DTU

The Hybrid Power Grid of Cape Verde: A Reference System for the Renewable Transition

Daniel V. Pombo, Dominique Alonso Sørensen,
Emerson Fonseca and Helder Andrade.

Agenda

- A Reference System of Isolated Grids
  - The Case of Cape Verde
- International Collaboration Targeting Global Problems
  - Success Examples
- The Dataset
  - Possible Studies
- Grid Strength Assessment
- Voltage Sensitivity Assessment
- Conclusions
- Data Repository

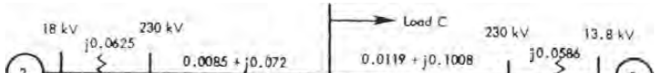
A Reference System of Isolated Grids

- Academy Researcher
- R&D Engineer
- Manufacturers
- Utilities
- TSO/DSO

} Validation

CHAPTER 4 RESULTS AND DISCUSSION

Sec. 12.8 Special Techniques for Analysis of Very Large Systems 813



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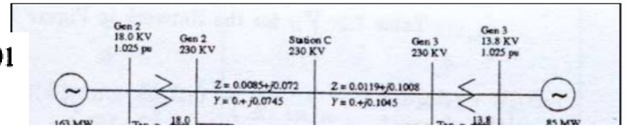

IEEE Transactions on Power Delivery, Vol. 4, No. 2, April 1989

NETWORK RECONFIGURATION IN DISTRIBUTION SYSTEMS
FOR LOS

IEEE Transactions on Industrial Informatics - TII-19-3941 1

A Benchmark Test System for Networked Microgrids

Mahamad Nabab Alam, *Member, IEEE*, Saikat Chakrabarti, *Senior Member, IEEE*, and Xiaodong Liang, *Senior Member, IEEE*

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Area 1

Fig. 2.18 Nine-bus system impedance diagram; all impedances are in pu on a 100-MVA base.

Figure 4.1 Western System Coordinating Council (WSCC) 3-Machines 9-Bus system.

A Reference System of Isolated Grids

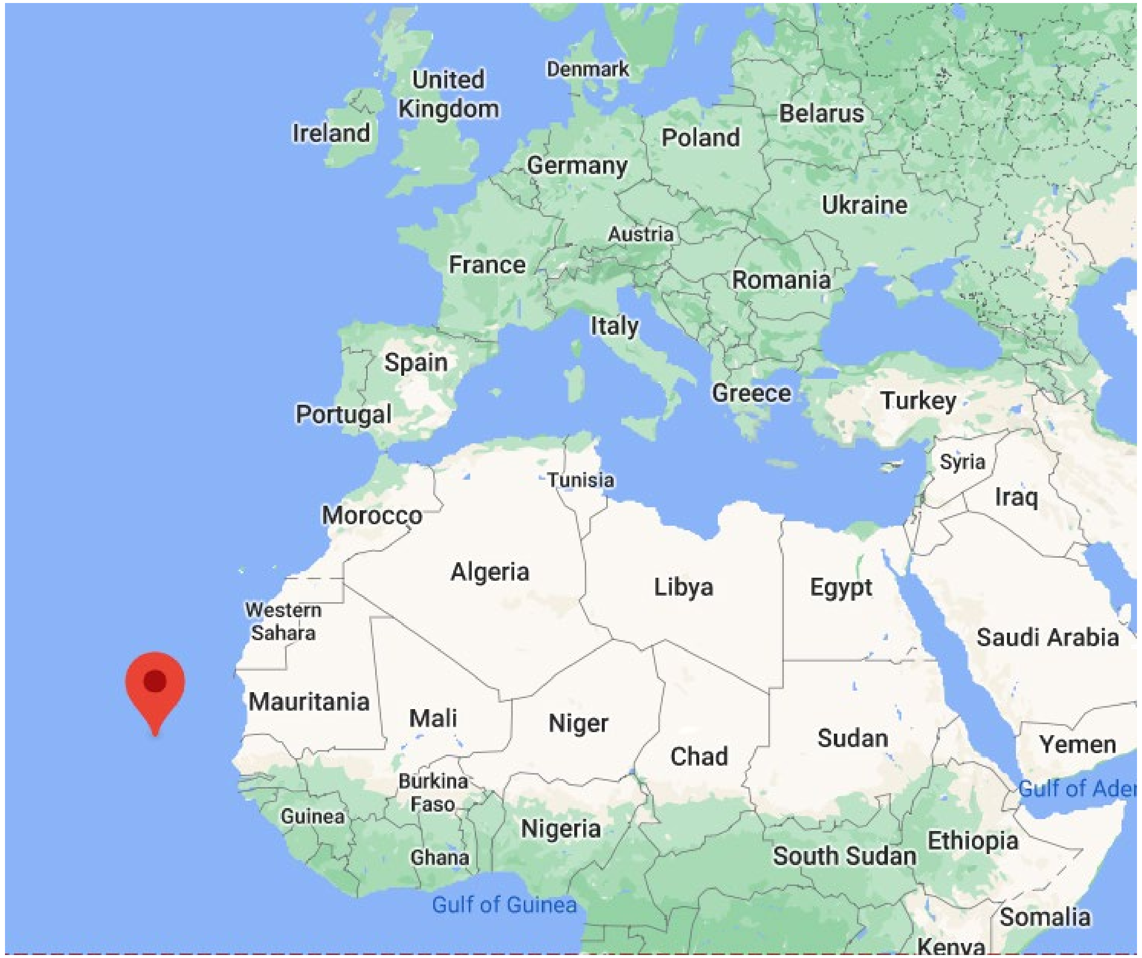
General Limitations:

1. Imaginary systems
2. Unrealistic topologies
3. Unpredictable physics
4. Incomplete and obscure datasets
5. Not suitable for Renewable penetration above 20 %
6. Do not consider power electronics role
7. Do not consider sector coupling

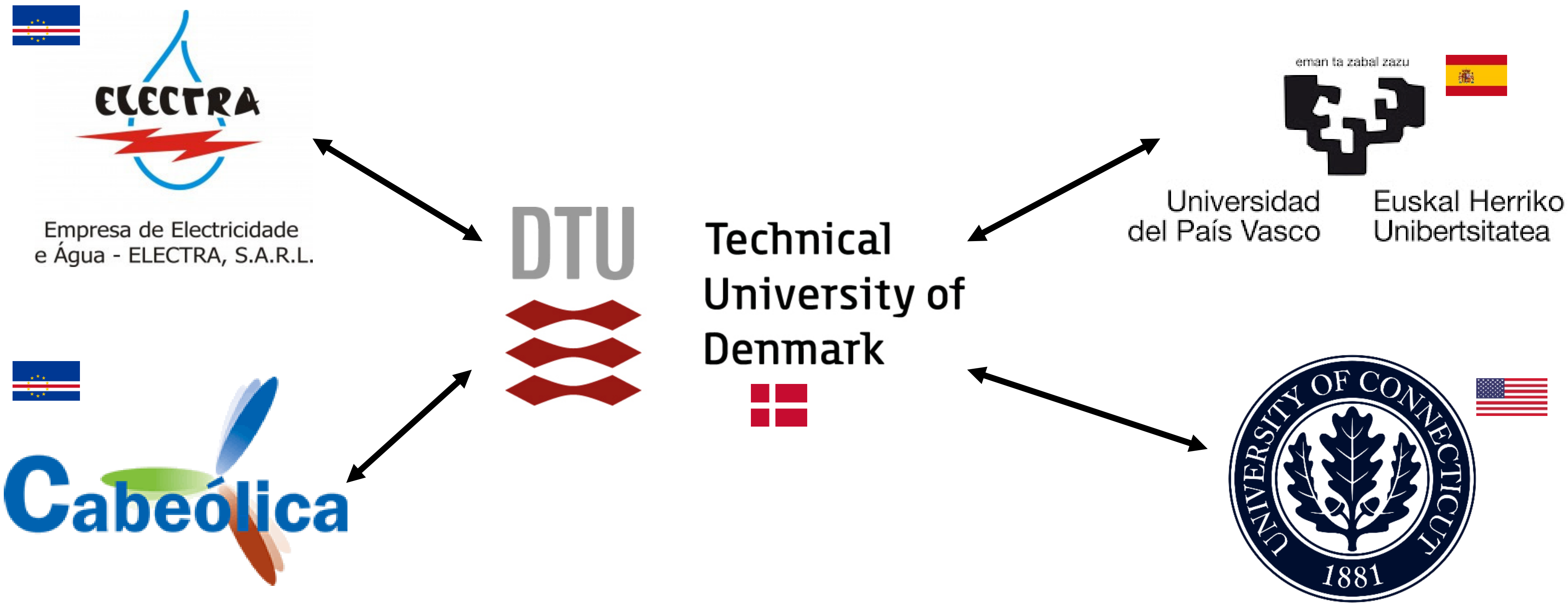
The Cape Verde Reference System:

1. Realistic topology of two different islands, São Vicente and Santiago.
2. Complete and transparent datasets (Open Access).
3. Present and future scenarios

The Case of Cape Verde



International Collaboration Targeting Global Problems



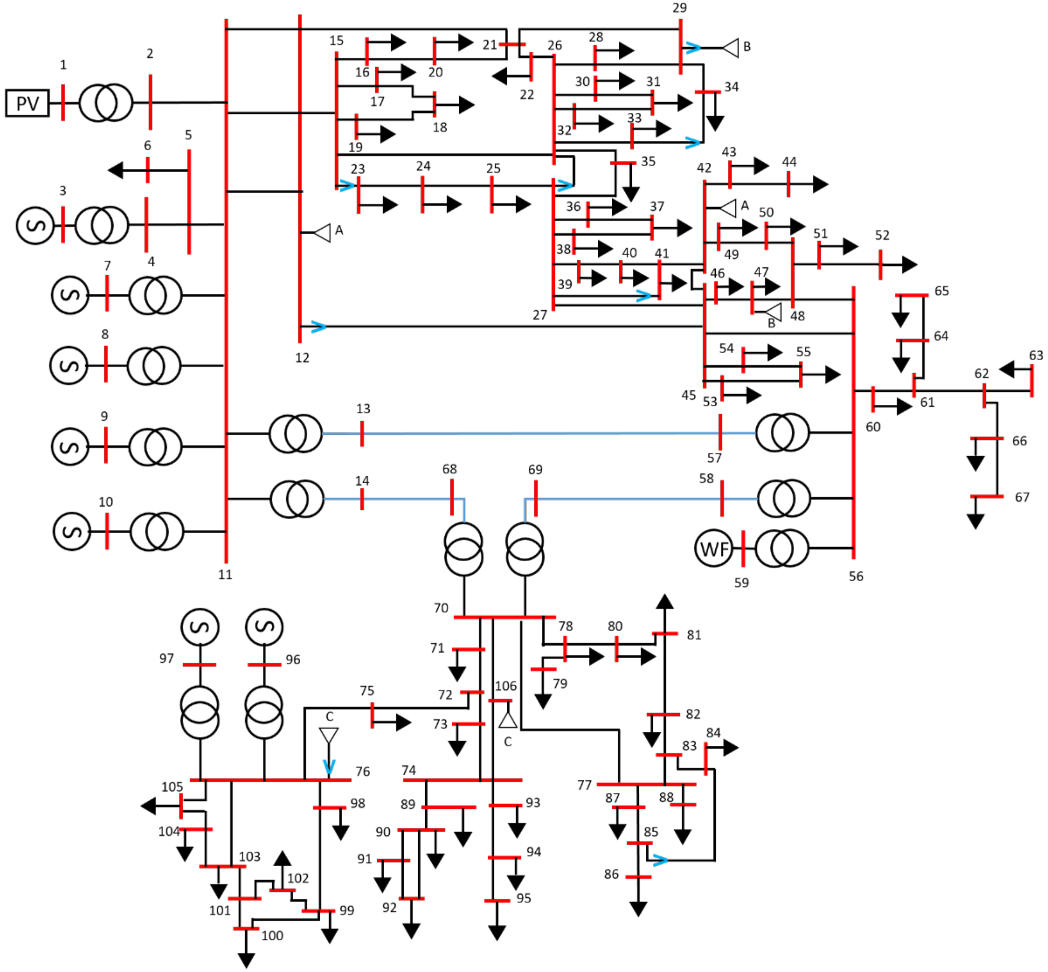
Success Examples

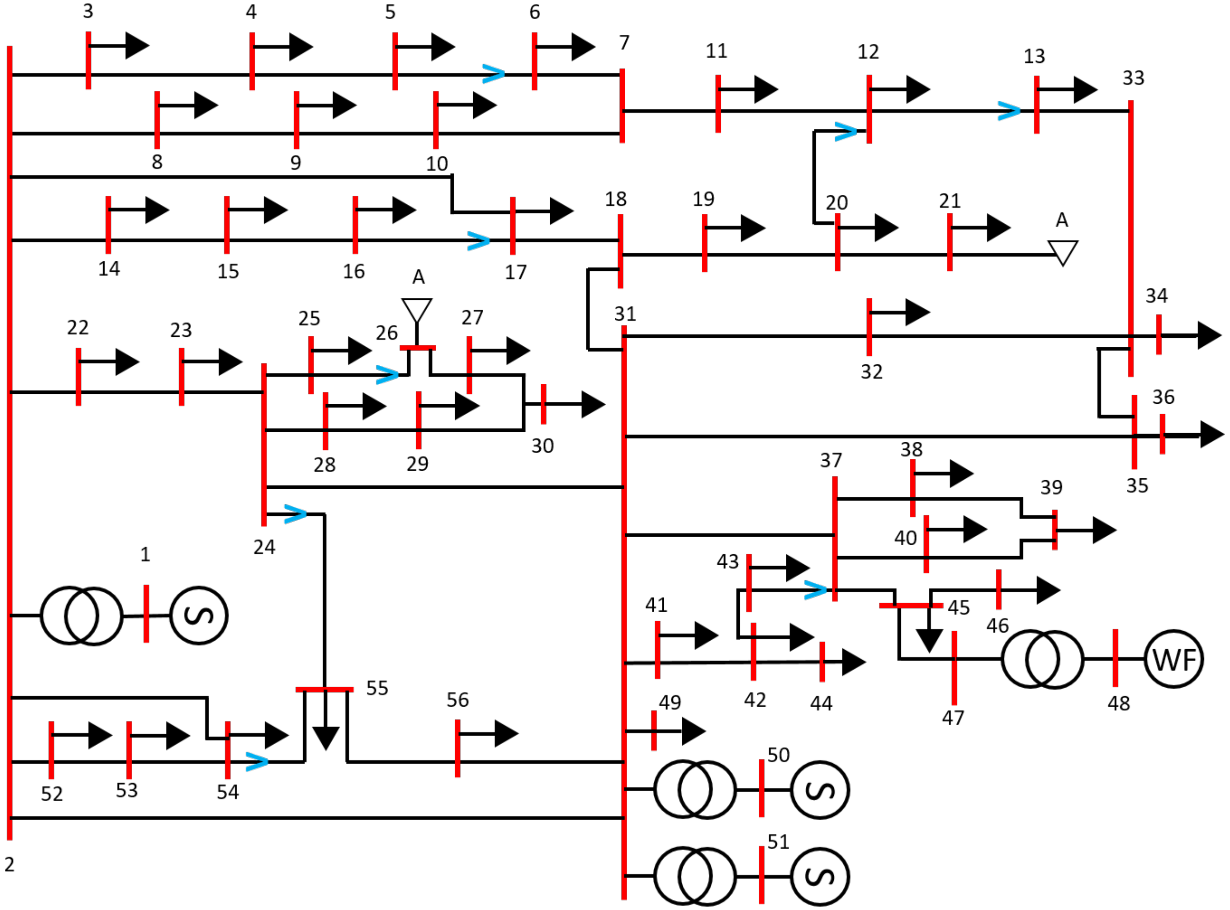
Comparing Disturbance-based Methods for Inertia Estimation in the island of Sao Vicente, Cape Verde
4th International Conference on Smart Energy Systems and Technlogies, 2021, Vaasa, Finland.

Sørensen, D.

Frequency Stability Assessment for the Future Power System of São Vicente Island.
IEEE PES Innovative Smart Grid Technologies 2021, Espoo, Finland,
Nguyen H. T., Pombo, D.V.

The Dataset

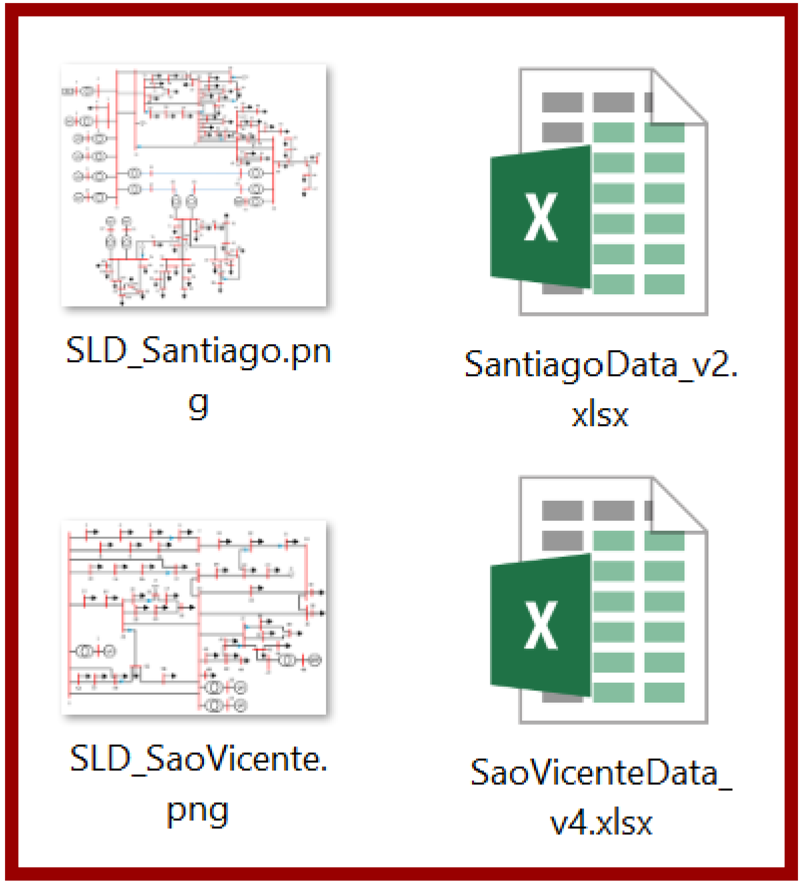




The Dataset

- Figures representing the SLDs
- An excel file for each island covering data for:
  - Load Flow Analysis
  - Dynamic Analysis
  - Load Profiles
  - Renewable Resource Profiles
  - Reliability Analysis
  - Resiliency Analysis

- DIgSILENT PowerFactory models (soon)
- RTDS models (soon)



Possible Studies

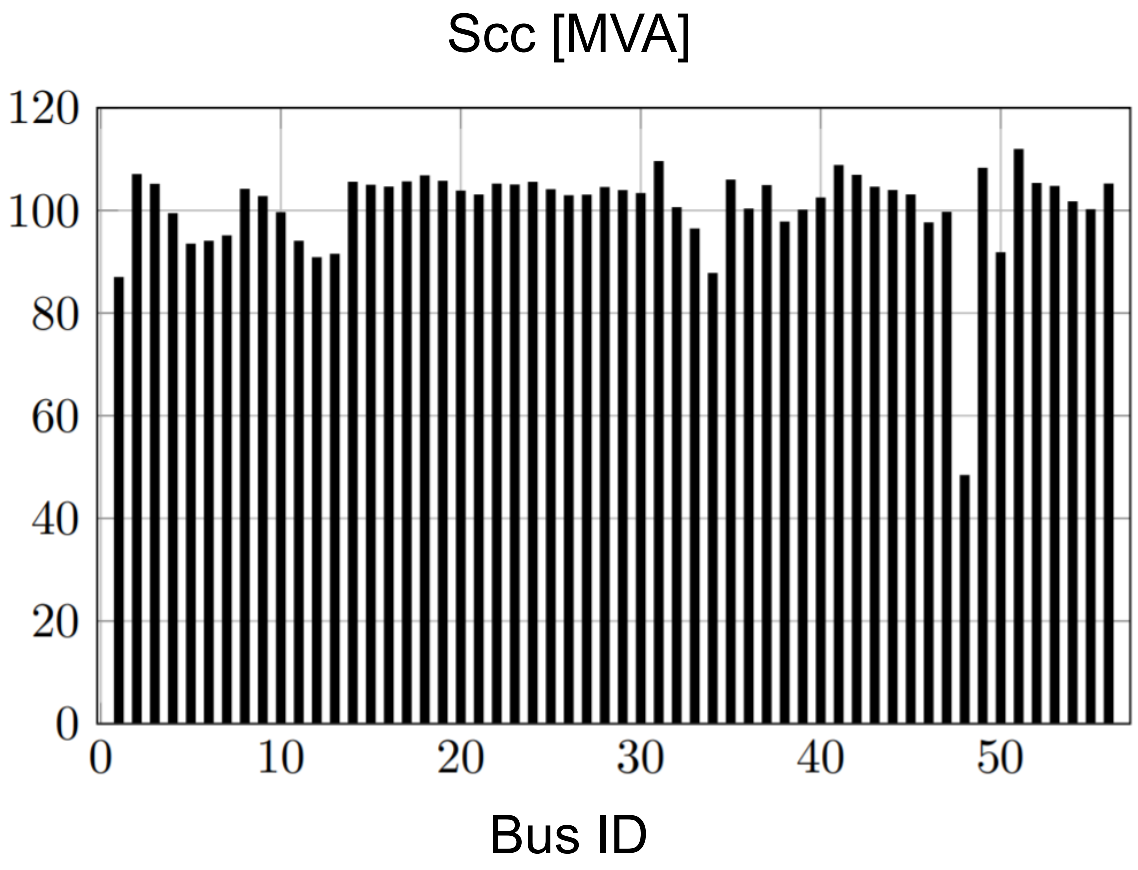
- Grid Expansion
- Radial vs Meshed Operation
- Optimal Power Flow
- Island Interconnection
- Black-Start
- Protection Selectivity
- Distributed Control
- Robust, data-driven Control
- Different Control Architectures
- RES-based frequency support
- Demand Response strategies
- Energy Storage Management
- Dispatch Strategies
- Unit Commitment
- Voltage Stability
- Sector Coupling
- Market Clearance
- Uncertainty Effect on Dispatch
- Inertia constant estimation
- Small signal stability
- Impact of RES on system stability
- Impacts on topological switching
- Short-Circuit Transitory
- Reliability Index Evaluation
- Contingency Evaluation
- Cascading Event Identification
- Fault & protection studies
- Extreme Event Definition &
- Extreme Event Response
- Resiliency Dependency on RES
- Losses caused by extreme events
- Technology Roadmap
- Power Quality
- Filter Dimensioning
- Pollution Reduction
- Flexibility Market Definition
- Data-Driven RES Forecasting
- Virtual Power Plant Deployment
- New installation dimensioning
- Inverse Current Flow Assessment
- Inertialess Power System Control
- Etc.

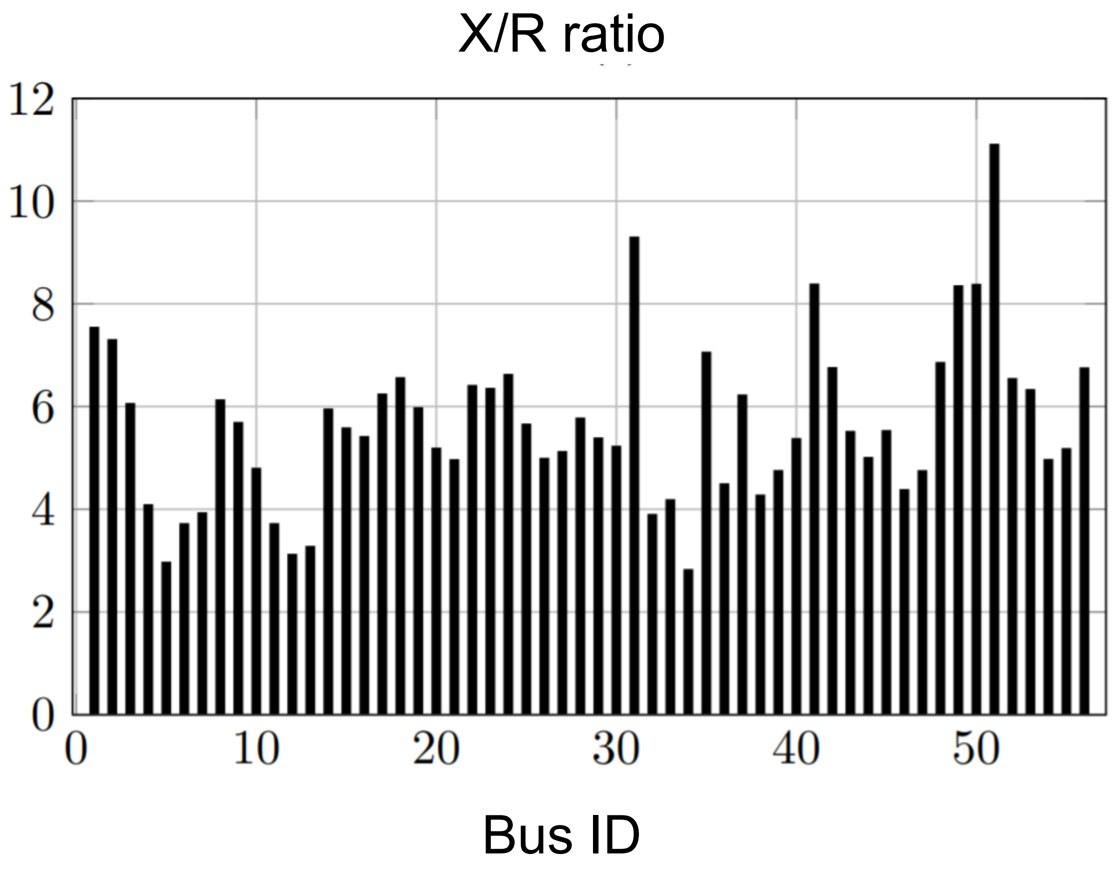
Grid Strength Assessment

- Short Circuit Ratio (SCR)
- Short Circuit Capacity (Scc)
- X/R Ratio

Grid Strength Metric	Strong Grids	Weak Grids
SCR	>10	<10 or <5
SCC	$>0{,}9$	$<0{,}9$
X/R = xrr	$>0{,}7$	$<0{,}5$

Grid Strength Assessment





Voltage Sensitivity Assessment

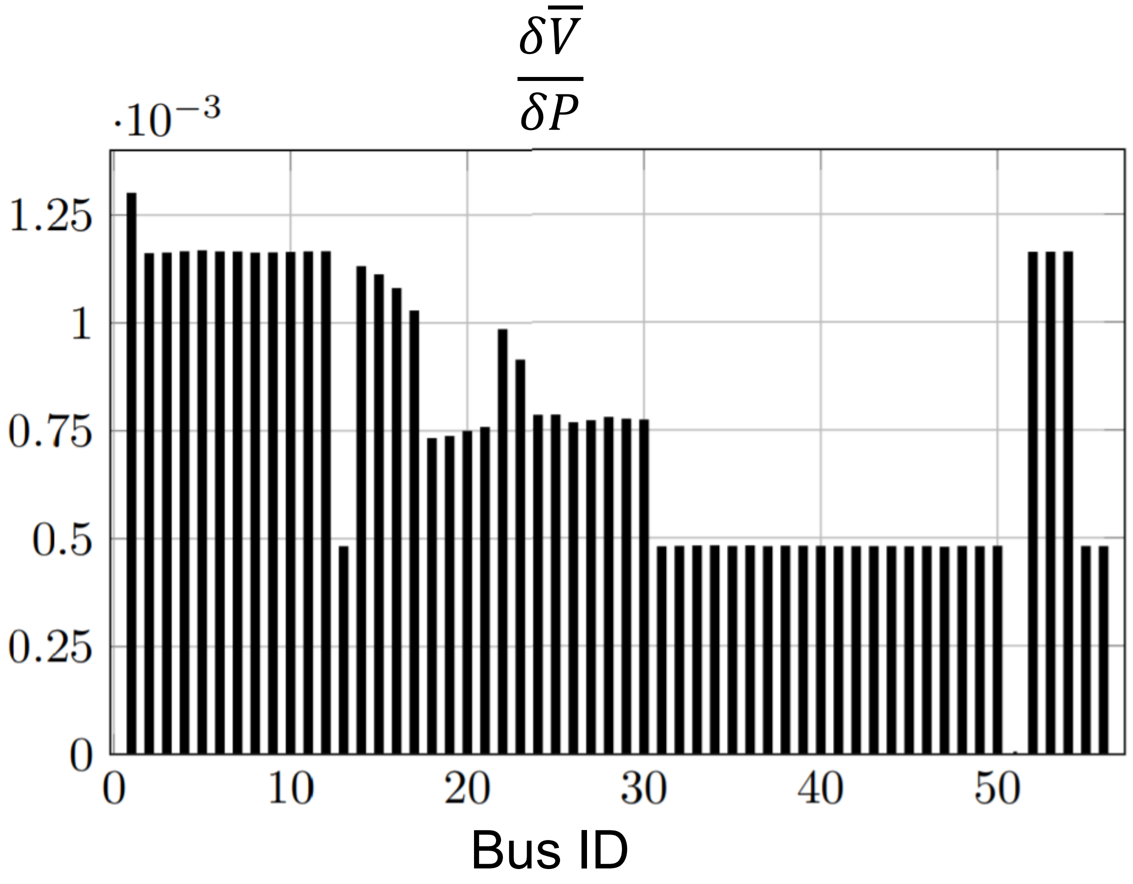
$$S = J\ V$$

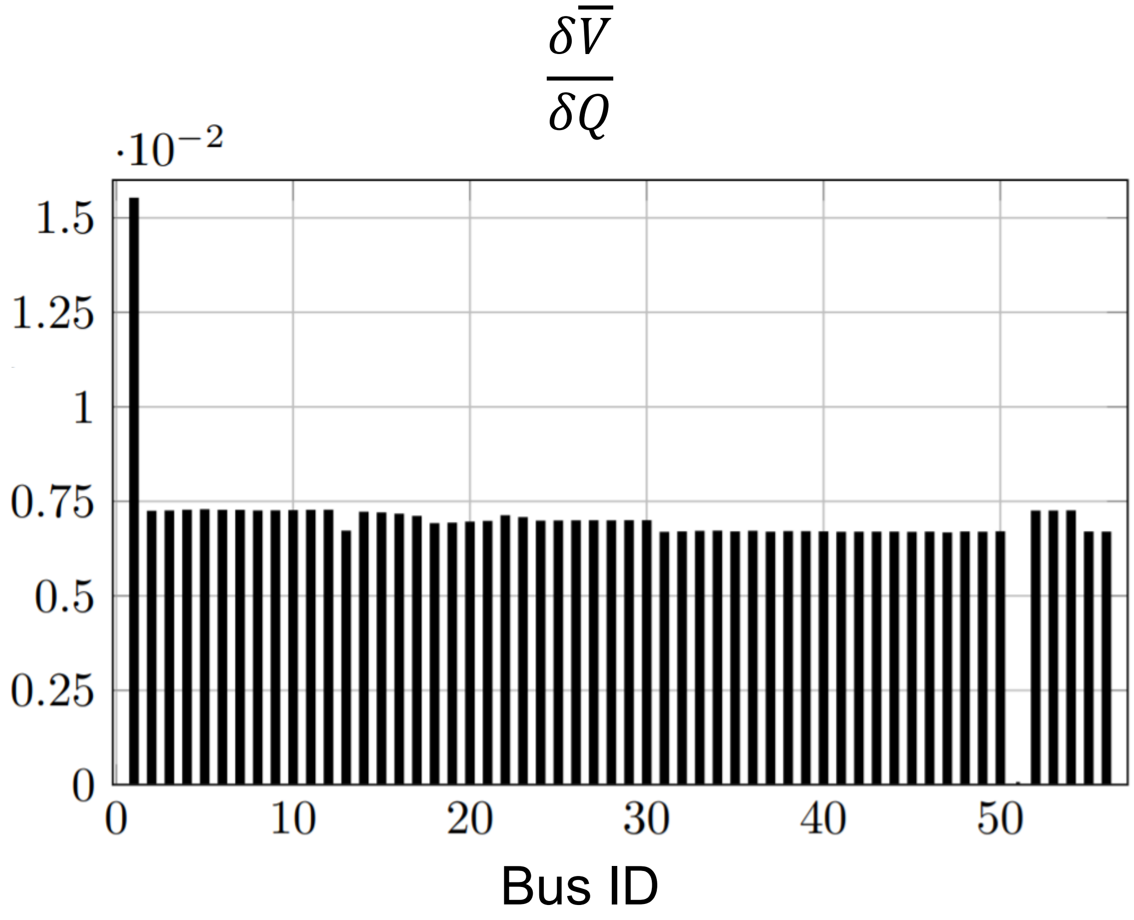
$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J1 & J2 \\ J3 & J4 \end{bmatrix} \begin{bmatrix} \bar{V} \\ V^{\theta} \end{bmatrix}$$

$$J = \begin{bmatrix} J1 & J2 \\ J3 & J4 \end{bmatrix} = \begin{bmatrix} \frac{\delta P}{\delta \bar{V}} & \frac{\delta P}{\delta V^{\theta}} \\ \frac{\delta Q}{\delta \bar{V}} & \frac{\delta Q}{\delta V^{\theta}} \end{bmatrix}$$

$$\begin{bmatrix} V^{\theta} \\ \bar{V} \end{bmatrix} = \begin{bmatrix} J1 & J2 \\ J3 & J4 \end{bmatrix}^{-1} \begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} S_{\theta P} & S_{\theta Q} \\ S_{VP} & S_{VQ} \end{bmatrix} \begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix}$$

Voltage Sensitivity Assessment





Conclusions

- SCR ≈ 10 MVA → weak.
- Buses 31 and 52 present the highest grid strength in the system.
- According to $\frac{\delta\overline{V}}{\delta P}$ there are three groups, buses 1-16, 17-30 31-50.
- Marginal voltage sensitivity variations between buses.

The Future of the Data Repository

Available at → https://data.dtu.dk/articles/dataset/_/13251524

Optimal generation expansion planning

- 10 and 20 years horizon
- Considers Hydro, Storage, Hydrogen, Renewables, Demand Response, etc.
- Includes system stability constraints.
- Python based library -> Pyomo.

Machine Learning-based Inertia Estimation for Real-Time Applications

- Co-simulation between DIgSILENT – PowerFactory and Python.
- Benchmarking against several reference methods.

The Role of Batteries in the Frequency Stability of São Vicente and Santiago

- Optimal Allocation of Batteries for Inertia/Frequency Provision
- Energy Storage vs Synchronous Condensers; advantages and disadvantages

Data Repository

Available at → https://data.dtu.dk/articles/dataset/_/13251524

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Let us know if you are missing something!

But also if you are using it, publishing, etc.

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