Q. **Volume III, Tab 19 – Replace Protective Relays**

Please provide a copy of the "draft transformer standard" prepared by Hydro in 2014.

A. Please see CA-NLH-037 Attachment 1.

NL Hydro Protection & Control Standard
Transformer Protection

1. Scope

This Standard forms the basis for applying and setting new or replacement transformer protection at NL Hydro. It describes the following elements of protection:

- Differential relay element (87T)
- High side phase instantaneous overcurrent relay element (50T)
- High side phase time delayed overcurrent relay element (51T)
- Neutral overcurrent relay element (51NT), where applicable
- Restricted Earth Fault (REF), where applicable
- Negative sequence differential element (87Q) where applicable
- Gas pressure relay (GA), winding temperature (WT), oil temperature (OT), and oil level (OL) indicators supplied by transformer manufacturer

Transformer protection is applied for the purpose of isolating the asset once an internal fault is encountered or in the event that an external fault is slow to clear thereby placing the transformer at risk of thermal or mechanical damage. Disconnecting a transformer in the event of an electrical or mechanical fault serves to limit the damage that can occur to the transformer itself and to protect other nearby equipment and personnel.

This standard will address protection as it relates to different categories of transformers in NL Hydro installed infrastructure (depending on the type of protection applied) with fully forced ratings as follows:

Category I – Large transformers 10 MVA and above (Dual differential + non electrical protection)

Category II – Small transformers in stations with relay protection less than 10 MVA (Overcurrent + non electrical)

Category III – Small transformers in stations less than 10 MVA (fused)

Protection of distribution transformers outside terminal stations and substations is not included in this standard.

Low voltage transformers (rated less than 750 V are excluded from the scope of this standard).

Where indicated on manufacturer's schematics, gas, winding and oil temperature and oil level alarms and trips are incorporated into the protection scheme. These trips operate directly into the tripping relay or the lockout relay as deemed necessary for the application and to protect the asset.

2. Definitions and Glossary

Neutral Overcurrent	Ground fault overcurrent protection applied to the neutral connection of the transformer using a single (neutral) CT (designated 50N or 51N)
Residual Overcurrent	Ground fault overcurrent protection connected to the residual connection of three phase CTs (designated 50G or 51G)
REF	Restricted earth fault protection
50T	Instantaneous Overcurrent Element. This element monitors the current in all phases and operates upon the level exceeding a preset value. Typically, no delay is applied.
51T	Time Delayed Overcurrent Element. This element monitors the current in all phases and operates on a curvilinear response of a logarithmic nature. This element has to be coordinated with the same form of downstream protection.
51NT	Time Delayed Neutral Overcurrent Element. This element monitors the current in the neutral of a transformer and operates on a curvilinear response of a logarithmic nature. This element has to be coordinated with the same element of downstream protection.
94T	Auxiliary Tripping Relay. This device is a high speed intermediate device operating between the protective relay and the breaker. It is non-latching and operates as a three phase trip.
86T	Lockout Relay. This device is an electromechanical device used for trip and block close operation. It must be manually reset following operation. The multiprocessor protection relay and the transformer gas, winding, and oil trips operate into this device.
87T	Differential Current Protection Element. This element monitors and operates for current imbalance within the transformer. It is typically not delayed in operation.
30GA	Gas Accumulation Trip with Target. This device monitors the gas accumulation in a transformer and operates at a level designated by the manufacturer. The 30 prefix indicates that the function incorporates a manually resettable visual operator.
30WT	Winding Temperature Trip with Target. This device monitors the temperature of the windings in a transformer and operates at a level designated by the manufacturer. The 30 prefix indicates that the function incorporates a manually resettable visual operator.
30OL	Oil Level Trip with Target. This device monitors the oil level in a transformer and operates at a level designated by the manufacturer. The 30 prefix indicates that the function incorporates a manually resettable visual operator.

30OT	Oil Temperature Trip with Target. This device monitors the oil temperature in a transformer and operates at a level designated by the manufacturer. The 30 prefix indicates that the function incorporates a manually resettable visual operator.
CT	Current Transformer.

3. Normative Reference Papers

IEEE/ANSI C37.2	ANSI Standard for Electrical Power System Device Function Numbers, Acronyms and Contact Designations.
IEEE Std C37.91-2000	IEEE Guide for Protective Relay Applications to Power Transformers
IEEE Std C37.110	IEEE Guide for the Application of Current Transformers Used for Protective Relaying Purposes
IEEE Std C57.109	IEEE Guide for Liquid-Immersed Transformers Through-Fault-Current Duration

4. Protection Requirements

4.1 Category I – Large Transformers 10 MVA and above

Transformers in this category are generally found in large to medium scale transmission terminal stations. To protect these transformers, two microprocessor based protection relays are to be used from separate manufacturers. These relays are utilized in two functionally equivalent schemes (Protection A and Protection B) with the exception of non-electrical protective devices. Transformer protection requires connection of the relay to CTs on high and low sides of the transformer.

The following functions shall be applied in both A and B protections:

- Restrained and unrestrained differential protection
- Phase time and instantaneous overcurrent (on the high voltage side only)
- Neutral and/or residual time overcurrent (on both high and low voltage sides).
- Tertiary zero sequence overcurrent (where CTs are provided inside the tertiary)
- REF shall be applied only in cases where neutral grounding impedances are applied that limit fault current to less than transformer rated current.

Non-electrical protection functions are not redundant, and shall be applied normally as part of the A protection system with automatic transfer to the B protection in the event of loss of power to the A protection.

Negative sequence differential protection exists in the SEL protective relays only and may be considered for future application in the A protection only.

In special cases (for example two LV windings) LV phase overcurrent protection might be applied instead of, or in addition to HV phase overcurrent protection.

4.1.1 CT connection and ratio selection

For legacy electromechanical protection systems, CTs usually required wye or delta connections to relays to account for phase shift across the transformer. However, since phase angle and current amplitude compensation can be made in the settings of microprocessor based relays, phase CTs used for protection systems specified in this standard will all be wye connected to the relays. Connecting CTs in wye configurations allow for residual current to be measured where required. The wye configuration also allows phase currents to be recorded by the protective relay, thereby facilitating disturbance analysis. CTs inside a tertiary delta shall be connected single phase to the 51N Tertiary element to measure zero sequence current (I0) if there is no load on the tertiary winding. If there is load connected to the tertiary, three CTs inside the delta shall be connected in parallel to remove the external load component and measure 3 times the zero sequence current. Note that the single tertiary CT will be shared by the 51N tertiary overcurrent function in both the A and B protection systems.

Where a sufficient number of CTs are available, Protection A relay is to use the furthest CTs out from transformer including the breaker where applicable and the Protection B relay is to use the next CT set inward. The relay settings are applied in the same way to both relays, therefore both relays should operate simultaneously for any given fault. In cases where sufficient CTs are not available for dedication to both the A and B protection systems, they may share a set of CTs as long as adequate test and isolation facilities are provided to allow either protection system to be taken out of service while the other remains in service.

A dedicated restraint input is desired from each CT that closes off the differential zone, to aid in fault analysis as shown in Figure 1 or Figure 2. CTs that are measuring currents from fault current sources shall never be summed external to the relay (as shown in Figure 3) since each CT must provide its own restraint current to the relay. However, CTs that are serving only loads may be summed if there are not sufficient restraint inputs available on the differential relay.

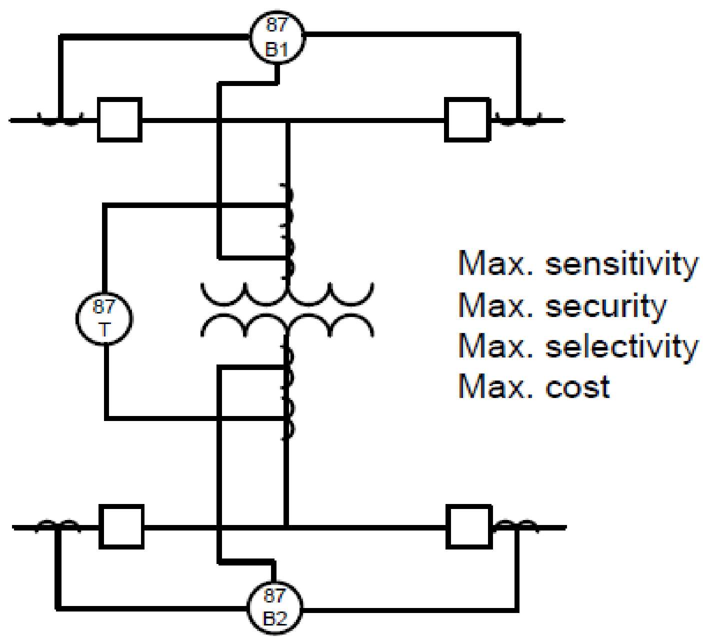


Figure 1 - Optimum application of transformer protection

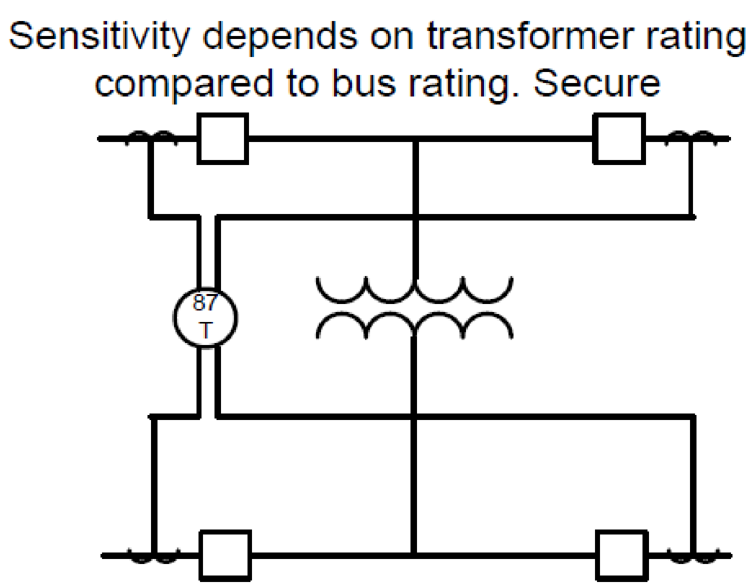


Figure 2 - Transformer differential protection with possible reduced sensitivity

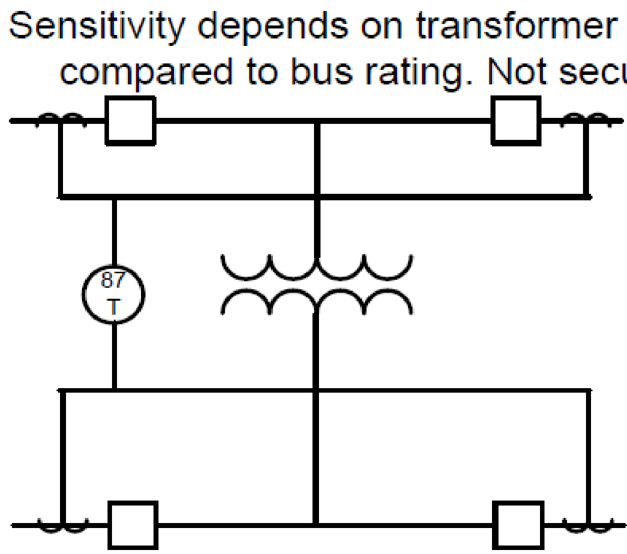


Figure 3 - Transformer differential protection with compromised security

Before protection is applied, several CT settings are required. One such setting is the current compensation which must be determined according to the transformer windings. The winding designation is typically user specified for new transformers, and found on the transformer nameplate for existing transformers (i.e. Yd11, Dy1, etc.). The high voltage winding would usually be set as the reference winding and the low voltage winding adjusted accordingly by a certain number of 30 degree counter-clockwise increments. Refer to the associated relay application manual which would typically have a table indicating current compensation based on winding configuration.

Any transformer winding which can be a path for zero sequence current that might flow during an external fault shall have the zero sequence current removed from the CT currents used for differential protection. This will be achieved by appropriate setting within the relay. For example, within the SEL relays the CT compensation shall be set to 12 if no phase shift is required, and in the case of the Alstom P64X as directed in the settings or operations section of the manual.

Ratios need to be selected for high, low, neutral and tertiary CTs. The first criterion when selecting the CT ratio is based on the maximum full load of the transformer subject to overloading criteria. An overload criteria of 120% as per NLH System Operating Instruction T-082 is presently used; this is the maximum permissible overload subject to ambient temperature. For example, for a 125 MVA transformer with a high side voltage of 230 kV, the top rating of 125 MVA gives 314 A primary current per phase on a Y CT. Taking into account an overloading of 120%, the primary current would be 377 A. Rounding up to the next even 100 ratio, we select 400/5 for the ratio. The tertiary CT ratio shall be selected to be approximately equal to the continuous rating of the tertiary winding. CTs connected to the transformer neutral shall have as low a ratio as possible while remaining within the maximum fault current constraint using the rule below.

The maximum internal fault current should not exceed 20 * I_{NOM} (where I_{NOM} is 5A) = 100A for the selected ratio for both the main winding and tertiary and neutral CTs. This is required for high and low voltage and tertiary windings and neutral CTs. This is the second of the two criteria for selecting CT ratios.

In instances where there are two breakers on the high or low side of the transformer, the CT rating is subject to bus load. The breaker CTs will be rated to accommodate bus loads, not necessarily the transformer maximum load and therefore will require a high ratio. It should be noted that this can impact sensitivity of the protection. In cases where the transformer protection sensitivity requirements noted in Section 4.1.2 cannot be met, if transformer bushing CT's are available, the bus zone shall be provided with its own differential protection using high ratio CTs and the transformer differential protection shall be connected to lower ratio bushing CTs as shown in Figure 1. If sufficient CTs are not available to provide dedicated transformer protection with desired sensitivity, then the differential protection shall be connected as shown in Figure 2, and the best achievable sensitivity using bus CTs will have to be accepted.

CTs need to be rated so that they do not saturate during normal transformer loading. CT saturation, which often occurs during faults, can lead to misoperation of relays but transformer differential protection relays are designed to discern saturation from actual faults.

CTs are selected so that their normal operation is in the linear region of their curve. The CT's burden consists of the accumulated resistances from the secondary devices and cabling (i.e. relays, meters, conductors, etc.). The CT secondary current multiplied by the applied burden results in a voltage across the CT secondary terminals. An example of a CT secondary excitation curve for a bushing CT in a 230kV breaker is provided in Figure 4. CT saturation occurs when the excitation current becomes nonlinear as indicated by being above the dashed line in Figure 4.

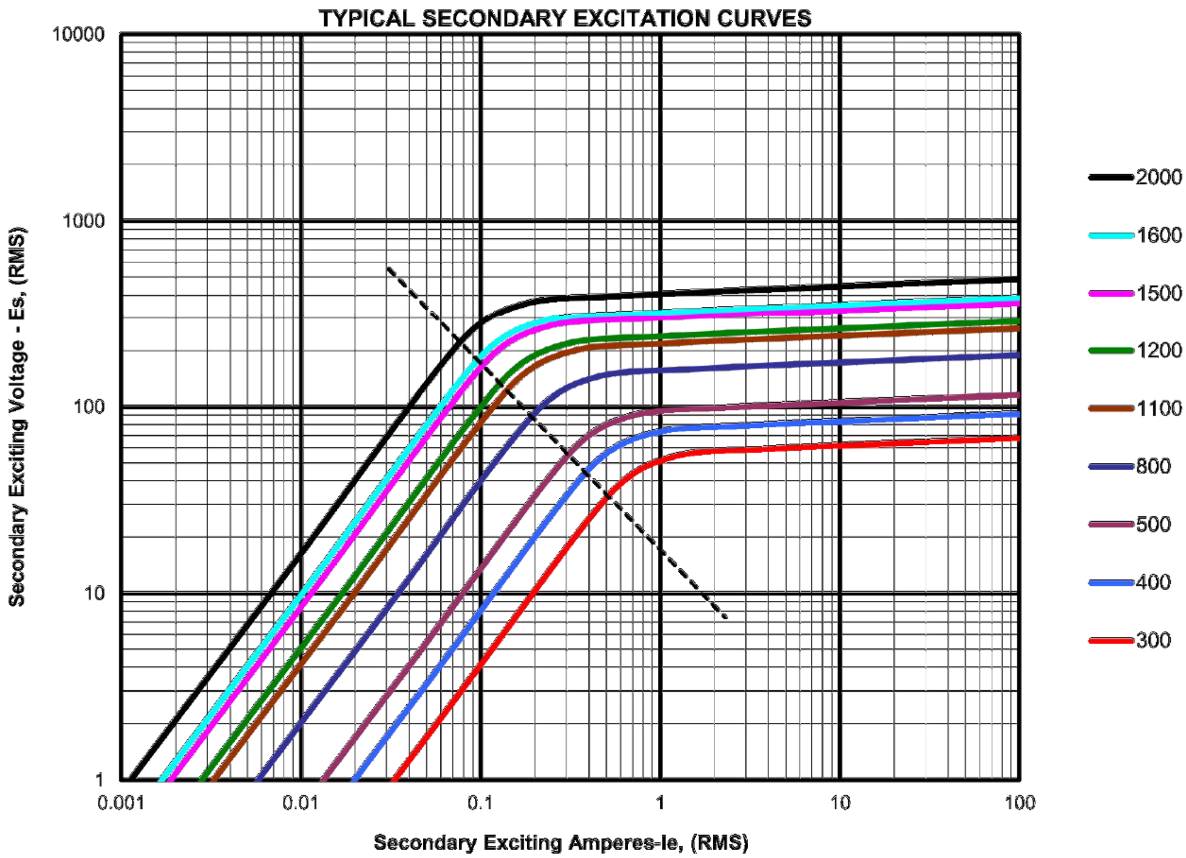


Figure 4 – CT Secondary Excitation Curve

Refer to C37.110 "IEEE Guide for the Application of Current Transformers Used for Protective Relaying Purposes" for further reading on this topic.

CT connections for special transformers

Some special types of transformers have winding configurations with special CT connections.

Auto transformers

Some auto transformers are supplied with neutral CTs on the common winding neutral. This neutral CT is not normally used.

Wye zig-zag transformers

These transformers have neutral connections on both the HV and LV sides.

4.1.2 Differential Protection (87T)

Differential Protection is applied to isolate the transformer in the event of an internal fault. Faults can occur within the transformer between windings or between turns in windings, or between winding and ground, resulting in high current levels that can cause severe damage within the transformer core. No coordination is necessary as this protection has no delay applied and is not subject to the operation of other upstream or downstream protection devices. Both A and B protection systems use restrained and unrestrained current differential protection elements. The commonly used restrained element uses a dual slope, variable percentage characteristic which provides more sensitive and secure protection as well as compensates for CT ratio mismatches, CT ratio errors, CT saturation, and errors caused by tap changing. Some relays (for example SEL 487E) may use a single (sensitive) slope combined with external fault detection and/or CT saturation detection that switches to a less sensitive slope for external faults. The unrestrained element provides for protection against high current faults which might produce CT saturation that prevents the restrained element from operating.

Restrained Element
All differential relays will have a minimum operating or pick up current (shown as Minimum Pickup in Figure 5 that determines the sensitivity of the device. The minimum setting depends on the CT ratio compared to the transformer rating. If the CT ratio has been selected according to the transformer rating, a sensitivity of 30%-50% of the self-cooled rating should be achievable and shall be considered the desired sensitivity. .

In addition, transformer differential relays include slope settings (slopes 1 and 2 in Figure 5) which may be set to override mismatch factors at low levels of current and may also override CT saturation at higher levels of through fault current taking into account recommendations from the relay manufacturer. At low current levels (up to the break point of the slope), the following errors need to be considered in determining the value of Slope 1:

- CT error (as much as -10% on one set of CTs only).
- Relay measuring error (up to +5% on one set of CTs, and -5% on the other set, for a total of 10%)
- Transformer no load loss error and magnetizing current (up to 2%)
- Transformer tap changer error (whatever is the maximum deviation from the midpoint tap)

The break point defines a transition between low slope and high slopes.

Above the break point, all the errors noted above will still exist, but for determining Slope 2, the CT error current shall be assumed to be as large as -40% on the CTs on one side, due to possible saturation.

When setting the slope, attention must be paid to the restraint quantity used. In the case of the SEL 387 relay and the P64X, the restraint current is half the sum of the magnitudes of all currents. In the case of the SEL 487E relay, the restraint current is the sum of the magnitudes of all currents.

The break point between slopes shall be set at two to three times the nominal CT secondary current. The lower break point provides greater security at the expense of reduced sensitivity. If CTs on one side or the other of the transformer are likely to saturate at low levels of through fault current, the break point should be set at 2 times rated.

The relay will trip when the current falls into the Operate region of the graph.

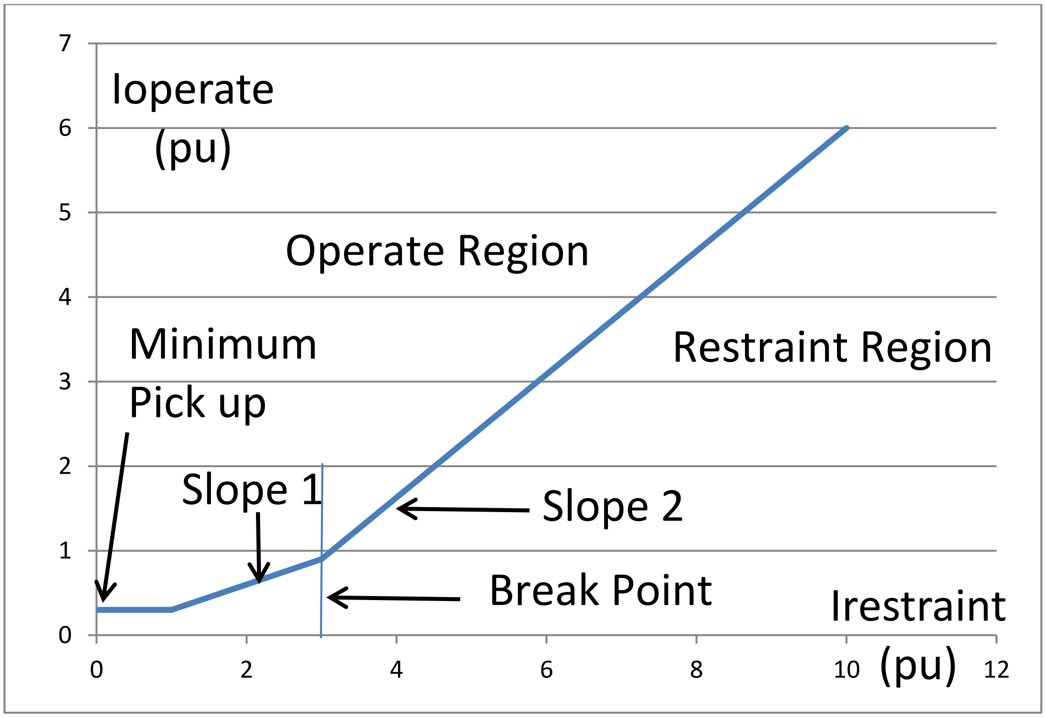


Figure 5 – Dual Slope Characteristic

When a transformer is energized, an inrush of current occurs that is seen by the high voltage terminals but not immediately by the low voltage terminals. This can be seen by the relay as a fault. During inrush of a transformer, there are significant 2nd and 4th harmonic content in the current. During overexcitation of a transformer, there is significant 5th harmonic content in the current. These harmonics can be used to discriminate between inrush and overexcitation conditions and fault conditions. Harmonic blocking and/or restraint are/is used for situations of inrush and overexcitation conditions. Values for blocking elements are based on historical evidence of transformer measurements.

Inrush suppression settings are based on industry historical knowledge. The industry standard level of 15% 2nd harmonic (and 4th harmonic if available) will be used unless experience determines that a lower level is required. In addition harmonic blocking with cross blocking will be applied to ensure that harmonic presence in any phase will block all phases. Note that for SEL387 relays, the term “non-independent” blocking is used to signify cross blocking. The differential element can operate due to inrush and overexcitation, therefore using harmonic blocking is valuable in the prevention of relay misoperation during these situations.

If available, an extra element sensing 5th harmonic at a value of 35% persisting for longer than 30 cycles may be used to trigger an event record.

Unrestrained Element

The unrestrained element responds to fundamental frequency only, therefore harmonic blocking does not apply. It will provide dependable protection in the event of CT saturation for high magnitude internal faults that could produce harmonics and block the more sensitive restrained element. A conservative setting is 1/Zt (in per unit of the naturally cooled rating of the transformer) where Zt is the transformer impedance in per unit. The setting must be lower than the maximum high side 3-phase fault current and current resulting from CT saturation but higher than the maximum inrush current.

4.1.3 Overcurrent Protection

Overcurrent protection is applied on the transformer high side to protect the transformer from internal faults. The selections of overcurrent instantaneous and time-delayed values are made based on load and fault levels from System Planning studies and coordinated with low side protection settings and transformer damage curve.

50T - Instantaneous Phase Overcurrent

Instantaneous Overcurrent protection is used to clear internal faults as fast as possible. NL Hydro standard setting is <u>130% of maximum 3-phase low side fault level</u>. It is noted that this element will be less sensitive than the unrestrained differential element, and adds little value to the transformer protection. It is provided for historical reasons only. It also facilitates plotting overcurrent relay characteristics for checking coordination.

51T - Phase Time Overcurrent

Phase Time Overcurrent protection is used to protect the transformer from slow clearing faults outside the protection zone of the transformer. There are various types of time overcurrent curves that can be applied. IEEE and US curves consist of moderately inverse, inverse, very inverse, extremely inverse, and short time inverse. IEC curves consist of standard inverse, very inverse, extremely inverse, short time inverse, and long time inverse. The 51T curve has to be coordinated between the transformer damage curve and the low side 51T curve(s). Standard damage curves can be found in the IEEE Standard C57.109 (see section 3 – Normative Reference Papers) and an example curve is shown in Figure 6. Transformer impedance is required in order to select appropriate damage curve. For existing transformers, this value can be obtained from the nameplate of the transformer. For new transformers, this value can be obtained from the purchase specification and/or factory test results. Relay coordination software such as Aspen One-Liner has standard damage curves built in to the relay coordination function.

The time current characteristic must also be secure against undesirable tripping due to magnetizing inrush. ASPEN OneLiner provides a conservative estimate of the inrush current that should be used to ensure the 51T function will be secure during energization.

The pickup value will be 150% of the maximum rating of the transformer unless other factors (such as cold load inrush) dictate a higher setting. The curve to be selected must be evaluated against those of immediate downstream protection. Typically, a very inverse curve (IEEE / US) would be used as provided in the microprocessor based relay manual. This curve closely matches the response of previously used very inverse time overcurrent electromechanical relays such as the GE IAC53 subject to adjustment of the time dial setting.

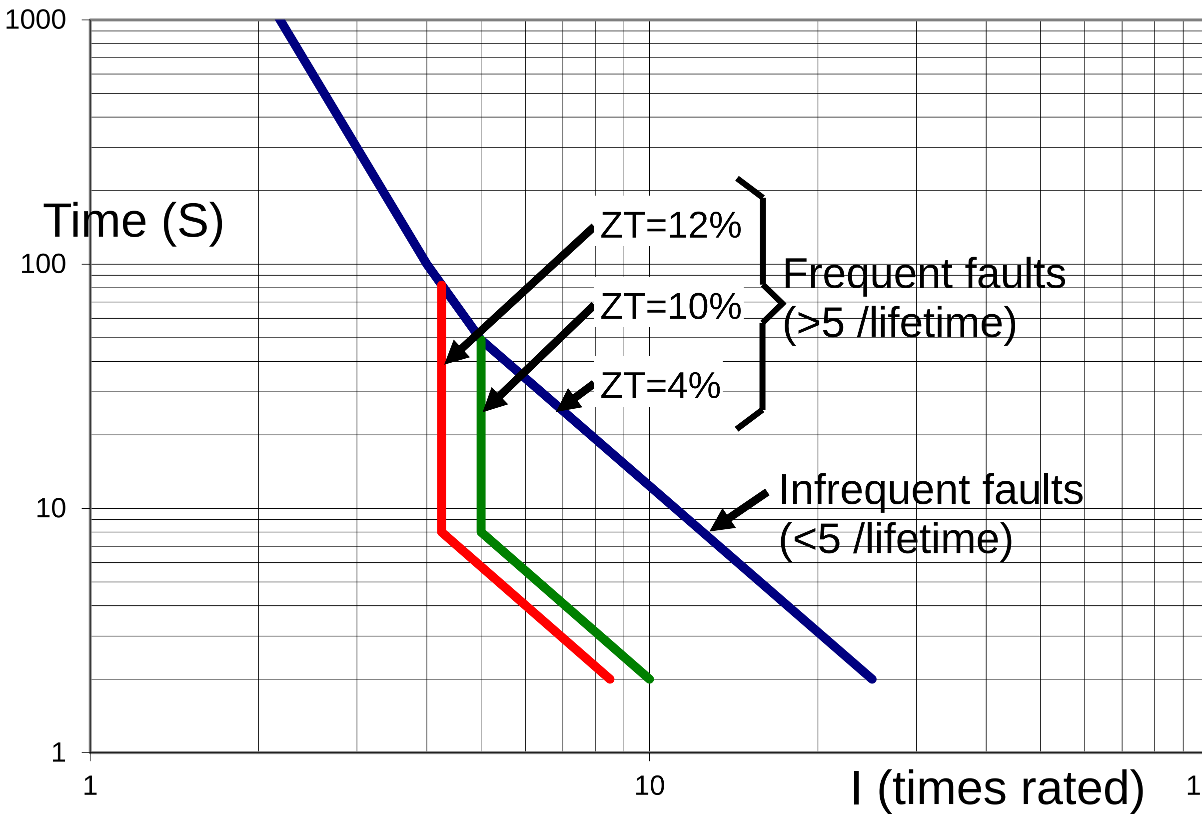


Figure 6 – Transformer Damage Curve

50N - Instantaneous Neutral Overcurrent
This element is not typically set unless special considerations warrant its use. In cases where ground fault current is restricted by a neutral ground impedance, a definite time delayed ground overcurrent function may provide better coordination with downstream protection than an inverse time function. In such cases the 50N definite time overcurrent function may be applied.

51N – Neutral Time Overcurrent
Neutral overcurrent protection is applied on the transformer low side neutral for all wye or zig-zag low side configurations (i.e. delta-wye, wye-zig-zag etc.) to protect the transformer from downstream faults in the event that downstream relays fail to clear the fault. The selections of overcurrent time-delayed values are made based on fault levels from fault studies and coordinated with external protection settings.

In the case of Wye zig-zag transformers where a neutral ground is provided on the HV winding, a 51N function shall also be provided to back up HV system ground fault protection.

The pick-up value and curve to be selected must be evaluated against those of immediate downstream protection. Typically, an inverse curve would be used. This curve matches closely the response of previously used inverse time overcurrent electromechanical relays such as the GE IAC51 subject to adjustment of the time dial setting.

50G – Instantaneous Residual Overcurrent
Residual overcurrent protection will provide fast and sensitive protection to delta connected transformer windings connected to the transmission system. Since it need not coordinate with any other devices, the only limitation on sensitivity is that it shall not operate in the case of CT saturation during energization (inrush) or during external faults on the other side of the transformer. A pickup setting of twice the transformer fully forced rated current will normally override these transient conditions.

51G Residual Time Overcurrent
Residual time overcurrent will provide more sensitive protection (than the 50G function) to delta connected transformer windings connected to the transmission system. The time delay will allow it to override transient CT saturation. A pickup setting of 25% of the transformer fully forced rated current with a very inverse time current characteristic and a time dial of 3 will normally override the transient CT saturation.

REF protection allows increased sensitivity for transformer protection in cases where ground fault currents are significantly lower than multiphase fault currents due to the addition of neutral grounding impedances. REF protection shall be included in the A and B protection systems in such cases.

4.1.4 Non-Electrical Protection

The non-electrical protection devices consist of those inherent to the design of the transformer as specified in the NL Hydro purchase specification or as supplied by the transformer manufacturer.

Dry contacts are provided from the transformer for each of the above elements as a minimum. Some elements are repeated for load tap changer oil conservator and additional windings. For new transformers, refer to the manufacturer's drawings to implement trip contacts.

The non-electrical protection normally trips through the A protection system. However since functionally equivalent redundant protection systems are provided, it is anticipated that the transformer could remain in service while the A protection is removed from service (for test or modification) for a significant period of time. Since NL Hydro's policy is to not allow the transformer to be operated for any length of time with the non-electrical protection being out of service, facilities shall be provided to switch the non-electrical protection to the B protection system automatically if power to the A protection system is lost.

4.1.5 Tripping and Isolation

All tripping for internal faults will operate into a lockout relay (86T one for each of A and B protections). The lockout relay will trip breaker(s), block close of tripped breakers and open of motor operated disconnects for complete isolation of the faulted transformer. Once the faulted transformer has been isolated by disconnect switches (where applicable) close blocking and continuous tripping of circuit breakers that can no longer energize the faulted transformer will be removed. Close blocking of the isolating switches will be retained until the lockout relay has been reset.

Tripping by most time overcurrent elements including the tertiary overcurrent element is expected for external faults or severe overload conditions only. Tripping by these elements will be non-lockout (94T) and with no automatic isolation. The exception will be tripping by the residual time overcurrent element when it is protecting a transformer delta winding. Operation of this element will only occur for an internal transformer fault.

All tripping will initiate breaker failure protection of transformers that can energize the fault.

4.1.6 NLH Standards of Acceptance for Transformer Protection Devices

<u>Microprocessor Protection Relays</u>
Standard two winding
Protection A: SEL-387E
Protection B: Alstom P643

Three winding (or special purpose application) without station service tertiary
Protection A: SEL-487E
Protection B: Alstom P643, P645

<u>Auxiliary Relays</u>

Tripping (94, 94X):	ABB RXMS1
Flag Indicators (30):	ABB RXSF1
Lockout (86):	Electroswitch LOR
	GE HEA61C

4.1.7 Schematic Development

A typical Single Line Protection Schematic (A and B scheme), as used by NL Hydro for a Category I transformer, is provided in Appendix A. A typical Protection DC Schematic (A and B scheme), as used by NL Hydro for a 230kV transformer, is provided in Appendix B. These schemes are used on transformers having an MVA rating of 10 MVA and higher.

4.2 Category II – Small transformers in stations with relay protection less than 10 MVA (Overcurrent + non-electrical)

4.2.1 CT connection and ratio selection

CT connections for Category II transformers are similar to the case for those of Category I with the exception that a differential CT connection arrangement is not required for this category of transformer. All other connection and ratio selection details follow as per Category I.

Phase CTs may be located on the breaker(s) supplying the transformer or on the transformer bushings.

If only one set of CTs is available, they may share a set of CTs as long as adequate test and isolation facilities are provided to allow either protection system to be taken out of service while the other remains in service.

These transformers will be provided with dual redundant protection systems. In circumstances where practical factors make the application of dual redundant protection systems non feasible, external backup protection may be accepted.

4.2.2 Overcurrent Protection

For transformers in this category, only overcurrent protection (and non-electrical protection where available) will be provided. The following functions are included in overcurrent protection systems:

1. HV phase instantaneous and time overcurrent (50/51P)
2. HV residual instantaneous and time overcurrent (50/51G)
3. LV neutral time overcurrent (51N) for backup protection for external faults
4. Non-electrical protection functions (where provided)

Special considerations for grounding transformers:

1. Negative sequence overcurrent protection (50/51Q) will be included to discriminate between internal faults that include negative sequence current and zero sequence current contributions to external fault.

Refer to Category I criteria for information on standard settings of overcurrent relays.

All protection for internal faults will trip a lockout relay (86T, one for each of the A and B protection systems where they are provided)

Tripping by neutral time overcurrent elements is expected for external faults only. Tripping by these elements will be non-lockout (94T).

4.2.3 NLH Standards of Acceptance for Transformer Protection Devices

Microprocessor Protection Relays
Protection A and B: SEL-501
(Note that identical A and B protections are accepted for these small transformers.)

Auxiliary Relays
Tripping (94): ABB RXMS1
Flag Indicators (30): ABB RXSF1
Lockout (86): Electroswitch LOR
GE HEA61C

4.2.4 Schematic Development

A typical Single Line Protection Schematic (A and B scheme), as used by NL Hydro for a Category II transformer, is provided in Appendix C. A typical Protection DC Schematic (A and B scheme), as used by NL Hydro for a Category II transformer, is provided in Appendix D. These schemes are used on transformers having an MVA rating below 10 MVA.

4.3 Category III – Small transformers in stations less than 10 MVA (fused)

Where relay protection is not considered practical, power fuses are applied to protect Category III transformers.

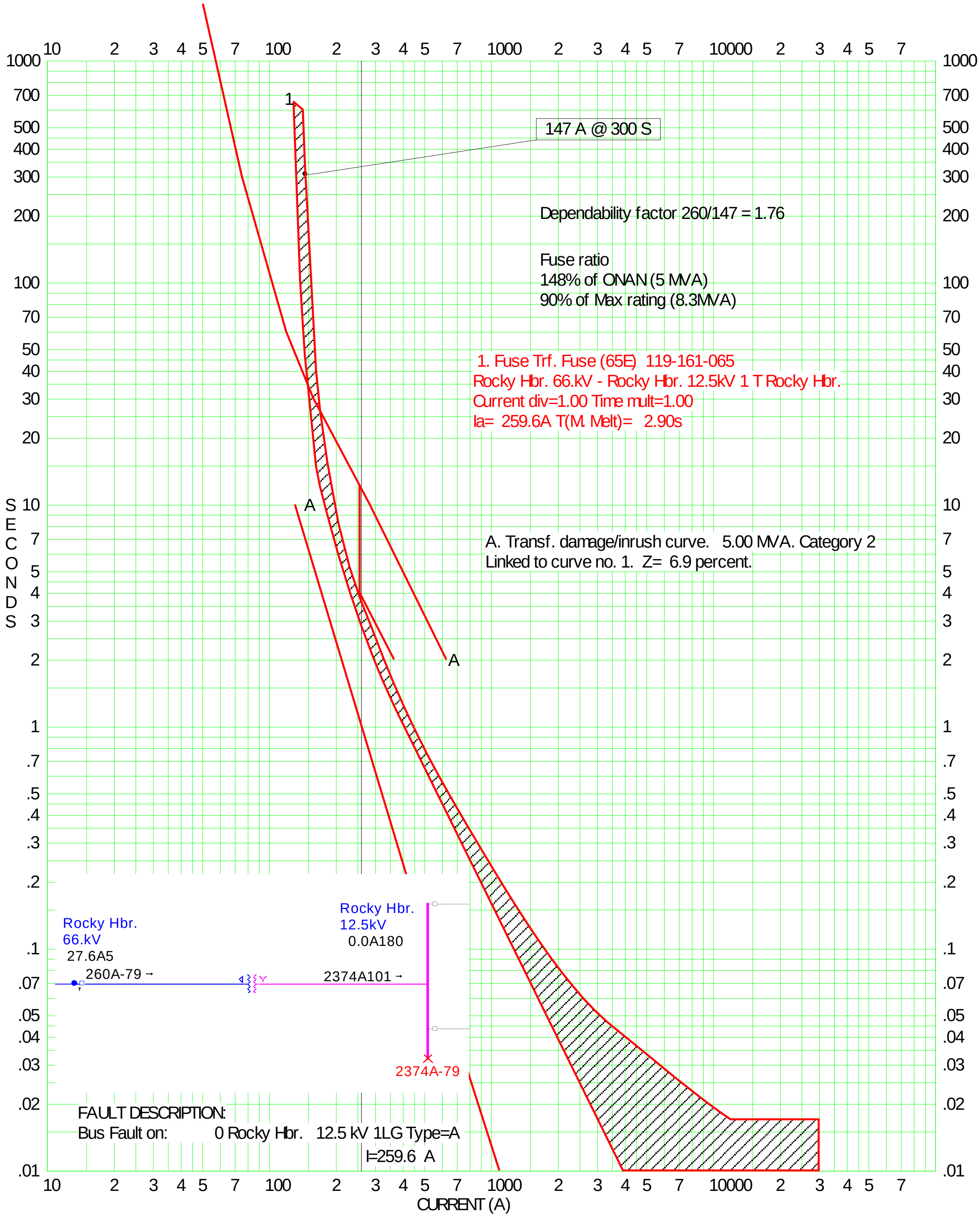
One protection criterion for selecting a fuse rating is that it should dependably detect all faults on the LV side of the transformer. "Dependable" protection shall mean that the minimum current through a fuse during a fault on the other side of the transformer shall be at least twice the total clearing current at 300 seconds. The most critical type of fault is a single line to ground fault on the wye side of a delta wye connected transformer. For this fault the maximum phase current in two phases of the delta side is only 57% of the ground fault current on the wye side (on a per unit basis). In certain cases, where it is considered to be not possible to achieve a dependability factor of at least 2, the factor may be reduced to as low as 1.7.

1 This sensitivity criterion may limit the loadability of the transformer to less than its fully forced rating in some cases, particularly in the case of delta-wye transformers.
2 Another criterion is that the fuse should operate below the transformer damage curve for fault conditions.
3 Additionally, the fuse must not be damaged by magnetizing or cold load inrush.

Figure 7 shows an example of a fuse applied at Rocky Harbour. It can be seen that the dependability factor is less than 2 in this case, but still above 1.7. It can also be seen that the fuse rating will not allow the transformer to be continuously loaded to its fully forced rating of 8.3 MVA. It can also be seen that the fuse rating of 148% of the naturally cooled rating of 5 MVA will barely allow a cold load to be picked up, assuming a cold load pickup factor of 1.5.

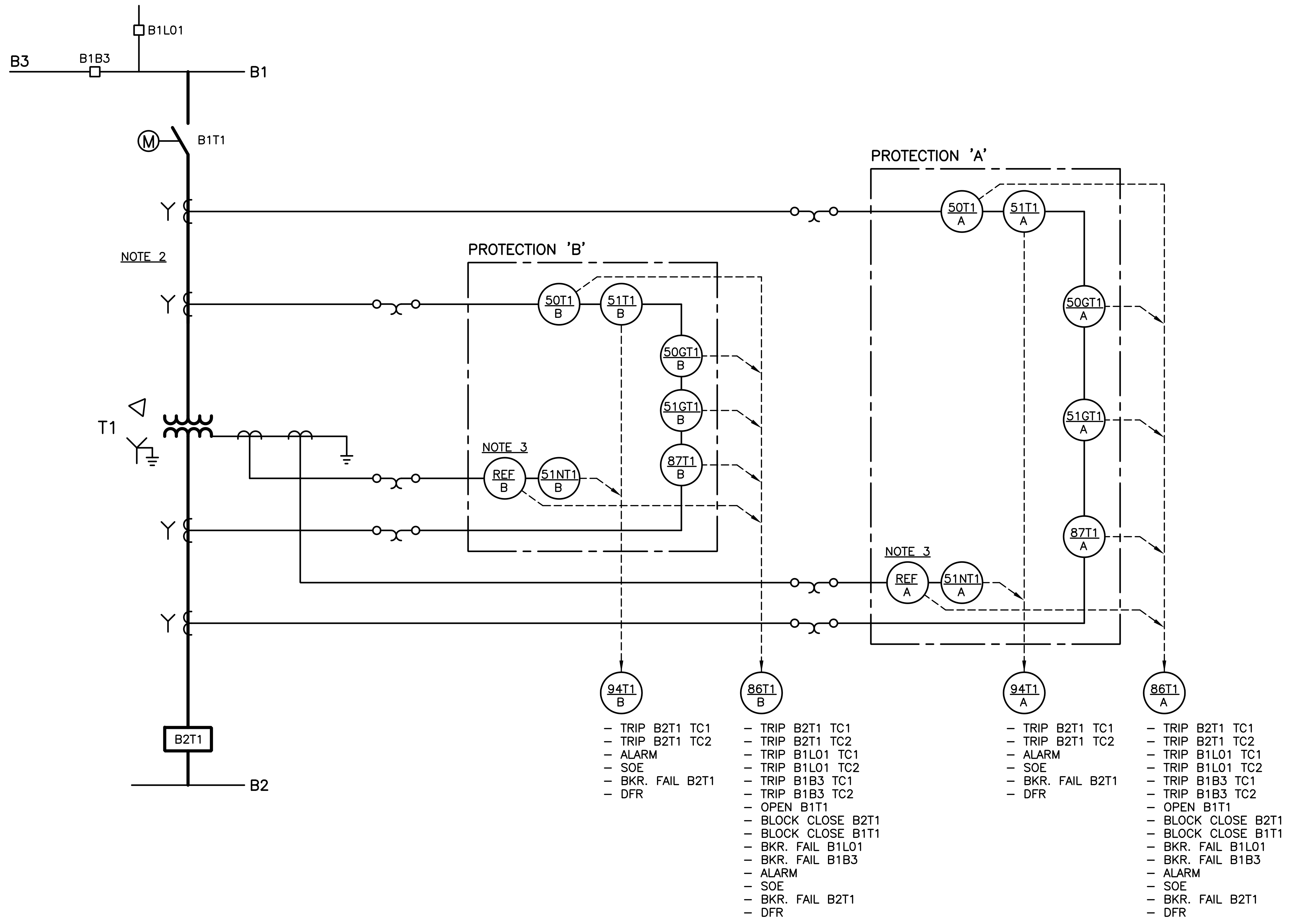
If satisfactory dependability and/or loadability cannot be achieved with fuses, relayed protection for the transformer will be required.

Fuses are not able to protect the transformer from overload conditions. Optionally if the transformer is provided with overload or high temperature non-electrical protection devices, they may be connected to trip distribution feeder(s) through the recloser(s).



Rocky Harbour T1 @Voltage 66	By C Henville
For Tfr Fuse sizing	No. Example 2
Comment 65E Fuse for Irated = 44A (5MVA ONAN at 66 kV)	Date 26 Nov. 2014

Figure 7 – Dependability Factor of 1.76 at Rocky Harbour



NOTE:

1. THIS DRAWING IS APPENDIX 'A' OF PROTECTION AND CONTROL 'TRANSFORMER PROTECTION STANDARD'.
2. ONLY ONE SET OF CT'S IS SHOWN ON EACH SIDE OF THE TRANSFORMER. OVERCURRENT FUNCTIONS MEASURE THE SUM OF ALL CURRENTS INTO A TRANSFORMER WINDING. DIFFERENTIAL FUNCTIONS ARE RESTRAINED BY CURRENTS ON EACH OF THE CT'S CONNECTED TO THE TRANSFORMER.
3. ELEMENT ONLY APPLIED WHEN NGR (NEUTRAL GROUNDING RESISTOR) ON Y AT THE DISCRETION OF DESIGNER.

DRAFT

newfoundland labrador hydro a nalcor energy company

Newfoundland and Labrador Hydro

NO.	DATE	DESCRIPTION	DWN.	DESIGN.	CHK.	APP'D

REVISIONS

ELECT.	SCALE:	N.T.S.
CIVIL	DESIGNED:	A.C. Warren
TRANS.	DRAWN:	D. Oliver
MECH.	DATE:	2014–12–09
P&C	CHECKED:	
TELC.	APPROVED:	

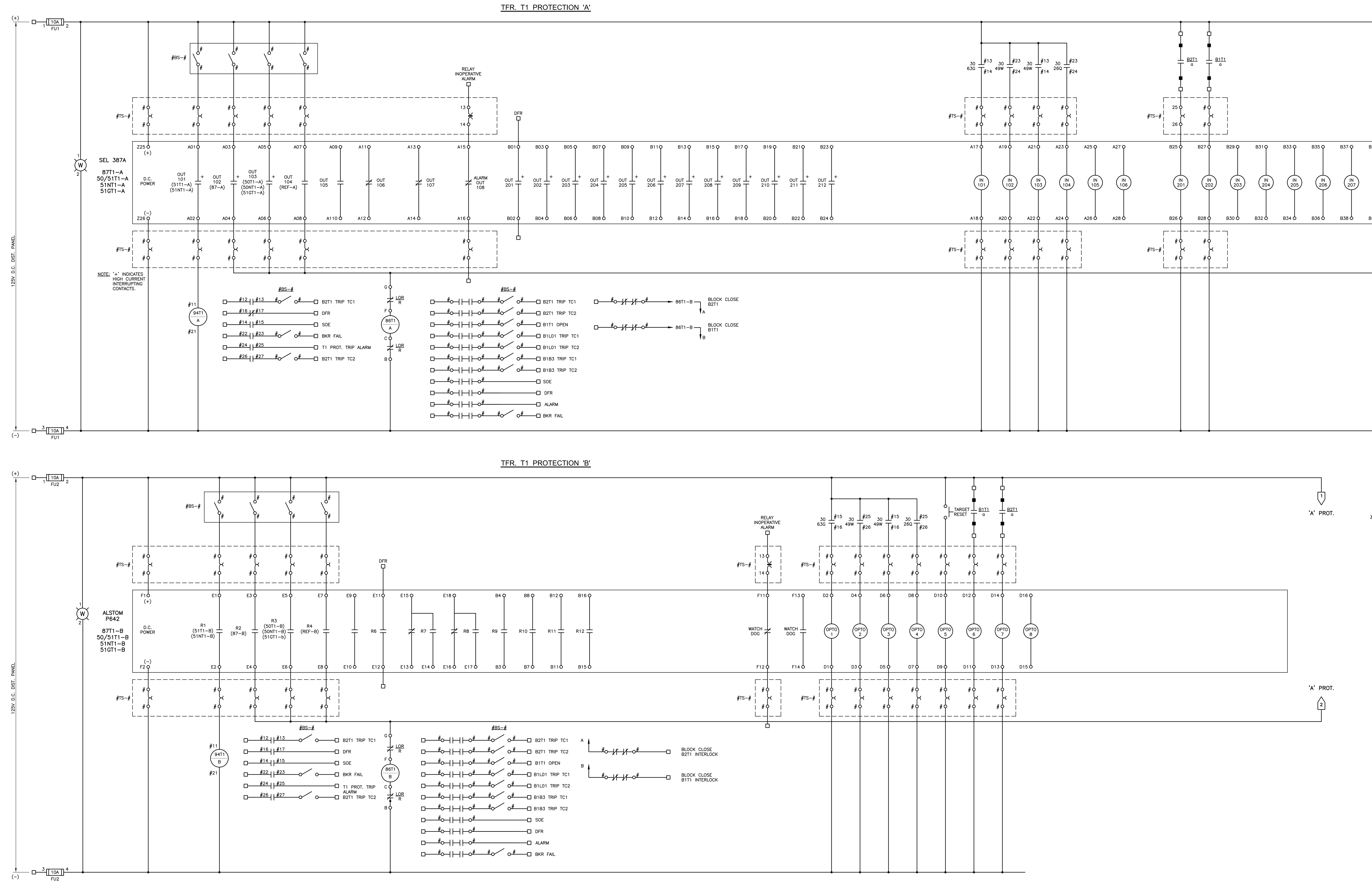
PROTECTION AND CONTROL STANDARD
CATEGORY I TRANSFORMER (Δ-Y)
TYPICAL SINGLE LINE PROTECTION DIAGRAM

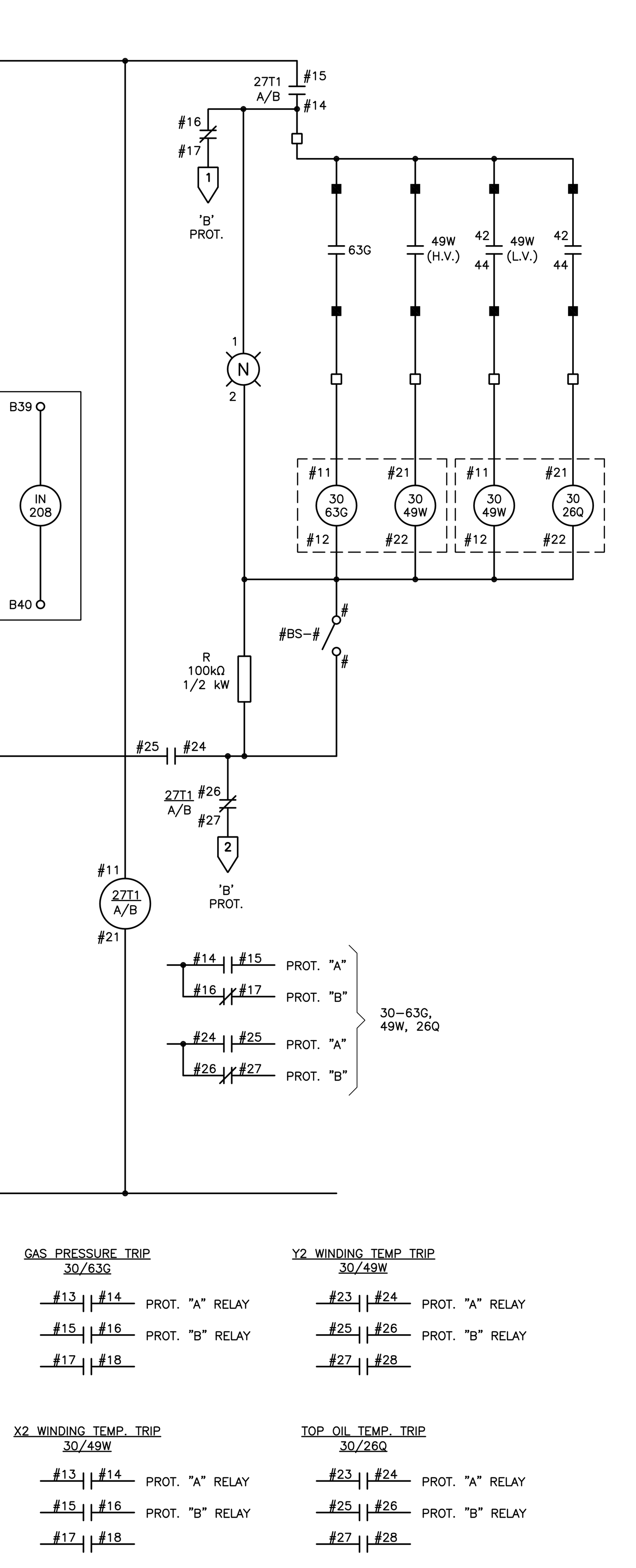
W.O. NO.

DWG. NO. A2 - 300 - E - 156

REV. 0

PLOT C.A.D.





DEVICE	DESCRIPTION	LOCATION	TYPE
87T1-A	TRANSFORMER PROTECTION 'A'	PNL.	SEL-387A
87T1-B	TRANSFORMER PROTECTION 'B'	PNL.	AREVA P642
30	AUXILIARY FLAG RELAY	PNL.	ABB RXSF1
27T1-A/B	AUXILIARY RELAY (TRANSFER)	PNL.	ABB RXMA1
94T1-A	TRIPPING RELAY	PNL.	ABB RXMS1
94T1-B	TRIPPING RELAY	PNL.	ABB RXMS1
86T1-A	LOCKOUT RELAY	PNL.	ELECTROSWITCH
86T1-B	LOCKOUT RELAY	PNL.	ELECTROSWITCH
TS1-	TEST SWITCH	PNL.	AREVA MMLG01
BS1-	BLOCKING SWITCH	PNL.	ABB FT-1

NOTE:
THIS DRAWING IS APPENDIX 'B' OF PROTECTION AND CONTROL "TRANSFORMER PROTECTION STANDARD".

DRAFT

newfoundland labrador hydro — a nalcor energy company

Newfoundland and Labrador Hydro

DWG.NO.	TITLE
REFERENCE DRAWINGS	

NO.	DATE	DESCRIPTION	DWN.	DESIGN.	CHK.	APP'D
REVISIONS						

ELECT.	SCALE:	N.T.S.
CIVIL	DESIGNED:	A.C. Warren
TRANS.	DRAWN:	D. Oliver
MECH.	DATE:	2015-03-05
P&C	CHECKED:	
TELC.	APPROVED:	

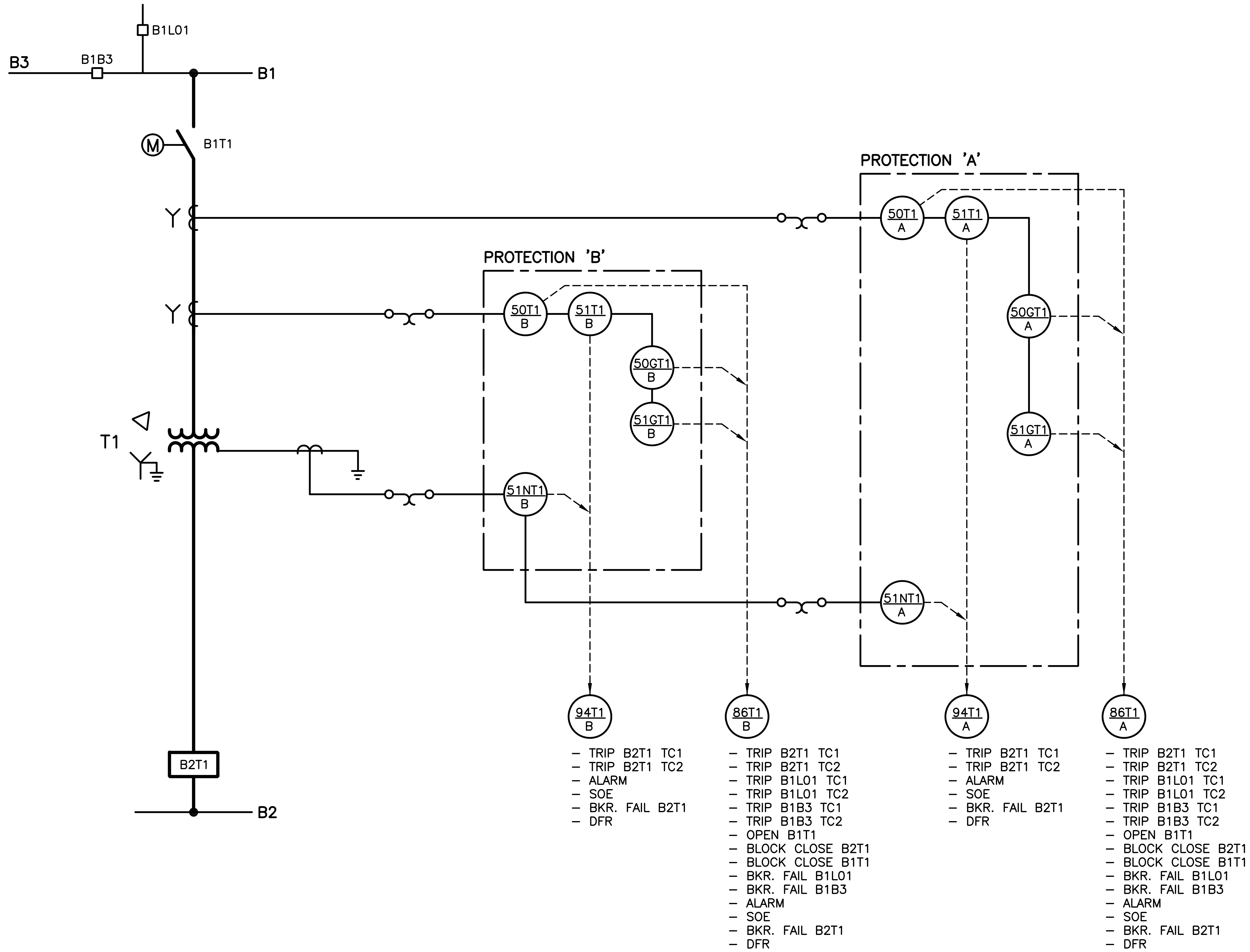
PROTECTION AND CONTROL STANDARD CATEGORY I TRANSFORMER PROTECTION 'A' & 'B' D. C. SCHEMATIC

W.O. NO.

DWG. NO. A0 - 300 - E - 055

REV. 0

PLOT SCALE 1:1 C.A.D.



NOTE:

1. THIS DRAWING IS APPENDIX 'C' OF PROTECTION AND CONTROL 'TRANSFORMER PROTECTION STANDARD'.

NO.	DATE	DESCRIPTION	DWN.	DESIGN.	CHK.	APP'D

REVISIONS

newfoundland labrador hydro — a nalcor energy company

Newfoundland and Labrador Hydro

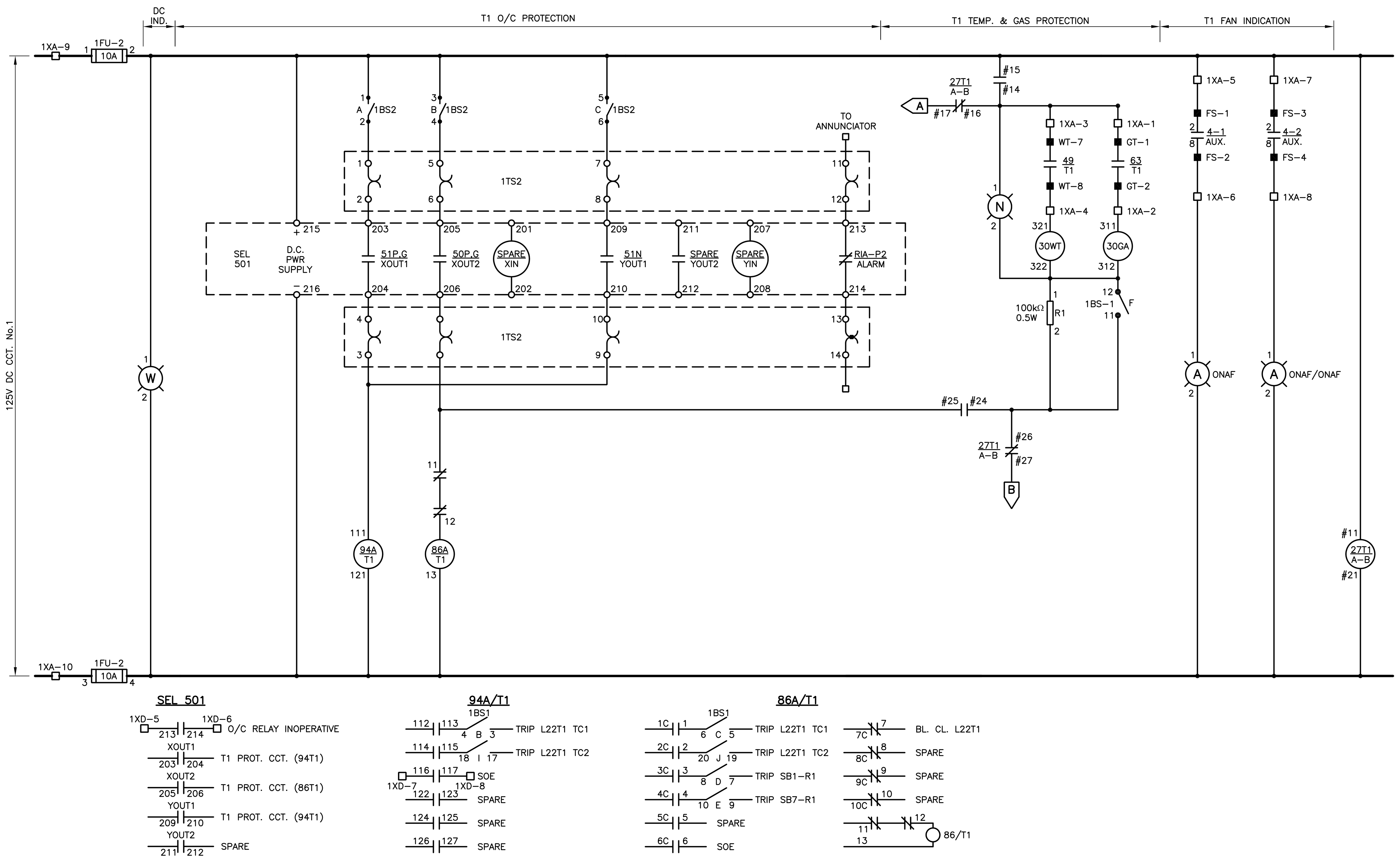
ELECT.	SCALE:	N.T.S.
CIVIL	DESIGNED:	A.C. Warren
TRANS.	DRAWN:	D. Oliver
MECH.	DATE:	2015-04-16
P&C	CHECKED:	
TELC.	APPROVED:	

PROTECTION AND CONTROL STANDARD
CATEGORY II TRANSFORMER (Δ-Y)
TYPICAL SINGLE LINE PROTECTION DIAGRAM

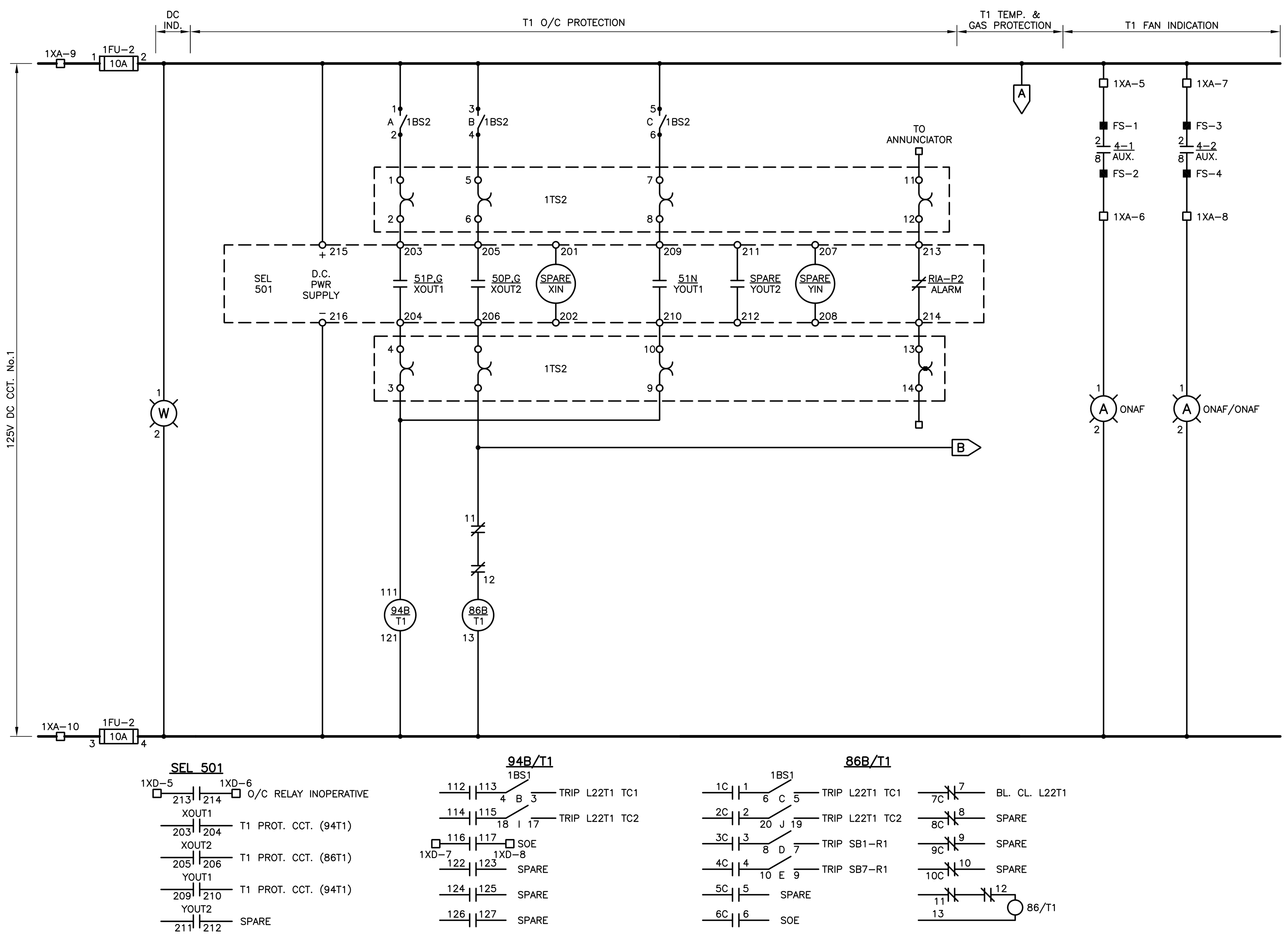
W.O. NO. | DWG. NO. A2 - 300 - E - 157 | REV. 0

PLOT C.A.D.

TRANSFORMER T1 PROTECTION 'A'



TRANSFORMER T1 PROTECTION 'B'



DEVICE	DESCRIPTION	LOCATION	TYPE
2/94 T1	TIMER RELAY	PNL 1	ABB RXKA1
50/51,N–T1	PHASE & NEUTRAL OVERCURRENT RELAY (X)	PNL 1	SEL 501
51NT1–2	NEUTRAL OVERCURRENT RELAY (Y)	PNL 1	SEL 501
86/T1	LOCKOUT RELAY	PNL 1	CGE–HEA
94/T1	TRIPPING RELAY	PNL 1	ABB RXMS1
30WT	TARGET RELAY (CAT. # RK271007HB)	PNL 1	ABB RXSF1
30GA	TARGET RELAY (CAT # RK271007HB)	PNL 1	ABB RXSF1
49/T1	WINDING TEMPERATURE INDICATION	T1 CAB	
63/T1	RAPID PRESSURE RISE RELAY	T1 CAB	

DWG.NO.	TITLE

REFERENCE DRAWINGS

NO.	DATE	DESCRIPTION	DWN.	DESIGN.	CHK.	APP'D

REVISIONS

HYDRO

NEWFOUNDLAND AND LABRADOR HYDRO

ELECT.	SCALE:	N.T.S.
CIVIL	DESIGNED:	A.C. Warren
TRANS.	DRAWN:	D. Oliver
MECH.	DATE:	2015–04–17
P&C	CHECKED:	
TELC.	APPROVED:	

PROTECTION AND CONTROL STANDARD
CATEGORY II TRANSFORMER
PROTECTION 'A' & 'B' DC SCHEMATIC

W.O. NO.

DWG. NO. B1- 300 - E - 158

REV. 0

PLOT SCALE 1:1 C.A.D.