FAST MONITORING OF VOLTAGE COLLAPSE MARGIN WITH SYNCHROPHASORS ACROSS TRANSMISSION CORRIDORS WITH MULTIPLE LINES IN COLOMBIA

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Industry Problem

- Power systems are only cover by n-1 contingencies.
- Multiple outages are prone to occur during bad weather or cyber-physical attacks.
- Contingencies and large transfers of power through the corridors increase the risk of voltage collapse and blackout.

Objective

A: Generation
B: Generation
C: Load

Graph showing voltage stability index (%) for different types of outages: n-0, n-1, n-2, n-3.
Reduction and Voltage Index

Steps

- Measure with a PMU $V_{g1}, V_{g2}, V_{\ell_1}, V_{\ell_2}, I_{g1}, I_{g2}, I_{\ell_1}, I_{\ell_2}$.
- Check the reactive power limit signal of the generation buses. In case that the generator bus reaches its reactive limit then the bus is considered as negative load.

$$S_g = S_{g1} + S_{g2} = V_{g1} \cdot I_{g1} + V_{g2} \cdot I_{g2}$$

$$S_{\ell} = S_{\ell_1} + S_{\ell_2} = V_{\ell_1} \cdot I_{\ell_1} + V_{\ell_2} \cdot I_{\ell_2}$$

- $I_{g\ell} = I_{g1} + I_{g2}$

- $V_g = \frac{S_g}{I_{g\ell}}$  
  
- $V_{\ell} = \frac{S_{\ell}}{I_{g\ell}}$

- Index = $\frac{P_{\ell} \times 100}{P_{max}}$

$$= \frac{200 P_{\ell} (X_{g\ell} - R_{g\ell} \tan \varphi)}{-V_g^2 R_{g\ell} - V_g^2 X_{g\ell} \tan \varphi + \sqrt{V_g^4 (1 + \tan^2 \varphi) (R_{g\ell}^2 + X_{g\ell}^2)}}$$
IEEE 25 Bus System Case – Cascade Analysis

[Diagram of the IEEE 25 Bus System Case with a legend indicating Voltage Stability Index and a bar chart showing the type of outage (n-0 vs. n-1).]
IEEE 25 Bus System Case – Cascade Analysis

[Diagram showing a power system with buses and transmission lines, with a bar chart indicating voltage stability index for different types of outages (n-0, n-1, n-2)].
IEEE 25 Bus System Case – Cascade Analysis

![Diagram of 25 Bus System]

![Bar Chart: Voltage Stability Index]

- Voltage Stability Index
- Type of Outage: n-0, n-1, n-2, n-3
IEEE 25 Bus System Case – Cascade Analysis

- Diagram showing a network of buses with lines connecting them.
- Graph showing voltage stability index for different types of outage:
  - n-0
  - n-1
  - n-2
  - n-3
  - n-4

The analysis likely involves studying the impact of outages on the system's stability.
IEEE 25 Bus System Case – Cascade Analysis

Diagram showing a power system with bus numbers 213, 212, 223, 211, 214, 215, 216, 219, 220, 218, 224, 221, 222, 225, and 217. A bar chart illustrates the voltage stability index for different types of outage, categorized as n-0, n-1, n-2, n-3, n-4, and n-5.
IEEE 25 Bus System Case – Cascade Analysis

[Diagram of a network with nodes labeled 213, 212, 223, 211, 214, 215, 216, 219, 220, 224, 218, 221, 225, 222, 217]

[Bar chart showing Voltage Stability Index for types n-0 to n-6]
IEEE 25 Bus System Case – Cascade Analysis
IEEE 25 Bus System Case - 240 Outages Analysis
Colombian Case – Cascade Analysis

Diagram showing the relationship between Generation and Load, with connections labeled as 1 to 6. A bar chart on the right shows the Voltage Stability Index for different types of outage, labeled n-0 to n-6.
Conclusion

• We show how to reduce multiple lines to a single line equivalent to which online monitoring of voltage stability with synchrophasors can be applied.

• The approach can give a fast, online indication of voltage stability that can accommodate both multiple contingencies and generator reactive power limits.

• This methodology, increase operator situational awareness under emergency conditions, and should be complementary to methods that make pre-contingency calculations from a model based on the state estimator.
Thank you