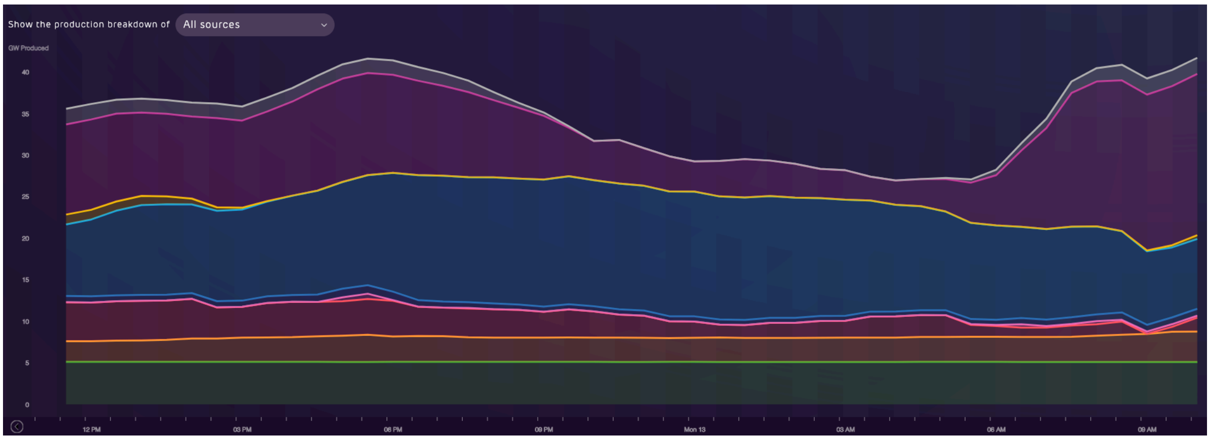
Data Science Task

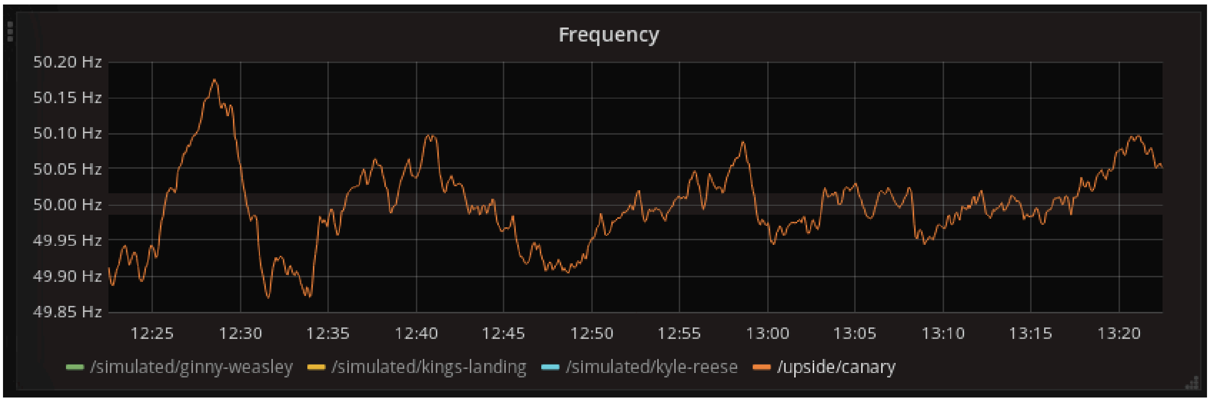
Background

Electrical energy cannot be stored at grid scale for long periods of time. This means that generation of power must match the load at a given time --- for example, load increases during world cup final half time as everyone breaks to put the kettle on, and this must be matched by dispatching power stations to provide that power realtime. The status of the grid can be seen live [here](#).



The national grid coordinates this balance using a number of mechanisms: they run [power markets](#) for people to trade power up to the half hour, and have [agreements in place](#) with large generators to request a change in power delivery.

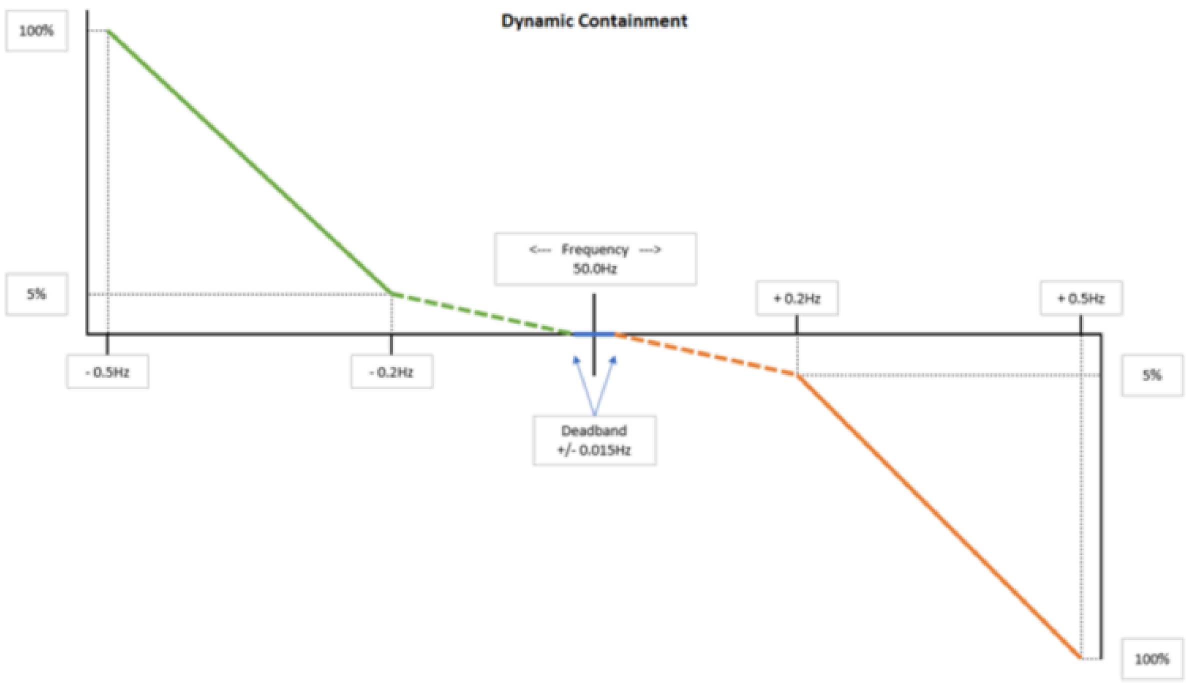
The power generation/consumption balance is reflected in the frequency of the AC power on the grid. The national grid works to balance this at 50Hz. If there is too much generation, it will climb above 50Hz, and if there is too little generation (e.g. due to a fault) then it will fall below 50Hz. The frequency can be seen live [here](#).



Sometimes, all of these mechanisms fail to maintain a regular 50Hz frequency on the grid. The National Grid contracts services to correct for this, one of which is [Dynamic Containment](#).

Dynamic Containment

The Dynamic Containment (DC) service is specified as a response curve, defining the device response power depending on the frequency of the grid:



The y-axis refers to the *contracted power*, described below in the problem parameters.

Note that it is possible to offer DC services in three flavours:

- “High” — respond to high frequency only (by importing power from the grid), do nothing in response to low frequency
- “Low” — respond to low frequency only (by exporting power to the grid), do nothing in response to high frequency
- “Both” — do both of the above

The National Grid puts additional constraints on the response, but these are beyond the scope of this task.

Problem Statement

Kraken Flex wishes to offer DC services to the grid using a number of batteries. Batteries are quick to respond and flexible, but have a fixed energy capacity: long periods of low frequency will empty the battery (and vice versa).

In order to be reasonably confident we can offer this service to the grid, we must be certain that the battery has enough energy stored to handle a long period of low frequency, and enough spare capacity to handle a long period of high frequency. One way of doing this is to calculate how long we can sustain 100% output (e.g. a 1MWh battery could output 500kW for two hours, so we can offer a 500kW service), however, this is very inefficient — in reality the frequency is very close to 50Hz most of the time, so the full output power is only required briefly under rare circumstances. Instead we can take a statistical approach, using past observations to guide our estimates of how much energy we will need for a given period.

Task

Assuming DC service as defined in Appendix A, produce a brief analysis showing:

- The state-of-charge of the battery when running the 'both' DC service with the three contracted powers given;
- The longest time we can expect to run a DC service without either running out of energy, hitting a full state-of-charge, or hitting power limits;
- Your informed opinions on running high, low, both services with different battery sizes: what service would you recommend with this battery?

Expect to take a few minutes to present your findings to us at the start of the interview.

To help you, we have provided some historical data in the form of frequency readings from one of our meters. The format for this is described in Appendix B.

You may use any languages or tools you deem suitable for the task, and any analytical techniques you think appropriate. We tend to use jupyter notebooks, python, or R, but we can probably read and understand most things. Please provide a README describing any dependencies or instructions.

Good luck!

Appendix A: Service Parameters

DC Service Parameters

Refer to the graph above for the shape

```
Deadband:         ±0.015Hz
Elbow:            0.2Hz at 5% power
Full Response:    0.5Hz at 100% power
Service Powers:   2, 5, and 10MW
```

Battery Parameters

The asset to be modelled is a simplified version of a grid-scale battery. It can be thought of as a simple 'bucket of electrons', with a bit of efficiency loss when charging. You may assume that it can be cycled infinitely without loss of capacity or any other physical wear.

```
Energy capacity:      4MWh
Max discharge rate:   5MW
Max charge rate:      4MW
Efficiency:           90%
```

The asset can start and end service at any state-of-charge required.

Appendix B: Data Format

Frequency data are given as a CSV using unix line endings, containing two columns:

- `Datetime` — an ISO8601 timestamp indicating when the reading was taken;
- `f_hz` — the frequency of the electricity grid in Hz.