Examples of Using Synchrophasors to Detect and Understand Grid Events and the Impact of Wind and Solar Generation

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Event Detection Triggers
Rapid Decrease in Generation Causes Frequency Drop

- Entered EEA at 1,000 MW Load-shed Ordered
- 35,343 MW Generation Capacity Out as of 1:23 am
- 248 MW Generation Outages
- 329 MW Generation Outages
- Additional 1,000 MW Load-Shed Ordered (Total 2,000 MW)
- Below 59.4 Hz for 4m:23s
- More Gen Units would have tripped if below 59.4 for 9h or more
- Additional 3,500 MW Load-Shed Ordered (Total 8,500 MW)
- Min Frequency 59.302 Hz
U.T. Rio Grande, McDonald Observatory, and Waco Voltage Phase Angle Changes Relative to Austin, Starting at 01:40, Feb. 15, 2021.
Why are Synchrophasors Important?

Here’s All You Need to Remember

Average Power Flow $P$ Through a Mostly Inductive Transmission Line (138kV and above)

$$ P = \frac{V_1 V_2}{X} \sin(\delta_1 - \delta_2) $$

Stability limit is when the angle difference reaches 90 degrees
If Power Transfer Between Two Grid Regions is Known, and the Phase Angle Difference is Also Known, then the Thevenin Equivalent Impedance Between the Two Regions can be Computed.

\[ P = \frac{V_1 V_2}{X} \sin(\delta_1 - \delta_2) \]
Most solar generation is relatively close to McDonald Observatory, and far from the PMU reference at Austin. Voltage angle difference between McDonald and Austin rises as solar generation rises. As a first approximation, MW flow is proportional to the **sine of the voltage angle difference**. You can see in the right-hand curve above that degrees per MW are smallest at zero degrees, and gradually move toward infinity at 90 degrees.
By experimenting with the number of equivalent 345 kV lines between McDonald Observatory and Austin, we find that 7 parallel lines place the sharply nonlinear range of Degrees per MW in the typical PV 3000 to 4000 MW daily range.
View from **Austin**, **Waco** and **McDonald** are oscillating in-phase. **UT Rio Grande** oscillation is small, and 180 degrees out of phase with **Waco** and **McDonald**.

View from **McDonald**, **UT Rio Grande** and **Austin** are oscillating in-phase, and **Waco** is not oscillating.

View from **UT Rio Grande**, **Waco** and **McDonald** are oscillating in phase. **Austin** oscillation is small and 180 degrees out of phase with **Waco** and **McDonald**.

View from **Waco**, **Austin** and **UT Rio Grande** are oscillating in-phase, and **McDonald** is not oscillating.
Questions?