Smart Inverter Capabilities on Distribution Feeders

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What is a Smart Inverter?

- An inverter that performs functions that when activated can autonomously (meaning functions in the inverter itself) contribute to grid support during excursions from normal operating voltage and frequency conditions by providing dynamic reactive/real power support, voltage and frequency ride-through, ramp rate controls, communication systems with the ability to accept external commands and other functions.

- Smart inverter capabilities have been available for years but have principally been used on transmission level interconnections/large plants (ie interconnects to PRC-024-2)

- Requirements in UL1741/IEEE 1547 were not compatible with smart inverter capabilities (i.e tight V/F trip limits, no voltage regulation, etc)

- New UL1741-SA, IEEE 1547A and utility interconnection requirements are beginning to take advantage of smart inverter capabilities down to distribution voltages and small plants/single inverters

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Smart Inverter Interconnection Requirements

- California Rule 21 and HECO Rule 14H Utility Requirements

- Certified to UL1741-SA

- Inverters require autonomous grid support functions including

  - Low/high voltage ride-though

  - Low/high frequency ride-though

  - Dynamic Volt/Var operation

  - Ramp rate controls

  - Reconnection with soft start
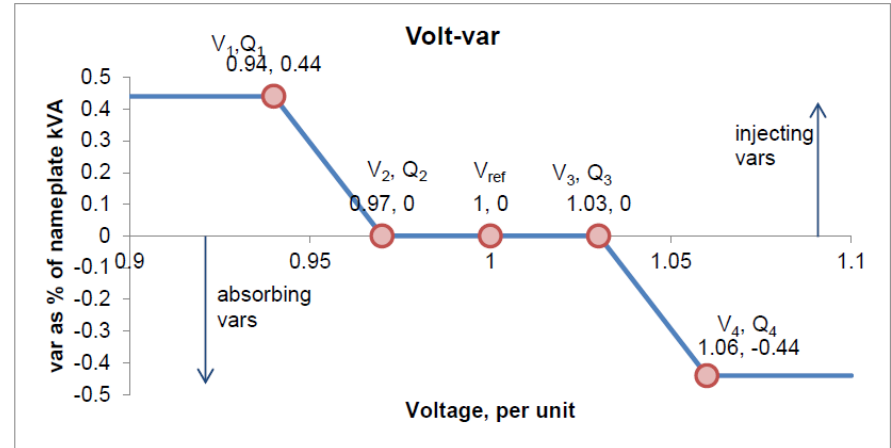
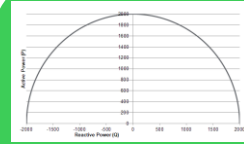 - Fixed power factor

  - Frequency/Watt

  - Volt/Watt

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Dynamic Volt/Var Operation
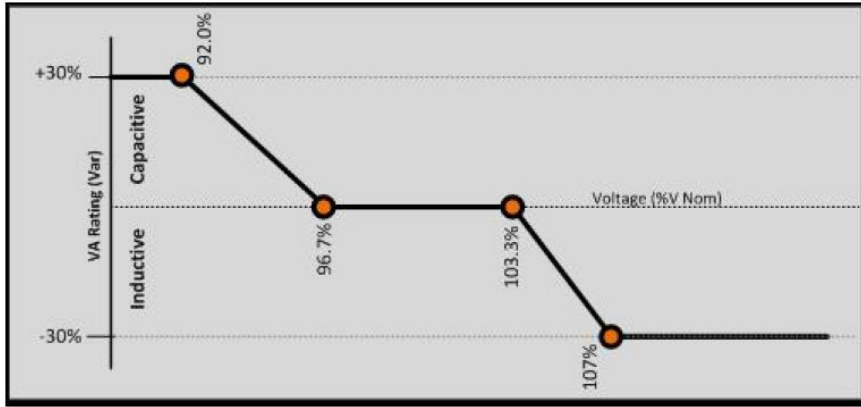
CA Rule 21

HECO Rule 14H

- Requirements can vary so inverters are designed with wide setting ranges

- Settings are parameterized so new firmware does not need to be developed and certified for each requirement
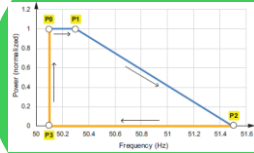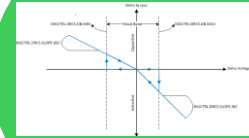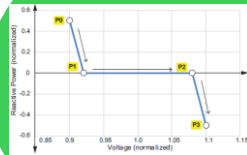
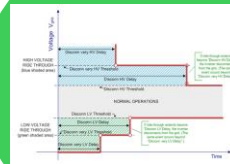# Advanced Grid Services

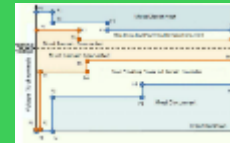0 to 1 PQ capability

Power curtailment control: P(f)

Dynamic Reactive Current
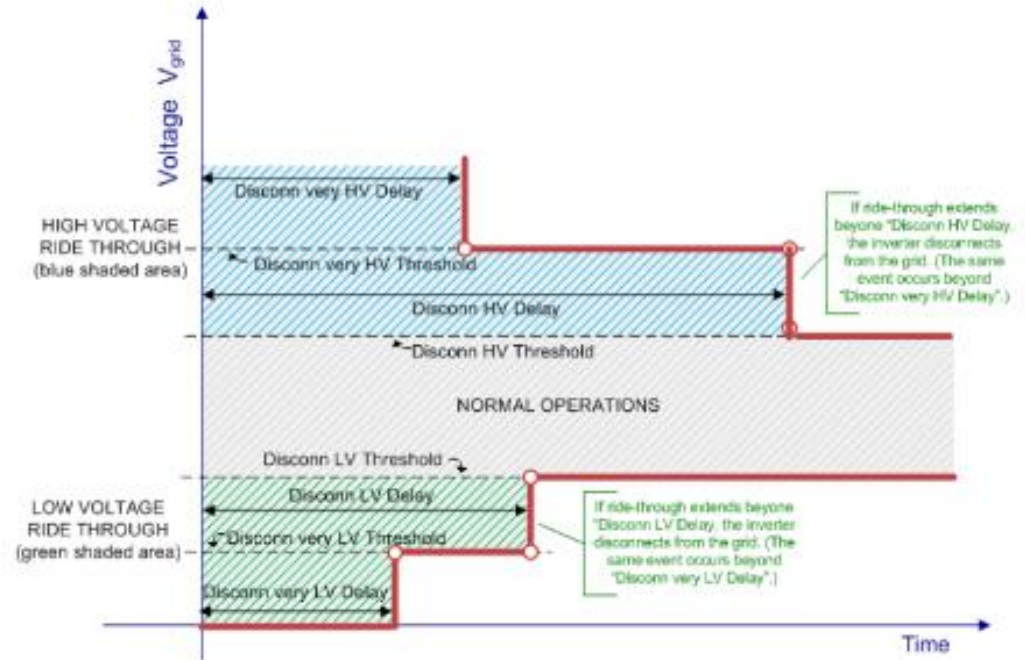
Q (V) control

Freq. Ride through

Voltage Ride through

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Voltage Ride Through

- Different curves dependent on interconnection requirements

- Up to 5 adjustable HV and LV thresholds and delays

- Down to 0% and up to 140% V

- Momentary cessation (inverter stops producing power but does not trip) or mandatory operation (inverter continues to produce power)

Frequency Ride Through

- Different curves dependent on interconnection requirements

- Up to 4 adjustable HF and LF thresholds and delays

- Down to 44 Hz and up to 66 Hz


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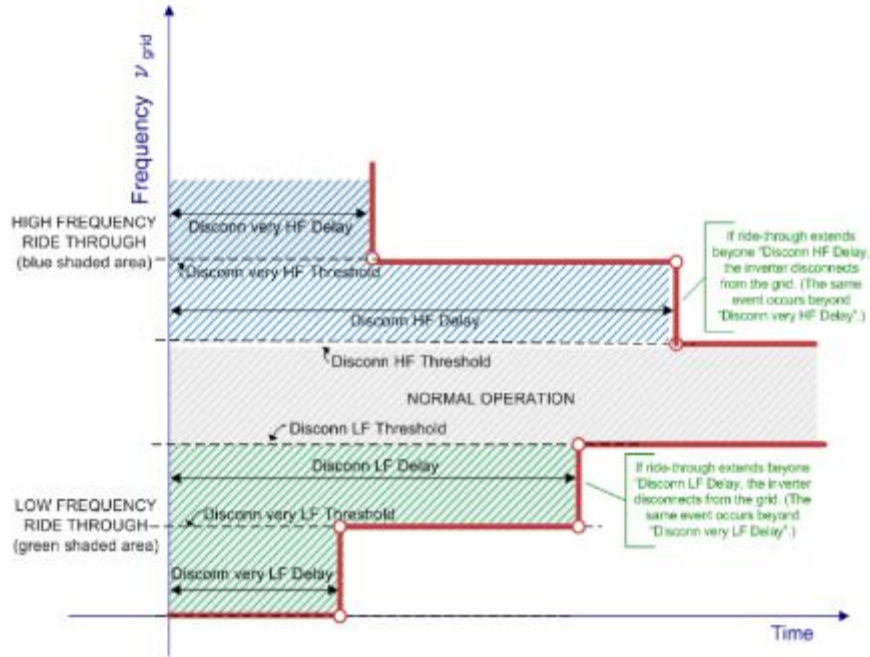
Frequency Watt Control

- Configurable multi-point curve with configurable set points, low pass filter, and ramp rates

- Only available for over frequency support as under frequency support requires storage
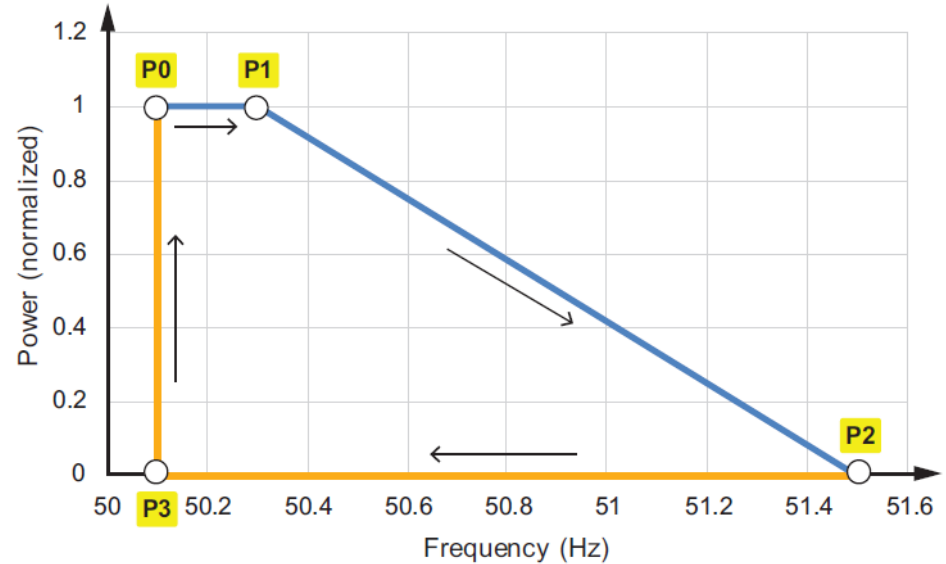
Volt Watt Control

- Configurable multi-point curve with configurable set points, low pass filter, and ramp rates

- Only available for over voltage support as under voltage support requires storage
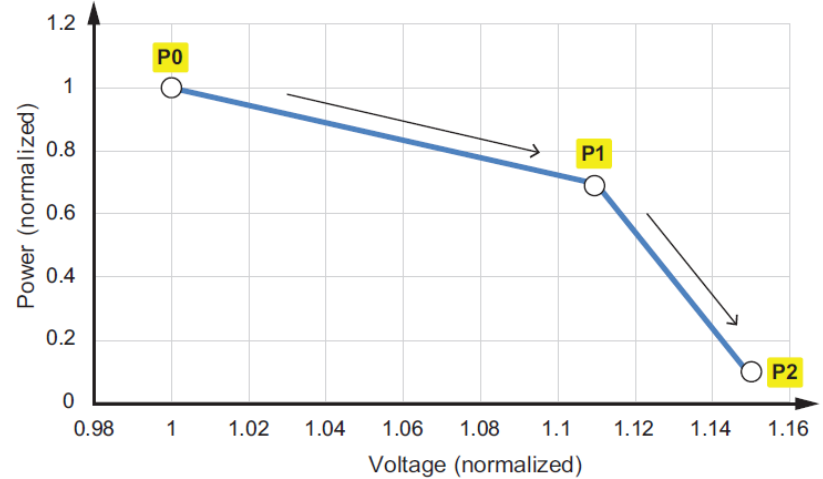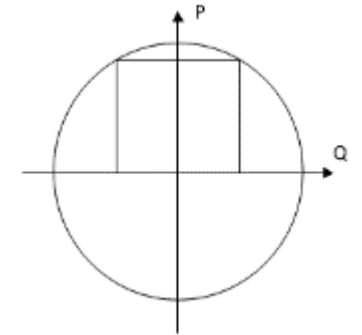
Var Capability

Inverter can be operated based on active or reactive power priority:

- Active power priority – inverters will deliver reactive power based on a set point up to the amount of reactive power available

- Power Factor Priority – inverters will deliver reactive power while maintaining power factor based on a setpoint.

- Reactive Power Priority – inverters will deliver reactive power depending on a reactive power setpoint. Active power will be limited depending on the KVA rating of the inverter.

- During PF or Q priority, active power is only limited when at the KVA rating of the inverter therefore in non full load conditions (ie off peak sunlight), the inverter will not have active power limitation
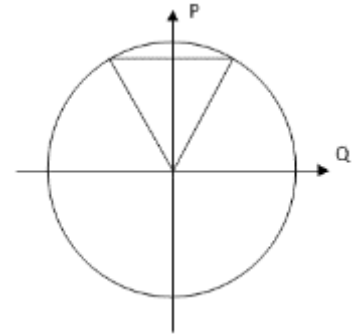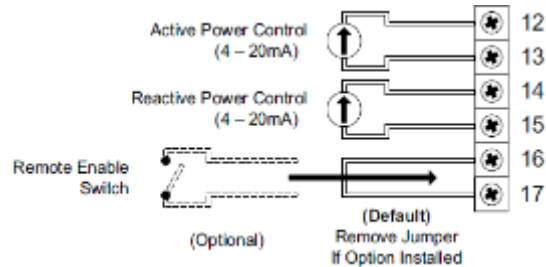

Q based on Power Factor

Q based on constant Kvar

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Var Capability

Setpoints for active power, reactive power, and power factor can be done three ways

- Locally on the inverter

- Remotely with Modbus TCP or Modbus RTU

- Remotely with 4-20 mA analog loops (active, reactive power or power factor)

External Control Connections

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Var at Night Feature

- Inverter is able to source reactive power during the day and at night

- At night, grid input remains connected, PV input is disconnected.

- All reactive power grid support features and commands work the same as when active power is available during the day

Volt-Var Control

- Configurable multi-point curve with configurable set points, low pass filter and ramp rates

- Optional enable/disable based on inverter operating active power level (e.g. turn it off at low power)

- Configurable whether it uses P priority or Q priority

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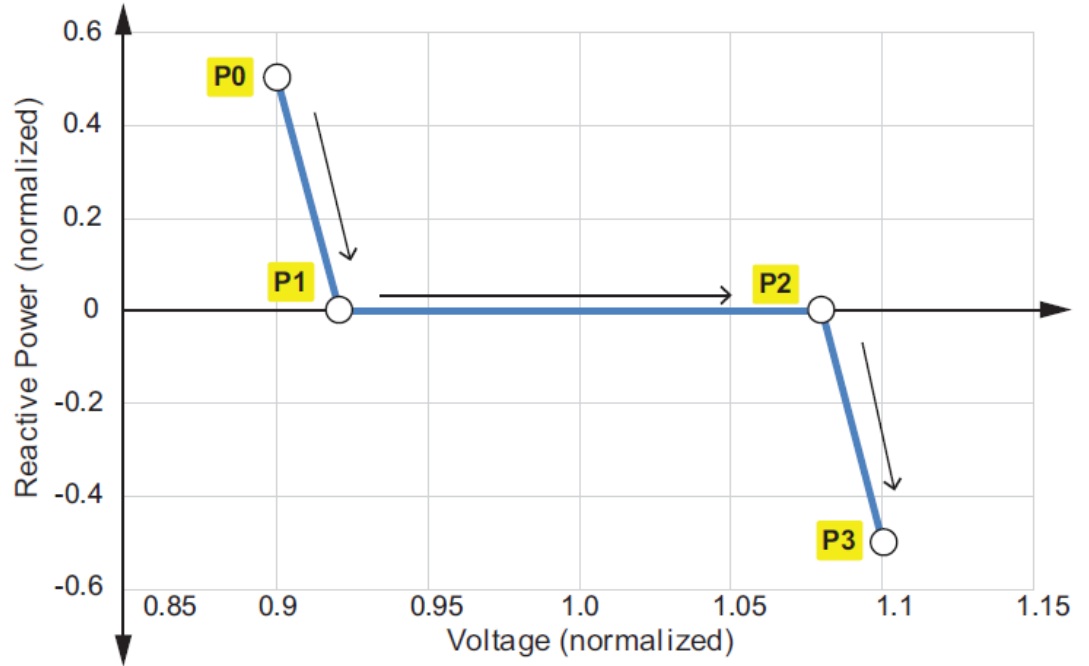
Power Plant Controller (PPC)

➢ In order to comply with grid requirements, the PPC offers better control and scalability when using multiple inverters (vs autonomous functions in the inverter itself):

- Embedded operation modes can be adjusted for each interconnection requirement

- The Point of Connection can be any voltage

- The PPC can communicate with the Grid Utility through various communication protocols (DNP3, IEC61850, IEC104, Analog and Digital Input/Output, …)

- Control can be coordinated with multiple inverters to meet POI requirements and optimize the plant

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Power Plant Controller

Main functions

➢ The PPC fulfills grid requirements regarding active and reactive power regulation (some functions requiring immediate inverter response such as ride through best done at the inverter)

➢ The PPC uses closed control loops for high-precision control at the Point of Connection.

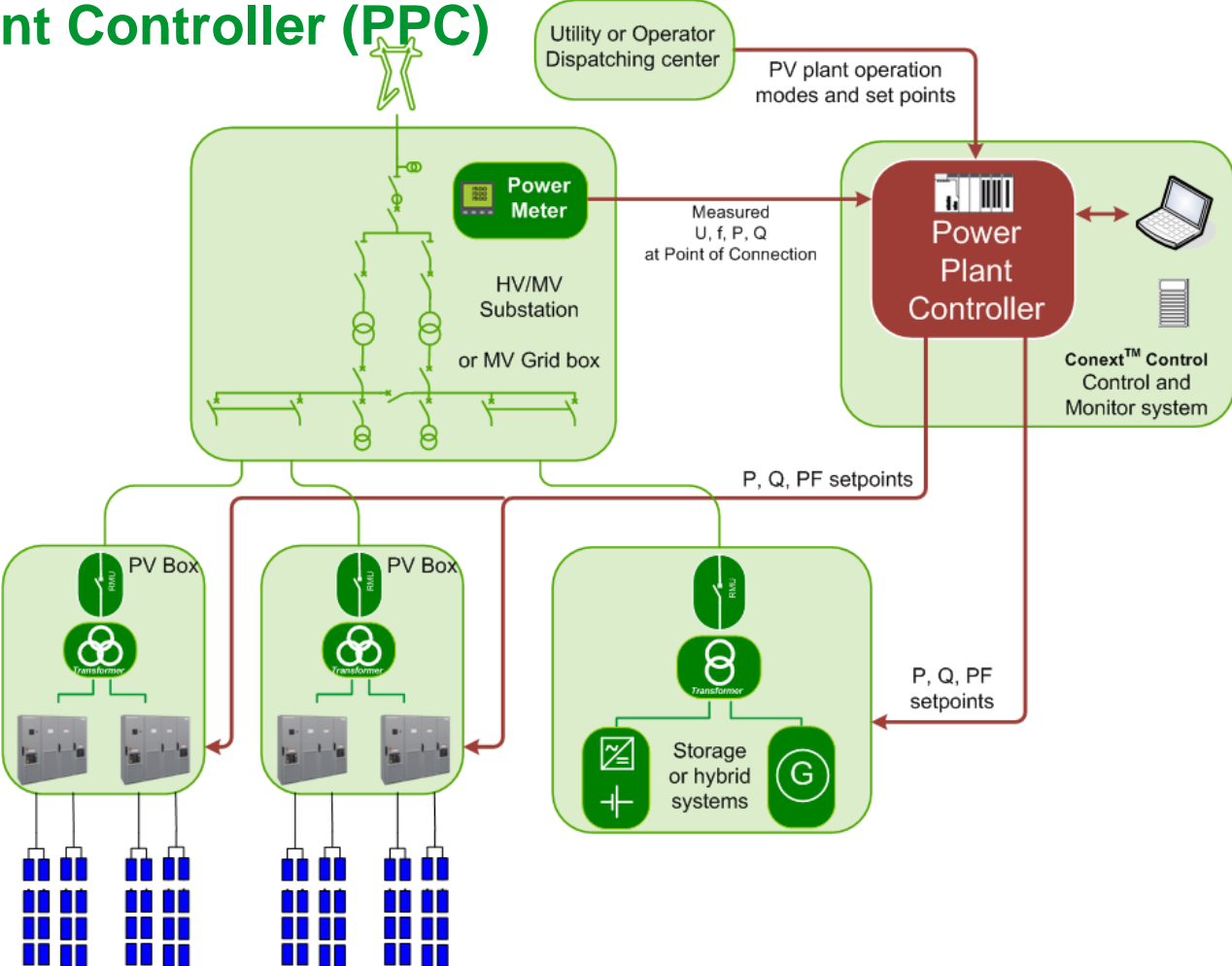☑ Embedded reactive power operation modes are:
-Voltage Control
-Power Factor Regulation
-Reactive Power

☑ Embedded active power operation modes are:
-Frequency Control
-Curtailment
-Ramp rate

Utility Grid

Regulation, grid support functions

Industrial IoT

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Power Plant Controller (PPC)

Power Plant Controller

Power Plant Controller - Example Installation

➢ Grid Voltage at the point of connection without PV plant voltage control

➢ Grid Voltage at the point of connection WITH Power Plant Controller operating in Voltage control mode
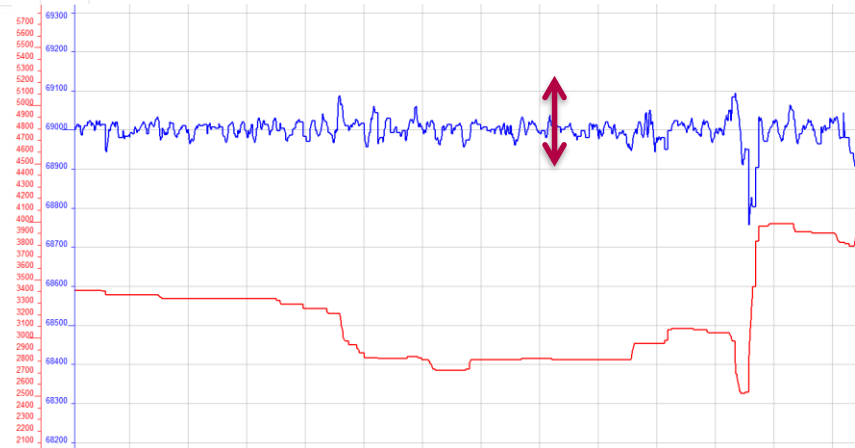
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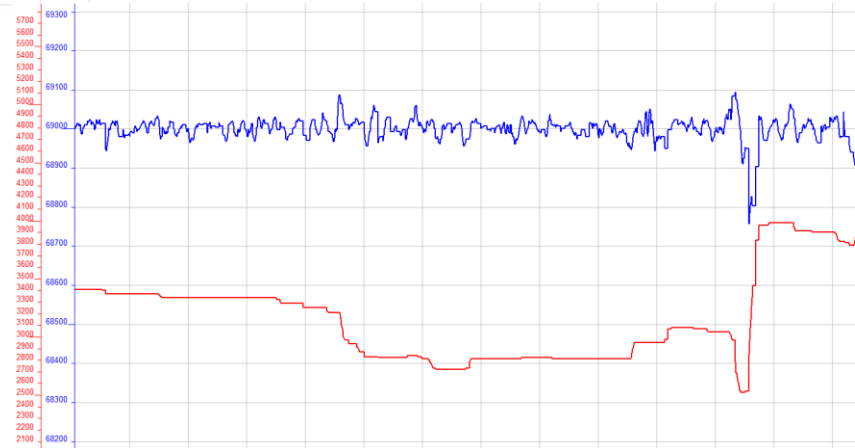
Power Plant Controller - Example Installation

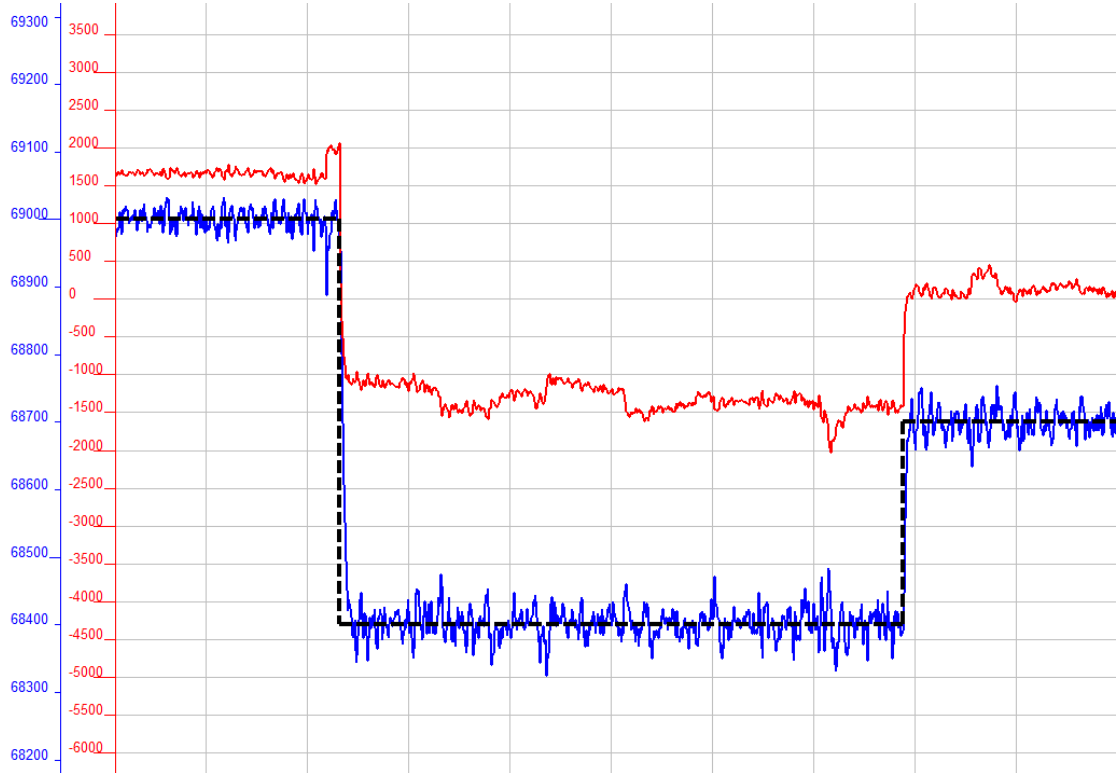
➢ Without Voltage Control:

Amplitude: 2 kV

➢ With PPC Voltage Control:
Amplitude 0.1 kV

➢ Reactive Power adjusted
by PPC

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Power Plant Controller - Example Installation

- ➢ **Blue**: Voltage
- ➢ **Red**: Reactive Power
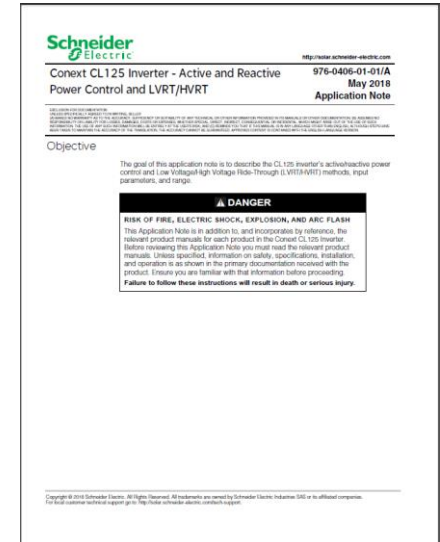- ➢ **Black**: Voltage Set point
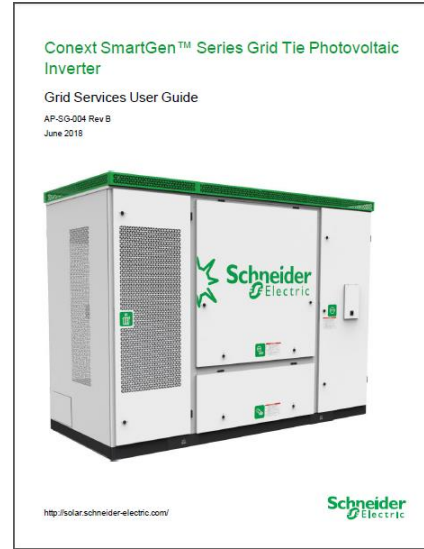
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