Australian Government
Australian Renewable Energy Agency

ARENA

Remote Australia's Renewables - Knowledge Sharing

Data Specification to Benefit Financial and Operational Yields

Prepared by CAT Projects

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1 CONTENTS

2 BACKGROUND

2.1 ARENA KNOWLEDGE SHARING

Effective knowledge sharing is central to ARENA achieving its objectives of improving the competitiveness and increasing the supply of renewable energy in Australia.

To assist ARENA with its Knowledge Sharing activities, particularly with respect to development of aggregate program assessments, these requirements and specifications are to be incorporated into Knowledge Sharing Plans.

The specifications set out in this document and accompanying spreadsheet to fill in are aimed at describing the minimum standard to reach. The data requirements are intended to reflect current best business practices in renewable energy sectors, and benefit both project proponents and ARENA alike.

Assuming that the data measurements are properly implemented, project proponents gain valuable data for insights into:

- Performance assessment: does the technology perform as expected or modelled?
- Yield protection via monitoring: system down-times and associated losses can be minimised.
- Warranty claims, for such cases of e.g. photovoltaic (PV) module degradation to integration issues.
- Operation & Maintenance, including scheduling and repairs.
- Financial decisions, such as project valuation and potential sale in the future: high-quality datasets of system performance allow a correct value to be placed on a system, or anticipate future investments.

ARENA can compare existing and future projects on value, cost and reliability, while additionally providing the market with anonymised or aggregated data. Potential projects can thus be benchmarked and be informed by ARENA-supported projects, leading to lower costs, or higher value obtained for stakeholders. Previous experience by ARENA and similar agencies worldwide has shown the positive and rapid impact of anonymized or aggregated data sharing to project proponents and key stakeholders.

In the case of photovoltaic systems, measurement of plane-of-array (POA) irradiance data is necessary for proper performance assessment and monitoring: it is used to calculate the Performance Ratio (PR), a key metric to analyse and compare PV system performance. POA irradiance data is of importance to both fixed and tracking PV systems. While not obligatory, an additional, spectrally matched reference cell for POA measurements is recommended.

Horizontal irradiance data is necessary for comparison with long-term data from satellite or similar established data sets, and is used for financial considerations. Together with weather data, ambient temperature, wind speed and direction, PV systems can be monitored to ensure that the actual yield matches the expected yield. Best practices for photovoltaic systems are highlighted further in the IEA PVPS Report Analytical Monitoring of Photovoltaic Systems.

Critically, the cost of long-term under-performance or lost power production far exceeds the cost of high-quality monitoring systems, particularly as effects compound over time. In this regard, it is recommended to opt for continuous data measurements and monitoring at the highest achievable rates and best measurement uncertainty[1] to ensure that the renewable energy technology delivers the expected return on investment.

2.2 USE OF DATA SPECIFICATION

These data specifications form ARENA's minimum requirements for data collection and reporting.

Where a specified parameter is not relevant, it is not required to be reported. However, if a specific data stream is required, it must be provided in accordance with this specification. Each project proponent will be provided with a list of required data streams relevant to their own project.

Unless otherwise noted, all data collection, storage and transmission requirements and specifications shall be regarded as mandatory as part of the project's funding agreement. Recipients with pre-existing funding agreements will be requested to revise their knowledge sharing plan to maximise consistency with this data specification.

[1] Best (or lowest) measurement uncertainty is also described as highest accuracy, although these concepts are **not** equivalent. The ISO/BIPM **GUM: Guide to the Expression of Uncertainty in Measurement** is the standard document to be adhered to.

3 STATIC PROJECT DATA

Section 3 parameters to be reported after project commissioning.

3.1 PROJECT AND TECHNICAL

Section	Description	Descriptor	Unit
Project Timeline	Date ARENA contract signed		
	Date finance contract signed		
	Date PPA signed		
	Date of commencement of construction		
	Initial scheduled date of practical completion		
	Actual date of practical completion		
	Commissioning date		
	Date of commencement of normal operation		
	End date of defects liability period		
PV System	PV array latitude		° (±DDD.ddd)
	PV array longitude		° (±DDD.ddd)
	PV array rated installed peak capacity (DC)	$P_{PV,DC}$	kW
	PV array total area (module area only)	A_{PV}	m^2
	PV array orientation from True North		° West or East of North, e.g. 15°W
	PV array tilt angle above horizontal	β_{PV}	°
	PV array fixed or tracking		Fixed, Single Axis (horizontal), Single axis (tilted), Dual Axis
	PV array rated open circuit voltage	$V_{OC,array}$	V
	PV array rated short circuit current	$I_{SC,array}$	A
	Quantity of modules		
	Module manufacturer		
	Module model		
	Module nominal/rated power at STC	P_{module}	W
	Quantity of modules per string		
	Quantity of strings per inverter		
	Inverter continuous rated output power (AC)	P_{inv}	kW
	Quantity of inverters		
	Total inverter continuous rated output (AC)	$P_{inv,total}$	kW
	Inverter manufacturer		
	Inverter model		
	Required attachments:	• PV module datasheets • Inverter datasheets	
Wind Power System	Wind farm latitude		° (±DDD.ddd)
	Wind farm longitude		° (±DDD.ddd)
	Wind farm total rated output	P_{wind}	kW
	Quantity of wind turbines		
	Wind turbine rated power	$P_{turbine}$	kW
	Wind turbine hub height	$h_{turbine}$	M
	Wind turbine manufacturer		
	Wind turbine model		
	Required attachments	• Wind turbine datasheets • Wind turbine power vs wind speed curves	

Section	Description	Descriptor	Unit
Storage system	Total storage capacity	E_{stor}	kWh
	Total storage capacity (C_{20}) at 20h discharge rate	C_{stor}	Ah or kWh
	Total storage capacity (C_X) at Xh effective discharge rate (specify X) – if X is different from 20 h.	C_{stor}	Ah or kWh
	Total usable/available storage	$E_{stor,avail}$	kWh
	Total usable/available storage (C_{20}) at 20 h discharge rate	$C_{stor,avail}$	Ah or kWh
	Total usable/available storage(C_X) at Xh effective discharge rate (specify X) – if X is different from 20 h.	$C_{stor,avail}$	Ah or kWh
	Storage technology		E.g.: Lead-acid, flywheel etc
	Storage manufacturer		
	Storage model		
	Rated output power (AC)	$P_{stor,out}$	kW
	Rated input power (AC)	$P_{stor,in}$	kW
	Design average daily depth of discharge	DOD_{daily}	%
	Max allowable depth of discharge	DOD_{max}	%
	Required attachments:	• Storage system datasheets • Storage system inverter datasheets • Storage system cycle life / DOD curves	
Demand and load management system	Demand and load management technology		E.g. pumps, hot water storage, controllable loads
	Demand and load management system manufacturer / supplier		
	Rated power of individual technology	$P_{dem,nom}$	kW
	Rated power consumption increase	$P_{dem,inc}$	kW
	Rated power consumption decrease	$P_{dem,dec}$	kW
	System response characteristic: duration of typical use		s or min
	System response characteristic: ramp rate (time between 10 % and 90 % of rated power)		ms or s
	Required attachments:	• Demand and load management system datasheet or description if no datasheet available • Individual demand/load management unit datasheet	
Non-renewable generation system	Total generator rated output	$P_{gen,total}$	kVA, alternator rating OR kW/MW prime power
	Estimated annual fossil fuel consumption before ARENA funded project		GJ/year, (specify diesel, gas or grid)
	Required attachments:	Schedule of gensets including: • Individual genset identifiers as used in data collection • Individual genset rated outputs • Individual genset standard operating regime (prime, baseload, backup or specify) • Individual genset manufacturer name and model details • Individual genset fuel consumption ratings • Individual genset datasheets	

Section	Description	Descriptor	Unit
Meteorological monitoring system	UTC Offset		±hh:mm
	Pyranometer manufacturer(s)		
	Horizontal pyranometer model		
	Plane-of-array pyranometer model		
	Plane-of-array pyranometer tilt angle	$\beta_{pyranometer}$	°
	Pyrheliometer manufacturer		
	Pyrheliometer model		
	Anemometer manufacturer		
	Anemometer model		
	Anemometer height	$h_{anemometer}$	m
	Wind vane manufacturer		
	Wind vane model		
	Wind vane height	$h_{windvane}$	m
	Hygrometer manufacturer		
	Hygrometer model		
	Rain gauge manufacturer		
	Rain gauge model		
	Temperature sensor manufacturer		
	Temperature sensor model		
	Temperature sensor location		E.g.: Ambient, Cell, Manifold etc
	Required attachments:	• Pyranometer data sheet • Pyrheliometer data sheet • Anemometer data sheet • Wind vane data sheet • Hygrometer data sheet • Rain gauge data sheet • Temp sensor data sheet	

3.2 CAPITAL EXPENDITURE AND FINANCE

3.2.1 CAPITAL EXPENDITURE

Note that itemised breakdown costs are the purchased costs from the supplier's site in Australia, this does not include the costs of freight to the project site, this is separately listed in Other: Transport. If equipment/products are sourced directly from an overseas supplier, costs are to be "landed". i.e. including import duties/taxes/fees, holding/handling fees and international freight. Where sub-contract pricing does not breakdown the prices exactly as documented, use best endeavours to establish breakdowns.

Section	Description	Inclusions / exclusions	Cost (Ex GST)
Total Project	Actual total project cost (as at practical completion)		
PV System	PV modules	Ex: delivery/freight	
	Framing / structural / footings	Ex: delivery/freight	
	Civil works / site preparation		
	Inverters	Ex: delivery/freight	
	Balance of system	Ex: delivery/freight	
	Knowledge sharing implementation equipment (e.g. metering)	Ex: delivery/freight	
	Labour		
	Total		
Wind Power System	Wind turbines (including towers)	Ex: delivery/freight	
	Civil works / site preparation		
	SCADA / control system	Ex: delivery/freight	
	Balance of system	Ex: delivery/freight	
	Knowledge sharing specific equipment (e.g. metering)	Ex: delivery/freight	
	Labour		
	Total		
Storage System	Storage units (e.g. batteries, flywheel, fuel cells, DUPS)	Ex: delivery/freight	
	Structural / housing	Ex: delivery/freight	
	Inverters / conversion equipment	Ex: delivery/freight	
	SCADA / control system	Ex: delivery/freight	
	Balance of system	Ex: delivery/freight	
	Knowledge sharing specific equipment (e.g. metering)	Ex: delivery/freight	
	Labour		
	Total		
Demand and load management system	Demand and load units (e.g. resistors, hot water storage, …)	Ex: delivery/freight	
	Civil works		
	Structural / housing	Ex: delivery/freight	
	SCADA / control system	Ex: delivery/freight	
	Balance of system	Ex: delivery/freight	
	Knowledge sharing specific equipment (e.g. metering)	Ex: delivery/freight	
	Labour		
	Other	Ex: delivery/freight	
	Total		

Section	Description	Inclusions / exclusions	Cost (Ex GST)
Non-renewable Generation System	Generation units (e.g. diesel gensets, gas turbines) including auxiliary components (e.g. exhaust, cooling etc)	Ex: delivery/freight	
	Fuel storage / infrastructure	Ex: delivery/freight	
	Civil / structural housing		
	SCADA / control system	Ex: delivery/freight	
	Balance of system	Ex: delivery/freight	
	Knowledge sharing specific equipment (e.g. metering)	Ex: delivery/freight	
	Labour		
	Grid Connection inc HV Cabling, switchrooms, Substation connection, Transformers		
	Total		
Other items	Meteorological instrumentation and logging equipment including labour	Ex: delivery/freight	
	Site acquisition costs		
	Legal costs		
	Financing costs – inc external finance advisors, establishment fees etc		
	Approvals costs – Development applications, environmental assessments, planning permits		
	Grid-connection costs – Application fees, connection fees		
	Mobilisation		
	Transport (freight)		
	Insurance costs – pre-operational stages		
	Engineering		
	Other		
	Total		

3.2.2 FINANCE AND OTHER DETAILS

These details are intended to be utilised to incorporate into standard financial models established by ARENA.

Section	Description	Inclusions / exclusions	Unit
Post Financial Close Finance Details	Debt / equity ratio		
	Value of other grants (e.g. R&D Tax Credit, State government grants, etc)		$ Ex GST
	Discount rate (if not Weighted Average Cost of Capital)		% pa
	Equity Net Present Value		$ Ex GST
	Cost of finance	Include notes on any linkages to Bank Bill Swap Rates and Margin	% pa
	Debt Tenor		years
	Debt Amortisation		years
	Cost of equity		% pa
	Contracted price per unit of electricity supplied		$ Ex GST / MWh
	Levelized Cost of Electricity (LCOE)		$ Ex GST / MWh
	Contracted Electricity Volume (year 1)	Include notes on maximum quantity if appropriate	MWh
	Assumed degradation	Include notes if assumed year 1 degradation is different to later years	% pa
	Electricity price indexation		% pa
	Assumed inflation		% pa
	Forecast O&M costs		$ Ex GST pa
	Forecast average delivered diesel/gas cost in year 1 (after Fuel Tax Credit)		$ Ex GST per litre (per GJ for gas)
	Insurance		$ Ex GST pa
	Diesel/gas maintenance costs		$ Ex GST pa
	Project lifetime		years
	PPA/Lease contract period		years
Procurement/ Construction Contract outcomes	Number of tenders received for primary contract(s)		
	Average price of tenders for primary contract(s)		
	Price of selected tenderer(s) for primary contract		
	Difference between pre tender estimate and awarded price		
	Total variations to contract during construction period		
	Contractor requested variations during construction period		
	Contingency amounts used (include justifications)		

4 OPERATION AND MAINTENANCE

4.1 QUARTERLY O&M REPORTING

Section 4 parameters are to be provided on a quarterly basis for at least two years following the commencement of operation of the project. Where data is collected monthly, the monthly data is to be provided separately in the quarterly reporting.

Section	Description	Inclusions / exclusions	Cost (ex GST)	Notes
Total	Actual Total O&M cost			
PV System	Equipment replacements	Ex: delivery/freight		
	Scheduled maintenance			
	Unscheduled maintenance			Non-planned, irregular maintenance, unrelated to contract defects
	Transport, mobilisation			
	Labour			
	Consumables	Ex: delivery/freight		
	Other			
Wind Power System	Equipment replacements	Ex: delivery/freight		
	Scheduled maintenance			
	Unscheduled maintenance			Non-planned, irregular maintenance, unrelated to contract defects
	Transport, mobilisation			
	Labour			
	Consumables	Ex: delivery/freight		
	Other			

Section	Description	Inclusions / exclusions	Cost (ex GST)	Notes
Storage System	Equipment replacements	Ex: delivery/freight		
	Scheduled maintenance			
	Unscheduled maintenance			Non-planned, irregular maintenance, unrelated to contract defects
	Transport, mobilisation			
	Labour			
	Consumables	Ex: delivery/freight		
	Other			
Demand and load management system	Equipment replacements	Ex: delivery/freight		
	Scheduled maintenance			
	Unscheduled maintenance			Non-planned, irregular maintenance, unrelated to contract defects
	Transport, mobilisation			
	Labour			
	Consumables	Ex: delivery/freight		
	Other			
Non-renewable Generation System	Equipment replacements	Ex: delivery/freight		
	Scheduled maintenance			
	Unscheduled maintenance			Non-planned, irregular maintenance, unrelated to contract defects
	Transport, mobilisation			
	Labour			
	Consumables	Ex: delivery/freight		
	Other			
Other items	Equipment replacements	Ex: delivery/freight		
	Scheduled maintenance			
	Unscheduled maintenance			Non-planned, irregular maintenance, unrelated to contract defects
	Transport, mobilisation			
	Labour			
	Consumables	Ex: delivery/freight		
	Insurance			
	Lease of land			
	Other			

5 TIME SERIES DATA

Section 5 parameters are required to be reported monthly for at least two years from commissioning.

Time-series data provides a detailed insight into the technical operation of a project to allow analysis of operational trends over time, snapshots of critical system events, as well as the ability to compare the performance and operation of more than one project against a common benchmark.

The ability to synchronise multiple data sets is essential to the efficient analysis of time-series data, therefore, it is extremely important to ensure all time-series data is recorded in accordance with the data specification, with particular care taken when configuring data collection systems.

5.1 MONITORING HARDWARE AND EQUIPMENT

5.1.1 SENSORS, TRANSDUCERS AND OTHER INSTRUMENTS

To ensure good quality data, it is imperative that all measurement, monitoring, logging and transmission equipment is of sufficient accuracy and quality.

Generally speaking, revenue grade metering and meteorological grade instruments should be used where possible. Specific accuracy class ratings for individual parameters are given in section 5.3.

5.2 DATA AND FILE FORMATS

5.2.1 DATA RECORDING FREQUENCIES

All data shall be sampled at 1 second intervals* and for the purpose of logging the samples shall be averaged over one of the following specified time periods, as agreed with ARENA:

- Low resolution: data averaged over 60 minute periods.
- Medium resolution: data averaged over 15 minute periods.
- High resolution: data averaged over 5 second periods.

Recorded data values shall be given the time stamp representing the final sample of the specified period

i.e. the medium resolution (15 minute) data point with the time stamp 12:15:00 represents the average of 900 samples measured between 12:00:01 and 12:15:00 inclusive. Similarly, the total or cumulative value is to be calculated per fixed time window.

Note that parameters are not expected to be provided at both low and high resolution. ARENA will advise which parameters are required and their respective resolution – this will vary between projects.

* One second sampling may be impractical for some parameters such as fuel consumption, rainfall and humidity. However, to help data collection, sampling data for all sources at the same frequency is recommended.

* Sub-second sampling may be required for some parameters such as frequency measurements to determine grid stability.

For novel applications and technologies, data must be measured and delivered to ARENA to demonstrate the value of these. For example, if a technology is described to deliver grid stability services, then data at the necessary resolution and frequency must be made available to verify that the technology delivers the expected value. For such cases, very high frequency data (e.g. at sub-second rates) for certain events may be required. Per best business practices, measurements at high frequencies should already be in place for these cases, such as grid stability, with the requirement therefore to select already measured data to demonstrate system functionality.

5.2.2 TIME STAMPS

Time stamps shall be in 24h format UTC with no offset for time zone or daylight savings. Time offset information to be contained in the Static Project Definition Data.

Time stamps shall be in the **AS ISO 8601-2007** standard time format (or the latest version of the standard), expressed as **UTC time** with the time zone offset from UTC indicated:
YYYY-MM-DDThh:mm:ss+hh:mm (e.g. 2016-11-16T**06**:20:35+**11**:00 is data point measured on 16 November 2016, at 19h20m35 seconds local time, in the Australian Capital Territory. The UTC offset can thus distinguish between this measurement which observes Daylight Saving Time and that from a project in Queensland, where the recorded time would be 2016-11-16T**07**:20:35+**10**:00). An extra time stamp field (column) for local time is acceptable; it is strongly recommended to have this conform to ISO 8601.

For projects with data collection already in place, the following format is acceptable: YYYY/MM/DD hh:mm:ss [24hrs].

All logging equipment shall be synchronised to a Network Time Protocol (NTP) or GPS time source, the suggested time source is: http://www.pool.ntp.org/zone/au

Time stamps shall be applied to data as close to the time of the event as possible. The timestamps of all concurrent data points shall be synchronised using NTP within 2 seconds.

Time series shall be contiguous with no gaps, regardless of the presence or absence of data values.

In the event of missing data values, time stamps shall be stored with empty space; or the "." (decimal point) character in place of the missing values.

5.2.3 FILE FORMATTING AND NAMING

All data shall be stored in CSV format with comma delimiting.

All data of the same time series shall be stored in single CSV files with data headers in the top row as detailed in Section 5.3

Data shall be dispatched in batches of data per quarter, with a single CSV file for each month. Filename convention as follows:

[PROJECT NUMBER]_[PROJECT NAME]_[YYYY-MM]_[DATA FREQUENCY].csv
E.G.: A00597_JUWI_201408_HIRES.csv

Where:
PROJECT NUMBER = the ARENA assigned project number
PROJECT NAME = the ARENA designated project name
YYMM = the year and month of the data contained in the file
DATA FREQUENCY = one of the following options (see 5.2.1):

- LOWRES = Low resolution, 60 minute averages
- MEDRES = Medium resolution, 15 minute averages
- HIRES = High resolution, 5 second averages

5.3 TECHNICAL DATA REQUIREMENTS

Range is understood as nominal range. E.g. for a Current Transformer, 50A/5A with 30 % safety margin, the range is 50A. Similarly, for irradiance: 1000 W/m² is standard, with peak values known to reach 1600 W/m² or more. If measurements are performed on high-voltage or high-power equivalents, use percentage of range. Acceptable resolution is permitted as an exception to the rule, and to be confirmed on a case-by-case basis.

Source	Datum	Unit	Header name	Resolution		Min. Accuracy/ standard	Point of measurement	Notes
				Recommended	Acceptable			
PV System	AC Output Real Power	kW	Ppv_kW	0.1 kW OR ≤ 1% of range	≤ 2% of range	NMI Class 0.5*	Inverter output AC bus before grid connection transformer	
	AC Output Reactive Power	kvar	Qpv_kvar	0.1 kvar OR ≤ 1% of range	≤ 2% of range	NMI Class 0.5*		
	Power Factor	none	PFpv	0.001 OR ≤ 0.1% of range	≤ 0.5 % of range	NMI Class 0.5*		Must include sign: + lead, - lag
	AC Output Current	A	Ipv_A	1 A OR ≤ 0.5 % of range	≤ 1% of range	NMI Class 0.5*		
	AC Output Frequency	Hz	fpv_Hz	0.1 Hz (≤ 0.25 %)	≤ 0.50 %	NMI Class 0.5*		
	AC output Total Harmonic Distortion	%	THDpv_%	0.1%	≤ 0.50 %	NMI Class 0.5*		
	Cumulative AC output Energy	kWh	Epv_kWh	0.1 kWh OR ≤ 0.05 % of hourly total	≤ 0.2% of hourly total	NMI Class 0.5*		
	PV plant availability	min	Avail_PV_min	1 min	1 min	N/A		System able to generate power
Wind System	AC Output Real Power	kW	Pwind_kW	0.1 kW OR ≤ 1% of range	≤ 2% of range	NMI Class 0.5*	Wind farm side of mains connection transformer	
	AC Output Reactive Power	kvar	Qwind_kvar	0.1 kvar OR ≤ 1% of range	≤ 2% of range	NMI Class 0.5*		
	Power Factor	none	PFwind	0.001 OR ≤ 0.1% of range	≤ 1% of range,	NMI Class 0.5*		Must include sign: + lead, - lag
	AC Output Current	A	Iwind_A	1 A OR ≤ 0.5 % of range	≤ 2% of range	NMI Class 0.5*		
	AC Output Frequency	Hz	fwind_Hz	0.1 Hz	≤ 0.2 Hz	NMI Class 0.5*		
	AC output Total Harmonic Distortion	%	THDwind_%	0.1%	≤ 0.50 %	NMI Class 0.5*		
	Cumulative AC output Energy	kWh	Ewind_kWh	0.1 kWh OR ≤ 0.05 % of hourly total	≤ 0.2% of hourly total	NMI Class 0.5*		
	Wind system availability	min	Avail_wind_ min	1 min	1 min	N/A		System able to generate power

*Or approved equivalent.

Source	Datum	Unit	Header name	Resolution		Min. Accuracy/ standard	Point of measurement	Notes
				Recommended	Acceptable			
Battery / Storage System	Net AC Real Power	kW	Pstor_kW	0.1 kW OR ≤ 1% of range	≤ 2% of range	NMI Class 0.5*	AC Output bus of conversion equipment	Must include sign for direction of power flow: + out of storage, - into storage
	AC Net Reactive Power	kvar	Qstor_kvar	0.1 kvar OR ≤ 1% of range	≤ 2% of range	NMI Class 0.5*		Must include sign for direction of power flow: + out of storage, - into storage
	Power Factor	none	PFstor	0.001 OR ≤ 0.1% of range	≤ 1% of range,	NMI Class 0.5*		Must include sign: + lead, - lag
	AC Net Current	A	Istor_A	1 A OR ≤ 0.5 % of range	≤ 2% of range	NMI Class 0.5*		Must include sign for direction of power flow: + out of storage, - into storage
	AC Frequency	Hz	fstor_Hz	0.1 Hz	≤ 0.2 Hz	NMI Class 0.5*		
	AC Total Harmonic Distortion	%	THDstor_%	0.1 %	≤ 0.50 %	NMI Class 0.5*		
	State of Charge	%	SOCstor_%	0.1 %	0.50 % of range	N/A		As most systems can only estimate this value, the calculated value for the system is acceptable. Sampling rate to be determined as appropriate to the system.
	Cumulative AC Energy Delivered (out)	kWh	Estorout_kWh	0.1 kWh OR ≤ 0.05 % of hourly total	≤ 0.2% of hourly total	NMI Class 0.5*		
	Cumulative AC Energy Absorbed (in)	kWh	Estorin_kWh	0.1 kWh OR ≤ 0.05 % of hourly total	≤ 0.2% of hourly total	NMI Class 0.5*		All values to be denoted with a negative sign
	Battery system availability	Min	Avail_bat_min	1 min	1 min	NA		

*Or approved equivalent.

Source	Datum	Unit	Header name	Resolution		Min. Accuracy/ standard	Point of measurement	Notes
				Recommended	Acceptable			
Demand management / load unit/s˜	AC Real Power Demand Increase	kW	Pdemincx_kW	0.1 kW OR ≤ 1% of range	≤ 2 % of range	NMI Class 0.5*	Individual unit isolation or connection point.	Units which are turned on / increase power consumption.
	AC Real Power Demand Decrease	kW	Pdemdecx_kW	0.1 kW OR ≤ 1 % of range	≤ 2 % of range	NMI Class 0.5*		Units which are turned off / decrease power consumption. Must include sign: -
	AC Reactive Power Demand Increase	kvar	Qdemincx_kvar	0.1 kvar OR ≤ 1 % of range	≤ 2 % of range	NMI Class 0.5*		
	AC Reactive Power Demand Decrease	kvar	Qdemdecx_kvar	0.1 kvar OR ≤ 1 % of range	≤ 2 % of range	NMI Class 0.5*		Must include sign: -
	Cumulative Run Time Increased Power Demand	h	Tdemincx_h	1 s	1 min	N/A		
	Cumulative Run Time Decreased Power Demand	h	Tdemdecx_h	1 s	1 min	N/A		
	Cumulative Increased Energy Demand Consumption	kWh	Edemincx_h	0.1 kWh OR ≤ 0.05 % of hourly total	≤ 0.2 % of hourly total	NMI Class 0.5*		
	Cumulative Decreased Energy Demand Consumption	kWh	Edemdecx_h	0.1 kWh OR ≤ 0.05 % of hourly total	≤ 0.2 % of hourly total	NMI Class 0.5*		Must include sign: -
	Demand system availability	min	Avail_demx_min	1 min	1 min	N/A		

˜Where x is unit identifier for sites with multiple demand management / load management units.

*Or approved equivalent.

Source	Datum	Unit	Header name	Resolution		Min. Accuracy/ standard	Point of measurement	Notes
				Recommended	Acceptable			
Generator/s˜	AC Output Real Power	kW	Pgenx_kW	0.1 kW OR ≤ 1 % of range	≤ 2 % of range	NMI Class 0.5*	Individual genset isolation point.	
	AC Output Reactive Power	kvar	Qgenx_kvar	0.1 kvar OR ≤ 1 % of range	≤ 2 % of range	NMI Class 0.5*		
	Power Factor	none	PFgenx	0.001 OR ≤ 0.1 % of range	≤ 1 % of range	NMI Class 0.5*		Must include sign: + lead, - lag
	AC Output Current	A	Igenx_A	1 A OR ≤ 0.5 % of range	≤ 1 % of range	NMI Class 0.5*		
	AC Output Frequency	Hz	fgenx_Hz	0.1 Hz	≤ 0.2 Hz	NMI Class 0.5*		
	AC output Total Harmonic Distortion	%	THDgenx_%	0.1 %	≤ 0.50 %	NMI Class 0.5*		
	Cumulative Fuel Consumption	l	Fuelgenx_l	0.1 l	≤ 1 l, ≤ 2 l if needed	N/A	Individual genset controller	
	Cumulative Run Time	h	Tgenx_h	1 min	1 min	N/A		
	Cumulative Output Energy	kWh	Egenx_kWh	0.1 kWh OR ≤ 0.05 % of hourly total	≤ 0.2 % of hourly total	NMI Class 0.5*	Individual genset isolation point.	
	Generator availability	min	Avail_genx_min	1 min	1 min			

˜Where x is generator identifier for sites with multiple gensets.

*Or approved equivalent.

Source	Datum	Unit	Header name	Resolution		Min. Accuracy/ standard	Point of measurement	Notes
				Recommended	Acceptable			
Load / Grid	Real Power	kW	Pload_kW	0.1 kW OR ≤ 1% of range	≤ 2 % of range	NMI Class 0.5*	Grid side of main isolation point of renewable energy generation system.	
	Reactive Power	kvar	Qload_kvar	0.1 kvar OR ≤ 1% of range	≤ 2% of range	NMI Class 0.5*		
	Power Factor	none	PFload	0.001 OR ≤ 0.1% of range	≤ 1% of range,	NMI Class 0.5*		Must include sign: + lead, - lag
	Voltage (Line-Line)	V	Vloadab_V Vloadac_V Vloadbc_V	1 V OR ≤ 0. 50 % of range	3 V OR ≤ 0.75 % of range	NMI Class 0.5*		Phase A-B Phase A-C Phase B-C
	Voltage (Line-Neutral)	V	Vloadan_V Vloadbn_V Vloadcn_V	1 V OR ≤ 0. 75 % of range	3 V OR ≤ 1.50 % of range	NMI Class 0.5*		Phase A Phase B Phase C
	Current (Phase)	A	Iloada_A Iloadb_A Iloadc_A	1 A OR ≤ 0. 50 % of range	3 A OR ≤ 1.50 % of range	NMI Class 0.5*		Phase A Phase B Phase C
	Frequency	Hz	fload_Hz	0.1 Hz	≤ 0.2 Hz	NMI Class 0.5*		
	Total harmonic distortion	%	THDload_%	0.1%	≤ 0.50 %	NMI Class 0.5*		
	Cumulative Energy delivered to loads	kWh	Eload_kWh	0.1 kWh OR ≤ 0.05 % of hourly total	≤ 0.2% of hourly total	NMI Class 0.5*		
	Total system availability	Min	Avail_grid_min	1 min	1 min	N/A		

*Or approved equivalent.

Source	Datum	Unit	Header name	Resolution		Min. Accuracy/ standard	Point of measurement	Notes
				Recommended	Acceptable			
Meteorological	Global Irradiance Plane of Array	W/m²	Ggpoa_W/m2	0.1 W/m²	10 W/m² OR ≤ 1% of range	WMO Class 1*	PV array common reference location	
	Direct Normal Irradiance	W/m²	Gdni_W/m2	0.1 W/m²	10 W/m² OR ≤ 1% of range	WMO Class 1*	PV array common reference location	
	Global Horizontal Irradiance	W/m²	Gghi_W/m2	0.1 W/m²	10 W/m² OR ≤ 1% of range	WMO Class 1*	PV array common reference location	
	Diffuse Horizontal Irradiance	W/m²	Gdhi_W/m2	0.1 W/m²	10 W/m² OR ≤ 1% of range	WMO Class 1*	PV array common reference location	
	Wind Speed	m/s	vwind_m/s[xm]	0.1 m/s	0.25 m/s	0.5m/s for WS<5m/s ±10 % for WS>5m/s	Representative of generation location Representative of generation location (collocated with anemometer)	If wind speed measurements are taken at more than one height, x denotes the height of the relevant anemometer.
	Wind Direction	°East of North	dwind_deg	0.1°	1°	N/A		
	Ambient Temperature	°C	Tamb_degC	0.1 °C	1 °C	N/A	Representative of generation location	
	PV Cell Temperature	°C	Tcell_degC	0.1 °C	1 °C	N/A	PV array common reference location	
	Rainfall	mm	Rain_mm	0.1 mm	1 mm	N/A	PV array common reference location	
	Relative Humidity	%	Hum_%	0.1 %	1 %	N/A	PV array common reference location	
	Meteo system availability	min	Avail_meteo_min	1 min	1 min		Data logging system / computer	

*Or approved equivalent.

5.4 DATA DEFINITIONS

AC net current (A)
Net current in amperes flowing at the output of the storage system, (current delivered to loads minus current supplied to storage system). This is measured as the sum of all three phases in a three-phase system.

AC net reactive power (kvar)
Net reactive power in kilovolt-amperes reactive flowing at the output of the storage system, (reactive power delivered to loads minus reactive power supplied to storage system). This is measured as the sum of all three phases in a three-phase system

AC net real power (kW)
Net real power in kilowatts measured at the output of the storage system (power delivered to loads minus power supplied to storage system). This is measured as the sum of all three phases in a three-phase system.

AC real power demand decrease (kW)
The decrease in AC apparent power demand in kilowatts, due to a demand management or load management unit turning off, or decreasing its power consumption. Examples are pumps which are turned off to lower total load. This is measured at the point of connection of the unit.

AC real power demand increase (kW)
The increase in AC apparent power demand in kilowatts, due to a demand management or load management unit turning on, or increasing its power consumption. Examples are resistors which are turned on to increase total load, e.g. to prevent generator under-loading, or hot-water heaters which are turned on at moments of excess renewable power. This is measured at the point of connection of the unit.

AC output apparent power (kVA)
The total apparent AC power in kilovolt-amperes, measured at the output of the generation system. This is measured as the sum of all three phases in a three-phase system.

AC output Current (A)
The total AC current in amperes, measured at the output of the generation system. This is measured as the sum of all three phases in a three-phase system.

AC output frequency (Hz)
The frequency of the AC voltage in hertz, measured at the output of the generation system.

AC output reactive power (kvar)
The total reactive power in kilovolt-amperes reactive, measured at the output of the generation system. This is measured as the sum of all three phases in a three-phase system.

AC output real power (kW)
The total real AC power in kilowatts, measured at the output of the generation system. This is measured as the sum of all three phases in a three-phase system.

AC output total harmonic distortion (%)
The total harmonic distortion of the AC power, measured at the output of the generation system. This is measured as the average of all three phases in a three-phase system.

Ambient temperature (°C)
The ambient temperature measured at the location of the generation system.

Cumulative AC energy absorbed (kWh)
The cumulative total of all energy in kilowatt-hours supplied to the storage system (charging). This is measured as the sum of all three phases in a three-phase system.

Cumulative AC energy delivered (kWh)
The cumulative total of all energy in kilowatt-hours delivered to loads from the storage system (discharging). This is measured as the sum of all three phases in a three-phase system.

Cumulative AC output energy (kWh)
The cumulative total of all energy generated since commissioning in kilowatt-hours, measured at the output of the generation system. This is measured as the sum of all three phases in a three-phase system.

Cumulative energy delivered into loads (kWh)
The cumulative total energy supplied to the load. This may be measured at multiple points depending on the topology of the generation system. This is measured as the sum of all three phases in a three-phase system.

Cumulative fuel consumption (litres)
The cumulative total volume of fuel consumed in litres since commissioning.
Cumulative run time (h)
The cumulative total time generation system is running and generating electricity.

Current (phase) (A)
The total current measured on each phase of the three-phase load. This is a total value that may be measured at multiple points depending on the topology of the generation system.

Diffuse horizontal irradiance (W/m^2)
Total diffuse solar irradiance measured on a horizontal plane, this excludes the direct component of sunlight and is usually measured using a pyranometer with a shadow ring or tracking shadow device that blocks the direct component of the sunlight.

Direct normal irradiance (W/m^2)
Solar radiation falling directly onto a surface normal to the sun, with the diffuse radiation excluded. This is usually measured using a pyrheliometer that tracks the sun.

Global Horizontal irradiance (W/m^2)
Total direct and diffuse solar irradiance measured on a horizontal plane. This is usually measured using a pyranometer.

Global irradiance – plane of array (W/m^2)
Total direct and diffuse solar irradiance measured at the same plane as the PV array. This is usually measured by a pyranometer a fixed tilt and can be used to benchmark a PV array's performance and calculate the performance ratio.

Power factor
The power factor of the supply, measured at the output of the generation system. The sign of the value indicates whether the power factor is leading (+) or lagging (-). This is measured as the average of all three phases in a three phase system.

PV cell temperature (°C)
The temperature measured at the rear of an exemplar PV module within the array via a surface contact sensor.

Rainfall (mm)
The cumulative rainfall in millimetres since 12am on the current day.

Relative humidity (%)
An indication of the level of moisture in the air. Relative humidity is the ratio of the amount of moisture in the air to the maximum amount of moisture which the air could hold at the same temperature, expressed in %, with 100 % being saturation.

State of charge (%)
The percentage of the battery capacity remaining (remaining battery capacity / total, full battery capacity).
This value is usually an estimated value and is representative of the entire storage system, all banks where multiple battery banks are connected in parallel.

System availability (min)
The duration that the system is available to operate as needed, taking into consideration system-specific characteristics. For example, PV systems are functional but powered down due to too low irradiance (e.g. at night) are defined as available. Conversely, a PV system that has been shut down or is offline and cannot generate power (e.g. when the sun rises later), is unavailable. Night-time unavailability in this case helps to determine time to repair or system restore. Similarly, a blackout or brownout has the system unavailable for operation.

Voltage (line-line) (V)
The voltages measured between pairs of phases of the three-phase load measured at the main point of generation.

Voltage (line-neutral) (V)
The voltages between each of the phases and the neutral of the three-phase load measured at the main point of generation.

Wind direction (°)
Direction of the wind measured downwind in degrees east of north, with 0° corresponding to due north.

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