

## PART 1 - Session Six:

# High Voltage Terminations and Compliance

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## Introduction

High Voltage installations once were the domain of supply authorities, large mines and processing plants.

With the deregulation of the electrical industry more and more private high voltage electrical installations are being encountered, and as such a need has been created for private contractors to undertake high voltage installations.

The paper intends to show the importance of high voltage electrical installations compliance prior to energising, including the relevant tests required by legislation and the importance of good engineering practices when terminating high voltage cabling.

## What is High Voltage?

ASNZS 3000 2007 Clause 1.4.98 nominates 3 different groupings or levels of Voltage being, Extra Low Voltage, Low Voltage and High Voltage and are defined as follows,

**Extra-low voltage:** Not exceeding 50V a.c. or 120 V ripple-free d.c.

**Low voltage:** Exceeding extra-low voltage, but not exceeding 1,000 V a.c. or 1 500 V d.c.

**High voltage:** Exceeding low voltage.

**The term medium voltage is no longer used to describe voltage levels in Australia.**

Whilst there are numerous standards and regulations within Australia regarding High Voltage electrical installations the three most commonly referred to documents are:

1. ASNZS 3000 – 2007- Electrical installations  
(Known as the Australian/New Zealand Wiring Rules) Section K

*In Australia, the provisions of Appendix K ASNZS 3000 2007 apply to electrical installations and those portions of electrical installations operating at high voltage.*

2. AS 2067 – 2008 - Substations and high voltage installations exceeding 1 kV a.c.
3. Energy Networks Association Guidelines

In Addition the relevant regulatory authority, electricity distributor or person in control might require proof that the design and construction of the high voltage electrical installation complies with relevant standards and regulations.

Queensland has dedicated high voltage accredited auditors that must inspect and audit a high voltage installation prior to energising. (Section 153 Electrical Safety Regulations)  
Other states have similar systems.

## High Voltage Electrical Tests

ASNZS 3000 – 2007 Clause K14 states:

High voltage testing is carried out to ensure suitability for service.

All high voltage materials and electrical equipment incorporated in a high voltage electrical installation shall be tested either before delivery to the site or after installation.

Such tests shall be made to the requirements of the relevant Australian, IEC or British Standards or other specifications.

Certificates indicating that the materials or electrical equipment have satisfactorily passed these tests may be required.

The completed high voltage electrical installation shall satisfy the tests set out in ASNZS 3000 -2007 Paragraphs K14.3 to K14.7.

### K14.3 Insulation resistance Test No. 1

Before the high voltage test referred to in Paragraph K14.4 is conducted, the insulation resistance of the complete electrical installation shall be measured to ensure that the high voltage test may be safely applied.

### K14.4 High voltage test

A high voltage test shall be applied either:

(a) Between phase conductors and between each phase conductor and earth, at a voltage that shall be slowly increased to not less than twice the working voltage plus 2000 V and maintained for a period of 1 min;

Or

(b) As specified in the relevant Australian, IEC or British Standard or manufacturer's specifications for any piece of electrical equipment connected to the high voltage electrical installation. Generally known in the industry as a "Soak Test".

There shall be no indication of failure or breakdown during this test.

#### *K14.5 Insulation resistance Test No. 2*

The test specified in Paragraph K14.3 shall be repeated. The insulation resistance so measured shall not be significantly less than the value of insulation resistance measured during the insulation resistance Test No. 1 of Paragraph K14.3.

#### *K14.6 insulating oil*

Insulating oil shall comply with AS 1883 or other appropriate specification.

#### *K14.7 earthing resistance*

Earthing resistance shall be measured for compliance with Paragraph K11.4.2 or Paragraph K11.5.2.

#### *K11.4.2 Resistance to earth*

The combined earthing system shall have a resistance to earth not greater than 1  $\Omega$ .

The resistance of 1  $\Omega$  may be achieved by connections to electrode systems, metallic cable sheaths or low voltage neutrals, provided that when any such connection is temporarily removed for test or maintenance purposes the resistance of the remaining earthing connections does not exceed 30  $\Omega$ .

Resistances to earth greater than 1  $\Omega$  may be appropriate where step and touch potentials are satisfactory.

### *K11.5.2 Resistance to earth*

The earth connections of the earthing systems shall be located, installed and maintained so that the resistance to earth shall not exceed the following:

(a) High voltage system	30 $\Omega$ .
(b) Low voltage system:	
Aggregate transformer rating up to 50 KVA.	30 $\Omega$ .
Aggregate transformer rating over 50 KVA but not more than 500 KVA.	15 $\Omega$
Aggregate transformer rating over 500 KVA	10 $\Omega$ .

The resistances specified in Items (a) and (b) shall be achieved independently of any connections between the neutral conductor and earth at other points within the electrical installation.

#### NOTE:

It is important that the resistance of earthing connections should be checked regularly during the life of the electrical installation.

*The period between tests should preferably be not more than two years, and such tests should be carried out during both wet and dry periods.*

## **Safety Features of High Voltage Installations**

### *What Other Cabling Can Be Run With High Voltage*

ASNZS 3000 -2007 Clause 3.9.8.3 states;

Cables of high voltage circuits and cables of low or extra-low voltage circuits shall not be enclosed in the same wiring system. Therefore no other cabling can be installed in the same conduit trunk or trench.

### *Restriction of Entry to High Voltage Installations.*

ASNZS 3000-2007 K5 requires that substations and electrical equipment should not be accessible to unauthorized persons; there are a number of ways to achieve this principle however the 3 common ways addressed in this paper are Safety Signage, Fencing and lock and key

### Safety Signs

Signs are generally designed to convey a message which may relate to a hazard, a prohibition, emergency or fire information.

The purpose of signs on electrical infrastructure is to:

- (a) Warn of the hazard.
- (b) Provide a deterrent to access or other unauthorised activity.
- (c) Provide contact information to the general public concerning the site.
- (d) Meet any legal obligation arising from duty of care to the public and staff

ENA DOC 015—2006 Schedule 1 – Sign schedule is more specific with different types of High Voltage installations however general legal obligations for installing signage in Australia require conspicuous, legible and indelible signs be provided in suitable positions as follows:

On the outside of a substation enclosure and at each means of access to the enclosure Wording on signs at these locations shall consist of bold letters not less than 40 mm high and shall contain the words

**“DANGER— HIGH VOLTAGE”**

On each cover or door, the removal or opening of which will provide access to high voltage parts wording on signs at these locations shall consist of bold letters not less than 12 mm high and shall contain the words

**“DANGER— HIGH VOLTAGE”**

At each entrance to a substation Wording on signs at these locations shall consist of bold letters not less than 40 mm high and shall contain the words

**“AUTHORIZED PERSONS ONLY”**



### Fencing

Fences are one of the primary means of limiting access to outdoor installations, such as high voltage substations. However, all fences can be penetrated given adequate time, climbing aids and/or tools.

Accordingly it is appropriate to consider security fences in conjunction with additional measures such as electronic intruder detection systems, public awareness, alarms and lighting.

AS 2067 - 2008 calls up 4 types of fencing areas an outdoor installation may have performing different functions, requiring different levels of security.

### *1. Boundary fence*

This type of fence is typically only used at larger sites where the protected area occupies a small part of the land owned by the organisation.

A boundary fence can perform the following functions:

- Identify the site boundary.
- Limit the access of vehicles to the site, reducing the possibility that vehicles will be used as an aid to scaling the main fence.
- In rural areas a boundary fence can prevent livestock from entering the property, reducing the probability of damage to the intruder resistant fence and landscaping vegetation.

### *2. Sterile zone fence*

At sites requiring a higher level of security a sterile zone equipped with electronic intruder detection equipment could be created outside the intruder resistant fence. A sterile zone fence defines the outer boundary of the station area and provides delineation of the area after which intruders will be detected.

A sterile zone fence offers a greater degree of protection than the boundary fence but does not require the same level of intruder resistance as an intruder resistant fence.

A sterile zone Fence should be sufficient to ensure a determined effort is required to breach it.

### *3. Intruder resistant fence*

The design, construction and maintenance of intruder resistant fences should limit the opportunity for intruders to climb over, through or pass under the fence without the aid of tools.

The intruder resistant fence offers a greater degree of protection than the boundary fence or the sterile zone fence. When used in conjunction with a sterile zone fence, the intruder resistant fence should be used to ensure intruders remain within the sterile zone area for sufficient time to be detected and response initiated.

**Height:** The total height of the fence structure, including topping, should be a minimum height of 2.9 metres. The fence panel height should be a minimum height of 2.4 meters.

**Topping:** Barbed wire, barbed tape, powered fence, spikes, etc.

#### 4. High voltage equipment enclosure fence (High voltage cage)

Substation HV equipment, such as capacitor banks, air cored reactors or auxiliary supply transformers, are often installed within switchyards at close to ground level.

Safety clearances are maintained by provision of fixed safety screens, often consisting of mesh fencing, safety screens. Any high voltage equipment enclosure fence should be located a minimum of 2 metres within the intruder resistance fence.

Danger Signs warning of the presence of high voltage equipment at low level should be attached to all sides of HV equipment enclosures and on entrance gates.

Extract ENA DOC 015—2006 Area Fence Structures

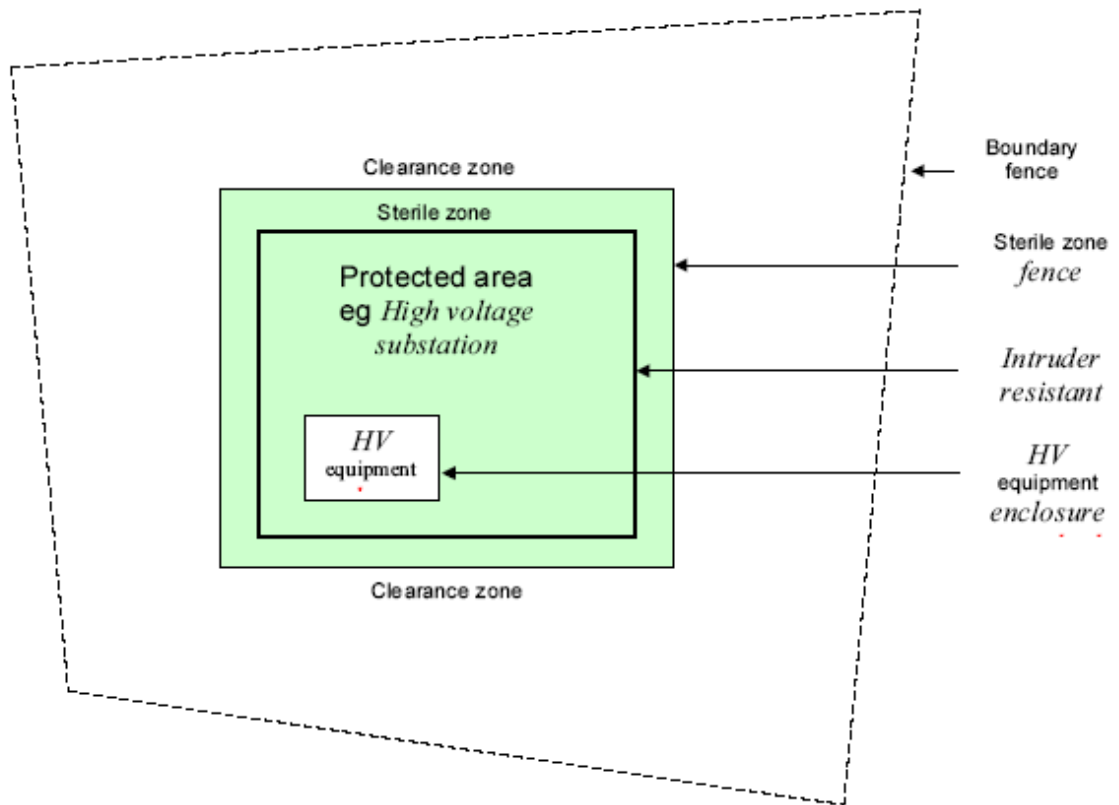


Figure 5.1 Examples of fence functions

### *Keys and Locks*

Lock and key systems perform the function of denying access to specific areas or spaces to unauthorised persons while allowing access to authorised persons through the use of mechanical locking devices.

It should be recognised that manual keys and locks do not offer any audit trail on usage (excluding modern swipe cards and security systems)

Appropriate and sufficient policies and procedures must support all the processes such as key issue and control protocols.

### *Emergency Exit Facilities*

Sufficient exit facilities shall be provided to enable a person to leave the vicinity of substation electrical equipment under emergency conditions and include the following.

- Unimpeded space around switchboards and transformers.
- One or more exit paths, particularly for large substations.
- Openings, such as doorways or gates that allow persons access to the switchboard, that are at least 0.75 m wide by 1.98 m high.
- Where a door or gate is provided as a means of egress, it shall open outwards and be arranged so that it can readily be opened from the inside without the use of a key.

## **Key Auditing Criteria Prior To Energising A High Voltage Installation**

1. The installation found to be 'not connected' prior to the audit.
2. Need to sight:
  - Appropriately licensed /competent persons have undertaken the work
  - Certificate of Testing & Compliance
  - Fault level of source,
  - Fault level at end of cable,
  - Fault Rating of equipment Fault Rating of Cable
  - Grid Earthing Results
3. Sight or witness
  - Insulation Test 1
  - Insulation test 2 HV
  - Earthing resistance

- Oil or Gas compliance tests
4. View Safety Clearances for equipment
  5. Safety Signage
  6. Review Fencing
  7. More than 1 Earth connection per earthing system
  8. Earthing system connection not made at a terminal bar in such a manner that any connection may be removed for testing without interference to others.
  9. Earthing conductors minimum size
  10. Cables radius as per manufacturers instructions

# Sample Test Sheet HV Cabling



Contractors License No. 55849



HV CABLE TEST REPORT									
Customer: P & C Smith					Location: Vet Clinic				
Unit I.D.: US 44					Job No.: 09 5841				
CABLE DETAILS									
Feeder: US 44 - GMS 2			Cable No.: U 2007.5						
Cable Type: <input checked="" type="checkbox"/> XLPE <input type="checkbox"/> URD		Conductor Type: <input checked="" type="checkbox"/> Copper <input type="checkbox"/> Alum.		Conductor Size (mm <sup>2</sup> ): 240		Cable Age (if known): new			
Rated Voltage: 12kV			Approx Length: 1,500 m		<input checked="" type="checkbox"/> 3 Cores		<input type="checkbox"/> 1 Core		
SHEATH INSULATION RESISTANCE TEST				TEST VOLTAGE: 1 kV		COMMISSIONING CHECKLIST			
• Readings in Megohms									
Instrument:		Serial No.:							
Single Core Cable (if applicable)			Three Cores Cable (if applicable)						
A		B		C		Overall			
N/A MΩ		N/A MΩ		N/A MΩ		600 MΩ			
CORE INSULATION RESISTANCE TEST				TEST VOLTAGE: 5 kV		Cable number marked: <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> N/A			
• Readings in Megohms						Screen/Sheath reconnected after test: <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> N/A			
Instrument:		Serial No.:				Frame Leakage insulation okay: <input type="checkbox"/> Yes <input type="checkbox"/> No <input checked="" type="checkbox"/> N/A			
Before H.V. Test									
A to B+C+E		B to A+C+E		C to A+B+E					
1 min 1,500 MΩ		1,500 MΩ		1,500 MΩ					
2 mins 1,500 MΩ		1,500 MΩ		1,500 MΩ					
5 mins 1,500 MΩ		1,500 MΩ		1,500 MΩ					
After H.V. Test									
A to B+C+E		B to A+C+E		C to A+B+E					
1 min 1,500 MΩ		1,500 MΩ		1,500 MΩ					
2 mins 1,500 MΩ		1,500 MΩ		1,500 MΩ					
5 mins 1,500 MΩ		1,500 MΩ		1,500 MΩ					
H.V. WITHSTAND TEST				<input type="checkbox"/> DC		TEST VOLTAGE: 21 kV			
• Readings in Megohms				<input checked="" type="checkbox"/> AC					
Instrument:		Serial No.:							
Connection		Duration		Leakage (mA)		Result			
A to B+C+E		15 mins		15		PASS			
B to A+C+E		15 mins		15		PASS			
C to A+B+E		15 mins		15		PASS			
DATE: 17/08/2008		TESTED BY: D. de Freitas		WITNESS:		APPROVED BY:			
EQUIP USED: Kyoritsu		SER NO: 121325		CAL EXP DATE: 11/11/08					
EQUIP USED: Hi-Pot - VLF		SER NO: 105082		CAL EXP DATE: 09/08/2008					

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## Terminating High Voltage Cable and Equipment

Terminations of high voltage cables and equipment should only be undertaken by trained competent and if required licensed personnel.

Different States and territories have different legislation regarding licensing for terminating splicing and installing high voltage electrical equipment.

Prior to undertaking any work on high voltage electrical installations (or any electrical work) it is important to ensure the person is appropriately licensed in the state or territory that the work is being undertaken.

Due to the high electrical pressure that will be passing through the termination it is important to ensure high voltage cables are properly terminated, this will in many cases avoid electrical fault issues such as power fluctuations brown outs overload and rework shutdowns.

With the vast number of brands, type and rating of high voltage termination equipment available, this paper cannot deal with each and every aspect of terminating high voltage cables or equipment, however six (6) key points apply to terminating all high voltage cables and equipment.

1. Ensure you have read and understood the manufacturers requirements
2. Ensure cables are prepared for termination as per manufacturers requirements
3. Ensure compatible lugs are used for the cable
4. Ensure the terminating surface is clean and clear of any dirt or grime
5. Ensure bolted terminations are tightened to manufacturers recommendations
6. Check, recheck and check again.



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