MOTIVATION [1]: Tiny and improbable operational changes lead to large effect

2006, November 4: A planned disconnection to let a ship pass beneath this overhead cables in Germany lead to a partial-European blackout

Why? Inappropriate operational planning

Renewables

EVs

The silence is deceptive

Many potential scenarios have to be assessed with detailed simulations

In the context of large integrated networks, radical new methods are required to ensure stable power system operation under high uncertainty.

IDEA: Use offline learned stability rules [2]

Enhance online decision making

ONLINE

Network state consists out of linear equations (for DC)

- Node balance
  \[ \sum_{i} I_x + \sum_{i} I_{xy} + \sum_{i} I_{yz} = 0 \quad \forall b \]
- Line flow equation
  \[ F_{xy} = \frac{\theta_x - \theta_y}{x} \quad \text{for bus phase angles line reactance} \]
- Variables
  - Power of loads are time-dependent, correlated and uncertain
  - Power of generators are uncertain, based on market clearing
  - Line flows have physical limitations

IEEE 6 bus system

How to explore the relevant variable space?

Sampling should
- be close to the expected boundary
- irrelevant
- relevant
- follow the expected correlation

CHALLENGE I: Sampling

Sample power level of buses (\( I_x \) and \( I_y \))

Sample line flows

Line flow space \( F_{xy} \) and \( F_{yz} \)

How to sample if important features are diverse?

CHALLENGE II: Rule quality

Unknown real stability boundary is nonlinear

Operators require intuitive, causal and non-complex rules

Linear classification (e.g., decision trees DTs, SVMs)

What if the system changes?

Dependent on the topology change the performance is very low:

CHALLENGE III: Implement operating rules

Account for stability rules in operators online decision making

- Operational planning
- System control of corrective actions

Formulate regions of DT leaf nodes as convex regions

- ...mixed stable/instable operation
- ...instable operation
- ...stable operation

Problem: Optimal operation is forced to an edge

...unfortunately this is where the test error is locally increasing

IDEA: Learn DT for operation not for prediction

Tune accordingly relevant hyper parameters

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REFERENCES