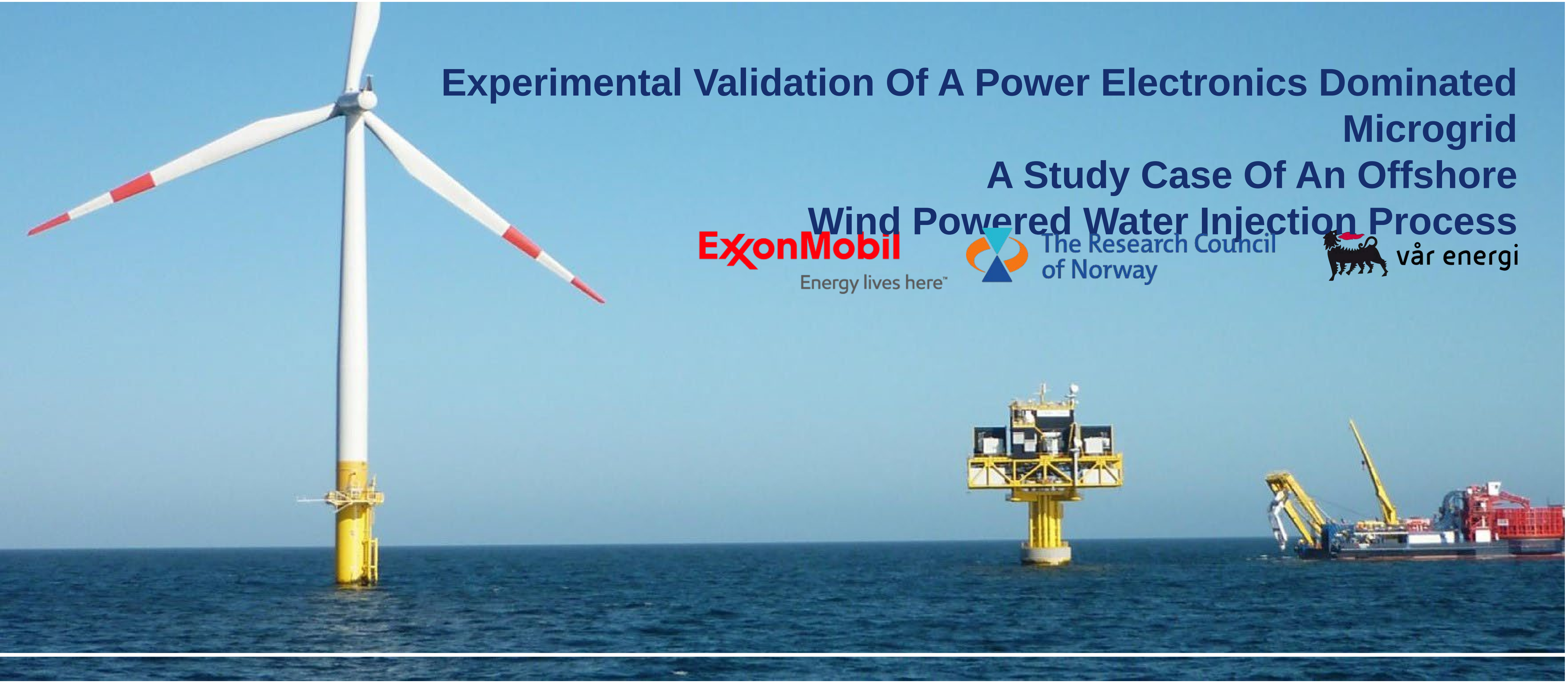
Experimental Validation Of A Power Electronics Dominated Microgrid
A Study Case Of An Offshore Wind Powered Water Injection Process



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- Experimental Setup
- Results
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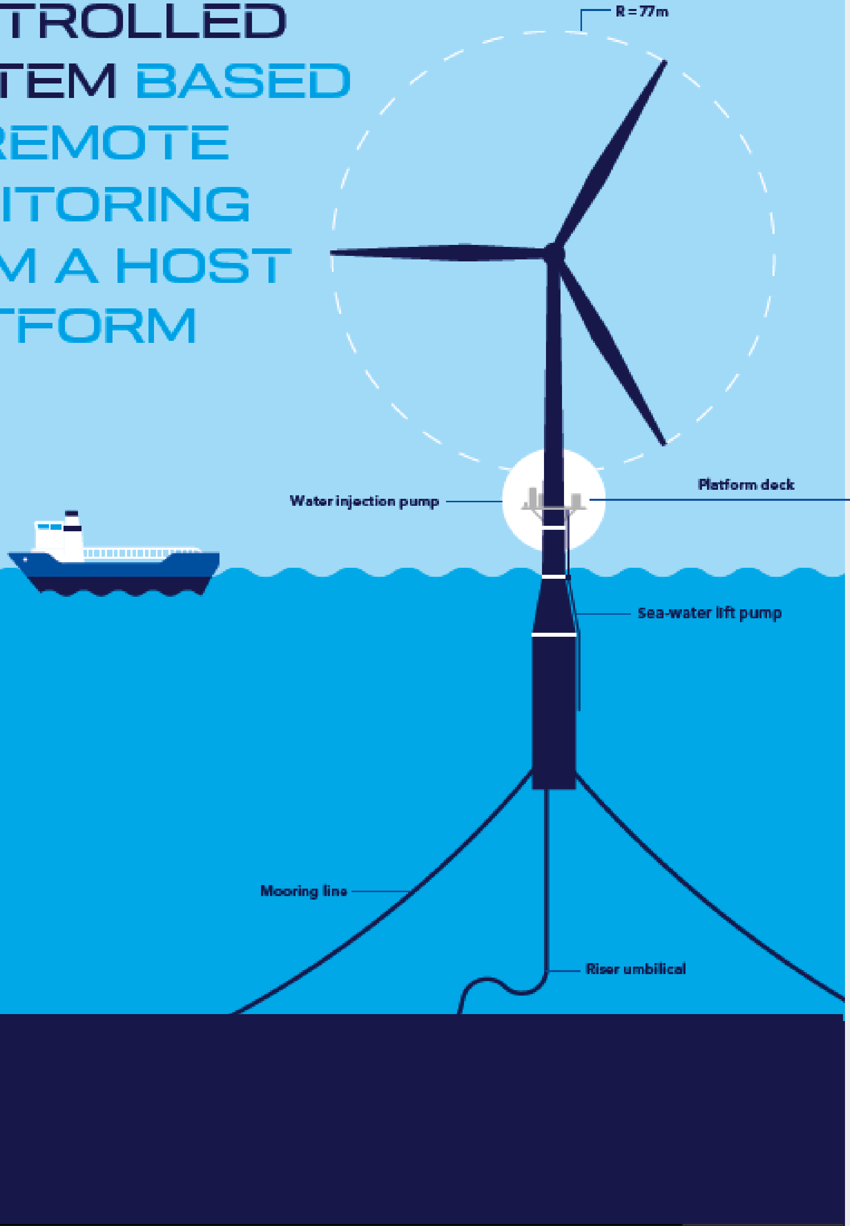
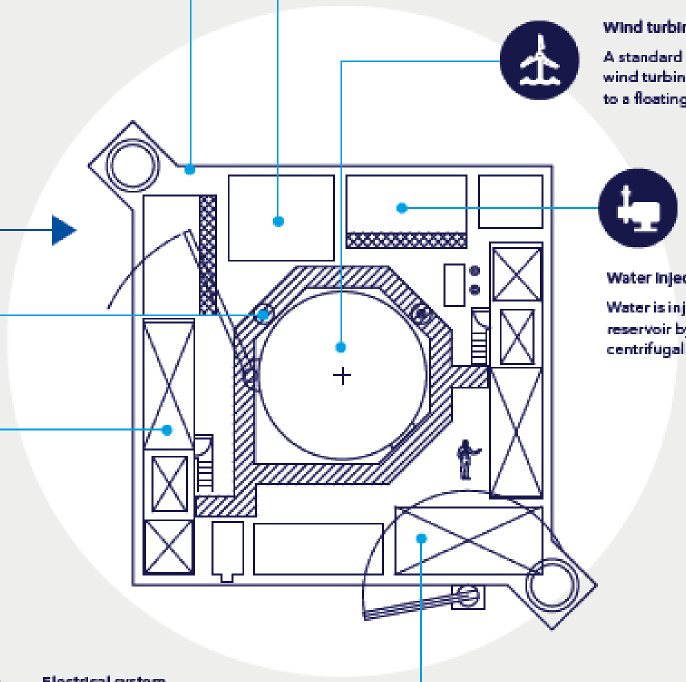
WIN WIN
WIND-POWERED
WATER INJECTION
Technically Feasible
Reduces Emissions
Flexible for Relocation
Meets Performance Targets
Cost-Competitive for Various Sites

WIN WIN – AN AUTONOMOUSLY CONTROLLED SYSTEM BASED ON REMOTE MONITORING FROM A HOST PLATFORM





Platform deck

A deck for process and electrical equipment is mounted to the floating foundation. The area is estimated to approximately 20 x 20 m. There are dedicated gangway landing areas for personnel access from service vessel.

Water treatment package

The seawater is screened using course strainers and treated with scale inhibitors and biocide. Biofouling is controlled by a hypochlorite generator package. Scale inhibitor and biocide storage tanks are stored on the platform, and refilled during maintenance activities.

Sea-water lift pump

The system uses sea water, which is pumped to the topside using submerged centrifugal lift pumps.

Wind turbine

A standard offshore wind turbine is mounted to a floating foundation.

Water injection pumps

Water is injected into the reservoir by multi-stage centrifugal injection pumps.

Electrical system

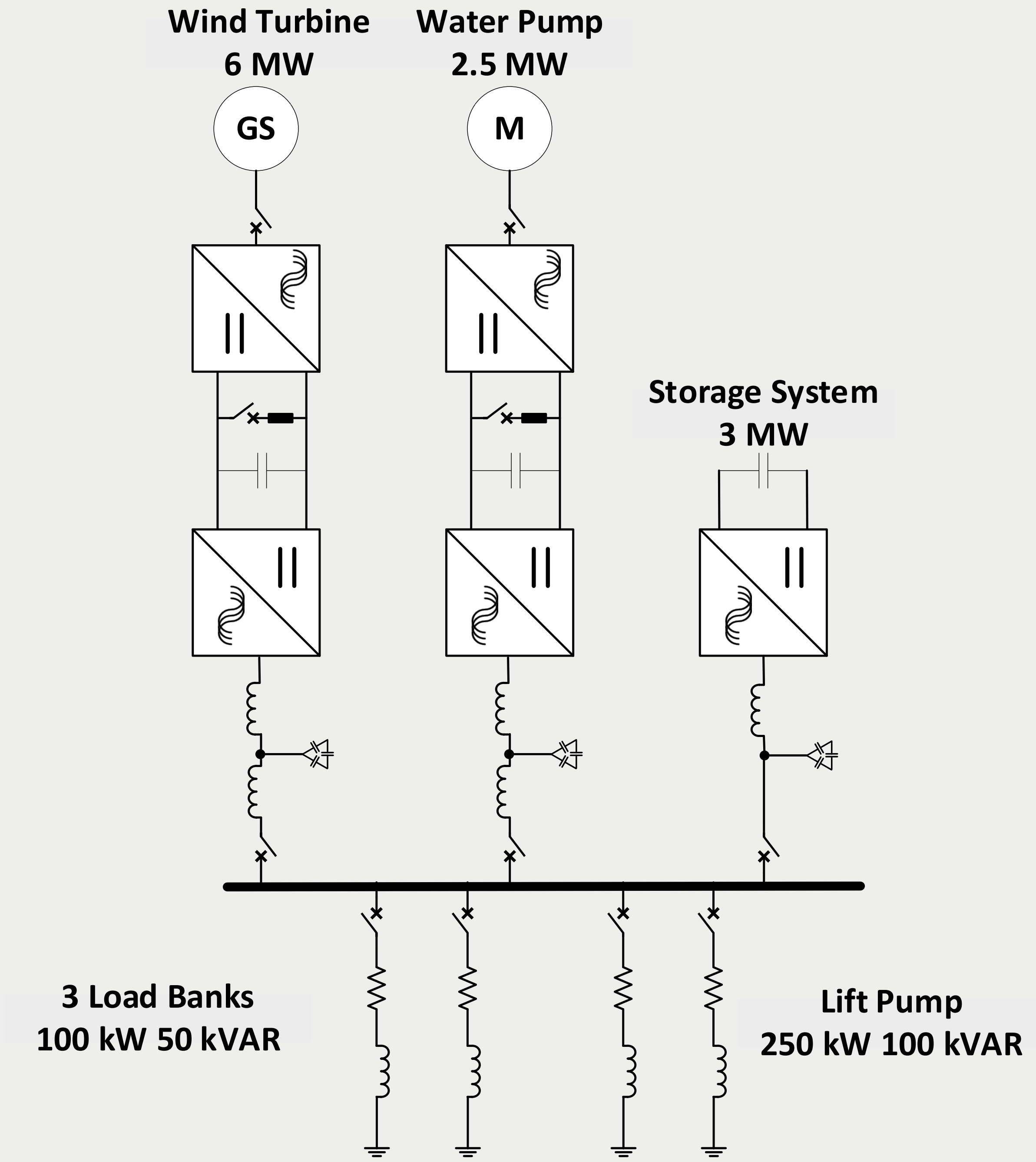
An electrical microgrid enables controlled start-up and shut-down of the system, and ensures that power demand matches power supply during operation. A battery bank ensures power to critical safety and communication functions during periods of no wind.

Communication

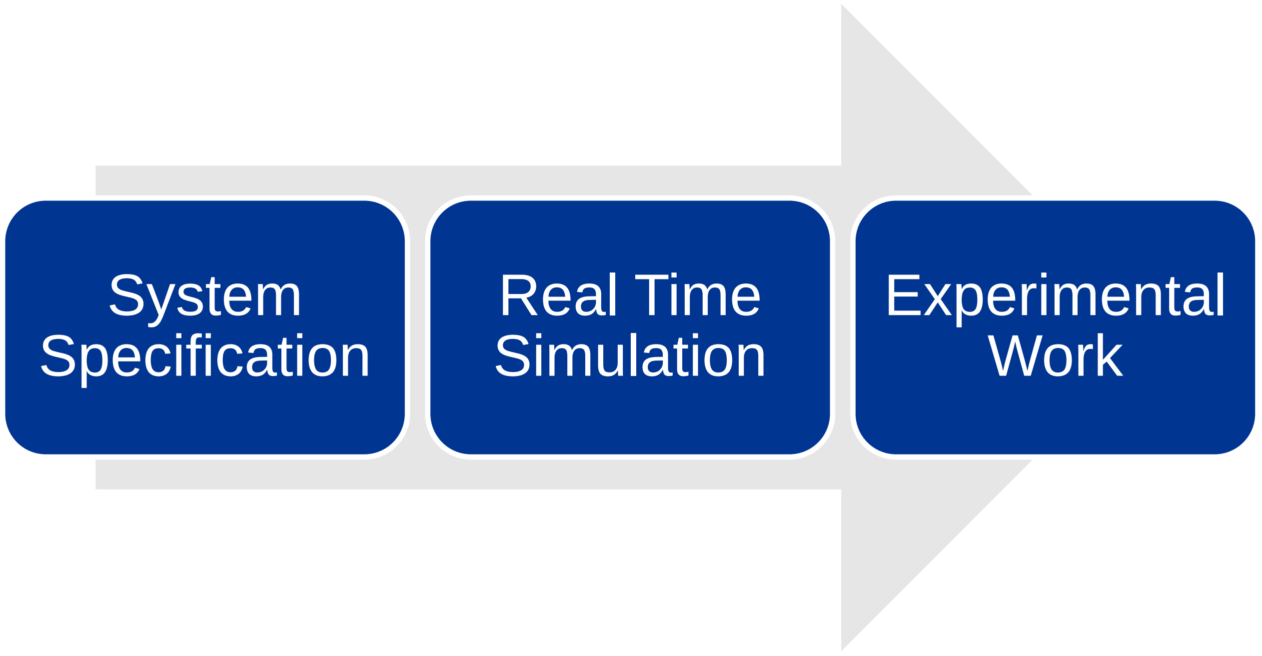
Communication with the host platform is enabled via satellite. A conventional control umbilical can also be used.

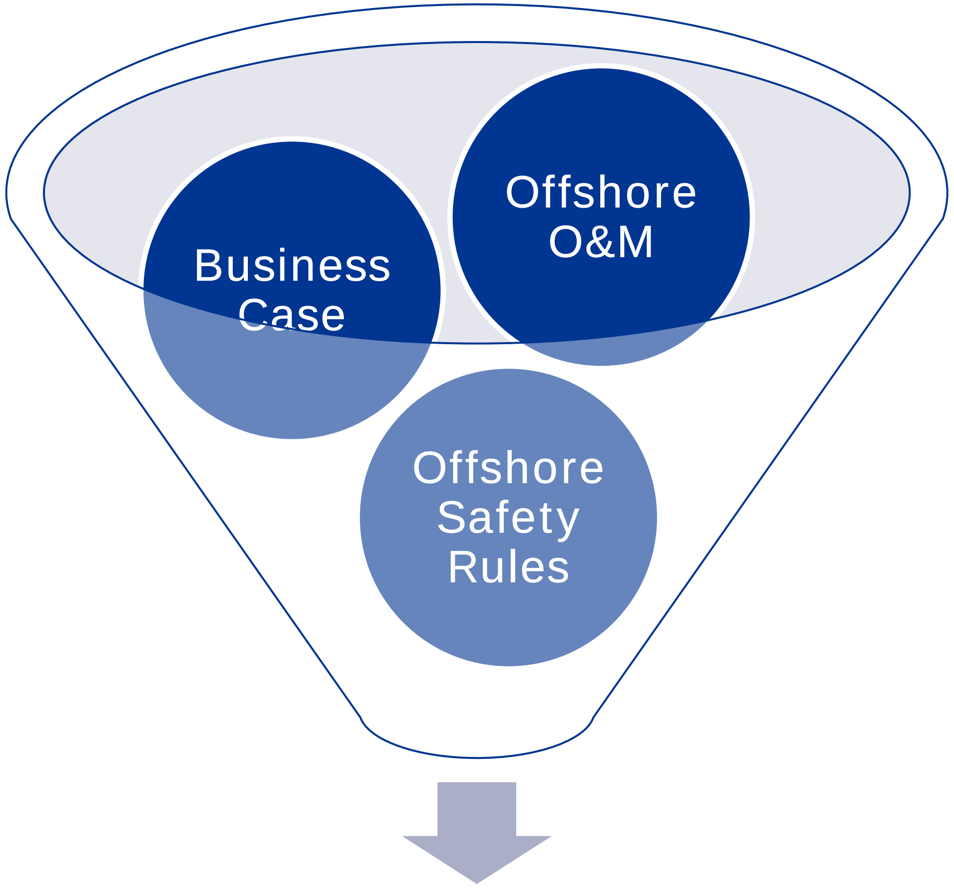
Technical characteristics of WIN WIN:

- MW scale microgrid
- The main subsystems use power electronics
- No coupling transformer
- Generation-driven process, i.e. water injection depends on available wind power
- Variable wind power



Validation Process



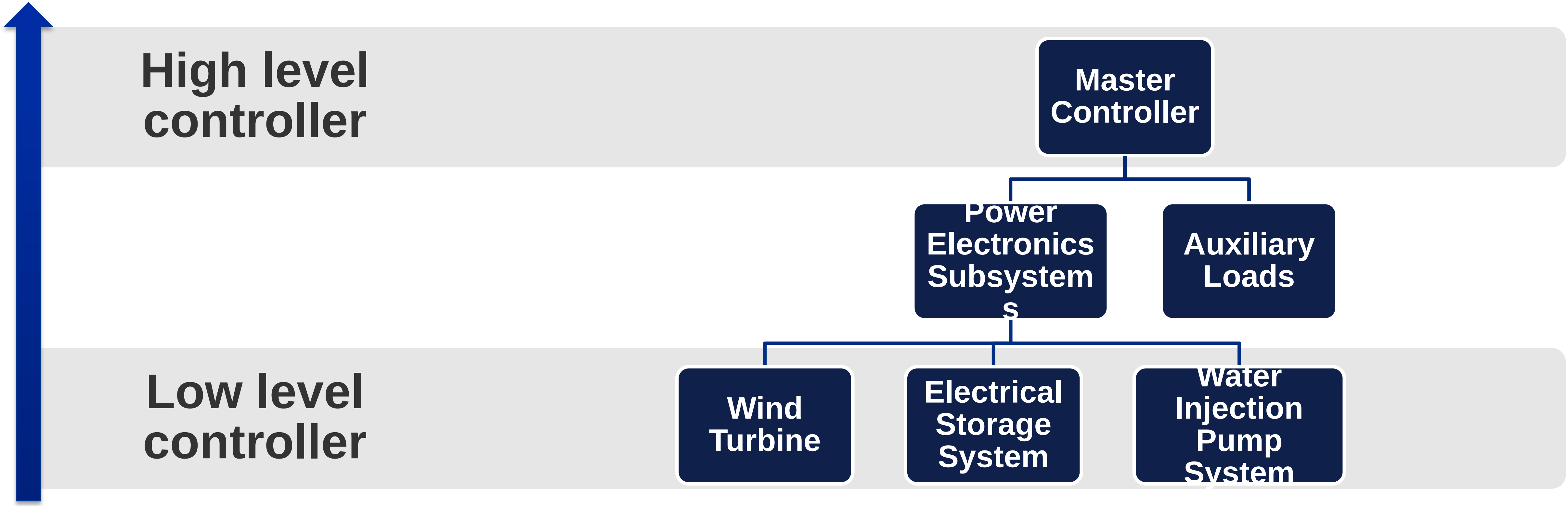


System Specification

- **Sizing of subsystems**
- **Operational philosophy**

Microgrid Controllers

Modelling of Controls



Low Level Controllers

Low Level Controller		
ESS Voltage controller	**WTS** Current controller Phase lock loop DC bus controller DC Chopper	**WIPS** Current controller Phase lock loop DC bus controller DC Chopper

Master Controller

ESS

WIPS

Master Controller

-Operation Philosophy

-Power Balance

-Alarms/Faults

WTS

AUX LOADS

Experimental Work

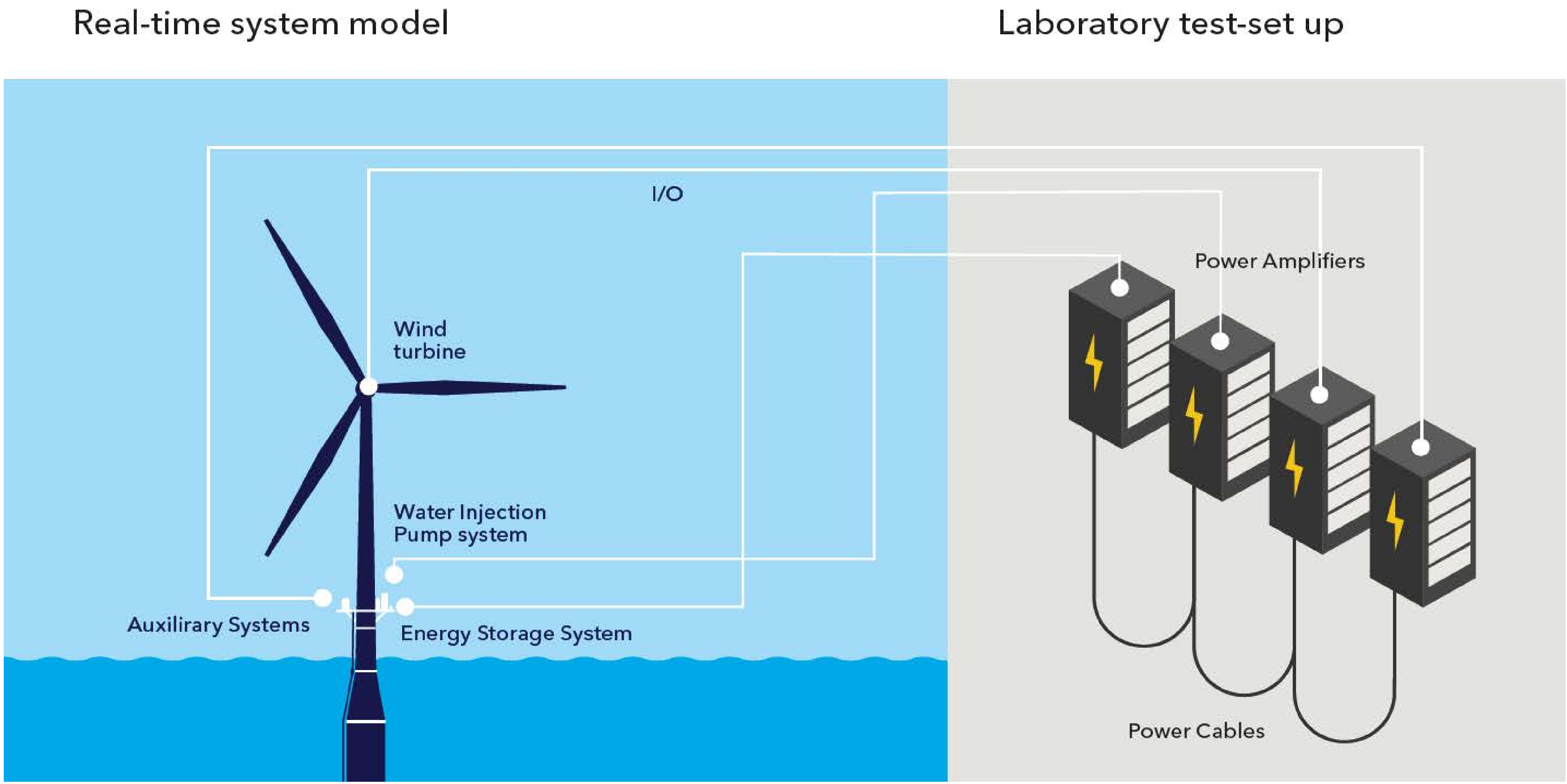
Flex Power Grid Laboratory – The Netherlands

Experimental work

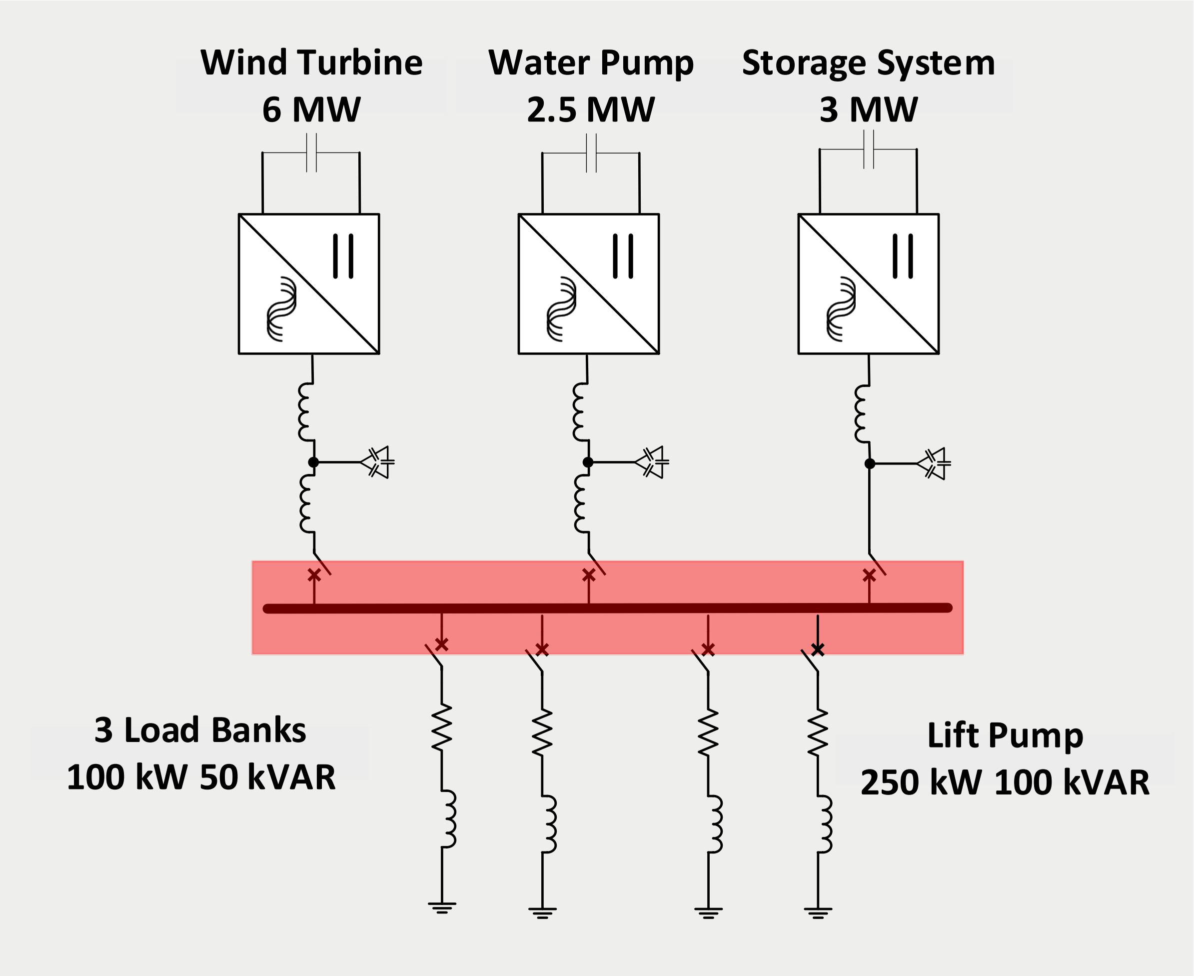
Operational philosophy
Non-generating standby
Start-up of microgrid and generation
Start-up of process plant for injection
Generating injection
Emergency - Disconnection of main Subsystems

- Functional testing vs. operational philosophy
  - Small signal stability
  - Power balance
- Indicators
  - Frequency
  - Voltage
- Assumption
  - All communication and control systems are redundant
- Cases
  - Disconnection of Water Injection Pump Subsystem
  - Disconnection of Wind Turbine System

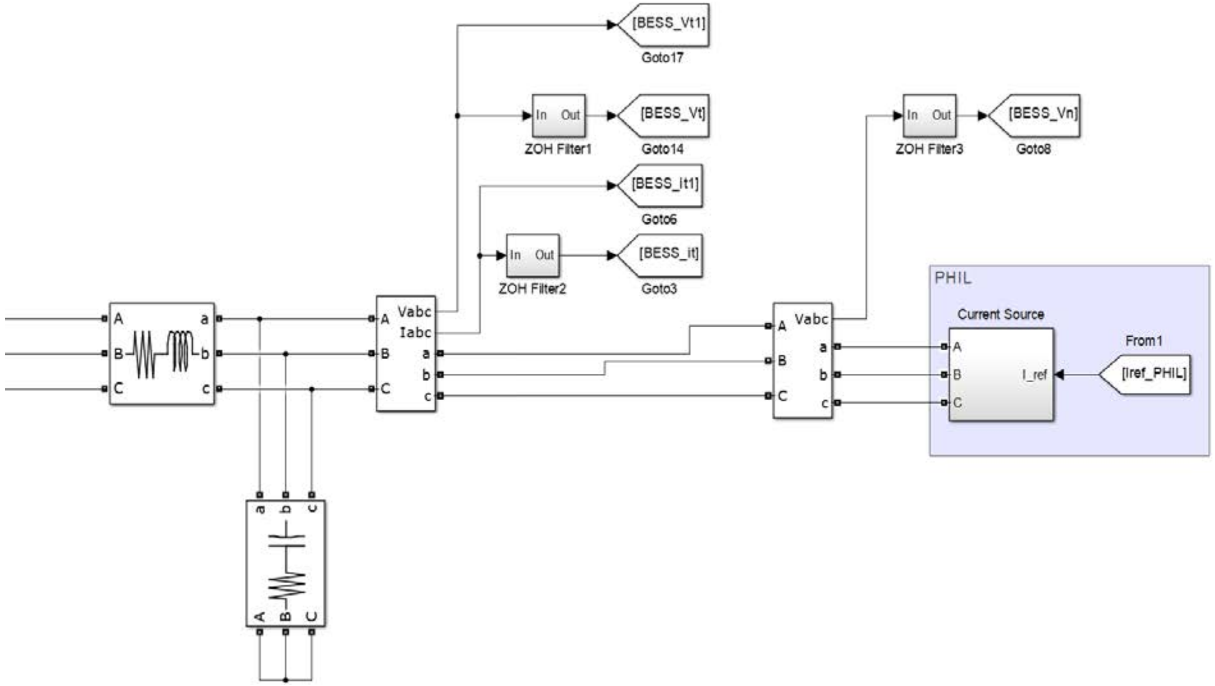
Power Hardware in the Loop



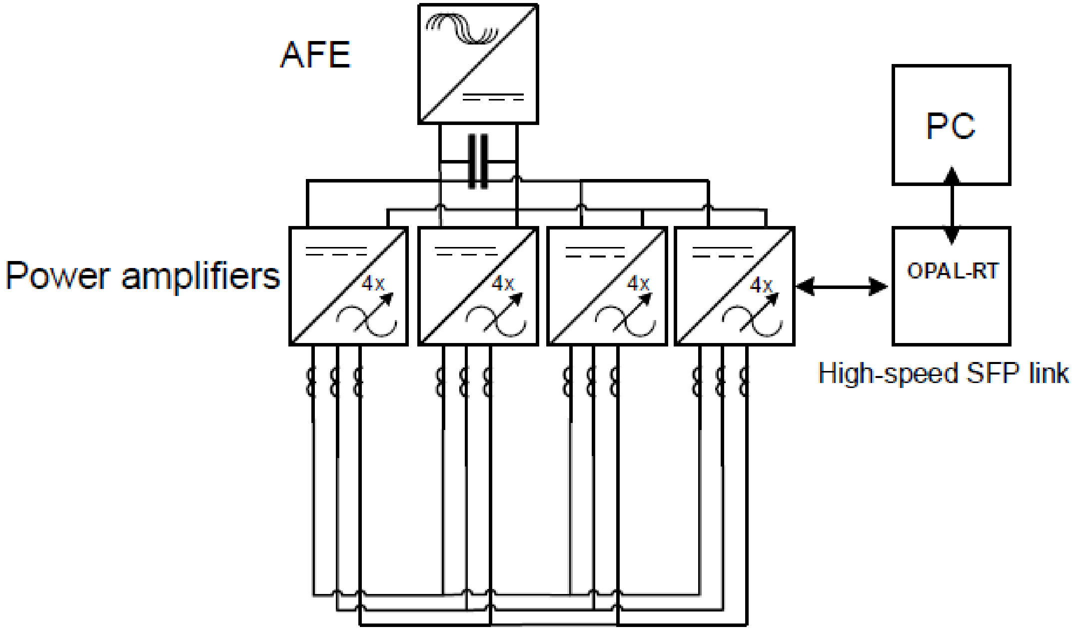
Model – Power Hardware in the Loop



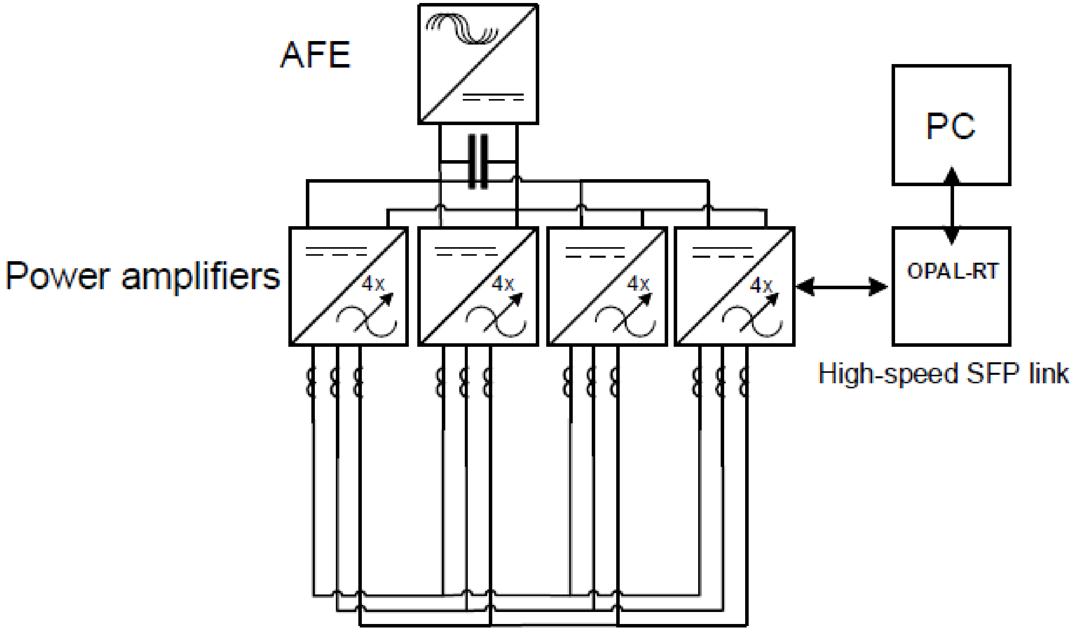
- Ideal transformer Method

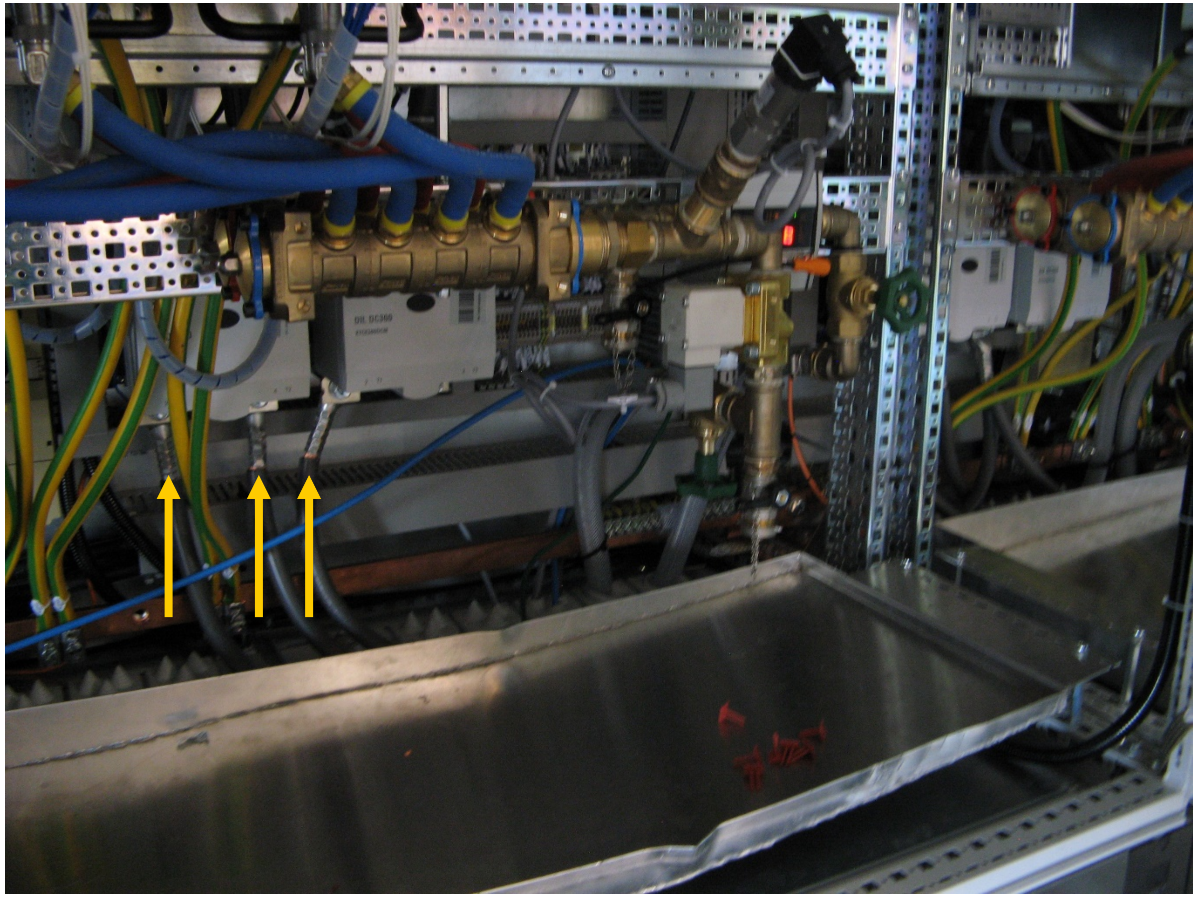


Power Circuit

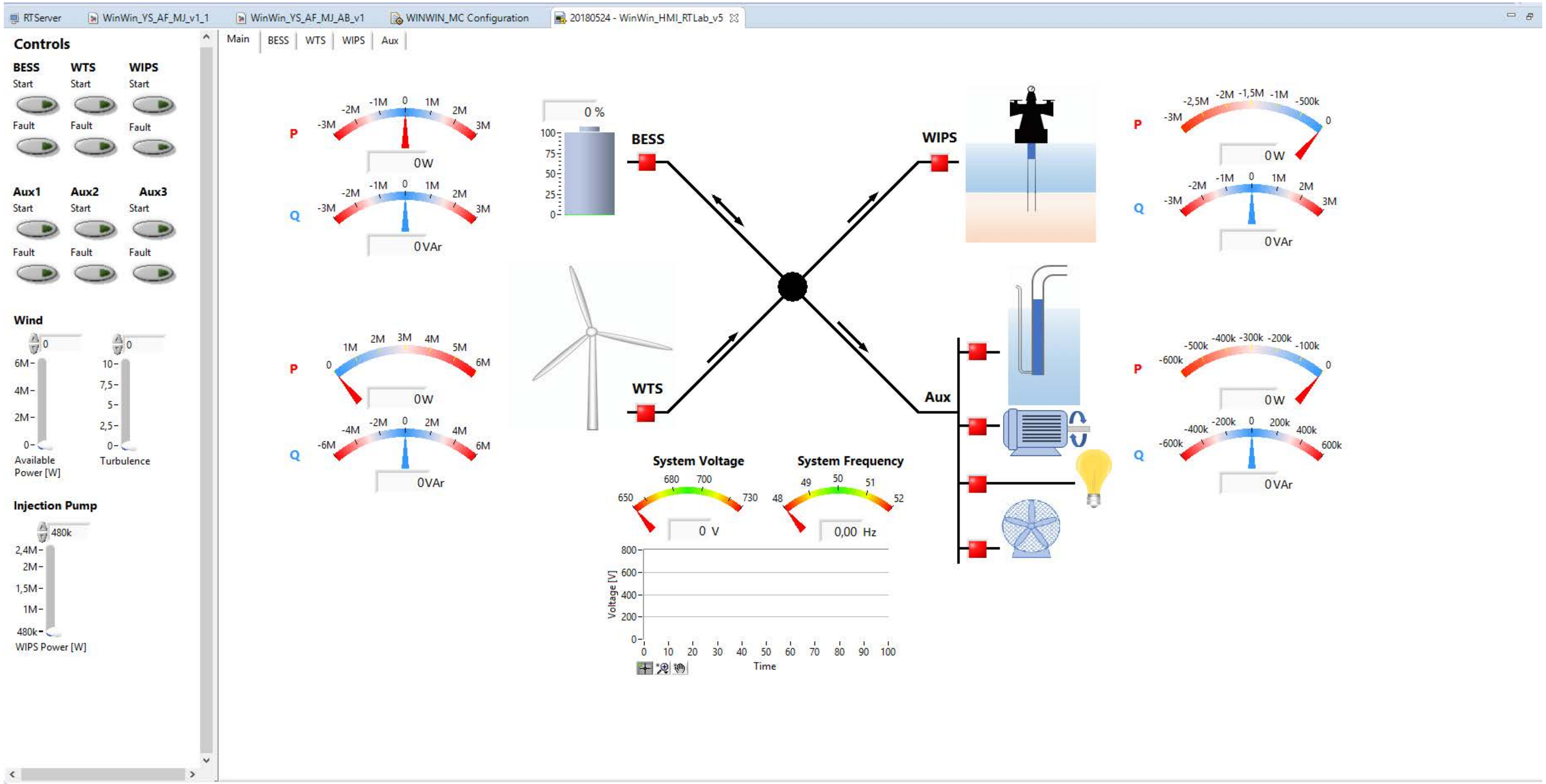


Power Circuit





Monitoring Interface



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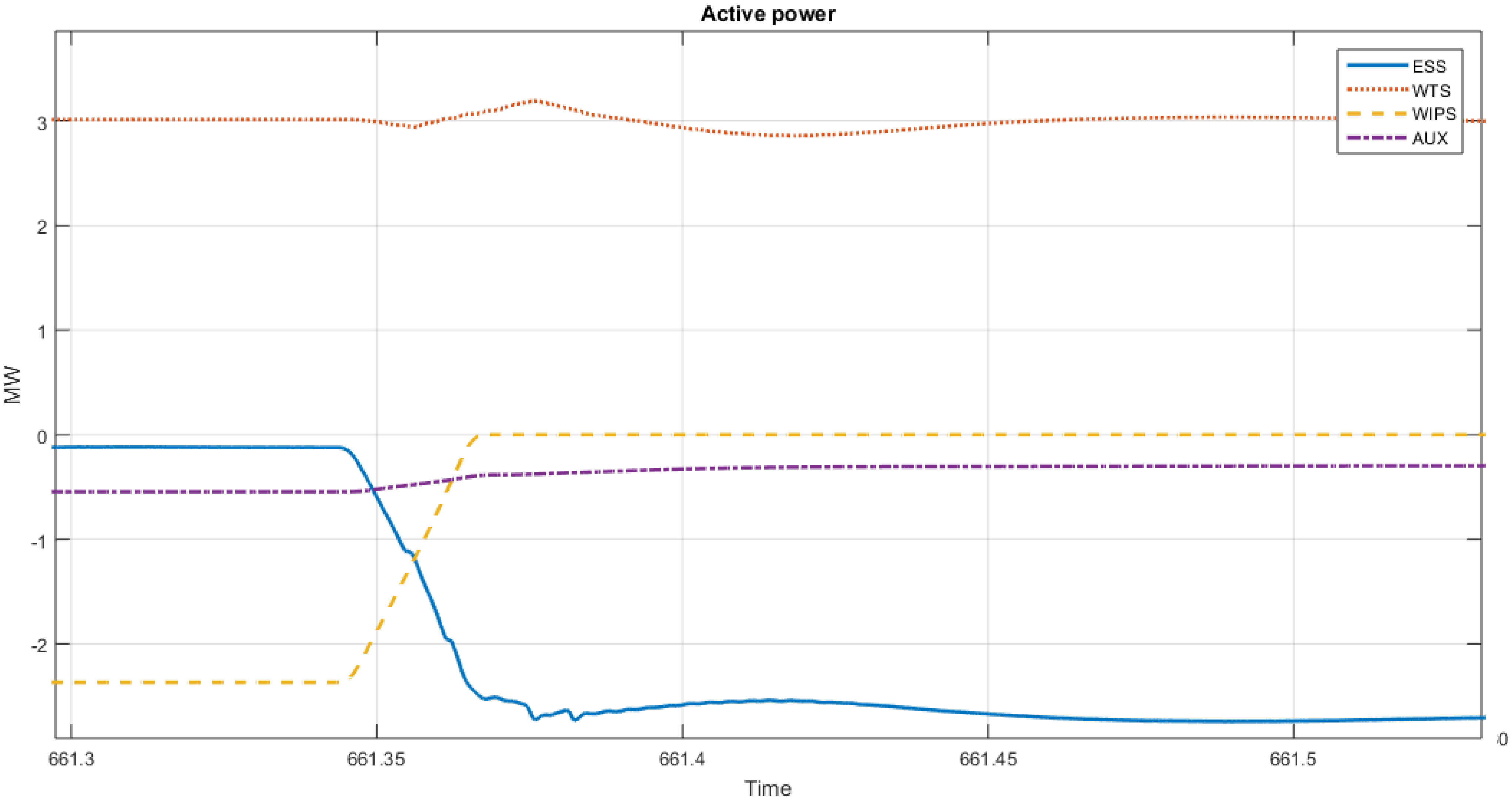
Test Cases Results

Disconnection Water Injection Pump System

1. Fault at WIPS
2. BRK WIPS opens
3. BRK Lift Pump opens
4. Power at WIPS goes to zero
5. Reactive Power
6. Voltage transient
7. ESS Support



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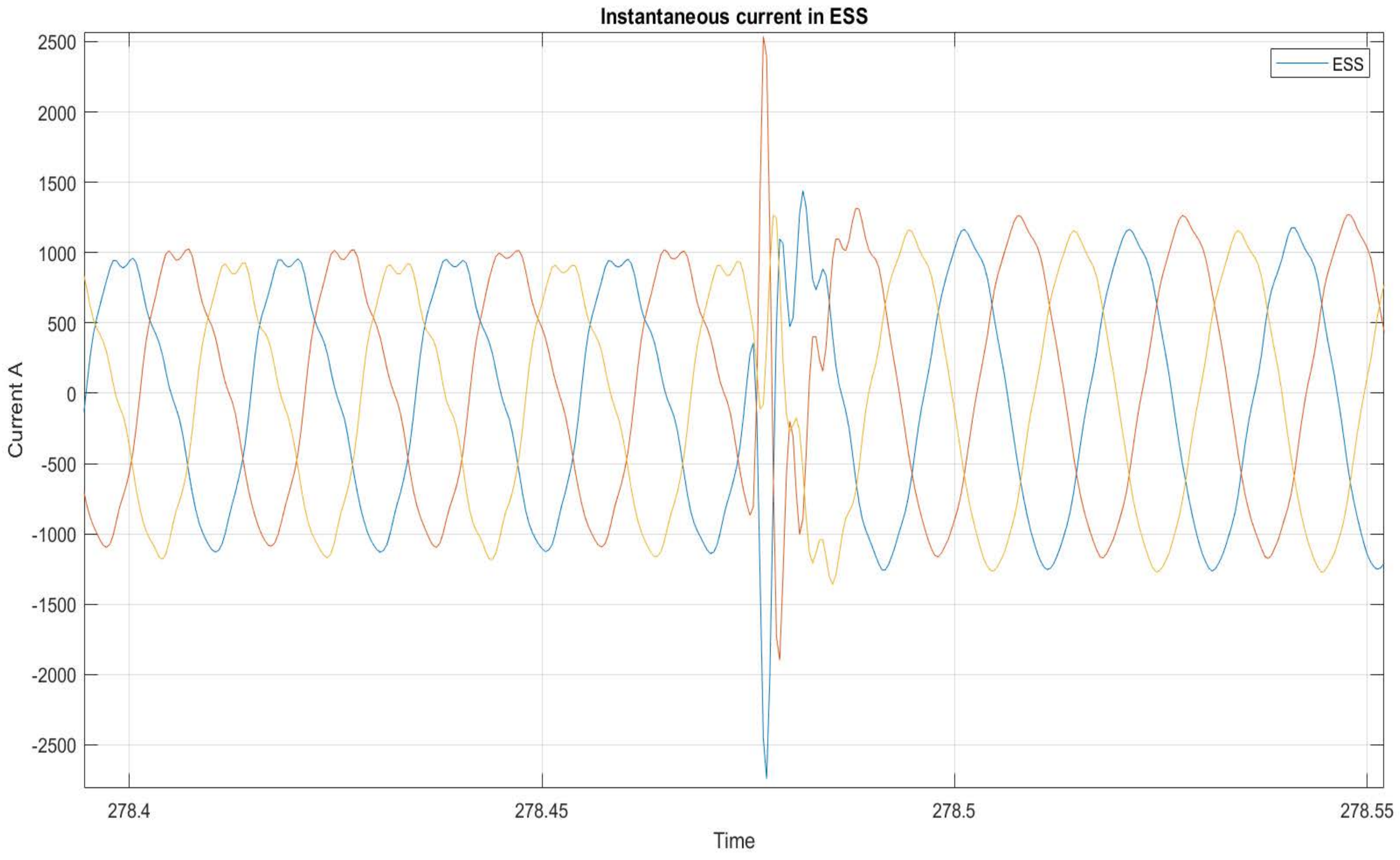
Disconnection of Wind Turbine System

1. Disconnection WTS due to a fault.
   – DC Chopper WTS
2. Almost simultaneously WIPS disconnection.
3. Almost simultaneously Lift pump disconnection.

- To observe:
- Voltage transient
  – Low point =655.9V_{rms}
- Current transient = -2.74kA



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Conclusions

Main findings

- All the proposed test cases have validated normal operation modes and the transitions between them.

- Critical cases are the disconnection of the WIPS and WTS subsystems
  - WIPS disconnection: overvoltage 12% more than the nominal voltage
  - WTS disconnection offline simulation: undervoltage 16% below nominal voltage

- Testbench has a natural capacitive reactive power nature.

Master controller

- The master controller oversees the power balance in the microgrid. If its logic during fault stages is not properly designed/tested it can compromise the small-signal stability.

- The master controller will be the second barrier for protection for the electrical microgrid.

- The master controller will impose the microgrid's compliance code for the subsystems WTS, ESS and WIPS.

Low-level controllers

- Careful design in the bandwidth of the phase locked loop (PLL) for in WTS and WIPS to avoid small-signal instability due to the low SCR.

- For the grid-connected voltage source converter (VSC), the voltage feed-forward should be carefully selected since it could cause negative resistance in a wide frequency spectrum as a result of digital delay.

- A system study on the harmonic emissions of the ESS subsystem should be considered to implement the correct filtering of measurements for the WIPS and WTS current controllers.

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THANK YOU

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