ISO Rules
Part 500
Division 502 Technical Requirements
Section 502.11 Substation Technical and Operating Requirements

Stakeholder Consultation Session Draft

August 20, 2019

Applicability

1 Section 502.11 applies to:

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

(b) the **ISO**.

Requirements

New and Existing Substation Transmission Facilities

2(1) On and after **[effective date of Section 502.11]** the **legal owner** of any new substation **transmission facility** which is to be directly connected to the **interconnected electric system** must comply with the provisions of this Section 502.11, prior to the new substation **transmission facility** being energized.

(2) Subject to subsection 2(1), the provisions of this Section 502.11 do not apply to a substation **transmission facility**:

(a) that was built in accordance with a previous technical requirement, technical standard, or **ISO rule**; or

(b) with a functional specification that refers to a previous technical requirement, technical standard, or **ISO rule**,

however, the substation **transmission facility** must remain in compliance with that previous technical requirement, technical standard, **ISO rule** or functional specification.

(3) The **ISO** may, in writing and notwithstanding subsection 2(2), require the **legal owner** of a substation **transmission facility** to comply with any or all of the provisions of this Section 502.11 if the **ISO** determines that such compliance is necessary for the safe and reliable operation of the **interconnected electric system**.

Functional Specification

3 The **ISO** must, in accordance and generally consistent with this Section 502.11 and any other applicable **ISO rules**, approve of a written functional specification containing further details, work requirements, and specifications for the design, construction, and operation of that substation **transmission facility**.

Ambient Temperature

4(1) The **legal owner** of a substation **transmission facility** must design the substation **transmission facility** to be capable of operating continuously within the minimum and maximum ambient temperatures as follows:

(a) for the minimum ambient temperature, as set out in the *Minimum Temperature* map posted

on the AESO website; and

(b) for the maximum ambient temperature,

(i) as determined by the **legal owner** of the substation **transmission facility** based on a minimum of 15 years of historical temperature data at or near the substation site with an occurrence frequency of no more than 0.1%; or

(ii) a maximum ambient temperature of plus 40° Celsius.

(2) The **legal owner** of a substation **transmission facility** must design the substation **transmission facility** to withstand a temperature change of 15° Celsius per hour.

Weather Loading Return Periods

5(1) The **legal owner** of a substation **transmission facility** that is located outdoors must design the outdoor substation **transmission facility** based on the minimum return periods for weather loading as follows:

(a) for a **major substation**, a 100 year return period; or

(b) for a substation other than a **major substation**, a 50 year return period.

(2) The **legal owner** of a substation **transmission facility** that is located outdoors must, subject to subsection 5(3) base the gust wind loading, and the wet snow and wind loading on historical weather data at or near the substation site.

(3) The **legal owner** of a substation **transmission facility** that is located outdoors must, if the historical weather data as required in subsection 5(2) is not available, use the *Gust Wind Loading* map or the *Wet Snow and Wind Loading* map posted on the AESO website, as applicable.

Grounding

6(1) The **legal owner** of a substation **transmission facility** must, at a minimum, ensure that the grounding grid meets the short circuit current level provided in the functional specification for that substation **transmission facility** at the in-service date.

(2) The **legal owner** of a substation **transmission facility** must, in accordance with **good electric industry practice**, review and upgrade the grounding grid to accommodate the short circuit current levels up to the maximum short circuit current levels provided in the functional specification for that substation **transmission facility**.

(3) The **legal owner** of a substation **transmission facility** must design the grounding system of the substation to operate as an effectively grounded system unless the **ISO** specifies otherwise in the functional specification for that substation **transmission facility**.

(4) The **ISO** must specify in the functional specification of a substation **transmission facility** the following estimated short circuit current levels at locations within the substation with a nominal voltage of 100 kV or higher:

(a) at the in-service date; and

(b) at least 7 years into the future from the in-service date.

Lightning and Other Surge Protection

7(1) The **legal owner** of a substation **transmission facility** must design the lightning surge protection to take into account the average lightning ground flash density level at or near the substation site.

(2) The **legal owner** of a substation **transmission facility** must ensure that a surge arrester used to meet the requirements of this subsection 7 has adequate protective levels for the protective distances required for transformers and transmission line entries.

(3) The **legal owner** of a substation **transmission facility** must, in designing the direct stroke lightning protection of the substation **transmission facility**, use the minimum mean-time-between-failure values set out in the following Table 1:

Table 1
Mean-time-between-failure requirement

Substation **transmission facility**	Mean-time-between-failure (years)
a substation **transmission facility** containing transformers with a secondary nominal voltage of 100 kV or higher	1000
all other substation **transmission facilities**	400

(4) The **legal owner** of a substation **transmission facility** must ensure that any transformer in the substation **transmission facility** has surge protection on all exposed terminals of the transformer, except a neutral terminal in the form of surge arresters, which must be placed as close to the transformer terminals as reasonably practicable.

(5) The **legal owner** of a substation **transmission facility** must ensure that a shunt capacitor or a shunt reactor in the substation **transmission facility** has surge protection.

(6) The **legal owner** of a substation **transmission facility** must install a surge arrester or surge arresters at each transmission line entrance.

(7) The **legal owner** of a substation **transmission facility** that contains gas-insulated switchgear must install a surge arrester at all exposed outdoor terminals of the gas-insulated switchgear.

(8) The **legal owner** of a substation **transmission facility** must ensure that an insulation coordination study is conducted to determine the required protective levels where surge arresters are applied to:

(a) a shunt capacitor bank at a nominal voltage greater than 100 kV;

(b) a shunt reactor bank connected to a **bulk transmission line**; or

(c) a **reactive power** resource with a primary nominal voltage of 100 kV or higher.

Continuous Operating Voltage Range

8 The **legal owner** of a substation **transmission facility** must design the substation **transmission facility** to be capable of operating continuously within the minimum and maximum voltage levels set out in the following Table 2:

Table 2
Required continuous operating voltage range

Nominal Voltage (kV)	Minimum Voltage (kV)	Maximum Voltage (kV)
138	124	150
144	130	155
240	216	264
260	234	275
500	475	550

Insulation Requirement

9(1) The **legal owner** of a substation **transmission facility** must, subject to subsections 9(2) and 9(3), design and operate the substation **transmission facility** to meet the minimum insulation requirement set out in the following Table 3:

Table 3
Minimum basic lightning impulse level ("BIL") and basic switching impulse level ("BSL") for components of an air-insulated substation transmission facility with a nominal voltage of 138 kV or higher

Substation transmission facility component	BIL (kV)	BIL (kV)	BIL (kV)	BSL (kV)
	138/144 kV	240/260 kV	500 kV	
post insulator and disconnect switch	550	900	1550	1175
circuit breaker and circuit switcher	650	1050	1800	1300
current and voltage transformer	650	1050	1800	1300
transformer winding (with surge arrester)	550	850	1550	1175

(2) The **legal owner** of a substation **transmission facility** that contains gas-insulated switchgear must design and operate the substation **transmission facility** to meet the minimum insulation requirements set out in the following Table 4:

Table 4
Minimum BIL and BSL levels for gas-insulated switchgear

Substation transmission facility component	BIL (kV)	BIL (kV)	BIL (kV)	BSL (kV)
	138/144 kV	240/260 kV	500 kV	
all equipment in a gas-insulated switchgear enclosure	650	1050	1550	1175

(3) The **legal owner** of a substation **transmission facility** rated at a nominal voltage of 72 kV or less must design and operate the substation **transmission facility** to meet the minimum insulation requirement set out in the following Table 5:

Table 5
Minimum BIL levels for components of an air-insulated substation transmission facility with a nominal voltage of 72 kV or less

Substation transmission facility component	BIL (kV)			
	13.8 kV	25 kV	34.5 kV	69/72 kV
circuit breaker	110	150	200	350
indoor switchgear, transformer (with surge arrester) and shunt reactor terminals	95	125	170	350
outdoor transformer (with surge arrester) and shunt reactor terminals	110	150	200	350
all other equipment	110	150	200	350

(4) The **legal owner** of a substation **transmission facility** must, where the substation **transmission facility** is located at an altitude exceeding 1,000 meters above sea level, consider the altitude factor in an insulation coordination study and in determining **equipment ratings**.

(5) The **legal owner** of a substation **transmission facility** must, in specifying any insulators and bushings for the substation **transmission facility**, take contamination levels into consideration.

(6) The **ISO** must specify whether an insulation coordination study is required for a **major substation** in the functional specification.

Terminal Components Cannot be Limiting Factor

10(1) The **legal owner** of a substation **transmission facility** must ensure that any terminal component inside the substation connecting it to a **bulk transmission line** is not the limiting factor of the **facility rating** of that **bulk transmission line**.

(2) The **legal owner** of a substation **transmission facility** must ensure that any terminal component inside the substation connecting that connects the substation to a **transformer** is not the limiting factor of the **facility rating** of that transformer.

Bus Arrangement

11(1) For the purposes of this subsection 11, a reference to a substation element means the following substation **transmission facilities**:

(a) a phase-shifting transformer;

(b) a load transformer with a rated capacity of 100 MVA or higher;

(c) a transformer with a secondary nominal voltage of 100 kV or higher;

(d) a transmission step-up transformer for a **generating unit**, an **aggregated generating facility** or an **energy storage facility**;

(e) a termination connecting a **bulk transmission line**; or

(f) a **reactive power** resource with a primary nominal voltage of 100 kV or higher.

(2) The **legal owner** of a substation **transmission facility** must ensure that a planned maintenance event of a substation element does not cause another substation element to be taken out of service, except where these substation elements are in series or as otherwise approved by the **ISO**.

(3) The **legal owner** of a substation **transmission facility** must ensure that a failure event of a circuit breaker or circuit switcher does not result in the tripping of more than 4 of a combination of:

(a) a transformer, including a transmission step-up transformer for a **generating unit**, an **aggregated generating facility**, or an **energy storage facility**; and

(b) a **bulk transmission line**,

provided however, that this provision does not apply to a circuit breaker or circuit switcher that is positioned to connect 2 individual bus sections.

(4) The **legal owner** of a substation **transmission facility** must, where a substation is connected with another substation through more than one **bulk transmission line** which each has a nominal voltage of 200 kV or higher, place each **bulk transmission line** such that a breaker failure event does not trip 2 or more of these **bulk transmission lines** simultaneously.

(5) The **legal owner** of a substation **transmission facility** must, if proposing a ring bus arrangement that has more than 6 nodes, submit the proposed arrangement to the **ISO** for review and approval.

(6) The **ISO** must review the proposed ring bus arrangement submitted pursuant to subsection 11(5) and either:

(a) ask the **legal owner** of a substation **transmission facility** to make changes to the design and submit a revised bus arrangement; or

(b) provide written approval of the proposed ring bus arrangement in the functional specification of the substation **transmission facility**.

(7) The **ISO** must specify the following parameters for the design of a bus arrangement in the functional specification of a substation **transmission facility**:

(a) the ultimate number of **bulk transmission line** terminations;

(b) the ultimate number of transformer terminations; and

(c) the ultimate **reactive power** resources at a primary nominal voltage of 100 kV or higher.

(8) The **legal owner** of a substation **transmission facility** must, unless otherwise specified in the functional specification for that substation **transmission facility**, design the high voltage bus to meet the minimum continuous current carrying capability set out in the following Table 6:

Table 6
Minimum continuous current carrying capability of high voltage bus

Substation transmission facility component	Minimum continuous current (A)		
	138/144 kV	240/260 kV	500 kV
main bus	1200	3000	4000
cross bus	600	2000	3000
transmission line terminal	600	2000	3000

Note: In Table 6, where a main bus includes a section of ring bus scheme, a section of simple bus scheme, or a bus of double bus scheme, but does not include a transfer bus; and a cross bus includes diameter sections of a double bus scheme.

(9) The **legal owner** of a substation **transmission facility** must, if a substation high voltage bus is not designed for the ultimate bus arrangement, ensure that the design is such that it can be converted into the ultimate arrangement, as specified in the functional specification of the substation **transmission facility**, without relocating any existing substation elements except a termination connecting a **bulk transmission line**.

(10) The **legal owner** of a substation **transmission facility** must, notwithstanding subsections 11(3) and 11(9), design the initial bus arrangement of a **major substation** such that a failure event of a circuit breaker or circuit switcher does not result in the tripping of more than 2 of a combination of:

(a) a transformer with a secondary nominal voltage of 100 kV or higher;

(b) a transmission step-up transformer for a **generating unit**, an **aggregated generating facility**, or an **energy storage facility**; and

(c) a **bulk transmission line**,

provided however that this provision does not apply to a circuit breaker or circuit switcher that is positioned to connect 2 individual bus sections.

Alternating Current Station Service Supply System

12(1) The **legal owner** of a **major substation** must design and operate the **major substation** to have at least 2 independent alternating current station service supply system sources, which can be any 2 of the following sources:

(a) a standby generator;

(b) a bus-connected station service transformer;

(c) a power voltage transformer;

(d) a transformer tertiary winding; or

(e) a distribution transformer connected to a nearby distribution line.

(2) The **legal owner** of a **major substation** must, in the case of a bus-connected station service

transformer that:

(a) serves to meet the requirement set out in subsection 12(1);

(b) is directly connected to a high voltage bus; and

(c) has a capacity of 3 MVA or larger,

install a circuit breaker or circuit switcher on the high voltage side of that bus-connected station service transformer.

Direct Current Station Service Supply System

13(1) The **legal owner** of a substation **transmission facility** must determine the battery size for the substation **transmission facility** based on *IEEE Standard 485 – IEEE Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications* or an industry standard that the **ISO** approves.

(2) The **legal owner** of a substation **transmission facility** must ensure that a substation direct current station service supply system is capable of providing a minimum of 8 hours of supply time for all direct current loads in the substation starting from when there is a the loss of all alternating current station service supply sources, including the final open-close-open operation of all related circuit breakers or circuit switchers.

(3) The **legal owner** of a substation **transmission facility** must ensure that a battery charger for a direct current station service supply system is capable of charging the connected battery in less than 24 hours from a fully discharged state to full capacity.

(4) The **legal owner** of a substation **transmission facility** must ensure that a rectifier for a battery charger is full wave and is capable of continuously supplying all direct current loads in normal operation when the battery is disconnected.

(5) The **legal owner** of a **major substation** must design and operate the substation to have 2 independent battery banks with the following characteristics:

(a) each bank has an independent battery charger;

(b) each bank has a minimum discharge time of 8 hours at the connected load;

(c) common mode failures are minimized; and

(d) transfer capability is available between the banks.

Transformer

14(1) The **legal owner** of a substation **transmission facility** must define transformer ratings based on *CSA Standard C88-M90 – Power Transformers and Reactors*.

(2) The **legal owner** of a substation **transmission facility** must, if specified in a functional specification for transformer ratings beyond the **normal rating** with a specified load cycle, test, record, and provide the test reports to the **ISO**.

(3) The **legal owner** of a substation **transmission facility** must ensure that the transformer ratings test report in subsection 14(2) includes information in accordance with *IEEE Standard C57.91 – Guide for Loading Mineral-Oil-Immersed Transformers and Step-Voltage Regulators* as applicable.

(4) The **legal owner** of a substation **transmission facility** must ensure that the test referred to in subsection 14(2) is 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*.

(5) The **legal owner** of a substation **transmission facility** must ensure that, if a transformer has a tap changer on the high voltage side, the transformer is capable of operating at the rated capacity when the operating voltage is lower than the nominal voltage but higher than the minimum voltage set out in subsection 8.

(6) The **ISO** must specify in the functional specification of a substation **transmission facility** whether an on-load tap changer is required for all transformers in the substation **transmission facility**.

(7) The **legal owner** of a substation **transmission facility** must, if an on-load tap changer is specified as in subsection 14(6), ensure that the tap changer has a minimum capability of ±10% of voltage range, with a maximum step size of 2.5%.

(8) The **legal owner** of a substation **transmission facility** must, if the functional specification of the substation **transmission facility** requires a transformer loss evaluation, perform the loss evaluation based on *IEEE Standard C57.120 – Loss Evaluation Guide for Power Transformers and Reactors* or another recognized industry standard.

(9) The **ISO** must, if it specifies that a transformer loss evaluation is required as in subsection 14(8), provide the following parameters in the functional specification of a substation **transmission facility**:

(a) 20 year loading levels;

(b) 20 year forecast of electricity cost; and

(c) all other necessary economic parameters.

(10) The **legal owner** of a substation **transmission facility** must determine the impedance value of the transformers in the substation **transmission facility** if the **ISO** does not specify the impedance value in the functional specification of the substation **transmission facility**.

(11) The **ISO** must, in the functional specification of a substation **transmission facility**, specify the impedance value of any of the following transformers:

(a) a transformer with a secondary nominal voltage of 100 kV or higher; or

(b) a transmission step-up transformer for a **generating unit**, an **aggregated generating facility**, or an **energy storage facility** that has a rated capacity of 400 MVA or higher.

(12) The **legal owner** of a **major substation** that has more than one transformer with a secondary nominal voltage of 100 kV or higher must design the transformers such that parallel operation can be executed, unless otherwise specified in the functional specification for that **major substation**.

Circuit Breaker or Circuit Switcher

15(1) The **legal owner** of a substation **transmission facility** must test any circuit breakers or circuit switchers in a substation **transmission facility** in accordance with the *IEEE C37* or *IEC 62271* collection of standards.

(2) The **legal owner** of a substation **transmission facility** must ensure that circuit breakers or circuit switchers operating at a nominal voltage of 100 kV or higher, in a closed position, are capable of performing an open-close-open sequence of operation after power loss to the operating mechanism, regardless of the type of operating mechanism.

(3) The **legal owner** of a substation **transmission facility** must ensure that any circuit breaker or circuit switcher meets the maximum operating cycles in the following Table 7.

Table 7
Maximum operating cycles of circuit breakers or circuit switchers

Nominal voltage (kV)	Maximum operating cycles
138/144	3.0
240/260	2.5
500	2.0

Note 1: The maximum operating cycles is measured as the number of cycles between when the trip circuit is energized and when the arc is fully extinguished in all poles, understandard testing conditions.

Note 2: a manufacturer type test is acceptable to demonstrate compliance with Table 7 requirements.

(4) The **legal owner** of a substation **transmission facility** must ensure that each circuit breaker on a **bulk transmission line** with a nominal voltage of 200 kV or higher is capable of single pole operation, unless the **ISO** specifies otherwise in the functional specification of the substation **transmission facility**.

Disconnect or Isolation Switches

16(1) The **legal owner** of a substation **transmission facility** must ensure that any disconnect switch or isolation device in a substation **transmission facility** is tested in accordance with the applicable *IEEE C37* or *IEC 62271* standards.
(2) The **legal owner** of a substation **transmission facility** must ensure all disconnect switches have ice breaking capability.

Shunt Capacitors

17(1) The **legal owner** of a substation **transmission facility** must install a circuit breaker or circuit switcher for a shunt capacitor bank that is connected to a bus with a nominal voltage of 100 kV or higher, or a tertiary winding of a transformer with at least one winding at a nominal voltage of 100 kV or higher.

(2) The **legal owner** of a substation **transmission facility** must, for a shunt capacitor bank connected to a bus with a nominal voltage of 100 kV or higher:

(a) review the switching transients to determine if controlled energization or a series in-rush reactor is required to ensure the shunt capacitor bank is properly protected; and

(b) if determined to be required in accordance with subsection 17(2)(a), implement the mitigation

prior to energization.

Shunt Reactors

18(1) The **legal owner** of a substation **transmission facility** must install a circuit breaker or circuit switcher for a shunt reactor bank that is connected to a bus or transmission line with a nominal voltage of 100 kV or higher.

(2) The **legal owner** of a substation **transmission facility** must, for a shunt reactor connected to a bus or transmission line with a nominal voltage of 100 kV or higher:

(a) review the switching transients to determine if controlled energization is required; and

(b) if determined to be required in accordance with subsection 18(2)(a), implement controlled energization prior to energization.

(3) The **legal owner** of a substation **transmission facility** must ensure that the impedance of a shunt reactor does not vary by more than 15% from the rated impedance up to 1.5 per unit of the nominal voltage.

(4) The **legal owner** of a substation **transmission facility** must, if a shunt reactor bank is connected to a transmission line at a nominal voltage of 100 kV or higher, ensure that the shunt reactor bank is either solidly grounded or grounded through a neutral reactor.

Revision History

Date	Description
yyyy-mm-dd	