MODELLING PITCH SYSTEM BEHAVIOUR WITH HIGH FREQUENCY DATA

CHALLENGE SETTERS INFO PACK

GENERIC REPORT

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In partnership with

Document History

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ORE Catapult

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

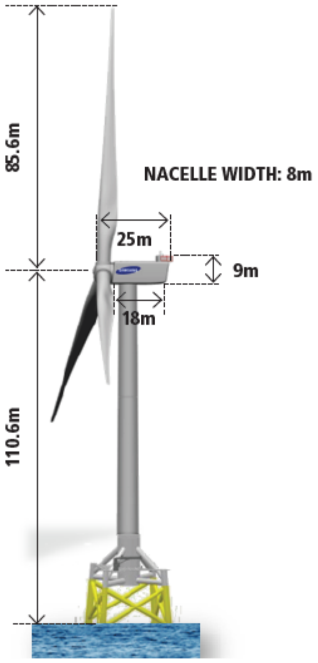

Figure 1: LDT specifications

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.

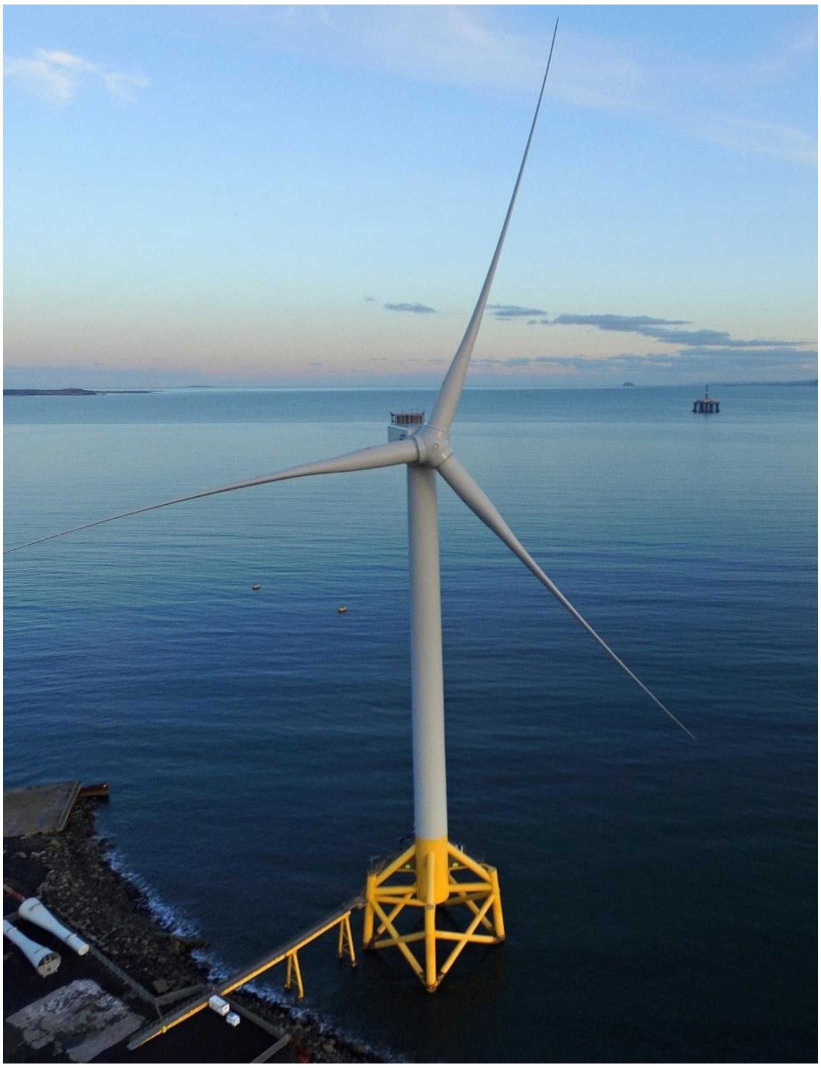

Figure 2: LDT

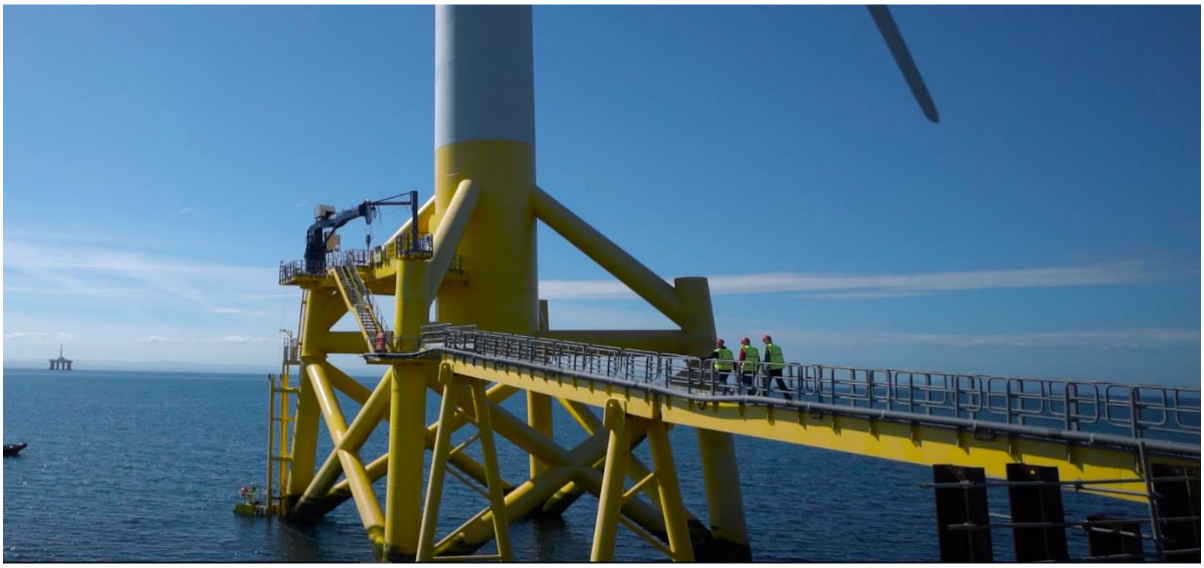

Figure 3: LDT gangway

2 Challenge Context

2.1 Challenge overview

One of the common causes of downtime of wind turbines are pitch system faults/failures – where the pitch system is the means of wind turbine blade rotation. The blades rotate to optimise the air flow over the blades (to generate lift) and to regulate the rotational speed of the turbine rotor. As such, the pitch system is an active part of the wind turbine control system.

Predicting the behaviour of the pitch system – or the deviation from normal operation of this system – could indicate an impending failure or fault. The aim of this challenge, therefore, is to use SCADA data (of high resolution) to determine how the pitch system operates and to detect deviations from normal behaviour.

2.2 Working with SCADA data

The data which is generated by an operational wind turbine is referred to as Supervisory Control and Data Acquisition (SCADA) data. LDT provides 574 SCADA signals which are available for analysis. Key signals which may be of particular interest for the context of this challenge, are detailed in Table 1. These are just a highlighted selection of signals commonly used when analysing data from wind turbines – additional signals which are available in the dataset may be of use to this challenge.

Note that the signal names have

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
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

Signal	SCADA Tag	Description	Units
	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

2.3 Common analysis methods

Common analysis techniques used with SCADA data are timeseries, scatter and histogram plots. These convey the normal operation of the turbine and are to go-to means of looking at SCADA data. There are several plots commonly used to understand wind turbine SCADA data, some are presented in Figure 4, Figure 5and Figure 6.

Figure 4 shows a typical power curve, which indicates the power generated by a wind turbine for a given windspeed. Where the windspeed is typically measured by a nacelle-mounted anemometer.

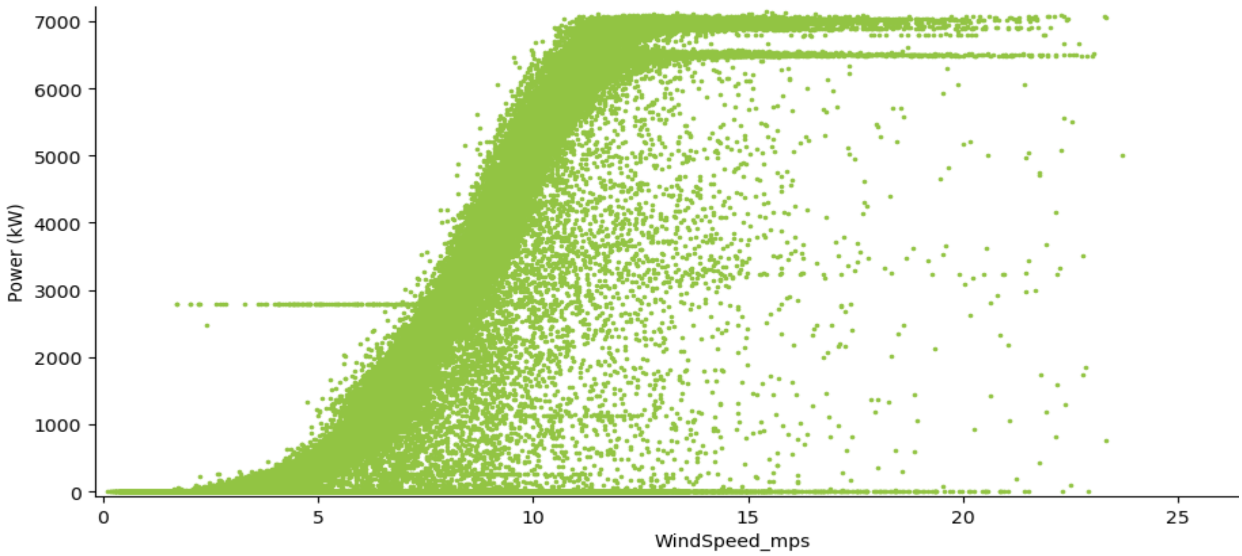

Figure 4: Windspeed versus power scatter plot

Figure 5 presents a Pitch-Power curve which presents the relationship between the wind turbine blade rotation and the power generated. This is often used to detect curtailment – which otherwise may be missed in a typical power curve. See more on curtailment in Section 2.4.

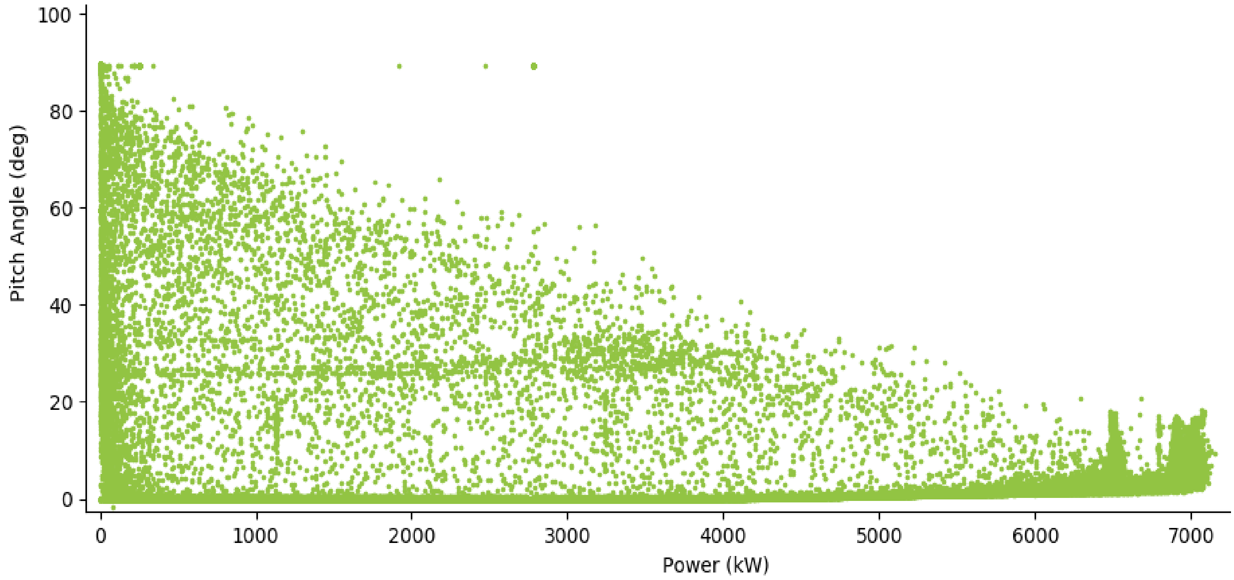

Figure 5: Power versus blade pitch scatter plot

Figure 6 presents a typical histogram used to determine the prevailing wind direction at a site. In Figure 6, the peak is evident around 230° - thus indicating this is the most common orientation of the wind turbine and therefore is the most common wind direction.

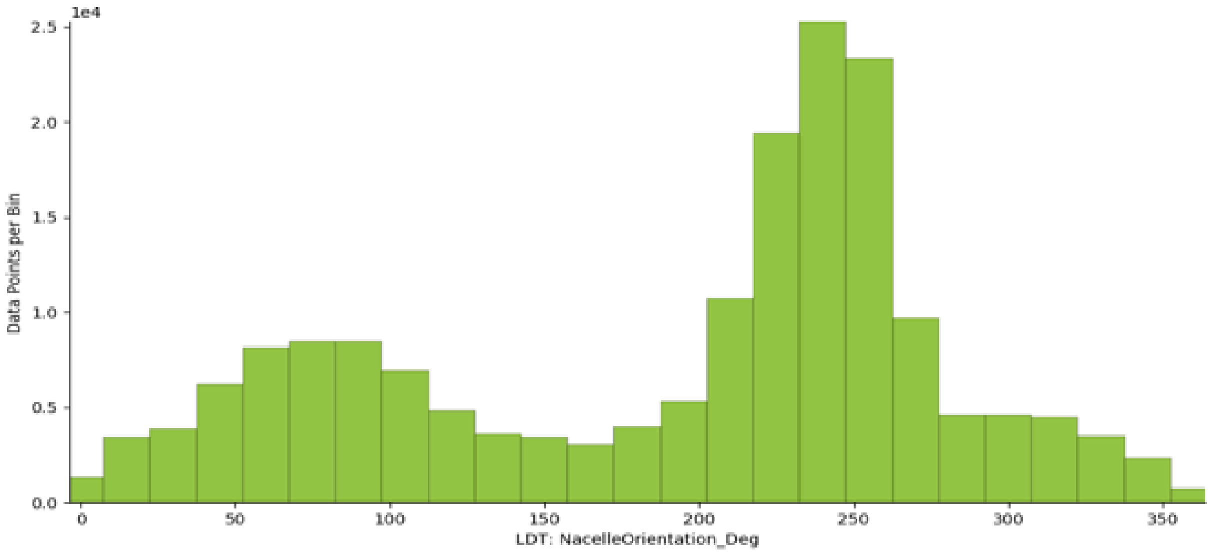

Figure 6: Nacelle direction histogram

2.4 A note on curtailment:

As previously mentioned, the pitch system is responsible for the rotation of the wind turbine blades. This is used to curtail wind turbines – where curtailment is the deliberate down-rating (i.e. deliberately reducing the maximum power output of a turbine). Curtailment is induced on a wind turbine for a number of reasons, including:

- **grid curtailment** due to limits on the power requirements of the grid
- **turbulence curtailment** due to turbulent wind flow which causes vibration of the wind turbine
- **shadow flicker curtailment** due to the orientation of the sun to the turbine which leads to flickering lights induced by the rotation of the wind turbine rotor
- **Power curtailment** due to the deliberate down rating of the turbine to save itself from damage due to a known fault of a key component

Curtailment is evident in the plots below, Figure 7 and Figure 8, as highlighted in pink in each graph. In these plots, the turbine has been deliberately down-rated. Therefore the turbine blades are pitched prior to reaching the normal rated power of the turbine. By pitching the blades the turbines sheds power by reducing the amount of lift the blades generate.

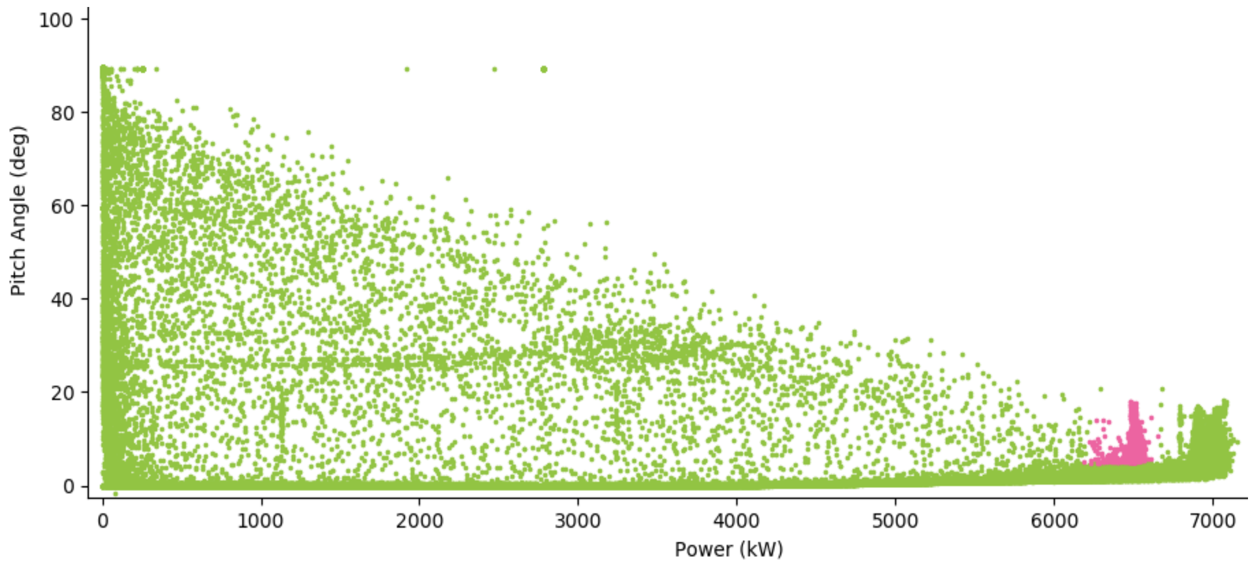

Figure 7: Power versus Pitch scatter plot - curtailment points highlighted

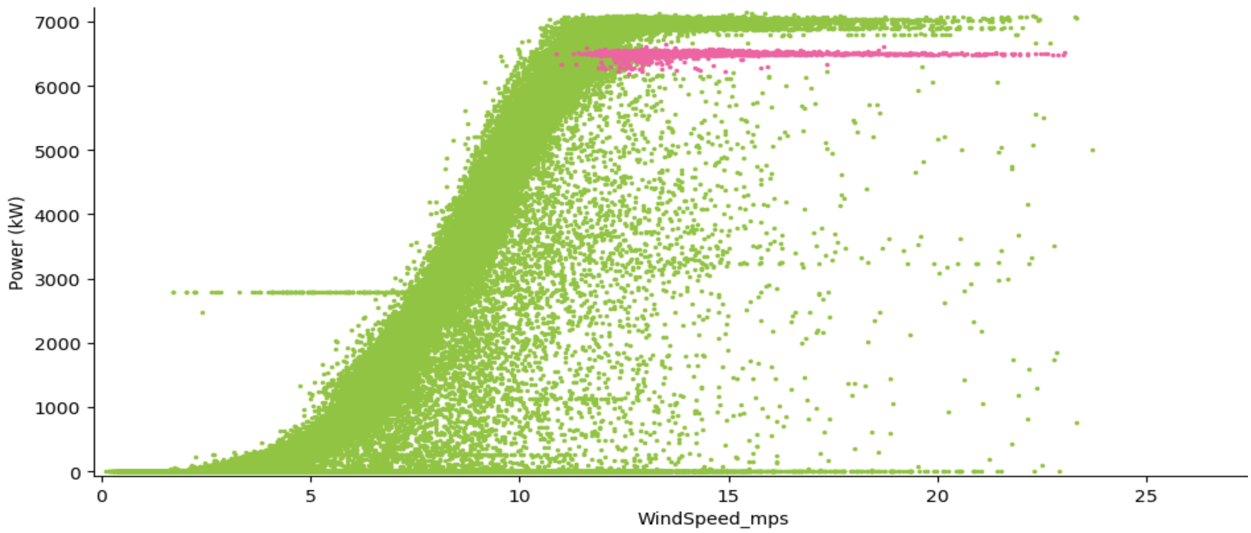

Figure 8: Windspeed versus Power plot - curtailment points highlighted

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