Standard - Panel Wiring and Terminals

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** This person will have the power to grant the process owner the authority and responsibility to manage the process from end to end.*

*** Frequency period is dependent upon circumstances– maximum is 5 years from last issue, review, or revision whichever is the latest. If left blank, the default shall be 1 year unless otherwise specified.*

Revision Control		
Revision	**Date**	**Description**
1	1/02/2023	Document format and updating
0	11/11/2016	Initial Document Creation – Based on an existing specification

STAKEHOLDERS *The following positions shall be consulted if an update or review is required:*	
Manager Engineering & Project Services	Asset Managers
Manager Systems & Network Planning	Manager Assets Services
Senior Manager Safety, Health and Wellbeing	

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1 PURPOSE

This standard outlines the requirements for internal small wiring, terminations and multicore cables in substations.

2 APPLICATION

All persons, including Horizon Power staff and contractors involved in the installation of substations for connection to Horizon Power's distribution network shall comply with these requirements, except as otherwise approved.

3 NORMATIVE REFERENCES

3.1 Standards

3.1.1 Australian Standards

The following standards are available at http://www.saiglobal.com.

[1] *AS 2067, Substations and high voltage installations exceeding 1 kV a.c.* Standards Australia, 2016

3.1.2 International Standards

The following standards are available at http://www.saiglobal.com.

[2] *IEC 60947.7.1, Low voltage switchgear – Part 7.1 Ancillary equipment - Terminal blocks for copper conductors*, International Electrotechnical Commission, 2009

3.2 Definitions and Abbreviations

For the purposes of this standard, definitions shall apply as in the relevant Australian Standards (AS 2067 [1]) with the addition of a few general definitions listed below in alphabetical order.

CT: Current Transformer

EF: Earth Fault

OC: Over Current

PVC: Polyvinyl Chloride

SCADA: Supervisory Control and Data Acquisition

VT: Voltage Transformer

4 WIRING

4.1 General

All wiring that originates and terminates within the one panel must be single core, unsheathed multi-stranded, PVC flexible insulated copper conductor. The only exception is for transducer outputs which must use paired screened cable.

New installation wiring must be:

- neatly enclosed in ducting with removable covers and must not exceed 50% of the duct volume
- run in the most efficient manner from point to point
- left sufficiently long and neatly looped to allow a minimum of two fresh terminations to be made, with the loop length approximately 200 mm
- be flexible cable installed in a cable loom where wiring crosses between a side sheet and a hinged panel

4.2 Wiring identification

4.2.1 Ferrules

All wiring must be ferruled at both ends.

Ferrules must be white insulating material with black character marking and have a glossy finish to prevent adhesion of dirt. They must not be affected by damp or oil.

Critchley ® type Z or Grafoplast ® ferrules must be used.

'C' type or saddle type clip on ferrules must not be used.

4.2.2 Prefix lettering

Wire identification must utilise a prefix letter, a number and then an optional suffix letter. Case earths (e.g. for relays) do not require identification.

Prefix letters must be as per Table 1. This scheme is derived from AS 2067 [1].

Each branch of any connection must have the same identification. Where it is necessary to separately identify branches that are connected at a common point (e.g. CT leads), they must be connected via a link or terminals joined with a removable connection.

Where more than one function is covered by common wiring (i.e. parallel circuits), the first appropriate prefix letter will be used.

Where the circuits split at a separable contact e.g. fuse, link, switch, relay contact, the prefix letter should change from the splitting point as required.

Where interposing, auxiliary and isolating transformers are used, the prefix letters must follow through the transformer, provided they do not couple/connect circuits that have different functions (e.g. interposing CT for metering branching off from protection circuits).

Table 1: Wiring Identification

Prefix Letter	Circuit Function	Wire Numbers
A	Current transformers for protection (excluding over current and bus-zone protection).	Protection Number 1[1] (10-29) Red Phase (30-49) White Phase (50-69) Blue Phase (70-89) Residual circuits and neutral current transformers (90) Earth wires connected directly to the earth bar Protection Number 2 (310-329) Red Phase (330-349) White Phase (350-369) Blue Phase (370-389) Residual circuits and neutral current transformers (390) Earth wires connected directly to the earth bar
B	Current transformers for bus-zone protection.	
C	Current transformers for over current protection (including combined protection devices such as OC/EF relays and protection/SCADA devices e.g. SEL351).	
D	Current transformers for instruments, metering and voltage control.	
E	Reference voltage for instruments, metering and protection.	
F	Reference voltage for voltage control. This includes Automatic Voltage Control.	
G	Reference voltage for synchronising.	
DD	Output side of current metering transducers.	Any number from 1 upward
DE	Output side of voltage metering transducers.	
DF	Output side of frequency transducers.	
DP	Output side of power factor transducers.	
DR	Output side of reactive power (MVAr) metering transducers.	
DT	Output side of temperature and condition monitoring metering transducers.	
DW	Output side of power (MW) metering transducers.	

[1] If additional numbers are required, multiples of 100 may be added to the above ranges, provided the 'Protection 1' numbering does not intrude on those of 'Protection 2'. E.g. Protection 1 Red Phase may also use 110-129 and 210-229

Prefix Letter	Circuit Function	Wire Numbers
H	AC Supplies	240 V and 415 V AC[2] (410-429) Red Phase (430-449) White Phase (450-469) Blue Phase (470-489) Neutrals (800-999) Other
J	DC Supplies	(3,4) 50 V DC Supplies (1,2) DC Battery Number 1 (32 V, 110 V or 230 V)[3] (301, 302) DC Battery Number 2 (32 V, 110 V or 230 V) [4] (800-999) Other
K	Closing and tripping circuits excluding those for SCADA control connections covered under W.	(1-300) Circuits supplied from DC Battery Number 1 (301-600) Circuits supplied from DC Battery Number 2 (800-900) Other
L	Alarm and indication circuits initiated by auxiliary switches and relay contacts, excluding those for SCADA light current indication and alarms covered under X.	As for K
M	Motor control circuits e.g. spring charge, transformer cooler and disconnector motors.	Any number from 1 upward
N	Tap-changer control, including automatic voltage control, tap position and progress indications.	Any number from 1 upward
O	An indication that the ferruling is not in accordance with this general scheme and that if it is not altered; double ferruling will be required for coordination with the remaining equipment in the substation.[5]	Any number from 1 upward

[2] If additional numbers are required, multiples of 100 may be added to the above ranges. E.g. Red Phase may also use 510-529, 610-629 and 710-729
[3] Depends on which is installed
[4] Depends on which is installed
[5] This is only to be used by manufacturers where the wire numbering required has not been supplied by Western Power.

Prefix Letter	Circuit Function	Wire Numbers
P	DC tripping circuits used solely for busbar protection.	As for K
R	Interlock circuits not covered above.	As for K
S	DC instruments and relays (with the exception of outputs from transducers covered above).	As for K
T	Pilot conductors and their connections to associated protection equipment.	As for K
U	Spare cores and connections to spare contacts.	Any number from 1 upward
V	Automatic switching circuits not integral to circuit breaker control schemes i.e. separately supplied or isolable from the circuit breaker control scheme.	As for K
W	SCADA control connections.	Any number from 1 upward
Y	Telephones.	Any number from 1 upward

4.3 Wire numbering

4.3.1.1 General

All replacement wires must be numbered to match the wire being replaced and must read left to right or bottom to top. All new wires must be numbered to match the termination drawings and must read left to right or bottom to top.

4.3.1.2 Line referencing

Line referencing must be used on protection schematics for all new circuits. When working on existing circuits that do not have line referencing, the existing drawing style may be used. An example of this would be adding a line to an AC drawing for an existing partially completed bay.

4.3.1.3 AC circuits

AC circuits wire numbering is as per the 'Wire Numbers' column of Table 1. The only exception to this is for the power transformer bund valve circuitry, for which the wire number is derived from the drawing line numbers on all new circuits.

4.3.1.4 Old DC circuits

The wire number may consist of one or more digits as required and as detailed in the 'Wire Numbers' column of Table 1. DC supply wiring normally at positive potential must have odd numbers and those from a negative source must have even numbers. The change from odd to even numbers must occur at the load (coil, resistor, lamp, relay etc.) that is closest to the negative supply.

4.3.1.5 New DC circuits

The wire number consists of three digits corresponding to the line from which the wire appears on, and a final sequential digit to make it odd or even. The final sequential digit is a 1, 3, 5, 7 or 9 for the positive supply and a 2, 4, 6 or 8 for the negative supply. The change from odd to even numbers must occur at the load (coil, resistor, lamp, relay etc.) that is closest to the negative supply. Refer to Figure 1 for an example.

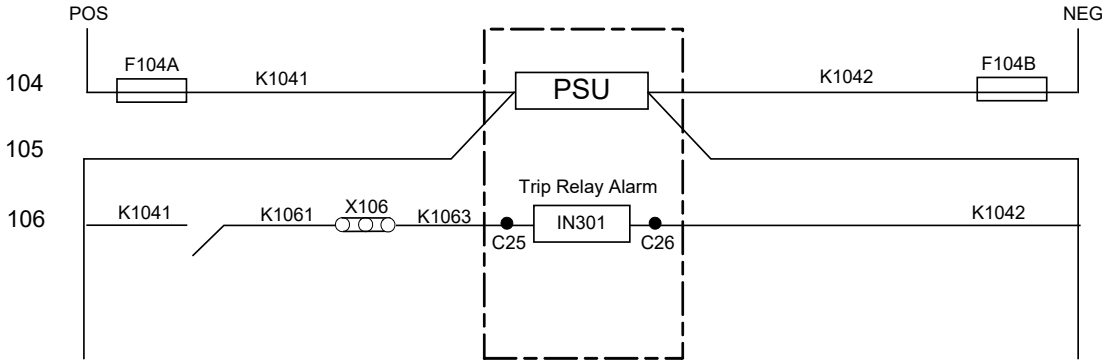

Figure 1: DC Circuit example

4.3.2 Suffixing

4.3.2.1 General

Suffix letters A, B, C etc. must be used when similar numbered wires are taken from separate units to a common panel e.g. as part of bus-zone protection. Suffix allocation is determined by the location of the asset within the substation. Refer to the substation single line diagram for suffix letter allocations.

4.4 Wiring sizes, colour and voltage grade

All wiring is to be PVC Flex V105 with a voltage grade of 0.6/1 kV. Paired screen cable used for instruments do not require the 0.6/1 kV voltage grade.

The wire sizes in Table 2 are the minimum requirements. Some installations may require larger cable due to load current and voltage drop limitations. This must be taken into account during design and shown on the appropriate drawings.

Table 2: Panel Wiring Sizes and Voltage Grades

Application	Wiring Size	Wiring Colouring
CT and VT Secondary	2.5 mm^2 (50/0.25)	Phase: Red, White and Blue; Neutral: Black
250 V AC Power (5 A)	1.5 mm^2 (30/0.25)	Phase: Red, White and Blue; Neutral: Black
440 V AC Power	2.5 mm^2 (50/0.25)	Phase: Red, White and Blue; Neutral: Black
Earthing	2.5 mm^2 (50/0.25)	Green/Yellow
110 V, 230 V and 250 V DC Control	1.5 mm^2 (30/0.25)	Grey
32 V DC Control	2.5 mm^2 (50/0.25)	Grey
DC Battery Supply	2.5 mm^2 (50/0.25)	Positive: Red; Negative: Blue
50 V DC Alarm and Indication	0.5 mm^2 (16/0.2)	Brown

Application	Wiring Size	Wiring Colouring
Metering and Transducers	1.5 mm^2 (30/0.25)	Violet
Pilot Equipment	1.5 mm^2 (30/0.25)	Pink
DC Battery Boards	4 mm^2 Triangle 6 mm^2 Triangle 16 mm^2 Triangle 35 mm^2 Triangle	Phase: Red, White and Blue; Neutral: Black

Refer to Table 3 for the wire colour abbreviations.

Table 3: Drawing colour abbreviations

Abbreviation	Colour
Bk	Black
Bn	Brown
Rd	Red
Og	Orange
Ye	Yellow
Gn	Green
Bu	Blue (including Light Blue)
Vt	Violet (purple)
Gy	Grey (slate)
Wh	White
Pk	Pink
Gd	Gold
Tq	Turquoise
Sr	Silver
GnYe	Green and Yellow

4.5 Current transformer wiring

Current transformer wiring must be continuous between the CT secondaries and the marshalling box. It must also be continuous from the marshalling box to the first terminal strip in the relay protection panel or metering panel. Here ‘continuous’ means no intermediate connections, for example inline crimps.

5 TERMINATION AND CONNECTORS

5.1 General

The terminations outline in Table 4 are all approved for use. Equivalent alternatives that are functionally the same may be considered if approved by the substation design engineer for that project.

Determining the correct type of termination for a wire into a terminal block or accessory must consider the following however the best fit practice on each installation will be followed.

5.1.1 Clamp type

Wires no less than 1.5 mm² and of 30 strands or less, may be terminated bare in clamp type terminal blocks or accessory terminations (excluding screw type clamp). It is permissible to terminate two wires into a clamp terminal provided they are specifically designed for this purpose. If the clamp is a screw type the wire strands must be protected by using a crimp lug.

5.1.2 Crimp type

Crimp type lugs must be used for all flexible type wire of 30 strands or more, or if the cross sectional area of the cable is less than 1.5 mm².

Wire connectors must be crimp type. Uninsulated is acceptable provided electrical clearance is maintained. Where insulated lugs are used, they must be “UTILE super grip” style. These lugs require a double crimp rather than a single crimp.

5.1.3 Linked terminals

Only one wire may be terminated in each terminal. If the terminal rail space prevents additional terminals from being added, the preferred method of connecting two or more leads is to use a group of bridged, “double bootlace”, or linked terminals. Where two wires are required to be terminated in one terminal then flat blade lugs must be used back to back. Note that lip blade lugs should only be used on vibration terminals.

5.1.4 Stud type terminals

For stud type terminals, eyelet type lugs must be used. Locknuts must be fitted to the stud on the rear face behind where the lug is be fitted. A flat washer must be fitted either side of the lug followed by a spring washer and a full thread nut. Washers must be made of non-corrosive or of equivalent material as that of the stud. Flat washers that form part of the conductive path must be of a high conductive material.

For stud type terminals, multiple wires (using eyelet lugs), up to maximum three, may be connected to the one terminal. Any more than this will compromise the clamping pressure across multiple contact surfaces.

Wherever a relay or equipment terminal is designed to accept an eyelet type crimp lug these should be used. Forked/open eyelet type lugs (except for CT circuits) may be accepted where ease of connection is a factor, and where circuit integrity can be maintained.

5.1.5 Krone terminals

Only one wire must be terminated at each Krone terminal point.

5.1.6 Bootlace lugs

Bootlace lugs are commonly supplied on manufacturer's equipment. It is acceptable to use bootlace lugs for the termination of field data type cables typically of 0.5 mm² or less. The use of bootlace lugs for other termination applications will be considered on merit or where the crimp lug is considered unsuitable for the particular application.

5.2 Approved terminals

Table 4 summarises the terminals that are approved for use within Horizon Power substations.

Table 4: Approval Terminals

Application	Approved Terminals
CT Secondary	WTD 6/1 EN (6 mm^2 41 A Feed-through) WTL 6/1 EN (6 mm^2 41 A Earth link)
VT Secondary	WTL 4 (4 mm^2 32 A Slide)
DC Control	WDU 4 (4 mm^2 32 A Feed-through) WTL 4 (4 mm^2 32 A Slide)
AC and DC Power	WDU 4 (4 mm^2 32 A Feed-through) WTL 4 (4 mm^2 32 A Slide)
Light Current (control, indication, alarm, metering, telephone, fault recorder)	WDU 4 (4 mm^2 32 A Feed-through) WTL 4 (4 mm^2 32 A Slide) WTR 2.5 STB (2.5 mm^2 24 A Blade)
Power: 6 mm^2 32A	WTD 6/1 EN (6 mm^2 41 A Feed-through)

Notes:

- Weidmuller are the manufacturers of all products in Table 4.
- Terminal ratings as per IEC 60947.7.1 [2].
- Terminals must be specified on drawings

5.3 Vibration proof terminals

All CT, VT and 50/110 V DC wiring on all power transformers and previously identified vibration areas must use vibration proof terminals (spring loaded) as per Table 4. CT circuits must use lip blade lugs.

5.4 Shrouding of terminals

All exposed terminals where access may be gained whilst the equipment is live must be shrouded. This also includes fuse holder connectors and relay terminals. Shrouding of terminals is to be shown on all appropriate drawings.

5.5 Orientation of disconnect terminals

Table 5 summarises the terminal orientation for vertical arrangements.

Table 5: Terminal Orientation

Application	Orientation
CT earth link terminal	Slide up to open
All other slide terminals	Slide down to open
SCADA blade terminals	Blade flicks up to open (to allow installation of shorting links to be installed on the field side of the terminals
All blade terminals	Blade flicks down to open

APPENDIX A REVISION INFORMATION

(Informative) Horizon Power has endeavoured to provide standards of the highest quality and would appreciate notification of errors or queries.

Each Standard makes use of its own comment sheet which is maintained throughout the life of the standard, which lists all comments made by stakeholders regarding the standard.

A comment sheet found in **DM# 4739275** can be used to record any errors or queries found in or pertaining to this standard. This comment sheet will be referred to each time the standard is updated.

Date	Rev No.	Notes
11/11/2016	0	Initial Document Creation – Based on an existing specification
1/02/2023	1	Document format and updating