INTEGRACIÓN EFICIENTE DE
ENERGÍAS RENOVABLES VARIABLES
AL SISTEMA COLOMBIANO

PROVIDENCIA ISLAND WHITE PAPERS: STAKEHOLDER ENGAGEMENT & COORDINATION IN INTERCONNECTION RULEMAKING

Michael Ingram

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Author
Michael Ingram
National Renewable Energy Laboratory

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On November 16, 2020, Hurricane Iota struck Providencia Island. Home to fewer than 7,000 residents, the Category 5 hurricane damaged over 95 percent of Providencia Island's energy and road infrastructure, property, and motor vehicles, causing its electricity grid to collapse overnight. The Colombian government took immediate action to address this catastrophe, and within 100 days, almost all electricity was restored. However, a realization emerged: while Providencia previously relied entirely on fossil fuels, Hurricane Iota created an opportunity for the island to rebuild a more sustainable and resilient energy infrastructure that could better withstand the ever-growing effects of climate change.

Together with USAID, ECOPETROL, the U.S. Department of Energy's National Renewable Energy Laboratory (NREL), the Scaling Up Renewable Energy (SURE) program, the United States Energy Association (USEA), and Colombia Inteligente, (then) President Iván Duque Márquez announced a working group in Colombia's Ministry of Mines and Energy. The working group conducted high-level technical analyses and workshops which led to the development of these four White Papers. The Providencia Island White Papers are a set of 4 papers designed to guide Providencia Island's sustainable energy transition. However, each paper also serves as a valuable resource for any islanded power system looking to transition to renewable energy sources.

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List of Acronyms

AGIR	authority governing interconnection requirements
BPS	bulk power system
DER	distributed energy resource
EPS	electric power system
IEEE	Institute of Electrical and Electronics Engineers
SOPESA	Sociedad Productora de Energía del Archipiélago de San Andres, Providencia y Santa Catalina

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1 Start Here

The starting point of engineering interconnection rules involves determining the technological and socioeconomic contexts that drive potential challenges and opportunities for renewable energy adoption and integration. Interconnection rules facilitate the development of transparent and efficient processes to ensure safe and widespread deployment of distributed energy resources (DERs). Their efficiency is driven by their ability to meet the needs and requirements of the stakeholders that are associated with the process at the operations level.

As such, a critical first step in updating interconnection rules is evaluating stakeholder interests and major drivers that warrant the creation or modification of interconnection rules. Developing an understanding of the viewpoints, expectations, and needs of the range of stakeholders involved, as well as gaining insight into the drivers for developing an interconnection rule, can help to ensure a result that aligns with various goals and expectations while maintaining appropriate boundaries on the scope of the effort.

The process of developing and updating interconnection rules is typically subdivided into three steps, as shown in Figure 1.

Figure 1. Subdivision of interconnection rulemaking process

2 Determine the Context

Two important activities constitute Step 1 of the interconnection rulemaking process. The first is assessing the context and drivers for updating the rule. The second consists of determining the stakeholders that affect and/or are affected by the interconnection rulemaking process.

This second step includes a review of stakeholder drivers of interconnection processes and technical changes. Conducting an initial assessment of stakeholder goals, along with the primary drivers and converting them into stakeholder requirements, can be useful in the development of key performance indicators and critical metrics for evaluating the efficiency of the proposed interconnection rules.

2.1 Assessing the Role of Stakeholders

Through stakeholder collaboration, interest groups, and entities with similar or different objectives can identify shared goals that go beyond individual interests and create a vision of what is achievable. Leveraging the goals and process validation metrics identified in the Step 1 activities to establish a shared purpose for the stakeholders can provide a strong framework for addressing complex problems in existing DER interconnection processes that otherwise isolated efforts cannot solve. In addition to promoting an inclusive and nonhierarchical participatory environment, this approach encourages a joint sense of responsibility among stakeholders to ensure the successful enforcement of interconnection rules.

The degree to which a stakeholder might be involved in the collaboration process could vary from a central decision-making role to a consultative role. Stakeholders such as utilities, developers, and customer advocates typically represent entities directly affected by interconnection rules. Thus, they are central to the interconnection rulemaking process and may be intricately involved in the development and enforcement of these rules.

At a higher level of abstraction, stakeholders can be classified into two categories: conveners of the interconnection working group and additional stakeholders. Figure 2 shows an overview of the major organizations and entities involved in the DER interconnection rulemaking process.

Conveners of the collaboration process must strategically plan the scope and duration of additional stakeholder involvement and monitor changes in their influence and primary objectives to ensure commitment to a common goal. A shared purpose can be a powerful driver of performance by providing both motivation and direction for members' joint problem-solving efforts. Failure to involve all stakeholders in collaboration efforts can lead to process implementation issues and technical or political difficulties in achieving DER interconnection objectives.

Transforming interconnection rulemaking into an open and participatory process for stakeholders from diverse backgrounds and knowledge bases allows the formulation of shared goals and objectives for the interconnection working group. This approach also mitigates the introduction of bias in the rule's objectives, which is often induced because of domination by the strongest or best-resourced interest groups.

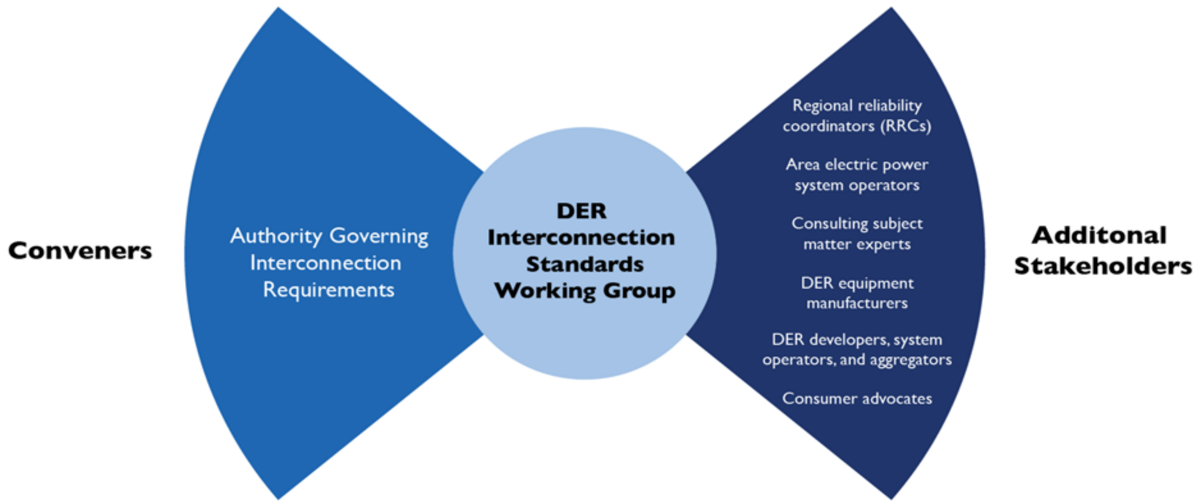

Figure 2. Overview of convener and additional stakeholders in the interconnection rulemaking process

3 Authority Governing Interconnection Requirements (AGIR)

The term and role of the AGIR[1] is introduced in the Institute of Electrical and Electronics Engineers (IEEE) Standard 1547-2018 and is exactly what its name implies: it is the entity that has the authority to set the interconnection requirements used in a local territory. In Colombia, the role of AGIR is fulfilled by the Comisión de Regulación de Energía y Gas (CREG).

The applicability of certain technical requirements and specifications is determined by the AGIR (IEEE 2018). Generally, the AGIR has responsibility to quantify impactful DER penetration levels, define use cases, set timelines, and update other relevant codes or rules.

[1] IEEE Std 1547-2018 defines the AGIR as a "cognizant and responsible entity that defines, codifies, communicates, administers, and enforces the policies and procedures for allowing electrical interconnection of DER to the area EPS. This could be a regulatory agency, public utility commission, municipality, cooperative board of directors, etc. The degree of AGIR involvement will vary in scope of application and level of enforcement across jurisdictional boundaries. This authority might be delegated by the cognizant and responsible entity to the area EPS operator or BPS operator" (IEEE 2018).

4 Electric System Operations

Sociedad Productora de Energía del Archipiélago de San Andres, Providencia y Santa Catalina (SOPESA) is the electric system operator on Providencia Island presiding over generation, transmission, and distribution. This *vertical integration* encompasses many of the roles depicted in Figure 2. SOPESA has responsibility for reliability (power system frequency) and the "area electric power system" (EPS) (lower-voltage distribution and delivery). These functional roles are described below, but no agent on Providencia Island holds these titles explicitly.

4.1 Bulk Power Operations: Regional Reliability Coordinators (RRCs)

At the transmission and bulk power levels, an RRC is the entity that maintains the real-time operating reliability of the bulk power system (BPS) (IEEE 2018). RRCs have "the operating tools, processes and procedures, including the authority to prevent or mitigate emergency operating situations in both next-day analysis and real-time operations" (NERC 2018). In areas that have high renewable targets that could include large shares of inverter-based resources and/or large amounts of distributed generation, RRCs across the mainland United States are paying increasing attention to these resources in planning studies. Certain technical requirements of inverter-based resources are of particular importance to SOPESA's RRC role on Providencia Island, including *voltage ride-through* and *frequency ride-through*, as well as potentially *grid-forming and black-start* capabilities.

4.2 Service Delivery: Area EPS Operator

In an interconnection, certain technical requirements are designed, very specifically, to meet the needs of a particular area EPS operator. These requirements can be influenced by the area EPS electrical configuration; area EPS operator distribution operation practices; decisions by the area operator on electrical safety, power quality, and protection coordination; specific requirements for testing and certification; requirements for voltage regulation; and requirements for communications or other interoperability or supervisory control and data acquisition system integration requirements. As elsewhere, these types of technical requirements are in large part at the discretion of SOPESA, the EPS operator, because they directly affect the safety and operation of the distribution system. In IEEE Standard 1547, many DER requirements fall into this category, including clauses on the prevention of unintentional islanding and adverse power quality.

5 Additional Stakeholders

Different stakeholders are involved in the interconnection decision-making process to varying degrees. It is critical to understand the impact that these stakeholders can have on the interconnection process and their relevance in driving the process.

People are often driven by the clear definition of goals and overarching purpose. When individuals (and the companies they represent) see how collaboration benefits a larger cause, they become more committed and engaged. Negotiating a common and shared purpose is a fundamental building block of successful collaboration. It can be important and helpful prior to updating the interconnection rule for the stakeholders to establish common definitions, nomenclature, and terms for key concepts to help facilitate further collaborative work. Meaningful collaborative participation might be hampered without this foundation of common understanding and how terms and concepts will be used in context with each other.

Taking the time to clarify definitions and terms at an early stage—before reaching conclusions or attempting action—will prevent unnecessary misunderstandings that delay the work.

6 Motivations for Updating Interconnection Rules

At a broad level, the major drivers of DER adoption and interconnection process revisions are categorized as technical, market, and policy. Different stakeholders might be motivated by one or more of these drivers at a given time. By making stakeholders an integral part of interconnection rulemaking considerations, the Comisión de Regulación de Energía y Gas can ultimately develop performance metrics that can be used for interconnection process validation. The following table outlines major technical, market, and policy drivers that should be considered while designing new interconnection rules.

Table 1. Drivers of DER Adoption and Interconnection Process Revisions

CATEGORY	GAP/ISSUES	OPPORTUNITY/SOLUTIONS
Technical	Improvements to DER hosting capacity[2]	*Hosting capacity* is the amount of DERs that can be added safely and reliably before system upgrades are required. Advanced inverter settings are an example of technical requirements that can improve hosting capacity.
	Improvements to situational awareness	Situational awareness involves three levels of operator information: (1) perception—observation of the current situation, (2) comprehension—relevance and impact on system requirements and (3) projection—forecast of consequences and recommended action (if any). DER status can improve situational awareness, especially at higher shares.
	Considerations for DER impacts on BPS reliability[3]	DER deployments at a scale large enough to impact the BPS are currently evident in only a handful of locations; however, planning for DER impacts to BPS reliability is actively occurring at a number of bulk system operators in the United States and internationally.
Market and Economic	Improved resilience[4]	DERs are emerging as a viable alternative to traditional backup power generation. Yet, to permit the dual benefits of backup power and on-site generation that reduces utility bills and enables continued operation despite interruptions, DERs must be configured to provide these capabilities (Zitelman 2020).
Policy	Translation of energy policy into requirements	Energy policy can have a large impact on the amount of DER installed capacity. Consequently, policy and related regulations (and/or market conditions) might result in enabling technical requirements.

[2] Utilities have typically relied on estimates or rules-of-thumb in considering interconnection requests, but rapid growth in DER interconnection requests has prompted some jurisdictions to explore more rigorous hosting analysis techniques and to develop hosting capacity maps to support more proactive DER integration planning. Updating technical requirements to adopt the latest standards (i.e., IEEE 1547-2018) can simplify hosting capacity analysis.
[3] For a discussion on this topic, see the white paper https://www.nerc.com/comm/PC_Reliability_Guidelines_DL/Guideline_IEEE_1547-2018_BPS_Perspectives.pdf.
[4] NREL defines *resilience* as "a system's ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions through sustainable, adaptable, and holistic planning and technical solutions" (Torres and Laws 2018).

References

IEEE. 2018. "IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces." https://standards.ieee.org/standard/1547-2018.html.

Torres, Juan, and Nick Laws. 2018. "Energy Resilience Through Grid Modernization and Renewables Integration." Presented at the Critical Infrastructure Resilience Workshop, December 7, 2018, Washington, D.C. https://www.nrel.gov/docs/fy19osti/72884.pdf.

Zitelman, Kiera. 2020. *Advancing Electric System Resilience with Distributed Energy Resources: A Review of State Policies*. Washington, D.C.: National Association of Regulatory Utility Commissioners. https://pubs.naruc.org/pub/ECD7FAA5-155D-0A36-3105-5CE60957C305.

Bibliography

Rickerson, Wilson, Jonathan Gillis, and Marisa Bulkeley. 2019. *The Value of Resilience for Distributed Energy Resources: An Overview of Current Analytical Practices*. Washington, D.C.: National Association of Regulatory Utility Commissioners. https://pubs.naruc.org/pub/531AD059-9CC0-BAF6-127B-99BCB5F02198.

Seguin, Rich, Jeremy Woyak, David Costyk, Josh Hambrick, and Barry Mather National. 2016. High-*Penetration PV Integration Handbook for Distribution Engineers*. Golden, CO: National Renewable Energy Laboratory. https://www.nrel.gov/docs/fy16osti/63114.pdf.

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