ACCIONA WINDPOWER

GRID INTEGRATION EXPERIENCE

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Introduction

- **TSO – DSO Grid Requirements:**
  - Voltage support: Normal and Transients.
  - International approach.
  - Improvements in: turbines and substation controls
- **AW turbine technology (AW1500/3000)**
  - Steady state features:
    - Reactive power capability
    - Wind Turbine Temperature Optimizer
  - Grid Transient features: Enhanced LV/HV RT capability
- **Substation General Management System.**
- **Future trends: Preliminary research results.**

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GRID SUPPORT REQUIREMENTS

Brief approach to grid operators' demands

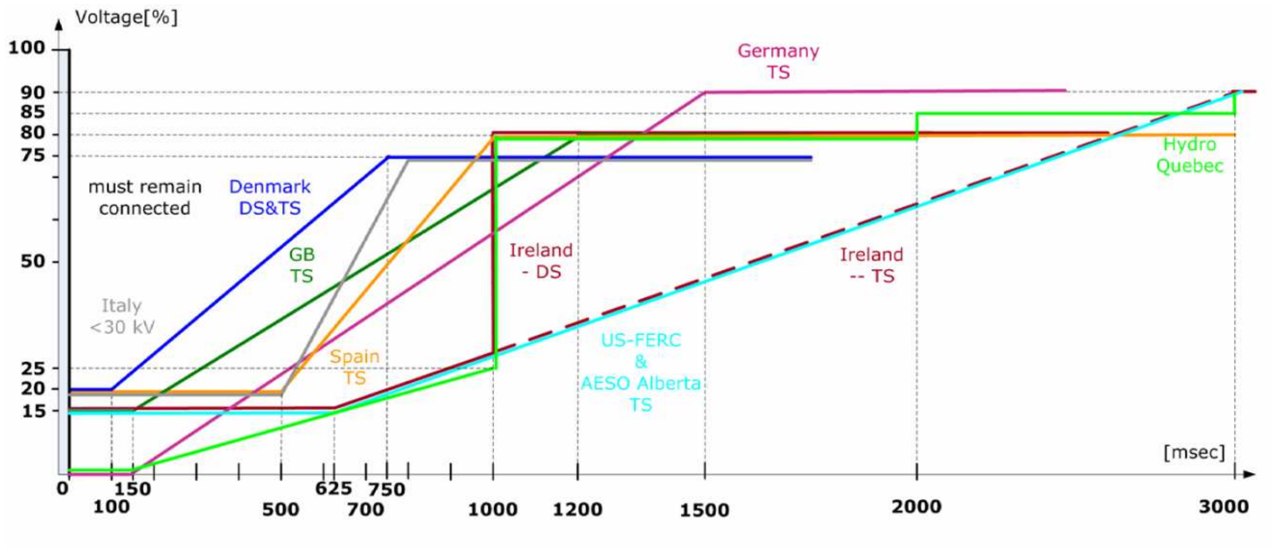
- Every country establishes distinct specs.
- Different requirements for transmission or distribution lines.
- Current demands mainly focused on following aspects:
    - Normal operation – small voltage variations.
    - Transients: LVRT and HVRT.
    - Active power limiting.
    - Quality: Flicker, harmonics, unbalance, etc
    - Protections, metering, etc
- Coming soon demands: frequency control

GRID SUPPORT REQUIREMENTS

Normal operation demands for Voltage Controls:

- 5% voltage steps response in 1 to 5 s.
- Reactive power range: +/- 35% Rated Power.
- Operation on voltage range (PCC): +/- 15%.
- Set point accuracy higher than 0.5 %.

Grid disturbances demands:



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GRID SUPPORT REQUIREMENTS

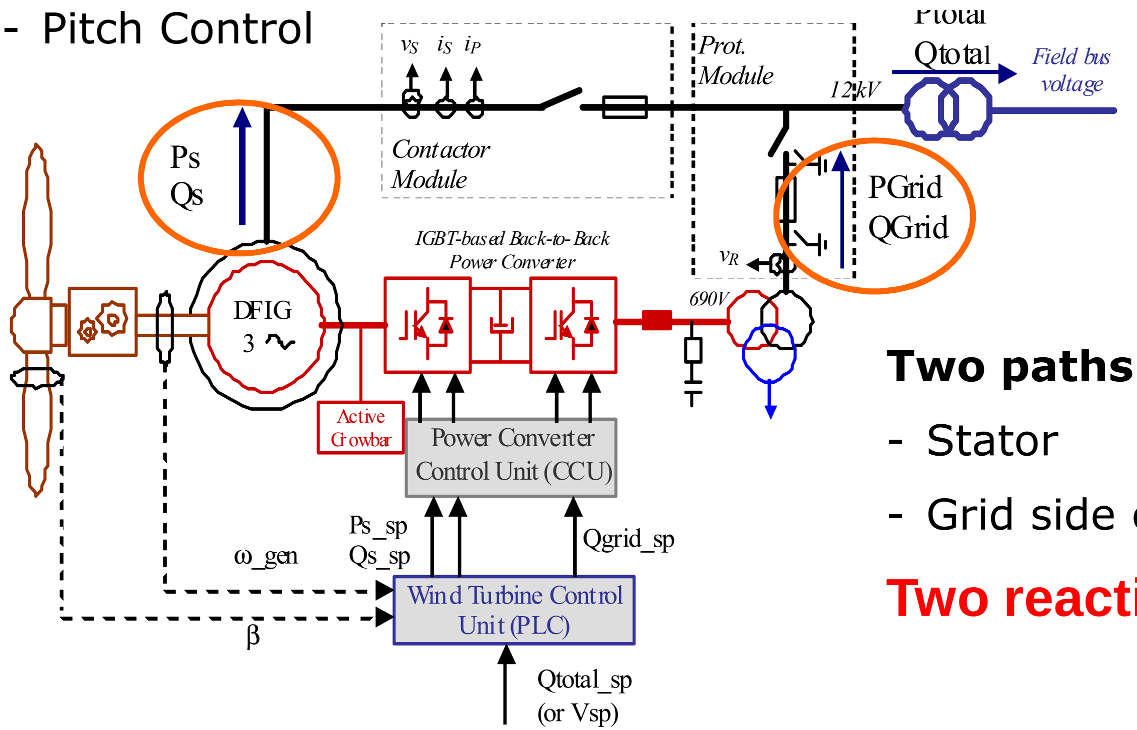
AW changes towards an enhanced grid integration

- **Turbine level:**
  - Increased reactive power range (40%).
  - Efficient reactive power management.
  - Improved LVRT/HVRT techniques.
- **Substation Level:**
  - Improved technology (control & comms).

2 ACCIONA WINDPOWER TECHNOLOGY: AW1500 / 3000

Main features:

- Doubly Fed Induction generator (12 kV):
- IGBT-Based Power converter
- Variable Speed
- Pitch Control



AW3000 and AW1500

Two paths to reach the power grid:

- Stator
- Grid side converter

Two reactive power sources

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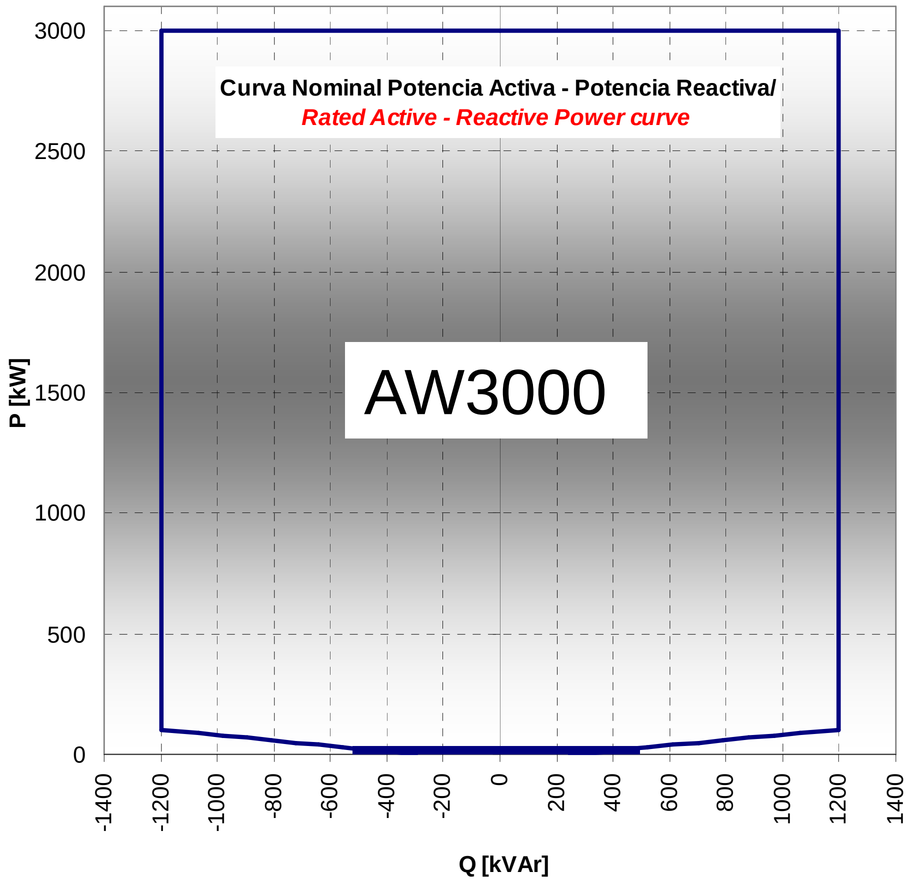
GENERATING REACTIVE POWER:
AW technology steady state operation features.

Extended Reactive Power Range: 40%



Increased generator & power converter ratings for an increased reactive power capability:

- From 100 kW to rated: up to +/-1200kVAr.
- Zero active power: +/-500kVA available.

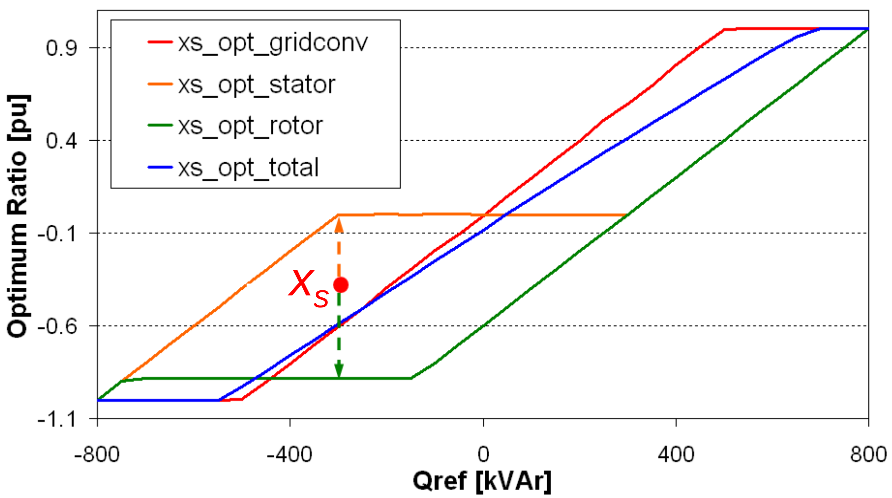
GENERATING REACTIVE POWER:
AW technology steady state operation features.

Wind Turbine Temperature Optimizer (WTTO)

Reactive power distributed between stator and grid side converter in order to minimize losses in the electrical component with the highest temperature (or higher thermal index, *th_x*)

$$Q_{Total\_Ref} = Q_{Stator\_Ref} + Q_{Grid\_Ref} \qquad x_S = \frac{Q_{Stator}}{Q_{Stator\_Max}}$$

$$Q_{Total\_Ref} = x_{S\_Ref} \cdot Q_{Stator\_Max} + Q_{Grid\_Ref}$$



$$th\_x = \frac{(T_x - T_{amb\_x})}{(T_{Lim\_x} - T_{amb\_x})}$$

PI controller to determine x_s:

Minimising temperatures or **th_x**

- Stator windings: x_s should move upwards
- Rotor windings: x_s should move downwards

GENERATING REACTIVE POWER:
AW technology steady state operation features.

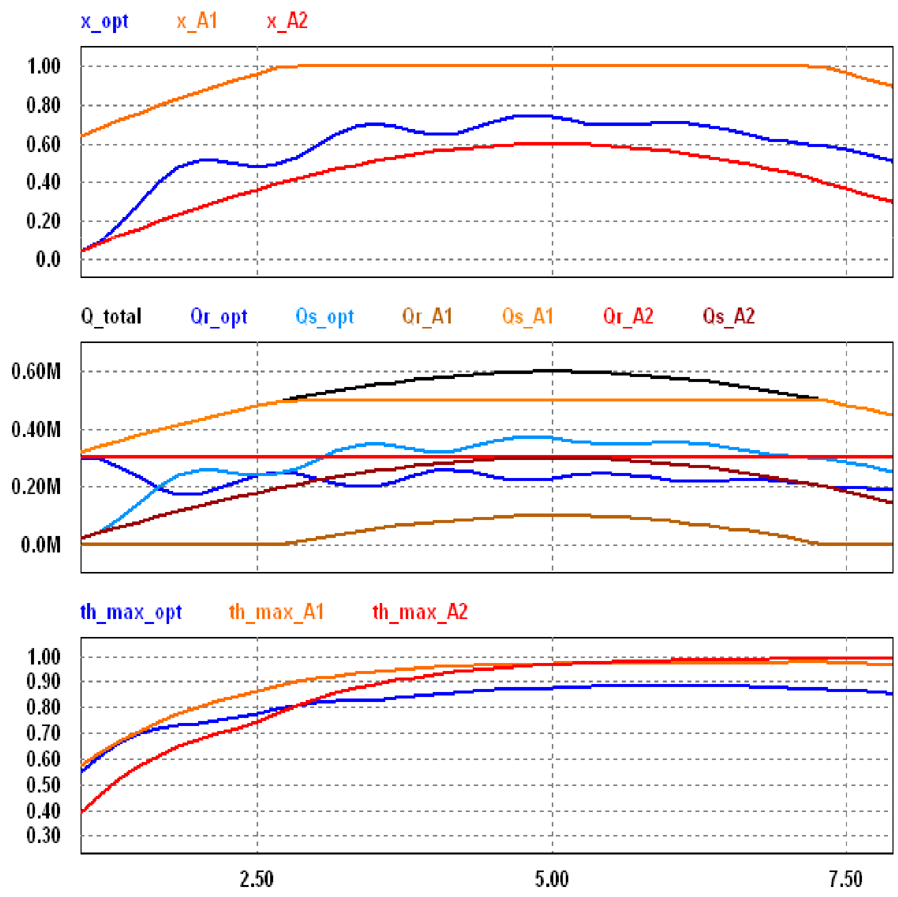
Wind Turbine Temperature Optimizer (WTTO): Results.

Comparison:

- A1: Generating Q by the stator, then grid side converter.
- A2: Generating Q by the grid side converter, then stator.

Results:

- Lower maximum temperatures.
- Smoother thermal dynamics.



Higher reliability and availability.

Enlarged life span.

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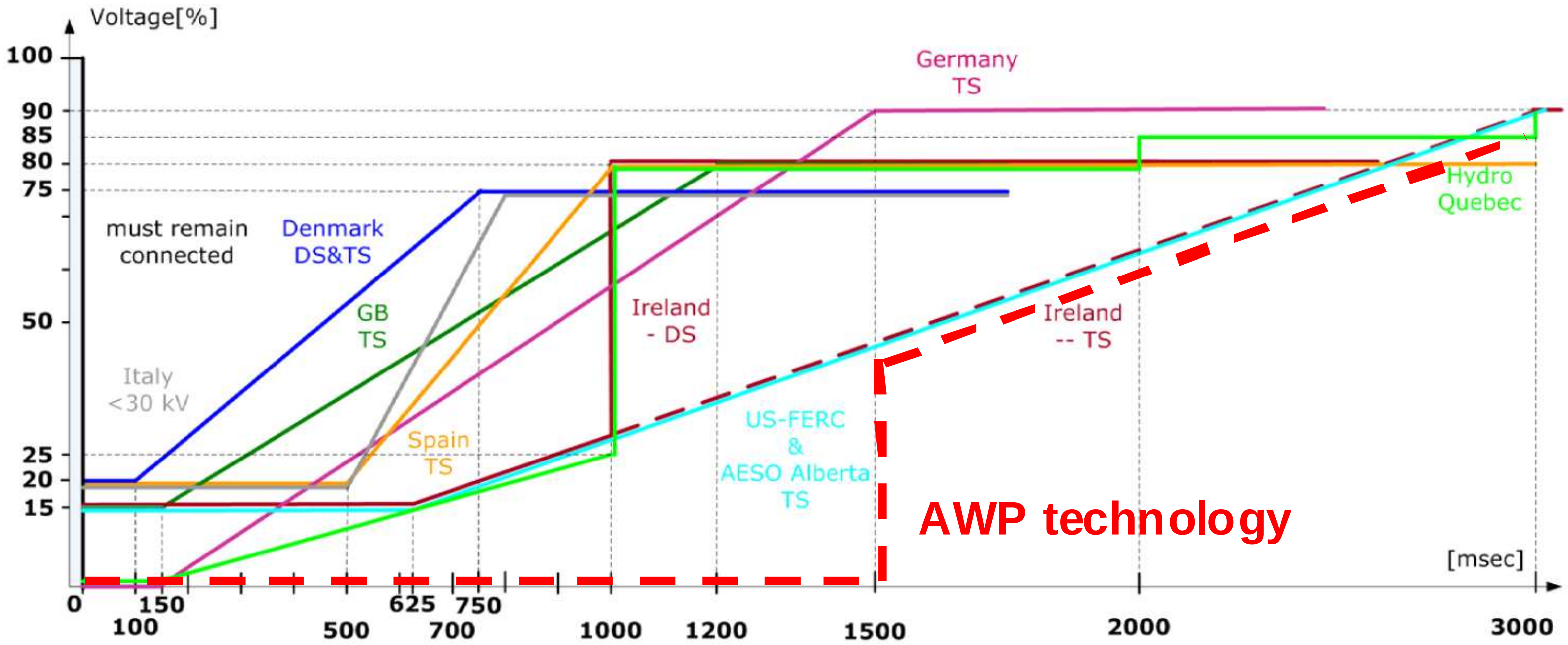
GRID DISTURBANCES:
AW technology operation features

Acciona windpower LVRT curve



How is AW able to offer such a response?

- Changes in the drive train design.
- Increased power converter ratings.
- **New control techniques.**

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3 GRID DISTURBANCES:
AW technology operation features

LVRT / HVRT New Torque and Pitch strategies

- LV & HV RT based on "available active power": depends on the remaining voltage and reactive current injection.
- Improved damping system: Available torque is used to damp oscillations even during grid faults.
- Fast Pitching: to get a pre-calculated steady angle given by the available active power.

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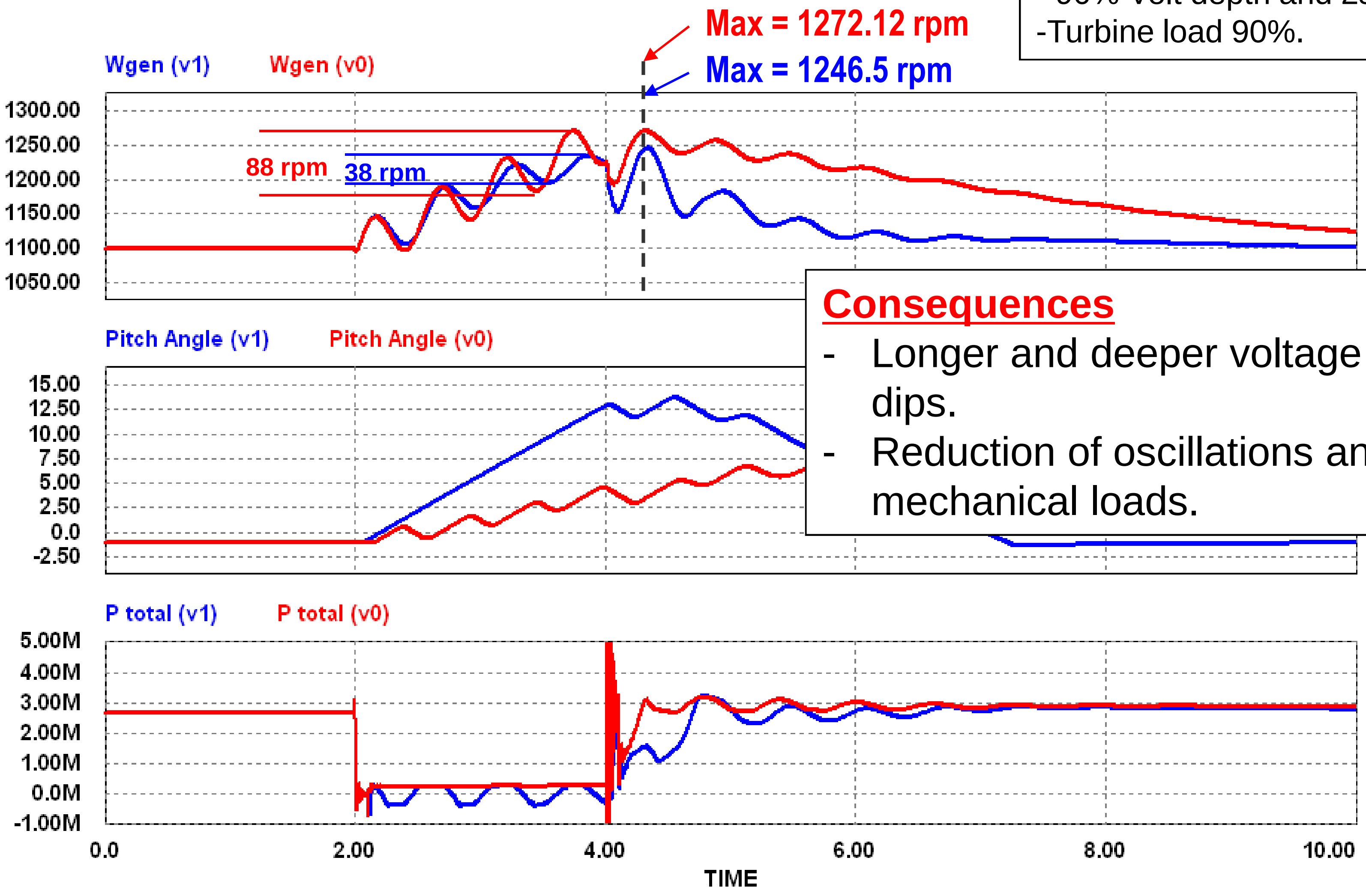
GRID DISTURBANCES: AW technology operation features

Example (LVRT test)
- 90% Volt depth and 2s long.
-Turbine load 90%.

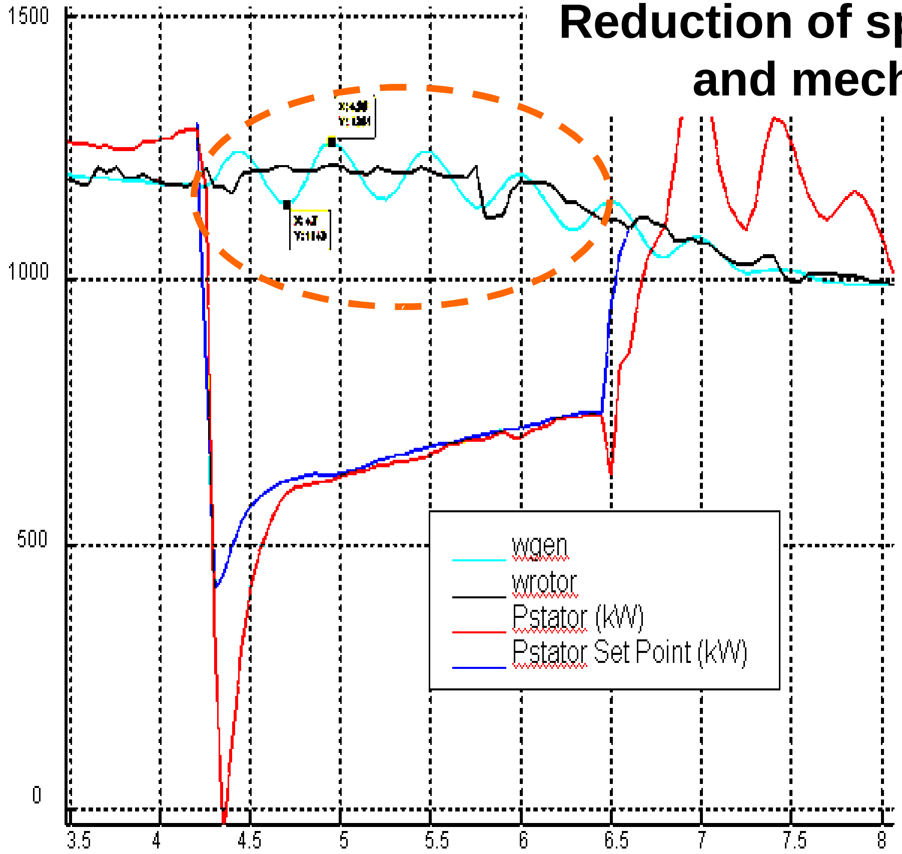


Consequences
- Longer and deeper voltage dips.
- Reduction of oscillations and mechanical loads.

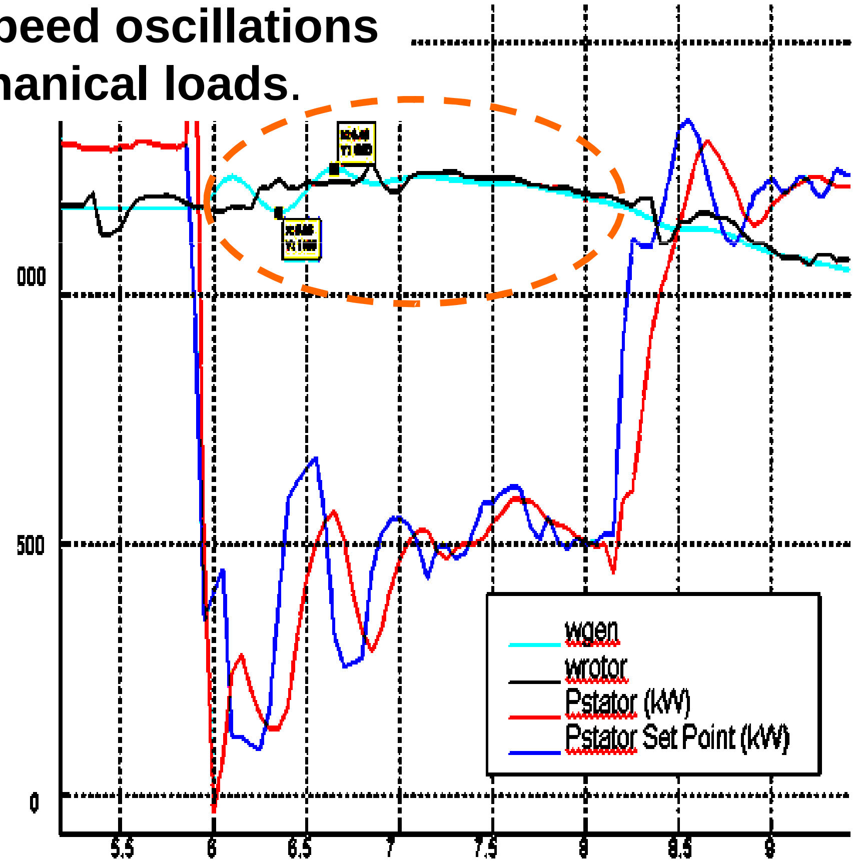
GRID DISTURBANCES:
AW technology operation features

LVRT / HVRT New Torque and Pitch strategy: Field tests results

Reduction of speed oscillations and mechanical loads.



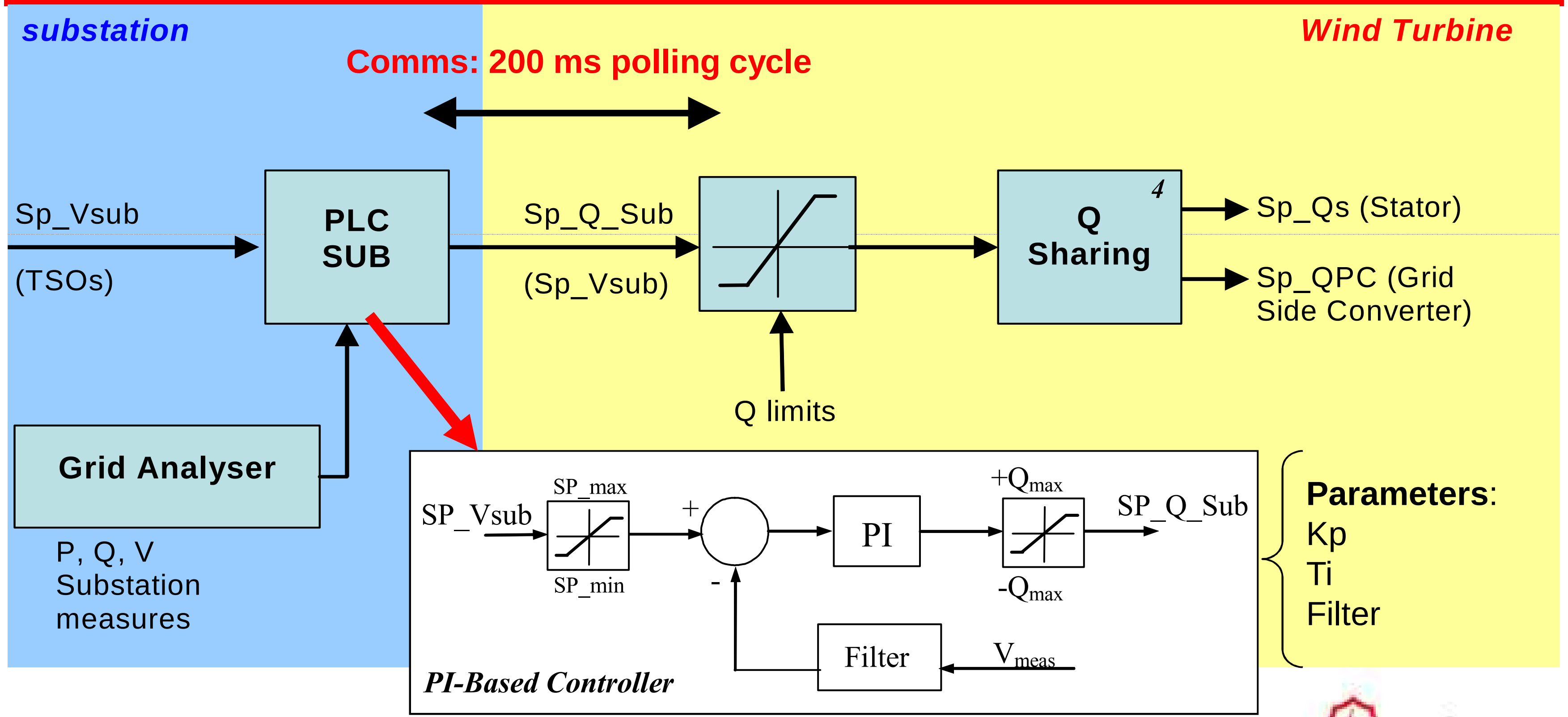
Previous Techniques



New Techniques

VOLTAGE CONTROL

1 .- Voltage Control Principles



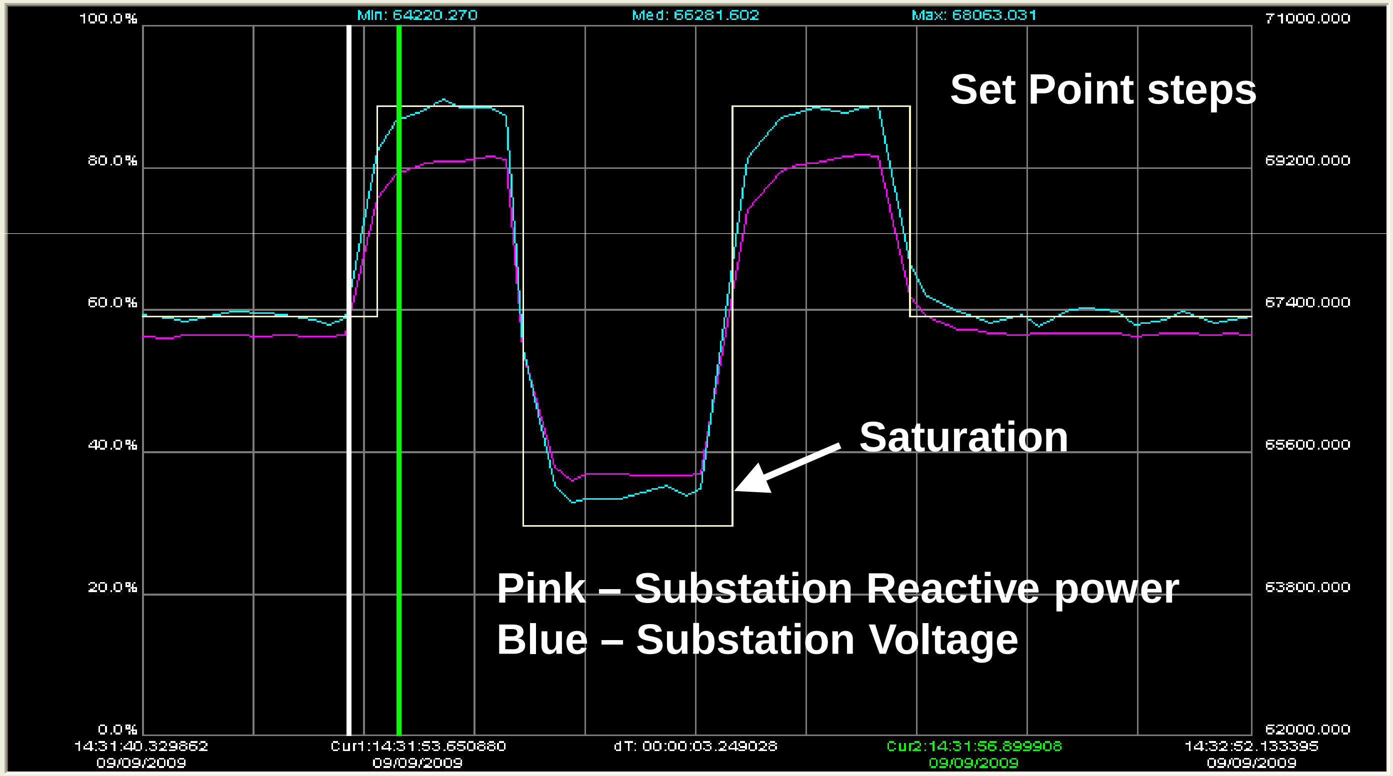
3 VOLTAGE CONTROL – WAUBRA (AUS)

2 .- WAUBRA (AUS) Last experience

- 128 wind turbines model AW1500.
- POI at 220 kV – 2 transformers 220 kV / 66 kV / 150 MW
- Five substations 66 kV / 12 kV.
- Two voltage controllers:
    - Transformer 1. 66 kV side.
    - Transformer 2. 66 kV side.
- Requirements:
    - Response for voltage steps of 5% in less than 5 secs.
    - Reactive capacity +/- 30% Rated Power.

VOLTAGE CONTROL – WAUBRA (AUS)

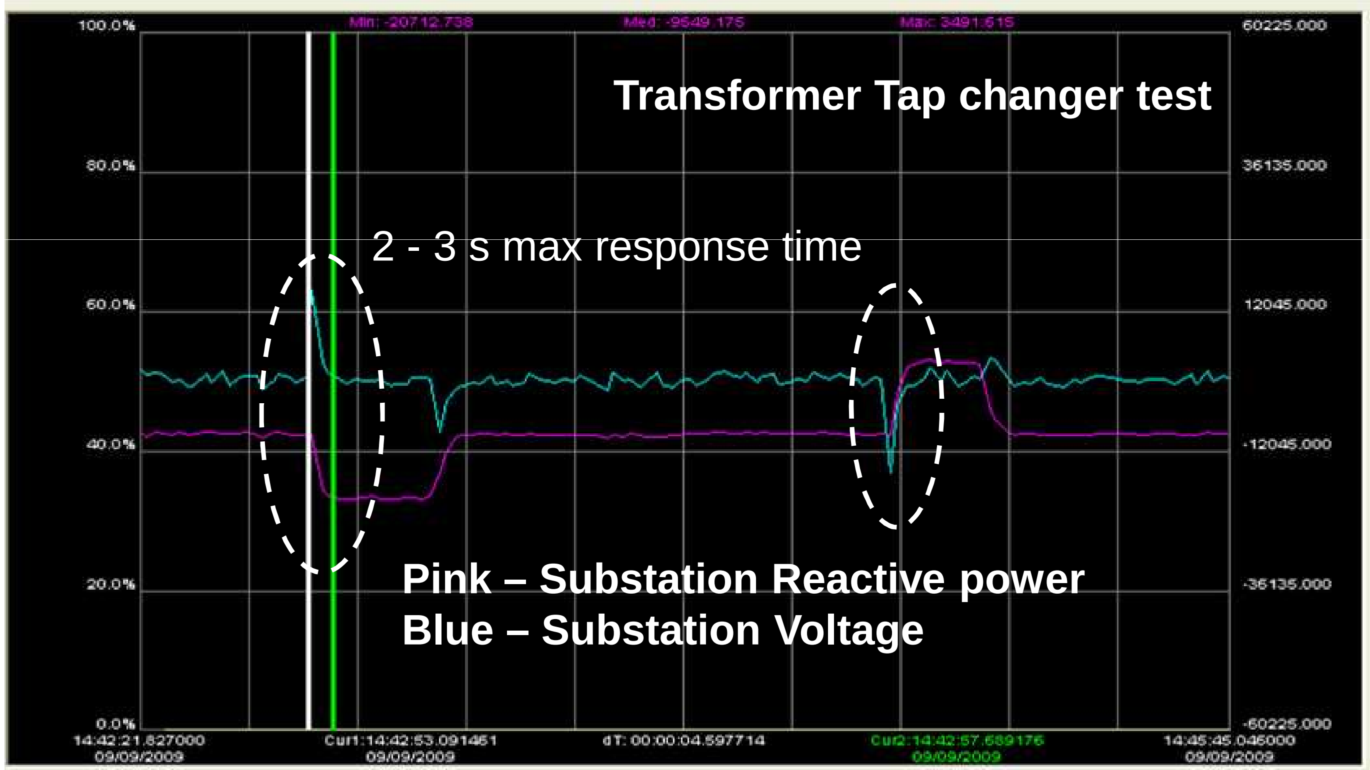
3 .- Set point step tests



Vis	Type	Color	Name	Eng. Un.	Cur 1 Val	Cur 2 Val	Min Value	Max Value
			WAUBR2.VtgCtrl.Substation Reactive Power ()		-7688.052	11478.955	-60225.000	60225.000
			WAUBR2.VtgCtrl.Substation Voltage ()		66115.661	67866.133	62000.000	71000.000
			WAUBR2.VtgCtrl.Substation Voltage SP ()		66000.000	68000.000	62000.000	71000.000

VOLTAGE CONTROL – WAUBRA (AUS)

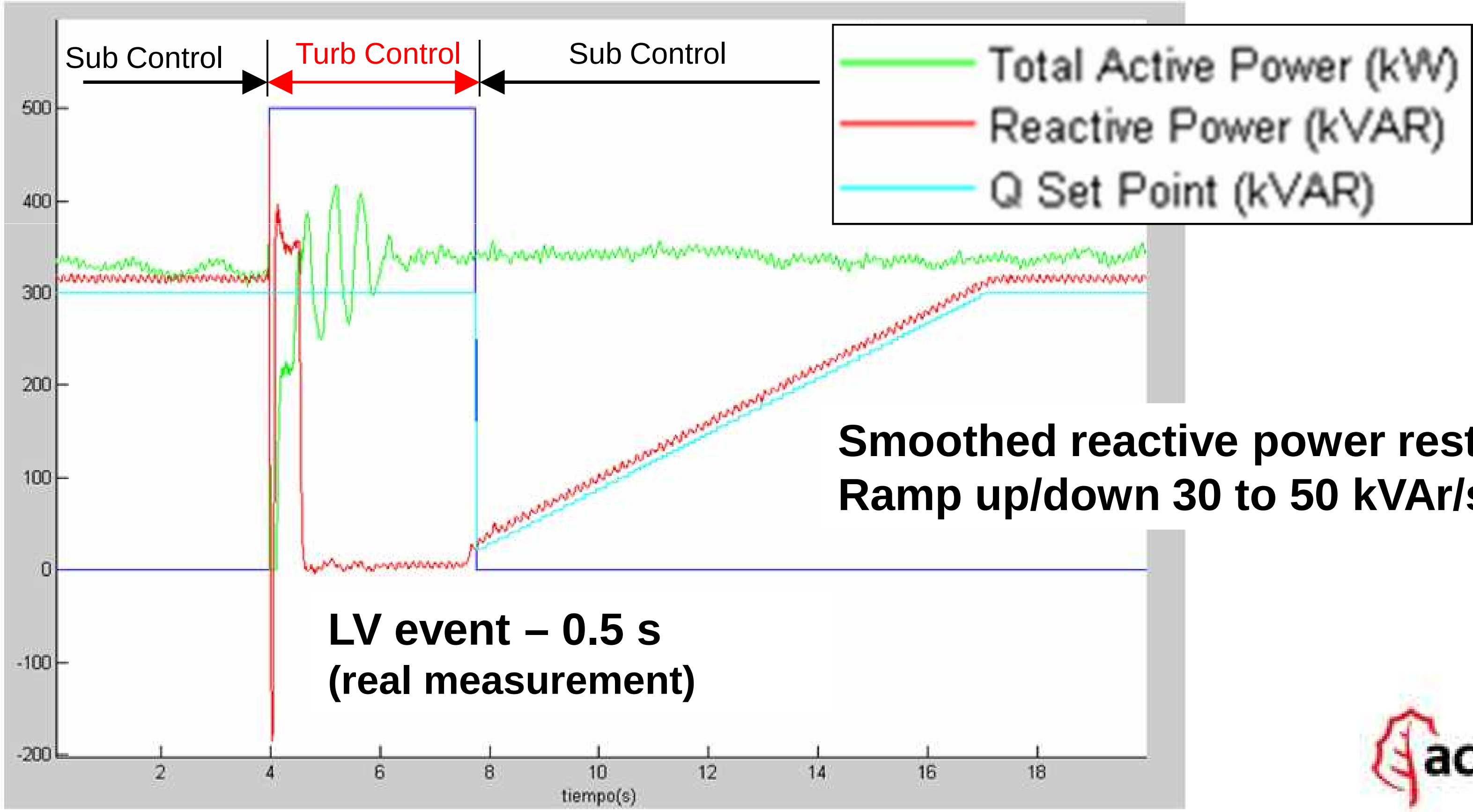
4.- Transformer Tap changer tests



Vis	Type	Color	Name	Eng. Un.	Cur 1 Val	Cur 2 Val	Min Value	Max Value
			WAUBR2.VtgCtrl.Substation Reactive Power ()		-9526.721	-20116.786	-60225.000	60225.000
			WAUBR2.VtgCtrl.Substation Voltage ()		66155.215	66063.310	62000.000	70000.000
			WAUBR2.VtgCtrl.Substation Voltage SP ()		66000.000	66000.000	66000.000	66000.000

3 VOLTAGE CONTROL

5 .- Coordination after LV or HV faults (Now, standard)



Smoothed reactive power restoration
Ramp up/down 30 to 50 kVAr/s

LV event – 0.5 s
(real measurement)

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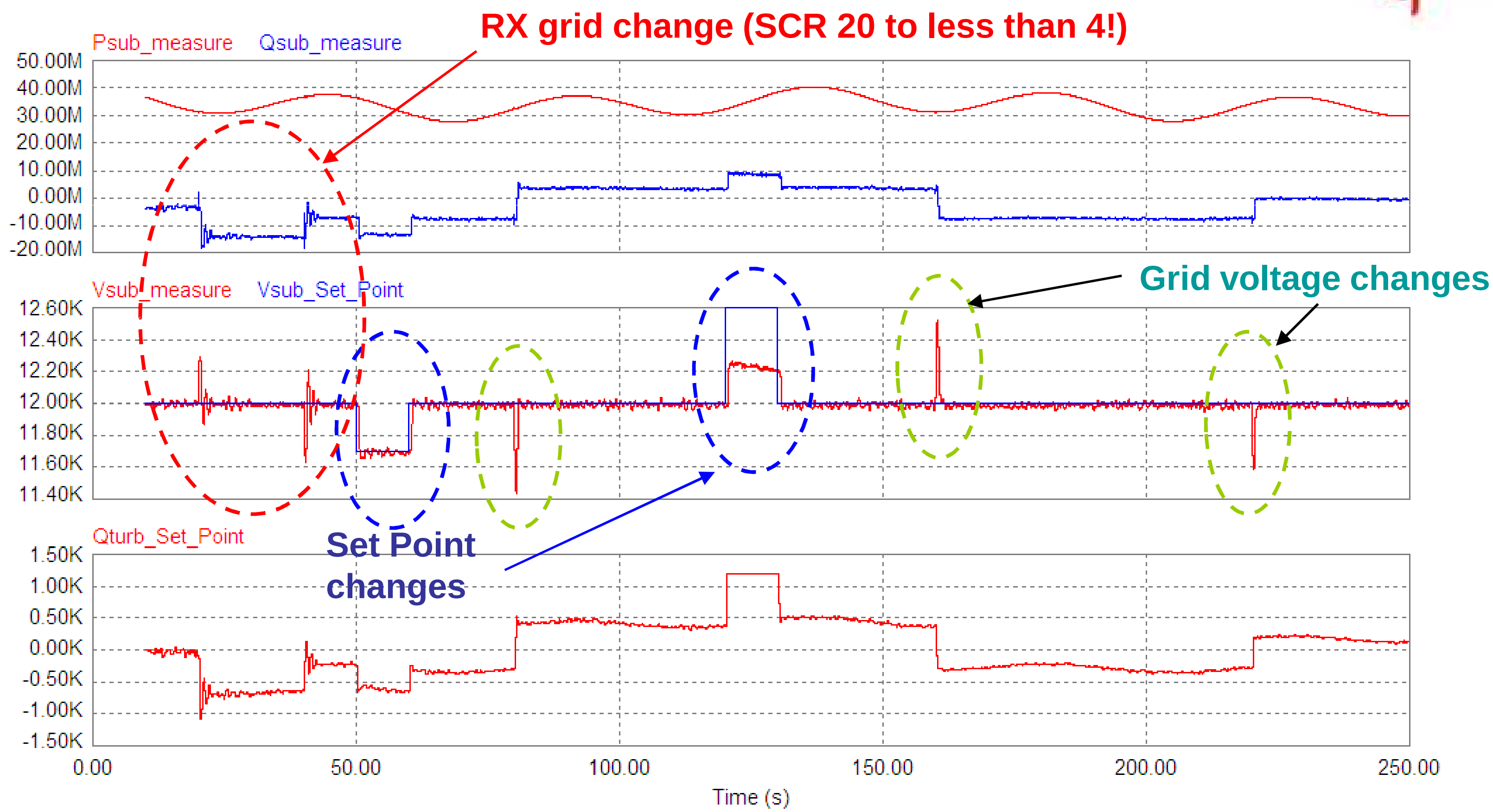
4 FUTURE DEVELOPMENTS

1 .- Improved Voltage control

- Same control for weak (SCR<2) or strong grids (SCR>10).
- Detection of the grid characteristics:
    - Fast grid impedance **selection** method.
    - Fast estimation algorithm of the Thevenin grid voltage.
- Principle of operation: Steady-state pre-calculated response.
- Accurate, robust and safe even with long polling times.
- Patents pending.

4 FUTURE DEVELOPMENTS

1 .- Improved Voltage control (1 – 2 s response)

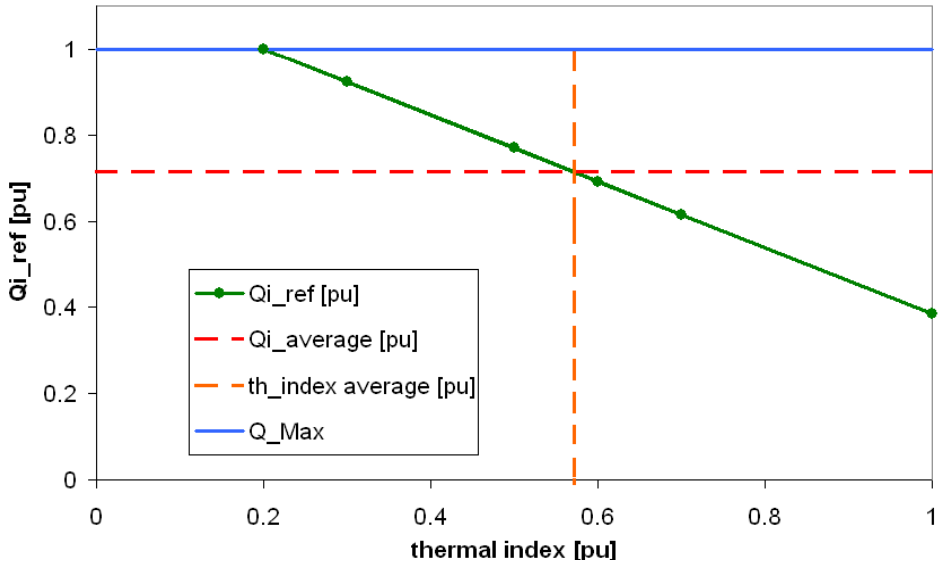


4 FUTURE DEVELOPMENTS

2 .- Wind Park Power Management

State information sent from every turbine (example, th_x) to the substation PLC is used to distribute global set points:

- Reactive power
- Active power



Improving:
- Efficiency
- Reliability

4 FUTURE DEVELOPMENTS

3 .- Accredited Grid Integration field test report

Field tests to demonstrate grid code compliance.

Certified Laboratory testing and accredited procedure

(in search of an international acceptability).

- Current situation: at Turbine level:
    - LVRT and HVRT according to most exigent grid codes.
    - Quality: Harmonics. Flicker. Etc.
- Future perspective:
    - Turbine level: Active power management. Islanding, etc
    - Substation level:
        - Voltage, active power and frequency controls
        - Protections. Harmonics. Flicker. Islanding. Etc.

CONCLUSSIONS

- AWP Grid Voltage support :
  - AW1500 and AW3000 Turbines:
    - Improved LVRT / HVRT behavior.
    - Extended Reactive Power range.
  - Substation: Accurate and reliable hardware and controls (improved close future solutions, R&D benefits).
- Acciona WindPower commitment to demonstrate Full Grid Code compliance through real and accredited field testing.