



Jonatan Danielsson, Lead Engineer, CIGRE-IEC 2016 2nd International Colloquium on EHV and UHV, Montreal, May 9-11 2016

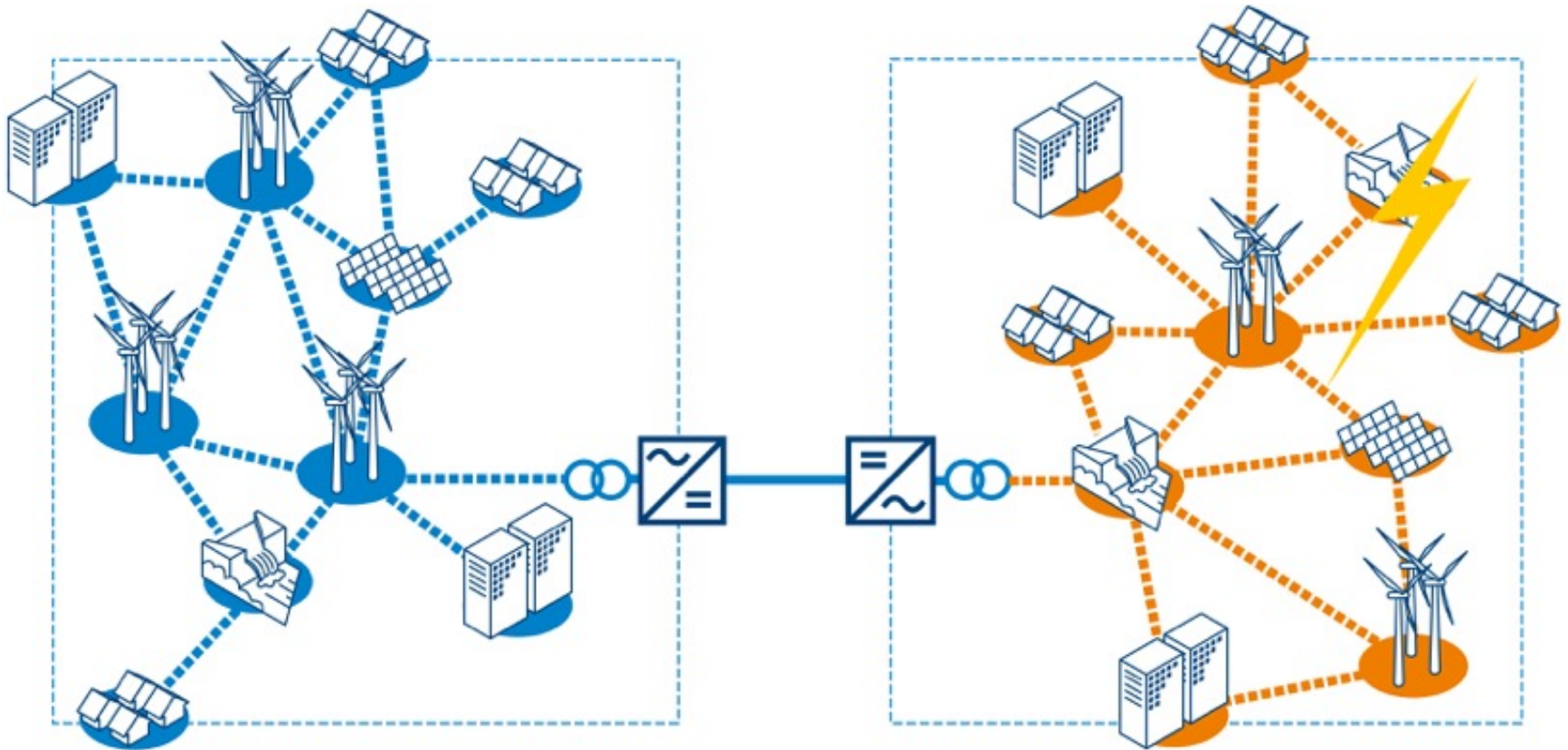
CIGRE-059 HVDC Black start Feature and its application

J Danielsson, P Hjalmarsson, J Karlsson

Outline

- Introduction
- HVDC controls
- Field testing
- Conclusions

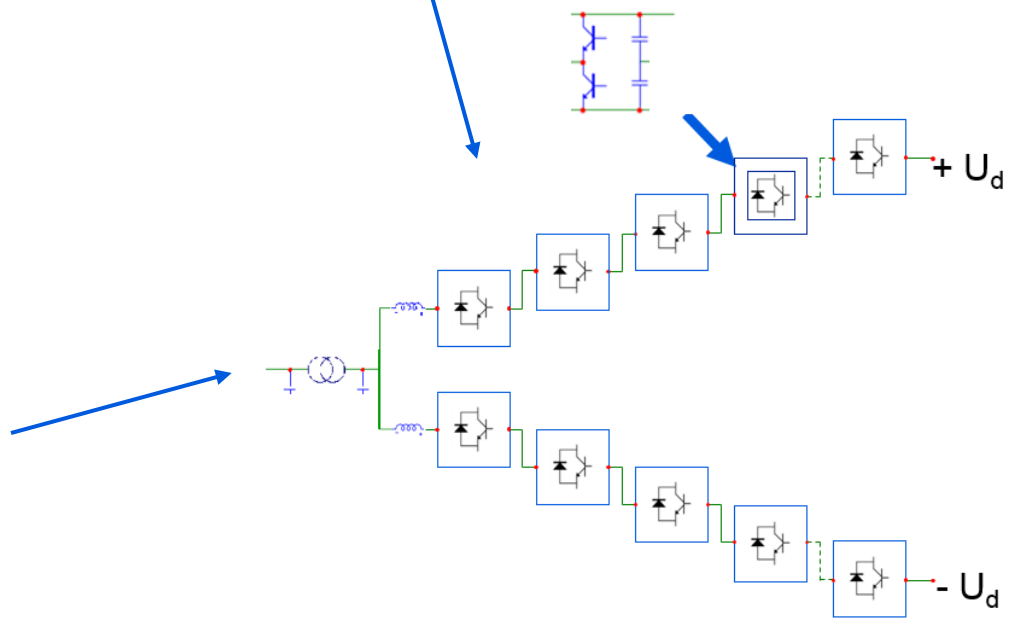
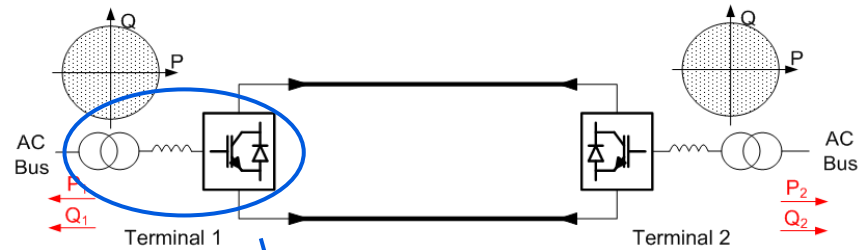
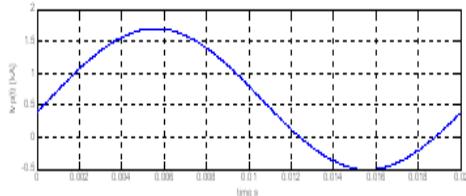
HVDC Black start Introduction



HVDC Black start HVDC controls

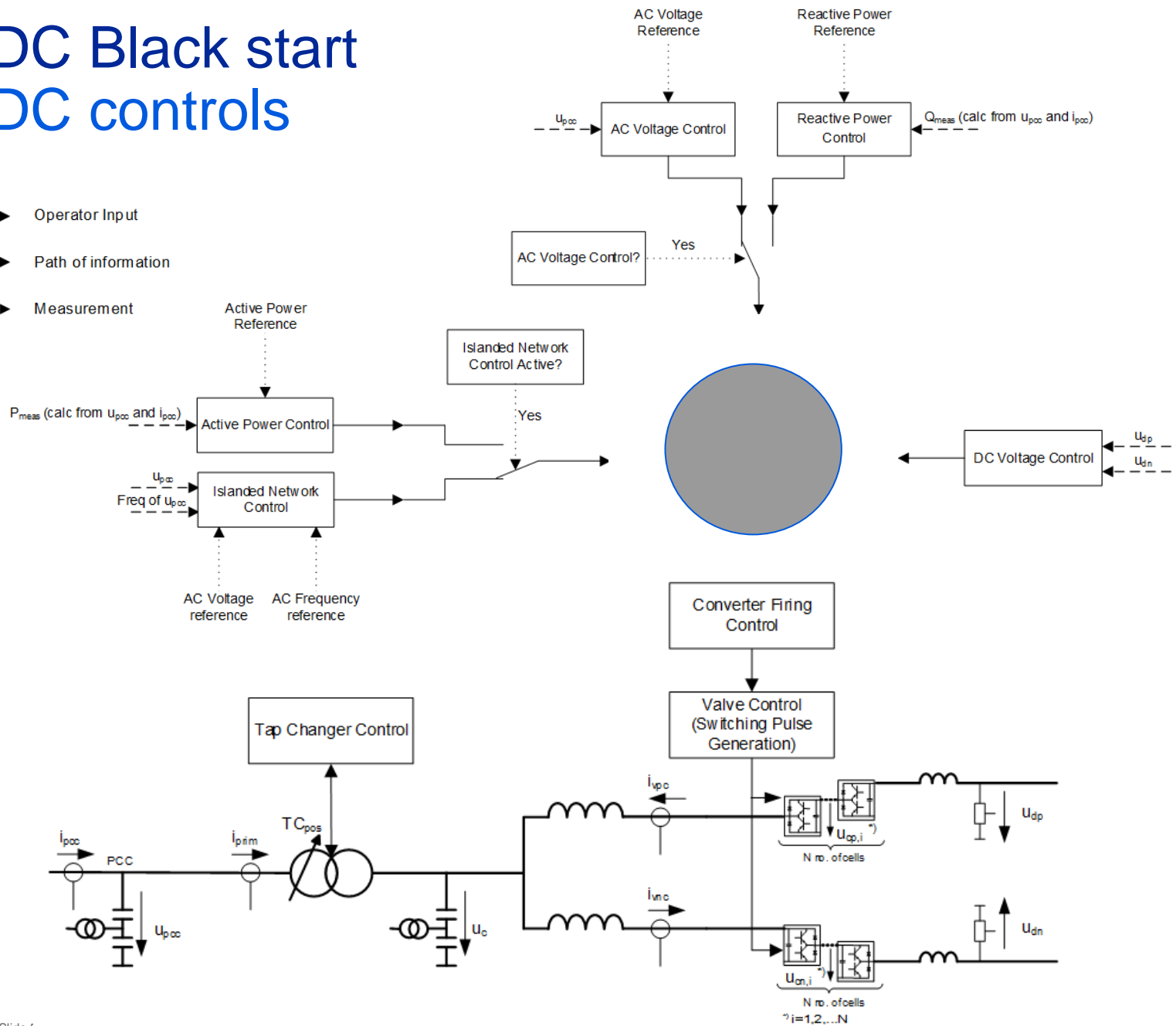
VSC (Voltage Source Converter)

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



HVDC Black start HVDC controls

-▶ Operator Input
- ▶ Path of information
- - - -▶ Measurement



HVDC Black start

Black start sequence

- Supporting station must be in operation
 - The DC system will be energized from the supporting station, which will be in DC voltage control mode
- A local power supply to support essentials loads is available at the converter in the blacked out network
- Islanded network control mode activated
- When DC side is charged the converter connected to the passive network is deblocked and the AC voltage is ramped up normal AC system voltage
- The converter operates as a stiff voltage source and will control the AC voltage amplitude, phase and frequency
- The AC network can now be restored according to a predefined AC network restoration plan

HVDC Black start Field testing ÅL-link

ÅL-link main data

Commissioning year	2015
HVDC technology	Voltage source converter
Power rating	100 MW
AC voltage	110 kV
DC voltage	± 80 kV
Length of submarine cable	158 km
Main reason for choosing HVDC	Length of sea crossing, asynchronous networks, reliable backup power, black start



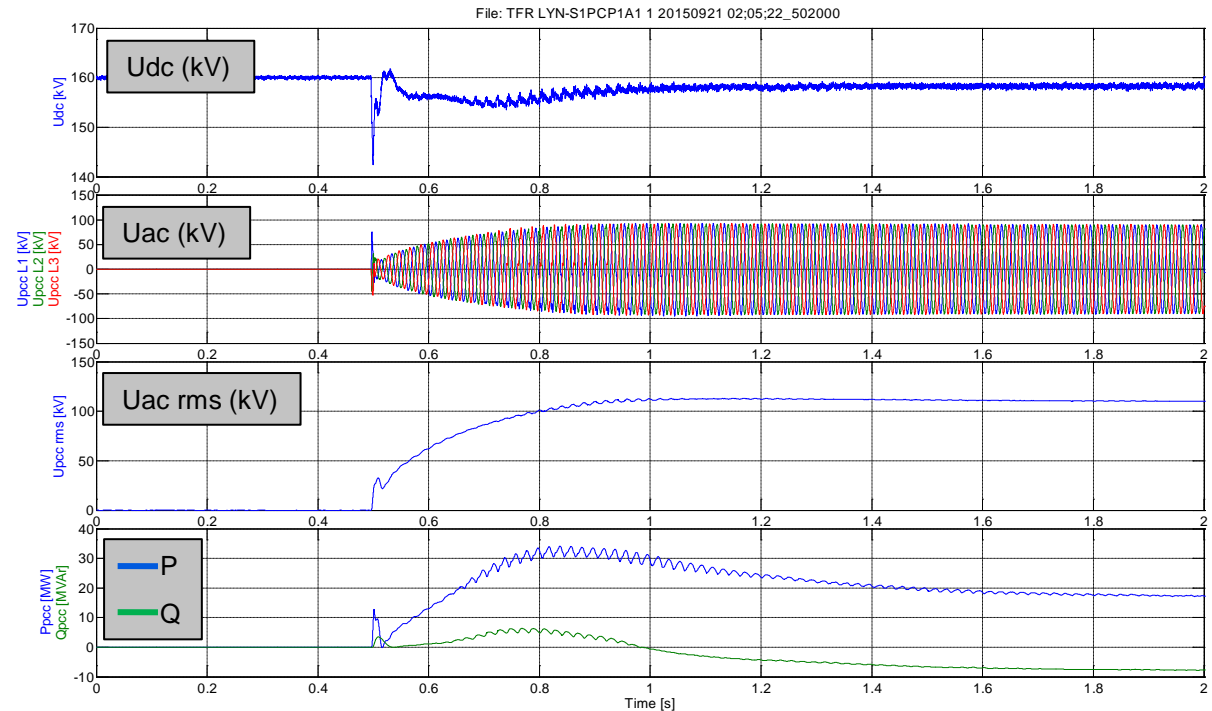
HVDC Black start Field testing ÅL-link – Black start test

Preconditions

- Converter on Åland de-energized
- DC cables energized
- Swedish AC cable connected

Black start test

- AC cable to Sweden disconnected
- Converter station diesel generator started to supply the station with necessary auxiliary power
- DC cables connected to energize the Åland converter
- Converter station AC breaker closed
- Deblock converter station to restore AC voltage
- Converter station diesel generator is switched off.



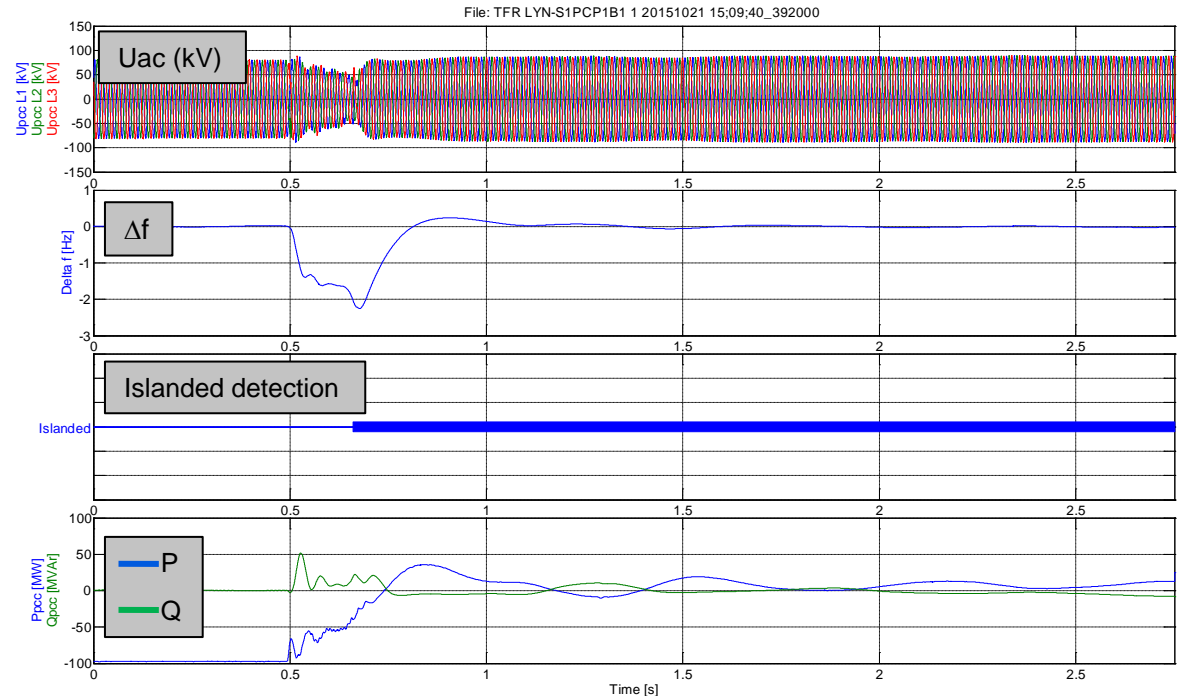
HVDC Black start Field testing ÅL-link – Islanded test

Preconditions

- AC and DC cables in service
- 90 MW export to Finland through the HVDC
- 80 MW import to Åland through the AC cable to Sweden
- Local generation on Åland to supply local loads and fulfill the export to Finland

Islanded test

- Local gas turbine tripped
- AC cable from Sweden was disconnected because of overload
- Åland is now islanded and attempting to export 90 MW to Finland
- The HVDC detects the island and switch to islanded operation preventing a blackout on Åland



Conclusions

A VCS HVDC link can:

- be started in a completely dead network
- control AC voltage amplitude, phase and frequency
- assist during the continued network restoration process with its dynamic voltage support, controllability, and ability to connect asynchronously to adjacent grids or to connect a smaller island with a larger system
- greatly reduce the time to restore the AC system network

Power and productivity
for a better world™

