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Proposed Eastern Interconnection and Western Electricity Coordinating Council Seams Study

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SUMMARY

The seam between the Eastern Interconnection (EI) and Western Electricity Coordinating Council (WECC) in the U. S. was created in the 1980s, and is essentially unchanged. Given approved transmission projects, technology advances, aging infrastructure, increasing renewable penetrations, and the value of load and resource diversity across the existing seams; today's interconnections may not be optimal for the long term.

The U. S. Department of Energy has funded major studies recently like the Western Wind System Integration Study and Eastern Renewable Generation Integration Study to evaluate the impacts of renewable developments in an effort to inform interregional and regional planning in the WECC and EI, respectively. These studies and models should be integrated together to identify opportunities and/or benefits associated with rethinking how the interconnection boundaries are planned or operated.

With the integration of the Western Area Power Administration-Upper Great Plains Region/Basin Electric Power Cooperative/Heartland Consumers Power District Integrated System into Southwest Power Pool (SPP) on October 1, 2015, SPP and its members will have direct control or influence over all Back-to-Back (B2B) HVDC ties between the EI and WECC bulk power grids in the U.S. It's important to note that there are several utilities in WECC that own/maintain, operate and schedule transfers on the B2B HVDC ties.

With aging infrastructure and the need to rebuild many major B2B HVDC ties and EHV transmission lines in the next decade or two, it is critically important that long-term strategic plans are developed to serve both regional and national needs in the most effective manner by developing interregional transmission plans that are strongly supported by stakeholders. A robust, hybrid AC and DC network could capture the potential value of load and resource diversity across the existing seam between the EI and WECC in the U. S.

The past decade has seen significant transmission expansion to integrate renewables and improve grid efficiencies. This effort was focusing within planning regions and on coordinated activities among planning regions based on existing interconnections. Limiting grid planning to existing interconnections must be addressed proactively to improve operating efficiencies as owners/operators begin to address the replacement of aging infrastructure.

KEYWORDS

Transmission Planning – Aging Infrastructure – Renewable Integration – HVDC – Corridors – Seams issues

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BACKGROUND

It can be argued that renewable developments in the U. S. plains region are stymied by the lack of transmission capacity to transport clean power to major load centers. To a large extent, wind generation developments in the U.S. are concentrated around the seams of the Eastern Interconnection (EI), Electric Reliability Council of Texas (ERCOT) and Western Electricity Coordinating Council (WECC) grids as shown in Figure 1.

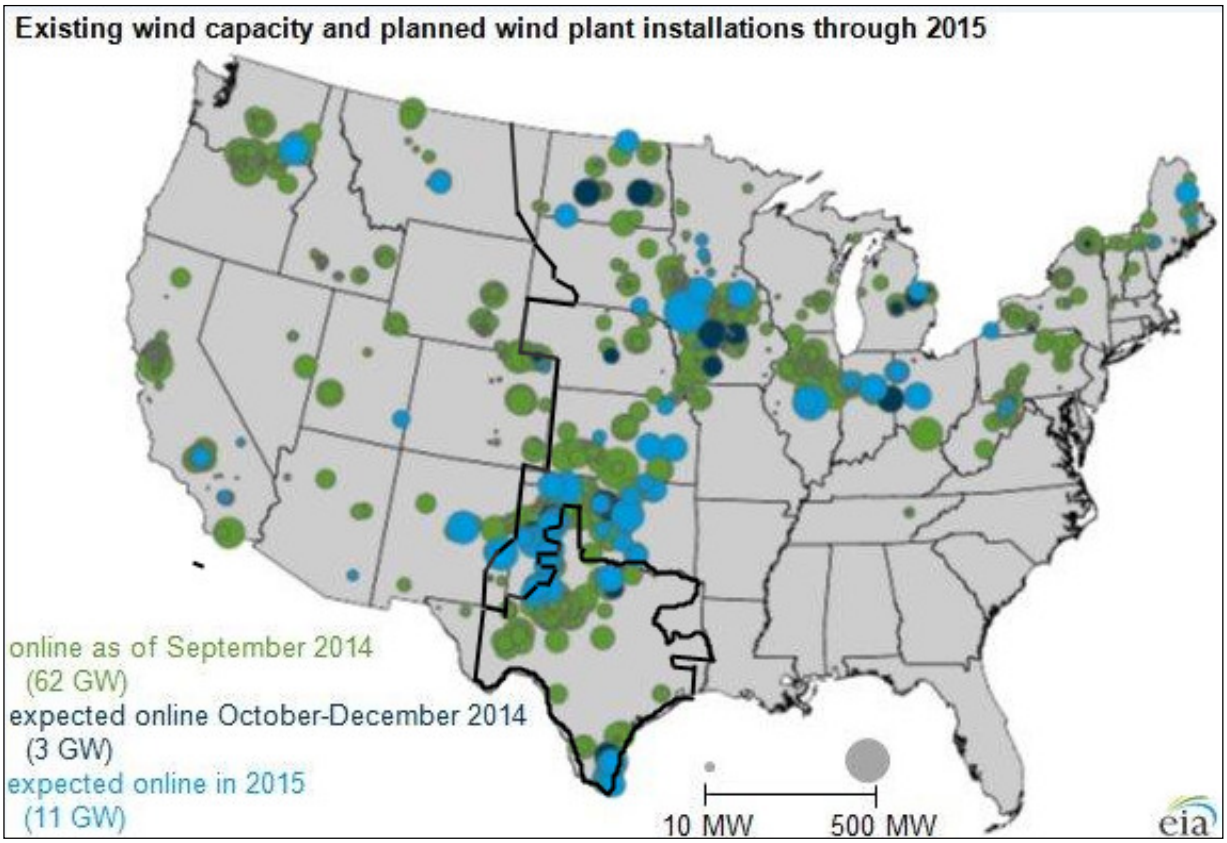

Figure 1. Recent and Projected Near Term U. S. Wind Developments

Significant additional renewable generation developments in the upper Great Plains of the U. S., although not in current projections, should not be discounted given the quality of the resources in those areas. Notably, wind is not the only renewable resource in the plains. As costs continue to decrease and performance/ efficiencies improve, utility scale and distributed solar developments in the US can be expected to grow and have a major impact on the future grid. Figures 2 and 3 are NREL diagrams which show the quality for wind and solar resources, respectively, with an outline of the existing SPP footprint which will be expanded to the Canadian border in the fall of 2015 and become the western edge of the EI in the U.S.

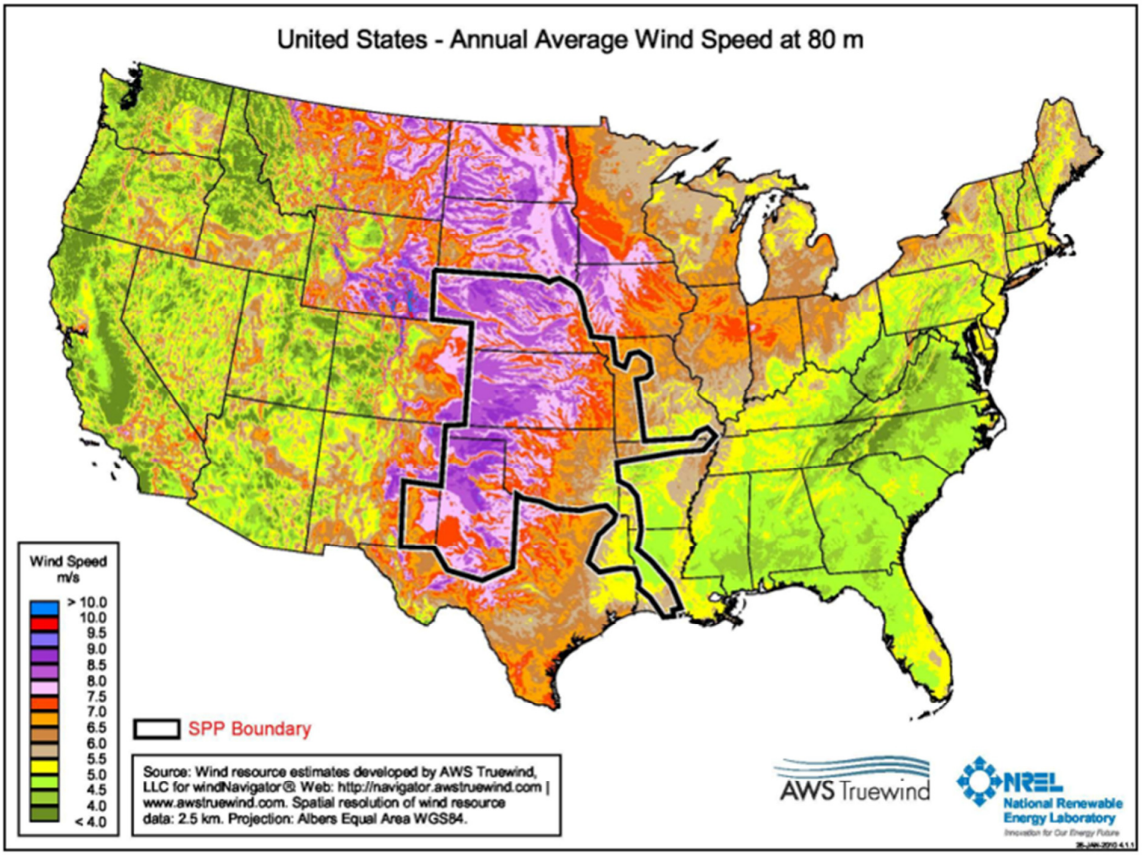

Figure 2. NREL Wind Resources with Existing SPP Footprint

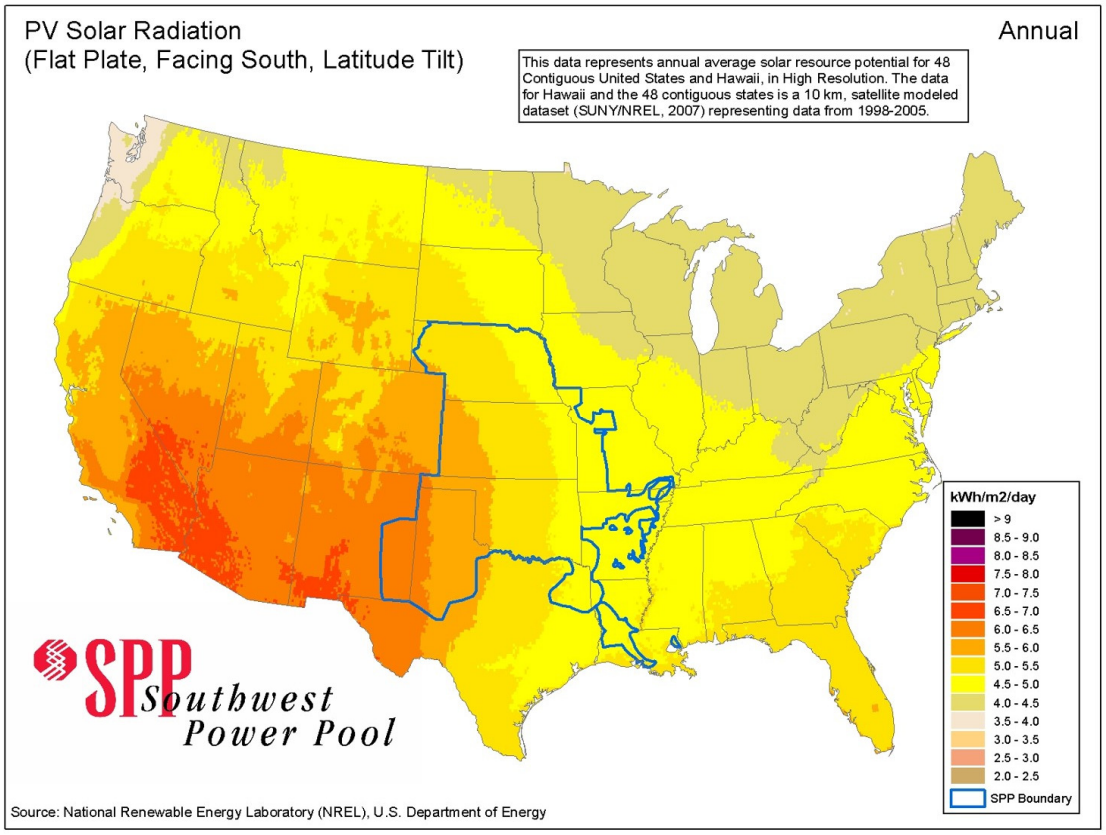

Figure 3. NREL Solar Resources with Existing SPP Footprint

Merchants are proposing large EHV AC and HVDC projects with no, or relatively weak, ties to the existing bulk power system near the source to move renewables to markets, but these projects may not be part of an efficient national grid in the long term. Studies like the Eastern Renewable Generation Integration Study (ERGIS) have shown that optimal grid performance is achieved with HVDC links integrated into the bulk power system network to accommodate transfers in both directions across these facilities to capitalize on load diversity and resource availabilities across broad geographic regions. A robust hybrid AC and DC network could capture the potential value of load and resource diversity across the existing seam between the eastern and western grids in the U.S., and potentially North America.

EXISTING INTERCONNECTIONS

The evolution of the bulk power system in the U. S. changed significantly in the 1970s and 1980s, and the interconnections have remained essentially constant for the last 40 years. Given approved transmission expansion projects, technology advances, aging infrastructure, and increasing renewable penetrations as part of the bulk power system, and the potential value of load and resource diversity across the existing seams, the current interconnections may not be sustainable, let alone optimal configurations in the long term. A map of the current interconnections in North America is shown in Figure 4.

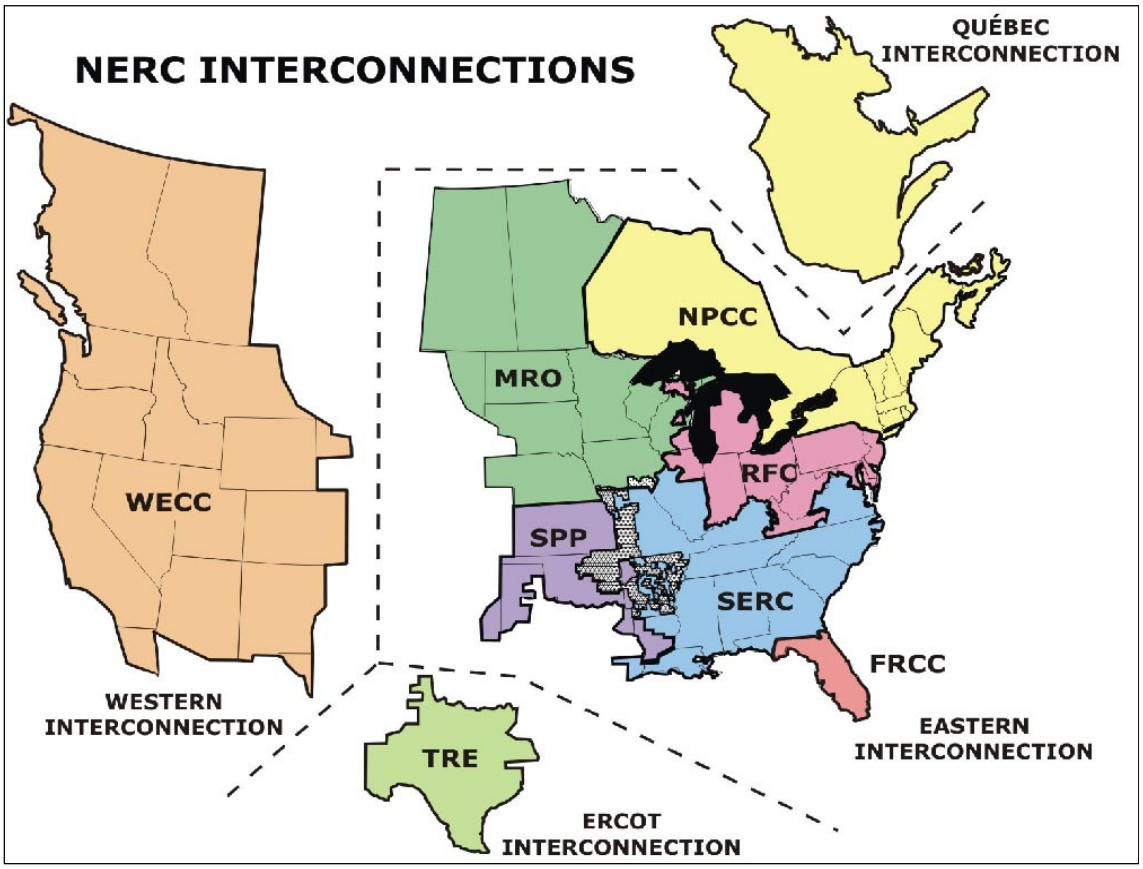

Figure 4. North America Electric Interconnections & Eight NERC Regions

The U. S. Department of Energy (DOE) has funded major studies like the Western Wind System Integration Study (WWSIS) and Eastern Renewable Generation Integration Study (ERGIS) to evaluate the impacts of renewable developments in an effort to inform interregional and regional planning in the WECC and EI, respectively. These studies and models should be integrated together to identify opportunities and/or benefits associated with rethinking how the interconnection boundaries are planned or operated.

Significant transmission expansion has been accomplished in the past decade to integrate high quality renewables and improve grid efficiencies within individual operating regions such as SPP and ERCOT. Significant transmission expansion efforts are underway in MISO with the Multi-Value Projects that are expected to improve renewable integration and improve grid efficiencies within that regional market. However, individual regions have little incentive to build transmission to other regions, as the cost of the transmission is typically borne by the originating regions' ratepayers, who may not benefit if the power is sold outside of their region. Quantifying and demonstrating the value of transmission has been a formidable task, particularly for interregional projects. Major EHV transmission projects can take 5-10 years or longer to plan, design, permit and construct. Cancellation of major projects due to a revised load forecast, modified fuel cost projection, or other relatively minor perturbations to select variables (which are typical business case drivers over relatively short time horizons) can be regretful for long life assets like EHV transmission facilities.

DOE-FUNDED STUDIES AND FINDINGS

DOE funded national grid studies in 1980 and 2002 (similarly titled the "National Power Grid Study" and the "National Transmission Grid Study", respectively) which did not include much support or engagement by industry. Any new seams study needs to include industry engagement as its primary method and may even provide a foundation for a broader National Grid Study that could facilitate more effective interregional and regional planning for the bulk power system.

DOE conducted three major studies during the past 10 years to assess the U.S. transmission grid in an effort to understand the extent to which existing transmission is sufficient to meet the nation's needs (and a fourth one is ongoing at the time of this writing). The first of these was in 2002 [2], which resulted in a recommendation:

"The National Energy Policy Development (NEPD) Group recommends that the President direct the appropriate federal agencies to take action that will remove constraints on the interstate transmission grid so that our nation's electricity supply will meet the growing needs of our economy. NEPD directs the Secretary of Energy to examine the benefits of establishing a national grid and to identify transmission bottlenecks and measures to address them."

This study resulted in identification of the twenty most congested paths in the Eastern and Western Interconnections, major bottlenecks in both, and constraints based on transmission loading relief (TLR) events and high price differentials across an interface. This study also motivated consideration of developing similar studies periodically, which the 2005 Energy Power Act (EPA) affirmed by requiring them every three years. The 2005 EPA also amended the Federal Power Act to give authority for Secretary of Energy to designate "any geographic area experiencing electric energy transmission capacity constraints or congestion that adversely affects customers as a national interest electric transmission corridor."

AGING INSTRASTRUCTURE AND FUTURE OPPORTUNITIES

With aging infrastructure and the need to rebuild many major EHV lines in the next decade or two, it is critically important that very long-term strategic plans are developed with industry support to ensure the investments serve both regional and national needs in the most effective fashion by developing interregional transmission plans that are strongly supported by stakeholders. A robust, hybrid AC and DC network could capture the potential value of load and resource diversity across the existing seam between the EI and WECC in the U.S. and provide opportunities for additional renewable generation.

Transmission enables and defines markets. Figure 5 illustrates the footprints of the organized markets in North America.

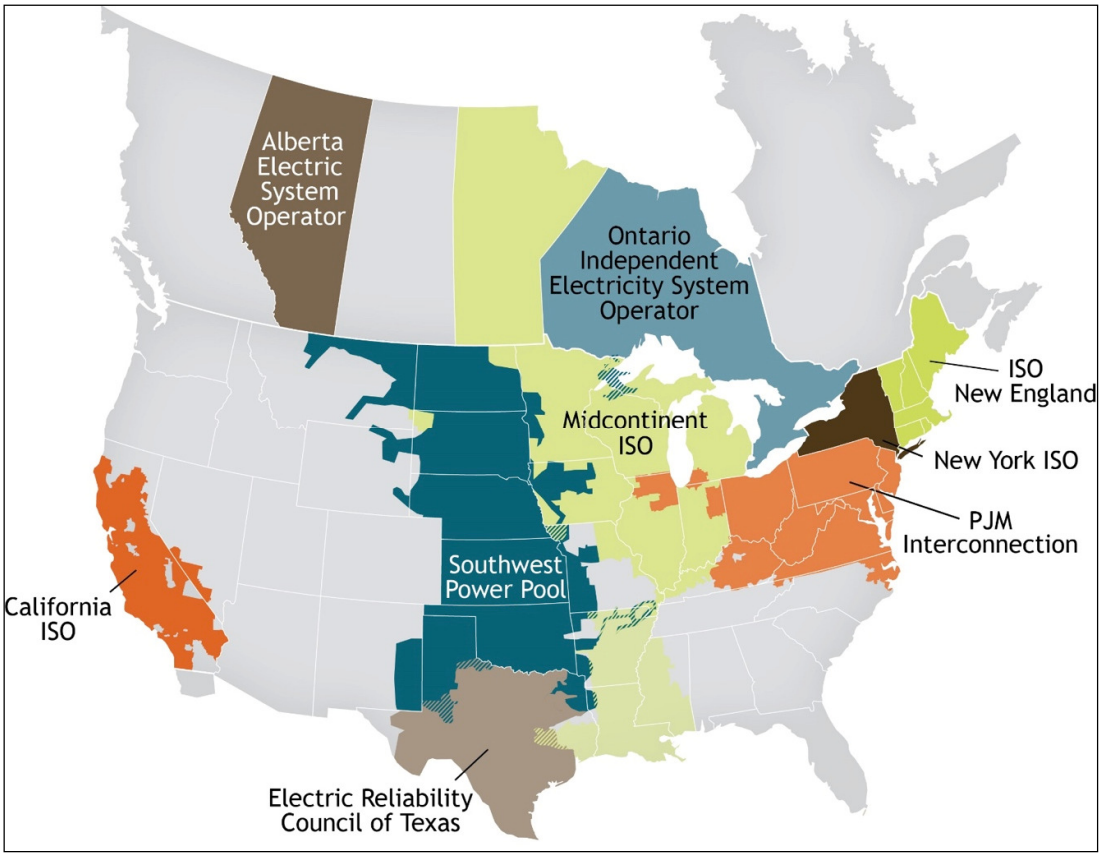

Figure 5. ISO/RTO footprints in late 2015

With the integration of the Western Area Power Administration (Western)-Upper Great Plains Region (UGP)/Basin Electric Power Cooperative (Basin Electric)/Heartland Consumers Power District (Heartland) Integrated System (IS) into Southwest Power Pool (SPP) on October 1, 2015, SPP and its members will have direct control or influence over all Back-to-Back (B2B) HVDC ties between the EI and WECC bulk power grids in the U. S. as shown in Figure 6. It's important to note that there are several utilities in WECC that own/maintain, operate and schedule transfers on the B2B HVDC ties.

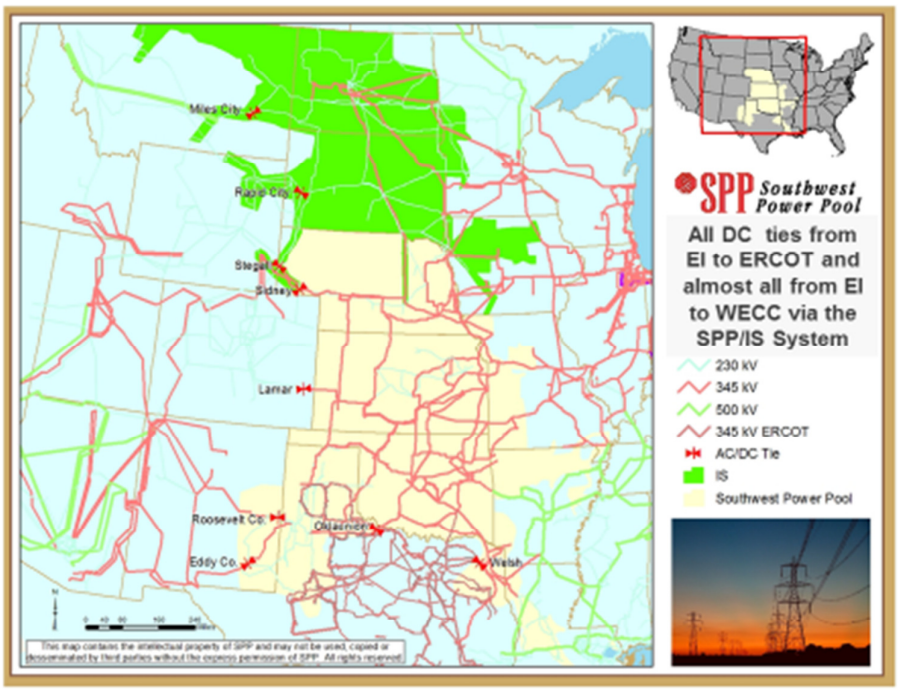

Figure 6. SPP footprint with Western/Basin IS Expansion and HVDC B2B Ties

The only other tie between the EI and WECC in North America is the McNeill tie in Alberta between Saskatchewan Power and Alberta Electric System Operator (AESO). The majority of the HVDC ties shown in Figure 4 in the U. S. are aging technology that is no longer supported by the original vendor. A listing of the original in-service date, capability and technology for the HVDC B2B ties in North America are shown in Table 1.

HVDC Station	Location	Vendor	Type	kV	Power (MW)	Year
David A Hamel	Stegall, NE	GE	LCC	50	100	1977
Eddy County	Artesia, NM	GE	LCC	82	200	1983
Blackwater	Clovis, NM	ABB	LCC	60	200	1984
Miles City	Miles City, MT	GE	LCC	82	200	1985
Virginia Smith	Sidney, NE	Siemens	LCC	50	200	1988
McNeill	McNeill, AB	Alstom	LCC	42	150	1989
Rapid City	Rapid City, SD	ABB	CCC	13	200	2003
Lamar	Lamar, CO	Siemens	LCC	63.6	210	2005

Table 1. HVDC B2B Stations between EI and WECC in North America

In 2009, PNM upgraded the controls and replaced the evaporative cooling system at Blackwater to extend the facilities useful life. Significant monies have been spent recently to refurbish the Oklaunion HVDC B2B station in the U. S which was placed in service originally in 1984. Many of the remaining HVDC ties will need to be refurbished in the next 10 years, if not sooner, to replace equipment, upgrade controls and capture capabilities and efficiencies that are warranted absent any consideration of optimal reconfiguration of the EI and WECC seams. Refurbishment of a single 200MVA HVDC station is very expensive (actual costs > $50M), so it is important that stakeholders are aware of the value of comprehensive, holistic evaluations of all potential alternatives to the status quo, replace-in-kind-in-place strategy.

NATIONAL AND REGIONAL GRID PLANNING

A recent study conducted by researchers at Iowa State University identified transmission additions to minimize generation and transmission investment costs plus energy production costs for a 50% (by energy) wind penetration at the national level [5, 6, 7]. The identified additional transmission paths are shown in Figure 5, where it is observed that seven of them utilize HVDC connecting the EI and WECC, as indicated by the white vertical ovals in the figure. Total capacity of these seven transmission paths was 75 GW. These results are not intended to suggest a particular topology or capacity for interconnecting the EI and WECC, but rather that there may be strong economic justification for increasing transmission capacity between them if wind development in the U. S. plains is high.

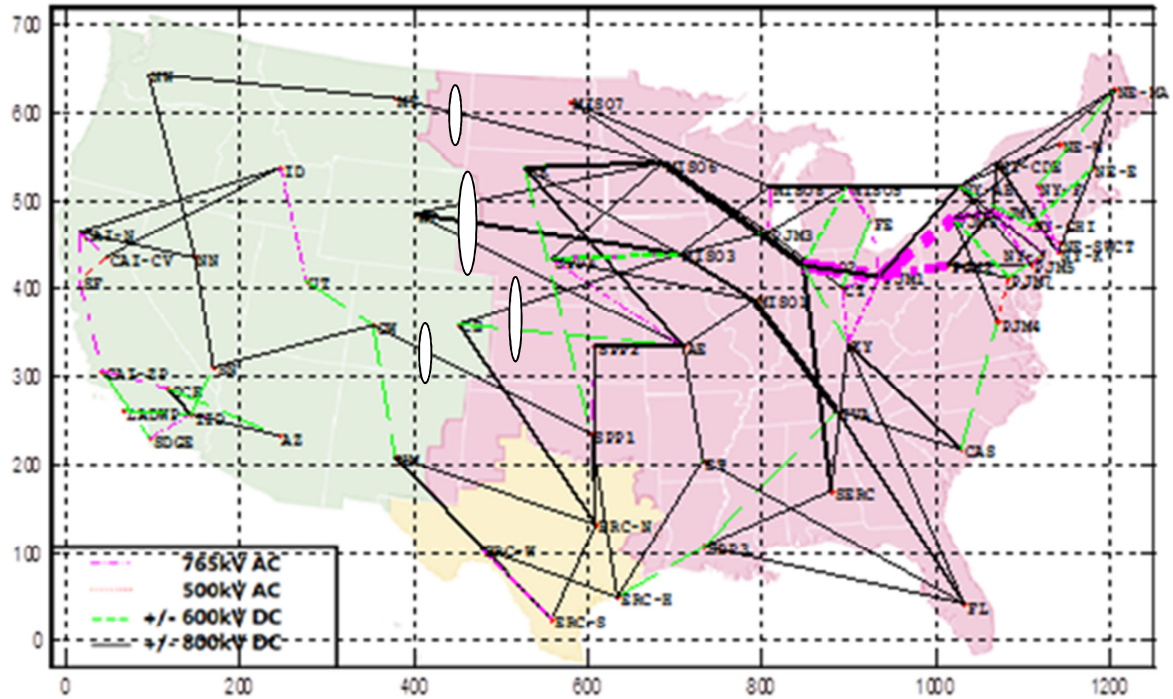

Figure 5 : Transmission investments to minimize total long-term costs of a 50% wind penetration

WestConnect and Transmission Owners have been evaluating the merits of projects which could provide significant capabilities in the eastern portions of Colorado and New Mexico. The most recent conceptual routes for the eastern most circuit of the High Plains Express (HPX) have been routed past the existing Lamar and Blackwater HVDC ties, as the result of outreach and stakeholder discussions in this projects' evolution. The proximity of these lines to the existing ties raises the question of whether further value could be obtained at relatively low cost by strengthening the connection points. A map which shows approved and conceptual transmission expansion in an around the seam of the EI and WECC is shown in Figure 6.

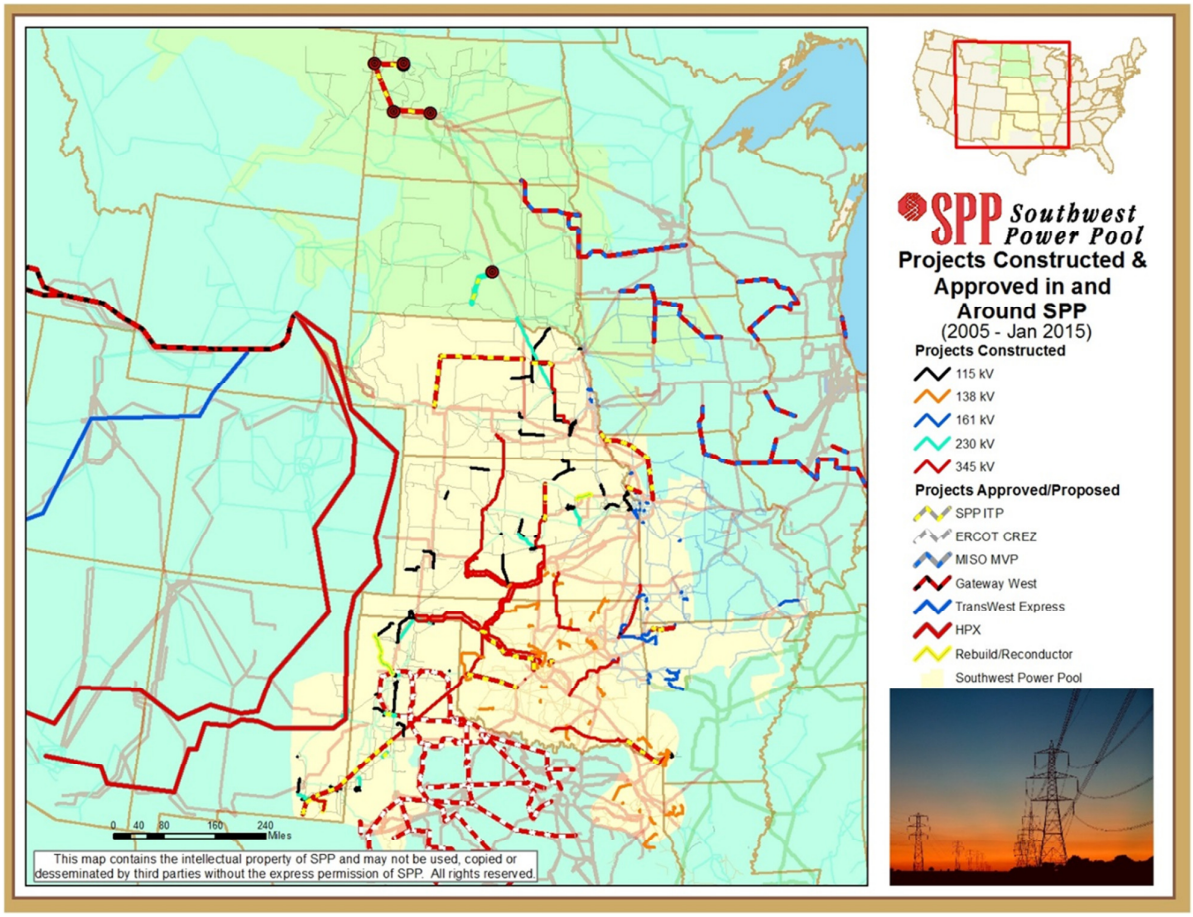

Figure 6. Major planned and conceptual transmission near EI and WECC seams

SPP has spent billions of dollars to create an efficient and effective network to address its regional needs based on a collaborative stakeholder-driven process. SPP has installed significant EHV capability in its western region to integrate renewables with single and double circuit 345kV lines designed for 3,000 Amp capabilities. Thousands of miles of EHV backbone lines in KS, OK and TX are in-service in SPP with additional approved projects underway to better integrate eastern NM into the SPP facilities in TX, as well as the Gerald Gentlemen – Thedford – Holt County 345kV project in Nebraska to integrate southwestern NE into existing Western UGP facilities in northeastern NE. These projects, as well as integration of the Western/Basin/Heartland IS into SPP regional planning, have already and are expected to continue to result in a significantly more capable network in the western portion of the EI. The western edge of the EI in 2015 is substantially different than the network which resulted in the HVDC B2B stations being installed in the late 70s and early 1980s between the EI and WECC.

Although somewhat dated, Figure 6 also includes several conceptual and/or proposed projects in WECC that are noteworthy for any future long term collaborative joint studies. This diagram includes projects like HPX and the Gateway projects, as well as TransWest Express and Sunzia projects which could become part of an efficient and effective bulk power system backbone for the U. S. grids.

PROPOSED SEAMS OPTIMIZATION STUDY

This proposed joint collaborative project would need to involve MISO, SPP, Xcel Energy, Western, PNM, EPE, WECC, WestConnect, and Basin Electric Power Cooperative and its members like Tri-State Generation & Transmission Cooperative, at a minimum, to scope out scenarios that ought to be considered to inform the dialogue about the existing and future seams between the eastern and western bulk power grids in the US. Saskatchewan Power and AESO should also be involved, particularly if this study could leverage and incorporate the results of the Pan-Canadian Study that is currently in process. Investigation should look at all possibilities and focus on potential reconfigurations and benefits associated with the bypass, upgrade or replacement in kind of existing lines, HVDC B2B Stations, as well as phase shifting transformer like that at Saskatchewan Power's Boundary Dam, with new standard design, controls and capabilities given current technologies which have been proven in bulk power systems.

Interests have been expressed in recent planning forums at WestConnect, as well as SPP, to build new and/or expand existing ties to get high quality renewables in the plains to markets. A strategic assessment to support interegional planning across the seam between the Eastern and Western grids is warranted.

WAPA published an "East/West AC Intertie Feasibility Study" in August 1994 which concluded that connected operations of the EI and WECC by AC interties may be feasible; although concerns were expressed, additional analyses were required and several issues needed to be addressed. [8] Preliminary assessments using current WECC and EI models show a north to south bias across the seam if existing ties were bypassed and the Laramie River Power Station east and west busses were connected. Under peak load conditions with minimal renewables, the power flows are projected clockwise from WECC in Montana and South Dakota into the EI and out of Nebraska/Wyoming into WECC through Colorado back into EI in Kansas through the Oklahoma and Texas Panhandles and finally back into WECC in New Mexico. Significantly different flows would be expected under realistic renewable expansion scenarios that reflect existing and planned additions of wind and solar resources based on traditional regional planning efforts that have not considered opportunities in collaborative and coordinated operations and planning with adjacent systems across existing HVDC B2B stations.

A comprehensive and collaborative joint planning study in warranted to inform regional, interregional and national grid planning. This study would model both the EI and WECC simultaneously, with different seams scenarios considered to identify potential changes to the existing HVDC B2B stations, and likely include significant HVDC expansion too. [9] By exercising the model over a range of scenarios, planning tools will identify the operational advantages and disadvantages of each scenario. Additionally, capital cost differences will be estimated for each scenario, for both transmission expansion and generator capacity savings. The operational cost savings will be compared to the capital costs to determine the relative benefit of each scenario. This study has been discussed at the recent 2015 Power Systems Engineering Research Center (PSERC) Summer workshop, and has been proposed as part of the Grid Modernization Laboratory Collaborative by the National Renewable Energy Lab (NREL) with key support from Argonne National Lab (ANL), as well as Oak Ridge National Lab (ORNL) and Pacific Northwest National Lab (PNNL).

This seams study has the potential to begin a longer-term conversation about optimal, long-term, interregional planning in the U. S. as well as the North America bulk power system. This planning process might result in significant expansion beyond current interregional transmission planning efforts which are limited to existing interconnections. This study is expected to benefit the U. S. by enabling the development of the highest-quality wind and solar resources for nation-wide consumption. This project is proposing a joint collaborative effort to identify effective and sustainable long term plans which could have a drastic impact on U. S. bulk power system grid operations and planning.

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