On Load and Directional Verification Test

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PURPOSE AND SCOPE

The aim of this reference is to provide explanatory information and clarify the on load testing requirements of MN000301W107 Commission New and Augmented High Voltage Plant.

RESPONSIBILITIES

The **Executive General Manager Network Optimisation** is the Process Owner responsible for approving this Reference.

The **General Manager Substations** is the Subject Matter Expert (SME) for the content of this Reference.

The **Commissioning and Maintenance Manager** is responsible for implementing and maintaining this Reference.

The **Manager Management Systems** is responsible for the endorsement of this Reference prior to submission for approval.

DEFINITIONS, ABBREVIATIONS AND ACRONYMS

CT Current Transformer

Principal Current Check A series of measurements that establishes that:

- The secondary phase current magnitude corresponds to the primary current (hot tong) or alternatively corresponds to the secondary current magnitude from an established CT core.
- The secondary phase current phase angle is 120 degrees between phases, has correct rotation, and has correct phase displacement to voltage.
- The residual current is zero.

Principal Voltage Check A series of measurements that establishes that:

- The secondary phase voltage magnitude corresponds with the secondary voltage from an established VT core.
- The secondary phase voltage phase angle is 120 degrees between phases, has correct rotation, and has correct phase displacement to an established VT core.
- The residual voltage is zero.

Unit Protection Any protection system that requires currents to be balanced in a through fault situation e.g. line differential, bus differential, transformer differential or restricted earth fault.

VT Voltage Transformer

REFERENCES

MN000301W107. Commission New and Augmented High Voltage Plant (Work Instruction)

ISOLATION OF PROTECTION SYSTEM

MN000301W107 Commission New and Augmented High Voltage Plant requires that all protection systems should normally be in service for energising of new plant. In order to meet the requirements to protect plant and minimise inadvertent protection operations, the normal commissioning sequence is therefore:

- Energise new plant with all protection in service and the network switched in a configuration that will cause no loss of load should the new protection operate inadvertently.

- For **Unit Protection** it is normally appropriate to isolate the protection being commissioned (providing that the plant is still suitably protected by duplicate / backup / alternative / temporary protection) while on load tests are carried out. Similarly, tests that force a relay to an “operate” condition should be carried out while protection is isolated (providing that the plant is still suitably protected by duplicate / backup / alternative / temporary protection).
- Carry out on load tests.
- Reverse protection isolation (if required).

ON LOAD TESTS

All protection systems should have a **Principal Current Check** and a **Principal Voltage Check** carried out.

It should also be confirmed that the spill or operate current in **Unit Protection** schemes is negligible.

Additional Requirements for Numeric Relays

To verify that numeric relays are facing in the right direction, the internal magnitudes and phase angles of currents and voltages (both primary and secondary quantities) for all phases and neutral should be checked against externally measured values. Real and reactive power flow magnitude and direction should also be verified. All other internally calculated relay values critical to the protection scheme should also be recorded and verified.

Additional Requirements for Non-Numeric Relays

Distance Protection - Alter current connection and / or system configuration and / or settings to force protection to a definite “operate” condition and a definite “restrain” condition on load. Repeat **Principal Current Checks** and **Principal Voltage Checks** as required after these alterations have been reversed to confirm that all secondary circuits have been left in the correct state.

Pilot wire Protection-- Confirm “restrain” condition with normal pilots and “operate” condition with crossed pilots.

Transformer Backup Earthfault (summed neutral connection) - Confirm that the third harmonic currents flowing in each transformer neutral CT secondary are approximately equal and are cancelled to zero when they flow through the relay. (Note: two starpoints on the network are required for circulating third harmonics i.e. two transformers in parallel, closed bus).

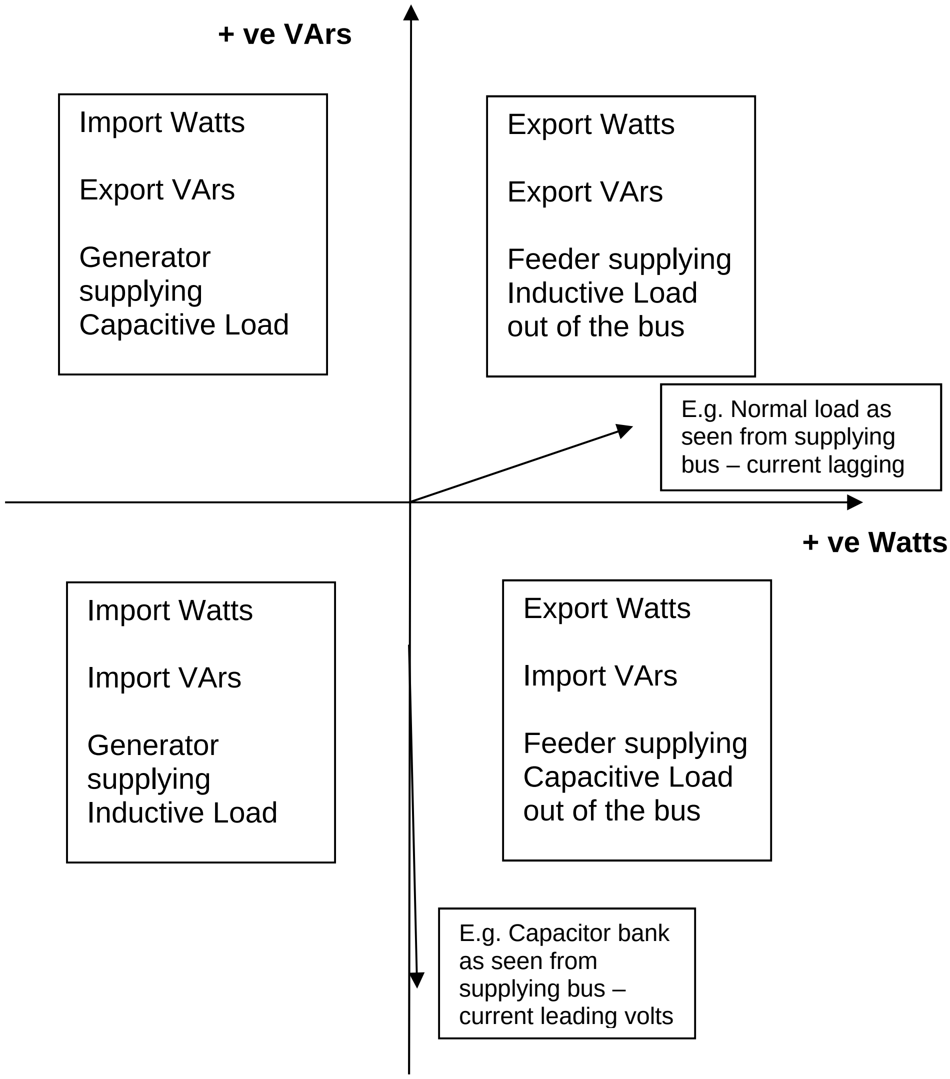
An alternate method of confirming the summed neutral connection is correct is by disconnecting one phase of one of the transformers. Refer to Appendix C for more information. Note: this configuration may not always be practical, but may be an option where the transformer neutral CT primary connections are inaccessible. This configuration may have protection and plant rating implications that need to be considered.

Directional Overcurrent, Directional Earth Fault - Alter residual voltage connection and current connection and / or system configuration and / or settings to force protection to a definite “operate” condition and a definite “restrain” condition on load. Repeat **Principal Current Checks** and **Principal Voltage Checks** as required after these alterations have been reversed to confirm that all secondary circuits have been left in the correct state. Refer to Appendix D for more information.

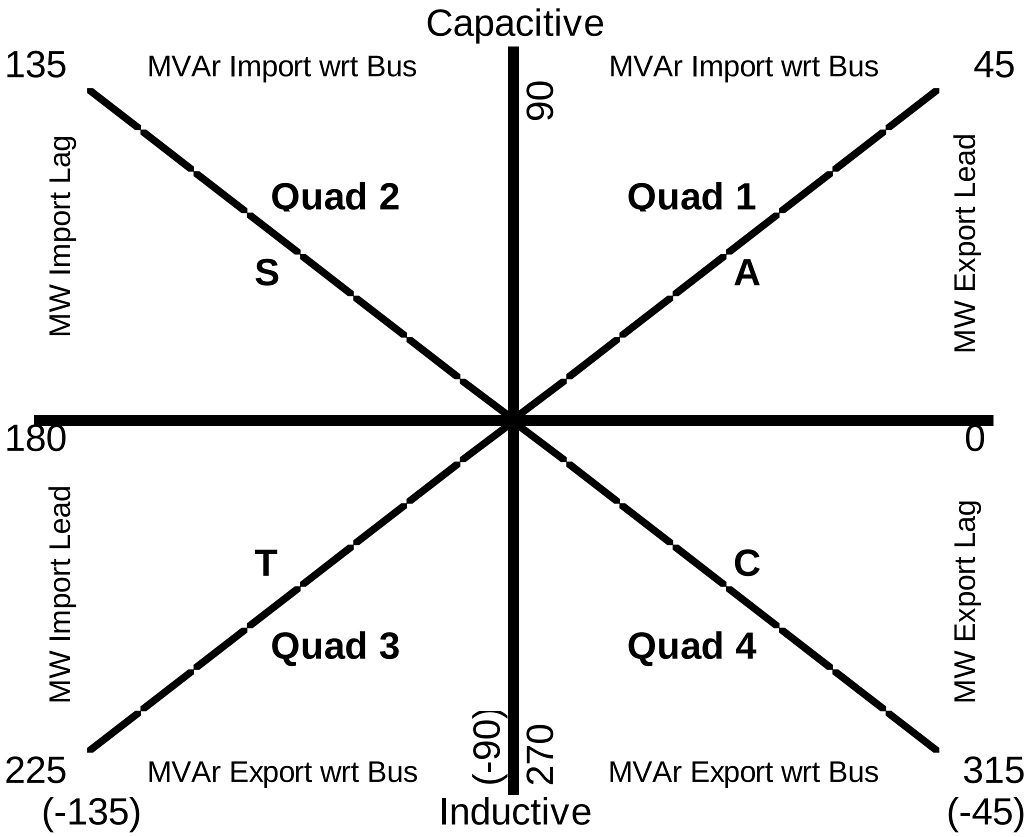
APPENDIX A – CONVENTIONS FOR DIRECTIONS

Convention for Watts and Vars

(as seen from the perspective of sitting on the bus looking into a bay)



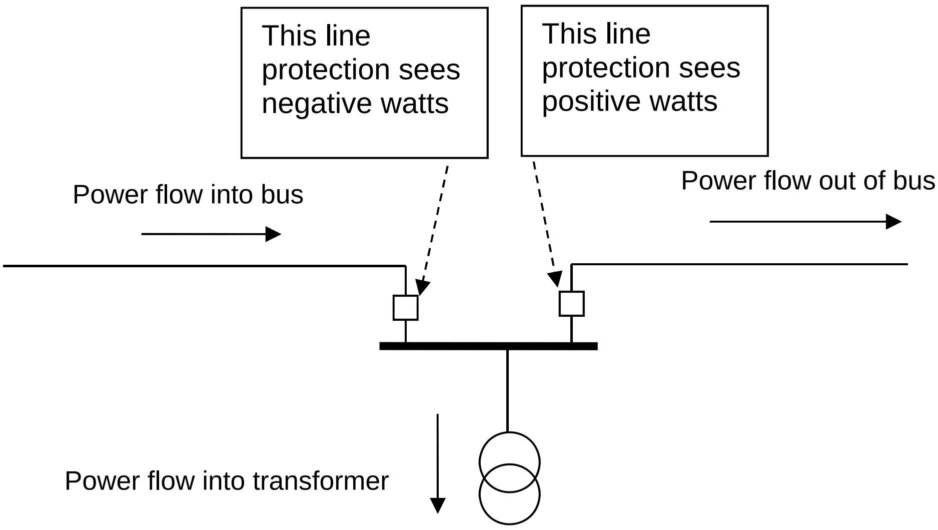
Convention for Watts and Vars in Quadrants One to Four



CAST = Cos, All, Sin, Tan positive in respective quadrants
CIVIL = Cap current leads volts, volts leads current Induct

Note: the diagrams on the previous two pages are the same data, just drawn differently to represent different preferences

Convention for Distance or Directional Protection on a feeder



Line Protection such as SEL311C, SEL 311L, SEL 321, SEL 351, Micom Px4x sees power flow out of the bus flowing into the protected feeder as **positive**.
Regardless of polarity of CTs and direction of current through relay, the net result is a positive MW indication for flow in the direction of the protected line.

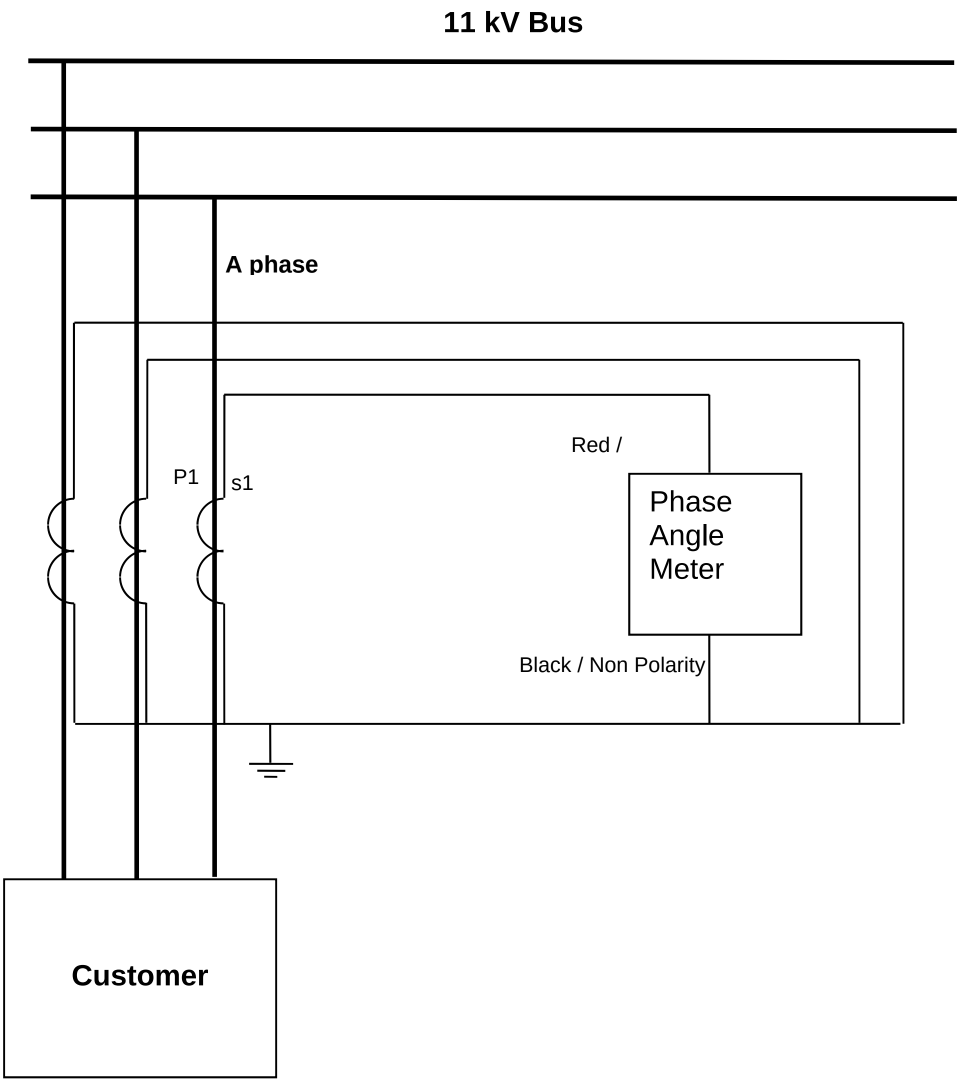
SCADA MW / MVAr Direction Convention

132 kV / 66kV feeders
+ve for export out of bus i.e. same as feeder protection

11 kV transformer metering
-ve for flow from transformer to 11 kV bus

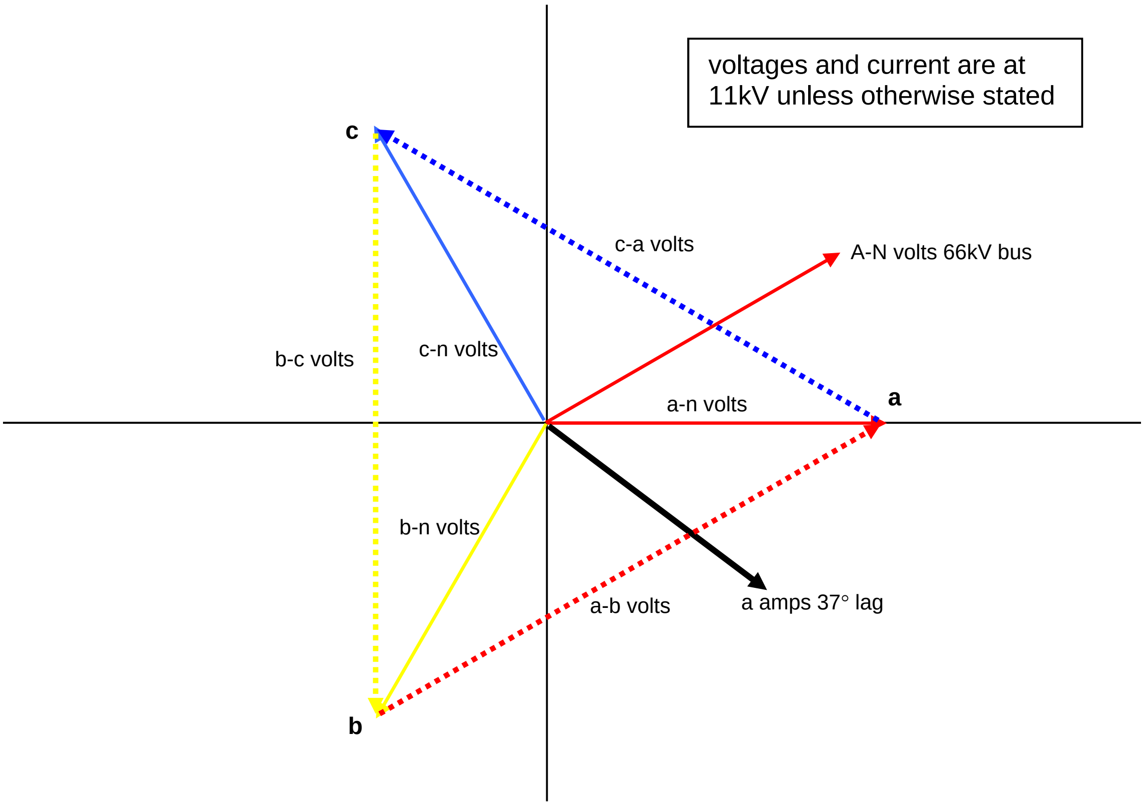
Example:
66 kv feeder into radial sub with 66 / 11 kV transformer shows -ve for incoming 66 feeder, +ve for 66 side of transformer, -ve for 11kV side of transformer

APPENDIX B - EXAMPLE OF PHASE ANGLE MEASUREMENTS



11 kV Bus is supplied from 66 kV bus via 66 / 11 kV Dyn1 Transformer

Customer Configuration	CT Connection	VT Connection	Phase Angle Meter Reading
Load, 0.8 pf 37° lag	As per diagram above	11 kV VT, A-N	37° lag
Load, 0.8 pf 37° lag	As per diagram above	11 kV VT, A-B	67° lag
Load, 0.8 pf 37° lag	As per diagram above	66 kV VT, A-N	67° lag
Load, 0.8 pf 37° lag	As per diagram above	66 kV VT, A-B	97° lag
Load, 0.8 pf 37° lag	As per diagram above except polarity of phase angle meter reversed	11 kV VT, A-N	217° lag 143° lead
Load, 0.8 pf 37° lag	As per diagram above except P1 / P2 reversed and s1 / s2 reversed	11 kV VT, A-N	37° lag
Generating exporting equal MW and MVAr into 11 kV bus (i.e. the generator sees a 45° lagging load)	As per diagram above	11 kV VT, A-N	225° lag 135° lead
Capacitor Bank	As per diagram above	11 kV VT, A-N	90° lead

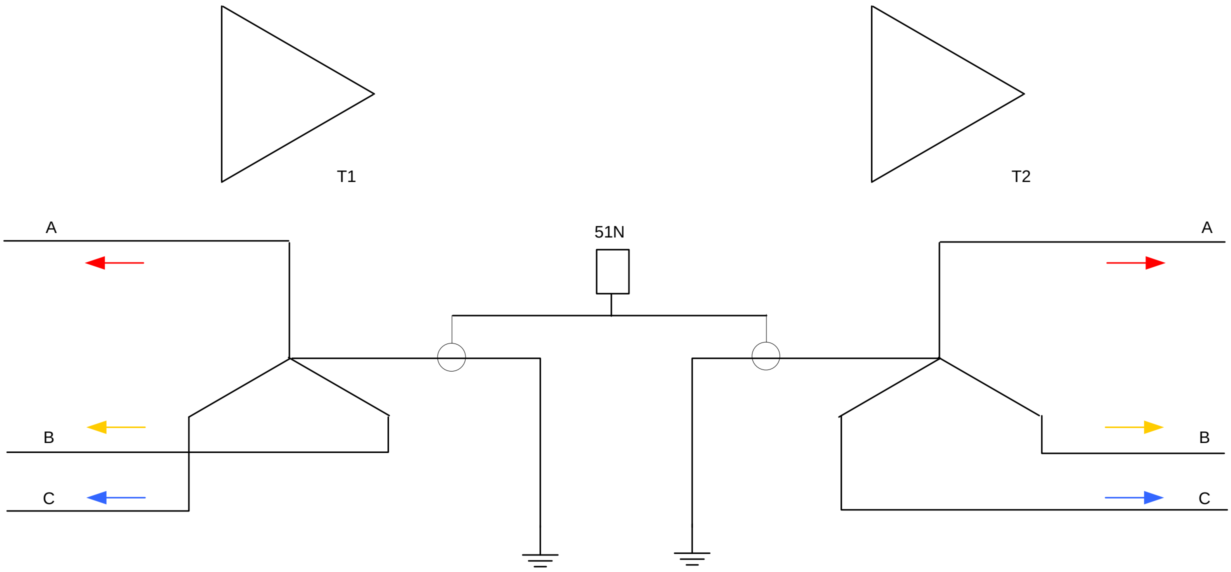


APPENDIX C - METHOD FOR CONFIRMING TRANSFORMER NEUTRAL EARTH FAULT CT POLARITY WHEN TWO OR MORE TRANSFORMERS HAVE SUMMATED NEUTRAL CTS

After carrying out on load checks to confirm the Differential and High Voltage Overcurrent protection a further test is required to confirm that the neutral CTs summate correctly.

To do this we need to remove one phase of the 11kV on one transformer to cause a circulating current in the neutral of the transformers. See diagrams below.

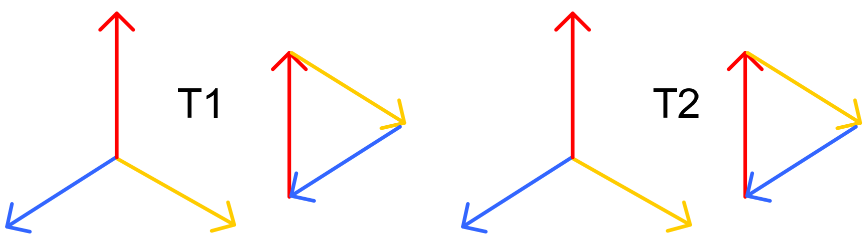
Normal configuration



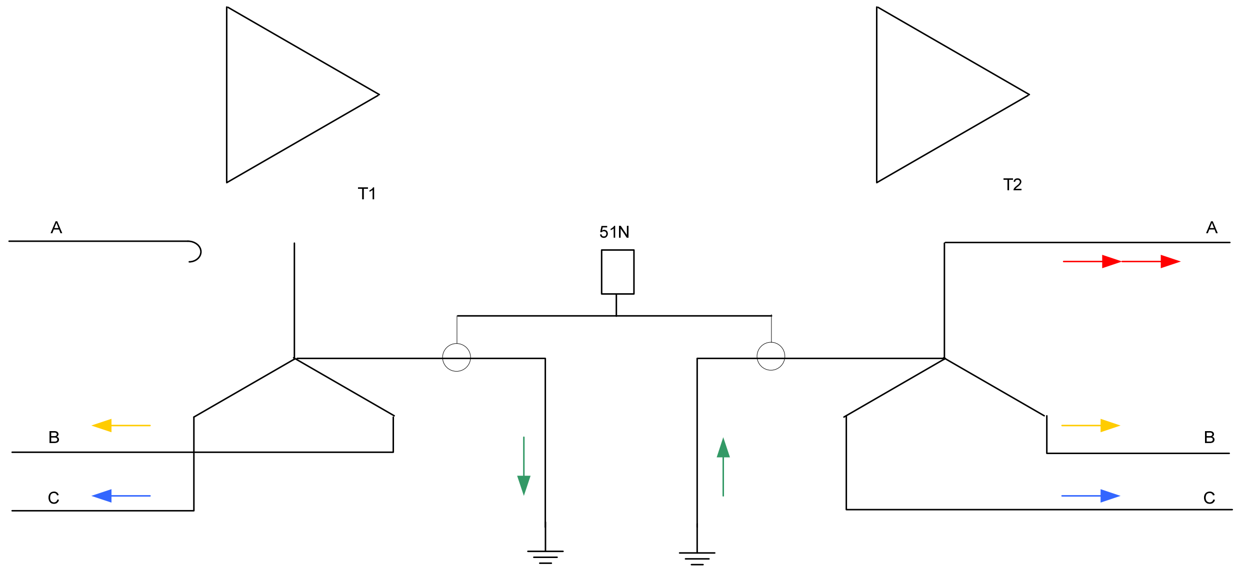
Under normal conditions when both transformers are paralleled each transformer shares the load.

ie. For a load of 2 pu, T1 A, B, and C phases have 1 pu and T2 A, B, and C phases have 1 pu, resulting in A, B, and C phases having 2 pu

No current flows in the neutral.

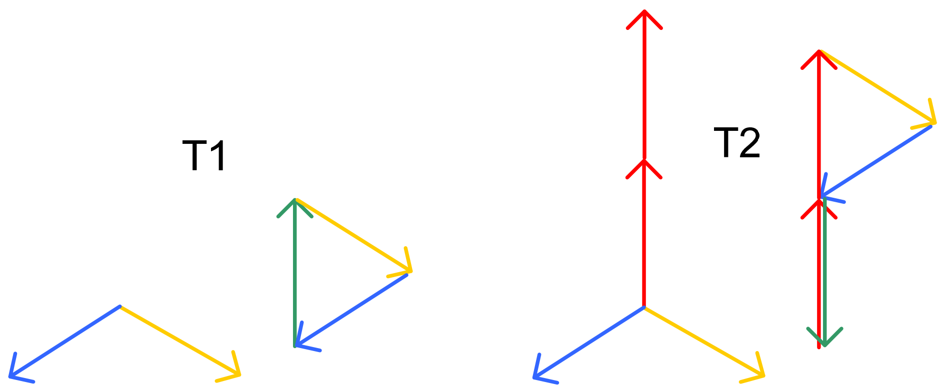


A Phase removed for testing



With A phase disconnected on one transformer a circulating current is produced in the neutral.

Ie. For the same 2 pu load, T1 A phase has 0 pu, B and C phases and neutral have 1 pu and T2 A phase has 2 pu, B and C phases and neutral have 1 pu, resulting in A, B and C phases having 2 pu



If the neutral CT polarity is correct, this current flow from one neutral to the other should result in a zero current in 51N relay. The polarity of one CT secondary connection should then be temporarily reversed to confirm the relay current becomes double the individual CT current.

Items to be considered:

- Will this configuration cause protection to operate?
- Is the plant rated to carry this current? e.g. neutral CT continuous primary rating, earthing transformer (if applicable) continuous rating.

APPENDIX D - ON LOAD TESTING OF DIRECTIONAL EARTH FAULT RELAYS

General Principals

1. Confirm residual current and voltage is zero. This verifies that all 3 current and voltage transformers are summed.

2. Temporarily modify CT and VT connections to provide an "operate" condition and a "restrain" condition. This verifies that the residual connections have not been reversed and that the relay is facing in the correct direction.

Notes:

- the relay should have a short time rating that restricts full voltage across the open delta connection or full current through the current coil.
- the load current should be high enough for correct polarisation.
- the polarising current may be enough to trip the earth fault relay.

3. If unclear indication is obtained for <u>both</u> the "operate" and "restrain" conditions, then look for problems like:

- wrong polarity on residual connections
- wrong RCA
- power factor of load
- wrong CT or VT connections. Note that things like transposition between phases of VT connections will not affect operation of the scheme since all of the VTs are summed, however it will affect testing since, for example, removing red phase VT when you think you are removing white phase VT will give a 120 degree error. It is always preferable to alter the RCA setting to go from "operate" to "restrain" rather than modify VT connections. Things like one or two VT polarity errors will be picked up by the residual voltage being 127 volts instead of zero, three VT polarity errors will give zero residual volts but opposite "restrain" and "operate" conditions.

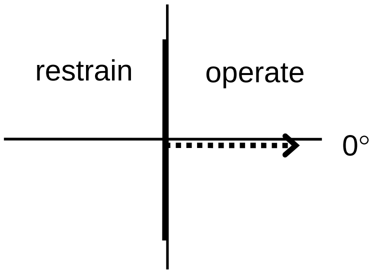
Example Connections / Settings for Verifying Direction during On Load Tests

1. Short white and blue phase CT secondaries to neutral and isolate from secondary relay wiring associated with the earth fault polarising element i.e. only red phase current goes through the earth fault polarising element, not the summed residual current.

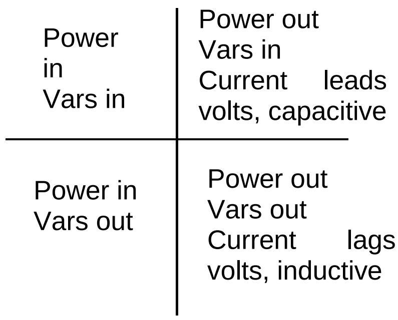
2. Remove red phase secondary from the VT residual circuit i.e. the sum of white and blue phase VT secondaries only goes to the earth fault polarising element, not the residual sum of all three phases.

Steps 1 and 2 above provide in phase polarising voltage and current to the relay – this looks like a close up red phase to earth fault i.e. red phase current and the red phase voltage has collapsed to zero.

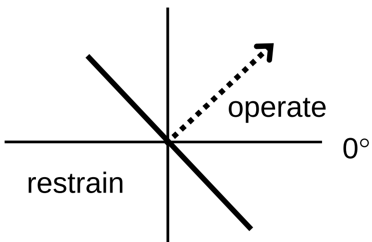
3. With the relay RCA set to 0 degrees, the relay will be in the "operate" condition when power is flowing out of the bus



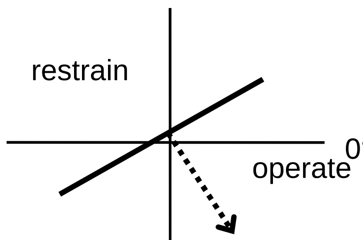
0° RCA



4. RCA can be altered if required. For example, if the system load was at 60° lagging, the relay would be in the "restrain" condition if set to +45° RCA but in the "operate" condition if set to -60° RCA



+45° RCA



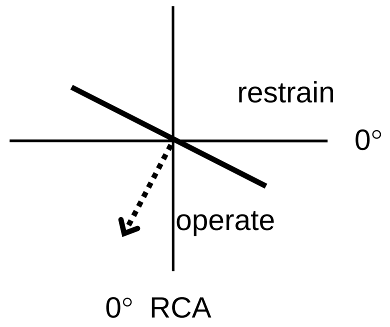
-60° RCA

TJEV directional earth fault has fixed –12.5 (lagging) RCA

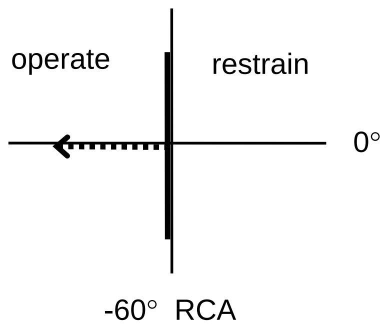
5. Alternatively, remove white phase secondary from the VT residual circuit i.e. the sum of red and blue phase VT secondaries only goes to the earth fault element, not the residual sum of all three phases.

Steps 1 and 5 above provide 120 degree out of phase polarising voltage and current to the relay (current leading)

6. With the relay RCA set to 0 degrees, when the system current lags the system volts by 120 degrees, the relay will see maximum torque.



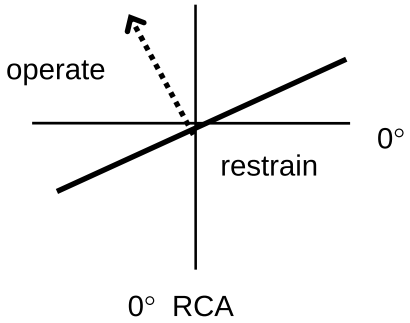
Similarly, with the relay set to -60 degrees RCA it will operate for any power flow into the bus.



7. Alternatively, remove blue phase secondary from the VT residual circuit i.e. the sum of red and white phase VT secondaries only goes to the earth fault element, not the residual sum of all three phases.

Steps 1 and 7 above provide 120 degree out of phase polarising voltage and current to the relay (current lagging)

8. With the relay RCA set to 0 degrees, when the system current leads the system volts by 120 degrees, the relay will see maximum torque.



Similarly, with the relay set to +60 degrees RCA it will operate for any power flow into the bus.