CIGRE-489

2022 CIGRE Canada Conference & Expo
Calgary, Alberta, Oct.31 – Nov. 3, 2022

Application of Static Synchronous Compensator (STATCOM) on the Yukon Integrated System

Ben Korbutiak, Arden Spachynski, ATCO Canada
Nihal Costa, Yukon Energy Corporation Canada
Robert Isbister Hitachi Energy Canada

SUMMARY

The Yukon Energy Corporation (YEC) is a publicly owned electrical utility that operates as a business, at arm's length from the Yukon government. Headquartered near the Whitehorse Rapids hydro plant in Whitehorse, it is the main generator and transmitter of electrical energy in the Yukon. Much of the electricity produced by YEC is from renewable sources, primarily from hydro plants located in Whitehorse, Aishihik and Mayo.

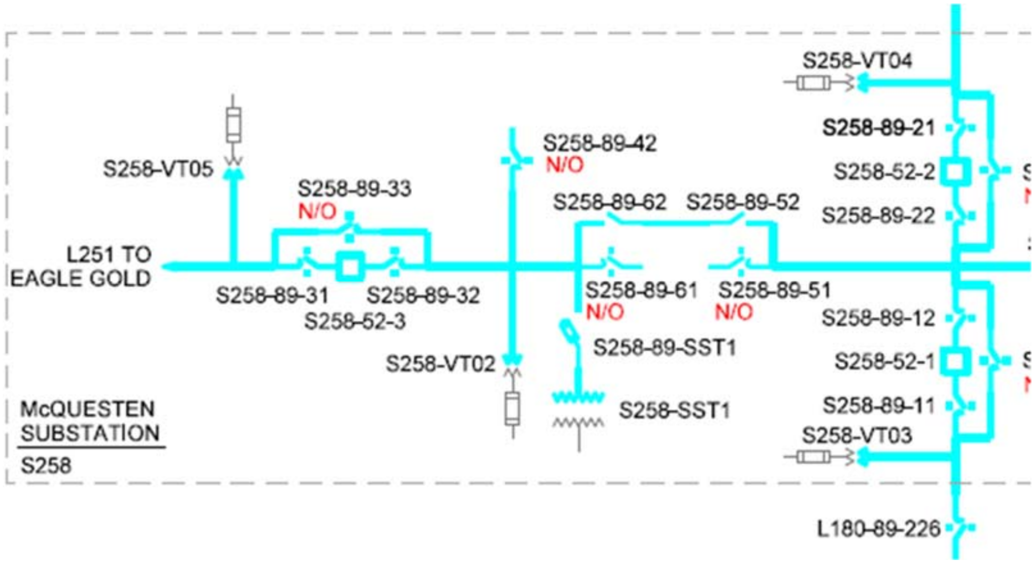
Situated approximately 85 kilometres north-northeast of the village of Mayo, the Eagle Gold Mine went into operation in 2018 utilizing a three-stage crushing plant in its extraction process. At the point of coupling with the YEC power grid, substation, the provided short circuit level is weak compared to the capacity of the Eagle Gold load and hence considerations as how to mitigate impending voltage fluctuations on the YEC system had to be evaluated. This paper will outline the project initiated by YEC for the selection and installation of the means for voltage stabilization in the Northeast section of its power grid with the impending increases south-north power swings with the Eagle Gold facility in full operation.

KEYWORDS

Static Synchronous Compensator (STATCOM), Reactive Power, Megavolt-ampere reactive (Mvar), Insulated Gate Commutated Thyristor (IGCT)

ben.korbutiak@atco.com

The Eagle Gold facility is supplied by a 69kV feed out of nearby McQuesten substation which connects back to Mayo substation at 69kV. Mayo substation is in turn connected to the 138/69kV Stuart Crossing South substation located approximately 50km south of the village of Mayo.



1. **System Evaluation**

   With the weak system strength at the McQuesten substation and the nature of the loading at the Eagle Gold facility, voltage fluctuations in the northern section of the YEC grid were becoming inevitable as the mining operation approached full capacity. Several options for voltage stabilization were initially studied. These included under-frequency load shedding schemes, fixed reactive components (capacitors, reactors), remedial action schemes (RAS) and dynamic reactive support at the 138kV bus of YEC's Stewart Crossing South Substation.

   A System Integration Study (SIS) suggested a Static Var Compensator (SVC) leading to the performance of a cost/benefit analysis , evaluating the options of an SVC, STATCOM, and synchronous condenser. The most viable economic and technically effective solution was found to be a STATCOM rated at +14 MVar (capacitive) and -10 MVar (inductive), installed on the the Stewart Crossing South 138 kV bus.

2. **Project Execution**

   YEC issued separate Requests for Proposals for "The Preparation Of a Detailed STATCOM Specification and Review of Vendor Bids" for Yukon Energy Corporation" and "Owner's Engineer for STATCOM for Yukon Energy Corporation". Based on previous experience with several internal SVC and STATCOM projects, including RFP preparation, Owner's Engineer, and operator, ATCO was the successful bidder on both RFPs.

The combined scope of work on ATCO's behalf included preparation of the technical specification and Request for Proposal (RFP), review of vendor bids, selection recommendation, system studies, review of vendors's designs, participation in factory acceptance tests (FAT), on site commissioning support and in service performance analysis. These activities were all performed with participation by YEC reprsentatives.

In addition, ATCO had involvment with the system connection between the McQuesten substation and the Eagle Gold facility having been sole sourced by YEC and Eagle Gold in 2018 to modify the substation design to a 69kV switching station for the connection and undertake the construction. For the connection of the STATCOM to the Stewart Crossing South substation, ATCO's role as Owner's Engineer included the vendor selection and oversight of the design, construction and commissioning of the modifications at the 138kV for the interconnection.

Of the submitted responses to the RFP, the most economical and technically feasible proposal was from Hitachi Energy (Hitachi) which was ABB Power Grids at the time. Hitachi offered a containerized option of a +/- 14 MVar STATCOM based on the PCS 6000 containerized system.

2.1. Challenges

- Environmental

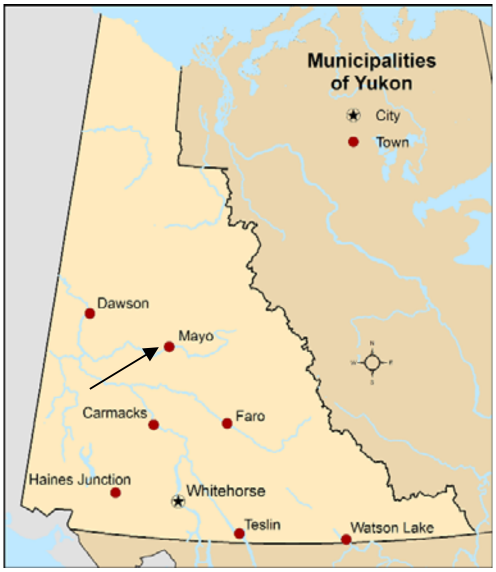
In the Yukon territory, the average air temperature over a 24 hour period in the coldest month, January, is -55°C. This presented a challenge to design the container and outdoor heat exchanger to withstand and perform in this extreme temperature. In addition, the Technical Specification of the RFP stipulated all outdoor major electrical apparatus, including the power transformer, to be rated down to -60°C.

- System

At the point of common coupling (PCC), the 138kV bus at the Stewart Crossing South substation, both the minimum and maximum short circuit levels are very weak and the system is also succeptible to frequency swings and voltage unbalances. The STATCOM performance requirements, as stipulated in the Technical Specification, had to be met for the complete range of short circuit levels, frequency variations of between 56-66 Hz, variations of operating voltages between 124-163kV and voltage imbalances, negative and zero sequence, up to 2% of nominal voltage. In addition, ATCO performed a Harmonic Impedance Study at the Stewart Crossing 138kV and this data, along with actual measured background harmonics at that location were submitted to the Vendor with the stipulation that STATCOM operation would not result in resonance conditions over the entire frequency spectrum of the study and measured harmonics.

- Geographical

The GPS coordinates of the designated STATCOM site are 63°20′34.4″ N, 136°40′46.8.W ″ near the village of Mayo.



Isolated location, approximately 4 ½ hour drive from Whitehorse.

- COVID

Upon award, the design phase of the project commenced in September of 2020, in the midst of the COVID pandemic. Subsequent on going travel restrictions impacted the ability to hold in person design review meetings, witness factory acceptance tests at the acutal locations, deployment of construction personnel, and equipment delivery issues due to the global shipping bottlenecks occuring at the time.

2.2. Performance Requirements

The Technical Specification stipulated performance criteria in the following areas:

- Step response:
  - elapsed time to reach 90% of its step magnitude in response to step change in reference voltage
  - maximum overshoot of instantaneous bus voltage relative to the magnitude of the voltage reference change
  - settling time, being the elapsed time to reach within 5% of the magnitude of the voltage reference change
- Start-up voltage:
  - Voltage reference to default to the existing system voltage at the 138kV bus
- Short Circuit Recovery Overvoltage Limit:
  - Following a close in 3 phase fault with successful reclosing, the recovery overvoltage to be within 6% of pre-fault voltage
- Overvoltage/Undervoltage Operation:
  - Defined minimum voltage to which the STATCOM will continue to generate reactive power

- Defined overvoltages to which the STATCOM will continue safe operation

The specified performance requirements in the above categories were very prescriptive and a challenge to fulfill due to the characteristics of the AC network.

2.3. Interfaces

- AC System Interconnection

The STATCOM connects to the 138kV bus at Stewart Crossing South substation with the point of interface at the 138kV STATCOM transformer arrestors . ATCO had the role of Owner's Engineer for the design, construction and commissioning of all related substation modifications, including civil, structural and electrical, encompassing a breaker addition with associated switches, instrument transformer additions, station service transformer, busbar expansion and associated interface protection and control design.

The breaker addition expanded the existing ring bus configuration but did not serve as a dedicated STATCOM breaker as the connection was now at two breaker node. This added some complication to the automatic start up sequence.

- SCADA

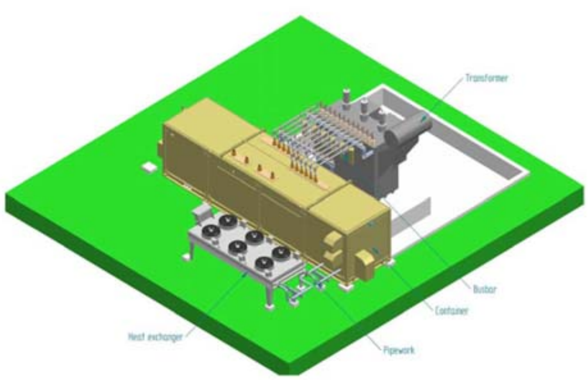
The STATCOM control system interfaces with the YEC SCADA system via DNP3 protocol and through a SEL-3530 Real Time Automation Controller located at the Stewart Crossing Substation as the remote control interface. Operators at the YEC control center were provided with control functions, status indications and alarms.

- Station Service

The source of station service is a transformer originating in the Stewart Crossing Substation switchyard.

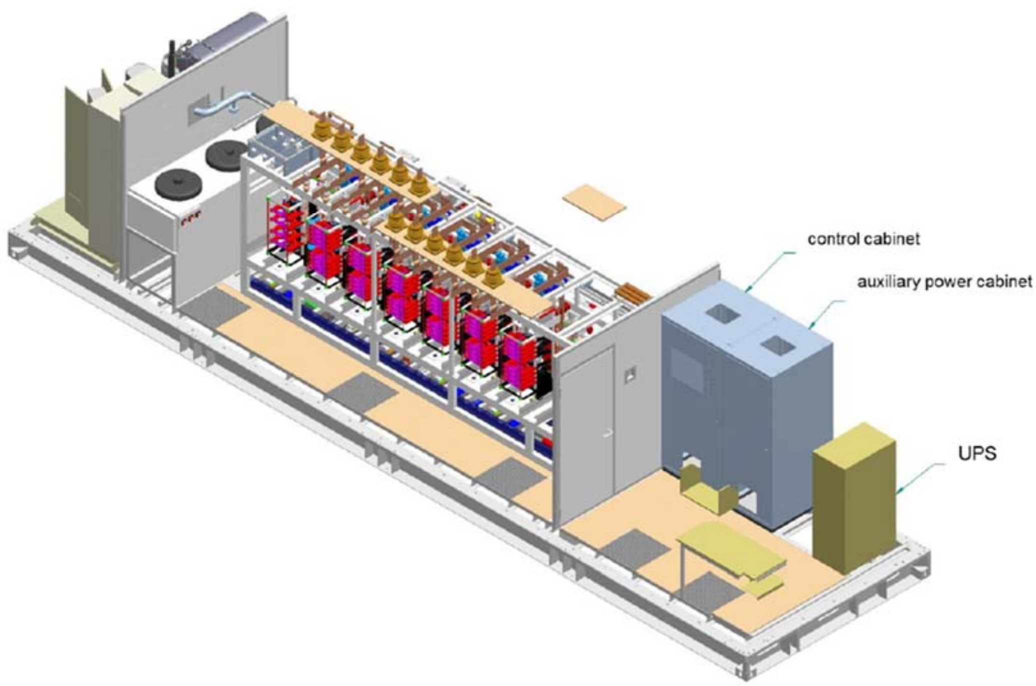
3. Design Features

Overall Layout



Container

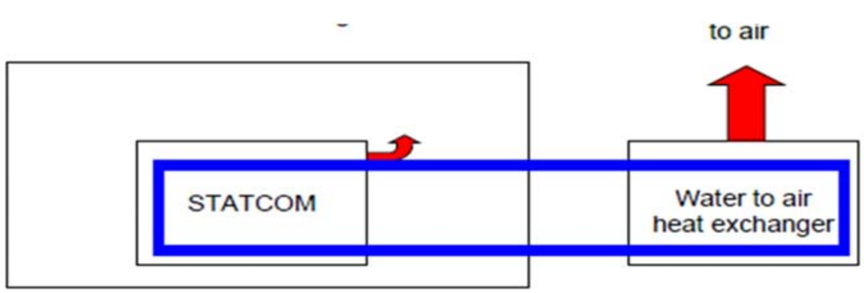
- System design and final assembly by Hitachi Energy, Turgi Switzerland
- Container rated for -60…+40°C
- Container layout:



  - Converter room is interlocked with operation
  - Cooling unit is accessed through outside door and can be during operation
  - Local operation is possible at local control terminal

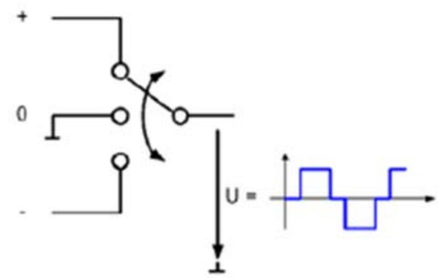
- Cooling System

  - Closed loop de-ionized water/glycol system
  - Two redundant water pumps
  - External water to air heat exchanger

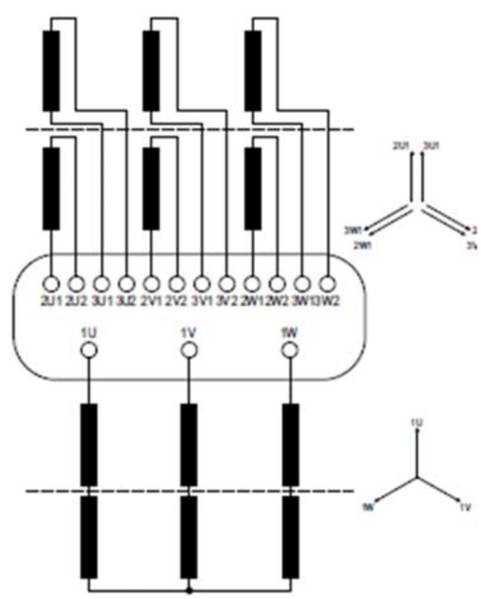


- Bypass valve in the cooling circuit diverts water circulation to within inside the container only for very low ambient temperatures
- Cooling room equipped with electrical flaps that are controlled automatically to seal the container in case of low ambient temperatures.

- Converter
  - Integrated Gate Commutated Thyristor (IGCT) technology
  - Power Electronic Building Block (PEBB) configuration
  - Three-level phase modules to produce an AC voltage from a DC source. Essentially, a switch with a three position output, positive (+), zero (0) or negative potential of the DC source:



- Transformer
  - Rated power – 14 / 2x7.02 MVA
  - Special connection to accommodate converter:



  - Rated voltage: HV – 138,000 V, LV1 & LV2 – 2589 V

4. Control Parameters

- Voltage Control Mode – Voltage Reference (Vref) range: 0.95…1.1 p.u. , slope: 2%....7%
- Reactive Power Control Mode – Reactive power demand -14…+14 MVar

5. Cold Start Procedure

Special measures are incorporated for operation at temperatures below -30°C and a cold start procedure is developed for specific ranges of low ambient temperatures.

- Container
  - 3 rooms with independent room cooling; limited cooling required for rooms during cold operation
  - Heaters installed in rooms to provide additional heating
- Cooling Water Circuit
  - Controlled bypass valve is used to allow water circulation only inside the container, bypassing external heat exchangers, at low ambient temperatures
  - Coolant temperature (T) monitored to regulate speed of outdoor fans and bypass valve operation such that at T< 12°C internal circulation only

- Heat Exchanger
  - Fans equipped with ring heaters
  - Added insulation provided for external pipes

- Transformer
  - Oil Nynas 10XN – excellent low temperature properties, low viscosity
  - Bottom oil temperature measured for control operation
  - Oil pipes between transformer, radiator and conservator are insulated and equipped with electrical pipe heating
  - Radiators equipped with heaters on top and bottom and turn on at temperatures below -35°C

- Operation
  - In ambient temperature range -30 …+40°C the system is in normal operation
  - In ambient temperature range -45 …-30°C outdoor fans will not operate, bypass valve may operate to keep coolant temperature above 10°C
  - Additional heaters may turn on to keep room temeratures above 5°C
  - Alarm is raised if transformer bottom oil temperature drops below -35°C. If so, STATCOM may be turned to Q mode to increase transformer loading
  - For cold start at ambient temperatures -60…-45°C pre-loading at 30% of rated power is envoked to bring transformer

bottom oil temperature to above -35°C provided bottom oil temperature is >-45°C to begin with. At bottom oil temperature <-45°C no load operation required to bring oil temperature up to -35°C

6. Factory Acceptance Tests

- Transformer
  - Performed in early June of 2021 at the Tranformer facility
  - Witnessed virtually due to COVID travel restrictions at the time by YEC and ATCO personnel

- Controls
  - Performed in mid June of 2021 at the Hitachi Energy facility in Turgi, Switzerland
  - Witnessed virtually due to COVID travel restrictions at the time by YEC and ATCO personnel

7. Site Commissioning

- Pre-commissioning commenced in early October of 2021, concluding with on line performance tests at the end of the month
- Testing witnessed by YEC and ATCO personnel, and included end to end SCADA verification of alarms, analog signals and control functions with the YEC Control Center

8. In Service

- Initial 30 day trial operation period commenced in early November of 2021
- Performed correctly for system events that occurred during the period with some tuning required for negative sequence override
- Extreme temperatures late in the month and into early December caused cooling sytem related outage due to pressure drops because of infow of large amount of cold coolant during switchoff of bypass valve. Temporary modifications made to modulate bypass valve operation to control volume of inflow.
- Trial period resumed on December 23rd and final acceptance issued 30 days later
- Permanent modifications to bypass valve operation completed in May of 2022
- To date, the performance of the STATCOM has met all dynamic performance requirements

9. Conclusion

Project successfully executed, numerous constraints and factors notwithstanding:

- Remote location of site
- Extreme climatic conditions
- Interconnecting to weak AC network
- Design, construction and commissioning during the midst of COVID pandemic
  - Design reviews conducted virtually
  - FATs witnessed virtually

- Travel restrictions and protocols for on site construction and commissioning personnel
- Global shipping issues