GAS TURBINES FOR ENERGY NETWORK SYMPOSIUM
BANFF, ALBERTA, CANADA
OCTOBER 2019

19-GTEN-306

PROJECT CASE STUDY: T-SOUTH RELIABILITY AND EXPANSION PROGRAM

Kyle Speed, Sr. Project Manager

Enbridge, Inc.
Kyle.Speed@enbridge.com

Keywords: *Enbridge, T-South, Reliability, Compression, Expansion*

Abstract

The T-South Reliability & Expansion Program (TSRE) involves the addition of compression facilities and reliability improvement projects on Enbridge's BC Pipeline Transmission South (T-South) system to add essential compressor station and system reliability, as well as accommodate an additional 190 million standard cubic feet per day (MMSCFD) of firm capacity. The T-South segment of Enbridge's BC Pipeline extends from Chetwynd, BC to the Canada-United States border near Abbotsford, BC. The work comprises of five new compressor unit additions/ replacements at existing stations, as well as various existing facility and pipeline upgrades. Coordination amongst multiple functional groups across Enbridge, external contractors and various community and indigenous stakeholders has been required in order for project goals to be met, due to the size and complexity of the program.

This paper focusses on the compressor unit addition/replacement scope of the TSRE program and provides a project case study emphasizing the Project Lifecycle from inception to in-service; development and project scope refinement; design challenges integrating with existing facilities; logistical challenges; as well as construction and commissioning. Further focus will be placed on the improvement of system reliability through compressor replacement/addition and how added horsepower provides the required extra capacity versus pipeline looping.

Introduction

Federally regulated by the National Energy Board (NEB), Enbridge's BC Pipeline stretches from Fort Nelson in Northern British Columbia and Gordondale at the BC/Alberta border southwards to Huntingdon/Sumas at the Canada/U.S. border. The BC Pipeline ships approximately 45 percent of all natural gas produced in British Columbia and supplies approximately 75 percent of the natural gas capacity to the BC Lower Mainland and the Pacific Northwest. The segment from Compressor

Station 2 (CS2), near Chetwynd, BC, to Huntingdon is known as Transmission South (T-South).

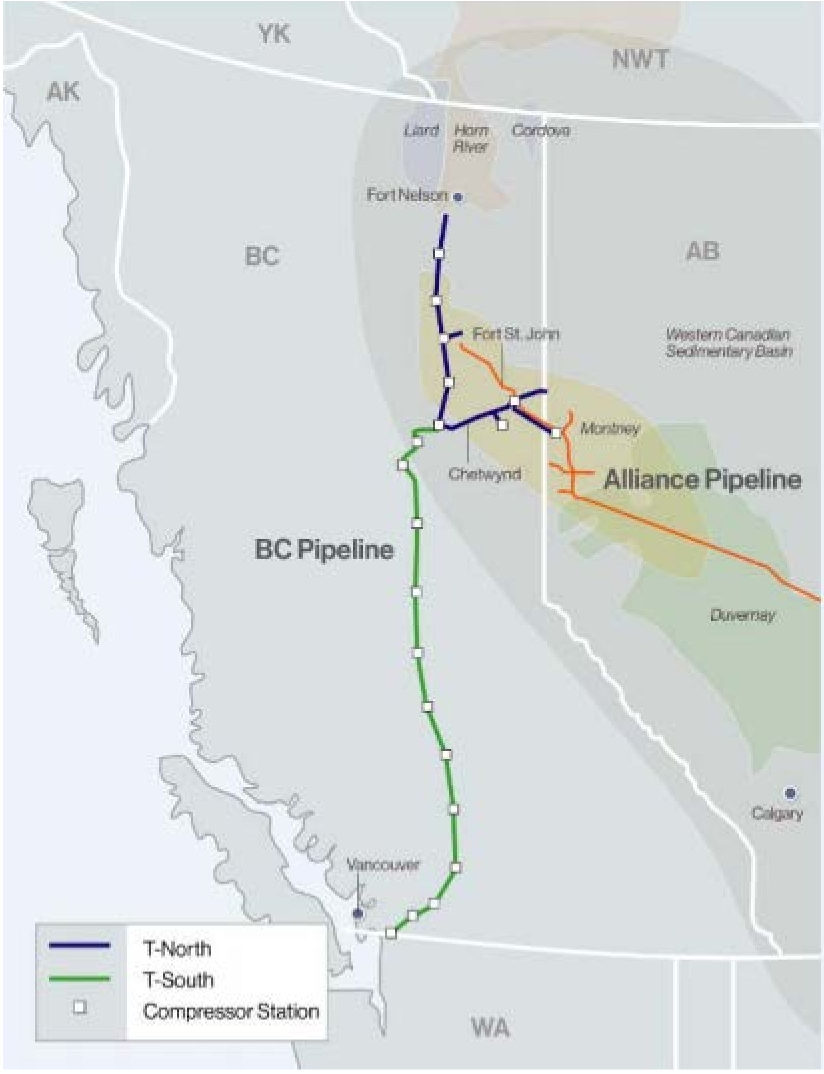

Figure 1: Enbridge's BC Pipeline System [1]

The T-South Reliability & Expansion Program (TSRE) involves the addition of compression facilities and reliability improvement projects on Enbridge's BC Pipeline T-South system to add essential compressor station and system reliability, as well as accommodate an additional 190 million standard cubic feet per day (MMSCFD) of firm capacity after a binding open season. The Program was sanctioned in October 2017 and is anticipated to be in service in the fourth quarter of 2021, pending regulatory approvals.

The Program is mainly comprised of compressor unit replacements/additions at existing T-South Compressor Stations:

- CS3 – Compressor Unit Addition;
- CS4A – Compressor Unit Replacement;
- CS4B – Compressor Unit Replacement;
- CS5 – Compressor Unit Addition;

- CS6A – Compressor Unit Replacement.

The new compressor units will replace aging compressor units that are reaching the end of their service life with more reliable and efficient units. The compressors being replaced are Cooper Coberra (Spey) 3045 gas turbines coupled to DeLeval PV30x30 natural gas pipeline compressors and a 1974 GE LM2500 GA101 gas generator with Ingersoll Dresser Rand GT61 power turbine (GE twin shank) coupled to a CDP230 turbo pipeline compressor. Where compressor unit additions are planned, the new units will provide a level of redundancy as these stations currently only have one operating compressor unit.

Figure 2: TSRE Project Locations [2]

In order to provide additional reliability and expansion volumes on the T-South system, the TSRE Program is proposing to install five Baker Hughes General Electric (BHGE) compressor units consisting of a PGT25+ turbine (LM2500+ aero derivative gas generator and power turbine) coupled to a PCL802 pipeline compressor (the PGT25+ units) along with associate main gas piping, supporting utilities, and infrastructure The Program follows a similar Enbridge project which also provided increased T-South reliability by replacing aging Spey and Westinghouse W92 compressor units with PGT25+ units. The new units are designed to work in series with existing compressor units at each site or on a standalone basis during maintenance activities on the other unit.

The choice of the LM2500+ unit met multiple project requirements and other benefits, including:

- Unit familiarity
- Horsepower optimization
- Inventory

In 2013/2014, a fundamental shift in demand occurred on T-South. With this increased demand, there have been fewer opportunities for Enbridge to undertake necessary maintenance or manage unplanned outages without significantly impacting the system's ability to meet shipper demand. This has resulted in an increased utilization of compression units across the T-South system. As runtime hours have increased, the number of unplanned repairs on the aging units has also increased [3].

In an effort to ensure adequate T-South reliability well into the future, Enbridge has prioritized the replacement of aging and increasingly obsolete compressor units. This is based on the following [3]:

- Lack of availability of original equipment manufacturer (OEM) parts, service, and technical support;
- Lack of competitive service providers;
- Emerging environmental regulations affecting aging equipment; and
- Expected run time.

Enbridge identified the Spey and the GE twin shank units as the top replacement priority. Production of the Spey unit stopped in 1989 and has not had OEM technical support for almost 20 years. The GE twin shank is nearly 45 years old and is no longer reliable or supportable. The TSRE Program will further Enbridge's compressor fleet replacement strategy by replacing a further these units with new PGT25+ units.

The Project Lifecycle

All projects consist of a lifecycle that carries any given project through conception to close out. There a typically four phases of the project lifecycle [4]:

1. Project Initiation/Development;
2. Project Planning;
3. Project Execution;
4. Project Closeout.

Each phase of the lifecycle establishes the framework for the progression of a project. There are multiple deliverable requirements within each phase of the lifecycle that are completed prior to moving to the next phase. At Enbridge, phase progression is controlled by a gating process. Typically, when a project team has completed the required deliverables in any given phase, a formal review of these deliverables, as well as a presentation to senior management is required. Once approval has been granted by senior management, the project can progress to the next phase. This gating process ensures that the project team is meeting the organization's expectations and requirements for project management and project deliverables are of a high quality. The gating process also ensures that senior management understands the project status and supports the decisions surrounding the project as it moves forward.

Project Development

Initially commercial or operational requirements drive the development of any new project. During project development, feasibility assessments are completed for the proposed project, project scope begins to be defined in order to meet project goals, and project stakeholders are engaged. The transition from development to detailed planning also starts to take place. Development of a sound project strategy will set the project up for success.

Throughout project development on TSRE, Enbridge performed a rigorous, iterative process to analyze possible project scopes that would meet the goals of increased system reliability on T-South, as well as increased gas volumes. This process is led by the Project Development functional group who engages multiple stakeholders within Enbridge, including Engineering, Operations, Environment, System Planning, Lands, Community and Indigenous Engagement, Supply Chain, System Integrity, and Business Development. Each stakeholder group provides valuable input into the scoping of the project, which allows for Project Development to appropriately scope the project.

During the development phase, and as scope becomes more defined, preliminary desktop and field studies take place. This includes engaging engineering and survey contractors, environmental contractors, and archaeology contractors. These preliminary studies help further refine the project scope and collect key data ahead of filing regulatory applications in the next phase.

With the goals of increased T-South system reliability, as well as adding expansion volume to the system, TSRE evaluated multiple scope options before narrowing the options to two main scope possibilities: a pipeline looping option and an added compression option. Ultimately, Enbridge chose the added compression option as it cost effectively met both of the project goals of reliability and expansion, as well as provided additional benefits for Operations, which is described further in the section below.

Pipeline Looping vs Added Compression

There are generally three main ways to add expansion volume to a gas transmission system [5]:

- Pipeline Looping;
- Added Compression facilities;
- A combination of pipeline looping and added compression.

Pipeline looping achieves additional volume by reducing the amount of pressure drop due to gas velocity in a particular pipeline segment. By reducing this pressure drop, increased flow rate through the pipeline is achieved. The gas volume is shared between the pipelines, although not necessarily equally depending on the diameter of the pipes [6].

Increasing flowrate results in increasing pressure drop in a particular pipeline segment. Adding compression at an intermediate facility between two points on a pipeline system boosts the pressure back up, thereby enabling increased flow rate in the overall pipeline system.

After an iterative project scoping process, TSRE moved forward with an added compression only scope. The selection of this scope cost effectively addressed two main objectives: increased system reliability by replacing aging, obsolete equipment with new, state of the art compressor technology and also provides the required expansion volume that had been contracted through the binding open season held in April 2017. The added compression option also provides additional operational benefits, including:

- Additional operational flexibility: Additional horsepower on the T-South system allows for the optimization of required horsepower across the system. Being able to use this available horsepower reduces capacity impacts during maintenance activities, improves system efficiency, and reduces operating hours and reliance on older equipment in the system.
- Inventory: By increasing the amount of similar units in the T-South system, Enbridge is able to reduce the amount of inventory and spare parts that are required.
- Staffing flexibility: Staff is able to more easily operate at multiple stations in the T-South system by having similar units throughout. This improves operational coverage and improves emergency response.
- Support agreements: A large fleet of similar units can lower unit and maintenance support agreement costs.

With added compression being chosen as the optimal project scope, detailed project planning could begin.

Project Planning

During this phase, detailed project plans begin being made. Project scope is further defined, but more importantly, further refined to meet project objectives during the project planning phase. The project team is identified early in this phase and an organization chart is created.

A key deliverable of this phase is the Project Execution Plan (PEP). This document is critical as it provides the framework for project execution. Input into the PEP comes from all functional groups involved in the project. The PEP defines how the project will be completed: identifying the project objectives and key milestones, how the project will communicate, how the project will manage risks, how the project will be monitored and controlled, how stakeholders will be engaged, how functional groups will execute their project tasks, and how the project will be closed out upon completion.

Baselining the project schedule during this phase is also very important as it lays the ground work for project progression, comparison tracking and forecasting. Once the identification of key milestones and timelines has been completed, each key milestone is then broken out into smaller tasks and deliverables that indicate what needs to be completed and when they need to be completed in order to meet the milestone dates. There are multiple milestone dates in each phase of the project that need to be met in order to accomplish the project objectives. Any variance to milestones and the baseline can be addressed and mitigated proactively.

Front End Engineering Design (FEED) begins in this phase and a third party Engineering Consultant (EC) is typically engaged. Initial design details are created, long lead materials and equipment are identified, a procurement plan is produced, and long lead procurement begins.

The project planning phase began in earnest in October 2017 for TSRE. The project was turned over to the execution team during this time and the project development phase came to a close. An Engineering Consultant was retained in October and FEED design activities began. Enbridge hosted a review session of lessons learned from a previous Enbridge project that had just been completed with the EC early into FEED activities. This provided a logical basis for which the EC would develop design plans initially. Enbridge also provided the EC with the required in-service date for the project at this time. The EC was then able to adapt and plan their design deliverables timeline to align with the required in-service date.

During this time, Enbridge began defining the technical requirements and procuring the compressor packages. After a sourcing process, consistency across the T-South system was identified as an important project goal, and the choice was made to purchase five GE PGT25+ compressor packages. While these units are larger than the aging units they are replacing, the additional horsepower allows for increased operational flexibility through an optimization of horsepower in the T-South system and reduced capacity impacts during maintenance and outage activities. The contracted expansion volumes are also accommodated. A key lesson learned from the previous compressor replacement project was to procure the compressor package early in the project planning phase as it allows the EC to have a more complete set of technical details of the unit earlier. This has the knock on effect of providing the required information to design other aspects of the project, such as the design of the compressor building into which it will be installed. Timely delivery of the compressor packages is also assured by taking this approach of purchasing the compressor packages early. Additional long lead procurement was also completed for the aerial gas coolers, large bore pipe, and large bore valves.

Enbridge takes great lengths to ensure that noise from compressors stations is minimized as much as practicable. Prior to purchasing the new compressor packages, the TSRE project team engaged a third party consultant to complete noise studies at each site. These studies identified the existing noise levels at each site, as well as the noise impact that the new units would have. With the data from these noise studies in hand, Enbridge worked with BHGE to provide technical noise mitigation solutions to the new packages. This included options for both inlet and exhaust silencing. In the design of the compressor buildings, additional insulation could be added to also enhance noise mitigation. These mitigation measures ensured that the noise levels at each compressor station would meet noise guidelines provided by the province of British Columbia once the new units were installed. In many cases, the replacement of the aging units with new units provided a lower overall noise level than what currently exists.

With emission regulations becoming more stringent, Enbridge also specified that BHGE include their dry low emission (DLE) technology in the new units. By incorporating this DLE technology into the new units, NOx levels could be reduced at sites where Spey units were being replaced.

As part of the project turnover to the execution team for TSRE, a set of key milestone dates established during the project development phase were provided. These dates were the basis for the generation of the project's overall baseline schedule. Each functional group involved in the project were presented with these dates and tasked with aligning their deliverables with the given milestone dates. Multiple schedule review meetings were held with the project team to review and discuss the formation of the baseline schedule. Through this process, consensus was drawn among the project team that the baseline schedule could be met in support of the given in-service date, as well as other key milestone dates.

One of the final deliverables of project planning was the submission of regulatory applications. The submission of these applications involves multiple stakeholders within the project team, including: Project Management, Engineering, Commercial, Community and Indigenous Engagement, Lands, Environment, System Integrity, and Regulatory Affairs. Submission of the applications was one of the first key milestones achieved by the TSRE team.

As FEED continued to progress closer towards detailed design, it became apparent that the integration of the new compressor units within the existing compressor stations would prove challenging. The engineering team led a series of site visits to each of the compressor stations to allow the EC to assess existing equipment at each site in order to check it's applicability to be used in conjunction with the new compressor unit to be installed. With each existing compressor station having a unique set of utility and auxiliary equipment in already operation, opportunity for a new set of common equipment presented itself, however, this integration would not be easy.

Integration of New Equipment in an Operating Brownfield Facility

After understanding existing equipment capabilities at each compressor station, the EC compiled a utilities matrix that outlined each piece of existing equipment at site versus what would be required once the new compressor units were installed. With the larger horsepower units being installed, utility demand also increased. Required sizing of emergency generators, battery banks, air compressors, utility heat medium (UHM) typically increased beyond the existing station capabilities. An important requirement of the TSRE project was that each compressor station act as a combined station. In other words, the existing compressor unit at each site needed to work in conjunction with the new unit. They cannot act independently from one another. This meant that many new utility systems needed to be procured to handle the load of the entire station or act as an additional supplement to existing equipment to accommodate the increased load requirements of the new unit. Most of the existing units that are operating at each compressor station were installed between the 1970's and early 2000's. Due to the vintage of some of the existing systems, installing a new compressor unit into an aging system becomes very challenging and costly. In most cases, it was more cost effective to replace some of this aging utility equipment with new equipment.

Project Execution

During the project execution phase, detailed work is performed by the project team in accordance with the PEP. Detailed engineering design is performed and completed, procurement of remaining materials and equipment is completed, preparations for construction are put into place, construction contractor selection is initiated and awarded, regulatory approvals are achieved, and general construction takes place.

TSRE is in this project phase. Engineering has completed their final design and model reviews for each station. All material and equipment has been procured and in some cases, is ready for delivery to site. Issued for Construction (IFC) drawing packages are now available and the EC is shifting focus to material and equipment deliveries, rather than design. Along with the IFC drawing packages, the EC has created Work Packages to accompany other documentation that comprises the Request for Proposal (RFP) for General Construction.

As material and equipment vendors complete their fabrication work and are ready to deliver to Enbridge, the project team has been working through the logistical challenges of receiving thousands of boxes of materials and equipment. Most materials and equipment are arriving at the project warehouse by the end of 2019 in anticipation for construction.

Figure 3: Delivery of BHGE PGT25 to CS3 in July 2019

Selecting contractors for construction follows a very important and detailed selection process. As physical construction is typically the highest cost item for any type of project ranging from 25 to 50% of total costs, particular focus is placed on construction execution. The first step in the construction phase is the RFP process. Separate RFP packages for each station have been created and issued to construction contractors. The project team has selected members to make up a selection team that reviews contractor bids and scores them on a commercial, technical, and local and indigenous content basis. Contractors are then shortlisted based on the evaluation of their bids. Detailed negotiations and clarifications then follow with the shortlisted contractors, prior to awarding contracts to the selected contractor(s).

Besides the commercial aspects of a contractor's bid, particular attention is placed on the technical portions of the bid. The selection team has requested detailed information from each contractor describing the contractor's capability to complete the project, including:

- Site-specific work plans;
- Safety plans;
- Relevant experience; and
- A proposed contractor organization chart, including resumes.

Enbridge is also interested in ensuring that the economic benefits of projects are maximized for local and indigenous communities. A Socio-Economic Requirements for Contractors (SERC) document is included in the RFP packages that details what the contractor must adhere to on Enbridge projects. Each SERC document is uniquely catered to each local area and helps connect contractors with local sub-contractors and businesses from nearby indigenous communities. A contractor's ability to utilize these businesses in their proposals to Enbridge bears an important weighting when selecting a contractor.

A key lesson learned on previous projects is to minimize field construction where possible in order to reduce exposure hours at site. This is done to improve field safety and to reduce more costly field execution. Therefore, the TSRE team chose to fabricate the piping spools and structural steel to the extent practical and logical. TSRE completed an in-depth sourcing event in 2018 to award a pipe spool and structural steel fabricator contract. The chosen fabricator will be responsible to fabricate all pipe spools for various piping systems, apply coating to pipe spools, fabricate structural steel components, and apply coating or galvanization to the structural steel. Limited hydrotesting of pipe spools will also be completed in the fabricators shop. This work will be completed ahead of general construction and all spools and structural steel will be available for the chosen construction contractor's use prior to construction commencing. By completing pipe spool and structural steel fabrication early, the construction contractor's field work timelines will be reduced.

Once regulatory approval has been received, pre-construction conditions have been cleared, a construction contractor has been selected, and construction planning has been completed, then construction execution commences. The start of construction is highlighted by a formal construction kickoff meeting between Enbridge, its third party representatives, and the selected construction contractor. This is a very significant milestone for any project. The start of construction will be the culmination of over three years of project work on TSRE. Construction will take approximately 12-14 months per site and similar activities will take place at each of the five sites.

Figure 4: Previous Enbridge Compressor Replacement under Construction, 2017 [7]

Construction begins with clearing and earthworks activities to prepare the site for other construction activities. Once this is complete, piling and concrete work for foundations and supports begins. Erection of buildings, equipment skids, and pipe rack installation follows. Pipe spools are installed, welded together, and hydro-tested according to the applicable codes, standards, and Enbridge specifications. Multiple compressor unit and station outages will be required at each site to tie in newly installed piping to existing station piping.

As construction kicks off, efforts will be made to engage a commissioning contractor. The commissioning contractor will be responsible for completing detailed pre-commissioning planning, including defining system boundaries for commissioning, as well as on site commissioning and start up support for various pieces of equipment once construction is complete. The commissioning team mobilizes to site as mechanical completion of construction is nearing, approximately 12 months after construction start. On site commissioning work takes approximately 2-3 months and will include compressor testing prior to startup of the new unit. BHGE will be involved with commissioning support of the new compressor unit and formal care and custody handover to Enbridge Operations takes place once a successful run test, typically for 100 hours, has been achieved.

Figure 5: Completed construction from previous Enbridge Project, 2017 [8]

After a successful run test, the TSRE project will formally be placed into service. Construction and commissioning contractors will begin demobilizing from site and minor deficiency items will be addressed. With the in-service date met and Operations having taken custody and control of the new compressor units, the TSRE project will start to move into the closeout phase of the project lifecycle.

Project Closeout

During this phase, all project activities become completed including operator training, designs are as-built and assets are entered into the maintenance system. Contractual obligations are confirmed and and contracts are closed. The compressor units and associated systems are also performance tested to confirm that the final installation meets the expectations of the customers and Operations. The project team then disbands to new projects. Prior to the project team disbandment, a final lessons learned session is held to collect information on items that the project team felt were memorable and could be learned from. These items can be both positive items to repeat and opportunities for improvement. The lessons learned gathered can then be provided to other projects that are in varying project phases or can form the starting basis for a new project. The documentation of lessons learned is a key final deliverable of the project. Final project documentation is archived and filed for future reference.

Summary

The TSRE project is anticipated to bring an increase in essential reliability for the T-South system. This increase in reliability not only will ensure that shippers can reliably ship existing T-South volumes, but also increased firm volumes of 190 MMSCFD. The project lifecycle, and the deliverables associated with each phase, help to ensure that projects are well planned, include the appropriate documentation, and assist with prudent decisions. Each project phase presents its own unique challenges and provides key learnings for the project team. This is part of what makes large infrastructure projects, such as TSRE, so interesting.

Acknowledgements

The author would like to acknowledge Jitendra Luthra, P. Eng for his continual support and guidance throughout the TSRE Program and for the encouragement to prepare this paper and accompanying presentation. The author would also like to acknowledge Dave Challoner, P. Eng for reviewing drafts of this paper and also for his encouragement and support to present at the GTEN 2019 Symposium.

References

[1] Enbridge Canadian Gas Transmission and Midstream: BC Pipeline. April 2019. https://noms.wei-pipeline.com
[2] T-South Reliability and Expansion Program. June 2019. https://www.enbridge.com/tsouth
[3] Westcoast Reply to Letters of Comment, National Energy Board File No.: OF-Fac-Gas-W102-2018-07 91, October 24, 2018.
[4] Project Management Institute. *Project Management Body of Knowledge*. 6th edition, Project Management Institute Inc., 2017.
[5] K. Botros, T. van Hardeveld. *Pipeline Pumping and Compression Systems: A Practical Approach*. 2nd edition, ASME Press, 2013.
[6] E. S. Menon, P. S. Menon. *Gas Pipeline Hydraulics*. Trafford Publishing, 2013.
[7] T-South Reliability and Expansion Project Factsheet. Mailout to Communities, June 2018.
[8] T-South Regional Project Update for Winter 2019. January 2019. https://www.enbridge.com/tsouth

Copyright