The Cascade Power Project

Advancing Canada's decarbonization through coal-to-gas shift and innovative gas turbine technology

SIEMENS energy

Abstract

The 900 MW Cascade Power Project in Edson, Alberta is one of the largest and most significant power plant developments in Canada in recent years.

Utilizing two highly efficient SGT6-8000H gas turbines supplied by Siemens Energy, each producing 450 MW in a 1x1 combined cycle configuration, this Combined Cycle Gas Turbine (CCGT) Power Plant represents a key milestone in the decarbonization of Alberta's power supply. It displaces high emitting power generation from coal plants with gas-fired, state-of-the-art combined cycle technology achieving a plant thermal efficiency of over 60%.

Once operational, this power plant alone is expected to reduce Alberta's CO2 emissions from power generation by up to five percent (5%), and supply highly efficient electricity to supply over eight percent (8%) of the province's average electricity demand. It is also expected to enable further penetration of renewable energy sources by providing dispatchable power and grid firming capability.

As part of this project, Siemens Energy has been selected to provide two SGT6-8000H gas turbines, two steam turbines, and two heat recovery steam generators in a combined cycle configuration, as well as long-term services. Kineticor Resource Corp., "Kineticor", is responsible for the management of the development, construction and operations of the Cascade Power Project on behalf of the project partners.

This paper will present the key features of the power plant and the advanced Gas Turbine technology used. It will also describe the project through its development and as a case study for the decarbonization of power generation.

Figure 1 - Project Overview

Introduction

The Cascade Power Project in Alberta is a significant energy venture aimed at contributing to the province's electricity generation capacity. This report provides a comprehensive technical overview of the project, including its location, design, power generation process, construction timeline, economic impact, and challenges faced during the project's implementation.

The project is a combined cycle power plant that uses natural gas as a primary fuel source for electricity generation. The project was developed by Kineticor and is owned by a consortium of global infrastructure investors and local First Nations communities. Kineticor remains responsible for the management of the project on behalf of the project partners. BPC, a joint venture between Overland Contracting Canada Inc., a Black & Veatch Company, and PCL Industrial Management, is the Engineering Procurement and Construction (EPC) contractor. The power plant aims to provide a reliable source of clean and efficient electricity to meet the growing energy demands in Alberta.

The $1.5B CAD project employed over 1,000 concurrent workers at peak and has amassed nearly 2 million work-hours to date.

The project is located approximately 16km southwest of the town Edson, Alberta, in the Yellowhead County at an elevation of approximately 935m above mean sea level. The site was strategically chosen due to its proximity to natural gas reserves, transmission infrastructure, and environmental considerations. The region offers a conducive environment for power generation, and the project's location minimizes the transmission losses associated with electricity delivery.

Project Development

Kineticor is a power developer and asset manager focused on generation across Canada and with a headquarters located in Calgary, Alberta, Canada. Their portfolio includes over 2,300 MW in various stages of operation and development. Siemens Energy was selected as the power island equipment supplier in May 2019 and contract negotiations with Kineticor and their architect engineer Burns and McDonnell took place over the next year. BPC and Siemens Energy received Full Notice to Proceed (FNTP) in August 2020, kicking off construction, and the Gas Turbines (GTs) were delivered in December 2021. The overlap of construction and commissioning occurred in the summer of 2023 and commissioning is expected to complete in early 2024.

With FNTP, the Siemens Energy bid team handed over to the project execution team. A project management plan and organization structure were developed. The Siemens Energy General Project Manager (GPM), as well as the majority of the Project Management Office (PMO) is located in Orlando, FL, but the execution of the project requires a global team from Siemens Energy and suppliers. With equipment coming from around the world, there are multiple PMOs in USA, Netherlands, Germany, and Canada. The scope of Siemens Energy is to supply equipment, operator and maintenance training, and Technical Field Advisory (TFA) to the Project. In addition, Siemens Energy is also providing a Long Term Service Agreement (LTSA) for 20 years. The site team, led by the Chief TFA, is a diverse group of more than 20 highly experienced installation and commissioning engineers from over 13 different countries across 3 continents.

Figure 2 - Project Location

The project is a combined cycle power plant consisting of two single shaft power trains with a total output of 450 MW per power train - a first of its kind in Canada. The power plant is intended to operate at baseload, but the technology was specifically chosen to have the ability for high cycling (starts and load changes) and fast ramp capabilities. The gas turbines are SGT6-8000H and the generators are SGen6-3000W, which have hydrogen inner cooled and water cooled stator winding. Both the gas turbines and generators were manufactured in Charlotte, NC. The steam turbines are a SST6-5000 series from Mülheim, Germany, with an Air-Cooled Condenser (ACC) supplied by others. The gas turbines and steam turbines are controlled with Siemens Energy Omnivise T3000 control system.

Figure 3 - Project Site

Throughout the course of four years, the project overcame several challenges. Early on, the project encountered supply chain impacts due to the COVID-19 global pandemic. In addition, the summer of 2023 saw the worst wildfire season ever recorded in North American history. Approximately 2,000 project workers and 8,400 residents of the town of Edson were forced to evacuate twice due to forest fires coming within 2 km of the town and 17 km from the site [1][2][3].

The extreme cold and harsh environment of a northern Canadian winter offered its usual challenges, as temperatures dipped as low as -43°C (-46°F) in 2021. The project also overcame several logistical challenges, such as moving two 353,000 kg generators over 4,000 km across the continent, and importing materials from around the globe. The Siemens Energy equipment alone required over 440 truck loads of deliveries.

Project Impact

The Cascade Power Project will lead the evolution to clean electricity generation in Alberta as the province transitions off coal-fired power. Once complete, Cascade is expected to be the largest and most efficient combined cycle power plant in the province, producing approximately 62% less CO2 equivalent per MWh than existing coal-fired generation, and at least 30% less CO2 equivalent per MWh than a typical coal-to-gas conversion. With Alberta contributing over 50% of Canada's GHG emissions from electricity generation, the project is expected to result in the largest emissions reduction opportunity in the country's electricity sector [4].

Cascade has quick-ramping technology, meaning it can turn on and off quickly, supporting the integration of future renewable energy projects in Alberta.

Providing a future-ready technology, the gas turbines are capable of firing a wide range of fuels, including up to 30 vol% of hydrogen (H2). Further supporting the energy transition, Siemens Energy has rolled out a roadmap for its gas turbines to have 100% hydrogen capability by 2030 [5].

Gas Turbine

At the heart of the power plant is the Siemens Energy SGT6-8000H gas turbine with outstanding performance and proven high operational flexibility. The air-cooled turbine provides a power output of 310 MW. With short start-up times and high load variations, the gas turbine offers low life-cycle costs and helps to meet fluctuating power demands. With more than 2.5 million fired hours, the SGT-8000H series provides advanced technology with verified reliability and proven availability [6].

Figure 4 - 8000H Overview [6]

The gas turbine's advanced technology offers increased power, efficiency, and sustainability when compared to its predecessors. Some features include an upgraded compressor exit diffuser (CED), platform combustion system (PCS), turbine airfoil enhancements, rotor disc material upgrades, and auxiliary hardware and instrumentation and controls modifications.

The Cascade gas turbines have the most advanced version of the platform combustion system (PCS), which includes design modifications and improvements to fuel injection and component cooling to maximize efficiency.

By utilizing the latest technologies, the overall carbon footprint per Megawatt-hour is reduced, offering a sustainable solution to replace coal-fired power generation.

The gas turbine boasts an evolved thrust bearing design with its Hydraulic Clearance Optimization (HCO) technology. The HCO allows precise control of the rotor's axial running position. This enables the turbine blade tip clearances to be increased during startup and shutdown to reduce rubbing and decreased during operation to increase efficiency. The HCO provides approximately 5 MW of additional power by reducing clearances as close to zero as possible.

Figure 5 - 8000H Global Fleet

Generator

Figure 6 - 8000H Installation at Cascade

The two units at Cascade are in a 1x1 single-shaft arrangement, meaning the gas turbine and steam turbine are connected to the same generator. This configuration leverages the additional torque provided by the steam turbine to enable the use of 2 larger generators, compared to 3 generators in a traditional 2x1 combined cycle power plant.

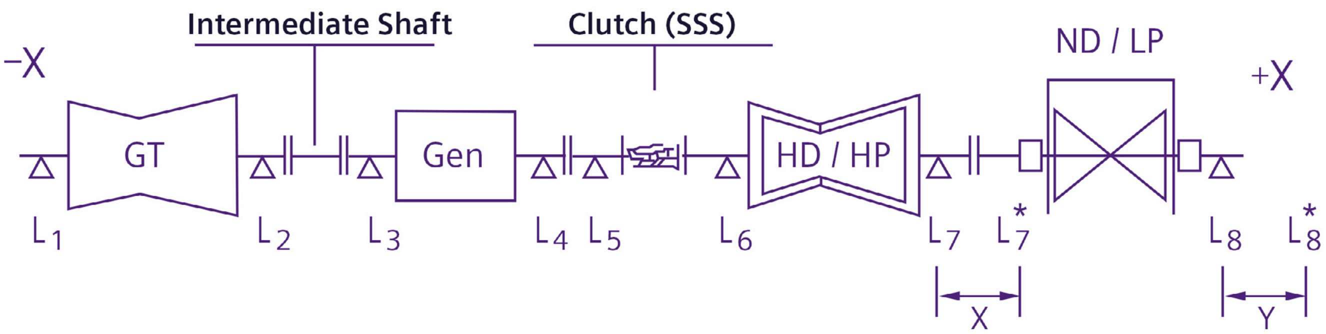

Figure 7 - Single-shaft Arrangement

Having a single generator connected to the grid and less Balance of Plant (BOP) equipment offers financial, operational, and footprint advantages for the single-shaft arrangement. For instance, one generator means one set of bus ducts, and one generator breaker, generator step-up transformer, and switchyard. In many cases, choosing a single-shaft arrangement rather than a multi-shaft design can result in capital expense savings of 3% to 5% for the plant [7].

A small gain in plant efficiency can also be achieved with this configuration, as one large generator typically has a slightly higher efficiency than two smaller ones. Single-shaft configurations also require fewer mechanical connections, which translates into lower losses.

Similarly, the simplification of Balance of Plant (BOP) systems, such as lube oil systems, can result in less maintenance, higher availability, and lower auxiliary power demand. Single-shaft configurations also have a more compact design than multi-shaft, leading to a smaller footprint for the plant [7]. This is especially advantageous on sites where equipment needs to be enclosed within a building, due to weather restrictions – as is the case with the Cascade project.

Having two combined cycle blocks, each with a single-shaft power train provides the Cascade plant with a high degree of operational flexibility, as it is expected to be able to run at 50% plant load while maintaining the same efficiency as 100% plant load.

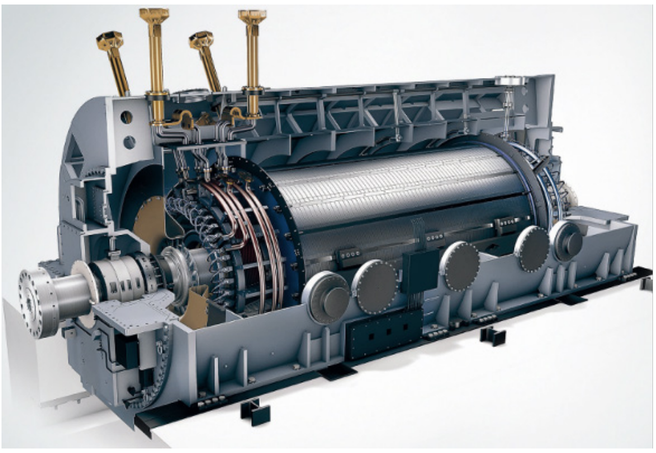

Figure8 - SGEN-3000W Cutaway [8]

Some key benefits of the SGEN-3000W Generator are high output capacity, operational flexibility, high reliability, small footprint, and easy service and maintenance [8].

These generators are equipped with Generator Condition Monitoring (GCM), which detects particles entrained in the generator cooling gas (H2) as a result of overheated insulating material. High concentrations of submicron particles are produced whenever any materials within generators are heated sufficiently to produce thermal decomposition. The hotspots can lead to catastrophic failure if not detected in a timely manner. If pyrolytic products are detected, the GCM initiates an alarm, and a fixed amount of hydrogen is automatically sampled, where particles are collected for laboratory analysis to determine their source.

Figure 9 – Construction Overview of Generator Centerline at Cascade

For further protection and reliability, the generators are equipped with the Siemens Energy GenAdvisor Monitoring and Diagnosis System. GenAdvisor enables data acquisition, storage, and visualization of sensor data. It monitors for partial discharges, interturn short circuits in the rotor, vibrations in the stator end windings, and voltages in the rotor forging as well as currents via the shaft grounding brushes [9].

The GenAdvisor monitoring system offers benefits such as lower maintenance costs due to condition-oriented maintenance, better estimation of maintenance requirements with trend analyses, and optimization of maintenance intervals and maintenance measures as well as operating service life of monitored components [9].

Steam Turbine

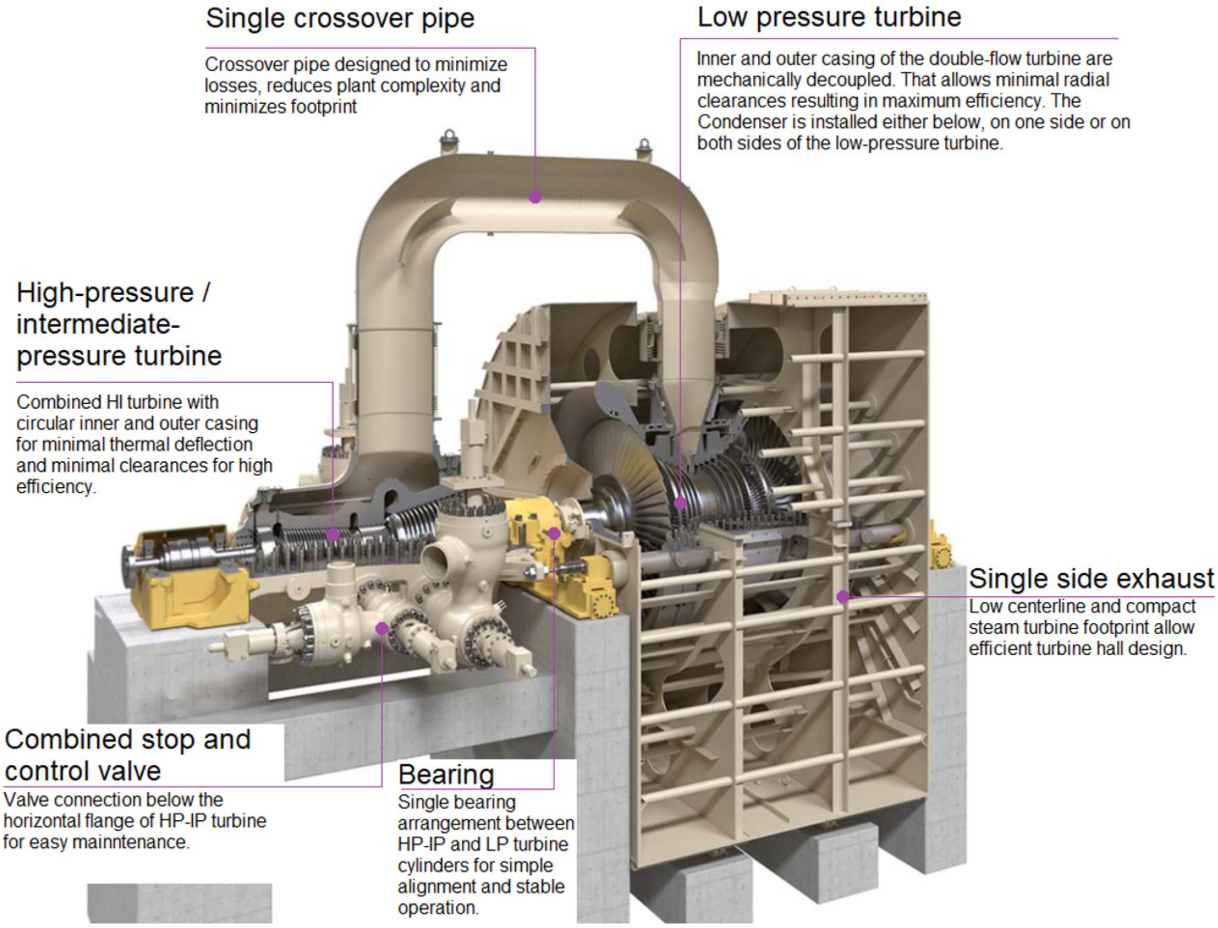

Figure 10 –SST-5000 Overview [10]

The SST-5000 steam turbine configuration at the Cascade project is comprised of one high-pressure turbine, one low-pressure turbine, and one condenser per unit. To maximize efficiency, radial clearances are kept to a minimum by the concentric arrangement of the rotor and casing. Center guides located below the turbine centerline are designed to prevent differential expansion from affecting this concentric alignment. In the combined HP/IP turbine, the center guides are located between the outer casing and the bearing pedestals, and in the LP turbine between the inner casing and the foundations. All displacement transverse to the turbine centerline originates at these guides, central alignment, however, remains unaffected.

Figure 11 - ST Crossover Pipe Installation at Cascade

As part of the single-shaft configuration, each unit is equipped with a SSS clutch to connect and disconnect the steam turbine drive to one end of the generator, which is being driven at the other end by the gas turbine. With the output side of the clutch (the generator and gas turbine) rotating at full speed, the input side of the clutch (the steam turbine) can be started and run up to full speed to automatically engage the clutch and connect the drive. The steam turbine can be shut down independently of the gas turbine and the clutch will automatically disengage to disconnect the drive.

The initials SSS denote the 'Synchro-Self-Shifting' action of the clutch, whereby the clutch driving and driven teeth are phased and then automatically shifted axially into engagement when rotating at precisely the same speed. The clutch disengages as soon as the input speed slows down relative to the output speed.

This design of SSS Clutch has pawls which are inactive at low speeds (below about 600 rpm while the steam turbine is accelerating or 300 rpm while the steam turbine is decelerating) so that the clutch will not engage due to the pawls at low speed. This feature is used so that the gas turbine can be stopped for maintenance whilst the steam turbine continues to be rotated at low speed by its turning gear to cool down. If the SSS Clutch does not automatically disengage, the steam turbine Turning gear motor is capable of reversing, allowing the operators to manually disengage the clutch.

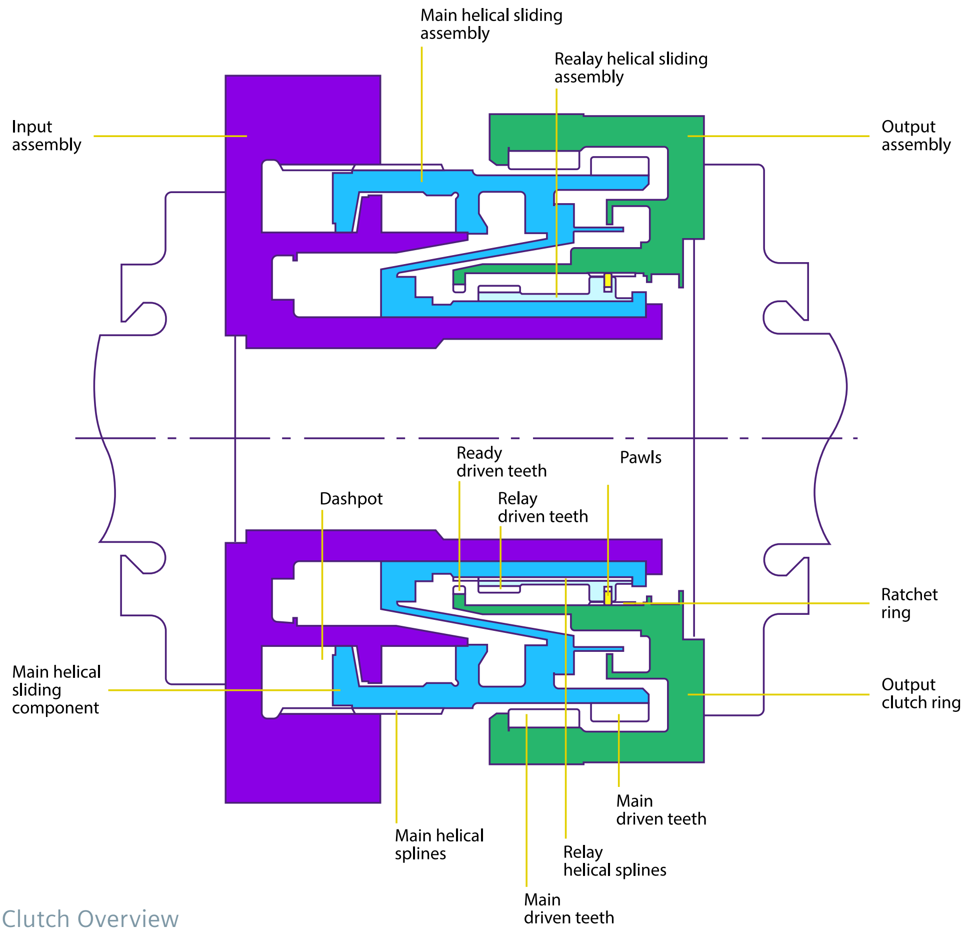

Figure 12 - SSS Clutch Overview

Heat Recovery Steam Generator (HRSG)

The HRSG supplied by NEM Energy b.v. as a sub-supplier to Siemens Energy is a Horizontal Natural Circulation DrumPlusTM design. With NEM's revolutionary DrumPlusTM Fast Start technology, no gas turbine start-up holds are required. The drums' thin wall allows unrestricted ramp-up of the gas turbine. The minimized thickness is a result of the small drum diameter. A key aspect is the external location of the water/ steam separators, allowing an optimal separator design without the limits set by the confined space in the drum [11].

This fast start technology contributes to the plant's overall ability to provide grid firming services. As renewable energy sources penetrate the market, the ability to ensure a stable and reliable power supply becomes increasingly important. The Cascade project is expected to be able to go from zero to combined cycle base load in approximately 50 minutes on a hot start and 180 minutes on a cold start.

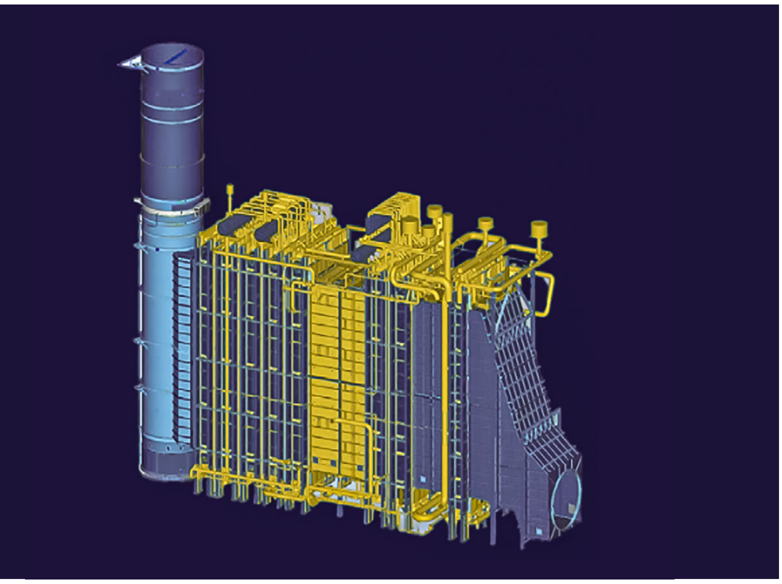

Figure 13 - HRSG DrumPlus Model [11]

Each unit consists of one HRSG with 3 pressure levels (HP, IP, LP) and supplementary firing with natural gas. The HRSG is a horizontal gas flow type, meaning that the gas turbine exhaust gas flow is horizontal, and the tubes are arranged vertically. The HRSG is based on natural circulation and the steam pressures of the HRSG adjust with steam turbine load.

The supplementary firing (duct burner system) is designed to increase the heat input to the HRSG in order to increase the steam production. It is anticipated that the burners will only be in operation with 100% gas turbine load at hot ambient conditions.

Figure 14 - HRSG Penthouse Installation at Cascade

These HRSGs include a penthouse enclosure for heat retention and increased effeciency.

Each HRSG also incorporates a condensate preheater (CPH) which is fed by the condensate extraction pumps. The feedwater to the HP and IP systems is taken from the outlet of the CPH by means of a multistage feedwater pump with intermediate tapping for the IP system.

The Selective Catalytic Reduction (SCR) System installed in each HRSG is designed to convert Nitrogen oxides (NOX) into nitrogen and water vapour. As the flue gas mixes with ammonia and flows over a catalyst bed, the NOX is reduced to Nitrogen (N2) gas and water (H2O) vapor. The NOX reduction system is commonly termed selective catalytic reduction and requires ammonia as a reducing agent. The system utilizes aqueous ammonia, which is mixed with exhaust gas in a vaporizer. Upon being vaporized, this mixture is directed back to the reactor where it is injected upstream of the catalyst bed. After mixing with the flue gas, a chemical reaction occurs as the catalyst bed is encountered.

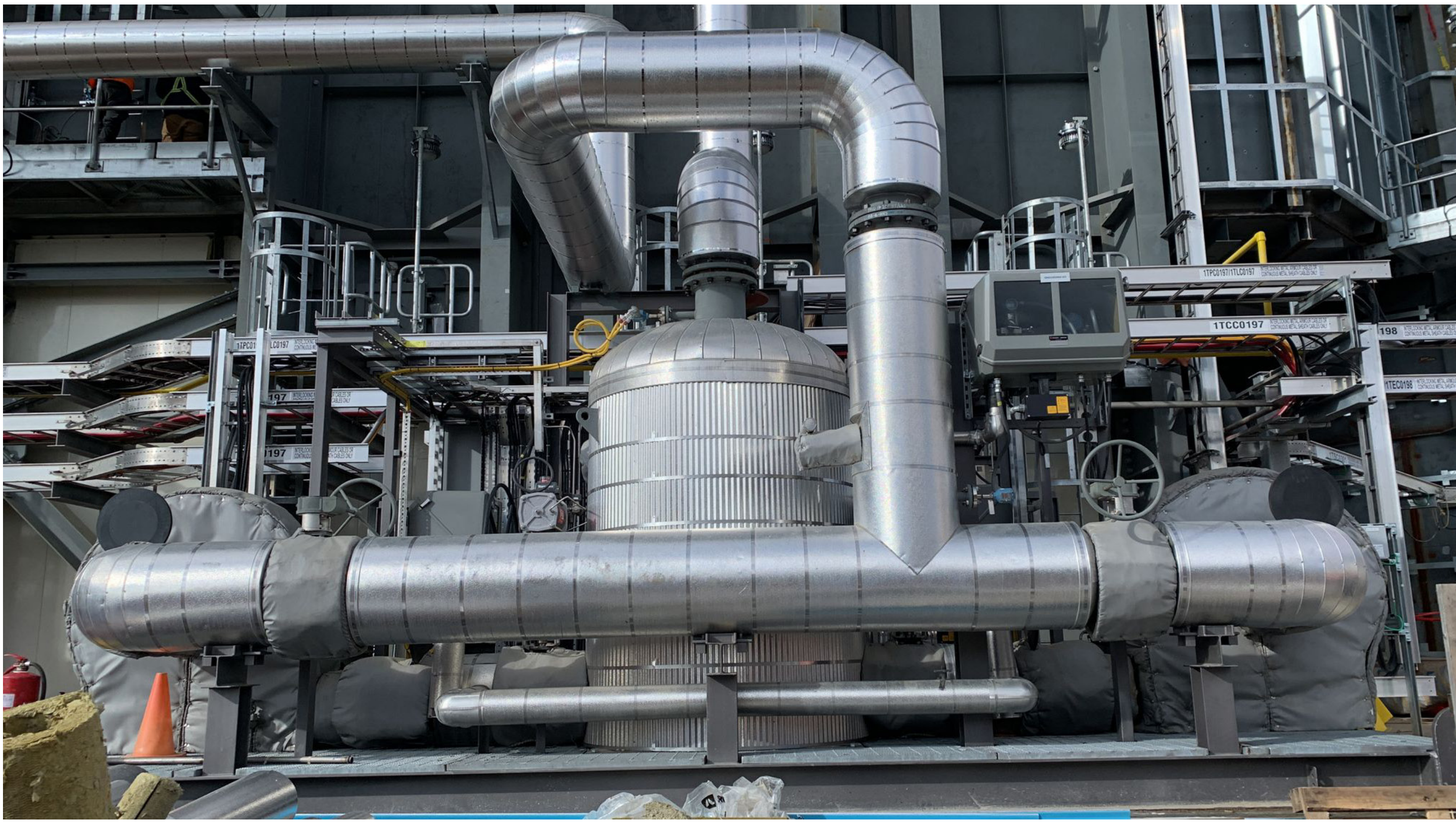

Figure 15 – SCR System at Cascad

The use of ammonia injection can reduce NOX emissions by up to 95% and keep the emissions levels as low as 6 ppmvd and 0.1kg/MW-hr NET per HRSG stack. Compared to coal, the NOX emissions of the Cascade project is expected to be 10-30 times lower than the worst emitters in Canada. At approximately 330 CO2 kg/MW-hr, Plant GROSS, the Cascade project is expected to be three times lower than the worst CO2 emitters by coal in Canada [12]. The combination of emission reducing systems and precise control over the gas turbine systems means that each HRSG can achieve the roughly same emission levels from 40% load to 100% load. This operational flexibility ensures that the Alberta grid can meet the fluctuating demand, while also allowing for future penetration of renewable energy in support of the energy transition to lower Canada's carbon footprint.

Balance of Plant

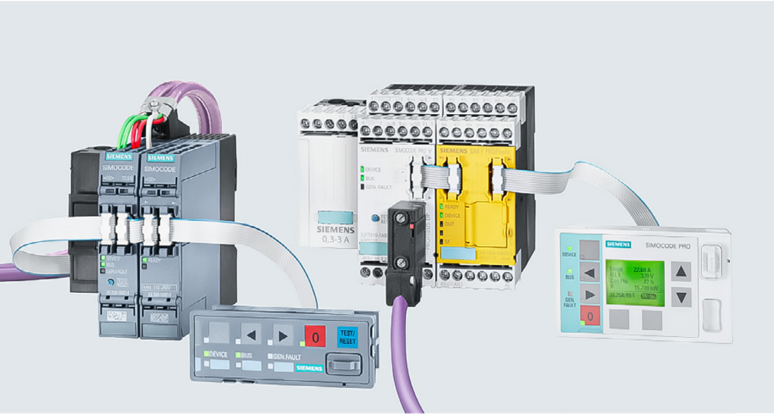

Figure 16 – SIMOCODE [13]

The Balance of Plant (BOP) equipment communicates to the turbines through a Distributed Control System (DCS) and utilizes the latest technology for improved operability, maintainability, and reliability. One such example is the control of the BOP motors. They use SIMOCODE pro (SIRIUS Motor Management and Control Device) from Siemens, which is a flexible and modular motor management system for motors with constant speeds in low-voltage applications. It optimizes the link between the control system and the motor feeder, increases plant availability and allows significant savings to be made during installation, commissioning, operation and maintenance. SIMOCODE pro is installed in the low-voltage switchgear system and links the higher-level automation system and the motor feeder intelligently.

This offers many benefits, such as the quantity of cabling required between the motor feeder and the Programmable Logic Controller (PLC) is reduced significantly by connecting the entire motor feeder to the process control system via the bus. Automated processes are decentralized by means of configurable control and monitoring functions in the feeder. This saves automation system resources and ensures that the feeder is fully functional and protected even if the control system or bus system fails. By recording and monitoring operating, service and diagnostics data in the feeder and process control system, plant availability is increased, and the feeder is easier to service and maintain. By replacing the control circuit hardware with an integrated control function, the quantity of required hardware components with wiring is reduced. This drives down storage costs and limits potential wiring errors [13].

Conclusion

Siemens Energy's mission is to support our customers in transitioning to a more sustainable world, based on our innovative technologies and our ability to turn ideas into reality. The Cascade Power Project aligns with the organization's strategic vision by advancing the province of Alberta's decarbonization efforts in switching from coal to gas fired power generation, while maintaining a reliable power source for ~900,000 homes. Once complete, the Cascade project is expected to be the largest and most efficient combined cycle power plant in the province and demonstrates a pioneering effort with advanced technology. Siemens Energy is proud to support the Cascade Power Project which will provide reliable, efficient, low emitting power generation in Alberta for decades to come.

Acronyms

BOP	Balance Of Plant
CPH	Condensate PreHeater
DCS	Distributed Control System
GCM	Generator Condition Monitoring
GHG	Green House Gas
GT	Gas Turbine
HCO	Hydraulic Clearance Optimizer
HP	High Pressure
HRSG	Heat Recovery Steam Generator
IP	Intermediate Pressure
LP	Low Pressure
LTD	Limited
MW	MegaWatt
MWh	MegaWatt-hour
PCS	Platform Combustion System
PLC	Programmable Logic Controller
PPMV	Parts per million by volume, dry basis
SCR	Selective Catalytic Reduction
SGEN	Siemens Energy Generator
SIMOCODE	SIRIUS Motor Management and Control Device
SSS	Synchro-Self-Shifting
SST	Siemens Energy Steam Turbine
ST	Steam Turbine

Sources

[1] M. Dion, 2023-06-07, Hundreds of Fires Are Out of Control in Canada's Worst-Ever Season, Bloomberg, accessed 2023-08-30, https://www.bloomberg.com/news/articles/2023-06-07/hundreds-of-fires-are-out-of-control-in-canada-s-worst-ever-season

[2] W. Snowdon, 2023-06-15, Wildfire evacuation orders lifting for residents of Edson, Alta., and Yellowhead County, CBC News, accessed 2023-08-30, https://www.cbc.ca/news/canada/edmonton/alberta-wildfire-update-edson-1.6877637

[3] S. Cook, 2022-01-05, Energy Jobs: Workers Flock to Central Alberta Town as 3 Energy Construction Projects Underway in Area, EnergyNow, accessed 2023-08-30 https://energynow.ca/2022/01/energy-jobs-workers-flock-to-central-alberta-town-as-3-energy-construction-projects-underway-in-area/

[4] Kineticor, n.d., Cascade Power Project, accessed 2023-08-30, https://kineticor.ca/operation/cascade-power-project/

[5] S. Patel, 2020-07-01, Siemens' Roadmap to 100% Hydrogen Gas Turbines, Power Magazine, accessed 2023-08-30, https://www.powermag.com/siemens-roadmap-to-100-hydrogen-gas-turbines/

[6] Siemens Energy, n.d., SGT6-8000H Heavy-duty gas turbine, accessed 2023-08-30, https://www.siemens-energy.com/global/en/offerings/power-generation/gas-turbines/sgt6-8000h.html

[7] A. Larson, 2018-07-01, Benefits of Single-Shaft Combined Cycle Power Plants, Power Magazine, accessed 2023-08-30, https://www.powermag.com/benefits-of-single-shaft-combined-cycle-power-plants/

[8] Siemens Energy, n.d., SGen-3000W generator series, accessed 2023-08-30 https://www.siemens-energy.com/global/en/offerings/power-generation/generators/sgen-3000w.html

[9] Siemens AG, 2017, GenAdvisor Monitoring and Diagnosis System, accessed 2023-08-30, https://assets.siemens-energy.com/siemens/assets/api/uuid:c62deae0-102b-45cf-9e9e-3cd940df8eb0/genadvisor-monitoring-diagnostics-system-pspg-b10216-00-7600-en-.pdf

[10] Siemens Energy, n.d., Utility steam turbines, accessed 2023-08-30, https://www.siemens-energy.com/global/en/offerings/power-generation/steam-turbines/utility-steam-turbines.html

[11] NEM Energy B.V., n.d., Heat Recovery, accessed 2023-08-30, https://nem-energy.com/wp-content/uploads/2023/02/NEM-Energy_Heat-Recovery_Brochure.pdf

[12] Commission for Environmental Cooperation, 2011-10-01, North American Power Plant Air Emissions, accessed 2023-08-30 http://www.cec.org/files/documents/publications/10236-north-american-power-plant-air-emissions-en.pdf

[13] Siemens AG, 2023-02-01, Industrial Controls Motor management and controlDevices SIMOCODE pro System Manual, accessed 2023-08-30, https://cache.industry.siemens.com/dl/files/957/109743957/att_918220/v2/Systemhandbuch_SIMOCODE_pro_en-US.pdf

Published by

Siemens Energy Canada Limited

For more information, please visit our website:
siemens-energy.ca