LCPDelta

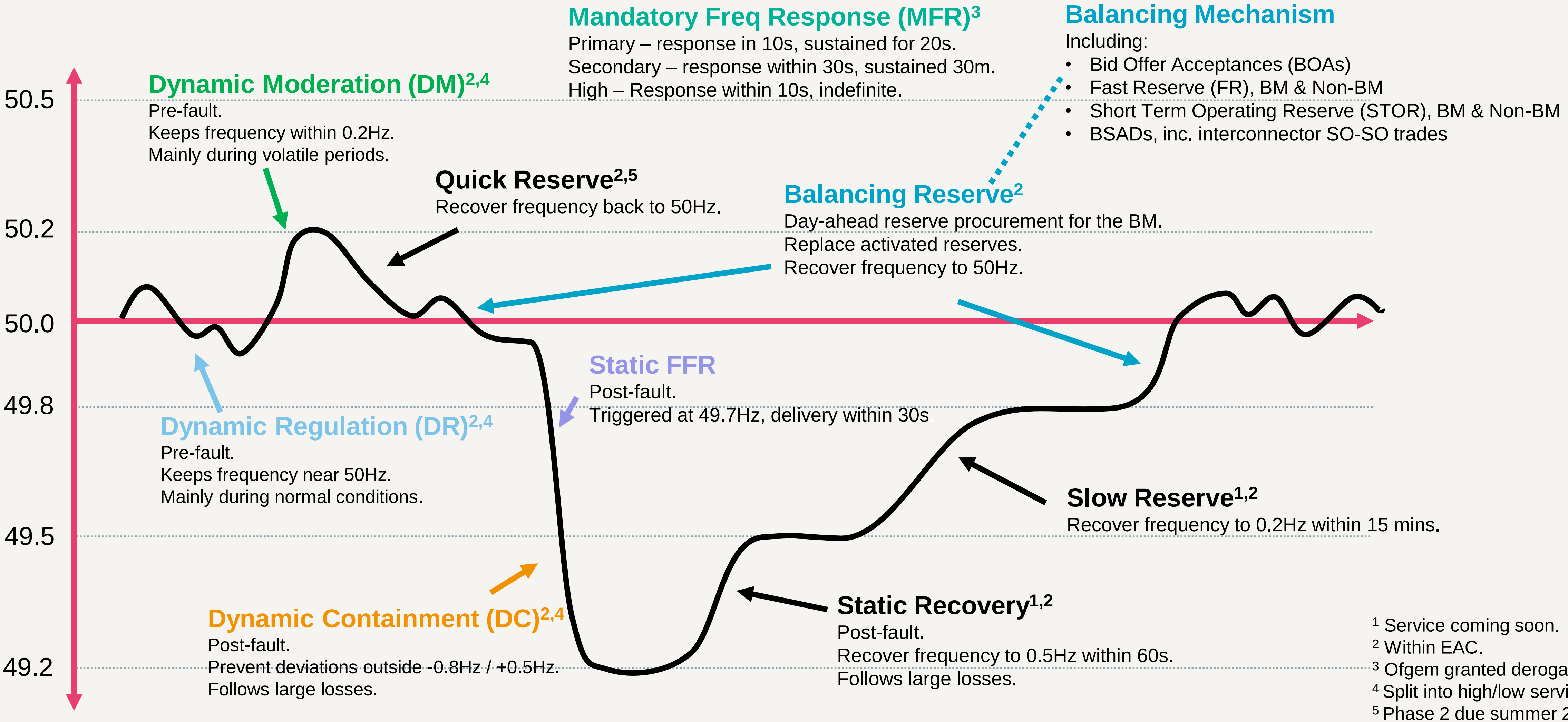
Project 1:

Frequency Response Forecasting for Battery Storage

Background

NESO Services

NESO, the GB system operator, have many tools available for maintaining frequency



[1] Service coming soon.
[2] Within EAC.
[3] Ofgem granted derogation.
[4] Split into high/low services.
[5] Phase 2 due summer 2025

Dynamic Frequency Response (DFR) services

For this project, we will focus on the 3 dynamic (continuously provided) services

Service	Speed (time to full response)	Delivery duration	Frequency range (of 50Hz)	Purpose
Dynamic Containment (DC)	<1 second	15 minutes	-0.8Hz / +0.5Hz	Post-fault
Dynamic Moderation (DM)	<1 second	30 minutes	+/- 0.2Hz	Pre-fault
Dynamic Regulation (DR)	<10 seconds	60 minutes	+/- 0.1Hz	Pre-fault

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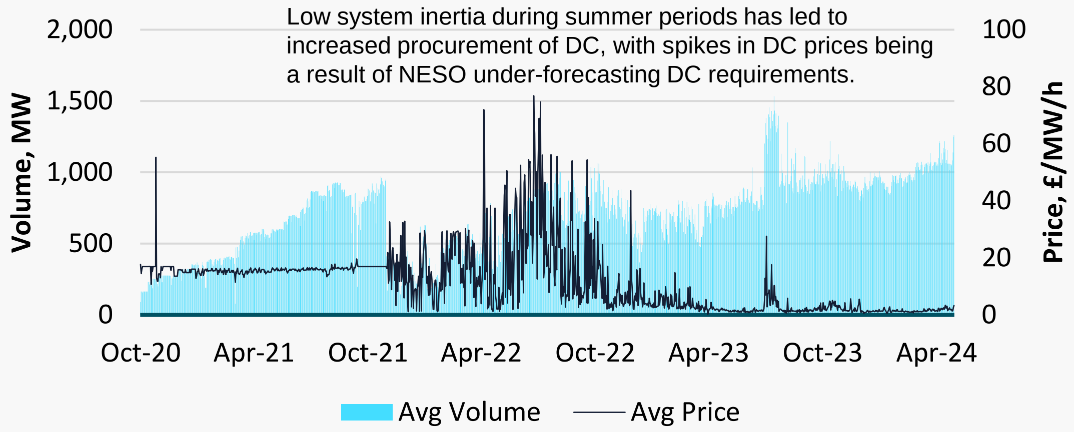
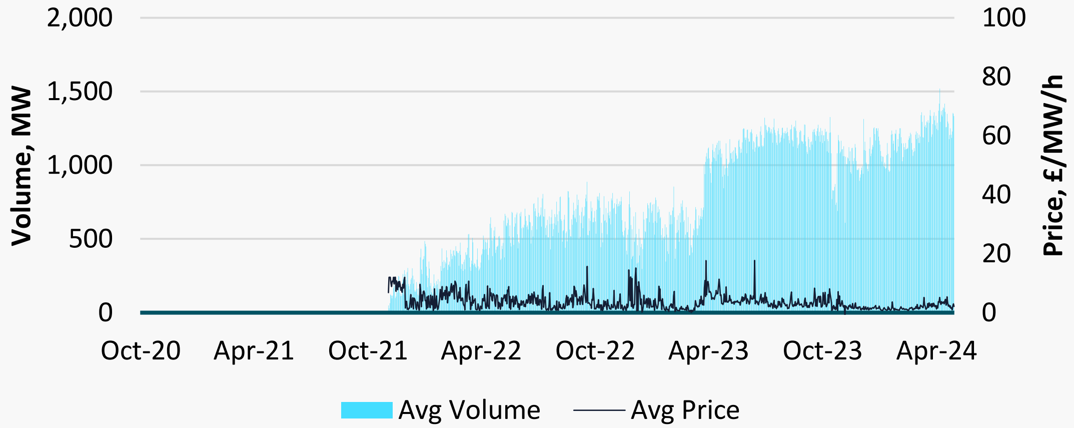
Dynamic Containment

The largest frequency response market within which battery storage participates

Dynamic Containment (Low) – volumes and prices



Dynamic Containment (High) – volumes and prices



Prices have fallen since DC capable capacity exceeded the DC requirement in winter-22. High power prices resulting from the ongoing war in Ukraine helped to buoy DC prices through 2022 but as commodity prices reduced through the winter period the excess in DC capable capacity resulted in prices falling.

The DC requirement is driven by forecasted demand, inertia, largest loss (including loss of mains protection) and the procurement strategies for FFR and stability pathfinders.

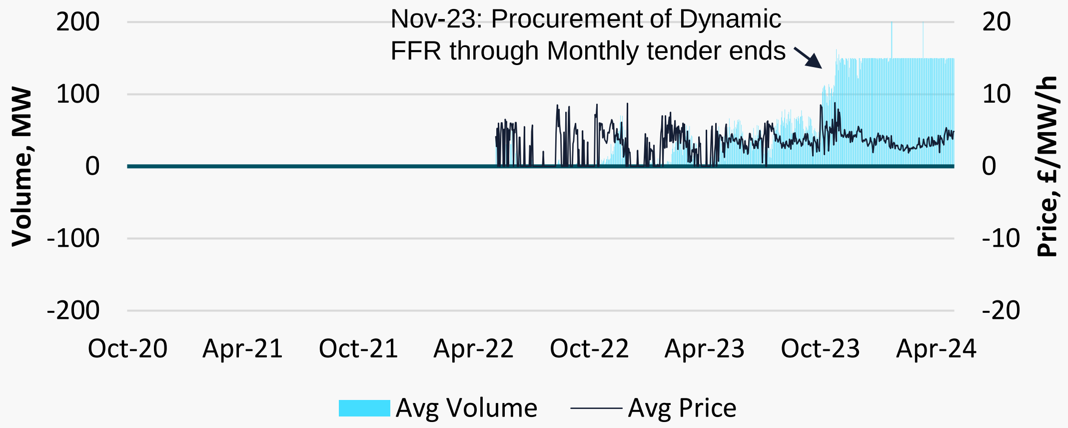
In Nov-23 DC, DM and DR began to be procured through the Enduring Auction Capability (EAC) platform. The launch of the EAC brought a number of changes:

- co-optimised procurement of DC, DM and DR through a single auction
- enabling of negative pricing; and
- updates to penalty calculations (as a result of negative prices being enabled).

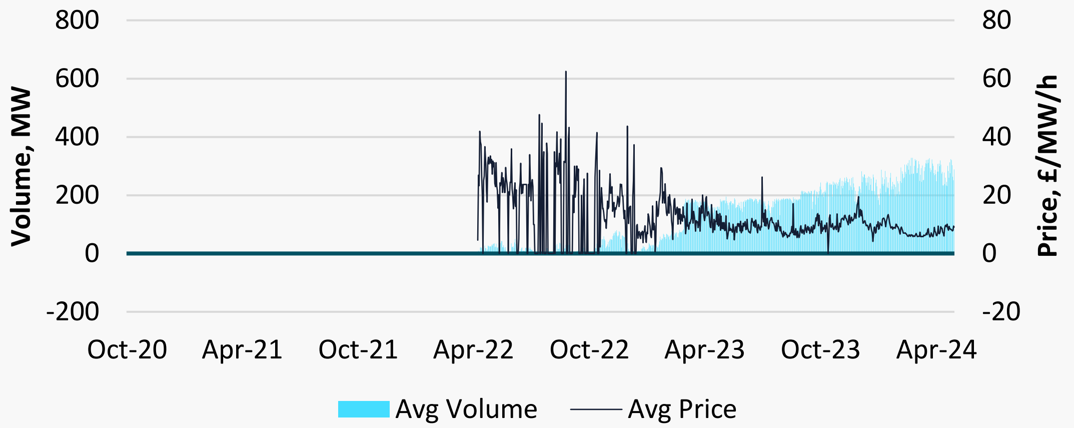
Dynamic Moderation & Dynamic Regulation

'Pre-fault' services

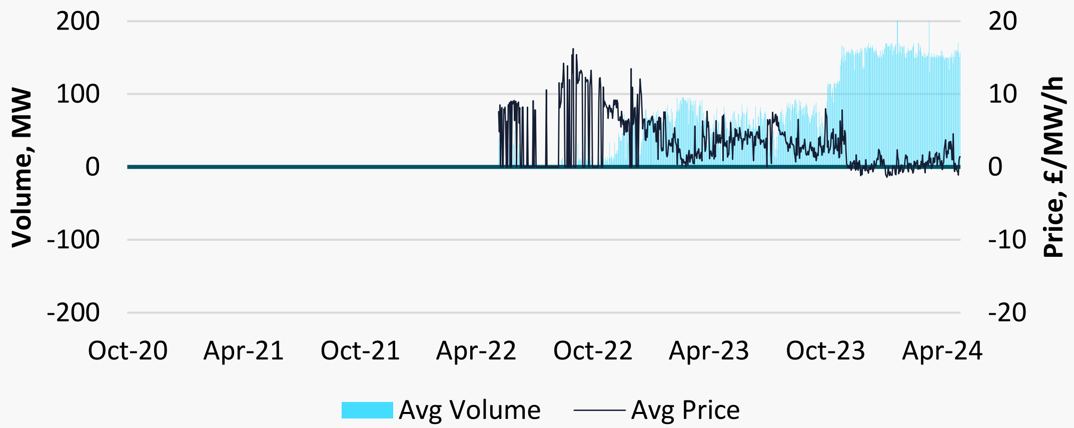
Dynamic Moderation (Low) – volumes and prices



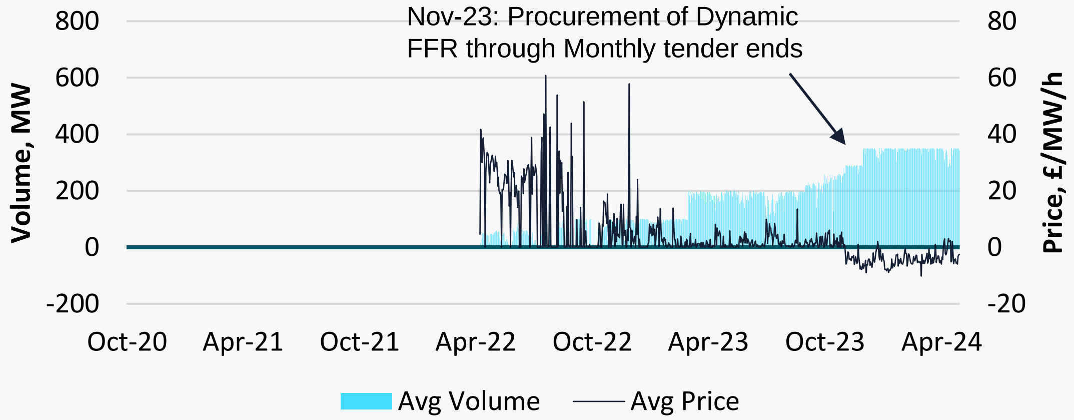
Dynamic Regulation (Low) – volumes and prices



Dynamic Moderation (High) – volumes and prices



Dynamic Regulation (High) – volumes and prices



Dynamic Frequency Response (DFR) auctions

Enduring Auction Capability

When do DFR auctions happen?

Auctions occur daily, where BESS bid to make themselves available to be activated on the delivery day if needed. Delivery windows are divided into 'EFA blocks' – 6x 4-hour periods starting from 11pm the previous day.

The auction for each delivery day is open from 14 days before the delivery day, up until 2.30pm on the day before delivery.

How does the auction work?

NESO forecasts the volume requirement up until the day of the auction, when this is finalised.

Units which meet the technical requirements of the service (almost entirely battery storage) then submit bids into the auctions for each services. They are 'pay-as-clear' auctions, meaning all units receive the highest price that NESO accepted for any unit.

Enduring Auction Capability (EAC)

Since the introduction of EAC in November 2023, units have been able to split their bids across the different services, as well as allowing negatively priced bids (units pay NESO to provide the service).

This has had the impact of increasing competitiveness in each auction and therefore reducing prices.

Bidding strategies

The bidding strategies that DFR providers use have become increasingly complex since the introduction of EAC. Typically, Dynamic Containment will be prioritised as this has by far the largest volume requirements.

In DR High, prices are now often negative as providers use this service to 'charge up', knowing they can sell the energy at a higher price than they are effectively buying it for.

Crucially, units committed to a DFR contract cannot compete in other markets, meaning DFR prices often move in line with wholesale prices.

Project Brief

Frequency Response Forecasting for Battery Storage

Why is price forecasting important?

Accurate DFR price forecasting…

- Allows battery operators to **optimise their capacity** in different markets to **maximise revenue**
- Helps the NESO **understand the drivers of DFR costs and allocate resources efficiently** at optimal costs
- Helps **support the energy transition** by allowing battery operators and owners to more accurately **forecast future revenues and encourage investment**

Key objectives for this project

Your team should focus on…

- **Developing a forecast model** for the day-ahead DFR service prices
- Use historical wholesale electricity prices, demand forecasts and DFR volume requirements, **to improve your model**
- **Assessing your model's accuracy** using metrics and visualise the results effectively

Optional extras you could choose to explore

If you have time, you could look at…

- Exploring **battery operator strategies**, e.g. trading-specific dynamics, affect prices
- Identifying and incorporating **additional factors**, such as generation mix, weather, seasonality, etc
- **Incorporating confidence intervals** or other uncertainty measures to improve the reliability of your forecast

If you're interested in energy trading or optimisation in the future, this project is the type of thing you could be involved in.

Datasets

Dataset	Description	Granularity	Time known	Lagged indicator[1]
DFR prices	**Target variable, across 6x services (DC/DM/DL High/Low)**	**4-hourly (EFA blocks)**	**D-1 @ 2.30pm**	**No**
DFR volume requirement	NESO forecast of DFR requirements per service	4-hourly (EFA blocks)	Up to D-1	No
DFR volumes accepted	Actual procured DFR volumes, across the 6 services	4-hourly (EFA blocks)	D-1 @ 2.30pm	Yes
Day-Ahead hourly prices/volumes	EPEX and N2EX prices and volumes	Hourly	D-1 @ 9-10am	No
Day-Ahead half-hourly prices/volumes	EPEX prices and volumes for half-hourly market (smaller than hourly, but more BESS)	Half-hourly	D-1 @ 3.30pm	Yes
National Demand Forecast	Demand forecast produces by NESO, excluding interconnectors and pumped storage	Half-hourly	D-1 @ 12pm	No

[1]A lagged indicator is only known after the target variable is known but can still be useful.

Getting started:

1. Undertake some further research on the DC, DM and DR markets, focussing on the differentiators between each and how this would affect prices (we can provide useful links if you reach out).
2. Assess the correlation between Day-Ahead prices and the prices in each market, taking account of the different time intervals of each.
3. Analyse the individual datasets, looking at trends over time and whether there are certain ‘step changes’ where patterns changed and whether there is an explanation for this (e.g the introduction of EAC).
4. Use the above research and analysis to inform the choice of time periods and datasets used for training and testing.
5. Start simple and focus on getting a working model for just one of the markets initially.
6. When expanding the modelling approach to the other markets, think about how to take account of the differences between each.
7. Once you have an initial model working, refer to p13 for some ideas on how to improve your model.

Frequency Response Forecasting for Battery Storage

What we expect you to deliver

The output of this work should be a Python notebook, alongside a Report of up to 5 pages, detailing:

- Your choice of modelling approach and what market information was important to consider
- Your selection of time periods for training and testing
- What data has been used as predictor variables, why and how?
- How you have taken account of the different times at which information is known?
- How your model performs against a testing dataset
- Any conclusions you can draw
- What you would do with more time, or more data?

Frequency Response Forecasting for Battery Storage

Ideas to think about:

- How do the high and low services differ from each other? E.g. DC-L vs DC-H
- Which markets are most/least correlated with your feature inputs?
- How might the dynamics of the market have been impacted by changes or by other products?
- How will your model incorporate timesteps and seasonality? EFA block, period, time, day, season, etc.
- How do day-ahead prices relate to DFR prices? Is there a strong correlation there? Why is this?
- What other data will impact DFR prices? E.g. generation, demand, outages, inertia, etc.
- What bidding strategies might DFR providers employ in the auctions and how could this affect prices?
- Any other data that might be available which could be useful? (you can request additional datasets). How might you include asset-level data in your model?

Glossary

Term	Definition
BESS	Battery Energy Storage System – a group of batteries used to store and release energy to the grid.
NESO	National Energy System Operator (formerly part of National Grid, now a not-for-profit owned by the UK government).
DFR	Dynamic Frequency Response – made up of Dynamic Containment (DC), Dynamic Moderation (DM), Dynamic Regulation (DR).
EPEX	A European power exchange which operates day-ahead and intraday markets for GB.
N2EX	The smaller of the two day-ahead exchanges, run by Nord Pool.
Ancillary Services	Services which maintain the stability of the grid, through frequency regulation or more technical requirements.
System Frequency	The frequency of alternating current (AC) in the grid, which is 50Hz in the UK. Electrical appliances only work within a very narrow tolerance of the system frequency.
EFA Block	'Electricity Forward Agreement' Block – the size of the procurement blocks for ancillary services, which consist of 6x 4-hour blocks, starting at 11pm the previous day.
EAC	Enduring Auction Capability – NESO's new platform for procuring frequency response

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