To: Kate Tohme, Massachusetts Department of Public Utilities

From: NSTAR Electric Company d/b/a Eversource, Massachusetts Electric Company and Nantucket Electric Company, each d/b/a National Grid, and Fitchburg Gas and Electric Light Company d/b/a Unitil

RE: Issues Related to SMART Applications for DC-Coupled Solar + Storage Systems

Date: August 9, 2019

This memo is in response to a request from Department of Public Utilities ("Department") staff for the electric distribution companies ("EDCs") to provide a summary of the issues related to applications in the SMART program for DC-coupled Solar Tariff Generation Units ("STGUs") with co-located energy storage systems ("ESS").

Background

The EDCs have received numerous interconnection applications for STGUs with DC-coupled ESS, that is, where both assets are connected behind and share a common inverter device. In addition, some customers have expressed an interest in having their DC energy flows metered for market participation and compensation purposes.

The Department of Energy Resources ("DOER") has suggested that: (1) all of the output from STGUs should be recognized as creating renewable energy certificates, and thus compensated through the SMART program, with the intent that electricity losses from battery charging cycles of DC-coupled ESS should be included as well; and (2) the EDCs should work with solar stakeholders to develop metering solutions that facilitate this principle for DC-coupled standalone STGUs with ESS.

DC-coupled STGUs with ESS can be slightly more efficient than AC-coupled systems, depending on how the ESS is operated, and typically have lower construction and installation costs. The table below provides a high-level illustration of the efficiency advantages of a DC-coupled system using simplified assumptions[1]. However, it should be noted that even though the AC-coupled system is paid on output before losses in the battery, and the charging pattern of the two systems is the same, the financial difference is actually very small between the two – about half of a percent in annual AC-energy and SMART payment terms. For the same number of charging cycles, AC-coupled systems do lose some additional total output: the additional losses of the AC-coupled system are approximately 9 MWh in this example, or approximately 0.5% of the annual output of the solar array.

All values in MWh, unless noted	**AC-Coupled**	***All values in MWh, unless noted***	**DC-Coupled**
PV Generation, in DC	1,778	PV Generation, in DC	1,778
PV, less DC to AC inverter loss	1,725		
AC-->DC Loss to Battery, 100 Cycles	-4.6	DC-->AC PV Only Loss	-49
Battery Losses, 100 Cycles	-7.5	Battery Losses, 100 Cycles	-7.5
DC-->AC Battery Output Loss	-4.3	DC-->AC Battery Output Loss	-4.3
Total AC-Coupled Output	1,708	Total DC-Coupled Output	1,717
Total Payment on PV Output (0.20 rate)	$345,000	Total Payment on PV Output	$343,400
		Difference from AC-Coupled	**$1,600/0.46%**

---

1 The system modeled assumes 1,300 kW DC modules, a 1,000 kW AC inverter with 3% losses, a 750 kW/1,500 kWh battery with 5% loss round-trip efficiency, and 100 charging cycles per year. PV Watts was utilized to estimate annual AC production, with change of the inverter loss from 96% to 97%.

The DOER has convened stakeholders from several solar developers to work with the EDCs to explore metering solutions for DC-coupled STGUs with ESS. Discussions to date have focused on technical issues related to DC-metering as well as development of a common understanding of the market and policy barriers related to DC-coupling of STGUs with ESS. Nonetheless, metering of DC electricity is currently not practiced by the EDCs and there is currently no short-term path to incorporating this into EDC standards or meter data operations, due to issues described in more detail below.

The solar stakeholders have proposed using customer-owned DC watt-hour meters to measure electricity flows into and out of a DC-coupled ESS. Under this proposal, the customer would be responsible for verifying the accuracy of the meter and would provide meter testing data to the relevant EDC or DPU, upon request. In addition, the customer would transmit metering data to the EDCs via a customer-owned Remote Terminal Unit after application of any necessary calculations. The data would then be further adjusted to account for the theoretical losses associated with a DC to AC conversion, as well as transformer losses, thereby creating an estimated equivalent production that is comparable to the SMART production metered for AC-coupled systems.

There are many issues with this proposal that the EDCs cannot support. First and foremost, these customer-owned meters would not meet the ANSI C12.20 standards applicable to AC utility meters, because no ANSI standard for DC meters currently exists.[2] In addition, it would take some time to create such nationally accepted standards and meters that meet those standards; possibly several years. Even if this issue were surmounted, this proposal would require significant changes to standard utility practices and information systems, as well as the SMART program as designed and currently implemented, requiring substantial time and effort by the EDCs. Some of the most critical issues are outlined below.

Technical Issues

- It is unclear whether the data reporting systems proposed by the solar stakeholders could integrate into the EDCs' existing meter data management systems (MV90), or what the resulting cost would be. The EDCs' meter data systems experts will meet with the solar stakeholders to better understand the specifics of the proposed data formats, the degree of adjustment, and the resulting confidence in using this data within the EDCs' systems. The EDCs are also concerned that using data from customer-owned meters and customer calculations would void the chain of custody that the EDCs rely upon for billing grade data.
- Significant IT upgrades are likely to be required to accommodate third-party data. Issues that would need resolution through IT investments would include billing system enhancements, data storage protocols, and establishment of a secure gateway for data transfer. These IT investments could be substantial and the timeline for their implementation may not meet the desires of the solar stakeholders.
- The proposed metering solutions are not consistent with current EDC metering standards. For systems that will participate in wholesale markets, the EDCs require meters that meet the standards in ISO-NE's Operating Procedure No. 18. ISO-NE has indicated that they are open to changing their current metering standards, however, a formal timeline for this change is not currently available. Additionally, ISO-NE has indicated that it is open to exploring the use of customer-owned DC-metering data as a method for apportioning between solar and storage assets the AC meter reads used for market settlement. This is distinct from the use case described by the solar stakeholders for adding generation to an AC meter read for additional incentive payments.
- In order to avoid over-compensating DC-coupled systems relative to AC-coupled systems, DC-metered generation must be de-rated in order to account for theoretical inverter and transformer losses. These losses can vary widely based on system configurations, temperature, and equipment choices, which are difficult to normalize, and may be wrong. Any additional compensation would also need to be adjusted for the reduction in energy and attributes that the EDCs would receive due to the losses.
- Allowance of self-reported data would prompt the following considerations:
  - Systems with both utility-owned and customer-owned meters would need to resolve issues with the timing of billing cycle reads;

[2] ANSI is the American National Standards Institute.

- Utility procedures would need to be developed to account for missed customer data reports. Missed reporting deadlines are a frequent problem associated with self-reported data and has been an ongoing issue with the state's Production Tracking System (PTS) that serves the SREC programs;
    - It is unclear what procedures the EDCs would be required to follow to verify customer-reported data and what costs associated with verification would be charged to individual system owners or recovered from all customers through the distributed solar charge;
    - Initial and ongoing meter testing requirements would need to be agreed upon; and
    - Issues related to EDC liability related to inaccurate customer-reported data would need to be resolved.

Tariff Issues

- The issue of customer-reported data was discussed at length during the SMART proceeding. The Department ruled that "the Distribution Companies will need to own the production meters so that they can accurately track production for incentive and energy payments of the SMART STGUs and energy storage systems." D.P.U. 17-140-A, at 79. The EDCs maintain that customer self-reporting of data is not an appropriate approach to compensation within a tariff-based incentive program.
- Allowing any self-reporting of generation data, even for a limited number of cases, is likely to prompt additional requests to allow for customer self-reporting for other system types.[3]
- There is a conflict in the SMART tariff with regard to making ESS DC energy losses eligible for SMART incentives, if the ESS is paired with an Alternative On Bill Credit (AOBC) Facility. The current tariff defines a standalone STGU as a system that has no associated load (other than parasitic or station loads). Further, any parasitic or station loads are netted out of the total generation eligible for SMART tariff incentives. If DC energy lost due to energy storage cycling becomes eligible for SMART incentives, it implies that these loads are not parasitic or station loads. As a result, DC-coupled solar facilities with ESS cannot meet the tariff definition of a standalone generator and qualify as an AOBC facility. There are dozens of standalone solar projects with battery storage that have applied to generate AOBCs, and they may be ineligible to be AOBC units without modifications to the tariff language.[4]
- The complicated metering, intricate data reporting, and time-intensive billing processes that would be required to accommodate DC-coupled STGUs with ESS seem unlikely to be easily scalable or cost-effective solutions for the broader potential DC-coupled solar and storage market.
- Unless and until DC-coupled STGUs with ESS are eligible to participate in ISO-NE's wholesale markets, in compliance with ISO-NE rules, ratepayers would not receive value for the full energy and attribute products, and thus less value from such projects within the SMART program, driving the overall cost of the program higher.
- A DC-coupled metering solution would result in variations for a project's total compensation between AOBC, Net Metering and QF generation compensation schemes. Because the PV metered production will differ from the production exported to the grid, configurations that have higher SMART incentive rates and lower energy crediting rates (i.e., QFs) will receive a higher overall compensation.

Alternative Solution Discussion

Because the EDCs cannot support the use of DC-metered data for utility billing purposes, they have begun to consider other possible solutions to this issue but have no firm recommendations at this time. The EDCs first preference is to only provide incentives for the actual energy delivered to the grid by such systems.

---

[3] As the Department is aware, SMART program meter data for behind the meter systems are used both for incentive payments and for charging customers the distributed solar charge. SMART program meters will be required to provide monthly reads well after any system's incentive performance period, making customer-reporting of generation data infeasible long-term as customers will have little reason to provide accurate and timely meter reads after the end of their incentive eligibility.

[4] Notably, this issue is not limited to DC-coupled standalone systems as AC-coupled S+S systems serve non-parasitic loads as well.

In the event that the DOER and the Department want to explore possible alternatives, they could consider increasing the ESS adder for such systems, or could perform an annual reconciliation or "true-up" that is intended to create parity on compensation of DC-coupled and AC-coupled systems. Increasing the adder would provide "rough justice" to account for energy losses, whereas the "true-up" would attempt to achieve more accurate compensation. For example, the DOER could leverage the year-one battery cycling data reporting framework it has established for qualification of the energy storage adder, and storage system owners could report their annual cycling data to DOER. At DOER's direction, the EDCs could then provide an annual "true-up" incentive payment to DC-coupled standalone systems at a rate that would equal the foregone tariff revenue associated with the battery losses, less associated energy and attribute value.

However, it should be noted that there are inherent advantages to standalone DC-coupled systems that have led developers to deploy them under the SMART program, despite the metering challenge discussed in this memo. DC-coupled storage designs allow developers to construct STGU + ESS systems that greatly exceed the size of those allowed under the SREC programs. For instance, one developer in Eversource's service territory is currently constructing a 12 MW DC standalone system with a DC-coupled 5 MW storage system. The addition of the DC-coupled battery allows for greatly increased DC/AC ratios, lowering relative interconnection costs, and allowing systems to serve loads well past sunset. The land use impacts and the overall increase in SMART program costs associated with systems of this scale may not have been originally contemplated in the SMART program design. Given these advantages, and the small total loss difference in terms of revenue and output, the EDCs question whether any solution or adjustment for DC-coupled STGUs and ESS is warranted.

August 9, 2019

Kate Tohme, Hearing Officer
Department of Public Utilities
One South Station
Boston, MA 02110

RE: ENGIE Storage Proposal on DC Metering for DC Coupled Solar plus Storage

Dear Hearing Officer Tohme:

ENGIE Storage appreciates the opportunity to share with the department its proposal for a DC Metering Solution for solar paired with storage under the SMART program. ENGIE SA is the world's largest provider of energy and energy-efficiency services and has a permanent Massachusetts presence, including through its energy storage and distributed solar businesses. ENGIE Storage is a national leader in the deployment of distributed energy storage systems for both behind-the-meter and front-of-the-meter applications. Founded in 2009, ENGIE Storage has offices in Boston, Massachusetts and Santa Clara, California with a strong regional focus in the Northeast. ENGIE Storage has over 100 MW of energy storage built or under contract and is actively engaged in Massachusetts with a large portfolio of energy storage projects under development through the SMART program, as well as the recent announcement of the company's 3MW energy storage system built to support Holyoke Gas and Electric.

The attached proposed metering configuration for DC Coupled solar plus storage systems under SMART presents a solution to ensure compliance with the SMART tariff and regulations, preserve the policy intention behind the program, and enable storage participation in ISO-NE markets. This continues to be an issue of key importance to both ENGIE Storage and industry and the company appreciates the department's consideration of the issue.

1. <u>Background and Precedent</u>

The Massachusetts Department of Public Utilities Standards for Interconnection of distributed generation greater than 60 kW requires revenue metering equipment for watt-hour measurement to meet the requirements contained in NEPOOL (ISO-NE) Operating Procedure No. 18 (OP-18), "Metering and Telemetering Criteria."[1][2] OP-18 requires settlement watt-hour metering to conform to American National Standards Institute (ANSI) C12 standards. The accredited standards committee C12 develops code for electricity metering that establishes acceptable performance criteria for AC watt-hour meters. For AC watt-hour metering devices, ANSI C12 standards have long been in place. However, an ANSI C12 standard for watt-hour DC metering does not yet exist. In late 2018, ANSI C12 started to develop new

[1] Mass & Nantucket Electric (National Grid); M.D.P.U. No. 1320 (Approved 10/1/2016).

[2] NStar (Eversource), M.D.P.U. No. 55 (Approved 2/18/2018).

ANSI standards for DC watt-hour metering, however it is expected to take years before it is finalized and approved.

In the early 2000s, ISO-NE had need for DC watt-hour settlement metering on the High Voltage DC (HVDC) transmission line from Quebec, Canada to New England. The Quebec – New England Transmission project, is a long distance high voltage DC (HVDC) line between Radisson, Quebec and Ayer, Massachusetts. Due to the lack of DC watt-hour metering standards, ISO-NE modified OP-18 in 2017 to include DC watt-hour metering devices for settlement on the HVDC transmission lines. The modification requires HVDC metering devices to meet or exceed the "accuracy requirements" of ANSI standards. The HVDC metering accuracy standard is defined in Section VII.A of OP-18.

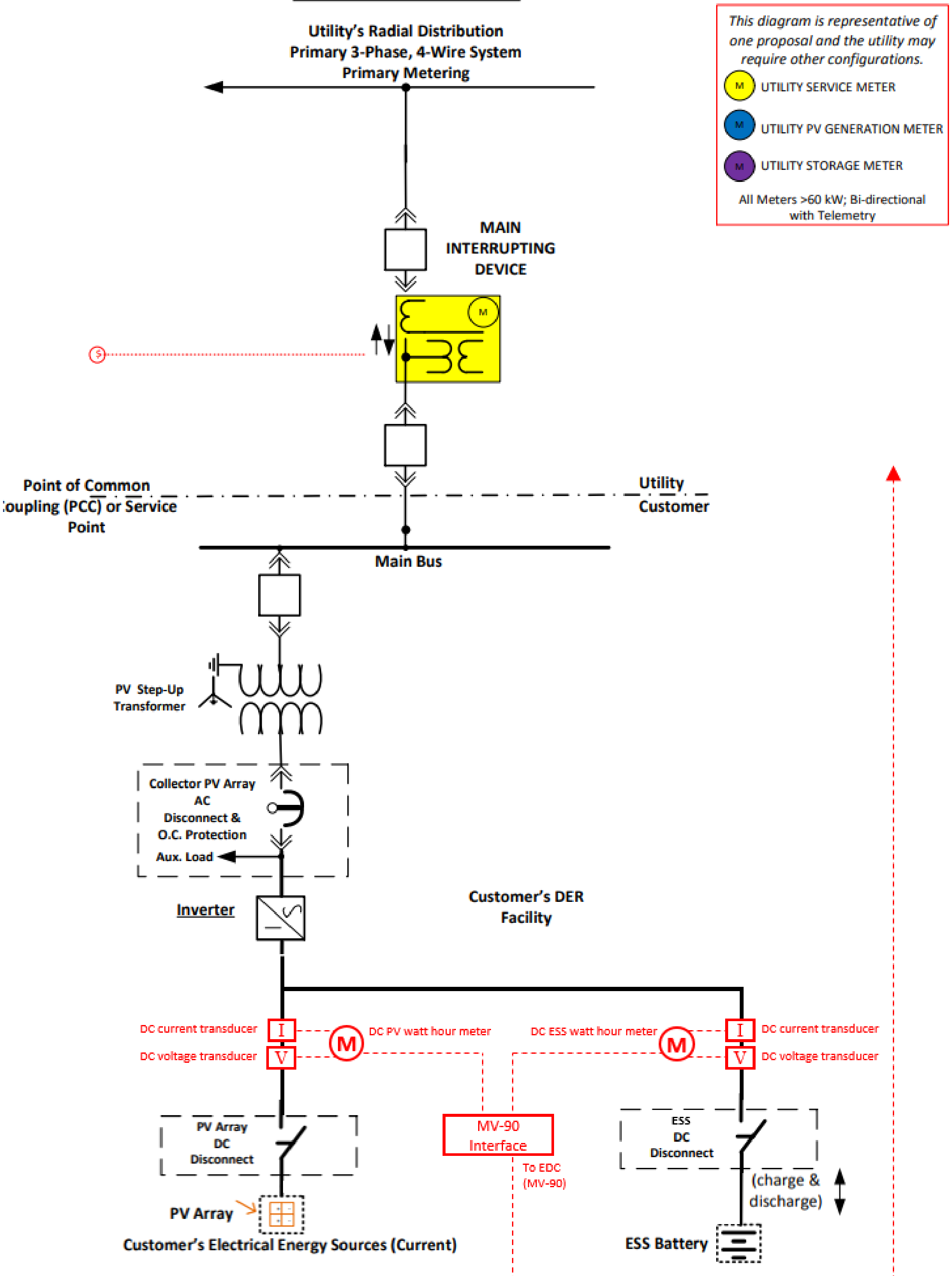
It should be noted that DC watt-hour meters used for HVDC are essentially the same devices used for lower voltage distributed PV and ESS generators. Much like AC watt-hour meters used for high voltage transmission lines are essentially the same devices used for lower voltage distribution lines, generators and services. Therefore, this proposal suggests following OP-18 accuracy standards for revenue DC metering PV and ESS distributed generators.

2. ENGIE Storage Proposed DC Metering Solution for DC Coupled Solar Plus Storage

The proposed metering configuration is shown below on the next page as a redline to the original EDC proposal and in *Attachment A.*

DC ESS Battery + STGU Paired AC Connection to Utility EPS 500kW and Greater
STAND ALONE MA SMART

6c



The configuration has four key considerations as follows:

i. A Point of Interconnection (POI) AC watt-hour utility (EDC) meter
    a. Same DPU DG watt-hour revenue metering requirements as now
ii. Customer-owned and maintained DC watt-hour metering devices for gross PV and ESS DG energy metering.
    a. Accuracy of the DC watt-hour meter will be 0.2% or better, which will meet or exceed the equivalent ANSI C12.20 solid state AC watt-hour meter accuracy requirement, in accordance with OP-18, Section VII.A.1.
        i. See *Attachment B* for the data sheet of a representative example of a DC watt-hour meter. The AccuEnergy AcuDC 243 can be ordered with an optional upgrade to a 0.2% accuracy as noted on the data sheet.
    b. Accuracy of the DC voltage and current input devices are within ANSI C57.13 accuracy limits. In accordance with OP-18, Section VII.A.3.
        i. See *Attachment C* for the data sheet of a representative example of a DC voltage transducer. The Verivolt IsoBlock V-1c can be ordered for compatibility with 1000VDC and 1500VDC systems.
        ii. See *Attachment D* for the data sheet of a representative example of a DC current transducer.
iii. Data transmission systems to enable the EDC MV-90 systems to read, store, and process the DC meter readings. Multiple technical solutions exist to enable data ingestion by the EDC MV-90 systems including:
    a. Preparation of meter data into MV-90 compatible datafiles by the generation owners for regular electronic submission to the EDCs
    b. Deployment of MV-90 compatible meter pulse recorders at the project sites for remote access by the EDC
iv. Loss-factor calculations for the adjustment of DC-metered energy values to the appropriate AC quantity, agreed upon with the EDCs. There are two loss factors for discussion:
    a. DC : AC conversion factor for SMART gross PV production calculation for use by the DOER. A fixed conversion loss factor based on established inverter efficiency ratings, such as the California Energy Commission (CEC) test protocol, would enable streamlined administration of the program.
    b. DC : AC conversion for ISO-NE wholesale market settlement for the solar and storage generators determined by measuring the AC meter at the Point of Interconnection against the DC sub meters located at the solar and energy storage.

3. DC Watt-Hour Revenue Metering Maintenance, Testing and Reading

The Customer will own and maintain the DC watt-hour metering. This proposal includes two processes to address this verification need. First, periodically compare the utility watt-hour revenue meter interval readings at the Point of Interconnection (POI) against the combined PV and ESS DC watt-hour metering interval readings. Second, accuracy test, and re-calibrate if necessary, the DC watt-hour meters once every two calendar years in accordance with the OP-18 standard. DC meter accuracy testing according to OP-18 (section IX.D.2. and IX.D.5) procedures and schedules for DC watt-hour meter testing. Watt-hour accuracy test paid for by the generator owner and performed by a qualified 3rd party testing company. Testing performed once every two calendar years per OP-18 (section IX.D.5). Test results provided to EDC & DPU on request.

4. Policy Imperative for DC Metering Solution for DC Coupled Solar Plus Storage

4.1 The proposed configuration for DC Coupled solar plus storage system is necessary to ensure compliance with the SMART tariff and regulations.

The SMART tariff and accompanying regulations state that all RPS Class I Renewable Generation Attributes and Environmental Attributes produced by a Solar Tariff Generation Unit, after reduction for parasitic or station load, shall be provided with an incentive. Furthermore, *"Solar Tariff Generation Unit" or ("STGU")* is defined in 225 CMR 20.00 to explicitly exclude energy storage. Any proposal for a DC Coupled SMART metering arrangement that does not enable for the measurement of gross PV production and proposes to credit SMART incentives to Renewable Generation Attributes and Environmental Attributes after reduction for energy storage round trip efficiency losses and would thus be in violation of the SMART tariff.

Key Supporting Language[3]:

- *"The SMART Provision provides for: (1) Incentive Payments for RPS Class I Renewable Generation Attributes and/or Environmental Attributes produced by a Solar Tariff Generation Unit."*
- *"Incentive Payments to STGUs will be in accordance with the formula specified in 225 CMR 20.08 and will be calculated for each monthly billing period as follows: IP = (BCR + CRA – GS – VOE) * kWhgen ... [where] kWhgen = kWh generated during the billing period. For STGUs, kWhgen will be measured after the reduction for parasitic or station load."*

The SREC program established precedent to meter RPS Class I Renewable Generation Attributes and Environmental Attributes at the generation unit (NEPool GIS Operating Rules). SMART incentives associated with Renewable Generation Attributes and Environmental Attributes should follow this precedent. For AOBC credits, solar generation should be measured at the solar generation unit and energy storage RTE losses settled at the energy storage meter through the wholesale settlement process with ISO-NE or at the GS1 rate if not registered in the wholesale market.

4.2. The proposed meter configuration for DC Coupled solar plus storage system is necessary to preserve SMART policy intentions.

[3] *National Grid Solar Massachusetts Renewable Target Program Tariff filed 12.3.18*

As stated in the *Solar Massachusetts Renewable Target Program (225 CMR 20.00) Guideline on Energy Storage: "Energy storage can provide a variety of benefits across the electricity supply chain from generation to transmission and distribution. Some of the specific benefits of energy storage when implemented in conjunction with solar photovoltaic systems include: improved power quality..., mitigating otherwise unnecessary substation upgrades often associated with installing solar, and the ability to shift solar energy production to peak demand."* In addition, the operational requirements in the Energy Storage Guideline further mandate that energy storage systems paired with solar provide value to ratepayers.

The proposed DC Coupled metering solution by the EDCs discourages charging the energy storage system from solar and discourages cycling of the energy storage system. These metering solutions create an economic constraint on storage systems, minimizing activity that creates ratepayer value. Under the SREC programs, renewable generation that did not reach the grid, but provided overall value to the grid was still credited. For example, rooftop solar diverted to charge an electric vehicle or reduce building load still received SREC credit. This logic has been extended into the SMART program for these same examples, and should be extended to energy storage. The solar consumed by these energy storage systems will generate ratepayer and environmental benefits.

Finally, the SMART program should seek to measure Renewable Generation Attributes and Environmental Attributes consistently across all STGUs whether AC Coupled or DC Coupled. In the December 2018 TSRG meeting there was consensus across industry, the DOER, and the EDCs that SMART credits should be measured based on gross PV output, without netting storage RTE losses. The precedent set on measurement of SMART credits for AC Coupled systems should be applied in consideration of how to best measure and account for SMART credits on DC Coupled systems.

4.3. The proposed configuration for DC Coupled solar plus storage system is necessary to **enable full storage participation in ISO-NE markets.**

ISO-NE Operating Procedures (ISO-NE OP-18 – Metering and Telemetering Criteria) requires each generator at a co-located SMART site to have a separate Wh meter to participate in ISO-NE markets. Batteries and solar assets must register as separate generators for the battery to provide reserves, regulation, dispatchable energy and other ancillary services to the ISO-NE wholesale grid. The key specifications from the ISO-NE Operating Procedure are detailed below:

Key Supporting Language:

- For an Asset to be eligible to participate in one or more Markets, the Asset must have Wh metering as defined in OP-18 (section IV.A.2)
- Metering is required for all Generator Assets and Load Assets which are modeled and defined in the ISO Energy Management System (EMS) and are eligible to participate in the hourly markets. (section V.A)
    - Dispatchable Asset Related Demands (DARDs) MW must be telemetered. (section V.A.1.b)
    - ATRR MWs must be telemetered. (section V.A.1.e)
    - A battery configured to provide ancillary services in the marker will consist of a DARD and ATRR

- Wh meters may either be located at the Interconnection Point between the Transmission Owner and the Market Participant's asset or not physically located at the Interconnection Point but compensated for excitation and load losses to the Interconnection Point (section IV.B.7.a)
- All metering devices used shall conform to applicable American National Standard Institute (ANSI) C-12 standards as amended from time-to-time. The accuracy standards to be observed are summarized in App C (section VII.A & section IX.A)

5. Resolution Process to Date

ENGIE Storage first met with the Department of Energy Resources to discuss concerns regarding metering configurations for DC Coupled solar plus storage systems under SMART in October 2018. The issue was then raised, but not resolved in both the December 2018 and March 2019 TSRG working groups. In May 2018 the Department of Energy Resources moderated an in-person discussion on the topic with representatives from the Electric Distribution Companies, as well as, ENGIE Storage, Nexamp, and Bluewave from industry. ENGIE Storage utilized this forum to further explain the proposed solution in detail. Following the meeting ENGIE Storage sent out technical documentation on the proposed solution for review. The Department of Energy Resources held two follow up calls to discuss ENGIE Storage's proposed solution. On the most recent call the Department of Energy Resources invited representatives from ISO-NE to join the call and provide feedback.

These Department of Energy Resources moderated conversations have been instrumental in moving the discussion forward and closing the gap on a workable solution for all parties. The primary concern expressed by the EDCs to this point has centered around ensuring that the proposed solution is MV90 compliant and compatible with existing EDC billing systems. To address this concern ENGIE Storage has modified its original proposal to include a MV90 interface instead of a RTU. The modified proposal suggests data transmission systems to enable the EDC MV-90 systems to read, store, and process the DC meter readings. On the most recent call, ISO-NE also noted an intention to explore plans for the ISO to implement a process to accept DC meter readings for the purpose of wholesale market participation. On its surface this appears to be a very interesting suggestion and ENGIE Storage is interested to learn more about the timeline and feasibility of this proposal.

ENGIE Storage appreciates the department's review of this issue and looks forward to further consideration and discussion of the proposed solution.

<u>Appendix</u>

Attachment A – Redlines of National Grid SMART DC metering diagram

Attachment B – Data sheet for a representative example of a DC watt-hour meter (AccuEnergy AcuDC 243)

Attachment C – Data sheet for a representative example of a DC voltage transducer (Verivolt IsoBlock V-1c)

Attachment D – Data sheet for a representative example of a DC current transducer (LEM IN-2000S)

AcuDC 240 Series

DC Power and Energy Meters

FEATURES

- DC Energy Management Systems
- Power Distribution for Telecommunication Room
- Solar Photovoltaic Systems
- Wind Power Generation
- DC Excitation System
- Industrial DC Control Systems
- Metallurgy and Electroanalysis Industries
- EV Charging Monitoring
- Data Center
- Cellular Tower Energy Monitoring

ISO9001 Certified

ACCUENERGY

AcuDC 240 Series DC Power Meter

INTRODUCTION

AcuDC 240 series power meter can be used for monitoring and controlling in DC systems. These meters can measure a wide range of parameters such as voltage, current, power and energy. It supports bi-directional current measurement, digital inputs for switch monitoring and relay outputs for remote controlling as well as an over-range alarming feature for voltage and current. Large signals, such as voltage and current can be converted to smaller signal using analog output. All data in the meter is accessible via RS485 using open Modbus RTU protocol. The large 3 line LCD display also provides easy to read real-time data directly on the meter front.

APPLICATIONS

- DC Energy Management Systems
- Power Distribution for Telecommunication Room
- Solar Photovoltaic Systems
- Industrial DC Control Systems
- Metallurgy and Electroplating Industries
- Wind Power Generation
- DC Excitation Systems
- Light Rail Transit Systems
- EV Charging Monitoring
- Data Center
- Cellular Tower Energy Monitoring

FEATURES

- DC power system metering
- Monitor and control power switches
- Alarming and analog output
- Standard 72x72mm, allows for drawer type panel installation
- Three line high-definition LCD display
- Accessible with SCADA, PLC systems
- Easy installation, simple wiring
- Data Logging: Offers 3 assignable historical logs where the all of the metering parameters can be recorded.
- The onboard memory is up to 4 MB and each log size is adjustable.

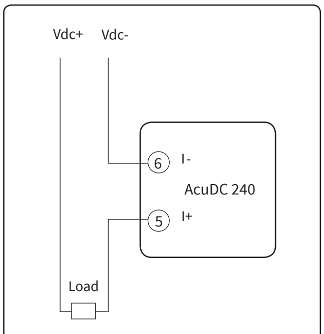


SPECIFICATIONS

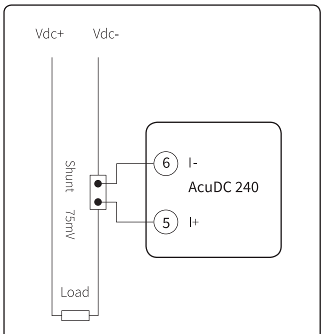
	Function		AcuDC 241	AcuDC 242	AcuDC 243
METERING	Voltage	V	●		●
	Current	I		●	●
	Power	P			●
	Energy	E			●
	Ampere-hour	Ah			●
I/O	2DI+2AO	Support DI count	⊙	⊙	⊙
	2DI+2RO		⊙	⊙	⊙
	2DI+2DO		⊙	⊙	⊙
	2DI+ ±15Vdc		⊙	⊙	⊙
DATALOGGING	All metering parameters can be recorded (Voltage, Current, Power, Energy, Ampere-hour, DI Count); Interval 1 minute; Can record 4 months				⊙
COMMUNICATION	RS485 , Modbus RTU		⊙	⊙	⊙
DISPLAY	LCD		●	●	●
DIMENSIONS	72×72×64.5mm (Cutout: 68×68 mm) / 2.835×2.835×2.539 inch (Cutout: 2.677×2.677 inch)				

Note: ●Standard; ⊙ Optional Blank: Not Available

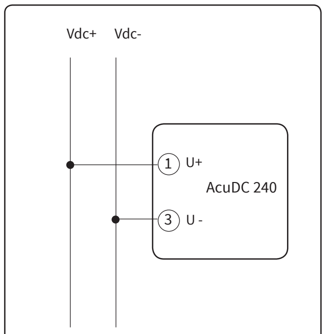
TYPICAL WIRING



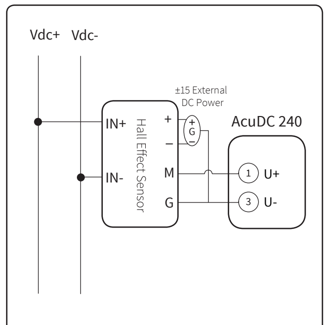
Current Direct Wiring



Current Wiring using Shunt

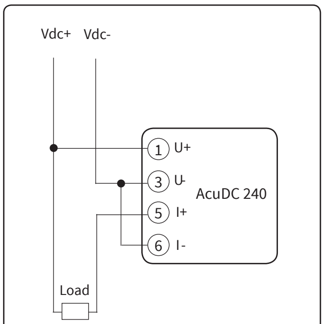


Voltage Direct Wiring

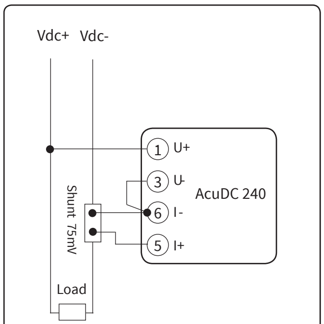


Voltage Wiring using Voltage Hall Effect Sensor

NOTE: Hall effect sensor can also be powered using the ±15V power supply from the X5 module.

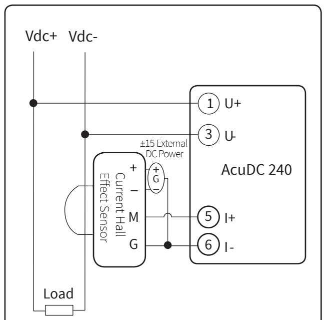


Voltage & Current Direct Wiring



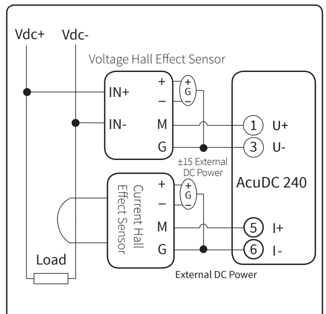
Voltage & Current Wiring using Shunt

NOTE: A physical jumper from terminal 3 to 6 must be connected.



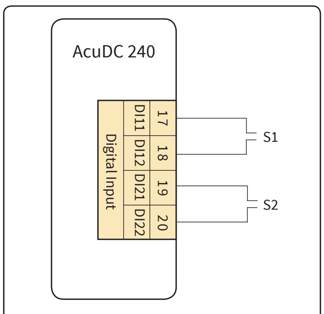
Voltage & Current Wiring using Current Hall Effect Sensor

NOTE: Hall effect sensor can also be powered using the ±15V power supply in the X5 module.

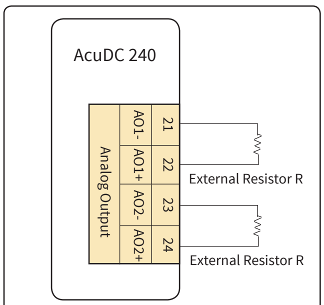


Voltage & Current Wiring using Hall Effect Sensors

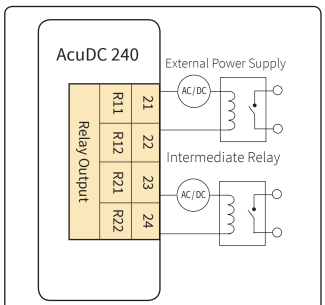
NOTE: Hall effect sensor can also be powered using the ±15V power supply from the X5 module.



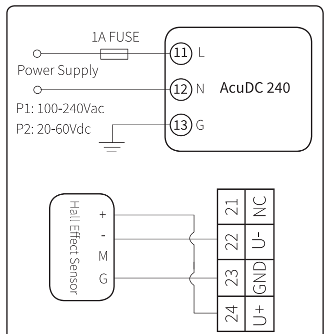
Digital Input



Analog Output
4~20mA, R<500Ω



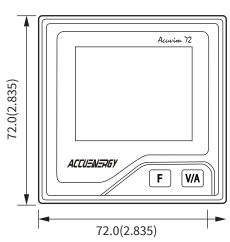
(External Power Supply < 250Vac or 30Vdc I<3A)



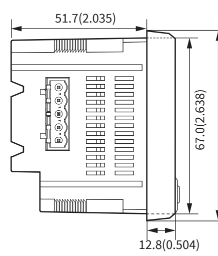
Power Supply Wiring

DIMENSIONS

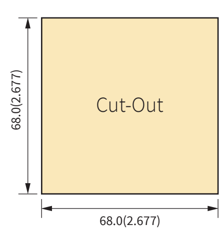
Unit: mm (inch)



FRONT



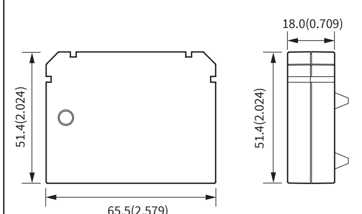
SIDE



PANEL CUTOUT

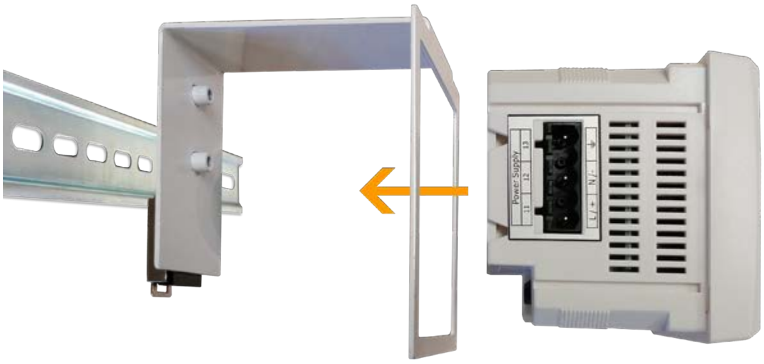
I/O Module

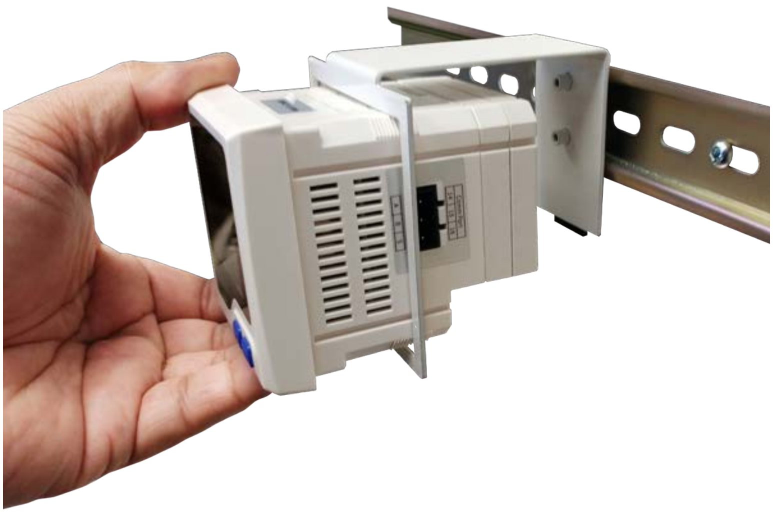
Unit: mm (inch)



AcuDC 240 Series DIN Rail Mounting Adapter

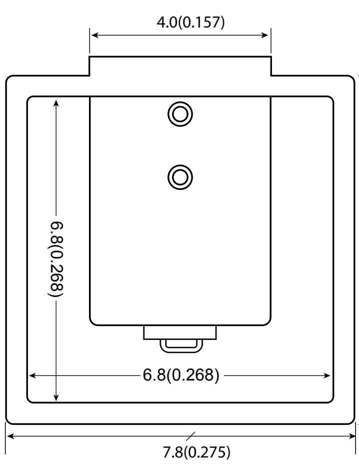
AcuDC 240 Series DIN Rails adapter provide easy installation of panel-mount AcuDC 240 series meter on DIN rail in all models and IO options.



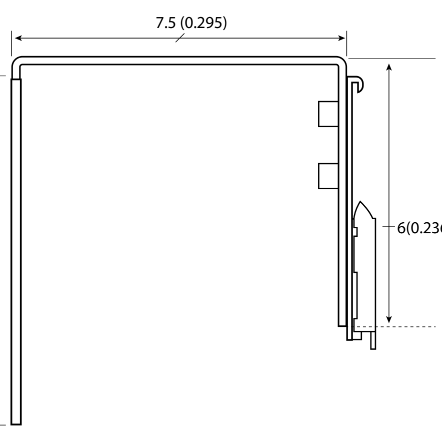


DIMENSIONS

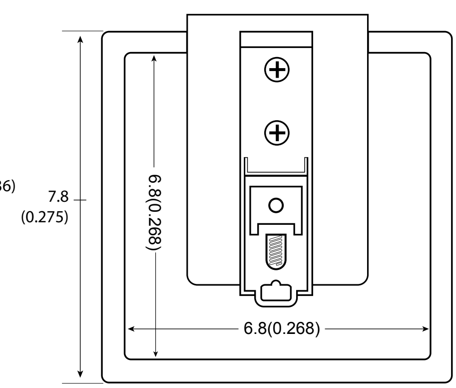
unit: mm (inch)



FRONT



SIDE



BACK

TECHNICAL SPECIFICATIONS

Parameter	Accuracy	Resolution	Range
Voltage	0.2%	0.001V	0~1200V
Current	0.2%	0.001A	0~±50000A
Power*	0.5%	0.001kW	0~±60000kW
Energy*	0.5%	0.01kWh	0~9999999.99kWh
Drift with Temperature	<100ppm/°C		
Stability	0.5‰/year		

* 0.2% accuracy on Power and Energy available upon request

Voltage	
Input Range	
Voltage	Direct Input0~1000V; Via Hall Effect Sensor0~1200V
Input Impedence	2MΩ
Load	<0.6W
Accuracy	0.2%
Current	
Input Range	0~±10A(Direct Input, pick up current 0.01A) 0~±50000A(Via Shunt or Hall Effect Sensor, programmable range)
Shunt	50~100mV(programmable)
Hall Effect Sensor	0~±5V/0-±4V, 4~20mA/12mA±8mA
Power Consumption	2W(Max)
Accuracy	0.2%
Digital Input	
Type	Dry Contact
Isolation Voltage	2500Vac

Communication	
Type	RS485, half duplex, Optical Isolated
Protocol	Modbus-RTU
Baud rate	1200~38400bps
Isolation Voltage	2500Vac

Output	
Relay Output (RO)	
Type	Mechanical contact, Form A
Max Load Voltage	250Vac/30Vdc
Max Load Current	3A
On Resistance	100mΩ (Max)
Isolation Voltage	4000Vac
Mechanical Life	5×10^6 times
Digital Output (Photo-Mos)	
Load Voltage Range	0~250Vac/dc
Load Current	100mA(Max)
Max Output Frequency	25Hz, 50% duty cycle
Isolation Voltage	2500Vac
Analog Output (AO)	
Range	4-20mA/0~20mA; 0~5V/1-5V
Accuracy	0.5%
Load Capacity	Current type, max load resistance: 750 Ohm Voltage type, max load current: 20 mA

Power Supply	
Input	(P1)100-240Vac, 50/60Hz, 100-300Vdc (P2) 20-60Vdc
Consumption	3W (typical value)

Environment	
Operation Temperature	-25°C ~ +70°C
Storage Temperature	-40°C ~ +85°C
Humidity	5%~95%Non-condensing

Standard Compliance	
Safety Standard	IEC 61010-1
EMC Standard	IEC 55011,IEC 61000-6-2,IEC 61000-3-2 IEC 61000-3-3

ORDERING INFORMATION

AcuDC 240 – □ – □ – □ – □ – □ – □

Datalogging
- ND: No Datalogging
- D: Datalogging (AcuRC 243 Only)

Communication
- NC: No Communication
- C: RS485, Modbus RTU

I/O Option
- X0: No I/O
- X1: 2DI+2AO (4~20mA/0~20mA)
- X2: 2DI+2AO (0~5V/1~5V)
- X3: 2DI+2RO
- X4: 2DI+2DO
- X5: 2DI+ ±15Vdc

Power Supply Option
- P1: 100-240Vac 50/60Hz, 100-300Vdc
- P2: 20-60Vdc

Current Option
- A0: 0~±10A
- A1: Shunt (50~100mV)
- A2: Current Hall Effect Sensor (4~20mA/12mA±8mA)
- A3: Voltage Hall Effect Sensor (0~±5V/0~±4V)

Voltage Option
- 1000V: Nominal Input Voltage 1000Vdc
- 600V: Nominal Input Voltage 600Vdc
- 300V: Nominal Input Voltage 300Vdc
- 60V: Nominal Input Voltage 60Vdc
- 5V: Via Hall Effect Sensor (0-5V/0-4V), ratio settable

Model
- AcuDC 241: Voltage Meter
- AcuDC 242: Current Meter
- AcuDC 243: Multifunction

Example: AcuDC 243 - 300 - A2 - P1 - X1 - C - D

VOLTAGE HALL EFFECT SENSOR ORDERING INFORMATION (0~5V output)

0.2% accuracy for Power and Energy

Special Order

Please contact your local Accuenergy representative for further details

CURRENT HALL EFFECT SENSOR ORDERING INFORMATION (4~20 mA output)

Special order

Please contact your local Accuenergy Representative for further details

Note:
When the input voltage is above 1000V, or the system design requires an isolation sensor, the voltage input can be selected as Via Hall Effect Sensor (0~5 V). The Voltage Hall Effect Sensor output range requires 0~5 V.

ORDERING INFORMATIOM	
Model	**DC DIN**

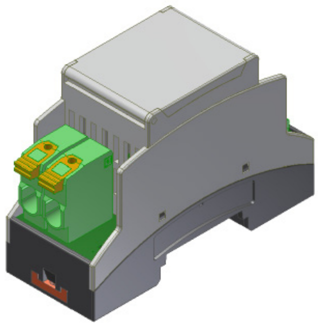
Accuenergy Corp.
Los Angeles-Toronto-Beijing
North America Toll Free: 1-877-721-8908
Web: www.accuenergy.com
Email: marketing@accuenergy.com

Revision Date: Sep., 2018 | Document #1504 E1112

ACCUENERGY
Make Energy Usage Smarter

IsoBlock V

Galvanicaly Isolated Differential Voltage Sensor



OVERVIEW

The IsoBlock V-1c has been designed to provide high-quality isolated differential voltage measurements for aplications requiring scaling of high voltages, as well as superior isolation.
Each IsoBlock V unit hosts an isolated channel that can be connected to separate measurement sources while providing a range of functional coverage up to 1500V. The input has its own isolated reference, and can be configured to suit user needs. The output signal from the IsoBlock unit is referenced in respect to the ground channel of the user's data acquisition system.
Verivolt designs its IsoBlock V modules with consideration for user great flexibility, and low power consumption.

SPECIFICATION

Eletrical	
Accuracy (percentage of reading) relative to output	±0.2% ± 0.5mV (±0.1% Custom)
Max total phase shift at 60Hz	< 0.05°
Max Input delay (100kHz versions)	< 3 μs
Isolation voltage from primary side to secondary side	> ±1500 V
Withstanding common mode surge voltage	±5000 V
Withstanding differential mode surge voltage	±2500 V

Mechanical	
Mounting Type	DIN Rail
Connectivity (Connector for power in and signal out to/ from the sensor)	Spring Cage connector
Outer Dimensions	1.4” x 3.5” x 2.5”
Channels	1 channel
Weight	198 g (7.0 oz)

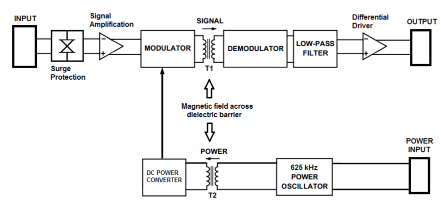
Performance	
Input ranges	50V, 100V, 150VAC, 300V, 500V, 500VAC, 750V, 1000V, 1500V, Custom
Bandwidth (-3dB point)	100kHz (up to 1MHz on custom)
Input-Output non-linearity	< 130 ppm
Output voltage	±10 V, 7VAC (±5V optional)
Gain temperature drift	±50 ppm/°C
Common mode rejection at 60Hz	112 dB
Power Supply Voltage	9V to 28 V
Output type	Differential pair
Output Offset Voltage (Referenced to output)	2σ < ±500 μV (typical) 4σ < ±1 mV (limit)
Differential Input impedance	> 10 MΩ
Insulation impedance	> 10 GΩ || 2pF
Output impedance	100Ω

Environmental	
Operating temperature	– 25 to 70 °C

- The isolation barrier of every device is tested with a 5 second partial discharge of 1800V for 5 seconds, with a detection threshold of 150pC.
- Withstanding common mode surge voltage is 2 seconds half sinewave.
- Withstanding differential mode surge voltage is 4 seconds half sinewave.

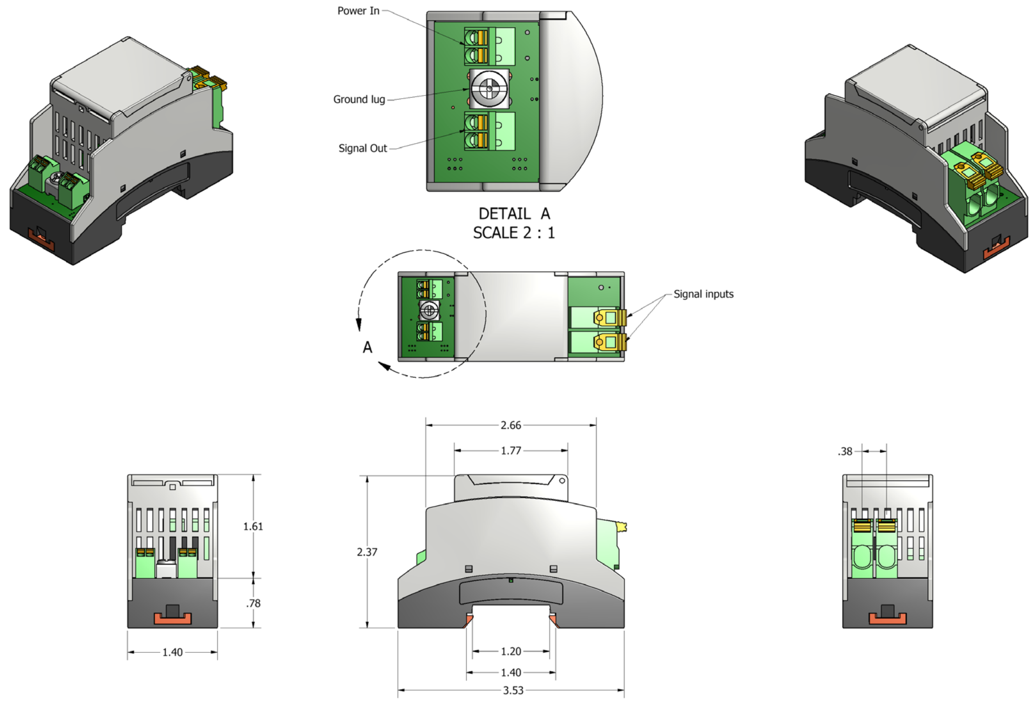
HARDWARE DESCRIPTION

The IsoBlock V module is designed to isolate and scale down high voltages found in industrial enviroments. The end result is a signal ready to connect to any data acquisition system, while galvanically isolating the source from it.
Each channel of the IsoBlock module has a galvanic isolation from the input to the output that can eliminate large common mode voltages. In addition to that, each channel also has a protection stage at the input that guards it from surges.
Following the input surge protection stage, there is an amplification stage that brings the input signal to a ±10V range. This signal is modulated into a magnetic field, and then transferred across a galvanic barrier. A demodulating stage recovers the original signal, followed by an anti-aliasing filter and a conditioning stage to output a ±10V differential pair. The figure below shows a block diagram of the process decribed above.



IsoBlock V single channel block diagram.

MERCHANICAL DIMENSIONS



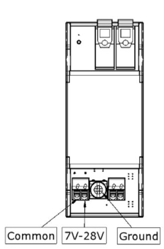
HARDWARE CONFIGURATION

A. Connect external power source to power the unit. For proper functioning the power supply should provide a voltage between 9V and 28V with at least 1W of continuous and 2W surge (<2ms) during module start-up.

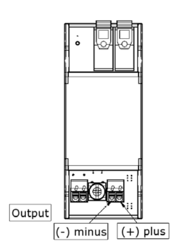
B. Securely connect wire in the 20-6 AWG range between the source of measurement and an available IsoBlock's input screw terminal.

C. Securely connect one end of a twisted pair to the output terminals, and the other end to the inputs of your data acquisition unit

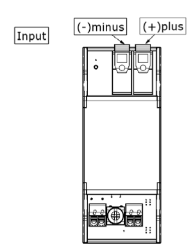
A



B



C



Standards and Certifications

- CE

CE

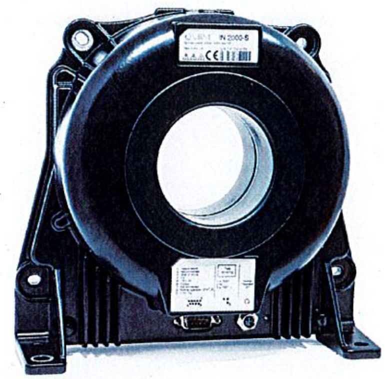
⚠ DANGER

THIS SENSOR IS NOT A SAFETY DEVICE AND IS NOT INTENDED TO BE USED AS A SAFETY DEVICE. This sensor is designed only to detect and read certain data in an electronic manner and perform no use apart from that, specifically no safetyrelated use. This sensor product does not include self-checking redundant circuitry, and the failure of this sensor product could cause either an energized or de-energized output condition, which could result in death, serious bodily injury, or property damage.

Current Transducer IN 2000-S

I_{PN} = 2000 A

For the electronic measurement of current: DC, AC, pulsed..., with galvanic separation between the primary and the secondary circuit.



Features

- Closed loop (compensated) current transducer using an extremely accurate zero flux detector
- Electrostatic shield between primary and secondary circuit
- 9-pin D-Sub male secondary connector
- Status signal to indicate the transducer state
- LED indicator confirms normal operation
- Metal housing to improve immunity to EMC & power dissipation
- Operating temperature −40 °C to 85 °C.

Advantages

- Very high accuracy
- Excellent linearity
- Extremely low temperature drift
- Wide frequency bandwidth
- High immunity to external fields
- No insertion losses
- Very low noise on output signal
- Low noise feedback to primary conductor.

Applications

- Feed back element in high performance gradient amplifiers for MRI
- Feedback element in high-precision, high-stability power supplies
- Calibration unit
- Energy measurement
- Medical equipment.

Standards

- EN 61000-6-2: 2005
- EN 61000-6-3: 2007
- EN 61010-1: 2010.

Application Domain

- Industrial
- Laboratory
- Medical.

Insulation coordination

Parameter	Symbol	Unit	Value	Comment
Rated insulation RMS voltage, basic insulation	U_b	V	1000	IEC 61010-1 conditions - over voltage cat III - pollution degree 2
Rated insulation RMS voltage, reinforced insulation			1000	IEC 61010-1 conditions - over voltage cat III - pollution degree 2
RMS voltage for AC insulation test, 50 Hz, 1 min	U_d	kV	6	Between primary and secondary + shield
		V DC	100	Between secondary and test winding
Impulse withstand voltage 1.2/50 µs	$\hat{U}_W$	kV	12.8	
Clearance (pri. - sec.)	d_{Cl}	mm	21	Shortest distance through air
Creepage distance (pri. - sec.)	d_{Cp}	mm	22	Shortest path along device body
Comparative tracking index	CTI		250	

Environmental and mechanical characteristics

Parameter	Symbol	Unit	Min	Typ	Max	Comment
Ambient operating temperature	T_A	°C	-40		85	
Ambient storage temperature	T_S	°C	-40		85	
Relative humidity	RH	%	20		80	
Dimensions						See drawing in page 8
Mass	m	kg		4.2		

Electrical data

At T_A = 25 °C, ±U_C = ±15 V, unless otherwise noted.
Lines with a * in the comment column apply over the −40 … 85 °C ambient temperature range.

Parameter	Symbol	Unit	Min	Typ	Max		Comment
Primary continuous direct current	$I_{P\,N\,DC}$	A	−2000		2000	*	
Primary nominal RMS current	$I_{P\,N}$	A	−2000		2000	*	
Primary current, measuring range	$I_{P\,M}$	A	−3000		3000	*	
Measuring resistance	R_M	Ω	0		1		See curve page 5
Secondary current nominal	$I_{S\,N}$	A	−1		1	*	
Number of secondary turns	N_S			2000			
Resistance of secondary winding	R_S	Ω		4			
Overload capability [1]	$\hat{I}_P$	kA	−10		10		@ pulse of 100 ms
Supply voltage	$\pm U_C$	V	±14.25	±15	±15.75		
Current consumption positive	$+I_C$	mA	180	200	225		Add I_S for total current consumption
Current consumption negative	$-I_C$		80	89	100		
Output RMS noise current 0 … 10 Hz [2]	I_{no}	ppm		0.1			
Output RMS noise current 0 … 10 kHz [2]				4			
Output RMS noise current 0 … 160 kHz [2]				20			
Output peak-to-peak noise current [2]	$I_{no\,pp}$	ppm		50			
Electrical offset current + self magnetization + effect of earth magnetic field [2]	$I_{O\,E}$	ppm	−10		10	*	
Temperature coefficient of $I_{O\,E}$ @ I_P = 0 A	$TCI_{O\,E}$	ppm/K		0.1			
Offset stability [2]		ppm/month	−1		1		
Linearity error [2]	ε_L	ppm		1	2		
				2	3	*	
Step response time to 90 % of $I_{PN\,DC}$	t_r	µs			1		di/dt of 100 A/µs
Frequency bandwidth (±1 dB)	BW	kHz		130			Small-signal bandwidth, 0.5 % of $I_{P\,N}$
Frequency bandwidth (±3 dB)	BW	kHz		140			
Test current	I_T	A			1		
Number of turns (test winding)	N_T			200			
Start-up time	t_{start}	s	2	5	15		

Notes: [1] Single pulse only, not AC. The transducer may require a few seconds to return to normal operation when autoreset system is running
[2] All ppm figures refer to full-scale which corresponds to a secondary nominal RMS current of 1 A.

Overload protection - Electrical specification - Status

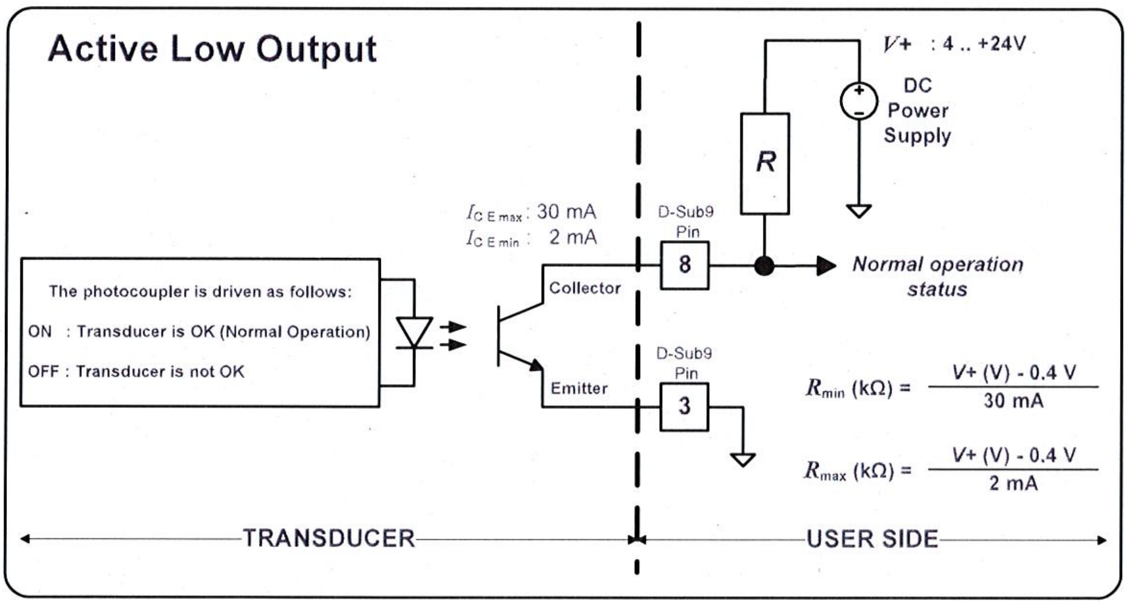
The overload occurs when the primary current I_P exceeds a trip level such that the fluxgate detector becomes completely saturated and, consequently, the transducer will switch from normal operation to overload mode.
This trip level is guaranteed to be greater than I_{PM} and its actual value depends on operating conditions such as temperature and measuring resistance.
When this happens, the transducer will automatically begin to sweep in order to lock on the primary current again.

The overload conditions will be:

- The secondary current I_S generated is a low frequency signal.
- The signal normal operation status (between pin 3 and 8 of the D-sub connector) switches to V+. In other words, the output transistor is switched off (i.e., no current from collector to emitter). See the status port wiring below.
- The green LED indicator (normal operation status) turns off.

The measuring can resume when the primary current returns in the measuring range between $-I_{PN}$ and $+I_{PN}$. Then the signal normal operation status switches to GND and the green LED indicator (normal operation status) is again lit.

Status/Interlock port wiring

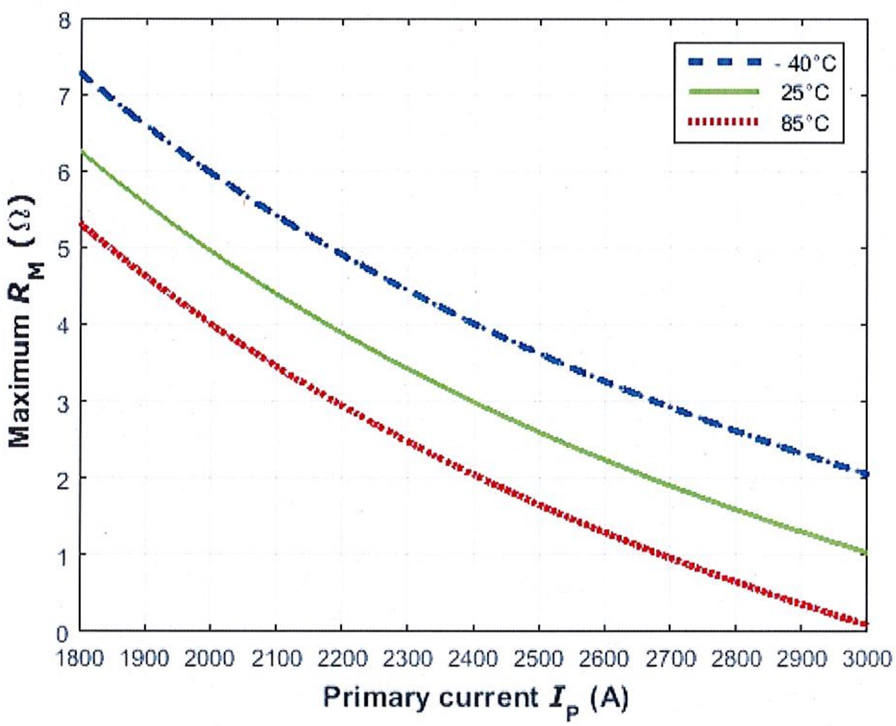


The following table shows how the normal operation status acts as below:

Normal operation status	Description
< 0.7 V	The transducer is OK (Normal operation)
V+	The transducer is not OK (Overload mode or supply fault)

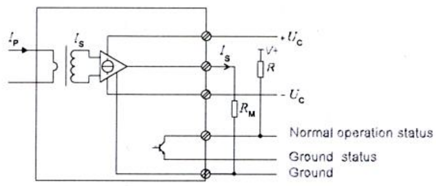
Maximum measuring resistor versus primary current and temperature

$\pm U_C$ = ±14.25 V



Performance parameters definition

The schematic used to measure all electrical parameters is shown below:



Transducer simplified model

The static model of the transducer at temperature T_A is:

$I_S = K_N \cdot I_P + \varepsilon$

In which

$\varepsilon = I_{OE}$ at 25 °C + $I_{OT}(T_A) + \varepsilon_L \cdot I_{PM} \cdot K_N$

Where,

$I_{OT}(T_A) = TCI_{OE} \cdot |T_A - 25\ °C| \cdot I_{PM} \cdot K_N$

I_S	: secondary current (A)
K_N	: conversion ratio (1: N_S)
I_P	: primary current (A)
I_{PM}	: primary current, measuring range (A)
T_A	: ambient operating temperature (°C)
I_{OE}	: electrical offset current (A)
I_{OT}	: temperature variation of I_{OE} at T_A (A)
ε_L	: linearity error

This is the absolute maximum error. As all errors are independent, a more realistic way to calculate the error would be to use the following formula:

$$\varepsilon = \sqrt{\sum_{i=1}^{N} \varepsilon_i^2}$$

Linearity

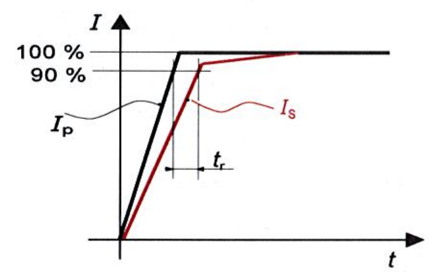
To measure linearity, the primary current (DC) is cycled from 0 to I_{PM}, then to $-I_{PM}$ and back to 0. The linearity error ε_L is the maximum positive or negative difference between the measured points and the linear regression line, expressed in parts per million (ppm) of full-scale which corresponds to the maximum measured value.

Electrical offset

The electrical offset current I_{OE} is the residual output current when the input current is zero.
The temperature variation I_{OT} of the electrical offset current I_{OE} is the variation of the electrical offset from 25 °C to the considered temperature.

Response time

The response time t is shown in the next figure.
It depends on the primary current di/dt and it's measured at nominal current.



Safety

This transducer must be used in limited-energy secondary circuits according to IEC 61010-1.

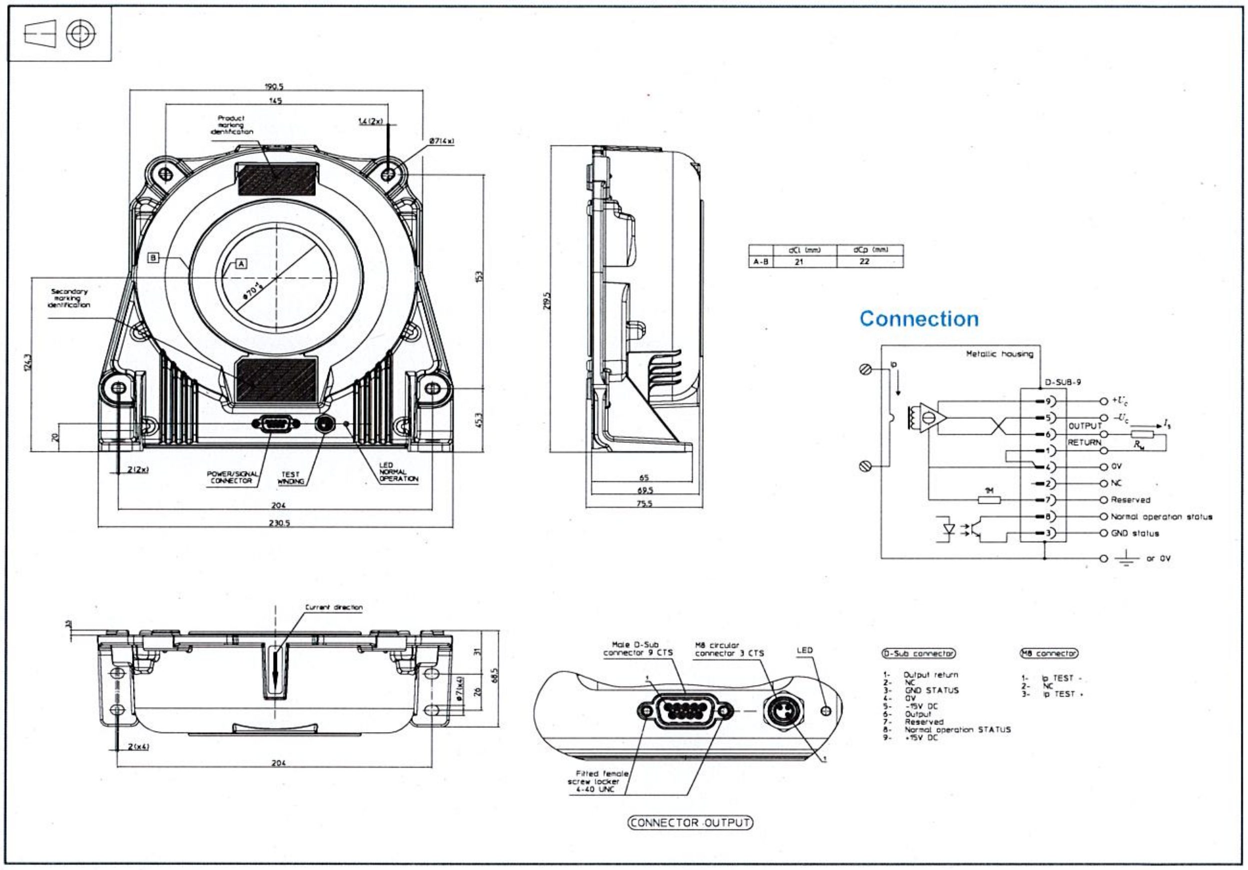
This transducer must be used in electric/electronic equipment with respect to applicable standards and safety requirements in accordance with the manufacturer's operating instructions.

Caution, risk of electrical shock
When operating the transducer, certain parts of the module can carry hazardous voltage (e.g. primary busbar, power supply). Ignoring this warning can lead to injury and/or cause serious damage.
This transducer is a build-in device, whose conducting parts must be inaccessible after installation.
A protective housing or additional shield could be used. Main supply must be able to be disconnected.

Remark

Installation of the transducer must be done unless otherwise specified on the datasheet, according to LEM Transducer Generic Mounting Rules. Please refer to LEM document N°ANE120504 available on our Web site: **Products/Product Documentation.**

Dimensions (in mm)



Connection

- Normal operation status (Pins 3 and 8)
  Normal operation means:
  - ±15 V (±U_C) present
  - zero detector is working
  - compensation current ≤ I_{PM} DC
  - green LED indicator is lit.

Mechanical characteristics

- General tolerance ±0.75 mm
- Transducer fastening
  - Horizontal mounting and vertical: 4 holes ⌀ 7 mm with 2 slots gap along transducer; 4 × M6 steel screws
  - Recommended fastening torque: 5.5 N·m
- Connection of secondary: on D-SUB-9, UNC 4-40
- All mounting recommendations are given for a standard mounting. Screws with flat and spring washers.

Remarks

- I_S is positive when I_P flows in the direction of the arrow.
- We recommend that a shielded output cable and plug are used to ensure the maximum immunity against electrostatic fields.
- Temperature of the primary conductor should not exceed 100 °C.
- We recommend to fix the potential of the housing to the ground.
- Installation of the transducer must be done unless otherwise specified on the datasheet, according to LEM Transducer Generic Mounting Rules. Please refer to LEM document N°ANE120504 available on our Web site: **Products/Product Documentation.**