# Advanced Inverters and Grid Support

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# Overview of Presentation

**Grid Reliability Functions**

- **Voltage Ride Through, Frequency Ride Through**

**Real Power Control Functions**

- **Frequency/Watt, Volt/Watt**

**Reactive Power Provisioning and Voltage Support**

- **Volt/Var**

**Impact on Anti-Islanding**

**Communications**

**Other Resources**

- **EPRI *"Common Functions for Smart Inverters, Version 3"***

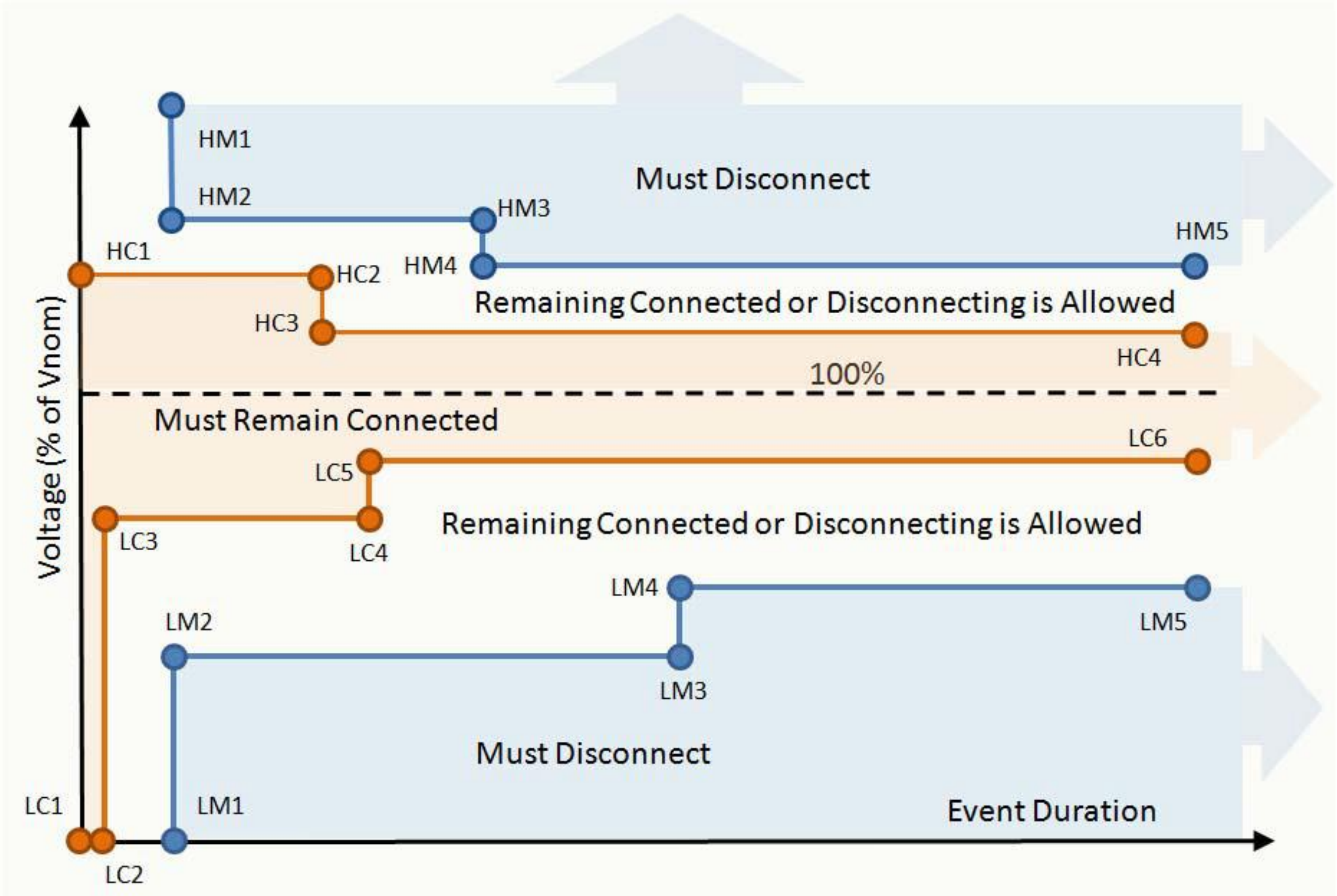
# Ride Through Functions

**Voltage and frequency ride through functions are the most important features needed to improve grid stability**

**Historically inverters were programmed to get offline quickly in response to grid voltage or frequency excursions**

- **Existing regulatory structures in the US did not adequately address ride through requirements.**
  - Requirements were written as “must disconnect” not as “must remain connected”
- **As levels of Distributed Energy Resources (DER) increase this strategy becomes problematic.**
- **Loss of large amounts of DER in advance of load shedding can lead to cascade failure.**

# L/H Voltage Ride Through




EPRI Common Functions For Smart Inverters V3, page 14-2

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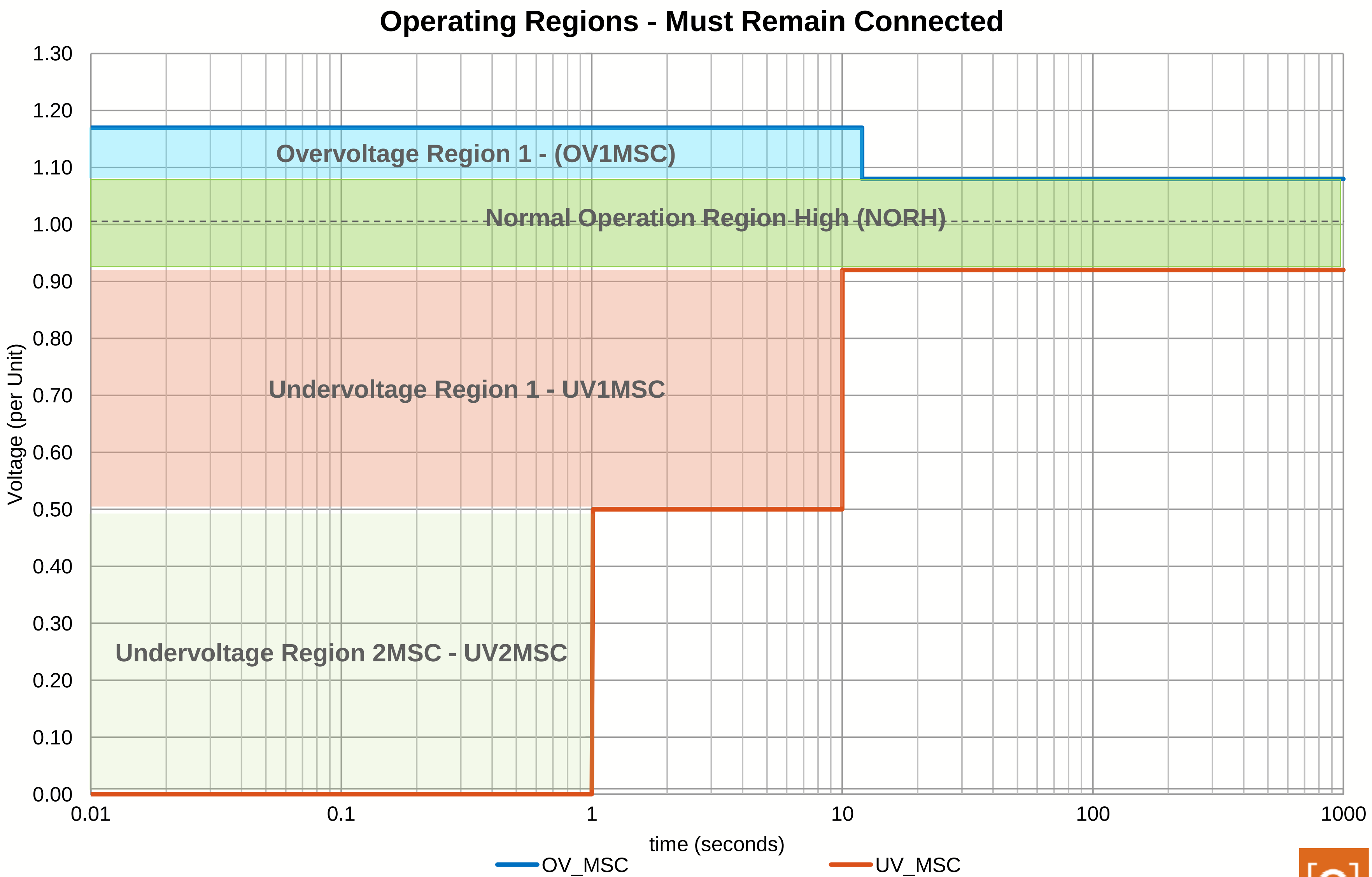
# Voltage Ride Through Issues

**Inverters can provide controlled full current down to near zero voltage for extended periods of time but… there are some issues.**

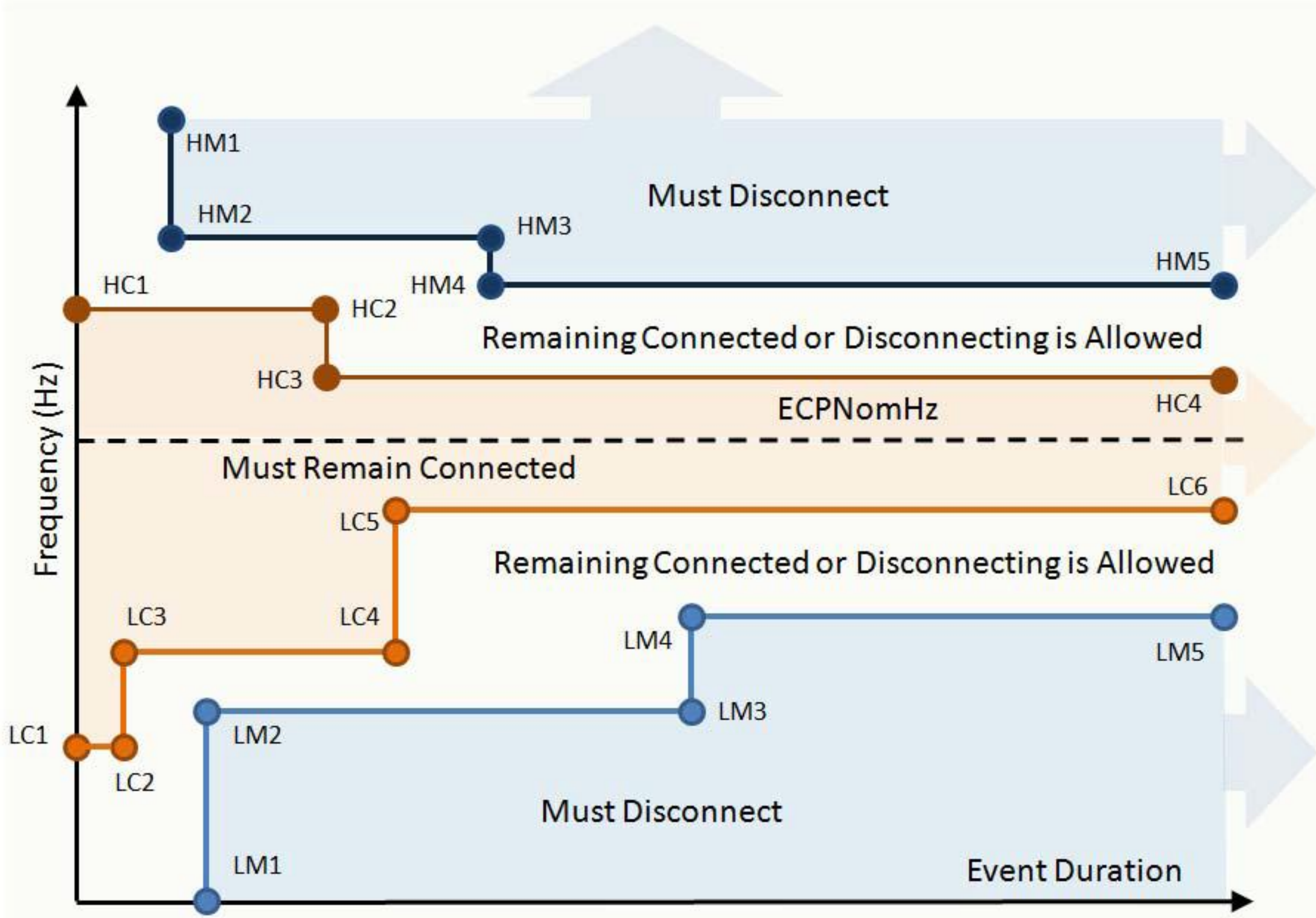
- **Very low voltages are normally seen in response to feeder faults and additional fault current may be undesirable.**
- **At very low voltages, frequency measurement signal to noise ratio deteriorates**
- **Very low voltage operation of inverters may increase power supply costs and complexity**

**Focus of requirements to date has been on what happens at beginning of event.  Of equal import is what happens when / how the DER returns to service.**

# L/H Voltage Ride Through



# Frequency Ride Through




EPRI Common Functions For Smart Inverters V3, page 15-2

# Frequency Ride Through Issues

**Inverters can provide controlled full current down to very low frequencies for extended periods.**

- **Frequency excursion is normally in response to system level events.**
- **Low frequency behavior needs to be coordinated with local load shedding schemes.**
- **Inverters are less sensitive to damage from low frequency operation than rotating machines.**

**During high frequency excursions ride through and Frequency / Watt functions are normally used together.**

- **Real power may be programmed to be at zero before reaching the ride through limits.**

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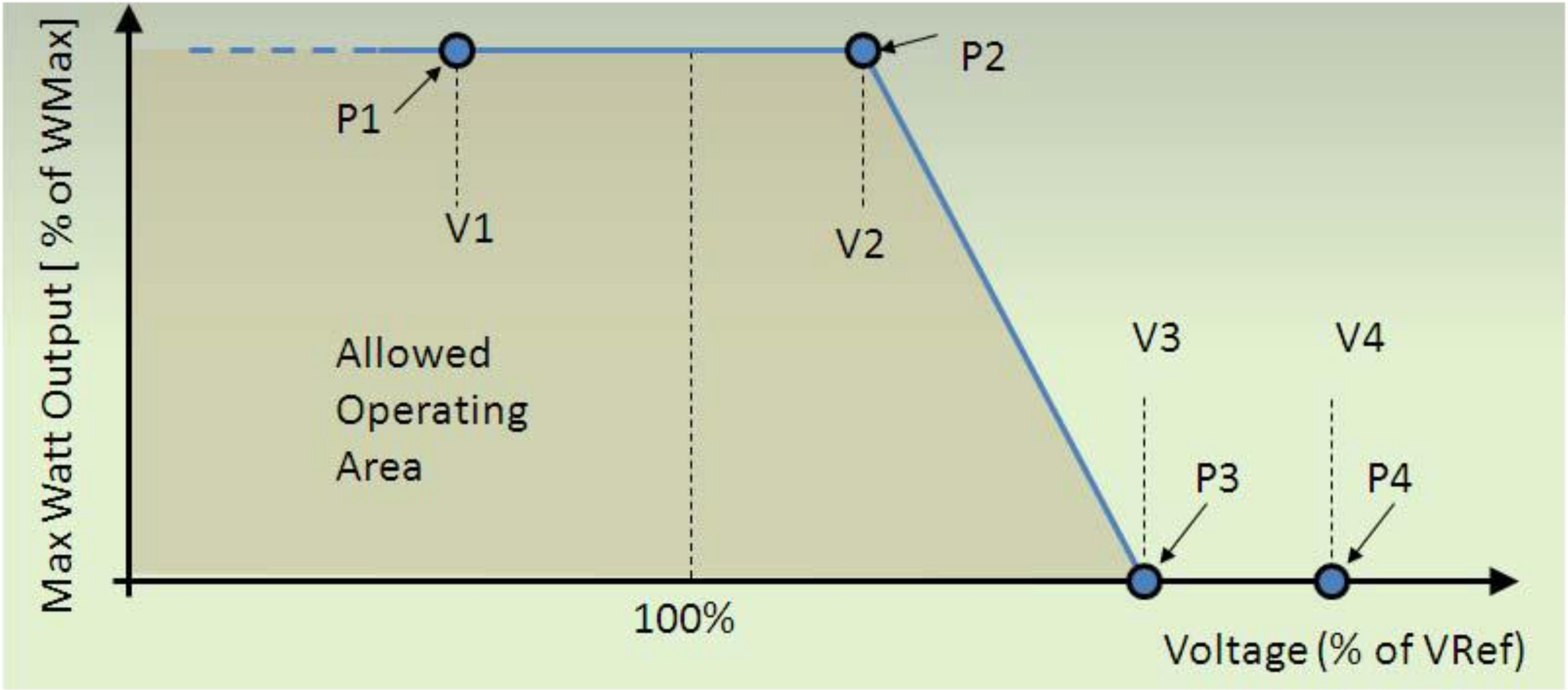
# Real Power Control Functions

**Real power control functions modulate real power output in response to changes in Voltage or frequency**

**Typical Real Power Control functions include:**

- **Volt / Watt**
  - Reduces real power output with rising voltage
  - May be possible to increase power with lower voltages if storage is present in the system
  - Can be used with ramp rate control on initial startup.
- **Frequency / Watt**
  - Reduces real power output with rising frequency
  - May be possible to increase power with lower voltages if storage is present in the system
  - Can be used with HF ride through for more stability

# Example: Real Power Control Function




## Example Volt Watt Diagram Parameters

- Dead band (Vnom – V2) = no power reduction
- Response Gradient %P/Volt = (P3-P2)/(V3/V2)
- Other considerations – Response time, averaging intervals, intentional delay

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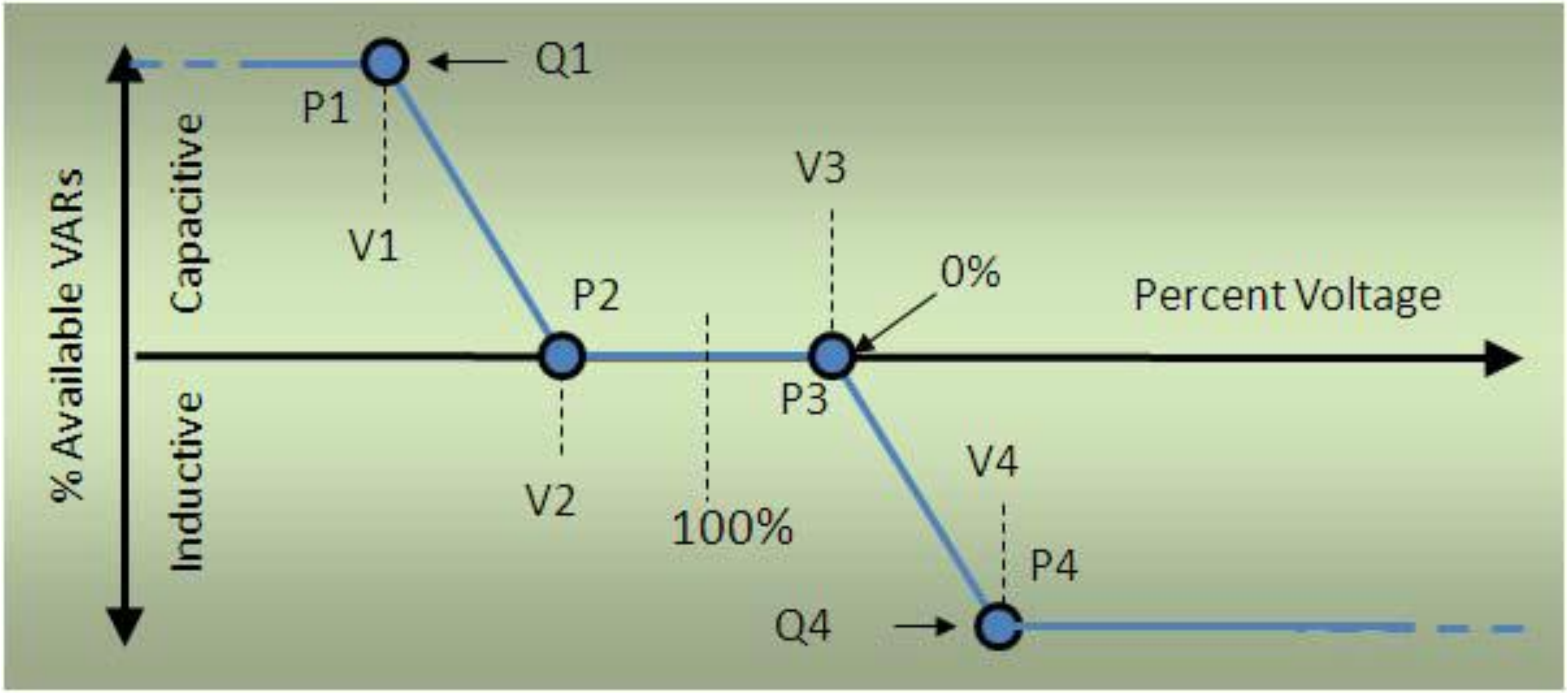
# Reactive Power Control Functions

**Reactive power control functions modulate reactive power output in response to changes in Voltage, or real power output.**

**Typical Reactive Power Control functions include:**

- **Volt / VAr with Watt priority (available VAr or VV11).**
  - Provides VAr support with no reduction in real power
  - VAr capacity varies inversely with solar resource
- **Volt / VAr with Var priority (available VAr or VV12).**
  - Provides VAr support and may reduce real power
  - VAr capacity is independent of solar resource
  - May require specific Tarriffs or Rates
- **Watt /Var (not common in the North America)**

# Example: Reactive Power Control Function




## Example Volt VAr Diagram Parameters

- Dead band (V3 – V2) = no power reduction
- Response Gradient %Qa/Volt = (Q4-Q3)/(V4/V4)
- Other considerations – Response time, averaging intervals, intentional delay

# Communication – Commanded Operation

Inverters respond in "near real time" to commands from the utility.

Example commanded modes:

- On/Off (P&Q = 0)
- Fixed Real Power (may require storage)
- Maximum Real Power
- Fixed Power Factor
- Mode Change – Profile A or Profile B

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# Communication – Autonomous Profiles

High speed SCADA communications is not cost effective for high numbers of smaller systems.

Inverters can be pre-programmed with one or more autonomous operating profiles.

- Inverters would then continue to operate according to this profile until commanded to do otherwise.
- Provides high speed response without need for high speed communications

Updates to profiles or changes in operating modes can occur over public IP networks

- Customer Network or Cellular Modem (M2M)

Mode changes might also be possible over AMI system.

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# Communication – Issues 1

**Cyber Security of communication to DER systems**

**No global standard communication protocols**

- **DNP 3 is one common protocol used by utilities.**
  - Not well suited to control of large numbers of inverters
  - Not used by all utilities
- **IEC 61850 Data model may be a common language**
  - Sunspec Mapping to IEC 61850 for inverters
  - DNP 3 to IEC 61850 for Utilities

**Response time will be dependent on communication system used**

**Not all systems will receive / respond to commands (Stochastic planning needed)**

# Questions

## Thank you for your attention

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