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VSC HVDC – A Powerful Stand-by Black Start Facility

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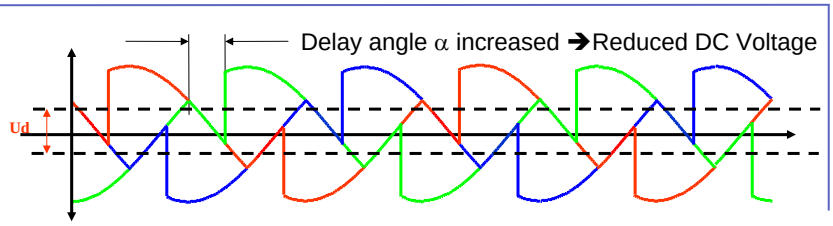
Summary

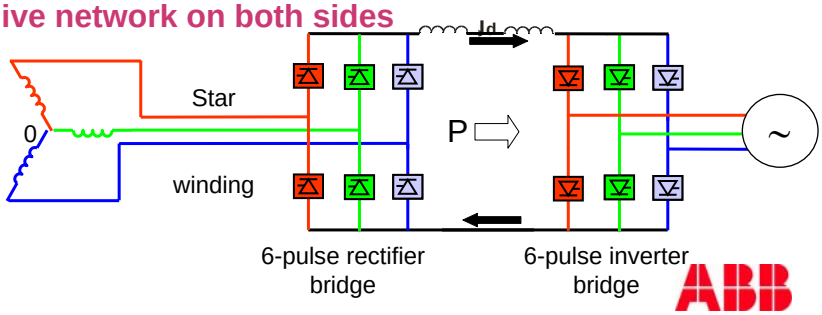
- Basic HVDC
- Estlink, a VSC HVDC link
- Black Start, a feature of Estlink
- Control modes
- Full-scale Black-start tests in Estonian grid
- Conclusions

Thyristor equipped HVDC system



Current source converters

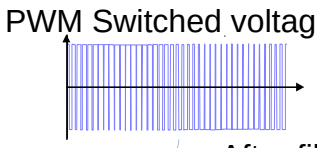
Need live network on both sides

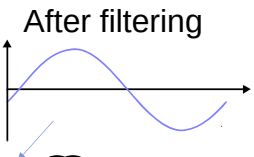


IGBT equipped HVDC system – VSC HVDC

HVDC Light® – Voltage Source Converter technology by ABB

- No AC network needed
- AC voltage is created from DC by PWM control
- DC voltage source is the DC capacitance





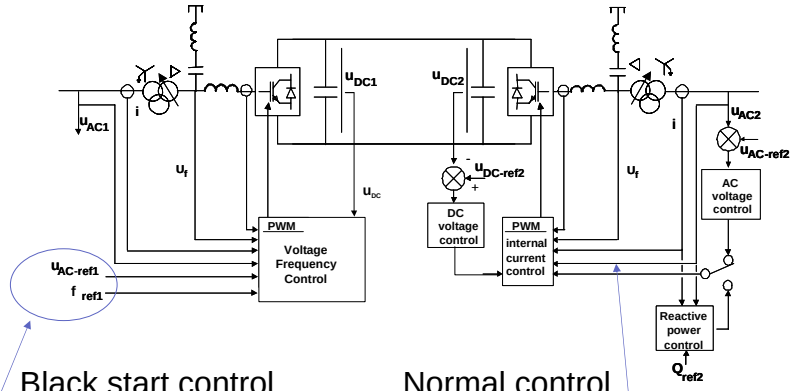
Estlink, a VSC HVDC transmission, …

- is a 350 MW HVDC Light® link crossing the Finnish gulf
- interconnects the national grids of Estonia and Finland
- has trading of electricity as main purpose
- can exchange a maximum of + or – 125 Mvars with each grid, independent of active power

Black Start of Estonian grid – an Estlink feature

- Estonian converter at Harku has a Black Start facility
- Purpose: provide fast auxiliary power to power plants after a black-out.
- Finnish grid and converter must be in operation
- Features
  - Key functions supported by batteries: control system, valve cooling pumps
  - Automatic or manual re-start after a blackout
  - Converter is self-supplied with auxiliary power from main transformer
  - Converter controls voltage amplitude, phase and frequency
  - Grid operator connects converter to grid, no automatic connections
  - Power transmission from/to other converter decided by load/generation
  - Soft, bumpless, return to normal power transmission mode after restoration

HVDC Light® control overview



Black start control

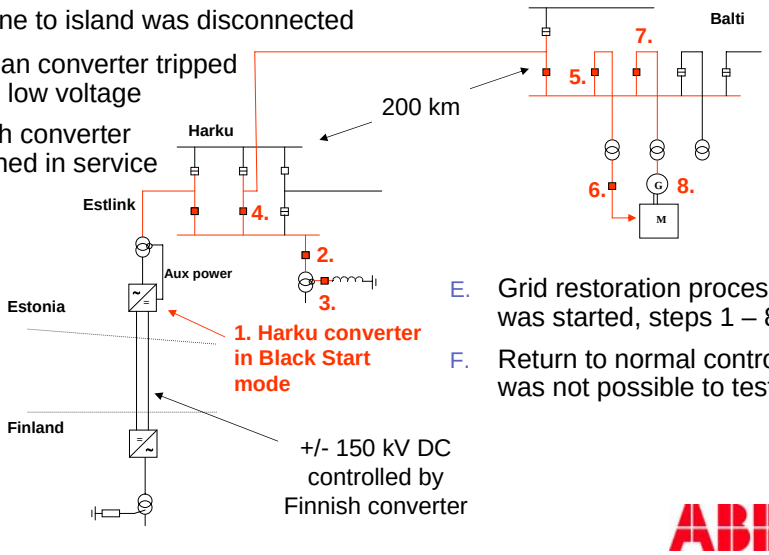
Internal, synthetic, AC voltage generator is reference for PWM switching

Normal control

Measured AC voltage is reference for PWM switching

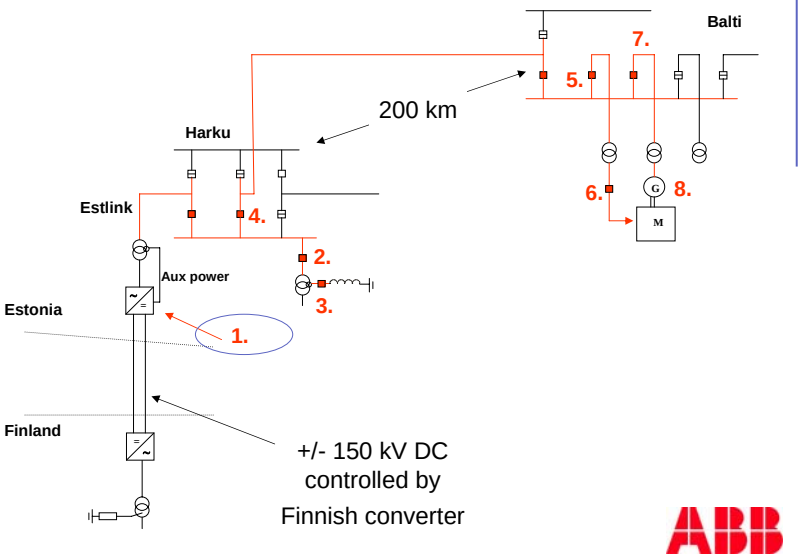
Black-start tests in Estonia 2007

A. Network island prepared by grid operator
B. Last line to island was disconnected
C. Estonian converter tripped due to low voltage
D. Finnish converter remained in service



E. Grid restoration process was started, steps 1 – 8
F. Return to normal control was not possible to test

Step 1. Starting up converter in Black-start mode



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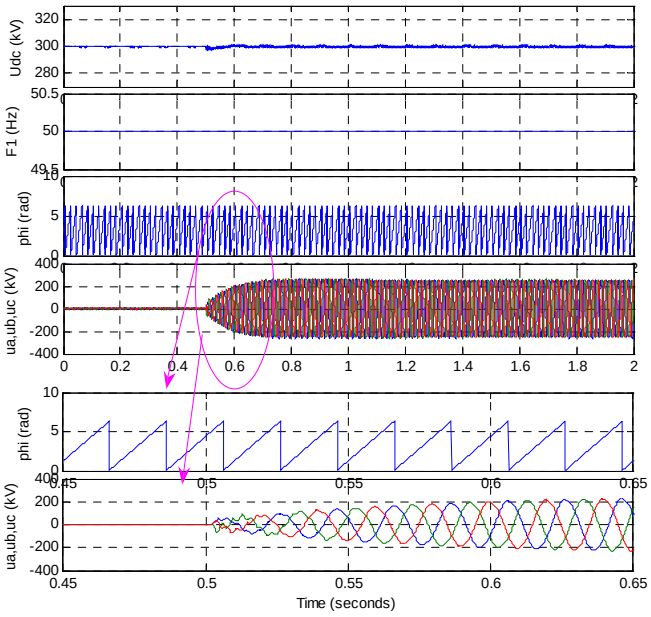
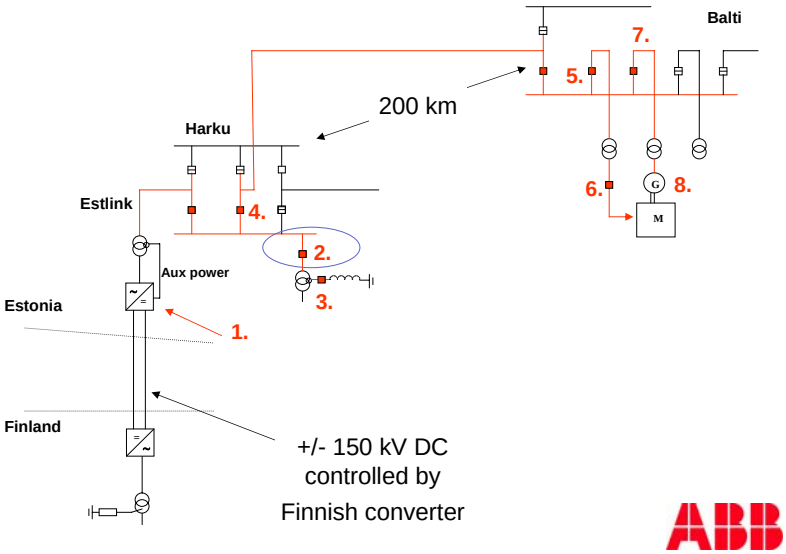


Step 2. Energizing a 250 MVA transformer



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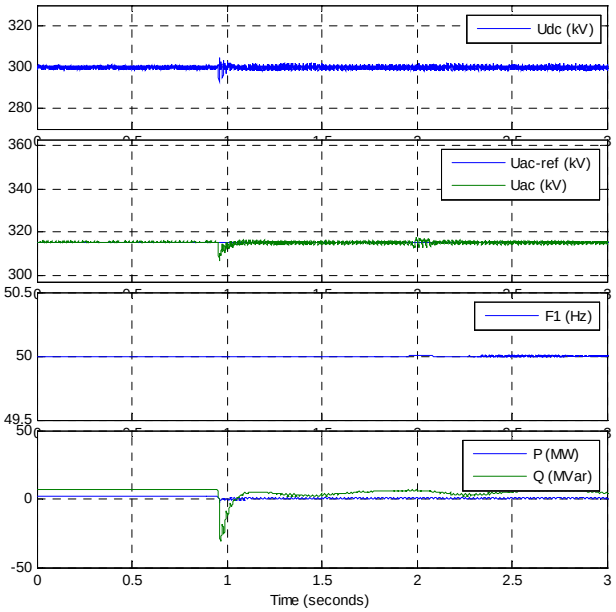
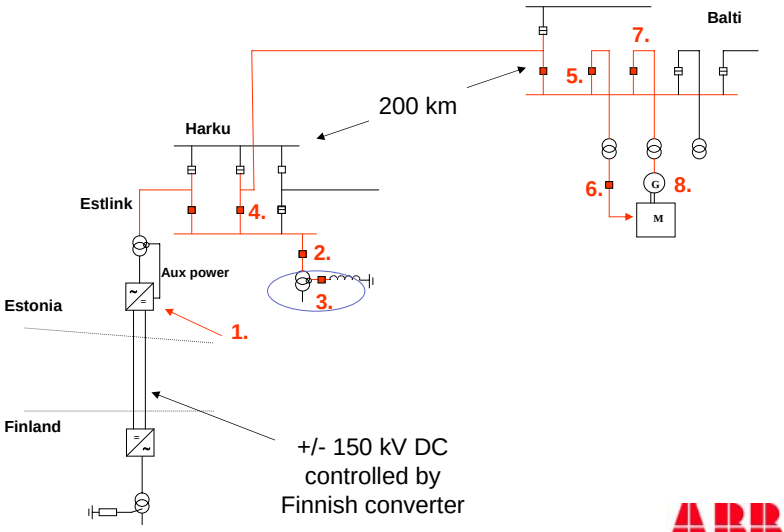


Step 3. Switching in a 50 Mvar shunt reactor



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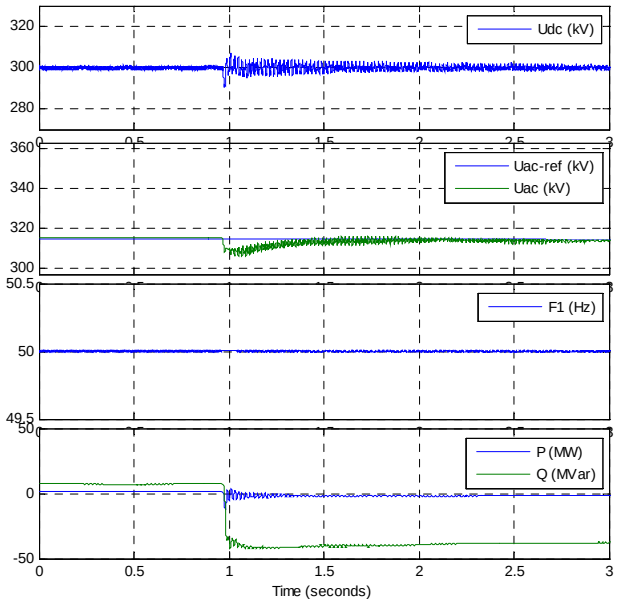
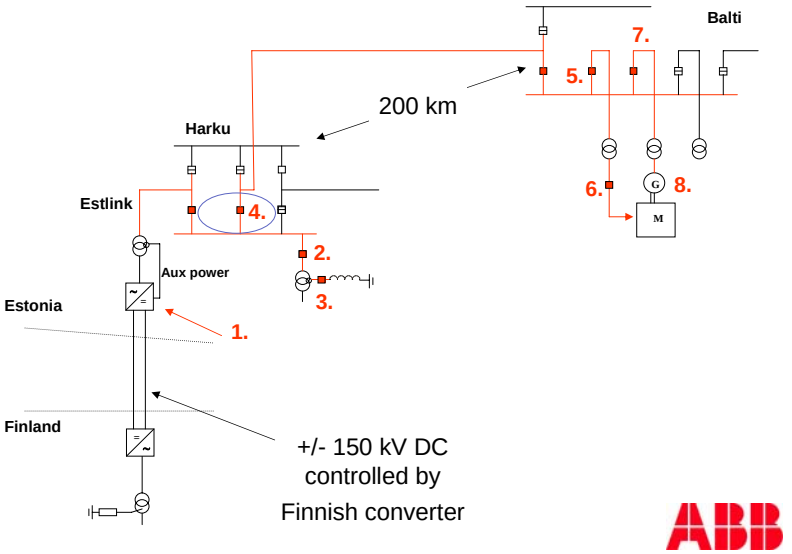


Step 4. Switching in a 330 kV line (200 km long)



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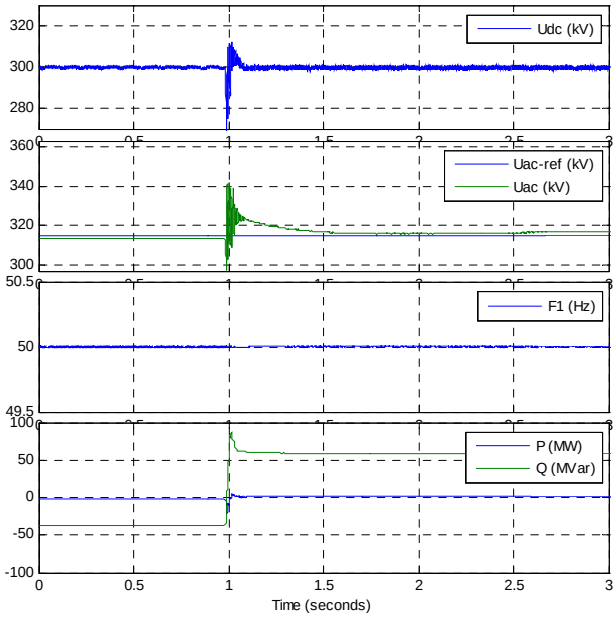
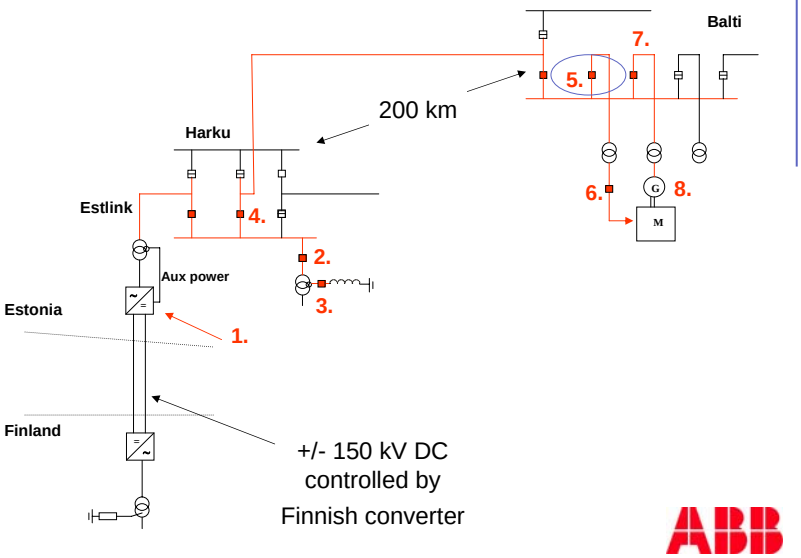


Step 5. Energizing a distant 25 MVA transformer



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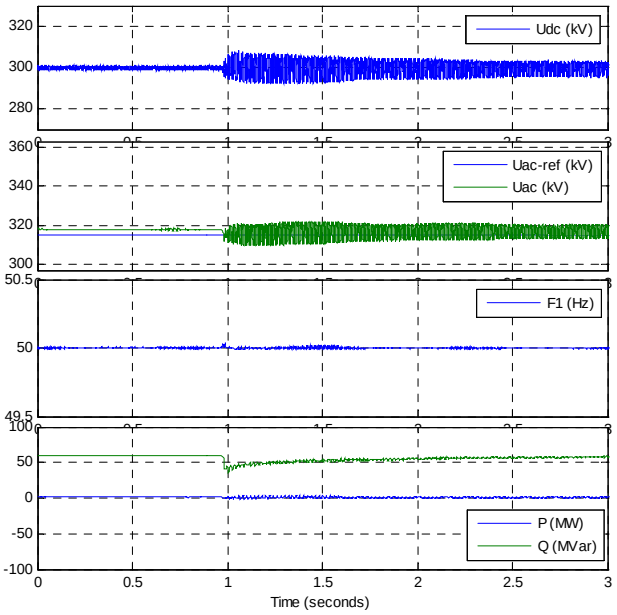
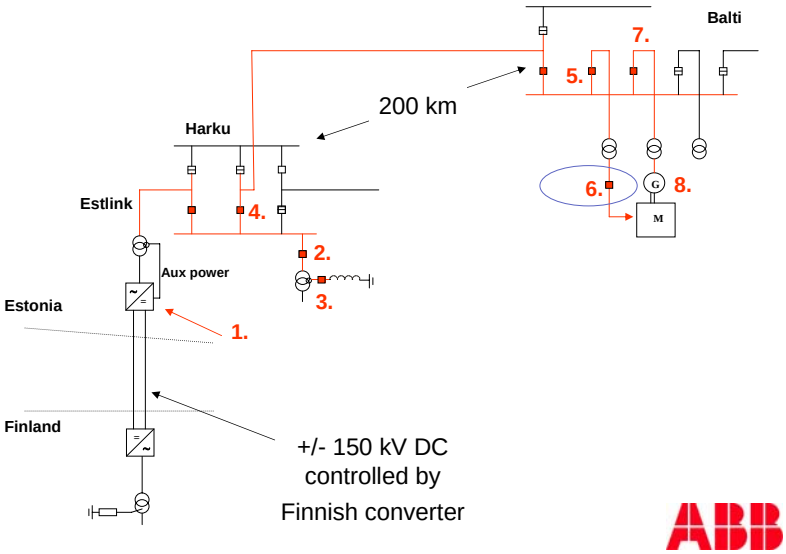


Step 6. Switching in a load of 10 MVA



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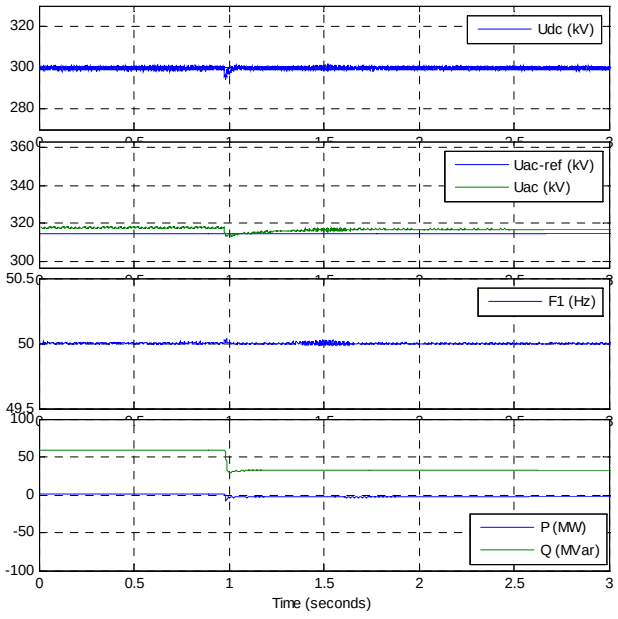
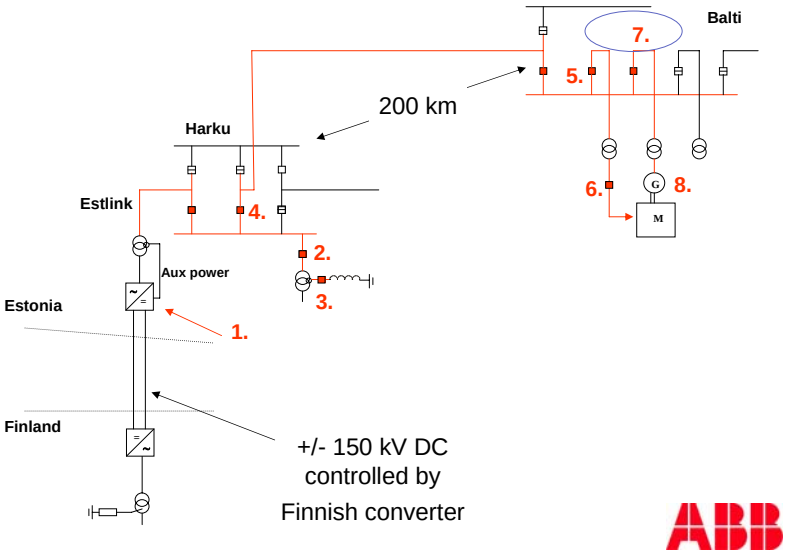


Step 7. Synchronized switching in a 250 MVA generator



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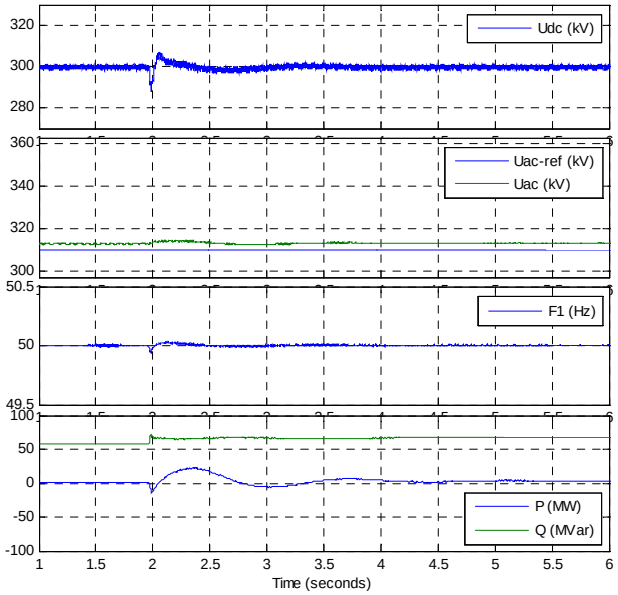
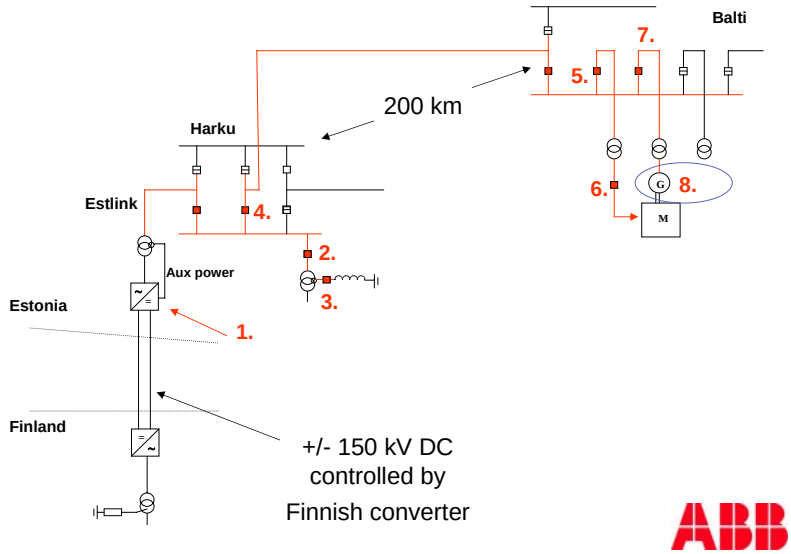


Step 8. Generator delivers active power



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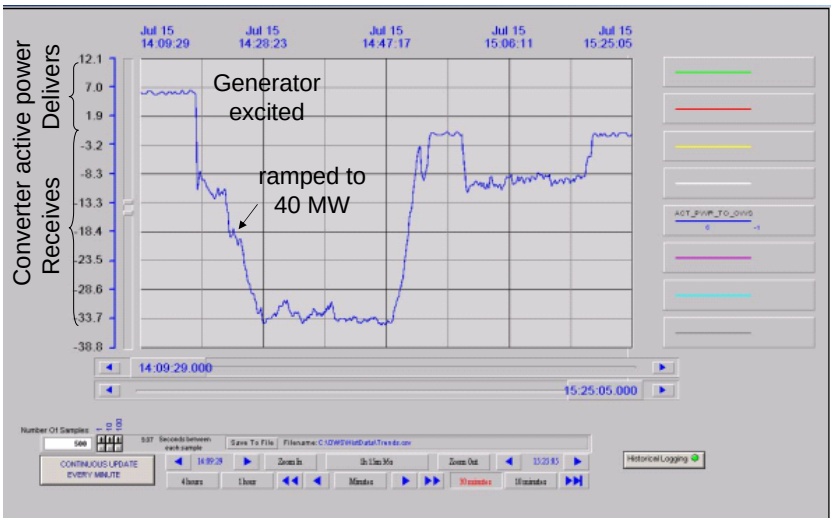

Trace shows active power at converter's grid connection point

Conclusions

- The tests performed have proven the VSC's
  - ability to absorb and generate power
  - fast voltage control capability when starting large motors and energizing long HV lines
  - capability to control the frequency
  - capability to co-operate with large generator

Advantages with using VSC for Black Start

- Reduced restoration time: A VSC is ready for re-connection as a generator in seconds after a black-out
- More safe and smooth restoration process due to fast AC voltage control
- Less need to balance generation and load during restoration: a VSC link can supply or consume active power up to its ratings
- Less investment in machines and starting motors for emergency situations
- Soft energization of load possible, reduces inrush currents


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