Fort McMurray Area Transmission Bulk System Reinforcement

Functional Specification

File No. RP-05-838

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APEGGA Permit to Practice P-8200

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1. INTRODUCTION

This Alberta Electric System Operator (“AESO”) Functional Specification (“the Specification”) is intended to provide an overview of the specifications that will be utilized in the RFQ/RFP as part of the competitive process for the development of new transmission facilities for interconnection with the Alberta Transmission System (“ATS”). The Specification also serves to delineate the work to be completed by various parties involved in the development of such facilities, provides reference to applicable standards and guidelines to be applied in the design of such facilities, outlines the electrical environment in which such facilities will operate, and provides reference to the applicable rules and templates for the format required for proposals and estimates to be submitted by the proponents.

2. DATA DISCLAIMER

The AESO has taken reasonable steps to verify this data where possible and believes it to be accurate.

3. PROPOSAL AND ESTIMATE

THIS DOCUMENT IS FOR ILLUSTRATIVE PURPOSES ONLY. THE FINAL FUNCTIONAL SPECIFICATION WILL BE INCLUDED IN THE RFP UPON APPROVAL AND IMPLEMENTATION OF THE COMPETITIVE PROCESS.

4. PROJECT OVERVIEW

4.1 PROPOSED FACILITY ADDITIONS

The objective of Fort McMurray area transmission bulk system reinforcement project (the "project") is to increase transfer capability into the Fort McMurray area to supply load growth in the Fort McMurray area.

The project consists of three stages of development. Projects identified in italics are NOT considered components of the CTI Fort McMurray project. They are provided to identify additional facilities that will influence the development of the Fort McMurray CTI project. The AESO believes this information is required as bidders consider this project. Facilities identified in italics will be direct assigned to incumbent TFOs.

The proposed facility additions and modifications of the project include the following:

Stage 1A (refer to Figure 3):

- Construct 500kV substation Thickwood Hills 951S with one (1) 500 kV circuit breaker, one 500 kV 200 MVAr line-end reactor (size to be determined).
- Construct approximately 100 km of 500 kV transmission line 9L44 from Thickwood Hills 951S to Livock 939S using single circuit structures. The transmission line will be operated at 240 kV.
- *Add one (1) 240 kV circuit breaker at 240 kV Livock 939S substation.*
- The target In Service Date (ISD) of stage 1A is approximately 2017.

Stage 1B (refer to Figure 4):

- Add one (1) 500/240 kV 1200 MVA transformer, one 500 kV circuit breaker to Thickwood Hills 951S.
- Construct approximately 390 km of 500 kV transmission line from Genesee 330P to Livock 939S and connect the line to the 500 kV transmission line between Livock 939S and Thickwood Hills 951S.
- *Add two 500 kV circuit breakers and one 500 kV 200 MVAr line-end reactor at Genesee 330P.*
- The target In Service Date (ISD) of stage 1B is approximately 2019.

<u>Stage 2 (refer to Figure 5):</u>

- Expand the Thickwood Hills 951S with the 2nd 500/240 kV 1200 MVA transformer, two (2) 500 kV circuit breakers, one 500 kV 200 MVAr line-end reactor.
- Construct approximately 410 km of 500 kV transmission line from Thickwood Hills 951S to Heartland 12S.
- *Add two 500 kV circuit breakers and one (1) 500 kV 200 MVAr line-end reactor at Heartland 12S.*
- The target In Service Date (ISD) of stage 2 is approximately 2021.

4.2 System Development Prior to the Project

The major system development prior to the project is expected to include the following additions and modifications (refer to Figure 2):

<u>Edmonton Region 240 kV Line Upgrades Project:</u>

- Add one 600 MVA 240 kV phase shifting transformer on the existing 240 kV transmission line 9L57 at Livock 939S.

<u>Northeast Voltage Support Project:</u>

- Add one 240 kV 100 MVAr capacitor bank at Dover 888S.
- Add one 240 kV 100 MVAr capacitor bank at Whitefish Lake 825S.
- Add two 138 kV 30 MVAr capacitor bank at Leismer 72S.

<u>ET Energy Poplar Island Project:</u>

- Construct 240 kV sub station Poplar Island 965S.

<u>Livock 240/144kV Reinforcement Project:</u>

- Construct 240 kV substation Livock 939S and re-terminate the Wesley-Brintnell line from Brintnell 876S to Livock 939S.

<u>Heartland Project:</u>

- Construct 500 kV substation Heartland 12S with one (1) 500/240 kV 1200 MVA transformers and four (4) 500 kV circuit breakers.
- Construct two 500 kV transmission lines from Ellerslie 89S to Heartland 12S.

<u>Fort McMurray 240kV Transmission Development Project:</u>

- Construct 240kV portion of the Thickwood Hills 951S substation, including 240kV switch yard, one 240kV SVC (size to be determined) and two 240kV capacitor banks (size to be determined).

- Add one 240kV transmission line from Thickwood Hills 951S to Poplar Island 965S.
- Cut the existing 240 kV transmission line 9L07 open near Thickwood Hills 951S and terminate both ends into Thickwood Hills 951S.
- Cut the existing 240 kV transmission line 9L58 between Ruth Lake 848S and Dover 888S. Construct approximately 32 km of 240 kV transmission line using single circuit structures to terminate both ends of 9L58 line into Thickwood Hills 951S.

4.3 Ultimate System Development

The ultimate system development of the Fort McMurray area bulk system could include the following additions and modifications (refer to Figure 6):

- Add 500 kV series capacitor banks to the 500 kV transmission lines from Thickwood Hills 951S to Genesee 330P and from Thickwood Hills 951S to Heartland 12S.
- Increase the capacity of each capacitor bank at Thickwood Hills 951S. Add dedicated circuit breakers to the 500 kV line-end reactors.
- Relocate the phase shifting transformer at Livock 939S from 9L57 to 9L15.

5. THE ULTIMATE DEVELOPMENT REPRESENTS THE POTENTIAL LONG TERM SYSTEM DEVELOPMENT, AND IS INCLUDED FOR SUBSTATION DEVELOPMENT PLANNING PURPOSES ONLY. SCOPE OF WORK

5.1 General

The proponent is accountable for all engineering, design, land or land-use acquisition, siting, applicable regulatory approvals and permits, material procurement, construction, commissioning, and associated permitting requirements for their facilities. The proponent shall coordinate as required on all design details (e.g., protection & control, grounding, insulation, point of interconnection, site layout, power quality, etc.) and develop Joint Operating Procedures and/or Interconnection Agreements as required to ensure that interconnected facilities are operated safely and reliably.

All final design and as-built facility information shall be supplied in the format and content as required by the AESO for purposes of updating and maintaining the AESO's technical records and system models. This information shall be submitted under signature of a registered Professional Engineer in Alberta who is representing the facility owner and is assuming responsibility for the preparation and accuracy of the submission. The AESO accepts no responsibility for facilities designed by or for any third party, or installed on a third parties behalf, to accomplish the interconnection. The facility owners shall ensure that their facilities have been inspected and declared safe for operation prior to energization. No facilities are to be energized until an Energization Certificate has been issued by the AESO.

5.2 Standards

All work undertaken by the proponent must be designed, constructed, and operated to meet the functional requirements of the Specification and all applicable standards, guidelines, codes and regulations governing such installations including, but not limited those listed below. All AESO documentation can be found on the AESO website (www.aeso.ca).

- AESO Operating Policies and Procedures
- AESO Measurement System Standard Rev 1 (dated September 18, 2007)

- AESO Generation and Load Interconnection Standard (dated September 19, 2006)
- Technical Requirements (Part 3) for Connecting Transmission Facilities (dated December 2, 1999)
- AESO Alberta Interconnected Electric System (AIES) Protection Standard (dated December 1, 2004)
- AESO Operational Voice Communication Standard (dated September 7, 2005)
- AESO SCADA Standard (dated September 6, 2005)
- AESO Transmission Modeling Data Requirements (dated April 29, 2003)
- AESO PMU Requirements Version 2.0 (dated July 6, 2005)
- AESO Transmission Line Standard DRAFT (dated April 24, 2007)
- AESO Alberta Reliability Standards (in effect: January 22, 2010)

In case there is a discrepancy between this functional specification and the aforementioned standards, this functional specification shall be the overriding requirement.

5.3 TRANSMISSION EQUIPMENT SPECIFICATIONS

5.3.1 General Environmental and Electrical Ratings

All transmission equipment must meet the following minimum specifications:

- Temperature rating of -50C for all outdoor equipment
- Minimum and maximum operating voltage ratings as indicated in Table 1
- Minimum continuous current ratings as indicated in Table 2
- Maximum fault levels as indicated in Table 3

Table 1: Minimum & Maximum Continuous Equipment Operating Voltages (kV)

Area	500 kV	240 kV
Minimum	500	220
Maximum	550	285

Table 2: Minimum Continuous Equipment Current Ratings (A)

Component	500 kV	240 kV
Main Bus[1]	4000	4600
Cross Bus[2]	3000	3000
Transmission Termination[3]	3000	3000
Capacitor Bank Termination[4]	N/A	600

1. Main bus includes all sections of ring bus scheme and single bus of simple bus scheme.
2. Cross bus includes diameter sections of breaker and a half or breaker and a third schemes.
3. Transmission termination includes all equipment from the connection to the cross bus up to the transmission line connection point, usually the transmission line disconnect switch.

4. Capacitor bank termination includes circuit breaker, isolating switches, CT's, pipe bus, risers, jumpers and connectors.

Table 3: Maximum Fault Levels (kA)

Nominal Voltage	500 kV	240 kV
Maximum Fault Levels	31.5	40

5.3.2 Circuit Breaker

A 500 kV circuit breaker shall satisfy the following specifications:

- The rated voltage shall be no less than the maximum continuous equipment operating voltages listed in Table 1
- The rated continuous operating current shall be no less than the minimum continuous equipment current ratings listed in Table 2
- The minimum symmetrical short-circuit breaking current rating shall be no less than the maximum fault levels listed in Table 3
- The nominal interrupting time shall be no more than 2 cycles. The nominal interrupting time is defined as the time interval between when a trip signal is received by the trip coil of the circuit breaker and when the arc is extinguished in all poles. The nominal interrupting time is applicable to interrupting currents with a magnitude ranges from zero to the rated interrupting current.
- Be capable of single-pole operation

5.4 Scope of Work – Stage 1A

5.4.1 500 kV Transmission Line 9L44

The scope of work for 500 kV transmission line 9L44 between Thickwood Hills 951S and Livock 939S includes the following (refer to Figure 3):

- Construct approximately 100 km of 500 kV transmission line 9L44 from Thickwood Hills 951S to Livock 939S (the "line 9L44") using single circuit structures. The circuit will be energized at 240 kV at stage 1A and the circuit will be numbered as 12L44 after it is energized to 500 kV in the future.
- The minimum continuous capacity of the line 9L44 shall be no less than 2400 MVA (2771 A at 500 kV). The actual line ratings shall be submitted to AESO in the form of a Summer rating at 30 degrees Celsius and a Winter rating at 0 degrees Celsius. The ratings shall be for an assumed wind speed of 0.6 m/s.
- The design and routing of the line 9L44 shall allow live line maintenance and shall consider that the line could be series compensated in the future. For example, open right-of-way on one side may be considered for line routing to accommodate live line maintenance requirement.
- The line 9L44 shall have optical fiber composite overhead ground wire (OPGW).

- The detail design of the structures and line optimization will be undertaken by the proponent.

- From a system reliability perspective, the minimum separation distance between structures of parallel transmission lines is to be selected so that a 240 kV structure failure will not affect a 500 kV structure, however a 500 kV structure failure can affect a 240 kV structure. The reason for this is to avoid having a 'lower' reliability transmission line affect a 'higher' reliability line.

- In circumstances where a 500 kV transmission line crosses over one or more 240 kV transmission lines, a 500 kV conductor failure should not affect more than one 240 kV transmission circuit. In locations where this criterion is impractical to achieve, TFO is to advise the AESO of the specific details.

- The demarcation points of line 9L44 are the first transmission line structures outside the fence of Thickwood Hills 951S and Livock 939S. Line 9L44 between the two demarcation points will be owned by the proponent. Line 9L44 outside the demarcation point will be deemed as part of substation Thickwood Hills 951S or Livock 939S and will be owned by ATCO.

5.4.2 500kV Substation Thickwood Hills 951S

The scope of work at Thickwood Hills 951S includes the following (refer to Figure 3):

<u>Transmission Equipment:</u>

- Add one (1) 500 kV circuit breaker meeting the specification outlined in section 5.3.2
- Add 500 kV bus into simple bus configuration that can be developed into folded breaker and a half configuration in the future. Each diameter of the folded breaker and a half shall have space for two line bays at either side of the bus.
- Add one 500 kV 200 MVAr line-end reactor with the provision of space to add a dedicated reactor switching breaker in the future. The size and type of the line-end reactor, as well as the neutral reactor for the line-end reactor need to be determined through future studies.
- The design of the substation shall consider the future and ultimate development of the project, as outlined in sections 4.3 and 4.4.

<u>Protection and Control:</u>

- The fault clearing system needs to cover all fault types and meet the associated maximum fault clearing times.
- The fault clearing system is generally defined to include:
    - Current and voltage instrument transformers
    - Protection relays
    - Teleprotection communication equipment
    - Circuit breakers
    - All functionally associated equipment

- Anticipated fault clearing times are to be calculated by adding the maximum operating time of all applicable equipment comprising the fault clearing system, without additional undefined time margin.
- The maximum operating time for each type of equipment, where applicable, is to include the variation of operating time associated with all possible fault inception times within the 60 Hz waveform.
- The actual maximum operating time for the equipment is to be confirmed through test measurement of the equipment, with the applicable specific configuration and settings applied. Results of the test measurement shall be provided to the AESO.
- The source impedance ratio (SIR) is to be included when determining equipment operating speeds to meet the required maximum fault clearing times.
- A single point of failure within the fault clearing system shall not cause a loss or diminishment of the functionality, with the exception of the primary winding of instrument transformers.
- The fault clearing system also needs to meet the functional requirement specified by the AESO AIES Protection Standard (“the Standard”), with the following exceptions:
    - The maximum fault clearing times described within this Functional Specification are to be used
    - The types of fault detection equipment or methods is not restricted to those described within the Standard
- The existing fault clearing, control systems and settings are to be reviewed and modified to accommodate the proposed equipment additions.
- If the fault clearing system includes teleprotection communication equipment, the associated teleprotection communication equipment is to meet the requirements in the AESO standards and the following WECC guidelines:
    - WECC Guidelines for the Design of Critical Communications Circuits (revised October 2002)
    - WECC Communications Systems Performance Guide for Protective Relaying Application (dated November 2001)
- In case there is a discrepancy between AESO standards and the WECC guidelines regarding communication requirements, the discrepancy shall be brought to the AESO for review.

SCADA:

- Provide SCADA information for the proposed equipment additions and modifications as required by the AESO SCADA Standard.
- Control Center data mapping and verification of SCADA information for the proposed equipment additions and modifications.

5.4.3 240 kV Substation Livock 939S – THIS IS NOT PART OF THE BID PACKAGE. IT HAS BEEN PROVIDED FOR INFORMATIONAL PURPOSES ONLY.

The scope of work at Livock 939S includes the following (refer to Figure 3):

<u>Transmission Equipment:</u>

- Add one (1) 240 kV circuit breaker meeting the specification outlined in section 5.3.2 to terminate line 9L44

<u>Protection and Control:</u>

- The fault clearing system needs to cover all fault types and meet the associated maximum fault clearing times listed in the tables above.
- The fault clearing system is generally defined to include:
  - Current and voltage instrument transformers
  - Protection relays
  - Teleprotection communication equipment
  - Circuit breakers
  - All functionally associated equipment
- Anticipated fault clearing times are to be calculated by adding the maximum operating time of all applicable equipment comprising the fault clearing system, without additional undefined time margin.
- The maximum operating time for each type of equipment, where applicable, is to include the variation of operating time associated with all possible fault inception times within the 60 Hz waveform.
- The actual maximum operating time for the equipment is to be confirmed through test measurement of the equipment, with the applicable specific configuration and settings applied. Results of the test measurement shall be provided to the AESO.
- The source impedance ratio (SIR) is to be included when determining equipment operating speeds to meet the required maximum fault clearing times.
- A single point of failure within the fault clearing system shall not cause a loss or diminishment of the functionality, with the exception of the primary winding of instrument transformers.
- The fault clearing system also needs to meet the functional requirement specified by the AESO AIES Protection Standard ("the Standard"), with the following exceptions:
  - The maximum fault clearing times described within this Functional Specification are to be used
  - The types of fault detection equipment or methods is not restricted to those described within the Standard
- The existing fault clearing, control systems and settings are to be reviewed and modified to accommodate the proposed equipment additions.
- If the fault clearing system includes teleprotection communication equipment, the associated teleprotection communication equipment is to meet the requirements in the AESO standards and the following WECC guidelines:
  - WECC Guidelines for the Design of Critical Communications Circuits (revised October 2002)
  - WECC Communications Systems Performance Guide for Protective Relaying Application (dated November 2001)

- In case there is a discrepancy between AESO standards and the WECC guidelines regarding communication requirements, the discrepancy shall be brought to the AESO for review.

<u>SCADA:</u>

- Provide SCADA information for the proposed equipment additions and modifications as required by the AESO SCADA Standard.
- Control Center data mapping and verification of SCADA information for the proposed equipment additions and modifications.

5.5 Scope of Work – Stage 1B

5.5.1 500 kV Transmission Line 12L44

The scope of work for 500 kV transmission line 12L44 between Thickwood Hills 951S and Genesee 330P includes the following (refer to Figure 4):

- Construct approximately 390 km of 500 kV transmission line from Genesee 330P to Livock 939S using single circuit structures.
- Disconnect 9L44 from Livock 939S and connect 9L44 to the new 500kV line from Genesee 330P to develop a 500kV line between Thickwood Hills 951S and Genesee 330P. Number the line as 12L44.
- The minimum continuous capacity of the line 12L44 shall be no less than 2400 MVA (2771 A at 500 kV). The actual line ratings shall be submitted to AESO in the form of a Summer rating at 30 degrees Celsius and a Winter rating at 0 degrees Celsius. The ratings shall be for an assumed wind speed of 0.6 m/s.
- The design and routing of the line 12L44 shall allow live line maintenance and shall consider that the line could be series compensated in the future. For example, open right-of-way on one side may be considered for line routing to accommodate live line maintenance requirement.
- The line 12L44 shall have optical fiber composite overhead ground wire (OPGW).
- The detail design of the structures and line optimization will be undertaken by the TFO. For PPS cost estimate purpose, the conductor can be assumed to be ACSR 3x1590.
- From a system reliability perspective, the minimum separation distance between structures of parallel transmission lines is to be selected so that a 240 kV structure failure will not affect a 500 kV structure, however a 500 kV structure failure can affect a 240 kV structure. The reason for this is to avoid having a 'lower' reliability transmission line affect a 'higher' reliability line.
- In circumstances where a 500 kV transmission line crosses over one or more 240 kV transmission lines, a 500 kV conductor failure should not affect more than one 240 kV transmission circuit. In locations where this criterion is impractical to achieve, TFO is to advise the AESO of the specific details.
- The demarcation points of line 12L44 are the first transmission line structures outside the fence of Thickwood Hills 951S and Genesee 330P. Line 12L44 between the two

demarcation points will be owned by one TFO. Line 12L44 outside the demarcation point will be deemed as part of the substation Thichwood Hills 951S or Genesee 330P and will be owned by ATCO and EPCOR respectively.

5.5.2 500kV Substation Thickwood Hills 951S

The scope of work at Thickwood Hills 951S includes the following (refer to Figure 4):

Transmission Equipment:

- Add one (1) 500/240 kV autotransformer bank at Thickwood Hills 951S meeting the following specifications:
    - The maximum continuous capacity rating is 1200 MVA for the autotransformer bank and 400 MVA for each single-phase unit. The minimum continuous rating, without forced cooling, is 600 MVA for the autotransformer bank and 200 MVA for each single-phase unit.
    - The rated voltage shall be no less than the maximum continuous equipment operating voltages listed in Table 1.
    - Tertiary windings are not required.
    - The autotransformer bank shall be solidly grounded.
    - The impedance of the autotransformer bank shall be lower than….
    - The autotransformer bank shall have a De-Energized Tap Changer (“DETC”) on the 500 kV side with a tap range of ±2×2.5% (500-550kV) for voltage variation on the 500 kV side.
    - The emergency overload rating of the transformer shall be xx% for xx minutes, followed by xx% for xx hours with a pre-overload of xx%. The overload capability shall be achieved with normal loss of life.
    - Transformer loss evaluation shall be based on the cost of losses as $xx/kW for both load losses and no load losses.
    - The autotransformer bank shall be able to be energized from a cold state at an ambient temperature of -50°C.
- Add one (1) 500 kV circuit breaker meeting the specification outlined in section 5.3.2
- Add 500 kV bus into double bus double breaker configuration that can be developed into folded breaker and a half configuration in the future. Each diameter of the folded breaker and a half shall have space for two line bays at either side of the bus.
- The design of the substation shall consider the ultimate development of the project, as outlined in sections 4.3.

Protection and Control:

- The fault clearing system needs to cover all fault types and meet the associated maximum fault clearing times listed in the tables above.
- The fault clearing system is generally defined to include:
    - Current and voltage instrument transformers
    - Protection relays

  - Teleprotection communication equipment
  - Circuit breakers
  - All functionally associated equipment

- Anticipated fault clearing times are to be calculated by adding the maximum operating time of all applicable equipment comprising the fault clearing system, without additional undefined time margin.
- The maximum operating time for each type of equipment, where applicable, is to include the variation of operating time associated with all possible fault inception times within the 60 Hz waveform.
- The actual maximum operating time for the equipment is to be confirmed through test measurement of the equipment, with the applicable specific configuration and settings applied. Results of the test measurement shall be provided to the AESO.
- The source impedance ratio (SIR) is to be included when determining equipment operating speeds to meet the required maximum fault clearing times.
- A single point of failure within the fault clearing system shall not cause a loss or diminishment of the functionality, with the exception of the primary winding of instrument transformers.
- The fault clearing system also needs to meet the functional requirement specified by the AESO AIES Protection Standard ("the Standard"), with the following exceptions:
  - The maximum fault clearing times described within this Functional Specification are to be used
  - The types of fault detection equipment or methods is not restricted to those described within the Standard
- The existing fault clearing, control systems and settings are to be reviewed and modified to accommodate the proposed equipment additions.
- If the fault clearing system includes teleprotection communication equipment, the associated teleprotection communication equipment is to meet the requirements in the AESO standards and the following WECC guidelines:
  - WECC Guidelines for the Design of Critical Communications Circuits (revised October 2002)
  - WECC Communications Systems Performance Guide for Protective Relaying Application (dated November 2001)
- In case there is a discrepancy between AESO standards and the WECC guidelines regarding communication requirements, the discrepancy shall be brought to the AESO for review.

<u>SCADA:</u>

- Provide SCADA information for the proposed equipment additions and modifications as required by the AESO SCADA Standard.
- Control Center data mapping and verification of SCADA information for the proposed equipment additions and modifications.

5.5.3 500kV Substation Genesee 330P - THIS IS NOT PART OF THE BID PACKAGE. IT HAS BEEN PROVIDED FOR INFORMATIONAL PURPOSES ONLY.

The scope of work at Genesee 330P includes the following (refer to Figure 4):

Transmission Equipment:

- Add two (2) 500 kV circuit breakers meeting the specification outlined in section 5.3.2
- Add one 500 kV 200 MVAr line-end reactor with the provision of space to add a dedicated reactor switching breaker in the future. The size and type of the line-end reactor, as well as the neutral reactor for the line-end reactor need to be determined through future studies.

Protection and Control:

- The fault clearing system needs to cover all fault types and meet the associated maximum fault clearing times listed in the tables above.
- The fault clearing system is generally defined to include:
    - Current and voltage instrument transformers
    - Protection relays
    - Teleprotection communication equipment
    - Circuit breakers
    - All functionally associated equipment
- Anticipated fault clearing times are to be calculated by adding the maximum operating time of all applicable equipment comprising the fault clearing system, without additional undefined time margin.
- The maximum operating time for each type of equipment, where applicable, is to include the variation of operating time associated with all possible fault inception times within the 60 Hz waveform.
- The actual maximum operating time for the equipment is to be confirmed through test measurement of the equipment, with the applicable specific configuration and settings applied. Results of the test measurement shall be provided to the AESO.
- The source impedance ratio (SIR) is to be included when determining equipment operating speeds to meet the required maximum fault clearing times.
- A single point of failure within the fault clearing system shall not cause a loss or diminishment of the functionality, with the exception of the primary winding of instrument transformers.
- The fault clearing system also needs to meet the functional requirement specified by the AESO AIES Protection Standard (“the Standard”), with the following exceptions:
    - The maximum fault clearing times described within this Functional Specification are to be used
    - The types of fault detection equipment or methods is not restricted to those described within the Standard

- The existing fault clearing, control systems and settings are to be reviewed and modified to accommodate the proposed equipment additions.
- If the fault clearing system includes teleprotection communication equipment, the associated teleprotection communication equipment is to meet the requirements in the AESO standards and the following WECC guidelines:
  - WECC Guidelines for the Design of Critical Communications Circuits (revised October 2002)
  - WECC Communications Systems Performance Guide for Protective Relaying Application (dated November 2001)
- In case there is a discrepancy between AESO standards and the WECC guidelines regarding communication requirements, the discrepancy shall be brought to the AESO for review.

SCADA:

- Provide SCADA information for the proposed equipment additions and modifications as required by the AESO SCADA Standard.
- Control Center data mapping and verification of SCADA information for the proposed equipment additions and modifications.

5.6 SCOPE OF WORK – STAGE 2

5.6.1 500 kV Transmission Line Thickwood Hills to Heartland

The scope of work for 500 kV transmission line between Thickwood Hills 951S and Heartland 12S (Thickwood – Heartland line) includes the following (refer to Figure 5):

- Construct approximately 410 km of 500 kV transmission line from Thickwood Hills 951S to Heartland 12S using single circuit structures.
- The minimum continuous capacity of the Thickwood-Heartland line shall be no less than 2400 MVA (2771 A at 500 kV). The actual line ratings shall be submitted to AESO in the form of a Summer rating at 30 degrees Celsius and a Winter rating at 0 degrees Celsius. The ratings shall be for an assumed wind speed of 0.6 m/s.
- The design and routing of the Thickwood-Heartland line shall allow live line maintenance and shall consider that the line could be series compensated in the future. For example, open right-of-way on one side may be considered for line routing to accommodate live line maintenance requirement.
- The Thickwood-Heartland line shall have optical fiber composite overhead ground wire (OPGW).
- From a system reliability perspective, the minimum separation distance between structures of parallel transmission lines is to be selected so that a 240 kV structure failure will not affect a 500 kV structure, however a 500 kV structure failure can affect a 240 kV structure. The reason for this is to avoid having a 'lower' reliability transmission line affect a 'higher' reliability line.
- In circumstances where a 500 kV transmission line crosses over one or more 240 kV transmission lines, a 500 kV conductor failure should not affect more than one 240 kV

transmission circuit. In locations where this criterion is impractical to achieve, TFO is to advise the AESO of the specific details.

- The demarcation points of the Thickwood-Heartland line are the first transmission line structures outside the fence of Thickwood Hills 951S and Heartland 12S. The Thickwood-Heartland line between the two demarcation points will be owned by one TFO. Thickwood-Heartland line outside the demarcation point will be deemed as part of the substation Thichwood Hills 951S or Heartland 12S and will be owned by ATCO and AltaLink respectively.

5.6.2 500kV Substation Thickwood Hills 951S

The scope of work at Thickwood Hills 951S includes the following (refer to Figure 5):

<u>Transmission Equipment:</u>

- Add one (1) 500/240 kV autotransformer bank at Thickwood Hills 951S meeting the following specifications:
  - The maximum continuous capacity rating is 1200 MVA for the autotransformer bank and 400 MVA for each single-phase unit. The minimum continuous rating, without forced cooling, is 600 MVA for the autotransformer bank and 200 MVA for each single-phase unit.
  - The rated voltage shall be no less than the maximum continuous equipment operating voltages listed in Table 1.
  - Tertiary windings are not required.
  - The autotransformer bank shall be solidly grounded.
  - The impedance of the autotransformer bank shall be lower than….
  - The autotransformer bank shall have a De-Energized Tap Changer (“DETC”) on the 500 kV side with a tap range of ±2×2.5% (500-550kV) for voltage variation on the 500 kV side.
  - The emergency overload rating of the transformer shall be xx% for xx minutes, followed by xx% for xx hours with a pre-overload of xx%. The overload capability shall be achieved with normal loss of life.
  - Transformer loss evaluation shall be based on the cost of losses as $xx/kW for both load losses and no load losses.
  - The autotransformer bank shall be able to be energized from a cold state at an ambient temperature of -50°C.
- Add two (2) 500 kV circuit breakers meeting the specification outlined in section 5.3.2
- Add one 500 kV 200 MVAr line-end reactor with the provision of space to add a dedicated reactor switching breaker in the future. The size and type of the line-end reactor, as well as the neutral reactor for the line-end reactor need to be determined through future studies.
- The design of the substation shall consider the ultimate development of the project, as outlined in sections 4.3.

<u>Protection and Control:</u>

- The fault clearing system needs to cover all fault types and meet the associated maximum fault clearing times listed in the tables above.
- The fault clearing system is generally defined to include:
    - Current and voltage instrument transformers
    - Protection relays
    - Teleprotection communication equipment
    - Circuit breakers
    - All functionally associated equipment
- Anticipated fault clearing times are to be calculated by adding the maximum operating time of all applicable equipment comprising the fault clearing system, without additional undefined time margin.
- The maximum operating time for each type of equipment, where applicable, is to include the variation of operating time associated with all possible fault inception times within the 60 Hz waveform.
- The actual maximum operating time for the equipment is to be confirmed through test measurement of the equipment, with the applicable specific configuration and settings applied. Results of the test measurement shall be provided to the AESO.
- The source impedance ratio (SIR) is to be included when determining equipment operating speeds to meet the required maximum fault clearing times.
- A single point of failure within the fault clearing system shall not cause a loss or diminishment of the functionality, with the exception of the primary winding of instrument transformers.
- The fault clearing system also needs to meet the functional requirement specified by the AESO AIES Protection Standard ("the Standard"), with the following exceptions:
    - The maximum fault clearing times described within this Functional Specification are to be used
    - The types of fault detection equipment or methods is not restricted to those described within the Standard
- The existing fault clearing, control systems and settings are to be reviewed and modified to accommodate the proposed equipment additions.
- If the fault clearing system includes teleprotection communication equipment, the associated teleprotection communication equipment is to meet the requirements in the AESO standards and the following WECC guidelines:
    - WECC Guidelines for the Design of Critical Communications Circuits (revised October 2002)
    - WECC Communications Systems Performance Guide for Protective Relaying Application (dated November 2001)
- In case there is a discrepancy between AESO standards and the WECC guidelines regarding communication requirements, the discrepancy shall be brought to the AESO for review.

SCADA:

- Provide SCADA information for the proposed equipment additions and modifications as required by the AESO SCADA Standard.
- Control Center data mapping and verification of SCADA information for the proposed equipment additions and modifications.

5.6.3 500kV Substation Heartland 12S - THIS IS NOT PART OF THE BID PACKAGE. IT HAS BEEN PROVIDED FOR INFORMATIONAL PURPOSES ONLY.

The scope of work at Heartland 12S includes the following (refer to Figure 5):

Transmission Equipment:

- Add two (2) 500 kV circuit breakers meeting the specification outlined in section 5.3.2
- Add one 500 kV 200 MVAr line-end reactor with the provision of space to add a dedicated reactor switching breaker in the future. The size and type of the line-end reactor, as well as the neutral reactor for the line-end reactor need to be determined through future studies.

Protection and Control:

- The fault clearing system needs to cover all fault types and meet the associated maximum fault clearing times listed in the tables above.
- The fault clearing system is generally defined to include:
  - Current and voltage instrument transformers
  - Protection relays
  - Teleprotection communication equipment
  - Circuit breakers
  - All functionally associated equipment
- Anticipated fault clearing times are to be calculated by adding the maximum operating time of all applicable equipment comprising the fault clearing system, without additional undefined time margin.
- The maximum operating time for each type of equipment, where applicable, is to include the variation of operating time associated with all possible fault inception times within the 60 Hz waveform.
- The actual maximum operating time for the equipment is to be confirmed through test measurement of the equipment, with the applicable specific configuration and settings applied. Results of the test measurement shall be provided to the AESO.
- The source impedance ratio (SIR) is to be included when determining equipment operating speeds to meet the required maximum fault clearing times.
- A single point of failure within the fault clearing system shall not cause a loss or diminishment of the functionality, with the exception of the primary winding of instrument transformers.
- The fault clearing system also needs to meet the functional requirement specified by the AESO AIES Protection Standard (“the Standard”), with the following exceptions:

  - o The maximum fault clearing times described within this Functional Specification are to be used
  - o The types of fault detection equipment or methods is not restricted to those described within the Standard

- The existing fault clearing, control systems and settings are to be reviewed and modified to accommodate the proposed equipment additions.
- If the fault clearing system includes teleprotection communication equipment, the associated teleprotection communication equipment is to meet the requirements in the AESO standards and the following WECC guidelines:
  - o WECC Guidelines for the Design of Critical Communications Circuits (revised October 2002)
  - o WECC Communications Systems Performance Guide for Protective Relaying Application (dated November 2001)
- In case there is a discrepancy between AESO standards and the WECC guidelines regarding communication requirements, the discrepancy shall be brought to the AESO for review.

SCADA:

- Provide SCADA information for the proposed equipment additions and modifications as required by the AESO SCADA Standard.
- Control Center data mapping and verification of SCADA information for the proposed equipment additions and modifications.

TRANSMISSION SYSTEM OPERATING CHARACTERISTICS

The following sections provide data to outline the electrical environment in which the facilities outlined in the Specification will operate. Proponents shall incorporate these characteristics into their facility designs and operating procedures as deemed appropriate.

5.7 SHORT CIRCUIT CURRENT LEVELS

The following short circuit current levels in Table 4 and Table 7 have been developed by the AESO based on information provided by Transmission Facility Owners (“TFO’s”), Generation Facility Owners ("GFO’s") and adjacent operating areas. Available fault current levels will continue to increase as generation, transmission, and system inter-ties are added to the ATS. Affected TFO's, GFO's and customers providing their own transmission facilities should consider this eventuality and exercise good engineering judgment in the specification of power interrupting equipment and the design and installation of safety grounding systems in and around high voltage power transmission lines and stations. The AESO cannot guarantee and accepts no responsibility for short circuit current growth that may exceed the capabilities of TFO or customer electric power delivery systems and equipment.

Table 4: Area 2015-2017 Anticipated Short Circuit Levels with Proposed Development

Substation Name and Number	Base Voltage (kV)	Pre-Fault Voltage (p.u.)	3-Φ Fault (kA)	Positive Sequence Impedance ($R_1 + j X_1$)

				(p.u.)
Thickwood Hills 951S	240			
Livock 939S	240			
Poplar Island 965S	240			
Dover 888S	240			
Ruth Lake 848S	240			
McMillan 885S	240			

NOTES: Vbase= Vbus ; MVAbase= 100.

Table 5: Area 2021-2023 Anticipated Short Circuit Levels with Ultimate Development

Substation Name and Number	**Base Voltage (kV)**	**Pre-Fault Voltage (p.u.)**	**3-Φ Fault (kA)**	**Positive Sequence Impedance (R_1 + j X_1) (p.u.)**
Thickwood Hills 951S	500			
Thickwood Hills 951S	240			
Livock 939S	240			
Poplar Island 965S	240			
Dover 888S	240			
Ruth Lake 848S	240			
McMillan 885S	240			

NOTES: Vbase= Vbus ; MVAbase= 100.

5.8 Voltage Levels

Table 6 provides the acceptable ranges of steady state voltage in the area of the proposed system modifications and additions. Please refer to AESO Transmission Reliability Criteria, Part II System Planning, Section 5.1, voltage standards for detail information. The document can be found through the following link:

http://www.aeso.ca/downloads/TransmissionReliabilityCriteriaVersion0cleancopupart2systemplanning.pdf

Table 6: Acceptable Range of Steady State Voltage (kV)

Nominal	**500**	**240**
Extreme Minimum	500	220
Normal Minimum	510	260
Normal Maximum	540	269
Extreme Maximum	550	285

5.9 INSULATION LEVELS

Table 7 provides the required Basic Impulse Levels ("BIL") levels for the ATS. Station equipment with lower BIL levels can be used provided protection and coordination can be maintained with judicious insulation design and use of appropriate surge arresting equipment.

Table 7: BIL Levels (kV)

Nominal Voltage Classification (kV rms)	**500**	**240**
Transformer Windings	1425	950
Station Post Insulators and Airbreaks	1550	1050
Circuit Breakers	1800	1050
Current and Potential Transformers	1800	1050

6. APPENDICES

6.1 SYSTEM CONFIGURATION - EXISTING

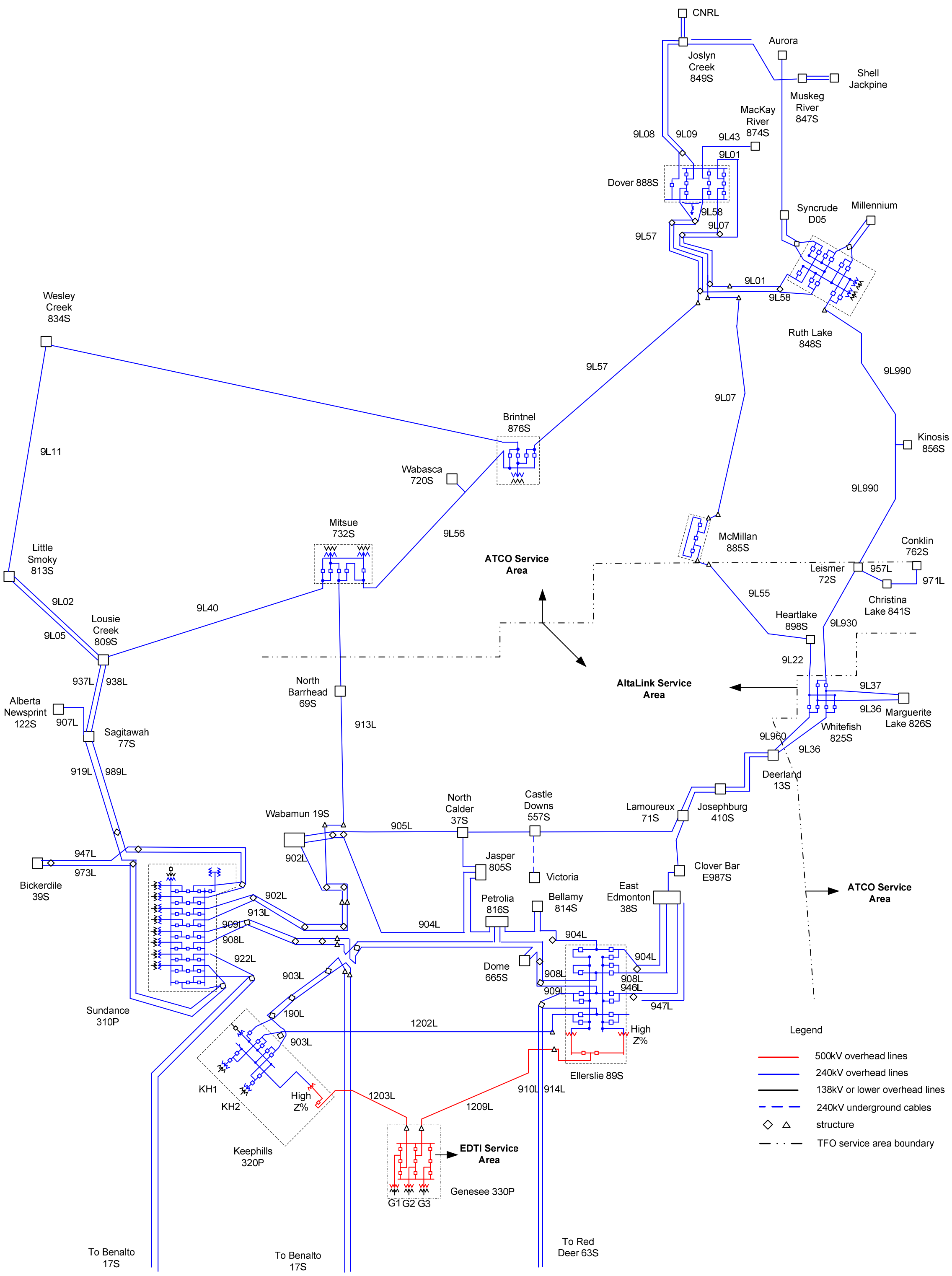

Figure 1: System Configuration – Existing

6.2 SYSTEM CONFIGURATION –DEVELOPMENT PRIOR TO THE PROJECT

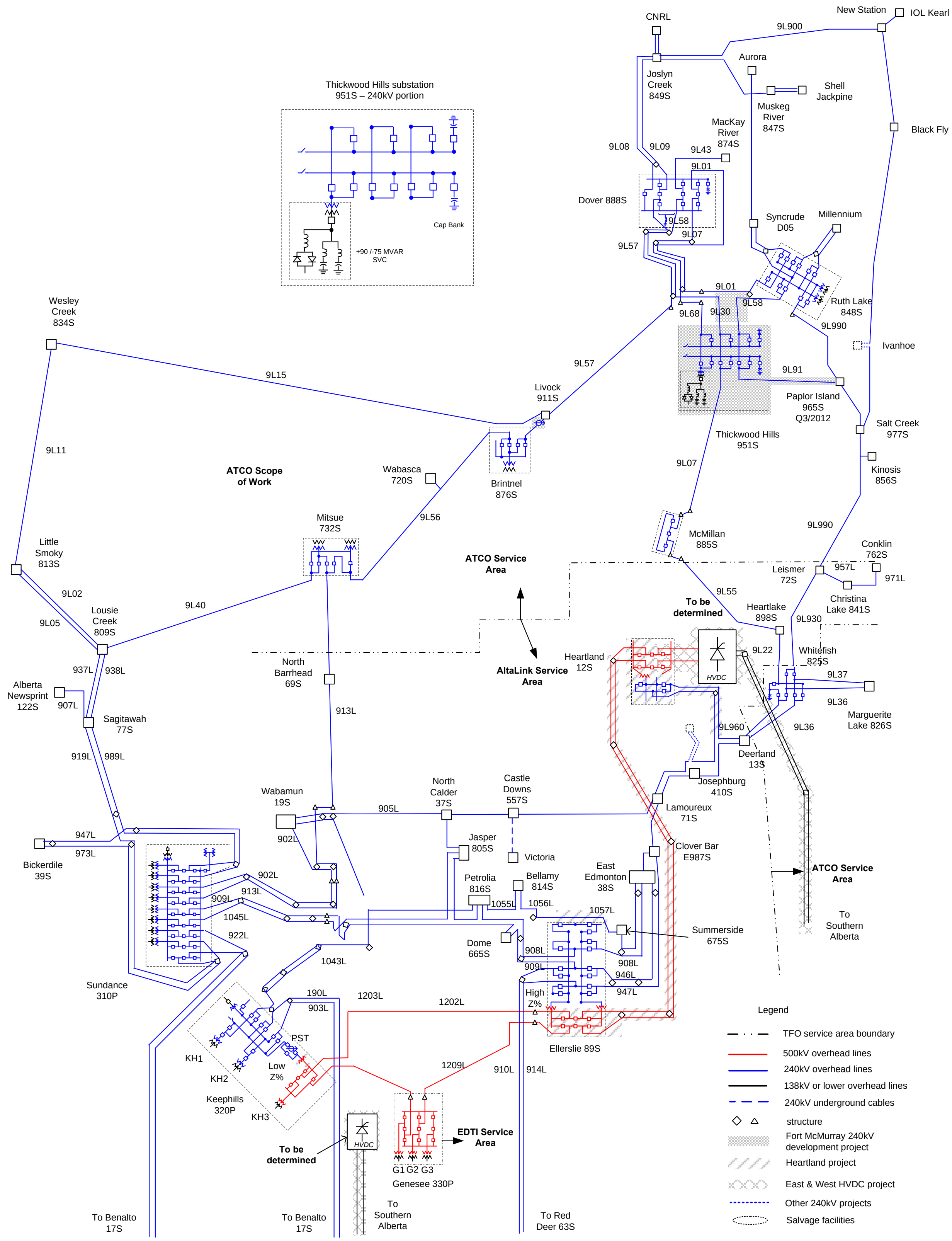

Figure 2: System Configuration –Development Prior to the Project

6.3 SYSTEM CONFIGURATION – PROPOSED DEVELOPMENT - STAGE 1A

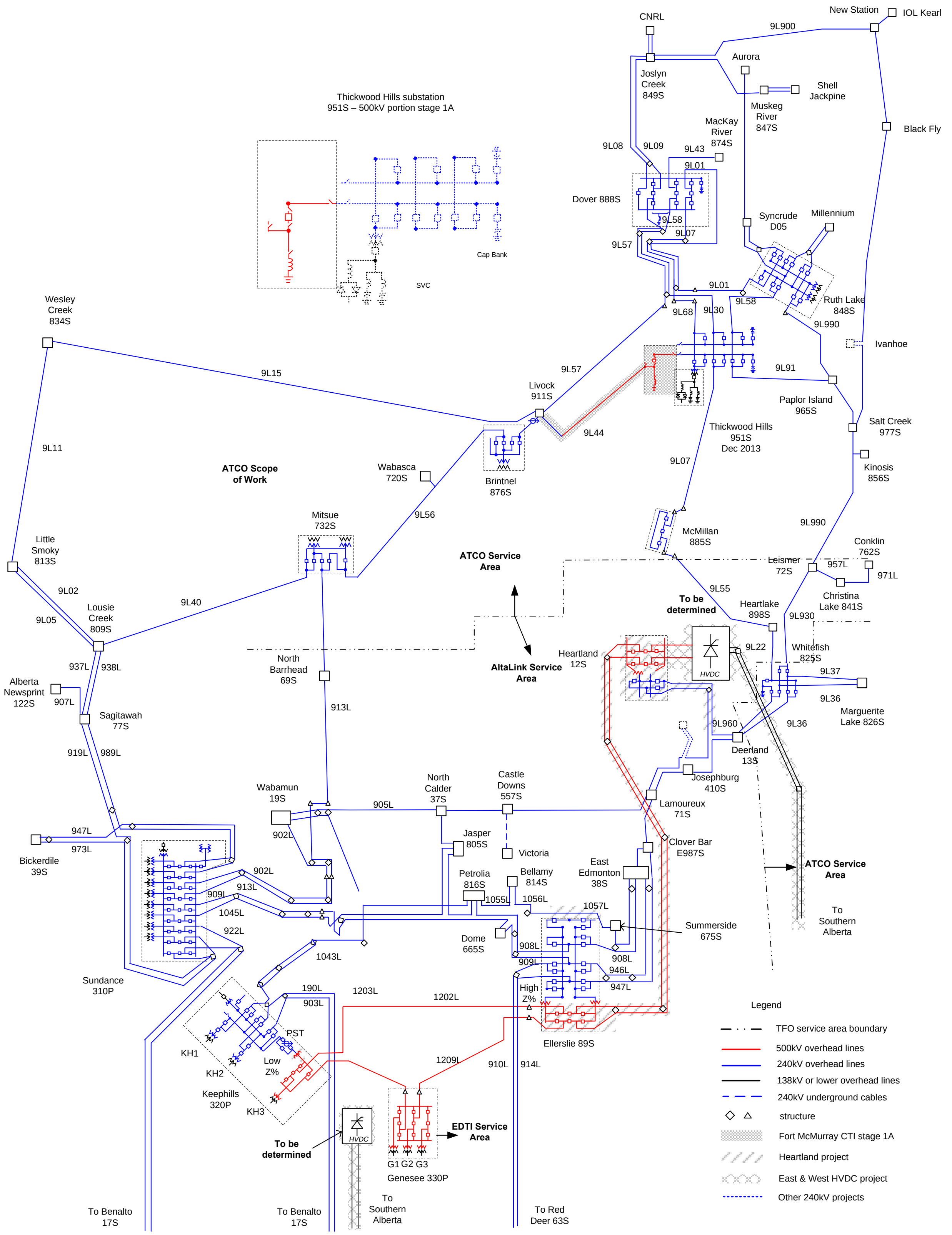

Figure 3: System Configuration – Proposed Development - Stage 1A

6.4 System Configuration – Proposed Development – Stage 1B

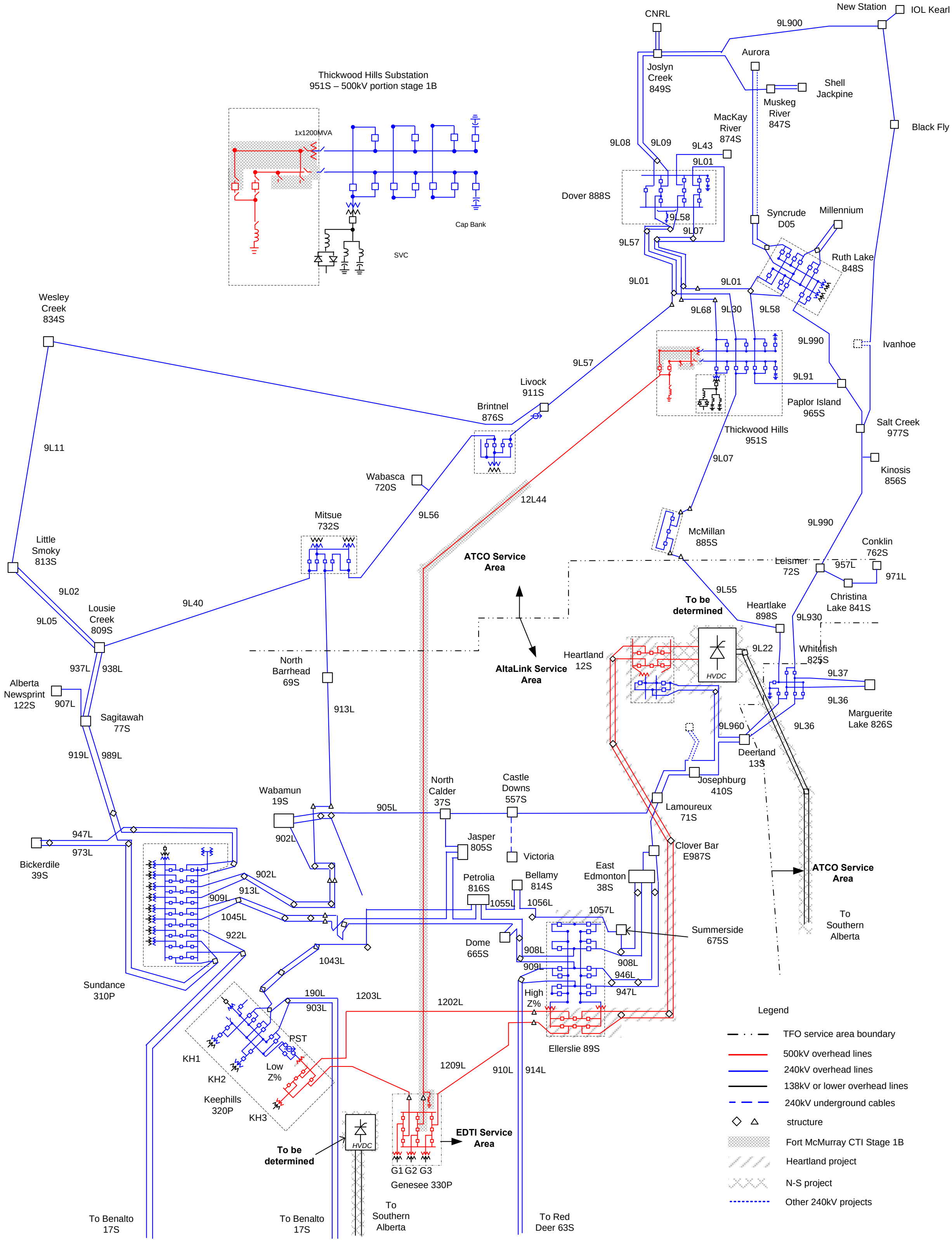

Figure 4: System Configuration – Proposed Development – Stage 1B

6.5 System Configuration – Proposed Development – Stage 2

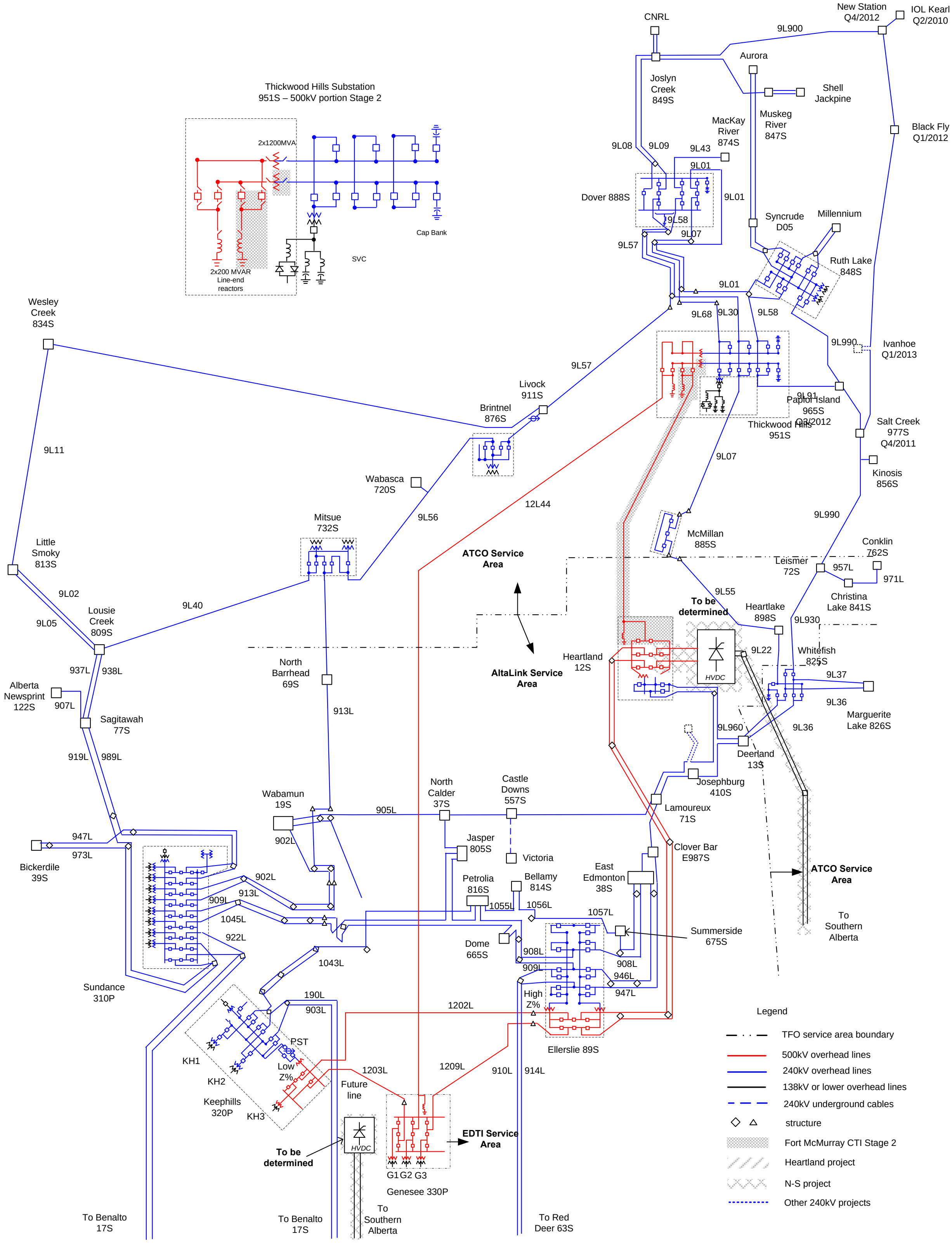

Figure 5: System Configuration – Proposed Development – Stage 2

6.6 System Configuration – Ultimate Development

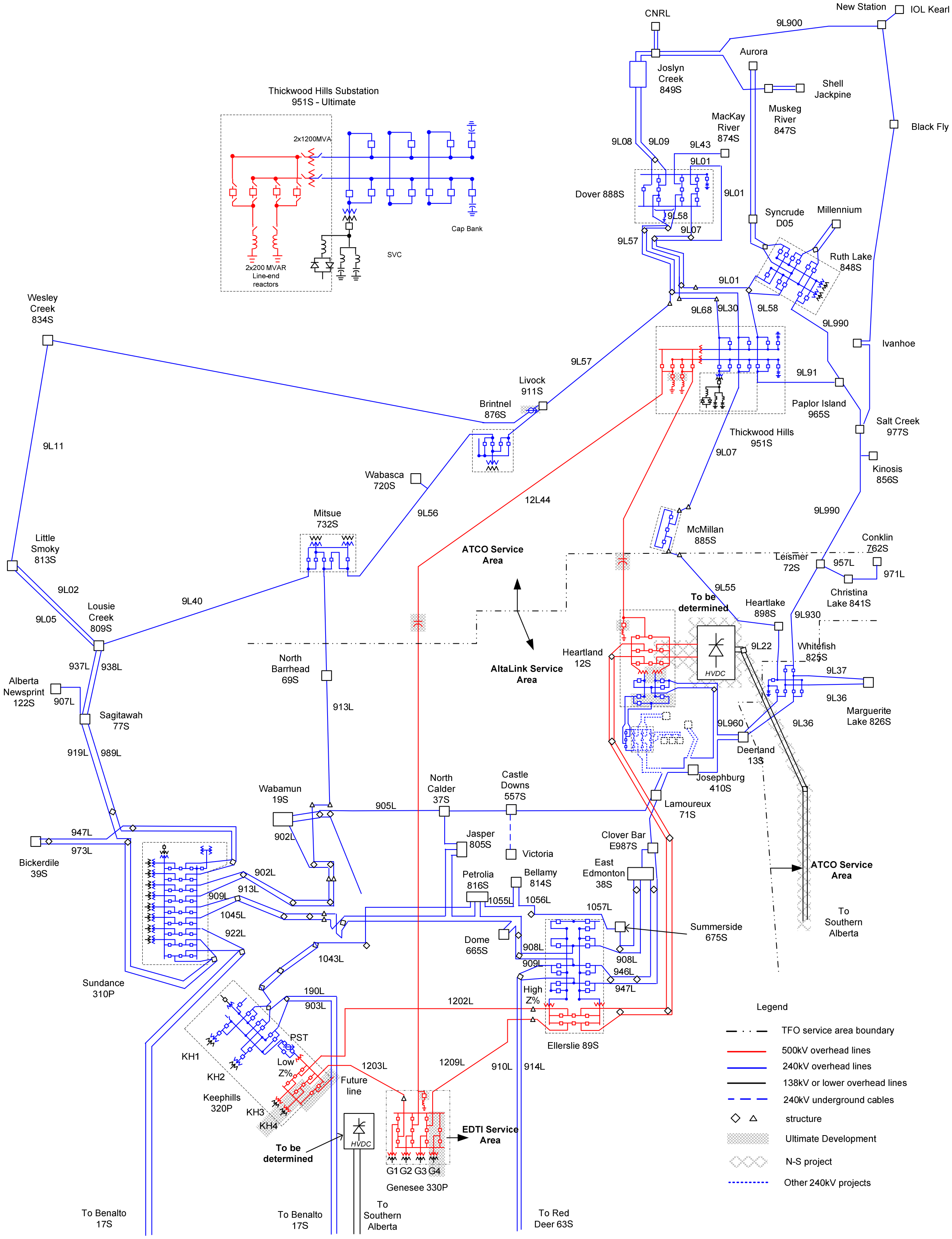

Figure 6: System Configuration – Ultimate Development