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IN RE: INTERCONNECTION REGULATIONS

CASE NO.: NEPR-MI-2019-0009
CEPR-MI-2018-0008

SUBJECT: Third Supplementary Comments on Distributed Generation and Microgrid Interconnection Regulation - Case No. NEPR-MI-2019-0009

THIRD SUPPLEMENTARY COMMENTS OF ROBERT A. GARCIA COOPER PROPOSING A NET EXPORT SEQUENTIAL IMPEDANCE ATTRIBUTION METHODOLOGY FOR PROPORTIONAL DISTRIBUTED ENERGY RESOURCE COST ALLOCATION PURSUANT TO JOINT RESOLUTION 5-2026

TO THE HONORABLE PUERTO RICO ENERGY BUREAU:

Attention: Edison Avilés Deliz, Chairman

COMES NOW Robert A. Garcia Cooper, in his individual capacity as state-certified Engineer in Training (EIT, Certificate No. 28591), licensed Expert Electrician (Perito Electricista, License No. 10971), PhD student in electrical engineering at the University of Puerto Rico at Mayaguez, published researcher in energy systems and resilience economics, Senior Member of the Institute of Electrical and Electronics Engineers (IEEE), and former electricity metering technician, Probador Especial de Contadores by its official Spanish title, at PREPA's Electricity Metering Research Center Centro de Estudios de Medición, and Wholesale Metering Districts of San Juan and Bayamón, and respectfully submits these third supplementary comments on the Revised Preliminary Draft Distributed Generation and Microgrid Interconnection Regulation published by the Puerto Rico Energy Bureau on July 13, 2026, pursuant to the Resolution and Order issued in the above-captioned proceeding.

On July 18, 2026, the undersigned filed Comments identifying measurement infrastructure gaps, smart inverter governance concerns, and equipment risk and liability issues. On August 7, 2026, the undersigned filed Supplementary Comments proposing a methodology for compensating active power displaced by Volt-VAR reactive power obligations. On September 2, 2026, the undersigned filed Second Supplementary Comments identifying procedural, capacity limit, commercial framework, and microgrid regulatory consistency gaps for non-inverter-based distributed generation. The undersigned now respectfully submits these third supplementary comments proposing a field measurement protocol for proportional cost allocation of distributed energy resource feeder upgrade costs. The undersigned submits this methodology with the specific recommendation that the Energy Bureau direct its incorporation, or a compatible equivalent validated through the stakeholder participation process, into the Technical Interconnection Requirements as the standard field measurement methodology for source impedance characterization and proportional cost allocation in supplemental review studies. The Technical Interconnection Requirements are the appropriate regulatory instrument for codifying field measurement protocols, minimum equipment specifications, and calculation procedures of the type proposed in these comments. The undersigned raises this recommendation at the outset so that the Bureau may consider these comments in that context throughout.

I. CONTEXT AND TIMING OF THIS SUBMISSION

During Virtual Stakeholder Workshop 2 Continuation Session held August 28, 2026, Engineer Gabriel Ferrer of Enphase Energy proposed network source impedance as a metric for proportional cost allocation of localized grid upgrade costs pursuant to the proportionality and benefit received principles of Joint Resolution 5-2026, and the Energy Bureau invited Engineer Ferrer to submit a complete methodology for the record. At that session, following a stakeholder request, Anthony Star of Synapse Energy Economics, consultants to the Energy Bureau and facilitators of the workshop proceedings, confirmed Monday September 14, 2026 as the relevant milestone.[1]

The undersigned intended to await Engineer Ferrer's methodology submission before presenting complementary observations. As of the date of this filing, Engineer Ferrer's methodology has not been submitted to the record. In order not to allow the pre-workshop comment period to lapse without placing this complementary measurement protocol on the record for the Bureau's consideration at Workshop 3, the undersigned respectfully submits the following methodology. The undersigned continues to hold Engineer Ferrer's contribution in high regard and intends to engage with his methodology directly once it is submitted to the record.

II. THE PROBLEM THIS METHODOLOGY ADDRESSES.

Joint Resolution 5-2026 mandates that costs be determined based on principles of reasonableness, proportionality, and benefit received, ensuring that such costs are not unfairly passed on to the

[1] Puerto Rico Energy Bureau. (2026, August 28). NEPR-MI-2019-0009 Virtual Stakeholder Workshop 2 Continuance [Video]. YouTube. https://youtu.be/vEIbfFpYriM?t=11808

customer base. The interconnection cost allocation framework currently under development in this proceeding must therefore identify each prior distributed energy resource's actual contribution to the feeder condition that requires the upgrade, rather than assigning the full upgrade cost to the last prosumer to interconnect.

As the undersigned documented in post-workshop comments filed August 27, 2026, the current legal framework under Act 114-2007 creates a first come first serve cost assignment structure that Engineer Alfonso Baretty, Senior Manager for Renewable Integration and Generation Assets at LUMA Energy, confirmed on the record during Workshop 2 as what the law leads to.[2] Engineer Ferrer's proposal to use network source impedance as the attribution metric is the right direction. It grounds cost allocation in physics rather than administrative sequence. The methodology proposed in these comments operationalizes that proposal with a specific, reproducible, field-executable measurement protocol.

The need for this measurement protocol is itself a consequence of state-induced conditions. Act 114-2007 established a first come first serve interconnection framework. Joint Resolution 5-2026 subsequently required proportionality and benefit received in cost allocation. The tension between these two instruments is a legislative creation. The need to measure each prior DER's actual contribution to the feeder impedance condition arises directly from the legislature's own subsequent requirement for proportionality. Additionally, the utility permitted prior DER interconnections over time, some of which failed applicable screening, allowing cumulative feeder impedance conditions to develop without systematic measurement of their aggregate effect. The new prosumer did not create this condition. They are the occasion for its discovery.

The measurement protocol proposed in these comments is applicable only when the new prosumer seeks export authorization. This distinction was confirmed on the record during Virtual Stakeholder Workshop 2 on August 25, 2026. When asked whether LUMA's interpretation of Act 114-2007 is that the term operating, as used in the statute's automatic interconnection provision for systems under 25 kW, means self-consumption and not export, with Engineer Alfonso Baretty responding affirmatively.[2]

Under LUMA's stated interpretation, the automatic interconnection right for systems under 25 kW guarantees self-consumption but not export. Export authorization would require a separate process involving a study to verify system safety and grid impact. The proposed regulation and the current regulatory framework do not explicitly codify this distinction, and the Energy Bureau has not yet ruled on it. However, if the Bureau adopts this interpretation or a similar approach, the measurement of prior DER contributions to feeder impedance conditions would be relevant only when the new prosumer seeks export authorization. A prosumer who interconnects for self-

[2] Puerto Rico Energy Bureau. (2026, August 28). NEPR-MI-2019-0009 Virtual Stakeholder Workshop 2 Continuance [Video]. YouTube. https://youtu.be/Axpq2OQPcOk?t=9020

consumption purposes does not inject current into the feeder and therefore does not generate a voltage rise condition requiring attribution analysis of prior DER contributions.

The cost of performing this measurement protocol is not a cost the new prosumer created. It arises from the cumulative consequence of prior state-permitted interconnections and the legislative tension between Act 114-2007 and Joint Resolution 5-2026. The undersigned respectfully submits that this measurement cost should be borne by the EPS Operator as a utility infrastructure characterization expense and should not be passed to the new prosumer as a condition of exercising an export right on a feeder whose impedance condition they did not create.

III. THE PHYSICAL PRINCIPLE

Feeder voltage rise at solar noon is caused by net export current flowing from distributed energy resource systems into the distribution feeder. The voltage rise at any service point equals the net export current flowing through the feeder source impedance between that service point and the distribution transformer. This relationship is expressed as delta V equals Z multiplied by delta I, where Z is the Thevenin equivalent source impedance seen from the point of common coupling.

The source impedance at any service point is measurable using the delta V over delta I method for line impedance estimation formally described and experimentally validated by Timbus et al.[3] The method derives source impedance from the ratio of the voltage change to the current change observed at the point of common coupling between two operating states. The method is validated across a wide range of power variation magnitudes, from 0.1 percent to 10 percent of nominal converter power, as documented in Table I of Timbus et al., with acceptable accuracy across all tested levels.

The authors note that the equations are valid only if the source voltage and grid impedance are not changing between the two sample instants. This contamination limitation is the critical parameter governing measurement protocol design and is addressed directly in Section V of these comments.

IV. WHY NET EXPORT RATHER THAN NAMEPLATE RATING

[3] Timbus, A.V., Rodriguez, P., Teodorescu, R., and Ciobotaru, M., "Line Impedance Estimation Using Active and Reactive Power Variations," IEEE, 2007, pp. 1273-1278. DOI: 10.1109/PESC.2007.4342176

The undersigned respectfully submits that net export at the point of common coupling at solar noon is the correct attribution basis for cost allocation, and that nameplate rating normalization produces an inequitable result for three reasons.

First, a large distributed energy resource system paired with a large daytime load that absorbs most of its solar generation produces minimal net export at the point of common coupling at solar noon. Its contribution to feeder voltage rise is proportionally small regardless of its nameplate rating. Allocating costs in proportion to nameplate rating would assign it a large cost share for a small actual contribution.

Second, a smaller system paired with minimal daytime load that exports nearly all of its generation produces large net export at the point of common coupling at solar noon. Its contribution to feeder voltage rise is proportionally large. Allocating costs in proportion to nameplate rating would assign it a small cost share for a large actual contribution.

Third, a household with a battery energy storage system that charges at solar noon reduces its net export to the feeder. Its contribution to feeder voltage rise is reduced. The measurement protocol rewards storage investment that mitigates feeder impact without requiring any special provision or exception in the regulatory framework.

Net export measurement at the point of common coupling captures the actual physical cause of the voltage rise problem directly. It does not require nameplate assumptions, irradiance correction, or household load profile modeling. The measurement is self-correcting because households with large daytime loads that absorb generation appear with small percentage impedance changes and households with minimal daytime loads that export aggressively appear with large percentage impedance changes. The measurement reflects the physical reality of what each DER is actually contributing to the feeder at the moment the voltage rise problem is most severe.

V. THE MEASUREMENT PROTOCOL

A. Equipment and Personnel

The measurement requires one power quality analyzer capable of simultaneously capturing voltage and current waveforms with phase angle resolution at the service entrance. This is standard utility test equipment that should be part of any utility planning department's field inventory engaged in distributed energy resource interconnection studies. No specialized injection equipment is required.

Two qualified personnel per OSHA requirements for work involving possible electrical contact above 50 volts are required at each measurement location. The National Electrical Code already requires an accessible disconnecting mechanism for every distributed energy resource installation, so the utility's access to disconnect each system is already established in the interconnection framework without requiring additional legal authority.

B. Test Conditions

The test shall be performed within one hour of solar noon on a day with measured global horizontal irradiance sufficient to ensure the distributed energy resource systems on the target feeder are operating at representative output levels. Solar noon is the optimal test window because distributed energy resource output is at its maximum and most stable, the rate of change of irradiance is at its minimum as the sun is at its highest point, and the voltage rise problem being characterized is most severe at this time.

C. Steady State Criterion

Before each measurement window begins, the crew shall confirm that the current at the point of common coupling has reached steady state, defined as variation of less than two percent over a ten second observation window. This criterion eliminates transient contamination from cloud cover events and ensures that the measurement captures stable operating conditions rather than transient behavior. The steady state criterion is the primary mechanism by which the contamination limitation identified by Timbus et al. is addressed in field implementation.

D. Measurement Sequence at Each Service Point

The crew visits each household with a distributed energy resource installation on the target feeder sequentially. At each point of common coupling the following sequence is performed.

Step one. Confirm steady state current with the distributed energy resource connected and exporting. Record a thirty second baseline window. Document the timestamp of the window start.

Step two. Disconnect the distributed energy resource via its NEC-required accessible disconnect. Confirm steady state current. Record a thirty second measurement window with the distributed energy resource disconnected. Document the timestamp.

Step three. Reconnect the distributed energy resource. Confirm steady state current. Record a thirty second return-to-baseline window. Document the timestamp.

Step four. Proceed to the next household.

Total time per household is approximately eight to ten minutes under stable irradiance conditions. A secondary radial circuit with geographically proximate households allows the crew to complete ten to fifteen households in approximately two hours. Because the households on a secondary radial circuit are physically close and the test proceeds rapidly, the irradiance conditions across sequential measurements are sufficiently comparable for regulatory cost allocation purposes.

E. Data Recording

The power quality analyzer records continuously throughout the test session without interruption. The crew documents manually the timestamps corresponding to each DER disconnection and reconnection event. These timestamps allow the analyst to identify precisely which thirty second windows correspond to which distributed energy resource being disconnected. No post-processing normalization for irradiance or household load is required. The continuous record also captures any ambient feeder variation throughout the session, providing context for evaluating data quality.

VI. THE ATTRIBUTION CALCULATION

A. Notation

The following notation is used throughout this section.

Z_i = IQR-filtered average source impedance during the first thirty second window, with the DER connected and exporting. This is the pre-disconnection baseline.

Z_0= IQR-filtered average source impedance during the second thirty second window, with the DER disconnected. This represents the Thevenin equivalent grid impedance at that service point independent of DER contribution.

Z_f = IQR-filtered average source impedance during the third thirty second window, with the DER reconnected and exporting. This is the post-reconnection return-to-baseline confirmation.

Z_{DER} = the DER-connected impedance used in the percentage change calculation, defined as:

$$Z_{DER} = \frac{Z_i + Z_f}{2}$$

Theoretically Z_i should be approximately equal to Z_f under stable feeder conditions. Averaging the two smooths out minor ambient variation and produces a more reliable estimate than either window alone. If Z_i and Z_f differ by more than a threshold to be established in the TIR measurement protocol, indicating that feeder conditions changed materially during the test at that household, the measurement should be flagged and repeated under more stable conditions.

I_{DER}= IQR-filtered average net export current during the connected windows. Export current carries a single consistent sign convention throughout this analysis. Import current, which characterizes the Z_0 measurement window, carries the opposite sign convention and is explicitly excluded from the interpolation analysis in Section VI.E. The two operating regimes are not mixed.

B. IQR Filtering

The data logger captures voltage and current simultaneously at a minimum resolution of one millisecond, producing 1,000 samples per second and 30,000 samples within each thirty second measurement window. The IQR filter is applied within each thirty second window as follows. The interquartile range is computed across all 30,000 samples in the window. Values outside the P25 to P75 boundary are excluded. The filtered average is computed from the remaining samples. This filter eliminates outlier measurements attributable to switching transients, cloud cover events, neighboring load changes, or any other short-duration disturbances inconsistent with steady state conditions, without requiring manual identification of specific contamination events or exclusion of any portion of the measurement window.

The minimum acceptable logging resolution for regulatory cost allocation purposes should be confirmed in the TIR measurement protocol. Higher resolution logging at the microsecond level may be appropriate for supplemental transient analysis or for more complete impedance decomposition into resistive and reactive components, but is not required for the source impedance magnitude estimation proposed in these comments.

C. Percentage Impedance Change

The percentage impedance change attributable to the DER at each service point is calculated as follows.

$$\%\Delta Z = \left(\frac{(Z_{DER} - Z_0)}{Z_0}\right) \times 100$$

Where $Z_{DER} = \frac{Z_i + Z_f}{2}$

This percentage change represents each distributed energy resource's marginal contribution to the effective source impedance at its own point of common coupling at solar noon. It reflects net export rather than gross generation because what the data logger measures at the point of common coupling is the net current crossing the meter, which is gross generation minus household self-consumption. Households with large daytime loads produce small percentage changes. Households with minimal daytime loads that export aggressively produce large percentage changes. Battery systems charging at solar noon reduce their net export and produce smaller percentage changes than they would if exporting freely.

D. Normalization and Cost Allocation

The percentage impedance changes from all n households on the target feeder are summed to produce the total measured DER contribution.

$Total = \Sigma\ \%\Delta Z_k$, for k = 1 to n

Each individual household's cost allocation share is its percentage change divided by the total.

$$Share_k = \frac{\%\Delta Z_k}{Total}$$

The cost allocation amount for household k is its share multiplied by the total upgrade cost C.

$Cost_k = Share_k \times Cost_{Total}$

For example, if three distributed energy resource installations produce percentage impedance changes of 30, 32, and 40 respectively, the total is 102. The cost allocation shares are 29.4 percent, 31.4 percent, and 39.2 percent respectively. If the required feeder upgrade costs ten thousand dollars, the three households pay $2,940, $3,140, and $3,920 respectively.

This normalization is self-consistent. It does not require any external reference standard, irradiance data, or nameplate rating assumption. The allocation shares always sum to 100 percent regardless of the absolute magnitude of individual measurements.

E. Storage Investment Estimation Without a Second Field Visit

The measurements collected during the protocol described in Sections V and VI.A through VI.D yield sufficient information to estimate the voltage impact reduction achievable through storage investment at each service point, without requiring a second field visit.

The voltage rise at the service point attributable to the DER's net export at solar noon is estimated as follows.

$$\Delta V_{DER} = Z_{DER} \times |I_{DER} - I_0|$$

If the prosumer invests in battery energy storage that absorbs a portion of their solar generation at solar noon, their net export current is reduced from I_{DER} to a smaller value $I_{reduced}$. Export current always carries the same sign convention as I_{DER} throughout this analysis. Import current from the Z_0 measurement window carries the opposite sign convention and is not mixed with export current in this interpolation. The analysis remains entirely within the export operating regime.

The new cost allocation share under reduced export is estimated through linear interpolation within the export regime as follows.

$$Z_{DER_{reduced}} = Z_0 + \left[\frac{(Z_{DER} - Z_0)}{I_{DER}}\right] \times I_{reduced}$$

$$\%\Delta Z_{reduced} = \left[\frac{(Z_{DER_{reduced}} - Z_0)}{Z_0}\right] \times 100$$

If $I_{reduced}$ equals I_{DER}, $Z_{DER_{\mathrm{reduced}}}$ equals Z_{DER} and the cost allocation share is unchanged. As $I_{reduced}$ decreases within the export regime, $Z_{DER_{\mathrm{reduced}}}$ approaches Z_0 and the cost allocation share decreases proportionally.

This interpolation remains entirely within the export operating regime. No sign convention change occurs. No operating regime crossing occurs. The reduction in export current is a monotonic decrease in the same direction as the original measurement, and the feeder's response to that reduction is proportional within the same regime. The linearity assumption embedded in the Thevenin equivalent model applies cleanly within a single operating regime and is the same assumption already present in the delta V over delta I method underlying this entire methodology.

At the conclusion of the first field visit the utility can therefore provide each prosumer seeking export authorization with three quantified values derived entirely from field measurements. First, their current voltage rise contribution at solar noon. Second, their current cost allocation share for any required upgrade. Third, the estimated cost allocation share reduction achievable at any specified level of export current reduction through storage investment.

The prosumer can then make an informed economic decision comparing the cost of their upgrade allocation share against the cost of a storage investment that would reduce or eliminate it. The economic benefit of storage in this context is not optimization of net metering credits, which would in fact decrease as less energy crosses the meter in the export direction, but rather reduced utility consumption driven by self-supply from stored solar energy outside the solar window.

The undersigned acknowledges that voltage regulation equipment on the feeder may respond to significant reductions in export current in ways that introduce second order deviations from the linear interpolation. For modest storage investments producing partial export reduction, these effects are expected to be negligible at residential scale. For large storage investments that substantially eliminate export, a confirmatory field visit may be warranted. The decision regarding whether a confirmatory visit is required for regulatory purposes should be established in the TIR measurement protocol.

VII. LIMITATIONS AND OPEN QUESTIONS

The undersigned respectfully identifies the following limitations of the proposed methodology for the Bureau's consideration.

First, the protocol addresses voltage rise on secondary conductors. Transformer thermal violations are a separate physical phenomenon requiring a separate attribution approach based on aggregate distributed energy resource contribution to transformer loading rather than individual service point impedance.

Second, the protocol measures each distributed energy resource's contribution to source impedance at its own point of common coupling. Cross-impedance effects between non-adjacent service points on the same secondary circuit are not captured. On a typical Puerto Rico residential secondary radial circuit with geographically proximate service points, these effects are expected to be small relative to the self-impedance measured at each point of common coupling, but this has not been formally quantified and represents a direction for further study.

Third, the solar noon test window reduces irradiance variability between sequential measurements but does not eliminate it entirely. On a geographically compact secondary radial circuit where the crew can complete measurements within approximately two hours, the residual variability is expected to be within acceptable bounds for a regulatory cost allocation approximation.

Fourth, the proposed methodology addresses the attribution of upgrade costs among existing distributed energy resource installations on the feeder at the time of the test. It does not establish a framework for updating the attribution as additional systems interconnect after the test is performed. A protocol for periodic re-measurement may be warranted as feeder conditions evolve.

VIII. RELATIONSHIP TO ENGINEER FERRER'S PROPOSAL AND RECOMMENDATION FOR TIR INTEGRATION

Engineer Ferrer's proposal to incorporate network source impedance as a cost allocation metric is the foundation upon which the methodology in these comments builds. The undersigned does not present this methodology as competitive with Engineer Ferrer's proposal but as a complementary operational protocol that provides a specific, reproducible, field-executable implementation path for the metric he identified. The undersigned intends to review Engineer Ferrer's methodology submission once it is on the record and to evaluate whether the two approaches are complementary, consistent, or whether either requires refinement in light of the other.

The cost responsibility argument is fully developed in Section II and is not repeated here. The undersigned reiterates only the recommendation that measurement costs incurred under this protocol be treated as a utility infrastructure characterization expense borne by the EPS Operator, consistent with the observations made in the undersigned's post-workshop comments filed August 30, 2026 in this proceeding.

The undersigned respectfully recommends that the Energy Bureau direct LUMA Energy, as part of the TIR development process, to consider incorporating the measurement protocol described in these comments, or a compatible equivalent validated through the stakeholder participation process, into the TIR as the standard field measurement methodology for source impedance characterization and proportional cost allocation in supplemental review studies. Codifying the protocol in the TIR would provide regulatory certainty to all parties, ensure that the measurement is conducted consistently across all affected feeders, establish the minimum data logger resolution requirement as a binding technical specification, and make the analytical procedure for storage investment estimation described in Section VI.E available to every prosumer seeking export authorization as a matter of regulatory right rather than utility discretion.

IX. DECLARATION

In compliance with applicable Energy Bureau procedural requirements, the undersigned declares as follows:

A) No party or attorney in this proceeding assisted in drafting these comments.

B) No party or attorney in this proceeding contributed funds or any other type of resource for the preparation or submission of these comments.

C) No person other than the undersigned contributed funds or any other type of resource for the preparation or submission of these comments.

Respectfully submitted,

In San Juan, Puerto Rico, on September 11, 2026.

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CERTIFICATE OF SERVICE

I hereby certify that on September 11, 2026, a copy of these Comments was filed with the Puerto Rico Energy Bureau under the title Third Supplementary Comments on Distributed Generation and Microgrid Interconnection Regulation, Case No. NEPR-MI-2019-0009, addressed to the attention of Edison Avilés Deliz, Chairman, and submitted electronically through the Energy Bureau's electronic filing tool at https://radicacion.energia.pr.gov/.

Robert A. Garcia Cooper