IEEE PES General Meeting 2008

Super Panel Session –

”Advances in Wind Energy Conversion”

Wind Parks as Power Plants - 2008

by

Steven W. Saylors, P.E.

Chief Electrical Engineer

Vestas Americas

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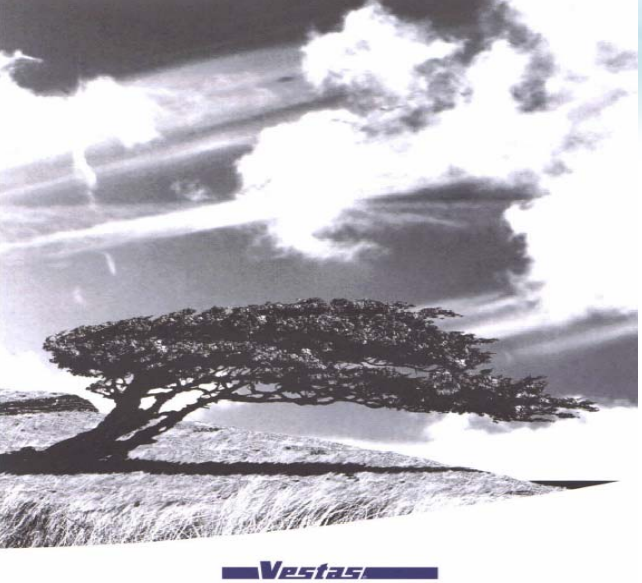


Introduction

- Wind energy – an ever larger proportion of the overall generation mix
- Potential for penetrations of 5 to 10% are realistic, 2030 Plan
- North American market differs from other global areas: Transmission versus Distribution connection
- Increasingly being required to perform comparably with more traditional generation sources

Historical Perspective

- Wind previously could be exempted from some grid interconnection requirements
  - Voltage Regulation/Powerfactor Control
    - Lagging Versus Unity Power Factor @ POI
  - Allowed to disconnect on system events
  - No Frequency Regulation
  - SCADA systems often had only limited functional control

Current Requirements in North America

- Treat wind parks more like a conventional (synchronous) power plant – OR - recognize the differences?
  - Do we change turbine design or employ third-party equipment (at turbine versus at substation)? Both?

- USA:

  Too many various entities→need for standardization → SMD

  Large Parks LGIA Order 2003 (20 MW <)
  - (2003A→ blank App. G)
    - FERC Final Rule Order No. 661 (completed App. G to LGIA)

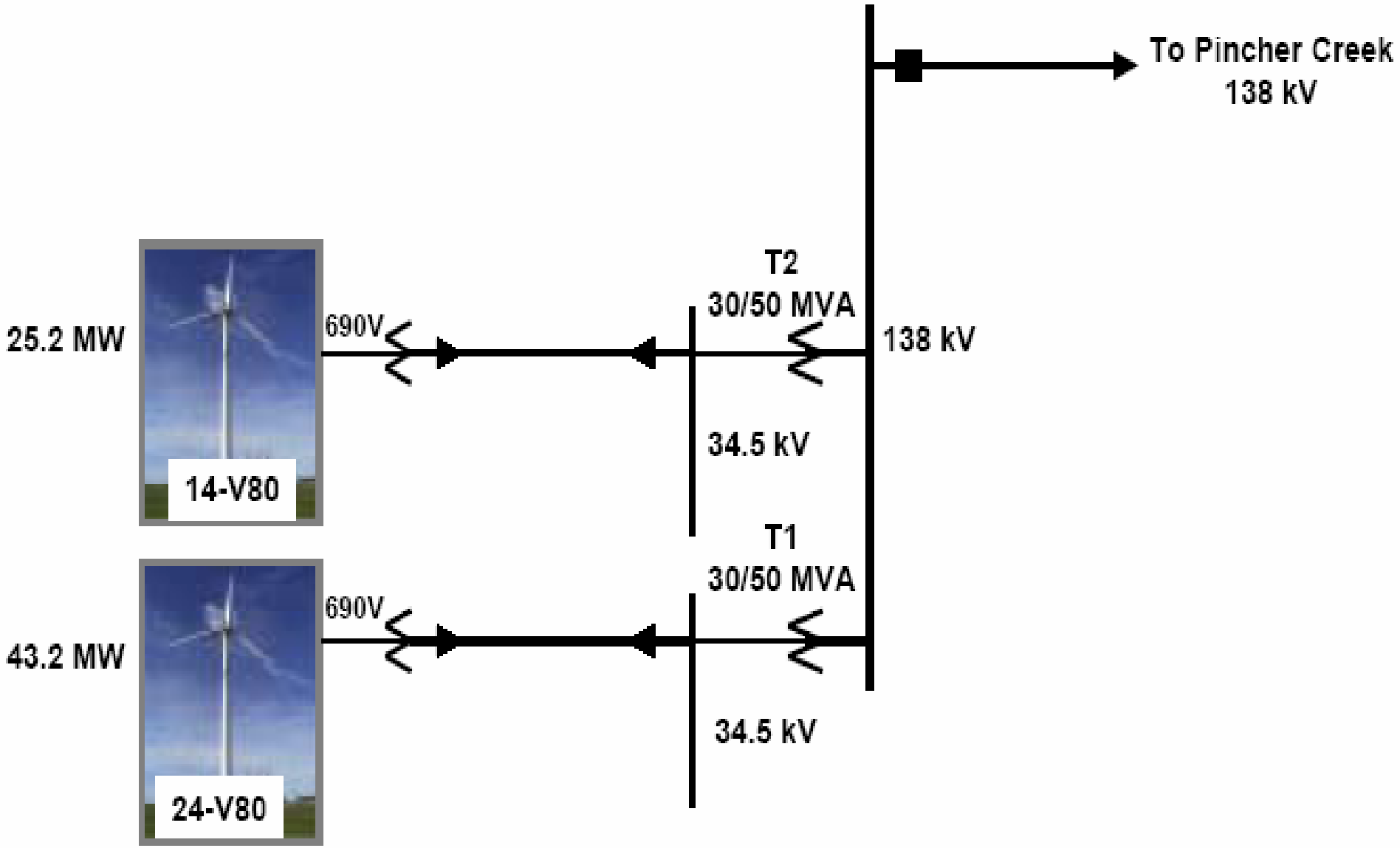
  versus **Small Parks SGIA (< 20 MW)**
  - IEEE Standard 1547 (Distribution-level connected resources)
- Canada:

  Provincial Technical Requirements
  - Garrad-Hassan Recommendations for Wind Grid Code

Evolving Interconnection Requirements

- WECC, ERCOT, NERC proposals
  - Voltage and Frequency Ride-Through - PRC-024
- Manitoba Hydro TSIR (2007) includes a section on WTG interconnection
- AESO looking at revising requirements from 2004

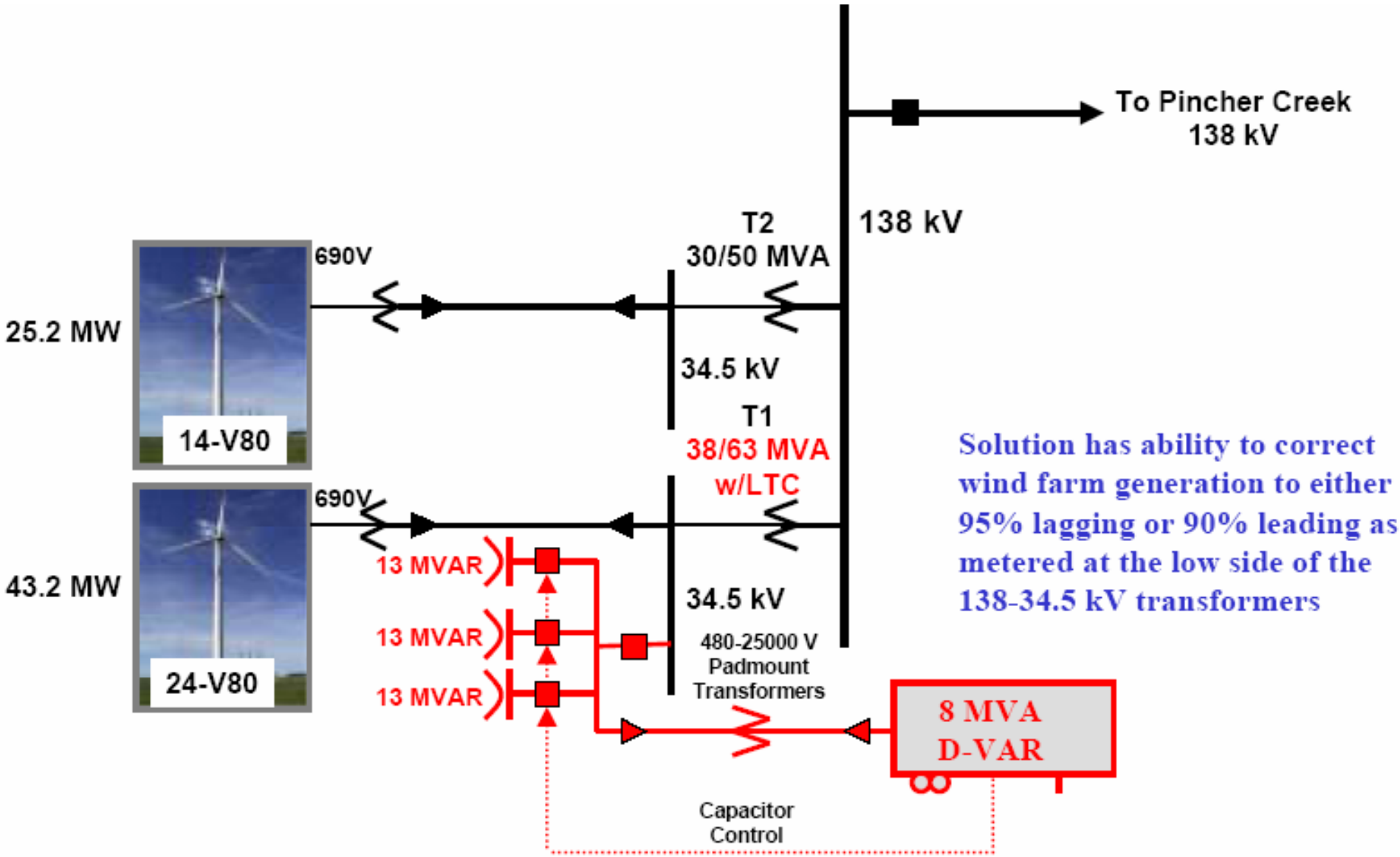
Simplified diagram for a typical large wind park.



Grid Connection Issue
Powerfactor and Voltage Control

- Turbine-based Control
  - DFIG can vary kVAR or PF within the limits of generator
  - Wound/Squirrel Cage Rotor use Switched Capacitor steps to compensate inductive draw of generator
- Substation-based Control
  - Static versus Dynamic Reactive Compensation
    - Lower cost statically switched elements are slow responding & will create step change in voltage
      - SCR at Point of Interconnection is important to keep within requirements of grid operator
    - FACTS devices provide very fast, linear control - but at higher cost

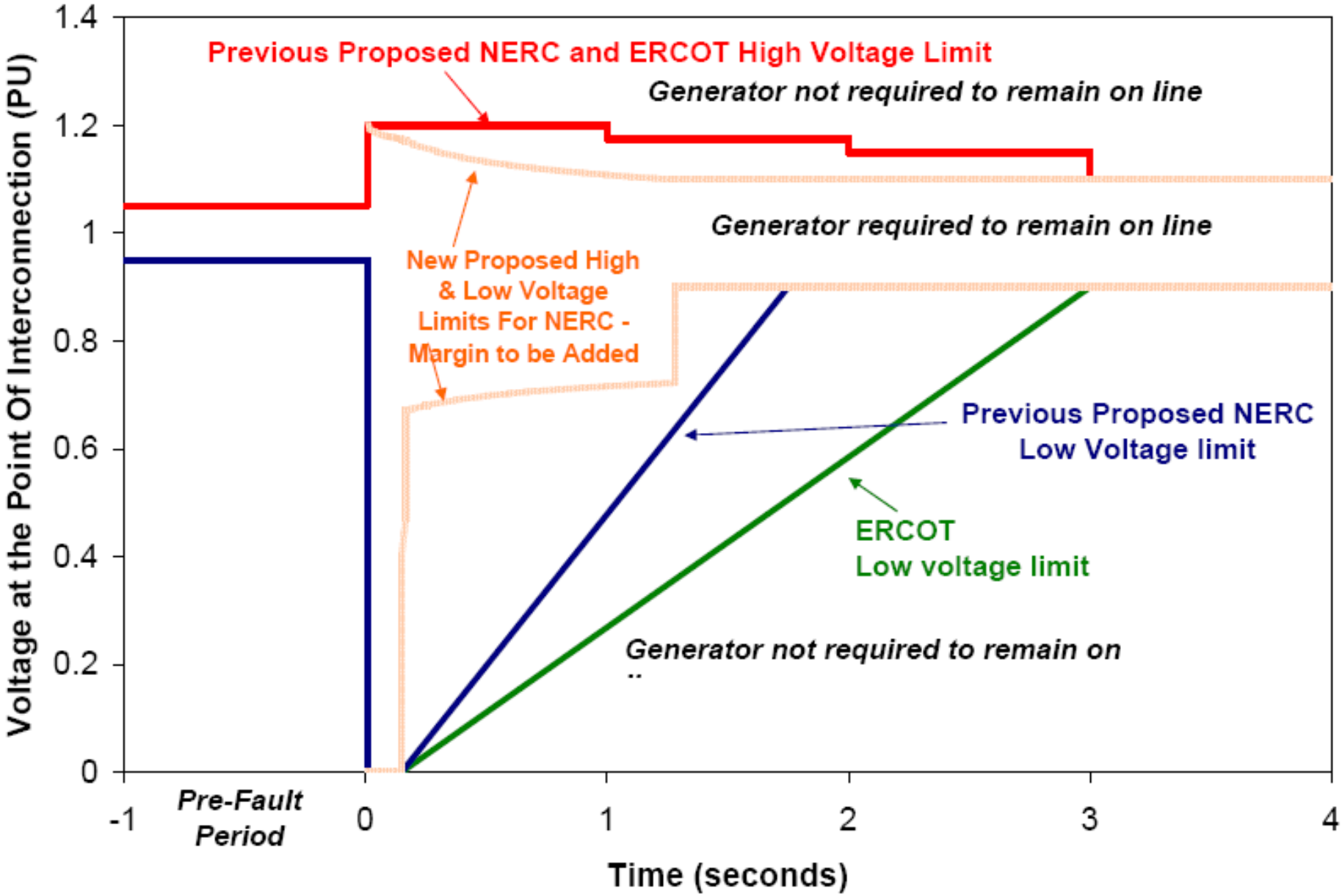
Statcom with switched capacitors installation



Solution has ability to correct wind farm generation to either 95% lagging or 90% leading as metered at the low side of the 138-34.5 kV transformers

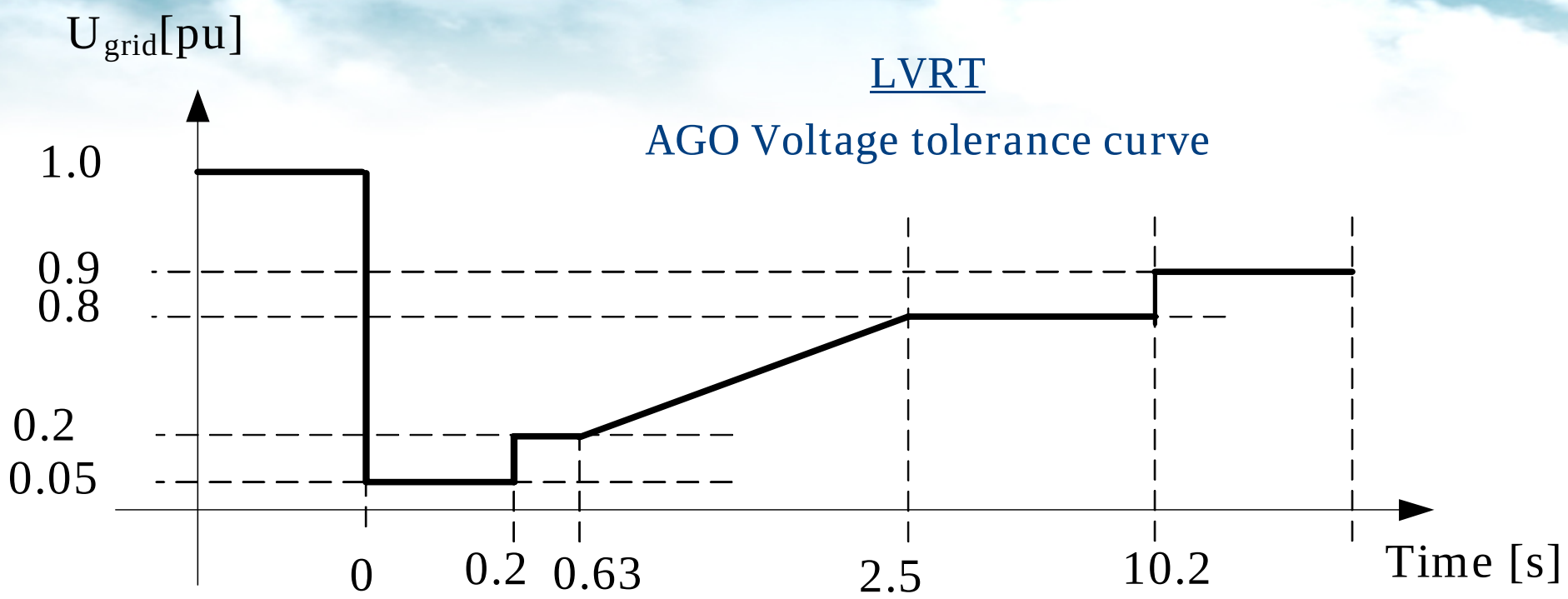
Grid Connection Issue
Voltage Ride Through

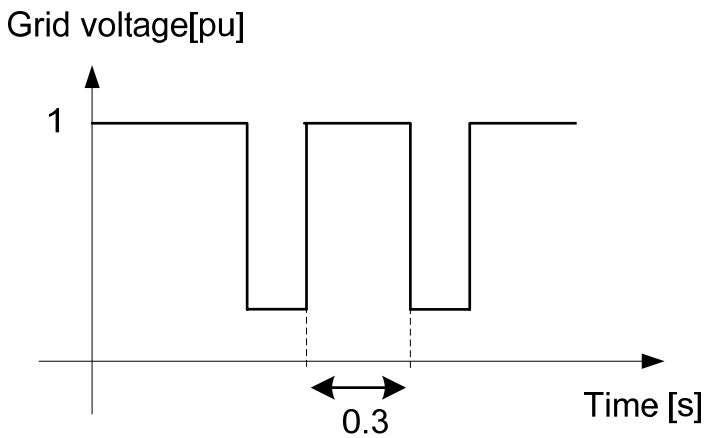
- LVRT (Turbine-based versus FACTS)
  - Most manufacturers design some degree of LVRT within turbines – need for Validation Testing
    - NERC recommendation to FERC LGIA App. G for Zero Voltage for up to 9 cycles (do away with Figure 1 Voltage Curve [E.ON derived])
- High Voltage Issues
  - Tripped XMSN line charging
  - Immediately after fault recovery (overshoot)


Previous Proposed NERC and ERCOT High Voltage Limit
Generator not required to remain on line
Generator required to remain on line
New Proposed High & Low Voltage Limits For NERC - Margin to be Added
Previous Proposed NERC Low Voltage limit
ERCOT Low voltage limit
Generator not required to remain on
Voltage at the Point Of Interconnection (PU)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-1
Pre-Fault Period
0
1
2
3
4
Time (seconds)

LVRT

AGO Voltage tolerance curve





Two voltage dips due to re closing.
Grid voltage versus time.

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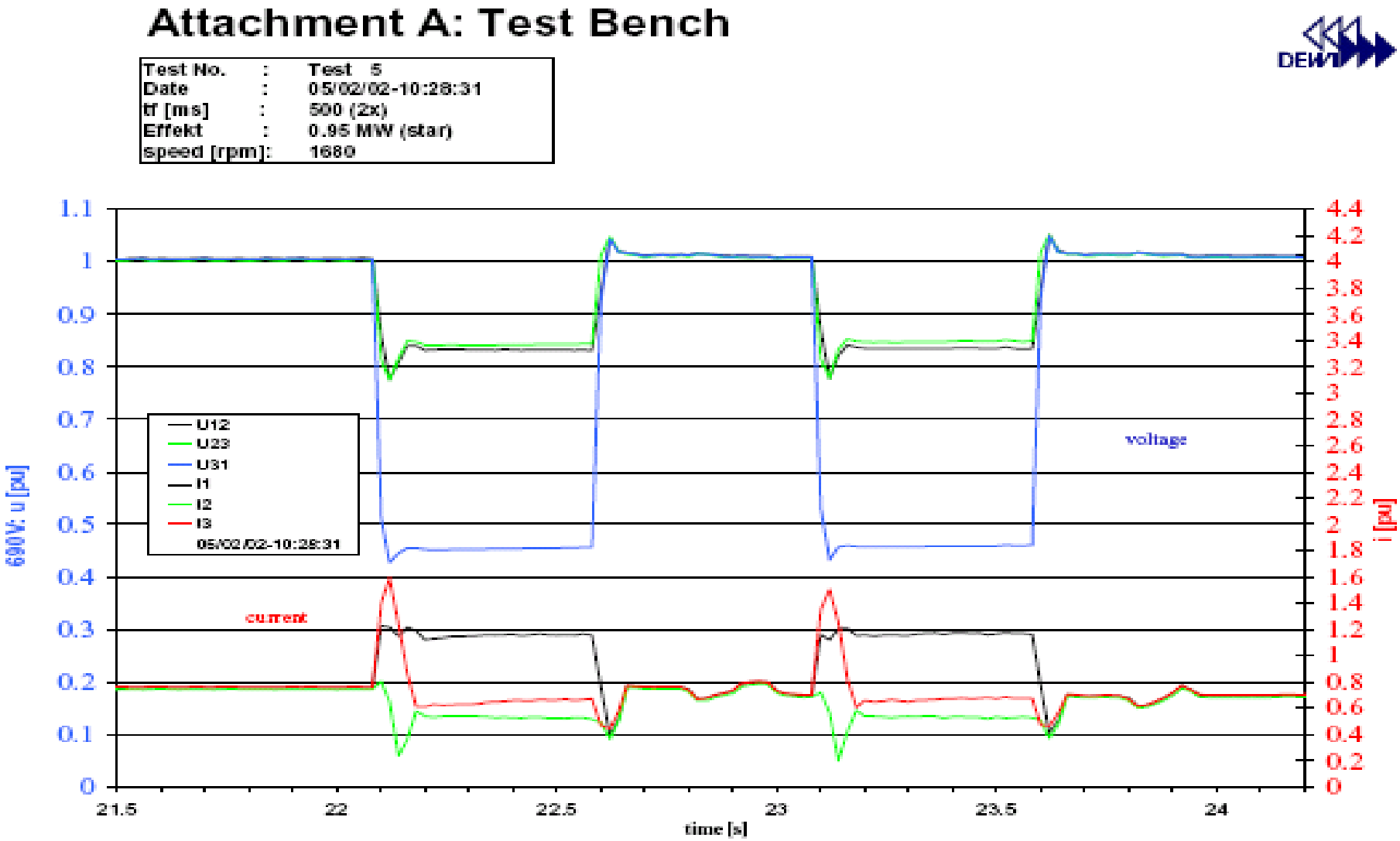
Two phase fault
-dual dip performance

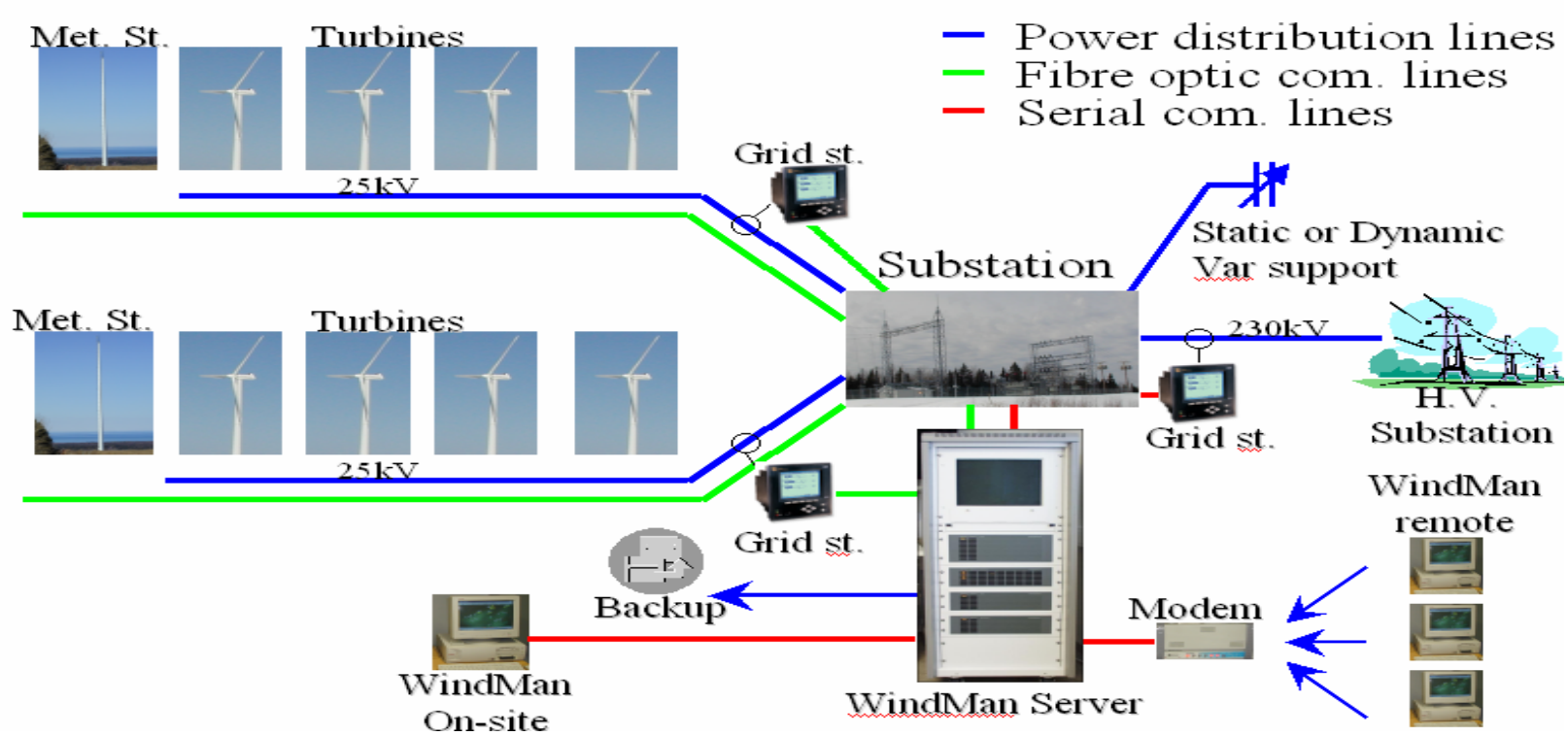


Grid Connection Issue
Power Plant Control

SCADA Servers and PPC Systems

- Allow individual turbines within park to operate as a single power plant
- Now go beyond just data collection and report generation
  - Remote control by park operator
  - Possible remote control by Dispatch (if desired)
    - system reliability concerns
    - economics of implementation
    - economics of operation
    - liability

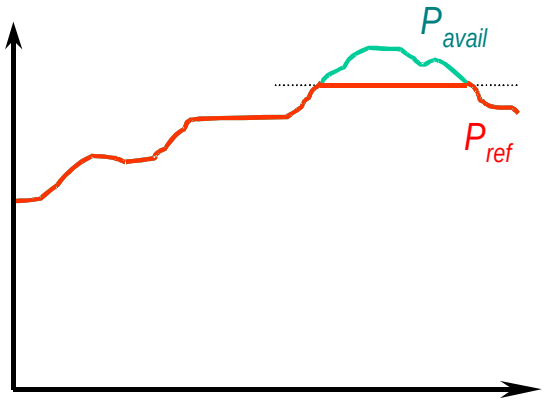
SCADA Servers



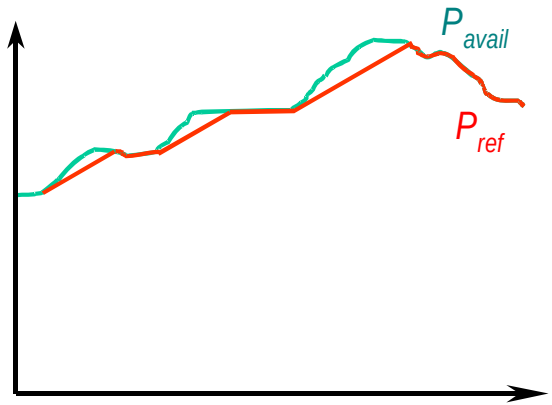
Grid Connection Issue
Real Power and Frequency Control

- Capability is just beginning to be discussed within the industry
  - Ramp Rate Control
    - Ramp Up (must coordinate with other system sources)
    - Ramp Down (prevent instantaneous loss of whole park when wind is over Cut-Out speed)
  - Maximum Power Limitation
  - Spinning Reserve Margin

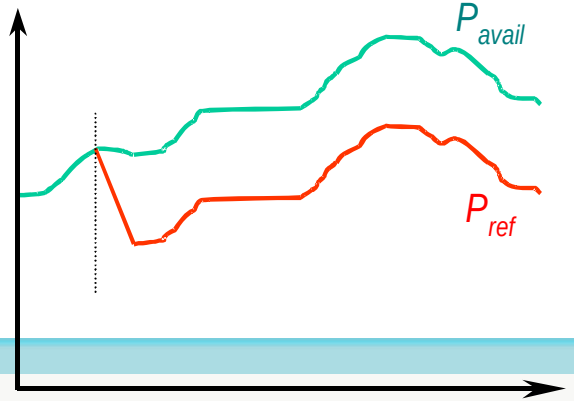
SCADA Control Functions For Improved Grid Operations



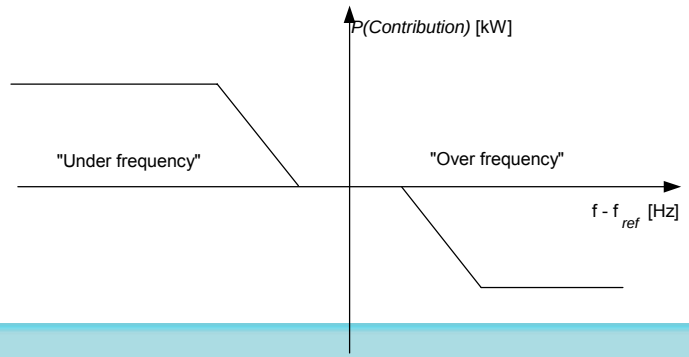
Active power control



Gradient power control



Delta power control



Frequency control

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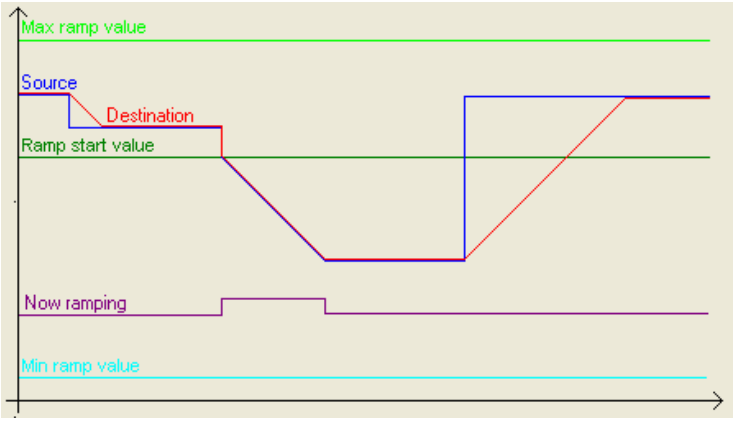
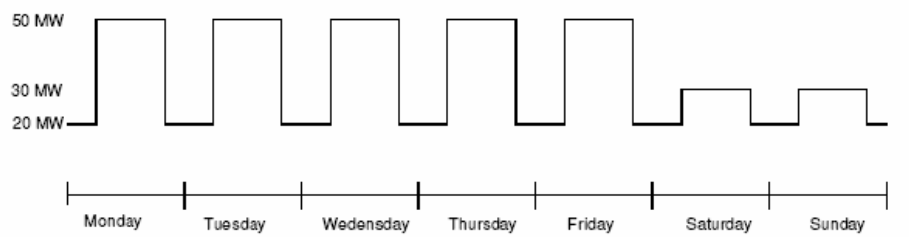
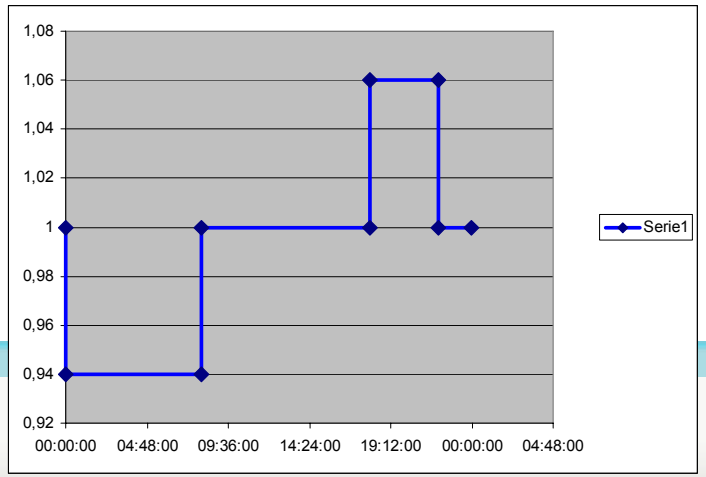
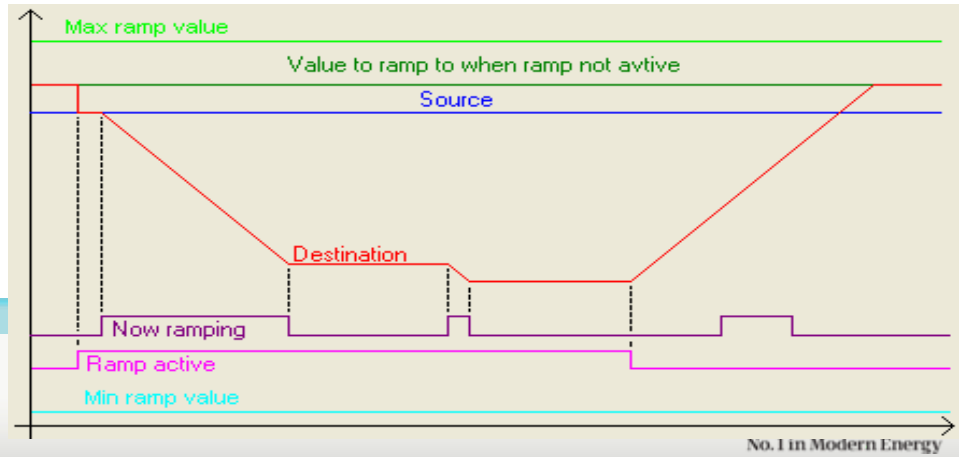
Scheduling and ramping

Many possibilities for advanced schedules and ramps









Grid Connection Issue
Turbine/Wind Park Simulation Modeling

- Models currently required in PSS/E, PSLF by system planners for interconnection studies
- Desire for Open Access through Simplified models that still provide appropriate results
- Need selectable Standard or Advanced Grid Option protection settings
- Reduced-Order PSS/E and PSLF models required to be validated against:
  - High-Order PSCAD/EMTP/DigSilent versions
  - Test Bench conditions
  - Actual field installed operations

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Vestas Americas
1881 SW Naito Parkway, Suite 100
Portland Oregon 97201

(503) 327-2000

www.vestas.com