

GridConnect

IEC 61131 Library for ACCELERATOR RTAC® Projects

SEL Automation Controllers

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RTAC LIBRARY

GridConnect

Introduction

The GridConnect library is designed for use with the SEL Real-Time Automation Controller (RTAC) family of products. It contains ready-to-use function blocks for controlling the point of interconnection (POI) between the utility grid and a solar power generation resource. The GridConnect library uses proportional integral (PI) controllers when in a closed-loop mode to regulate output set points.

Overview

The GridConnect library contains the following four function blocks:

- fb_MasterPlantController: Regulates POI between the utility and the solar facility.
- fb_PvInverter: Interfaces with a photovoltaic inverter.
- fb_StorageInverter: Interfaces with a battery storage inverter.
- fb_Capacitor: Interfaces with a capacitor.

The user must map all necessary input/output (I/O) signals to interface the function blocks to their various pieces of external equipment, but the GridConnect library automates all data exchange between the function blocks themselves.

Feature Summary

This library contains the following features for interconnection of a solar facility to the utility grid.

Reactive Control at POI

- Closed-loop control of power factor
- Closed-loop control of reactive power (constant VAR)
- Closed-loop control of voltage

- Closed-loop power factor compensation
- Closed-loop voltage compensation
- Open-loop control of power factor (POI set-point pass-through)

Power Limit Control at POI

- Closed-loop control of power output (i.e., advanced power limit control)
- Open-loop control of power output (i.e., simple power limit control)

Frequency Regulation at POI

- Automatic adjustment of plant power output in response to system frequency changes
- Automatic adjustment of storage device output in response to system frequency changes

Additional Features

- POI voltage limit override when in power factor or reactive power control or compensation modes
- POI power factor limit override when in voltage control or compensation modes
- Integrated control of PV inverters, storage inverters, and capacitors to provide precise control at the POI

Special Considerations

- Copying classes from this library causes unwanted behavior. This means the following:
 1. The assignment operator “:=” must not be used on any class from this library; consider assigning pointers to the objects instead.

```
// This is bad and in most cases will provide a compiler error
  such as:
// "C0328: Assignment not allowed for type
  class_GridConnectObjectObject"
myGridConnectObjectObject := otherGridConnectObjectObject;
```

```
// This is fine
someVariable := myGridConnectObjectObject.value;
// As is this
pt_myGridConnectObjectObject := ADR(myGridConnectObjectObject);
```

2. Classes from this library must never be VAR_INPUT or VAR_OUTPUT members in function blocks, functions, or methods. Place them in the VAR_IN_OUT section or use pointers instead.

- Classes in this library have memory allocated inside them. As such, they should only be created in environments of permanent scope (e.g., Programs, Global Variable Lists, or VAR_STAT sections).

Supported Firmware Versions

You can use this library on any device configured using ACSELERATOR RTAC® SEL-5033 Software with firmware version R143 or higher.

Master Plant Controller

Overview

The master plant controller (hereafter referred to as the Controller) is operated in several different control modes, each having the objective of controlling or compensating power factor, reactive power, or voltage. The desired mode is provided as an input on the fb_MasterPlantController function block. The controller is enabled by asserting the Enable input and is disabled by deasserting the Enable input. Top level mode and enable/disable control inputs are described in *Table 1*.

Table 1 Master Plant Controller Control Mode Parameters

Parameter	Description
ControlMode	POI control mode: <ul style="list-style-type: none"> ► 0 = Power Factor Control ► 1 = VAR Control ► 2 = Power Factor Compensation ► 3 = Voltage Compensation ► 4 = Voltage Control ► 5 = Open-Loop Power Factor Control
Enable	POI control enable
PLimitMode	Power limit mode: <ul style="list-style-type: none"> ► 0 = NoLimit ► 1 = Simple ► 2 = Advanced

When the controller is in open-loop power factor control mode it passes the power factor set point to the power factor reference for all inverters in the facility. This mode is used as a fall-back mode (when POI measurements are not reliable).

In closed-loop mode the controller automatically adjusts either the power, power factor, or VAR reference signal of the inverter to perform control or compensation at the POI.

The controller automatically adjusts the power limit reference signal of the inverters to limit the cumulative power output of the plant.

Control Modes

The GridConnect library supports six different control modes. This section provides details about the following modes: power factor, voltage, VAR, and open-loop power factor. The remaining two modes are compensation modes and are detailed in *Compensation Modes on page 5*.

Power Factor Control

When the controller is in power factor control mode, it adjusts the power factor reference of the inverter to provide precise adjustment of the power factor at the POI. The controller uses a proportional integral (PI) controller for these adjustments. For this mode to function properly, the inverter must be in power factor control mode (as opposed to VAR control mode). If the inverter is not in power factor control mode, the controller will periodically attempt to send a mode change control. The inverter is considered unavailable to the master controller if it is unable to change modes.

Closed-loop behavior of power factor control is adjusted using the inputs defined in *Table 2*.

Table 2 Closed-Loop Power Factor Control Parameters

Parameter	Description
PFCControlSetpoint	POI power factor control set point (positive values = lagging, negative values = leading)
PFCControlDeadband	POI power factor control dead band
PFKp	Proportional tuning parameter for power factor control. Default is 1.
PFKi	Integral tuning parameter for power factor control. Default is 0.

VAR Control

When the controller is in VAR control mode, it adjusts the VAR reference of the inverter to provide precise adjustment of VAR flow at the POI. The controller uses a PI controller for these adjustments. For this mode to function properly, the inverter must be in VAR control mode (as opposed to power factor control mode). If the inverter is not in VAR control mode, the controller will periodically attempt to send a mode change control. The inverter is considered unavailable to the master controller if it is unable to change modes.

Closed-loop behavior of VAR control is adjusted using the inputs defined in *Table 3*.

Table 3 Closed-Loop VAR Control Parameters

Parameter	Description
QSetpoint	POI VAR control set point
QDeadband	POI VAR control dead band
QKp	Proportional tuning parameter for VAR control
QKi	Integral tuning parameter for VAR control

Voltage Control

When the controller is in voltage control mode, it adjusts the VAR reference of the inverter to provide precise adjustment of the voltage magnitude at the POI. The controller uses a PI controller for these adjustments, and separate tuning parameters (VK_p and VK_i) are provided for this mode. For this mode to function properly, the inverter must be in VAR control mode (as opposed to power factor control mode). If the inverter is not in VAR control mode, the controller will periodically attempt to send a mode change control. The inverter will be considered unavailable to the master controller if it is unable to change modes.

Closed-loop behavior of voltage control is adjusted using the inputs defined in *Table 4*.

Table 4 Closed-Loop Voltage Control Parameters

Parameter	Description
VSetpoint	POI power voltage set point
VDeadband	POI voltage control dead band
VK _p	Proportional tuning parameter for voltage control. Default is 1.
VK _i	Integral tuning parameter for voltage control. Default is 0.

Open-Loop Power Factor Control

When the controller is in open loop power factor control mode, it passes the power factor set point to the power factor reference for all configured inverters. For this mode to function properly, the inverter must be in power factor control mode (as opposed to VAR control mode). If the inverter is not in power factor control mode, the controller will periodically attempt to send a mode change control. The inverter will be considered unavailable to the master controller if it is unable to change modes.

Power factor ramp rate changes are also passed to the inverters. Settings relating to power factor control that are passed through to configured inverters are listed in *Table 5*.

Table 5 Open-Loop Power Factor Control Parameters

Parameter	Description
PFCControlSetpoint	POI power factor control set point
InverterPFRampRate	Power factor ramp rate

Compensation Modes

The GridConnect library supports both power factor and voltage compensation. These modes regulate the controlled value (power factor or voltage) in a response proportional to the percentage of plant output power or voltage.

It is important to note that these modes use different settings than other control modes, and they do not observe the limits that constrain those other modes. Limits that do not apply to compensation modes are as follows:

- PFLagLimit and PFLeadLimit
- VLimitHigh and VLimitLow
- QLimitHigh and QLimitLow

These compensation modes should instead be limited by their own curve set points as defined in the following sections.

Power Factor Compensation

When the controller is in power factor compensation mode, it regulates the power factor at the POI based on how much power the plant is generating. This mode uses the same PI controller tuning parameters as the Power Factor control mode. The relationship between power factor and plant power output is a slope defined by a power factor compensation gradient setting (its units are PF/%kW). Control of the POI power factor is limited by a compensation limit setting, as well as a low power cutoff setting. Inputs that adjust the operation of the controller when in power factor compensation mode are defined in *Table 6*.

This mode requires that the inverters be in power factor control mode. Any inverter not in power factor control mode is flagged as unavailable to the master controller and is periodically sent a mode change control signal.

Table 6 Power Factor Compensation Parameters

Parameter	Description
PFCompensationSetpoint	Power factor compensation set point
PFCompensationCutoff	Power factor compensation cutoff
PFCompensationGradient	Power factor compensation gradient
PFCompensationLimit	Power factor compensation limit
PFKp	Proportional tuning parameter for power factor control. Default is 1.
PFKi	Integral tuning parameter for power factor control. Default is 0.

Voltage Compensation

When the controller is in voltage compensation mode, it regulates VAR flow at the POI based on voltage at the POI. This mode uses the same PI controller tuning parameters as the Voltage Control mode. In this mode the plant can provide VAR support for grid voltage, even at night or when real power output is otherwise very low. The relationship between VAR output and voltage magnitude follows a curve defined by voltage and VAR set points (as illustrated in *Figure 1* and *Table 7*). These inputs can be adjusted at any time, which will change the curve being used by the controller for voltage compensation. If these inputs are made variable, it is important to ensure that they have correct and intended values at all times, including at controller startup.

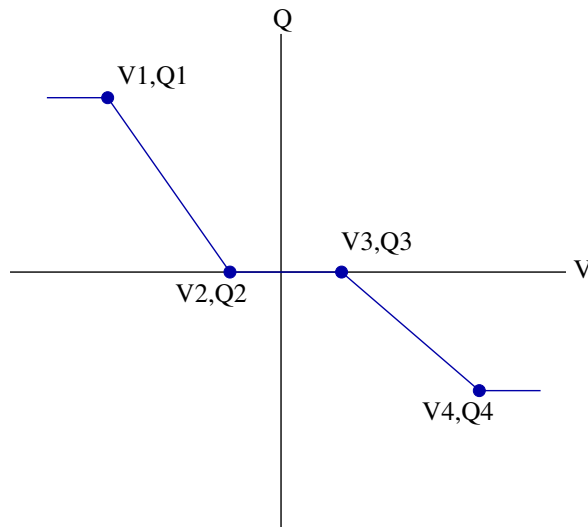


Figure 1 Voltage Compensation Curve

This mode requires that the inverters be in VAR control mode. Any inverter not in VAR control mode is flagged as unavailable to the master controller and is periodically sent a mode change control signal.

Table 7 Voltage Compensation Parameters

Parameter	Description
VCompensationV1	Voltage compensation voltage set point 1. Units are kV. Default is 0.
VCompensationV2	Voltage compensation voltage set point 2. Units are kV. Default is 0.
VCompensationV3	Voltage compensation voltage set point 3. Units are kV. Default is 0.
VCompensationV4	Voltage compensation voltage set point 4. Units are kV. Default is 0.
VCompensationQ1	Voltage compensation reactive power set point 1. Units are kVAR. Default is 0.
VCompensationQ2	Voltage compensation reactive power set point 2. Units are kVAR. Default is 0.
VCompensationQ3	Voltage compensation reactive power set point 3. Units are kVAR. Default is 0.
VCompensationQ4	Voltage compensation reactive power set point 4. Units are kVAR. Default is 0.
VKp	Proportional tuning parameter for voltage control. Default is 1.
VKi	Integral tuning parameter for voltage control. Default is 0.

Capacitor Control

The master controller calculates the reactive power required to achieve the active control objective (i.e., VAR, voltage, or power factor at the POI). Additionally, the master controller calculates the reactive power available to be added or removed using inverters and capacitors. Generally, the active PI control pursues the control objective by operating capacitors first (if available) and complementing that operation by adjusting the power factor reference to the inverters. If inverters collectively output more than 75 percent of the rating of the

next capacitor selected to operate for 60 seconds, the capacitor will close (as long as the CapacitorOperationPeriod interval is not violated). In this manner, the master controller will attempt to use capacitors to make coarse control adjustments at the POI, and use the inverters to reach and maintain fine control at the POI.

Storage Inverter Control

The GridConnect library provides a storage inverter function block. It will use the storage inverter’s ability to discharge energy to the POI in order to maintain POI real power ramp rate as photovoltaic (PV) power output decreases. This is referred to as downramp control.

Power Output Limit

When the controller is enabled, it sets the power limit reference signals to the inverters based on the power limit mode.

NoLimit Power Limit Mode

The controller sets the power limit reference signal to 100 percent for all inverters.

Simple Power Limit Mode

The power limit set point is calculated based on a percentage of the total power rating of the inverters that are online and available to be controlled. While the real power set point is in kW, the real power set point of each inverter will be the same in terms of the rating of each inverter. For example, if there are 40 inverters at 500 kW rating each, the total power rating is 20 MW. If the power limit set point is 15 MW, each inverter will be limited to 75 percent of 500 kW, or 375 kW. If some of the 40 inverters are not online, the total power rating of will be less. For example, if two inverters are offline, each of the remaining online inverters should be limited to 79 percent of 500 kW, or 395 kW.

In some cases, there may be inverters that are online and producing power but which are not available to be controlled. For example, the controller does not attempt to control inverters that are in one of the following states:

- The inverter is in local mode and is excluded from operation.
- The inverter indicates that a fault is present.
- The inverter controller detects a communications failure alarm.

When one of these conditions is true, the controller assumes that the power output of these inverters will remain constant and adjusts the power limit of the remaining inverters to compensate. In the example below, if the two offline inverters were actually online, generating 250 kW each but not available to be controlled, then the controller will calculate the power limit as shown in *Equation 1*. Each inverter will then output this percentage multiplied by its individual real power rating.

$$PowerLimit = \frac{POIPowerSetPoint - ConstantPower}{AvailableInverterRating} = \frac{15MW - 2 * 0.250MW}{19MW} = 76.3\% \quad (\text{Equation 1})$$

The simple power limit mode does not address any non-uniform cloud cover issues or the presence of local load.

Advanced Power Limit Mode

The power output of an inverter is very sensitive to fluctuations in solar radiation. A disturbance, such as a cloud, quickly reduces the power output of some inverters while other inverters in the facility may have unused capacity. Additionally, a storage inverter may be used to provide energy at the POI in these cases. The advanced power limit acts to aggregate the fast-changing power output available at individual inverters to produce a steady power output at the POI. Additionally, the changes to the power limit reference are limited by the specified power limit ramp rate of the inverter.

If an inverter does not respond to the power set point, the master controller will limit the inverter power set point to 115 percent of the present power output of the inverter. This adaptive power limit reduces potential high-power excursions because of inverter wind up when the available power increases quickly because of cloud cover clearing. A user-settable time delay is employed to determine when the adaptive power limit should be applied. This time delay should be set to at least twice the expected data update period for the inverter power measurement. Because the advanced power limit mode uses data from the individual inverters in a closed control loop, it is important that data from the inverters be updated to the controller at least every 5 seconds.

The user may adjust the behavior of the advanced power output limit using the parameters listed in *Table 8*.

Table 8 Advanced Power Output Limit Parameters

Parameter	Description
PSetpoint	POI power limit set point (kW)
PDeadBand	POI power limit dead band (kW)
PKp	Proportional tuning parameter for power control
PKi	Integral tuning parameter for power control
PRating	POI power output rating (kW)
InverterPLimitRampRate	Inverter power limit ramp rate (% power rating/second)
InverterPLimitDelay	Time between the last valid inverter response and application of the adaptive power limit

Frequency Regulation

The following settings determine how the controller performs frequency regulation. It is able to do so using either the non-storage generation assets (general PV plant output) or by using storage devices. Frequency regulation is performed according to a curve defined by inputs on the Master Plant Controller. These inputs can be adjusted at any time, which will change the curve being used by the controller for frequency regulation. If these inputs are made variable, it is important to ensure that they have correct and intended values at all times, including at controller startup. These inputs are described in *Table 9* and *Figure 2*.

Table 9 Frequency Regulation Parameters

Parameter	Description
FRegulationF1	Frequency regulation frequency set point 1. Units are Hz. Default is 0.
FRegulationF2	Frequency regulation frequency set point 2. Units are Hz. Default is 0.
FRegulationF3	Frequency regulation frequency set point 3. Units are Hz. Default is 0.
FRegulationF4	Frequency regulation frequency set point 4. Units are Hz. Default is 0.

Table 9 Frequency Regulation Parameters (Continued)

Parameter	Description
FRegulationP1	Frequency regulation real power set point 1. Units are % of PlantPRating above or below PSetpoint. Default is 0.
FRegulationP2	Frequency regulation real power set point 2. Units are % of PlantPRating above or below PSetpoint. Default is 0.
FRegulationP3	Frequency regulation real power set point 3. Units are % of PlantPRating above or below PSetpoint. Default is 0.
FRegulationP4	Frequency regulation real power set point 4. Units are % of PlantPRating above or below PSetpoint. Default is 0.

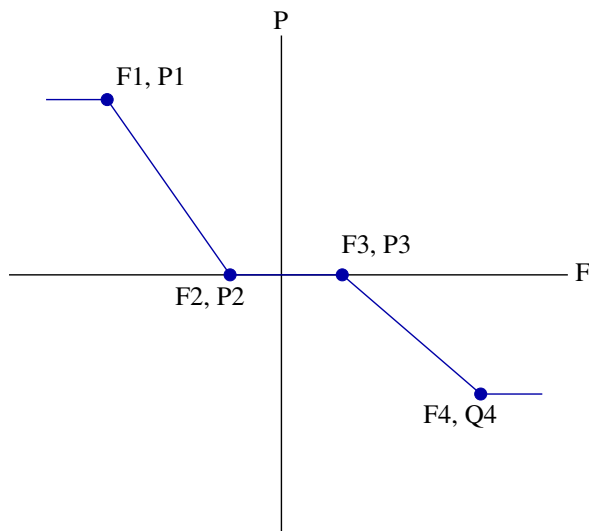


Figure 2 Frequency Regulation Curve

Disabled

When Frequency Regulation is disabled, the controller does not perform any adjustment of real power set points in response to frequency input.

Plant

When Frequency Regulation is in Plant mode, the controller uses any available capacity in configured non-storage generation devices to perform frequency regulation. The output adjustment of these non-storage devices is changed at a rate according to the EvaluationInterval setting on the controller in accordance with the PLimitRampSetpoint setting. This mode uses the plant’s non-storage generation devices. If an increase in power output is desired in response to a frequency event, some margin must be left (the plant needs to be run at less than maximum capacity) proportional to the slope of the frequency regulation curve and the expected severity of frequency events.

HighSpeedStorage

When Frequency Regulation is in HighSpeedStorage mode, the controller uses any available capacity in configured storage devices to perform frequency regulation. The output of these storage devices is adjusted every RTAC task cycle, which allows this feature to quickly react to changes in frequency using stored energy. This mode does not apply any ramp rate control to the set point delivered to storage devices.

Enumerations

Enumerations make code more readable by allowing a specific number to have a text equivalent. Either the raw integer value can be assigned to a value that requires an enumeration or the text of the enumeration itself can be assigned. When viewing the values online, the enumeration text is displayed instead of the integer value.

enum_ReactiveControlMode

This enumeration is used to set and indicate the desired reactive power control mode of the Master Plant Controller.

Enumeration	Value	Description
PFCControl	0	Power factor control mode
VARControl	1	VAR control mode
PFCcompensation	2	Power factor compensation mode
VoltageCompensation	3	Voltage compensation mode
VoltageControl	4	Voltage control mode
OpenLoopPFCControl	5	Open-loop power factor control mode

enum_PLimitMode

This enumeration is used to set and indicate the real power control mode of the Master Plant Controller.

Enumeration	Value	Description
NoLimit	0	Maximum power limit set to 100 percent of inverter capacity
Simple	1	Equally divide inertia power limit amongst all available inverters (see <i>Simple Power Limit Mode on page 8</i>)
Advanced	2	Allows an individual inverter maximum power output to adapt based on present power output. Allows use of storage inverter to maintain ramp rate during cloud cover (see <i>Advanced Power Limit Mode on page 9</i>).

enum_FrequencyRegulationMode

This enumeration is used to set and indicate the frequency regulation mode of the Master Plant Controller.

Enumeration	Value	Description
Disabled	0	Frequency regulation is disabled
Plant	1	Frequency regulation is performed by automatically adjusting PSetpoint, which controls the output of non-storage generation assets
HighSpeedStorage	2	Frequency regulation is performed by automatically adjusting StoragePSetpoint, which controls configured storage assets

Function Blocks

The library contains the function blocks required to build a GridConnect control system.

fb_MasterPlantController (Function Block)

The Master Plant Controller function block provides the control algorithms and I/O interface for controlling the POI between the utility and a solar generating facility.

Inputs

Name	IEC 61131 Type	Description
ControlMode	enum_ReactiveControlMode	POI control mode. Default is OpenLoopPFControl. For more information see <i>Enumerations on page 11</i> .
Frequency-RegulationMode	enum_FrequencyRegulationMode	Frequency Regulation mode. Default is Disabled. For more information see <i>Enumerations on page 11</i> .
Enable	BOOL	POI control enable. Default is FALSE.
EnableStorageDownramp-Control	BOOL	Enable downramp control using storage inverters. Default is FALSE.
QuickStop	BOOL	Stop signal. Sets power output to zero, disregarding ramp rates. Disables master controller. This signal will go through to connected inverters even if the master controller is already disabled.
PlantP	REAL	POI real power measurement. Units are kW. Default is 0. (Positive values = flow from plant to grid.)
PlantQ	REAL	POI reactive power measurement. Units are kVAR. Default is 0. (Positive values = flow from plant to grid)
PlantPF	REAL	POI power factor measurement. Default is 1. Units are PF. (Positive values = lagging, negative values = leading.)
PlantV	REAL	POI voltage measurement. Units are kV. Default is 1.
PlantF	REAL	POI frequency. Units are in Hz. Default is 60.
PlantMeasurementsGood	BOOL	POI measurement quality indication. Default is FALSE.
QSetpoint	REAL	POI reactive power control set point. Units are kVAR. Default is 0.
QDeadband	REAL	POI reactive power control dead band. Units are kVAR. Default is 250.

Name	IEC 61131 Type	Description
QKp	REAL	Proportional tuning parameter for VAR control. Default is 1.
QKi	REAL	Integral tuning parameter for VAR control. Default is 0.
QLimitHigh	REAL	Reactive power high limit
QLimitLow	REAL	Reactive power low limit
PFSetpoint	REAL	POI power factor control set point. Units are PF. Default is 1. (Positive values = lagging, negative values = leading)
PFDeadband	REAL	POI power factor control dead band. Units are PF. Default is 0.0002.
PFKp	REAL	Proportional tuning parameter for power factor control. Default is 1.
PFKi	REAL	Integral tuning parameter for power factor control. Default is 0.
PFLagLimit	REAL	POI lagging power factor limit (positive). Units are PF. Default is 0.95.
PFLoadLimit	REAL	POI leading power factor limit (negative). Units are PF. Default is -0.95.
PFCompensationSetpoint	REAL	Power factor compensation nominal set point. Units are PF. Default is 0.
PFCompensation-LowPowerCutoff	REAL	Power factor compensation low-power cutoff. Units are in % (value should be between 0 and 100). Default is 0.
PFCompensationGradient	REAL	Power factor compensation gradient. Units are in PF/kW. Default is 0.
PFCompensation-LowPFLimit	REAL	Power factor compensation low power factor limit. Units are PF. Default is 0.
VCompensationV1	REAL	Voltage compensation voltage set point 1. Units are kV. Default is 0.
VCompensationV2	REAL	Voltage compensation voltage set point 2. Units are kV. Default is 0.
VCompensationV3	REAL	Voltage compensation voltage set point 3. Units are kV. Default is 0.
VCompensationV4	REAL	Voltage compensation voltage set point 4. Units are kV. Default is 0.
VCompensationQ1	REAL	Voltage compensation reactive power set point 1. Units are kVAR. Default is 0.
VCompensationQ2	REAL	Voltage compensation reactive power set point 2. Units are kVAR. Default is 0.
VCompensationQ3	REAL	Voltage compensation reactive power set point 3. Units are kVAR. Default is 0.
VCompensationQ4	REAL	Voltage compensation reactive power set point 4. Units are kVAR. Default is 0.
VSetpoint	REAL	POI voltage control set point. Units are kV. Default is 1.
VDeadband	REAL	POI voltage control dead band. Units are kV. Default is 0.02.
VKp	REAL	Proportional tuning parameter for voltage control. Default is 1.
VKi	REAL	Integral tuning parameter for voltage control. Default is 0.
VLimitHigh	REAL	POI high voltage limit. Units are kV. Default is 1.05.

Function Blocks

Name	IEC 61131 Type	Description
VLimitLow	REAL	POI low voltage limit. Units are kV. Default is 0.95.
dV_dQ	REAL	POI ratio of the expected change in voltage to a change in reactive power. Units are Volts/VAR. Default is 0.01.
FRegulationF1	REAL	Frequency regulation frequency set point 1. Units are Hz. Default is 0.
FRegulationF2	REAL	Frequency regulation frequency set point 2. Units are Hz. Default is 0.
FRegulationF3	REAL	Frequency regulation frequency set point 3. Units are Hz. Default is 0.
FRegulationF4	REAL	Frequency regulation frequency set point 4. Units are Hz. Default is 0.
FRegulationP1	REAL	Frequency regulation real power set point 1. Units are % of PlantPRating above or below PSetpoint (from 0 to 100). Default is 0.
FRegulationP2	REAL	Frequency regulation real power set point 2. Units are % of PlantPRating above or below PSetpoint (from 0 to 100). Default is 0.
FRegulationP3	REAL	Frequency regulation real power set point 3. Units are % of PlantPRating above or below PSetpoint (from 0 to 100). Default is 0.
FRegulationP4	REAL	Frequency regulation real power set point 4. Units are % of PlantPRating above or below PSetpoint (from 0 to 100). Default is 0.
PLimitMode	enum_PLimitMode	Power limit mode. Default is NoLimit. For more information, see <i>Enumerations on page 11</i> .
PSetpoint	REAL	POI power limit set point. Units are kW. Default is 50000.
PDeadband	REAL	POI power limit dead band. Units are kW. Default is 500.
PKp	REAL	Proportional tuning parameter for power control. Default is 1.
PKi	REAL	Integral tuning parameter for power control. Default is 0.
PFRampSetpoint	REAL	Plant power factor ramp rate (power factor change/second). Units are PF/second. Default is 0.02. Setting to 0 will result in no ramp supervision.
QRampSetpoint	REAL	Plant reactive power ramp rate (reactive power change/second). Units are kVAR/second. Default is 10. Setting to 0 will result in no ramp supervision.
PLimitRampSetpoint	REAL	Plant power limit ramp rate (real power change/second) Units are kW/second. Default is 10. Setting to 0 will result in no ramp supervision.
PLimitDelay	TIME	Time between the last valid inverter response and application of the adaptive power limit. Units are seconds. Default is 120.
StoragePSetpoint	REAL	Storage real power set point. Units are kW. Default is 0.
PlantPRating	REAL	POI power output rating. Units are kW. Default is 50000.
PlantQRating	REAL	POI reactive power rating. Units are kVAR. Default is 50000.
PlantLowPowerCutoff	REAL	Power output below which no power factor control will occur. Units are kW. Default is 25.

Name	IEC 61131 Type	Description
EvaluationPeriod	TIME	Time between closed-loop control algorithm execution. Default is T#5S.
ControlRetryPeriod	TIME	Time between control retries to field devices. Default is T#20S.
CapacitorOperationPeriod	TIME	Minimum time between capacitor operations. Default is T#5M.
InverterMode-ChangeControlDelay	TIME	Time to delay sending set points after an inverter mode change. Default is T#10S.

Outputs

Name	IEC 61131 Type	Description
ConnectToPlantDevices	POINTER	Connect to all plant devices.
Enabled	BOOL	Master controller is enabled.
QuickStopAsserted	BOOL	QuickStop input pin is asserted.
PFCControlMode	BOOL	Master controller is in power factor control mode.
QControlMode	BOOL	Master controller is in reactive power control mode.
PFCCompensationMode	BOOL	Master controller is in power factor compensation mode.
VCompensationMode	BOOL	Master controller is in voltage compensation mode.
VControlMode	BOOL	Master controller is in voltage control mode.
OpenLoopPFCControlMode	BOOL	Master controller is in open loop power factor control mode.
NoLimitPCControl	BOOL	Master controller is in NoLimit power control mode.
SimplePCControl	BOOL	Master controller is in Simple power control mode.
AdvancedPCControl	BOOL	Master controller is in Advanced power control mode.
PlantFRegulationEnabled	BOOL	Plant frequency regulation mode is enabled.
StorageFRegulationEnabled	BOOL	High speed storage frequency regulation mode is enabled.
PFOutOfBand	BOOL	Power factor at the POI is outside the dead band.
QOutOfBand	BOOL	VAR flow at the POI is outside the dead band.
VOutOfBand	BOOL	Voltage at the POI is outside the dead band.
PFLagAlarm	BOOL	Power factor lagging beyond the limit at the POI (generating more kVAR).
PFLeadAlarm	BOOL	Power factor leading beyond the limit at the POI (consuming more kVAR).
VHighAlarm	BOOL	Voltage above the high limit at the POI.
VLowAlarm	BOOL	Voltage below the low limit at the POI.
ConditionedDVDQ	REAL	Conditioned DVDQ input. Conditioning checks to make sure the input is greater than zero.
ConditionedPFCCompensationLowPowerCutoff	REAL	Conditioned PF Compensation Cutoff. Conditioning checks to make sure the input is between 0 and 100.
ConditionedPFCCompensationSetpoint	REAL	Conditioned PF Compensation Setpoint. Conditioning checks to make sure input is within PF lag and lead limits.
ConditionedPFSetpoint	REAL	Conditioned PF Setpoint. Conditioning checks to make sure input is within PF lag and lead limits.
ConditionedPLimitSetpoint	REAL	Conditioned power limit set point. Conditioning checks to make sure input is between 0 and PRating.
ConditionedQSetpoint	REAL	Conditioned reactive power limit set point. Conditioning checks to make sure input is between leading and lagging QRating.
ConditionedPFRampSetpoint	REAL	Conditioned power factor ramp rate set point. Conditioning checks to make sure input is between 0 and 1.

Function Blocks

Name	IEC 61131 Type	Description
ConditionedQRampSetpoint	REAL	Conditioned reactive power ramp rate set point. Conditioning checks to make sure input is between 0 and ConditionedQRating.
ConditionedPLimitRampSetpoint	REAL	Conditioned real power ramp rate set point. Conditioning checks to make sure input is between 0 and ConditionedPRating.
ConditionedVSetpoint	REAL	Conditioned voltage set point. Conditioning checks to make sure input is between the VLimitHigh and VLimitLow inputs.
ConditionedPRating	REAL	Conditioned real power rating. Conditioning checks to make sure input is greater than 0.
ConditionedQRating	REAL	Conditioned reactive power rating. Conditioning checks to make sure input is between lagging and leading reactive power limits.
DownrampEventActive	BOOL	This output asserts when a downramp event is active. This input will only assert if the EnableStorageDownrampControl input is asserted.
FrequencyRegulationEventActive	BOOL	This output asserts if a real power set point is being adjusted due to an ongoing frequency regulation event.
StorageDownrampControlEnabled	BOOL	Storage downramp control is enabled.

fb_PvInverter (Function Block)

The PV Inverter function block provides the control algorithms and I/O interface for one photovoltaic inverter in a solar generating facility.

Inputs

Name	IEC 61131 Type	Description
ConnectToMasterController	POINTER	Connect this input to a master controller instance.
Offline	BOOL	Communications channel to the inverter control device is offline (1 = Offline). Default is FALSE.
RemoteEnabled	BOOL	Inverter control device is available to remote master control. Default is FALSE.
Fault	BOOL	Inverter control device is reporting a fault. Default is FALSE.
OnStatus	BOOL	On/off status of the inverter. Default is FALSE.
OnCommandInput	BOOL	Command to turn on the inverter control device. Default is FALSE.
OffCommandInput	BOOL	Command to turn off the inverter control device. Default is FALSE.
Include	BOOL	Latch to include inverter in the master control. Default is FALSE.
Exclude	BOOL	Latch to remove inverter from the control. Default is FALSE.
PFModeEnabled	BOOL	Inverter is in power factor control mode.
QModeEnabled	BOOL	Inverter is in reactive power control mode.
InverterP	REAL	Real power output from inverter. Units are kW.
InverterQ	REAL	Reactive power output from inverter. Units are kVAR.
InverterPF	REAL	Power factor at inverter (generative +, consumptive -). Units are PF.
InverterPFLagLimit	REAL	Inverter lagging power factor limit (positive). Default is 0.8. Units are PF.
InverterPFLeadLimit	REAL	Inverter leading power factor limit (negative). Default is -0.8. Units are PF.
PFSetpointFeedback	REAL	Power factor set point feedback. Units are PF.
QSetpointFeedback	REAL	Reactive power set point feedback. Units are kVAR.
PLimitSetpointFeedback	REAL	Power limit set point feedback. Units are kW.
PFRampFeedback	REAL	Power factor ramp feedback. Units are PF/sec.

Name	IEC 61131 Type	Description
QRampFeedback	REAL	Reactive power ramp feedback. Units are kVAR/sec.
PLimitRampFeedback	REAL	Power limit ramp feedback. Units are kW/sec.
PRating	REAL	Power rating for the inverter. Units are kW. Default is 0.
QRating	REAL	Reactive power rating for the inverter. Units are kVAR. Default is 0.

Outputs

Name	IEC 61131 Type	Description
IncludedInMasterControl	BOOL	Inverter is included in master control. Will assert when inverter is on, included, and not excluded.
OnCommand	BOOL	Pulse to turn on inverter.
OffCommand	BOOL	Pulse to turn off inverter.
QuickStop	BOOL	Asserts to send stop signal to inverter. This output can assert when required even if the master controller is not enabled.
PFModeCommand	BOOL	Command to put inverter in power factor mode.
QModeCommand	BOOL	Command to put inverter in reactive power mode.
PFSetMag	REAL	Power factor output. Units are PF.
PFTrigger	BOOL	Power factor trigger (1 = Write).
QSetMag	REAL	Reactive power output. Units are kVAR.
QTrigger	BOOL	Reactive power trigger (1 = Write).
PLimitSetMag	REAL	Power limit output. Units are kW.
PLimitTrigger	BOOL	Power limit trigger (1 = Write).
PFrampSetMag	REAL	Power factor ramp output. Units are PF/sec.
PFrampTrigger	BOOL	Power factor ramp trigger (1 = Write).
QRampSetMag	REAL	Reactive power ramp output. Units are kVAR/sec.
QRampTrigger	REAL	Reactive power trigger (1 = Write).
PLimitRampSetMag	REAL	Power limit ramp output. Units are kW/sec.
PLimitRampTrigger	BOOL	Power limit ramp trigger (1 = Write).
InputAlarm	BOOL	One or more inverter inputs are in an invalid state.

The InputAlarm indicates that one or more inverter inputs are in an invalid state. Providing invalid inputs can result in undesired behavior. The InputAlarm output will assert if any of the following are true:

- ▶ PFMModeEnabled and QModeEnabled are both TRUE.
- ▶ Inverter is not in correct reactive power mode after three times the master controller's ControlRetryPeriod setting.
- ▶ OnCommandInput and OffCommandInput are both TRUE.
- ▶ IncludeCommand and ExcludeCommand are both TRUE.
- ▶ InverterPF, PFSetpointFeedback, InverterPFLagLimit, or InverterPFLeadLimit are less than -1 or greater than 1.
- ▶ PRating is less than 0.
- ▶ QRating is less than 0.

fb_StorageInverter (Function Block)

The Storage Inverter function block provides the control algorithms and I/O interface for one storage inverter in a solar generating facility.

Inputs

Name	IEC 61131 Type	Description
ConnectToMasterController	POINTER	Connect this input to a master controller instance.
Offline	BOOL	Communications channel to the inverter control device is offline (1 = Offline). Default is FALSE.
RemoteEnabled	BOOL	Inverter control device is available to remote master control. Default is FALSE.
Fault	BOOL	Inverter control device is reporting a fault. Default is FALSE.
OnStatus	BOOL	On/off status of the inverter. Default is FALSE.
OnCommandInput	BOOL	Command to turn on the inverter control device. Default is FALSE.
OffCommandInput	BOOL	Command to turn off the inverter control device. Default is FALSE.
IncludeCommand	BOOL	Command to include inverter in the master control. Default is FALSE.
ExcludeCommand	BOOL	Command to remove inverter from the control. Default is FALSE.
PFModeEnabled	BOOL	Inverter is in power factor control mode.
QModeEnabled	BOOL	Inverter is in reactive power control mode.
InverterP	REAL	Real power output from inverter. Units are kW.
InverterQ	REAL	Reactive power output from inverter. Units are kVAR.
InverterPF	REAL	Power factor at inverter (generative +, consumptive -). Units are PF.
InverterPFLagLimit	REAL	Inverter lagging power factor limit (positive). Default is 0.8. Units are PF.
InverterPFLeadLimit	REAL	Inverter leading power factor limit (negative). Default is -0.8. Units are PF.
PFSetpointFeedback	REAL	Power factor set point feedback. Units are PF.
QSetpointFeedback	REAL	Reactive power set point feedback. Units are kVAR.
PSetpointFeedback	REAL	Real power set point feedback. 0 to +PRating indicate battery charging (consume kW), and 0 to -PRating indicate battery discharge (output kW). Units are kW.
PFrampFeedback	REAL	Power factor ramp feedback. Units are PF/sec.
PRampFeedback	REAL	Real power ramp feedback. Units are kW/sec.
QRampFeedback	REAL	Reactive power ramp feedback. Units are kVAR/sec.
PRating	REAL	Power rating for the inverter. Units are kW. Default is 0.
QRating	REAL	Reactive power rating for the inverter. Units are kVAR. Default is 0.

Outputs

Name	IEC 61131 Type	Description
IncludedInMasterControl	BOOL	Inverter is included in master control. Will assert when inverter is on, included, and not excluded.
OnCommand	BOOL	Pulse to turn on inverter.
OffCommand	BOOL	Pulse to turn off inverter.
QuickStop	BOOL	Asserts to send stop signal to inverter. This output can assert when required even if the master controller is not enabled.

Name	IEC 61131 Type	Description
PFModeCommand	BOOL	Command to put inverter in power factor mode.
QModeCommand	BOOL	Command to put inverter in reactive power mode.
PFSetMag	REAL	Power factor output. Units are PF.
PFTrigger	BOOL	Power factor trigger (1 = Write).
QSetMag	REAL	Reactive power output. Units are kVAR.
QTrigger	BOOL	Reactive power trigger (1 = Write).
PLimitSetMag	REAL	Power limit output. Units are kW.
PLimitTrigger	BOOL	Power limit trigger (1 = Write).
PFRampSetMag	REAL	Power factor ramp output. Units are PF/sec.
PFRampTrigger	BOOL	Power factor ramp trigger (1 = Write).
QRampSetMag	REAL	Reactive power ramp output. Units are kVAR/sec.
QRampTrigger	REAL	Reactive power trigger (1 = Write).
PLimitRampSetMag	REAL	Power limit ramp output. Units are kW/sec.
PLimitRampTrigger	BOOL	Power limit ramp trigger (1 = Write).
InputAlarm	BOOL	One or more inverter inputs are in an invalid state.

The InputAlarm indicates that one or more inverter inputs are in an invalid state. Providing invalid inputs can result in undesired behavior. The InputAlarm output will assert if any of the following are true:

- PFModeEnabled and QModeEnabled are both TRUE.
- Inverter is not in correct reactive power mode after three times the master controller's ControlRetryPeriod setting.
- OnCommandInput and OffCommandInput are both TRUE.
- IncludeCommand and ExcludeCommand are both TRUE.
- InverterPF, PFSetpointFeedback, InverterPFLagLimit, or InverterPFLeadLimit are less than -1 or greater than 1.
- PRating is less than 0.
- QRating is less than 0.

fb_Capacitor (Function Block)

The Capacitor Control function block provides the control algorithms and I/O interface for one capacitor in a solar generating facility.

Inputs

Name	IEC 61131 Type	Description
ConnectToMasterController	POINTER	Connect this input to a master controller instance.
Offline	BOOL	Communications channel to the capacitor control device is offline (1 = Offline). Default is FALSE.
RemoteEnabled	BOOL	Capacitor control device is available to remote master control (1 = Remote). Default is FALSE.
Fault	BOOL	Capacitor control device is reporting a fault (1 = Fault). Default is FALSE.

Examples

Name	IEC 61131 Type	Description
OnStatus	BOOL	On/off status of the capacitor. Default is FALSE.
OnCommandInput	BOOL	Command to turn on the capacitor. Default is FALSE.
OffCommandInput	BOOL	Command to turn off the capacitor. Default is FALSE.
IncludeCommand	BOOL	Command to include capacitor in the master control. Default is FALSE.
ExcludeCommand	BOOL	Command to remove capacitor from the master control. Default is FALSE.
CapacitorV	REAL	Voltage at the capacitor terminals. Units are kV. Default is 0.
QRating	REAL	Reactive power rating of the capacitor. Units are kVAR. Default is 0.
VRating	REAL	Voltage rating of the capacitor. Units are kV. Default is 0.
SequenceNumber	UINT	Capacitor is dependent on another capacitor being closed first. Default is 0. <ul style="list-style-type: none"> ▶ 0 = Cap is not dependent on other Caps. ▶ 1 = Cap is the first to be turned on and the last to be turned off. ▶ 2 = Cap will only be turned on if Caps with a sequence number of 1 is ON first. ▶ 3 = Follows 2. ▶ ... ▶ g_c_CAP_MAX = Follows $g_c_CAP_MAX - 1$.

Outputs

Name	IEC 61131 Type	Description
IncludedInMasterControl	BOOL	Capacitor is included in master control. Will assert when capacitor is included and not excluded.
OnCommand	BOOL	Pulse to turn on capacitor.
OffCommand	BOOL	Pulse to turn off capacitor.

Examples

These examples demonstrate the capabilities of this library. Do not mistake them as suggestions or recommendations from SEL.

Implement the best practices of your organization when using these libraries. As the user of this library, you are responsible for ensuring correct implementation and verifying that the project using these libraries performs as expected.

Modeling a Solar Generation Facility**Objective**

A user has a solar facility that needs to be controlled. The facility is laid out as shown in *Figure 3*.

Utility

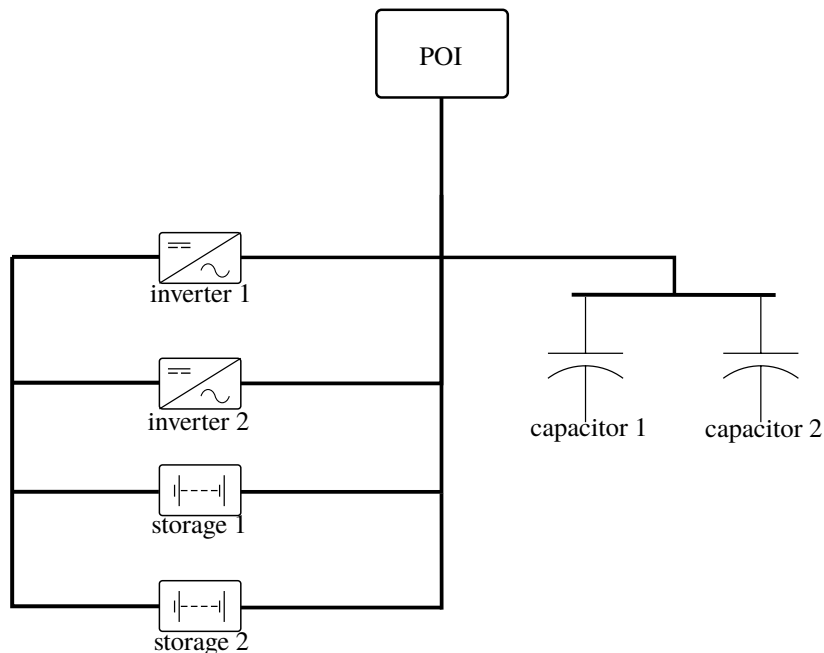


Figure 3 Solar Facility One-Line Diagram

Data Source Assumptions

Typically, all inputs to the function blocks used in this model would be connected to data from an incoming communication channel. However, to make the illustration of this example more clear, all inputs are contained in Global Variable Lists.

Solution

Once the user has identified all the elements of the model and decided the source for all required data, the only work remaining is to construct the model in a program as shown in *Code Snippet 1*.

Code Snippet 1 prg_GridConnectMain

```

VAR
  MasterController      : fb_MasterPlantController;
  Inverter1, Inverter2  : fb_PvInverter;
  Storage1, Storage2   : fb_StorageInverter;
  Capacitor1, Capacitor2 : fb_Capacitor;
  hasRunOnce           : BOOL;
END_VAR

(**** SETTINGS ****)
IF NOT hasRunOnce THEN
MasterController.QDeadband      := 0; // kVAR
MasterController.QKp            := 0.4;
MasterController.QKi            := 0.04;

```

Examples

```

MasterController.QLimitHigh           := 3000; // kVAR
MasterController.QLimitLow           := -1300; // kVAR

MasterController.PFDeadband          := 0.001; // PF
MasterController.PFKp                 := 0.2;
MasterController.PFKi                 := 0;
MasterController.PFLagLimit          := 0.8; // PF
MasterController.PFLeadLimit         := -0.8; // PF
MasterController.PFCompensationSetpoint := 1.0; // Unity PF
MasterController.PFCompensationLowPowerCutoff := 15; // 15%
MasterController.PFCompensationGradient := -0.002; // PF / %kW
MasterController.PFCompensationLowPFLimit := 0.8; // +- 0.8 PF

MasterController.VDeadband           := 0.05; // kV
MasterController.VKp                 := 0.3;
MasterController.VKi                 := 0.03;
MasterController.VLimitHigh          := 42; // kV
MasterController.VLimitLow           := 38; // kV
MasterController.dV_dQ               := 0.0002; // kW/kVAR
MasterController.VCompensationV1     := 38; // kV
MasterController.VCompensationV2     := 40;
MasterController.VCompensationV3     := 40;
MasterController.VCompensationV4     := 41;
MasterController.VCompensationQ1     := 2000; // kVAR
MasterController.VCompensationQ2     := 0;
MasterController.VCompensationQ3     := 0;
MasterController.VCompensationQ4     := -2000;

MasterController.FRegulationF1       := 59; // Hz
MasterController.FRegulationF2       := 59.7;
MasterController.FRegulationF3       := 60.3;
MasterController.FRegulationF4       := 61;
MasterController.FRegulationP1       := 10; // % of plant rated kW
MasterController.FRegulationP2       := 0;
MasterController.FRegulationP3       := 0;
MasterController.FRegulationP4       := -10;

MasterController.PDeadband           := 2; // kW
MasterController.PKp                 := 0.4;
MasterController.PKi                 := 0.04;

MasterController.PFRampSetpoint       := 0.02; // PF/sec
MasterController.QRampSetpoint       := 20;
MasterController.PLimitRampSetpoint   := 50;
MasterController.PLimitDelay         := T#60S;

MasterController.PlantPRating         := 1000; // 1MW
MasterController.PlantQRating         := 8000; // 800 kVAR
MasterController.PlantLowPowerCutoff := 5; // kW
MasterController.EvaluationPeriod     := T#1S;
MasterController.ControlRetryPeriod   := T#2S;
MasterController.CapacitorOperationPeriod := T#120S;
MasterController.InverterModeChangeControlDelay := T#30S;

// Inverter 1 Settings
Inverter1.IncludeCommand              := TRUE;
Inverter1.ExcludeCommand              := FALSE;
Inverter1.InverterPFLagLimit          := 0.8;
Inverter1.InverterPFLeadLimit         := -0.8;

```



```
Inverter1.PRating           := 500; // kW
Inverter1.QRating          := 450; // kVAR

// Inverter 2 Settings
Inverter2.IncludeCommand   := TRUE;
Inverter2.ExcludeCommand   := FALSE;
Inverter2.InverterPFLagLimit := 0.8;
Inverter2.InverterPFLeadLimit := -0.8;
Inverter2.PRating          := 500; // kW
Inverter2.QRating          := 450; // kVAR

// Battery 1 settings
Storage1.IncludeCommand    := TRUE;
Storage1.ExcludeCommand    := FALSE;
Storage1.InverterPFLagLimit := 0.8;
Storage1.InverterPFLeadLimit := -0.8;
Storage1.PRating           := 200; // kW
Storage1.QRating           := 150; // kVAR

// Battery 2 settings
Storage2.IncludeCommand    := TRUE;
Storage2.ExcludeCommand    := FALSE;
Storage2.InverterPFLagLimit := 0.8;
Storage2.InverterPFLeadLimit := -0.8;
Storage2.PRating           := 200; // kW
Storage2.QRating           := 150; // kVAR

// Capacitor 1 Settings
Capacitor1.IncludeCommand  := TRUE;
Capacitor1.ExcludeCommand  := FALSE;
Capacitor1.QRating         := 200; // kVAR
Capacitor1.VRating         := 7.2; // kW
Capacitor1.SequenceNumber  := 0; // First to turn on

// Capacitor 2 Settings
Capacitor2.IncludeCommand  := TRUE;
Capacitor2.ExcludeCommand  := FALSE;
Capacitor2.QRating         := 200; // kVAR
Capacitor2.VRating         := 7.2; // kW
Capacitor2.SequenceNumber  := 0; // First to turn on

hasRunOnce := TRUE;
END_IF

(**** MODE, STATUS, AND SET POINT CONTROLS ****)
MasterController.ControlMode :=
    DINT_TO_INT(vt1_PlantControls.ReactiveControlMode.stVal);
MasterController.PLimitMode  := DINT_TO_INT(vt1_PlantControls.RealPowerMode.stVal);
MasterController.Enable      := vt1_PlantControls.Enable.stVal;
MasterController.EnableStorageDownrampControl := vt1_PlantControls.EnableDownrampControl.stVal;
MasterController.EmergencyStop := vt1_PlantControls.EmergencyStop.stVal;

MasterController.QSetpoint   := vt1_PlantControls.QSetpoint.instMag;

MasterController.PFSetpoint  := vt1_PlantControls.PFSetpoint.instMag;

MasterController.VSetpoint   := vt1_PlantControls.VSetpoint.instMag;

MasterController.PSetpoint   := vt1_PlantControls.PSetpoint.instMag;
```

Examples

```

MasterController.StoragePSetpoint                := vtl_PlantControls.StoragePSetpoint.instMag;

(**** I/O ****)
// Master Controller I/O
MasterController.PlantP                          := vtl_POIData.PlantP.instCVal.mag;
MasterController.PlantQ                          := vtl_POIData.PlantQ.instCVal.mag;
MasterController.PlantPF                         := vtl_POIData.PlantPF.instCVal.mag;
MasterController.PlantV                          := vtl_POIData.PlantV.instCVal.mag;
MasterController.PlantF                          := vtl_POIData.PlantF.instCVal.mag;
MasterController.PlantMeasurementsGood           := vtl_POIData.IsPoiDataGood.stVal;

// Inverter 1 I/O
Inverter1.Offline                               := vtl_InverterData.IsInverter1Offline.stVal;
Inverter1.RemoteEnabled                         := vtl_InverterData.IsInverter1RemoteEnabled.stVal;
Inverter1.Fault                                 := vtl_InverterData.IsInverter1InFaultedState.stVal;
Inverter1.OnStatus                              := vtl_InverterData.IsInverter1On.stVal;
Inverter1.PFModeEnabled                         := vtl_InverterData.IsInverter1InPFMode.stVal;
Inverter1.QModeEnabled                          := vtl_InverterData.IsInverter1InQMode.stVal;
Inverter1.InverterP                             := DINT_TO_REAL(vtl_InverterData.Inverter1P.stVal);
Inverter1.InverterQ                             := DINT_TO_REAL(vtl_InverterData.Inverter1Q.stVal);
Inverter1.InverterPF                             := DINT_TO_REAL(vtl_InverterData.Inverter1PF.stVal)/1000;
Inverter1.PFSetpointFeedback                    :=
    DINT_TO_REAL(vtl_InverterData.Inverter1PFSetpointFeedback.stVal)/1000;
Inverter1.QSetpointFeedback                     :=
    DINT_TO_REAL(vtl_InverterData.Inverter1QSetpointFeedback.stVal);
Inverter1.PLimitSetpointFeedback                 :=
    DINT_TO_REAL(vtl_InverterData.Inverter1PLimitSetpointFeedback.stVal);
//NOTE: No ramp feedback available from inverters
vtl_InverterData.Inverter1PackedControls.stVal.0 := Inverter1.OnCommand;
vtl_InverterData.Inverter1PackedControls.stVal.1 := Inverter1.OffCommand;
vtl_InverterData.Inverter1PackedControls.stVal.2 := Inverter1.EmergencyStop;
vtl_InverterData.Inverter1PackedControls.stVal.3 := Inverter1.PFModeCommand;
vtl_InverterData.Inverter1PackedControls.stVal.4 := Inverter1.QModeCommand;
vtl_InverterData.Inverter1PFSetpoint.oper.setMag := Inverter1.PFSetMag*1000; // Move significant
    figures left of decimal
vtl_InverterData.Inverter1PFSetpoint.oper.trigger := Inverter1.PFTrigger;
vtl_InverterData.Inverter1QSetpoint.oper.setMag   := Inverter1.QSetMag;
vtl_InverterData.Inverter1QSetpoint.oper.trigger  := Inverter1.QTrigger;
vtl_InverterData.Inverter1PSetpoint.oper.setMag   := Inverter1.PLimitSetMag;
vtl_InverterData.Inverter1PSetpoint.oper.trigger  := Inverter1.PLimitTrigger;
vtl_InverterData.Inverter1PFRampSetpoint.oper.setMag := Inverter1.PFRampSetMag;
vtl_InverterData.Inverter1PFRampSetpoint.oper.trigger := Inverter1.PFRampTrigger;
vtl_InverterData.Inverter1QRampSetpoint.oper.setMag := Inverter1.QRampSetMag;
vtl_InverterData.Inverter1QRampSetpoint.oper.trigger := Inverter1.QRampTrigger;
vtl_InverterData.Inverter1PRampSetpoint.oper.setMag := Inverter1.PLimitRampSetMag;
vtl_InverterData.Inverter1PRampSetpoint.oper.trigger := Inverter1.PLimitRampTrigger;

// Inverter 2 I/O
Inverter2.Offline                               := vtl_InverterData.IsInverter2Offline.stVal;
Inverter2.RemoteEnabled                         := vtl_InverterData.IsInverter2RemoteEnabled.stVal;
Inverter2.Fault                                 := vtl_InverterData.IsInverter2InFaultedState.stVal;
Inverter2.OnStatus                              := vtl_InverterData.IsInverter2On.stVal;
Inverter2.PFModeEnabled                         := vtl_InverterData.IsInverter2InPFMode.stVal;
Inverter2.QModeEnabled                          := vtl_InverterData.IsInverter2InQMode.stVal;
Inverter2.InverterP                             := DINT_TO_REAL(vtl_InverterData.Inverter2P.stVal);
Inverter2.InverterQ                             := DINT_TO_REAL(vtl_InverterData.Inverter2Q.stVal);
Inverter2.InverterPF                             := DINT_TO_REAL(vtl_InverterData.Inverter2PF.stVal)/1000;
Inverter2.PFSetpointFeedback                    :=
    DINT_TO_REAL(vtl_InverterData.Inverter2PFSetpointFeedback.stVal)/1000;

```

```

Inverter2.QSetpointFeedback          :=
    DINT_TO_REAL(vt1_InverterData.Inverter2QSetpointFeedback.stVal);
Inverter2.PLimitSetpointFeedback     :=
    DINT_TO_REAL(vt1_InverterData.Inverter2PLimitSetpointFeedback.stVal);
//NOTE: No ramp feedback available from inverters
vt1_InverterData.Inverter2PackedControls.stVal.0 := Inverter2.OnCommand;
vt1_InverterData.Inverter2PackedControls.stVal.1 := Inverter2.OffCommand;
vt1_InverterData.Inverter2PackedControls.stVal.2 := Inverter2.EmergencyStop;
vt1_InverterData.Inverter2PackedControls.stVal.3 := Inverter2.PFModeCommand;
vt1_InverterData.Inverter2PackedControls.stVal.4 := Inverter2.QModeCommand;
vt1_InverterData.Inverter2PFSetpoint.oper.setMag := Inverter2.PFSetMag * 1000; // Move significant
    figures left of decimal
vt1_InverterData.Inverter2PFSetpoint.oper.trigger := Inverter2.PFTrigger;
vt1_InverterData.Inverter2QSetpoint.oper.setMag := Inverter2.QSetMag;
vt1_InverterData.Inverter2QSetpoint.oper.trigger := Inverter2.QTrigger;
vt1_InverterData.Inverter2PSetpoint.oper.setMag := Inverter2.PLimitSetMag;
vt1_InverterData.Inverter2PSetpoint.oper.trigger := Inverter2.PLimitTrigger;
vt1_InverterData.Inverter2PFRampSetpoint.oper.setMag := Inverter2.PFRampSetMag;
vt1_InverterData.Inverter2PFRampSetpoint.oper.trigger := Inverter2.PFRampTrigger;
vt1_InverterData.Inverter2QRampSetpoint.oper.setMag := Inverter2.QRampSetMag;
vt1_InverterData.Inverter2QRampSetpoint.oper.trigger := Inverter2.QRampTrigger;
vt1_InverterData.Inverter2PRampSetpoint.oper.setMag := Inverter2.PLimitRampSetMag;
vt1_InverterData.Inverter2PRampSetpoint.oper.trigger := Inverter2.PLimitRampTrigger;

// Battery 1 I/O
Storage1.Offline                     := vt1_InverterData.IsStorage1Offline.stVal;
Storage1.RemoteEnabled                := vt1_InverterData.IsStorage1RemoteEnabled.stVal;
Storage1.Fault                       := vt1_InverterData.IsStorage1InFaultedState.stVal;
Storage1.OnStatus                    := vt1_InverterData.IsStorage1On.stVal;
Storage1.PFModeEnabled               := vt1_InverterData.IsStorage1InPFMode.stVal;
Storage1.QModeEnabled                := vt1_InverterData.IsStorage1InQMode.stVal;
Storage1.InverterP                   := DINT_TO_REAL(vt1_InverterData.Storage1P.stVal);
Storage1.InverterQ                   := DINT_TO_REAL(vt1_InverterData.Storage1Q.stVal);
Storage1.InverterPF                  := DINT_TO_REAL(vt1_InverterData.Storage1PF.stVal)/1000;
Storage1.PFSetpointFeedback          :=
    DINT_TO_REAL(vt1_InverterData.Storage1PFSetpointFeedback.stVal)/1000;
Storage1.QSetpointFeedback           :=
    DINT_TO_REAL(vt1_InverterData.Storage1QSetpointFeedback.stVal);
Storage1.PLimitSetpointFeedback       :=
    DINT_TO_REAL(vt1_InverterData.Storage1PLimitSetpointFeedback.stVal);
//NOTE: No ramp feedback available from inverters
vt1_InverterData.Storage1PackedControls.stVal.0 := Storage1.OnCommand;
vt1_InverterData.Storage1PackedControls.stVal.1 := Storage1.OffCommand;
vt1_InverterData.Storage1PackedControls.stVal.2 := Storage1.EmergencyStop;
vt1_InverterData.Storage1PackedControls.stVal.3 := Storage1.PFModeCommand;
vt1_InverterData.Storage1PackedControls.stVal.4 := Storage1.QModeCommand;
vt1_InverterData.Storage1PFSetpoint.oper.setMag := Storage1.PFSetMag * 1000; // Move significant
    figures left of decimal
vt1_InverterData.Storage1PFSetpoint.oper.trigger := Storage1.PFTrigger;
vt1_InverterData.Storage1QSetpoint.oper.setMag := Storage1.QSetMag;
vt1_InverterData.Storage1QSetpoint.oper.trigger := Storage1.QTrigger;
vt1_InverterData.Storage1PSetpoint.oper.setMag := Storage1.PLimitSetMag;
vt1_InverterData.Storage1PSetpoint.oper.trigger := Storage1.PLimitTrigger;
vt1_InverterData.Storage1PFRampSetpoint.oper.setMag := Storage1.PFRampSetMag;
vt1_InverterData.Storage1PFRampSetpoint.oper.trigger := Storage1.PFRampTrigger;
vt1_InverterData.Storage1QRampSetpoint.oper.setMag := Storage1.QRampSetMag;
vt1_InverterData.Storage1QRampSetpoint.oper.trigger := Storage1.QRampTrigger;
vt1_InverterData.Storage1PRampSetpoint.oper.setMag := Storage1.PLimitRampSetMag;
vt1_InverterData.Storage1PRampSetpoint.oper.trigger := Storage1.PLimitRampTrigger;

```

Examples

```

// Battery 2 I/O
Storage2.Offline := vtl_InverterData.IsStorage2Offline.stVal;
Storage2.RemoteEnabled := vtl_InverterData.IsStorage2RemoteEnabled.stVal;
Storage2.Fault := vtl_InverterData.IsStorage2InFaultedState.stVal;
Storage2.OnStatus := vtl_InverterData.IsStorage2On.stVal;
Storage2.PFModeEnabled := vtl_InverterData.IsStorage2InPFMode.stVal;
Storage2.QModeEnabled := vtl_InverterData.IsStorage2InQMode.stVal;
Storage2.InverterP := DINT_TO_REAL(vtl_InverterData.Storage2P.stVal);
Storage2.InverterQ := DINT_TO_REAL(vtl_InverterData.Storage2Q.stVal);
Storage2.InverterPF := DINT_TO_REAL(vtl_InverterData.Storage2PF.stVal)/100;
Storage2.PFSetpointFeedback :=
    DINT_TO_REAL(vtl_InverterData.Storage2PFSetpointFeedback.stVal)/100;
Storage2.QSetpointFeedback :=
    DINT_TO_REAL(vtl_InverterData.Storage2QSetpointFeedback.stVal);
Storage2.PLimitSetpointFeedback :=
    DINT_TO_REAL(vtl_InverterData.Storage2PLimitSetpointFeedback.stVal);
//NOTE: No ramp feedback available from inverters
vtl_InverterData.Storage2PackedControls.stVal.0 := Storage2.OnCommand;
vtl_InverterData.Storage2PackedControls.stVal.1 := Storage2.OffCommand;
vtl_InverterData.Storage2PackedControls.stVal.2 := Storage2.EmergencyStop;
vtl_InverterData.Storage2PackedControls.stVal.3 := Storage2.PFModeCommand;
vtl_InverterData.Storage2PackedControls.stVal.4 := Storage2.QModeCommand;
vtl_InverterData.Storage2PFSetpoint.oper.setMag := Storage2.PFSetMag * 1000; // Move significant
figures left of decimal
vtl_InverterData.Storage2PFSetpoint.oper.trigger := Storage2.PFTrigger;
vtl_InverterData.Storage2QSetpoint.oper.setMag := Storage2.QSetMag;
vtl_InverterData.Storage2QSetpoint.oper.trigger := Storage2.QTrigger;
vtl_InverterData.Storage2PSetpoint.oper.setMag := Storage2.PLimitSetMag;
vtl_InverterData.Storage2PSetpoint.oper.trigger := Storage2.PLimitTrigger;
vtl_InverterData.Storage2PFRampSetpoint.oper.setMag := Storage2.PFRampSetMag;
vtl_InverterData.Storage2PFRampSetpoint.oper.trigger := Storage2.PFRampTrigger;
vtl_InverterData.Storage2QRampSetpoint.oper.setMag := Storage2.QRampSetMag;
vtl_InverterData.Storage2QRampSetpoint.oper.trigger := Storage2.QRampTrigger;
vtl_InverterData.Storage2PRampSetpoint.oper.setMag := Storage2.PLimitRampSetMag;
vtl_InverterData.Storage2PRampSetpoint.oper.trigger := Storage2.PLimitRampTrigger;

// Capacitor 1 I/O
Capacitor1.Offline := vtl_CapacitorData.IsCapacitor1Offline.stVal;
Capacitor1.RemoteEnabled := vtl_CapacitorData.IsCapacitor1RemoteEnabled.stVal;
Capacitor1.Fault := vtl_CapacitorData.IsCapacitor1InFaultedState.stVal;
Capacitor1.OnStatus := vtl_CapacitorData.IsCapacitor1On.stVal;
Capacitor1.CapacitorV :=
    DINT_TO_REAL(vtl_CapacitorData.Capacitor1Voltage.stVal);
vtl_CapacitorData.Capacitor1On.operPulse.ct1Val := Capacitor1.OnCommand;
vtl_CapacitorData.Capacitor1Off.operPulse.ct1Val := Capacitor1.OffCommand;

// Capacitor 2 I/O
Capacitor2.Offline := vtl_CapacitorData.IsCapacitor2Offline.stVal;
Capacitor2.RemoteEnabled := vtl_CapacitorData.IsCapacitor2RemoteEnabled.stVal;
Capacitor2.Fault := vtl_CapacitorData.IsCapacitor2InFaultedState.stVal;
Capacitor2.OnStatus := vtl_CapacitorData.IsCapacitor2On.stVal;
Capacitor2.CapacitorV :=
    DINT_TO_REAL(vtl_CapacitorData.Capacitor2Voltage.stVal);
vtl_CapacitorData.Capacitor2On.operPulse.ct1Val := Capacitor2.OnCommand;
vtl_CapacitorData.Capacitor2Off.operPulse.ct1Val := Capacitor2.OffCommand;

```

```
(*** FUNCTION BLOCK EXECUTION ***)
MasterController();
Inverter1(ConnectToMasterController := MasterController.ConnectToPlantDevices);
Inverter2(ConnectToMasterController := MasterController.ConnectToPlantDevices);
Storage1(ConnectToMasterController := MasterController.ConnectToPlantDevices);
Storage2(ConnectToMasterController := MasterController.ConnectToPlantDevices);
Capacitor1(ConnectToMasterController := MasterController.ConnectToPlantDevices);
```

Release Notes

Version	Summary of Revisions	Date Code
3.5.1.0	<ul style="list-style-type: none"> ➤ Allows new versions of ACSELERATOR RTAC to compile projects for previous firmware versions without SEL IEC types “Cannot convert” messages. ➤ Updated internal calculations to better handle cases where inverter ratings are inadvertently set to zero. ➤ Must be used with R143 firmware or later. 	20180921
3.5.0.2	<ul style="list-style-type: none"> ➤ Renamed library components to conform to library extensions naming conventions. ➤ Add quick stop feature. ➤ Add control mode: VAR control. ➤ Add control mode: PF Compensation. ➤ Add control mode: Voltage Compensation. ➤ Updated control mode: Voltage control now employs direct VAR control of the inverters. ➤ Add frequency regulation for plant response. ➤ Add frequency regulation for storage system response. ➤ Add support for energy storage system. ➤ Add downramp control (real power support for storage systems). 	20180427
0.1.5.2	<ul style="list-style-type: none"> ➤ Fixed VAR Control mode. ➤ Added an additional dead band detection exclusively for VAR mode, because inverter control is only enabled if an out-of-dead-band is signaled. ➤ Corrected the initialized values in the instruction manual. ➤ Added separate tuning parameters for VAR control mode. 	20150708
0.1.5.1	<ul style="list-style-type: none"> ➤ Added ability to control multiple capacitors. ➤ Added VAR control mode to types of POI control. 	20150605
1.4.3	<ul style="list-style-type: none"> ➤ Added SEL-3555 and SEL-3532 to the MOT Checker. 	20141231
1.4.2	<ul style="list-style-type: none"> ➤ Changed library dependencies to use the newest version always. 	20140812
1.4.1	<ul style="list-style-type: none"> ➤ Added PL_MODE to GC_MSPC for user selection of one of three power limit modes. <ul style="list-style-type: none"> ➤ “NoLimit” means all power limit outputs are set to 100%. ➤ “Simple” means the power Limit setpoint is converted to a percentage of the P ratings of the available invertersg. The same percent output limit is sent to each inverter. This simplification does not address any non-uniform cloud cover issues. ➤ “Advanced” means use the PI controller based limiter (requires inverter data updates <5 seconds). 	20140122
1.3.1	<ul style="list-style-type: none"> ➤ Added INV_PL_DELAY input pin to GC_MSPC. ➤ Delay time between inverter not responding to power set point and application of the adaptive power limit. 	20131104
1.2.2	<ul style="list-style-type: none"> ➤ Changed MSPC.V input default value to 1.0. ➤ Changed MSPC.V_SP input default value to 1.0. ➤ Changed MSPC.V_DB input default value to 0.02. 	20130919
1.2.1	<ul style="list-style-type: none"> ➤ Add POI QUALITY and ENABLE pins. ➤ Added ENABLED output pin to GC_MSPC. 	20130722
1.1.8	<ul style="list-style-type: none"> ➤ Enhanced power limit control. Added per inverter power limit anti-windup logic. 	20130529

Version	Summary of Revisions	Date Code
1.1.7	<ul style="list-style-type: none"> ➤ Modified set point bias logic during voltage or powerfactor excursions beyond critical limits. ➤ Decoupled PF control dead band and lag/lead alarm generation from voltage limits. 	20130506
1.1.6	<ul style="list-style-type: none"> ➤ Decrease power limit ramp rate output dead band to 0.01%/Sec. ➤ Corrected predictive aggregate inverter response logic. ➤ Limit power limit control output between 0 and 100% in open loop and closed loop mode. 	20130412
1.1.5	<ul style="list-style-type: none"> ➤ GC_INV - Corrected trigger logic to allow PF_TRIG output to reset between control intervals. 	20130206
1.1.4	<ul style="list-style-type: none"> ➤ GC_MSPC - Corrected closed loop cycle time pulse generation. 	20130206
1.1.3	<ul style="list-style-type: none"> ➤ GC_MSPC Function Block Bug Fixes: <ul style="list-style-type: none"> ➤ Corrected Retry pulse generation. ➤ Corrected Closed loop cycle time pulse generation. ➤ Corrected Version output pin. 	20130201
1.1.2	<ul style="list-style-type: none"> ➤ Added RTAC MOT support. 	20121126
1.1.1	<ul style="list-style-type: none"> ➤ Initial release. 	20120906