ESIG

ENERGY SYSTEMS INTEGRATION GROUP

ESIG REPORT

Interregional Transmission for Resilience: Using Regional Diversity to Prioritize Additional Interregional Transmission

EXECUTIVE SUMMARY

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As extreme weather events become more of a concern for the electric power industry, power system resilience is seen as an increasingly valuable grid quality that offers measurable advantages to consumers. Events such as Winter Storm Uri in 2021, which resulted in widespread outages and loss of life, highlight the critical need for a resilient grid that can withstand and recover from such disruptions. While the industry has well-established standards and procedures for evaluating reliability and resource adequacy needs, the increasing industry focus on grid resilience indicates that these standards may not be sufficient to address the unique challenges posed by high-impact, low-frequency events such as winter storms, summer heat waves, and concurrent power plant outages.

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Interregional transmission can increase grid resilience by enabling the transfer of electricity across large geographical areas, thereby mitigating the impacts of local or regional disruptions. Increased transfer capability between regions can help balance supply and demand during periods of stress due to high load, inclement weather, high generator outages, low renewable output, or a combination of these. Interregional transmission improves grid resilience by allowing regions to access diverse resources in other regions that are not simultaneously affected by the same weather conditions.

However, despite the potential benefits, current planning processes often overlook the resilience value of interregional transmission, focusing on local reliability solutions within the local territory or only a small geographical region. This report offers planners a framework for assessing transmission's adequacy and resilience benefits at a national scale and prioritizing transmission investments that offer the greatest benefits for system resilience.

Need for a National-Scale Solution to a Nationwide Risk

Recent extreme weather events have reinforced that these events are often larger than local planning regions and can move across multiple regions as the storms progress, a dynamic that points to the need for a national-scale solution. This need is broadly recognized, as underscored by recent actions by the Federal Energy Regulatory Commission (FERC) and Congress. FERC Order 1920

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mandates the consideration of interregional transmission projects in regional planning, and the proposed BIG WIRES Act, if enacted, would establish a minimum transfer capability between regions as a function of their peak load. And the North American Electric Reliability Corporation (NERC) has been tasked with quantifying existing transfer capabilities and recommending prudent additions to ensure reliability, highlighting the importance of this topic to grid planners and policymakers as uncertainty grows around maintaining grid reliability, adequacy, and resilience in the face of a changing resource mix, new loads, and the effects of climate change.

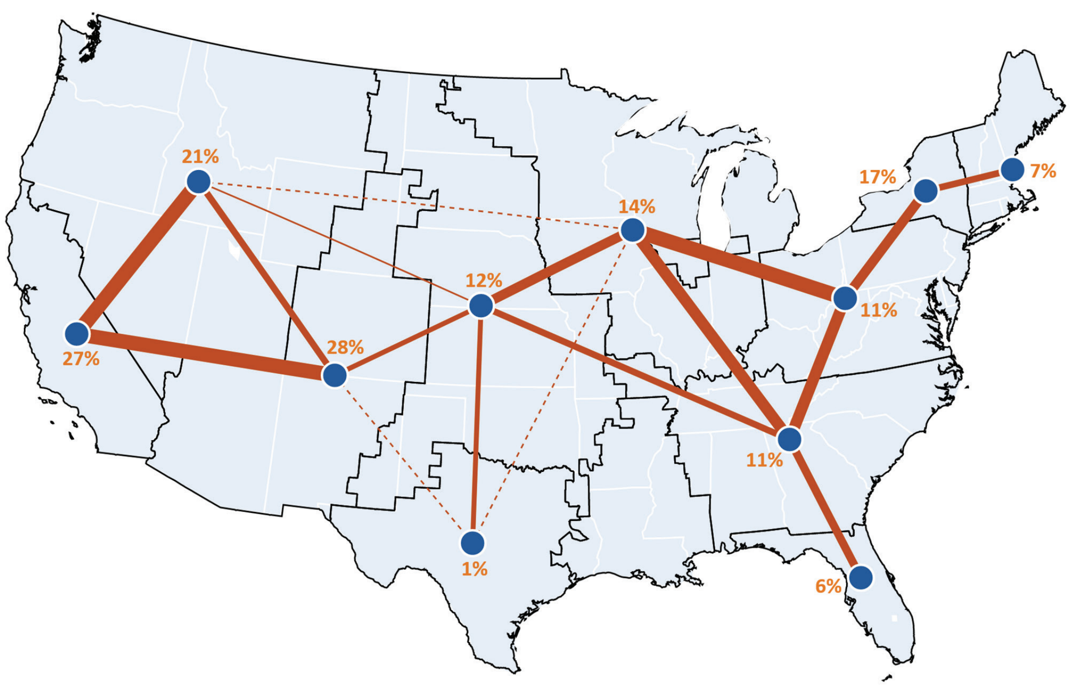
Given the variety of options to improve grid resilience, it is important to have robust procedures to assess expected benefits and allow cost/benefit comparisons of solutions. This study first provides a nationwide assessment of current interregional transmission capability. To date, there is no consistent, rigorous method for planning additional transfer capability between regions. The Energy Systems Integration Group's Transmission Resilience Task Force developed the methodology detailed in this report to aid in evaluating the resilience benefits of interregional transmission, providing planners with a quantitative approach to prioritizing new transfer capability to increase resilience. Future work from the Transmission Resilience Task Force will apply these methods for a specific region to provide more detailed quantification of the benefits that interregional transmission can provide during grid stress conditions.

Today's Interregional Transfer Capability

This study estimated existing interregional transmission capabilities using historical flow data from the Energy Information Administration Form 930, analyzing five years of hourly interchange data (2019-2023) at the FERC Order 1000 level. We evaluated the transfer capability between regions and the total transfer capability for each region. Figure ES-1 shows the magnitude of each region's existing transfer capability with its neighbors as a percentage of the region's peak load modeled in this study.

FIGURE ES-1

Existing Interregional Transmission Paths Across the U.S., by FERC Order 1000 Region



The blue dots represent the FERC Order 1000 regions, with orange lines showing the magnitude of the transfer capability between each pair of regions. Dotted lines represent no existing transfer capability, but the potential for immediate neighbors to create transfer capability. The thickness of the solid lines indicates the relative amount of transfer capability in each case. Note, transfer capabilities for U.S. regions with connections to Canadian regions are not included in these values.

Source: Energy Systems Integration Group; data from Energy Information Administration 930 Hourly Electric Grid Monitor.

These findings show that current transfer capabilities for most regions of the country are below 20% of a region's peak load. Given this assessment of existing interregional transfer capabilities, this study presents a methodology to assess where the potential greatest resilience benefits can be realized when increasing interregional transfer capabilities.

Evaluating Resource Availability by Region to Assess Priorities for Additional Interregional Transmission

To support planners evaluating and designing interregional transmission projects, an assessment is needed of each region in the U.S. in terms of hourly variability in wind and solar resources, the unavailability of thermal generators due to correlated outages and maintenance plans, and each region's ability to import or export power to its neighbors. This study provides an initial methodology that can be adapted to meet an individual planning region's needs with a reasonable representation of the neighboring power systems and markets. The study results also inform national efforts to assess resilience benefits from interregional transmission.

This national assessment of the potential benefits from interregional transmission begins with an evaluation of the diversity in hourly electricity demand and resource availability across multiple weather conditions in all regions with consideration of hourly, weather-dependent inputs on loads and resource availability. To assess the diversity of customer demand and resource availability in regions across the U.S., we looked at both normal operating conditions and extreme conditions within a set of hourly weather data representing weather from 2007 through 2013 on a future grid. This study calculated an hourly energy margin that measured hourly available wind and solar, seasonal hydro capacity, and available thermal capacity after accounting for maintenance and weather-dependent outages. The available capacity was compared against hourly loads, inclusive of a capacity margin as a percentage of hourly load, and storage net generation.

This broad, national assessment of hourly energy margins is meant to be complementary to a region's detailed production-cost and resource adequacy assessments by assessing weather-dependent resource availability across a wide geographical area. This is typically not done for production-cost and resource adequacy assessments due to data, analytical, and computational limitations. Instead, system planners often model their own region in a high degree of detail, while incorporating limited or even no representation of neighboring regions. Calculating the hourly energy margin offers a simplified yet robust view of the surplus or deficit in available resources in each region across every hour of a weather year, enabling planners to identify surplus resources and potential support regions during grid stress events such as extreme heat or cold or low renewable resource output. This level of external awareness is critical for assessing the resilience benefits that increasing interregional transmission capability can provide.

Results presented in this report were developed using seven weather years of data and future resource mixes developed by the National Renewable Energy Laboratory across the continental U.S. In addition, the hourly energy margin calculation is adaptable to any number of weather years, load data, future resource mixes, or other planned system changes, making it a flexible tool for assessing interregional resource diversity.

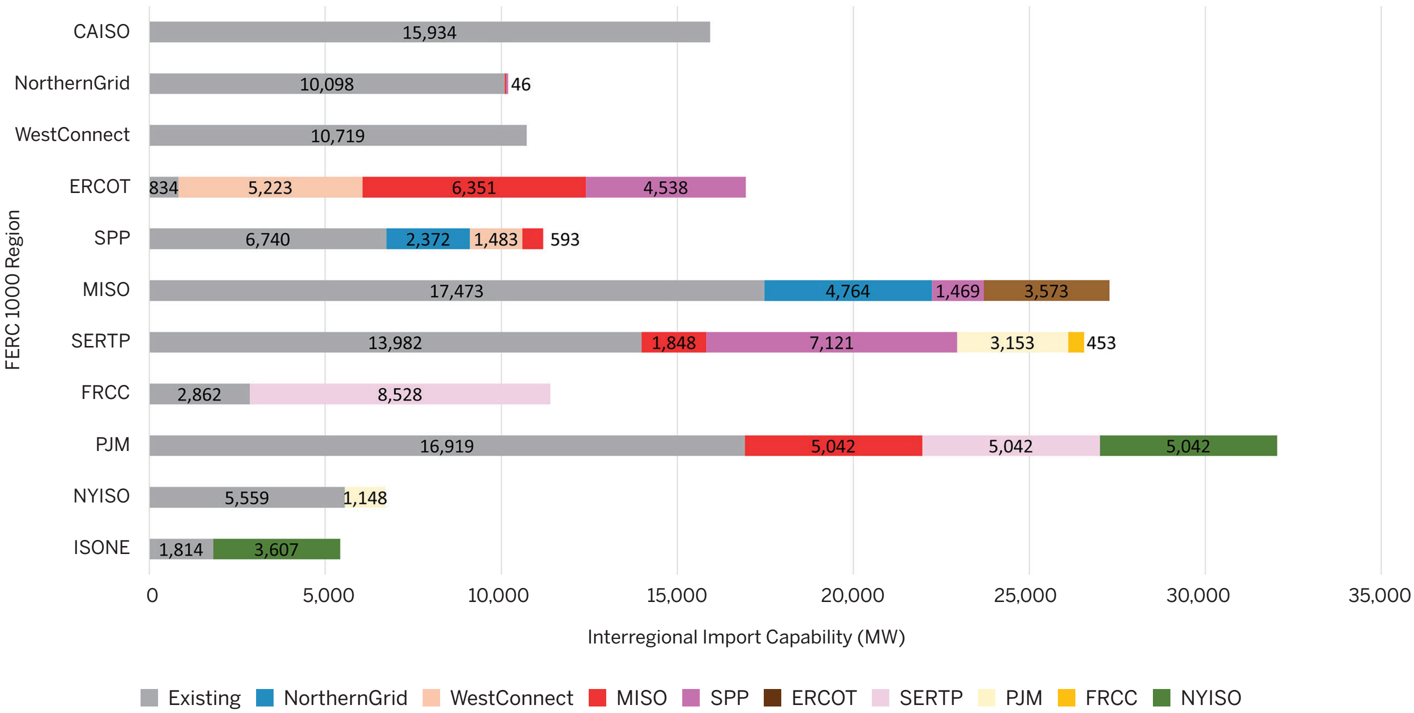
The hourly energy margin calculation is adaptable to any number of weather years, load data, future resource mixes, or other planned system changes, making it a flexible tool for enhancing transmission grid planning to ensure long-term resilience.

A Case Study to Prioritize the Optimal Locations for Building Interregional Transmission

Using these hourly energy margins, a case study was conducted based on the goal from the proposed Building Integrated Grids With Inter-Regional Energy Supply Act (BIG WIRES) of establishing a minimum interregional transmission capability of up to 30% of a region's peak load. We used the hourly energy margin analysis to determine the preferred connections and magnitude of increased interregional transmission for each region.

FIGURE ES-2

Interregional Non-Coincident Import Capability Added by the Model, by FERC Order 1000 Region, to Allow Each Region to Import 20% of Its Peak Load



The figure shows the additional interregional transmission capability that would be needed between FERC Order 1000 regions to enable them to import 20% of their peak load, and where the additional capability is coming from. Gray areas of bars represent each region's existing transfer capability. Colored areas of bars represent transfer capability needed between that region and the respective other region(s).

Notes: CAISO = California Independent System Operator; ERCOT = Electric Reliability Council of Texas; FRCC = Florida Reliability Coordinating Council; ISONE = Independent System Operator of New England; MISO = Midcontinent Independent System Operator; NYISO = New York Independent System Operator; SERTP = Southeastern Regional Transmission Planning; SPP = Southwest Power Pool.

Source: Energy Systems Integration Group.

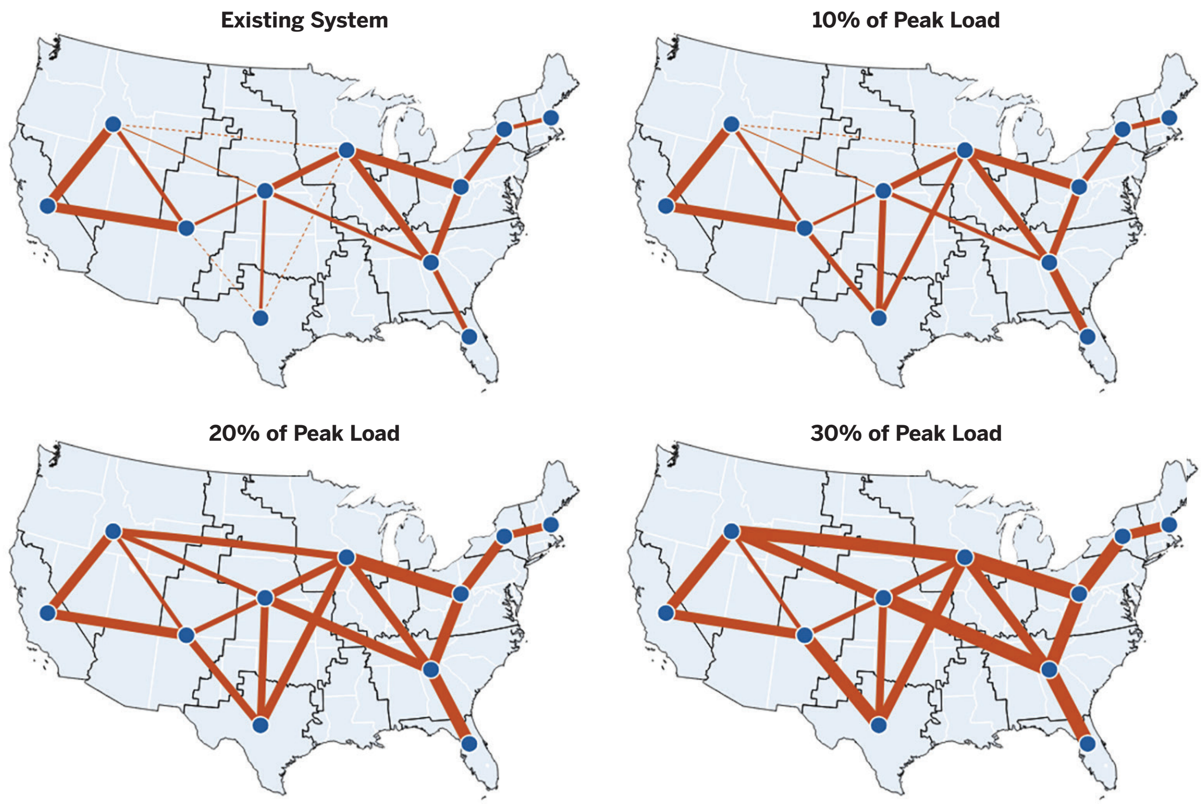
To determine where additional interregional transfer capability should be added, we established a priority dispatch order in which a region first uses its own resources, then resources from its immediate neighbors (if they have surplus), and, lastly, resources from neighbors' neighbors, if they have surplus. This methodology prioritizes transfers for reliability and intentionally evaluates only relative resource surplus or deficits rather than differences in resource costs or electricity prices. The model was thus able to identify which neighboring regions would typically have deeper reserves during a given region's lower-margin periods (having less surplus relative to load). In effect, priority was given to neighbors that offered the greatest access to diversity in resources or load (highest relative energy margin). Results for expanding transfer capabilities to 20% of a region's peak load using this method are shown in Figure ES-2. Gray portions of the bars represent each region's existing transfer capability, and colored portions represent additional capacity from neighboring regions that was prioritized by the model.

All three levels of transfer capability case are shown in Figure ES-3 (p. 5).

Results from the case study indicate that increasing transfer capabilities between the Eastern and Western Interconnections, and between isolated areas like the edges of the Northeast, Southeast, and ERCOT, could significantly enhance regional grid resilience. At the system-wide level, achieving 10%, 20%, and 30% import capability for all FERC Order 1000 regions would

FIGURE ES-3

Existing U.S. Interregional Transfer Capability Between FERC 1000 Regions, and the Size of Connections Needed for 10%, 20%, and 30% Minimum Transfer Capability



At the top left (existing system), lines connect the center of FERC Order 1000 regions and show where existing interregional transmission connections (solid lines) exist today. Dotted lines represent connections that do not exist today, but where regions are geographical neighbors and connections could be established. The other three maps show modeled increases in transfer capability according to whether a region needed to have sufficient transfer capability to import 10%, 20%, or 30% of its peak load. Lines increase in thickness to show increased transfer capabilities as regions achieve different levels of import capability relative to their peak load. By the 20% scenario, all modeled potential connections exist, and the transfer capability increases steadily as the percentage-of-peak-load requirement goes up.

Source: Energy Systems Integration Group.

require additional transfer capability in the range of 11.4 GW, 71.4 GW, and 149.0 GW, respectively. Most of this increase would be concentrated in ERCOT, MISO, the Southeastern Regional Transmission Planning region, Florida Reliability Coordinating Council, and PJM, given the magnitude of current capabilities.

Suggested Practices

This study demonstrates a framework for planners to assess hourly energy margins for both internal and external systems and to determine resource availability across regions, identifying surplus capacity under diverse weather scenarios to aid interregional transmission planning. The method is intended to be practical and adaptable, allowing for broad nationwide assessments, across all hours of the year and across many weather years. The method is applicable on both a regional and a national scale using synthetic historical weather data and future climate change weather data across many different resource mixes to evaluate the timing of surplus and deficits in resource availability. Based on this assessment, Table ES-1 (p. 6) presents four key practices for planners to consider when evaluating interregional transmission plans and their resilience.

TABLE ES-1
Four Key Practices for Interregional Transmission Planning

Prioritize regions with less existing interregional transfer capability	Regions with interregional transmission capability that does not meet the targeted transmission capability as a percentage of their peak load would be prioritized for increasing transfer capability.
Prioritize transfer capability that increases imports from regions with uncorrelated risks	Transmission would be prioritized from regions likely to have a surplus during times of tight supply conditions elsewhere. This requires assessing hourly variations in surpluses and deficits for all regions.
Focus on immediate neighbors	Efforts to increase interregional transmission would focus on connections between geographically closer regions in order to minimize costs.
Allow for power to flow from a neighbor's neighbor	To evaluate interregional transmission, one needs to adequately represent a region's access to load and resource diversity beyond its immediate neighbors and accommodate the movement of power from adjacent regions, establishing a more interconnected and supportive network.

Future studies calculating interregional transfer capabilities must recognize that these values are dependent on grid conditions and resource mixes—they are not static. Resource additions and retirements and load growth will affect both transfer capabilities and the availability of diverse resources across regions. Similarly, weather events affect both the availability of renewable resources and the outage risks for conventional thermal generation. This means more scenario modeling is required both to determine transfer capability during high-risk events given load and resource availability and to assess system resilience and reliability during extreme weather events as well as normal conditions. Knowing what transfer capabilities are during stressful grid conditions is crucial for maintaining reliability and ensuring a resilient grid.

Also of note, the results of this study indicate that using FERC Order 1000 regions to define interregional transfers may overstate transfer capabilities and understate the potential risks from extreme grid conditions by underrepresenting internal constraints, especially in very large Order 1000 regions such as WECC-NW and MISO. As such, the size and boundaries of study regions should also be a consideration in developing future assessments of increased interregional transfer capability.

As the industry faces significant uncertainty around future load growth, a changing resource mix, and a changing climate, there is a growing need to ensure that electricity systems remain robust and adaptable. Interregional transmission facilitates a more resilient grid by increasing the availability of diverse energy sources to help serve load during critical periods. These potential benefits underscore the importance of strategic planning and investment in infrastructure that can withstand and adapt to the evolving demands of our climate and societal needs. By prioritizing the expansion and enhancement of interregional connections, we can help ensure that the grid remains capable of meeting the emerging challenges of tomorrow.

Interregional Transmission for Resilience: Using Regional Diversity to Prioritize Additional Interregional Transmission by the Energy Systems Integration Group's Transmission Resilience Task Force is available at https://www.esig.energy/interregional-transmission-for-resilience/.

To learn more about the topics discussed here, please send an email to info@esig.energy.

The Energy Systems Integration Group is a nonprofit organization that marshals the expertise of the electricity industry's technical community to support grid transformation and energy systems integration and operation. https://www.esig.energy.