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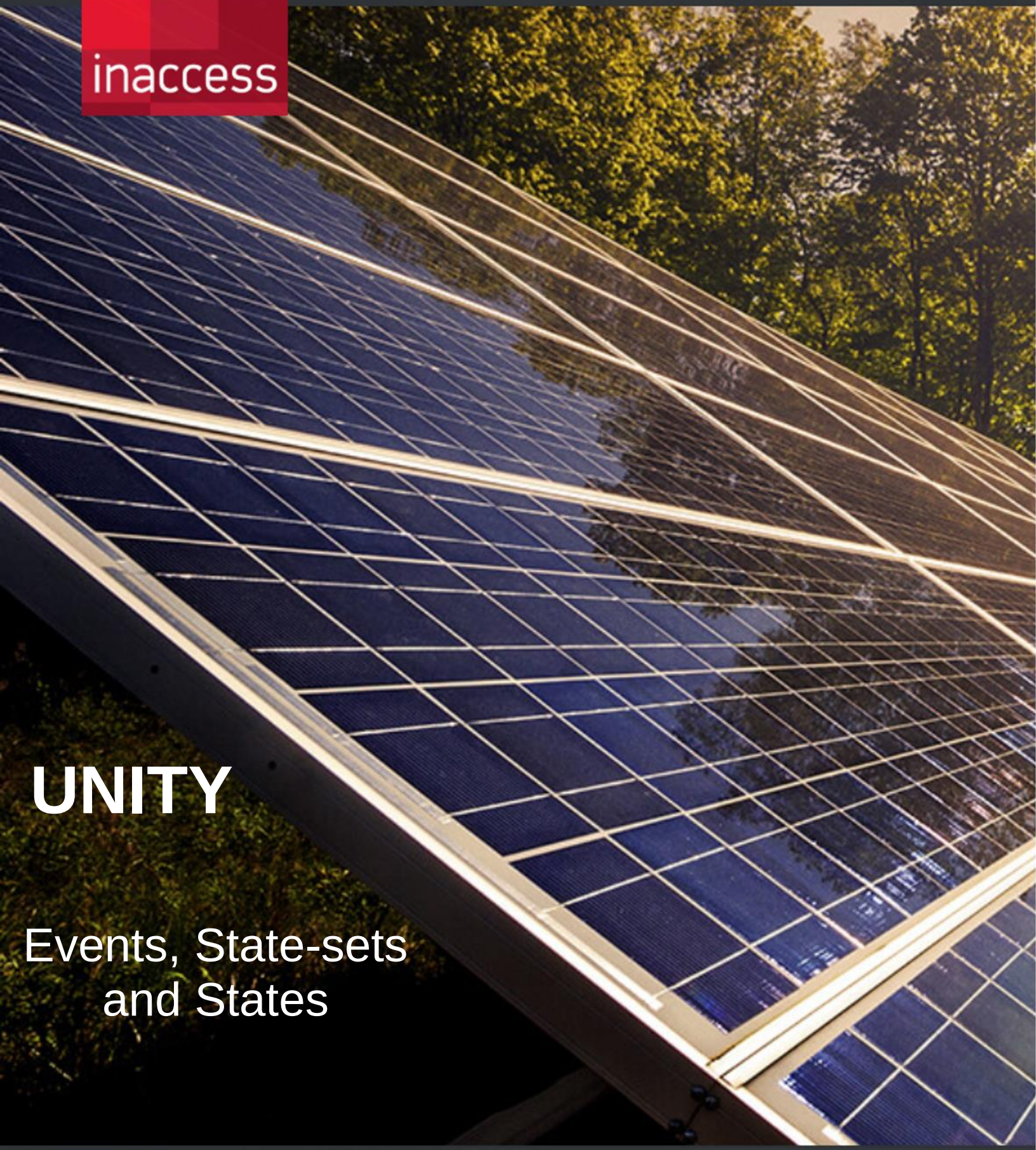

UNITY

Events, State-sets and States

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1. Introduction

In order to represent status information, the Central Monitoring System (CMS) supports:

- A number of state sets associated with each hierarchy node.
- A number of states associated with each state set.

Each state set encodes a set of states, which are mutually exclusive, i.e. the entity to which it refers can be found in only one of them. Changes among states are triggered by state-change events, which can be generated by a variety of sources:

- Supervised equipment: In that case, the Local Monitoring System (LMS) deployed in the solar plant reads out the events from the device and forwards them to the CMS in order for the latter to update the status it maintains.
- The LMS: The Local Monitoring System generates additional events based on the thresholding of measurements, the combination of other events and/or measurements (derived events) as well as other criteria and transmits them to the CMS.
- The CMS: Finally, the Centralized Monitoring System generates events in much the same way as the LMS does.

One more important notion used to classify events is the severity (a number on a scale from 0 - everything normal to 100 – critical failure), which is associated with the state each independent state set is in and consequently to the event which led the state set there. An "alarm" is then an event which has a severity above a threshold.
All events which triggered the transition of a state set from one state to the other are archived within the CMS with timestamping information, indication of the state that the state set was driven to after the reception of the particular event and its severity.
The remainder of this document groups the state sets and associated states with their descriptions, according to either the type of the supervised equipment or the operational aspect they concern. It is evident that the supported events are the same as the supported states for each state set, since an event leads the state set to a specific state.
Finally, Annex A provides a list of all available events, their severity and cross-reference with the descriptions of each related state set.

2. The state-sets, states and events supported by the CMS

The following sections present in detail the state-sets, states and events supported by the CMS.

2.1 Status information provided by inverters

The support of inverter status is a very tricky issue due to the following facts:
1. Each inverter manufacturer provides their own set of states the inverter can be found in
2. The user needs to be able to understand the state the inverter is in quickly and efficiently without having to refer to the component datasheet
The approach which we have followed within the CMS using our experience was to group error and status messages coming from the inverters to a pre-defined set of states, which has been found to be representative across a large set of inverter components from several manufacturers (SMA, KACO, Fronius, Kostal, Refusol, Danfoss, Gamessa, Xantrex, Power Electronics and others). This state-set, presented in the following table, can be expanded at will; however care is needed so as not to invalidate its primary target of providing easily understandable yet concise information to the operator.

Table 1 – Inverter status information

State set	State mnemonic	State description
Inverter status	Normal	The inverter is operating normally
Error	The inverter is in error but is producing	
Stopped	The inverter has stopped producing	
Disturbance	The inverter has been disconnected from the grid	
Unknown	The inverter has produced a status/error code that is characterized as Unknown in the datasheet	
Night shutdown	The inverter has shutdown for the night	
Communication Error	The LMS cannot communicate with the inverter	

Waiting	The inverter is waiting for the grid to stabilize or the panels to reach the operating voltage	

An indicative example is the SMA Sunny Boy family (MiniCo inverter), which provides an confusing state-set. This particular inverter family has the problem that the communication board is supplied with power from the sun and consequently, during the night, the LMS cannot communicate with it and indicates a failure. To resolve this issue, we are using the irradiance measurement to classify a communication failure either as such or as a night shutdown condition.
It is understandable that the grouping presented above is carried out by the LMS depending on the inverter model. Since it would be unacceptable to discard the original messages that were used for this grouping, the LMS records them with the timestamp of their appearance and forwards them to the CMS as a primary parameter being represented as a series of string-encoded messages. In that way, if detailed debugging is needed, the operator can always use the component datasheet and these parameters to find out what has happened. These parameters are:

- Inverter Status Log, containing status codes received by the inverter.
- Inverter Error Log, containing error codes received by the inverter.
- Inverter Protocol Adapter Status Log, containing status codes received by the protocol adapter module, enabling the communication of the inverter with any devices beneath it (e.g. array boxes), an architecture followed by certain manufacturers.

The CMS also supports a number of manufacturer-specific states, grouped to state sets according to the table below.

Table 2 – Inverter manufacturer-specific states

State set	State mnemonic	State description
DSP fault status	Fault not present	The DSP of the inverter is malfunctioning
	Fault present	
Generic inverter fault status	Fault not present	The inverter has experienced a generic fault
	Fault present	
Logical inverter fault status	Fault not present	The inverter has experienced a logical fault
	Fault present	
DC switch status	Closed	The switch on the DC side of the inverter is closed
	Open	The switch on the DC side of the inverter is open

AC switch status / Output Switch status	Closed	The switch on the AC side of the inverter is closed
	Open	The switch on the AC side of the inverter is open
Current status	Normal	The inverter has not internally experienced an overcurrent condition
	Overcurrent	The inverter has internally experienced an overcurrent condition
	Short circuit	The inverter indicates a short circuit
Neutral current status	Normal	The inverter has not experienced an overcurrent condition on the neutral
	Overcurrent	The inverter has experienced an overcurrent condition on the neutral
DC voltage status	Normal	The voltage on the DC side of the inverter is within limits
	Undervoltage	The voltage on the DC side of the inverter is under the lower limit
	Overvoltage	The voltage on the DC side of the inverter is over the higher limit
AC voltage status	Normal	The voltage on the AC side of the inverter is within limits
	Undervoltage	The voltage on the AC side of the inverter is under the lower limit
	Overvoltage	The voltage on the AC side of the inverter is over the higher limit
Inverter voltage status / Output Voltage Status	Normal	The voltage on the AC side of the inverter is within limits
	High	The voltage on the AC side of the inverter is under the lower limit
	Low	The voltage on the AC side of the inverter is over the higher limit
Inverter warning status	Warning not present	There does not exist a warning for the inverter (as defined within its datasheet)
	Warning present	There exists a warning for the inverter (as defined within its datasheet)

Reactive power regulation status	Off	The inverter is not regulating its output reactive power
	On	The inverter is regulating its output reactive power
Reactive power limitation status	Off	The inverter is not limiting its output reactive power
	On	The inverter is limiting its output reactive power
Reactive power	Regulation Off	The inverter is not regulating its output reactive power
Reactive power	Regulation On	The inverter is regulating its output reactive power
Reactive power	Limitation Off	The inverter is not limiting its output reactive power
Reactive power	Limitation On	The inverter is limiting its output reactive power
Active power	Limitation Off	The inverter is not limiting its output active power
	Limitation On	The inverter is limiting its output active power
Active power command response	Rejected	The inverter has rejected a command to adjust its output active power
	Accepted	The inverter has accepted a command to adjust its output active power
Inverter output status	Not Limited	The inverter is not limiting its output active power
	Limited	The inverter is limiting its output active power
Inverter remote control status / Remote control switch status	Off	The inverter is not regulating its output active power
	On	The inverter is regulating its output active power
Manual mode status	Off	The inverter is not in manual mode
	On	The inverter is in manual mode
Inverter Door status	Closed	The inverter door is closed
	Open	The inverter door is open
Emergency stop status	Normal	No emergency stop has been performed
	Emergency stop	An emergency stop has been performed (in most cases through a button in the field)

Fan fault status	Fan operational	The fan(s) within the inverter is working properly
	Fan fault	The fan(s) within the inverter has experienced a fault
Output frequency status	Normal	The output frequency of the inverter is normal
	Error	The output frequency of the inverter is outside the acceptable limits
DC current status	Normal	The current on the DC side of the inverter is normal
	Overcurrent	The current on the DC side of the inverter is high
AC current status	Normal	The current on the AC side of the inverter is normal
	Overcurrent	The current on the AC side of the inverter is high
Grid status	Grid ready	The grid conditions are within the operational envelope of the inverter
	Grid not ready	The grid conditions are outside the operational envelope of the inverter
DC input status	DC input ready	The conditions of the inverter DC input are within the operational envelope of the inverter
	DC input not ready	The conditions of the inverter DC input are outside the operational envelope of the inverter
Inverter Blocked Status	Not Blocked	The inverter is in normal operation
	Blocked	The inverter is blocked
Inverter Fuse Status	Closed	The inverter fuse is working normally
	Open	The inverter fuse is blown
Inverter sync status	Synced	The inverter is synchronized
	Not Synced	The inverter is not synchronized
Inverter temperature status	Normal	The inverter temperature is normal
	Overtemperature	The inverter temperature is high
Earth fault status	Present	The inverter indicates an earth fault (a short circuit between phase and earth)
	Not Present	No earth fault present

Inverter selective block status	Not Blocked	The inverter is in normal operation
	Blocked	Some of the inverter modules are blocked

No thresholds are used to generate the alarms presented above, since they are directly provided by the supervised equipment.

2.2 Status information provided by strings

The same approach, followed for the modeling of status information from the inverters, has also been applied to strings (or string monitor units – SMUs). The following table summarizes the states in which the respective status set can be found, together with a description.

Table 3 – SMUs Status information

State set	State mnemonic	State description
SMU status	Stopped	The SMU has stopped measuring
Measuring	The SMU is measuring (normal state)	
Error	The SMU is in the error state	
Unknown	The SMUhas produced a status/error code that is characterized as Unknown in the datasheet	
Communication error	The LMS has stopped communicating with the SMU	

The CMS also supports a number of manufacturer-specific states, grouped to the same state set according to the table below.

Table 4.1 – SMUs manufacturer-specific states

State set	State mnemonic	State description
SMU status	Offset adjustment 1	The SMU is performing offset adjustment (method 1)
	Offset adjustment 2	The SMU is performing offset adjustment (method 2)
	Diagnostics	The SMU is carrying out a diagnostics sequence

SMU calibration status	Normal	The SMU calibration procedure has ended normally
	Error	There is an error during the SMU calibration procedure
SMU Fuse status	Normal	The SMU fuse is operating normally
	Blown	The SMU fuse has blown because of an overcurrent condition
SMU overtemperature status	Normal	The SMU measuring card temperature is normal
	Overtemp	The SMU measuring card temperature is high
SMU self-test status	Normal	The SMU self-test procedure has ended normally
	Failed	The SMU self-test procedure has failed
String currents unbalanced status	Normal	The string currents of the same SMU are balanced
	Unbalanced	The string currents of the same SMU are not balanced
String fault status / Strings in fault status	Normal	The string is in normal operation
	Fault	There is failure in the string
String negative fuse status	Normal	The string negative pole fuse is operating normally
	Blown	The string negative pole fuse has blown because of an overcurrent condition
String positive fuse status	Normal	The string positive pole fuse is operating normally
	Blown	The string positive pole fuse has blown because of an overcurrent condition
String overcurrent status	Normal	The current of the string is normal
	Overcurrent	The current of the string is high
String overvoltage status	Normal	The voltage of the string is normal
	Overvoltage	The voltage of the string is high

The status and error codes, as received by the DC box, are recorded by the LMS using the following parameters:

- SMU Status Log, containing status codes received by the SMU.
- SMU Error Log, containing error codes received by the SMU.

No thresholds are used to generate the alarms presented above, since they are directly provided by the supervised equipment.

The field-deployed controller also executes an algorithm generating additional state-sets targeted

to the detection of problems with individual strings. The algorithm operates as follows:
1. For each string, the current value is compared with a pre-defined threshold, equal to 0.5 A, only when the irradiance is above 200 W/m2. If the value of the current is below that threshold for 5 minutes, the "String current status" state variable goes to the "Current low" state.
2. For each SMU, an average of the currents of the strings terminated on that SMU, weighted by their nominal power is calculated. Then, the current of each string is compared to that average. If it is smaller or larger than a predefined threshold of 10% for 5 minutes AND the irradiance is above 200 W/m2, the state variable denoted as "String current abnormal status" goes from the "Normal" to the "Abnormal" state.
These states are summarized in the table below.

Table 4.2 – Individual String current states

State set	State mnemonic	State description
String Current Alarm	None	The string current is non-zero, as described above
	Current Low	The string current is zero, as described above
String Current Abnormal	None	The strings currents of the same SMU are similar, as described above
	Current Abnormal	There are significant deviations among the string currents of the same SMU

Finally, per DC box the total current of all strings connected to this DC box is calculated. This value is compared with a pre-defined threshold, equal to 0.05 A, only when the irradiance is above 200 W/m2. If the value of the current is below that threshold for 5 minutes, the "DC box output current alarm" state variable goes to the "Low" state.
These states are summarized in the table below.

Table 4.3 – DC Box current states

State set	State mnemonic	State description
DC box output current alarm	Normal	The total current of all strings connected to the DC box is non-zero, as described above
	Low	The total current of all strings connected to the DC box is zero, as described above

2.3 Status information provided by protection devices

The protection devices detect a number of conditions which are extremely important for the operation of the PV plant. Since the detection of such conditions demands a very

high sampling rate of the AC voltages and currents, it is carried out entirely within the protection device which also manages the protective relay to acutely disengage portions of the electrical circuit if judged as necessary. The LMS then acquires the detected events as well as the events regarding the subsequent actions taken by the protection device and forwards them to the CMS to update the status.
Due to the extensive standardization of the substation automation application domain, the states that a protection device can be found in belong to an a-priori known set and have specific and manufacturer independent codes, which provided within [1]. The same designation has been followed in the sections that follow. No thresholds are used to generate the alarms presented below, since they are directly provided by the supervised equipment.

2.3.1 Voltage and frequency status

The voltage, frequency and occasionally rate-of-change of frequency, measured at specific points of the electrical network within a PV plant have to remain within state regulated limits. If deviations occur, the relay is tripped.
The CMS groups the voltage and frequency-related protection states events into several state sets presented in the table below. Voltage and frequency related protections are activated only at the PCC.

Table 5 – Voltage and frequency status

State set	State mnemonic	State description as per the ANSI code
Voltage status	Overvoltage on one or more phases	59, 3U>> (high set stage)
	Undervoltage on one or more phases	27, 3U<< (high set stage)
	Voltage normal	Voltage within limits
	Instantaneous overvoltage	59, 3U>>> (instantaneous stage)
	Minor overvoltage	59, 3U> (low set stage)
	Instantaneous undervoltage	27, 3U<<< (instantaneous stage)
	Minor undervoltage	27, 3U<<< (low set stage)
Frequency status	Overfrequency	81O
	Underfrequency	81U
	Frequency normal	Frequency within limits
	Overfrequency or Underfrequency	81O or 81U
ROCOF status	High	7F
	Normal	The rate of change of frequency is within limits

Neutral voltage displacement status	Normal	Neutral voltage displacement condition not present
	Instantaneous present	59N, Uo>>> (instantaneous stage)
	High present	59N, Uo>> (high set stage)
	Low present	59N, Uo> (low set stage)

2.3.2 Current status

Current status information is used to detect overcurrent conditions between phases and neutral as well as between phases and earth at various parts of the electrical network within the PV plant. The CMS groups the current-related protection device status into several state sets presented in the table below. Protections related to current are activated at the PCC as well as the MV ring (in this case the source is the plant), the transformers (in this case the source is the transformer block) as well as the auxiliary service transformer (in this case the source is yet again the plant).

Table 6 – Current status

State set	State mnemonic	State description as per the ANSI code
Current status	Overcurrent	50/51, 3I>> (high set stage)
	Normal	Current within limits
	Instantaneous overcurrent	50/51, 3I>>> (instantaneous stage)
	Minor overcurrent	50/51, 3I> (low set stage)
Earth fault status	Normal	Earth fault condition not present
	Instantaneous present	50N/51N, Io>>> (instantaneous stage)
	High present	50N/51N, Io>> (high set stage)
	Low present	50N/51N, Io> (low set stage)

2.3.3 Relay status

Each protection device is paired with a protective relay which it commands so as to isolate parts of the electrical network within the PV plant. The events from the protective relay which encode its current position are then fed back to the protection device, read by the LMS and forwarded to the CMS. The CMS groups the relay-related protection device states into several state sets presented in the table below.

Table 7 – Relay status

State set	State mnemonic	State description
Trip relay status	Relay tripped	The protective relay has tripped (readback reading)
Trip relay status	Relay closed	The protective relay is closed

2.4 Status information related to power quality

During production, regulations in certain countries mandate that the PV plant should produce power of acceptable quality so as to maintain the overall power quality of the grid within limits. The related events are generated by the LMS using data from multimeters and pyranometers to determine whether it is day. The CMS groups the power quality-related protection device states into several state sets presented in the table below. Multimeters can be installed to measure any point in the circuit and the source shall have to be appropriately selected and may be the plant (PCC, ring and auxiliary power supply multimeters) or the transformer/inverter block/inverter (transformer LV and MV multimeters as well as the inverter output multimeter).

Table 8 – Power-related status information

State set	State mnemonic	State description
Current imbalance status	High on one or more phases	It is day and the currents of the 3 phases are unbalanced
	Normal	It is day and the currents of the 3 phases are not unbalanced
Power factor status	Low	It is day and the power factor is below 0.9
	Normal	It is day and the power factor is not below 0.9
Current THD-R status	High on one or more phases or the neutral	It is day and the THD-R is above 5%
	Normal	It is day and the THD-R is below 5%
DC injection status	High	It is day and DC current is being injected into the grid
	Normal	It is day and DC current is not being injected into the grid

Since the thresholds are mandated by the related standards, they are not settable by the user.

2.5 Status information provided by transformer protection devices

Transformers are protected against threatening conditions in several ways, depending on their type:

➢ For both dry and oil-type transformers, the temperature is monitored using a thermostat with 2 contacts, one indicating a mild increase of the temperature above the nominal level (temperature alarm) and the second indicating a serious deviation, probably caused by an internal fault. When this situation is

encountered, the protective relay is tripped and the transformer is automatically disconnected from the grid

- Oil-type transformers of the air-breathing conservator-type are protected against internal failures by an ingenious electromechanical device called the Buchholz relay. This device issues an alarm and disconnects the transformer from the grid under certain conditions
- Oil-type transformers of the hermetically-sealed totally-filled tank type are protected against internal failures by a device called DGPT (Detection of Gas, Pressure and Temperature), since the principles of operation of the Buchholz relay do not apply. The DGPT detects the existence of gas as well as changes in the internal pressure of the transformer (both indicating electrical arcs within the transformer). Protection from overtemperature is implemented as presented above

Buchholz relays, thermostats and DGPT devices are monitored by the LMS which forwards the related events to the CMS to update the status. The CMS groups the transformer protection-related protection device states into several state sets presented in the following table.

Table 9 - Transformer protection devices status information

State set	State mnemonic	State description
Buchholz relay status	Normal	The Buchholz relay protection function has not been activated
	Alarm	The Buchholz relay protection function has provided an alarm
	Trip	The Buchholz relay protection function has disconnected the transformer from its feeder
Oil Temperature indicator status	Normal	The temperature protection function has not been activated
	Alarm	The temperature protection function has provided an alarm
	Trip	The temperature protection function has disconnected the transformer from its feeder
Gas pressure status	Normal	The gas pressure inside the transformer is normal
	High	The gas pressure inside the transformer is high

Pressure relief valve indicator status	Normal	The gas pressure protection function has not been activated
	Alarm	The gas pressure protection function has provided an alarm
	Trip	The gas pressure protection function has disconnected the transformer from its feeder
Oil level status	Normal	The oil level inside the transformer is normal
	Low	The oil level inside the transformer is low
Generic transformer alarm status	Normal	No alarm is present
	Present	An alarm is present
Magnetic oil gauge status	Normal	The volume f transformer insulation oil is normal
	Alarm	The transformer insulation oil tank is almost empty
Oil temperature status	Normal	The transformer oil temperature is normal
	High	The transformer oil temperature is high
	Very High	The transformer oil temperature is very high
Winding temperature status	Normal	The transformer winding temperature is normal
	High	The transformer winding temperature is high
	Very High	The transformer winding temperature is very high
Winding Temperature indicator status	Normal	The winding temperature protection function has not been activated
	Alarm	The winding temperature protection function has provided an alarm
	Trip	The winding temperature protection function has disconnected the transformer from its feeder

No thresholds are used to generate the alarms presented above, since they are directly provided by the supervised equipment.

2.6 Status information related to weather conditions

The LMS thresholds certain of the parameters it records through meteo sensors to provide meteorological status information encoded in the state sets and states presented in the table below, together with the settings used to set the related thresholds.

Table 10 – Weather conditions-related status information

State set	State mnemonic	State description	Related setting (threshold)
Temperature status	Normal	The temperature is normal	
	Low	The temperature is low	Ambient air temperature low threshold (default value = -20 oC)
	High	The temperature is high	Ambient air temperature high threshold (default value = 40 oC)
Wind Speed status	Normal	The wind speed is normal	
	High	The wind speed is high	Wind speed high threshold (default value = 30 m/s)
Precipitation status	Normal	The precipitation (rain height) is normal	
	High	The precipitation is high	Precipitation high threshold (default value: disabled)
Module temperature status	Normal	The temperature is normal	
	Low	The temperature is low	Module temperature low threshold (default value = -10 oC)
	High	The temperature is high	Module temperature high threshold (default value = 70 oC)

2.7 Status information related to the shelters

The LMS encodes the status information provided by the related sensors installed in the shelter rooms on the state sets and states presented in the table below, together with the settings used to set the related thresholds.

Table 11 – Shelters-related status information

State set	State mnemonic	State description	Related setting (threshold)
Room temperature status	Normal	The room temperature is normal	
	Low	The room temperature is low	Room temperature low threshold (default value = 1 oC)
	High	The room temperature is high	Room temperature high threshold (default value = 40 oC)

Fire status	Not on fire	There is no fire in the room	
	On fire	There is fire in the room	
Flood status	Not flooded	There is no flood in the room	
	Flooded	There is flood in the room	
Occupancy status	Not occupied	There is no one in the shelter room	
	Occupied	There is someone in the shelter room	
Door status	Closed	The shelter room door is closed	
	Left Open	The shelter room door is open	
Door override status	Lock not overridden	Access control manually overridden	
	Lock overridden	Access control in normal operation	
Emergency lock status	On	Emergency lock has been activated	
	Off	Emergency lock has not been activated	

2.8 Status information related to KPIs

The CMS supports the following KPI-related state sets:

- Performance ratio status. This state set has 2 states, "Normal" and "Low" with obvious meaning. The threshold is provided through the "Performance ratio low threshold" setting (default values are 65% for the plant node, 75% for the inverter group node and 40% for the inverter node).
- Availability Level status. This state set is based on the calculation of the availability at inverter and plant level. It has 2 states, "Normal" and "Low" with obvious meaning. The threshold is provided through the "Availability level low alert threshold" setting (default value is 90%).
- SMU Availability Level status. This state set is based on the calculation of the availability at DC box and plant level. It has 2 states, "Normal" and "Low" with obvious meaning. The threshold is provided through the "SMU availability level low alert threshold" setting (default value is 90%).
- String Availability Level status. This state set is based on the calculation of the availability at string and plant level. It has 2 states, "Normal" and "Low" with obvious meaning. The threshold is provided through the "Sting availability level low alert threshold" setting (default value is 90%).

These states are summarized in the following table:

Table 12 – KPIs-related status information

State set	State mnemonic	State description
Performance ratio status	Normal	The performance ratio is normal (as detailed above)
	Low	The performance ratio is low (as detailed above)
Availability Level status	Normal	The availability (calculated based on the inverters) is normal (as detailed above)
	Low	The availability (calculated based on the inverters) is low (as detailed above)
SMU Availability Level status	Normal	The availability (calculated based on the DC boxes) is normal (as detailed above)
	Low	The availability (calculated based on the DC boxes) is low (as detailed above)
String Availability Level status	Normal	The availability (calculated based on the strings) is normal (as detailed above)
	Low	The availability (calculated based on the strings) is low (as detailed above)

2.9 Status information related to the security system

The LMS encodes the status information provided by the security system on the state sets and states presented in the table below.

Table 13 – Security system-related status informnation

State set	State mnemonic	State description
Alarm status	Off	The respective alarm zone hasn't generated an alarm
	On	The respective alarm zone has generated an alarm
Actuator status	Off	The respective actuator hasn't been actuated
	On	The respective actuator has been actuated

No thresholds are used to generate the alarms presented above, since they are directly provided by the supervised equipment.

2.10 Status information provided by common electrical network components

A large set of common electrical network components is modeled within CMS:

- Surge arresters: These are devices which protect sensitive equipment from the effect of surges caused by lightning strikes. Surge arresters must be replaced after they have carried out their duty
- Circuit breakers: These devices detect overcurrent conditions across their terminals and interrupt the circuit automatically; however they can be reset to their closed state through local intervention
- Fuses: These devices operate as circuit breakers but must be replaced after they have carried out their duty
- Switches: These devices are used to interrupt a circuit upon receiving a proper command
- Contactors: These devices are electrically controlled switches used for switching a power circuit, similar to a relay except with higher current ratings
- Indicators: These are general-purpose indications from a wide variety of equipment. The condition they encode is signified by the name of the indicator

The CMS groups the states the abovementioned devices can be found in into several state sets presented in the table below.

Table 14 – Common electrical network components status information

State set	State mnemonic	State description
Surge arrester status	Normal	The surge arrester is operating normally
	Damaged	The surge arrester is damaged and needs replacement
Circuit breaker status	Open	The circuit breaker is open
	Closed	The circuit breaker is closed
	Unknown	The circuit breaker is in an unknown state (neither open nor closed)
Circuit breaker trip status	Tripped	The circuit breaker has opened because of a trip
	Normal	The circuit breaker has not opened because of a trip
Fuse status	Normal	The fuse is operating normally
	Blown	The fuse has blown because of an overcurrent condition
Switch status	Open	The switch is open
	Closed	The switch is closed
	Unknown	The switch is in an unknown state (neither open nor closed)

Indicator status	Off	The condition the indicator signifies does not exist
	On	The condition the idicator signifies exists
	Unknown	It is unknown whether the condition the indicator signifies exists
CB Command	Open	A command has been sent to open the circuit breaker
	Close	A command has been sent to close the circuit breaker
	No command	No command to open or close the circuit breaker has been sent
CB reset	Reset	A command to reset the circuit breaker has been sent
	No command	No command to reset the circuit breaker has been sent
Circuit breaker spring charged status	Charged	The spring of the circuit breaker is charged
	Not charged	The spring of the circuit breaker is not charged
	Communication error	There is no communication
	Malfunction	There is a problem with the charging of the spring
Contactor status	Normal	The contactor is in normal operation
	Fault	The contactor has a fault
Reclose switch status	On	The switch is closed
	Off	The switch is open
Load on mains status	Not Present	Local loads are powered by mains
	Present	Local loads are powered by site generator

No thresholds are used to generate the alarms presented above, since they are directly provided by the supervised equipment. The criticality of each state is obviously related to the position of the supervised electrical network component within the single-line diagram of the plant. This in turn means that the severity of each state-change event is defined independently for each state variable instance of each plant during the plant provisioning phase.

2.11 Status information related to the communication among LMS and supervised equipment

The LMS maintains a set of state sets, one for each piece of supervised equipment which indicates whether the supervised equipment is operational and data can be communicated to it, as presented in the table below.

Table 15 - LMS and supervised equipment communication-related status information

State set	State mnemonic	State description
Operational Status	OK	The supervised equipment is operating OK
	Malfunction	The supervised equipment is malfunctioning
Communication status	Normal	The LMS is communicating with the supervised equipment
	Error	The LMS cannot communicate with the supervised equipment
Manual bypass status	Off	The supervised equipment is in normal operation
	On	The supervised equipment is in manual bypass mode
Manual Mode Status	Manual Mode Off	The supervised equipment is in normal operation
	Manual Mode On	The supervised equipment is in manual mode
Operational error status	Normal	The supervised equipment is operating OK
	Not Operational	The supervised equipment is malfunctioning

No thresholds are used to generate the alarms presented above, since they are directly provided by the supervised equipment.
Taking into consideration that a failure of the supervised equipment most often appears as a communication problem as far as the LMS is concerned, the meaning of these 2 state sets is intermixed and may call for further investigation possibly including a site survey. As far as inverters and array boxes are concerned, the communication status state set has been incorporated within the respective “Inverter status” and “SMU status” ones (see sections 2.1 and 2.2).
The type of the events presented above is apparently “Communication fault”.
Regarding the source, it depends on the region of the plant the supervised device has been installed in according to the previous sections.

2.12 Status information related to the communication among CMS and LMS

The CMS also determines whether it can or cannot communicate with the LMS, both at the IP and application level. The necessary states are grouped in state sets as per the table below.

Table 16 – CMS and LMS communication-related status information

State set	State mnemonic	State description
Link Status (applies to the plant router and each controller independently)	Online	IP connectivity is operational
	Offline	IP connectivity has been interrupted
Controller Status (applies only to each controller independently)	Normal	Connectivity with the PAC is operational
	Interrupted	Connectivity with the PAC has been interrupted during an operation
	Unavailable	The PAC cannot be reached
Site Online in CMS	Y	The data of the site in CMS are up to date
	N	The newest data of the site in CMS is at least 1 hour old

No thresholds are used to generate the alarms presented above, since they are directly provided by the supervised equipment.

2.13 Status information related to trackers

The LMS encodes the status information provided by trackers on the state sets and states presented in the table below.

Table 17 – Trackers-related status information

State set	State mnemonic	State description
Tracker at setpoint status	Yes	Tracker has reached its setpoint
	No	the tracker is outside the dead band (around the calculated angle) for longer than 5 minutes
Tracker control / Tracker operation status	Auto	Auto (local) mode moves the tracker according to the solar position calculations
	Manual	Manual (SCADA) mode moves the tracker to the angle inputted into the manual position register

Tracker controller status	On	Tracker controller is in normal operation
	Off	Tracker controller is off
Controller Wind Status	normal	Wind speed is normal
	high	Wind speed is high
Local Wind Sensor Status	Normal	Local wind stow sensor is operating normally
	Tripped	Local wind stow sensor is currently tripped
Central Wind Sensor Status	Normal	Central wind stow sensor is operating normally
	Tripped	Central wind stow sensor is currently tripped
Wind Stow Timer Counting Down	Yes	A wind sensor was tripped, the controller has placed the tracker into wind stow position, and a 30-minute countdown is in progress
	No	The above condition is not present
Tracker Clearing an Obstruction	Yes	The tracker is in obstruction clearing mode
	No	The tracker is not in obstruction clearing mode
Tracker Motor Locked (Out)	Yes	The tracker motor is locked out from running the entire duration of the obstruction clearing mode
	No	The above condition is not present
East limit switch status	On	The tracker has reached its east limit
	Off	The tracker has not reached its east limit
Motor reverse	Yes	The tracker motor is in reverse
	No	The tracker motor is not in reverse
Motor forward	Yes	The tracker motor is in forward
	No	The tracker motor is not in forward

No thresholds are used to generate the alarms presented above, since they are directly provided by the supervised equipment.

2.14 Status information related to UPS

The LMS encodes the status information provided by UPSs on the state sets and states presented in the table below.

Table 18a – UPS-related status information

State set	State mnemonic	State description
Charging status	Charging	The UPS battery is charging
	Not Charging	The UPS battery is not charging
Discharging status	Discharging	The UPS battery is discharging
	Not discharging	The UPS battery is not discharging
Power source	On AC Power	The UPS is fed with power from the mains
	On Battery	The UPS is on the battery

No thresholds are used to generate the alarms presented above, since they are directly provided by the supervised equipment.

The LMS also thresholds certain of the parameters it records through the UPS to provide the status information encoded in the state sets and states presented in the table below, together with the settings used to set the related thresholds.

Table 18b – Battery level-related status information

State set	State mnemonic	State description	Related setting (threshold)
Battery level status	Normal	The battery level is normal	
	Low	The battery level is low	Battery level low threshold (default value = 30%)
	Very Low	The battery level is very low	Battery level lolo threshold (default value = 10%)

3. References

1. IEEE Std C37.2, "IEEE Standard Electrical Power System Device Function Numbers and Contact Designations", 2 May 2002

4. Annex A – List of Events

Signal	Status	Severity	Comments
AC current status	Normal	0	See Table 2
AC current status	Overcurrent	100	See Table 2
AC switch state	Closed	0	See Table 2
AC switch state	Tripped	100	See Table 2
AC switch state	Open	0	See Table 2
AC voltage status	Normal	0	See Table 2
AC voltage status	Undervoltage	100	See Table 2
AC voltage status	Overvoltage	100	See Table 2
Active Power	Limitation Off	0	See Table 2
Active Power	Limitation On	0	See Table 2
Active power command response	Rejected	0	See Table 2
Active power command response	Accepted	0	See Table 2
Actuator status	Deactivated	0	See Table 13
Actuator status	Activated	0	See Table 13
Alarm status	Off	0	See Table 13
Alarm status	On	100	See Table 13 (severity configurable at provisioning time)
Alarm status	On	80	See Table 13 (severity configurable at provisioning time)
Alarm status	On	50	See Table 13 (severity configurable at provisioning time)
Alarm status	On	30	See Table 13 (severity configurable at provisioning time)

Alarm status	On	0	See Table 13 (severity configurable at provisioning time)
Availability level status	Normal	0	See Table 12
Availability level status	Low	100	See Table 12 (plant level)
Availability level status	Low	80	See Table 12 (inverter level)
Battery level status	Normal	0	See Table 18b
Battery level status	Low	60	See Table 18b
Battery level status	Very Low	100	See Table 18b
Buchholz relay status	Normal	0	See Table 9
Buchholz relay status	Alarm	50	See Table 9
Buchholz relay status	Tripped	100	See Table 9
CB command	Open	0	See Table 14
CB command	Close	0	See Table 14
CB command	No command	0	See Table 14
CB reset	No command	0	See Table 14
CB reset	Reset	0	See Table 14
Central wind sensor status	Normal	0	See Table 17
Central wind sensor status	Tripped	20	See Table 17
Charging status	Not Charging	0	See Table 18a
Charging status	Charging	30	See Table 18a
Circuit breaker spring charged status	Charged	0	See Table 14
Circuit breaker spring charged status	Not charged	80	See Table 14
Circuit breaker spring charged status	Communication error	50	See Table 14
Circuit breaker spring charged status	Malfunction	80	See Table 14
Circuit breaker status	Closed	0	See Table 14
Circuit breaker status	Open	100	See Table 14
Circuit breaker status	Unknown	30	See Table 14
Circuit breaker trip status	Normal	0	See Table 14
Circuit breaker trip status	Tripped	100	See Table 14
Communication status	Normal	0	See Table 15
Communication status	Error	50	See Table 15 (severity configurable at provisioning time)

Communication status	Error	30	See Table 15 (severity configurable at provisioning time)
Contactor status	Normal	0	See Table 14
Contactor status	Fault	60	See Table 14
Controller Status	Normal	0	See Table 16
Controller Status	Interrupted	50	See Table 16
Controller Status	Unavailable	100	See Table 16
Controller wind status	Normal	0	See Table 17
Controller wind status	High	20	See Table 17
Current imbalance status	Normal	0	See Table 8
Current imbalance status	High on one or more phases	30	See Table 8
Current status	Normal	0	See Table 2 and Table 6
Current status	Overcurrent	70	See Table 6
Current status	Overcurrent	100	See table 2
Current status	Short circuit	100	See table 2
Current status	Instantaneous overcurrent	30	See Table 6
Current status	Minor overcurrent	50	See Table 6
Current THD-R status	Normal	0	See Table 8
Current THD-R status	High on one or more phases or the neutral	30	See Table 8
DC box output current alarm	Normal	0	See Table 4.3
DC box output current alarm	Low	70	See Table 4.3
DC current status	Normal	0	See Table 2
DC current status	Overcurrent	100	See Table 2
DC injection status	Normal	0	See Table 8
DC injection status	High	30	See Table 8
DC input status	DC input ready	0	See Table 2
DC input status	DC input not ready	0	See Table 2
DC switch state	Closed	0	See Table 2
DC switch state	Open	100	See Table 2
DC voltage status	Normal	0	See Table 2
DC voltage status	Undervoltage	100	See Table 2
DC voltage status	Overvoltage	100	See Table 2
Discharging status	Not Discharging	0	See Table 18a
Discharging status	Discharging	60	See Table 18a

Door override status	Lock not overridden	0	See Table 11
Door override status	Lock overridden	30	See Table 11
Door status	Closed	0	See Table 11
Door status	Left Open	100	See Table 11
DSP fault status	Fault not present	0	See Table 2
DSP fault status	Fault present	100	See Table 2
Earth fault status	Not present	0	See Table 2
Earth fault status	Present	100	See Table 2
Earth fault status	Normal	0	See Table 6
Earth fault status	Instantaneous present	30	See Table 6
Earth fault status	High present	100	See Table 6
Earth fault status	Low present	50	See Table 6
East limit switch	Off	0	See Table 17
East limit switch	On	0	See Table 17
Emergency lock status	Off	0	See Table 11
Emergency lock status	On	60	See Table 11
Emergency stop	Normal	0	See Table 2
Emergency stop	Emergency Stop	100	See Table 2
Fan fault	Fans Operational	0	See Table 2
Fan fault	Fan Fault	100	See Table 2
Fire Status	Not on fire	0	See Table 11
Fire Status	On fire	100	See Table 11
Flood Status	Not flooded	0	See Table 11
Flood Status	Flooded	100	See Table 11
Frequency status	Frequency normal	0	See Table 5
Frequency status	Overfrequency	80	See Table 5
Frequency status	Underfrequency	80	See Table 5
Frequency status	Overfrequency or Underfrequency	80	See Table 5
Fuse status	Normal	0	See Table 14
Fuse status	Blown	100	See Table 14
Gas pressure status	Normal	0	See Table 9
Gas pressure status	High	80	See Table 9
Generic inverter fault	Fault not present	0	See Table 2
Generic inverter fault	Fault present	100	See Table 2
Generic transformer alarm status	Normal	0	See Table 9
Generic transformer alarm status	Present	50	See Table 9

Grid status	Grid ready	0	See Table 2
Grid status	Grid not ready	100	See Table 2
Indicator status	On	100	See Table 14 (severity configurable at provisioning time)
Indicator status	Off	0	See Table 14
Indicator status	Unknown	30	See Table 14
Indicator status	On	80	See Table 14 (severity configurable at provisioning time)
Indicator status	On	50	See Table 14 (severity configurable at provisioning time)
Indicator status	On	30	See Table 14 (severity configurable at provisioning time)
Indicator status	On	0	See Table 14 (severity configurable at provisioning time)
Inverter blocked status	Not Blocked	0	See Table 2
Inverter blocked status	Blocked	30	See Table 2
Inverter Door Status	Closed	0	See Table 2
Inverter Door Status	Open	100	See Table 2
Inverter fuse status	Closed	0	See Table 2
Inverter fuse status	Open	50	See Table 2
Inverter output status	Not Limited	0	See Table 2
Inverter output status	Limited	30	See Table 2
Inverter remote control status	Off	0	See Table 2
Inverter remote control status	On	30	See Table 2
Inverter selective block status	Not Blocked	0	See Table 2
Inverter selective block status	Blocked	30	See Table 2
Inverter Status	Unknown	80	See Table 1
Inverter Status	Normal	0	See Table 1
Inverter Status	Night shutdown	0	See Table 1
Inverter Status	Error	80	See Table 1
Inverter Status	Stopped	100	See Table 1

Inverter Status	Disturbance	80	See Table 1
Inverter Status	Communication Error	80	See Table 1
Inverter Status	Waiting	0	See Table 1
Inverter sync status	Synced	0	See Table 2
Inverter sync status	Not Synced	30	See Table 2
Inverter temperature status	Normal	0	See Table 2
Inverter temperature status	Overtemperature	60	See Table 2
Inverter voltage status	Normal	0	See Table 2
Inverter voltage status	High	60	See Table 2
Inverter voltage status	Low	60	See Table 2
Inverter warning status	Not Present	0	See Table 2
Inverter warning status	Present	50	See Table 2
Link Status	Online	0	See Table 16
Link Status	Offline	30	See Table 16
Load on mains status	Not Present	0	See Table 14
Load on mains status	Present	100	See Table 14
Local wind sensor status	Normal	0	See Table 17
Local wind sensor status	Tripped	20	See Table 17
Logical inverter fault	Fault not present	0	See Table 2
Logical inverter fault	Fault present	100	See Table 2
Magnetic oil gauge status	Normal	0	See Table 9
Magnetic oil gauge status	Alarm	100	See Table 9
Manual bypass status	Off	0	See Table 15
Manual bypass status	On	100	See Table 15
Manual Mode Status	Manual Mode Off	0	See Table 15
Manual Mode Status	Manual Mode On	30	See Table 15
Motor forward	No	0	See Table 17
Motor forward	Yes	0	See Table 17
Motor reverse	No	0	See Table 17
Motor reverse	Yes	0	See Table 17
Neutral current status	Normal	0	See Table 2
Neutral current status	Overcurrent	100	See Table 2
Neutral voltage displacement status	Not present	0	See Table 5
Neutral voltage displacement status	Present	80	See Table 5
Neutral voltage displacement status	Normal	0	See Table 5

Neutral voltage displacement status	Instantaneous present	30	See Table 5
Neutral voltage displacement status	High present	100	See Table 5
Neutral voltage displacement status	Low present	50	See Table 5
Occupancy Status	Not occupied	0	See Table 11
Occupancy Status	Occupied	30	See Table 11
Oil level status	Normal	0	See Table 9
Oil level status	Low	80	See Table 9
Oil temperature indicator status	Normal	0	See Table 9
Oil temperature indicator status	Alarm	100	See Table 9
Oil temperature indicator status	Trip	100	See Table 9
Oil temperature status	Normal	0	See Table 9
Oil temperature status	High	80	See Table 9
Oil temperature status	Very high	100	See Table 9
Operational error status	Normal	0	See Table 15
Operational error status	Not Operational	100	See Table 15
Operational Status	ok	0	See Table 15
Operational Status	Malfunction	100	See Table 15 (severity configurable at provisioning time)
Operational Status	Malfunction	50	See Table 15 (severity configurable at provisioning time)
Output frequency status	Normal	0	See Table 2
Output frequency status	Error	60	See Table 2
Output switch status	Close	0	See Table 2
Output switch status	Open	100	See Table 2
Output voltage status	Normal	0	See Table 2
Output voltage status	High	60	See Table 2
Output voltage status	Low	60	See Table 2
Performance Ratio status	Normal	0	See Table 12
Performance Ratio status	Low	50	See Table 12
Power factor status	Normal	0	See Table 8
Power factor status	Low	30	See Table 8
Power source	On AC Power	0	See Table 18a

Power source	On Battery	60	See Table 18a
Precipitation status	Normal	0	See Table 10
Precipitation status	High	100	See Table 10
Pressure relief valve indicator status	Normal	0	See Table 9
Pressure relief valve indicator status	Alarm	100	See Table 9
Pressure relief valve indicator status	Trip	100	See Table 9
Reactive Power	Regulation Off	0	See Table 2
Reactive Power	Regulation On	0	See Table 2
Reactive Power	Limitation Off	0	See Table 2
Reactive Power	Limitation On	0	See Table 2
Reactive power command response	Rejected	0	See Table 2
Reactive power command response	Accepted	0	See Table 2
Reclose switch status	On	0	See Table 14
Reclose switch status	Off	0	See Table 14
Remote control switch status	Local	0	See Table 2
Remote control switch status	Remote	0	See Table 2
ROCOF status	Normal	0	See Table 5
ROCOF status	High	80	See Table 5
Site Online in CMS	Y	0	See Table 16
Site Online in CMS	N	30	See Table 16
SMU availability level status	Normal	0	See Table 12
SMU availability level status	Low	80	See Table 12 (plant level)
SMU calibration status	Normal	0	See Table 4.1
SMU calibration status	Error	10	See Table 4.1
SMU fuse status	Normal	0	See Table 4.1
SMU fuse status	Blown	80	See Table 4.1
SMU overtemperature status	Normal	0	See Table 4.1
SMU overtemperature status	Overtemp	60	See Table 4.1
SMU self test status	Normal	0	See Table 4.1

SMU self test status	Failed	60	See Table 4.1
SMU status	Stopped	100	See Table 3
SMU status	Measuring	0	See Table 3
SMU status	Offset adjustement 1	0	See Table 4.1
SMU status	Offset adjustement 2	0	See Table 4.1
SMU status	Diagnostics	0	See Table 4.1
SMU status	Communication error	40	See Table 3
SMU status	Unknown	80	See Table 3
SMU status	Error	80	See Table 3
String availability level status	Normal	0	See Table 12
String availability level status	Low	90	See Table 12 (plant level)
String Current Abnormal	None	0	See Table 4.2
String Current Abnormal	Current Abnormal	50	See Table 4.2
String Current Alarm	None	0	See Table 4.2
String Current Alarm	Current Low	60	See Table 4.2
String currents unbalanced status	Normal	0	See Table 4.1
String currents unbalanced status	Unbalanced	30	See Table 4.1
String fault status	Normal	0	See Table 4.1
String fault status	Fault	30	See Table 4.1
String negative fuse status	Normal	0	See Table 4.1
String negative fuse status	Blown	80	See Table 4.1
String overcurrent status	Normal	0	See Table 4.1
String overcurrent status	Overcurrent	60	See Table 4.1
String overvoltage status	Normal	0	See Table 4.1
String overvoltage status	Overvoltage	60	See Table 4.1
String positive fuse status	Normal	0	See Table 4.1
String positive fuse status	Blown	80	See Table 4.1
Strings in fault status	Normal	0	See Table 4.1
Strings in fault status	Fault	30	See Table 4.1
Surge arrester status	Normal	0	See Table 14
Surge arrester status	Damaged	100	See Table 14
Switch status	Open	100	See Table 14 (severity configurable at provisioning time)
Switch status	Closed	0	See Table 14

Switch status	Unknown	30	See Table 14
Switch status	Open	80	See Table 14 (severity configurable at provisioning time)
Switch status	Open	50	See Table 14 (severity configurable at provisioning time)
Switch status	Open	30	See Table 14 (severity configurable at provisioning time)
Tracker at setpoint status	Yes	0	See Table 17
Tracker at setpoint status	No	10	See Table 17
Tracker control	Auto	0	See Table 17
Tracker control	Manual	0	See Table 17
Tracker controller status	On	0	See Table 17
Tracker controller status	Off	0	See Table 17
Tracker motor lock status	Yes	20	See Table 17
Tracker motor lock status	No	0	See Table 17
Tracker obstruction clearing mode status	No	0	See Table 17
Tracker obstruction clearing mode status	Yes	10	See Table 17
Tracker operation status	Auto	0	See Table 17
Tracker operation status	Manual	0	See Table 17
Trip relay status	Relay closed	0	See Table 7
Trip relay status	Relay tripped	100	See Table 7
Voltage status	Voltage normal	0	See Table 5
Voltage status	Overvoltage on one or more phases	80	See Table 5
Voltage status	Undervoltage on one or more phases	80	See Table 5
Voltage status	Instantaneous overvoltage	30	See Table 5
Voltage status	Minor overvoltage	50	See Table 5
Voltage status	Instantaneous undervoltage	30	See Table 5
Voltage status	Minor undervoltage	50	See Table 5
Wind Speed status	Normal	0	See Table 10
Wind Speed status	Hi	100	See Table 10
Wind stow timer counting down	No	0	See Table 17

Wind stow timer counting down	Yes	0	See Table 17
Winding temperature indicator status	Normal	0	See Table 9
Winding temperature indicator status	Alarm	100	See Table 9
Winding temperature indicator status	Trip	100	See Table 9
Winding temperature status	Normal	0	See Table 9
Winding temperature status	High	80	See Table 9
Winding temperature status	Very high	100	See Table 9