AESO Discussion Paper

Proposed New Substation Rule
(Section 502.11 of the ISO rules)

November 25, 2016

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1 EXECUTIVE SUMMARY

Substations are an important element in modern electric power systems and are expected to play an increasingly critical role in the new era of smart grid, where they will become the hubs to enable a wide range of generation sources to be connected and to safely and reliably exchange electric energy for generators and loads under various operating conditions.

Since August 2015, the AESO has led an industry technical workgroup[1] ("WG") made up of subject matter experts from the major transmission facility owners ("TFOs") and some distribution facility owners ("DFOs"), for the purposes of identifying, prioritizing and discussing the issues and possible solutions related to the minimum technical requirements for the design, construction, commissioning and operation of future transmission substations. The proposed requirements presented in this Discussion Paper[2] are based primarily on the input received from the WG. These requirements are proposed to be included in new Section 502.11 of the ISO rules ("Proposed New Section 502.11") respecting future transmission substations operating at a voltage of 100 kV or higher[3]. The purpose of this Discussion Paper is to present the proposed minimum technical requirements for transmission substations to stakeholders for their consideration, and to seek input from stakeholders regarding the proposed requirements.

Although these requirements constitute the "baseline" equipment and systems for transmission substations, the AESO will not be precluded from specifying additional facilities or functionalities in the functional specification for the transmission project, based on the location and impact of the project on system reliability and performance.

A substation is a collection of a variety of equipment that is arranged and connected in an ordered fashion to perform coordinated functions to enable electric power to flow from generators to consumers[4]. Proposed New Section 502.11 will be organized by major equipment groups and systems within transmission substations due to their distinctive operating characteristics, cost, manufacturing and testing processes. The following major topics are the focus of this Discussion Paper:

- reliability and availability;
- safety and security requirements;

[1] See Appendix I for details regarding the engagement process for the WG.

[2] Note that the Terms of Reference for the Substation Rule 502.11 Workgroup provided that the input received from WG members was to form the basis of a future recommendation paper to be released by the AESO. However, the input received from WG members has been included in this Discussion Paper for the purposes of seeking further input from stakeholders regarding the proposed requirements to be included in Proposed New Section 502.11. As such, this Discussion Paper has been issued in the place of the recommendation paper.

[3] For simplicity, a substation with a voltage of 100 kV or higher is called a "transmission substation" in this Discussion Paper.

[4] IEEE 100 CD (*Standards Dictionary: Glossary of Terms and Definitions*) defines a substation as "An assemblage of equipment for purposes other than generation or utilization, through which electric energy in bulk is passed for the purpose of switching or modifying its characteristics…A substation is of such size or complexity that it incorporates one or more buses, multiplicity of circuit breakers, and usually is either sole receiving point of commonly more than one supply circuit, or it sectionalizes the transmission circuits passing through it by means of circuit breakers".

- service conditions;
- grounding;
- insulation withstand levels and insulation coordination;
- bus configuration;
- station service supply systems;
- power transformers;
- circuit breakers (or load interrupting devices); and
- shunt capacitors and shunt reactors.

It should be noted that Proposed New Section 502.11 will apply to transmission substations that are directly connected to the Alberta interconnected electric system (“AIES”). Substations operating at a distribution voltage level within the service area of a DFO or within an industrial system will not be within the scope of Proposed New Section 502.11. Furthermore, it should be noted that Proposed New Section 502.11 will apply to transmission facilities on a prospective basis, unless the AESO specifies otherwise in the project functional specification document for existing transmission facilities.

The AESO proposes to take the following next step:

- Seek input from stakeholders regarding whether the proposed requirements in this Discussion Paper reflect the minimum technical requirements for transmission projects involving new or modified transmission substations.

2 INTRODUCTION

Substations are an integral part of the operation of the AIES, as they act as the “neurons” of the AIES by enabling effective monitoring, control and reliable transfer of electric energy. To achieve efficient and effective transmission of electricity over long distances, substations transform voltage from high to low, or from low to high, and perform many other functions to ensure that electricity flows from generating plants to large consumers or load centres under various operating conditions. The main functions of a substation include the following:

- Control the flow of electric energy by switching various current interrupting devices and other equipment to respond to various operating conditions;
- Control and regulate voltage by using transformer tap changers or other reactive power compensation devices, schemes or methods;
- Switch loads on or off to prevent loss of synchronism and stability and to maintain the system frequency and voltage within acceptable limits;
- Protect generation, transmission and distribution facilities by using appropriate sensors, relaying systems and fault interrupting devices; and
- Collect and disseminate various data and information to control centres for the purpose of monitoring, protection and control.

Substations can be classified, depending on their intended functions, based on their voltage levels, service environment (outdoor or indoor), insulation type (air insulated or gas insulated), and applications (generation substation, switching station, transformer substation, industrial substation, or mobile substation). A substation contains some or all of the following equipment or equipment groups:

- busbars including post insulators and string insulators;
- power transformers;
- circuit breakers and disconnect switches;
- structures for towers, gantries and equipment supports;
- surge arresters;
- overhead shield wire or lightning masts;
- auxiliary power systems for station service supply;
- instrument transformers;
- grounding system comprising ground mats and ground electrodes;
- communication cables and systems for protection and control;
- capacitor banks and/or reactor banks, or other reactive power compensation devices; and
- control building.

To date, there are a total of 717 transmission substations operating in the AIES at a voltage of 138 kV or higher[5]. Of these transmission substations, 570 substations (or 80%) are owned and operated by TFOs, with the remainder (20%) owned and operated by various industrial consumers and generators. The following table presents the age groupings of these substations.

Table 1 – In Service Years of Transmission Substations Operating at 138 kV or Higher

In Service Years	Number of Substations	%
0 – 5	69	9.6%
6 – 10	21	2.9%
11 – 20	53	7.4%
21 – 30	2	0.3%
>30	572	79.8%
Total	**717**	**100.0%**

According to Table 1, the majority of AIES transmission substations are over 30 years old, such that they may need to be upgraded or replaced in the future. There are generally two approaches to meeting the future upgrade/replacement needs for the substations:

1. Retrofit existing substations. This approach includes upgrading and expanding an existing substation using latest equipment and technology to improve the overall performance. Sometimes material changes to the substation layout are required.

[5] Based on information extracted from the TASMo database, owned and maintained by the AESO, as of June 2016.

2. Build new substations. This includes designing substations that meet all new criteria using the latest equipment and technologies.

2.1 DEVELOPMENT OF PROPOSED NEW SECTION 502.11

The AESO is an independent, not-for-profit organization responsible for the safe, reliable and economic planning and operation of the AIES. The AESO has been granted the authority to make ISO rules pursuant to s. 20 of the *Electric Utilities Act* ("EUA").

In May 2015, the AESO initiated the development of Proposed New Section 502.11 to identify and define the minimum technical requirements for transmission substation design, construction, commissioning and operation, based on the following factors:

- reliable operation of the AIES,
- economic efficiency,
- protection of transmission facilities, and
- safety of utility personnel and the general public.

Beginning in August 2015, the AESO led a WG to support the development of the minimum technical requirements for future transmission substations to be included in Proposed New Section 502.11. This Discussion Paper presents some of the proposed requirements to be included in Proposed New Section 502.11, which have been largely derived from WG discussions. These requirements apply to either new transmission substations, or to new equipment installed at existing transmission substations undergoing modifications.

The major drivers for developing Proposed New Section 502.11 are described as follows:

- Transmission substations play a vital role in the reliable operation of the AIES. They generally provide the capability to enable electric energy to flow in the desired path under various operating conditions. Substation configuration can have a far-reaching impact on the operation and maintenance flexibility of the transmission system. Proposed New Section 502.11 will ensure that transmission substations are configured and designed to support the reliable operation of the AIES, while providing sufficient flexibility for future expansion.

- Transmission substations have traditionally accounted for a considerable portion of the cost of transmission projects, and this trend is expected to continue into the future. For example, the AESO found that between 2005 and 2014, the cost of transmission substation equipment for major connection and system projects was approximately 30% of the total cost of all such projects. Proposed New Section 502.11 would allow better management of connection costs for transmission substations by providing consistent equipment performance requirements and ratings.

- The AESO has observed differences between TFOs in their substation design practices and policies. Consistency across TFO substation design would be beneficial as the AIES is increasingly connected with long and cross-service-territory transmission facilities. For example, the DC station service supply system plays a vital role in any transmission substation, and if it fails, the breakers and other devices would become inoperable. Currently there has been no consistent minimum requirement for DC station service supply systems, such as the form and the size (capacity) of the batteries. Another example is the expandability of a transmission substation for the sake of long term planning, which refers to the ease and cost-effectiveness of alterations to the substation configuration to accommodate load growth in the long term. The initial design of a new transmission substation, or substantial modification to an existing transmission substation, should allow for future expansion at the lowest cost possible without completely rebuilding from the ground up, or having to take long major outages to reconfigure the substation layout.

- Currently, the AESO relies entirely on the project functional specification to specify detailed transmission substation equipment requirements for transmission projects, on a project-by-project basis. Proposed New Section 502.11 will reduce the level of detail in the functional specification, as it will provide the minimum technical requirements applicable to all transmission substations.

- Pursuant to s.5 of the *Transmission Deficiency Regulation*, a market participant may submit a proposal to the AESO for the construction and temporary operation of a transmission facility to provide system access service. AESO approved proposals for transmission facilities follow the AESO's Market Participant Choice connection process[6]. Portions or all of the transmission substations and transmission lines that are proposed to be constructed in accordance with s.5 of the *Transmission Deficiency Regulation* will be transferred to the incumbent TFO once commissioned. The Proposed New Section 502.11 will specify the relevant standards and minimum quantity and quality of equipment required for transmission substations to ensure consistent standards are applied by both the market participant and the incumbent TFO.

3 PROPOSED CONTENT

3.1 GUIDING PRINCIPLES

The following guiding principles were widely accepted by the WG for setting out the minimum technical requirements for transmission substations in Proposed New Section 502.11:

a. The rule should focus primarily on the minimum functional requirements of equipment and systems that are required to support and promote the safety and reliability of the AIES. The rule should not be regarded as a design specifications document.

b. To the extent possible, any reliability requirements should be measurable, and the associated performance data should be collectible without prohibitive costs.

c. The rule should follow good electric industry practice. Considerations should always be given to the existing design and procurement practices of TFOs and market participants to ensure reasonable continuity of design and equipment compatibility.

d. The rule should provide flexibility for the operation and maintenance of transmission substations to the owners. Sufficient flexibility will be provided to allow for the use of new equipment and systems, while taking into account cost implications to balance out initial and long-term costs.

e. The rule should be applicable to transmission substations owned by industrial systems, designated

[6] See http://www.aeso.ca/connect for more details.

as such by the Commission ("ISDs"), and meeting the criteria. This is to ensure any transmission substations, regardless of the ownership, having an impact on AIES reliability, are subject to the same rule.

f. The rule should be consistent with all existing Alberta Reliability Standards ("ARSs") and technical rules. Furthermore, duplication where the provisions are already defined in an ARS and other ISO rules is to be avoided.

g. The rule will address the vast majority of facility additions. The AESO can elect to specify unique requirements for a particular transmission substation project through the project functional specification should circumstance dictate.

3.2 MAJOR VS. GENERAL SUBSTATION

Transmission substations have varying degrees of impact on the operation of the AIES, because of their operating voltage class, location, size, type of load and the connectedness to other facilities. A major substation is one that contains facilities that, if compromised, would lead to a loss of a large number of customers for an extended period of time or cause significant risk to public health and safety. For these reasons, some utilities in North America[7] define a "major substation" class and consequently demand enhanced equipment and system performance requirements for these major substations including, but not limited to, bus configuration, station service supply system and redundancy of control and protection equipment. The AESO currently specifies in the project functional specification the additional equipment and/or functionality requirements for major substations.

Proposal #1

The AESO proposes, and the WG agrees, to classify future transmission substations in Alberta into two categories:

1. General substations. A general substation is a transmission substation that is not a major substation as defined below. It is expected that most new transmission substations will fall into this category.

2. Major substations. A major substation is a transmission substation that has a significant impact on the reliability of the AIES and requires a higher level of equipment performance. A major substation will be referred to as a "Type 1 substation" throughout this Discussion Paper.

A "Type 1 substation" will include any one of the following:

- a 500 kV transmission substation; or
- a 240 kV transmission substation having, or planning to have, at least six (6) bulk transmission line terminations and/or system power transformer[8] terminations, as specified in the project functional specification; or

[7] An example is the "ISO New England Planning Procedure – Transmission Owners and ISO-NE Substation Bus Arrangement Guideline Working Group Report", 2006.

[8] In a transmission substation, a system power transformer is a transformer with at least one secondary voltage operating at 100 kV or higher that is used to transmit power between transmission networks.

- a transmission substation designated as Type 1 substation by the AESO in its sole discretion in the project functional specification regardless of the voltage and number of terminations.

The reason to draw a distinction between “general substations” and “Type 1 substations” is to support the reliability of the AIES, as Proposed New Section 502.11 will require enhanced equipment and system performance for Type 1 substations. It should be noted that the categorization of transmission substations based on its impact on the reliability of the AIES generally aligns with current TFO design practices.

Furthermore, the categorization of “Type 1 substations” also aligns closely with the North American Electric Reliability Corporation (“NERC”) CIP-014-2, *Physical Security* (“CIP-014”), which requires enhanced physical and cyber security controls and plans for any 500 kV substation, or 240 kV substation having at least 5 transmission lines connecting to at least 3 other substations. Although a Type 1 substation is more likely than a general substation to be a transmission facility to which CIP-014 applies, the reverse may not necessarily be true.

The AESO will establish criteria under which a transmission substation may be designated as a “Type 1 substation” regardless of the voltage and number of terminations. These criteria will be based on good engineering judgment and the forecasted ultimate configuration of the substation. The AESO will elaborate on these criteria in an Information Document (“ID”).

3.3 APPLICABILITY

The applicability section of an ISO rule identifies the entities to which the rule applies. In developing the applicability section of Proposed New Section 502.11, the AESO and the WG considered the following:

- Consistency with all existing ARSs and technical ISO rules; and
- Most ARSs and ISO rules are applicable to the bulk electric system (“BES”), which includes generators and transmission facilities generally operating at voltages of 100 kV or higher. [9]

Proposal #2

The AESO proposes, and the WG agrees, that the following wording be included in the applicability section of Proposed New Section 502.11:

Section 502.11 applies to

- the **legal owner** of a **transmission facility** with at least one (1) rated voltage equal to or greater than one hundred (100) kV; and
- the **ISO**.

[9] With respect to the ISO rules, see for example Section 502.2 of the ISO rules, *Bulk Transmission Technical Requirements*, and Section 502.3, *Interconnected Electric System Protection Requirements*, which apply to transmission facilities.

As previously noted, Proposed New Section 502.11 will apply to transmission substation projects on a prospective basis. Proposed New Section 502.11 will apply to all greenfield transmission substations, and to brownfield transmission substations with new equipment installed. For those brownfield transmission substations undergoing equipment additions or modifications, only the new equipment will be subject to the Proposed New Section 502.11, unless the AESO specifies otherwise in the project functional specification.

3.4 RELIABILITY AND AVAILABILITY

The reliability of a substation is measured by the ability of the substation equipment to perform its intended functions for a defined period of time without failure in a specified service environment. The availability of a substation is the percentage of time in which the substation is capable of providing service. In general, reliability does not account for maintenance or repair events, while availability includes such events.

It is generally recognized that, the higher the system voltage, the higher the power transfer capability for the facilities and, therefore, the greater the need for higher reliability requirements to support the overall reliability of the AIES. For example, it is generally expected that a 500 kV facility should perform more reliably than a 138 kV facility. A failure on a 500 kV facility will have a far greater impact on the AIES in terms of the magnitude (number of end-use customers) and the scope (geographical area) than a failure on a lower voltage facility.

The AESO and the WG considered whether the Proposed New Section 502.11 should only include the minimum performance targets for transmission substations, such as the System Average Interruption Duration Index ("SAIDI"), System Average Interruption Frequency Index ("SAIFI") and Customer Average Interruption Duration Index ("CAIDI") performance indices, which have been commonly used by distribution utilities for benchmarking and trending purposes. While these indices have been successfully applied to distribution systems for decades, they are difficult to apply to transmission substations other than individual delivery points, for the following reasons:

- Unlike a traditional vertically integrated utility that directly interacts with end-use customers, in Alberta a TFO does not necessarily have visibility of end-use customers. A TFO's customers are merely the DFOs and a limited number of large industrial customers. As such, the customer based performance indices, such as SAIDI, SAIFI and CAIDI, are simply not meaningful for the bulk transmission facilities although they can be useful for defining performance requirements at individual delivery points;
- It is difficult to identify the number of end-use customers connected to a specific transmission substation in real time operation. A transmission substation that is part of a looped network may have some dedicated loads but mostly has "shared customers" with other transmission substations. It is not possible to track these shared customers in real time as the system configuration changes in response to system conditions; and
- It is not practical to specify a single performance target for transmission substations as the requirements for reliability vary based on the location of a transmission substation and the type of loads. An example is an urban transmission substation typically with multiple source transmission

lines vs. a rural transmission substation typically with a single source line or no more than two source lines.

In the AESO's view, the more suitable reliability measures for a transmission substation would be based on adequate equipment capacity, availability and performance to reduce system disturbances and maintain power quality, in-line with the Alberta bulk transmission system planning criteria, such as N-1, N-1-1, and N-2 events[10]. In order to meet the mandatory reliability requirements stipulated in the ARSs, the substation bus arrangement must be appropriately designed and the corresponding equipment requirements specified. It should be noted that the past practice of designing transmission substations based on equipment functionality and performance has served the industry well and the AESO sees no reason to substantially deviate from this historical practice.

Based on the above, the AESO proposes that Proposed New Section 502.11 should be focused on the functional and performance requirements of equipment in transmission substations to achieve desired reliability, rather than customer-based performance targets such as the SAIDI, SAIFI and CAIDI indices. In the AESO's view, including the following technical aspects in the initial transmission substation design and construction stage will result in optimized reliability and availability of transmission substation facilities:

a. Establishing appropriate bus configurations that minimize maintenance outages, optimize forced outage restoration and allow for cost-effective future expansion;
b. Specifying and testing equipment to meet industry recognized technical standards and practices;
c. Basing electrical clearances on insulation co-ordination requirements, maintenance working clearances, and consideration for animal intrusions;
d. Using surge arresters effectively for controlling lightning and switching surges, and installing appropriate direct lightning protection devices for high voltage equipment;
e. Ensuring total system protection coordination[11];
f. Ensuring all switching equipment has sufficient withstand capability for fault current and overvoltages for a specified substation life span; and
g. Ensuring all substation components can handle all the site-specific environmental conditions for a specific return period.

The following are some examples of reliability-related requirements proposed to be included in the Proposed New Section 502.11:

- Creation of a major substation category (referred to as a "Type 1 substation" for this Discussion Paper) to recognize the higher functionality and performance requirements;
- A faulted element must not result in losing another bus-connected transformer element in the same transmission substation; and
- Defining maximum operating time for circuit breakers to ensure faults are cleared as quickly as

[10] See Alberta reliability standards TPL-001-AB-0, *System Performance Under Normal Conditions*, TPL-002-AB-0, *System Performance Following Loss of a Single BES Element,* TPL-003-AB-0, *System Performance Following Loss of Two or More BES Elements*, and TPL-004-AB-0, *System Performance Following Extreme BES Events*. These reliability standards define the planning criteria to ensure that the Alberta transmission system performs adequately under normal and contingency conditions.

[11] Protection coordination has been addressed in ISO Rules Section 502.3, and is not included in Proposed New Section 502.11.

possible and maintain system stability.

3.5 SAFETY AND SECURITY REQUIREMENTS

The owner of a transmission substation should ensure that the substation is designed, constructed, commissioned and operated in a manner that is compliant with all provisions of any applicable codes and regulations. The design, construction and commissioning should also comply with any order, ruling, permit or license that the Commission issues.

In Alberta, the Alberta Electrical Utility Code ("AEUC") has the force of legislation. Although the AEUC refers in general to the requirements of the Canadian Standards Association (CSA) C22.3 collection of standards ("CSA C22.3"), there are some requirements in the AEUC (most notably ground clearances) that exceed the values in CSA C22.3 collection of standards.

In the event of any conflict between the applicable safety provisions and requirements set out in the Proposed New Section 502.11 and the codes and regulations, the design, construction, commissioning and operational specifications for any new transmission substation must meet or exceed the most stringent provision or requirement.

3.6 SERVICE CONDITIONS

Service conditions for transmission substations refer primarily to the extreme adverse weather or environmental conditions that substation equipment are exposed to and within which they must be able to perform their intended functions.

The most significant extreme weather parameters in substation design are:

- lowest ambient temperature,
- maximum ambient temperature, and
- maximum wind velocity, ice thickness and wet snow buildup.

Other environmental parameters to be considered to ensure performance reliability include:

- altitudes above 1000 meters affecting equipment ratings and electrical clearances, as per IEEE C37.100.1 (*Standard of Common Requirements for High Voltage Power Switchgear Rated above 1000V*); and
- air pollution levels affecting outdoor bushing and insulator creep distances, as per IEEE C37.100.1 or IEC 60815-1 (*Selection and Dimensioning of High-Voltage Insulators Intended for Use in Polluted Conditions, Part 1*).

In 2010, the AESO commissioned a temperature study[12] (the "AESO 2010 temperature study") to analyze the frequency of extreme temperatures that occurred throughout the province between 1953 and 2007.

[12] The study report is titled "Cold Temperature Frequency Analysis for Alberta", authored by Custom Climate Services Inc. on July 6, 2010.

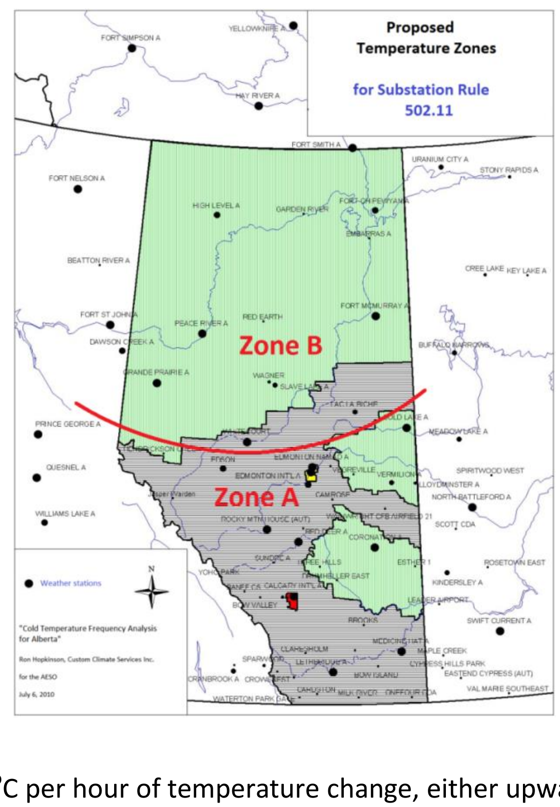
The findings of this study were considered in the development of Section 502.2 of the ISO rules, *Bulk Transmission Line Technical Requirements* ("Section 502.2").

Currently, the AESO does not define multiple temperature zones in the province based on geographical areas for transmission substation equipment. The AESO specifies in the project functional specification a single lowest ambient temperature of -50°C for all transmission projects regardless of the project's geographical location. If a TFO requests an exemption from this lowest ambient temperature, the AESO evaluates the request on a project-by-project basis. The AESO has recognized that, for transmission substation design and equipment specifications, the use of ambient temperatures that are more reflective of the local conditions may result in potential cost savings associated with equipment procurement, as a wider selection of equipment may be available. Therefore, the AESO suggests that appropriate temperature zones be defined based on the results of the AESO 2010 temperature study.

Proposal #3

Based on input received from the WG, the AESO proposes that the following requirements regarding service conditions be included in Proposed New Section 502.11:

a. Two temperature zones will be created for Proposed New Section 502.11. As shown in the graph, the lowest ambient temperatures of Zone A and Zone B are -40°C and -50°C respectively. The demarcation line between Zone A and Zone B is along Edmonton north and Cold Lake north, as shown in the diagram below. This demarcation line is based on the AESO 2010 temperature study, which identified a 0.1% occurrence frequency for the lowest temperature between 1953 and 2007.



b. The maximum ambient temperature will be location specific, and be based on the historical temperature profile with an occurrence frequency of at least 0.1% of the time. The TFO or incumbent TFO will determine the specific applicable maximum ambient temperature for a transmission substation project.
c. A maximum temperature change rate of 15°C per hour will be required. This means that equipment in transmission substations must be able to withstand up to 15°C per hour of temperature change, either upward or downward, without failures or degraded operation.

d. Proposed New Section 502.11 should use the same wind maps as in Section 502.2.
e. Contamination, which is site specific, must be considered as part of the environmental conditions when specifying insulators and bushings. Pollution and contamination must be considered in transmission substation design.

Return period for weather-related loads

f. Weather related loads for Type 1 substations will be for a one hundred (100) year return period.
g. For general substations, the return period will be fifty (50) years.

For snow, icing and wind limits

h. It is proposed that an ID will be created that will include minimum design parameters for the major TFOs in a table form (Some of the weather-related parameters are location specific. Transmission substation design must be based on local environmental conditions). This is to ensure reasonable compatibility and consistent functionality of equipment within each TFO's service area and within the AIES.

3.7 GROUNDING

The grounding system in a transmission substation is essential to provide safety to people working inside and in the vicinity of facilities and to protect the electrical equipment from damage under fault conditions. The design of the grounding system is location specific, as one of the critical input parameters is the soil characteristics.

The AESO recognizes that TFOs conduct grounding studies for transmission substation projects based on the methods and procedures specified in established standards, such as IEEE Standard 80 (*Guide for Safety in AC Substation Grounding*), IEEE Standard 81 (*Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Grounding System*) and IEEE Standard 837 (*Standard for Qualifying Permanent Connections Used in Substation Grounding*). To assist TFOs in their grounding studies, the AESO has been providing forecasted short circuit levels in the project functional specification document.

Proposal #4

The AESO proposes that the following term be included in the AESO's *Consolidated Authoritative Document Glossary*:

"effectively grounded system" means an electric power system grounded through a sufficiently low impedance such that for all system conditions the ratio of zero-sequence reactance to positive-sequence reactance is positive and less than three (3), and the ratio of zero-sequence resistance to positive-sequence reactance is positive and less than one (1).

Proposal #5

Based on input from the WG, the AESO proposes that the following minimum requirements respecting transmission substation grounding be included in Proposed New Section 502.11. These requirements generally reflect current design practice.

a. AEUC, IEEE Standard 80 and CSA C22.1-Part 1 (for low voltage installations) must be followed in transmission substation grounding system design;
b. In designing the grounding system in a transmission substation, the owner of the transmission substation must take into consideration that the AIES is an effectively grounded system;
c. For a new transmission substation project or any transmission substation projects involving new equipment installation or additions, a grounding study will be conducted to verify that the current or new grounding grid is adequate to handle the specified short circuit levels; and
d. The AESO is required to provide the following short circuit levels in the project functional specification to the owner of the transmission substation:
    (a) at the commissioning date; and
    (b) at least ten (10) years into the future from the commissioning date.

3.8 INSULATION COORDINATION

Another important aspect of substation design is the required insulation strength and insulation coordination, which is the selection and coordination of the dielectric strength of all electric equipment, and the surge protection devices, in relation to the operating voltages and transient overvoltages which can appear on the system to which the equipment is exposed. The overall objective is to reduce the probability of damage to equipment and disturbance to power delivery caused by insulation failure to an economically and operationally acceptable level. The insulation strength should be coordinated such that equipment with non-restorative insulation, such as power transformers and cables, provides a higher level of insulation resulting in a larger safety design margin than equipment with restorative insulation.

The AESO and the WG agree that proper coordination of insulation withstand strength between HV, MV and LV equipment must be specified to ensure that an insulation failure will be confined to the location on the AIES where it will result in the least damage, be the least expensive to repair and cause the least disturbance to the continuity of the supply of electricity. Although Proposed New Section 502.11 is primarily for facilities operating at ≥100 kV voltage, insulation strength will be specified for not only the HV equipment, but also MV and LV equipment installed at the same transmission substation.

Proposal #6

Based on input from the WG, the AESO proposes that the following minimum requirements respecting insulation requirements be included in Proposed New Section 502.11.

a. The design of the lightning surge protection for all transmission substation equipment must take into account the average lightning ground-flash density level for the site location of the substation.

b. Split the basic impulse insulation level into basic lightning impulse insulation level ("BIL")[13] and basic switching impulse insulation level ("BSL")[14]. This is especially necessary for equipment operating at 300 kV or higher voltage. Traditionally, the AESO has not specified BSL levels for transmission substation equipment in the project functional specification. However, switching impulses often represent the more severe air insulation withstand condition than lightning impulses at voltages of 300 kV and higher.

c. Establish a 260 kV nominal voltage class for all the 240 kV buses north of the Whitefish Lake 825S substation and north of the Sagitawah 77S substation. Historically, the northeast and northwest areas of the AIES have been interconnected via long 240 kV transmission lines, often lightly loaded. These areas have been operating at higher voltages than the remainder of the 240 kV system. See i. below for more details.

d. Use a maximum continuous operating voltage ("MCOV") of 150 kV (instead of 152 kV) for all equipment at a 138 kV nominal voltage. This is to align with current TFO procurement experience to enable selection of equipment in a cost-effective manner and allow compatibility between new and existing equipment. See i. below for more details.

e. Include BIL levels for 13.8/25/34.5/69 kV equipment for coordination purposes. This is for any equipment inside a transmission substation and is necessary for properly selecting surge arresters for all the voltage levels. See l. below for more details.

f. For gas insulated transmission substation ("GIS") equipment, insulation requirements must be consistent with the requirements for an air insulated transmission substation ("AIS"). See j. and k. below for more details.

g. The following mean time between failures ("MTBF") will be the minimum requirement for lightning failure in transmission substation design:

Equipment	MTBF (years)
Transformers	1,000
Bus and other equipment	400

h. Surge arresters must be installed at each transmission line entrance, unless an insulation coordination study demonstrates otherwise.

i. The following table presents the acceptable range of voltages that the transmission substation equipment must be able to operate within on a continuous basis[15]:

[13] The BIL refers to the electrical strength of insulation expressed in terms of a standard lightning impulse under standard atmospheric conditions. This Discussion Paper uses the IEEE abbreviation of "BIL", while IEC uses the term "LIWL" (lightning impulse withstand level).

[14] The BSL refers to the electrical strength of insulation expressed in terms of a standard switching impulse under standard atmospheric conditions. This Discussion Paper uses the IEEE abbreviation of "BSL", while IEC uses the term "SIWL" (switching impulse withstand level).

[15] Normal Continuous Minimum and Maximum voltages are associated with Category A condition (or system normal). The Emergency Continuous Minimum voltage and MCOV (Maximum Continuous Operating Voltage) are associated with Category B, C and D contingencies. The AESO plans the transmission system to operate within these voltages after automatic adjustments have been made to those on-load tap changer transformers and reactive compensation devices.

Nominal (kV)	Emergency Continuous Minimum (kV)	Normal Continuous Minimum (kV)	Normal Continuous Maximum (kV)	MCOV (kV)
138	124	135	145	150
144	130	137	151	155
240	216	234	252	264
260*	234	247	266	275
500	475	500	525	550

* For all 240 kV buses from Whitefish Lake 825S north and Sagitawah 77S north

j. For AIS, the following minimum BIL and BSL levels in kV must be met.

Nominal Voltage Classification (kV rms)	138/144	240/260		500	
	BIL	BIL	BSL	BIL	BSL
Post insulators and Disconnect switches	550	900	750	1,550	1,175
Circuit breakers/switchers	650	1,050	850	1,800	1,300
CTs and VTs	650	1,050	850	1,800	1,300
Transformer windings (with surge arresters on both ends)	550	850	750	1,550	1,175

k. For GIS, the following minimum BIL and BSL levels in kV must be met.

Nominal Voltage Classification (kV rms)	138/144	240/260		500	
	BIL	BIL	BSL	BIL	BSL
Disconnect switches, buswork, switchgear, CTs and VTs	750	1,050	850	1,550	1,175

l. The following minimum BIL levels in kV apply to the MV and LV equipment in the same transmission substation, for insulation coordination purposes.

Nominal Voltage (kV rms)	13.8	25	34.5	69/72
Circuit breakers	110	150	200	350
Indoor switchgear, transformer and shunt reactor windings (with surge arresters)	95	125	170	350
Transformers, shunt reactors bushings (with surge arresters)	110	150	200	350
All other equipment (CTs, VTs, busbars, etc.)	110	150	200	350

m. Altitude factor should be considered where a transmission substation is located at an altitude exceeding 1000 meters.

3.9 BUS CONFIGURATION

Bus configuration refers to the physical arrangement of various elements and components in a substation relative to one another. It is an important task in the initial design of a substation, because a bus configuration, once chosen, determines such factors as land requirement, reliability of supply and delivery, flexibility of operation and maintenance, protection system complexity, and the initial and future cost.

The basic driver of choosing an appropriate bus configuration is to facilitate the operational functions of a substation in an electrical network. A practical design of substation bus configuration should be based on good electric industry practice and should achieve the following objectives:

- reliability,
- simplicity of design and construction,
- ease of maintenance of equipment,
- minimize the outage time during maintenance or forced outage, and
- allow for extension or expansion with load growth in a cost-effective manner.

For reliability, the bus configuration should prevent unintentional substation shutdown, limit outages, and permit rapid restoration of service after an outage. The WG agrees with the following guiding principles for the bus design of a future transmission substation. Bus configuration should

- support and promote safety and reliability of the AIES;
- provide maximum maintenance and operating flexibility; and
- balance out initial and future needs and costs.

Proposal #7

Based on WG's input, the AESO proposes that the following minimum requirements respecting bus configuration be included in Proposed New Section 502.11. The following proposed requirements are generally consistent with the AESO's current practice for developing functional specifications and TFO design principles for bus configuration. Furthermore, these proposed requirements generally align with the connection requirements of utilities in North America.

<u>For all transmission substations including Type 1 substations</u>

a. A faulted substation element[16] must not result in the loss of another bus-connected transformer element in the same transmission substation. This basically means that if a transmission substation is designed to accommodate more than one power transformer, each transformer should be connected to a separate bus section. A transmission substation is often initially constructed with one transformer, and expanded with more transformers in the future. In this case, the design should provide space for a bus tie breaker bay for future expansion.

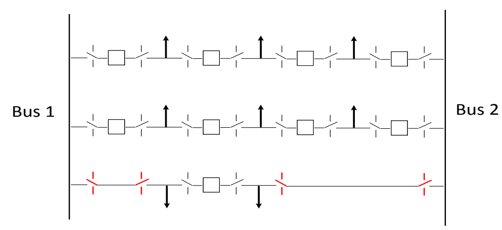
[16] For the purposes of Proposed Section 502.11, the term "substation element" includes a power transformer, circuit breaker, instrument transformer, switched capacitor, switched reactor, or reactive power compensator.

b. No additional substation elements will have to be taken out of service for an extended period to accommodate maintenance of a substation element. However, it is acceptable to momentarily remove another substation element to enable the removal and isolation, through switching, of a substation element requiring maintenance.

c. The ampacity of all terminal components connecting a transmission line or power transformer must be no less than the maximum operating rating of the line or the transformer.

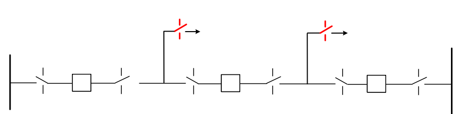
d. A breaker failure event should not trip all the circuits which terminate at the same remote transmission substation, or the same generating station. This means that all circuits connecting the same transmission substations at both ends (such as double circuit lines) must be placed at different diameters between buses or bus sections.

e. In an incomplete breaker-and-half and breaker-and-third diameter, disconnect switches close to the bus should be installed to minimize outage time during the installation of the remaining breakers in the future. The following figure illustrates this requirement graphically:

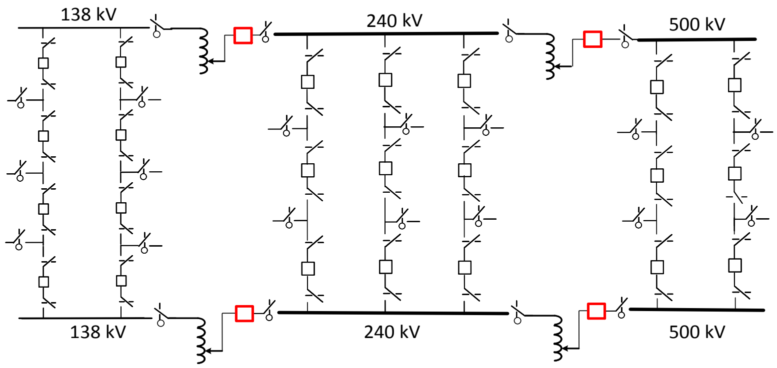


f. A ring bus configuration is acceptable with up to six nodes. A ring bus with more than six nodes will be approved by the AESO on a case-by-case basis in the project functional specification. This is to limit the risk of a system split when maintenance is being performed on a circuit breaker element. Such split can cause the source transmission line to be isolated from other transmission lines and transformers.

g. A disconnect device at the line side must be installed for each transmission line, power transformer and/or generator connection. The following diagram illustrates this requirement:



h. If all three transmission voltage levels (138/144, 240/260 and 500 kV) are present, failure of an autotransformer must not result in tripping more than four (4) circuit breakers. This requirement is to minimize the scope and duration of excessive outages across multiple voltages. The following figure illustrates this requirement:



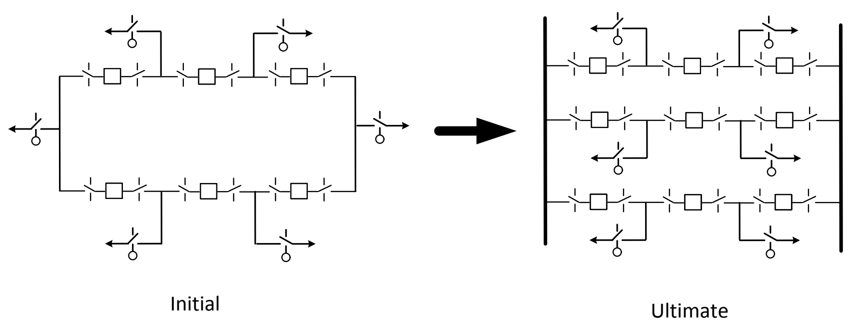
i. The AESO is to specify the ultimate number of terminations and voltage compensation devices in the project functional specification. Such information in the project functional specification must be consistent with the AESO's planning horizon and long term planning practice.

j. For busbars, the following minimum continuous current carrying capability must be met.

Component	**138/144 kV**	**240/260 kV**	**500 kV**
Main bus (A)	1,200	3,000	4,000
Cross bus (A)	600	2,000	3,000
Line terminal (A)	600	2,000	3,000

k. In the ID associated with Proposed New Section 502.11, examples and detailed explanation of typical bus configurations in Alberta, and the pros and cons of each of them will be provided. The purpose of these examples is to provide tools and relevant information for a TFO and/or market participant to evaluate different bus configuration alternatives for new or modified transmission substations. The information presented in Appendix II is proposed to be included in the ID.

l. If a transmission substation is initially designed with a simple bus or ring bus, the design must be such that it can be converted into the ultimate configuration without having to relocate any existing equipment, if an ultimate configuration is specified in the project functional specification. The following diagram shows how a transmission substation, initially designed as a ring bus layout, can be converted into a breaker-and-half layout.



m. In a ring bus, positioning of equipment should be such that lines are not terminated in positions which will ultimately be buses in the ultimate configuration, if an ultimate configuration is specified in the project functional specification.

For Type 1 substations only

n. A faulted substation element (N-1 event) must not result in the loss of any other substation elements. This requirement means that for Type 1 substations, only a breaker-and-half or ring bus configuration may be chosen, as a single bus arrangement with or without transfer bus would not meet this requirement.

3.10 AC STATION SERVICE SUPPLY SYSTEM

Both the AC and DC station service supply systems represent an important part of substation design and operation. These systems are of paramount importance to the reliable and safe operation of a substation. The reliable operation of a substation becomes even more important during disturbances and faults in the transmission system.

The AC station service supply system may include a station service transformer or transformers, standby generator, AC transfer switches, AC panel boards and protection devices. The AC station service supply system typically supplies AC power to the heating and cooling unit, ventilation fan and lighting in the control building, yard lighting, outdoor equipment cabinet heaters, pumps, compressors, and transformer cooling fans.

The following illustrates some of the technical requirements respecting AC station service supply system by various utilities in USA and Canada:

- AC station service supply system must be capable of operating continuously without malfunction or overheating in the voltage range and load current requirements of the substation;
- AC station service supply system must be installed to meet electrical codes and industry standards; and
- AC station service supply system must be monitored and alarmed for abnormal conditions.

Proposal #8

Based on input from the WG, the AESO proposes that the following minimum requirements respecting AC station power supply be included in Proposed New Section 502.11:

For Type 1 substations only

a. Dual independent AC station service supply system sources must be provided. The term "independent source" will be explained in the proposed ID (note: an independent AC source can be a standby generator, MV bus-connected station service transformer on different buses, HV power VT, transformer tertiary winding, and distribution line to a pad-mounted transformer).

b. If a station service transformer, having a capacity of 1 MVA or larger, is directly connected to an HV bus, a circuit breaker or circuit switcher is required on the HV side of the station service transformer.

3.11 DC STATION SERVICE SUPPLY SYSTEM

The DC station service supply system for a substation provides DC power to the various sensors and relays and the control and operating mechanisms for a large variety of equipment. The DC station service supply system is generally comprised of batteries, battery chargers, switches, panel boards and protective devices. The battery charging system is connected directly to the AC station service supply system. Proper design, sizing, and maintenance of the components that make up the DC station service supply system are required.

In the past the AESO has not specified the DC station service supply system for most transmission substations in the project functional specification. Currently in Alberta, there appear to be varying design principles and standards applied by TFOs with respect to battery capacity. In the AESO's view, and the WG agrees, a consistent minimum requirement of the battery system is necessary.

In North America, most utilities require at least eight (8) hours of discharge time for the batteries. Other technical requirements respecting DC station service supply systems in various USA and Canadian utilities include the following:

- The DC station service supply system must be capable of operating continuously without malfunction or overheating in the voltage range and load current requirements of the substation;
- Battery sizing must be as per IEEE standard 485 (*Recommended Practice for Sizing Lead Acid Batteries for Stationary Applications*) to carry all the required DC loads during an AC power failure;
- Batteries with a minimum life expectancy of twenty (20) years must be installed; and
- Battery chargers must be able to provide full rated DC output current with battery disconnected.

Proposal #9

Based on input from the WG, the AESO proposes that the following minimum requirements respecting DC station service supply systems be included in Proposed New Section 502.11:

<u>For all transmission substations including Type 1 substations</u>

a. Battery sizing must be determined as per IEEE standard 485 or an equivalent standard that is approved by the AESO.
b. The batteries must be able to provide eight (8) hours of discharge time from the loss of AC station service supply system. The battery bank must be sized to be able to keep the transmission

substation control and alarm system powered for at least eight (8) hours upon loss of the AC station service supply system sources, and provide one (1) minute of close-open power to the breaker or breakers required to re-energize the transmission substation AC station service supply system source.

c. The batteries must be able to charge to full capacity within twenty four (24) hours or less from a fully discharged battery state.
d. The AC/DC rectifiers in the battery charger must be high efficiency and low output ripple without battery being connected, and must be able to supply its full DC output current rating with battery disconnected. This means that the battery charger should be full-wave and have suitable filter circuit to minimize output ripple effect.

For Type 1 substations only

e. Two independent battery banks, Bank A and Bank B, with independent chargers, must be provided. Either Bank A or Bank B must have a minimum discharge time of eight (8) hours at the connected load. Common mode failure must be avoided. Furthermore, manual transfer capability should be provided between the two battery banks.

3.12 POWER TRANSFORMERS

Typically power transformers represent the single most expensive equipment in most substations and it often takes months or even years to replace a power transformer if it fails. As such, power transformers must be properly sized and rated, and protected. Some protection requirements for power transformers have already been addressed in Section 502.3 of the ISO rules, *Interconnected Electric System Protection Requirements* ("Section 502.3"), such as the type of protection system and the redundancy requirement.

Proposal #10

Based on input from the WG, the AESO proposes that the following minimum requirements regarding power transformers be included in Proposed New Section 502.11.

In the WG's view, it is premature at this moment to specify any special requirements on power transformers to address geomagnetic disturbance ("GMD") effects, as the NERC EOP-010, *Geomagnetic Disturbance Operations*, has not been adopted in Alberta as yet.

a. All substation power transformers must have surge protection on both the high and low sides of the transformers in the form of surge arresters.
b. Transformer ratings must be based on CSA C88 M90 or later versions. The CSA C88-M90 was published in 1990 and was reaffirmed in 2009.
c. FCBN (full capacity below nominal) is required for all power transformers with HV tap-changers. This means that a transformer with HV tap-changer must be able to deliver its rated capacity when the voltage source is lower than the rated voltage within the acceptable range.

d. The AESO must specify whether a LTC (load tap changer) is required or not for power transformers in the project functional specification.
e. For all transformers, the tap changer should be such that it provides a minimum voltage regulation range of +/-10%, unless the AESO specifies otherwise in the project functional specification.
f. Any ratings beyond the nameplate rating, if specified in a functional specification with a specified load cycle, must be recorded and provided to the AESO.
g. The load cycle test to meet functional specification requirement in “f” must be performed in accordance with IEEE Standard C57.119 (*Recommended Practice for Performing Temperature Rise Tests on Oil-Immersed Power Transformers at Loads beyond Nameplate Rating*). The test report must include, to the maximum extent possible, all information as specified in IEEE Standard C57.91 (*Guide for Loading Mineral-Oil-Immersed Transformers and Step-Voltage Regulators*).
h. Transformer loss evaluation must be carried out, if stipulated by the AESO in a project functional specification. The AESO is required to provide, in the project functional specification, 20-year loading levels and the economic parameters (which is similar to line optimization studies in Section 502.2) for the TFO or market participant to conduct such evaluation.
i. The impedance value of a transformer is the responsibility of the TFO or the owner of the transformer. However, the AESO may prescribe the impedance value of a transformer in the project functional specification.
j. For system transformers, consideration should be given to the design and control such that parallel operation is capable. For load transformers, parallel operation will be determined by the TFO and load customers.
k. Transformer testing is the responsibility of the TFO and must meet the test procedures outlined in CSA C88 (*Power Transformers and Reactors*). Currently, TFOs require either type testing or routine testing of the transformers.

3.13 CIRCUIT BREAKERS

The purpose of a circuit breaker is to

- interrupt and clear, as quickly as possible, short circuit current brought on by a short-circuit on a faulted equipment;
- clear faults as quickly as possible to maintain system stability;
- reduce the probability and degree of harm to the general public, utility personnel, and property;
- reduce the amount of damage the faulted equipment sustains, thus containing repair costs, service interruption duration, and impact on the environment; and
- clear transient faults to enable service restoration as quickly as possible.

Proposal #11

Based on the input from the WG, the AESO proposes that the following minimum requirements regarding circuit breakers be included in Proposed New Section 502.11:

a. All circuit breakers, at a closed position, must be able to perform an open-close-open sequence of operation after power loss to the operating mechanism, regardless of the type of operating mechanism.
b. All circuit breakers must be tested in accordance with IEEE C37 or IEC 62271 collection of standards. These standards define common requirements for circuit breaker ratings, design and construction, and testing.
c. All disconnection or isolation devices must be tested in accordance with IEEE C37 or IEC 62271 collection of standards.
d. Single-pole circuit breakers are required for 240/260 kV or 500 kV transmission substations, unless the AESO specifies otherwise in the project functional specification.
e. The following table shows the maximum operating time for opening circuit breakers or circuit switchers. The operating time is defined as the time between when the trip circuit is energized and when the arc is extinguished in all poles.

Nominal Voltage (kV)	Maximum Operating Time (cycles)
138/144	3.0
240/260	2.5
500	2.0

3.14 SHUNT CAPACITORS AND SHUNT REACTORS

Capacitor banks are an effective source of voltage support, especially during peak load periods and during fault conditions, when the demand for reactive compensation is high. The switching cycle of a capacitor bank may often occur several times a day.

At a minimum, the switching devices for capacitor banks should be able to provide transient control to ensure acceptable quality of power to customers. It is known that excessive transient conditions at the substation capacitor bank bus can cause nuisance tripping of certain loads, such as variable speed drives. Transient overvoltages can also cause deterioration or damage to equipment insulation, control wiring, and cause extra operating duty for surge arresters.

Proposal #12

Based on input from the WG, the AESO proposed that the following minimum requirements regarding shunt capacitor banks and reactor banks located in transmission substations be included in Proposed New Section 502.11:

a. A circuit breaker or circuit switcher must be installed for tertiary winding or HV connected shunt capacitor bank or reactor bank.

b. For any shunt capacitor bank additions, the legal owner must review the switching transients to determine if controlled energization (e.g., controlled closing, transient current-limiting reactors, pre-insertion resistors, etc.) is required.

c. The AESO will identify, in the project functional specification, the requirement for a suitable switching device for a shunt capacitor bank or shunt reactor bank. The legal owner of the facility will be responsible for the detailed requirements for the switching device.

d. The impedance of a shunt reactor must not vary by more than 15% from the rated impedance up to 1.5 p.u. of the rated voltage.

e. Line connected shunt reactors must be either solidly grounded or grounded through a neutral reactor.

APPENDICES

APPENDIX I: INDUSTRY WORKGROUP

On June 25, 2015, the AESO issued a letter of invitation to the public inviting participation in the WG to develop a proposed new rule "substation and technical operating requirements".

A number of parties expressed interest in the workgroup, including:

- AltaLink L.P.,
- ATCO Electric,
- ENMAX Power Corporation,
- EPCOR Distribution & Transmission, and
- FortisAlberta Inc.

The following table lists the representatives from each organization in the WG. These representatives participated in the technical discussions throughout the process.

Organization	Primary	Alternate
AESO (chair)	Ligong Gan Lead Engineer	Dan Shield, Director, Engineering Fred Ritter, Chief Engineer
AltaLink	Cory Akins Principal Engineer - Substations	Colin Clark Principal Engineer - Major Equipment and HVDC/FACTS
ATCO	Arden Spachynski Principal Engineer, Substation Engineering	Darrell Wilvers Senior Technical Supervisor, Innovation
EPCOR	Lucian Ciocoiu Senior Manager, Transmission Assets	Liviu Bogdan Substation Asset Manager
ENMAX	Len Huynh Manager, Electrical Engineering	Bryce Hughes Transmission Planning Engineer
Fortis	Richard Bahry, Director, Engineering	

SUBSTATION RULE 502.11 WORKGROUP
TERMS OF REFERENCE (Final)
September 18, 2015

1. Purpose

The AESO is responsible for the safe, reliable and economic planning and operation of the Alberta Interconnected Electric System ("AIES"), under the *Electric Utilities Act* and its regulations. The AESO develops and publishes binding ISO Rules, including Operating Policies and Procedures (collectively "ISO Rules"), pursuant to the Act and its regulations.

This Terms of Reference document is to notify stakeholders that the AESO intends to develop a New ISO Rule, Section 502.11 (and may also develop an associated Information Document), which will address the minimum technical requirements for future transmission substations to ensure the integrity and reliable operation of the AIES. To this end, the AESO is forming an industry workgroup to identify, prioritize and discuss the issues and possible solutions related to the minimum transmission substation technical requirements.

2. Membership

The membership of the New ISO Rule 502.11 Workgroup ("WG") will be drawn from the Alberta electric industry. The AESO encourages participation from all Transmission Facility Owners (TFOs) and major industrial customers that have ownership and direct involvement in transmission substation design, construction and operation. Although the participation in the WG is open to the whole industry, the AESO reserves the right to limit the WG membership for the sake of efficiency. Membership in the WG will be limited to one individual per organization unless otherwise agreed to by the AESO. The WG will be chaired by the AESO representative.

The WG members must agree to the following:

- be willing to participate in all work of the WG, and to act in a professional and open manner;
- be willing to share experience and knowledge with other WG members;
- be willing to sign a confidentiality agreement protecting commercially sensitive data and information that may be shared among the WG members;
- have sufficient technical knowledge, or carry a primary technical responsibility within their organizations, related to transmission substation design, construction, commissioning and operation; and
- be willing to undertake investigations into specific technical issues as determined by the WG.

The membership of WG may be published on the AESO website.

3. Scope

The scope of the workgroup discussions will be as follows:

- WG members will provide input and ideas that will form the basis of a future recommendation paper to be released by the AESO;
- The AESO is committed to carefully examining and analyzing all information and suggestions from the WG in the development of the recommendation paper. The AESO is committed to communicating with the WG members on the contents of the recommendation paper prior to its finalization;
- WG members may present ideas and recommendations to the WG for consideration and discussion in an open and responsive manner;
- The WG will focus primarily on the technical rules. However, WG members may be required to assist the AESO and other WG members in understanding and evaluating the financial implications of potential technical options;
- WG members will not be precluded from participating in the ISO Rule consultation process or in any related Alberta Utilities Commission ("AUC") proceeding in their own capacity, independent from the AESO;
- The AESO, in consultation with the WG, will determine if an independent or third party assessment of the entirety or a portion of the draft rule will be needed.

4. Principles

The AESO has developed a set of principles, set out in Appendix A, to ensure its consultation is inclusive, transparent, fair and efficient.

5. Meetings

- The WG chair will be an AESO representative and will be at all meetings;
- The WG will meet monthly, or otherwise as determined by the AESO and the WG;
- The AESO will ensure minutes of meetings are taken. However, minutes of meeting will not be posted on the AESO website;
- The WG chair will make efforts to distribute the agenda and materials to the WG prior to any meetings.

6. Consultation Steps and Schedule

The table below presents a preliminary schedule for the proposed New ISO Rule 502.11. Note that the proposed dates are subject to change.

ISO Rule Consultation Process Steps	**Activity and Documents**	**Proposed Schedule**
Step 1	The AESO invites participation in the WG by way of a Terms of Reference document	Jun/15
Step 2	WG members provide written comments to the AESO on the proposed Terms of Reference and briefing materials (if	by Jul 15/15

	any)	
Step 3	The AESO replies to stakeholder's written comments (if any)	by Sep 4/15
Step 4	The AESO holds technical meetings with WG members to identify, review and discuss the minimum technical requirements of New ISO Rule 502.11	Sep/15 – Jan/16
Step 5	The AESO drafts and circulates a recommendation paper to WG members setting out the minimum technical requirements proposed to be included in New ISO Rule 502.11	Jan/16
Step 6	The WG members review the recommendation paper and provide written comments (if any) back to the AESO	Feb/16
Step 7	The AESO reviews comments from WG members and provides written responses. The AESO finalizes the technical requirements	Apr/16
Step 8	The AESO starts drafting New ISO Rule 502.11 and circulates to WG members for final comments	May/16 – Jul/16
Step 9	The AESO finalizes proposed New ISO Rule 502.11, and issues a Letter of Notice for the New ISO Rule 502.11 to all industry stakeholders	Sep/16
Step 10	Industry stakeholders provide written comments on the proposed New ISO Rule 502.11	Oct/16
Step 11	The AESO replies to stakeholder comments and invites position letters from stakeholders	Nov/16
Step 12	The AESO files final proposed New ISO Rule 502.11 with the AUC	Dec/16

Appendix A
AESO CONSULTATION PRINCIPLES FOR ISO RULE DEVELOPMENT

The AESO principles for consultation on draft ISO rules are intended to provide guidance respecting the conduct of both the AESO and stakeholders. The AESO principles for consultation are as follows:

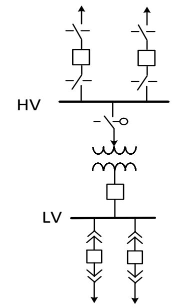
1. The ISO rules consultation process will be inclusive, transparent, fair and efficient and will be understood and accepted by all parties.
2. All parties will act in good faith and in a fair and respectful manner when engaged in the ISO rules consultation process.
3. The AESO has a statutory obligation to ensure the safe and reliable operation of the Alberta interconnected electric system ("AIES") and to promote a fair, efficient and openly competitive

market for electricity. In the ISO rules consultation process, the interests of individuals must be considered in the context of the reliable operation of the AIES and in the public interest as a whole.

4. The ISO rules consultation process, particularly with respect to the degree of detail of information provided by the AESO and stakeholders, the time required for review of that information, and the amount of related discussion, will be commensurate with the importance, complexity, potential impacts, and urgency of the draft ISO rules changes.
5. The AESO will commence consultation early in the ISO rules consultation process to allow sufficient time for stakeholder participation and will provide stakeholders with complete, accurate, timely and comprehensible information. AESO information will be made available in a manner that stakeholders can readily understand and with adequate time for review and consideration.
6. The ISO rules consultation process will involve a full discussion of the views of the stakeholders in order to enable the AESO to make the best decision possible in the context of the AESO statutory mandate.
7. The AESO may develop a written Terms of Reference for each ISO rules consultation process, which may include description of relevant issues, establishment of working groups, one or more technical conferences, and a proposed schedule of key dates. The AESO will seek stakeholder input before finalizing the Terms of Reference.
8. Stakeholders will be given the opportunity to provide written comments in response to AESO documentation made available during the ISO rules consultation process.
9. Each stakeholder will raise all concerns or suggestions for improvement, and provide those concerns or suggestions for improvement in writing for discussion with others participating in the ISO rules consultation process and to share information necessary for others to understand and evaluate those concerns or suggestions.
10. All Terms of Reference, AESO information, comments from stakeholders with AESO replies, agendas and action items will be in writing and may be posted on the AESO website. Only those comments received from stakeholders in writing will be considered by the AESO when finalizing draft ISO rules.
11. When finalizing the draft ISO rules, the AESO will have regard for all written stakeholder input received during the ISO rules consultation process and will provide a written explanation where the draft ISO rules changes could not address a stakeholder concern or accommodate a stakeholder suggestion.
12. While written input from stakeholders during the ISO rules consultation process will inform the AESO's decision-making, the responsibility for the decision rests with the AESO, pursuant to its statutory mandate.

APPENDIX II: TYPICAL SUBSTATION LAYOUTS

SINGLE BUS LAYOUT



The single bus layout is the simplest layout and is usually used for Points of Delivery connected via single line (radial or t-tap) or, in some cases, in-out to the transmission network. It consists of a single main bus which is energized at all times and to which all transmission lines and power transformers are connected. Each line or transformer termination is electrically connected to the main bus through a single circuit breaker and disconnect switch. If the load is expected to stay static or have minimal long term growth, a radial or t-tap interconnection with a simple bus layout may be considered. An in-out interconnection may be considered if the interconnected transmission line has poor performance (e.g., an outage rate more than doubling the 5-year system average). For substations with more than one power transformer, an examination on more reliable bus layout would be required to limit the risk of losing supply to the entire substation for an extended period of time.

Characteristics of single bus layout

- Simplicity of design and construction, which makes it cost effective for dedicated loads or remote loads;
- Lengthy outages would occur for maintenance work or any problems with the bus, or the transformer;
- Reliability of supply is largely dependent on the performance of the interconnecting transmission line. This is especially true for radial or t-tap interconnections.
- It is impossible to perform maintenance work on the main bus or the transformer without taking the entire station out of service;
- Once in service, the entire station must be de-energized to extend the main bus or to connect an additional transmission line or transformer to the main bus.

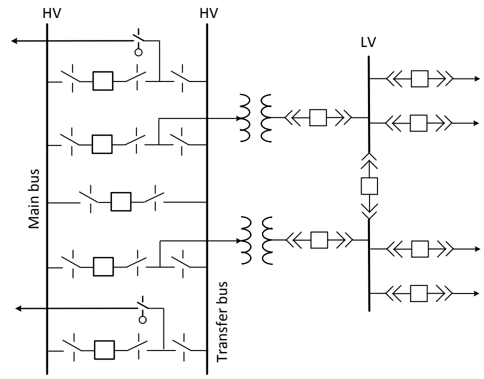
Expandability

A single bus layout may not be suitable for expansions as the substation is normally small and compact in size. If future expandability is not considered during the original design, expansion can be expensive and may require long interruptions of service to customers.

MAIN AND TRANSFER BUS LAYOUT

A main and transfer bus layout consists of two independent buses with the main bus energized all the times in normal operation. In normal design, the transfer bus is of smaller size than the main bus. This configuration has not been popular in Alberta on the high voltage side of a substation, although it has been often found in the 25 kV or 13.8 kV systems.

During normal operation, the main bus behaves like a single bus configuration. However, when it is necessary to remove a circuit breaker from service for maintenance or repair, it is possible to switch the element connected to the circuit breaker to the transfer bus such that no loss of service occurs. In the event of maintaining the main bus, the critical loads or, in some cases, all loads on the main bus may be transferred to the transfer bus to ensure continuity of supply.



Characteristics of main and transfer bus layout

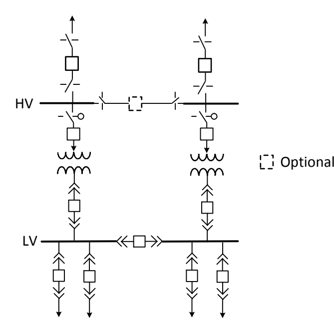
- Any circuit breaker can be taken out of service for maintenance without loss of supply, by transferring loads to the transfer bus through the bus tie breaker.
- The cost is increased compared to single bus layout due to an extra bus and the bus tie breaker, and the resulting increased complexity of the protection system.
- Similar to single bus layout, failure of the main bus or any circuit breaker would still result in the loss of supply of the entire substation.

Expandability

A main and transfer bus layout may be expandable to a folded breaker-and-half or other configurations, if expandability is properly considered in the initial design. If future expansion is not considered in the original design, expansion may be relatively expensive.

SECTIONALIZED BUS LAYOUT

A sectionalized bus layout is an extension to the single bus configuration. This layout allows two or more single bus sections to be electrically connected via bus sectionalizing devices. The sectionalizing devices can be disconnect switches or combined with a circuit breaker, which are operated normally open or closed depending on the system requirements. This design provides some enhanced levels of reliability to the load over a single bus configuration. The sectionalized bus design has several considerations that determine the applicability of the arrangement.



- If the load is expect to stay static or have minimal growth that would not be forecast to exceed 30-45 MVA within 10 years, a sectionalizing design may be considered. The 30-45 MVA trigger is a threshold value that has been used historically in Alberta and other jurisdictions and is, in general, a level when other distribution and back-up measures start to arise.
- Where double feed is provided for any single load, it is generally desirable to have sectionalized bus layout with each line connected to separate bus sections.

- Sectionalized bus layout without a circuit breaker is generally not recommended for urban areas due to the increased outage exposure and sensitivity of urban load to the continuity of supply. A circuit breaker provides increased reliability by reducing the possibility of interruption to the entire substation.

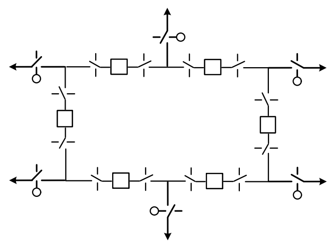
Characteristics of sectionalized bus layout

- Cost effective for smaller but more sensitive loads if such loads are able to tolerate momentary line outages.
- Without a sectionalizing circuit breaker, the substation can still be returned to service shortly after a permanent fault on one of the interconnecting transmission lines or one of the power transformers.
- Without a sectionalizing circuit breaker, maintenance of the sectionalizing disconnect requires a full substation outage (unless a second sectionalizing disconnect is provided in series with the first one).
- With a sectionalizing circuit breaker, each section behaves as a separate bus bar and an outage on each bus section would not impact the other bus section.

Expandability

A sectionalizing bus layout is typically set up to expand into a ring bus, a breaker-and-half or a breaker-and-third provided expansion is considered in the initial design and sufficient land is provided for future substation expansion. If expansion is not incorporated into the initial design, moving to a ring bus or a breaker-and-third configuration may be expensive.

RING BUS



This configuration requires the same number of circuit breakers as feeders but allows all circuits to remain in service while one circuit breaker is out of service for maintenance. During normal operation, all circuit breakers are closed. A ring bus design provides increased security of supply with multiple sources, no bus exposure, and has high operating flexibility for planned and forced outages. This configuration is designed for substations with large transformer loads that require a high degree of reliability. The design is generally limited to six or less nodes to prevent undesirable system fragmentation, which can manifest itself into segmentation of key parts of the bulk transmission network.

Characteristics of ring bus layout

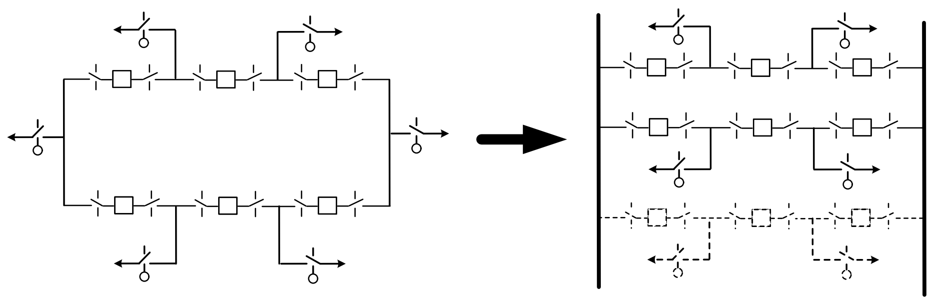
- This layout is relatively cost effective with only one breaker per line or transformer termination.
- With reduced stability and reliability, this configuration allows for any breaker or bus section maintenance without disrupting any line or transformer. The system is effectively a single bus layout during any breaker maintenance.
- Increased level of reliability and operational flexibility compared with a single bus layout in that any single line fault does not disrupt the substation supply. However, a second contingency outage may

cause system fragmentation and/or the potential loss of a portion of the station load.

- A breaker failure event will normally cause the loss of a second circuit, but not the entire substation. However the loop cannot be restored until the circuit breaker is repaired.
- Design of the protection and control system is slightly more complex as each circuit protection must operate on two circuit breakers and each circuit breaker is controlled by two circuit protection systems.

Expandability

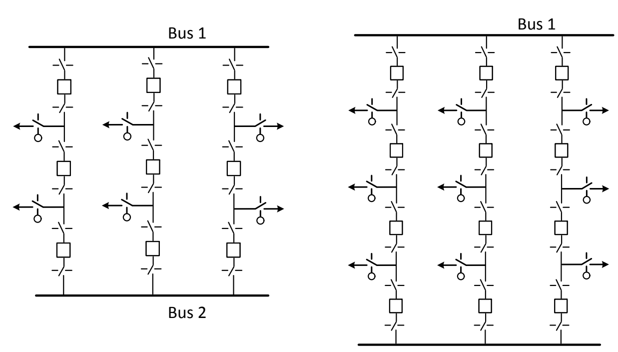
It is common practice to build a substation initially as a ring bus, which can be easily converted to a breaker-and-half or other configurations, if this is considered in the initial design, as the following diagram illustrates. The ultimate number of elements to be built at the substation should be defined at the initial design, otherwise expansion and integration of a breaker section can be expensive and space consuming.



BREAKER-AND-HALF AND BREAKER-AND-THIRD BUS LAYOUT

Application

In a breaker-and-half or breaker-and-third design, each line or transformer termination can be served from two directions, similar to a ring-bus layout. Either layout increases the security of supply with multiple sources, minimizes bus exposure, and allows for maintenance without supply outages. These configurations are always explored for these substations which are set up as area hubs and/or have very large loads (e.g., ≥100 MVA) that are sensitive to the loss of supply in the form of either momentary or sustained outages. They are often the choice of design for supplying large urban centres. However, the choice of the specific design depends largely on the cost consideration, voltage



Breaker-and-half

Breaker-and-third

level, reliability requirement, load criticality, and other factors.

Either a breaker-and-half or breaker-and-third design contains two main buses that are energized all the times in normal operation. The breaker-and-half configuration is prominently used in Alberta for 240 kV and 500 kV voltages. The breaker-and-third layout can be found in many substations operating at 138/144 kV in Alberta.

In Alberta, it is common practice to connect a power transformer directly off a main bus, or autotransformers between main buses, through only disconnect switches. In this case, if there be a fault in the autotransformer, it would trip all circuit breakers directly connected to the main buses.

Characteristics of breaker-and-half and breaker-and-third layout

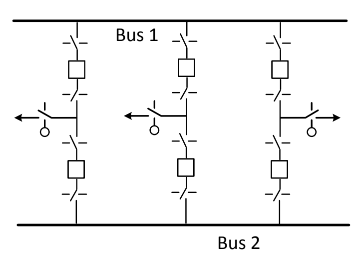
- There is generally an increased space requirement due to the number of circuit breakers and the associated equipment, and consequently a higher cost.
- Higher reliability and operating flexibility for maintaining system continuity under breaker failure events, bus faults, or a contingency during breaker and or bus maintenance.
- Either bus can be taken out of service at any time without loss of service to any loads.
- A breaker failure event of the shared circuit breaker would interrupt power flow to both circuits, but not the entire substation. Additionally, faults on either of the main buses cause no circuit interruptions.
- Maintenance of a bus or bus disconnect switch requires opening of all circuit breakers connected to the bus, but does not require an outage of any feeder.
- In extreme situations, the substation can still transfer power with both buses out of service by opening all bus-connected circuit breakers. In these operating modes, the substation is split and the circuits are fragmented. This is unique for this scheme.
- The control and protection systems and schemes are more involved and complex since the shared circuit breakers have to respond to faults on two circuits. Auto-reclose schemes associated with the shared circuit breakers is more complex since they have to handle different control modes depending on which transmission line trips.

Expandability

A breaker-and-half and breaker-and-third layouts are flexible in handling future expansions. The only major factor which limits the expandability of the substation is the available land.

DOUBLE BREAKER

In a double-breaker design, each line or transformer termination is served from two circuit breakers. This configuration provides the highest level of security of supply and is generally intended for these large generation stations or transmission substations which are considered as the most critical facility to the operation of the system.



Characteristics of double breaker layout

- This configuration is the most expensive design per circuit due to the number of circuit breakers and the associated equipment, and the resulting land requirement.
- Highest reliability and operating flexibility for maintaining system continuity for breaker failure events, bus faults, or a contingency during breaker and or bus maintenance.
- A breaker failure event of a circuit breaker would interrupt power flow to only one circuit, not impacting any other circuits.
- Either bus can be taken out of service at any time without loss of service to any loads.
- The control and protection system and schemes are only slightly more complex than the single bus configuration.

Expandability

A double breaker layout is flexible in handling future expansions. The only major factor which limits the expandability of the substation is the available land.