Large-Scale Wind Generation: Impact on Grid Reliability

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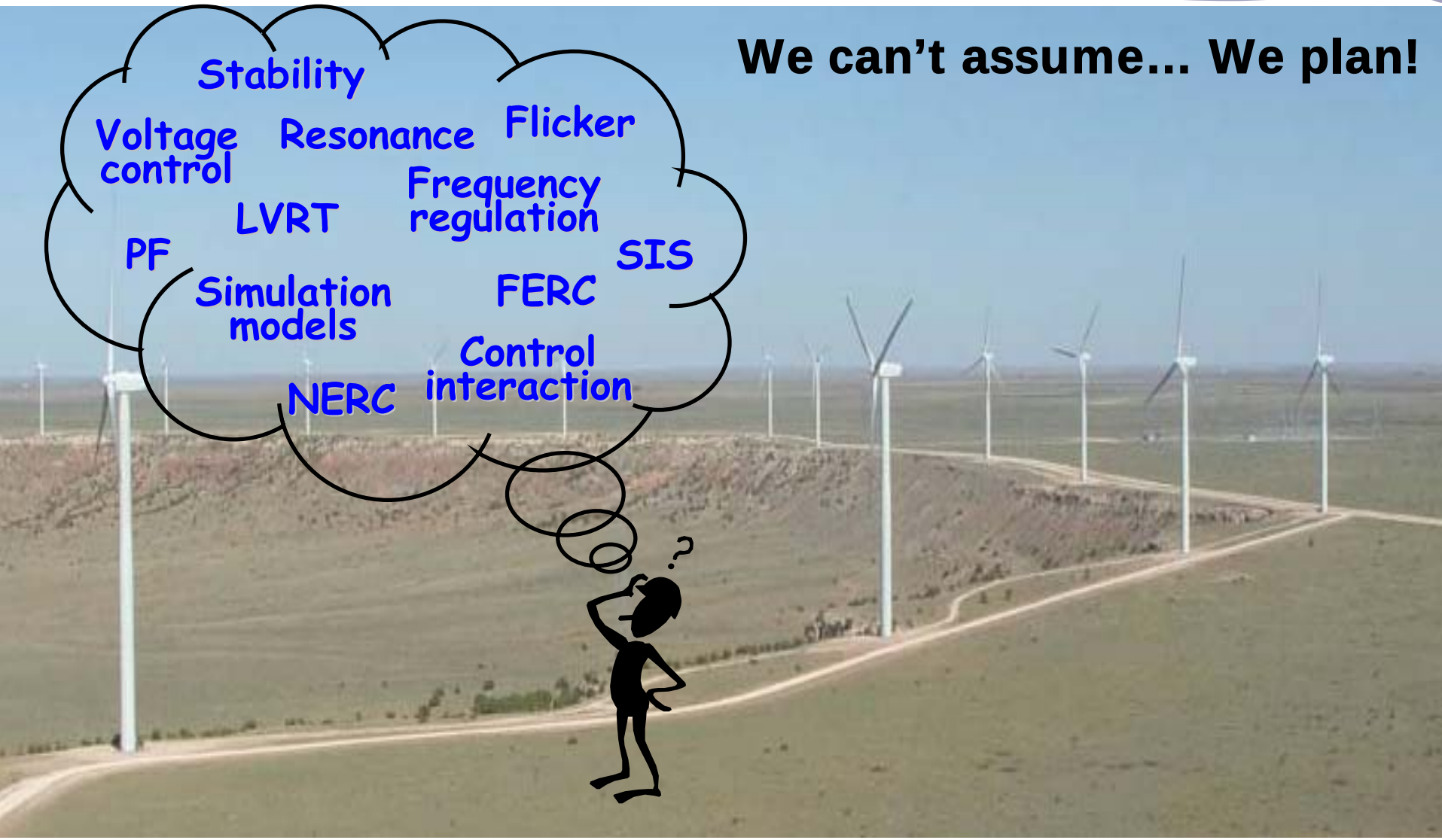
Large-Scale Wind Power Plants

Nice! But do they play nice with the Grid?



Wind generation and the power grid

Why we are paying attention

- Power system infrastructure critical; stakes are high

Major Blackouts in the US

November 9, 1965 – NY Blackout
30 Million people, 20 GW impacted

July 13, 1977 - New York City
9 Million people, 6 GW impacted

July 2, 1996 – Western US
2 Million people, 11 GW impacted

August 10, 1996 – Western US
7.5 Million people, 28 GW impacted

August 14, 2003 – Eastern US/CA
50 Million people, 65 GW impacted; $6B

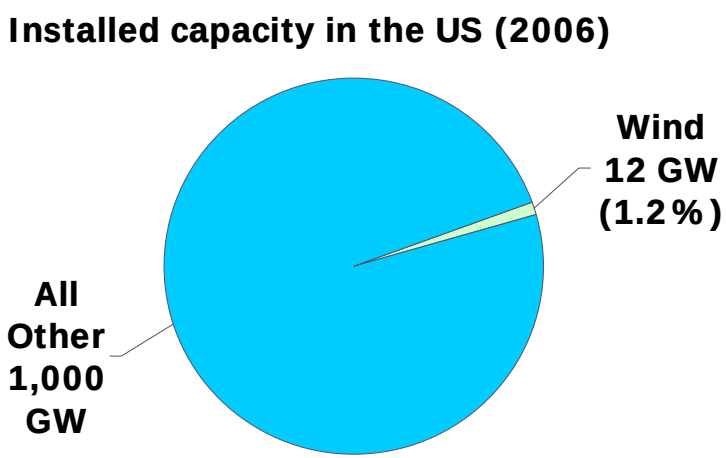
Toronto, Ontario, on the evening of August 14 2003. [www.wikipedia.org]

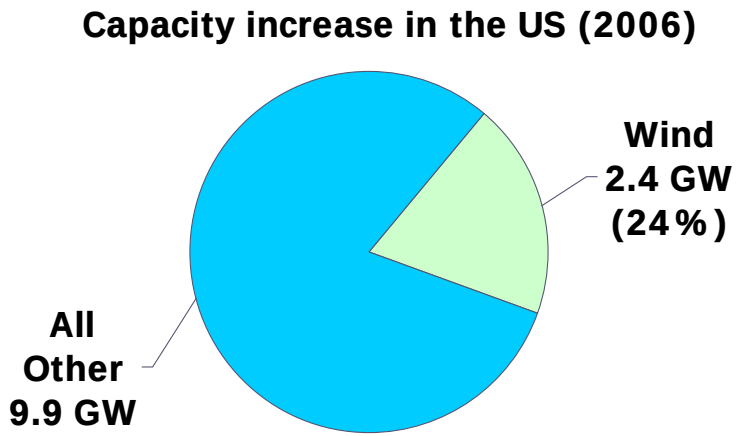
- New focus on grid reliability
  - Standards mandatory, stiff penalties for noncompliance

Wind generation and the power grid

Why we are paying attention

- A relatively small player in the US, but growing fast



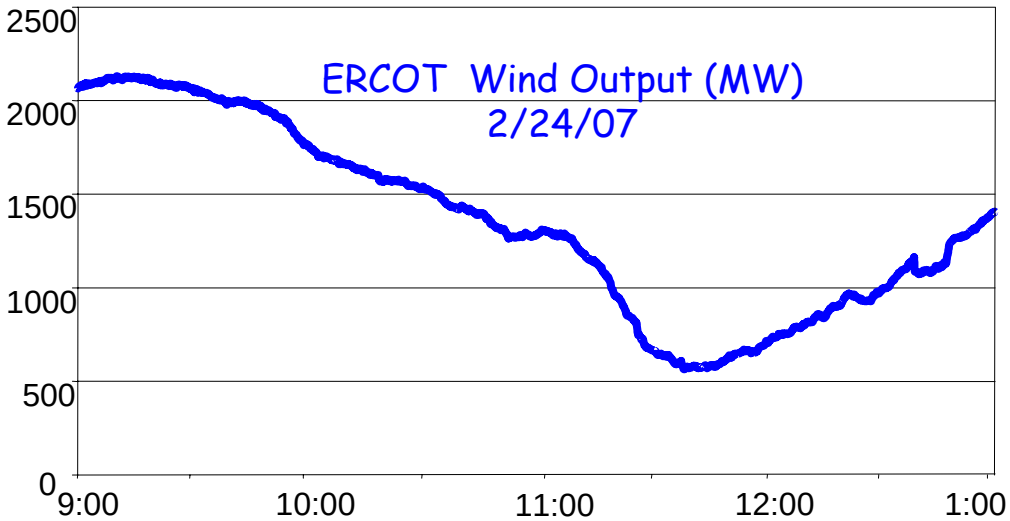


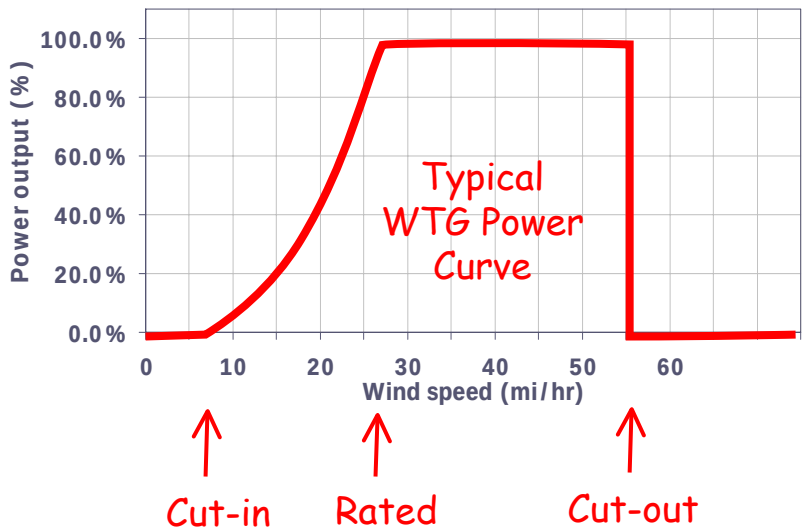
- More significantly:
  - High growth rate pattern expected to continue
  - Wind penetration levels higher in some areas
  - Wind penetration even higher during light load periods

Loss of generation due to high wind

A recent example from Texas

- ERCOT wind event, February 24, 2007
  - High winds in central TX caused wind generation tripping
  - Wind production fell 73% (1.5 GW) in 2 hr
  - 750 MW/hr generation drop off combined with 1000 MW/hr load pick up was difficult to deal with





Loss of generation due to high wind

Some thoughts

- Should we be concerned?
  - Large scale wind generation tripping due to high winds is not a credible event due to geographical diversity
  - Large drop off over time (hours) is possible
  - This can be difficult to handle unless operators and system are prepared
- How can the risk be addressed?
  - Learn from this experience!
  - Wind event forecasting
  - Pre-emptive controlled shutdown
  - Increase spinning reserves

Loss of generation due to grid events

An recent example from Europe

- UTCE breakup - November 4, 2006
  - Grid event caused system breakup, 15 Million affected
  - Wind output 15 GW accounted for 5.5% of the load at the time; ~10 GW (67%) tripped after the event
  - In the western island (generation deficit area), 5 GW out of 6.5 GW wind tripped (40% of total generation lost)
  - In the north-eastern island (generation surplus area), 5.5 GW out of 8.5 GW wind tripped initially, but most reconnected automatically within an hour, exacerbating over-frequency

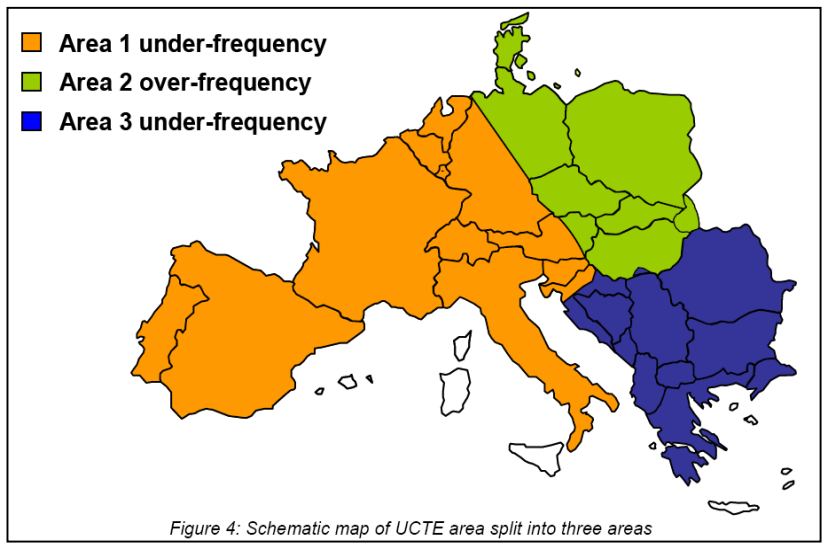


Figure 4: Schematic map of UCTE area split into three areas

Loss of generation due to grid events

An recent example from Europe

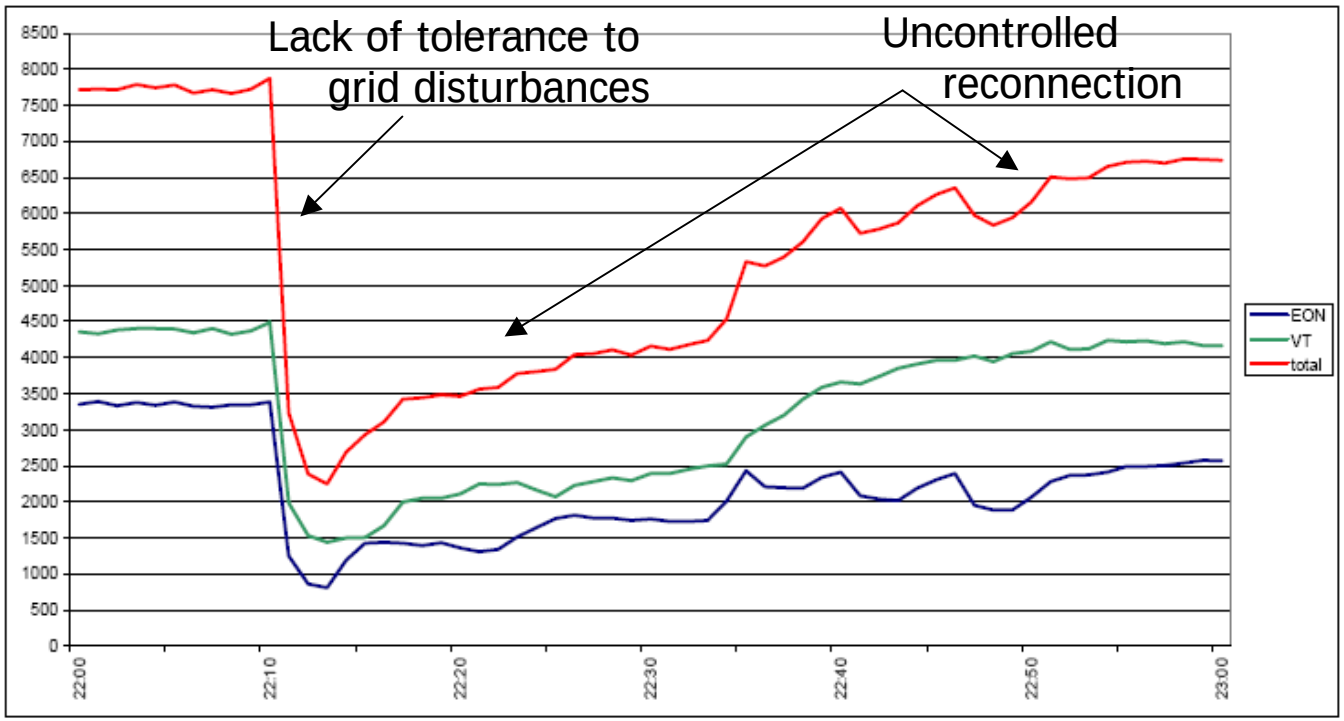


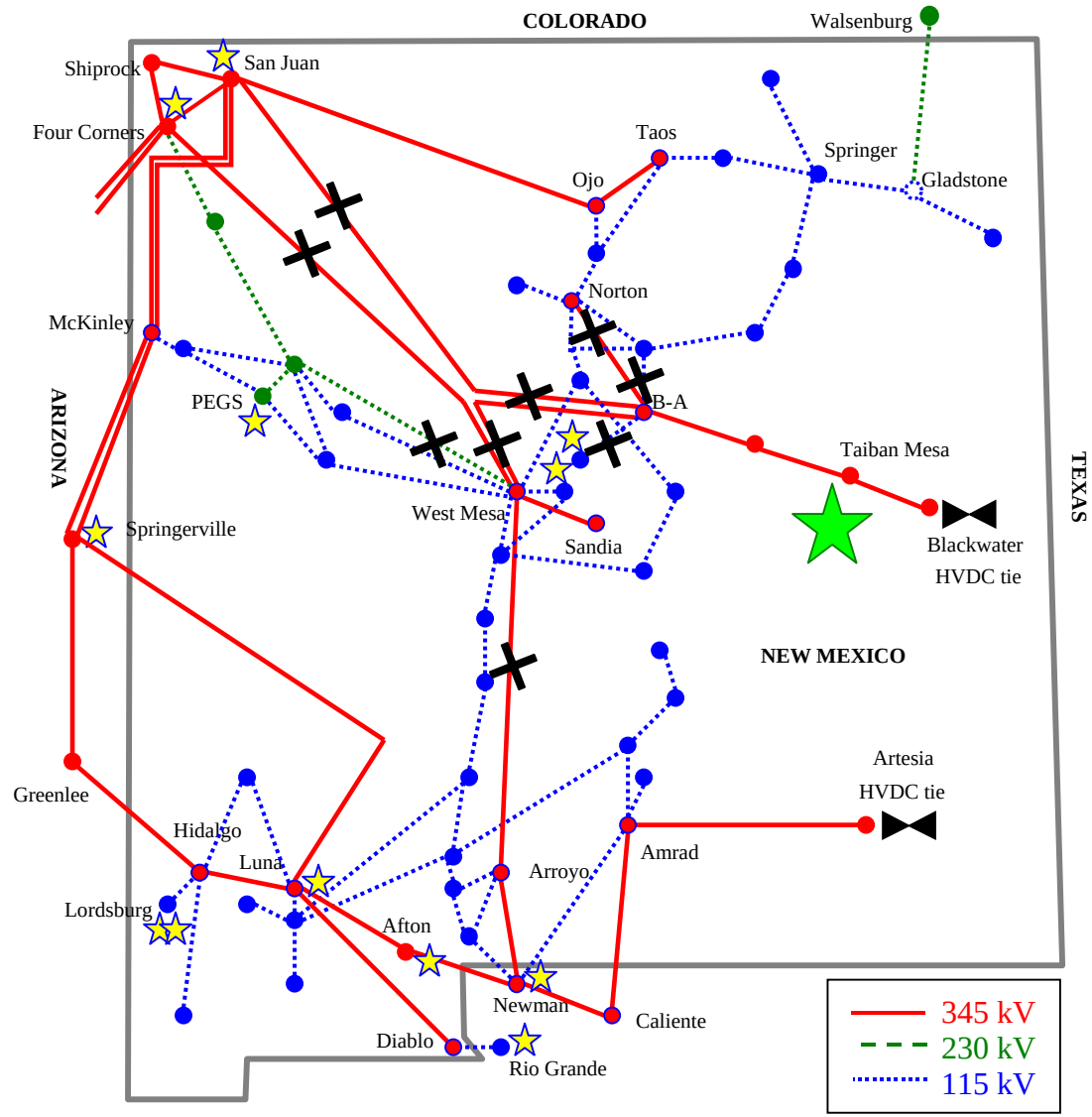
Figure 13: Output of windmills (VE-T, E.ON Netz, from 22:00 to 23:00

Note: wind turbines operated as designed in this case.

- Wind not a “root cause”, but low tolerance to disturbances & uncontrolled reconnection compounded impacts

Loss of generation due to grid events

A little closer to home

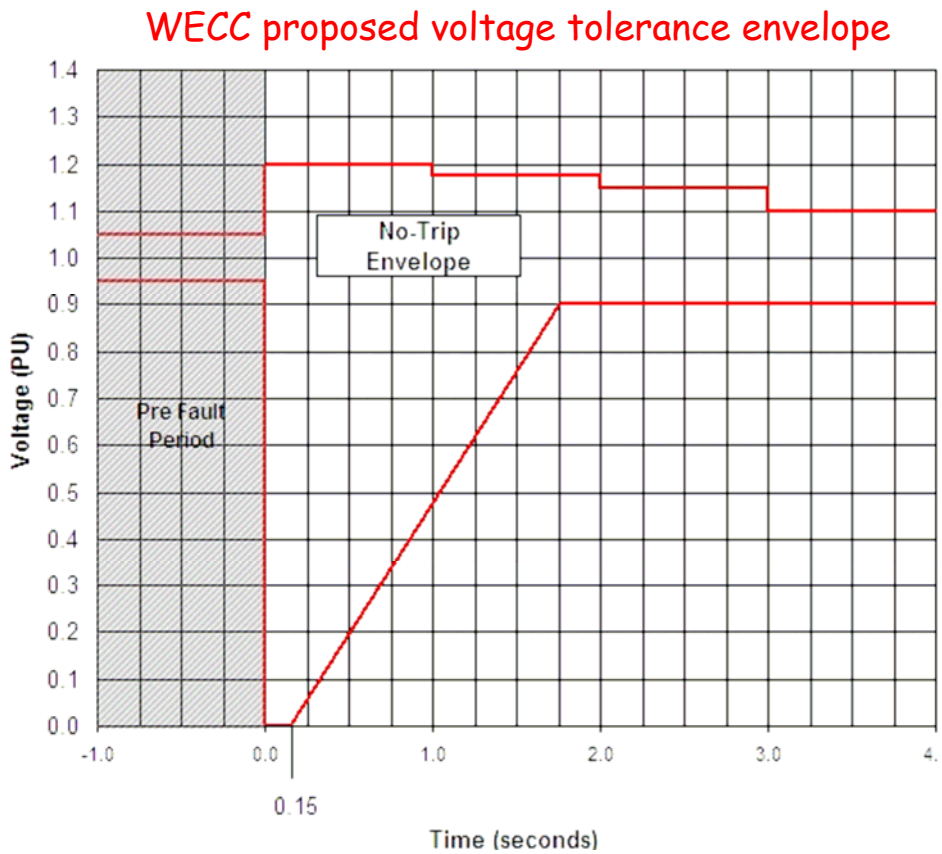


- PNM, 2003: Simulations showed that proposed 204 MW wind power plant would trip for remote grid faults
  - Protection threshold of 0.7 pu common then
- Study established need for fault tolerance
  - No US reliability criteria directly applicable then; some activity in Europe
  - PNM developed its own LVRT criterion and raised issue to WECC

Loss of generation due to grid events

Some thoughts

- Significant progress has been made; but there are a few issues left to conquer...
  - Standards have been developed; not all reconciled yet
  - Modern WTGs have better intrinsic voltage tolerance
  - External dynamic reactive power support often used with certain types of WTGs



Speaking of reactive power support…

We are not there yet!

- Reactive power support is required to maintaining grid stability
- In the US: FERC Order 661A Power Factor Design Criteria (Reactive Power), under the "wind generators are different" philosophy:
  - Maintain a power pf within a range of +/- 0.95 at the POI… **if** the System Impact Study (SIS) shows that this is needed for safety or reliability
  - Be able to provide dynamic voltage support… **if** (or to the extent that) the SIS shows that this is required for safety or reliability

This isn't really a "Standard" here. Needs more work.

Speaking of reactive power support…

We are not there yet!

- Interpretation of PF capability requirements vary
  - Amount and type of reactive power (static/dynamic) needed varies with system conditions, and over time
  - SIS does not evaluate reactive needs under all conditions
  - In some cases, the full +/-0.95 PF capability range is required, regardless of what the SIS shows
- In actual operation, control requirements also vary
  - Power factor control – Maintain PF near a target
  - Reactive control – Maintain VAr output near a target
  - Voltage control – Maintain voltage schedule at a bus

Questions?

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