PV AND WIND GRID INTEGRATION WITH POWER PLANT CONTROLLERS

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Sumary: The aim of this document is to describe the Power Plant Controller (PPC) for PV (Photovoltaic) Plants and Wind Farms developed by Ingelectus Innovative Electrical Solutions. Ingelectus PPC is a reliable and flexible solution that is able to control a series of different element present in PV and Wind power plants to achieve TSO (Transmission System Operator) or DSO (Distribution System Operator) requirements at the POI (Point of Interconnection).

Key words: PPC, PV, Wind farms, Contoller, Grid Code, Network integration

Overview

The aim of this document is to describe the Power Plant Controller (PPC) for PV (Photovoltaic) Plants and Wind Farms developed by Ingelectus Innovative Electrical Solutions.

Ingelectus PPC is a reliable and flexible solution that is able to control a series of different element present in PV and Wind power plants to achieve TSO (Transmission System Operator) or DSO (Distribution System Operator) requirements at the POI (Point of Interconnection).

This system is capable of meeting the international requirements for grid stability management using closed loop controls offering the following functionalities:

- Active Power Reference, with or without ramp rate limiter (increase or decrease if its possible limited).
- Active Power Curtailment, with or without ramp rate limiter.
- Frequency response depending on the frequency deviations.
- Voltage Control. AVR (Automatic Voltage Regulator)
- Reactive Power control.
- Power factor control

It is suitable for PV and Wind power plants with different type of inverters, or other technologies such as DFIG (Double Fed Induction Generators), BESS (Battery Energy Storage Systems), STATCOM (Static Synchronous Compensator) or Capacitor Banks.

With simulation tools, such as PTI Siemens PSSE, the behavior of the Power Plant Controller can be tested before the commissioning of the power plant. The parameterization and configuration of the Power Plant Controller can be performed with via remote access.

The PPC has an easy and intuitive web-interface that shows the user information of the status of the controllers, the controlled elements (PV, Wind machines, STATCOMs, etc.) and the references

Active Power Control

Active power control is the combination of two modules, Curtailment or Active Power Reference and Frequency Response. Through a closed-loop control, active power reference will be sent to inverters, wind machines or BESS. Both modules can be initiated independently. When there is no control mode initiated, the typical control will be maximum power point tracking from the inverters or wind machines.

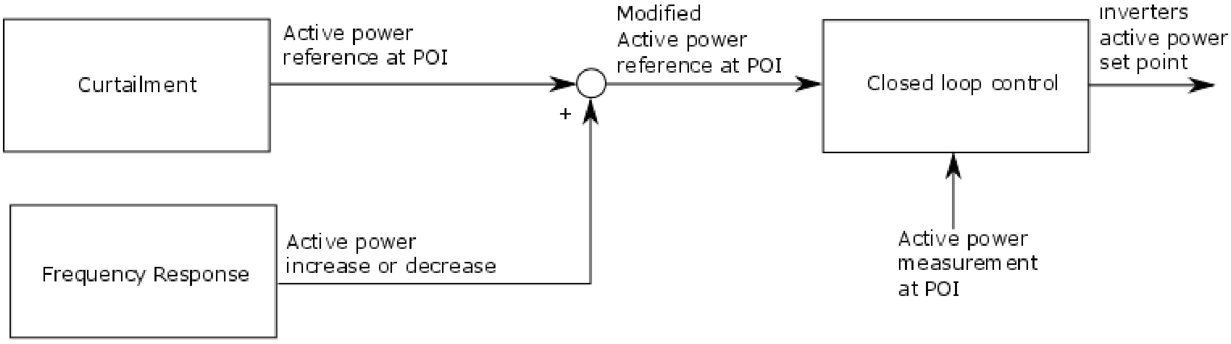

Figure 1. Active power closed control loop.

Curtailment and Active Power Reference

Curtailment and Active Power Reference module can be enabled or disabled, if it is disabled the plant will not follow the curtailment reference. A ramp rate limiter for active power can be set so that the active power increase or decrease, if the technology allows it, is limited.

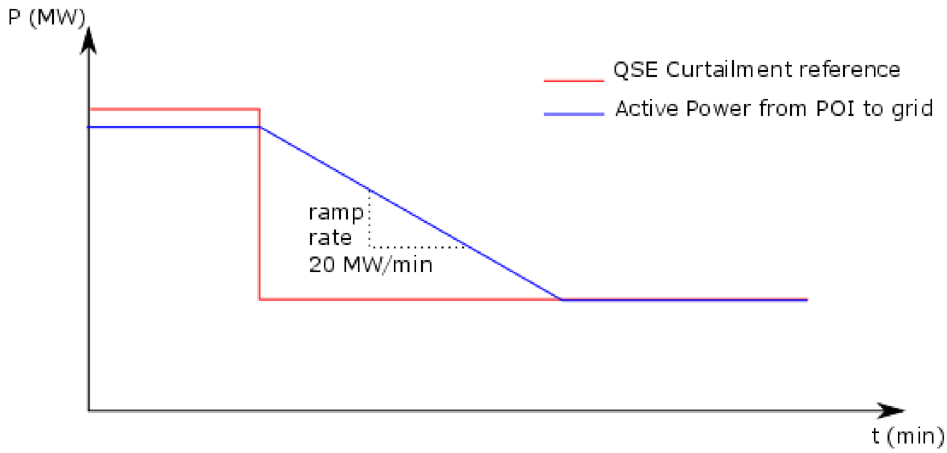

Figure 2. Active power ramp rate limiter..

Primary Frequency Response (PFR)

The PPC will provide real power primary frequency response, proportional to frequency deviations from scheduled frequency, similar to a governor response. Frequency response is not limited by, and is decoupled from, the ramp rate control. The active power vs frequency curve is as follows.

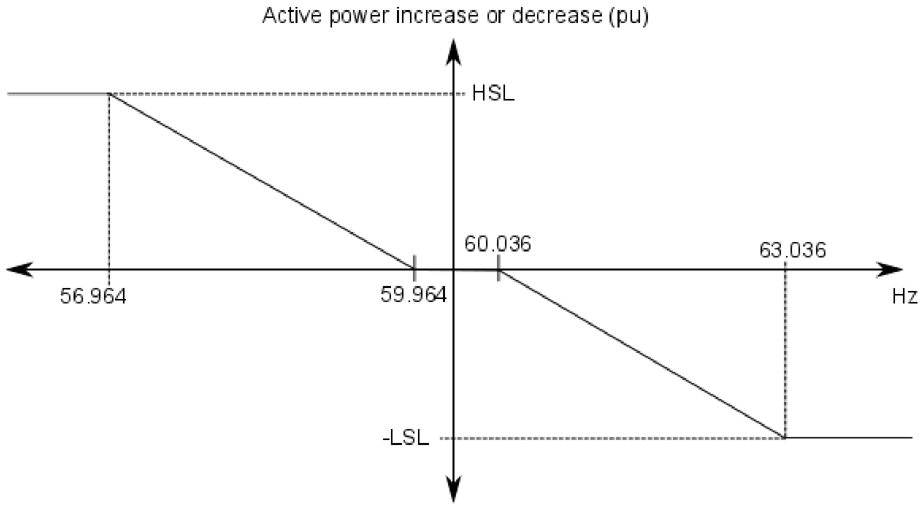

Figure 3. Frequency response curve.

If a frequency event occurs and the curtailment mode is enabled the active power increase or decrease will be applied to the current curtailment reference. In case of the curtailment mode is disabled, the active power increase or decrease will be applied to the active power measurement at POI just when the frequency event started.

Reactive Power Control

There are three separate reactive power modules for different applications that ensure the stabilization the utility grid.

Voltage Control (VRS)

This module will have as reference inputs the voltage and droop and will provide a response similar to an AVR. Through a closed-loop control, reactive power reference will be sent to inverters, wind machines, STATCOM, etc.

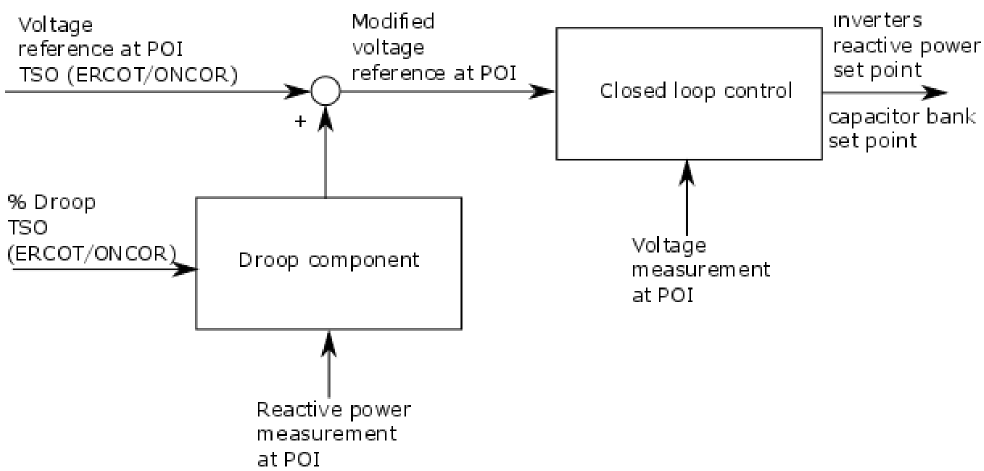

Figure 4. AVR closed control loop.

The PPC will implement a primary control (droop) voltage-reactive with configurable setting voltage and regulation slope. The formula for calculating the steady-state droop voltage (v'_{ref}) is:

$$v'_{ref} = v_{ref} - k_{droop} * Q/Q_{total}$$

Where:

- v_{ref} desired voltage at POI (in pu)
- k_{droop} droop constant (%)
- Q measured Q at POI (Mvar)
- Q_{total} maximum reactive power of the plant (Mvar)

The following figure represents the response of the PPC when a voltage reference (VRS) is changed. The green lines represent the Q-V droop of the PV or Wind power plant while the red line represents the power systems Q-V characteristic. In case of changing the reference value of the VRS of the PV plant from V0 to V1, the reactive power injection changes from the initial value Q0 to Q1.

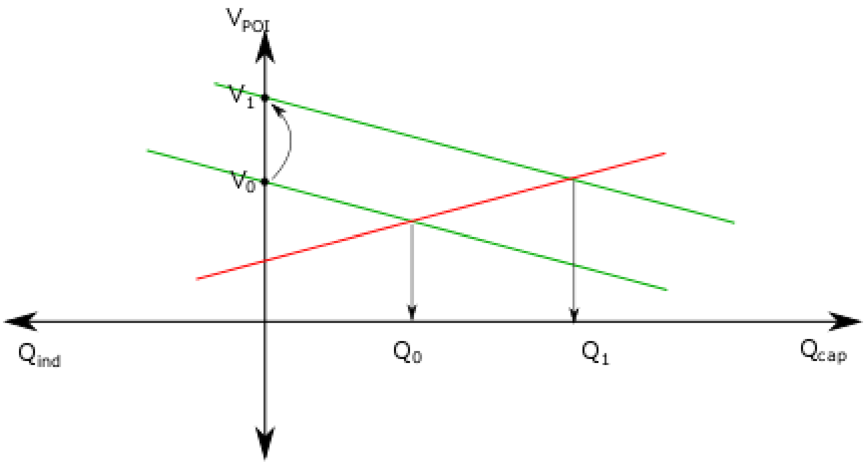

Figure 5. Voltage droop V vs Q curve.

Reactive Power

In order to ensure the reactive power, the PPC calculates the set point based in the value of the reactive power reference. It is based in a PI closed loop controller:

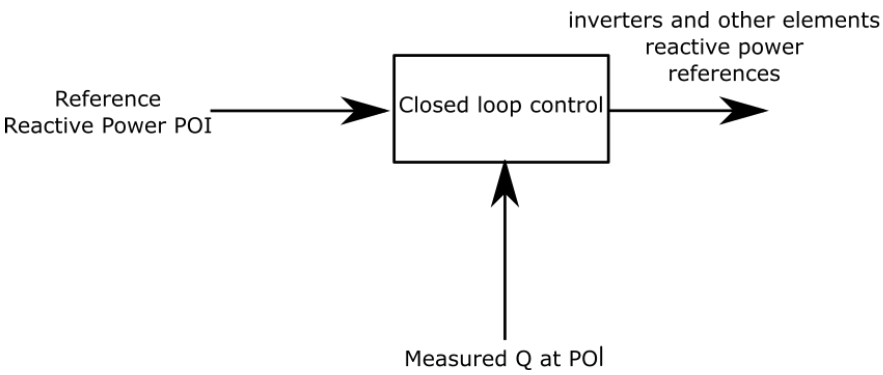

Figure 5. Reactive power closed control loop.

Power Factor Control

In order to ensure the power factor, the module calculates the set point based in the value power factor and the dead band configured. It is based in a PI controller after a power factor to reactive power conversion:

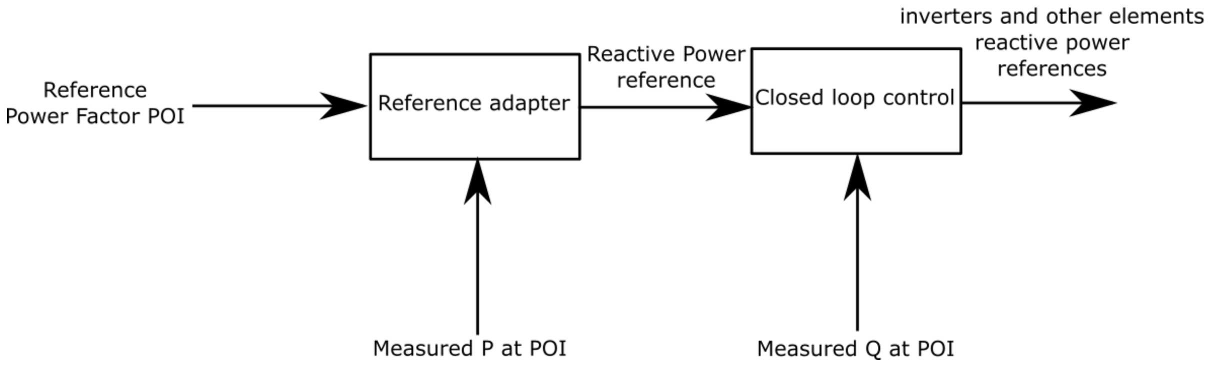

Figure 6. Power Factor closed control loop.

The reference conversion is calculated based in the formula:

$$q_{ref} = tan(acos(pf_{ref})) * p_{poi}$$

Where:
q_{ref} reactive power reference
pf_{ref} power factor reference
p_{poi} active power flowing through POI

CONCLUSIONS

Los resultados de las simulaciones realizadas demuestran el potencial del EE. de cara a optimizar la operación y planificación de las redes de distribución de media y baja tensión, con las siguientes funcionalidades:

- Identificación/detección de medidas erróneas. Esta medida errónea puede deberse a un fallo en el sensor de medida, por problema en comunicaciones, por la existencia de un fraude, etc.
- Mejorar los balances de energía, permitiendo una mejor detección de pérdidas no técnicas.
- Desagregación de las pérdidas totales técnicas y no técnicas.
- Evaluar las sobretensiones y subtensiones de la red.

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