Simulations and Tests of a Danish Smartgrid – The Cell Controller Pilot Project

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In Cooperation with
DEVELOPMENT IN THE DANISH POWER SYSTEM

Source: Energinet.dk
• Increased security of supply
• Sufficient domestic resources must be available to maintain a balance between demand and generation
• Improved operator knowledge of actual system conditions both locally and centrally
• Efficient system control particularly during emergencies
• Active usage of distributed generators
• Black starting capabilities using distributed generators
• Organising distributed generators into controllable Virtual Power Plants
THE CELL CONTROLLER
PILOT CELL: HOLSTED 60 KV GRID AREA

- Installed CHP: 37 MW
- Installed Wind: 39 MW
- Max Load: 61 MW
- 150/60 kV Trafo: 100 MVA
CELL CONTROLLER CONCEPT

• Each Cell can be regarded as a Virtual Generator with same or better controllability compared to a traditional power station unit of equal size
• Local distribution companies attain strongly increased possibilities of distribution network on-line monitoring and active control
• Automatic Cell transition to controlled island operation in case of imminent transmission system break-down
• Black-start of transmission system
• Robust Cell Controller Concept designed to encompass all new types of DG units and controller functionalities

➔ Increase in security of supply
➔ Any new functionality as pure software development
➔ Re-design for the future Danish electric power system
LEVEL OF FUNCTIONALITY OF THE CELL CONTROLLER

- Monitoring total load and production within the Cell
- Active power control of synchronous generators
- Active power control of wind farms and large wind turbines
- Reactive power control by utilising capacitor banks of wind turbines and grid
- Voltage control by activating AVR's on synchronous generators
- Frequency control by activating SGSs on synchronous generators
- Capability of operating 60 kV breaker on 150/60 kV transformer
- Capability of operating breakers of wind turbines and load feeders
- Automatic fast islanding of entire 60 kV Cell in case of severe grid fault
- Automatic fast generator- or load shedding in case of power imbalance
- Voltage, frequency and power control of islanded Cell
- Synchronising Cell back to parallel operation with the transmission grid
- Black-starting support to transmission grid in case of black-out
CHPS IN TEST AREA 1

Billund: 3x 3.6 MVA

Hejnsvig: 2x 1.3 MVA
WINDTURBINES IN TEST AREA 1

4x 1000 kW Windturbine
NEG Micon NM60/1000

Monitoring
SYNCHRONOUS CONDENSER AND DUMP LOAD (SLC)

800 kVA synchronous condenser for voltage control

1000 kW dump load for frequency control
SIMULATION: ISLAND OPERATION WITH WINDTURBINES

- Islanding
- Resynchronisation
- Active Power
- Reactive Power
- Frequency Dip
- Frequency
SIMULATION: DUMP LOAD (SLC)
SIMULATION: WINDTURBINE

Active Power

Reactive Power

Switching of capacitor bank
SIMULATION: SYNCHRONOUS CONDENSER

Active Power

Reactive Power

Switching of capacitor bank

Frequency

Voltage
MEASUREMENT RESULTS

Mini Island

- 60 kV
- 10 kV
- 0.4 kV

Cell Controller

Hejnsvig

Billund

KT21

KT22

KT21

GRØ

KVV

MØL

CEN

SØK

VOB

AGB

BID

HEJ

GEN1

HEJ

GEN2

HEJ

SC

HEJ

SLC

HEJ

WT1

HEJ

WT2

HEJ

WT3

HEJ

WT4

BID

GEN1

BID

GEN2

BID

GEN3

KLN

GLB

FUG

CHP

TRØ

MEASUREMENT RESULTS

16
MEASUREMENT TEST 1: „MINI ISLAND“
FREQUENCY
MEASUREMENT TEST 1: „MINI ISLAND“
VOLTAGE
At time of island, cell generation (which includes over 1 MW of wind power) exceeds load by 470 kW.

Frequency increases immediately, but SLC and CHP governors react to compensate.

During island, cell frequency fluctuates as wind generation varies from 800 to 1350 kW. Cell Controller reacts and maintains cell within all grid code given boundaries.

Cell reconnected to grid.
Once a reconnection to the grid is requested, the Cell Controller brings cell frequency and voltage phase within range of grid values. The Master Synchronizer reconnects only when cell frequency and voltage phase are sufficiently close to the grid values.
MEASUREMENT TEST 3: IMPORT/EXPORT CONTROL
MEASUREMENT TEST 3: IMPORT/EXPORT CONTROL

Billund CHP

Setpoint

Actual value

Hejnsvig CHP

1 hour
ACHIEVED TEST RESULTS

✓ Grid connected import/export control (virtual generator operation)
✓ Emergency transfer to sustained hybrid island operation
✓ Islanded wind only operation with SC and SLC
A utility scale smart grid concept has been successfully demonstrated.

Lessons learned from the project:

• By adding ICT to the system a higher security of supply can be achieved, however it also adds new sources of failure.

• Modelling and simulations are powerful tools to test new control strategies before going into the field. In case of island operation dynamic simulations are necessary!
THANK YOU FOR YOUR ATTENTION!