

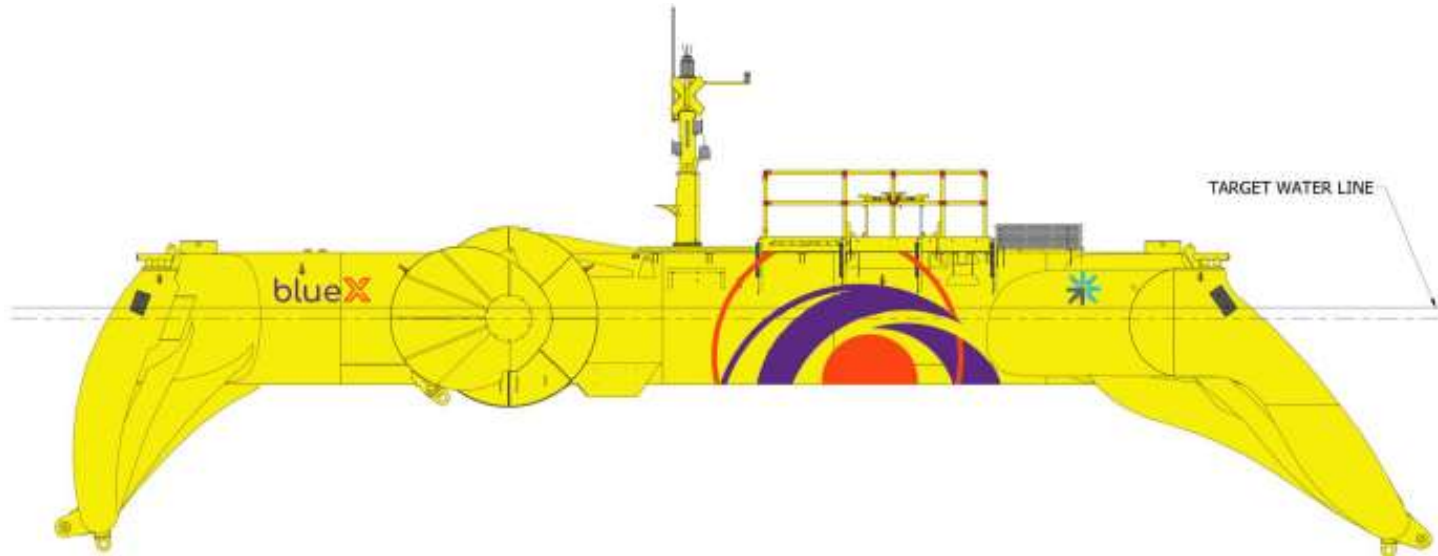
Supervisory Control Software and Data Acquisition on Mocean's BlueX Wave Energy Converter

Background to ISC



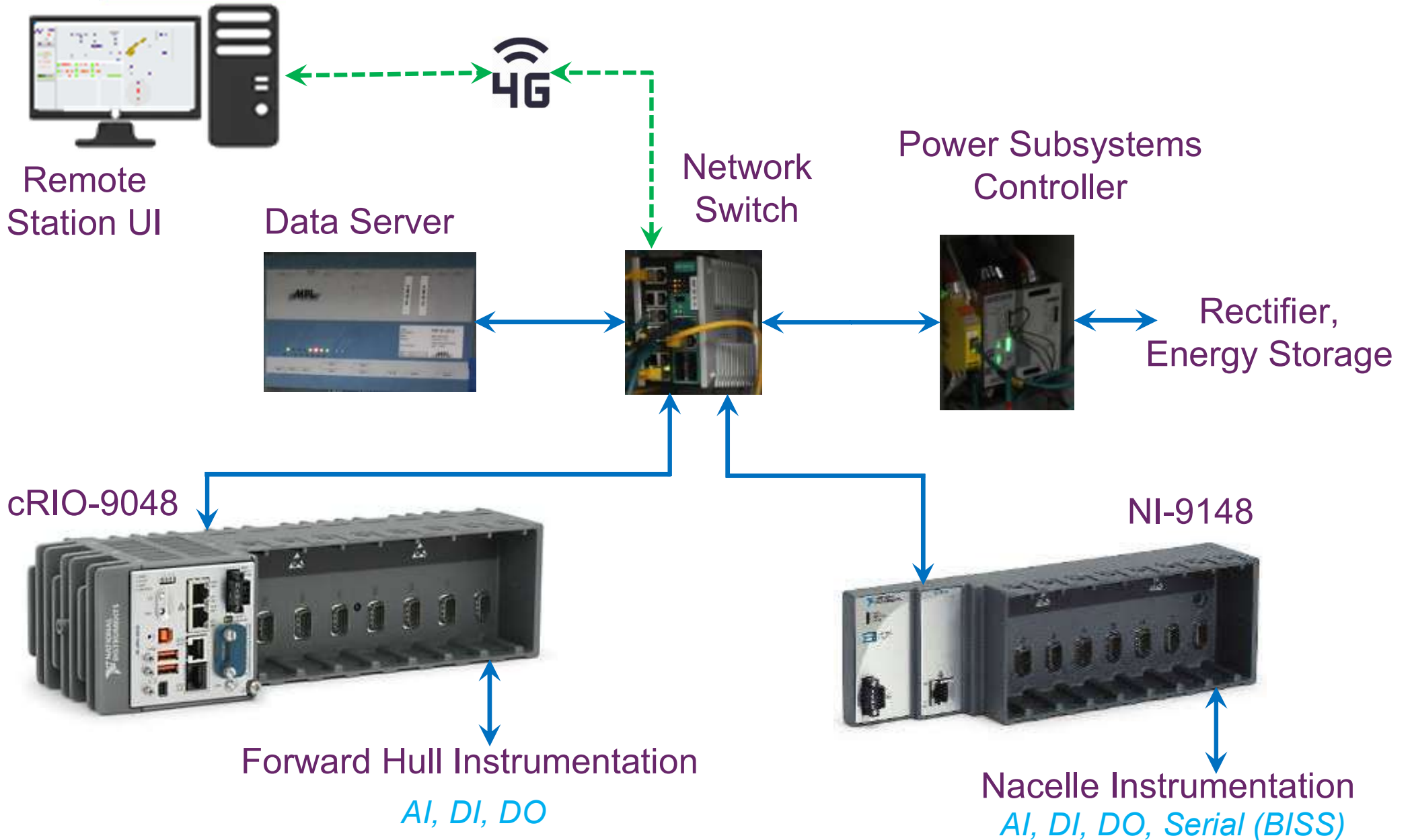
- Control engineering consultancy based in Glasgow
 - Founded 1987 - as a spin-out from Strathclyde University
- Works across many sectors:
 - Renewables, Oil/Gas; Power Generation; Automotive; Marine
- Small – 5 full time, 4 part time employees
- However, we work with some very large companies:
 - BP; Shell; General Motors; Toyota; Boeing; BAE Systems; Rolls Royce Marine; SSE; Scottish Power; Alstom; EDF

Mocean Energy BlueX WEC



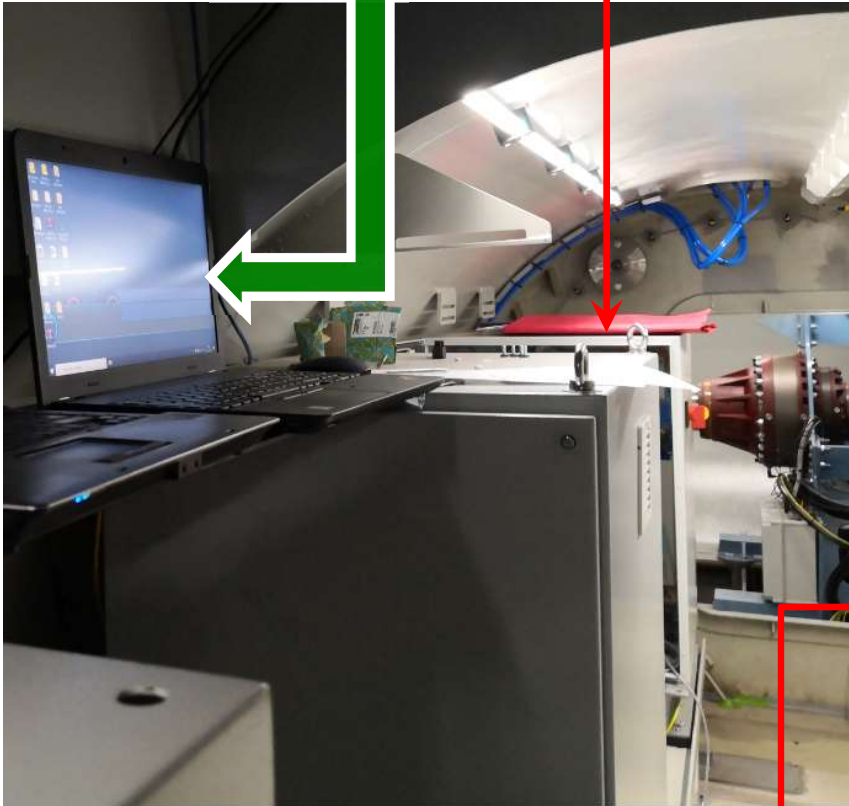
- Hinged raft; single hinge connecting forward and aft section
- Hinge rotational kinetic energy transformed into electricity via the power take off (PTO) system
- Hinge encloses rotary permanent magnet generator (PTO)
- Power systems and energy storage enclosed in the forward hull section
- Communications tower connects to remote SCADA host on-shore

Control Subsystems Topology



WEC Instrumentation

Development PC



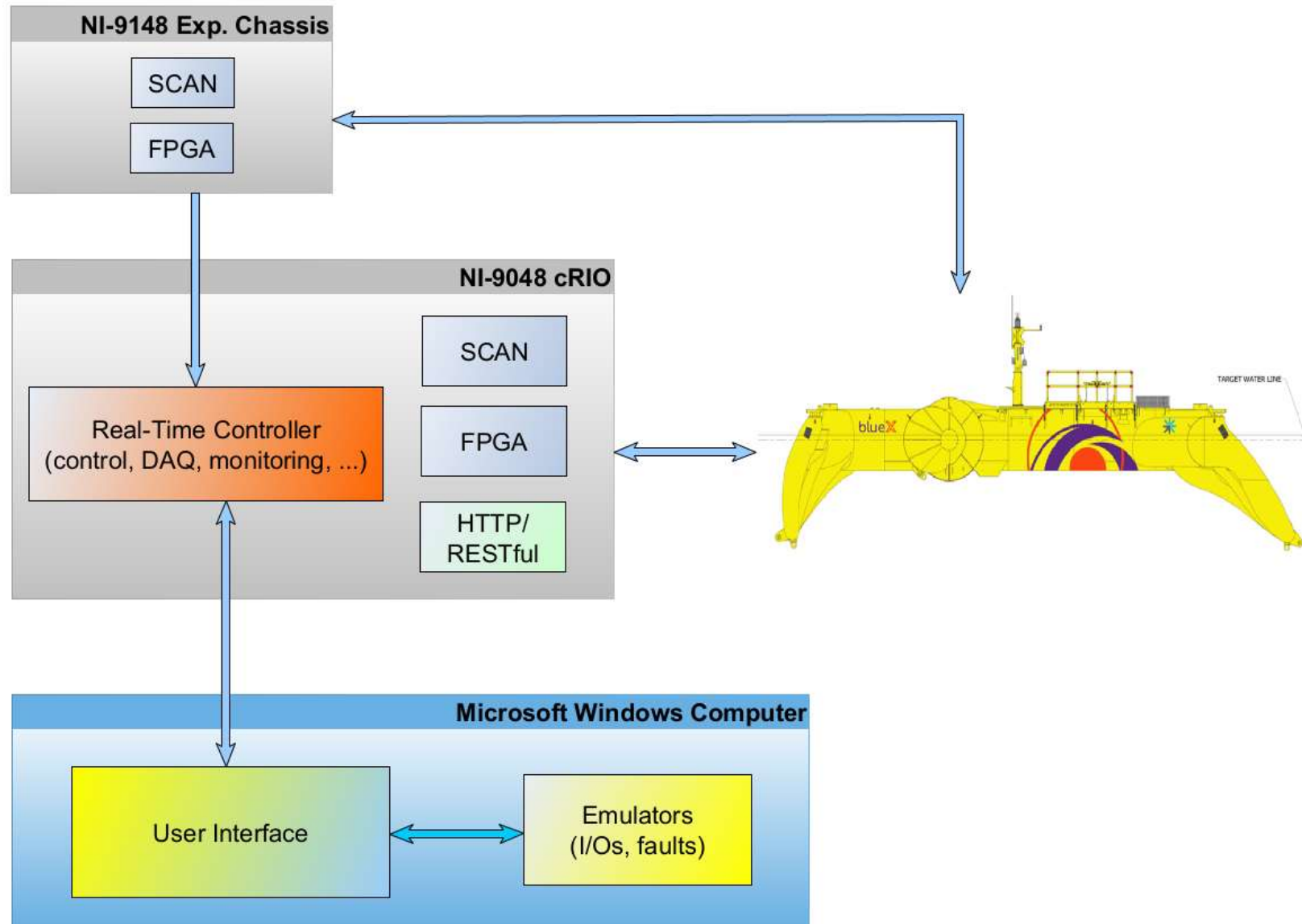
4-20mA and $\pm 10V$ signals for motion, temperature, generator and power systems currents and voltages, hinge torque, oxygen/hydrogen, vibration, mooring tension, generator and hinge velocity BiSS encoders, overvoltage relays, smoke detectors, earth leakage, bilge pumps control signals, ...



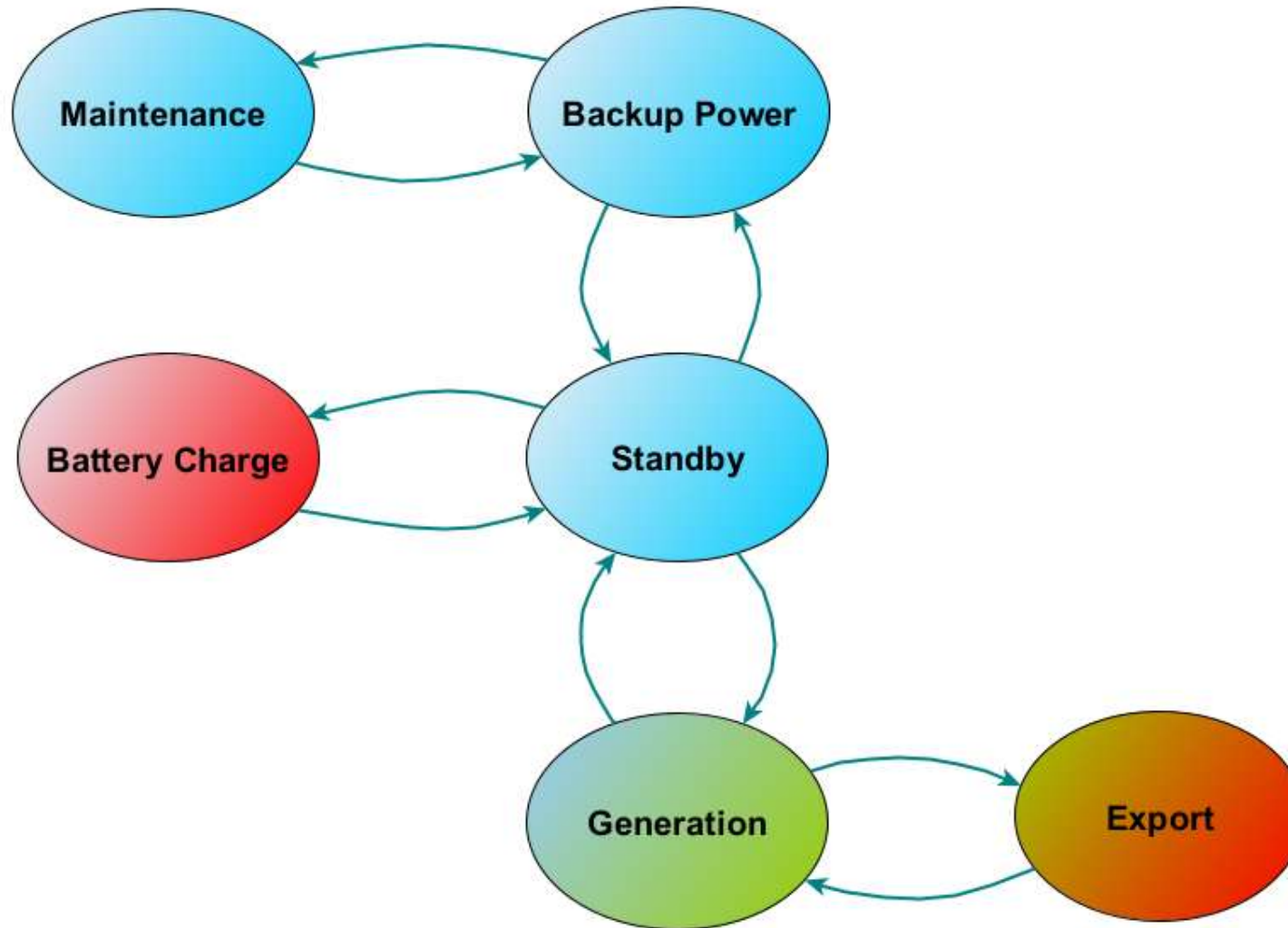
Control Functionality

1. WEC state transition mechanism
2. Power generation / export, manual / auto mode
3. Subsystems configuration (generator segment, rectifier damping etc.)
4. Subsystems brainbox coils status monitoring
5. Rectifier and Inverter CAN messages, alarms and warnings
6. Weather and battery status monitoring
7. Sensor data acquisition and conditioning
8. Data logging and transfer to data server
9. Safety system and fault handling
10. Remote user interface

High-Level Controller Architecture



WEC Operating Modes



Fault and Survival Conditions



- Fault Condition:
 - ❑ Either indicated by measurements or from the Rectifier/Inverter status
 - ❑ HLC transmits to Standby state transition and generates warning messages
 - ❑ HLC system reset can be performed once the fault is resolved
- Survival Condition
 - ❑ Dedicated to the condition of generator overvoltage
 - ❑ HLC transitions to Survival mode to isolate the generator coils
 - ❑ Finally, it transitions to Standby mode and inform operator

Remote User Interface (over 4G)



BlueX Remote User Interface
— □ ×

File Edit Operate Tools Window Help

📊
⚙️
✂️

TARGET ONLINE

SYSTEM HEALTHY

WEC MODE SELECTOR

BACKUP POWER

STANDBY

GENERATION

MAINTENANCE

BATTERY CHARGE

GENERATOR CONTROL

Manual Auto

GENERATOR CONFIGURATION

12 Segments

GMSA TIMER RESET

EXPORT CONTROL MODE

Manual Auto

MANUAL EXPORT

Off On

POWER CONTROL CABINET

POWER DISTRIBUTION CABINET

745.5 DC Bus Voltage (V)
 50 Yuasa SoC (%)
 3.2 Time on Batt (Days)
 100 UPS SoC (%)
 4.5 Time on UPS (Hrs)
 100 Hibernation UPS SoC (%)

-1.546 Roll (Deg)
 0.656 Pitch (Deg)
 176.800 Yaw (Deg)
 1.019 Press (Bar)
 10.300 Temp (C)
 44.800 Wdir (Deg)
 3.110 Ws (kn)

58.866482 Latitude -2.742277 Longitude

Blue X

Current Generator Config: 12 Segments
GMSA Output: Standby
Power Export Enabled:

● Gen Voltage

● Hinge Torque

● Smoke Alarm-Hull

● Thermal Overvoltage OL 2

● Gen Current

● Hinge Velocity

● Smoke Alarm-Nacelle

● Thermal Overvoltage OL 4

● DC Current

● Gen Velocity

● Rectifier

● Thermal Overvoltage OL 6

● DC Bus Voltage

● Earth Leakage (Generation)

● Inverter

● Thermal Overvoltage OL 12

● Mooring Tension

● Earth Leakage (Export)

● Generator Segments

17/10/23, 16:51:49 - Moved to Standby
 17/10/23, 16:51:42 - BBCoilStatusRead (init 2):
 Mode In: Standby
 Mode Out: Standby
 Contactor Status: 0 0 1 0 1 0 0 0 0 0 1 1 1
 17/10/23, 16:51:42 - INITIALISATION COMPLETED SUCCESSFULLY
 17/10/23, 16:51:42 - Data logging enabled
 17/10/23, 16:51:42 - TargetN FPGA initialised
 17/10/23, 16:51:37 - TargetC FPGA initialised
 17/10/23, 16:51:33 - cRIO chassis connected
 17/10/23, 16:51:33 - Nacelle chassis connected
 17/10/23, 16:51:30 - SSC interface connected
 17/10/23, 16:51:30 - UPS interface connected
 17/10/23, 16:51:30 - Hibernation UPS interface connected

WEC Mode & Rectifier Status

WEC Mode: Standby

Inverter Status

16:52:27

BlueX in Action

- Operational at sea continually and unmanned for 13 months.
- Generated extensive performance data that can be applied for Mocean's other commercially available devices (Blue Star and Blue Horizon).



<https://www.youtube.com/watch?v=fbhyaiGvOLM>

Challenging Aspects

- EMI interference corrupting measurements
- Data lag, alignment and time synchronisation
- Coordination of multiple different loosely coupled systems
- Integration of multiple instrumentation and communications protocols
- Incremental requirements and development over several phases
 - Initial design, fabrication, standalone deployment (comms added)
 - Later, operation with different generator segments
 - Later still, combine wave power with subsea energy storage to power subsea equipment - RSP demonstrator <https://www.mocean.energy/renewables-for-subsea-power-project-completes-milestone/>

ISC Services - Improving Performance Through Understanding and Application of Control Technologies

- Consultancy
- Software engineering
- Training courses

Dr Andy Clegg, Managing Director, ISC Ltd

Tel: +44 (0) 141 847 0515

Direct: +44 (0) 141 225 0127

Web: www.isc-ltd.com

36 Renfield Street, Glasgow, G2 1LU, Scotland, UK