Modeling the Effects of Integrating Distributed Energy Resources with the Electric Power System

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Grid 2030 Roadmap: DG is a Key Technology

DEMONSTRATIONS

- Develop testing and simulation capability for highly decentralized systems (M)
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HARDWARE INTEGRATION

- Design of acceptable "black box" for DG interconnect
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COMPONENTS AND MATERIALS

- Costs of load leveling technologies and plug and play technologies, i.e. bulk electricity storage and distributed generation technologies
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RELIABILITY

2030

- Final grid self healing real time
  - Monitoring
  - Simulation
  - Response
- Final grid
  - Real time pricing signals – grid level
  - Demand response
- Accommodates massive power flow variation daily and annually → storage and excess capacity

ANALYTICAL AND PERFORMANCE TOOLS

- Better dynamic modeling of the U.S. power systems

END-USE INTEGRATION

- Network integration of DG
  ◆◆◆◆◆◆◆
  - Develop engineering solutions
  - Demonstrate solutions
  - Develop standards

There are many technical challenges that stand in the way of reaching these targets and ultimately "Grid 2030." Load-leveling technologies (bulk electricity storage, DG) are too expensive. These "plug and play" technologies must reach price levels where they are attractive to entice utility investment and installation.

realistically. Distributed generation, distributed resources, and demand-side management will need to be considered together and not separated in planning, and making sure that distributed resources contributes to a robust system is essential.

- Study impact of distributed generation system
  ◆◆◆◆
  N-M

Introduction

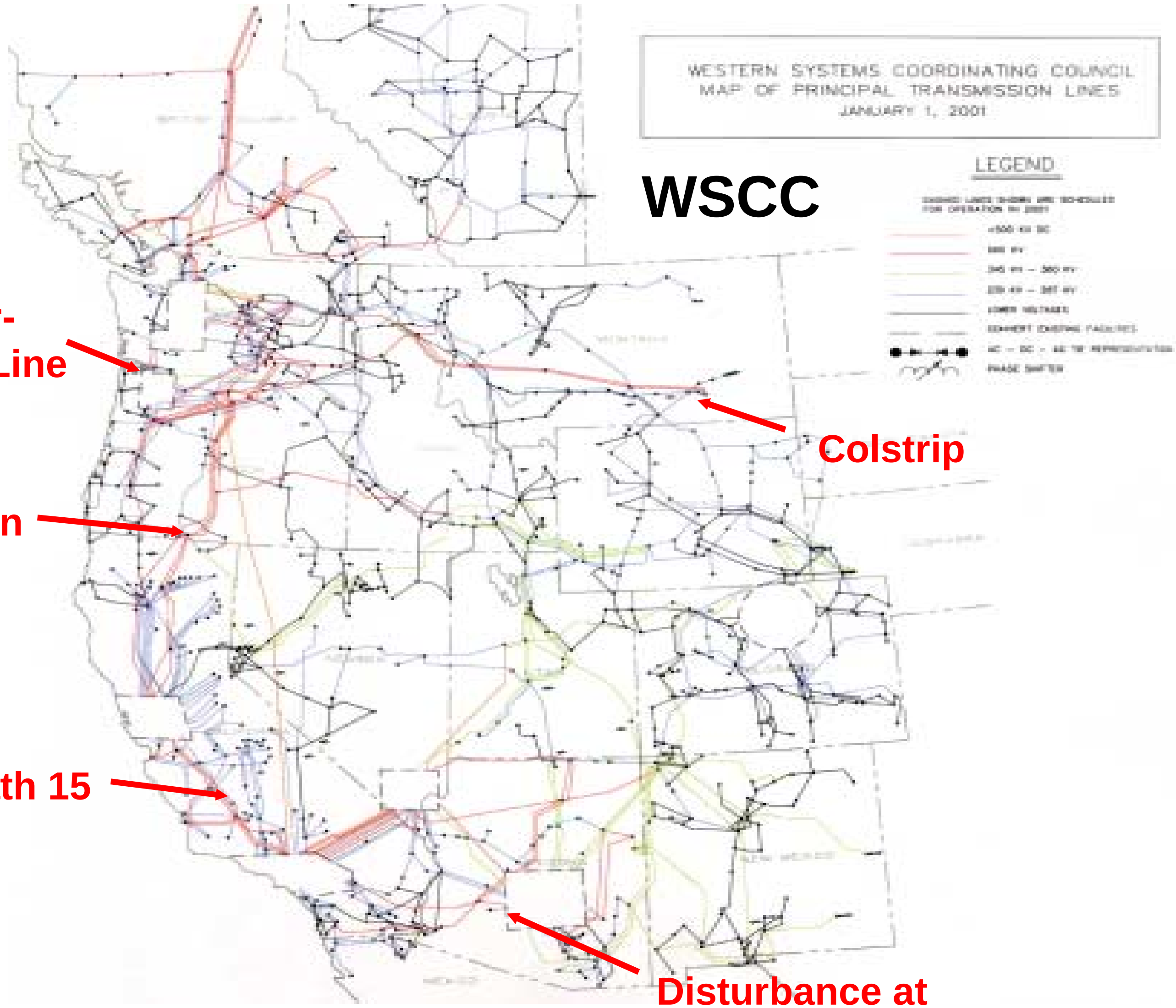
- **GE interconnect project is performing crucial investigation of DG and EPS integration issues (Support OETD system integration goal)**
  - Quantitative insight into the critical issues
  - Results are useful to the industry in defining interconnection standards

- **GE proposed a systematic approach to addressing interconnect solutions (Support OETD Interconnection cost reduction goal)**
  - Reduce hassle factor in the interconnection process through pre-testing and pre-certification of standard-compliant interconnects.
  - Achieve full benefits and value for DG through a universal interconnect platform with modular, scalable and progressive functionalities.

- **Bulk Power System, "Backbone" , Issues are More Important than Ever**

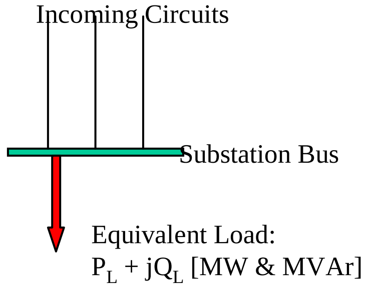
Understanding is essential for DR to achieve its full potential

Case Study - DR Impact on Bulk Power System



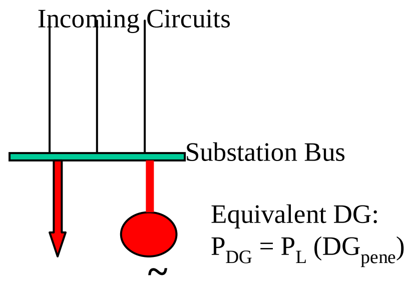
>6000 DGs Modeled:

Base Case Load Bus Representation



Adding DG

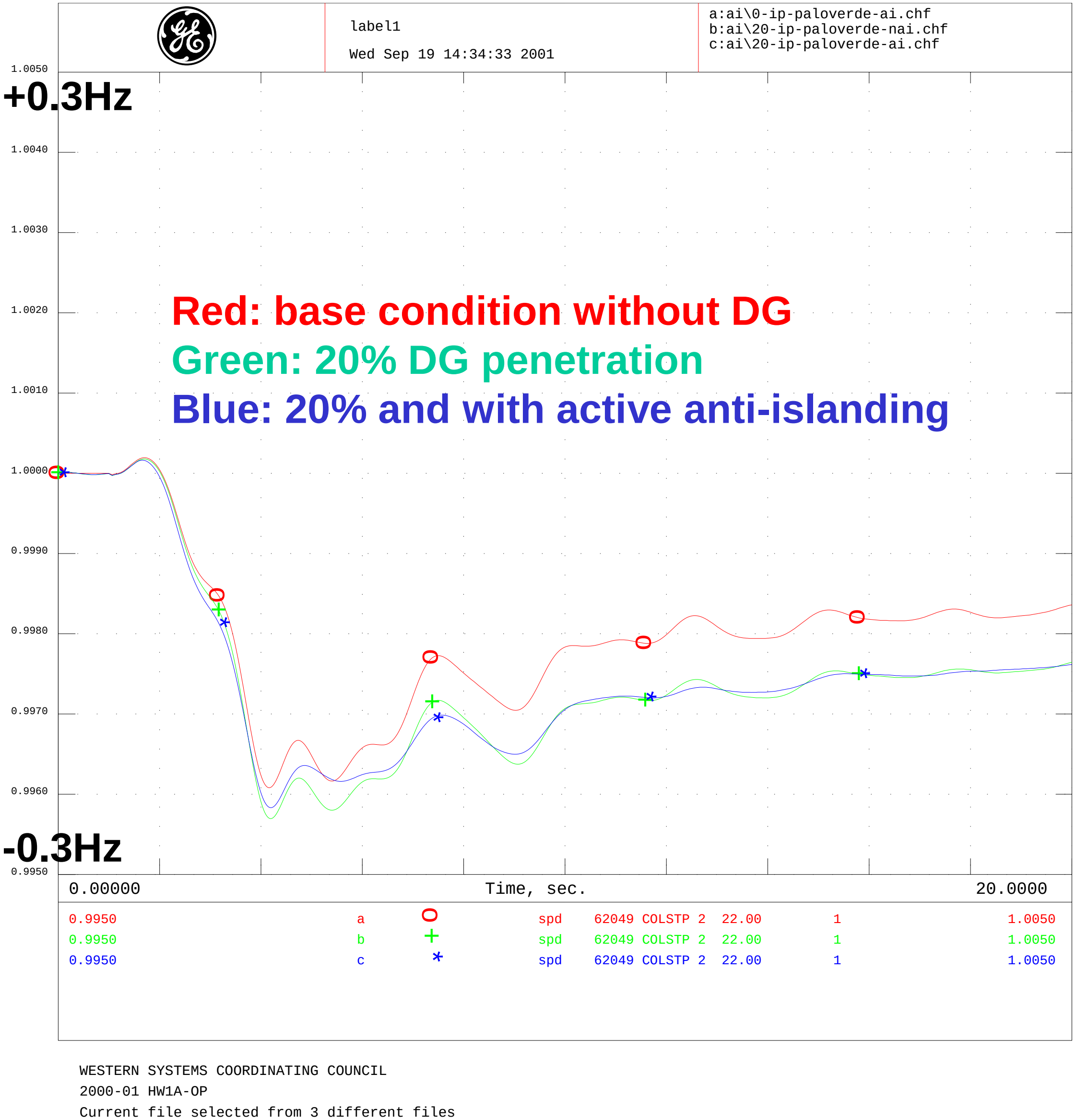
DG + Load Bus Representation



Equivalent Load:

$P_L\,(1 + DG_{pene}) + jQ_L\,(1 + DG_{pene})$

Active Anti-Islanding Impact on Bulk Power System



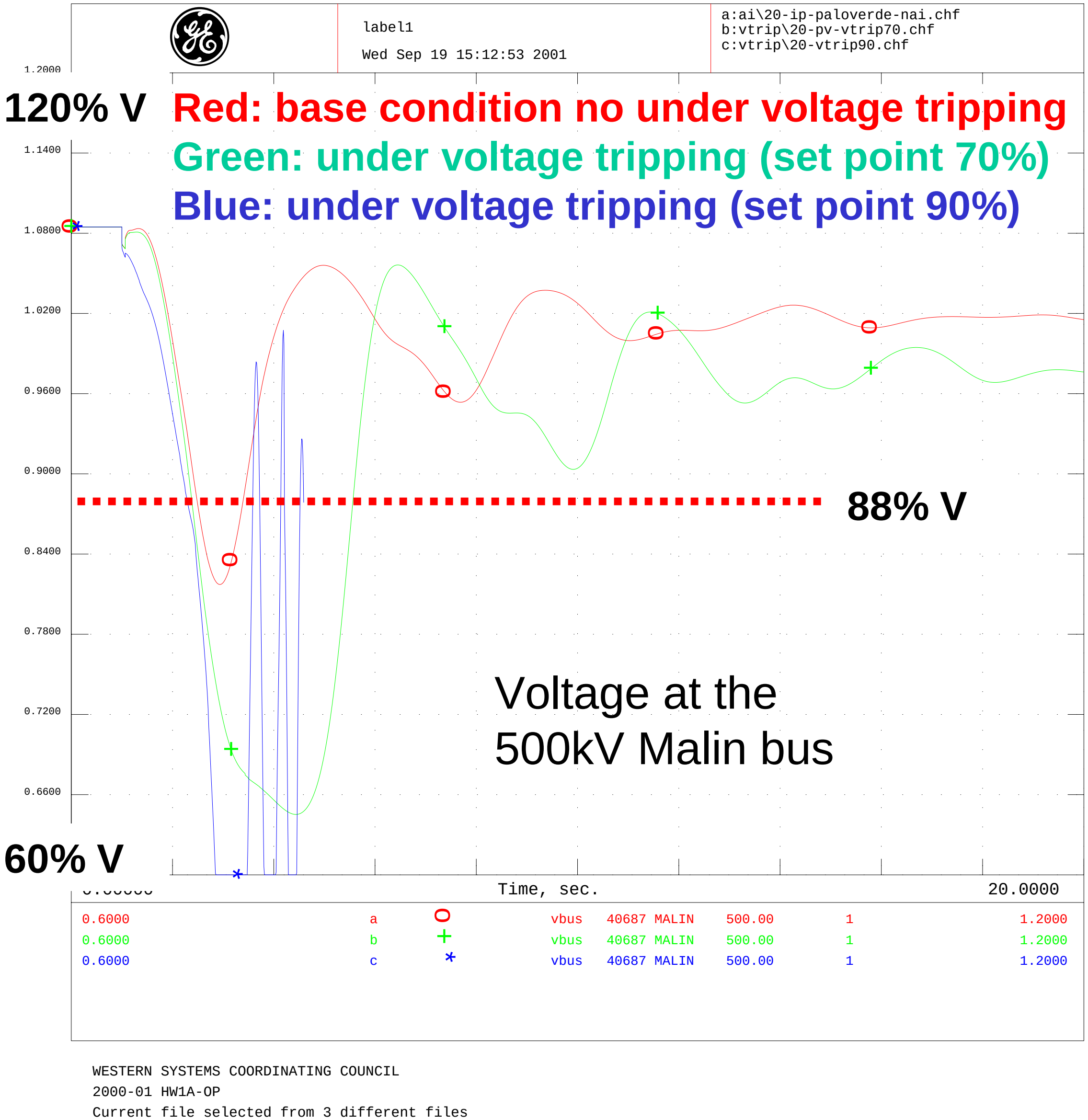
- Disturbance event: a very large power station with multiple units generating over 3000 MW in WSCC system is assumed to be tripped off-line by some common-mode disturbance.

- The case illustrates that the aggregate impact of the active anti-islanding scheme is benign to the system performance

- The lack of frequency regulation by DGs aggravates the common-mode frequency depression

Bulk System frequency dynamics with high DG Penetration and impact of Anti-islanding

DG Tripping impact on Bulk System Stability



- P1547 standard dictates disconnect for voltages <88% within 2 seconds.
- It is important to note that this specifies the *minimum* voltage and the *maximum* time to trip. Thus, DGs will be in violation if they trip slower or at too low a voltage. However, the DGs may trip faster and at higher voltages than this without violation.
- The case (blue trace) with the 90% trip point is very unstable

Bulk system voltage dynamics with low voltage DG tripping (20% DG penetration).

P1547 Voltage Response

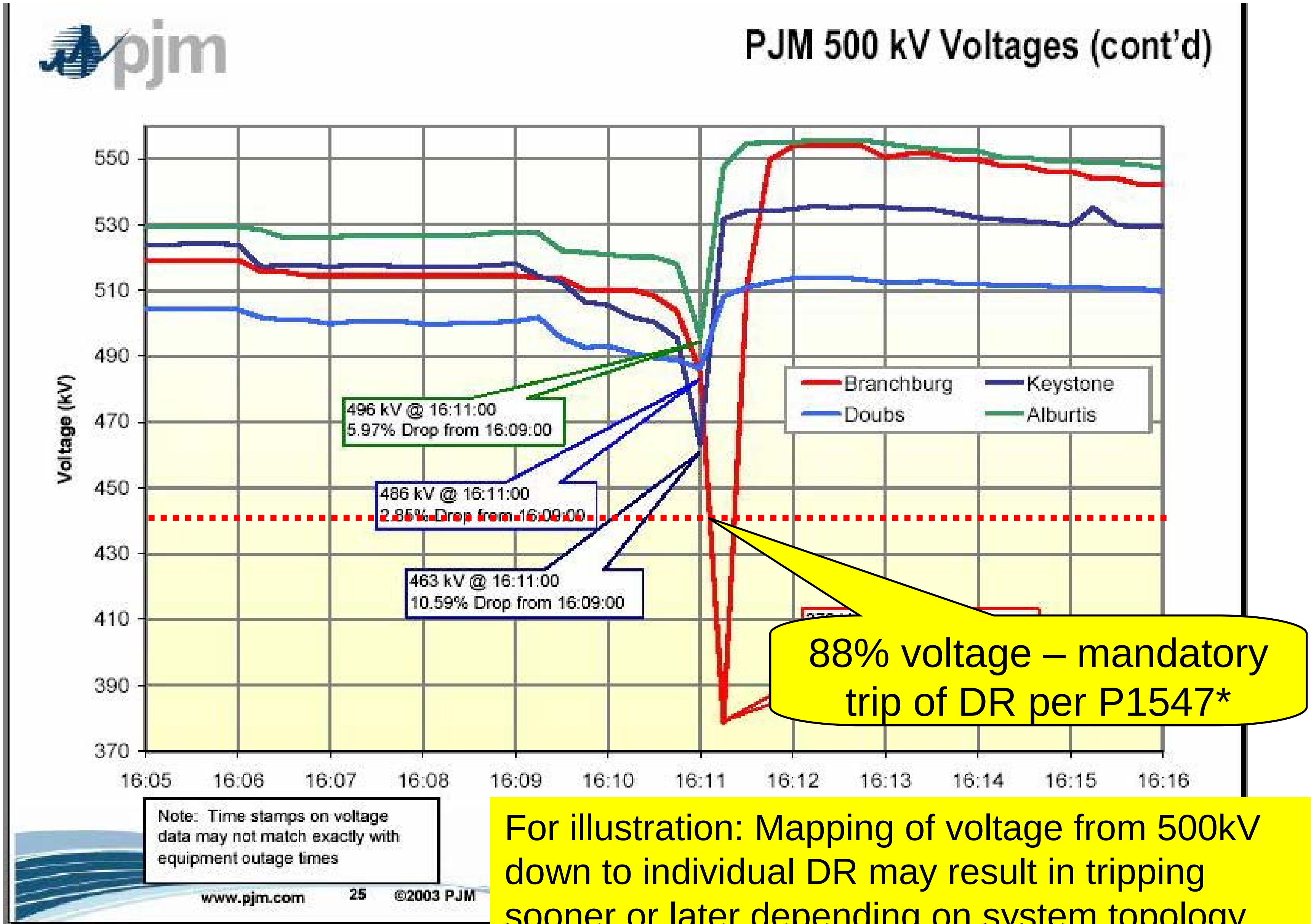
Table 1—Interconnection system response to abnormal voltages

Voltage range (% of base voltage[a])	Clearing time(s)[b]
V< 50	0.16
50 ≤ V< 88	2.00
110 < V < 120	1.00
V ≥ 120	0.16

[a]Base voltages are the nominal system voltages stated in ANSI C84.1-1995, Table 1.

[b]DR ≤ 30 kW, maximum clearing times; DR > 30kW, default clearing times.

August 14, 2003: EHV Transmission Voltages



For illustration: Mapping of voltage from 500kV down to individual DR may result in tripping sooner or later depending on system topology

P1547 Frequency Response

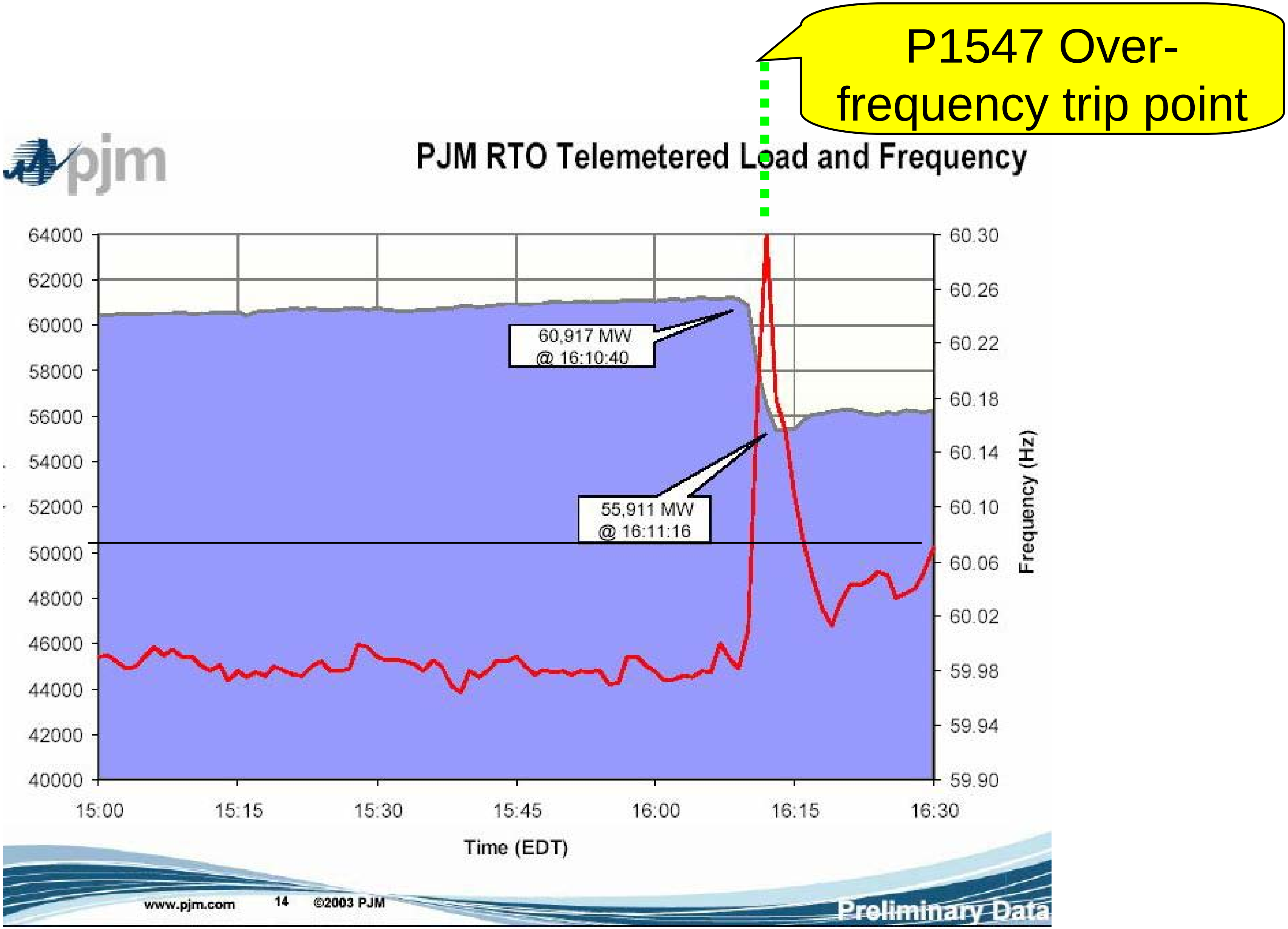
INTERCONNECTING DISTRIBUTED RESOURCES WITH ELECTRIC POWER SYSTEMS Std 1547-2003

Table 2—Interconnection system response to abnormal frequencies

DR size	Frequency range (Hz)	Clearing time(s)[a]
≤ 30 kW	> 60.5	0.16
	< 59.3	0.16
> 30 kW	> 60.5	0.16
	< {59.8 – 57.0} (adjustable set point)	Adjustable 0.16 to 300
	< 57.0	0.16

[a]DR ≤ 30 kW, maximum clearing times; DR > 30 kW, default clearing times.

August 14, 2003: Frequency



Drawing on industry experience with wind generation

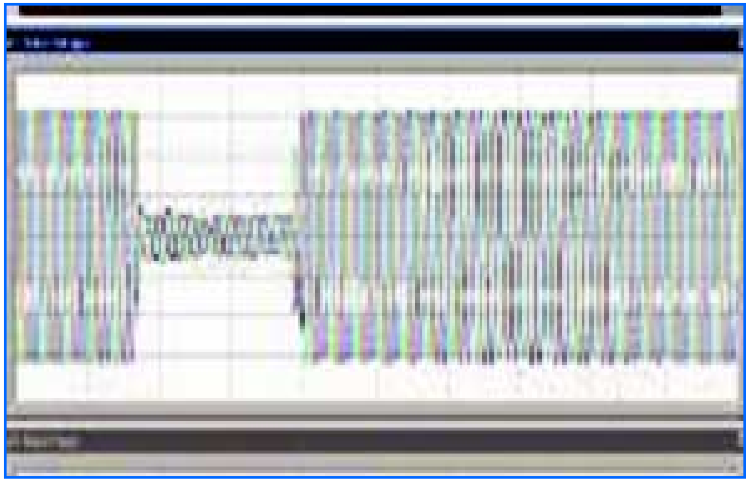
Europe and much of the rest of the world is moving towards a variety of ‘grid codes’, in which a set of performance requirements are imposed on the windfarm, largely independent of the site.

Requirements for most North American applications are being governed by the power system requirements particular to that site – but ‘grid codes’ are likely to follow soon.

Response to voltage events has emerged as THE critical issue

What is Low-Voltage Ride-Through (LVRT)?

The increased ability of wind-turbine generators to tolerate and continue operation after *voltage dips* – those voltage depressions that occur during grid faults.



Why LVRT now?

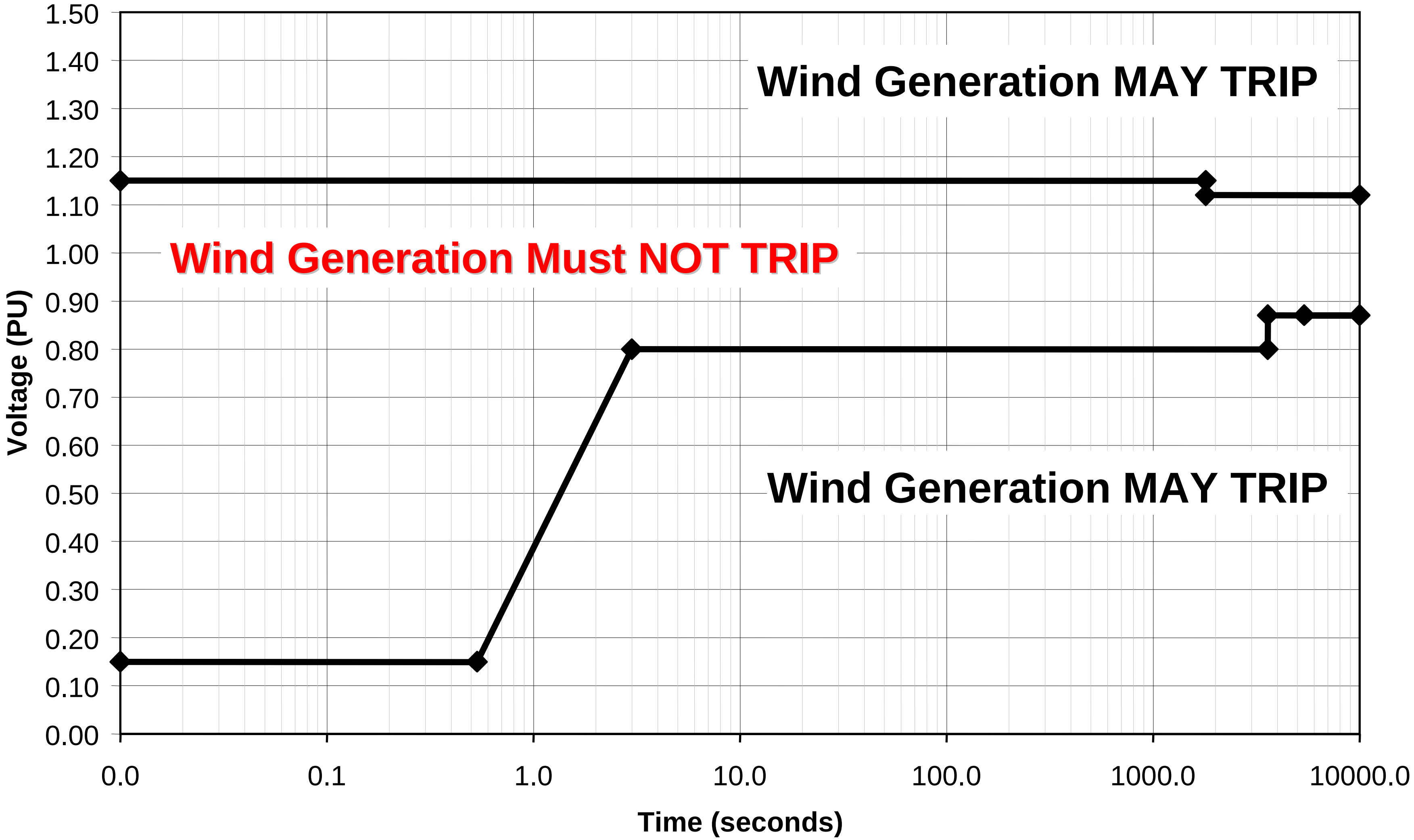
Wind Farms are becoming important contributors to the operation of the bulk power system:

- **For grid reliability, requirements for continuity of power from wind generation are increasing.**

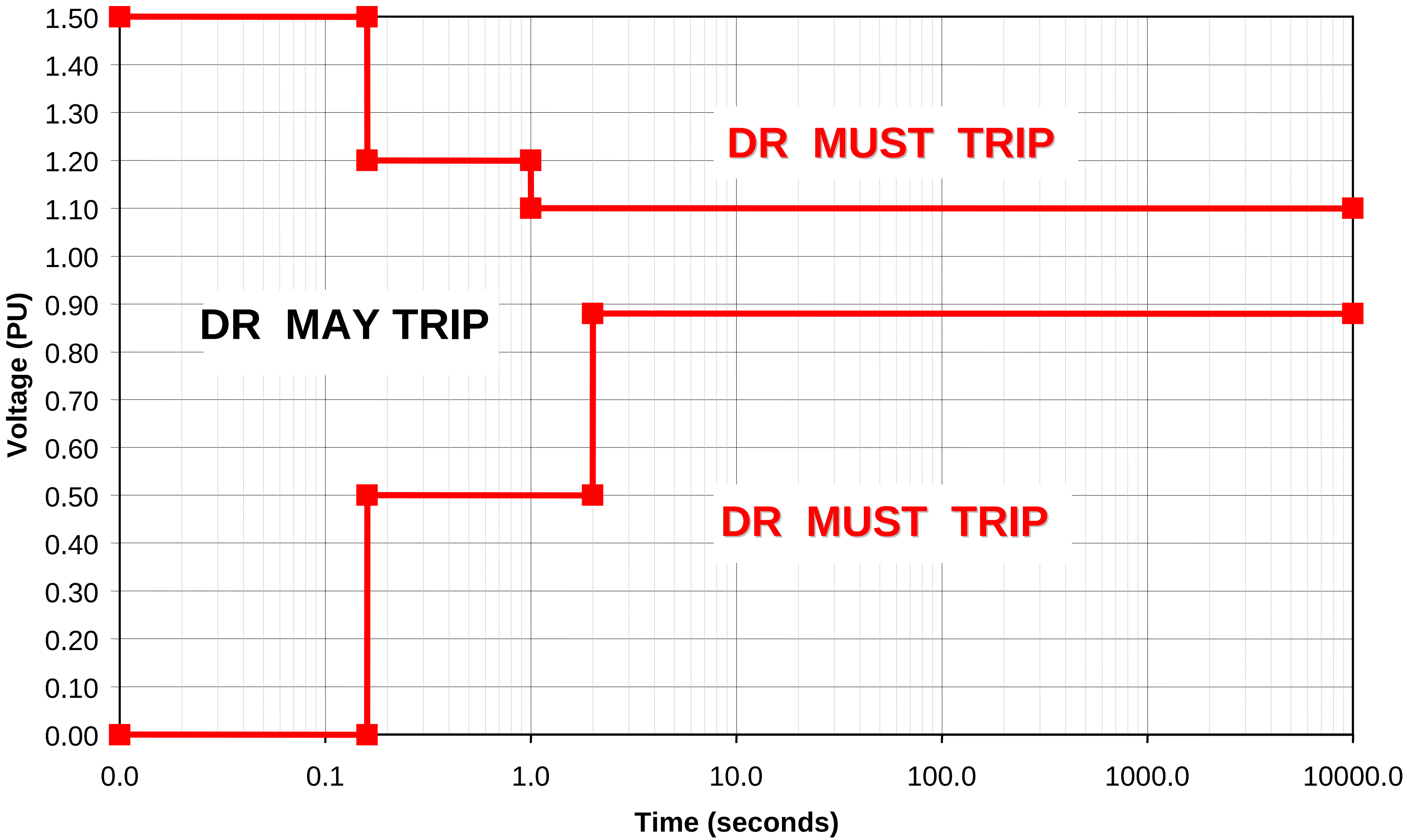
- **The historical desire to have WTGs that are embedded in distribution systems trip quickly is no longer the norm.**

Wind is a ‘victim’ of its own success – what can the DG community learn?

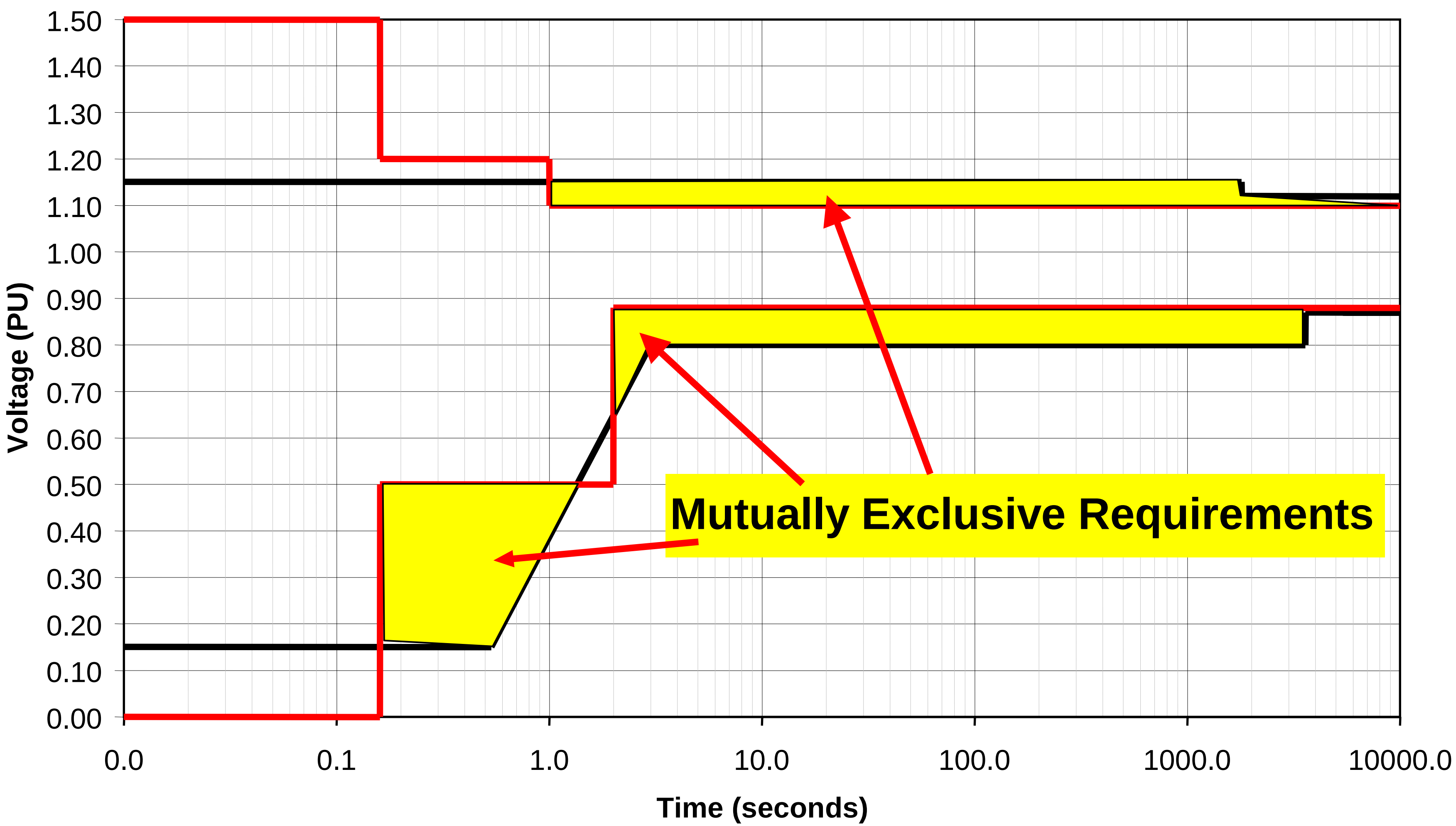
Statutory Response of WTGs to Emergency Voltage (e-ON example)



P1547 Response of DRs to Emergency Voltage



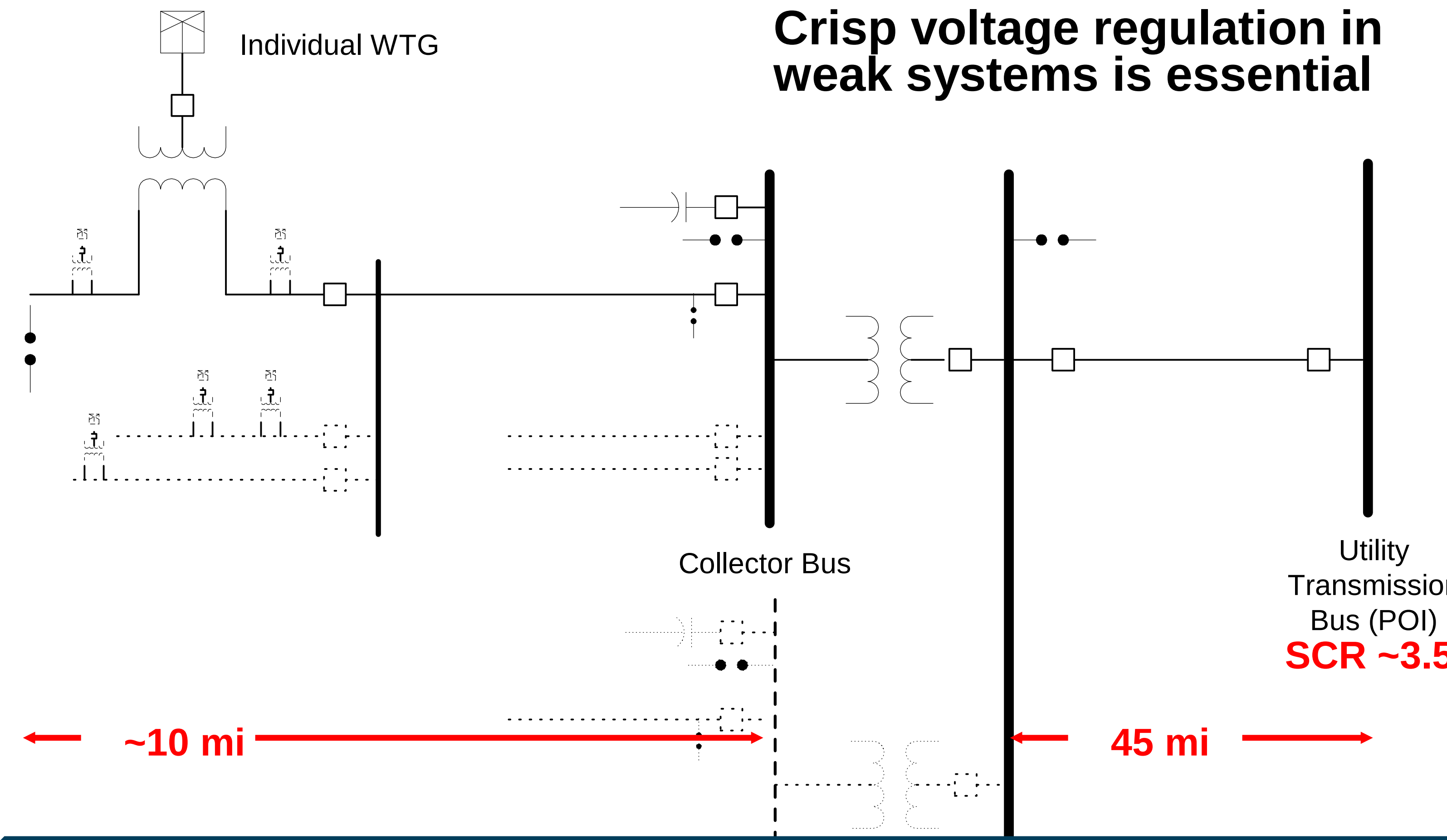
Statutory Response of WTGs to Emergency Voltage (e-ON example) v.s. 1547



Wind is a being aggressively pushed to stay on-line

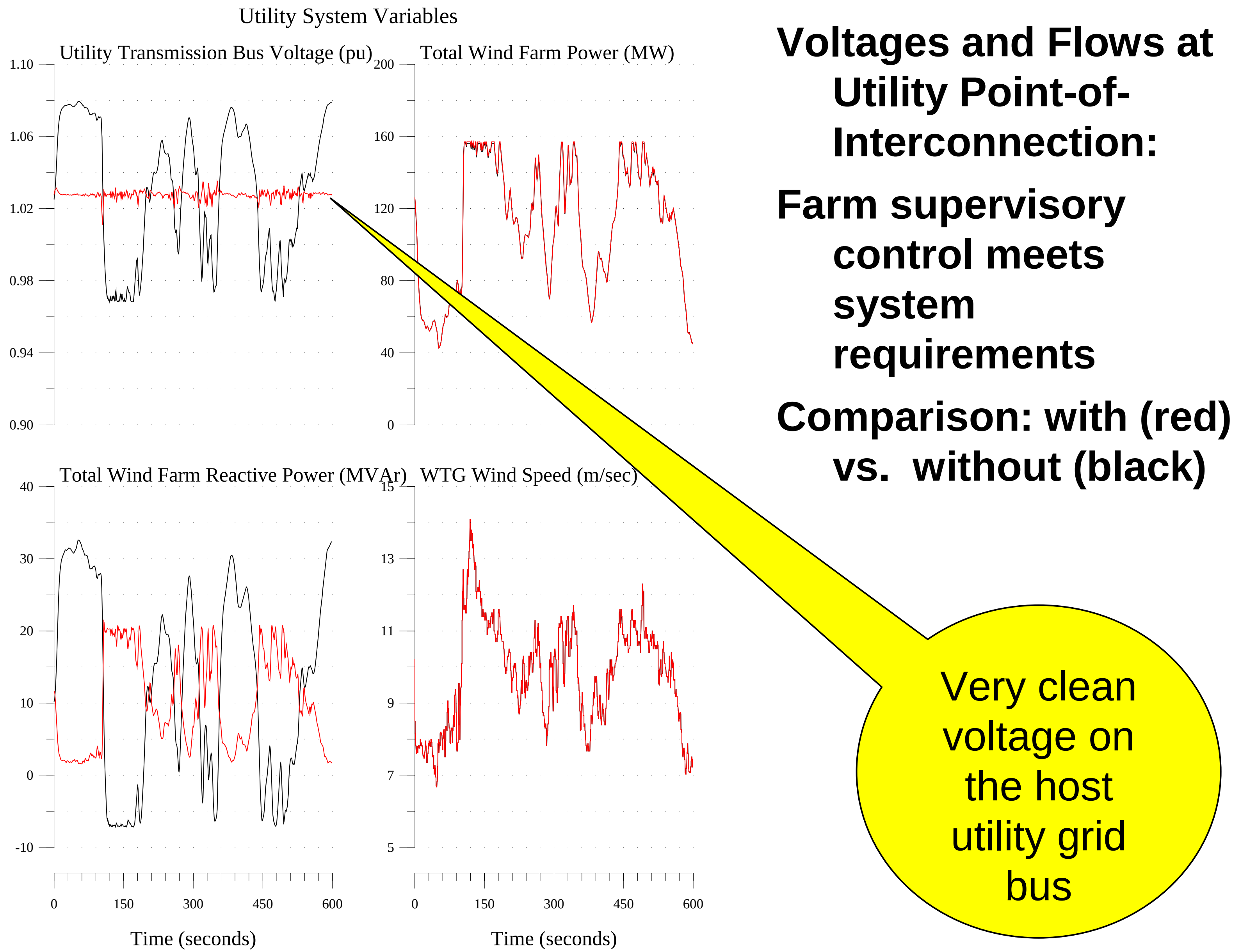
Another emerging issue: Voltage Regulation

Crisp voltage regulation in weak systems is essential



DG in physically remote and/or weak systems must participate

Another emerging issue: Voltage Regulation



Voltages and Flows at Utility Point-of-Interconnection:

Farm supervisory control meets system requirements

Comparison: with (red) vs. without (black)

Summary

• The power system isn't infinite; big events do happen

• Dynamics matter; control philosophy is important

• Local concerns don't necessarily jibe with systemic (backbone) requirements

• For DG a key issue will be 'good citizenship'

• Advanced Anti-Islanding concepts are needed to maximize system benefits

• GE project is focused on critical technology issues and building on experiences in related technology

Making the correct choices now provides for the future of DG