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1 Purpose

This Information Document provides general information supporting section 502.3 of the ISO rules, *Interconnected Electric* System *Protection Requirements*. Sections 5 to 10 in this Information Document provide additional information that stakeholders may find useful. Each section 5 to 10 indicates the corresponding ISO rules subsection.

2 Related Authoritative Documents

The AESO's authoritative documents consist of ISO rules, the ISO tariff and the Alberta reliability standards. Authoritative documents contain binding rights, requirements and obligations for market participants and the AESO. Market participants and the AESO are required to comply with provisions set out in its authoritative documents.

Market participants are encouraged to review the following related authoritative documents:

(1) Section 502.3 of the ISO rules, *Interconnected Electric* System *Protection Requirements*. Section 502.3 sets out the minimum technical protection requirements when designing and constructing facilities.

3 Background

In Alberta, transmission facilities and generating facilities can be designed and constructed by a number of entities, including the legal owner of a transmission facility, the legal owner of an industrial complex and others such as wind farm developers and those developing merchant lines for power import and/or export.

To ensure a consistent approach to the design, engineering and construction of protection systems within Alberta, the AESO has developed section 502.3, which addresses the minimum technical requirements in the areas of protection systems while considering reliability, safety and economics.

4 Definitions

In section 502.3 there are a number of references to the defined term "protection system". For clarity, the definition of protection system does not include:

(a) non-electrical protection, such as gas pressure relays, temperature relays, etc.; or

(b) the main contacts of the circuit breakers or other interrupting devices; and

regarding the attributes of the breaker trip coils, does not include:

(c) the availability and readiness of the trip coils is part of the protection system (i.e. the trip coil is not burnt out);

(d) the activation of the trip coils is part of the protection system (i.e. the trip coil is energized correctly when required); or

(e) the energization of the trip coils operating the breaker is NOT part of the protection system (i.e. the circuit breaker main contact open correctly when required).

2500, 330-5th Avenue SW, Calgary, Alberta T2P 0L4 Phone: 403-539-2450 Fax: 403-539-2949
www.aeso.ca www.poweringalberta.com

5 Applicability to New and Existing Facilities Connected to the Interconnected Electric System (Subsection 1)

Section 502.3, in general, does not apply to existing protection systems presently connected to the interconnected electric system. However, as noted in subsection 3(2) of section 502.3, the AESO reserves the right, on a case-by-case basis, to require retrofitting existing, non-compliant transmission facilities or generation facilities in accordance with the provisions of section 502.3 for those facilities the AESO deems critical to the interconnected electric system.

Existing protection systems, including maintenance replacements, meeting the original designs do not normally need to be modified to comply with section 502.3, except as might be required for safety reasons by the authority having jurisdiction.

In general, section 502.3, applies to the design, engineering and construction on or after the effective date of section 502.3. For maintenance of existing protection systems, the authoritative document in effect at the time of the original design (or a subsequent edition with which the installation has been brought into compliance) applies.

For those legal owners of a transmission facility that own both facilities greater than one hundred (100) kV and facilities less than one hundred (100) kV, these requirements only apply to the facilities with a rated voltage equal to or greater than one hundred (100) kV. The AESO will address facilities with a rated voltage less than one hundred (100) kV directly in a project's functional specification.

6 Functional Specifications (Subsection 4)

From time to time, it may be necessary to design facilities that deviate from section 502.3. In these cases, the AESO will document the deviations in the approved functional specification for the project.

7 Protection System General Requirements (Subsection 6)

All protection systems must remain coordinated for any single power system element out of service.

7.1 Requirement for Two (2) Protection Systems (Subsection 7)

Each protection system is to be independent such that no single element failure will prevent both protection systems from working. Typically, the "A" protection system trips the "A" breaker coil, and the "B" protection system trips the "B" breaker coil. Cross triggering (the "A" protection system tripping both the "A" and "B" breaker coils) or other arrangements are acceptable provided no single element failure will prevent both protection systems from working.

Given the importance of the protection systems, it is generally expected that modern protection relays will be used which have a life expectancy of twenty (20) years or more.

7.2 Protection Relay Operate Times (Subsection 8)

To ensure appropriate protection relays are specified, maximum operate times are provided in subsection 8. These operate times may be determined by manufacture specifications or test results. Total clearing times which include the protection relay operate times, communication time, and breaker operate time will either be addressed in future requirements or in the projects functional specification.

7.3 Voltage Transformers

To ensure that protection systems have accurate voltage inputs and are not isolated for the protected element by an open breaker, potential transformers are required on each segment of bus.

If a bus tie breaker is installed on a substation bus, then three-phase voltage transformers are to be installed on each section of the bus that can be isolated by this breaker. This will only apply if the sectionalizing device (i.e. breaker) can be controlled or is automatically opened through protection operation and will not apply if the sectionalizing device is a manually operated switch.

This will apply to all bus configurations including simple bus, breaker and a half, breaker and a third, and ring bus arrangements.

7.4 Current Transformers (Subsection 12)

Per subsection 7(2) of section 502.3, each protection systems must be independent and may not share the same current core or voltage transformer winding. However, other devices used for other purposes such as metering, digital fault recorders, SCADA, power quality, or other unrelated protection systems may share a current core with the protection system where necessary, provided appropriate analysis has been undertaken.

Typically, current transformer ratios are selected to accommodate the present and anticipated ten (10) year fault level as identified in the project functional specification such that the current transformer ratios do not have to be changed for the first ten (10) years. The maximum available current transformer ratio is selected based on the ultimate fault level.

For each protection system application, saturation should be reviewed and account for both alternating current and direct current components in the primary current. The pre-magnetization of the current transformer core should also be consideration along with the X/R ratio. In IEEE C37.110-2007, recommendations are given in section 4.5.3 to determine the effects if no detailed calculation formula are provided by the relay manufacturer.

7.5 Protection System Power Supply (Subsection 13)

Regarding the redundancy of direct current battery systems, it is considered redundant if right at the batteries, a main “A” fuse is used to feed all “A” protection systems and a main “B” fuse is used to feed all “B” protection systems. This topic will be reviewed in further detail as part of the development of the ISO rules related to substations.

7.6 Event Capture (Subsection 14)

For new protection systems, event capture is required. For retrofits into existing facilities, consideration should be given to connecting adjacent protection systems but it is not mandatory. To meet the 1.0ms requirement GPS clocks are typically utilized.

Generally, it is recommended that a sampling rate of at least sixteen (16) samples per cycle and COMTRATE format should be used per IEEE C37.111-1999.

8 Bulk Transmission Line

8.1 Ground Fault Resistance Coverage (Subsection 15)

Ground fault impedance has been changed from “20 ohms” in the December 1, 2004 version of the *Alberta Interconnected Electric System Protection Standard* to “a minimum of five (5) ohms” in subsection 15 of section 502.3.

The reasoning for this change is as follows:

(a) Past practices on the interconnected electric system for line-to-ground fault protection using Mho characteristic impedance protection has been to provide a minimum of five (5) ohms coverage as follows:

  (i) for a ten (10) ohm line with a Mho characteristic impedance protection, the maximum fault resistance coverage is five (5) ohms without any infeed consideration; and

  (ii) legal owners of transmission facilities have not had issues with fault resistance coverage with this approach.

(b) For the last few years, some line protection settings have been applied with twenty (20) ohms fault resistance coverage. However, there is no clear indication that this approach increases the operational reliability of the line protections, but it did increase the efforts and resources to a large degree in developing the relay settings.

(c) A review of industry technical papers provided the following:

  (i) Page 127 of *Protective Relaying for Power Systems* (IEEE Press) states “Even with a 100-ohm tower-footing resistance and low-conductivity ground wires, the L-G fault impedance is only 3 ohms".

(ii) Page 10-61 of *Applied Protective Relaying* (Westinghouse) states "While the ground wires have reduced the tower footing effect from 10 ohms to 2.8 ohms….". This implies the fault resistance is about 2.8 ohms with ground wires installed.

(iii) Page 249 of *Protective Relaying Theory & Applications* (ABB) states "While the ground wires have reduced the tower footing effect from 10 ohms to 2.8 ohms….". This implies the fault resistance is about 2.8 ohms with ground wires installed.

(d) In the opinion of the Protection Rules Working Group, the increase in efforts, resources and cost does not result in any measureable enhancement in the reliability of line protections.

Given the above points, the Protection Rules Working Group decided to change the ground fault resistance coverage requirement from "20 ohms" to "a minimum of five (5) ohms".

For further clarity, the required protection relay operate times identified in subsection 7 are not intended to be applied in conjunction with the five (5) ohm impedance. Slower clearing times for ground faults are acceptable as they do not cause stability issues.

8.2 Auto Reclosing – 240kV and higher (Subsection 16)

IEEE C37.104 provides guidance regarding minimum line dead times. In Alberta, zero point seven five (0.75) seconds has typically been applied for single pole trip and reclose times. For evolving faults that start as single pole and evolve to multi-phase, all phases are to be tripped and no reclosing is permitted.

As one attempt to reclose is permitted, and single pole trip and reclose is done unconditionally from both ends (and possibly with multiple breakers at each end), reclosing may involve multiple breakers closing. This multi breaker closing is an acceptable practice.

8.3 Line Distance or Impedance Protection (Subsection 20)

At a minimum, two (2) zones of protection are required.

8.4 Line Differential Protection Systems (Subsection 21(2))

Upon failure of communications, the line differential element is typically blocked and a distance or overcurrent element can be utilized to provide backup protection.

8.5 Stub Protection (Subsection 22)

For breaker and a half bus configuration, a stub will occur when a transmission line's motorized air break is open leaving a section of bus and very short piece of line. This section must be protected utilizing high speed overcurrent protection.

8.6 Protection System Communications (Subsection 23)

The existing AESO Protection Standard calls for an availability of 99.99% which can be achieved with overhead power ground wire or digital microwave. A communication system with a lower availability may be considered if it designed in "fail safe" manner such that the protected facility is removed from service upon failure of the communication system.

8.7 Positive, Negative, Zero and Mutual Impedances (Subsection 27)

Based on recent experience by Alberta legal owners of transmission facilities, it has been identified that actual impedance values (positive, negative, zero, sequence and mutuals) can differ significantly from calculated values.

For five hundred (500) kV alternating current bulk transmission lines, the AESO recommends that actual measurements be taken to confirm calculated values for positive, negative, zero, sequence and mutual impedances. As measuring mutual impedances requires line outages, if the values differ, it is up to the legal owner of the transmission facility to determine which measurements are more appropriate to use for protection setting purposes.

8.8 Protection System Setting Verification (Subsection 28)

In addition to the real time digital simulator (RTDS) testing, legal owners may wish to consider the use of electromagnetic transients program (EMTP) simulation to verify settings. Further details may be found in the following paper:

[Morched, A.S.] Morched, A.S., Ottenvangers, J.H., Marti, L., "Multi-port Frequency Dependent Network Equivalents for the EMTP" IEEE Transactions on Power Delivery, Vol.8, No.3, July 1993

9 Substations

9.1 Transformers (Subsection 29)

Alarm levels for thermal alarms must be set such that action may be taken to unload the transformer. An overload trip level is also acceptable but must be set at least at the level of the second alarm.

9.2 138kV and 144kV Substation Bus Protection (Subsection 31(2))

Subsection 31(2) is intended to allow studies to be undertaken to determine if remote protection systems provide adequate coverage such that redundant bus protections is not required. If studies indicate remote clearing occurs within 0.6 seconds then this subsection may be utilized. It is anticipated that this may allow for lower cost solutions for simple in / out substations in remote areas.

9.3 Substation Shunt Capacitor Banks (Subsection 33)

Ungrounded capacitor banks are allowed at one hundred and thirty eight/one hundred and forty four (138/144) kV provided sufficient switching capacity of the circuit breaker and insulation of the capacitor banks are taken into account.

For substations where parallel capacitors banks are installed, consideration should be given to:

(a) the over-current protection to be immune from sympathetic tripping during switching of the second capacitor banks;

(b) over-voltage protection to protect capacitor banks against continuous over-voltage condition; and

(c) under-voltage protection to ensure the capacitor is discharged prior to re-energization.

9.4 Breaker Fail Protection (Subsection 35)

For breaker fail protection there is no need for redundancy if a standalone relay is used (independent of the primary protection relays). However, if the breaker fail function is incorporated into the primary protection, then it must be redundant such that if one protection system is taken out for maintenance, there is still one protection system and breaker fail functionality in service.

Consideration should be given to the use of breaker status contacts (52b contact) as an input to the breaker failure protection to supplement the current supervised element with respect to low level fault conditions. Low level faults will not cause stability issues so the breaker fail times have been specified for solid single line to ground or three phase faults.

For new one hundred and forty four (144) kV or lower voltage substations, remote protections will easily cover faults at least to the high side of the transformer, but will not see faults located at the secondary bus. If there is no transformer breaker, this creates a risk of a fault not being cleared.

If communications are planned for other purposes, then the additional requirement to send a breaker fail signal to the remote breakers can be accommodated at minimal cost.

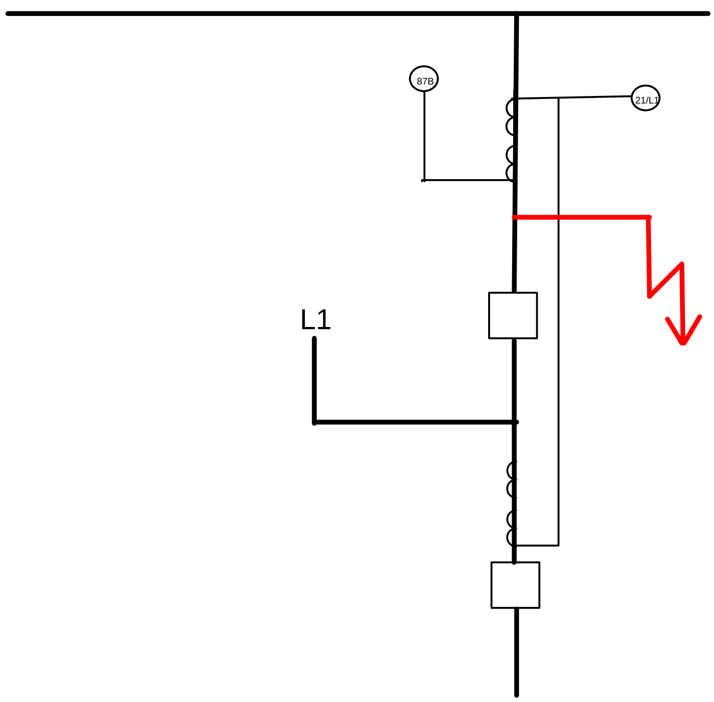
If no communications are planned for other purposes, then communications can be added that are only required to meet a ninety nine point five (99.5%) percent availability. The use of a “fail safe” communication system (i.e. upon communications failure the facility is automatically disconnected) with a lower availability may also be proposed to the AESO for consideration.

Further, as a fault on the high side of the transformer with a breaker failure will most likely be cleared by remote zone 2 elements, stability issues or thermal overloads are not a concern. For secondary transformer faults, remote zone 2 or zone 3 elements will not see the fault. However, the fault magnitude will be low due to the transformers impedance. Given the low fault level, it is unlikely that this will cause issues on the high voltage system. Therefore, provided the legal owner of the facility can demonstrate that they have a means of clearing the remote ends without damaging any equipment beyond the faulted transformer, an extended clearing time is acceptable.

If the above cannot be met and the substation location is such that any communications are prohibitively costly, consideration should be given to adding a transformer high side fault interrupting device and eliminating this issue.

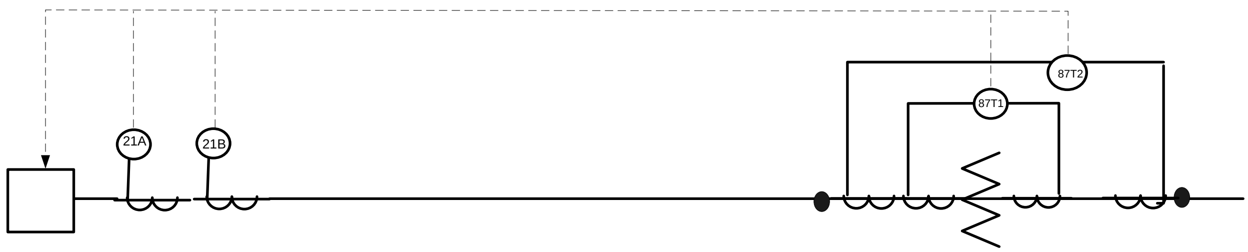
Further to subsection 35(7) of section 502.3, system stability is based on the primary redundant protection systems clearing the fault. For breaker fail conditions it is assumed one (1) breaker opens, and two (2) out of three (3) poles open on the failed breaker as at five hundred (500) kV and two hundred forty (240) kV the poles are independent. The remaining single line-to-ground fault can be cleared per the breaker fail times and with additional time for communications to remote ends without stability concerns.

Further to subsection 35(8) of section 502.3, the following diagram shows an inherent issue of using free standing current transformers. The fault shown will cause the line protection and breakers to operate but will not clear the fault. The breaker fail protection will detect this and clear the adjacent breakers. The likelihood of this event is very low. This is a common industry practice and is acceptable.



9.5 Substation Transformer Ended Lines (Subsection 36)

The following arrangement is considered an acceptable substation transformer ended line. Typically, space is left to add a breaker in the future to either accommodate a second transformer or to add a second line for the sake of system development.



10 Generating Unit and Aggregated Generating Facility Protection

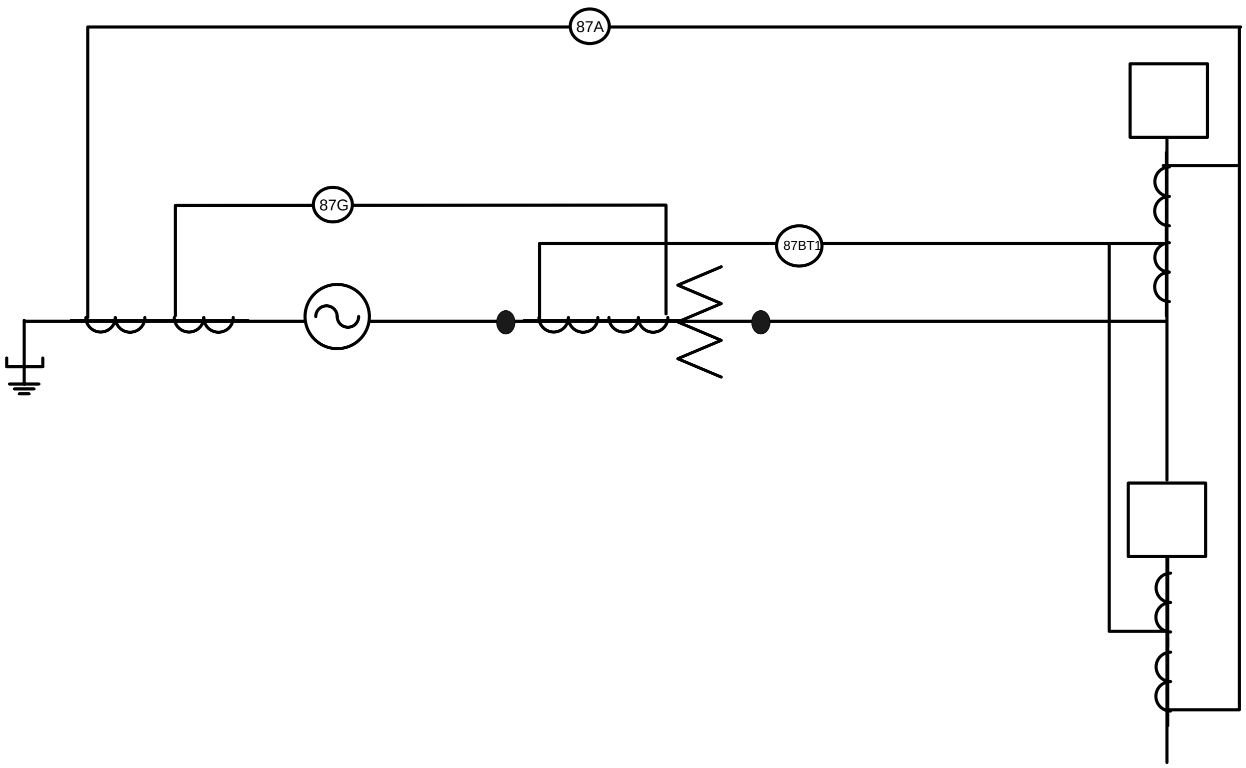
The following documents provide a good overview regarding generating unit and transmission facility coordination:

1) NERC – "*Power Plant and Transmission System Protection Coordination*" – Technical Reference Document Revision 1 - 08/02/10.
2) IEEE Work Group J5 of PSRC "*coordination of generator protection with generator excitation control and generator capability*"

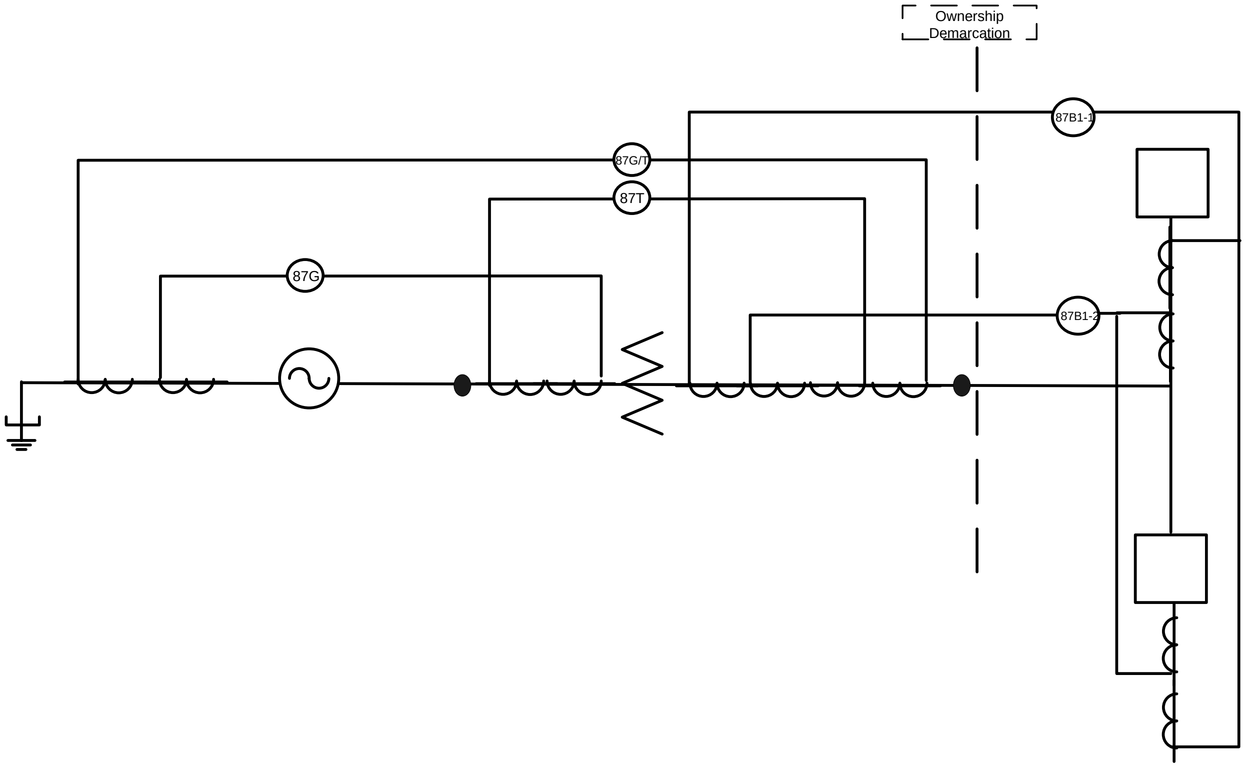
10.1 Sixty (60) Hz Synchronous Generating Units (other than wind) Electrical Protection (Subsection 42)

Two (2) electrical protection systems are required for the generating unit, unit transformer and high side bus. Depending on the facility layout, legal owners may wish to combine these zones and have one protection system cover one (1), two (2) or all three (3) of these zones. At a minimum, two (2) protection systems would be required to provide the required redundancy. Further, careful consideration should be given to combining these zones as the ability to identify the fault location will be reduced. Also, on past projects, concerns have arisen where different parties owned overlapping zones as their construction and energization schedules have not aligned and concerns were also expressed regarding liability for equipment damage if protection failures occurred. For facilities with multiple parties involved, careful consideration should be given to the following alternate arrangement.

Minimum Requirement:



Alternate:



Typically one (1) of the protection systems for the generating unit provides one hundred (100%) percent stator ground fault protection.

11 Power Swing Blocking or Tripping

Nothing specific has been included in section 502.3 regarding power swing blocking or tripping. If the AESO identifies a need for this functionality it will be identified in the projects functional specification.

12 Remedial Action Schemes

The AESO is presently reviewing WECC's remedial action scheme criteria and will determine how to implement this criteria in the future. At this time all remedial action scheme requirements will be identified in project functional specifications.

Revision History

2012-12-31	Initial Release