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SPECTRA ENERGY T NORTH N4 STATION UPGRADE PROJECT SOLAR TITAN 250 + C85 UNIT ADDITION

Jitendra Luthra –Principal Project Manager Spectra Energy

(jkluthra@spectraenergy.com)

Mark Knodle – T250 Program Manager Solar Turbines

(KNODLE_MARK_S@solarturbines.com)

Gil Quesnelle- Principal Engineer Spectra Energy

(GQuesnelle@spectraenergy.com)

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Abstract

Spectra Energy Corp (NYSE: SE), a FORTUNE 500 company, is one of North America's premier pipeline and midstream companies. Based in Houston, Texas, the company's operations in the United States and Canada include more than 22,000 miles of natural gas, natural gas liquids, and crude oil pipelines, approximately 305 billion cubic feet (Bcf) of natural gas storage, as well as natural gas gathering and processing, and local distribution operations. The company also has a 50 percent ownership in DCP Midstream, the largest producer of natural gas liquids and one of the largest natural gas gatherers and processors in the United States. In British Columbia, Spectra Energy's sweet gas transportation system stretches from Fort Nelson, in the northeast, to Gordondale at the British Columbia/Alberta border, and to the southern-most point at the British Columbia/U.S. border at Huntington/Sumas.

With the results of a binding open season for the "T-North" segment of the system, additional capacity was required from the Fort Nelson Plant receipt point to Compressor Station 2 .The additional flow rate required more horsepower to be added at Compressor Station N4. This unit addition serves to provide the additional horsepower for the expansion at N4. Spectra Energy chose the newly developed "Solar Titan 250 Gas Turbine Driven C85 Compressor unit" for this application.

This paper outlines the collaboration between Spectra Energy and Solar Turbines in successful implementation of the project to introduce the first Titan 250 Turbine (T250) & C85 Compressor in Canada to the Spectra Energy Fleet.

The paper is presented in 3 sections.

***Section 1** presented by the Spectra Energy Project Team describes the business case, project justification, selection of Solar Turbines T250 Unit, and project*

management processes of engagement, and risk sharing and mitigation with Solar Turbines T250 Program Team in the execution of the project.

Section 2 *presented by Solar Turbines Program Management provides an update on the Titan 250 Fleet since product introduction at IAGT conference back in October 2009. The section presents new applications involving Spectra pipeline compressor power generator applications using T250's, Fleet Support, and a description of Solar's Insight Remote Monitoring - for best availability and reliability.*

Section 3 *presented by Spectra Energy Operations provides a background on implementing the new compressor set at N4. This section lists lessons learned & the impact to Operations, criteria used for selecting parts and tooling and deciding upon the Long Term Service Agreement (LTSA) with Solar (Spectra Canada's Operating Philosophy) and the partnership with Solar going forward.*

The paper is a case study of collaboration between Owner/Operator companies and Vendor/Manufacture companies in introduction of new gas turbine technology to existing Owner company fleets. The project management and the technology development processes are applied in a risk sharing and collaborative way to achieve Project success.

Section 1 Project Execution

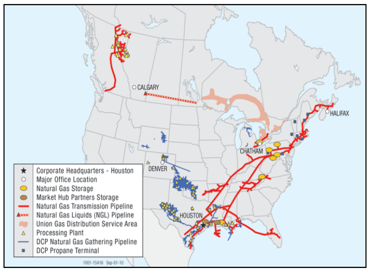
1.1 Introduction

Spectra Energy operates one of the largest gathering, transmission and gas processing businesses in the United States and Canada, and connects western Canadian natural gas supply sources with growing Canadian and U.S demand. The company has experienced significant growth in northeast British Columbia and the Western Canadian Sedimentary Basin, one of the most important gas supply regions in North America.

In British Columbia, Spectra Energy's mainline transportation system stretches from Fort Nelson, in northeast British Columbia, Gordondale at the British Columbia/Alberta border, and to the southern-most point at the British Columbia/U.S. border at Huntington/Sumas.

The Spectra energy West Mainline transmission system includes:

- About 2,900 kilometers (1,700 miles) of natural gas transmission pipeline which can transport 2.4 billion cubic feet of natural gas per day
- 18 compressor stations with a compression horsepower of 685,000
- 8 interconnecting 3rd party pipelines
- The transmission system is fully regulated by Canada's National Energy Board and the southern mainline has served markets in British Columbia's lower mainland and the US Pacific Northwest since 1957



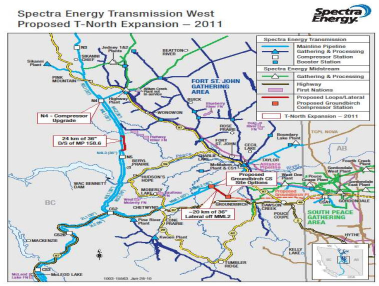


Figure1- Spectra Energy Overview Map

Figure 2- T-North Expansion Map

1.2 Spectra Energy T North N4 Unit Addition Project

With the results of the binding open season for T-North, a total addition of 170 MMcfd of additional Fort Nelson Mainline (FNML) long-haul capacity was required from the Fort Nelson Plant (FNP) receipt point to Compressor Station 2 (CS 2).

1.2.1 Facility Requirement

The Project was designed as a combination of pipeline looping and horsepower addition to efficiently transport the additional volume. The following facilities and were required:

- 24 km of loop extension of 36” between Compressor Stations N4 and N5
- Addition of 1 x 30000 ISO hp Unit at N4

The design of the N4 station before the installation of the T250 Unit was approximately 1.15 Bcf/d. Post installation, it handles approximately 1.5- 1.55 Bcf/d. More importantly, T250 unit also increases the head differential for the station as well.

1.2.2 N4 Compressor Unit Addition- Business Case

The additional flow rate required more horsepower to be added at N4. The additional unit was required to operate in series with one of the existing GE LM 1500 units. This unit addition serves to provide additional horsepower to be used for the expansion.

The new unit was designed to accommodate the following:

- Initial Phase - To operate as a leading unit, in series mode, with one of the existing LM 1500 units.
- Final Phase - In future expansion, N4 station will operate with all 3 units.

Originally, a Titan 130 engine was meant to replace the engine in an older, LM 1500 unit set. However, shortly after, Spectra Energy received additional commitments from gas producers, which required the installation of a higher 30,000 horsepower unit to handle the volume in series with existing LM 1500 unit. It required careful yard piping configuration due to the congested site location and addition of an aerial cooler at the N4 station.

Figure3-N4 Station Aerial view **Figure 4-N4 Titan 250 Unit**

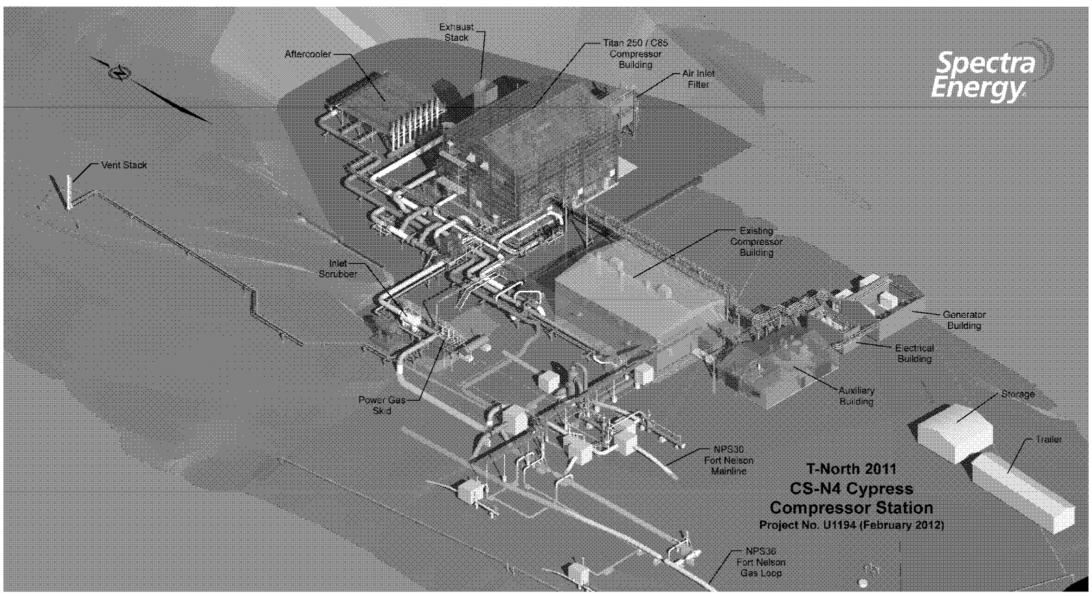


Figure 5-N4 Station Upgrade Overview

1.2.3 Unit Selection Considerations

Spectra Energy has been a Solar customer for more than 45 years with several recent installations from Solar's product line for both gas transmission and gas processing applications. In total, Spectra Energy's Western Canada fleet consists of 23 packages, 16 of which generate more than 4,500 horsepower each. The fleet's total horsepower combined is close to 200,000. Capital cost, successful operating history, schedule, quality, and operational requirements were all considerations to unit selection.

A Solar Titan 250 unit (T250), with ISO 30,000 HP, was selected to be added. A C85-2 stage compressor with D4F B4R wheels was identified to be suitable.

The published HP and efficiency performance met the system design model. The footprint of the modular skids was suitable for installation in the existing N4 station.

1.3 Key Drivers and Risks

Selection of the Solar T250 Unit necessitated careful consideration of the key drivers and risks.

1.3.1 Key Drivers

1. Solar Design Philosophy using skidded units – works well for installation & commissioning at remote Spectra station sites.
2. Reliability and Operability- familiar to Spectra thru the fleet experience.
3. T250 Build on modular design expanded from existing technologies (Titan 130).
4. T250 maintenance program was developed similar to existing units and leveraged existing support network in Western Canada.
5. Solar's "Order fulfillment process for Project Delivery" helped in developing the Solar and Spectra Team engagement.
6. Cost and delivery commitments were defined under the purview of Spectra Solar Strategic Agreement.

1.3.2 Risks

1. T250 was a newly developed unit – It was a prototype unit with less than 16,000 fired hours for the fleet. This was perceived as a key risk for Spectra to deliver the committed customer gas volumes reliably.
2. Un-proven Performance & Reliability in High Elevation and Cold Weather Applications - Solar had no test data for the T250 engine in extreme cold temperatures (40F to -40F) expected at northern BC station sites.

1.3.3 Risk Sharing and Mitigation

A comprehensive effort was undertaken in a series of meetings and workshops among team members and specialists from Solar to engage on risk mitigation processes. We list a few of the key initiates and commitments made to share and mitigate risks.

Solar initiatives and commitments

1. Solar Senior Management commitment to support on all issues
2. Extensive testing regime in development of unit
3. Exhaustive listing of issues and design improvement
4. Complete transparency on sharing of all issues
5. Inclusion of this unit in a "Field Evaluation Program"- committed field service monitoring and engineering support.
6. Insight remote monitoring program - part of Field Evaluation Program
7. Immediate and well coordinated response to unit issues post commissioning involving engineering, manufacturing and field support

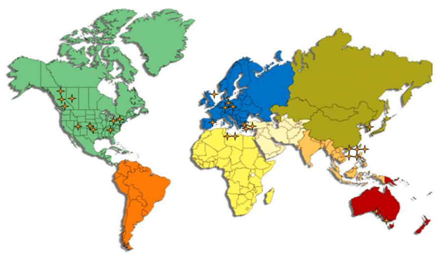
Spectra initiatives and risk sharing

1. Spectra Senior Management Support
2. System design - consider spare capacity on the system in case the unit is down due to issues
3. Continuous team engagement with Solar team.
4. Witness testing and collaboration on issues
5. Adjust construction schedules to accommodate delays
6. Collaborate in commissioning
7. Ensure detailed communication on all issues to Operations and other Stakeholders - no missed messages.
8. Patience – allow Solar to work issues

Section 2.0- Titan 250 Gas Turbine System Update

The 30,000 horsepower *Titan* 250 gas turbine system and matching gas compressor family were introduced in 2006. They are the latest additions to the Solar industrial gas turbine product line, and the launch unit was started in 2009 with a C85 compressor set in at a natural gas transmission site in Tennessee, USA. This compressor station is an important node supporting a 17,000 km pipeline system serving over 6 million customers.

Since then, over 25 production orders have been placed in a wide range of complex Oil and Gas and Power Generation applications around the world. These projects span ten countries, all climate ranges, and include pipeline transmission, mid-stream gas processing, offshore oil and gas production, and electrical power generation in combined heat and power applications.



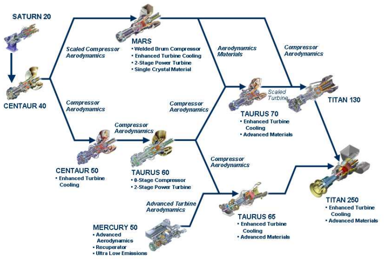
The fleet has already accumulated over 125,000 hours of combined operating experience, and 16 sites should be in operation by year end 2013. Five sites have accumulated almost 20,000 hours of operating experience, and several users have already placed repeat orders.

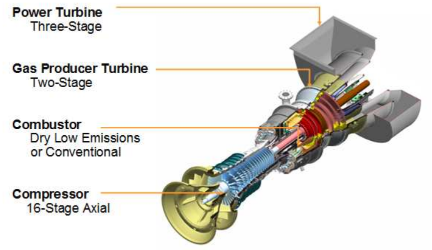
2.1 Titan 250 Gas Turbine Engine Overview

The Titan 250 produces 30,000 horsepower of shaft output at 40% efficiency. The low risk industrial gas turbine engine's design leverages core aerodynamic, material and cooling technologies that have been developed and proven in over 14,500 units in the field.

The Titan 250 gas turbine is a hybrid of three well proven models, and is only available in a two shaft model with a:

- 16-stage axial-flow compressor with a pressure ratio of 24:1
- Dry low emissions or conventional combustion system
- Two-stage gas producer turbine operating at a firing temperature of 1204℃
- Three-stage all-shrouded blade power turbine

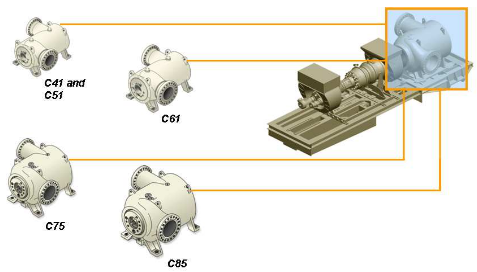




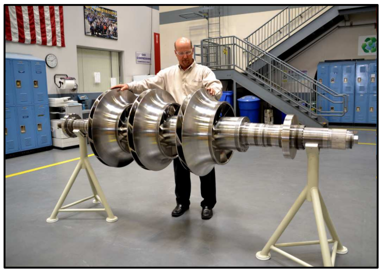
2.2 Matching Gas Compressors Overview

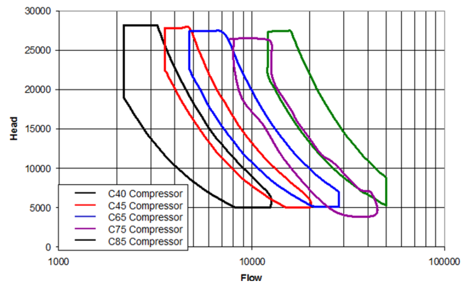
A family of five high efficiency centrifugal gas compressors have been developed to be driven by the Titan 250's output power and shaft speed.

The C85 and C75 compressors were developed for pipeline applications and are low risk geometrically scaled versions earlier and smaller compressor models. The C85 is available with one or two impellers, and the C75 is available with either two or three impellors depending on the project specific head and flow requirements.



The C41, C51 and C61 multi-stage compressors were developed for higher pressure, lower flow, upstream processing and production applications and are also geometrically scaled from earlier and smaller compressor models.





2.3 Field Evaluation Program and Equipment Health Monitoring

The C85 compressor set for the N4 station upgrade was the eighth Titan 250 package shipped and the fifth Titan 250 package started. High availability was critical, and additional challenges were presented by site's remote location and cold winter ambient temperatures. To ensure the N4 project was successful, this compressor set package was included as part of the 12-unit Field Evaluation Program. During this evaluation period, additional instrumentation, monitoring and inspections take place to maximize equipment availability.

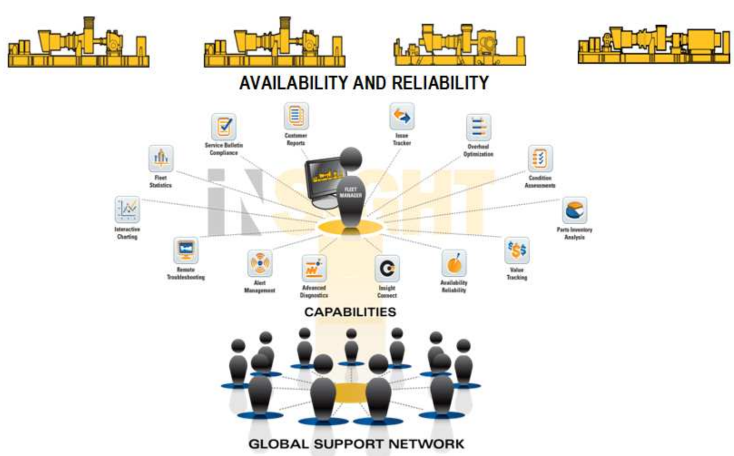
2.3.1 Field Evaluation Program

The scope and duration of the Field Evaluation Program is specifically tailored for each site and application. Through a series of workshops with the Product Development Team, the N4 Project Team and the Operational Teams from both parties, a ten-step support program was implemented.

1. Failure Modes Effect Analysis – Drove data-based decisions
2. Operational and critical service parts - Optimum stock levels and location
3. Field service tools - Optimum stock levels and location
4. Trained personnel - Rotated in advance through other Titan 250 sites
5. Spare engines - Spare GT dedicated for N. America, other around the world
6. Equipment Health Monitoring System (InSight) - Remote diagnostics
7. Local Fleet Manager - Single Point of contact
8. Global Fleet Manager - San Diego-based enterprise knowledge centre
9. Mobile Emissions Trailer - To help optimize performance and emissions
10. Communication - Regular updates and monthly key performance indicators

2.3.2 Equipment Health Monitoring System

The cornerstone of the field evaluation program is the Equipment Health Monitoring (EHM) system which enables data collection, data conversion and data transmission to a central database for diagnostic analysis of both the engine and gas compressor. The Remote Monitoring and Diagnostics (RM&D) module combines advanced diagnostics, condition monitoring, remote trouble shooting, e-mail or PDA alert notifications, predictive recommendations, and equipment operations summary reports. These results were shared through a secure website, and provided real time information to the operations and design teams to help optimize performance and increase availability.

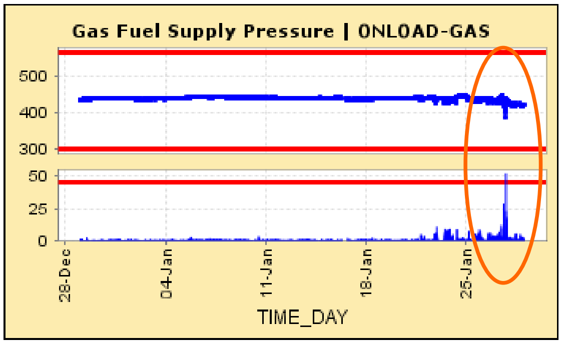


2.3.3 Examples and Results

The Titan 250 engine, package and matching gas compressors are Solar's most extensively instrumented turbmachinery systems to date. In conjunction with the EHM and RM&D system several potential operational issues were detected early, and corrective action was taken to minimize down time. The following examples illustrate some of these issues.

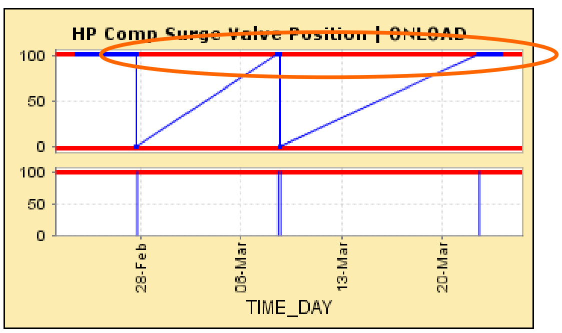
<u>High Gas Fuel Supply Pressure</u>

A step increase in fuel pressure was noted, and the local Fleet Manager contacted the customer who then found a faulty regulator in the upstream equipment.



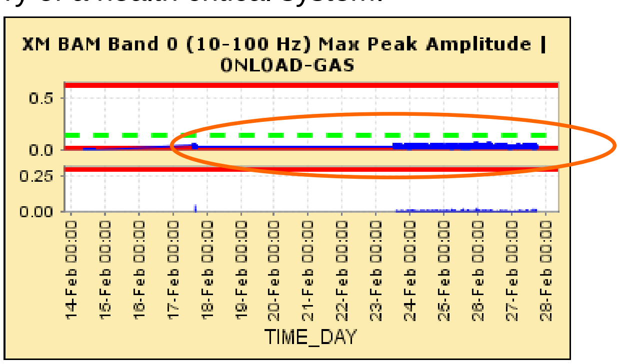
<u>High Pressure Compressor Surge Valve – Position Error</u>

The Fleet Manager received several alerts, and found the Rosemount Tri-loop devices for surge control to be causing the position error.



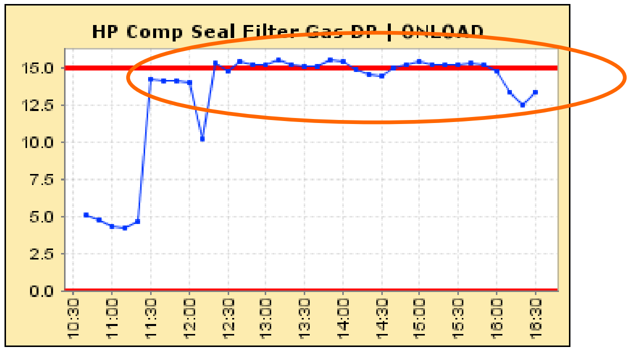
<u>Combustion System Acoustics - Kissler Probe Error</u>

EHM data showed that the lower global vibration limit was exceeded. The Fleet Manager mobilized manpower and found that the Kissler probe on the Burner Acoustic Monitoring (BAM) system had failed. This pro-active response allowed the soonest recovery of a health critical system.



Seal Gas Filter - Clogged

A sudden increase of the HP comp seal gas filter Differential Pressure (DP) initiated a site investigation where rust and other contamination were found in the pipe work. The filter was replaced and this prevented an unplanned down time event.



Section 3 - New Unit integration

Unit integration for the purposes of this paper will describe the experiences and processes focusing on three topics:

3.1 Startup Experiences
3.2 Spares Philosophy and Selection
3.3 Preventative Maintenance

3.1 Start-up Experiences

Commissioning and start-up of the package was straight forward. OEM technician(s) proceeded to perform a series of checks and calibrations as outlined in the OEM commissioning package / instructions. There were no serious issues observed except for the Torque meter which could not communicate with the Unit Control Panel (UCP). Start-up was smooth. Light-off occurred successfully on the first attempt.

One of the major reasons for few site issues can be attributed to the level to which the package was completed in the OEM facility thus minimizing site construction of the package components. This included major components that often pose problems when assembled at site:

- UCP: The UCP was mounted on the skid and not installed remotely. This allowed the OEM to fully test every instrument and connection with the UCP in ideal conditions. The exceptions are the Balance of Plant (BOP) interconnects (fuel skid, compressor main gas isolation valves, recycle valves, etc). These point to point and calibrations are required to be completed in the field as being third party supplied.
- Major piping: The major piping came pre-assembled and cleaned from the assembly facility. The only piping that needed to be fabricated at site was the interconnect piping between the GT skid to the oil cooler and the lube oil vent line. Cleaning and flushing effort is minimized by using stainless steel piping and improves the odds of success.

No package stands alone but forms part of a station. As such the station has its own Station Control Panel (SCP) that controls all of the station functions and must communicate with the UCP in order to transfer operating set points or emergency shutdown signals and receive key unit data in return. The majority of the communications requirements posed little problems between these panels but one proved difficult and to this day is not resolved:

- Solar controls use % speed as the main identifier of unit speed, normally 0 – 100%. This works great with modern controllers with 4 – 20 mA signals which can easily be scaled for 0 – 100.
- For the Titan 250 Solar, changed the speed range for the Gas Producer (NGP) from 0 – 100% to 0 – 102.5 % NGP. This was done to allow for a power increase. For expediency Solar simply adjusted the maximum speed to 102.5% NGP in the UCP.
- Part of the SCP function is to take speed control of multiple units of different power and capacities to operate in series and balance the load between them using algorithms in the SCP. This posed a large problem where the SCP

scaling was 0 – 100% and could not be changed to 0 – 102.5% without having to re-write significant areas of code.

- This scaling difference does not pose a problem when the unit is operated alone. When operated alone, unit speed is controlled by the UCP based on a set point input from the SCP. For these other Set Point inputs the 0 – 100% range remained and was not a problem. When controlling with these set points the full Gas Producer speed of 0 – 102.5% remains available.
- No simple fix could be worked out so the compromise was to sacrifice maximum power available and leave the SCP input range as 0 – 100% NGP when in SCP speed control.
- This speed range change was not well communicated to the people programming the SCP. Lesson here is to confirm the speed ranges early to confirm if they are standard or not.

On a lighter note, the remote HMI provided by the OEM was installed in a control cabinet in the station main control room due to space limitations. Meaning, in order to locate the screen, keyboard and mouse on the control room desk, a screen, keyboard and mouse emulator was required. This was to be Spectra supplied. The wrong emulator was first identified. The proper emulator was then identified but the wrong one was delivered. Not until the third try did it get fixed, however, this did not happen until well after the site test run was completed. For the start-up and test run the control room HMI had to be operated out of the cabinet, in the corner, where only one individual could have access. This was also well away from the station HMI screens. Starting up a new machine, notably a new model to the fleet, always draws a crowd looking at the control screens to see how the unit is performing. In this case it resulted in people literally stacked up looking over the next guy's shoulder to get a view of the HMI screen. It also posed a problem training the station operators on how to use the remote HMI screens to operate and monitor the unit. Advice here is do not wait until the last minute to get the remote HMI screens working where they can be properly used to operate the unit.

The last issue worthy of mention that posed a problem during the unit start and test running phase had to do with emergency trips. The NGP rotor on this machine is very heavy and tends to bow when hot and not turning. To prevent the bowing during normal stops a separate turning motor is included with the package to slowly roll the engine over for a period of time until the rotor cools sufficiently where bowing is no longer a concern. The problem with the emergency trip system design is that this slow roll function is disabled. Any hard button trip (on the UCP cabinet, in the compressor building and in the main control building) or remote trip from the SCP results in a unit trip, or "Fast Stop, Slow Roll Disabled". When this occurs there is 10 minutes to get the unit turning motor or starter motor engaged and start rotating the NGP rotor. If this does not occur the UCP locks out the unit for 12 hours. Solar experience after a trip has shown the rotor bows sufficiently by then to result in rotor lock (worst case) or higher vibration (best case). Unfortunately it typically takes longer to clear the trips to allow the turning motor or starter motor to be engaged resulting in the engine lock out taking place.
Solar does include a soft button "Fast Stop, Slow Roll Enabled" on the HMI screens. This will Emergency Shut down (ESD) the unit but allows the oil pump to remain on and engage the turning motor. In this installation that meant there are a soft button on the local HMI screen mounted into the UCP cabinet and another soft button

located on a Remote HMI screen. The following serves to clarify some of the Slow Roll Enabled or Disabled ESD function problems:

- All station ESD trips require the unit to trip immediately but many do not require the gas turbine to be locked out. The communication between the SCP and the UCP was only set up for the Fast Stop, Slow Roll Disabled to be engaged. There were no provisions to have a distinguishing signal that would allow Slow Roll to be enabled or Disabled depending on the trip scenario.
- To manually engage the Fast Stop, Slow Roll Enabled trip the operator must use the soft button. In both HMI screens these soft buttons are NOT located on the main screens where an operator would normally be monitoring the unit. They must drill down to the applicable screen to find the soft button. So in an emergency the operator must decide if having a Slow Roll Enabled trip is acceptable, then remember where to drill down to the correct screen in order to find the soft button and push it. This only applies when the operator is on site.
- Note that human nature and industry standard during an emergency is to hit the Big Red Button to ESD the unit than to remember where to find the soft button in a moment of panic.
- This needs to be reviewed by Solar to make this more operator friendly and smart for un-manned installations. As a minimum there should be a hard button on the control panel for a Fast Stop, Slow Roll Enabled as well as one for the Slow Roll Disabled. Having a selectable option in the panel communications would also serve to prevent nuisance lock outs when in un-manned operation.

One feature that is standard in the Solar turbo-compressor control suite is the Process Controller. Spectra Energy is finding this controller to be very useful and eliminated this control software that previously resided in the SCP. This control allows for external set points, compared to a process variable from an internal or external signal and has the software control to maintain the set point. In this case there are 3 + 1 set point inputs. The set point is maintained by a combination of unit speed control as well as cold recycle valve position. The recycle valve control allows for rapid adjustments to fast changing process conditions. Subsequently, as the slower reacting unit speed adjusts the cold recycle valve will begin to close again. This control process needs to be tuned at the site during the test running but has proven to be very successful.

- The one stand alone set point is Speed control and does not interact with the other three when the Process controller is enabled. As previously described there is a need for direct unit speed control.
- The three remaining set points are controlled to whichever one is achieved first. The logic will then maintain the set point accordingly. These are:
    - Discharge pressure control
    - Suction pressure control
    - Flow control
- For this installation only, the pressure control set points are used when Process Control is enabled. The set points are communicated from the SCP which is remotely set by Gas Control via the SCADA link or locally set (manual).
- The flow controller remains active but the default flow signal set point was simply set high and out of the way to prevent it from ever reacting. This

pipeline compression installation does not need flow control to meet the compression needs.

3.2 Spares

3.2.1 Selection Criteria

The definition of a Critical Part will vary from user to user, business models and/or effect on reliability. Some considerations are:

- cost of the down time (production revenue loss) >= cost of the widget (empirical Logic)
- Repair time >= lead time (empirical Logic)
- Downtime effects on production. If the machine is the sole source of production this will weigh heavily on the spare parts selection process. A failure will have less of an impact if the machine is one of many.

There is a whole field of study in this area and the author does not claim to be an expert. Since this was a study in adding one Gas Turbine Compressor package to the fleet, the Critical parts selection process was kept simple. In this case the Reliability Engineer looked for answers to the following questions in order to define what would be a Critical Spare:

- How long can the machine remain out of service for an unscheduled outage (break down)? This speaks to the lead time for procuring the material as well as the repair time. In this case it was determined to be 4 weeks maximum.
- What are the work force maintenance capabilities? Can they perform the maintenance tasks required for PM as well as breakdown maintenance? What tasks are deemed beyond the work force capability? In this case, the opinion was that components that are located on the outside of the gas turbine (CDP bleed valves, VGV Actuators, etc) can easily be replaced by the work force provided they had the training. Internal engine components, even when there is a procedure in the manual for field repair was concluded to require specialist help (OEM Field personnel).
- What is the component / widget / part likelihood of failure? This was more of a subjective exercise, based more on the experience within the company dealing with these, or similar, materials / components having other Solar turbine models in the fleet. A more deterministic ranking methodology could also be applied based on MTBF data but was not in this exercise.
  - For instance the Titan 250 has an AC electric motor used for starting the gas turbine. The motor has a 17 week lead time. This is well beyond the 4 week criteria outlined above to qualify as a critical spare, however, the likelihood of a standard AC motor failing was deemed to be quite low. It was just not believed that this motor would “move” from inventory often. As such the motor did not meet the criteria for being a critical spare.
- What is the available budget for spare parts and tooling?

Based on the answers to the above questions the criteria for what is deemed to be a Critical Spare was accomplished. The following became the first cut selection criteria:

- Parts / assemblies with a lead time for delivery greater than 4 weeks
- Consumable parts that are required to install the critical parts / assemblies
- Exclude parts which had a low likelihood of failure
- Parts / assemblies that can be used in the field
- Costs not to exceed $1.25M (to also include special tooling)

3.2.2 Special Tooling

Up front in this process Solar outlined that they are planning on having a full set of specialized tooling available in North America for the gas turbine and the compressor. The tooling cannot be guaranteed to any one customer but instead would be available on a first come first served basis. The tooling would also require Solar technicians on site to perform the work using these Solar owned tools. This added a twist on the plan for selecting what tooling to acquire.
The selection of the tooling was simplified to that which is required to perform maintenance on this turbo compressor package, tempered by the critical parts being selected. Since management accepted that the machine could be down for up to four weeks it appeared that none of the critical parts tools would be required as there would likely be sufficient time to get the Solar owned tools to the site. However, Spectra could not be certain the tooling would be available. Because of the uncertainly in the tool availability it was decided that the following criteria would be used for selecting which specialty tools would be procured:

- Essentially if a part / assembly were deemed to be critical then any specialized tooling required for performing installation of that part / assembly is logically included. There is no logic in acquiring a part / assembly as an inventory critical spare if there is no tooling available to install them.
- When the process of incorporating this turbo-compressor package into the fleet was started it was with the intent that preventative maintenance (PM) activities would be undertaken by Spectra employees. Therefore, the tooling list also included those items needed for doing PM maintenance.

3.2.3 Preventive maintenance (PM) Parts

Along with the Critical Parts, the list of parts required to perform PM tasks were reviewed as well. Spectra Energy Transmission (West), in particular the Pipeline division, preference is to keep a supply of the materials required to carry out PM tasks on hand. Some of these may have long lead times and some do not. The parts are held in inventory to keep the PM planning simplified. Normally one set of parts are held but this can grow depending on the total number of units to be serviced and/or commonality of the parts between different gas turbine models. For the Titan 250, with only one installed at this time, one set of PM spares were ordered and will be maintained.

3.2.4 Non-Critical Spares

In the assessment, a number of parts were identified as being important but did not meet the Critical Spares threshold. However it is obvious that these parts / assemblies will be required some day so they were flagged for input into the company's material management system. This makes it easier to order this material in the future as having all of the pertinent information needed to order a part is incorporated into the materials management structure. This structure will be explained later.

3.2.5 Parts identification Process

The normal practice to kick this process off is that the OEM supplies the customer with a list of parts they believe should be purchased to support the turbo-compressor package. These lists include how many can be found on the package and how many the OEM suggest be purchased as a spare. Solar was no different. However, the Solar documentation for this unit had two main differences compared to previous submissions by Solar or other OEMs. What they provided was a “Consolidated Ownership Report (COR)” list.

- The list included the parts lists from other packages that were previously purchased and installed by Spectra Energy West. One can quickly see which parts or assemblies were common between the various packages
- The list was organized into 6 Service Parts and Tooling categories:
  - SPY1, Operational Consumable Parts: Parts required for performing the annual and semi-annual PM tasks.
  - SPY2, Insurance Critical Items: This is the OEM list of Critical parts based on their definition.
  - SPY3, Insurance Non-Critical Items: This is the OEM list of non-critical parts based on their definition.
  - SPY4, Repair Kits / Components: A list of service kits where applicable. Essentially a kit that may include a critical part as well as the consumable materials that would be required to perform the maintenance.
  - SPY5: Not used
  - SPY6, Maintenance Tools: Level 1 tooling to perform scheduled maintenance or for trouble shooting uses.
  - SPY7, Special tools: Level 2 tooling required to perform specific maintenance tasks. This subset of tooling generally requires training prior to performing the maintenance task.

The above list structured in this manner made it easier to scrutinize the list and assess which parts were required. The scrutiny incorporated many different checks:

- By listing the parts that were compatible with the other packages previously purchased by Spectra Energy West it was possible to search the Spectra materials management system to find out if this part / assembly may have already been procured and/or have a unique Spectra Energy West material #.
- In determining if the stock count for a compatible part needed to be adjusted to reflect a larger fleet size.
- Quickly determining which parts were not compatible with other packages thus allowing for closer scrutiny regarding criticality to determine whether one would be required for inventory.

Based on the above criteria, assessing compatibility and reviewing the list the list broke down for parts to:

- Total # of parts listed (SPY1 – 4): 326

- Total # of parts passing selection criteria: 205
- Total # of common parts already in the system: 56
- Of the 56 # of them that needed no changes: 51
- Total # of parts that needed to be created or changed: 154
- Actual part item count ordered: 139 (including multiples of same part)
- Total cost of 139 parts: $795,791.60

For the tools

- Total # of tools listed: 80
- Total # of tools passing selection criteria: 43
- Total cost of 43 Tools: $423,342.66

There was one major obstacle preventing this process from taking place with the goal the tools and spares would be delivered in time for the unit start-up. Pitfall was the availability of the package manuals. To assess whether the part or tool is required or not requires access to the Maintenance Manual and the Illustrated Parts List. However, these are not normally delivered by the OEM until shortly before unit start-up to allow for final as-builds to be incorporated. Hence the conflict when there are long lead time items to be ordered. The cryptic Material Data management descriptions used for these parts and tools provided by the OEM are NOT sufficient in determining what is and is not required for our business need. This delayed the selection and acquisition process as it required lots of communication between the Solar and Spectra to understand what part number was for what part. The result was that many of the Critical Parts were not delivered until after unit start-up.

Spectra Energy SAP Material Management System

Spectra Energy uses the Material Management module offered in the SAP logistics and accounting software package. This module is used as delivered but Spectra Energy does apply some custom conventions and rules for making it meet the need. These are:

- Every part or assembly will have a unique Spectra Energy identification number, known as a material number. This unique number will have the following information included:
    - The OEM part #
    - The OEM purchasing information
    - A third party part # (if applicable)
    - Third part supplier purchasing information
    - Safety Stock level (minimum quantity to be held in inventory)
    - Actual stock level
    - How many are reserved for planned work
    - Whether the part is repairable
    - How many are out for repair
- The OEM part numbers have been modified to make searching simpler. Periods, commas, dashes and spaces typically found in part numbers are removed, leaving only the alpha-numerical code. Example: Solar Seal boost pump PN# 1074064-200 would be converted to 1074064200.
- Vendor specific information is kept in a separate, but linked SAP Purchasing Module. This information consists of a Spectra Energy unique identifier number for each particular vendor and location, to include:
    - Vendor location address

- o Vendor location contact information
- o Any specific Purchasing notes regarding this particular vendor
- o For chain suppliers with many outlets each outlet will have a unique identifier number

3.3 Planned Maintenance

The planned maintenance scheme that was created was based on previous PM plans developed for other Solar turbo-compressor packages already in service. From these, a specific plan was created to meet the need of this new package. SET PM plans are laid out to cover the entire operating cycle of the engine from new to a zero hour overall where it starts all over again. The plan incorporates the terms of the Master Service Agreement between all of Spectra Energy (US and Canada) and Solar Turbines based on a per fired hour cycle. The Maintenance Module of SAP is incorporated to track and administer the PM planning.
The Solar Maintenance Instruction manual outlines that maintenance is to be done Daily, Weekly, Semi- Annually (or 4000 hrs) and Annually (or 8000 hrs). SET (West) Pipeline have moved away from time (hour) based PMs and shifted over to a calendar based scheduling for the Level 1 PM maintenance (filter changes, instrument calibrations, water washes, etc). Except as outlined below the PM plan for this T250 package would follow the Annual plan outlined in the Solar manual and have all of the Semi-annual items shifted to the Annual plan. The operating history of the SET Pipeline has aligned well with this maintenance philosophy. There are seasonal high contract demand periods and this way the PM work can scheduled not to fall during these high demand periods. For planning purposes the PM is then broken down by major maintainer discipline, Mechanical and Electrical. From this and the fired hour agreement the following plan was established:

- Bi-Annual PM (Mechanical: water wash, borescope inspection, oil sample). This would effectively take place in early to mid fall to ensure a clean and healthy engine before the peak season and again in late spring to have a good look after the peak season.
- Annual PM (Mechanical: filters [oil and fuel], Leak Checks, etc; Electrical: instrument calibrations, PLC Bios Battery replacement, etc) and to include those items in the bi-annual PM.
- 30,000 Overhaul / Exchange as per the Fired Hour Agreement. This also includes an inlet filter condition (destructive) evaluation.
- The daily and weekly checks have been left to operator due diligence and are not tracked

The above PM plan was to be implemented on completion of the warranty period. However, before this could happen SET (West) entered into a Long Term Service Agreement with Solar where Solar is now tasked with performing all of the PM tasks. Because this was a second agreement to the Fired Hour Agreement the overhaul / exchange PM remains. So the PM plan that has now been implemented in SAP is:

- Semi –Annual PM: Solar to schedule when the items in the Maintenance Instruction manuals are to take place. Like above these will be scheduled by SET in conjunction with Solar personnel availability to happen in the Fall and Spring
- 30,000 Overhaul / Exchange

The original overhaul plan proposed by Solar for the Titan 250 was to perform an exchange of the Gas Producer hot end every 30,000 hours, the complete Gas Producer every 60,000 hours and the PT section every 90,000 hours. The unit design allowed for this to take place in the field. However, the fired hour agreement does not allow for this plan to take place so the highest overhaul cycle being applied is 30,000 run hours to the entire gas turbine.

The Fired Hour Agreement highlights are:

- Covers sections on service, repair, overhaul, exchange and new purchases
- Operation for 30,000 hours between overhaul.
- Warranty clauses defined by applicable sections (new unit purchase or overhaul)
- There are provisions to exceed the 30,000 hour operation upon getting a Solar inspection and permission. The extensions can only be for 4000 hours and cannot exceed 40,000 hours.
- Costs are based on a two tiered structure. The main cost is the fired hour rate up to 30,000 operating hours. There is a subsequent lower fired hour rate for hours operated above 30,000 hours.

4.0 Conclusion

With close collaboration among the Owner/Operator and Vendor/Manufacturer Companies, new Gas Turbine units with new technologies can be applied to the existing operating fleets. The Titan 250 engine, package and matching gas compressor unit is proving itself in operating fleets with the field evaluation and support program. There is room for risk sharing and mitigation by open communications, planning and collaboration. There are lessons learned from start-up, commissioning and planning of spare parts and planned maintenance programs of this project for future projects.