# CONTROL AND SCADA SYSTEM DESIGN, D4.2 DOE ADVANCED TIDGEN

***D-TD20-10153***

***Revision 0 – 4/27/2018***

Ocean Renewable Power Company, LLC
254 Commercial St., Ste. 119B
Portland, ME 04101
Phone (207) 772-7707
*www.orpc.co*

# 1 PURPOSE

This document is the technical report deliverable, D4.2, for the Advanced TidGen®:

| | |
|---|---|
| **Award No.:** | DE-EE0007820, effective 11/1/2016 |
| **Project Title:** | Advanced TidGen® Power System |
| **Prime Recipient:** | ORPC Maine |
| **Principal Investigator:** | Jarlath McEntee, P.E. |

The document provides details regarding the control system and SCADA system preliminary design for Task 4 of the Advanced TidGen® project. Milestone and deliverable descriptions are below. **Note that simulation files are not applicable due to the development approach ORPC has adopted for the project.**

| | | | | |
|---|---|---|---|---|
| 4.1 | Milestone | Preliminary control system and SCADA design for tidal system operation completed, with control system models supporting capability to maintain maximum power point operation through tidal and turbulence ranges. | 8 | 3 |

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|---|---|---|---|---|---|---|---|---|---|
| 3 | **Task 4: Software & SCADA Design and Integration** | M4.1 | Report | **D4.1:** Technical report on control system development, supporting simulations and SCADA system requirements | pdf | Protected | <50MB | None | MHK-DR |
| 3 | Task 4 | M4.1 | Data: simulation files | **D4.1:** Supporting MATLAB simulation files | Matlab /Simulink files | Protected | <10MB | Requires software license | MHK-DR |

# 2 SCADA AND CONTROL SYSTEM DESCRIPTION

The SCADA and control system of the Advanced TidGen® is separated into three areas of responsibility:

1. Control of turbine speed to maintain optimum efficiency, remain within allowable torque limits and remain below the limit of the power electronics. The "Control System" refers to this area of responsibility.
2. Supervisory control of the system including turning the system on and off, switching control system states and preparing the system for deployment and retrieval. The "SCADA system" refers to this area of responsibility.

3. Monitoring the performance and health of the system, alerting the SCADA system to any faults and logging sensor and status information for historical review. The "Condition Monitoring System" or CMS refers to this area of responsibility.

The control system operates on hardware independent of the SCADA and CMS and can manage any faults specific to the operation and health of the generator. The Advanced TidGen® operates two independent control systems, one for each row of turbines.

The SCADA and CMS operate on the same hardware. Unlike previous ORPC systems, the hardware is located on the device and can operate the device independently from the on-shore station. This allows for a controlled shutdown of the device in the event of a loss of communication or power from the shore station and continued monitoring of system health.

## 2.1 Communications Architecture

The Advanced TidGen® will utilize a local ethernet network on the system to communicate between various enclosures, data acquisition modules and to network to the shore station. The controllers for each generator communicate over CAN-A bus and thus operate on a separate network. CAN-A is still relatively new to industrial automation and few industrial PLCs or DAQ systems can utilize the CAN bus, thus the backbone of the communication system was selected to be ethernet based. The communications schematic can be found in Appendix A.

# 3 Control Theory

The control theory selected for this project was the $K\omega^2$ – a nonlinear feedforward controller. An analysis of alternative control theories is presented in ***D-TD20-10028 R00 – Preliminary Control System and SCADA Design DOE Advanced TidGen D4.1.***

Previous projects focused on control approaches evaluated four types of controllers which were tested in simulation, emulation, a laboratory flume, and the field[1]. Trends in simulation were verified through experiments, which also provided the opportunity to test assumptions about turbine responsiveness and control resilience to varying scales of turbulence. The clear message was that the feedforward $K\omega^2$ controller out-performs feedback controllers in almost all aspects and modes of evaluation. The controllers proved a substantial improvement over the baseline performance of the TidGen® turbine, in terms of energy capture.

## 3.1 Theory

Derived from the dynamic model of turbine operation, the nonlinear feedforward $K\omega^2$ controller commands a torque,

$$\tau_c = K\omega^2 = \frac{1}{2}\rho A R^3 \frac{\eta(\lambda)}{\lambda^3}\omega^2$$

[1] EE0006397_ORPC_FINAL_TECHNICAL_REPORT

which brings the turbine to a desired operating point on its performance curve ($\eta(\lambda)$). In the case where $K$ results in the turbine operating at peak efficiency, this optimal gain is referred to in this report as $K^*$. $K$ values larger or smaller in magnitude than $K^*$ result in operation to the "left" or "right" of the peak (slower or faster than optimal $\lambda$, respectively). Optimal performance requires a well-defined performance curve and accurate measurement of $\omega$. Note that unlike a feedback controller, the control torque equation does not explicitly prescribe a fixed set-point. Rather it controls the turbine to a set-point based on the estimate for the plant dynamics. This controller is shown schematically in Figure 1.

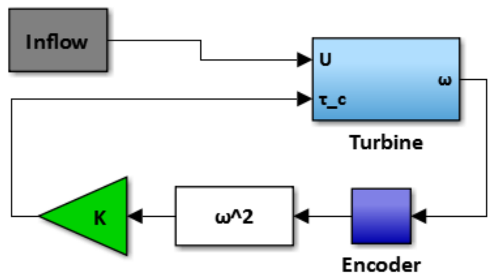



*Figure 2.1 Kω2 controller schematic. This feedforward controller creates a torque command based on the speed of the turbine and the plant characteristic K.*

# 4 SCADA Design

The SCADA system is the link between the control system and the on-shore operation. The system can run in manual, semi-automatic and automatic mode. The processes are described step-by-step in appendix B.

In manual mode, the operator has complete control of the system, capable of switching states without automatically handling faults reported by the CMS. Important status readings will be displayed to the operator, however if the readings are outside normal operating conditions, the system will not take corrective action. Manual mode is intended for use during commissioning to more readily establish baseline readings and determine the operational conditions, as well as stress testing the system.

Semi-automatic mode is like manual in that the operator controls the switching of system states, however unlike manual control, the SCADA system will automatically handle any faults presented by the CMS. This may include a gentle or emergency shutdown of the system or change of control system commands to maintain integrity of the system. When an operator is present for maintenance, installation or removal the system is in semi-manual control.

Automatic mode is where the system is most likely to spend time. The SCADA system handles complete control of state switching; performing start-up and spin up of the turbines when the flow speeds reach useable levels, changing control mode between $K\omega^2$, torque limited operation, power limited operation, and shutdown as necessary. Any faults reported by the CMS will automatically be handled. In common faults, such as motor overspeed due to higher than expected current speeds, the SCADA system will automatically restart the Advanced TidGen® at the next tide cycle. Other faults such as bearing over temperature or water ingress in sealed compartments will alert operators and keep the system shutdown until operators can intervene. This last feature is required by DNVGL, any fault the triggers a shutdown will prevent a restart until the fault is cleared and an operator has restarted the system.

# 5 Condition Monitoring

The condition monitoring system serves two purposes. The first is to provide a constant assessment of the health of the Advanced TidGen® while in operation. The second is to monitor performance and environmental information unnecessary to the operation of the Advanced TidGen® but useful for improving the design and functionality in the future. An instrumentation and equipment list can be found in Appendix C. The instrumentation and equipment are assigned unique identifiers according to ISA 5.1 Standards.

## 5.1 Warning and Fault Limits

Sensors critical to the health and operation of the Advanced TidGen® are given warning and fault limits, used as indicators to the operator of abnormal behavior. Warnings are used as indication that a part of the system is entering an uncommon operational state. Warnings do not indicate a failure is occurring or imminent on their own, only to raise awareness and begin careful attention to all other systems. Faults are conditional limits that, when exceed the SCADA system must respond immediately, such as a shutdown of the system if a leak is detected in a compartment.

Most warning and fault limits cannot be determined before initial deployment. During the commissioning phase, the Advanced TidGen® will be operated at lower power outputs, with faults set low to both ensure the SCADA system is handling faults and to gain experience in what the steady state operational conditions are. In this phase, the SCADA system is typically left in a manual or semi-automatic mode and has constant operator attention making note of system parameters. Once defined, the system can be left in automatic control safely.

## 5.2 Data Logging and Backup

A critical component to the CMS is logging and backup of sensors and control system parameters. The system must handle many inputs with varying levels of importance and sampling frequencies and keep a record of them backed up in multiple locations in the event of a failure anywhere along the network line.

Depending on the current and previous state of the system, the data logging procedure is different. Those procedures and conditions are as follows:

- **Rolling Log**: A continuous log of the last hour of system status and intersystem communications is kept. This log is continually overwritten, stored locally and not logged unless some condition requires it.
- **Power Production Operation**: When the system is operating normally and actively producing power, system health and status information is logged at most every minute. Voltage and

current are monitored at each generator, converter, and before and after the transmission line. Leak sensors are not logged.

- **Shutdown Operation**: When the system is shutdown, such as between tide cycles, system position and environmental conditions are logged. Power systems and leaks systems are not logged.
- **On Fault**: When a fault in the system is detected, the rolling log is immediately backed up locally and to the shore station. The system then enters a high data rate logging of all power production and rolling log parameters until the system has successfully shutdown.
- **On Shore Connection Loss**: When the Advanced TidGen® loses connection to the shore station, the On Fault logging begins. Once complete standard Rolling Log and Shutdown Operation logs are suspended and a low power, low rate log is initiated. Only critical system parameters are recorded. This is to preserve adequate storage space for logs on the device, until re-connection or recovery is performed and to minimize the power draw of the system, ensuring the longest period of operational time while connection to the shore is lost.

The logs are kept in three separate locations. The first is locally on the device, where at least the last 24 hours of operations is kept. These logs are automatically backed-up by the shore-station every 6 hours. Depending on the shore-station storage capacity, months to years of historical data is kept. Each day, the logs are backed-up to an offsite location accessible by ORPC for monitoring and review.

It is important to differentiate between monitoring and logging. All sensors on the Advanced TidGen® are actively monitored by the CMS. Monitored sensors are sampled at the program clock frequency, typically faster than 10Hz. This information is also displayed to the operator at the shore station in real time. Logged data is kept for historical review and must be stored. Sensors such as leak detection, enclosure pressure and temperature, oil pressure and humidity do not change frequently and do not provide any useful information historically, therefore are not logged, but actively monitored.

# 6 Development Path and Subsystem Testing

The development of the control system is largely independent of the Advanced TidGen® design and development path. The remaining development of the SCADA and Control system is:

1. Identification of any outstanding sensors not yet defined.
2. Internal layout of electronics enclosures and associated wiring diagrams
3. Subsea cable specification
4. Software development of the PLC code
5. Interface testing with vendor equipment such as the converter and brake
6. User Interface development for the PLC code

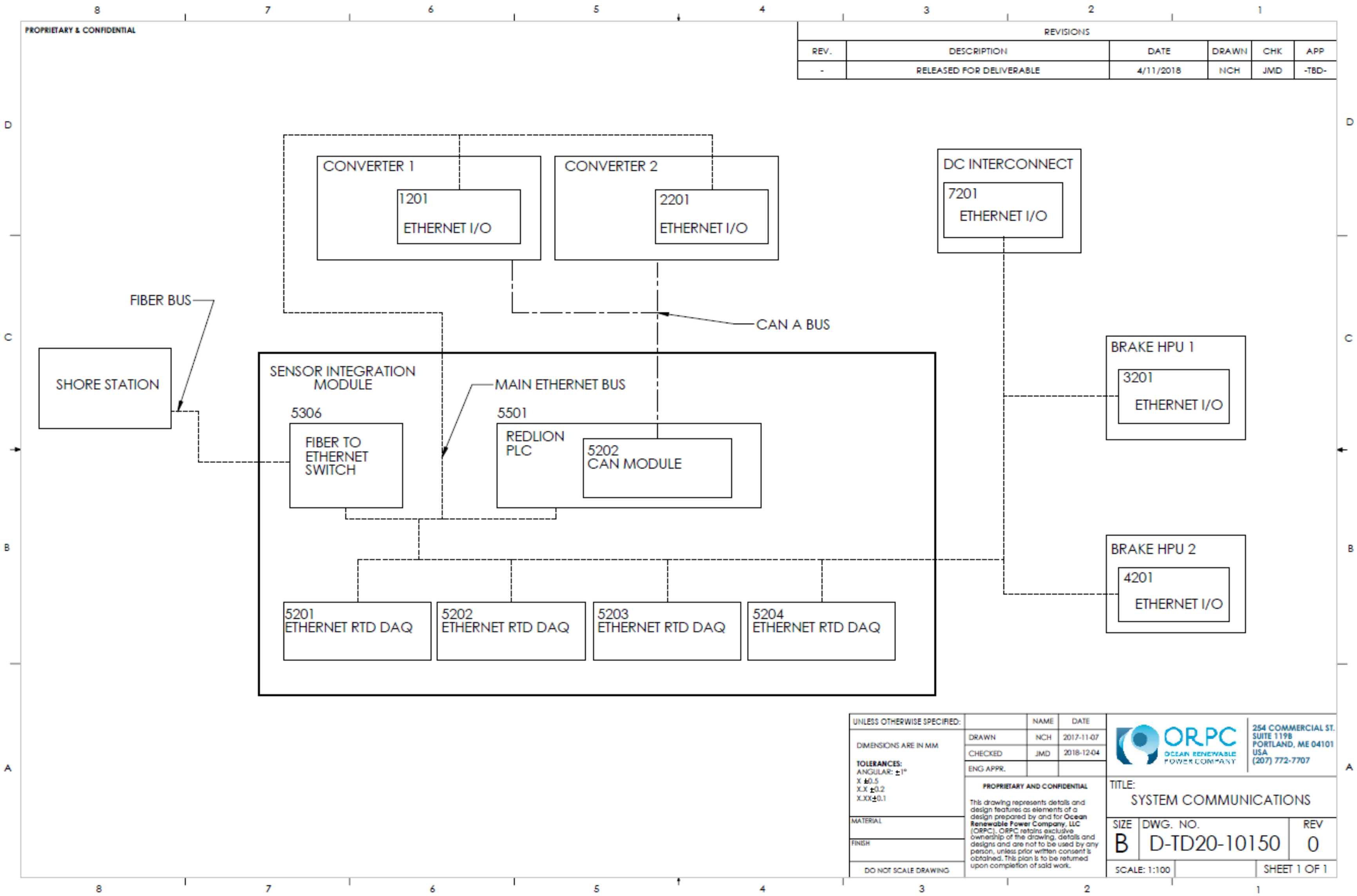
The last phase of the development takes place after final assembly of the system and before installation. A system integration test will checkout all sensors are reading properly and that the generators and brakes operate successfully.

ORPC is currently developing the next generation RivGen®, schedule for deployment a year before the first installation of the Advanced TidGen®. In the interest of keeping components and design common between products, the RivGen® will utilize the same SCADA and control system architecture as the Advanced TidGen® despite being a significantly smaller device. As a part of the development and testing of the SCADA and control system, ORPC will install the system on the RivGen® and perform software development and testing early. The core software and user interface will be able to be copied directly to the TidGen® system. Doubling as a test system, the RivGen® does not use the same converter electronics and generator as the TidGen®, however the driveline, enclosures and environmental monitoring are all sufficiently similar that determination of warning and fault limits for the TidGen® can start with that of the RivGen®. In all, the development of the RivGen® SCADA and control system will significantly reduce the development time and risk of the Advanced TidGen®.

# 7 Related Documents

- D-TD20-10150 – System Communications Schematic
- D-TD20-10155 – TidGen® 2.0 Control System Process
- D-TD20-10148 – Instrumentation and Equipment List

# APPENDIX A – D-TD20-10150 SYSTEM COMMUNICATIONS SCHEMATIC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REVISIONS
REV.
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4/11/2018
NCH
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CONVERTER 1
1201
ETHERNET I/O
CONVERTER 2
2201
ETHERNET I/O
DC INTERCONNECT
7201
ETHERNET I/O
FIBER BUS
CAN A BUS
SHORE STATION
SENSOR INTEGRATION MODULE
MAIN ETHERNET BUS
5306
FIBER TO ETHERNET SWITCH
5501
REDLION PLC
5202
CAN MODULE
BRAKE HPU 1
3201
ETHERNET I/O
BRAKE HPU 2
4201
ETHERNET I/O
5201
ETHERNET RTD DAQ
5202
ETHERNET RTD DAQ
5203
ETHERNET RTD DAQ
5204
ETHERNET RTD DAQ
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MM
TOLERANCES:
ANGULAR: ±1°
X ±0.5
X.X ±0.2
X.XX±0.1
MATERIAL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
NCH
2017-11-07
CHECKED
JMD
2018-12-04
ENG APPR.
PROPRIETARY AND CONFIDENTIAL
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ORPC
OCEAN RENEWABLE POWER COMPANY
254 COMMERCIAL ST.
SUITE 119B
PORTLAND, ME 04101
USA
(207) 772-7707
TITLE:
SYSTEM COMMUNICATIONS
SIZE
B
DWG. NO.
D-TD20-10150
REV
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SCALE: 1:100
SHEET 1 OF 1

# APPENDIX B – D-TD20-10155 – TIDGEN® 2.0 CONTROL SYSTEM PROCESS

ORPC
OCEAN RENEWABLE POWER COMPANY

## TIDGEN® 2.0 CONTROL SYSTEM PROCESS

***D-TD20-10155***

***Revision 0 - 4/11/2018***

Ocean Renewable Power Company, LLC
254 Commercial St., Ste. 119B
Portland, ME 04101
Phone (207) 772-7707
*www.orpc.co*

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# 1 Revision History

| Revision | Rev. Date | Description | Originator | Approver |
|---|---|---|---|---|
| 0 | 4/11/2018 | Initial release | N. Hayes | C. Marnagh |

# 2 Purpose

This document describes the flow of commands for the TidGen® 2.0 SCADA and CMS systems. General states are defined as well as critical metrics for proceeding to the next state. This document does not define all metrics necessary, nor describes the alarm and fault triggers and the SCADA system responses.

# 3 Cold Start

1. Apply control system power
    1.1. Wait for PLC startup
2. Confirm status of all external devices
3. Confirm DC export contactors closed
4. Enable row one brake HPU
5. Confirm row one brake operations
    5.1. Oil Pressure OK
    5.2. Oil Temperature OK
    5.3. Brake engaged
    5.4. Brake not over travelled
6. Enable row two brake HPU
7. Confirm row two brake operation
    7.1. Oil Pressure OK
    7.2. Oil Temperature OK
    7.3. Brake engaged
    7.4. Brake not over travelled
8. Confirm status of generator one
9. Confirm status of generator two
10. Perform automatic backup of data log test
11. Wait for back-up batteries to reach capacity
12. System ready for start

# 4 Automatic System

In Automatic mode, the turbine start procedure handle the switching of control modes as the tidal flow increases in velocity while the turbine stop procedure handles the switching as the flow decreases. At any time if the flow does not increase enough to switch to the next control system, SCADA will move from the turbine start routine to the turbine stop. This will be the case if the TidGen® is in lower flow sites and still keep the SCADA system universal between all installed devices.

## 4.1 Turbine Start

1. Monitor water speed/Tidal clock
   1.1. If water speed > 1.0m/s proceed to next step
2. Turn on brake HPU
3. Wait for HPU warmup
   3.1. Oil pressure OK
   3.2. Oil temperature OK
4. Release Generator parking brake
   4.1. Open short-circuit contactor
   4.2. Close main contactor
5. Start generator in speed control
6. Switch generator to $k\omega^2$ controller
   6.1. Record RPM as *starting RPM*
7. Switch generator to torque control when reaching 45kN-m torque
   7.1. Record as power as *kω² power limit*
8. Switch generator to power control when reaching 225kW output
   8.1. Record power as *torque control power limit*
   8.2. If power drops below *torque control power limit* jump to step 10.
9. Open contactor when generator reaches 93RPM.
   9.1. Record flow speed as *power limit water speed*

## 4.2 Turbine Stop

1. Monitor water speed
   1.1. If water speed < 3.5m/s move to next step
2. When flow speed drops below *power limit water speed*
   2.1. Enable power limited control
3. When power drops below *torque control power limit*
   3.1. Enable torque limited control
4. When power drops below *kω² power limit*,
   4.1. Enable $k\omega^2$ control
5. When RPM drops below *starting RPM*
   5.1. Enable speed control mode
   5.2. Ramp generator speed to 0.
   5.3. Generator enters 'Park pending' state
6. Engage mechanical brake
7. Turn off mechanical brake HPU when generator parking brake enabled.
   7.1. Close short-circuit contactor

## 4.3 System monitoring

1. Record all CMS signals at 1Hz
2. Monitor sensor alarm limits
3. If warning occurs, trigger datalogging of non-CMS signals, send warning to shore station
4. Monitor sensor fault limits

5. If fault occurs, trigger system shutdown, trigger datalogging of CAN bus values & HPU valves and commands until shutdown complete

### 4.4 Data Logging

1. Record all CMS signals at 1Hz
2. Store 1 hour of data to disk
3. PLC sync 6 hours of files to shore station through FTP
4. After 24 hours of data, overwrite files.

# APPENDIX C – D-TD20-10148 – INSTRUMENTATION AND EQUIPMENT LIST

| | | | | | ALARM TRIP LIMITS | | FAULT TRIP LIMITS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| TAG NUMBER | SERVICE DESCRIPTION | MANUFACTURER | MODEL NO. | SYSTEM CONNECTION | LOW | HIGH | LOW2 | HIGH3 | SIGNAL TYPE | I/O |
| CR-001A | Buoyancy tank humidty | OMEGA | HX71-MA | Alarm System | N/A | 15% RH | N/A | 15% RH | Analog | In |
| CR-001B | Buoyancy tank humidty | OMEGA | HX71-MA | Alarm System | N/A | 15% RH | N/A | 15% RH | Analog | In |
| CR-001C | Buoyancy tank humidty | OMEGA | HX71-MA | Alarm System | N/A | 15% RH | N/A | 15% RH | Analog | In |
| CR-001D | Buoyancy tank humidty | OMEGA | HX71-MA | Alarm System | N/A | 15% RH | N/A | 15% RH | Analog | In |
| CR-001E | Buoyancy tank humidty | OMEGA | HX71-MA | Alarm System | N/A | 15% RH | N/A | 15% RH | Analog | In |
| CR-001F | Buoyancy tank humidty | OMEGA | HX71-MA | Alarm System | N/A | 15% RH | N/A | 15% RH | Analog | In |
| WR-001A | Bridle line tension | | | System Monitoring | 450kN | 575kN | 375kN | 675kN | Analog | In |
| WR-001B | Bridle line tension | | | System Monitoring | 450kN | 575kN | 375kN | 675kN | Analog | In |
| WR-001C | Bridle line tension | | | System Monitoring | 450kN | 575kN | 375kN | 675kN | Analog | In |
| WR-001D | Bridle line tension | | | System Monitoring | 450kN | 575kN | 375kN | 675kN | Analog | In |
| PR-001A | Device water pressure | Omni Instruments | PTM/N-32-2-10-55-513-05-1-4-U-K | System Monitoring | N/A | 400kPa | N/A | 450kPa | Analog | In |
| PR-001B | Anchor water pressure | Omni Instruments | PTM/N-32-2-10-55-5013-05-1-4-U-K | System Monitoring | N/A | N/A | N/A | N/A | Analog | In |
| ZR-001AX | Device Surge Acceleration | | | System Monitoring | N/A | N/A | N/A | N/A | Analog | In |
| ZR-001BY | Device Sway Acceleration | | | System Monitoring | N/A | N/A | N/A | N/A | Analog | In |
| ZR-001CZ | Device Heave Acceleration | | | System Monitoring | N/A | N/A | N/A | N/A | Analog | In |
| ZR-001DX | Device Roll Rate | | | System Monitoring | N/A | N/A | N/A | N/A | Analog | In |
| ZR-001EY | Device Pitch Rate | | | System Monitoring | N/A | N/A | N/A | N/A | Analog | In |
| ZR-001FZ | Device Yaw Rate | | | System Monitoring | N/A | N/A | N/A | N/A | Analog | In |
| TR-002 | Water temperature | | | System Monitoring | N/A | N/A | N/A | N/A | Analog | In |
| SR-002A | Water point velocity | Valeport | 803002-A | System Monitoring | N/A | 3.5m/s | N/A | 4.0m/s | Analog | In |
| SR-002B | Water point velocity | Valeport | 803002-A | System Monitoring | N/A | 3.5m/s | N/A | 4.0m/s | Analog | In |
| SR-002C | Water point velocity | Valeport | 803002-A | System Monitoring | N/A | 3.5m/s | N/A | 4.0m/s | Analog | In |
| SR-002D | Water point velocity | Valeport | 803002-A | System Monitoring | N/A | 3.5m/s | N/A | 4.0m/s | Analog | In |
| TR-005 | Enclosure Temperature | ProSense | XTP50N-030-N40140F | Alarm System | | | | | Analog | In |
| PR-005 | Enclosure Pressure | Endress | PMP21-CA1M2KJVU | Alarm System | | | | | Analog | In |
| CR-005 | Enclosure Humidity | OMEGA | HX71-MA | Alarm System | N/A | 15% RH | N/A | 15% RH | Analog | In |
| YR-005A | Converter 1 DC +Contactor | ABB | GAF460-11 | System Operation | | | | | Digital | Out |
| YR-005B | Converter 1 DC -Contactor | ABB | GAF460-11 | System Operation | | | | | Digital | Out |
| YR-005C | Converter 2 DC +Contactor | ABB | GAF460-11 | System Operation | | | | | Digital | Out |
| YR-005D | Converter 2 DC -Contactor | ABB | GAF460-11 | System Operation | | | | | Digital | Out |
| IR-005A | DC Link Current 1 | Automation Direct | DCT200-42-24-F | System Monitoring | N/A | 200 A | N/A | 230A | Analog | In |
| IR-005B | DC Link Current 2 | Automation Direct | DCT200-42-24-F | System Monitoring | N/A | 200 A | N/A | 230A | Analog | In |
| ER-005A | DC Link Voltage 1 | MAGNELAB | DVT-1000 | System Monitoring | 950VDC | 1050VDC | 900VDC | 1100VDC | Analog | In |
| ER-005B | DC Link Voltage 2 | MAGNELAB | DVT-1000 | System Monitoring | 950VDC | 1050VDC | 900VDC | 1100VDC | Analog | In |
| TR-006 | Enclosure Temperature | ProSense | XTP50N-030-N40140F | Alarm System | | | | | Analog | In |
| PR-006 | Enclosure Pressure | Endress | PMP21-CA1M2KJVU | Alarm System | | | | | Analog | In |
| CR-006 | Enclosure Humidity | OMEGA | HX71-MA | Alarm System | N/A | 15% RH | N/A | 15% RH | Analog | In |
| ER-007A | DC Link Voltage | | | System Monitoring | 950VDC | 1050VDC | 900VDC | 1100VDC | Analog | In |
| IR-007A | DC Link Current | | | System Monitoring | N/A | 200 A | N/A | 230A | Analog | In |
| ER-007B | AC Voltage | | | System Monitoring | | | | | Analog | In |
| IR-007B | AC Current | | | System Monitoring | | | | | Analog | In |
| SR-007 | AC Frequency | | | System Monitoring | | | | | Analog | In |
| TR-101A | Bearing Temperature | | | Alarm System | N/A | 100C | N/A | 175C | Analog | In |
| TR-101B | Bearing Temperature | | | Alarm System | N/A | 100C | N/A | 175C | Analog | In |
| TR-101C | Bearing Temperature | | | Alarm System | N/A | 100C | N/A | 175C | Analog | In |

| | | | | | ALARM TRIP LIMITS | | FAULT TRIP LIMITS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| TAG NUMBER | SERVICE DESCRIPTION | MANUFACTURER | MODEL NO. | SYSTEM CONNECTION | LOW | HIGH | LOW2 | HIGH3 | SIGNAL TYPE | I/O |
| TR-101D | Bearing Temperature | | | Alarm System | N/A | 100C | N/A | 175C | Analog | In |
| TR-101E | Bearing Temperature | | | Alarm System | N/A | 100C | N/A | 175C | Analog | In |
| TR-101F | Bearing Temperature | | | Alarm System | N/A | 100C | N/A | 175C | Analog | In |
| TR-101G | Bearing Temperature | | | Alarm System | N/A | 100C | N/A | 175C | Analog | In |
| TR-101H | Bearing Temperature | | | Alarm System | N/A | 100C | N/A | 175C | Analog | In |
| TR-101J | Bearing Temperature | | | Alarm System | N/A | 100C | N/A | 175C | Analog | In |
| TR-101K | Bearing Temperature | | | Alarm System | N/A | 100C | N/A | 175C | Analog | In |
| TR-101L | Bearing Temperature | | | Alarm System | N/A | 100C | N/A | 175C | Analog | In |
| TR-101M | Bearing Temperature | | | Alarm System | N/A | 100C | N/A | 175C | Analog | In |
| SR-101 | Driveshaft Speed | | | System Monitoring | N/A | 93 RPM | N/A | 110 RPM | Digital | In |
| TR-102A | Oil Temperature | | | Alarm System | | | | | Analog | In |
| LR-102A | Oil Level | | | Alarm System | | | | | Analog | In |
| CR-102 | Oil Humidity | | | Alarm System | | | | | Analog | In |
| TR-102B | Sump Temperature | | | Alarm System | | | | | Analog | In |
| LR-102B | Sump Level | | | Alarm System | | | | | Analog | In |
| PR-102A | Line Pressure | | | Brake Operation | | | | | Analog | In |
| PR-102B | Brake Pressure | | | Brake Operation | | | | | Analog | In |
| YR-102A | Starter Solenoid | | | Brake Operation | N/A | N/A | N/A | N/A | Digital | Out |
| YR-102B | Starter Solenoid | | | Brake Operation | N/A | N/A | N/A | N/A | Digital | Out |
| PR-102C | Pressure Switch | | | Brake Operation | N/A | N/A | N/A | N/A | Digital | In |
| YR-102C | Solenoid Position | | | Brake Operation | N/A | N/A | N/A | N/A | Digital | In |
| YR-102D | Solenoid Position | | | Brake Operation | N/A | N/A | N/A | N/A | Digital | In |
| YR-102E | Solenoid Position | | | Brake Operation | N/A | N/A | N/A | N/A | Digital | In |
| YR-102F | Solenoid Position | | | Brake Operation | N/A | N/A | N/A | N/A | Digital | In |
| YR-102G | Brake On Position | | | Brake Operation | N/A | N/A | N/A | N/A | Digital | In |
| YR-102H | Brake Off Position | | | Brake Operation | N/A | N/A | N/A | N/A | Digital | In |
| YR-102J | Brake Limit Position | | | Alarm System | N/A | N/A | N/A | N/A | Digital | In |
| TR-102 | Enclosure Temperature | ProSense | XTP50N-030-N40140F | Alarm System | | | | | Analog | In |
| PR-102 | Enclosure Pressure | Endress | PMP21-CA1M2KJVU | Alarm System | | | | | Analog | In |
| CR-102 | Enclosure Humidity | OMEGA | HX71-MA | Alarm System | | | | | Analog | In |
| LR-103 | Oil Level | | | Alarm System | | | | | Analog | In |
| CR-103 | Oil Humidity | | | Alarm System | | | | | Analog | In |
| TR-103A | Oil Temperature | | | System Monitoring | | | | | Analog | In |
| TR-103B | Oil Temperature | | | System Monitoring | | | | | Analog | In |
| TR-103C | Stator Temperature | | | Alarm System | | | | | Analog | In |
| TR-103D | Stator Temperature | | | Alarm System | | | | | Analog | In |
| ZR-103A | Connector Acceleration | | | System Monitoring | | | | | Analog | In |
| ZR-103B | Connector Acceleration | | | System Monitoring | | | | | Analog | In |
| ZR-103C | Connector Acceleration | | | System Monitoring | | | | | Analog | In |
| TR-104 | Enclosure Temperature | ProSense | XTP50N-030-N40140F | Alarm System | | | | | Analog | In |
| PR-104 | Enclosure Pressure | Endress | PMP21-CA1M2KJVU | Alarm System | | | | | Analog | In |
| CR-104 | Enclosure Humidity | OMEGA | HX71-MA | Alarm System | | | | | Analog | In |
| TR-201A | Bearing Temperature | | | Alarm System | N/A | 100C | N/A | 175C | Analog | In |
| TR-201B | Bearing Temperature | | | Alarm System | N/A | 100C | N/A | 175C | Analog | In |
| TR-201C | Bearing Temperature | | | Alarm System | N/A | 100C | N/A | 175C | Analog | In |

ORPC

| | | | | | ALARM TRIP LIMITS | | FAULT TRIP LIMITS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| TAG NUMBER | SERVICE DESCRIPTION | MANUFACTURER | MODEL NO. | SYSTEM CONNECTION | LOW | HIGH | LOW2 | HIGH3 | SIGNAL TYPE | I/O |
| TR-201D | Bearing Temperature | | | Alarm System | N/A | 100C | N/A | 175C | Analog | In |
| TR-201E | Bearing Temperature | | | Alarm System | N/A | 100C | N/A | 175C | Analog | In |
| TR-201F | Bearing Temperature | | | Alarm System | N/A | 100C | N/A | 175C | Analog | In |
| TR-201G | Bearing Temperature | | | Alarm System | N/A | 100C | N/A | 175C | Analog | In |
| TR-201H | Bearing Temperature | | | Alarm System | N/A | 100C | N/A | 175C | Analog | In |
| TR-201J | Bearing Temperature | | | Alarm System | N/A | 100C | N/A | 175C | Analog | In |
| TR-201K | Bearing Temperature | | | Alarm System | N/A | 100C | N/A | 175C | Analog | In |
| TR-201L | Bearing Temperature | | | Alarm System | N/A | 100C | N/A | 175C | Analog | In |
| TR-201M | Bearing Temperature | | | Alarm System | N/A | 100C | N/A | 175C | Analog | In |
| SR-201 | Driveshaft Speed | | | System Monitoring | N/A | 93 RPM | N/A | 110 RPM | Digital | In |
| TR-202A | Oil Temperature | | | Alarm System | | | | | Analog | In |
| LR-202A | Oil Level | | | Alarm System | | | | | Analog | In |
| CR-202 | Oil Humidity | | | Alarm System | | | | | Analog | In |
| TR-202B | Sump Temperature | | | Alarm System | | | | | Analog | In |
| LR-202B | Sump Level | | | Alarm System | | | | | Analog | In |
| PR-202A | Line Pressure | | | Brake Operation | | | | | Analog | In |
| PR-202B | Brake Pressure | | | Brake Operation | | | | | Analog | In |
| YR-202A | Starter Solenoid | | | Brake Operation | N/A | N/A | N/A | N/A | Digital | Out |
| YR-202B | Starter Solenoid | | | Brake Operation | N/A | N/A | N/A | N/A | Digital | Out |
| PR-202C | Pressure Switch | | | Brake Operation | N/A | N/A | N/A | N/A | Digital | In |
| YR-202C | Solenoid Position | | | Brake Operation | N/A | N/A | N/A | N/A | Digital | In |
| YR-202D | Solenoid Position | | | Brake Operation | N/A | N/A | N/A | N/A | Digital | In |
| YR-202E | Solenoid Position | | | Brake Operation | N/A | N/A | N/A | N/A | Digital | In |
| YR-202F | Solenoid Position | | | Brake Operation | N/A | N/A | N/A | N/A | Digital | In |
| YR-202G | Brake On Position | | | Brake Operation | N/A | N/A | N/A | N/A | Digital | In |
| YR-202H | Brake Off Position | | | Brake Operation | N/A | N/A | N/A | N/A | Digital | In |
| YR-202J | Brake Limit Position | | | Alarm System | N/A | N/A | N/A | N/A | Digital | In |
| TR-202 | Enclosure Temperature | ProSense | XTP50N-030-N40140F | Alarm System | | | | | Analog | In |
| PR-202 | Enclosure Pressure | Endress | PMP21-CA1M2KJVU | Alarm System | | | | 150kPa | Analog | In |
| CR-202 | Enclosure Humidity | OMEGA | HX71-MA | Alarm System | | | | | Analog | In |
| LR-203 | Oil Level | | | Alarm System | | | | | Analog | In |
| CR-203 | Oil Humidity | | | Alarm System | | | | | Analog | In |
| TR-203A | Oil Temperature | | | System Monitoring | | | | | Analog | In |
| TR-203B | Oil Temperature | | | System Monitoring | | | | | Analog | In |
| TR-203C | Stator Temperature | | | Alarm System | | | | | Analog | In |
| TR-203D | Stator Temperature | | | Alarm System | | | | | Analog | In |
| ZR-203A | Connector Acceleration | | | System Monitoring | | | | | Analog | In |
| ZR-203B | Connector Acceleration | | | System Monitoring | | | | | Analog | In |
| ZR-203C | Connector Acceleration | | | System Monitoring | | | | | Analog | In |
| TR-204 | Enclosure Temperature | ProSense | XTP50N-030-N40140F | Alarm System | | | | | Analog | In |
| PR-204 | Enclosure Pressure | Endress | PMP21-CA1M2KJVU | Alarm System | | | | | Analog | In |
| CR-204 | Enclosure Humidity | OMEGA | HX71-MA | Alarm System | | | | | Analog | In |

| EQUIPMENT TAG. | AREA | EQUIPMENT TYPE | EQUIPMENT NAME | MANUFACTURUER | MFG. PART NO. |
|---|---|---|---|---|---|
| 1201 | TGU 1 CONVERTER BOX | DAQ (AIO, DIO) | Ethernet enabled I/O | Red Lion | E3-16AI20M-1 |
| | | | | | |
| 2201 | TGU 2 CONVERTER BOX | DAQ (AIO, DIO) | Ethernet enabled I/O | Red Lion | E3-16AI20M-1 |
| | | | | | |
| 3201 | TGU 1 HPU ENCLOSURE | DAQ (AIO, DIO) | Ethernet Multi I/O | Red Lion | E3-MIX24880-1 |
| 3602 | TGU 1 HPU ENCLOSURE | FLUID TRANSPORT (BLOWERS, COMPRESSORS, PUMPS) | HPU Pump | TwiFlex | |
| 3703 | TGU 1 HPU ENCLOSURE | CONTAINMENT (TANKS, VESSELS, SUMPS) | HPU Tank | TwiFlex | |
| | | | | | |
| 4201 | TGU 2 HPU ENCLOSURE | DAQ (AIO, DIO) | Ethernet Multi I/O | Red Lion | E30MIX24880-1 |
| 4602 | TGU 2 HPU ENCLOSURE | FLUID TRANSPORT (BLOWERS, COMPRESSORS, PUMPS) | HPU Pump | TwiFlex | |
| 4703 | TGU 2 HPU ENCLOSURE | CONTAINMENT (TANKS, VESSELS, SUMPS) | HPU Tank | TwiFlex | |
| | | | | | |
| 5501 | SENSOR INTEGRATION MOUDLE | CONTROLLER (MOTOR DRIVE, SYSTEM PLC) | SCADA PLC | Red Lion | GRAC00C5 |
| 5202 | SENSOR INTEGRATION MOUDLE | DAQ (AIO, DIO) | CAN Module | Red Lion | GMCAN000 |
| 5203 | SENSOR INTEGRATION MOUDLE | DAQ (AIO, DIO) | Analog Input Module | Red Lion | GMINI800 |
| 5204 | SENSOR INTEGRATION MOUDLE | DAQ (AIO, DIO) | Analog Input Module | Red Lion | GMINI800 |
| 5205 | SENSOR INTEGRATION MOUDLE | DAQ (AIO, DIO) | Analog Input Module | Red Lion | GMINI800 |
| 5306 | SENSOR INTEGRATION MOUDLE | COMMUNICATION (SWITCH, CONVERTER, SERVER) | Fiber to Ethernet Converter & Switch | MOXA | EDS-316-SS-SC |
| 5107 | SENSOR INTEGRATION MOUDLE | POWER (SUPPLY, CONVERTER) | 24 VDC PSU | SOLA | SDN 5-24-100P |
| 5108 | SENSOR INTEGRATION MOUDLE | POWER (SUPPLY, CONVERTER) | 24 VDC Battery | SOLA | SDU-24-BAT |
| 5109 | SENSOR INTEGRATION MOUDLE | POWER (SUPPLY, CONVERTER) | 24 VDC Battery | SOLA | SDU-24-BAT |
| 5110 | SENSOR INTEGRATION MOUDLE | POWER (SUPPLY, CONVERTER) | 24 VDC Battery Module | SOLA | SDU-10-24 |
| 5111 | SENSOR INTEGRATION MOUDLE | POWER (SUPPLY, CONVERTER) | 25 VDC Battery Module | SOLA | SDU-10-24 |
| 5212 | SENSOR INTEGRATION MOUDLE | DAQ (AIO, DIO) | Ethernet RTD ACQ | Red Lion | E3-10RTD-1 |
| 5213 | SENSOR INTEGRATION MOUDLE | DAQ (AIO, DIO) | Ethernet RTD ACQ | Red Lion | E3-10RTD-1 |
| 5214 | SENSOR INTEGRATION MOUDLE | DAQ (AIO, DIO) | Ethernet RTD ACQ | Red Lion | E3-10RTD-1 |
| 5215 | SENSOR INTEGRATION MOUDLE | DAQ (AIO, DIO) | Ethernet RTD ACQ | Red Lion | E3-10RTD-1 |
| | | | | | |
| 7201 | DC-LINK JUNCTION | DAQ (AIO, DIO) | Ethernet Multi I/O | Red Lion | E30MIX24880-1 |
| | | | | | |
| 8401 | STRUCTURE | MOTOR | Rolls Royce Marine Generator | Rolls Royce Marine | 50490-0002 |
| 8402 | STRUCTURE | MOTOR | IKM Generator | IKM | |
| | | | | | |
| 6101 | SHORE STATION | POWER (SUPPLY, CONVERTER) | Inverter | SATCON | |
| 6102 | SHORE STATION | POWER (SUPPLY, CONVERTER) | Transformer | | |
| 6203 | SHORE STATION | DAQ (AIO, DIO) | Ethernet Analog Input | | |
| 6304 | SHORE STATION | COMMUNICATION (SWITCH, CONVERTER, SERVER) | Fiber to Ethernet Converter & Switch | MOXA | EDS-316-SS-SC |
| 6505 | SHORE STATION | CONTROLLER (MOTOR DRIVE, SYSTEM PLC) | System PC | | |