ETH Data Days 2023: Predicting Power Imbalances in European Grid

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Who We Are

Our Team

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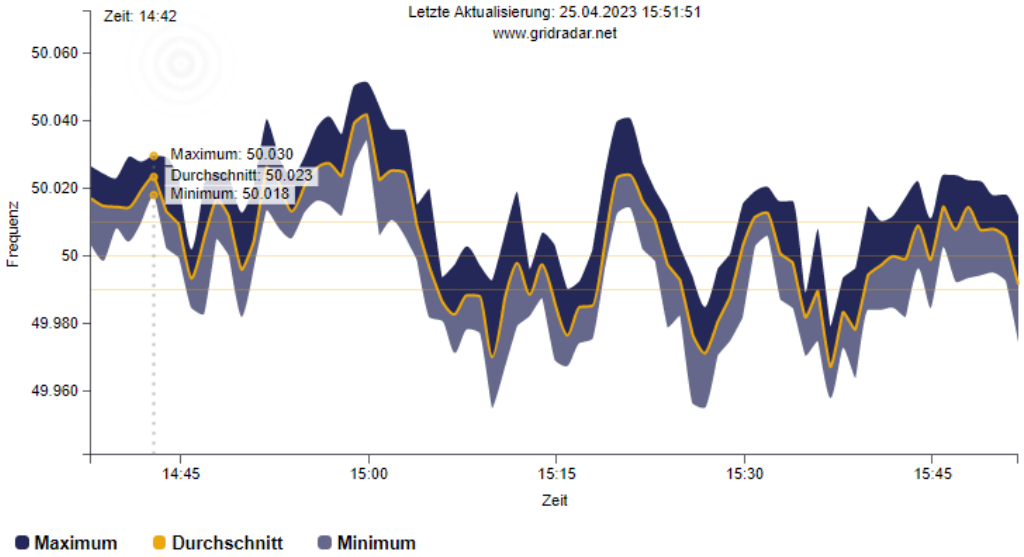
The Challenge

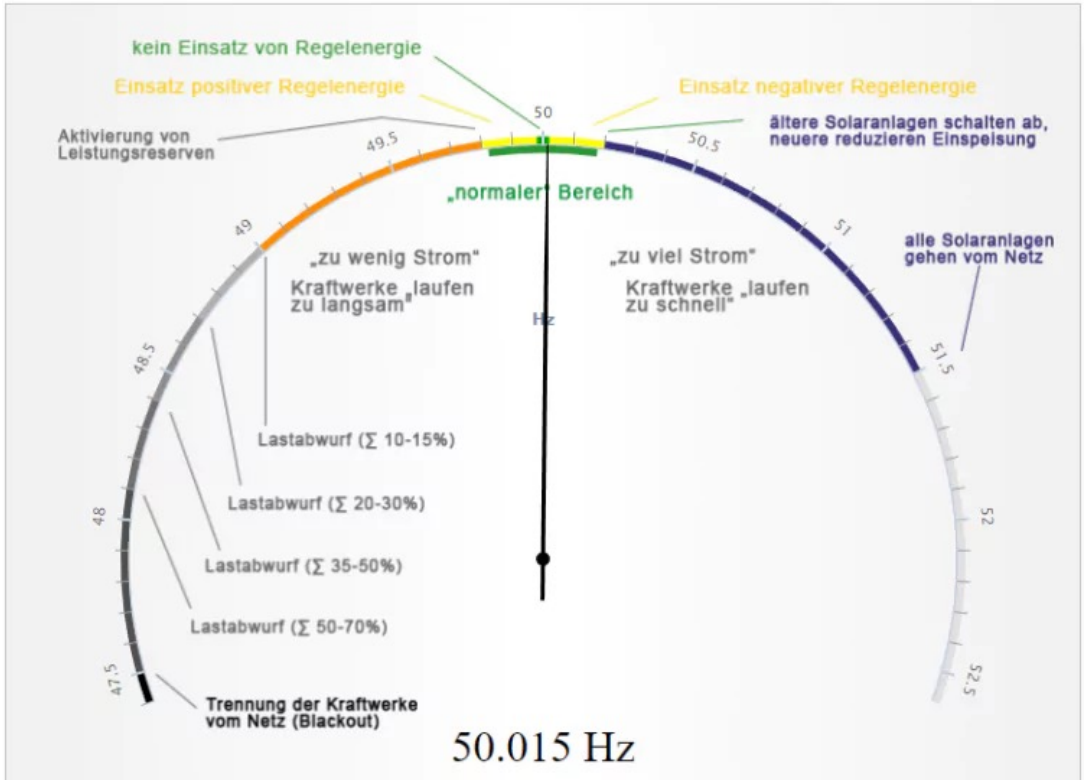
The European Grid

- European Grid runs @ ***50HZ.***
- Supply must match demand at all time.
- Difference between demand and scheduled production is known as **grid imbalance**.
- Grid imbalances are compensated for by grid operators using **restoration reserves**.



The European Grid

- Normally, frequency stays in range of ±180mHz of 50Hz.
- Exceptionally there are deviations up to ±200mHz.
- Variations of less than ±20mHz are not corrected.



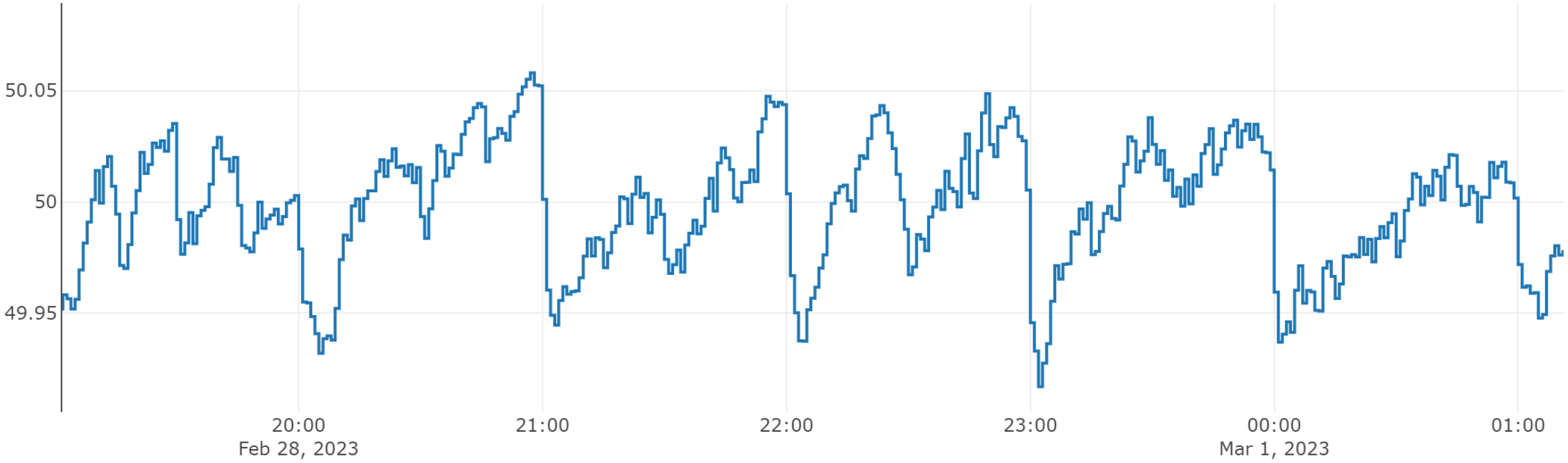
The European Grid

- Main causes of drop in frequency:
  - Unexpected changes in consumption or production:
    - Changes in weather influencing renewables.
    - Unplanned powerplant outages.

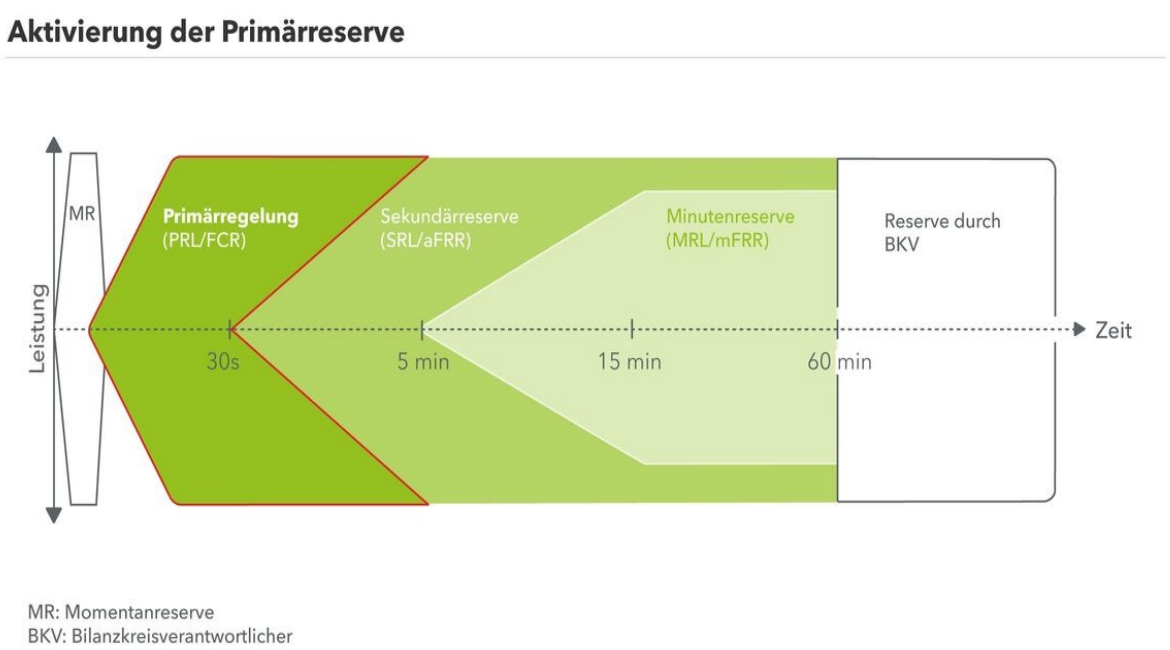
- Restoring frequency at higher loads requires more power than at lower load.
    - Ex: To restore 1Hz at 150GW of load requires 16.5GW of reserve power. At 300GW, you need 18.5GW.

The European Grid

- Certain patterns can be noticed. Ex:
  - During down ramps, the frequency suddenly drops at the start of an hour and rises again slowly as power plants mainly produce in blocks of 1h but consumption reduces gradually.

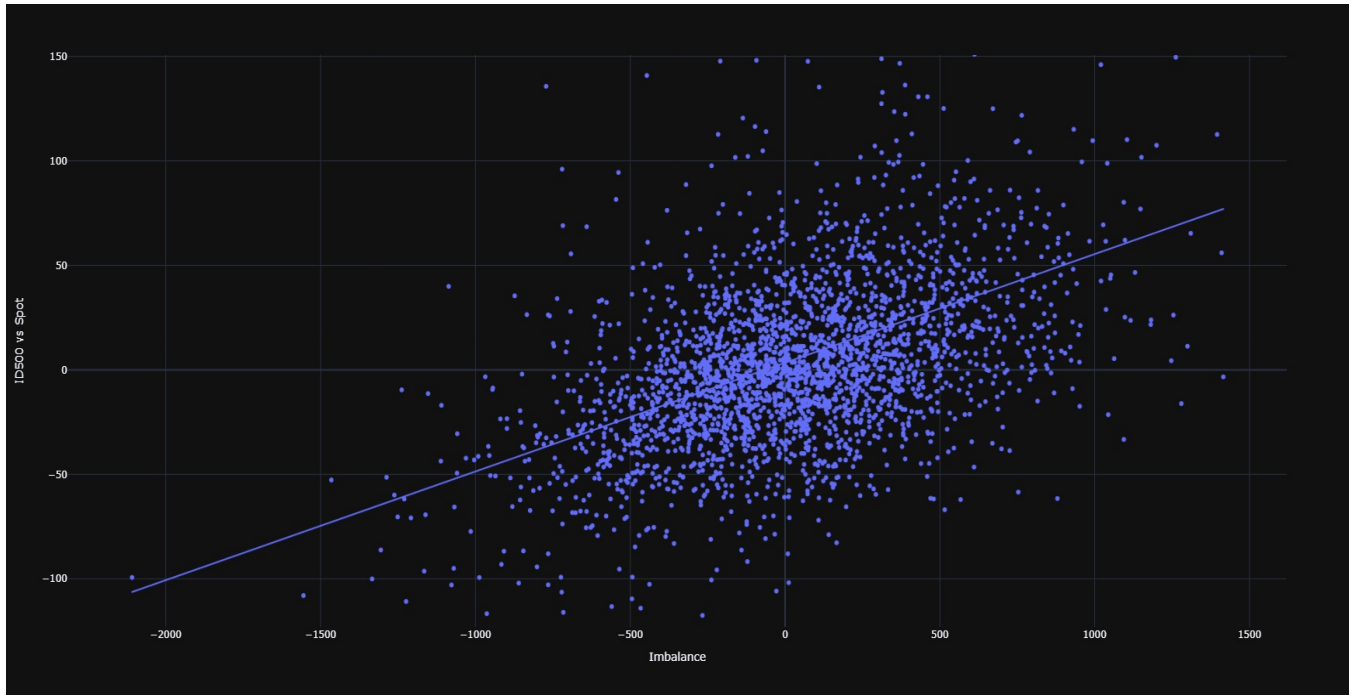


The European Grid



- There are three main types of restoration reserve:
  - Primary: Primärregelleistung/ Frequency Containment Reserve.
  - SCR: Sekundärreserve/ Automatic Frequency Restoration Reserve.
  - MRL: Minuteregelleistung/ Manual Fre quency Restoration Reserve.
  - IGCC: International Grid Control Cooperation. Power from other countries to stabilize the grid.

Why this matters



- Supply and demand are the main drivers of price.
- Increase in demand/ reduction in supply -> Prices go up.
- Increase in supply/ reduction in demand -> Prices go down.
- Important for the Renewables team to know when to flatten position.

The Data

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ts	frequency
2023-01-01 00:00:00+01:00	50.040
2023-01-01 00:00:01+01:00	50.049
2023-01-01 00:00:02+01:00	50.049
2023-01-01 00:00:03+01:00	50.037
2023-01-01 00:00:04+01:00	50.037
2023-01-01 00:00:05+01:00	50.037
2023-01-01 00:00:06+01:00	50.037
2023-01-01 00:00:07+01:00	50.028
2023-01-01 00:00:08+01:00	50.028
2023-01-01 00:00:09+01:00	50.020
2023-01-01 00:00:10+01:00	50.020
2023-01-01 00:00:11+01:00	50.016
2023-01-01 00:00:12+01:00	50.016
2023-01-01 00:00:13+01:00	50.011
2023-01-01 00:00:14+01:00	50.011
2023-01-01 00:00:15+01:00	49.986
2023-01-01 00:00:16+01:00	49.986
2023-01-01 00:00:17+01:00	49.984
2023-01-01 00:00:18+01:00	49.984

- Data from 2022-03-01 to 2023-01-31
- Left: Equidistant frequency in 1s resolution.
- Right: Non-equidistant indicator in 1min resolution with values –2, -1, 1, and 2.
  - Negative values: Grid has too much power.
  - Larger amplitudes: Larger imbalances in grid.

ts	indicator
2023-01-01 00:03:00+01:00	1
2023-01-01 00:04:00+01:00	2
2023-01-01 00:05:00+01:00	1
2023-01-01 01:04:00+01:00	1
2023-01-01 14:05:00+01:00	-1
2023-01-01 14:06:00+01:00	-2
2023-01-01 14:07:00+01:00	-2
2023-01-01 14:08:00+01:00	-2
2023-01-01 14:09:00+01:00	-2
2023-01-01 14:10:00+01:00	-1
2023-01-01 14:11:00+01:00	-1
2023-01-02 06:58:00+01:00	-1
2023-01-02 06:59:00+01:00	-1
2023-01-02 10:46:00+01:00	1
2023-01-03 06:18:00+01:00	-1
2023-01-03 06:19:00+01:00	-1
2023-01-03 06:20:00+01:00	-2
2023-01-03 06:21:00+01:00	-1
2023-01-03 06:22:00+01:00	-1
2023-01-03 06:23:00+01:00	-1

The Data

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- Main dataset: Fundamentals of German market in 15min granularity.
- Forecast and actuals data for consumption and renewable production.
- Actuals data for the various restoration reserves and official published imbalance volume.

ts	solar	wind_offshore	wind_onshore	forecast_solar	forecast_wind_offshore	forecast_wind_onshore	forecast_consumption	consumption_actual	afrr_up	afrr_down	mfrr_up	mfrr_down	imbalance
2023-01-01 00:00:00+01:00	0.0	2737.0	28583.0	0.0	2435.0	31243.0	42609.0	38883.0	1.673	73.540	0.0	0.0	888.212
2023-01-01 00:15:00+01:00	0.0	2974.0	28633.0	0.0	2361.0	30116.0	42152.0	38565.0	55.113	141.479	0.0	0.0	-141.457
2023-01-01 00:30:00+01:00	0.0	3268.0	29209.0	0.0	2388.0	29250.0	41520.0	38438.0	0.353	296.693	0.0	0.0	-460.637
2023-01-01 00:45:00+01:00	0.0	3258.0	28417.0	0.0	2211.0	29635.0	40889.0	38260.0	28.737	67.527	0.0	0.0	-451.114
2023-01-01 01:00:00+01:00	0.0	3142.0	29288.0	0.0	2141.0	28852.0	40431.0	37894.0	571.152	2.476	0.0	0.0	1152.926
2023-01-01 01:15:00+01:00	0.0	3594.0	29331.0	0.0	2347.0	29651.0	39862.0	37792.0	231.138	2.504	0.0	0.0	464.774
2023-01-01 01:30:00+01:00	0.0	3775.0	29039.0	0.0	2478.0	29492.0	39342.0	38201.0	34.519	3.962	0.0	0.0	319.154
2023-01-01 01:45:00+01:00	0.0	3833.0	29562.0	0.0	2792.0	30594.0	38849.0	37855.0	18.508	3.600	0.0	0.0	168.572
2023-01-01 02:00:00+01:00	0.0	4039.0	28916.0	0.0	2924.0	31020.0	38663.0	37434.0	2.119	58.420	0.0	0.0	-301.099
2023-01-01 02:15:00+01:00	0.0	3868.0	29687.0	0.0	3049.0	29717.0	38551.0	37224.0	0.236	184.270	0.0	0.0	-415.818
2023-01-01 02:30:00+01:00	0.0	3745.0	29052.0	0.0	2850.0	29597.0	38062.0	37003.0	0.065	172.601	0.0	0.0	-331.233
2023-01-01 02:45:00+01:00	0.0	3717.0	29409.0	0.0	2912.0	30148.0	37687.0	36752.0	0.144	414.085	0.0	0.0	-270.679
2023-01-01 03:00:00+01:00	0.0	3628.0	27701.0	0.0	2962.0	30311.0	37247.0	36562.0	0.397	130.028	0.0	0.0	-294.104
2023-01-01 03:15:00+01:00	0.0	3545.0	27070.0	0.0	3005.0	29512.0	37266.0	36049.0	0.305	312.153	0.0	0.0	-501.489
2023-01-01 03:30:00+01:00	0.0	3506.0	26629.0	0.0	3036.0	28651.0	37175.0	35957.0	0.070	289.969	0.0	0.0	-327.845
2023-01-01 03:45:00+01:00	0.0	3174.0	26634.0	0.0	3019.0	28757.0	37134.0	35990.0	0.156	217.785	0.0	0.0	-131.484
2023-01-01 04:00:00+01:00	0.0	3286.0	26954.0	0.0	2998.0	27783.0	37393.0	35851.0	6.629	6.604	0.0	0.0	292.160
2023-01-01 04:15:00+01:00	0.0	3548.0	26439.0	0.0	2824.0	27806.0	37457.0	35645.0	1.542	39.439	0.0	0.0	-29.245
2023-01-01 04:30:00+01:00	0.0	3646.0	26086.0	0.0	2861.0	27859.0	37343.0	35624.0	0.040	211.638	0.0	0.0	-337.044
2023-01-01 04:45:00+01:00	0.0	3369.0	26276.0	0.0	2750.0	28114.0	37114.0	35726.0	0.057	148.560	0.0	0.0	-202.068
2023-01-01 05:00:00+01:00	0.0	3391.0	27321.0	0.0	2913.0	28407.0	36958.0	35880.0	0.309	299.932	0.0	0.0	-524.126
2023-01-01 05:15:00+01:00	0.0	3280.0	26893.0	0.0	2867.0	28057.0	36462.0	35876.0	1.690	48.813	0.0	0.0	-128.482
2023-01-01 05:30:00+01:00	0.0	3333.0	26480.0	0.0	2952.0	28268.0	36016.0	35916.0	2.630	18.947	0.0	0.0	-99.972

The Objective

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- Build a model that can predict imbalance volumes:
  - The metric should be RMSE.
  - Live frequency and indicator data must be cutoff 10 minutes before start of a quarter.
  - Live true fundamentals (consumption, renewables, restoration reserves, imbalance) must be cutoff 30 minutes before start of quarter.

Scoring System

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- Model: 40%
  - RMSE performance.
  - Feature Engineering.
  - Model Explanatory Analysis.
- Code: 20%
  - Cleanliness (linting, requirements file, use of functions or classes)
  - Reusability
- Pitch and Demo: 20%
- Others: 20%

Sources

- https://www.next-kraftwerke.de/wissen/primaerreserve-primaerregelleistung
- https://www.netzfrequenz.info/regelleistung
- https://gridradar.net/de/blog/post/forecasting-modell-fuer-die-richtung-des-srl-abrufs-deutschland