LEARNING FROM TURBINE ALARMS INTEGRATED WITH SCADA

CHALLENGE SETTERS INFO PACK

GENERIC REPORT

AUTHOR // Alistair Lee
DATE // 15/09/2020

In partnership with

Document History

Revision	Date	Prepared by	Checked by	Approved by	Revision History
Rev 1	15/09/2020	Alistair Lee	Craig Stout	Craig Stout	Final

Contents

1 Levenmouth Demonstration Turbine (LDT)

The Offshore Renewable Energy Catapult (ORE Catapult) own and operate a 7MW Samsung demonstration offshore wind turbine, located at Levenmouth in Fife, Scotland. The turbine is located a mere 40 m off the coast of Fife – connected to shore by a gangway as shown in Figure 2 and Figure 3.

LDT offers access to the worlds largest and most advanced open access offshore wind turbine dedicated to research and demonstration activity. Since acquiring the turbine in 2015, ORE Catapult have enabled access to LDT for over 120 SMEs for technology development, testing or demonstration. The turbine is now also a source of data for external parties to use for research and development activities - data is hosted on our online Platform for Operational Data (POD) – access POD via the ORE Catapult webpage here.

LDT specifications are provided in Figure 1 below. See more info on the turbine via the ORE Catapult webpage - linked here.

Features

Wind class
IEC Class I_A/ S_B

Rotor dia.
171.2m

Capacity
7MW at grid side

Hub height
110.6m

Blade length
83.5m

Total height
196m blade tip to sea level

Generator
Medium voltage PMG (3.3kV)

Converter
Full power conversion

Drive train
Medium speed (400rpm)

Rated frequency
50Hz

Rotor speed
5.9 ~ 10.6rpm

Wind speed
3.5 ~ 25m/s

Temp. range
Survival
-20°C to +50°C
Operating
-10°C to +25°C

Lightning protection level
Level 1 (IEC 62305-1)

Corrosion category (ISO 12944-5)
Inside : C4
Outside : C5-M

Design life
25 years

Control system features

- Independent and collective pitch control modes
- Active drivetrain damping
- Active load control
- Blade load monitoring

Complementary measurement opportunities

- Access hatches on roof
- Land-side flat locations for lidar installation (including 1 pad with electrical connections)
- On-site IEC met mast with cup anemometry currently installed
- Deck space on transition piece for small instruments

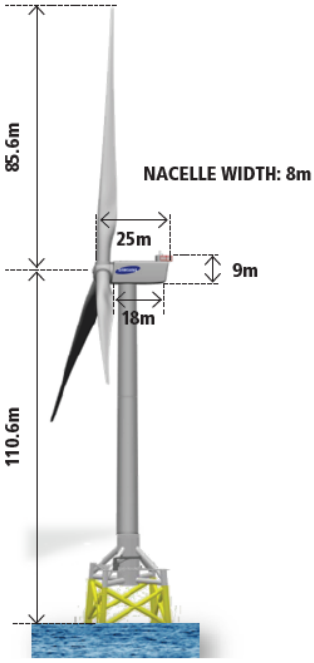

Figure 1: LDT specifications

LDT has hundreds of sensors that capture data on all aspects of the turbine's performance – 574 signals are currently available for analysis. This data consists of measurements such as: power generation, rotational speeds and orientations, oil and ambient air temperatures and pressures, environmental conditions, boolean operations and electronic measurements. Additionally, alarm data is available which provides a timeseries log of all of the alarms activating on the turbine at any one time.

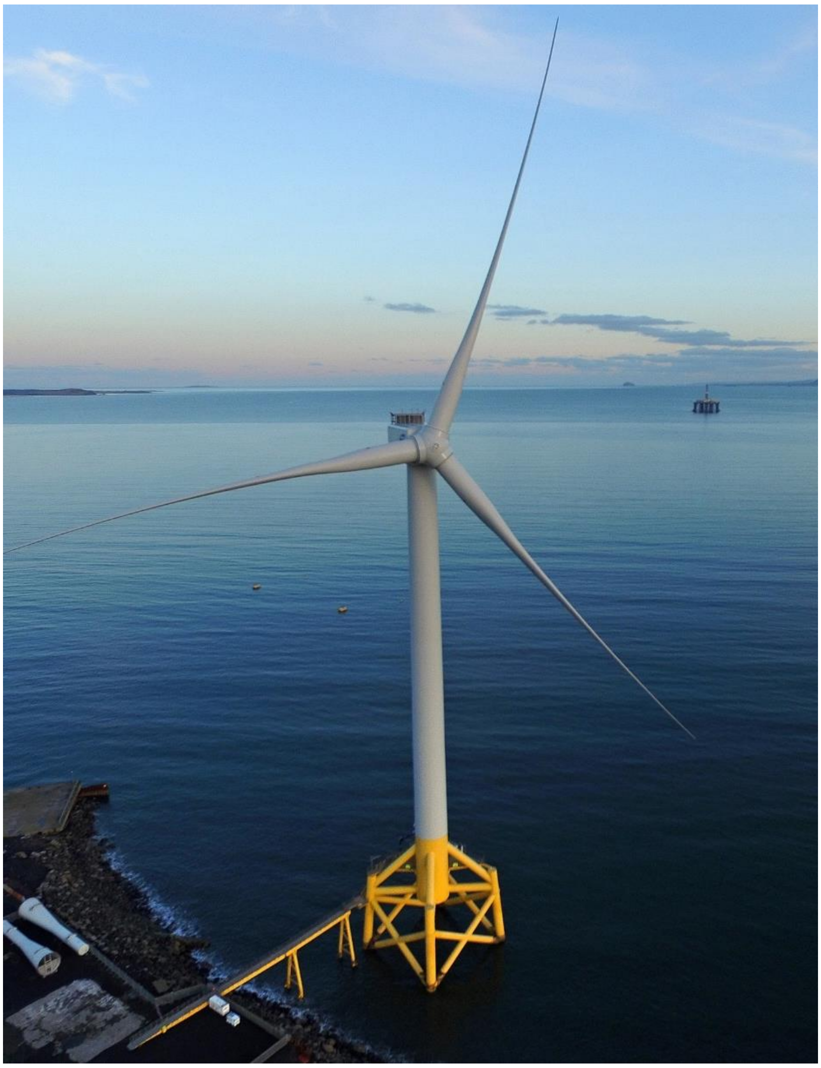

Figure 2: LDT

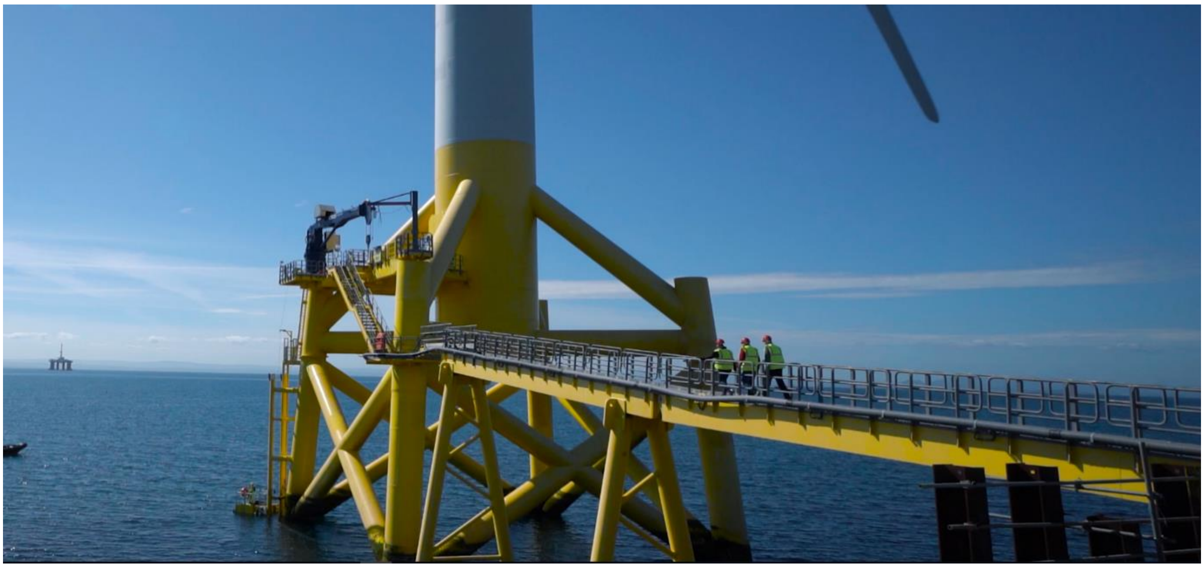

Figure 3: LDT gangway

2 Challenge Context

Offshore wind turbines generate many different data streams, two of the most easily accessed are Supervisory Control and Data Acquisition (SCADA) signals and Alarm records. Whilst these data streams are commonly used separately, a lot of value gain can be achieved by combining them in analyses.

This challenge asks participants to combine these two data streams to analyse turbine shutdown events. What alarms are active when the turbine shuts down? Are there commonalities between shutdown types? Are certain SCADA streams more active during a shutdown? What can be determined as the route cause alarm during a shutdown?

A shutdown event is normally determined by analysing the SCADA data, then asking the question as to what alarms are active over this period. At the ORE Catapult, the rotor speed is analysed to determine shutdown events, looking for periods where the rotor speed reduces to 0 rpm, then looking at how quickly the rotor speed reduced from an operational speed to 0 rpm, giving a ramp-down rate in rpm/s. When looking for these events it is important to discount times when the rotor stops rotating due to low wind scenarios, i.e. the wind speed dropping below the cut in wind speed for the turbine.

A potentially more accurate way of analysing shutdown events would be to investigate the generator speed instead of the rotor speed. This could give more accuracy to the investigation and may give more indication as to how much load is going through the turbine. A similar process would be used as has been described for analysing the rotor speed, but periods where the generator speed drops to 0 rpm would be investigated.

2.1 Main SCADA Tags

The main SCADA tags when investigating shutdowns are provided in Table 1.

Table 1: Useful SCADA signals

Signal	SCADA Tag	Description	Units
Power	Iconics DA OPC.P135S1_Site_T01.Turbine.SubIprPrivPwr	Active power	W
Pitch Angle/Position	Iconics DA OPC.P135S1_Site_T01.Turbine.SubPtchPosition1	Blade 1 pitch angle	°
	Iconics DA OPC.P135S1_Site_T01.Turbine.SubPtchPosition2	Blade 2 pitch angle	°
	Iconics DA OPC.P135S1_Site_T01.Turbine.SubPtchPosition3	Blade 3 pitch angle	°
Pitch Rate	Iconics DA OPC.P135S1_Site_T01.Turbine.SubPtchRate1	Blade 1 pitch rate	°/s
	Iconics DA OPC.P135S1_Site_T01.Turbine.SubPtchRate2	Blade 2 pitch rate	°/s
	Iconics DA OPC.P135S1_Site_T01.Turbine.SubPtchRate3	Blade 3 pitch rate	°/s

Signal	SCADA Tag	Description	Units
Wind Speed	Iconics DA OPC.P135S1_Site_T01.Turbine.WindSpeed1	Windspeed from anemometer 1	m/s
	Iconics DA OPC.P135S1_Site_T01.Turbine.WindSpeed2	Windspeed from anemometer 2	m/s
	Iconics DA OPC.P135S1_Site_T01.Turbine.WindSpeed3	Windspeed from anemometer 1	m/s
Rotor Rotational Speed	Iconics DA OPC.P135S1_Site_T01.Turbine.RotorSpeedAve	Average rotation speed over a minute	RPM
Generator Speed	Iconics DA OPC.P135S1_Site_T01.Turbine.GenSpeedRelay	Generator speed obtained from inductive pickups	Rad/s
Nacelle Direction	Iconics DA OPC.P135S1_Site_T01.Turbine.NacPosition1	Nacelle position from yaw encoder 1	°
	Iconics DA OPC.P135S1_Site_T01.Turbine.NacPosition2	Nacelle position from yaw encoder 2	°
Ambient Temperature	Iconics DA OPC.P135S1_Site_T01.Turbine.AmbTemp	Ambient Temperature	°C

2.2 Alarms of interest

Pitch system alarms are a common occurrence for LDT and these alarms lead to a large amount of the turbine's shutdowns. This might be an area of interest for participants, investigating what the SCADA pitch signals are doing during a period where a pitch alarm is active and/or causing a shutdown.

2.3 Example of Slow Shutdown

In the shutdown event visualised in Figure 4 is a slow shutdown. Here, it can be seen that the turbine is at rated rotor speed (~11 rpm) but fluctuating between just before rated power and full rated power (7MW). During this period the rotor is at full speed so the turbine will be controlling the pitch of the blades to ensure it can capture the full energy from the wind and shed any extra energy that may be captured, ensuring the power does not exceed 7MW.

A shutdown event is then triggered, and the rotor speed reduces, going through an intermediate period at around 5 rpm where the rotor speed normalises for a period before reducing again. Once the turbine has shutdown, it remains off.

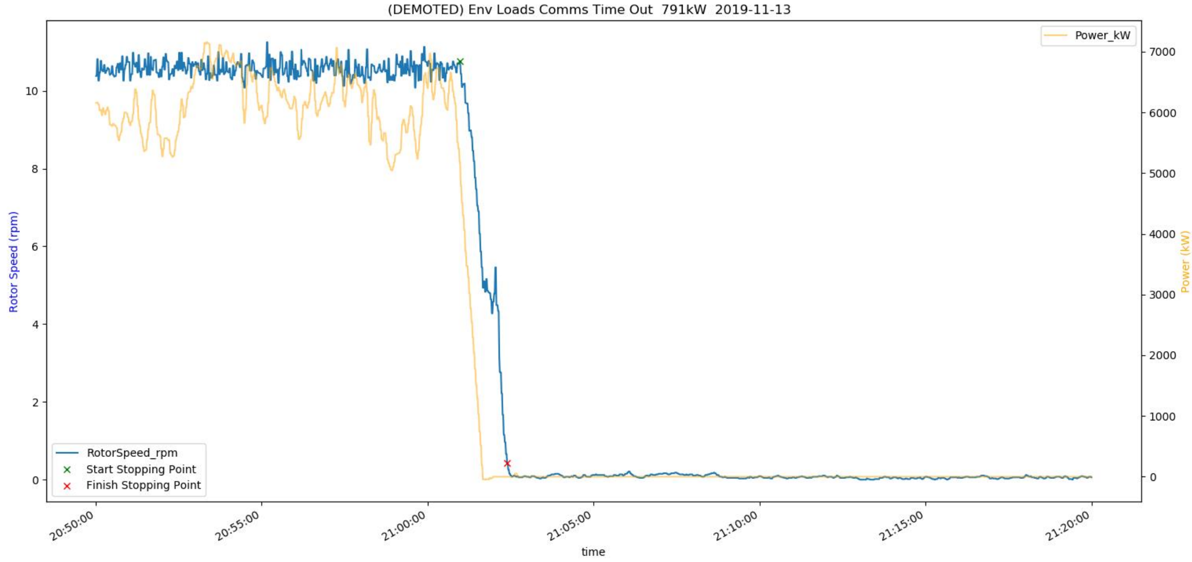

Figure 4: Example of slow shutdown

2.4 Example of Fast Shutdown

The shutdown visualised in Figure 5 is as a fast shutdown, a type of shutdown that is generally avoided. In this shutdown scenario both the rotor speed and power are not yet at their rated values but are at a constant level. A shutdown event is then triggered and the rotor speed rapidly reduces to 0 rpm. Faster shutdowns like this are seen as more damaging on the turbine as a rapid shutdown like this, where breaking from the blades is used in addition to breaking from the rotor, will put excessive loads on the rotor system as well as the blades. When investigating fast shutdowns participants should look at the rotor speed to see how quickly this reduces (rpm/s), the pitch should also be investigated to see how this varies before, during and after this period.

This shutdown is particularly interesting as after the shutdown event the turbine powers back up before repeating the same shutdown procedure. Repeated shutdowns such as this, should be investigated by the participants to ask the question, why is this happening?

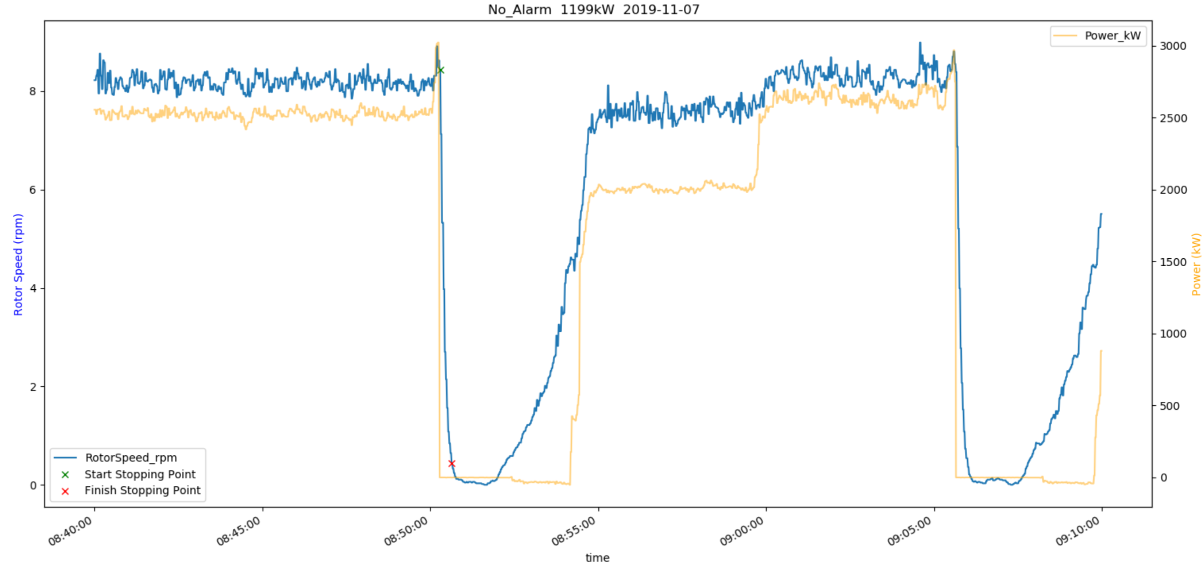

Figure 5: Example of fast shutdown

3 Working with Alarm Data

When an event occurs on the Levenmouth Demonstration Turbine, multiple alarms go off in parallel. In the below example (see Table 2) an event has occurred, and two alarms have gone off in close succession of each other. These alarms are stored as a timestamp when the alarm turns on, then a following timestamp when the alarm turns off, this behaviour can be seen in Table 2.

When an event occurs and multiple alarms are raised, these alarms are grouped together into what is called a "cluster". The time allowed between alarms, to still be included in the same cluster, is up for discussion and everything from 10s to 60mins is used within industry. Increasing this time comes with the risk that different events will be combined into the one cluster, whereas reducing this time comes with the risk that one event is broken into two clusters. A cluster can then be defined by one alarm, the alarm which is seen as the most important (the route cause alarm), common practise is that the first occurring alarm is used, although it is known that this is not necessarily the route cause alarm.

Table 2: Cluster of alarms

ID	Unit	Event Time (GMT)	Type	Code	Value	Description	User	Comment
4649702	T01	25/08/2020 23:57:24	Alert2	T867	Off	PcsDcVoltage		
4649701	T01	25/08/2020 23:57:22	Alert2	T867	On	PcsDcVoltage		
4649700	T01	25/08/2020 23:57:08	Alert2	T867	Off	PcsDcVoltage		
4649699	T01	25/08/2020 23:57:06	Alert2	T867	On	PcsDcVoltage		

For the Levenmouth turbine, the alarm "A_TestRN" (see below example in Table 3) means that the turbine has been restarted and all alarms have turned off. This happens when a hard reset of the turbine is required. When this occurs, there will not be individual timestamps for the different alarms turning off (in Table 2 this would be ID4649702 and 4649700), in this case it should be assumed that all alarms have turned off.

Table 3: Turbine reset alarm

ID	Unit	Event Time (GMT)	Type	Code	Value	Description	User	Comment
4648122	T01	20/08/2020 15:19:08	Alert5	T277	Off	A_TestRN		

A good way of analysis the turbine alarms is to go through the alarms in chronological order, keeping a record of all alarms that are on. If the alarm subsequently turns off, store the alarm as a historical alarm with an on and off time. For Table 2 this would result in Table 4. If the alarm "A_TestRN" occurs, store all alarms that are on as historical alarms, with an on and off time, with the off time being the time the alarm "A_TestRN" occurred.

Table 4: Processed alarms

ID	Type	Code	Description	Time On	Time Off
1	Alert2	T867	PcsDcVoltage	25/08/2020 23:57:06	25/08/2020 23:57:08
2	Alert2	T867	PcsDcVoltage	25/08/2020 23:57:22	25/08/2020 23:57:24

Contact

GLASGOW

Inovo
121 George Street
Glasgow
G1 1RD

T +44 (0)333 004 1400

BLYTH

National Renewable Energy Centre
Offshore House
Albert Street
Blyth, Northumberland
NE24 1LZ

T +44 (0)1670 359 555

LEVENMOUTH

Fife Renewables Innovation Centre (FRIC)
Ajax Way
Leven
KY8 3RS

GRIMSBY

O&M Centre of Excellence
Port Office
Cleethorpe Road
Grimsby
DN31 3LL

ABERDEEN

Subsea UK
30 Abercrombie
Court Prospect Road,
Westhill
Aberdeenshire
AB32 6FE

CORNWALL

Hayle Marine Renewables Business Park
North Quay
Hayle, Cornwall
TR27 4DD

PEMBROKESHIRE

Bridge Innovation Centre
Pembroke Dock
Pembrokeshire
SA72 6UN

CHINA

11th Floor, Lan Se Zhi Gu No.5
Ke Ji Avenue, Hit-Tech Zone
Yantai City
Shandong Province
China

LOWESTOFT

Orbis Energy
Wilde Street
Lowestoft,
Suffolk
NR32 1XH

Email us: info@ore.catapult.org.uk
Visit us: ore.catapult.org.uk

Engage with us: