Alaska Railbelt Grid Modernization and Resiliency Plan

White Paper

Brian J. Hickey P. E.
Executive Director, Railbelt Regional Coordination

Author’s Note on Sources:

The work presented in this paper and the Grid Modernization and Resiliency Plan (GMRP) and its attendant U.S. Department of Energy Grid Resilience and Innovation Partnerships (GRIP) applications is built upon the extensive study work conducted throughout the Railbelt over the past several decades. These studies were carried out by various individuals and organizations, serving different operational and planning purposes. While none of these studies were specifically tailored to meet the challenges posed by the Governor's mandate discussed below, each one contributed in its own way to the knowledge and understanding that formed the basis of the GMRP. The author wishes to express sincere gratitude to all those involved. Though this list is not exhaustive, it includes the following studies:

• 1990 Bradley Lake Final Operating study – Power Technologies Inc. (PTI); Bradley Lake Project Management Committee (BPMC) Technical Coordinating Committee (TCC)

• 1992 Transmission Long-Range Plan - Southern Engineering Inc.; Chugach Electric Association (CEA)

• 1992 Study of SVC with 230 kV interconnection – Asea Brown Boveri (ABB); BPMC-TCC

• 1990 Underfrequency Loadshed Study-PTI and Railbelt utilities Alaska Intertie Intertie Operating Committee (IOC)

• Bradley Lake Small Signal Instability effort – Electric Power Systems, VATech Hydro Inc; BPMC, Ad hoc Committee on Bradley Lake Instability,

• 2003 Southern Intertie-Environmental Impact Statement (EIS) – Intertie Participants Group (IPG), Power Engineers Inc.

• 2004 Bradley Lake Deflector Divider Model Tests- VATech Hydro; BPM, C Ad hoc Committee on Bradley Lake Instability

• 2009 Susitna Hydro Transmission Study - Electric Power Systems Inc.; Alaska Energy Authority (AEA)

• 2010 Railbelt Integrated Resource Plan - Black and Veatch Inc.; AEA

• 2017 Railbelt Integrated Resource Transmission Plan - Electric Power Systems Inc.; AEA

• 2020 Alaska Railbelt Power System Oscillation Anchorage BESS Unit Impact Analysis – Siemens-PTI; CEA

• 2021 South Central Battery Energy Storage System (BESS) Reliability and Economic Evaluation Report - Chugach Internal Study; Chugach-National Economic Research Associates (NERA)

• 2022 Railbelt Oscillation Investigation and Mitigation study - Electric Power Systems Inc.

• 2023 Grid Resilience and Innovation Partnership (GRIP) Railbelt Application Technical and Policy Committees

In addition to these more formal studies, numerous unpublished near- term and mid-term operating studies have informed our understanding of the Railbelt grid’s requirements and behavior.

Finally, this work draws upon the author's approximately 40 years of experience in planning, operating, maintaining, and troubleshooting the Railbelt grid. As the design details of the GMRP are further elaborated and the plan's elements are implemented, additional specific studies will be necessary to

optimize and validate the plan's assumptions. The author extends special thanks to David Burlingame and Dr. Jim Cote of Electric Power Systems Inc, Ed Jenkin of Matanuska Electric Association, Inc., The Bradley Lake Project Management Committee, and the numerous Railbelt executives, engineers, and planners whose invaluable contributions made the development of the GMRP possible.

-Brian Hickey P.E. July 13th, 2023

To paraphrase Sir Isaac Newton:

"If we have seen further, it is by standing on the shoulders of giants."

Introduction

The Railbelt electric grid is at an inflection point. The convergence of approaching grid decarbonization and the beneficial electrification of vehicles and space heating combined with the decline of the Cook Inlet natural gas fields create a complex multivariable problem that involves technical feasibility, technology development, financial capability, economic uncertainty, and political will. Further, all of these variables are changing over time. Limited financial resources, the islanded nature of the grid and the harsh environment make missteps particularly challenging. One underpinning of any solution to these challenges is a resilient transmission grid of sufficient transfer capability to facilitate the development of a fuel-diverse clean energy generation fleet. By its very nature variable generation, such as wind and solar, and renewable dispatchable generation such as hydroelectric and perhaps future small modular nuclear are only deployable in specific geographic locations. Through economies of scale, larger projects result in lower per unit costs per kilowatt-hour. To maximize project size, the transmission grid must be resilient enough and have sufficient transfer capability to promote remote utility participation in any grid project irrespective of the utility's geographic proximity to project.

Importantly, the decline and eventual exhaustion of the Cook Inlet natural gas fields will have profound implications for the electrical fundamentals of the Railbelt grid. The discovery of the Cook Inlet field dates back to 1957, and oil production reached its peak in 1973. Since then, Cook Inlet has been the primary source of fuel for 80% or more of the electricity generated in the Railbelt, as well as providing home heating fuel to around 140,000 out of 270,000 homes in the area.

However, in early 2022, Hilcorp Inc., the only remaining major oil and gas producer in the Inlet, notified utilities that they did not have line-of-sight to natural gas resources in terms of quantities, deliverability, and price range that align with current gas contracts. These contracts are set to expire before the 2028-2033 timeframe. As a result of Cook Inlet's decline as a fuel source, transitioning away from Cook Inlet natural gas will necessitate the development of new regionally diverse generation sources. This shift, in turn, will require resilient and high-capability transmission interconnections. It represents a significant paradigm shift for Railbelt grid planners, engineers, and operators.

The current transmission grid with single, stability limited, ties between regions grew up around the model of generating electricity from Cook Inlet natural gas, serving residents of the Central and Southern regions on a firm basis, and selling non-firm economy energy north to Golden Valley (GVEA) across the state-owned Alaska Intertie (AI). GVEA maintained sufficient non-natural gas fossil fuel-fired[1] generation to meet its own load and reserve requirements during periods of increased weather risk, times when the AI was out of service, or non-firm purchase opportunities were insufficient to meet GVEA load. The addition of the Bradley Lake project in the early 1990s stressed this system and a second intertie was contemplated and constructed from Fairbanks as far as Healy. The remaining portions of the second intertie (Healy to Beluga and Beluga to Soldotna) fell prey to the vagaries and fluctuations of a small per-capita economy based primarily on the price of crude oil and were not completed.

[1] GVEA machines are fueled by oil from the Trans Alaska pipeline in the form of HAGO or Naphtha, or coal from a single mine located in Healy, AK. Healy Coal also provides significant home heating through combined heat and power plants at Fort Wainwright, Eielson AFB, Downtown Fairbanks and The University of Alaska Fairbanks

Current Status

The current Railbelt electric grid is unique in North America as it is technically a fully functioning long-distance electrical grid on a very small scale. The Railbelt is characterized by three load-generation regions with four load-balancing areas (LBA). Soon we expect the Central region to move to a single LBA, reducing the number of LBAs from four to three. The load-generation concentrations, known as the Northern Region (Fairbanks-Delta Junction), the Central Region (Anchorage-MatSu), and Southern Region (the Kenai Peninsula), are tied together with two long transmission lines operating at 138kV and 115KV.

The grid provides electricity to approximately 75% of the state's residents and generates 80% of the electricity in Alaska. It extends over 700 miles from the Bradley Lake Project, located at the head of Kachemak Bay near Homer, Alaska (in the Southern Region) to Delta Junction in Interior Alaska, roughly the distance from Washington, DC to Atlanta, GA, as depicted in Figure 1. The grid traverses inhospitable subarctic mountainous terrain and the Cook Inlet with its tremendous tides and currents.

Figure 1: Alaska's Relative Size

The region is laced with highly active seismic zones and is subject to volcanic eruptions, forest fires, flooding, and fierce annual winter storms. The grid's assets vary from high voltage (138 kV and 230 kV) submarine cable crossings in Cook Inlet[2] to remote "helicopter/riverboat-access-only" river crossings and numerous transmission structures well above 2000 feet of elevation (sub-arctic).

Unlike numerous areas in the contiguous lower forty-eight states, the Railbelt has received minimal federal investment in grid development. The Eklutna Hydroelectric Project, initially constructed in the 1950s, was the last major federal project in the Railbelt that included a transmission line component. This project was rebuilt by the Bureau of Reclamation's Alaska Power Administration after the 1964 "Good Friday" Earthquake and sold by the Federal government to Central Region utilities in the early 1990s.

Due to the high cost of transmission lines, the regions are moderately interconnected, primarily at 69kV, 115kV, 138KV, 230kV. A tight power pool operates in the Central region, and an active economy energy market exists between regions but is severely limited by transmission constraints. There is no formal interconnection queue. A reserve-sharing pool exists between all three regions. Historically, due to weak interconnections the regions have planned for capacity separately. The Railbelt grid is technically characterized as "transient stability limited," with machines under dynamic stress swinging against other machines within the region; and with regions swinging against each other across the light interregional

[2] Cook Inlet is a silt laden 180-mile inlet reaching from Knik Arm to the Gulf of Alaska. The Inlet has the fourth highest tidal range in the world at 35 feet and contains an endangered subspecies of the Beluga whale.

interconnections. These single interregional ties are limited to approximately 75-80 MW (~10% of the grids peak load). The grid is susceptible to and has experienced large-scale[3] small-signal instability oscillations.

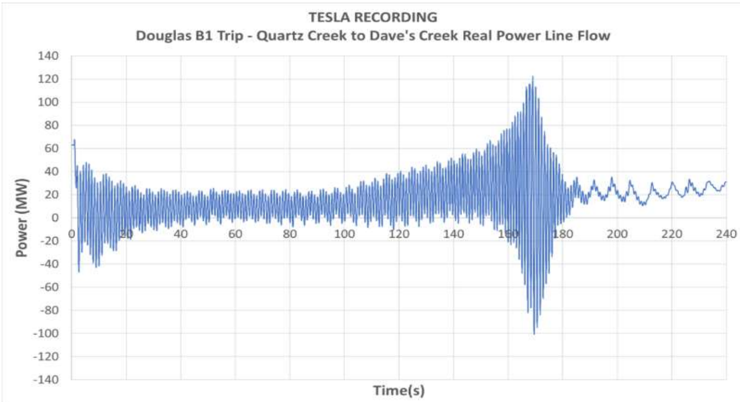


Figure 2- June 3 2021-Representative Natural frequency Oscillation

Voltage stability, which varies from marginal to good depending on the specific area, has been improved with the addition of six static VAR compensators at critical locations.

The Railbelt grid operates under a subset of North American Electric Reliability Corporation (NERC) standards modified to account for the scale and nature of the interconnection (the grid's system bias is variable and ranges from 3-10 MW/.1 hertz). The grid has a sophisticated under-frequency load shed scheme which sheds load to match generation in four stages with varying time delays and, in some cases, considering frequency rate-of-change. Traditional day-ahead and real-time security constrained economic dispatch are run in each LBA with net interchange, and frequency monitored and managed to NERC CPS 1 and 2. Dynamic events on the grid occur and resolve very quickly (2-10 seconds) when compared with the much larger North American grids which resolve in tens of minutes. The grid's peak demand is roughly 750 MW compared to ERCOT's peak demand of 85,000 MW. The grid's annual energy consumption is approximately 4,500 GWH compared to ERCOT at 339,000 GWH.

The Grid Modernization and Resiliency Plan

In September of 2022 the Governor of the State of Alaska challenged Railbelt energy leaders to articulate a vison and plan that would transform the Railbelt transmission system and prepare it for a fuel diverse clean energy future. The Grid Modernization and Resiliency Plan (GMRP) was born of this challenge. Railbelt leaders brought together regional experts to develop a broad based plan to increase interregional transfer capability by 2-3 times, add resiliency to the degree that there are at least two full capacity transmission lines between each region and from any major generating station to the grid, and further, to construct a line that integrates the Copper Valley region into the Railbelt grid, providing an alternate feed to the ground based missile defense system at Fort Greely and the Northern Warfare Training Center at Black Rapids, connecting the Valdez Trans Alaska Pipeline terminal to the Railbelt grid, and providing potential access to the Tiekel River project, a Bradley lake sized hydroelectric prospect, about 45 miles north of Valdez, as well as additional potential wind and solar resources.

As noted above, today the broader energy landscape in Alaska and across the world is being reshaped by multiple change drivers. Geopolitical shifts are dramatically altering global energy markets. Decarbonization policies and technological advancements, shaped by increasingly dramatic climate change, are both the result of and contributor to a shift in focus on energy and the environment. Regionally, uncertainty around Cook Inlet natural gas and broader fuel supply issues for utility companies

[3] Oscillations have been measured with a peak of 220 MW, a 1.1 second period and sustained for over 90 seconds on a grid with a summer valley peak load of approximately 500MW.

is a critical – and shared – challenge looming on the near-term horizon. The Railbelt's weakly interconnected grid is inadequate to meet the challenges of a sustainable, fuel diverse, decarbonized future.

In response to this shared challenge, the Team has come together to develop a broad-based, long-term plan to ensure the future energy viability of the Railbelt from a social, economic, and technical perspective. The transmission aspect of that plan is the GMRP.

The Team will propose that the GMRP be incorporated into Alaska's broader State Energy Plan as that document is developed in the coming months.

Figure 3 is a graphic representation of the entire Railbelt with the full GMRP overlayed on the existing system. The GMRP is fundamentally a 230kV overlay on the existing grid using the reconstruction of existing lines wherever practical and adding redundancy between regions and between large generation facilities and the grid. The plan includes the addition of three ~ 40 MW 2-hour Battery Energy Storage Systems (BESS), one in each of the three regions. In Figure Two, yellow highlights indicate new intertie projects; rust and red highlights existing facility reconstruction projects; and the blue "C" indicates a smart grid control project (controlling the BESS and HVDC submarine cable) to maximize use of both existing and new grid components as they are developed. This plan is transformational in that it will reshape the Railbelt in a way that will help usher in a sustainable fuel diverse low carbon future.

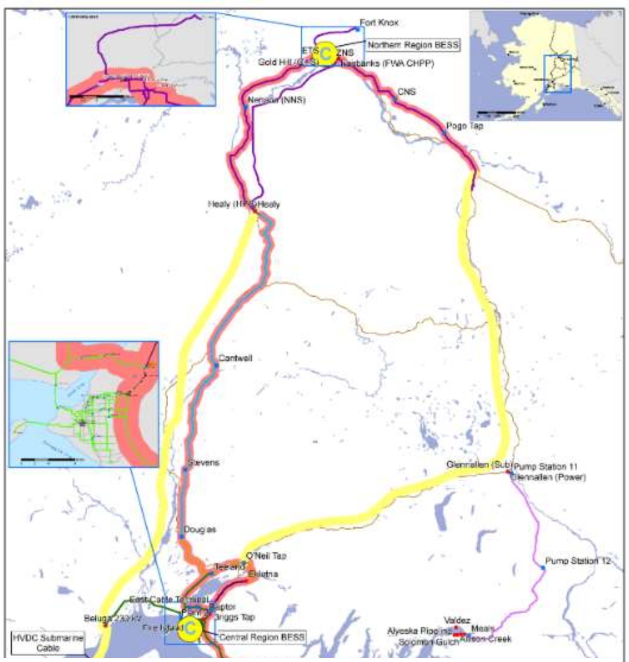
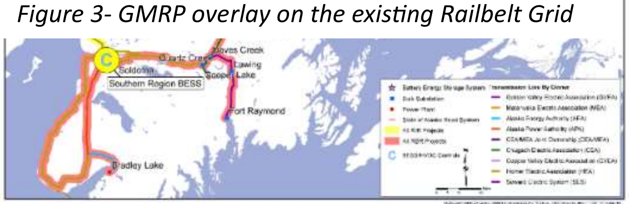


Figure 3- GMRP overlay on the existing Railbelt Grid



Transmission Corridors

Except for broadly defined transportation corridors (highway rights of way (ROW)), regional transportation plans, and the Municipality of Anchorage (MOA) utility corridor plan)[4], no formal transmission corridor designations exist in the Railbelt today.

From a transmission corridor perspective, Figure 3's rust and red highlights represent existing transmission lines in ROW or other permitted uses, not in dedicated transmission corridors. In the same figure, yellow highlights indicate requirements for new transmission lines. In either case the designation of dedicated transmission corridors would ease and speed future transmission construction.

[4] HDR Alaska Inc. (Nov. 2003)., Kenai Peninsula Borough Transportation Plan update; Fairbanks North Star Borough (FNSB) Community Planning Dept. (SEP 2005); Mat-Su Planning department (2022), Mat-Su Long Range Transportation Plan-https://matsugov.us/plans/lrtp; MOA Planning (2007), Utility Corridor Plan-https://www.muni.org/Departments/OCPD/Planning/Publications/Pages/UtilityCorridorPlan.aspx

We anticipate that all new transmission interties will be subject to route evaluation under the *National Environmental Policy Act* (NEPA) process. However, current thinking suggests the following routing: for the new intertie from Soldotna to tidewater at Nikiski, we expect it to be in the existing 115 kV right-of-way (ROW) and the Kenai Peninsula Borough (KPB) transportation corridor. Next, using existing bathymetric data, a preliminary corridor has been established for the HVDC submarine cable portion crossing Cook Inlet from Nikiski to Beluga and is shown in Figure 4.

Regarding the intertie from Beluga to Healy, the corridor would follow the AKLNG pipeline ROW from a near convertor station tidewater to AKLNG MP 525[5] at Healy, AK.

For the Roadbelt Intertie from Wasilla to Glenallen and north to Fort Greeley, we anticipate it generally following the highway ROW or existing transmission lines from Wasilla to Sutton. However, there would be a slight offset to the north of the highway from Sutton to just south of Glenallen. Afterward, it would return to following the highway from Glenallen north to Fort Greely.

If the Tiekel River Project, located approximately 45 miles north of Valdez (about 18 miles south of Pump 12 on Figure Two), is determined to be a viable project, a second line from Glenallen to Tiekel would be required. Path diversity would necessitate a second corridor, which is yet to be determined.

Our estimated total cost for the GMRP is $2.87B over fifteen years. Without significant Federal and State investment, the GMRP and this Project are beyond the financial capabilities of the Railbelt utilities.

Value Proposition

The value proposition of the GMRP for residents of the Railbelt grid is clear. This project will position the Railbelt for a fuel-diverse, sustainable, and clean energy future while lowering energy costs through the efficient utilization of scarce Cook Inlet natural gas. It is a crucial step as we transition away from declining Cook Inlet natural gas towards a clean energy future. Within the Railbelt proper, there are numerous tribal and disadvantaged communities that will benefit from the GMRP.

Having multiple transmission lines connecting different regions will have a significant positive impact on interregional transfer reliability. To illustrate this, let's consider an incident that occurred in 2019. The Swan Lake fire caused the Southern Region to be isolated from the Northern/Central region for approximately six months. As a result, the Northern and Central regions were disconnected from the Bradley Lake Hydroelectric Project. This led to the utilities north of the open intertie having to burn tens of thousands of MCF (thousand cubic feet) of additional Cook Inlet natural gas, resulting in significant costs for ratepayers amounting to millions of dollars.

Moreover, this same transmission line is regularly taken out of service on a scheduled basis for 30-90 days every other year. The existence of a second line between Soldotna and Beluga would eliminate these interregional islanding events altogether. A similar case can be made for the need for a second line between Beluga and Healy and the Roadbelt intertie's effect on Copper Valley and Interior Alaska Reliability.

By establishing these additional transmission lines, the Railbelt grid would be able to avoid such disruptions and ensure more reliable and cost-effective energy transfer between regions.

[5] https://agdc.maps.arcgis.com/apps/webappviewer/index.html?id=75c71217dd3048ad92121cdf2b593c55

Some of the key benefits of the proposed routing of the Intertie from Beluga to Healy along the existing AK LNG Pipeline route is that it will enable the future electrification of pipeline compressors. Additionally, it will open significant new terrain on the west side of the Susitna River drainage for the development of wind and solar resources. The Roadbelt intertie will not only bring lower average electricity costs to the Copper Valley region but also enhance the resilience of critical defense infrastructure. Moreover, it will provide the Railbelt access to additional potential hydro, wind, and solar resources in the Copper Valley and interior.

Initial estimates indicate that the project can reduce fuel costs by 10%-15% in the Railbelt alone, through the maximization of interregional transfer capability, real-time reallocation of spinning reserves, and improved regulation.

For non-Railbelt communities that receive Power Cost Equalization (PCE) funds, which are predominantly tribal and often disadvantaged, the value proposition lies in the direct economic benefits. As we keep Railbelt's power costs down and thereby increase the PCE energy subsidy, these stakeholders will experience positive economic outcomes. Furthermore, in a general sense, for all rural villages, including those not covered by PCE, as well as the Department of Energy (DOE) and the nation, the process of decarbonizing a small-scale, fully functioning grid will yield valuable insights and best practices for executing similar regional activities.

Lastly, by improving the resiliency, reliability, and efficiency of the Railbelt grid, we will provide a more secure energy supply to critical military defense infrastructure located in the three Railbelt regions. This enhancement contributes to national security and global stability.

In conclusion, the Railbelt electric grid stands at a critical juncture, facing the challenges of grid decarbonization, electrification, and the declining Cook Inlet natural gas fields. These complex issues involve technical feasibility, technology development, financial capability, economic uncertainty, and political will, all of which are constantly evolving. With limited financial resources and the grid's isolated nature in a harsh environment, missteps are particularly challenging. However, a resilient transmission grid with sufficient transfer capability is a fundamental component of any solution. It will enable the development of a fuel-diverse, clean energy generation fleet and maximize the potential of renewable resources.

The decline and eventual exhaustion of the Cook Inlet natural gas fields will profoundly impact the Railbelt grid. This fuel source, which has been the primary provider for electricity generation and home heating, will require new generation sources to be regionally diverse. As a result, resilient and high-capability transmission interconnections are necessary, representing a significant shift for grid planners, engineers, and operators.

Multiple transmission lines between regions will greatly enhance interregional transfer reliability, as demonstrated by past events such as the Swan Lake fire. The existence of a second line would prevent interregional islanding events and mitigate the need to burn additional natural gas at a significant cost slowing the depletion of the Cook Inlet natural gas fields. Similarly, the intertie from Beluga to Healy and the Roadbelt intertie would provide various benefits, including access to renewable resources, lower electricity costs, and enhanced defense infrastructure resilience.

The Grid Modernization and Resiliency Plan (GMRP) outlines a comprehensive strategy to address these challenges. Incorporating the GMRP into Alaska's broader State Energy Plan is crucial. The plan involves the reconstruction of existing lines, the addition of battery energy storage systems, and the establishment of dedicated transmission corridors. The estimated cost of the GMRP is $2.87 billion over fifteen years, necessitating significant federal and state investment.

The value proposition of the GMRP is clear. It will position the Railbelt for a fuel-diverse, sustainable, and cost-effective clean energy future. The benefits extend to tribal and disadvantaged communities, as well as non-Railbelt regions that receive Power Cost Equalization funds. Additionally, the lessons learned from decarbonizing the Railbelt grid will provide valuable insights for similar regional and national activities. Finally, enhancing the grid's resiliency, reliability, and efficiency contributes to national security and global stability.

The transformation of the Railbelt grid is essential to meet the challenges of a changing energy landscape. The GMRP offers a pathway towards a sustainable and resilient future, supporting economic, social, and technical considerations. By embracing this plan and investing in the necessary infrastructure, the Railbelt can pave the way for a fuel-diverse, low-carbon future that benefits its residents, the state of Alaska, and the nation as a whole.