Network Standard

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Design for Substation Overpressure

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Scope

This standard provides performance requirements for the design of new major substations to withstand or manage overpressure caused by the failure of electrical equipment within the substation building.

This standard applies to new installations as follows:

- where there is a safety risk of injury to persons in the vicinity as a result of structural damage, building failure or the effects of substation overpressure; or
- where loss of the facility or supply is unacceptable to Ausgrid, based on technical advice from Ausgrid Engineering.

The application of this standard shall be dependent on a site-specific risk assessment in accordance with Section 2.

This standard does not address the safety risks that are independent of the building, such as those related to equipment design and electrical protection.

This standard does not take into account the effect of projectiles resulting from an overpressure event.

Refer to NS113 for specific requirements relating to overpressure and vent design in chamber substations.

Reference Documents

All work covered in this document shall conform to all relevant Legislation, Standards, Codes of Practice and Network Standards.

Ausgrid Documents

NS001 Glossary of Terms

NS113 Site Selection and Construction Design Requirements for Chamber Substations

NS187 Passive Fire Mitigation Design of Substations

NS200 Major Substations Ventilation Design Standard

Other Standards and Documents

AS/NZS 1170 Structural design actions (Set)

AS 1530.4 Methods of fire tests on building materials and structures - Fire-resistance tests of elements of building construction

AS 1940 The storage and handling of flammable and combustible liquids

AS 3600 Concrete structures

AS 3700 Masonry structures

AS 4072.1 Components for the protection of openings in fire-resistant separating elements - Service penetrations and control joints

AS 4100 Steel structures

CIGRE TB 602 Tools for the Simulation of the Effects of the Internal Arc in Transmission and Distribution Switchgear

ENA Doc 001-2019 National Electricity Network Safety Code

National Construction Code Series (NCC)

Acts and Regulations

Electricity Supply (General) Regulation 2014 (NSW)

Electricity Supply (Safety and Network Management) Regulation 2014

Work Health and Safety Act 2011 and Regulation 2017

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Clause	Standard Requirements

1 General

1.1 Overpressure is a rapid rise in the enclosure pressure caused by high voltage electrical equipment failing in an enclosed compartment. Where this occurs indoors in a room there is a risk of damaging the building.

1.2 Arc fault overpressures are dependent on room volume, available venting, fault level, duration of the electrical fault and type of equipment. The impact of arc fault overpressures reduces as the room volume increases.

1.3 Oil fuelled deflagrations create much larger peak pressures than arc faults for any given volume and occur over a shorter duration. The impact of deflagrations can increase with an increase in room volume but are subject to many variables.

1.4 As a result of the much larger peak pressure in an oil fuelled deflagration, the substation vents are larger and require the use of a free open vent design, unless approved otherwise.

1.5 Venting for both arc fault induced overpressures and deflagrations is intended to reduce the risk of damage to structures and injury to persons in the vicinity.

1.6 Where electrical equipment is located outdoors, the risk of overpressure damage to structures and persons in the vicinity is reduced.

1.7 The failure of electrical equipment may also result in fire. The separation distances and other measures to protect against fire are provided in NS187.

1.8 The vessel robustness can play a part in reducing the risk of the vessel breaching under fault conditions. Smaller vessels which offer a higher steel thickness to size ratio are more resistant to rupture.

2 Risk assessment of site

2.1 The application of this standard is intended for new major substations housing high voltage equipment in an enclosed building and shall be dependent on a site-specific risk assessment. The risk assessment shall assess the following:

- potential damage to Ausgrid assets or surrounding property;
- the potential risks to life and safety;
- existing and potential future uses of neighbouring properties;
- the criticality of the substation and substation building, including loss of supply, redundancy and other issues as determined by Ausgrid Engineering; and
- losing fire segregation as the consequence of an overpressure event.

2.2 Ausgrid Engineering shall advise what parts of this Network Standard are required in a substation design, based on the completed risk assessment.

3 Design for arc induced overpressures

3.1 Arc induced overpressure in an enclosure

3.1.1 Venting

3.1.1.1 Arc induced overpressure will occur as a result of an uncontrolled arc.

3.1.1.2 For the majority of substations, venting for arc faults is required. The pressures developed in an unvented arc fault can reach unmanageable levels if the fault is not cleared adequately.

3.1.1.3 Where there are no purpose-installed arc fault vents provided, some nominal inadvertent venting may be provided through the breaching of doors or other low strength systems.

3.1.2 Internal arc classification (IAC)

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Refer to Annexure A for a description of switchgear which has an IAC rating to control and vent arc energy and by-products.

3.2 Arc fault in the open air

3.2.1 Where an equipment failure occurs in the open air, the potential for local overpressure effects to cause damage to adjoining assets is minimal. Hence, there are no additional design requirements.

3.2.2 Separation distances and other measures to protect against fire shall be applied as detailed in NS187.

3.2.3 Flying debris such as fragments of insulators, ancillary components or vessel access covers may also be a hazard. Mitigation measures for flying debris are not addressed in this standard.

3.3 Vent area and enclosure strength

3.3.1 For the design of enclosures, the methodology and modelling techniques used for determining design overpressures shall be subject to the approval of Ausgrid Engineering. Analysis methods that may be suitable include those described in CIGRE TB 602.

3.3.2 Vent area design shall be based on the use of a minimum enclosure ultimate strength of 1.5 kPa to resist the average design overpressure.

3.3.3 Where the available vent area is restricted, and the enclosure ultimate strength is required to exceed 1.5 kPa, the enclosure shall be designed to resist the expected resulting design overpressures.

3.3.4 For enclosure strengths required to exceed 1.5 kPa, the enclosure ultimate strength shall be based on the calculated design overpressure multiplied by the following load factors:

- overpressure imposed loads – a load factor of 1.5;
- other imposed loads – the appropriate combination load factor for fire from AS/NZS 1170.0;
- permanent loads – a load factor of 1.0 applicable for fire from AS/NZS 1170.0; and
- capacity reduction factor – the appropriate material-based capacity reduction factor.

3.3.5 The vent design for high voltage enclosures shall be based on:

- the maximum potential arc energy within the enclosure;
- the location of the high voltage arc source in relation to the vent;
- compartment ultimate strength (which shall be a minimum of 1.5 kPa);
- compartment size;
- available vent area; and
- other services in the compartment.

3.3.6 Refer to Section 5 for details and requirements relating to building design and strengthening for induced overpressures.

3.4 Requirements for arc fault venting

3.4.1 Functional requirements

3.4.1.1 The open uncovered vents that are used primarily for natural ventilation may be sufficient for arc fault venting.

3.4.1.2 Where additional dedicated arc fault vents are required, these vents shall be covered wherever practicable to minimise the ingress of dust and other contaminants.

3.4.1.3 Where dust ingress and contamination are not an issue, the use of free open vents for arc fault venting shall be subject to the approval of Ausgrid Engineering.

3.4.1.4 Where covered vents are used, the functional requirements shall be as follows to ensure the vents operate efficiently and safely:

- vents shall not become projectiles;

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- vents shall be secure against unauthorised access;
- vents shall be restricted in weight to 12.0 kg/m^2;
- vents shall be non-combustible or fire rated as required;
- vent operation shall be proven as required by Clause 5.6;
- vents shall not contravene the fire rating requirements of the building;
- vents which may open under high wind conditions (refer to Clause 3.4.2) shall be located to mitigate the impact of wet weather on indoor equipment;
- the location of vents shall comply with the safe egress requirements of the NCC; and
- vents shall be maintained to ensure they remain operable.

3.4.1.5 Where practicable, covered vents shall be designed to operate (open/close) during an overpressure event, as opposed to failing under overpressure loads (i.e. vents which break away and cannot be re-closed).

3.4.1.6 Vent systems that are designed to fail under overpressure loads shall require the approval of Ausgrid Engineering

3.4.2 Vent release pressure

3.4.2.1 The minimum actual vent release pressure for covered vents for arc fault induced overpressures shall be 1.0kPa, except where the release pressure needs to be increased due to local wind loading conditions based on the wind terrain category.

3.4.2.2 The maximum actual vent release pressure, irrespective of local wind conditions, shall be 1.5 kPa, except where higher release pressures have been approved by Ausgrid Engineering.

3.4.3 Vented gases

Vented gases shall be directed to a safe area.

4 Design for deflagrations

4.1 Deflagration in an enclosure

4.1.1 The development of a destructive deflagration caused by oil filled electrical equipment is rare and is dependent on many factors, which include:

- the robustness of the oil filled vessel;
- the reliability of the equipment;
- the mode of failure; and
- the enclosure conditions.

4.1.2 During a vented deflagration, the pressure in the enclosure will continue to rise until the maximum pressure is reached as the flame front continues to propagate through unburnt fuel.

4.1.3 The use of venting for the enclosure reduces the maximum pressure that would be expected without any venting, by releasing the overpressure by-products to a safe area.

4.2 Deflagration in the open air

4.2.1 Where an equipment failure occurs in the open air, the potential for local overpressure effects to cause damage on adjoining assets is minimal, except for assets in close proximity. Hence, there are no additional design requirements for equipment in open spaces, except for specific locations approved by Ausgrid Engineering.

4.2.2 Refer to Clause 3.2 for the requirements relating to fire protection and flying debris which also apply to deflagration events.

4.3 Vent area and enclosure strength

4.3.1 The design of enclosures, associated vents and mitigation measures for deflagration events shall be based on one of the following design approaches:

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- Empirical Methods – required for assets where the consequences of failure are not likely to cause injury; or
- Computational Fluid Dynamics (CFD) – required for approved major assets (e.g. CBD zone substations) and for locations where the consequences of failure are likely to cause injury or fatalities.

4.3.2 The use of a CFD analysis to assess potential deflagration events shall be subject to the approval of Ausgrid Engineering.

4.3.3 For both major and other assets, the enclosure may need to be strengthened for a vented deflagration to prevent permanent building structural damage or a catastrophic failure of the structure.

4.3.4 Where additional strengthening of the enclosure is required, the enclosure shall be designed for the expected overpressures that may be developed in a deflagration. The enclosure design shall use the appropriate load factors as indicated below, or as otherwise approved by Ausgrid Engineering:

- overpressure imposed loads – a load factor of 1.5 for designs using Empirical Methods;
- overpressure imposed loads – a load factor of 1.0 for designs using Computational Fluid Dynamics;
- other imposed loads – the appropriate combination load factor for fire from AS/NZS 1170.0;
- permanent loads – a load factor of 1.0 applicable for fire from AS/NZS 1170.0; and
- capacity reduction factor – the appropriate material-based capacity reduction factor.

4.3.5 The enclosure strength and vent design shall be based on:

- the fuel source type (normally insulating mineral oil with a deflagration index of 100 Bar.m/sec);
- the reasonably achievable compartment ultimate strength;
- the compartment size;
- available vent area;
- other services in the compartment (such as deluge systems and ventilation ducts);
- the compartment aspect ratio;
- the proximity and type of adjoining property and the likelihood of impact by shock waves or unburnt fuel. For adjoining properties at high risk, a CFD analysis may be required; and
- the likelihood of the presence of pedestrian traffic. For a high likelihood of pedestrian traffic, a CFD analysis may be required.

4.3.6 For locations where venting upwards is viable, the risk exposure to neighbouring properties and pedestrian traffic will be reduced when compared to venting towards the adjoining property.

4.3.7 For approved major assets and high-risk locations, the design shall utilise a CFD analysis with a range of fuel mixtures. The CFD analysis shall be undertaken by suitably qualified persons experienced with oil filled equipment failures and CFD analysis.

4.3.8 All compartments designed to manage overpressures shall be constructed from ductile materials such as reinforced concrete.

4.3.9 Refer to Section 5 for requirements relating to building design and strengthening for induced overpressures.

4.4 Requirements for deflagration vents

4.4.1 Functional requirements

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4.4.1.1 Deflagration vents shall be of the free open vent design, except where approved otherwise under Clause 4.4.2. This design will most effectively vent the deflagration event, based on the potentially high proportion of hydrogen in the cracked oil by-products.

4.4.1.2 The functional requirements for free open vents shall be as follows to ensure they work efficiently and safely:

- vent components (e.g. louvres) shall not become projectiles;
- vents shall be secure against unauthorised access;
- vents shall be non-combustible or fire rated as required;
- vents shall not contravene the fire rating requirements of the building; and
- the location of vents shall comply with the safe egress requirements of the NCC.

4.4.1.3 The proposed deflagration vent system shall be submitted to Ausgrid Engineering for review and approval. Written evidence shall be provided to demonstrate compliance with the functional requirements.

4.4.2 Vent release pressure

4.4.2.1 Where a free open vent design cannot be used, an alternative vent design proposal shall be submitted to Ausgrid Engineering for review and approval.

4.4.2.2 The additional functional requirements for covered vents shall be as follows to ensure they operate efficiently and safely:

- vents shall be designed to operate (open/close) during a deflagration event;
- vents shall be restricted in weight to 12.0 kg/m^2;
- vent operation shall be proven as required by Clause 5.6; and
- vents shall be maintained to ensure they remain operable.

4.4.2.3 The minimum actual vent release pressure for covered vents for deflagration overpressures shall be 1.0 kPa, except where the release pressure needs to be increased due to local wind loading conditions based on the wind terrain category.

4.4.2.4 The maximum actual vent release pressure, irrespective of local wind conditions, shall be 1.5 kPa, except where higher release pressures have been approved by Ausgrid Engineering.

4.4.3 Vented by-products

Vented by-products shall be directed to a safe area.

5 Building design for induced overpressures

5.1 General

5.1.1 The requirements in this Section shall apply where the building is to be designed for managing the effects of an overpressure event.

5.1.2 The building shall be designed to withstand the effects of arc fault or deflagration overpressures without permanent deformation or structural damage in accordance with this standard.

5.1.3 During initial design for a new major substation, a report shall be prepared for Ausgrid Engineering outlining the requirements for managing overpressures. Detailed building design shall not be undertaken until Ausgrid Engineering reviews and approves the recommendations of the report.

5.2 Building elements

5.2.1 Design requirements

5.2.1.1 Where pressure relief venting design maintains the factored compartment overpressures below the minimum enclosure ultimate strength of 1.5 kPa during an arc fault or deflagration, the requirements of this Clause do not apply.

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5.2.1.2 Building compartments designed to withstand factored overpressures greater than 1.5 kPa (ultimate) shall comply with the following requirements:

- compartments shall be made from materials which fail in a ductile manner wherever practicable;
- the design shall use only 25% of the ultimate strength of any non-ductile material, where brittle materials need to be used;
- for CBD sites, non-ductile, brittle elements shall not be used in rooms which will house high voltage equipment; and
- a capacity reduction factor of 0.75 shall be applied to the prescribed design in AS 3700 for reinforced concrete block construction.

5.2.2 Columns

5.2.2.1 Where columns are incorporated into the walls of compartments that are designed to withstand overpressures, there shall be no direct connection of the walls to the columns, except with the approval of Ausgrid Engineering.

5.2.2.2 Where connection of walls to columns is unavoidable, the columns shall be designed to withstand four times the connection capacity.

5.2.3 Walls

5.2.3.1 Where unreinforced masonry walls are subject to overpressures, the walls shall not have any vertical load bearing function or be relied upon for the overall lateral stability of the building.

5.2.3.2 This Clause does not apply to wall construction of reinforced concrete, or reinforced core filled concrete block.

5.3 Building ventilation

5.3.1 Ventilation for substation buildings shall comply with NS200.

5.3.2 The requirements for overpressure design shall be assessed separately from the building ventilation requirements.

5.3.3 Any permanent openings that are provided primarily for building ventilation shall be included as part of the vent area available for overpressure relief.

5.3.4 For arc fault events, any additional dedicated overpressure relief openings shall be of covered vent design (unless approved otherwise) to minimise infiltration and dust entry.

5.3.5 For deflagration events, any additional dedicated overpressure relief openings shall be of the free open vent design (unless approved otherwise) in accordance with this standard.

5.3.6 Wherever practicable, any overpressure relief panels shall be suitably located, designed and insulated to minimise the thermal load from the panels into the building.

5.4 Openings in walls

5.4.1 Openings for windows shall not be used in walls that are subject to overpressures, and openings for other purposes shall be minimised.

5.4.2 Where openings are necessary and are also required to be fire rated, the relevant fire seals or closures for the openings shall be designed to withstand the expected overpressures.

5.4.3 For openings that are not required to be fire rated, the seals or closures do not need to be designed for overpressures. These items can be damaged and subsequently replaced following an overpressure event.

5.4.4 Design measures shall be taken to secure the seals or closures from becoming projectiles, and to avoid major damage to the supporting framework or structure.

5.5 Free open vents

Where free open vents are provided, there shall be no adverse impact on the compartment's ventilation, or other substation design requirements.

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5.6 Testing and proving of vents

5.6.1 The vent design for each substation will be dependent on the equipment installed and the different shape and size of the building compartments.

5.6.2 Vent system designs shall be either tested or otherwise proven by methods such as calculations. This is based on the wide variety of vent designs and the impracticality of testing each vent.

5.6.3 Vent systems that are designed to fail under overpressure loads shall require the approval of Ausgrid Engineering. For these designs, material properties and actual release pressures can vary, resulting in vents that may not operate as intended by the Designer.

5.6.4 All testing and calculations for proof of vent operation shall be submitted to Ausgrid Engineering for approval prior to detailed design.

5.7 Strengthening for overpressures

5.7.1 Where strengthening is required, additional or supplementary building elements may utilise steel or any other material specifically for strengthening or stiffening the enclosures for overpressure loadings.

5.7.2 The additional building elements for overpressure are intended to support loads which are over and beyond the normal building design loads, and hence they do not need to be fire rated.

5.7.3 Where a fire rating is required for the building compartment, any additional building elements for overpressure that are exposed shall not, during a credible fire, deform in way that adversely affects the main building structure.

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Annexure A: Internal Arc Classification (IAC)

A1 General

A1.1 An uncontrolled arc originating in a compartment of indoor high voltage switchgear will create arc induced overpressure within the vessel which defines that compartment of the switchgear.

A1.2 Where the switchgear has an IAC rating, the purpose of that rating is to control and vent the arc energy and by-products in such a manner as to provide a safe area for operators in the vicinity of the switchgear.

A1.3 Depending on the specific IAC rating, the arc energy and by-products may be either:

- vented into the switchroom which forms the enclosure for the switchgear; or
- collected into and dissipated within an arc chamber which forms part of the switchgear for the purposes of the switchgear IAC rating; or
- collected into and directed through an arc chamber and vented, via the arc chamber, through the switchroom wall to a safe area external to the switchroom. The arc chamber forms part of the switchgear for the purposes of the switchgear IAC rating.