



“T&D Technologies to support the Growth of Wind Power”

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American Superconductor Corporation

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Innovative Energy, T&D, and Water Solutions

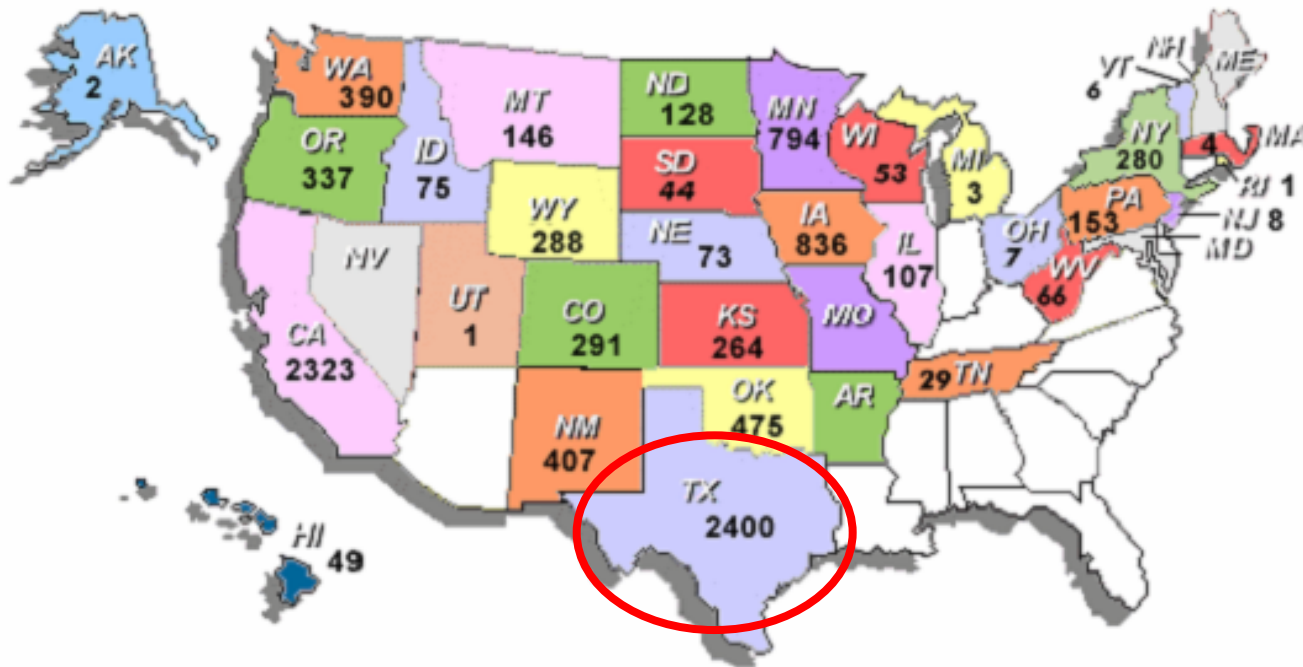
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Wind Generation in the USA

Wind Energy Projects Throughout the United States of America

Click on the shaded states to access information on existing and planned wind energy projects. Installed MW for each state in black.

Updated: August 4, 2006



TOTAL INSTALLED U.S. WIND ENERGY CAPACITY: 10,039 MW as of July 31, 2006

Hurdles to the Future Growth of Wind Power

- Regulatory Uncertainty – PTC, State RPS
- Economics of Wind Generation
- Negative Impacts on Utility Grid
- Meeting Interconnection Requirements

Wind Generation Impacts on the T&D Grid

- High VAR consumption (induction machines)
- Voltage fluctuations
- Inability to regulate voltage
- Tripping off due to low or high voltage
- Voltage sags and flicker
- Harmonics

Joint NERC/ FERC Interconnection Standards for Wind Energy (Dec 2005)

FERC Order 661A Provisions:

- Power Factor of +/- 95% at the point of interconnection
- Voltage regulation capability
- Low Voltage Ride Through (LVRT) capability to prevent tripping of wind turbines during voltage sag events

Options to address these standards

- Add capability within the wind generator turbine itself (GE, Vestas, Enercon...)
- Add reactive compensation equipment at the collector bus level (DVAR STATCOM, capacitors, reactors)
- Add a combination of improved turbine capability plus equipment at the collector bus
- Add equipment at the HV point of common coupling (Large STATCOM or SVC)

A Solution at the Collector Bus has many Advantages

- Less expensive for larger wind installations
- Provides full voltage regulation capability even when wind plant is not generating
- Solution is modular and expandable

D-VAR[®] Basics

What are **D-VAR[®]** Devices?

- Power Electronics (IGBT) based technology available from American Superconductor
- **D**ynamic **V**ARs... Fully Integrated air cooled STATCOM with ability to deliver 2.67 times its continuous current (2 sec)
- Instantaneously injects precise amounts of reactive power into a network
- Can be *seamlessly* integrated with static shunt devices as part of a larger solution



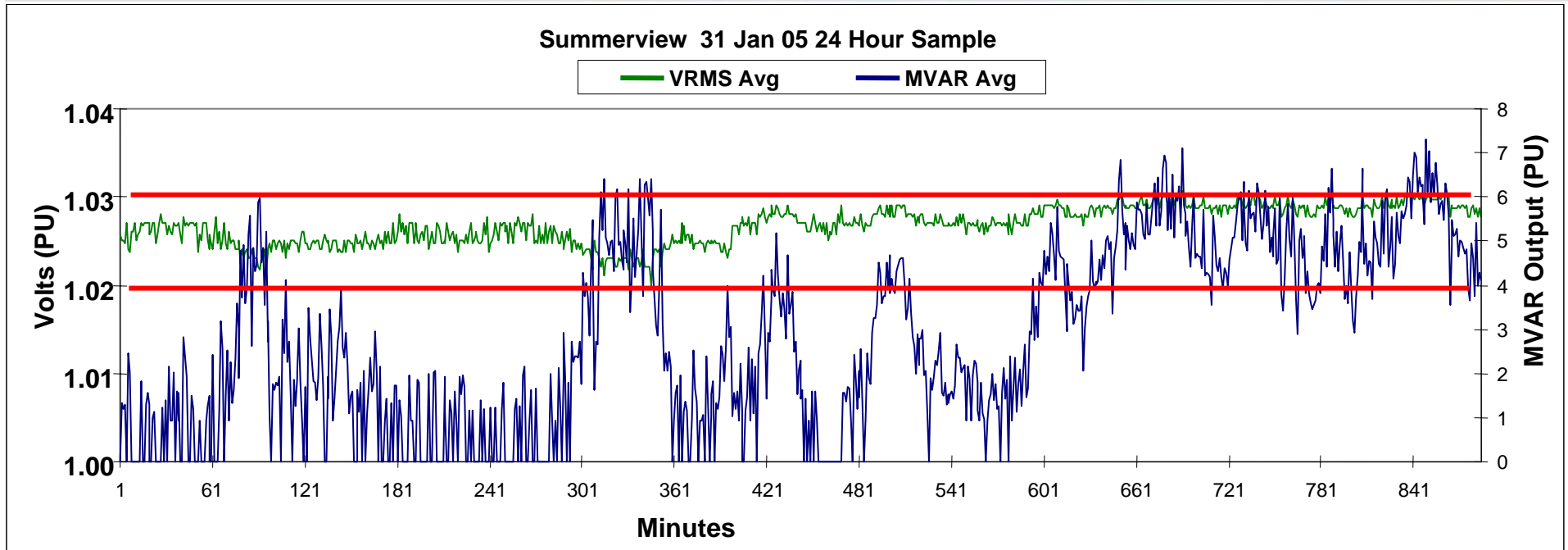
D-VAR mitigates wide variety of voltage and power quality related transmission problems

S. Australia - Wind Interconnection Requirements

- Deliver +/-93% PF at 132 kV bus at full generation
- Half of PF correction capability shall be dynamic
- Regulate transmission system voltage
- Avoid tripping wind farm for nearby transmission grid faults and high voltage (LVRT, HVRT)

Requirements can be met primarily by installing dynamic and static reactive resources

D-VAR[®] Voltage Regulation at 68 MW Wind Farm



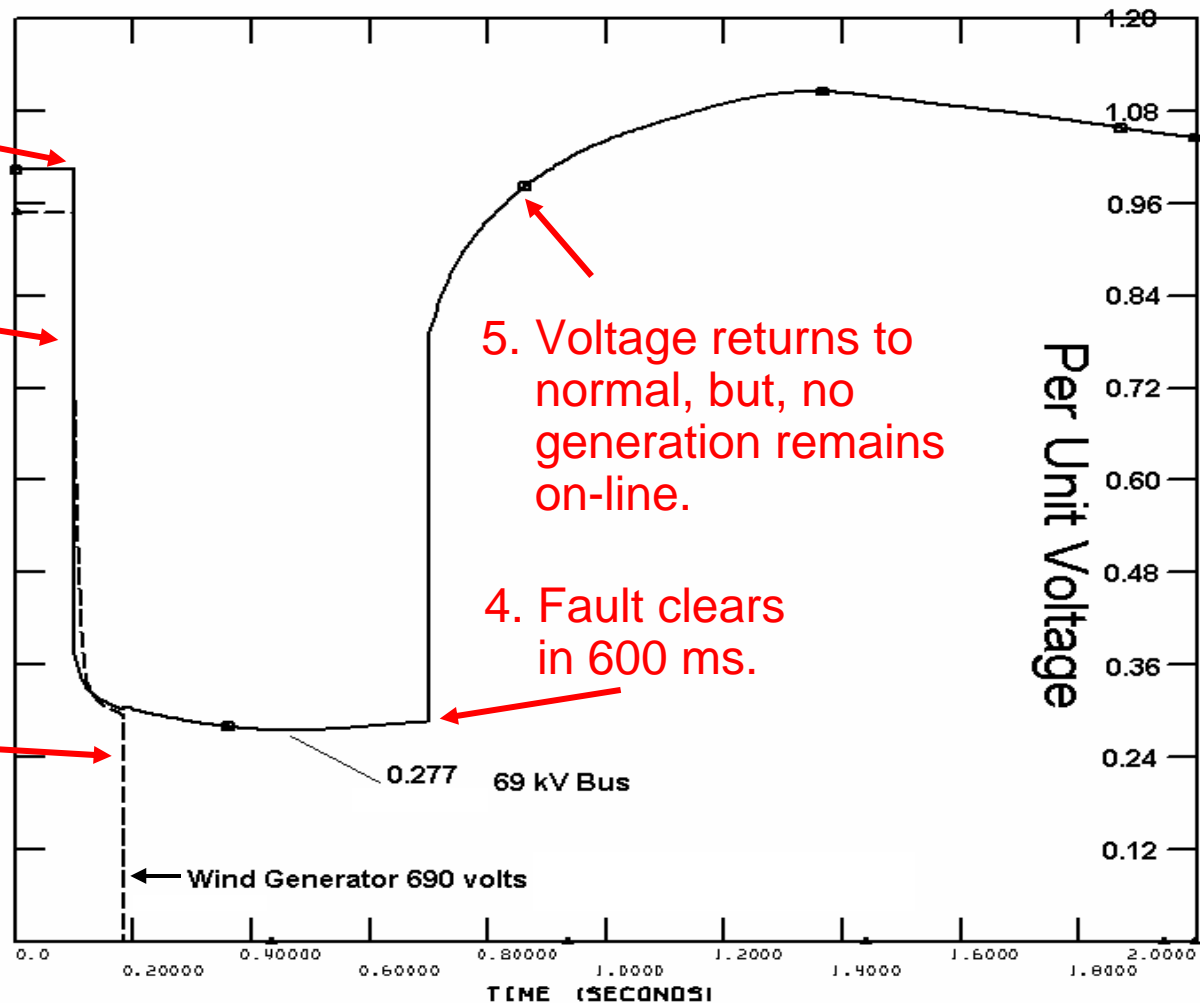
Wind Farm Voltage Regulation Parameters

- Voltage target is 102.5 PU +/-0.5%
- D-VAR[®] system has an 8 MVA inverter

Impact of Voltage Sag on Wind Farm without Ride-Through Capability

BASE CASE 600 MS FAULT

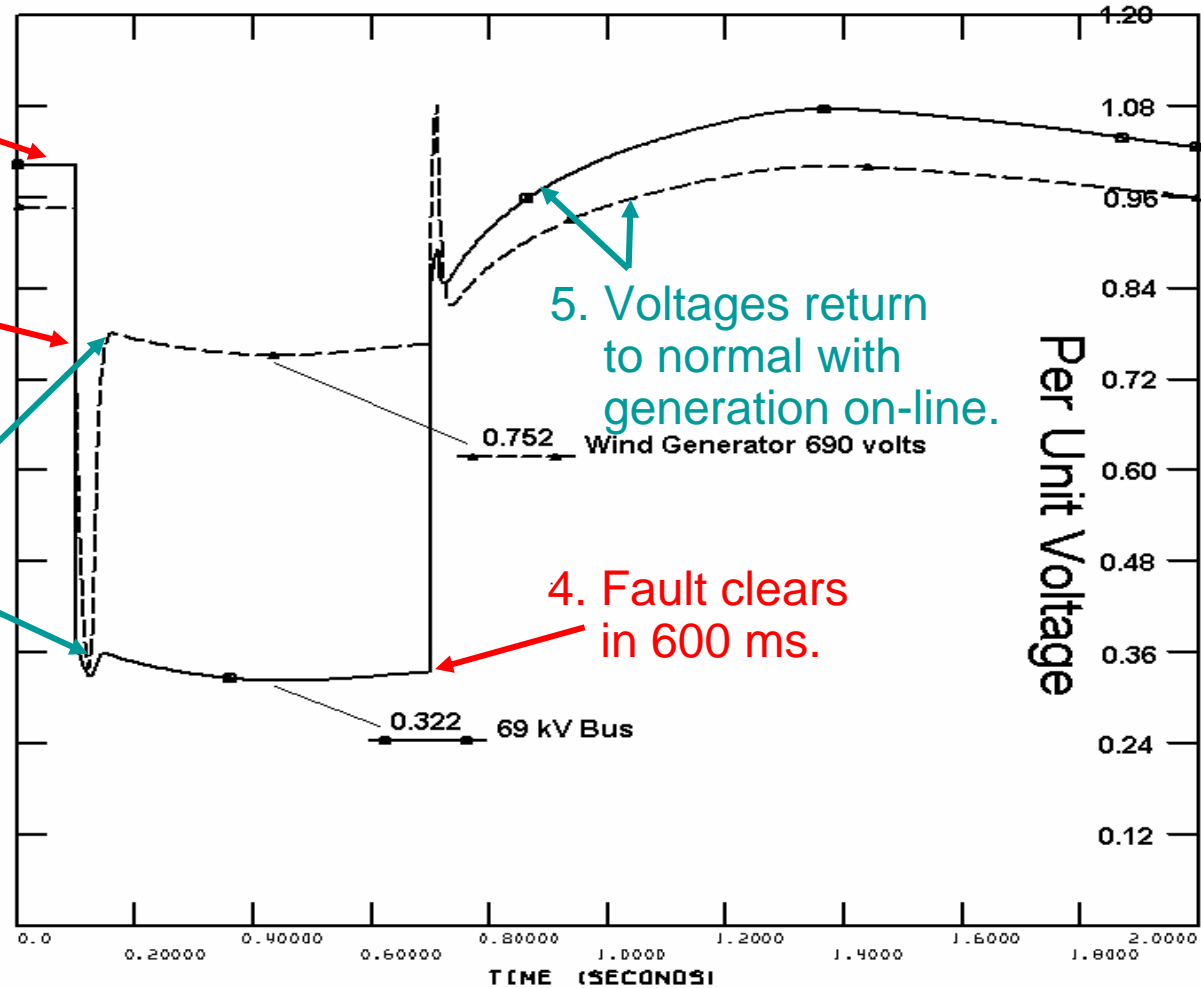
1. Fault on utility transmission grid.
2. Transmission system voltage drops rapidly.
3. Wind generation trips off-line because voltage is below 0.75 pu at generator terminals for 5 cycles.



Impact of voltage sag on wind farm with D-VAR ride-through capability

SOLUTION CASE 600 MS FAULT

- 1. Fault on utility transmission grid
- 2. Transmission system voltage drops rapidly.
- 3. D-VAR detects low voltage and injects reactive energy to quickly rebuild voltage at the wind generator above 0.75 pu threshold



- 4. Fault clears in 600 ms.
- 5. Voltages return to normal with generation on-line.

Generation rides through the fault!
No tripping of generation occurs.

Conclusions

- Wind Power is a rapidly growing energy resource
- Grid/Wind farm related impacts are growing as well
- Equipment is currently available to solve problems at the wind farm/grid interface and to support the future growth of Wind Power
- Interconnection requirements (power factor, voltage regulation, HVRT and LVRT) can be met with a combination of dynamic (FACTS) devices, static reactive devices and turbine improvements

Thank You!

Questions?

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