MS Thesis Progress Report for Sem 2, 2020-21

Data Analysis for Predicting Instabilities in Power Systems

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Introduction

Transient vs Steady State Stability

Transient Stability	Steady State Stability
A sudden, out-of-trend, high magnitude change in a state variable(s) causes blackouts.	Accumulation of several seemingly minor trends in state variables over time, ultimately leading to a critical point where a small change could cause blackouts.
Chief parameters of concern are ROCOF, frequency nadir, steady-state frequency deviation.	Autocorrelation and covariance are some of the commonly used parameters for prognosis.
Inertia is a fundamental parameter here.	Inertia plays a minor role here.

Bifurcations and Critical Slowing Down

Bifurcation: A qualitative change in the ‘motion’ of a dynamical System due to a quantitative change in one of its parameters. Serious bifurcations, called Critical Bifurcations, cause the system to become unstable from stable.

Bifurcations and Critical Slowing Down

Critical Slowing Down: Dynamical Systems exhibit early statistical warning signs before collapsing:

- Increased recovery times from perturbations.
- Increased signal variance from the mean trajectory.
- Increased flicker and asymmetry in the signal

The above three properties can be identified by increasing variance and autocorrelation in time-series measurements taken from the system.

Theory

Autocorrelation Definition

$$\int_{-\infty}^{\infty} x(t) * x(t+\tau)\, dt = c(\tau) \tag{1}$$

Autcorrelation Decay

$$c(\tau) \propto \exp(-\alpha\tau) \tag{2}$$

$$c(\tau) \sim \exp(-\tau/T) \tag{3}$$

Procedure

Procedure

- On similar lines of [1], accessed a bunch of real-world frequency time-series data and plotted their:
    - bulk distribution (pdf)
    - auto-correlation curves
- Obtained explanation for the *signature dynamics* of each grid.

Results

Results

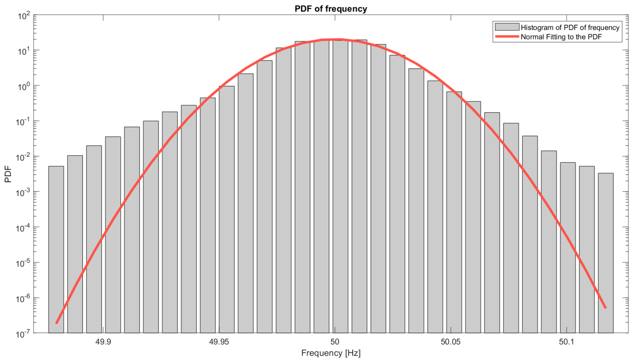

Figure 1: Continental European Grid frequency PDF: Heavier tails than a Gaussian Distribution.

Results

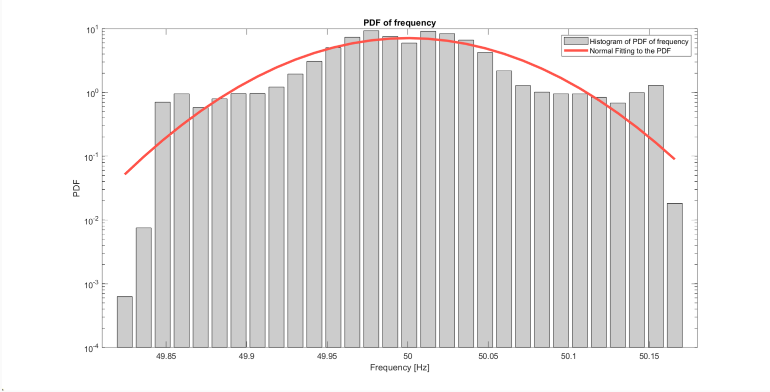

Figure 2: Mallorcan (an islanded Spanish grid) frequency pdf

Results

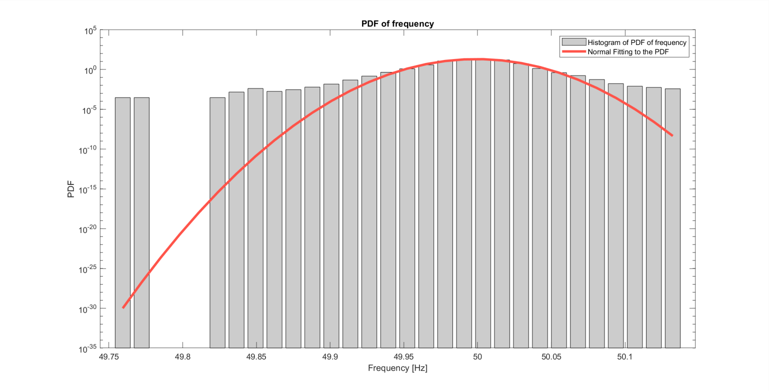

Figure 3: French grid frequency pdf including a blackout

Results

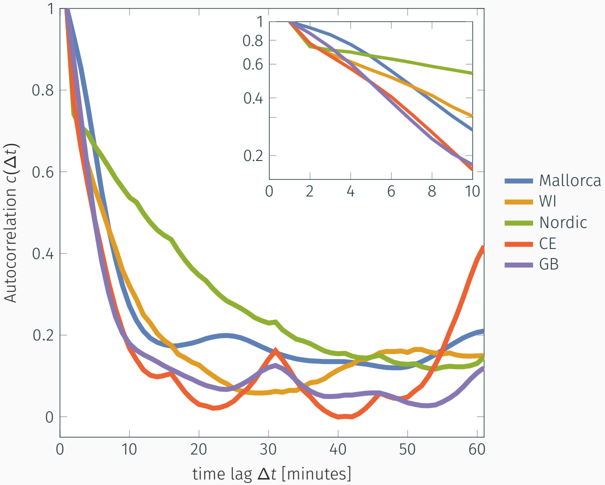

Figure 4: Autocorrelation decay of different synchronous regions.

Results

Table 1: Inverse-correlation values for different grids

Grid name	Inverse-correlation value T^{-1} [min^{-1}]
Mallorca	0.0654
Western Interconnection	0.0498
Nordic	0.0235
Continental Europe	0.0829
Great Britain	0.0879

Figure 5: Inverse correlation time is proportional to the damping constant of the grid.

Future Work

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- Examine different mathematical processes for modelling and examining the steady state stability of the grid.
- Research on optimum sampling rates as done in [2]
- Attempt to simulate different control strategies for increasing grid stability
- Collect Indian grid frequency data from the laboratory and perform the above tasks

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References

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[1] Benjamin Schäfer et al. “Non-Gaussian power grid frequency fluctuations characterized by Lévy-stable laws and superstatistics”. In: *Nature Energy* 3.2 (2018), pp. 119–126. ISSN: 2058-7546. DOI: 10.1038/s41560-017-0058-z. URL: http://dx.doi.org/10.1038/s41560-017-0058-z.

[2] Leonardo Rydin Gorjão et al. “Open database analysis of scaling and spatio-temporal properties of power grid frequencies”. In: *Nature Communications* 11.1 (2020), p. 6362. ISSN: 2041-1723. DOI: 10.1038/s41467-020-19732-7. URL: https://doi.org/10.1038/s41467-020-19732-7.