AUSTRALIAN RAIL TRACK CORPORATION LTD

Discipline: Engineering (Electrical) **Category: Standard**

Protection System Requirements for the High Voltage Network

PDS 09

Applicability

ARTC Network Wide	✓	**CRIA (NSW CRN)**	

Primary Source

RIC Standard EP 19 00 00 02 SP version 3.1

Document Status

Version	Date Reviewed	Prepared by	Reviewed by	Endorsed	Approved
1.3	1 September 2010	Standards	National Bridges & Structures Eng / Mgr Standards	Exec Manager SS&P 23/09/2010	CEO

Amendment Record

Version	Date Reviewed	Clause	Description of Amendment
1.1	5 January 2005		Reformatted to ARTC Standard
1.2	11 March 2005	Disclaimer	Minor editorial change
1.3	1 September 2010	2.3	Replaced reference to superseded NSW Standard BSS 02 with applicable Australian Standard for tunnel fire safety

Contents

1 Scope and Application

This document covers the Protection System requirements for the ARTC High Voltage AC Network for 33kV, 66kV and 132kV system voltages. The scope of this publication does not currently include requirements for the high voltage AC network at 2kV and 11 kV system voltages. This will be incorporated in a future revision of this specification.

This document does not include protection requirements for the 1500V DC system.

These protection requirements cover general design principles for protection schemes, as well as requirements relating specifically to the protection equipment. They do not include equipment used for detection and measurement of non-electrical protection parameters (such as oil and gas sudden pressure change, fibre optic temperature measurement), other than to specify necessary interface details.

The correct design, implementation and management of the overall protection system are critical to the safe and reliable operation of the ARTC power system. As such, all design processes for the protection system must follow the ARTC Engineering Design Management Procedures.

All new installations, modified and refurbished existing installations must comply with the requirements in this document.

High voltage protection systems existing at the date of release of this document are not affected by the requirements of this document.

2 References

The following documents are either referenced in this standard or can provide further information. The edition is current at the time of publication of this document.

2.1 International Standards

- IEEE C.37.2 1996 Standard electrical power system device function numbers and contact designations.

2.2 Australian Standards

- AS 1102 1996 Graphical symbols for diagrams. Switchgear, control gear and protective devices.
- AS 1675 1986 Current Transformers – Measurements and Protection
- AS 2067 1984 Switchgear assemblies and ancillary equipment for alternating voltages above 1 kV
- AS 1243 1982 Voltage Transformers for Measurement and Protection
- Applicable Australian Standard for tunnel fire safety

2.3 ARTC Engineering Standards

- PGS 01 ARTC Electrical System General Description
- POP 01 Electrical Power Equipment – Integrated Support Requirements
- PDS 11 Electrical Power Equipment – Design Ranges of Ambient Conditions
- PDS 12 Common requirements for Electrical Power Equipment
- EP 00 00 00 00 MP Electric Power Technical Maintenance Plan (RailCorp publication)
- EP 03 02 00 01 SP Controls and Protection for Rectification Equipment (RailCorp publication)
- PCP 07 System Commissioning tests

- PPS 03 33kV AC Indoor Switchgera – Non-Withdrawable
- ED0001 P –ED0021 P inclusive Engineering Design Management Procedures

2.4 Industry Publications

- Network Protection & Automation Guide (Alstom)
  (previously titled: Protective Relays Application Guide)
- Alstom/Areva Protection Relay Application Guides

3 Definitions and Abbreviations

Auxiliary Supply	Supply for the operation of electronic protection relays, energisation of multi-trip relay coils, energisation of HV ACCB trip coils and general control circuit operations. Nominally 120V DC or 50V DC.
Dedicated Pilot Cable	A communication cable that is used only for the control, indication and pilot wire functions between two substations. The cable is continuous between substations.
Low Voltage Compartment	The compartment on the high voltage switchgear where the protection relays, control equipment and wiring is installed. The compartment is usually accessed by a hinged door and does not require any isolation or operation of the switchgear for safe access.
Substation	The following are locations within the ARTC electrical network which are classified as system substations for the purpose of this document. • Any location that includes a high voltage circuit breaker. • Traction substation • High voltage switching station • High voltage switchroom (except 2kV) 2kV locations, pole top and other distribution substations that use HV fuses for protection are not classed as system substations.
ARTC	Australian Rail Track Corporation
RTU	Remote Telemetry Unit (Interface to SCADA system)
SCADA	Supervisory Control and Data Acquisition system
Supervisory	A connection to the Electrical Operating Centre to allow the remote operation of equipment and provision for remote monitoring of status and alarms using a SCADA system.
ACCB	Alternating current circuit breaker
CT(s)	Current Transformers(s)
DC	Direct Current
IT	Inter-trip

4 General Protection Philosophy

4.1 General

In designing the protection schemes for ARTC's high voltage network, the following general principles shall be applied:

- All high voltage faults shall be detected and able to be cleared by two independent sets of protection (primary and backup). Either may be circuit breakers or fuses.
- The primary and backup protection schemes shall be independent. All HV circuit breakers shall be equipped with dual trip coils.
- Where primary and backup protection is installed in the same substation, that substation shall have two battery systems. Some substations are exempt from this requirement. This exemption is based on risk exposure considering safety, operational impact, economic and environmental considerations.
- The thermal limit current of the CT's shall not constrain the rating of associated power system elements.
- Primary protection shall be implemented using unit schemes.
- The protection schemes shall be designed to eliminate or manage "blind spots".

4.2 Protection Settings

- The protection shall be set to operate at not more than 2/3 of the minimum phase to phase fault and not more than 2/3 of the minimum earth fault.
- The overcurrent protection settings shall, as far as practicable, be at least 1.5 times the maximum load current.
- Fault clearing times shall ensure damage to equipment is minimised.

4.3 Grading

- The protection shall be graded to ensure that the fault is cleared by the protection closest to the fault, and the area of interruption is minimised.
- A 0.3 second grading margin shall be provided for protection 'in series' except that breaker fail timers shall be 0.2 second.
- Relay settings shall be, as far as practicable, at least 1.5 times the highest downstream setting.

5 Specific Protection Equipment Requirements

5.1 Protection Equipment Design Principles - All New HV Switchgear

To ensure the independence and integrity of protection schemes the following principles shall apply:

Mandatory

- Protection current transformers shall be connected to protection equipment only. Approved transducers used for interfacing with the SCADA are to be regarded as protection equipment. Appendix E lists approved transducers.
- Primary and backup protection schemes shall be implemented using separate relays and these relays shall be of a different technology.
- Where the primary and backup scheme trip the same HV circuit breaker, the following shall apply:

- The primary and backup schemes shall use separate trip coils, one trip coil for the primary scheme the second trip coil for the backup scheme. Refer to Appendix A.2 for standard trip coil arrangements.
- The backup scheme (protection relay, trip coil control and supply) shall have a separate auxiliary supply.
- Where two DC auxiliary supplies are required (see clause 5.4) the primary protection scheme is to be supplied by battery A and the backup protection scheme supplied by battery B.

- SCADA monitored trip circuit supply supervision with local indication shall be provided for all tripping circuits.
- The auxiliary supply for each bus-zone protection scheme (protection and multi-trip relays) shall have its auxiliary supply from a dedicated circuit originating at the distribution board. Fuse protection and monitoring shall be provided with the monitoring relay connected to the SCADA system.
- Individual protection schemes to be connected to dedicated current transformers.

5.1.1 Interfacing New Protection Schemes With Existing Equipment

It is acceptable to have more than one protection scheme (maximum two schemes) connected to the same set of CT's as long as the following applies:

- It is not economically feasible to install additional CT's (eg. Circuit breaker would have to be replaced, additional post type CT's would be required.)
- The protection schemes are not the primary and backup protection for the same equipment.
- A failure of the CT's will not result in a piece of equipment having no protection due to an existing compromise in the protection system.
- The output of the current transformers shall be sufficient for the burden of all the connected protection schemes and associated equipment to ensure each scheme operates as required up to the available fault level.

5.2 Current Transformers (CT)

5.2.1 General Requirements

All protection and metering CT's shall comply with AS 1675.

The CT shall be easily replaceable and shall be installed with polarity markings assuming supply from the bus in all cases. All secondary leads shall be terminated in individual links in the appropriate compartment where the CT is installed and the earth point formed by using a proprietary cross connection for the links being used. The CT's shall be earthed at one point. This single point earth is to be within the applicable LV compartment.

CT's shall be rigidly clamped to prevent movement under short circuit conditions. They shall be provided with rating plates and terminal markings as specified in AS 1675. The rating plates shall be mounted in such a manner that they are visible, and the secondary terminals shall be readily accessible. Duplicate rating plates shall be mounted in the instrument compartment with connection diagram.

ARTC's preferred value for the rated secondary current is 5A.

CT's shall safely withstand the mechanical and thermal stresses set up by a short circuit equal to the full short circuit rating of the switchgear. CT's shall have a minimum thermal limit current at least 1.5 times rated current unless modified by the RFT for the specific location.

See 6.1.5 for CT location requirements for 33 & 66 kV Feeders.

See 6.3.3 for CT location requirements for HV Busbars and Bus-Ties.

See 6.5.7 for CT location requirements for System Transformers.

5.2.1.1 Additional Requirements for CT's with a Rated Secondary Current of 1 Amp.

If it is proposed to use CT's with a rated secondary current of 1A, then the following issues shall be complied with.

- Provision of a detailed design solution for the secondary wiring under system fault conditions. This design solution must address the voltage withstand ratings of all connected equipment as the secondary voltages developed are five times larger than if the CT's have the preferred value of 5A.
- A complete integrated system support analysis of using the non-standard protection equipment must be economically justified. See 5.8 Integrated Support System for details.

5.2.2 Multiple Ratio Current Transformers

Where multiple ratio CT's are used, the links associated with changing the CT ratio shall be fit for purpose.

The CT terminals shall be clearly marked to enable correct changing of the ratio. The associated rating plate shall also be marked with the information to enable correct changing of the ratio.

5.2.3 Protection Current Transformers

Protection CT shall be of a class entirely suitable for the connected equipment so as to give correct operation under all service and fault conditions.

The following composite error shall apply:

- Differential schemes – 2.5%
- Overcurrent & earth fault – 10%

The rated short-time is 3 seconds.

Appendix B has a table listing the typical ratio and designation of current transformers, which are preferred for use in the ARTC electrical network.

5.2.4 Measurement Current Transformers

Measurement CT's shall be of a class entirely suitable for the application as specified i n AS 1675.

As a general guide the following are typical class of accuracy used in the ARTC network:

- 0.5M for general tariff metering such as supplies to shops, workshops etc.
- 2M for general measurement such as transducers and ammeters.

The measurement current transformers shall have the same ratio and thermal current limit as the associated protection CT's on the circuit.

5.2.5 Current Transformer Secondary Wiring

All CT secondary wiring shall be provided with test links at the marshalling strip within the respective low voltage compartment. The test links shall be Weidmuller SAKC10 or equivalent.

The wiring shall be connected to the associated protection relay (or meter) via a test block that allows isolation of the relay / metering and short-circuiting of the current transformer secondary. If the relay test blocks are not integral with the relay enclosure, test blocks of the type Areva MMLG01 shall be provided.

The test blocks shall be located adjacent to the respective protection relay.

The current transformer secondary wiring shall be coloured as detailed below:

- AØ : red
- BØ : white

- CØ : blue
- Neutral : black

The wiring shall be a minimum size of 2.5mm^2 and have an insulation rating of 0.6/1 kV. Where 2.5mm^2 wiring is used it shall have a stranding of 50/0.25mm. All wiring connections to CT's and to protection relays shall be made using double grip ring type pre-insulated crimp lugs.

Wiring identification shall be in accordance with AS2067. Refer to PDS 12 Common Requirements for Electrical Power Equipment, for details of cable identification requirements.

5.3 Voltage Transformers

5.3.1 General Requirements

Voltage transformers shall be provided for all three phases and can either be a 3 phase voltage transformer or 3 single phase voltage transformers.

Voltage transformers shall be manufactured and tested in accordance with AS 1243. They shall have a rated primary voltage as specified by the switchgear and have two secondary windings with a voltage factor of 1.9 for 30 seconds as follows:

PERFORMANCE CATEGORY	RATED VOLTAGE	ACCURACY CLASS	RATED BURDEN
A	110 V	5 P	8 mS
B (residual)	110/√3 V	3 R	8 mS

TABLE 2: Voltage Transformer Specifications

The neutral point of the star connected primary shall be earthed. The neutral point of the star connected secondary winding shall be brought out and connected to suitably insulated terminals located in the LV compartment and earthed.

The voltage transformers shall be protected by suitably rated circuit breakers connected in the low voltage circuit as close as possible to the transformer terminals

For maintenance, and for the commissioning of protection relays, it shall be possible to simulate the voltage conditions that would occur during earth faults and the supplier shall explain how this is achieved. A typical way to achieve this is to remove the high-voltage fuse in any one phase and earth that phase of the voltage transformer.

5.3.2 Voltage Transformer Secondary Wiring

The voltage transformer secondary wiring shall be coloured as per the current transformer wiring with the exception of the open delta wiring, which shall be purple.

5.3.3 Voltage Transformer Alarms

A three phase, phase failure relay shall be connected to the star connected secondary winding of the voltage transformer. The phase failure relay shall provide a normally closed 'VOLTAGE TRANSFORMER FAIL' alarm contact as well as visual indication. The relay shall detect both under-voltage and negative phase sequence voltage unbalance on the load side of the main circuit breaker.

5.4 Auxiliary Supply (DC)

To ensure integrity of the ARTC electrical network is maintained when an auxiliary supply fails, **strategic** substations are required to have **two independent** substation **battery systems.**

The criteria determining this requirement are:

- Connectivity of the substation (4 or more high voltage feeders) within the ARTC electrical network.
- Maximum high voltage fault level and the margin to the rated short-time withstand current capacity of the switchgear installed at the substation.
- Criticality of the substation within the rail system. (eg. Main supply substation for city circle, rail tunnel, rail junction).
- Where primary and backup protection is installed in the same substation, that substation shall have two battery systems. Some substations are exempt from this requirement. This exemption is based on risk exposure considering safety, operational impact, economic and environmental considerations.
- Complexity of the protection schemes and any resulting compromises in the protection coordination.

The associated main distribution boards of the battery systems are to be capable of being paralleled.

Refer to Section 5.1 for specific requirements relating to protection schemes when there are two auxiliary supplies at a substation.

5.5 Protection Relays

All protection relays shall be flush mount and withdrawable. The auxiliary supply to the protection relays shall be 120V DC or 50V DC as determined by the substation battery.

Appendix A has a table listing the typical protection relays, which are currently preferred for use in the ARTC electrical network.

When specifying the type of protection relay to be used consideration must be given to ensure adequate integrated system support including availability of system spares. See 5.2.1.1 Additional Requirements for CT's with a Rated Secondary Current of 1 Amp.

Alternatives to relays specified in Appendix A must be approved by the Principal Design Engineer, Electrical.

5.6 Protection Alarms

Every operation of a protection relay shall result in an individual alarm being sent to the SCADA system and provide a local indication. The alarm shall enable the Electrical System Operators to accurately identify the protection scheme that has operated.

If a protection relay has more than one function (eg AØ and CØ overcurrent elements), then each function shall have a separate alarm output.

Other alarms associated with the protection schemes include:

- Relay Fault
- Breaker Fail
- Pilot Fail
- Broken Conductor
- Pilot Wire "Auxiliary Supply Fail"
- Buchholz Gas/ Buchholz Oil
- Intertrip Receive
- BusZone Auxiliary Supply

- TCS

The input from the voltage transformer to directional protection relays shall be supplied via a separate circuit breaker that has voltage free auxiliary contacts. These contacts are to be connected to the SCADA system to give a “DIRECTIONAL PROTECTION SUPPLY” alarm when the circuit breaker trips.

5.7 Inter-Trip Arrangements

5.7.1 Preferred Technology

Optical fibre pilots are preferred for intertripping.

Refer to Appendix A.1 Preferred Protection Relays Currently preferred for Use in the ARTC Electrical Network for type of inter-trip relay.

5.7.2 Fibre Optic Pilots

Where fibre optic pilots are available, the inter-tripping may be achieved utilising pilot wire relays that have inter-tripping as a function of the relay.

5.7.3 Copper Pilots

Where inter-trip arrangements are required for a feeder, it is preferred the inter-trip scheme is implemented using a dedicated pair of pilots for the scheme.

If there are no spare pilots in the existing pilot cable, the inter-trip may be achieved by manipulating the feeder pilot wire scheme.

A minimum of 15kV isolation shall be provided to avoid transfer of voltages across the pilots. This may be achieved by using an inter-trip relay that provides isolation at either end of the scheme.

5.8 Integrated Support System

An Integrated Support System exists for protection equipment. This current system is based on 5 Amp CT’s and protection relays nominated in A.1 Protection Relays

Currently Preferred for Use in the ARTC Electrical Network. Any proposal to use non preferred schemes, relays or CT’s would require an economically justified integrated support analysis. The analysis shall include relevant requirements of

POP 01 and take account of the following:

- Test and support equipment
- Relay programming software
- Staff training
- Spares analysis and procurement
- Maintenance requirements analysis
- Operation and maintenance manuals

6 Specific Equipment Applications

6.1 33kV & 66kV Feeders

6.1.1 Standard Protection Schemes

The following schemes shall be provided for the protection of 33kV and 66kV feeders:

	ARTC network feeder	Bulk Supply Feeder
Primary Protection	•Pilot wire	•Directional over-current and earth fault (looking towards supply point) **and** •Pilot wire or •Distance protection (zone 1, last 20% Zone 2) at the supply end
Backup Protection	•over-current and earth fault (may be directional if required by system configuration to achieve discrimination) **and** •circuit breaker fail	In accordance with the other Network Operator's policy

TABLE 1: 33kV & 66kV Feeder Protection Schemes

6.1.2 Primary Protection

If the pilot circuit is not run via a dedicated pilot cable, an instantaneous over-current and earth fault check relay shall be provided in series with the pilot wire relay to prevent nuisance tripping of the feeder.

All pilot wire schemes shall include pilot circuit supervision. This can be implemented either as a function of the pilot wire relay or using dedicated pilot circuit supervision equipment.

6.1.3 Backup protection

The unit protection on the feeder shall be backed up by an over-current and earth fault scheme. This scheme shall operate via a circuit breaker and current transformers that are not part of the primary scheme.

6.1.4 Circuit Breaker Fail Scheme

The failure of a circuit breaker to open in response to a protection trip command shall be detected and the appropriate upstream circuit breaker(s) tripped. A time delay shall be provided to avoid nuisance tripping.

It is preferred that the feeder pilot wire relay provides this function. Where the pilot wire relay does not have this function an overcurrent and earth fault relay (with directional capabilities) shall be provided to implement the breaker fail scheme.

6.1.5 Location of Current Transformers

It is preferred that the CT's are located on the busbar side of the feeder circuit breakers.

However where this is not practicable, the current transformers for feeder protection can be located on the line side of the feeder circuit breaker. In this arrangement an inter-trip shall be provided to trip the feeder circuit breaker at the far end of the feeder whenever the local feeder circuit breaker is tripped. The far end circuit breaker is only required to trip if fault current is flowing through that circuit breaker.

Refer to Section 5.7 Inter-Trip Arrangements for further details on inter-tripping.

Where no feeder circuit breaker is provided on one end, the current transformers shall be located on the far side of the bus section circuit breaker and the line side of the circuit breakers for any rectifier or other teed off circuit fed from that section of the bus.

The scheme shall trip the bus section circuit breaker and any circuit that could be a source of supply.

See Appendix F for typical Pilot Wire arrangements.

6.1.6 Metering Requirements

Every feeder shall be provided with an ammeter and all bulk supply feeders shall be provided with kWh metering.

Details of the ammeter, metering and their connection are specified in the appropriate switchgear standard.

The requirements for 33kV indoor switchgear are detailed in PPS 03 33kV AC Indoor Switchgear – Non-Withdrawable.

6.2 11 kV feeders

Requirements to be added in future versions of this document.

6.3 High Voltage Busbars & Bus-Tie Cables

6.3.1 Primary Protection

All 33kV and 66kV indoor switchgear and bus-tie cables shall have high impedance bus zone protection as the primary protection.

As an alternative to traditional bus zone protection schemes using CT's, a fault detection scheme that has been type tested and is an integral system within the switchgear can be offered.

Strategically important outdoor 33kV and 66kV busbars shall also have high impedance bus zone protection as the primary protection. The System Control Engineer will make the determination of whether an outdoor busbar requires bus zone protection.

Separate schemes shall be provided for each section of the busbar.

The tripping of circuit breakers on an indoor switchboard shall be via a manually reset multi-trip relay. The tripping of circuit breakers on an outdoor busbar shall be via an automatically reset multi-trip relay.

6.3.2 Backup Protection

The backup protection for a busbar shall be upstream over-current and earth fault protection.

6.3.3 Location of Current Transformers

The current transformers for protection of the busbar shall be located on the line side of all circuit breakers.

The scheme shall trip all circuit breakers on the relevant section of the busbar.

The current transformers for protection of the bus-tie cables shall be located on the busbar side of the tie circuit breaker. The scheme shall be arranged to trip the circuit breakers at both ends of the tie cable.

Where the current transformers for the feeder, bus-tie, or transformer circuits are not located on the busbar side of the circuit breaker and the bus zone scheme is used to cover the blind spots between the circuit breakers and the CTs, the bus-zone scheme shall also initiate tripping of the circuit breakers at the far end of the feeder or tie cable, or on the other winding of the transformer.

6.4 Rectifier Transformer and Power Cubicle

6.4.1 Primary Protection

The primary protection for the rectifier transformer and power cubicle shall be provided by an A~ and C~ instantaneous overcurrent and instantaneous earth fault relay.

The overcurrent elements are required to operate when a fault on the +1500V DC busbar (when there is a 400V arc) is detected.

A current transducer shall be provided in the B~ protection circuit. The transducer output shall be connected to the panel ammeter and analogue input to SCADA.

See RailCorp publication EP 03 02 00 01 SP – Controls and Protection for Rectification Equipment, for further detailed information on these requirements.

6.4.2 Backup Protection

The backup protection scheme for the rectifier transformer and power cubicle shall be provided by a separate protection scheme, which is located in the same substation. The protection relay shall be an AØ, BØ and CØ instantaneous overcurrent and instantaneous earth fault relay.

6.4.3 Circuit Breaker Fail Scheme

The failure of the circuit breaker to open in response to a protection trip command shall be detected and the associated bus-zone MTM relay shall be energised. A time delay of 0.2 seconds shall be provided to avoid nuisance tripping.

The backup protection relay shall be used to provide this function.

6.4.4 Protection Interface Requirements

Please refer to RailCorp publication EP 03 02 00 01 SP – Controls and Protection for Rectification Equipment, for further detailed information on the protection interface requirements.

6.5 System Transformers

6.5.1 Standard Protection Schemes

All 33kV and 66kV transformers 1 MVA or greater in size shall have transformer differential as the primary protection and overcurrent and earth leakage as the backup protection. The transformers shall be fitted with a buchholz oil & gas relay.

6.5.2 Primary Protection

The transformer differential scheme shall be arranged to trip both the primary and secondary circuit breakers.

The tripping of the circuit breakers shall be via a multi-trip relay. If the transformer is cable connected the multi-trip relay shall be a manually reset relay.

6.5.3 Backup Protection

Overcurrent and earth fault shall be provided as the backup transformer protection.

The tripping of the circuit breakers shall be via a multi-trip relay. If the transformer is cable connected the multi-trip relay shall be a manually reset relay.

Three phase over current protection shall be provided on the high or low voltage side of the transformer as backup protection to the outgoing feeder overcurrent protection.

6.5.4 Circuit Breaker Fail Scheme

The failure of a circuit breaker to open in response to a backup protection trip command shall be detected and the associated bus-zone MTM relay energised. A time delay of 0.2 seconds shall be provided to avoid nuisance tripping.

The three phase overcurrent protection relay on the same side of the transformer as the scheme being backed up shall provide this function.

6.5.5 Neutral Leakage

Neutral leakage shall be provided as backup protection to feeder earth fault. The scheme shall trip both the primary and secondary circuit breaker of the transformer via an automatically reset multi-trip relay.

6.5.6 Buchholz Relay

A buchholz relay shall be provided in the oil line between the conservator and the main tank.

Operation of either the oil or gas element of the buchholz relay shall trip both the primary and secondary circuit breakers via a manually reset multi-trip relay.

Each element of he buchholz relay shall have voltage free alarm contacts, which are connected are connected to the SCADA system.

6.5.7 Location of Current Transformers

It is preferred that the current transformers for the differential protection are located on the busbar side of both the primary and secondary circuit breakers.

Where this is not practicable, it is acceptable that the current transformers for transformer protection be located on the transformer side of the transformer circuit breaker.

The current transformers for the neutral leakage protection shall be located on the neutral to earth connection of the transformer.

7 Appendix A - Protection Relay Types

The following tables detail the requirements for protection relays when new switchboards are installed in the ARTC electrical Network.

The tables detail the protection relays which are currently preferred for use in the ARTC electrical network and when installing a new switchboard in an existing system whether the existing pilot wire relays are required to be replaced.

A.1 Protection Relays Currently Preferred for Use in the ARTC Electrical Network

SCHEME	EQUIPMENT	RELAY TYPE
Pilot wire	Supply point feeder	MHOB04 or MICOM P521/P540 (mandatory if fibre optic available)
	ARTC feeder	MBCI or MICOM P521/P541 (mandatory if fibre optic available)
OC, EF, DOC, DEF	Feeder	KCEG142, MICOM P127
	Rectifier - primary	MCAG33
	Rectifier - backup	KCEG142 or MICOM P127
	Current check	MCAG39 or MICOM P127
	System Transformer	MICOM P127
Bus-zone	Busbar	MCAG34
Transformer differential	System Transformer	KBCH130, MBCH12, MICOM P632
Neutral leakage	Transformer	KCEG142 or MICOM P125
MTA		MVAJ 11
MTM		MVAJ 13
Intertrip		GCM05 (15kV isolation)
TCS		RMS 1 TM 10

TABLE A1: Protection Relays

A.2 ACCB Trip Coils - Standard Equipment Connection

The following table details the ACCB trip coils and associated relays that are connected to each trip coil. This table is based on typical protection schemes used in ARTC. Protection designs for specific locations must be verified by ARTC.

EQUIPMENT	PROTECTION SCHEME	TRIP COIL NUMBER	NOTES
Feeder Protection	Pilot wire	1	
	Overcurrent & Earth Fault	2	
	Inter-trip	1	
Bus-zone & Bus-Tie	Busbar protection – trips via MTM	2	1
	Cable Bus-tie protection – trips via MTM	1	
System Transformers	Differential – trips via MTM or MTA	1	
	Overcurrent – trips via MTA	1,2	2
	Neutral Leakage – trips via MTA	2	
Rectifier Transformers	Instantaneous Overcurrent & Earth Fault- primary	1	
	Instantaneous Overcurrent & Earth Fault - backup	2	

TABLE A2: Trip Coils

Notes:

1) The operation of the bus-zone protection energises an MTM relay, which trips all ACCB's on the section of the busbar. The trip coil number applies to all ACCB's that are tripped.

2) If the differential protection operates via an MTM then the overcurrent protection shall trip via trip coil 2.

A.3 Interfacing With Existing Pilot Wire Schemes

The following table details whether the existing pilot wire scheme needs to be upgraded when a new switchboard is to be installed, and is interfacing with an existing pilot wire protection scheme.

SCHEME	EXISTING EQUIPMENT	SCHEME TO BE REPLACED	NOTES
Pilot wire	HO2	YES	
	HO4	NO	2
	HMB4	NO	1,2
	MHOB04	NO	1
	MBCI	NO	1
	MICOM P521/P541	NO	

TABLE A2: Interfacing With Existing Pilot Wire Schemes

Notes:

1) If there are fibre optic pilots available between substations or fibre is to be installed, then pilot wire relays that use fibre optic for their communication (MICOM P521 /P541) shall be used.

2) If system spares are required to be used to create/interface with an H04 or HMB4 scheme then the Protection Engineer shall be consulted to ensure there are adequate spares available. If the number of spares available is at the minimum required amount, then the pilot wire scheme shall be replaced.

8 Appendix B - Current Transformers

The following tables detail the ratio and designation of current transformers, which are to be used in the ARTC electrical network for typical schemes.

The current transformer designation details are calculated based on the following parameters:

- Maximum CT secondary lead (loop) length of 20m with 2.5mm^2 size cable for indoor equipment and a lead (loop) length of 150m with 16mm^2 size cable for outdoor equipment.
- CT core knee point flux density of 1.45T
- System X/R = 20
- MICOM P521 relay, refer to general equations for X/R<40 and t_{Idiff} = 0.1 s.
- MBCI relay, refer to general equations, X=1, large X/R, Kt = 20.
- Overcurrent and earth fault relays, Vk = $I_n^* I_f^* (R_{relay}+R_{ct}+R_{leads})$, with relay burdens as specified by the manufacturer.

Where the equipment to be protected is not in the following tables or the standard parameters above are not applicable then the protection CT requirements will need to be specifically determined. Typical examples of these scenarios are:

- Lead lengths > 20m.
- System transformers with a size or voltage not specified below.
- Transformers with a different configuration.
- Feeders with a higher capacity than 500A.

B.1 Rectifier Instantaneous Overcurrrent & Earth Fault

EQUIPMENT	VOLTAGE /SIZE	CT RATIO	RELAY TYPE	CT DESIGNATION
Rectifier Tx – 33kV	5.3, 4.28 & 2.5MVA	300/200/5	MCAG33	10 P100F20 (specified on 200 tap)
			MICOM P127	10 P50F20 (specified on 200 tap)
Rectifier Tx – 66kV	5.3, 4.28, 2.5MVA	150/100/5	MCAG33	10 P100F20 (specified on 100 tap)
			MICOM P127	10 P50F20(specified on 100 tap)

TABLE B1: Rectifier Protection Relays & CT's

B.2 Overcurrent and Earth Fault

CT's for use on overcurrent and earth leakage on feeders have been sized on a fault level of 31.5kA at 33kV and 15.75kA at 66kV.

EQUIPMENT	VOLTAGE /SIZE	SCHEME	CT RATIO	RELAY TYPE	CT DESIGNATION
66kV Feeder		OC & EF	250/5	KCEG142	10P150
				MICOM P127	10P150
33kV Feeder		OC & EF	500/400 /300/5	KCEG142	10P300 (specified on 300 tap)
				MICOM P127	10P300 (specified on 300 tap)
33/11 KV Tx (5MVA)	33KV	OC & EF	150/5	MICOM P127	10P50F20
	11 KV	OC & EF	450/5	MICOM P127	10P50F20
		NL	150/5	MICOM P127	10P50F20

TABLE B2: Overcurrent and Earth Fault Protection Relays & CT's

B.3 Pilot Wire Schemes

CT's for use on pilot wire schemes have been sized on a fault level of 31.5kA at 33kV and 15.75kA at 66kV

EQUIPMENT	CT RATIO	RELAY TYPE	CT DESIGNATION
66kV Feeder	250/5	MBCI or MICOM P521 /P541	0.3PL115R0.3
	250/1	MBCI or MICOM P521/P541	0.05PL50R0.8
33kV Feeder	500/400/300/5	MBCI or MICOM P521 /P541	0.3 PL200R0.3 (specified on 300 tap)
	500/400/300/1	MBCI or MICOM P521 /P541	0.05 PL80R0.8 (specified on 300 tap)

TABLE B3: Pilot Wire Protection Relays & CT's

B.4 Bus-Zone Schemes & Transformer Differential

The overall design of a bus-zone scheme is critical to ensure stability for through faults. The requirement for stabilising resistors to ensure stabililty and for metrosils to limit CT output voltage is required to be determined for each individual scheme.

Please refer to the Alstom MCAG34 application brochure for methods of calculation and requirements.

CT's for use on bus-zone schemes have been sized on a fault level of 31.5kA.

EQUIPMENT	RELAY TYPE	CT RATIO	CT DESIGNATION
33kV Buszone	MCAG34	1250/5	0.1 PL200R0.4
33/11 kV Tx 5MVA, Dyn1 (differential)	KBCH130, MBCH12, MICOM P632	33kV - 150/5	2.5P50F20
		11 kV - 450/2.89	2.5P50F20

TABLE B4: Bus-Zone & Transformer Differential Protection Relays & CT's

9 Appendix C - Protection Relay Identification

Device numbers and functions shall generally be in accordance with IEEE C.37.2. The detailed implementation shall be as set out below.

Relay Identifier	Description
50A	Instantaneous Overcurrent Relay (A phase)
50C	Instantaneous Overcurrent Relay (C phase)
50/L	Instantaneous Overcurrent Relay (A,C & E; feeder)
51A	Inverse Time Overcurrent Relay (A phase)
51 C	Inverse Time Overcurrent Relay (C phase)
63	Buchholz Relay
64	Instantaneous Earth Fault Relay
67	Directional Overcurrent Relay
87/B	Differential Protective Relay (busbar – high impedance)
87/L	Differential Protective Relay (feeder - pilot wire scheme)
87/T	Differential Protective Relay (transformer)
MTA	Multi Trip Automatic Reset Relay
MTM	Multi Trip Manual Reset Relay
TBK1, 2	Test Block
TCS	Trip Circuit Supervisory Relay

TABLE C1: Protection Relay Identification

10 Appendix D - Standard Test Block Wiring

AREVA MMLG01 TEST BLOCK STANDARD TERMINAL ALLOCATIONS

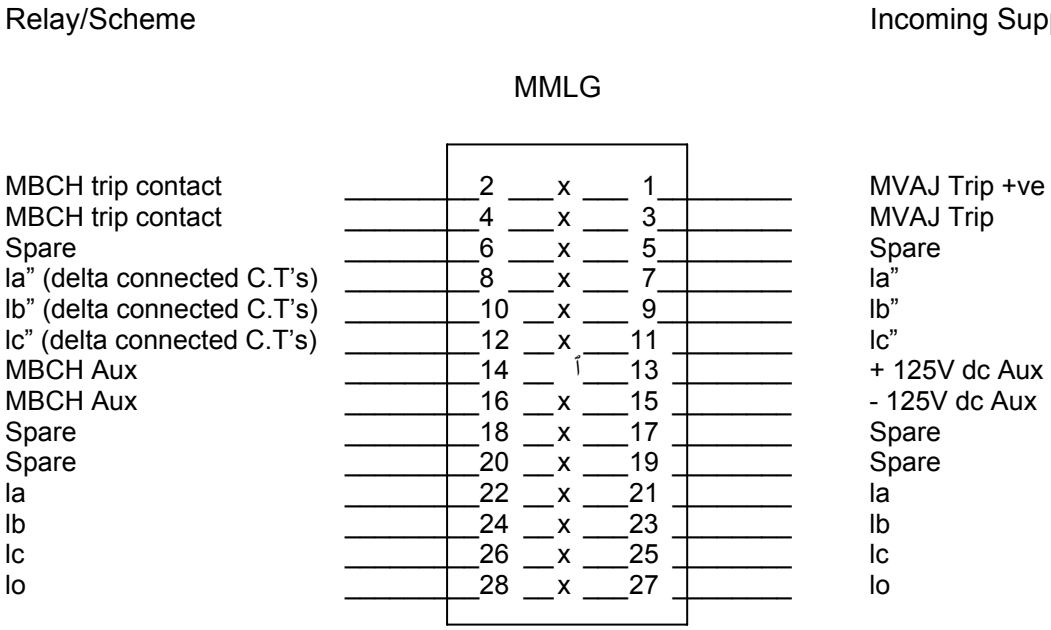
PILOT WIRE PROTECTION: RELAYS MBCI+MCRI Check

Relay/Scheme	MMLG	Incoming Supplies
MBCI trip contact (1)	2 x 1	52 Trip +ve
MBCI trip contact (3)	4 x 3	52 Trip
MCRI check contact (1)	6 x 5	MBCI inhibit (11)
MCRI check contact (3)	8 x 7	
Pilot 1 MBCI (17)	10 x 9	Pilot 1
Pilot 2 MBCI (18)	12 x 11	Pilot 2
MBCI&MCRI Aux	14 x 13	+ 125V dc Aux
MBCI&MCRI Aux	16 x 15	- 125V dc Aux
Spare	18 x 17	Spare
Spare	20 x 19	Spare
Ia (MBCI&MCRI)	22 x 21	Ia
Ib (MBCI &MCRI)	24 x 23	Ib
Ic (MBCI&MCRI)	26 x 25	Ic
Io	28 x 27	Io

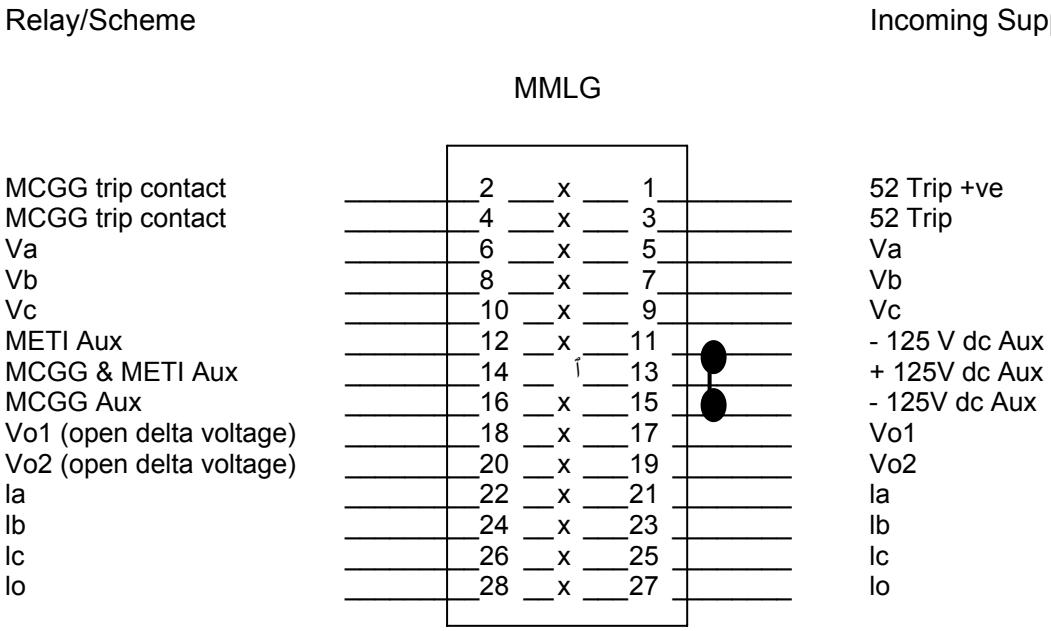
DIRECTIONAL OC/E FEED PROTECTION/BREAKER FAIL: RELAY KCEG140

Relay/Scheme	MMLG	Incoming Supplies
KCEG140 trip contact	2 x 1	52 Trip +ve
KCEG140 trip contact	4 x 3	52 Trip
Va	6 x 5	Va
Vb	8 x 7	Vb
Vc	10 x 9	Vc
Vn	12 x 11	Vn
KCEG140 Aux	14 x 13	+ 125V dc Aux
KCEG140 Aux	16 x 15	- 125V dc Aux
KCEG140 Breaker fail trip contact	18 x 17	CB/fail trip +ve
KCEG140 Breaker fail trip contact	20 x 19	CB/fail multitrip
Ia	22 x 21	Ia
Ib	24 x 23	Ib
Ic	26 x 25	Ic
Io	28 x 27	Io

TRANSFORMER DIFFERENTIAL PROTECTION: RELAY MBCH



DIRECTIONAL OC/E FEEDER PROTECTION: RELAY MCGG52 + METI



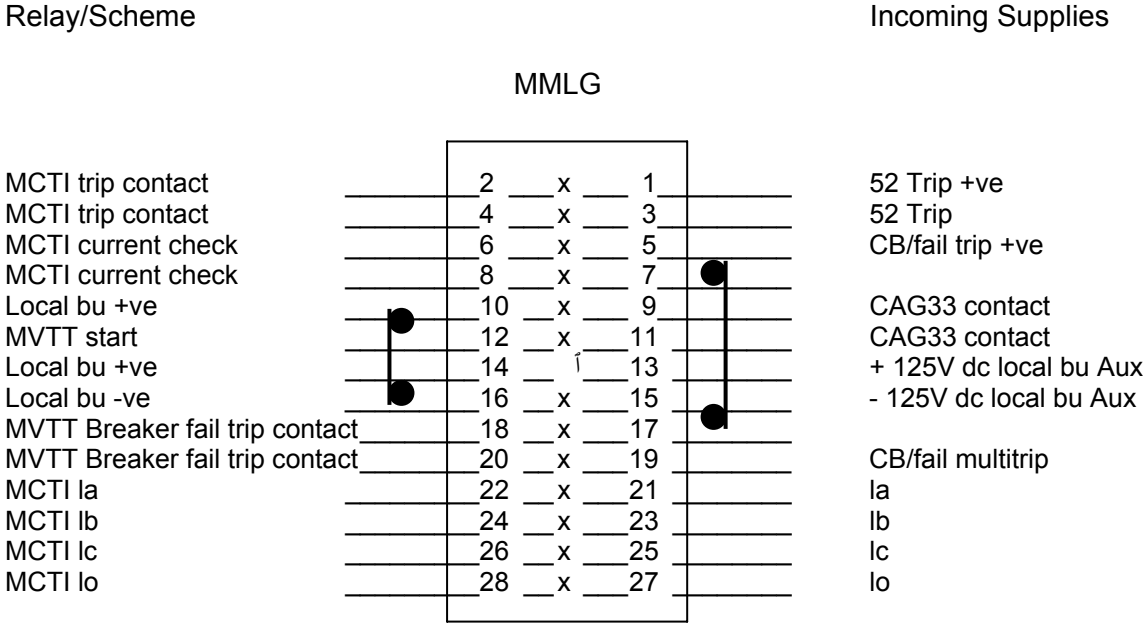
OVERCURRENT & EARTH FAULT FEEDER PROTECTION: RELAY MCGG52/82

Relay/Scheme		Incoming Supplies
	MMLG	
MCGG trip contact	2 x 1	52 Trip +ve
MCGG trip contact	4 x 3	52 Trip
Spare	6 x 5	Spare
Spare	8 x 7	Spare
Spare	10 x 9	Spare
Spare	12 x 11	Spare
MCGG Aux	14 x 13	+ 125V dc Aux
MCGG Aux	16 x 15	- 125V dc Aux
Spare	18 x 17	Spare
Spare	20 x 19	Spare
Ia	22 x 21	Ia
Ib	24 x 23	Ib
Ic	26 x 25	Ic
Io	28 x 27	Io

BUS ZONE PROTECTION: RELAY MCAG34

Relay/Scheme		Incoming Supplies
	MMLG	
MCAG trip contact	2 x 1	MVAJ13 Trip +ve
MCAG trip contact	4 x 3	MVAJ13 Trip
Spare trip contact	6 x 5	Spare trip contact
Spare trip contact	8 x 7	Spare trip contact
Spare	10 x 9	Spare
Spare	12 x 11	Spare
Spare	14 x 13	Spare
Spare	16 x 15	Spare
Spare	18 x 17	Spare
Spare	20 x 19	Spare
Ia	22 x 21	Ia
Ib	24 x 23	Ib
Ic	26 x 25	Ic
Io	28 x 27	Io

RECTIFIER LOCAL BACKUP PROTECTION: RELAYS MVTT14 + MCTI39



11 Appendix E - Voltage and Current Transducers

Transducers that are to be used to provide the SCADA system with current and voltage information relating to the high voltage network shall have the following general characteristics:

- Output of 0…20mA
- Mean sensing
- Self powered

The following transducer is approved for connection in the protection current transformer circuit.

- ALSTOM Istat 300; Type 3CAEA5

The following transducer is approved for connection in the voltage transformer circuit.

- ALSTOM Istat 300; Type 3VAEA5

12 Appendix F - Pilot Wire Schemes