Part of Energy Queensland

Substation Standard

Standard for HV Equipment Ratings

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Abstract: The purpose of the standard is to provide the ratings for equipment within Energy Queensland substations.

Keywords: rating, voltage, insulation, equipment

CONTENTS

FIGURES

TABLES

EQUATIONS

1 Overview

1.1 Purpose

Each item of high voltage (HV) equipment within a substation has ratings that guarantee performance under certain operating conditions. These ratings must be considered during planning and design stages to ensure the equipment is fit for purpose within the application.

The purpose of this standard is to outline the ratings of HV equipment to be installed within Energy Queensland (EQL) substations and the HV circuits leaving the substation. This standard will ensure a minimum level of safety and performance and provide a common approach for all new HV equipment installed in EQL substations.

1.2 Scope

This standard shall be applied to all HV equipment to be installed within EQL substations and all HV circuits leaving the substation up to the first external connection point. Although this standard doesn't cover secondary systems, it does include where applicable, secondary ratings of HV equipment. The ratings in this standard shall apply to all HV equipment that is:

- designed and built by manfacturers (e.g. outdoor current transformer, indoor switchgear, power transformers)
- designed and built by EQL (e.g. landing spans, outdoor bus, bays)

This standard includes HV equipment ratings outlined in Australian and international standards, and business strategy ratings outlined by EQL. These ratings include:

- Environmental
- Mechanical
- Electrical
    a) Voltage
    b) Insulation levels
    c) Current

This standard interacts with other EQL standards and manuals, and should be considered a starting point for substation planning, designs and technical specifications. The standard assumes the Standard for Selection of Surge Arresters (STNW3033) – 3055929 and Standard for Insulation Co-ordination (STNW3034) – 3058912 standards have been applied. The expected operating conditions, availability of equipment and materials, coordination of ratings, planning criteria and Australian standards are all considered when deciding which equipment is available for use in EQL substations.

Excluded from this standard are:

- How to design an EQL substation or switching station
- How to operate the EQL HV network
- Plant and equipment outside an EQL substation or switching station
- Plant and equipment inside an EQL substation owned by others (unless EQL is liable)
- Protection systems and secondary systems in general

- Site specific equipment sized specifically to the location (eg. capacitor banks, STATCOMs, SVCs)

This standard does not apply retrospectively to HV installations that don’t present a safety hazard.

2 References

Refer to the standards listed in the table below for all undated standards referenced in this document.

2.1 Legislation, Regulations, Rules, and Codes

Document	Type
Electrical Safety Code of Practice – Works, 2020 (Queensland Government)	Code
Queensland Electricity Act, 1994 (Queensland Government)	Legislation
Queensland Electricity Regulation, 2006 (Queensland Government)	Regulation
Queensland Electrical Safety Act, 2002 (Queensland Government)	Legislation
Queensland Electrical Safety Regulation, 2013 (Queensland Government)	Regulation
Queensland Work Health and Safety Act, 2011 (Queensland Government)	Legislation
Queensland Work Health and Safety Regulation, 2011 (Queensland Government)	Regulation

2.2 Controlled Documents

Guide for Reactive Plant in Substations (STNW3048) - 3059908

Standard for Plant Rating (Manual) - 4179110

Standard for Substation Protection (STNW1002) - 2948492

Standard for Substation Design Requirements (STNW3003) - 20468486

Standard for Climate and Natural Hazard Resilience (STNW3007) - 3057510

Standard for Clearances in Air (STNW3013) - 3054141

Standard for Busbar Conductor Selection (STNW3014) - 3062690

Standard for Cables and Cable Installation (STNW3018) - 12737281

Standard for DC Supplies (STNW3022) - 3062917

Standard for Selection of Surge Arresters (STNW3033) - 3055929

Standard for Insulation Co-ordination (STNW3034) - 3058912

Standard for Audible Noise in Substations (STNW3041) - 22968176

Standard for Electric and Magnetic Field Design (STNW3042) - 3060782

Standard for Interlocking (STNW3046) - 3060386

Standard for Switchgear Selection (STNW3051) - 12743722

Standard for Sub-transmission and Distribution Planning - 11539388

2.3 Uncontrolled Documents

Guidelines on AFLC Primary Connections - STNW3020

Standard for AC Supplies – STNW3023

Standard for Substation Earthing – STNW3028

TSD0248 – Standard Power Transformers Contract CW43101

2.4 Other Sources

(AS/NZS 1429.2, 2009)	Electric cables - Polymeric insulated - Part 2: For working voltages above 19/33 (36) kV up to and including 87/150 (170) kV
(AS 1531, 1991)	Conductors - Bare overhead - Aluminium and aluminium alloy
(AS 2374.1.2, 2003)	Power transformers – Part 1.2: Minimum Energy Performance
(AS 4398.1, 1996)	Insulators - Ceramic or glass - Station post for indoor or outdoor use - Voltages greater than 1000V a.c.
(AS/NZS 60076.1, 2014)	Power transformers - Part 1: General
(AS 60076.4, 2006)	Power transformers - Part 4: Guide to the lightning impulse and switching impulse testing - Power transformers and reactors
(AS/NZS 60076.6, 2013)	Power Transformers - Part 6: Reactors
(AS 60076.10, 2023)	Power transformers - Part 10: Determination of sound levels
(AS 60099.4, 2022)	Surge arresters - Metal-oxide surge arresters without gaps for a.c. systems
(AS 61869.1, 2024)	Instrument transformers - Part 1: General Requirements
(AS 61869.2, 2021)	Instrument transformers - Part 2: Additional requirements for current transformers
(AS 61869.5, 2021)	Instrument transformers - Part 5: Additional requirements for capacitive voltage transformers
(AS 62271.1, 2019)	High-voltage switchgear and controlgear
(AS 62271.100, 2019)	High-voltage switchgear and controlgear - Part 100: High-voltage alternating-current circuit-breakers
(AS 62271.102, 2019)	High-voltage switchgear and controlgear - Part 102: Alternating current disconnectors and earthing switches
(AS 62271.200, 2019)	High-voltage switchgear and controlgear - Part 200: A.C. metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV
(IEC 60050-605, 1983)	International Electrotechnical Vocabulary (IEV) - Part 605: Generation, transmission and distribution of electricity - Substations
(SA TS 60815.1, 2020)	Selection and dimensioning of HV insulators intended for use in polluted conditions

3 Definitions and Abbreviations

3.1 Definitions

For the purposes of this standard, the following definitions apply.

Accuracy class (IEV)	A designation assigned to an instrument transformer, the current (or voltage) error and phase displacement of which remain within specified limits under prescribed conditions of use
Apparatus (IEV)	Device or assembly of devices which can be used as an independent unit for specific functions
Asset (IEV)	Physical entity or digital entity that has value to an individual, an organisation or a government
Bay (IEV)	The part of a substation or switching station which the switchgear and control-gear relative to a given circuit is contained
Brownfield project	A project at a location that has existing infrastructure
Common ratings	Ratings that can be found on all high voltage plant and equipment inside a substation
Commissioning (IEV)	Activities undertaken to prepare a system or product prior to demonstrating that it meets specific requirements
Device (IEV)	Material element or assembly of such elements intended to perform a required function
Distribution feeder	Any feeder emanating from a zone substation and supplying one or more distribution transformers, generally at 6.6kV, 11kV, 22kV but not precluding 33kV.
Equipment (IEV)	Single apparatus or set of devices or apparatuses, or the set of main devices of an installation, or all devices necessary to perform a specific task
Greenfield project	A project at a location that has no existing infrastructure
Highest system voltage	The highest r.m.s value of phase-to-phase voltage for which the equipment is designed in respect of its insulation as well as other characteristics which relate to this voltage
Installation (IEV)	One apparatus or a set of devices and/or apparatuses associated in each location to fulfil specific purposes, including all means for their satisfactory operation
Insulation (IEV)	All the materials and parts used to insulate conductive elements of a device. Set of properties which characterise the ability of an insulation to provide its function.
Insulation Coordination (IEV)	Selection of the dielectric strength of equipment in relation to the operating voltages and overvoltage’s which can appear on the system for which the equipment is intended and considering the service environment and the characteristics of the available preventing and protective devices.

Lightning Impulse Withstand Voltage	LIWV is the electrical strength of insulation expressed in crest value of a standard lightning impulse under standard atmospheric conditions. The standard lightning impulse is an impulse voltage having the front time 1.2 μs and a time to half value of 50 μs (1.2x50 μs)
Nominal value (IEV)	Value of a quantity used to designate and identify a component, device, equipment, or system
Peak Withstand Current	The value of peak current that a circuit or a switching device in the closed position can withstand under prescribed conditions
Permanently connected equipment (IEV)	Equipment that can only be connected to or disconnected from the electrical network by using a tool
Phase displacement (IEV)	The angular difference between the phasors representing the voltage between the neutral point and the corresponding terminals of two windings of a transformer with a positive-sequence voltage system applied to the HV terminals.
Plant (IEV)	Complete set of technical equipment and facilities for solving a defined technical task. I.e. A plant includes apparatus, machines, instruments, devices, means of transportation, control equipment and other operating equipment
Power Frequency Withstand Voltage	PFWV is the electrical strength of insulation expressed in r.m.s value of a standard short-duration power frequency voltage under standard atmospheric conditions. The standard short-duration power frequency voltage is a sinusoidal voltage with frequency between 48 Hz and 62 Hz, and duration of 60 s
Rated value	Value of a quantity used for a specification purpose, established for a specified set of operating conditions of a component, device, equipment, or system
Routine test	A test required under the standard to be conducted on all units after production and prior to shipment to the customer.
Short circuit break capacity	A breaking capacity for which the prescribed conditions include a short circuit at the terminals of the switching device
Short circuit make capacity	A making capacity for which the prescribed conditions include a short circuit at the terminals of the switching device
Short-time withstand current	The current that a circuit or a switching device in the closed position can carry during a specified short-time under prescribed conditions of use and behaviour
Shall	Indicates that a statement is mandatory
Should	Indicates a recommendation advisable (non-mandatory)
Sub-transmission feeder	Any feeder with a voltage of 66kV or 33kV, suppling either a zone substation, or a single customer taking supply at that voltage.
Switching Station	A station connecting between transmission circuits or sub-transmission circuits or distribution circuits including switchgear and associated equipment

Technical specification	Document that prescribes technical requirements to be fulfilled by a product, process, or service
Transient overvoltage	Short duration overvoltage of a few milliseconds or less, oscillatory, or non-oscillatory, usually highly damped
Transmission feeder	Any feeder with a voltage of 110kV or above, suppling either a transmission substation, a switching station, a zone substation, or a single customer taking supply at that voltage.
Transmission (bulk supply) Substation	A substation connecting between transmission circuits or between sub-transmission circuits and distribution feeders including transformers, circuit breakers and associated equipment
Type test	A test required under the standard to be conducted once off to verify the design of a product.
Voltage factor	The multiplying factor to be applied to the rated primary voltage to determine the maximum voltage at which a transformer must comply with the relevant thermal requirements for a specified time and with the relevant accuracy requirements
Zone Substation	A substation connecting between sub-transmission circuits or between sub-transmission circuits and distribution feeders including transformer’s, circuit breakers and associated equipment

3.2 Abbreviations

This list does not include well-known unambiguous abbreviations, or abbreviations defined at their first occurrence within the text.

2HE	Two Hour Emergency (rating)
AC	Alternating current (or a.c.)
ACR	Automatic Circuit Recloser
AFLC	Audio Frequency Load Control
AR	Auto Reclose
AS	Australian Standard
BIL	Basic Insulation Level
BZ	Bus Zone
CB	Circuit Breaker
CFO	Critical Flashover Voltage
CT	Current Transformer
CVT	Capacitive voltage transformer
DC	Direct current (or d.c.)
DIS	Disconnector
ECR	Emergency Cyclic Rating

ELV	Extra low voltage (not exceeding 50V AC or 120V ripple free DC)
EMF	Electro-Magnetic Field
ES	Earth Switch
ET	Earthing Transformer
EQL	Energy Queensland Limited
EQSS	Energy Queensland Substation Standard
GIS	Gas Insulated Switchgear
GT	Ground Transformer
HV	High Voltage (greater than 1000V AC or 1500V DC)
IEC	International Electrotechnical Commission
IED	Intelligent External Device
IEEE	Institute for Electrical and Electronic Engineers
IEV	International Electrotechnology Vocabulary
I_k	Rated short-time withstand current (symmetrical)
I_p	Rated peak withstand current (unsymmetrical)
I_r	Rated continuous current
IVT	Inductive Voltage Transformer
LIWV	Lightning Impulse Withstand Voltage
LV	Low voltage (exceeding ELV, but not exceeding 1000V AC or 1500V DC)
MEN	Multiple Earthed Neutral
MVA	Mega Volt Ampere
NCR	Normal Cyclic Rating
NEF	Neutral Earth Fault
NER	Neutral Earthing Resistor/Reactor
OHEW	Overhead Earth Wire
OPGW	Optic Ground Wire
PCD	Pitch Circle Diameter
PFWV	Power Frequency Withstand Voltage
p.u.	per unit
PVC	Polyvinyl Chloride
r.m.s	Root mean squared
RPEQ	Registered Professional Engineer of Queensland
t_k	Rated duration of short-circuit current I_k
SA	Surge arrester

SIVW	Switching impulse voltage withstand
STATCOM	Static Synchronous Compensator
SVC	Static var Compensator
SWER	Single Wire Earth Return
U_d	Rated short-duration power-frequency withstand voltage
U_m	Rated highest voltage rating (some equipment references U_r)
U_n	Rated nominal voltage rating
U_p	Rated lightning impulse withstand voltage
U_s	Rated switching impulse withstand voltage
var	Volt Ampere Reactive (Mvar, kvar)
VT	Voltage Transformer
XLPE	Cross Linked Polyethylene

4 Actions and responsibilities

The responsible teams for ratings at EQL are as follows:

Table 1: Team Responsibilities

Authority	Responsibilities
Substation Standards	Standard for substation ratings, providing equipment options that can meet this standard
Asset Capability & Utilisation	Assign plant ratings to commissioned EQL substation plant.
Asset Planning	Ensure EQL meets this standard during planning activities
Substation Design	Electrical and Civil Engineering RPEQ. Site-specific application of this standard

5 System Ratings

5.1 Frequency

All equipment connected to the EQL HV AC network shall be rated at 50Hz and must be capable of continuous operation in system normal conditions and in the periods immediately following critical events where frequency may be disturbed. The frequency ranges during normal conditions and during frequency variations are listed in Table 2.

Table 2: Frequency Standard (Ref Standard for Sub-Transmission & Distribution Planning – 11539388)

Condition	Containment	Stabilisation	Recovery
Accumulated time error	5 seconds		
No contingency event or load event	49.75 to 50.25Hz*, 49.85 to 50.15Hz 99% of the time ^	49.85 to 50.15Hz within 5 minutes	
Generation event or load event	49.5 to 50.5Hz	49.85 to 50.15Hz within 5 minutes	
Network event	49 to 51Hz	49.5 to 50.5Hz within 1 minute	49.85 to 50.15Hz within 5 minutes
Separation event	49 to 51Hz	49.5 to 50.5Hz within 2 minutes	49.85 to 50.15Hz within 10 minutes
Multiple contingency event	47 to 52Hz	49.5 to 50.5Hz within 2 minutes	49.85 to 50.15Hz within 10 minutes
^ - This is known as the normal operating *frequency* band * - This is known as the normal operating *frequency* excursion band			

5.2 Voltage

The values in Table 3 are the planned nominal U_n and highest continuous U_m operating system voltages for the EQL HV network. All new HV equipment shall match the system voltages in Table 3 unless there is genuine concern about continuous operation outside of the highest voltage U_m or forward planning to increase the system voltage in the future. The highest voltage in multi-voltage equipment shall be considered. Equipment used for synchronisation may be subjected to voltages outside of those listed Table 3.

If the system voltage is expected to operate outside of the highest voltage U_m in Table 3 for periods other than short-time excursions, then consider:

- Sourcing equipment with a larger U_m
- Confirming the volt-hertz ratio of equipment such as power transformers
- Confirming the thermal limits of equipment such as VT's

Table 3: EQL Network HV System Voltages

System Nominal Voltage U_n (kV)	System Highest Voltage U_m (kV)
6.6	7.2
11	12
22	24
33	36
66	72
110	123
132	145
220	245

5.3 Phasing

Phasing refers to the identification of a particular phase on the HV network based on a single reference, where the phase is then allocated an operational phase identifier such as A, B or C. Manufacturers phase markings are assigned during the manufacturing process.

All new installations should have phasing where:

- Operational phase identifiers match a single reference point
- Operational phase identifier match manufacturers phase markings (unless otherwise identified on phasing and polarity diagrams)

Legacy systems and equipment are often the main reason for the mismatches and designers should take opportunities where possible to align operational phase identifiers to a single reference and to the manufacturers phase identifiers.

5.4 Phase shifts

Phase shifts are a by-product of transformer internal connections. Phase shifts differ in Ergon and Energex, and even within ex-BCC and ex-SEAQ sites in the Energex network. Phase shifts are noted with reference to a single point on the transmission network. Refer to the Energex phasing drawings series PHSTD for further information in the Energex area.

6 Current Ratings

6.1 General

This section outlines the continuous, short-time withstand, and peak withstand minimum current ratings of all EQL HV equipment that conduct loads other than those loads supplied to secondary systems equipment. The current ratings of secondary system load will be provided in future sections specific to individual pieces of equipment.

Continuous and short-time withstand current ratings represent the thermal limitations of HV equipment and are based on conditions prescribed by the designer of the equipment and the standards this equipment is manufactured to.

The operational current ratings of HV equipment are based on these ratings and also factor in environmental conditions, the installation method and load type. This standard doesn't cover operational current ratings. The EQL *Plant Ratings Manual* shall be used to determine operational current ratings.

The continuous current ratings are a business decision based on the following:

- Availability of manufacturers' equipment and materials
- How the network is operated
- Daily and seasonal load patterns
- Thermal time constants for equipment
- Customer requirements
- Most cost-effective solution
- Ageing rate and loss of life
- Standardising to reduce design and procurement costs
- Reducing equipment variations to minimise ongoing maintenance costs

For this reason, changes in business decisions and availability of equipment will often impact the continuous and short-time withstand current ratings of HV equipment.

The peak withstand current rating of HV equipment indicates the maximum forces under fault that the HV equipment can withstand.

The mechanical forces HV equipment is subjected to under fault and load conditions must be considered. Mounting of HV equipment within proximity to other equipment conducting fault current and load must be considered.

6.2 Continuous (nominal) current

6.2.1 Distribution feeder bay

A distribution feeder will be connected to one or more customers and the load flow may be in either direction. All equipment within the substation distribution feeder bay including the feeder exit conductor that carries this load current shall be rated to a minimum continuous current rating of 450A per phase with the following exemptions:

- Small rural substations where network planning confirm the risks and cost benefits through standardisation are not justifiable
- Special customer connection points that exceed this rating
- Double feeder CB distribution bays may exceed this rating
- Energex feeder exits may be limited to 315A

Table 4 shows the minimum continuous current and power ratings at a 1p.u. distribution voltage.

Table 4: Minimum continuous current ratings

Nominal voltage U_n (kV)	Energex		Ergon	
	Rated primary continuous current I_r 1-phase rating (A)	Power @ 1p.u. voltage 3-phase rating (MVA)	Rated primary continuous current I_r 1-phase rating (A)	Power @ 1p.u. voltage 3-phase rating (MVA)
11	315	6	450	8.57
22			450	17.15
33			450	25.72

An example of the equipment found in a common distribution feeder bay may include current transformer, circuit breaker, disconnector, feeder exit conductor and bus bar.

6.2.2 Transmission or sub-transmission feeder bay

Transmission and sub-transmission feeder continuous current ratings depend on the application and customer requirements. Table 6 below outlines the minimum continuous current ratings for each application and exemptions are only available for special customer connections.

Table 5: Transmission and sub-transmission feeder bay minimum continuous current ratings

Nominal voltage U_n (kV)	Feeder location	Rated primary continuous current I_r 3-phase rating (A)	Power @ 1p.u. voltage 3-phase rating (MVA)
33	RMU	630	36
	GIS	1250	71.4
	Outdoor CB	1600	91.5
	Powerlink	2625[1]	150[1]
66	Outdoor CB	1250	142.9
	GIS	1600	182.9
	Powerlink	1315[1]	150[1]
	Powerlink	2100[2]	240[2]
110	Outdoor CB/GIS	1600	304.8
132	Outdoor CB/GIS	1600	365.8
220	Outdoor CB	1250	476.3

[1] Powerlink applications on 100MVA transformers with a short-term maximum load limit of 150MVA

[2] Powerlink applications on 160MVA transformers with a short-term maximum load limit of 240MVA

Examples of the equipment found in a common transmission or sub-transmission feeder bay may include current transformer, circuit breaker, disconnector, feeder exit conductor and bus bar.

6.2.3 Transformer bay

A HV power transformer comprises of two or more 3-phase terminals where each 3-phase terminal is connected to a winding. The current ratings for each 3-phase terminal are based on the power and voltage rating of the winding. A transformer bay is all the equipment associated with each 3-phase terminal of a transformer. When applying the continuous current rating at each 3-phase terminal, consideration should be given for the following:

- Forced cooling rating
- Overload capability
- Direction of load flow and ratings for each direction
- Online or de-energised tap changer location
- Online or de-energised tap changer range and extremities

All equipment associated with a specific 3-phase terminal shall have a continuous current rating equal to or greater than the most onerous condition of that terminal based on the listed items above. An example of the equipment found in a common transformer bay may include HV current transformer, HV circuit breaker, HV disconnector, HV bus bar, LV current transformer, LV circuit breaker, LV disconnector, LV bus bar.

Refer to Annex A.1 for calculation of these currents. In cases where there may be dual circuits connected to a single 3-phase terminal, consideration must be given to the transformer winding current rating and through current rating.

6.2.4 Bus bay

Bus bays include the bus, circuit breaker, disconnectors, and CT's.

The bus rating should be equal to or greater than the bus tie circuit breaker or disconnector rating.

The rated normal current of a bus tie circuit breaker should be:

- Equal to that of the incoming CB's, where a two-section single bus has one incoming feeder on each section.
- Equal to or greater than the highest load transfer between the sections, where a two-section single bus has multiple incoming feeders on each section.
- Greater than the highest possible load transfer for a ring bus

In an ultimate three transformer substation, the bus-tie cable and breaker shall be capable of providing two-thirds the short time emergency load transfer capability of the largest transformer.

6.2.5 Other bays

Other bays may include:

- AFLC coupling cell (see STNW3020 for sizing calculations)
- Capacitor bank
- Reactor
- Station service transformer (see STNW 3023 for Substation AC supplies)
- Filters

- STATCOM/SVC
- SYNCON

The bay needs to be rated for the load, taking into account the nature of the load and requirements for reactive current switching.

6.3 Network fault current ratings

6.3.1 General

Network faults must be considered during the planning and designing of HV equipment within substations. HV equipment is subjected to thermal effects and mechanical forces under faulted conditions where a fault may cause pre-mature failure or unacceptable reduction in life expectancy.

Fault currents are subject to change based on normal and emergency network configurations and sources of supply.

The following items should be considered when selecting HV equipment for use in EQL substations:

a) Sourcing fault data for all fault types (3 phase, single phase to ground and 2 phases to ground). All fault types should be considered to select the most onerous for analysis. In some instances, single phase to ground or 2 phases to ground faults are more onerous than 3 phase faults. The phase fault current shall be used to define equipment ratings and the ground fault current shall be used to define earthing requirements.

b) Plant in the network that directly affect fault levels. For example, synchronous generators, motors, synchronous condensers etc.

c) Plant in the network that can indirectly affect fault levels due to switching configurations. For example, links, RMU's, circuit breakers, reclosers etc.

d) Symmetrical fault current at a specific location and specific voltage. More detail is provided in section 6.3.2.

e) Asymmetrical fault currents at a specific location and voltage. The X/R ratio and DC time constant of the system may influence the equipment that can be selected. More detail is provided in section 6.3.3.

f) Fault clearing times of main and backup protection.

g) Driving voltage

6.3.2 Fault withstand capability levels

Short circuit fault levels vary with network configuration. The fault current ratings of all network equipment should be designed to exceed the maximum fault level of the network they belong to at any time.

Table 7 shows the nominal fault withstand capability ratings of plant at each system voltage. These values are typical target fault ratings. In some instances, the values given for existing installation may not align with standard modern ratings. In these cases, site-specific fault levels should be considered in planning for any network augmentation.

Table 6: Nominal Fault Withstand Current Ratings of HV Equipment

Nominal Voltage U_n (kV)	EQL fault withstand current rating I_k (kA)	EQL fault withstand time rating t_k (s)
11	25[(1)]	3
22	25	3
33	31.5	3
66	25	3
110	40	1
132	40	1
220	25	3

[1]EQL has a small number of substations where the 11kV fault levels exceed this rating. Control measures must be implemented to reduce the risk. In addition at smaller sites the fault level may be low enough for use of reclosers (16kA) or ring main switchgear (20kA)

6.4 Peak withstand current ratings for switchgear

The peak withstand current rating specifies the ability of switchgear to withstand asymmetrical fault currents, also known as the 'make' rating. The peak withstand current rating is dependent on the DC time constant, X/R ratio of the network and the symmetrical fault current rating.

Table 8 shows the peak withstand current ratings of equipment at standard system voltages. A DC time constant of 45ms is considered to cover the majority of cases on a 50Hz network, which equates to an X/R ratio of 14 and a peak factor of 2.5. The peak withstand current ratings are calculated by multiplying the symmetrical fault withstand current ratings in Table 7 by the peak factor.

Table 7: Minimum Peak Withstand Current Ratings of HV Equipment

Nominal Voltage U_n (kV)	Peak withstand current I_p (kA)
11	62.5[1]
22	62.5
33	78.75
66	62.5
110	100
132	100
220	62.5

[1]As per clause 6.3, actual peak values to be 2.5 times the RMS values at sites where switchgear is greater or less than 25kA rms short circuit rating.

These minimum peak withstand current ratings shall be adhered to when rating switchgear.

It should be noted that there are a few locations in the Ergon Energy network where short circuit levels exceed an X/R ratio of 14. In these situations, a reduction in the allowable symmetrical fault withstand current rating I_k shall be applied.

6.5 Dynamic ratings

Some equipment, usually power transformers but also overhead conductors and underground cables, may be fitted with additional sensors and load data such that a real time thermal model can be calculated and continuously updated, providing a dynamic rating to the controller. These models take into account existing environmental and load parameters to update the dynamic rating in real time. It can provide information on allowable load for a particular duration or allowable duration for a particular load before insulation limits are reached that will significantly limit asset life.

Further information can be obtained from the Asset Capability and Utilisation team.

7 Earthing

Earthing of HV equipment shall be correctly designed and sized based on the maximum fault levels and fault clearing time.

Refer to the *Standard for Substation Earthing STNW3028* for details.

8 Environmental

8.1 General

All HV equipment must be suitable for operation within the environment it is installed, including the geographical location and indoor or outdoor applications. Rating of HV equipment shall take into consideration all the environmental conditions to ensure premature reduction in life expectancy does not occur.

8.2 Climatic and Seismic

Climatic and seismic ratings shall be taken from the Standard for Climate and Natural Hazard Resilience (STNW3007) - 3057510 for all HV equipment.

8.3 Insulator performance

The EQL HV network covers the majority of Queensland and is subject to various environmental conditions and hence pollution performance requirements. Site pollution severity should be assessed for indoor and outdoor applications at each site that new equipment with HV insulators is installed. The following items should be assessed when installing HV equipment with insulators:

- Site pollution severity
- Orientation and mounting
- Profile
- Length and creepage distance
- Capacitance grading or shielding included
- Polymeric or porcelain housing

A site pollution severity class “d-Heavy” (*SA TS 60815.1*) shall be the minimum level for all outdoor HV equipment, where “e-very heavy” may be selected at very heavily polluted locations.

- Site pollution severity class “d-heavy” has a unified specific creepage distance of 43.3mm/kV (USCD is mm/kV where kV is $U_m/\sqrt{3}$)
- Site pollution severity class “e-heavy” has a unified specific creepage distance of 53.7mm/kV (USCD is mm/kV where kV is $U_m/\sqrt{3}$)

Due to the hazards associated with HV porcelain and oil filled insulators, EQL is working towards oil-free and polymeric outer envelopes on all HV equipment. Transformer HV bushings that are porcelain or oil filled shall not be installed in any new EQL applications and a voltage rating U_n greater than 33kV shall have condensers. Outdoor insulators that are located on 11kV parts of the networks shall have a voltage rating U_n of 22kV to reduce the likelihood of phase to ground faults caused by living beings.

9 Insulation voltage

Insulation voltages are the maximum short-term overvoltages (PFWV) and transient voltage stresses (LIWV) that can be presented to HV equipment. The rated insulation values in Table 9 shall be applied to all equipment within EQL substations with the exception of surge arresters. The Standard for Insulation Co-ordination (STNW3034) - 3058912 shall be used to manage over-voltages within EQL substations.

Table 8: Insulation ratings (not exceeding 1000m above sea level)

Nominal voltage U_n (kV)	Power frequency withstand voltage PFWV (kV)	Lightning impulse withstand voltage LIWV (kV_p)
6.6	20	60[1] 75
11	28	75[1] 95
22	50	125[1] 150
33	70	170[1] 200
66	140	325
110	230	550
132	275	650
220	460	1050

1 Indoor switchgear with a nominal voltage rating of 33kV or below can apply lower values of LIWV and PFWV if designed to IEC standards and insulation coordination studies have been completed, proving the equipment is protected from lightning and transferred surges with adequate margins (Refer to Standard for Selection of Surge Arresters (STNW3033) - 3055929).

10 Equipment specific ratings

10.1 General

Equipment specific ratings are exclusive to each piece of HV equipment that were not covered in the previous common ratings sections.

10.2 Surge arresters

Surge arrestors shall be designed according to the Standard for Insulation Co-ordination (STNW3034) - 3058912 and sized according to the Standard for Selection of Surge Arresters (STNW3033) - 3055929 to protect the HV equipment within EQL substations.

10.3 Instrument transformers

10.3.1 Voltage transformers

Voltage transformers including IVT's and CVT's shall have a primary voltage rating equal to the system nominal voltages U_n from Table 3. Voltage transformers shall have the ratings outlined in Table 10. Outdoor oil-filled VT's shall include a pressure relief device.

The voltage factor F_V is the multiplying factor applied to the primary voltage rating to outline the maximum voltage that can be applied for a duration of time. The minimum voltage factors are provided below in Table 10 and are to ensure the thermal requirements of the VT are adequate.

Table 9: VT Primary and Secondary Voltage Ratings

VT primary voltage (kV)	VT secondary voltage (V)	Continuous rating F_V	30-second effectively earthed rating F_V	8-hour non-effectively earthed rating F_V	Min Rated Burden (Outdoor)	Min Rated Burden (Indoor)
6.6/√3	110/√3	1.2		1.9[1]	50	25
11/√3	110/√3	1.2		1.9[1]	50	25
22/√3	110/√3	1.2		1.9[1]	50	25
33/√3	110/√3	1.2		1.9[1]	50	25
66/√3	110/√3	1.2	1.5		50	50
110/√3	110/√3	1.2	1.5		50	50
132/√3	110/√3	1.2	1.5		50	50
220/√3	110/√3	1.2	1.5		50	50

[1] Ungrounded applications shall use an F_V of 1.9 for 8 hours.

VT ratings include:

- Accuracy class of 3P for protection purposes
- Accuracy class of 0.2M for revenue metering purposes, and 1.0M for other purposes
- 3-limb cores for 3-phase VT's unless specific applications require low reluctance zero sequence flux path where 5-limb cores are available

CVT’s shall not be used for any new installations or planned replacements for voltages 66kV and above. CVT’s shall only be used for Power Line Carriers (PLC’s)/Wave Traps and emergency replacement of failed equipment if no suitable IVT is available.

10.3.2 Current transformers

10.3.2.1 General

This section outlines the protective and metering CT ratings for all applications including outdoor CT’s and those mounted in:

- GIS
- Switchgear other than GIS
- Transformers
- Circuit breakers
- Neutrals of transformers and other equipment
- Metering units

Outdoor oil-filled CT’s shall include a pressure relief device.

Current transformers shall contain an earthed shield between the primary conductor and all secondary conductors, to protect the secondary circuit from damage due to breakdown of high voltage insulation. CT cores shall be earthed.

The P1 terminal polarity shall be in phase with S1 and likewise P2 with S2. CT’s with multiple cores shall have core 1 located at the P1 end and have consecutive numbered cores until the last core at P2 terminal. Each core shall be magnetically independent of any other core.

The CT primary current rating shall exceed the minimum continuous current ratings specified for each system voltage in Section 6. The CT secondary current rating I_{sr} preference is 1A, however 5A options are available for certain applications.

I_{cth} is the continuous thermal current rating of primary and secondary terminals with rated burden connected without exceeding the allowable temperature rise. The secondary winding should be capable of carrying the thermal continuous current without overheating, while the primary winding will not be required to carry more than its rated normal current $I_{pr.}$

10.3.2.2 Protective CT’s

Protection CT’s may be used in high or low impedance schemes. Selecting the correct CT for the application is paramount to provide adequate performance under load and fault conditions.

All protective CT’s shall be PX class low-leakage reactance type CT’s where the remanent flux limits are not stipulated.

An iterative process is required to select the correct CT and ratio. Protection relays will provide a CT selection guide to ensure the performance is adequate to use in the application.

For PX class current transformer cores, the knee point voltage E_k can be provided to the manufacturer or calculated as follows:

$$E_k = K_x(R_{ct} + R_b)I_{sn}$$

Equation 1: CT Equation for Knee Point Voltage

Where:

E_k = Knee point voltage (V)

K_x = Dimensioning factor for each core to the highest ratio specified

R_{ct} = Maximum resistance of the secondary winding at 75°C (Ω). To be decided by the manufacturer to best provide the performance requirements.

R_b = Rated resistive burden (Ω). This value can range and may differ between Ergon Energy and Energex.

I_{sn} = Rated secondary current (A)

The exciting current I_e at the rated knee point voltage shall have a maximum of 100mA.

Refer to Annex A.2 for calculation examples.

10.3.2.3 Metering CT's

Metering CT's allow the measurement and monitoring of various power quality performance requirements in accordance with Schedules 7.2 and 7.3 of the NER (National Electricity Rules).

Metering CT's shall have an instrument security factor of 10.

Where metering CT's are tested in Australia, a NATA certified accuracy test certificate shall be supplied. Where metering CT's are tested overseas, an ILAC certified accuracy test certificate shall be supplied.

10.3.3 Power voltage transformers

Power voltage transformers may be installed in applications where voltages 33kV and below are unavailable to connect a station service transformer for 230/400VAC reticulation. Details regarding power voltage transformers are provided below:

- Single phase device rated at 25kVA.
- Outdoor oil or gas filled PVT's shall include a pressure relief device
- Secondary voltage rating of 230VAC phase to ground
- Multiple taps to maintain 230V ac se4condary for up to 1.1 PU primary voltage

10.4 Transformers

10.4.1 Power

Power transformers shall have a primary voltage rating equal to the system nominal voltages U_n from Table 3.

There are a variety of allowable tapping ranges for on-load tap changers and de-energised tap changers, depending on the voltage and power rating of the power transformer. Standard tapping ranges are listed in Table 12. On-load tap changers shall include the ability for bidirectional load flows up to the power rating.

Where forced cooling is applied, pumps with directed oil flow should be used first due to their efficiency and reduced noise compared to fans.

Table 13 shows standard electrical vector configurations for specific power transformer primary and secondary voltage ratings.

Table 10: Standard Tapping Ranges for Power Transformers

Power Transformer Voltage Levels	Number of Taps	Tapping Range	Tap Changer Type
132/66/11, 132/22, 110/33, 66/11, 33/11	23	-17.5% +10%	OLTC
66/11	5	-5% +5%	DETC
132/11, 110/11	27	-22.5% +10%	OLTC
220/132(66)/11	17	-12% +12%	OLTC

Table 11: Standard Electrical Vector Configurations for Power Transformers

Power Transformer Voltage Levels	Electrical Vector Configuration
33/11	Dyn11
66/11	Dyn1
110/11	YNd11
110/33	YNyn0+d
132/11	YNd11
132/22	YNd
132/66/11	YNa0d
220/132(66)/11	YNa0d

Preferred values of rated power at maximum cooling are:

3.15, 6.3, 10, 15, 20, 25, 31.5, 40, 63, 80, 100, 120 MVA

Refer to the *Standard for Plant Rating Manual* for normal cyclic and emergency transformer overload rating factors. Operating ratings differ depending on the category of the substation (domestic, industrial, mixed predominantly domestic etc) and the ambient temperature.

Commonly recognised **minimum values** of short circuit impedance are as per Table 1 IEC 60076-5 reprinted below. Required values for sites may be subject to planning studies. Values less than the minimum below will require agreement from the manufacturer on ability to withstand short circuit currents.

Table 12: Recognised minimum values of short circuit impedance for transformers with two separate windings (Ref IEC 60076-5 Table 1)

Short Circuit Impedance at Rated Current	
Rated Power (MVA)	Minimum short circuit impedance (%)
>2.5 to 6.3	7.0
>6.3 to 25	8.0
>25 to 40	10.0
>40 to 63	11.0
>63 to 100	12.5
>100	>12.5

Preference should be given to using current contract items where possible. Refer to Technical Instruction TSD0248 for standard power transformers on contract.

10.4.1.1 Neutral earth impedance

Transformer applications that require the ground fault current to be reduced for safety may introduce an impedance between the power transformer neutral and earth. The preferred impedance method is to install a neutral earthing reactor (NER). Transformers 8MVA and above in the Energex area will generally have an impedance earthed neutral.

A 33kV neutral earthing reactor shall have an impedance of 16Ω and a short time rating of 1kA for 3 seconds.

An 11kV neutral earthing reactor shall have an impedance of 6Ω. The performance of an 11kV neutral earthing reactor shall be as follows:

- Short time rating of 1kA for 3 seconds on the 6Ω tap.
- Continuous current rating of 40A.

10.4.2 Earthing transformers

To provide an earth reference to systems without a neutral point, earthing transformers are connected to outputs of main transformers. Earthing transformers shall have a zigzag connection and connection symbol Z_n. The impedance of this earthing transformer will limit the magnitude of earth faults, similar to a neutral earthing reactor. The zero-sequence impedance of zigzag earthing transformers shall be selected based on the desired zero-sequence impedance and ground fault current. The performance of these transformers will depend on the required earth fault level at the terminals of the low voltage winding.

10.4.3 Station service (House supply)

Station service transformers shall have a primary voltage rating equal to the system nominal voltages in Table 3. The secondary voltage of the station service transformer shall be rated at 400/230VAC and have an electrical vector configuration of Dyn11. A typical number of taps are 5 or 7.

The sizing of the station service transformer depends on the auxiliary load of the substation. Factors that affect auxiliary load include AFLC, air conditioning, lighting etc.

10.4.4 Others

Other transformers include those associated with:

- STATCOMs
- Battery energy storage systems
- AFLCs

10.5 Circuit breakers

Circuit breakers shall meet the requirements of the Standard for Switchgear Selection (STNW3051) - 12743722. Interlocking of circuit breakers within switchgear is covered in the Standard for Interlocking (STNW3046) - 3060386.

Selection of circuit breakers for HV applications should be based on voltage rating, location of breaker (e.g. transformer breaker, capacitor bank circuit breaker etc) and fault current rating.

Circuit breakers designed to switch an earth onto HV conductors for the purpose of operational earthing shall be fault-make rated.

10.6 Disconnectors and earth switches

Disconnectors and earth switches shall meet the requirements of the Standard for Switchgear Selection (STNW3051) - 12743722. Interlocking of disconnectors and earth switches is covered in the Standard for Interlocking (STNW3046) – 3060386.

In this section, disconnectors and earth switches do not refer to circuit breakers used as earth switches; these are covered in the circuit breaker section.

Selection of disconnectors and earth switches for various HV applications should be based on voltage rating, height of the structure and left/right/dual earth switch requirement (if applicable).

Disconnectors with spring assisted arcing contacts may be able to break minor currents such as line charging or transformer magnetisation, but such switching capability shall be assessed by the equipment manufacturer.

New installations of fault-throw earth switches are not permitted in EQL.

10.7 Busbar and landing spans

Busbars designed and built by EQL shall adhere to the Standard for Busbar Conductor Selection (STNW3014) - 3062690. Landing spans must have current ratings equal to or greater than the bay ratings they are associated with.

Switchgear and GIS shall have bus ratings provided by the manufacturer and tested in accordance with IEC standards. Where ambient temperatures are likely to exceed type tested limits of 40^0C ambient, designers shall incorporate a safety margin into the design, or employ other measures to improve the situation e.g. forced ventilation of busbars, air conditioning of room etc.

10.8 HV cables and screens

HV cables in substations shall conform to the requirements of the Standard for Cables and Cable Installation (STNW3018) - 12737281. Where possible, standard HV cables shall be used to minimise stores and spares holdings. Ratings are required for the following HV cables in a substation:

- Power transformer cables
- Feeder cables
- Capacitor bank cables
- Local supply transformer cables
- Distribution bus tie cables

Cable screens shall be suitably sized to carry the earth fault current for the anticipated duration. Refer to Table 1 in *STNW3018* for these cable parameters.

10.9 Special equipment

Refer to the relevant standards for specific ratings of the below equipment:

- Harmonic filter
- Capacitor bank
- Reactors, shunt, inrush etc.
- Coupling cell/AFLC
- STATCOM
- SYNCON
- SVC

11 Special equipment purchases

In applications where the site conditions are outside of the allowable ratings of the equipment available on an EQL contract, there are provisions to source suitable HV equipment.

To approach the market for other HV equipment, contact the Asset Standards team. Any party that approaches the market without Asset Standards team involvement bears the responsibility of any future issues with the equipment e.g. warranty period, future maintenance etc.

Annex A

Informative

A.1 Transformer bay example

Figure 1 shows a single line diagram of a 3-terminal 132/66/11kV 63-63-10 MVA ODAN YNa0d transformer bay.

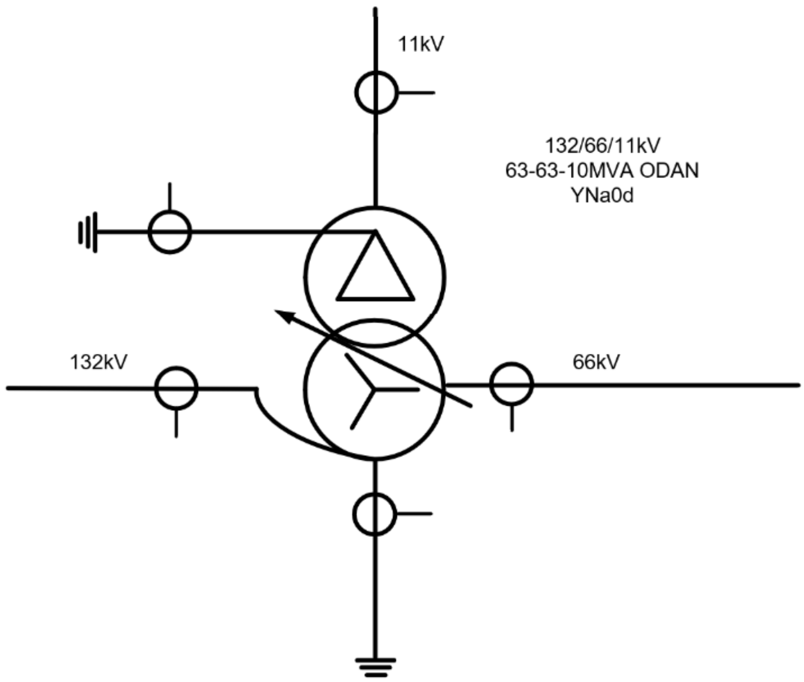

Figure 1: 132/66/11kV Transformer Bay Single Line Diagram

The example below shows how to calculate the minimum continuous current rating for each bay of this three-terminal transformer.

Example 1: YNa0d 50/63MVA ODAN 132/66/11kV (23tap -17.5% +10%)

1.2p.u. long-time emergency rating and 1.15p.u. short-time emergency rating

$$HVterminal(top\ tap) = 1.2 * \frac{63MVA}{132kV * \left(1 - \frac{17.5\%}{100}\right) * \sqrt{3}} = 331A\ (minimum\ rating)$$

$$MVterminal(top\ tap) = 1.2 * \frac{63MVA}{66kV * \left(1 - \frac{17.5\%}{100}\right) * \sqrt{3}} = 662A\ (minimum\ rating)$$

$$LVterminal\ (1p.u.V) = 1.2 * \frac{10MVA}{11kV * \sqrt{3}} = 630A\ (minimum\ rating)$$

A.2 CT PX class rating examples

The following variables are used when analysing PX class CT's.

- I_{pr} – Rated primary current (application specific)
- I_{cth} - Continuous thermal current (shall not exceed I_{pr})
- I_{sr} – Rated secondary current (1A preferred or 5A in special applications)
- Turns ratio – I_{pr} / I_{sr} (application specific)
- E_k – Rated knee point voltage (CT and tap specific)
- I_e – Rated knee point exciting current (maximum of 100mA)
- R_{ct} – Secondary winding resistance of the CT (provided by manufacturer)
- R_b – Rated resistive burden
- K_x – Dimensioning factor
- $E_k = K_x \times (R_{ct} + R_b) \times I_{sr}$ – Knee point voltage can be calculated instead of specified (Equation 1)

CT example 1 – 0.1Px2400R8.0 on 1600/1 (1600/1200/1000/400/1)

I_e – 100mA at 1600/1

E_k – 2400V at 1600/1

R_{ct} – 8Ω at 1600/1

In this example, the rated resistive burden R_b is 1.2Ω. Hence the dimensioning factor at 1600/1 is:

$$K_x = \frac{E_k}{(R_{ct} + R_b) \times I_{sr}}$$
$$K_x = \frac{2400}{(8 + 1.2) \times 1}$$
$$K_x = 260.9$$

CT example 2 – 0.01Px K_x250 R_b1.2 on 2000/1 (2000/1600/1000/800/1)

I_e – 10mA at 2000/1

K_x – 250 at 2000/1

R_b – 1.2Ω

In this example, if the secondary winding resistance R_{ct} is 3Ω, then the kneepoint voltage on the 2000/1 tap is:

$$E_k = K_x \times (R_{ct} + R_b) \times I_{sr}$$
$$E_k = 250 \times (3 + 1.2) \times 1$$
$$E_k = 1050V$$