Rheem Australia Pty Ltd ABN 21 098 823 511

Australian Energy Market Operator
Level 22
530 Collins Street
Melbourne, VIC 3000

By email: mass.consultation@aemo.com.au

21st June 2022

Subject: AEMO "Market Ancillary Services Consultation – May 2022" – Very Fast FCAS

Thank you for the opportunity to respond to the current AEMO consultation for the proposed delivery of Very Fast FCAS services per the "Market Ancillary Service Specification Consultation" dated May 2022.

This is a joint response on behalf of both Rheem Australia Pty Ltd (Rheem) and Combined Energy Technologies Pty Ltd (CET), as we have a complementary interest in the NSW DER Consultation Paper.

As the largest Australian manufacturer of water heaters with products in over 4 million Australian homes, we offer a wide range of traditional and renewable energy water heater models to the domestic water heating market under the Rheem, Solahart, Vulcan, Aquamax & Everhot brands. Under our Solahart brand we are the third largest supplier of photovoltaic (PV) systems in the country. Over the last four years we have also commenced the manufacture and installation of smart electric water heaters, controlled remotely by our technology partner, Combined Energy Technologies.

Combined Energy Technologies is an Australian technology company specialising in energy management for residential, commercial and micro grid systems. CET provides home gateway devices and has extensive experience in the integration and orchestration of systems with multiple DER devices including the integration of solar PV, batteries, water heating, electric vehicle chargers, pool pumps and A/C for the benefit of the homeowner, retailer and the grid. Our references to DER should be read to include both generation and flexible load assets.

Together, Rheem and CET are already actively participating in the emerging DER market with thousands of online, mixed, orchestrated DER sites across the NEM and the WEM. Over the past decade we have identified and resolved many issues (at live field sites) to ensure that mixed, smart DER sites can be orchestrated to achieve the best financial outcomes for consumers, whilst providing a foundation for grid support services and hence grid security of supply.

This experience has given us a unique insight and particular interest into the issues raised in the consultation and has directed our responses to the questions raised within the paper.

If the energy market is to be truly democratised, it is extremely important that any changes to market rules and associated technical specifications for participation in grid services (such as FCAS) are made with the consumer at the centre of the solution. This will ensure that current and future investment in smart DER by households continues to be made. Fundamental to this approach will be that new rules do not favour a particular technology, technology class, or technology manufacturer, and that technology neutrality is not impeded by barriers to entry in creating or modifying energy market rules. Our specific responses attached are underpinned by this approach.

Our recommendations and questions are supported by empirical data from an existing fleet of thousands of NEM consumer sites of mixed DER. The data from these sites support our technical, architectural, and commercial conclusions which are in alignment with the principles of the National Electricity Objective (NEO).

As Australian based manufacturers we have made a large R&D investment in bringing to market cost effective metering compliant with 50ms FCAS metering and have a desire to ensure technology neutrality in the design of new market services, commercial fairness, and adherence to the principles of the NEO.

In summary we:

- Support 50ms metrology as a sampling rate for any 0.5 or 1.0 second Very Fast FCAS Market, and;

- Though not highlighted as an open consultation issue, support retention of NMI level metering for Very Fast FCAS services.

Further, we have provided within our response cost estimates (Please see our Question 24 response) for our MASS compliant DER power meter offering (with 50ms sampling rate), which has better than a 0.01Hz accuracy / 0.001Hz frequency resolution. This cost-effective power metering product is designed and engineered in Australia and is deployed on many thousands of our BTM mixed DER sites across the NEM and WEM. Our power meter includes a local, open, industry standard Modbus interface accessed via either Ethernet or PLC, for use with any DER seeking to participate in the Contingency FCAS market.

In preparing this response to the current Very Fast FCAS MASS review, we have focussed on the findings of the University of Melbourne study. Having analysed their report, we have provided detailed comments on their findings, particularly how they compare to our own field observations from high-speed (50ms sampling rate) metering across many thousands of BTM DER sites where our metering is deployed. Our comments and observations are relevant to the data set used, the calculation of error, determination of error across aggregated DER, and hence the determination of a final metrology sampling rate along with any discount rates that AEMO may apply. We wish to thank AEMO for affording us the opportunity to explore many of these questions in our meeting of Friday June 17th, 2022.

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Our detailed comments and observations are contained primarily within our responses to questions 11 and 40 of the consultation and are based on empirical data and observations from our field deployments, however we would make the following overarching points:

- In our view, analysis of a few battery samples, whether in the lab or in real life deployments, are not representative of the extent of performance variations that we have observed across many thousands of real-life deployments, and we believe that any extrapolated results from a test on a few batteries (The report notes there were three) are in no way an indicator of field-based performance (response times etc) of any particular battery brand or battery technology across a wider aggregation of devices.
- Rheem and CET have thousands of BESS across our fleet of deployed BTM HEMs orchestrated sites on which to base our conclusion. All of our sites have 50ms (per previous MASS) meter sampling rates. Our consistent observations and empirical data gathered from the field is that performance (response times etc) of any particular battery brand or battery technology is affected by many factors which are constantly changing. We see variation in response times and ramp rates (up and down) of BESS technology in the field as a result of, but not limited to, battery/ambient temperature, battery charge state, line voltage, local disturbances (ripple etc), battery operational status etc. These factors all affect the response times of every individual battery and are constantly changing.
- In contrast, we would contend that particular switched loads, such as Rheem's variable power grid interactive water heater Powerstore, have extremely predictable and repeatable response times as they are not affected by any of the aforementioned performance modifiers that affect batteries. Hence in our experience, any analysis that is based on a normal distribution assumption may be applicable for certain switched loads as identified above but in our opinion should not be used as a basis of analysis for batteries in the determination of assessment errors.
- Given these issues, we believe that there is a need for further analysis by AEMO of large aggregations of field derived data across a variety of battery models / vendors. This should include a review of the analysis methodology used, and supports a case for regular high speed post event sampling verification at a 50ms sampling rate resolution. Any relaxation of the sampling rate to be greater than 50ms in a new Very Fast FCAS market of 0.5 or 1 second in duration may risk grid security of supply. In any case, given that cost effective, open access metering at a 50ms sampling rate is available (from ourselves and others) a 50ms sampling rate requirement is a no risk cost effective risk mitigating solution that can be adopted by AEMO, whilst at a minimum preserving the fidelity of the Very Fast FCAS market.

Due to the significance of the decision being made, we would suggest that AEMO give due consideration to commissioning a secondary study with the National Metering Institute (NMI). As the Government's independent body that tests and certifies measurement instruments, including revenue meters currently used within the NEM and WEM, the NMI would be the logical choice to carry out a parallel independent assessment.

Support for the above positions is included in our attached responses to the consultation questions. As this submission has been prepared using the expertise of several of Rheem and

CET's personnel, I would ask that any enquiries related to the submission are directed in the first instance to myself. I will then co-ordinate follow up responses to your enquiries or further meetings with the appropriate personnel within our organisations.

Yours Sincerely

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Market Ancillary Service Specification Consultation - May 2022

Submission to Issues paper template

This template has been developed to assist Consulted Persons in providing submissions on the questions posed in the Issues Paper. AEMO encourages Consulted Persons to use this template to assist AEMO when considering the views expressed on each issue.

Consulted Persons should feel free to address only those questions that are of particular interest/concern to them and delete those they are not responding to.

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1 Background	
1.4 Industry advice	
Question 1:	Are there any further issues for investigation by the Consultative Forum that are relevant to the specification of Very Fast FCAS?
Response: Please see our response to Question 40.	
3 Capability of different technologies to deliver Very Fast FCAS	
Question 2:	Do you agree with the capabilities expressed in Table 3? If not, please advise which of these you do not agree with and provide evidence to support alternative capabilities.
Response: In our experience across thousands of BTM mixed DER sites that we control / orchestrate across the NEM and WEM, we consistently find that Solar PV is slow to ramp up and we have observed inconsistent speed of ramp down.	
Question 3:	Are there any technologies not mentioned in Table 3 that could potentially provide Very Fast FCAS? If so, what characteristics (including response time) could be expected of them? Please provide evidence to support their capabilities.
Response: No comment re Table 3. However, relevant to performance of technologies please see our response to Question 40 re Melbourne University Findings in respect to switched loads and proportional controllers.	

Question 4:	How could wind farm and solar farm operators be incentivised to participate in the Very Fast FCAS markets? What are the technical barriers impeding participation? For example, this may be a conflict of voltage disturbance controls with frequency response controls.
Response: We have no comment here.	
Question 5:	Are there any other issues relevant to the capability to provide Very Fast FCAS by different technologies that AEMO should consider?
Response: We have no comment here.	
4 Proposed design of Very Fast FCAS markets	
4.2 Guidance from other FFR Markets	
Question 6:	Are there any specific useful lessons to be learned from other FFR markets around the world?
Response: We have no comment here.	
4.3 Proposed design of Very Fast FCAS markets	
4.3.2 AEMO's proposed high level market design	
Question 7:	Are there any issues with the concept of shifting Fast FCAS to accommodate a similar, but faster, Very Fast FCAS? Is there a better alternative that is compatible with the Amending Rule?
Response: We have no issues with either alternative. Our technology capabilities support participation in current and proposed markets with cost effective 50ms sampling accuracy.	
Question 8:	Are there any other issues relevant to market design that AEMO should consider?
Response: We have no comment here.	
4.3.3 Impact of inertia	
Question 9:	Are there any other issues relevant to the impact of inertia that AEMO should consider?
Response: We have no comment here.	
4.3.4 Primary Frequency Response	
Question 10:	Are there any other issues relevant to the interaction between Very Fast FCAS and PFR that AEMO should consider?
Response: We have no comment here.	

4.4 Existing capability to deliver Very Fast FCAS	
Question 11:	Does a 1-second response time specification automatically exclude certain technologies from being able to participate in the Very Fast FCAS markets? Which ones and why?

Response:

In our experience across thousands of BTM mixed DER sites (generation and flexible load) that we control / orchestrate across the NEM and WEM, we consistently find that many Solar PV Inverters and Battery Energy Storage Systems (BESS) may be excluded by a 1 second response time requirement due to vendor specific ramp rate limits, external and environmental factors, operational status and interface latency. We have thousands of BESS across our fleet of deployed BTM HEMs orchestrated sites on which to base our statements.

All of our sites have 50ms (per previous MASS) metering. Our consistent observations and empirical data gathered from the field indicate that lab-based and "point in time" field based analysis of BESS performance are not good indicators or predictors of future field-based performance (response times etc) of any particular battery technology. We see many factors affecting the ramp rates (up and down) of BESS technology in the field including but not limited to battery/ambient temperature, battery charge state, line voltage, local disturbances (ripple etc), battery operational status etc. These all affect the response times of a battery. Conversely, for loads such as Rheem's smart grid interactive water heater, our response times are consistent and predictable and not effected by the aforementioned external factors, as are batteries. We are happy to share further with AEMO our extensive experience in this area.

We have provided further commentary in our response to Question 40 in respect to the Melbourne University analysis / statements on the response of switched loads vs proportional controllers (batteries and variable load).

Question 12:	Is there anything else AEMO should consider in maximising the pool of potential Very Fast FCAS?

Response:

50ms metering is appropriate to ensure the greatest confidence in the deployment of the widest technology pool for participation in Very Fast FCAS. Please see also our responses to Question 11 and Question 40.

5 Specification of Very Fast FCAS and associated changes to the MASS

5.2 Proposed key parameters for Very Fast FCAS

5.2.1 Response time, timeframe and initiation delay

Question 13:	Will some technology types be locked out of the Very Fast FCAS markets if the maximum response time is specified as 0.5 seconds rather than 1 second?

Response:

While there are no specific technologies that are completely excluded by a change to a 0.5-second response time, we expect the pool of available solutions in each technology category would be significantly reduced due to technical timing constraints. For example, charge-pump anti-glitch protections for relay drivers used in discrete load control often have hardware-defined delay times in the order of 100-300ms, leaving little headroom for metering, control, and communications delays.

Question 14:	Are there benefits to setting the response time for Very Fast FCAS faster than 1 second that AEMO should consider?

Response:

We have no comment here.

Question 15:	Are there any other issues relevant to the proposed response time and timeframe that AEMO should consider?
Response: We do not think the benefits of a 0.5-second response time (vs. 1-second) justify the increased technical demands on Very Fast FCAS technologies and the resulting reduction in the pool of solutions for Very Fast FCAS.	

5.2.2 Market ancillary service offer requirements

Question 16:	Are there any other issues relevant to the proposed market ancillary service offer requirements that AEMO should consider?
Response: Relevant to performance of technologies, please see our response to Question 40 re Melbourne University findings in respect to switched loads and proportional controllers.	

5.2.3 Reference frequency levels

Question 17:	Are there any other issues or concerns relevant to AEMO's proposal to apply the current definitions of 'Raise Reference Frequency' and 'Lower Reference Frequency' to Very Fast FCAS?
Response: We have no issues / comment here.	

5.2.4 Frequency Ramp Rate

Question 18:	Are there any other issues relevant to RoCoF that AEMO should consider?
Response: We have no further comment here post our discussions with AEMO (Akeelesh Kusrutsing).	

5.3 Control system requirements

Question 19:	Is AEMO's proposal to permit the use of a 'combination' controller, namely, a hybrid of proportional and switched controls for Very Fast FCAS appropriate? Please provide reasons for your response.
Response: We believe that permitting the use of a combination controller is appropriate as it provides an opportunity for some existing Very Fast FCAS technologies to maximise their response without significant downsides.	
Question 20:	Are there any other issues relevant to the proposed control system requirements for a combined FCAS controller that AEMO should consider?
Response: Not at this time	
Question 21:	Are there other FCAS delivery methods that AEMO should consider allowing for Very Fast FCAS?
Response: We do not have comments at this time	

5.4 Verification and measurement requirements

5.4.3 Frequency measurements

Question 22:	What is the error margin and resolution for frequency measurements by high-speed metering installed by Fast FCAS Providers that could be retrofitted to existing Ancillary Service Facilities for participation in Very Fast FCAS markets?

Response:

Please see our responses to Questions 23, 24, 25 and 26.

Question 23:	What is the error margin and resolution for frequency measurements by high-speed metering that is not currently in use in the NEM, but is available for use in the Very Fast FCAS markets?

Response:

The current CET metering solution that is deployed on many thousands of BTM DER (generation and flexible load) orchestrated sites across the NEM and WEM has a 0.01Hz accuracy, with better than 0.001Hz resolution.

Question 24:	What is the cost of high-speed metering that captures frequency measurements with a margin of error lower than <0.1 Hz?

Response:

The following wholesale pricing is for the current CET metering solution that is deployed on many thousands of BTM DER (generation and flexible load) orchestrated sites across the NEM and WEM. Full specifications can be found in the included ***CET-HD-PM2-1 Product Brief V1*** which confirms accuracy and resolution as per our answers to Question 23 (i.e., margin of error lower than <0.1Hz):

The CET-HD-PM2-1 is a 6 Channel Power Meter that comes in an IP66 enclosure. An open Modbus interface is supported with access via Ethernet or PLC. Unit pricing and options pricing are as follows:

Unit Pricing:
CET-HD-PM2-1 6 channel IP66 power meter to minimum 50ms FCAS specification.
$A 318.00 Ex GST Ex Works Sydney Australia

CT harness to support 2 bundles of 3 CTs
$A 35.00 Ex GST Ex Works Sydney Australia

CT Bundle – 3 by 60A CTs
$A 48.00 Ex GST Ex Works Sydney Australia

CT Bundle – 3 by 120A CTs
$A 72.00 Ex GST Ex Works Sydney Australia

Note 1: Bespoke CT bundles supported – pricing on request.
Note 2: Volume pricing available on request.
Note 3: All prices are supply only

Question 25:	Can metering providers submit the specifications of their high-speed metering currently available, or in use by Fast FCAS providers?

Response:

Please see the ***CET-HD-PM2-1 Product Brief V1*** included in our response

Question 26:	Are measurement rates of <100ms feasible for your technology? What is the nature and extent of changes that would need to be made to support rates of <100ms?
Response: YES, our metering technology (with no changes required) as deployed on many thousands of BTM DER (generation and flexible load) orchestrated sites across the NEM and WEM supports <100ms measurement rates and meets 50ms settling time requirements. We do not need to make any changes. Please see the ***CET-HD-PM2-1 Product Brief V1*** included in our response. Further our metering technology supports open control interfaces and protocols (Modbus over Ethernet or PLC) and can be utilised with any technology participating in FCAS / Very Fast FCAS markets. We provide an extremely cost-effective product that can be easily integrated into an existing FCAS installation for 50ms metering.	
Question 27:	Are there any other issues relevant to the proposed verification and measurement requirements that AEMO should consider?
Response: We support retention of 50ms sampling at an NMI level for the proposed Vary Fast FCAS service. Please see also our answers to Questions 11 and 40.	
5.5 Overload capacity	
Question 28:	How long can overload capacity be sustained?
Response: We do not have comments at this time.	
Question 29:	What percentage of a generating unit's nameplate rating is equivalent to the overload capacity?
Response: We do not have comments at this time.	
Question 30:	How often can overload capacity be triggered in a 5-minute trading interval?
Response: We do not have comments at this time.	
Question 31:	Can overload capacity be delivered proportionally to the frequency deviation, or can it only be delivered by a step change in active power?
Response: We do not have comments at this time.	
Question 32:	Is there an energy payback after overload capacity is delivered?
Response: We do not have comments at this time.	
Question 33:	What technologies other than BESS have overload capacity that be sustained for at least 6 seconds?

Response: We do not have comments at this time.	
Question 34:	Are there any other issues relevant to the potential use of overload capacity for Very Fast FCAS that AEMO should consider?
Response: We do not have comments at this time.	
5.6 Changes to other FCAS	
5.6.1 Interaction between Very Fast FCAS and Fast FCAS	
Question 35:	Can Consulted Persons identify any case where a decrease in Fast FCAS capability could be observed?
Response: YES. Please see our answers to Questions 11 and 40 in respect to observed BESS response variability across our thousands of BTM DER sites (generation and flexible load) across the NEM and WEM.	
Question 36:	Are there any other issues relevant to the interaction between Very Fast FCAS and Fast FCAS that AEMO should consider?
Response: We do not have comments at this time.	
5.6.2 Interaction between Very Fast FCAS and Slow FCAS and Delayed FCAS	
Question 37:	Are there any issues relevant to the interaction between Very Fast FCAS and Slow FCAS and Delayed FCAS that AEMO should consider?
Response: None that we are aware of.	
5.6.3 Interaction between Very Fast FCAS and Regulation FCAS	
Question 38:	Are there any issues relevant to the interaction between Regulation FCAS and Very Fast FCAS that AEMO should consider?
Response: None that we are aware of.	
5.6.4 Revision to FCAS measurement	
Question 39:	Are there alternatives to capping the registered Very Fast FCAS capacity to the actual peak active power change to minimise the discrepancy between the amount of FCAS enabled and the actual contingency size?
Response: We have no comment here.	
Question 40:	Are there any other issues relevant to the proposed market ancillary service offer requirements that AEMO should consider?

Response:

In looking to complete this response to the current Very Fast FCAS MASS review, we were anticipating the University of Melbourne study to best inform our response. Reporting clarity is very important to our organisation and many others that provide or advocate for solutions around DER FCAS participation and have provided our feedback to this process based on a current understanding of AEMO's intended direction.

Having analysed the Melbourne University Report, we had observations and questions relevant to the data set used, the calculation of error, determination of error across aggregated DER and hence the determination of a metrology sampling rate and any discount rates that may apply. We thank AEMO for the Friday 17th June 2022 technical discussion which has clarified many of our questions.

Our further comments and observations are based on the empirical data we have derived, and our continued observations from our field deployments of DER. We still contend that lab or field-based analysis of a few battery samples, whether in the lab or in real life deployments, are not representative of the extent of performance variations that we have found across many thousands of real-life deployments. We believe that any extrapolated results from a test on a few batteries (the report notes that there were three) are in no way an indicator of field-based performance (response times etc) of any particular battery brand or battery technology across a wider aggregation of devices.

Questions and observations that come to mind and have been left open within the report include:

1) Do the batteries respond identically? Given that we know that batteries do not respond identically, what are the required level of proof, sample size, and under what conditions should testing and analysis be completed to ensure accurate representation of an aggregated fleet of batteries?
2) Given the above, what level of non-identical response is acceptable to AEMO when contemplating using an 'assumed identical response and average' type scheme and why?
3) Does AEMO have any independent analysis of average assumed identical response vs real response?
4) What 'identical' fleet averaging methodologies would AEMO accept and why (e.g. pure statistical distributions, determined from real data, derating, number of devices, evidence, etc.)?
5) What are acceptable frequency triggering mechanisms for response? Do they have to conform to the same accuracy requirements as measurement?
6) Can AEMO offer any insight into the methodology used for their sampling (e.g. reading of an instantaneous voltage from the raw waveform)? What sample rate was the waveform sampled at, what window was used, etc? This is very relevant to the report conclusions as ***it drastically changes the meaning of a 200ms sample*** (for example) depending on how the data is processed.
7) Was there any consideration given to sample offset to determine most favourable and least favourable metering (i.e. generation of f and P value) offsets? Again, relevant because it may drastically change the analysis.
8) Was there any consideration given for harmonics and real-world noise beyond the three-battery sample size? This would need to be considered / analysed for both triggering and metering. ***This is again relevant because it can drastically change the analysis, especially with different metering offsets or sampling and averaging methodologies***

Supporting our views and questions above, we have evidence from thousands of BESS across our fleet of deployed BTM, HEMS orchestrated sites on which to base our statements. All of our sites have 50ms (per previous MASS) metering sampling rates. Our consistent observation from empirical data gathered from the field is that performance (response times etc) of any particular battery brand or battery technology is affected by many factors which are constantly changing. We see variation in response times and ramp rates (up and down) of BESS technology in the field as a result of, but not limited to, battery/ambient temperature, battery charge state, line voltage, local disturbances (ripple etc), battery operational status etc. These factors all have an effect on the response times of every individual battery and these responses constantly change as the factors change. In contrast, we would contend that particular switched loads, such as Rheem's variable power, grid interactive PowerStore water heater have extremely predictable and repeatable response times as they are not affected by any of the aforementioned performance modifiers that affect batteries. ***Hence in our experience, any analysis that is based on a normal distribution assumption may be applicable for certain switched loads as identified above but should not be used as a basis of analysis for batteries in the determination of assessment errors.***

These modifiers to battery operation we believe support the need for analysis of large aggregations of field derived data across a variety of battery models / vendors. This should include a review of the analysis methodology used and ***supports a case for regular high speed post event sampling verification at a 50ms sampling rate resolution, which at the very minimum will preserve fidelity in any 0.5 or 1 second Very Fast FCAS market.***

Concluding remarks:

Any relaxation of the sampling rate to be greater than 50ms in a new Very Fast FCAS market of 0.5 or 1 second in duration in our view ***may risk grid security of supply***. In any case, given that cost effective metering at a 50ms sampling rate is available (from ourselves and others), a 50ms sampling rate requirement is a no risk, cost effective, risk mitigating solution that can be adopted by AEMO whilst at a minimum preserving the fidelity of the Very Fast FCAS market.

5.7 Proposed handling of Contingency Event Time

Question 41:	Are there any other issues relevant to the proposed removal of Contingency Event Time that AEMO should consider?

Response:

None that we are aware of.

Question 42:	In there a better alternative to the baseline compensation approach than the one proposed by AEMO? Please provide reasons for your response.

Response:

We do not have comments at this time.

6 Issues not under consideration

6.4 Geographic diversity

Question 43:	Are there any other issues relevant to geographic diversity that AEMO should consider?

Response:

None that we are aware of.

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Power Meter

CET-HD-PM2-1

Product Brief

V1

Technical Specifications

Type: Combined Energy Power Meter

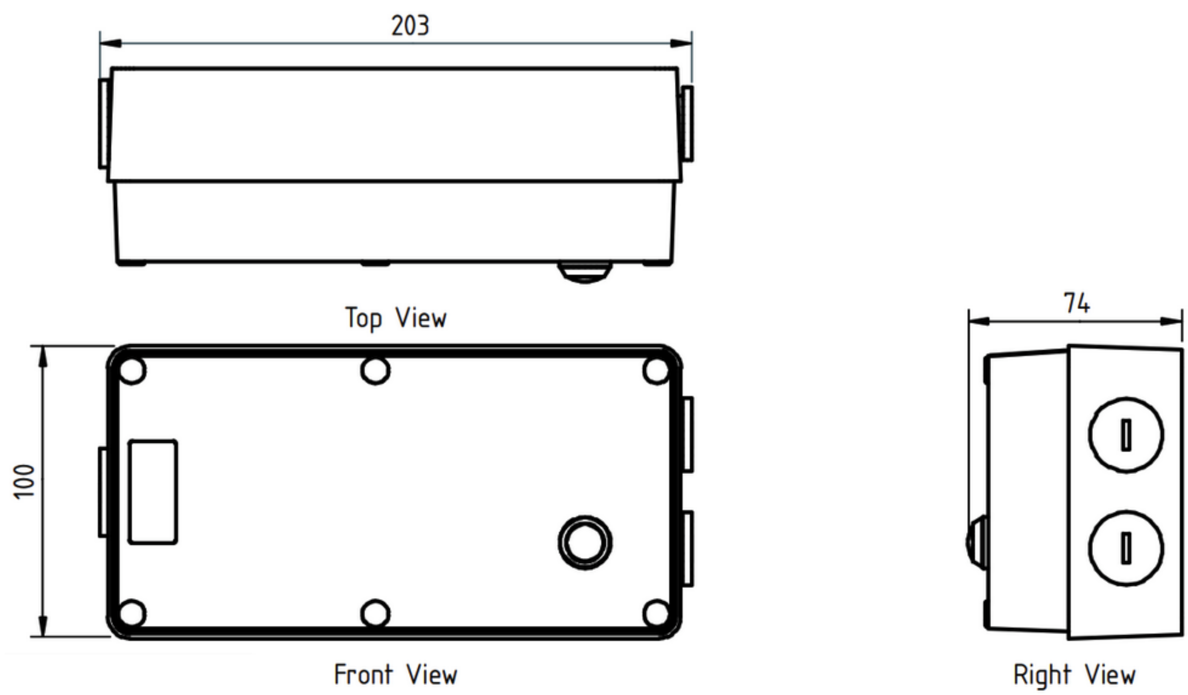
Model: CET-HD-PM2-1

Power Supply Input: 100 - 240VAC 1W + N 50/60Hz 80-30mA

Metering Input: 100 - 240VAC 3W + N + E 50/60Hz 1mA

Average power consumption: <8W

Dimensions: 203 x 100 x 74mm



Mass: 0.57kg

Operating Temperature Range: 0C to +50C

IP Rating: IP56

Standards:

- IEC 60950-1, AS/NZS 60950-1 - Information Technology Directive
- EN 50561-1 – Electromagnetic Compatibility for PLC products

Feature Summary

Power Metering:

- Three-phase voltage
- 6 current channels (clip-on CT)
- Voltage, Current, Frequency, Power Factor, Active/Reactive Power, Active/Reactive Import/Export Energy, Phase-Phase angle
- Class 1 accuracy
- MASS-compliant frequency trigger and logging functionality

Communications Interfaces:

- 1 x Power-Line Communications (PLC) modem
- 1 x Wired Ethernet (RJ45, 10/100 Base-T)
- 1 x RS485 port (RJ11, Serial / Modbus RTU)

Outputs:

- 1 x 50mA TRIAC output for control of third-part relay/contactor

Backup Power Supply Connection:

- Separate power supply connection option for systems with battery backup

Human Interfaces:

- 1 x Front panel button for manual network reset and diagnostics view
- 2 x LED status indicator (built into front panel button)

Included Accessories:

- Enclosure mounting accessories

Optional Accessories:

- Combined Energy CT Bundles (up to 2)
    - Available in 60A, 120A and 200A versions with 3 CTs per Bundle
- Combined Energy CT Harness (required to connect CT Bundles to Power Meter)
    - Available in 0.5m and 3m lengths

Power Meter Specifications

General	
Accuracy	Class 1
Bandwidth	DC to 500Hz Digital low-pass bandwidth limit
Sample Rate	5kS/s per channel 15kS/s (frequency measurement)
Voltage Inputs	3
Current Inputs	6 channels
Current sensor type	Clip-on Current Transformer (CT)
Channel features	Fully independent
	Configurable voltage-to-current channel assignment
	Configurable channel polarity
	Diagnostics for inputs and configuration
	Automatic CT Bundle identification / calibration compensation
Communications Interface	Modbus *(via PLC, Ethernet)*

Channel Metrics	
RMS Voltage (V)	Resolution: auto-scaling, 0.001V max.
RMS Current (I)	Resolution: auto-scaling, 0.001A max.
Frequency (f) *(at Phase A input)*	Resolution: auto-scaling, 0.00001Hz max.
Active Power (P)	Resolution: auto-scaling, 0.1W max.
Apparent Power (S)	Resolution: auto-scaling, 0.1VA max.
Reactive Power (Q) *(from P, S, pf)*	Resolution: auto-scaling, 0.1VAr max.
True Power Factor (pf) *(true power factor from pft)*	Resolution: auto-scaling, 0.00001 max.
Apparent Power Factor (pfA) *(true power factor from pftA)*	Resolution: auto-scaling, 0.00001 max.
Displacement Power Factor (pft)	Resolution: auto-scaling, 0.00001 max.

(displacement power factor from fundamental only)	
Apparent Displacement Power Factor (pftA) *(displacement power factor from P/S)*	Resolution: auto-scaling, 0.00001 max.
Distortion Power Factor (pff) *(distortion power factor from THDv, THDi)*	Resolution: auto-scaling, 0.00001 max.
Voltage Channel Total Harmonic Distortion (THDv)	Resolution: auto-scaling, 0.001 max.
Current Channel Total Harmonic Distortion (THDi)	Resolution: auto-scaling, 0.001 max.
Voltage Phase Offset (pV) *(fundamental only, relative to VA)*	Resolution: auto-scaling, 0.1deg max.
Current Phase Offset (pI) *(fundamental only, relative to assigned voltage channel)*	Resolution: auto-scaling, 0.1deg max.

Channel Reporting Options	
Fast Data *(V, I, f, P, S)*	½ wave update, 2 wave window
Instantaneous Data *(All metrics)*	1s update, 1s window[1]
Statistics *(V, I, f, P, S, Q, pf)*	Minimum, Maximum, Simple Moving Average with 1s update, 5s window Minimum, Maximum, Cumulative Moving Average with 1s update, running window (reset by remote host)

Other Metrics	
Harmonic Analysis	For all voltage and current channels up to 9th harmonic
Waveform Capture	For all voltage and current channels 16-bit, 5kS/s, 300 sample memory per channel, arbitrary trigger

Energy Metering	
Energy Accumulators	Non-volatile import/export active and reactive energy accumulation for all current channels *Reactive energy from fundamental phase angle and |Q| from P and S.*
Update rate	Approx. 0.5Hz
Resolution	1 Wh / 1 VArh

[1] *some of the source data may have a calculation window that exceeds 1s*

FCAS - Metering	
Acquisition Rate	½ cycle (100Hz / 10ms nominal)
Acquisition Window *(maximum settling time)*	2 cycle (25Hz / 40ms nominal)
Active power *(sum of configured channels)*	Accuracy: +/- 1%
Frequency (f) *(at Phase A input)*	Accuracy: +/- 0.01Hz
Ripple control signal rejection	Rejection above 450Hz, suppression above 120Hz

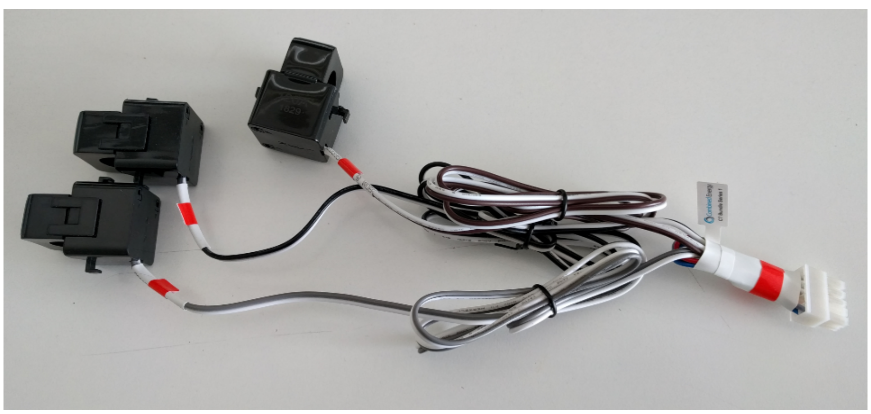
FCAS - Alarm	
Arm/clear	Controlled by remote host
Trigger	Latching trigger on configurable frequency deviation
Response time	<1 second (typical 300-500ms)

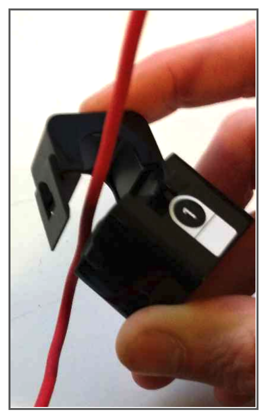
FCAS - Event Logging	
Arm/disarm	Controlled by remote host
Time reference	Set by remote host at initialisation (volatile)
Non-volatile storage endurance	>10 years
Trigger conditions	Frequency deviation (configurable) Frequency rate deviation (configurable)
Logging rate	2 cycle (25Hz / 40ms nominal)
Frequency logging	Unit: Hz Storage Resolution: 0.000244Hz Storage Range: approx. 42-58Hz
Active power logging	Unit: Watts Storage Resolution: Float / auto-scaled (at least 0.1W) Storage Range: Float / auto-scaled
Metadata logging	Disturbance timestamps, time reference, operational markers
Pre-event logging period	>6 seconds
Post-event logging period	>70 seconds (extended by re-trigger during logging)

CT Harness and CT Bundles

The Combined Energy **CT Harness** system enables easy connection of up to 6 Current Transformers (CTs) to Combined Energy metering products:

The CT Harness accepts up to two **CT Bundles**, each with three CTs:





The purple **USB-C cable** provides a single-cable link between the CT Harness and the CET-HD-PM2. The USB-C cable can be easily pulled through conduits to access external switchboards, and features a rotationally-invariant termination at the CET-HD-PM2: