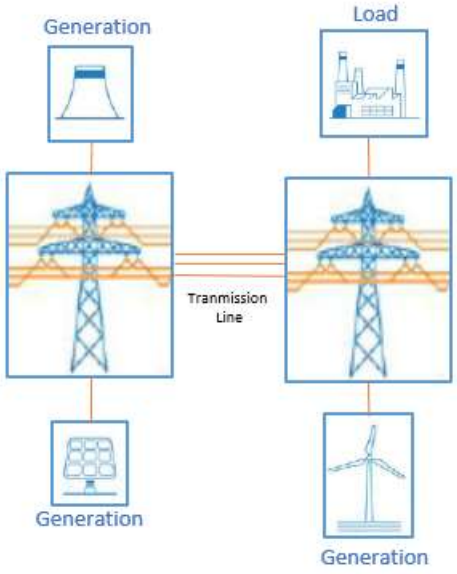
Impact



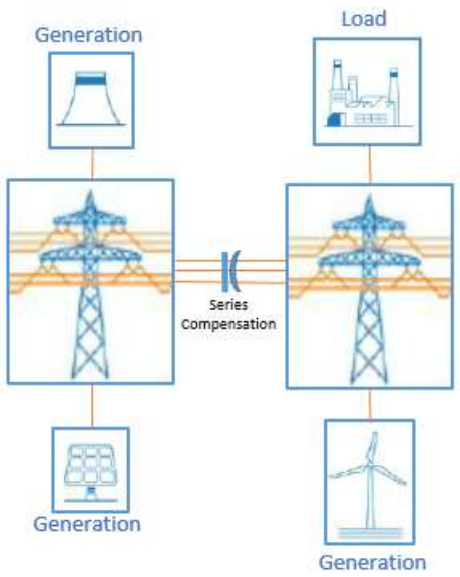
Harmonic Overvoltages leads to equipment damage

Power Consulting
Series Compensation

Before



After



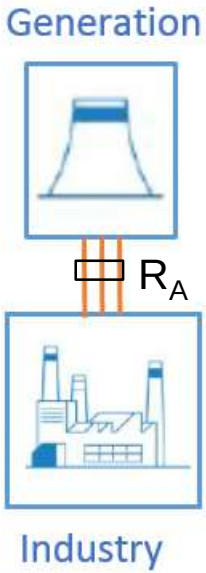
Series Compensation is added

Impact

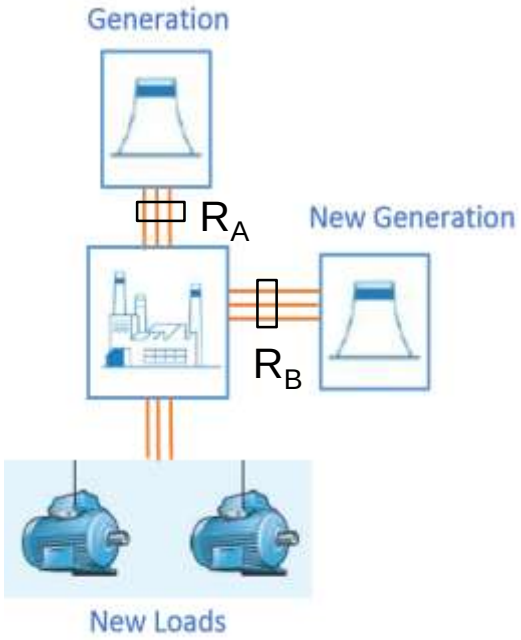
Sub synchronous Resonance (SSR), SSTI at near by generators

Power Consulting
Protection

Before



After



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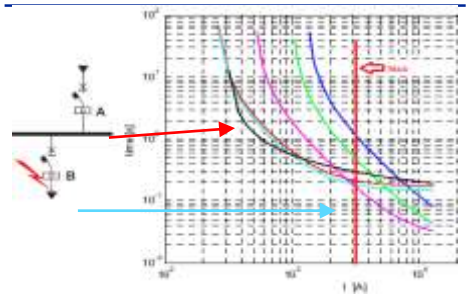


Relay mal-operation. Not fast fault clearing.
Loss of synchronism, instability of the system.
Equipment failure due to non-operation of primary protection and total blackouts

Power Consulting
Earthing Adequacy

Before

After

Expansion of existing substation

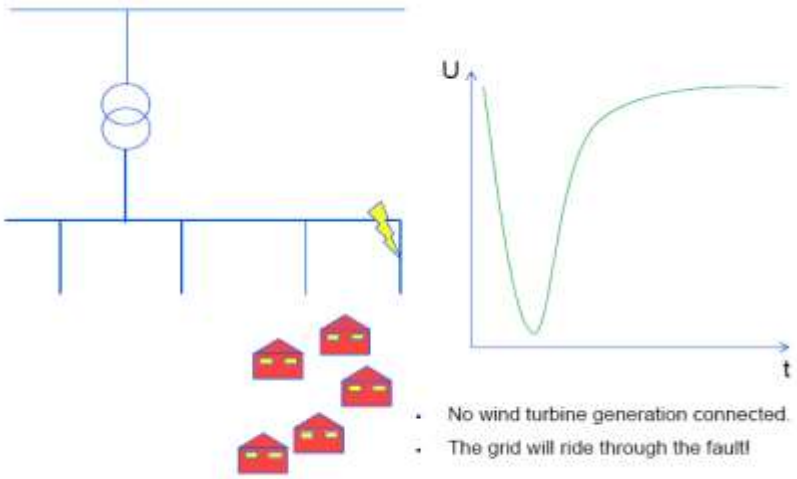
Impact

Personal and equipment safety at stake, Protection malfunction

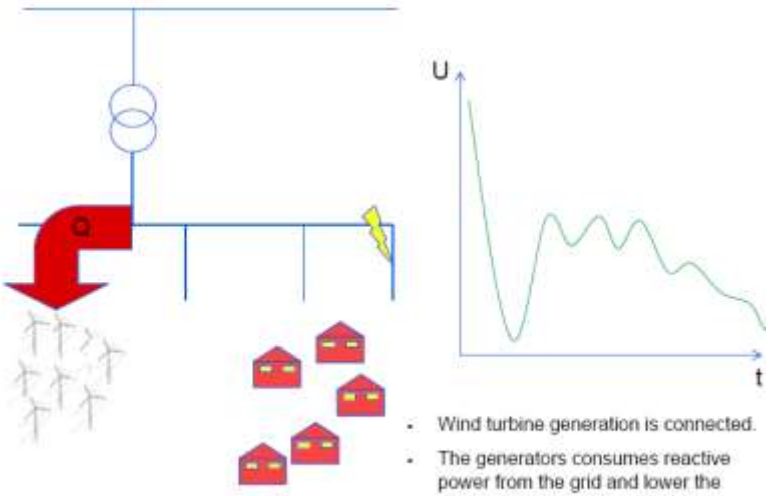
More renewable lead to more challenges

- Not a predictable source of energy
- Voltage fluctuations and instabilities
- Maintaining reactive power balance
- Harmonics
- Loss of system inertia
- Rate of change of frequency
- Fault ride through

Fault Ride Through

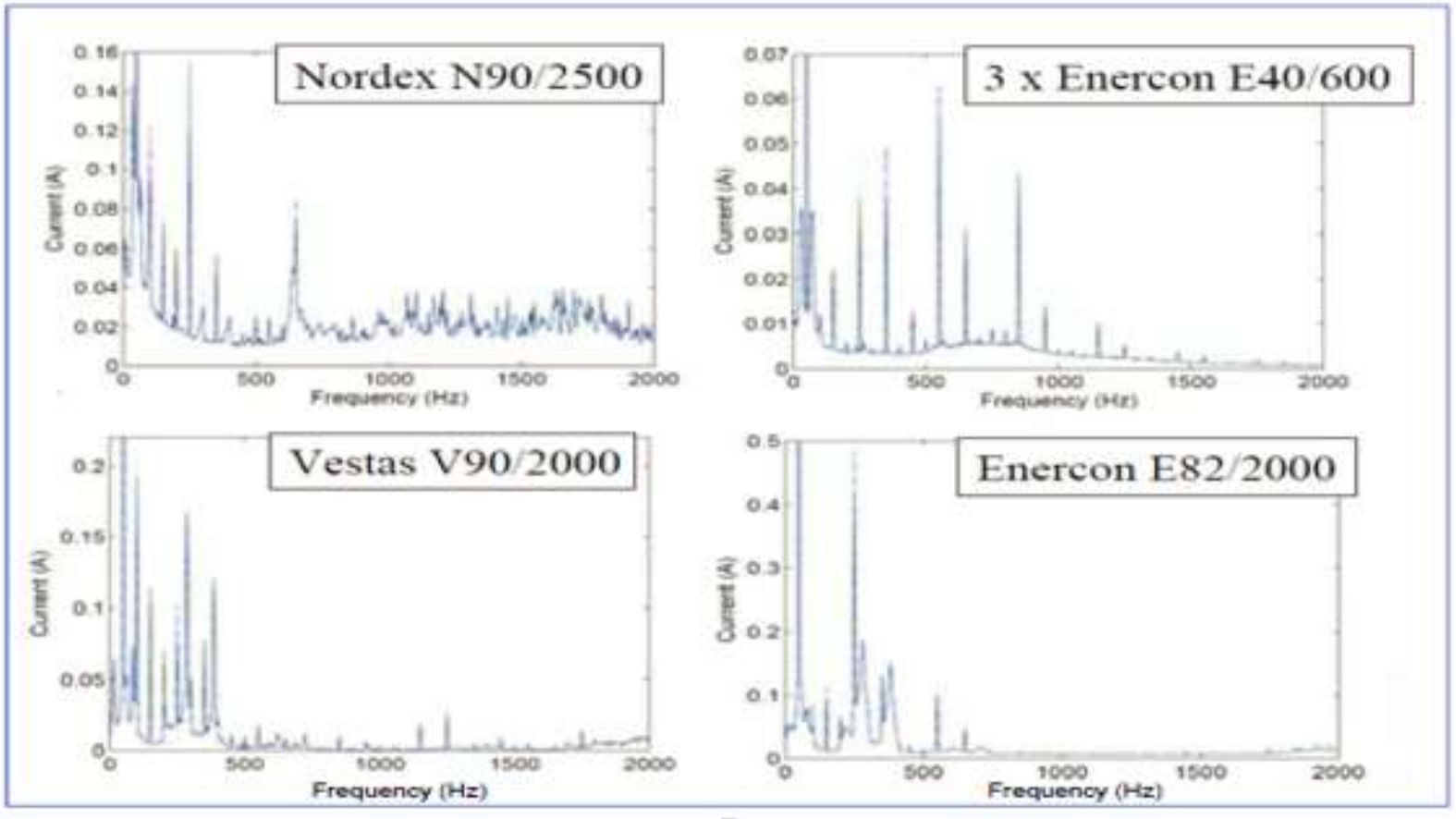


- No wind turbine generation connected.
- The grid will ride through the fault!



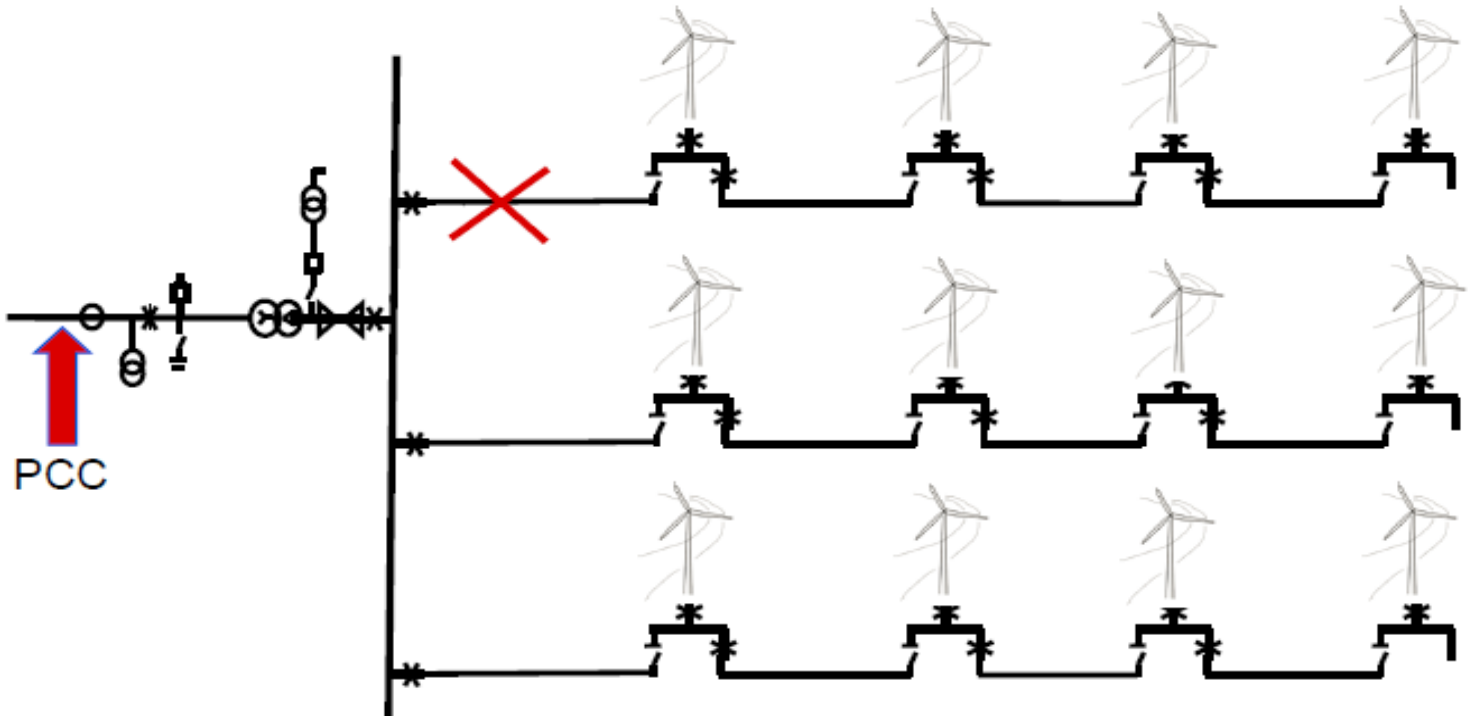
- Wind turbine generation is connected.
- The generators consumes reactive power from the grid and lower the voltage even more.
- The generators trip due to low voltage and due to trip of wind generators!

Harmonics

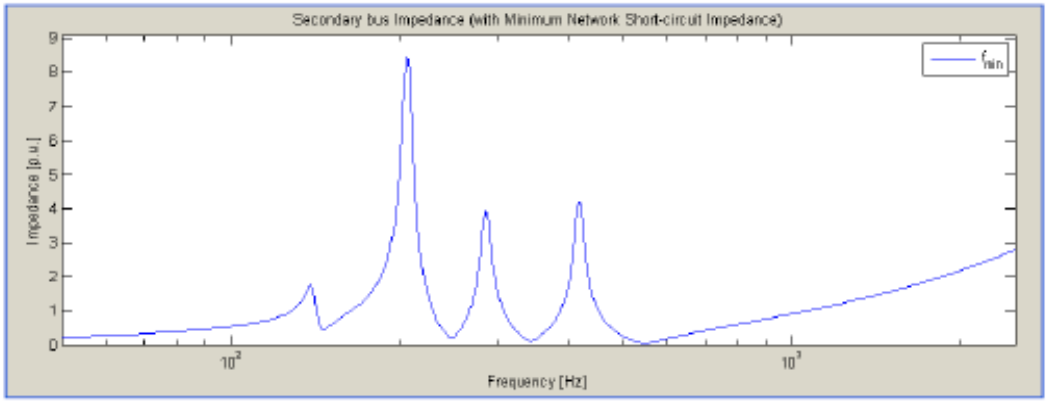


Harmonics

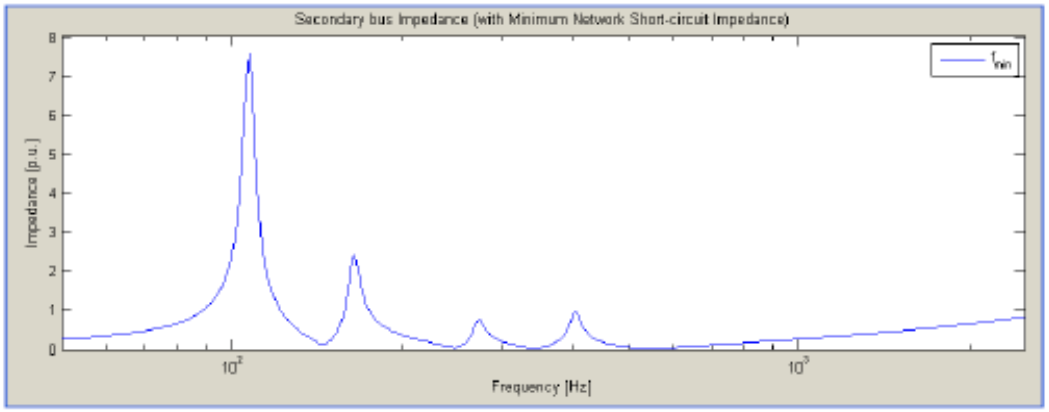
Disconnection of an array will give the system a new impedance spectrum.



Harmonics



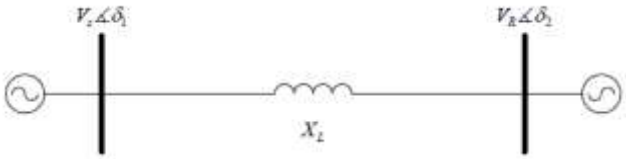
- Impedance spectrum during normal operation!



- Impedance spectrum when some cable arrays have been disconnected
- The result is that we have new resonance frequencies and a new spectrum of harmonics!

IEEE -Top 11 Technologies of the Decade

Flexible AC Transmission System

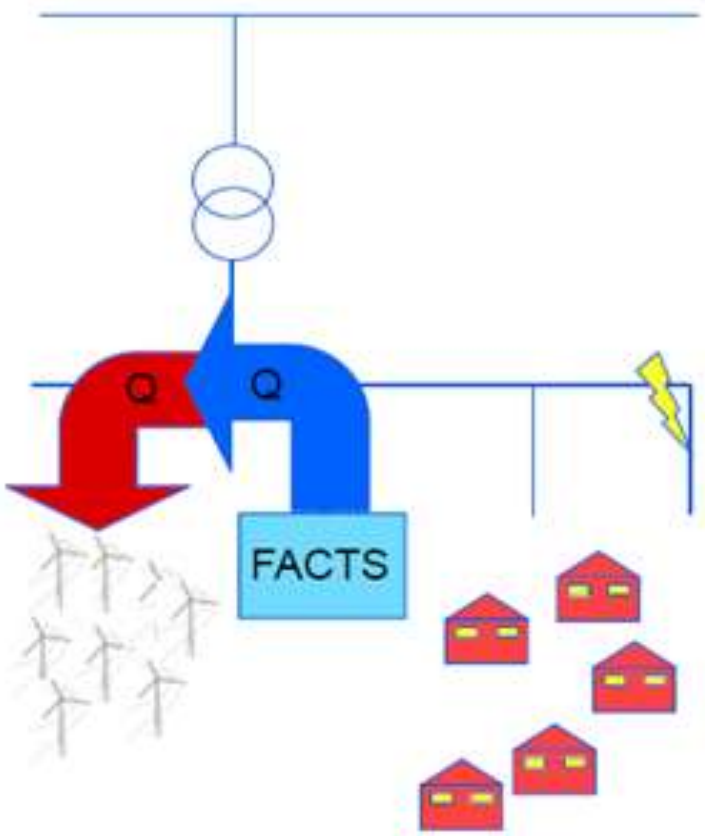


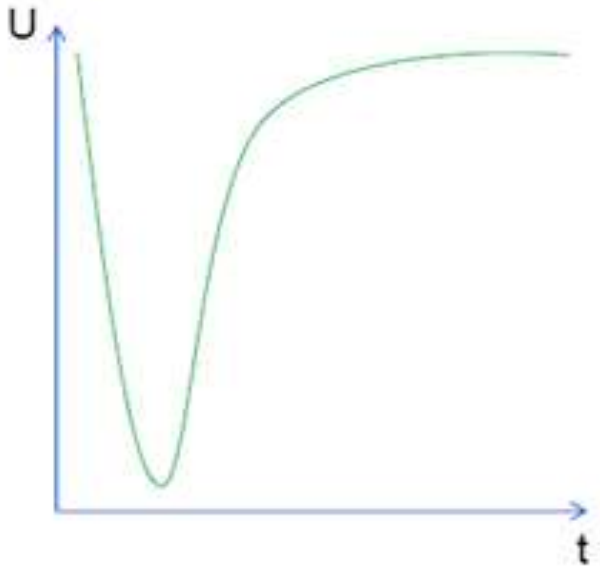
$$P = \frac{V_1 . V_2}{X_{12}} \sin\delta_{12}$$

Shunt Compensation

Series Compensation

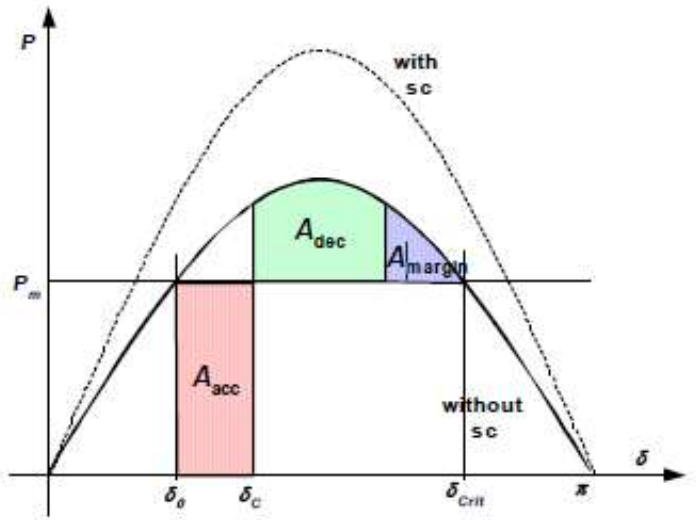
Fault Ride Through



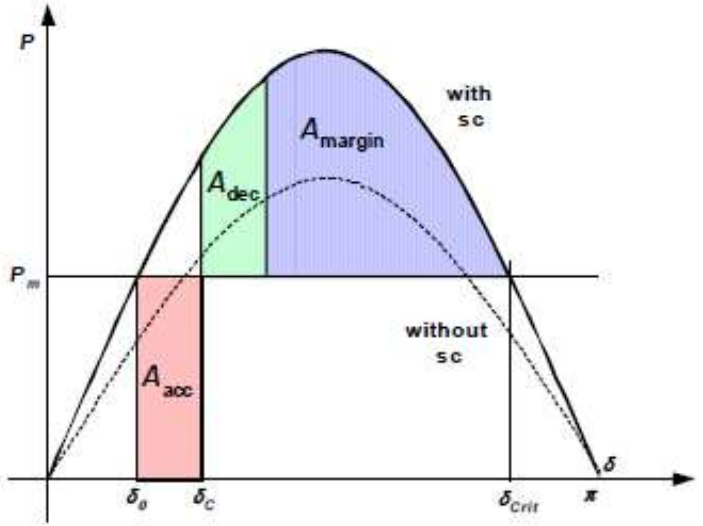


- By installing FACTS, the fault ride through capability will be increased.
  - In many cases a more cost effective solution.

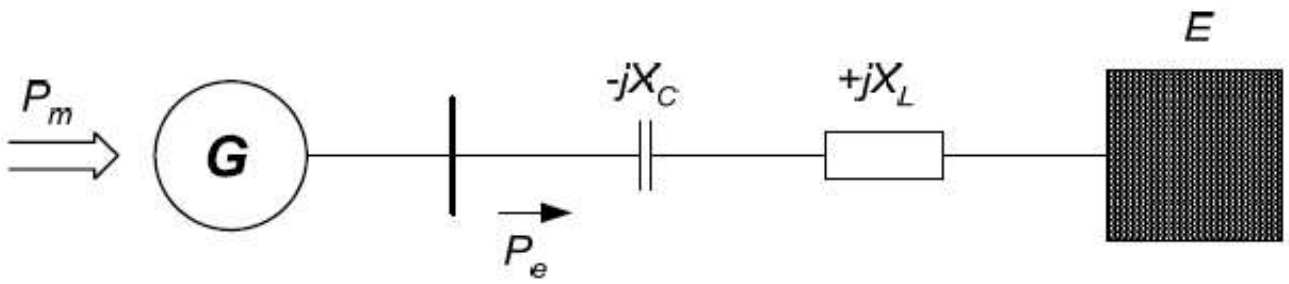
FACTS - Series Compensation



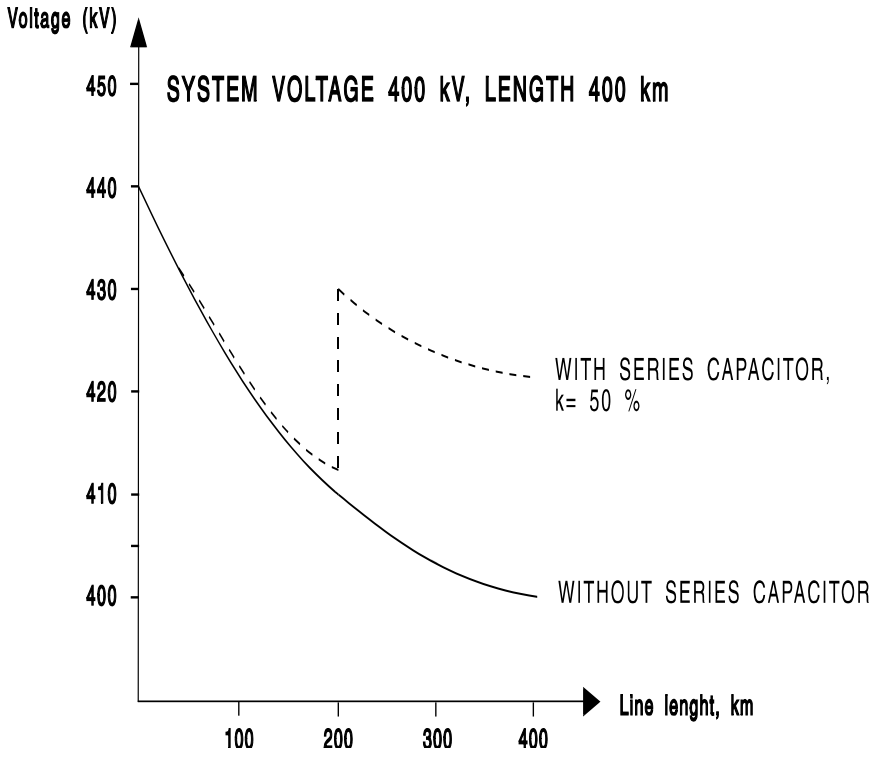
No series compensation



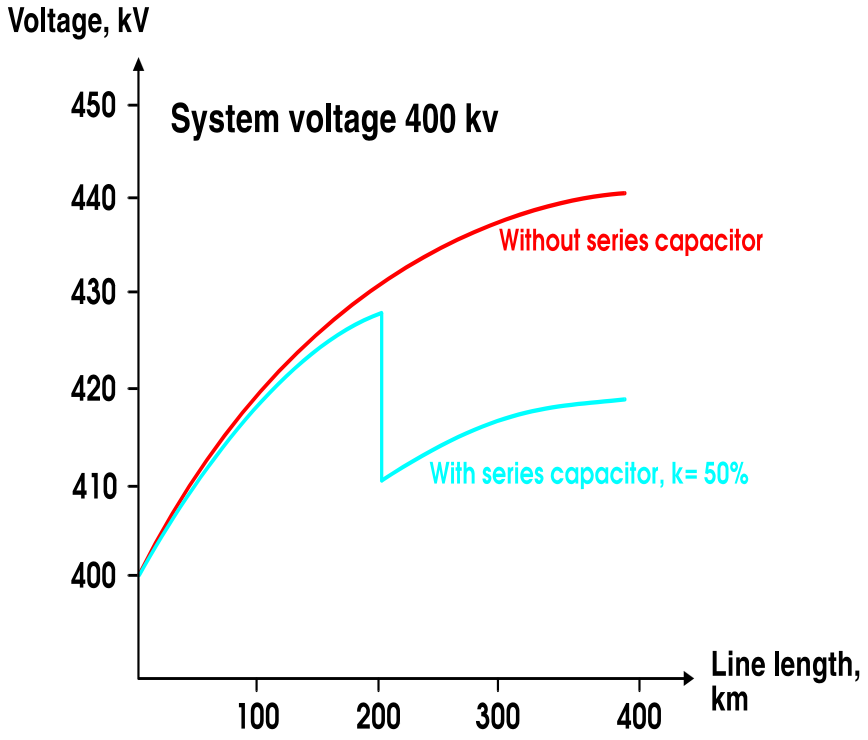
With series capacitor



FACTS - Series Compensation



Voltage profile, loaded T.L.



Voltage profile, open ended T.L.

Energy Storage

Key benefits

Flicker compensation

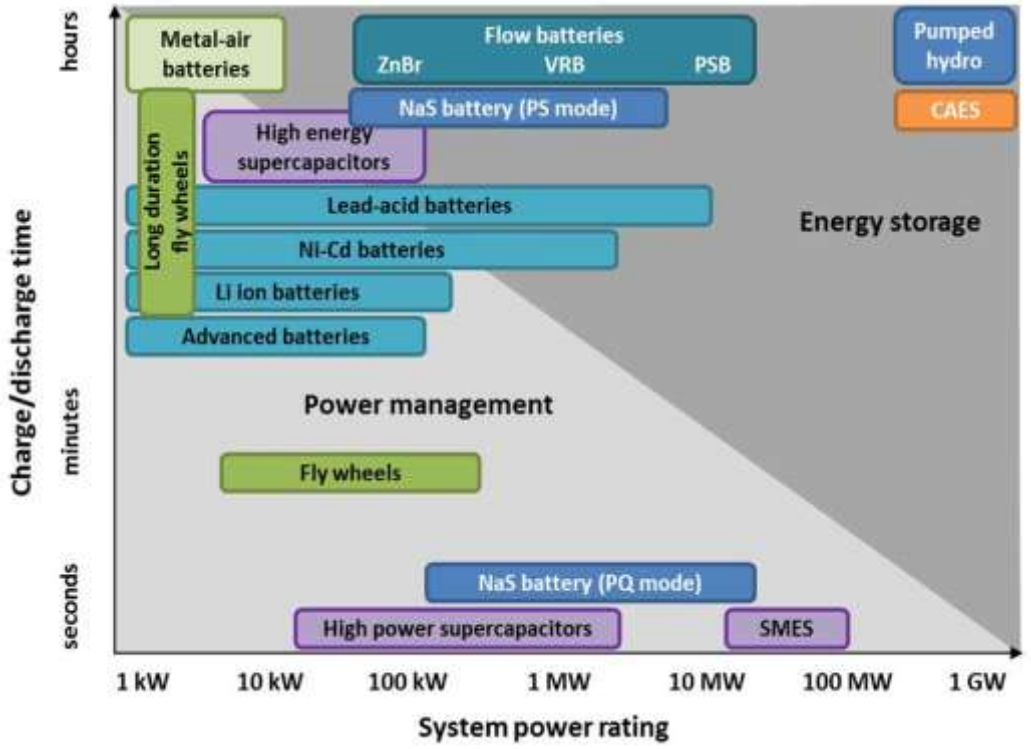
Voltage sag correction

Reactive power control

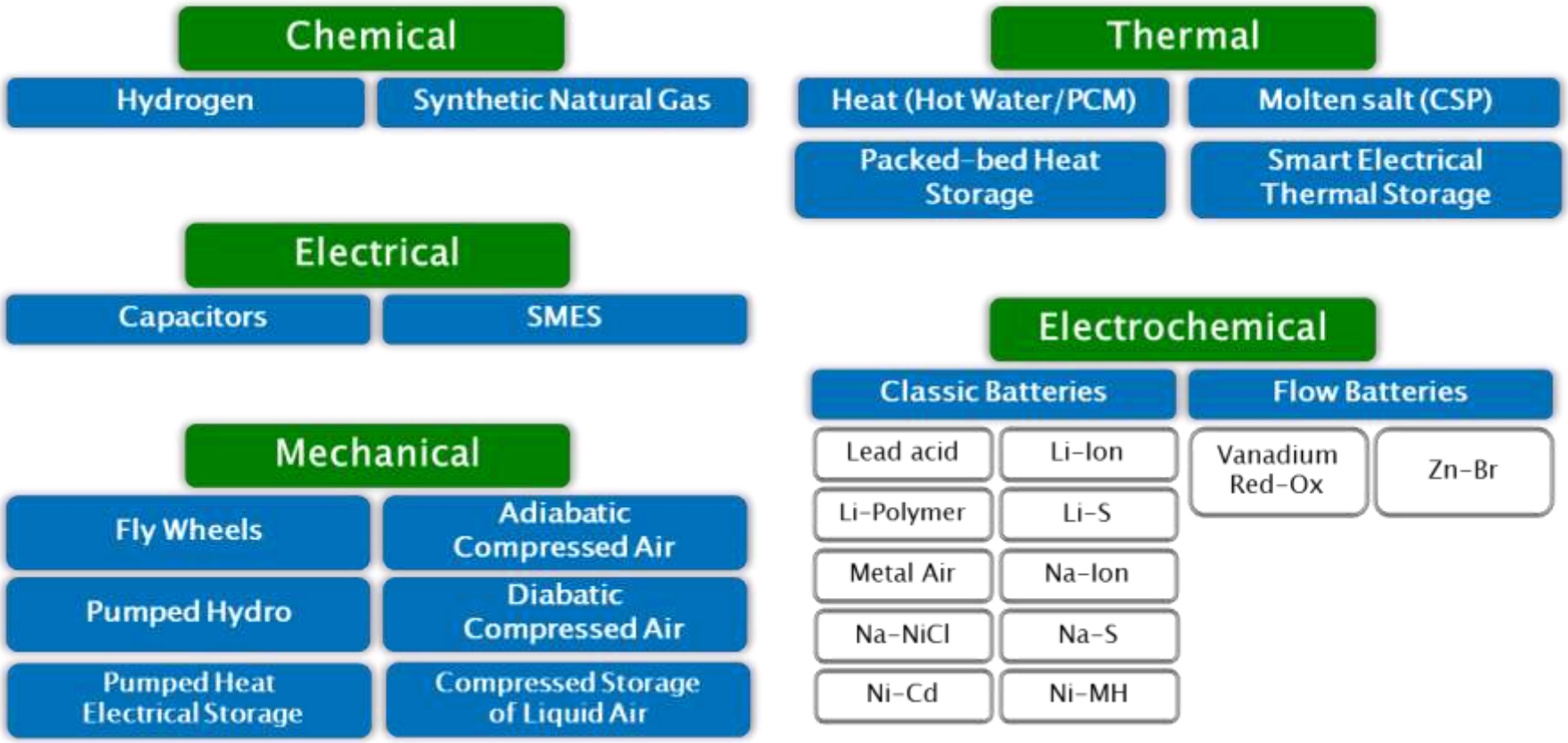
Spinning reserve

Load leveling

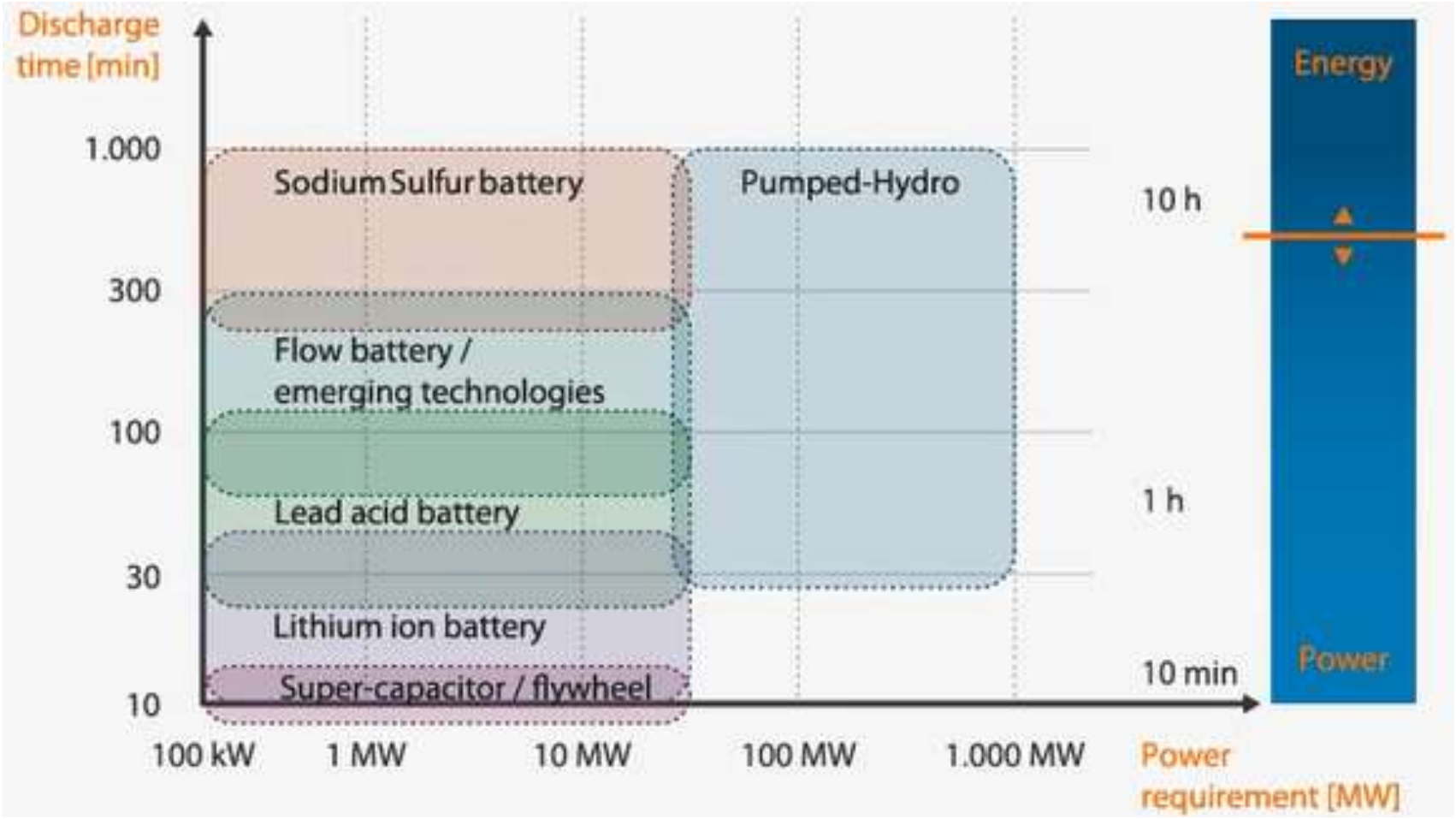
Peak shaving



Storage Categories



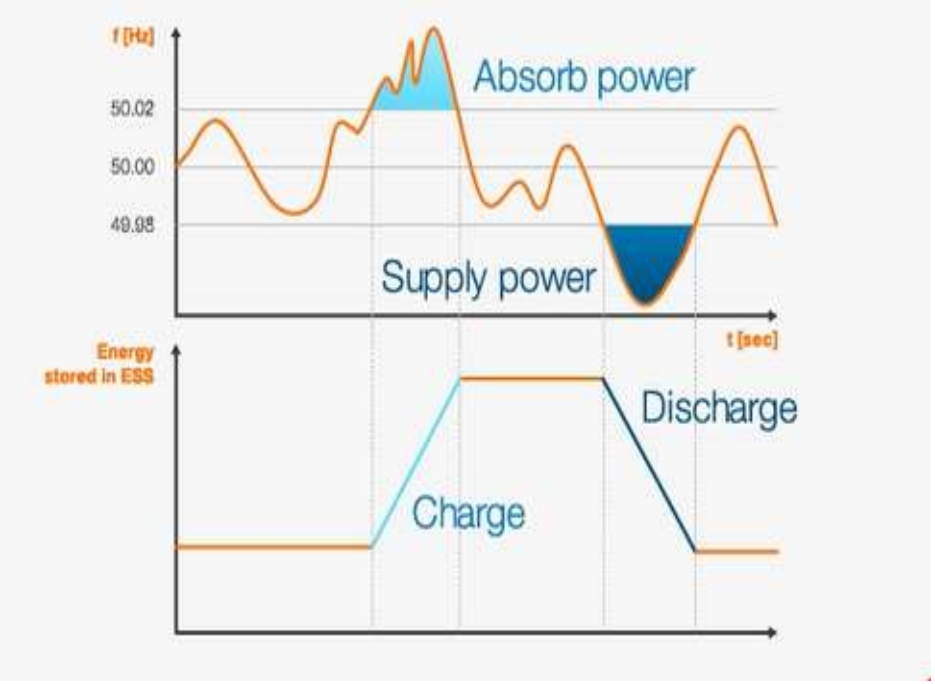
Technology Landscape



ESS – Frequency Regulation

The energy storage system is charged or discharged in response to an increase or decrease of grid frequency.

This approach to frequency regulation is a particularly attractive option due to its rapid response time and emission-free operation

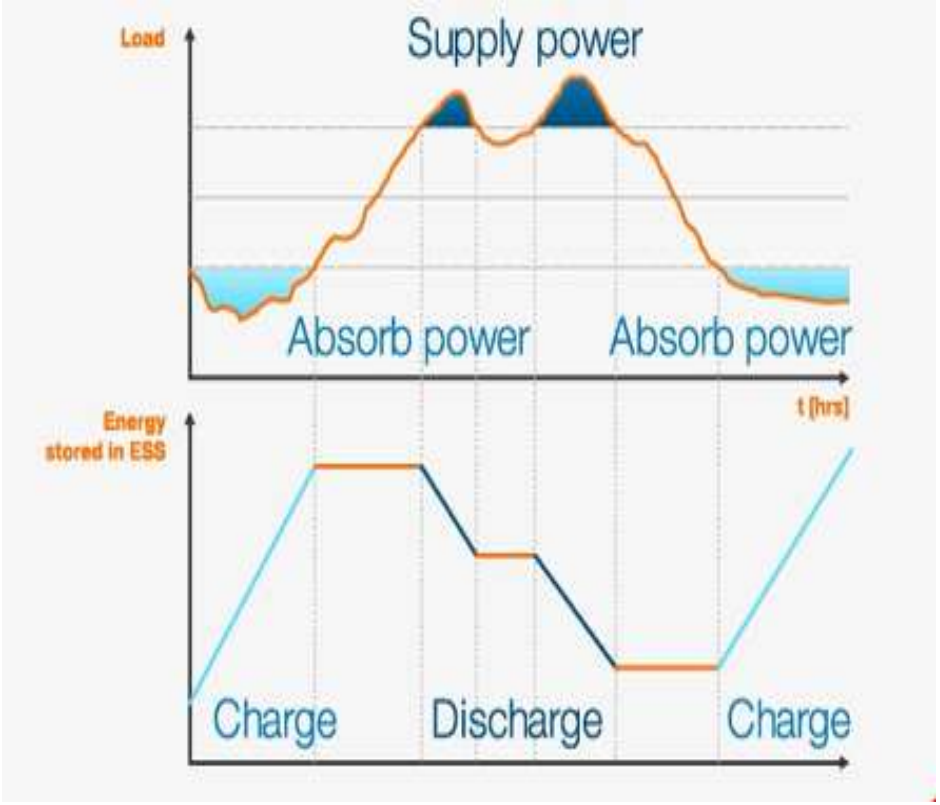


ESS - Load Levelling

Storing power during periods of light loading on the system.

Delivering it during periods of high demand.

During these periods of high demand the energy storage system supplies power, **reducing the load on less economical peak-generating facilities.**

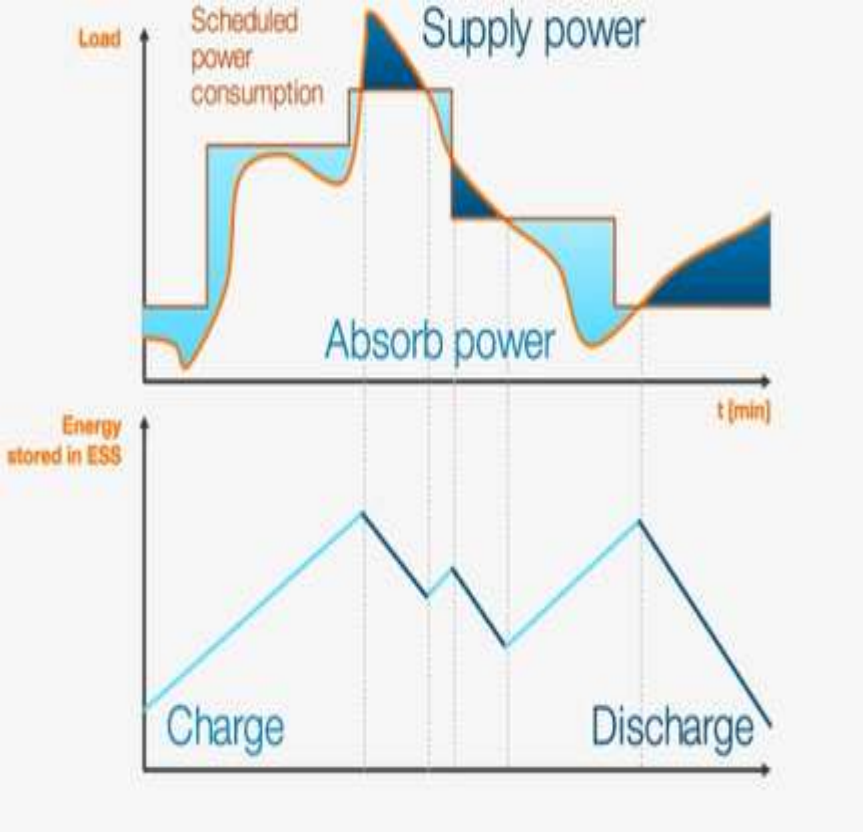


ESS - Peak Shaving

Peak shaving is **similar to load leveling, but may be for the purpose of reducing peak demand rather than for economy of operation.**

Avoid the installation of capacity to supply the peaks of a highly variable load.

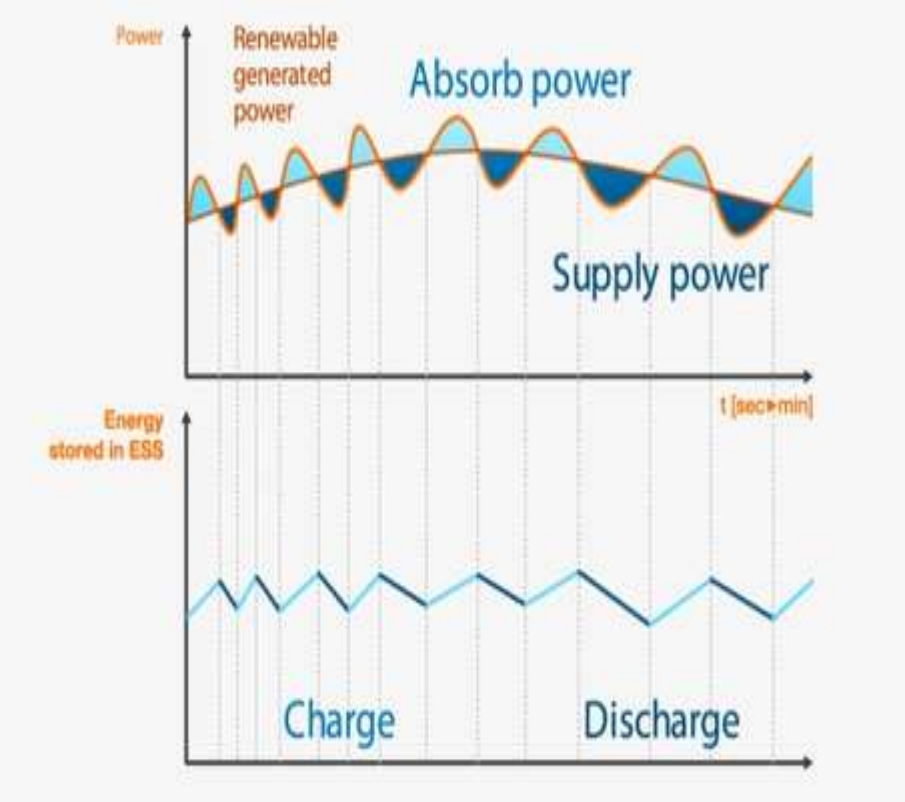
Often owned by the consumer, rather than by the utility.



ESS – Capacity Firming

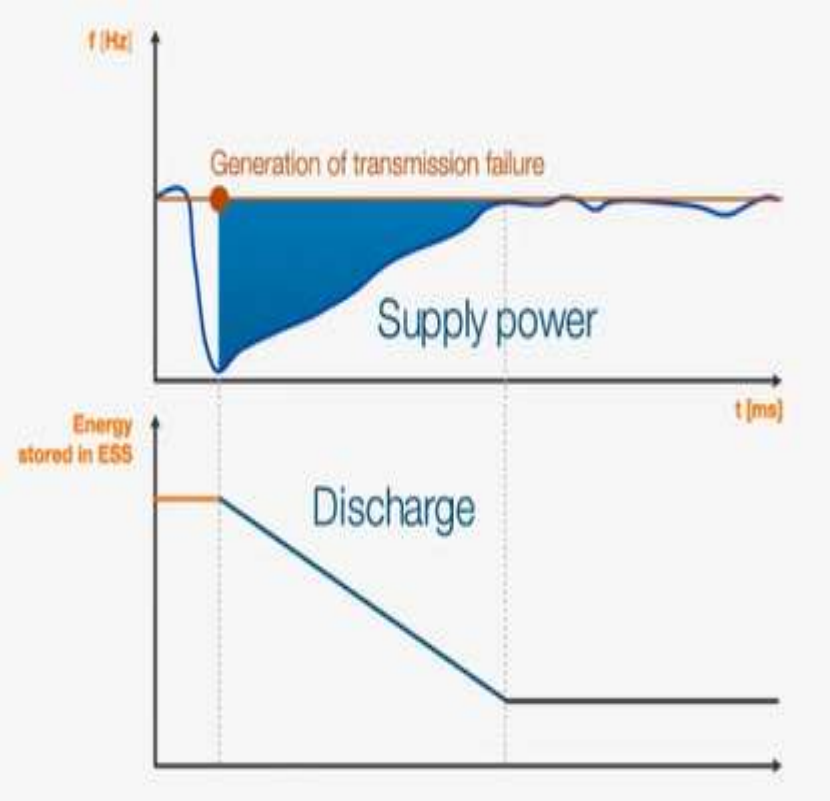
Power output from a renewable power plant, such as wind or solar, **can be maintained at a committed (firm) level for a period of time.**

The energy storage system smooths the output and controls the ramp rate (MW/min) to eliminate rapid voltage and power swings on the electrical grid.

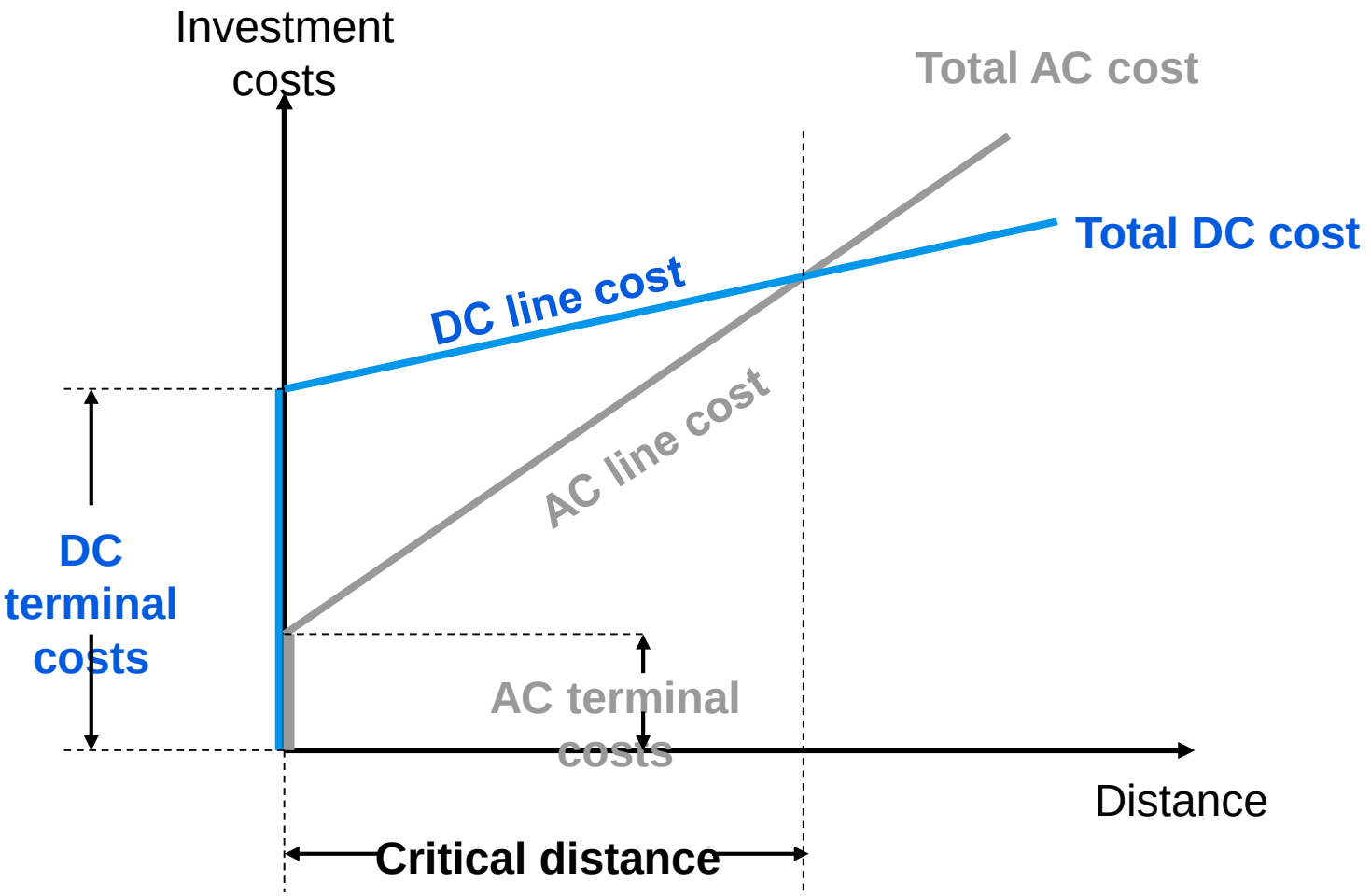


ESS – Spinning Reserve

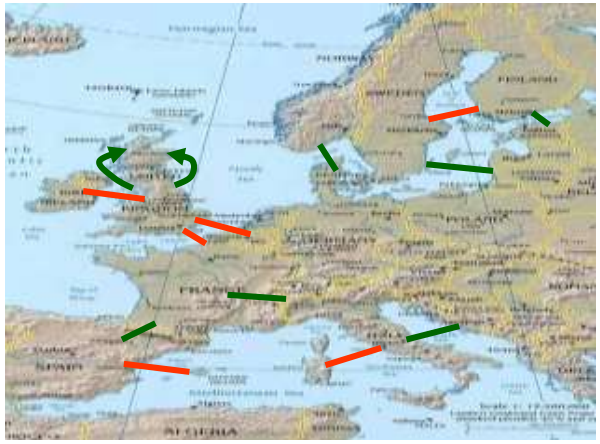
To provide effective spinning reserve, the energy storage system is maintained at a level of charge ready to respond to a generation or transmission outage.



HVDC or HVAC?



HVDC is a growing technology



- Connecting remote generation
- Offshore wind connections
- Interconnecting grids
- DC links in AC grids
- Power from shore

Source: www.abb.com

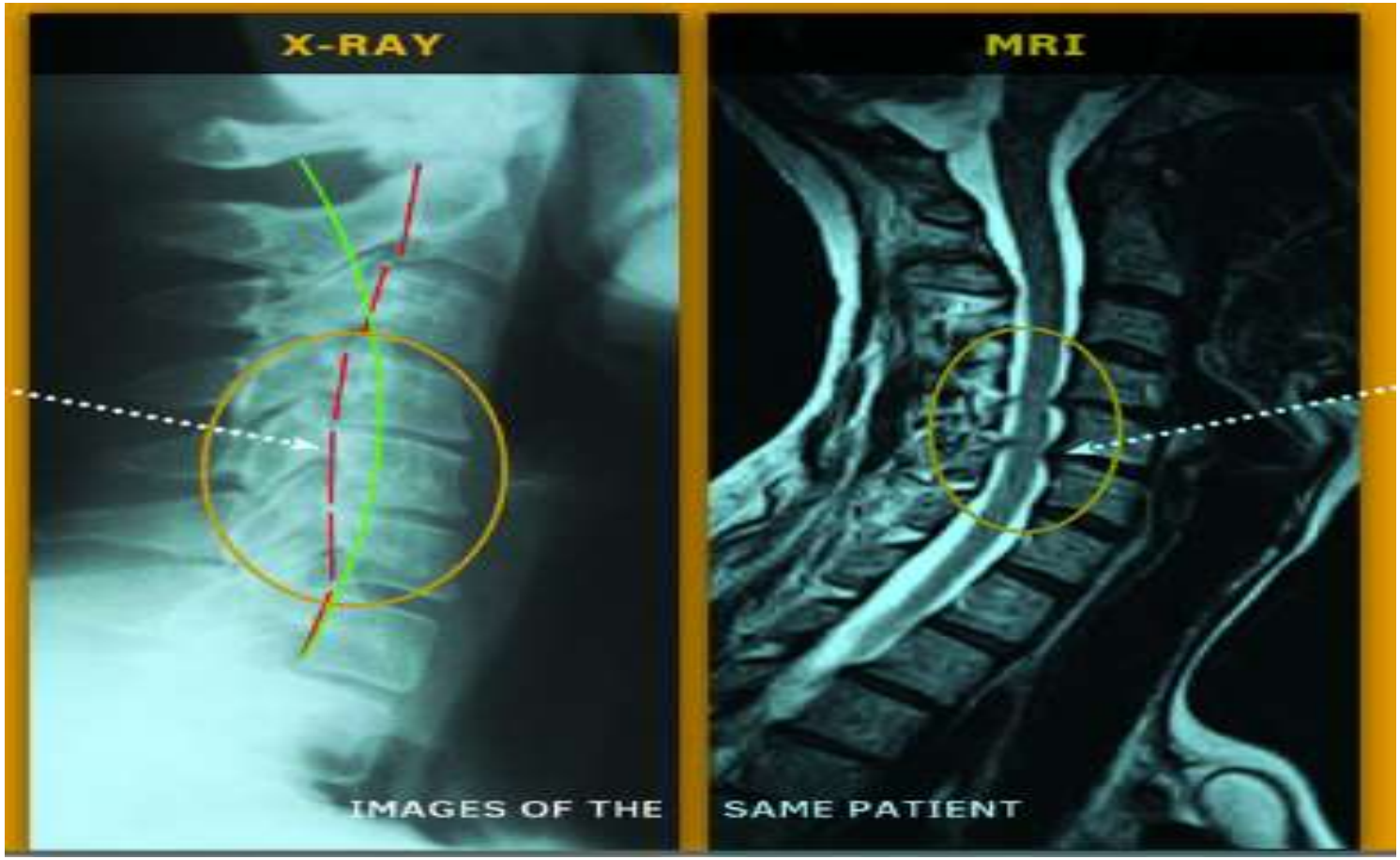
Largest HVDC Transformer

Link

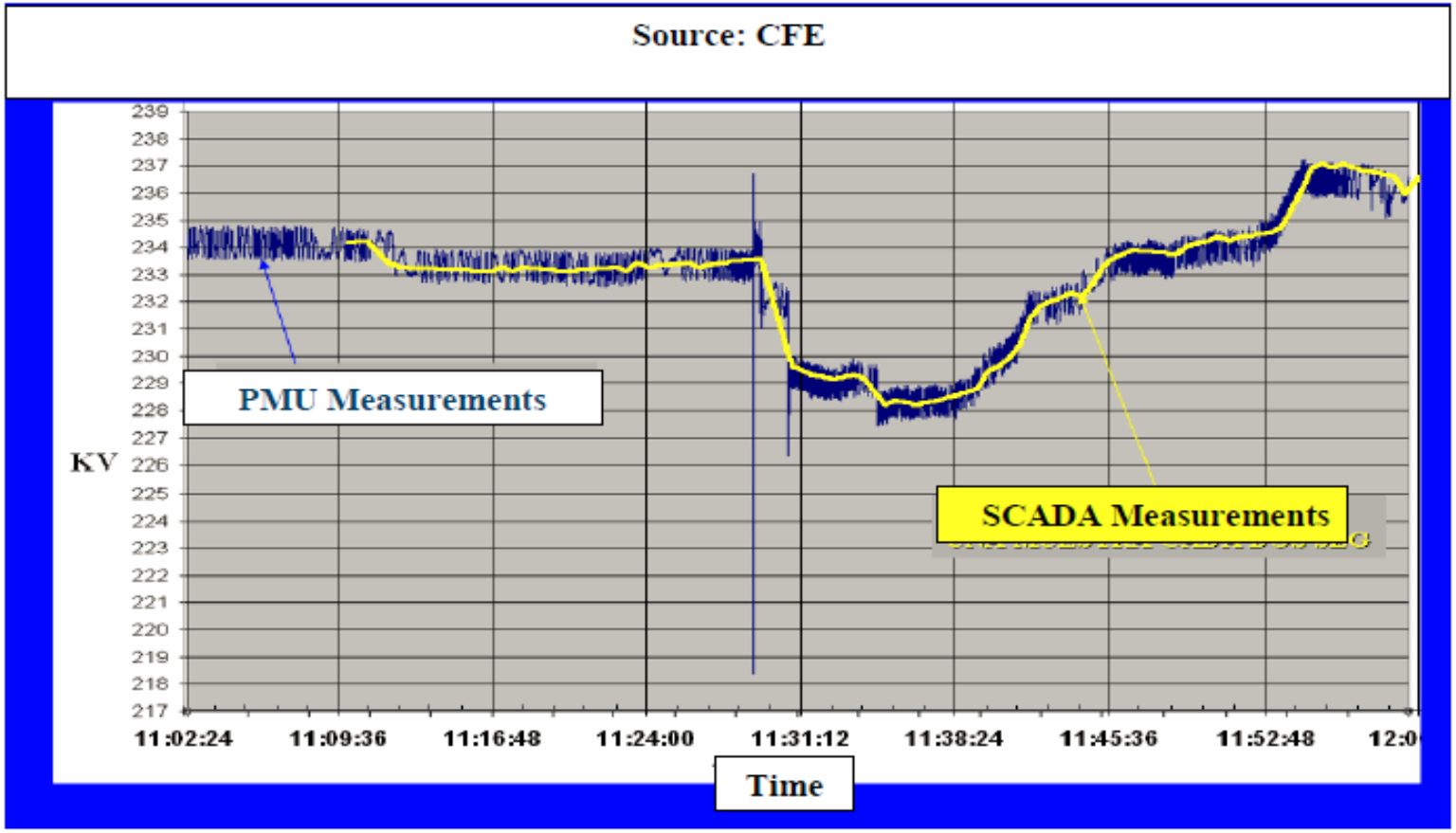
Major Blackouts

Article	People affected (M)	Location	Date
Northeast blackout of 1965	30	United States, Canada	9 Nov 1965
Southern Brazil blackout	97	Brazil	11 March 1999
India blackout	230	India	02 January 2001
Northeast blackout of 2003	55	United States, Canada	14–15 Aug 2003
Italy blackout	55	Italy, Switzerland, Austria, Slovenia, Croatia	28 Sep 2003
Java–Bali blackout	100	Indonesia	18 Aug 2005
Brazil and Paraguay blackout	87	Brazil, Paraguay	10-11 Nov 2009
India blackout	330	India	30 July 2012
India blackout	670	India	31 July 2012

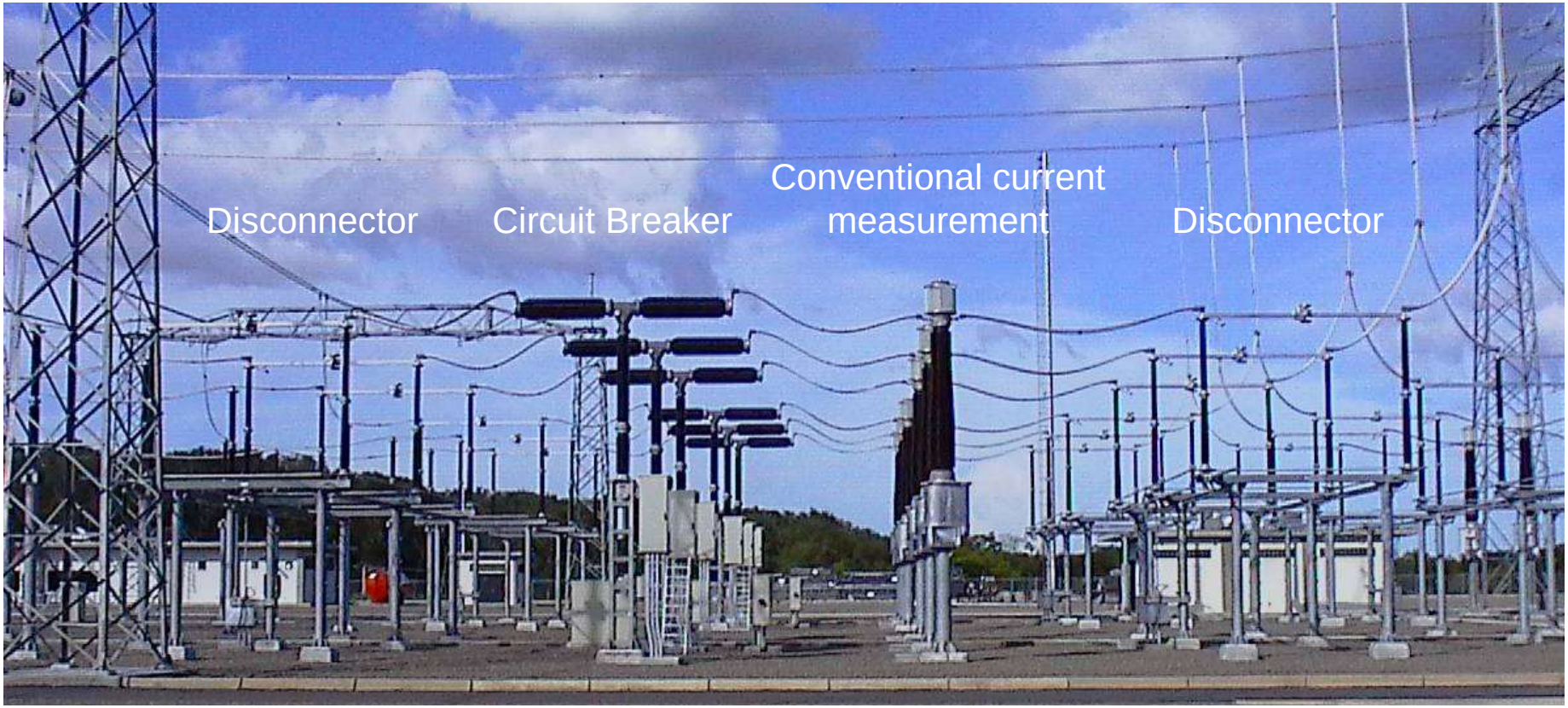
SCADA vs PMU



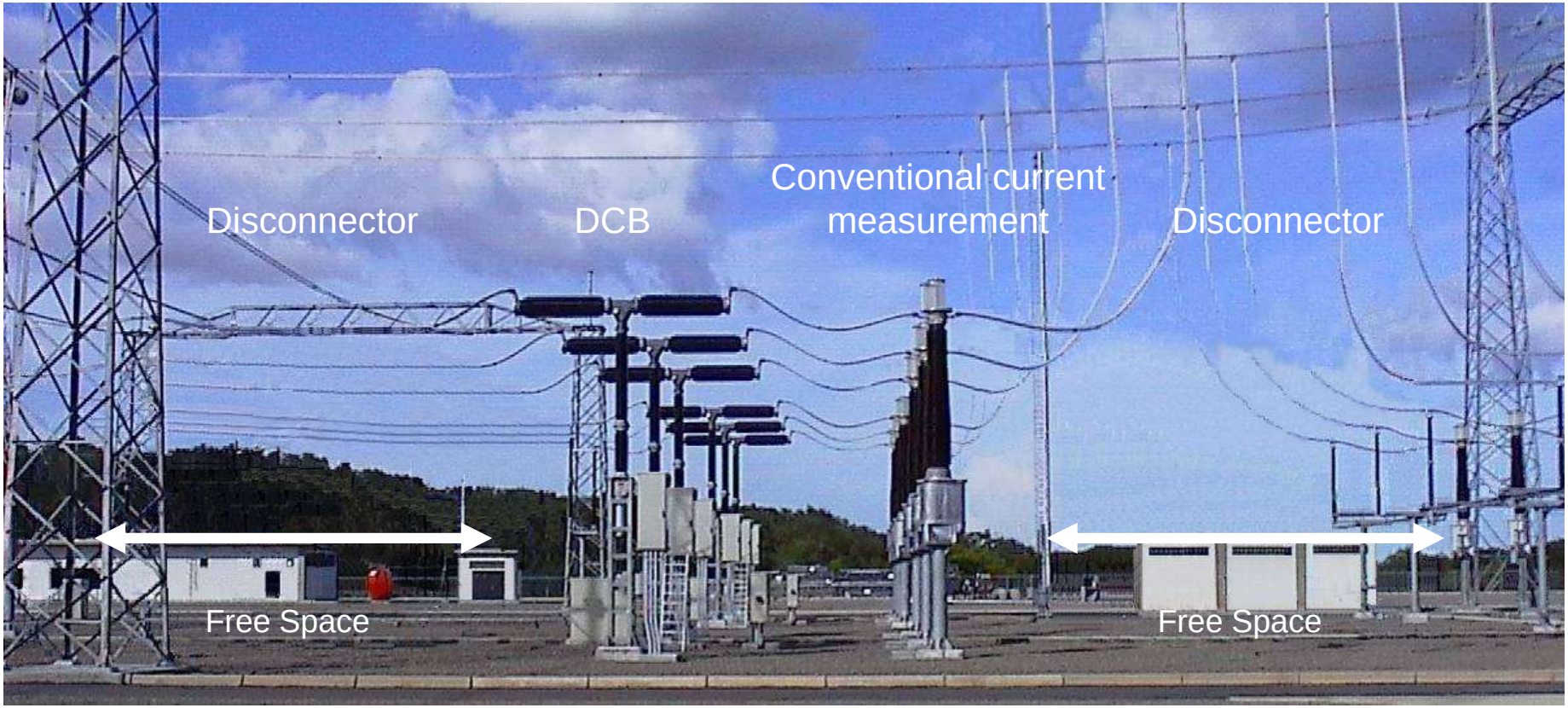
SCADA vs PMU



Saving space and money

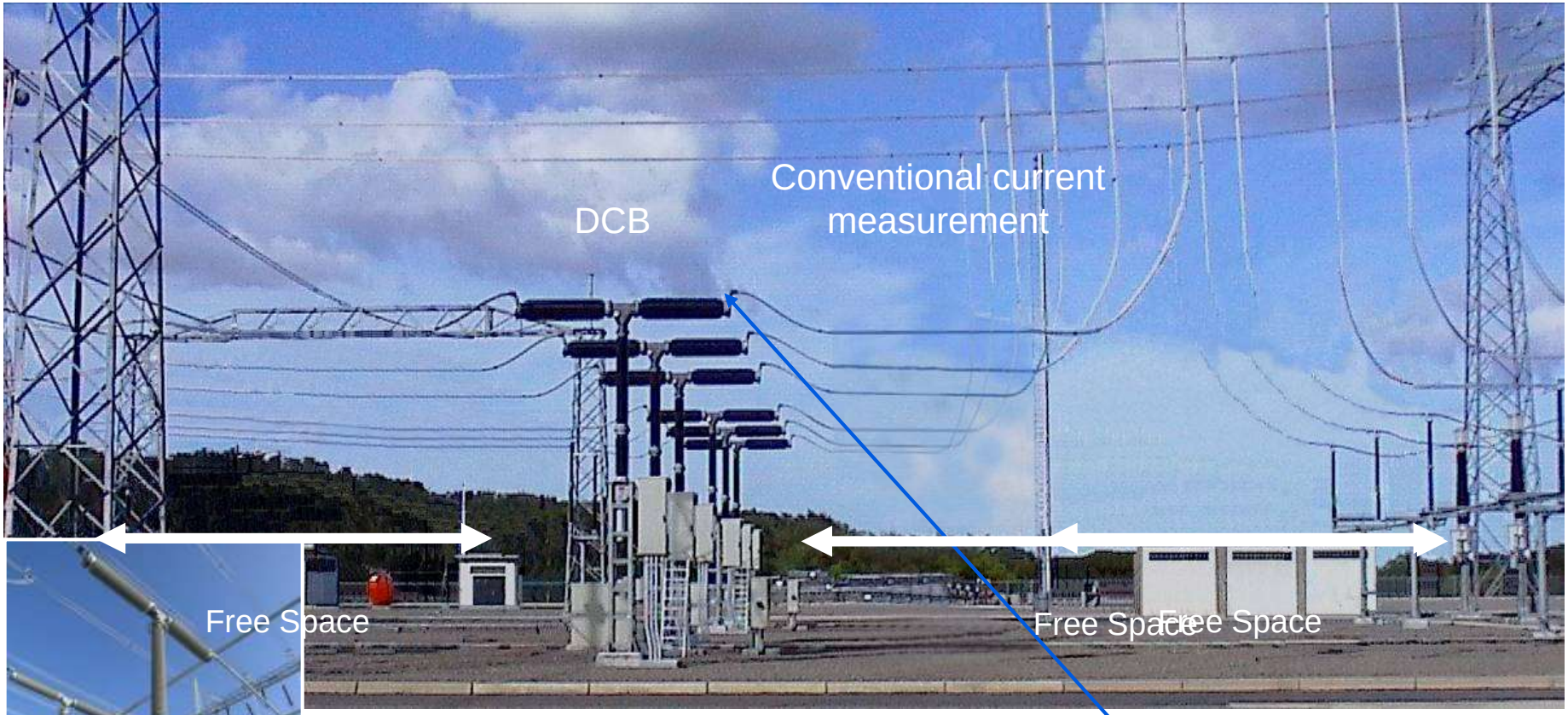


Saving space and money



Reduced Space!, Increased Availability!, Lowered Costs!

Saving space and money



Disconnecting Circuit Breaker

Digital Optical Current Transducer

DCB + FOCS

PASS – Example of space saving

AIS

H5
configuration

PASS

H5
configuration

Compact GIS Solution
Space Saving & Fast Deployment

Installing Compact GIS

Compact GIS

Underground substation
Space Saving

At traffic circles or under road crossings

Underneath parks or green space

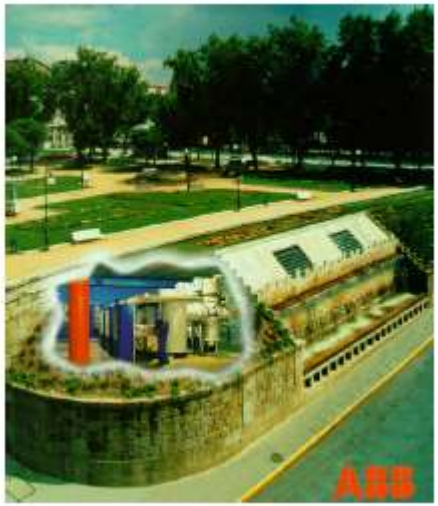
In a parking deck

Below a building or building complex

Into other public places (airports, sports complexes etc.)

→ The ABB underground concept is free to be integrated into any urban complex

GIS Substations



Co_2 - Circuit Breaker
Environmental Impact

The 145 kV pilot installation in Sweden has been working perfectly for the past two years.

Power and productivity
for a better world™