

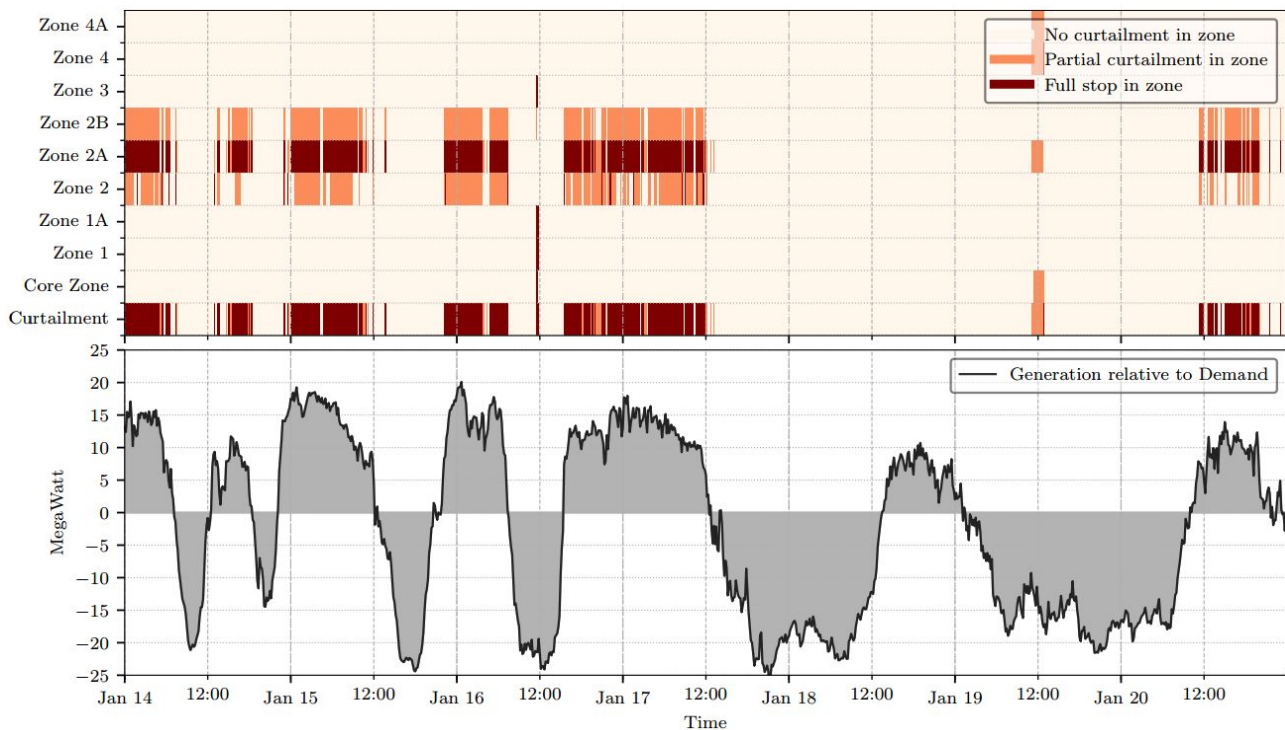
Powering the Orkney Cloud

Modeling and Understanding Curtailment in Orkney

MSc Thesis Executive Summary

The **Active Network Management (ANM)** system in Orkney issues curtailment of generators in order to ensure the stability of the electrical grid. However, there has been a lot of **uncertainty about the concrete logic** of the ANM, making it hard for orcadians to determine when and why their turbines are being curtailed. This summary covers the main findings about **ANM behaviour and curtailment modeling and forecasting**. The full thesis report is available [here](#).

The analysis is based on the **real-time data** exposed by Scottish and Southern Electricity Networks (SSEN) on their ANM-subpages,¹ showing **current power generation and demand** for all of Orkney, as well as the **curtailment status in each ANM-zone**.² Data was collected in 10-minute intervals since December 2018 to construct a **historical dataset**. This dataset is then used to **evaluate assumptions** about the ANM and **derive models** describing the behaviour of the ANM, as well as to provide interesting **visualisations** of the patterns of curtailment:³



The generation relative to the demand, along with the curtailment status in each individual zone for January 14th-20th 2019.

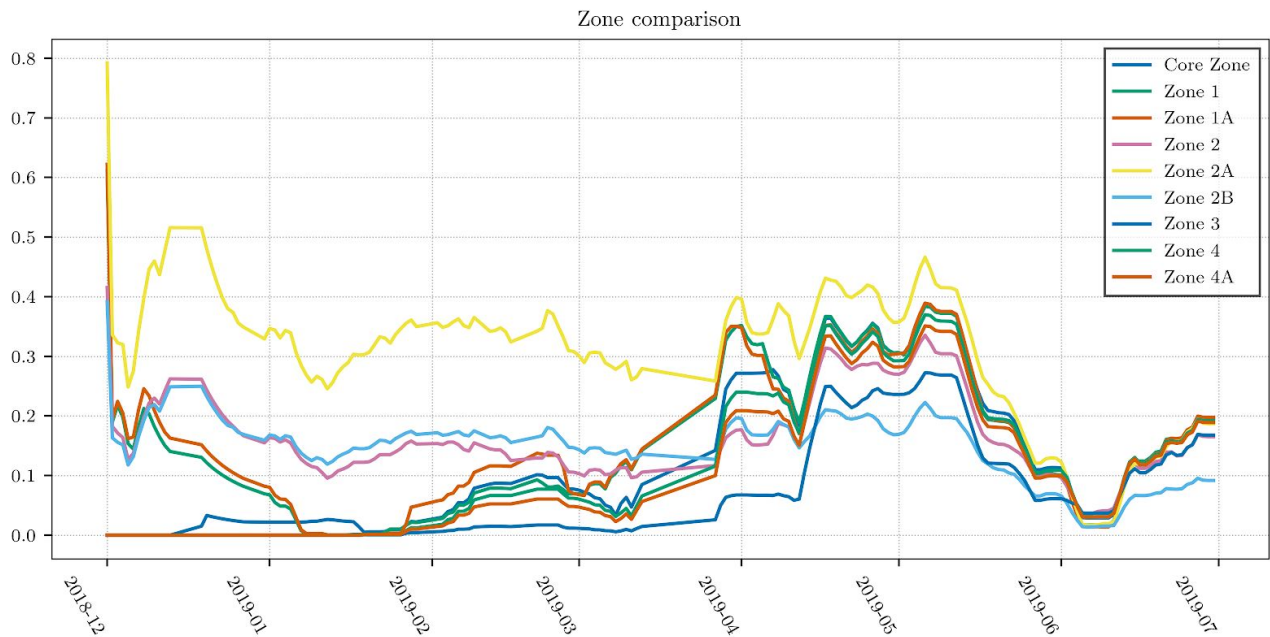
¹ <https://www.ssen.co.uk/ANM/> and <https://www.ssen.co.uk/ANMGeneration/>

² These statuses only indicate *whether* curtailment is present, and not how many watts is currently curtailed. This means that the analysis focuses on *time with curtailment* and not so much the *degree of curtailment*.

³ A service is available to generate these graphs at <http://curtailment.net/>

ANM Behaviour:

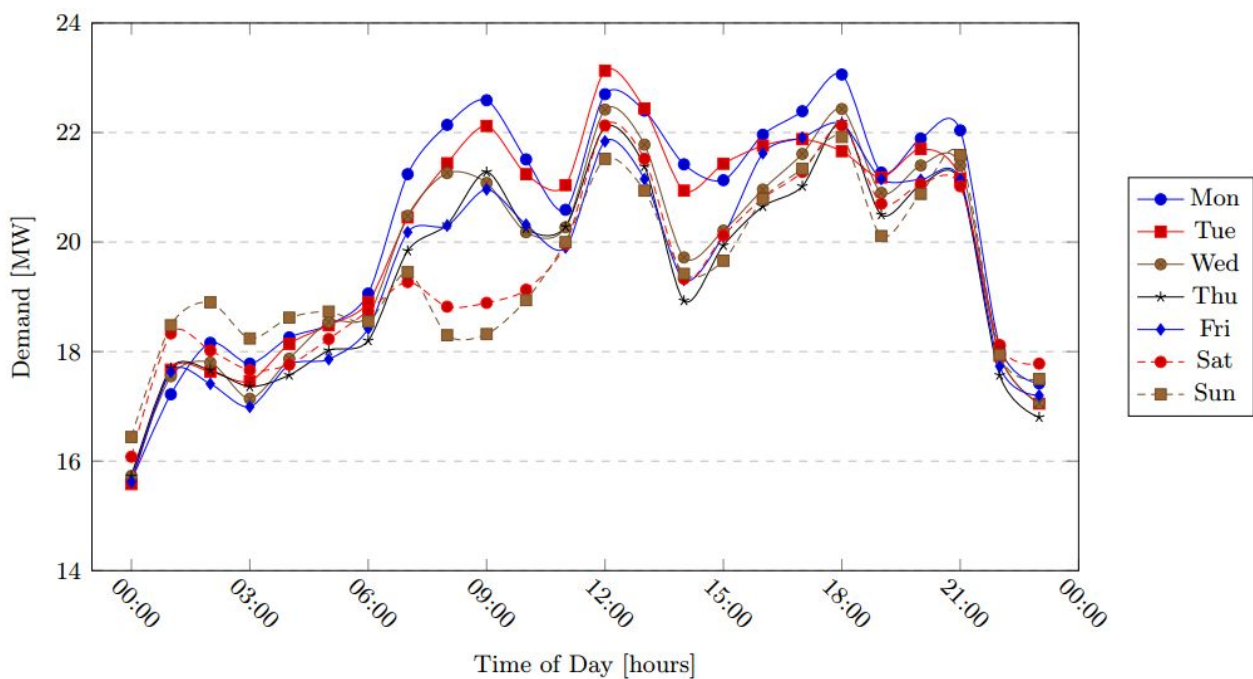
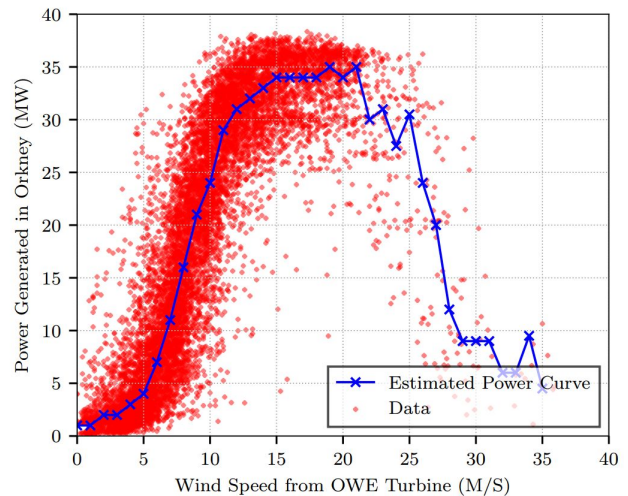
1. As the only outgoing power transmission cable from Orkney is a 20MW cable to Scotland, we assume that curtailment will happen when power generation exceeds the current demand by 20MW. **This assumption does not hold**, as this model has extremely poor accuracy on our dataset (**41%** accuracy on a binary classification).
 - For comparison, a model that **always predicts curtailment** has an accuracy of **59%**.
 - The best performing model issues curtailment, when generation is **just 5MW above demand**
2. When doing anomaly detection and data cleaning, we found that **52% of all reported curtailment was anomalous**, as defined by a small set of rules.
 - A large part of this curtailment happened although **current demand was higher than current generation**.
 - Several times curtailment **was only issued in a single zone**, seemingly unaffected by the statuses in the other zones
3. The prioritization of which generators to curtail is supposed to follow a **“Last on, first off”-principle**, ordered by contract date. But from our data we can see that the ordering of **which zones are most heavily curtailed, changes over time**. This is the case both when redacting anomalies and without.
 - In the following graph, we can see that Zone 2B goes from being the second most curtailed, to the least curtailed.



A rolling average of the time with curtailment in each zone (0 = never, 1 = always), from December 2018 through June 2019. The rolling average has a window size of 14 days.

Modeling and forecasting curtailment:

1. As the vast majority of Orkney energy production is wind-based, the generation can be estimated by looking at the **relationship between wind speeds and power generation** in each of our data samples. From this we can extract a combined **power curve for all of Orkney**.
2. It is possible to **estimate the demand in orkney** by looking at the time-of-day and day-of-week.



3. We use **the difference between the estimated generation and the estimated demand** as an indicator of whether curtailment will be issued. Through statistical analysis, we construct a **risk-curve**, describing the probability of curtailment based on the difference between generation and demand.
4. By combining this wind-and-time model with external weather forecasts, we can **forecast curtailment 5 days into the future** with up to **91% certainty**.
 - This model was evaluated on 66,000 weather forecasts sourced from the UK Met Office
 - The **forecasting service** is available at <http://forecast.curtailment.net/>

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