Technical Report R151-20

Technical Review of Auxiliary Metering for Hybrid Solar PV and Battery Energy Storage Systems

Submitted To

New York State Dept of Public Service
New York State Energy Research and Development Authority

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Contents

Pterra, LLC ("Pterra") conducted a technical review of auxiliary metering applied to hybrid solar photovoltaic (PV) and battery energy storage systems (BESS). This work was performed under contract to New York State Energy Research and Development Authority (NYSERDA) and on the direction of the New York State Department of Public Services (NYSDPS).

NYSDPS engaged several parties to review the need for an auxiliary meter from different perspectives. *This review by Pterra is conducted from a technical perspective*. The main technical contention is the accuracy difference between having a single service meter at the PV+BESS plant and an additional auxiliary meter at the plant, i.e., a two-meter configuration.

For PV+BESS systems, the net energy can vary over the course of a day. During the day, the PV output results in energy being delivered to the grid. The BESS may charge from the PV by drawing part of the PV's output, then discharge later combining with the output of the PV to the grid. In both these instances, the load on the meter will typically be above 10% of the IT rating. However, for the following condition the load on the meter can fall below 10% of the IT rating: when both the PV and BESS are not netting a large amount of energy, the auxiliary loads comprised of heating/cooling and line and transformer losses are the main load on the meter. The auxiliary loads can vary by type and size of facility but will generally be at or below 10% of the IT rating. This condition may occur 10 out of every 24 hours for the facility.

Three industry standards are applicable to metering accuracy:

- ANSI C12.1-2008 American National Standard for Electric Meters, Code for Electricity Metering specifies that "the performance of all watthour meters is considered to be acceptable when the percent registration is not less than 98% or more than 102%." This standard is consistent with present practice by NYSDPS for in-service meters.
- IEEE Standard C57.13.6 defines accuracy classes, one of which, the standard accuracy, applies to the most commonly used current transformer for metering. The standard accuracy class allows a maximum error of 0.6% for loading within 10-100% of the CT's rating. Below 10% of the IT rating, there is no error range specified by the standard.
- ANSI C12.20-2015 American National Standard for Electricity Meters defines 0.5 and 0.2 Accuracy Classes for meters, where the 0.5 class electric meter should be accurate to within +/-0.5% of true value at full load. These meter accuracy classes are based on readings under full load and unity power factor. However, the accuracy deteriorates under lower load conditions when power factor is less than unity.

An assessment of the technical differences in accuracy between one and two-meter configurations for PV+BESS facilities was conducted. The assessment considered the basic technology of meters and associated instrument transformers, primarily current transformers, applicable standards and practices and used simulations of sample PV+BESS facilities to examine the error characteristics under different operating scenarios.

The conclusions of the simulations are as follows:

- For basic net metering schemes, the maximum potential metering error **increases** with the addition of a 2nd meter based on the accuracy standard set forth in DPS 16 NYCRR Part 92 which designates as "Out of limit" in-service meters that test outside the range of 98% to 102%.
- Using the accuracy performance of CTs under IEEE Standard C57.13.6 as a basis, a second meter does reduce the maximum potential error.
- The differential in maximum error between one and two-meter schemes decreases as the magnitude of the auxiliary load decreases relative to the plant capacity.
- If alternative pricing schemes are applied (other than net metering) an economic assessment is needed to determine if requiring an auxiliary meter is still warranted

In addition to the use of an auxiliary meter, other jurisdictions also consider the following alternative schemes:

- Use of sub-meter/s to register usage at various electrical nodes of the facility where auxiliary loads may be fed.
- Estimated usage based on spot measurements at regular intervals such a year or month.
- Estimated usage based on a formula agreed upon by the facility and utility.

The following additional conclusions are made based on alternative schemes from other jurisdictions:

- The magnitude of the decrease or increase in maximum error between one and two-meter schemes are in the range of 0.25% of the total annual registry. Use of an estimated cost for the potential registry differential may be more economical than actually installing a second meter.
- Even if a second meter is required, use of sub-meters may avoid costs of wiring the meter from the point of interconnection although careful use of compensation is needed to avoid double-counting.

Section 1. Introduction

Pterra, LLC ("Pterra") conducted a technical review of auxiliary metering applied to hybrid solar photovoltaic (PV) and battery energy storage systems (BESS), otherwise referred to in this report as "PV+BESS" systems. This work was performed under contract to New York State Energy Research and Development Authority (NYSERDA) and on the direction of the New York State Department of Public Services (NYSDPS).

1.1. Overview

In collaborative discussions of the NYSDPS' Interconnection Technical Working Group (ITWG), the issue of requiring a second meter for service to auxiliary loads of a PV+BESS system, termed herein as "auxiliary" meter, came up. Several positions papers were presented including:

- "2/6/2020 ITWG Industry Response Auxiliary Metering for ESS Projects", memo by the New York Solar Energy Industries Association & ITWG Industry Group to NYSDPS, dated February 27, 2020
- "2/27/2020 ITWG Industry Response - Auxiliary Metering for ESS Projects," *confidential* memo by Joint Utilities of New York – Interconnection Technical Working Group, dated April 24, 2020
- "ITWG Industry Response - Auxiliary Metering for ESS Projects", memo by New York Solar Energy Industries Association & ITWG Industry Group to NYSDPS, dated March 31, 2020

NYSDPS engaged several parties to review the need for an auxiliary meter from different perspectives. *This review by Pterra is conducted from a technical perspective*.

The main technical contention is the accuracy difference between:

- Having a single service meter at the PV+BESS plant
- Additional auxiliary meter at the plant, i.e., a two-meter configuration

Sample configurations for the single-meter and two-meter are shown in Figure 1-1 and Figure 1-2, respectively.

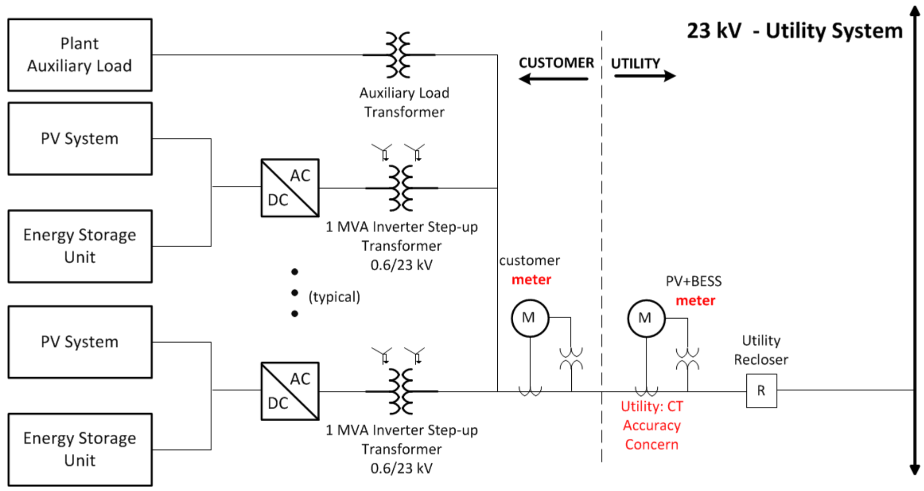

Figure 1-1: Sample Configuration for a Single-Meter PV+BESS Installation

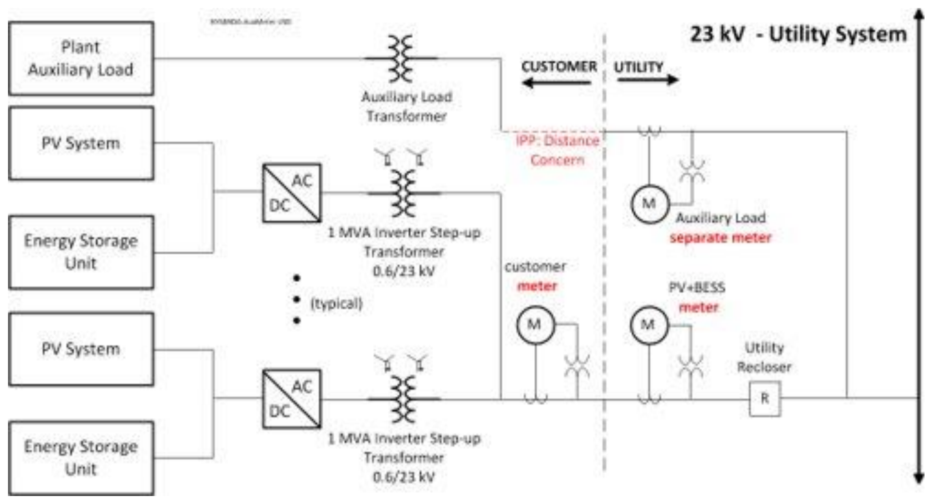

Figure 1-2: Sample Configuration for a Two-Meter PV+BESS Installation

1.2. Meter and Instrument Transformer Accuracy

The current transformers used for metering fall under different accuracy classes specified by IEEE Standard C57.13.6. These accuracy classes are illustrated in Figure 1-3.

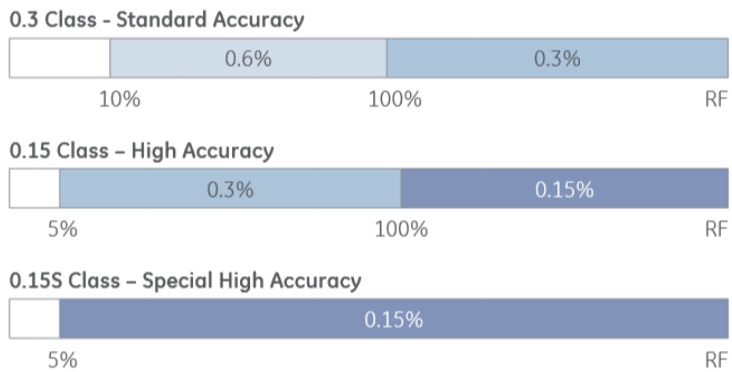

Figure 1-3: Accuracy Classes for Instrument Transformers Specified in IEEE Standard C57.13.6

For the 0.3 Class – Standard Accuracy instrument transformers (IT), the maximum error is 0.6% for loading that is within 10-100% of the IT's rating. For loading above 100% of the IT Rating up to the Rating Factor (RF) times the IT rating, the maximum error is 0.3%. Below 10% the IT rating, there is no error range specified by the standard.

The 0.15 and 0.15S extended accuracy classes have their error ranges as shown in Figure 1-3, with loading below 5% of the IT rating having no specified error range.

For PV+BESS systems, the net energy can vary over the course of a day. During the day, the PV output results in energy being delivered to the grid. In certain situations, the BESS may charge from the grid when the PV is not producing resulting in energy being withdrawn from the grid. In both these instances, the load on the meter will typically be above 10% of the IT rating. However, for the following condition, hereinafter referred to as the "auxiliary load only" condition, the load on the meter can fall below 10% of the IT rating:

- Auxiliary Load Only condition - when both the PV and BESS are not netting a large amount of energy, the auxiliary loads comprised of heating/cooling and line and transformer losses are the main load on the meter. The auxiliary loads can vary by type and size of facility but will generally be at or below 10% of the IT rating.

A typical daily cycle for a 1950 kW PV+BESS plant is shown in Figure 1-4. In this example, the Auxiliary Load Only condition is present 9 out of the 24 hours.

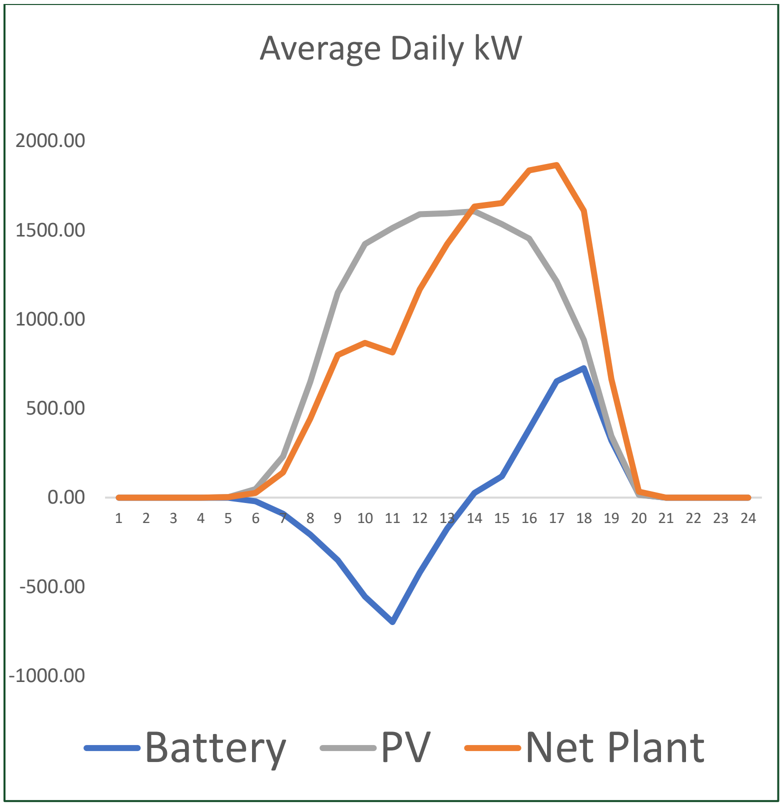

Figure 1-4: Typical Daily Cycle for a 1950 kW PV+BESS Plant

Since the load on a single meter during Auxiliary Load Only conditions fall in the region where no error range is specified by IEEE Standard C57.13.6, the expressed belief is that it is necessary to have an auxiliary meter in order to accurately register the plant demand.

Not discussed in the ITWG meetings and the related memos submitted by members of the working group is the topic of watt meter accuracy. ANSI C12.20-2015 American National Standard for Electricity Meters defines two Accuracy Classes for meters:

- a 0.5 class electric meter should be accurate to within +/-0.5% of true value at full load.
- a 0.2 class electric meter should be accurate to within +/-0.2% of true value

These meter accuracy classes are based on readings under full load and unity power factor. However, the accuracy deteriorates under lower load conditions when power factor is less than unity.

1.3. Scope of Services

Pterra's scope of work comprised of:

- Researching technical information from manufacturers of devices and instrument transformers used by NY utilities for metering, specifically with respect to accuracy for metering purposes.
- Researching types and characteristics of loads that may be subject to auxiliary metering at developer sites.
- Reviewing existing standards applicable to metering accuracy.
- Surveying other jurisdictions with regards to requirements auxiliary metering.
- Conducting simulations to evaluate accuracy performance of metering configurations.

1.4. Structure of the Report

This report is comprised of the following sections:

- Metering Practices
- Test Simulation of a Sample Facility
- Conclusions

Section 2. Metering Practices

This section presents a summary of metering practices in New York and other jurisdictions as determined from research, interview, questionnaires and manufacturer cutsheets.

2.1. Metering Practice for DER in New York

Metering for Distributed Energy Resources (DER) in New York falls under the purview of the NYSDPS. The guiding document for metering facilities such as PV+BESS installation is the Department of Public Service 16 NYCRR Part 92 Operating Manual (March 14, 2003), hereinafter referred to as the "Manual."

The Manual specifies testing regimes for new and existing meters, including statistical testing for new fleets of meters being deployed and for Referee Testing of a meter to determine whether it is defective or incorrect to the detriment of the customer. Specific sections of the Manual of interest to this study are:

- Section 4.a.iv - Test Methods for Energy Meters – Test Loads. Watt-hour meters shall be tested at two load points
    - Heavy Load: 60% - 110% of the "ampere rating"[1]
    - Light Load: 5% - 10% of the "ampere rating"
- Section 4.a.ii - Test Methods for Energy Meters – Determination of watt-hour meter performance
    - The final average percentage registration of a watt-hour meter, also known as final average accuracy, shall be determined by multiplying the average of the test results at heavy load by four, adding the average of the test results at light load and dividing the total by five:

$$\textbf{Final Average Accuracy (FAA)} = \frac{4\ \mathrm{HL} + \mathrm{LL}}{5}$$

Meter testing is based on performance at heavy and light load with average accuracy weighted towards the heavy load performance. From the IT accuracy perspective, assuming a 0.3 Class – Standard Accuracy current transformer (CT) for a CT-rated meter, the tests apply as follows:

- Heavy Load Tests apply to the 0.6% maximum error range of the 0.3 Class

[1] Nameplate rating.

- Light Load Tests apply to 10% of CT rating and below region where no error range is specified

To a questionnaire from Pterra, the NYSDPS Metering department responded with the following: (*Text in italics are as revised by Pterra for easier interpretation. Any errors due to the changes are the responsibility of Pterra.*)[2]

> "CT-rated meters are subject to one of the following three test methods:
>
> - Variable Interval- The minimum number of meters of each type to be tested (*annually is to be based on*) a formula including the number of meters that tested outside of the range of 98% to 102%. If (*the number of meters exceeds the allowable limit*), a special remediation program is to be introduced to reduce the population of out of limit meters.
> - Periodic- All watt-hour meters installed on customers' premises shall be tested at least once every 8 years.
> - Selective- The minimum number of meters of each type to be tested *(annually is to be based on*) a formula (*that considers*) the number of meters that tested outside of the range of 98% to 102%.
>
> For 'In-Service Testing,' meters will be considered outside the accuracy range if the final average registration accuracy is outside the range of 98% to 102%; the accuracy of an electric meter is determined by a watt-hour test standard that is calibrated and traceable to NIST."

The NYSDPS Metering department response classifies "out of limit" meters as those which test outside the range of 98% to 102%. This defines a de facto standard for meter performance that allows a maximum error of 2%.

The de facto standard is consistent with ANSI C12.1-2008 American National Standard for Electric Meters, Code for Electricity Metering which states that "the performance of all watthour meters is considered to be acceptable when the percent registration is not less than 98% or more than 102%."[3]

Pterra asked the Joint Utilities of New York – Interconnection Technical Working Group (referred to in this report as the "JU") what types of current transformers (CTs) are used for CT-rated meters.[4] In summary:

- Most utilities use 0.3% standard accuracy class as a default

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2 NYSDPS Metering and Rates departments, response to Pterra questions, May 19, 2020. Full text included in this report as Appendix A.

3 ANCI C12.1-2008 Section 5.1.

4 JU response to Pterra questionnaire, June 5, 2020. Full text included in this report as Appendix B.

- A CT rated for 0.15% extended range accuracy class may be used in specific circumstances. For example, NYSEG/RG&E[5] may use extended accuracy CTs to gain improved accuracy at lower current magnitudes. Most of these "select" cases involve the need to measure both load and generation at a single metering point.

These two CT accuracy ranges represent different overall accuracy performances for metering which tend to allow less error than the de facto 2% standard noted earlier.

Furthermore, Con Edison[6], in its response to Pterra's questionnaire, also noted that it uses meters with 0.2% and 0.5% nameplate class accuracy. These refer to accuracy classes in ANSI C12.20-2015 American National Standard for Electricity Meters.

The JU notes that the type of meters used for single-meter multi-use facilities such as CHP, gas plant or stand-alone BESS are:

- Net,
- Bidirectional,
- Time-of-use,
- Recorder-equipped meters,
- Load profile or interval

Meters that fail performance testing are discarded. The utilities do not apply correction factors to the metered quantities. NYSEG/RG&E notes that most modern solid state meters cannot accommodate dynamic error compensation of IT's and in fact, some do not even have an accuracy adjustment function.

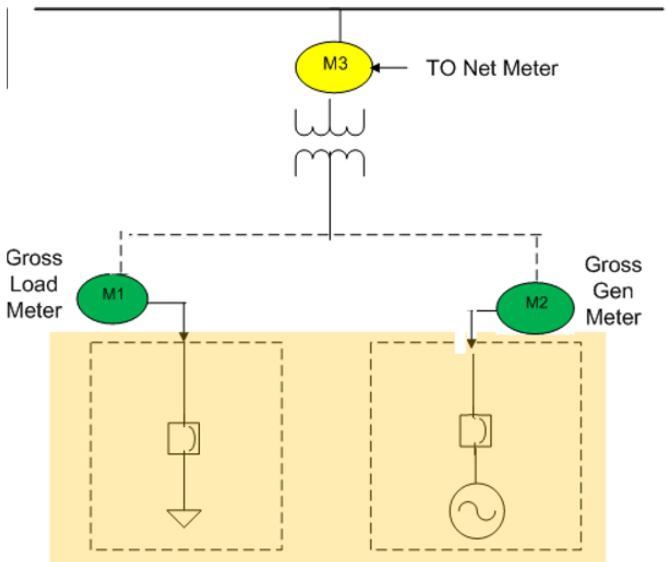
In instances where a meter is not located at the point of interconnection, loss compensation may be applied. The JU responses note that this is acceptable industry practice but is more typical for interconnections administered by the NYISO. Loss compensation is noted here as it may be necessary for alternatives such as the use of sub-meters (See Section 2.2).

2.2. Metering Practice in Other Jurisdictions

Distributed energy resources (DER) in New York that participate in the wholesale energy market are subject to the metering requirements of the NYISO[7]. Under the NYISO guidelines[8], meters must meet or exceed ANSI C12.20 standards. Instrument transformers must meet or exceed specifications of ANSI/IEEE C57.13 for standard accuracy class 0.3 or better.[9]

[5] New York State Electric and Gas and Rochester Gas and Electric, both Avangrid companies.
[6] Consolidated Edison of New York, Inc.
[7] New York Independent System Operator.
[8] NYISO, Manual 25, Revenue Metering Requirements Manual, September 2019.
[9] See Section 1.2 for a brief description of the accuracy requirements for ANSI C12.20 and C57.13.

NYISO requires a two- or three-meter system to separately measure the net energy, gross load and gross generation components of a Behind-the-Meter Net Generation Resource (BTMNG). Figure 2-1 illustrates the various metering configurations.



Note: Option 1: M3, M2 compensated for high side of GSU, M1 compensated for high side of GSU

Note: Option 2: M3, M1 compensated for high side of GSU (NYISO estimates M2 compensated for high side of GSU)

Note: Option 3: M3, M2 compensated for high side of GSU (NYISO estimates M 1 compensated for high side of GSU)

Figure 2-1: NYISO Metering Configurations for Behind-the-Meter Net Generation Resource (Source: NYISO Manual 25, p. 7)

In California, the Public Utilities Commission issued a ruling that two meters are not required[10] for in-front-of-the-meter systems and station power treatment for storage resources located behind the utility meter and participating in the wholesale market as a demand response resource. The Commission directed that Load Serving Entities and storage providers determine and establish up-front their desired metering configuration. While the CPUC was in the process of making this ruling, California utilities proposed several options for recording station power consumption for storage resources in their station power tariff filings, which the CPUC found

[10] See CPUC docket D.17-04-039.

reasonable and have thus approved. The individual utility metering options are as follows.

- Pacific Gas and Electric (PG&E) options comprised of:
    - "Option 1 – Station Power Load Reference – Station Power Load Reference value will be established by measuring its Retail Station Power loads at Idle Charging State, prior to issuance of the Permission To Operate (PTO) letter by PG&E. This reference point will be set initially via field tests and will at each anniversary adjust based on the maximum demand values obtained in the prior 12 months.
    - Option 2 – Separate Retail Station Power Meter – Retail Station Power is separately metered, the bill will be determined from actual usage data obtained from either the Retail Station Power grid-tie meter or the station power sub-meter.
    - Option 3 – Estimation of Metered Data – PG&E and Customer shall agree on the derivation methodology and included as specified in this Special Agreement for Retail Storage Station Service For In Front Of The Meter Storage Applications. Such derivation may include reliance upon third-party metering. Metering and other reasonable basis must be agreeable to both PG&E and Customer."

Option 1 and 3 allow for some form of estimation in place of adding a meter to the plant configuration.

Option 2 refers to a "sub-meter", i.e., a separate revenue meter embedded in the client facility. This is a practice more commonly found in say multi-tenant buildings where individual tenants have their own sub-meters apart from the building's main meter. A sample configuration of a PV+BESS facility with a single sub-meter is shown in Figure 2-2. The sub-meter may also be located on the load side of the auxiliary load transformer. Compensation methods are needed to adjust for losses and avoid double counting in any configuration with one or more sub-meters.

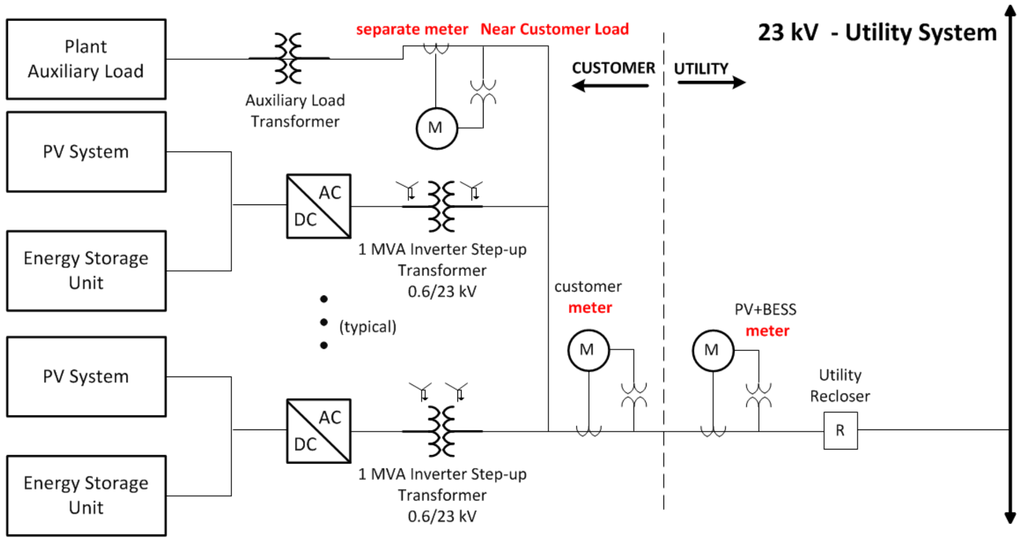


Figure 2-2 Sample Metering Configurations with a Single Sub-meter Located Near the Customer Load

- San Diego Gas and Electric (SDG&E) offered the following metering options[11]:
  - "All electric charging service under this Schedule may be separately metered via an independent grid tie for Station Power load and a separate tie for Wholesale Power load. The Station Power service meter shall to the extent practicable reasonably capture all Station Power loads. Any Station Power loads not captured should be reported to SDG&E at the time of interconnection or at any time when the customer first becomes aware of such Station Power loads, and shall be documented on Form 195-1000.
  - All electric charging service under this Schedule may be separately metered via a sub-metering arrangement. The Station Power service sub-meter shall to the extent practicable capture all Station Power loads. Any Station Power loads not captured should be reported to SDG&E at the time of interconnection or at any time when the customer first becomes aware of such Station Power loads, and shall be documented on Form 195-1000.

[11] "Metering Provisions. SDG&E and the customer shall negotiate measurement and metering provisions that allow for the determination of Station Power and Wholesale Power, as defined herein, within the parameters of at least one of the three options described below. Any agreed upon measurement and metering provisions must allow compliance with all applicable interconnection tariffs and must be documented on Form 195-1000. All metering, equipment and protective relays necessary to implement the provisions of the Schedule are at the customer's expense."

- SDG&E will at its discretion accept alternative metering and measurement arrangements to the extent that the metering and measuring arrangement reasonably capture Station Power load and do not impose an unreasonable administrative burden on SDG&E."

The first and second bullets above apply to auxiliary metering and sub-metering, respectively. The third bullet opens the possibility for other unspecified metering arrangements.

Overall, there are a variety of practices with regards to metering applicable to the auxiliary load of PV+BESS facilities. These include:

1. Use of an auxiliary meter or a separate meter for the facility’s auxiliary loads.
2. Use of sub-meter/s to register usage at various electrical nodes of the facility where auxiliary loads may be fed.
3. Estimated usage based on spot measurements at regular intervals such a year or month.
4. Estimated usage based on a formula agreed upon by the facility and utility.

Section 3. Test Simulation of a Sample Facility

This section describes the simulation testing of a sample PV+BESS facility with respect to metering accuracy. The material presented comprise of:

- Maximum error in metering
- assumptions and data applied to building an hourly model for a year-long operation of the sample facility
- applicable metering standards
- simulation and sensitivity analysis of the sample facility's accuracy performance

3.1. Maximum Error in Metering

CT-based metering assumes a linear relationship between the current being measured and the current that is registered on the meter as defined by the CT ratio. However, instrument transformer conversion is nonlinear due to the effect of core excitation. A sample excitation curve for a CT, shown in Figure 3-1, illustrates the nonlinear behavior of the CT, especially at the lower range of the CT rating.

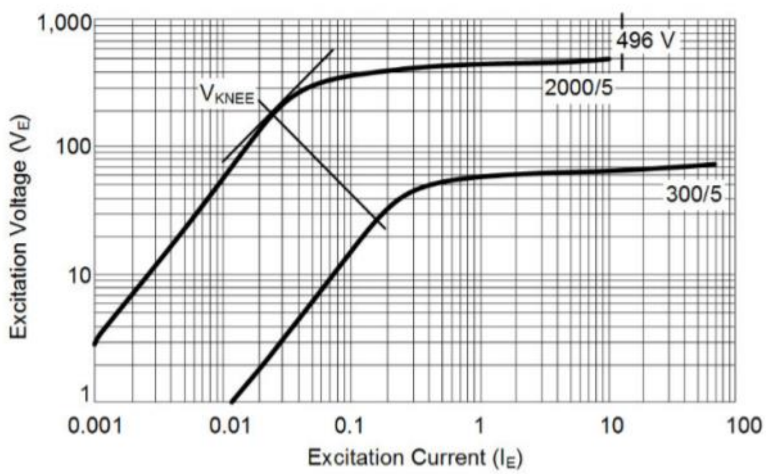


Figure 3-1: Sample Excitation Curve (source: Schweitzer Engineering Laboratories, Inc.)[12]

Similarly, the phase angle between the primary and secondary currents will vary due to the excitation current.

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[12] "Beyond the Knee Point: A Practical Guide to CT Saturation," Ariana Hargrave, Michael J. Thompson, and Brad Heilman Schweitzer Engineering Laboratories, Inc., 44th Annual Western Protective Relay Conference, October 2017.

The difference between the linear CT ratio measurement and the actual CT current reading is the "error".

As noted in Section 1.2, the IEEE standard for instrument transformers allow for a specified maximum permissible error over most of the operating range of ITs. In the case of a standard accuracy CT, the maximum permissible error for CT loads between 10% and 100% of the CT rating is 0.6%. The actual value of the error may vary from 0-0.6% over the specified range of CT loading depending on how a manufacturer calibrates the CT. Furthermore, the error can be plus/minus (+/-), or above or below the correct current transformation.

For purposes of defining an index for accuracy, consider the maximum permissible error over a time period, P. The sum of the individual maximum errors for each interval of time within the period is e_{maxP}. For an energy meter, this means that the maximum possible kWh error for, say a period of a year, is the sum of the individual maximum kWh error per hourly reading. Dividing e_{maxP} by the total actual energy of the CT load gives the maximum percent error, e_{max}.

If all the load on a standard accuracy CT is within the 10-100% range of the CT rating, then e_{max} is 0.6%. Likewise, if all the load on an extended accuracy CT (0.15 class) is within 5-100% of the CT rating, then the e_{max} is 0.3%.

However, if some of the load falls in the region of measurement where no accuracy performance is specified, then the value of e_{max} will deviate from the specification of the IEEE standard. The magnitude of deviation will depend on the excitation characteristics of the CT and burden of the CT.

The index e_{max} indicates that the metering error can be as high as this value but can also be zero. Also, the metering error can be an over-reading or an under-reading. This index does not represent the effects of external magnetic fields, temperature, capacitive coupling and other local environmental factors.

For purposes of evaluating accuracy, e_{max} is an expression of a higher potential for error in the meter registry. However, it does not indicate that the error is higher, only that there is a potential for such.

As an additional note, the error limits assume that the burden rating of the IT is not exceeded. The load and burden on a CT are illustrated in Figure 3-2.

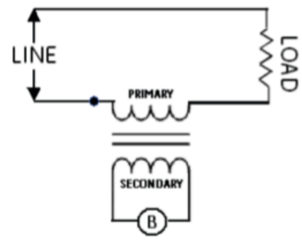

Figure 3-2: Load and Burden on an Instrument Transformer

The load is the current being measured, while the burden is where the converted measurement is recorded. Burden on a CT is given in terms of resistance in ohms. To comply with the IEEE accuracy prescriptions, the burden should remain within the burden rating of the transformer.[13]

3.2. The Sample Facility

The accuracy index is tested on a representative sample facility. This is a PV+BESS system with the following specifications:

- PV Capacity (kW-DC): 4163
- Inverter AC Power Rating (kW-AC): 1950
- BESS Nameplate Power (kW-AC): 1950
- BESS Usable Capacity (kWh-AC): 4460

The facility is equipped with separate transformers for the PV, BESS and auxiliary load. Hourly production and consumption data for the sample facility were provided by New York Solar Energy Industries Association & ITWG Industry Group Industry ("Industry").

The average daily production and consumption of the sample facility are shown in Figure 1-4. The PV and BESS outputs are net of no-load, collector and transformer losses.

In a PV+BESS system, the typical loads during the Auxiliary Load Only condition comprise of cooling/heating load, and line and transformer losses. The average daily auxiliary load as provided by Industry for the sample facility is shown in Figure 3-3.

Assuming a single net energy meter, the total annual energy measured based on the provided data is 5,384,750 kWh.

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[13] This mainly requires adequately sized equipment and conductors. For example, a long lead from the CT to the recording device will require larger conductors to avoid exceeding the burden rating of the CT.

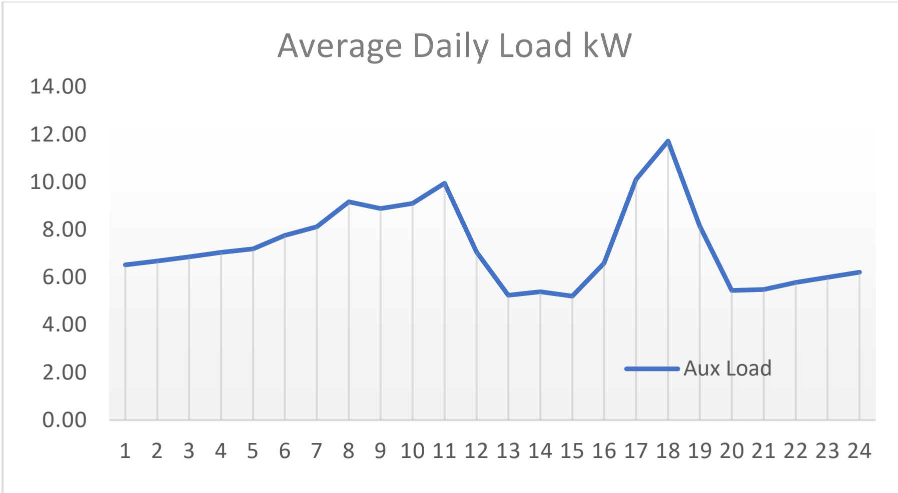

Figure 3-3: Average Daily Auxiliary Load for Sample Facility as Provided by Industry

For the purposes of simulation, several variations were applied to this model, as follows:

- Variation in the number of sunny days during the year:
    - "Full Sun" model – follows the original data on PV output provided by Industry
    - "Low Sun" model – assumes that 25% of the days in the Full Sun model have no PV output
- Variation in the magnitude of auxiliary load:
    - Low Auxiliary Load – follows the original auxiliary load data provided by Industry where the average daily auxiliary load varies from 0.27 to 0.6% of plant rating
    - High Auxiliary Load – increased auxiliary loads with maximum at just below 10% of plant rating

Notes on model scalability: Since the intent of simulation testing is to examine the metering accuracy performance with one or two-meters, the model may be scaled up or down with approximately similar accuracy performance. When using CT-rated meters, the CT high side is typically sized to be 100-125% of the plant. As noted previously, IEEE standards do not specify an accuracy performance below 10% of rating for standard accuracy CTs and below 5% for extended accuracy CTs. The differential in accuracy performance between one and two-meter configurations is expected to be highest when more of the auxiliary loads fall below the 10% or 5% IEEE limits.

3.3. Standards for Accuracy

There are number of standards that apply to service metering practices that are likewise applicable to metering of PV+BESS facilities. For the purposes of this report, the following standards are applied in the simulations of the sample facility.

1. Standard Level 1 – 2% Accuracy. This is based on the NYSDPS standard for in-service meters which allows for accuracy of meters to be within 98%-102% of loads being measured. This standard is also reflective of accuracy guidelines in ANSI C12.1-2008 American National Standard for Electric Meters, Code for Electricity Metering.
2. Standard Level 2 – 0.6% error above 10% of rated current based on Standard Accuracy CTs per IEEE Standard C57.13.6.[14] Below 10% rated current, error will follow typical excitation curve of device[15].
3. Standard Level 3 – 0.3% error above 5% of rated current based on Extended Accuracy CTs per IEEE Standard C57.13.6. Below 5% rated current, error will follow typical excitation curve of device.

In addition, another standard applicable to accuracy of meters is ANSI C12.20-2015 American National Standard for Electricity Meters. This standard defines the 0.5 and 0.2 classes for electric meters.[16] Simulations were not performed based on this standard since its accuracy levels are similar to those of Levels 2 and 3 above.

3.4. Simulations of Sample Facility

An 8760-hour simulation of the operations of the sample facility for various assumptions was conducted. For each simulation, the maximum kwh error and e_{max} values for a basic net metering scheme were calculated for a single meter and two-meter configuration for each of the 3 Standard Levels.

The scenarios that were tested are as follows:

- Scenario 1: Full Sun, High Auxiliary Load
- Scenario 2: Full Sun, Low Auxiliary Load
- Scenario 3: Low Sun, High Auxiliary Load
- Scenario 4: Low Sun, Low Auxiliary Load

Additional assumptions:

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[14] Since the data for the sample facility does not exceed 100% of the CT rating, the 0.3% maximum error for load above 100% rating is not applied.
[15] For this study, GE instrument transformer characteristics were used.
[16] A 0.1 class meter is also available.

- For Standard Levels 2 and 3, the metering CT is rated for the full plant capacity of 1950 kW.[17]
- For Standard Level 2, the maximum permissible error for measurements below 10% of the facility rating is the lower of 10% and the percent error of the CT at the median value of all measurements during the Auxiliary Loads Only condition.
- For Standard Level 3, the maximum permissible error for measurements below 5% of the facility rating is the lower of 10% and the percent error of the CT at the median value of all measurements during the Auxiliary Loads Only condition.

The results for Scenario 1, 2, 3 and 4 are shown in Table 3-1 to Table 3-4.

Scenario 1 shows that:

- The largest maximum error occurs at Level 1 Standard, where e_{max} is 2%, at 101 MWhr for a single meter. A two-meter configuration has a combined maximum error of 114 MWh increasing the e_{max} by 0.25%. **Under this standard, the maximum error increases with the addition of a second meter**.
- The Level 2 and Level 3 Standards show lower maximum errors overall. The single meter Level 2 maximum error is 55 MWhr with an e_{max} of 1.10%. (Note that if all the measurements were within the 10-100% range of the CT, then the nominal e_{max} will be 0.6%, matching the maximum error for this Standard Level.) The single meter Level 3 maximum error is 31 MWhr with e_{max} of 0.62% (up from the nominal 0.3%). For two-meter configurations, the Level 2 maximum error is 45 MWhr, while for Level 3 it is 21 MWhr for Level 3. **Both measurements show decreasing maximum error with the addition of a second meter**.

For Scenario 2, the auxiliary load levels are reduced from the Medium Load of Scenario 1 to the Low Load in this scenario. The results show:

- A higher total energy flowing through the single meter at 5,302 MWhr compared to 5,064 MWhr in Scenario 1.
- Similar to Scenario 1, the Level 1 maximum error increases with the addition of a second meter, while in the Level 2 and 3 simulations, the maximum error decreases with the second meter.
- The magnitudes of Δe_{max} are much smaller at 0.04-0.05% compared to 0.18-0.25% for Scenario 1. **The lower magnitude of auxiliary loads reduces the differential in maximum errors between single and two-meter configurations**.

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[17] Commercial CTs may not be available for the current rating at the plant's full load but for the purpose of this simulation the assumption is that such a CT is available.

Scenario 3 examines the effect of Low Sun conditions on the comparative maximum errors. The results show:

- The total energy flowing through the single meter is now much lower as 4,112 MWhr compared to 5,064 MWhr in Scenario 1.
- Similar to Scenario 1, the Level 1 maximum error increases with the addition of a second meter, while in the Level 2 and 3 simulations, the maximum error decreases with the second meter.
- The magnitudes of Δe_{max} are about the same at 0.17-0.25% compared to 0.18-0.25% for Scenario 1, but with **the lower number of sunny days, the magnitudes of maximum error at all Levels are less than those of Scenario 1**.

The effect of a combination of Low Sun and Low Auxiliary Load is considered in Scenario 4.

- Similar to Scenarios 1, 2, 3 and 4, the Level 1 maximum error increases with the addition of a second meter, while in the Level 2 and 3 simulations, the maximum error decreases with the second meter.
- Similar to Scenario 2, the maximum error differentials between one and two-meter configurations are low for all Levels. This is due to the Low Auxiliary Loads.
- The Δe_{max} is 0.06% compared to Scenario 2's range of 0.04-0.05%. While the Δe_{max} is sensitive to the Low Auxiliary Load, it is not much affected by Low Sun conditions.

Table 3-1: Results of Simulation for Scenario 1: Full Sun, Medium Auxiliary Load

	Single meter		Two-meter						Difference	
			Main meter		Aux meter		Combined			
Total Energy through Meter	5,064,149		5,384,750		320,601		5,064,149			
Standard	Max kWhr error(+/-)	e_{max}	Max kWhr error(+/-)	e_{max}	Max kWhr error(+/-)	e_{max}	Max kWhr error(+/-)	e_{max}	Max kWhr error(+/-)	Δe_{max}
Level 1 Standard	101,283	2.00%	107,695	2.00%	6,412	2.00%	114,107	2.25%	12,824	0.25%
Level 2 Standard	55,478	1.10%	41,569	0.77%	3,547	1.11%	45,116	0.89%	(10,362)	-0.20%
Level 3 Standard	31,216	0.62%	20,068	0.37%	1,900	0.59%	21,968	0.43%	(9,248)	-0.18%

Table 3-2: Results of Simulation for Scenario 2: Full Sun, Low Auxiliary Load

	Single meter		Two-meter						Difference	
			Main meter		Aux meter		Combined			
Total Energy through Meter	5,320,630		5,384,750		64,120		5,320,630			
Standard	Max kWhr error(+/-)	e_{max}	Max kWhr error(+/-)	e_{max}	Max kWhr error(+/-)	e_{max}	Max kWhr error(+/-)	e_{max}	Max kWhr error(+/-)	Δe_{max}
Level 1 Standard	106,413	2.00%	107,695	2.00%	1,282	2.00%	108,977	2.05%	2,565	0.05%
Level 2 Standard	44,294	0.83%	41,569	0.77%	385	0.60%	41,953	0.79%	(2,340)	-0.04%
Level 3 Standard	23,061	0.43%	20,068	0.37%	384	0.60%	20,452	0.38%	(2,610)	-0.05%

Table 3-3: Results of Simulation for Scenario 3: Low Sun, Medium Auxiliary Load

	Single meter		Two-meter						Difference	
			Main meter		Aux meter		Combined			
Total Energy through Meter	4,112,284		4,371,680		259,396		4,112,284			
Standard	Max kWhr error(+/-)	e_{max}	Max kWhr error(+/-)	e_{max}	Max kWhr error(+/-)	e_{max}	Max kWhr error(+/-)	e_{max}	Max kWhr error(+/-)	Δe_{max}
Level 1 Standard	82,246	2.00%	87,434	2.00%	5,188	2.00%	92,622	2.25%	10,376	0.25%
Level 2 Standard	45,481	1.11%	34,340	0.79%	3,900	1.50%	38,241	0.93%	(7,240)	-0.18%
Level 3 Standard	25,870	0.63%	17,009	0.39%	1,920	0.74%	18,929	0.46%	(6,941)	-0.17%

Table 3-4: Results of Simulation for Scenario 4: Low Sun, Low Auxiliary Load

	Single meter		Two-meter						Difference	
			Main meter		Aux meter		Combined			
Total Energy through Meter	4,307,560		4,371,680		64,120		4,307,560			
Standard	Max kWhr error(+/-)	e_{max}	Max kWhr error(+/-)	e_{max}	Max kWhr error(+/-)	e_{max}	Max kWhr error(+/-)	e_{max}	Max kWhr error(+/-)	Δe_{max}
Level 1 Standard	86,255	2.00%	87,434	2.00%	1,282	2.00%	88,716	2.06%	2,461	0.06%
Level 2 Standard	37,217	0.86%	34,340	0.79%	385	0.60%	34,725	0.81%	(2,492)	-0.06%
Level 3 Standard	20,076	0.47%	17,009	0.39%	384	0.60%	17,393	0.40%	(2,683)	-0.06%

Table 3-5: Results of Simulation for Scenario 5: Full Sun, High Auxiliary Load

	Single meter		Two-meter						Difference	
			Main meter		Aux meter		Combined			
Total Energy through Meter	4,871,788		5,384,750		512,962		4,871,788			
Standard	Max kWhr error(+/-)	e_{max}	Max kWhr error(+/-)	e_{max}	Max kWhr error(+/-)	e_{max}	Max kWhr error(+/-)	e_{max}	Max kWhr error(+/-)	Δe_{max}
Level 1 Standard	97,436	2.00%	107,695	2.00%	10,259	2.00%	117,954	2.33%	20,518	0.41%
Level 2 Standard	62,582	1.28%	41,569	0.77%	5,676	1.11%	47,244	0.93%	(15,338)	-0.30%
Level 3 Standard	28,552	0.59%	20,068	0.37%	3,040	0.59%	23,108	0.46%	(5,444)	-0.11%

Section 4. Conclusions

An assessment of the technical differences in accuracy between one and two-meter configurations for PV+BESS facilities was conducted. The assessment considered the basic technology of meters and associated instrument transformers, primarily current transformers, applicable standards and practices and used simulations of sample PV+BESS facilities to examine the error characteristics under different operating scenarios.

The conclusions of the assessment are as follows:

- For basic net metering schemes, the maximum potential metering error **increases** with the addition of a 2nd meter based on the accuracy standard set forth in DPS 16 NYCRR Part 92 which designates as "Out of limit" in-service meters that test outside the range of 98% to 102%.
- Using the accuracy performance of CTs as a basis, a second meter does reduce the maximum potential error.
- If alternative pricing schemes are applied (other than net metering) an economic assessment is needed to determine if requiring an auxiliary meter is still warranted
- The magnitude of the decrease or increase in maximum error is in the range of 0.17-0.25% of the total annual registry. Use of an estimated cost for the potential registry differential may be more economical than actually installing a second meter.
- Even if auxiliary metering is required, use of sub-meters may avoid costs of wiring the meter from the point of interconnection although careful use of compensation is needed to avoid double-counting.

Appendix A. NYSDPS Metering and Rates Groups Responses

Following are the NYSDPS Metering and Rates Group responses to Pterra questions dated May 19, 2020. The Metering Groups' responses are shown in blue and the Rates Group's responses are in red text.

(The NYSDPS Metering Group) have answered the questions that were specifically related to the scope of electric metering, as presented in the Part 92 Operating Manual ("Manual"). Unfortunately, there isn't language in the Manual that specifically addresses some of the other concerns presented by the requesting party. However, we believe there are questions that are better suited to be addressed by other divisions within the agency.

- Is there a specific accuracy of instrument transformer required to use for metering? (Per IEEE C57.13.6-2004: 0.3 Class Standard Accuracy, 0.15 Class High Accuracy or 0.15S Class Special High Accuracy)
  - There is no language in the Manual specifying the accuracy class of an instrument transformer
  - The Manual only refers to the information required for "test records" of meters and instrument transformers:
    - A test record of the most recent test of each watt-hour meter shall be retained for a period of at least 6 years, and the test records of any prior tests shall be retained for a period of at least 2 years;
    - Test records for meters used in conjunction with instrument transformers and shunts shall give the correction, as specified in Section 4 (a) (ii) (4) above, which shall be applied to the percentage registration of the watt-hour meter;
    - Test records for meters used in conjunction with phasing transformers shall give the actual voltage ratios between marked terminals of each phasing transformer;
    - The test record for each current transformer shall indicate the ratio correction factors and phase angles at 10% and 100% of rated primary current with ANSI burden B-0.2 or with any higher burden at which the transformer is to be used. The test record for each potential transformer shall indicate the ratio correction factor and phase angle at normal utilization voltage and with such burdens as to give assurance of satisfactory in-service performance;
    - The test record for an instrument current or potential transformer shall indicate the frequency, the ratio

        correction factor and phase angle for each burden at which the transformer was tested;

        - A test record shall be provided for each phasing transformer;

        - The test record shall be retained while the transformer to which it applies remains in service at the specified location and becomes void upon the removal of such transformer or shunt

- How often are revenue meters tested? Please clarify the meaning of 98% and 102% accuracy.
    - Meter Service Providers are responsible for in-service testing of all meters under its control. CT-rated meters are subject to one of the following three test methods:
        - Variable Interval- The minimum number of meters of each type to be tested in each ensuing calendar year shall be based on the performance of meters of that type during a 12-month period which shall have terminated not more than 4 months prior to the start of the calendar year by using a formula including the number of meters that tested outside of the range of 98% to 102%. If the number of meters of any type being tested is less than 20, the annual test rate will be 4%, new meter types shall be tested at a rate of 4% or 100 meters(whichever is less) for the first year of service. If a calculated rate exceeds 8%, a special remediation program is to be introduced to reduce the population of out of limit meters.
        - Periodic- All watt-hour meters installed on customers' premises shall be tested at least once every 8 years.
        - Selective- The minimum number of meters of each type to be tested in each ensuing calendar year shall be based on the performance of meters of that type during a 12-month period which shall have terminated not more than 4 months prior to the start of the calendar year by using a formula including the number of meters that tested outside of the range of 98% to 102%. There are exceptions for devices determined to have performance issues, minimum test population and new meter types in the first year of service.
    - For "In-Service Testing," meters will be considered outside the accuracy range if the final average registration accuracy is outside the range of 98% to 102%; the accuracy of an electric meter is determined by a watt-hour test standard that is calibrated and traceable to NIST

- If one meter is used for a ESS+PV facility, is the energy measured based on a net metering rate?
    - Not Applicable; maybe the rates section can address? Energy and demand are measured by the utility meter and the utility bills for charges based on the service classification assigned to the utility meter.
- If an auxiliary meter is provided for a ESS+PV facility, will its measured energy be based on a retail rate?
    - Not Applicable; maybe the rates section can address? An auxiliary meter will be charged the assigned service classification rates.
- Is there an option for facilities to have a baseline energy for auxiliary load instead of a continuously metered use?
    - We need further clarification regarding the statement "baseline energy for auxiliary load"
- Would a sub-meter (an auxiliary meter that is located inside the facility instead of at the Point of Common Coupling (PCC) with the utility) be allowed?
    - We're not aware of any Commission regulations regarding this request; it is not mentioned in the Manual
- Are there auxiliary metering requirements for other types of facilities other than ESS+PV?
    - We're not aware of any Commission regulations regarding "Auxiliary Metering Requirements"; it is not mentioned in the Manual

Appendix B. JU Response to Pterra Survey

(This section redacted for confidentiality.)