Grid Interconnection Issues for Wind Generation

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Topics I Will Cover

- What are the key technical and operational interconnection issues?
- What are the electrical and power quality impacts of wind turbines
- Examples of distributed wind generation interconnections and the key issues involved.

Single 900 kW Wind Turbine
Connected to Distribution Line
Near Waverly, Iowa

Key Technical Issues

- Power Quality when connecting to the distribution system
  - Voltage levels during operation
  - Voltage flicker during turbine start up and two-speed generator switching
- Operation of substation and line voltage regulators
- Protecting the distribution grid and wind turbine during grid disturbances.

Voltage Levels During Operation

- Voltage levels can rise rise at the point of interconnection
  - Most pronounced during full generation and light load periods
- For distribution connected wind turbines, voltage levels can exceed design standards out near the wind turbine point of interconnection
  - Especially if the substation bus voltage levels are already near the design limit and during low feeder load periods

Example of Operating Voltage Level Issue

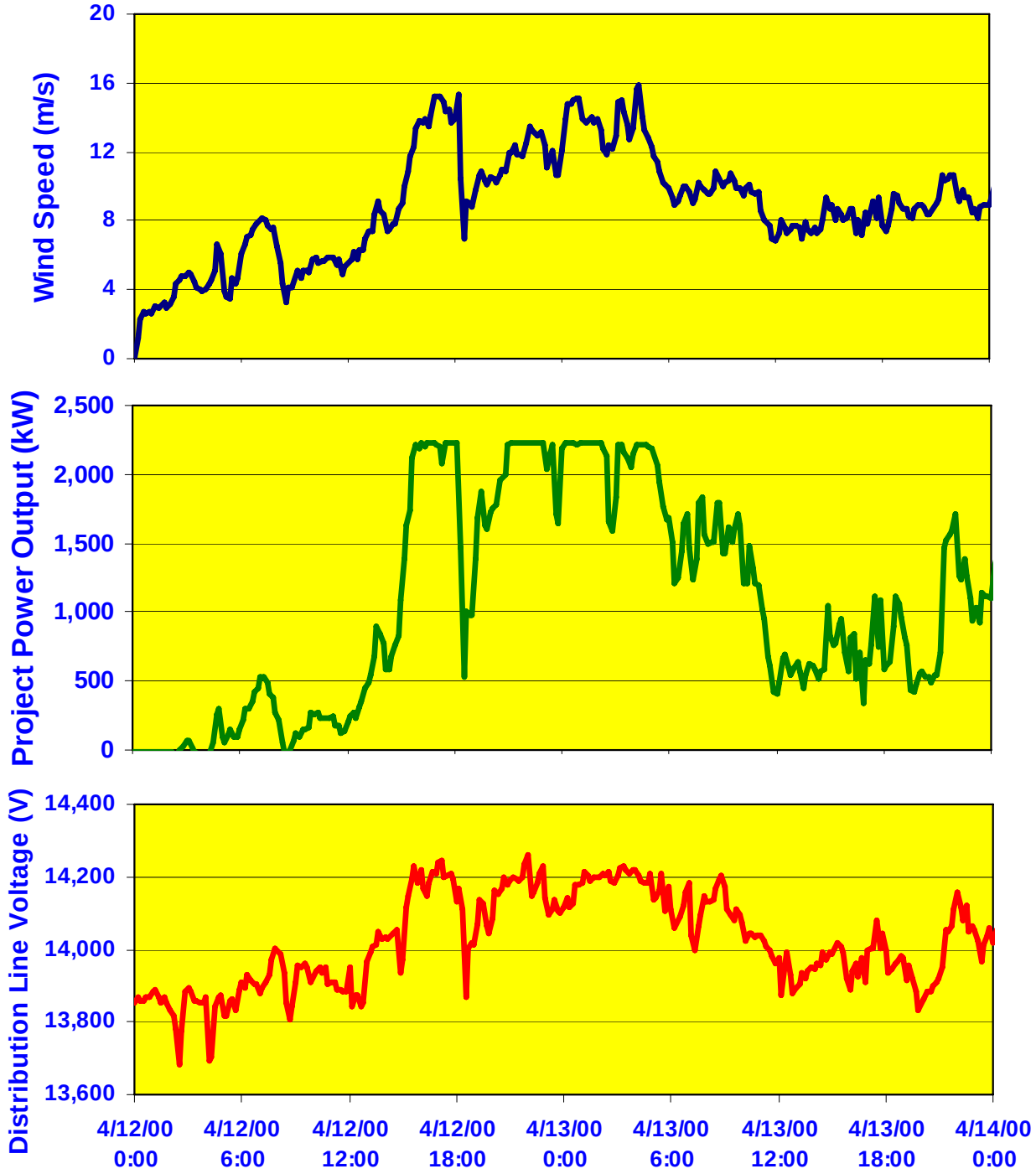
Iowa Distributed Wind Generation Project Near Algona, Iowa

Long Distance and Small Wire! Must operate turbines at 90-92% lagging power factor to keep voltage from getting too high.

Wind Speed

Power Output

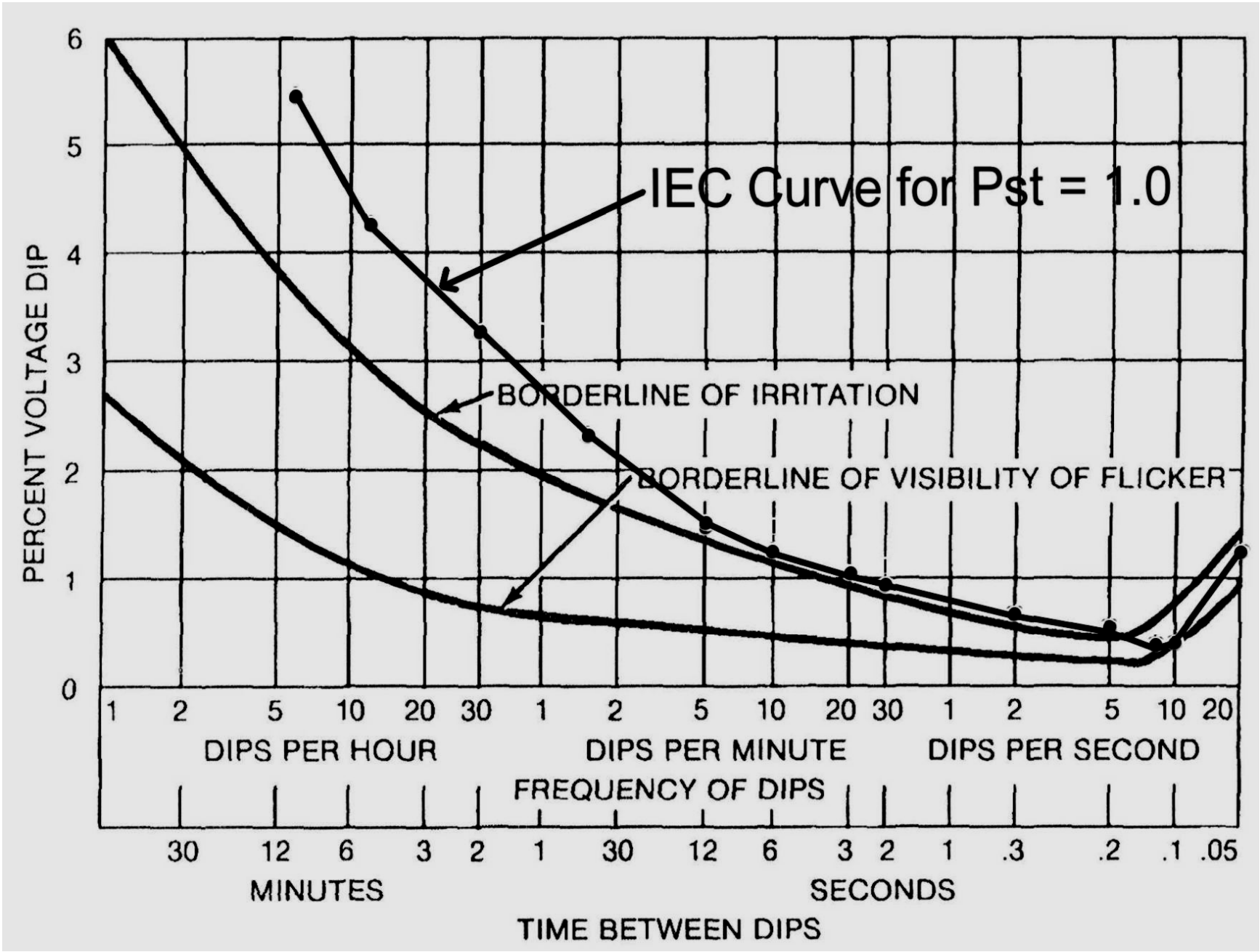
Distribution Line Voltage



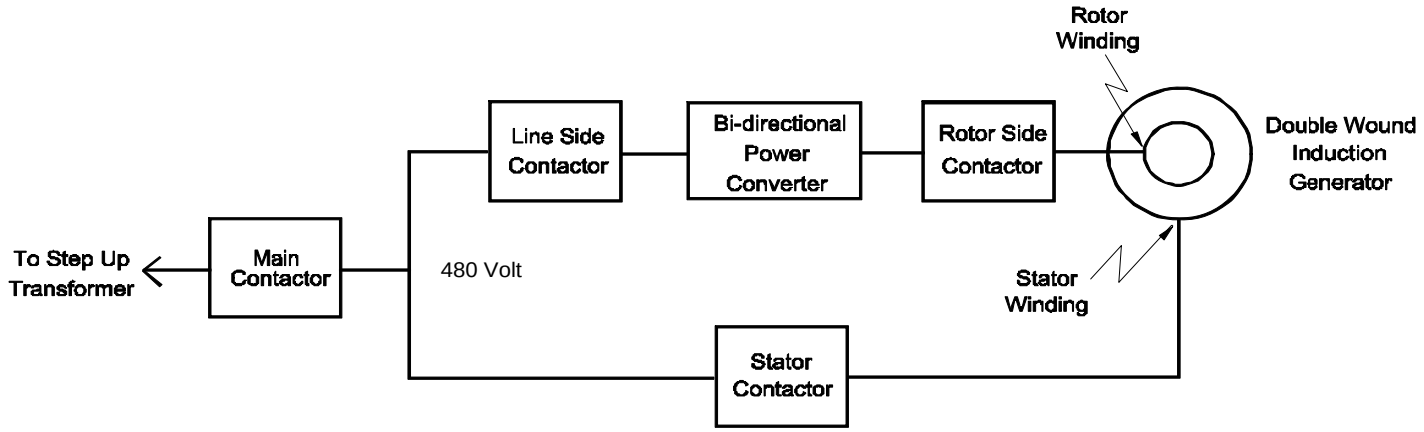
Voltage Flicker From Wind Turbines Connected to the Distribution System

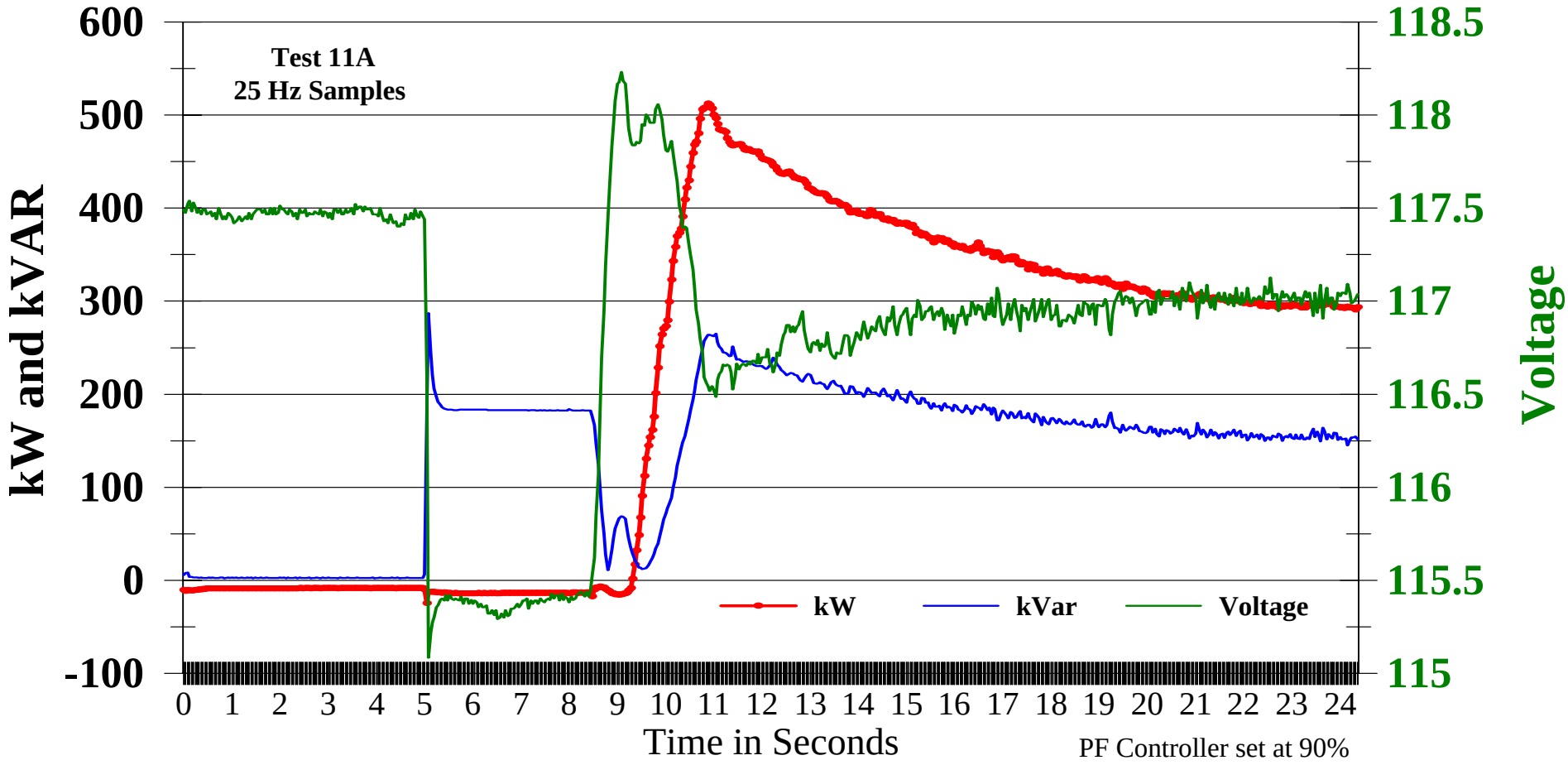
- During generator startup and generator switching, there will be inrush currents which will cause line voltages to dip or flicker
- Voltage flicker may or may not be noticeable or objectionable
  - Depends upon magnitude and how often it occurs
  - Magnitude of flicker depends upon the stiffness of the line
    - Voltage level (4.16 kV, 12.5 kV, etc.)
    - Distance from substation
    - Size of substation transformer
    - Wind turbine electrical design
  - See IEEE Flicker Curve.

IEEE & IEC Flicker Curves



Wind Turbine Startup at Algona, Iowa





Wind Turbine Transient Currents

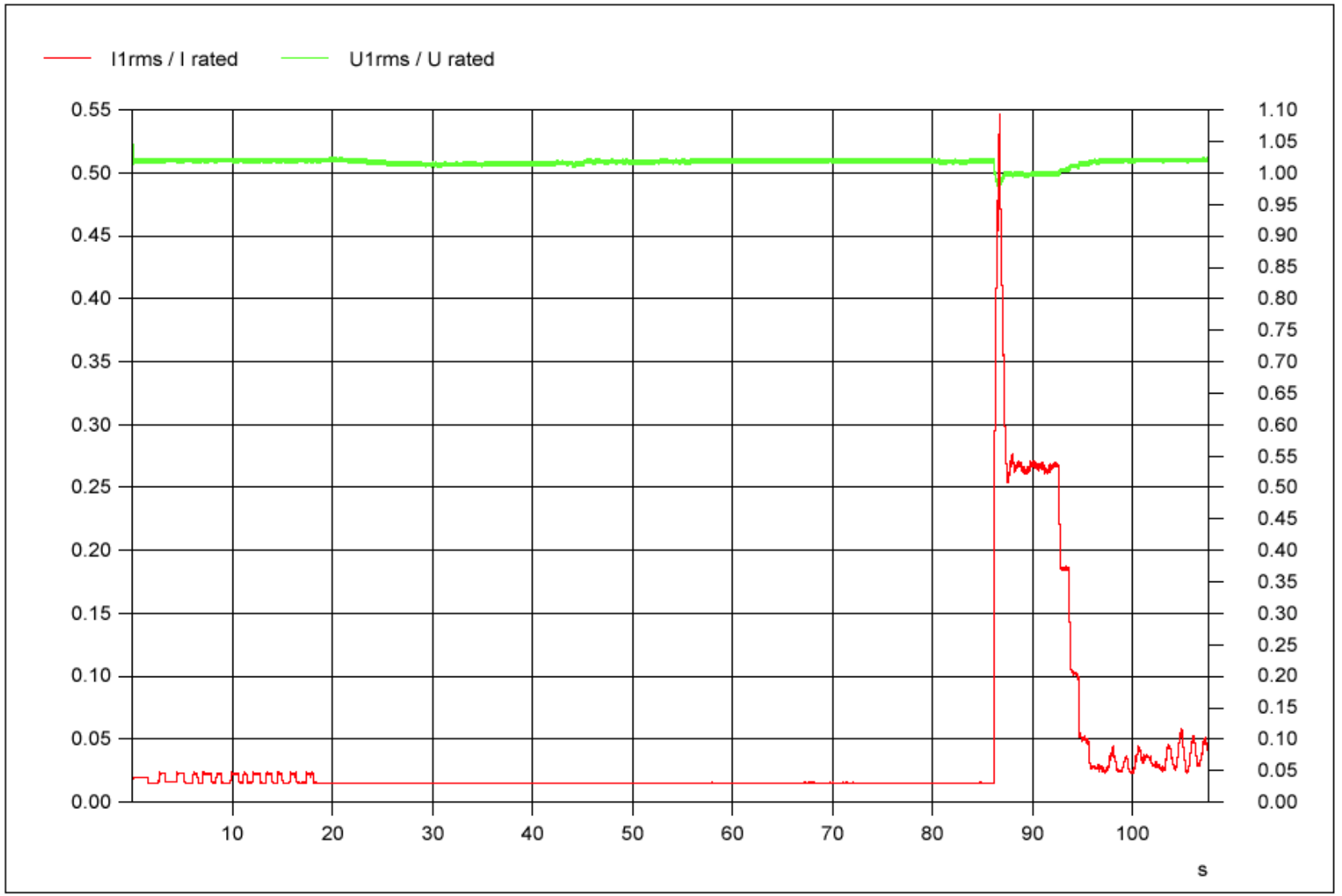


Figure 3.2.5 : Normalised rms-values for current and voltage against time for phase L1

Wind Turbine Transient Power

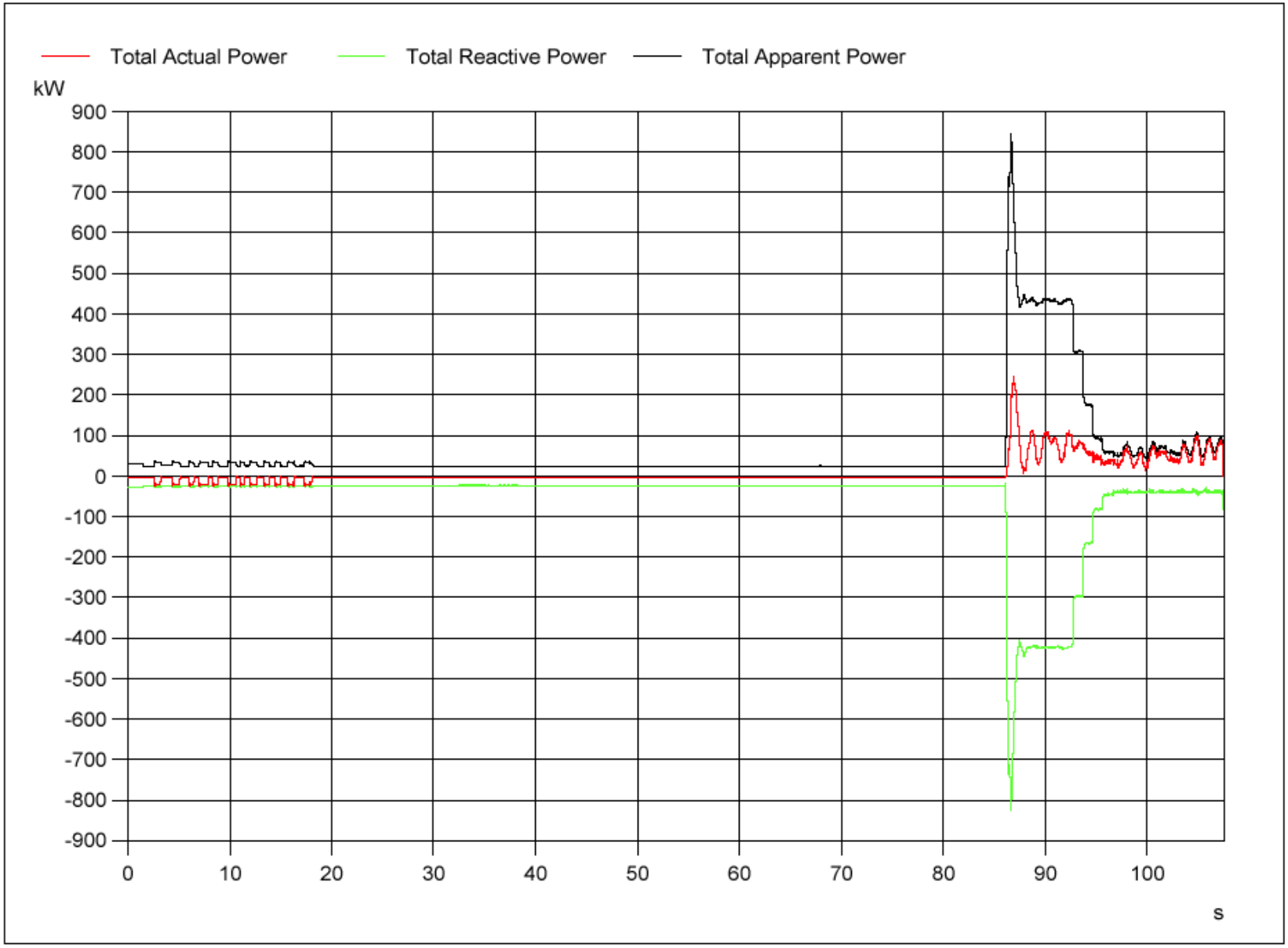


Figure 3.2.6 : Active, reactive and apparent power against time

Example of Voltage Flicker Issue

Two 950 kW turbines connected to a 4/0 ACSR rural feeder 2.75 miles from a 69/12.47 kV 7.5 MVA substation by Fairmont, MN

Due to the characteristics of these turbines, voltage flicker was a key design issue.

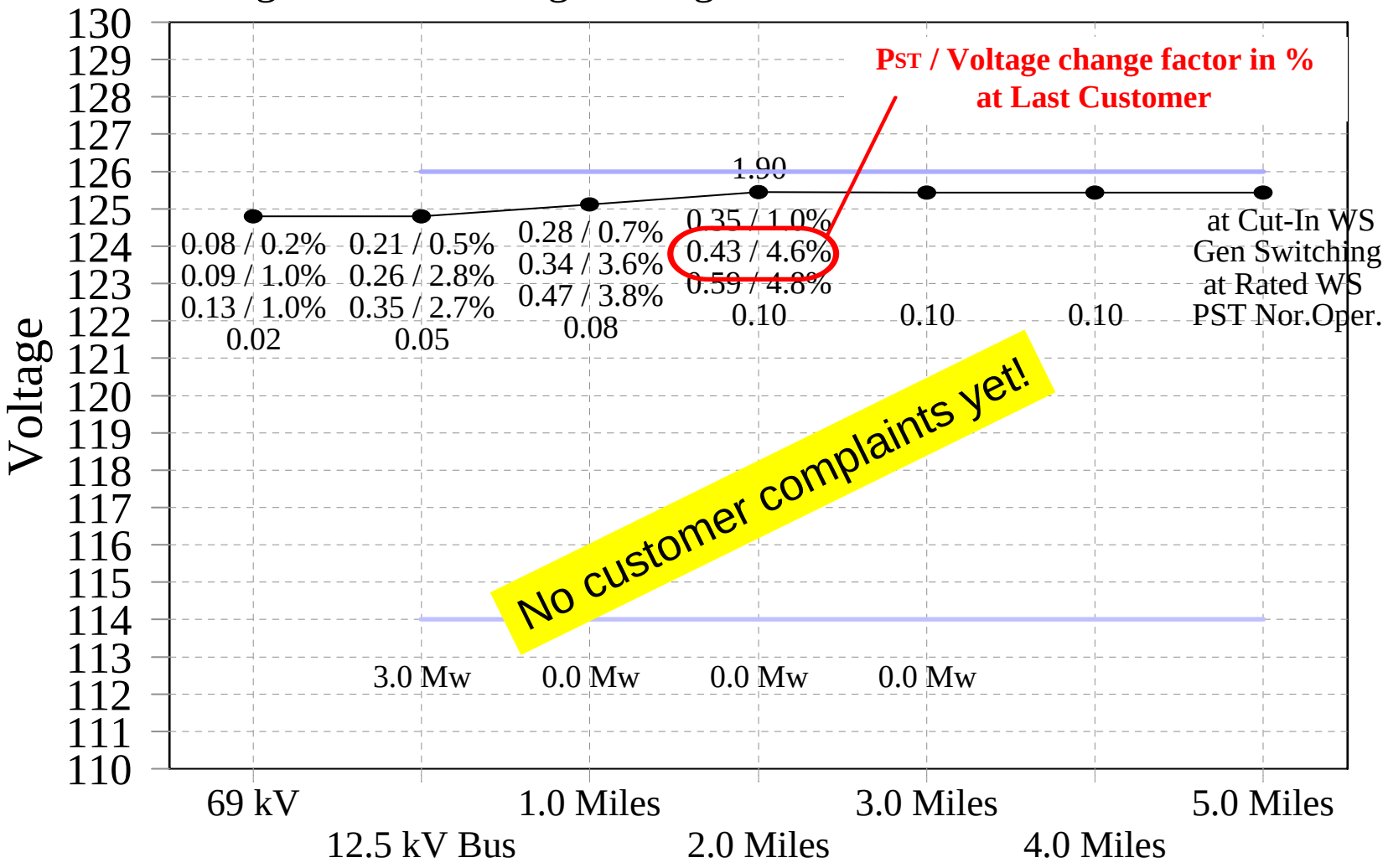
Two larger 1650 kW wind turbines were added to the same feeder nearby. The worst case scenario (with light and variable winds causing repeated turbine startups) puts the voltage flicker near the design limits (see next slide)

Example of Flicker Evaluation

Proposed Site With 2 NEG-M 950 WTG

NEG-Micon 950 kW with 4/0 ACSR

Voltage Profile, Voltage Change & Flicker Disturbance Factors



For IEC 61400-21 Data Format

Two Projects Where Power Quality Issues Were Very Important Design Issues

Lenox, Iowa

- 750 kW WT
- Very weak grid
- Required a 2 mile long dedicated 4.16 kV UG circuit which tapped a 4.16 kV feeder about 0.25 miles from the substation
- Voltage flicker issues required downsizing the wind turbine to 750 kW

Wall Lake, Iowa

- 660 kW WT
- Connected to a weak 2.4 kV distribution system
- Had to connect directly to the substation bus to avoid voltage flicker issues.

Summary

- For wind projects connected to the distribution system
  - Operating voltage levels and voltage flicker are two factors that will determine where turbines can be placed on the distribution system
- For wind projects connected to the transmission system:
  - Voltage flicker is not an issue
  - Operating voltage levels can occasionally be an issue