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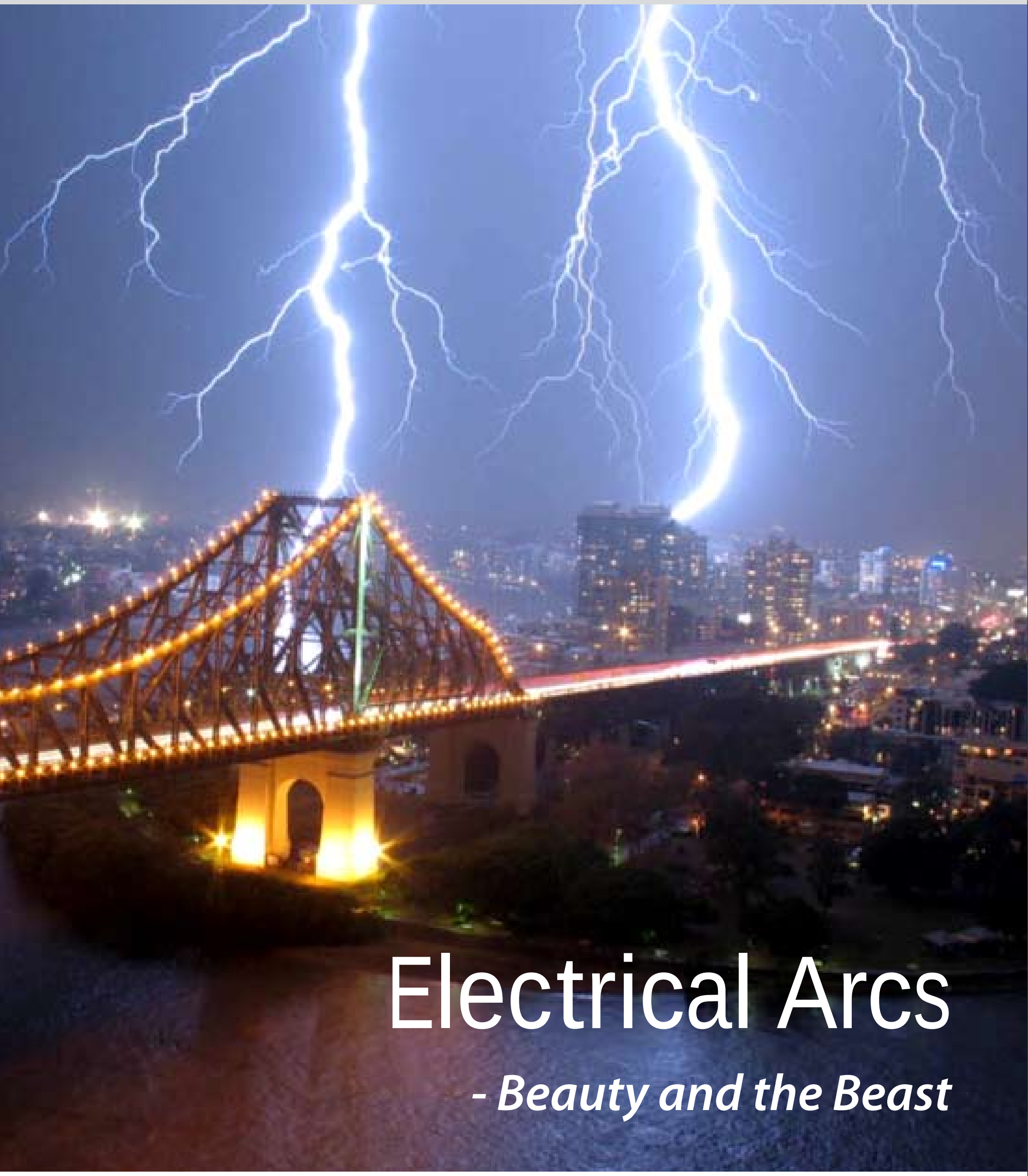
TECHNICAL NEWS

INDUSTRIAL SWITCHGEAR & AUTOMATION SPECIALISTS

NHP



Electrical Arcs

- Beauty and the Beast

FEATURING

An electrical arc occurs when there is an electrical breakdown of a normally non-conductive media, such as air, which produces a plasma discharge resulting in current flow. It is normal for an arc to occur when an electrical circuit is switched. As a consequence, switch gear is designed to contain and quench an arc. However, arcs can also occur in abnormal, circumstances, triggered by a variety of factors such as a breakdown of insulation, conductive items accidentally being placed across live busbar or even animals straying across live conductors. Unfortunately, such occurrences can be quite destructive.

In this issue of TNL, we explore the reasons why arcs occur, and more importantly, identify how we can mitigate the risk of arc creation and possible damage to supply systems.

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An electrical arc is one of the more spectacular phenomena within the world of electricity. Like a bolt of lightning, an arc is both a wondrous and beautiful form in nature, yet extremely powerful and potentially very destructive. Technically, an arc is defined as a luminous discharge of electricity across an insulating medium, usually accompanied by the partial vaporisation of electrodes. Yet arcs are very common, and usually result from any form of electrical switching. The key is to understand how to control and extinguish the "predictable" arcs that are inherent in the normal operation of switchgear, as well as to identify and suppress the unwanted arcs that can accidentally occur within electrical installations.

WHAT IS AN ARC FAULT?

In simple terms, an arc fault occurs when an electrical current flows across an air gap between two conductive surfaces. Some of the most common causes of an arc fault include:

- Loose or corroded connections exposing live conductors
- Damaged, frayed or pinched wires
- Poorly terminated or loose electrical connections
- Damaged plug in appliance cords and equipment
- Mechanical damage to conductors caused by wayward drill bits, nails or screws driven into live cables or bus bars
- Back hoes/earth moving equipment cutting through mains
- Rodents, reptiles or insects entering live switchboards
- Ionized gases released from switchgear clearing short circuits
- Accidental contact between live conductors and test probes or other tools

When an arc is initiated, the live conductors are in close enough proximity to create sparking. The arc itself is caused by uncontrolled conduction of electrical current from phase to phase, or from phase to earth/neutral, and this ionises the surrounding air. When conductive metal is vaporized, a pressure wave develops. A phase to phase, or phase to earth/neutral arc fault can escalate into a three phase arc within a millisecond. The heat energy and intense light produced at this stage is known as the arc flash.

Short circuits and arc faults are extremely dangerous and potentially fatal. The product of arc fault current and voltage generates a massive release of energy that manifests itself in heat and light. The arc temperature can reach four times that of the surface of the sun, causing third degree burns and possible blindness to anyone in close proximity to the arc flash, and potentially igniting other flammable substances. These high temperatures vaporize conductors instantaneously. Copper vapour expands to 67,000 times the volume of solid copper. This pressure wave can often blow open panels and doors with explosive force, releasing the gases into the atmosphere and potentially exposing the remaining live conductors. These gases help sustain the arc and the duration of the arc is primarily determined by the time it takes for over current protective devices to open the circuit. The arc can actually extinguish itself in some instances. However, when a protective device identifies the arc as a "normal" load it will not clear the fault. When this occurs, the arc becomes "unlimited" and can continue to vapourise metal and copper until it literally burns holes in metal panels and propagates fire throughout a facility. Metal is blasted and splattered from the fault location. The shock wave is strong enough to damage anything or anyone within the immediate vicinity.

AN ARC FAULT IS A VERY DESTRUCTIVE FORCE

METHODS OF PREVENTING DAMAGE CAUSED BY ARC FAULTS

Now that we can appreciate the potential damage that can be caused by arcs, how do we prevent the arc from occurring? In low voltage installations, most arc damage occurs at the switchboard due to the presence of exposed copper conductors. There is a hierarchy of techniques designed to limit the effect of an arcing fault within a switchboard design:

1. **ACTIVE arc fault suppression:** achieved by using the appropriate settings on protective devices, OR by using optically triggered arc detect technology
2. **PASSIVE arc prevention:** achieved by insulating bus bars or by applying appropriate forms of separation in accordance with AS/NZS3439.1:2002
3. **CONTAINMENT:** constructing an enclosure that can sustain extreme mechanical force and can safely vent the arc away from the "personnel" zone

To understand the various techniques that can be applied to achieve the desired results, it is relevant to refer to AS/NZS3000:2007 and AS/NZS3439.1:2002.

AS/NZS3000:2007 Clause 2.5.5 identifies a number of methods of reducing the risk of arc initiation or reducing the potential damage caused by an arc for boards where the nominal current exceeds 800 A.

Method 1: Apply forms of separation

AS/NZS3000:2007 Clause 2.5.5.2 nominates the Forms of separation that apply to reduce the initiation of an arc within a switchboard.

These Forms are defined by AS/NZS3439.1, as per the extract below, and a minimum of IP2X (touch proof) is required internally. These two requirements limit the possibility that an arc can be initiated but must not be misconstrued as "arc fault containment". Ultimately, if each bus bar phase is individually insulated then it is almost impossible to initiate a phase to phase or phase to earth arc.

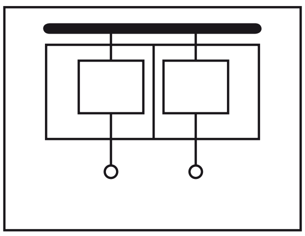
AS/NZS3000 lists the acceptable forms of separation as follows:

- Form 3b, 3bi, 3bh, 3bih
- Form 4a, 4ah, 4aih, 4b, 4bi, 4bh, 4bih

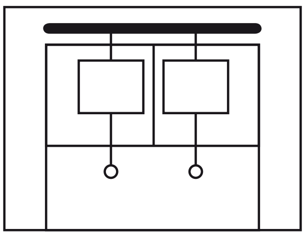
Noting that the (i) determines that the insulation can be used to provide separation, and the (h) allows the housing of the protective switchgear to be used to provide separation. The difference between Form 3 and Form 4 is illustrated in the extract from AS/NZS3439, below.

Form 3

Separation of busbars from the functional units
+
Separation of functional units from one another
+
Separation of terminals from functional units



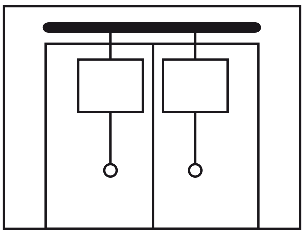
Form 3a: Terminals not separated from busbars



Form 3b: Terminals separated from busbars

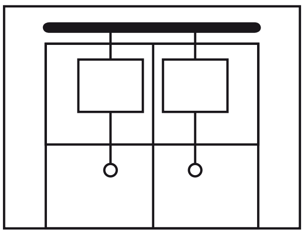
Form 4

Separation of busbars from the functional units and terminals
+
Separation of functional units from one another
+
Separation of terminals associated with functional unit from those of another function



Form 4a: Terminals in same compartment as associated functional unit

IEC 1123/99



Form 4b: Terminals not in same compartment as associated functional unit

At the highest level, Form 3 and Form 4 separation helps to prevent arc initiation. Note that arcs tend to travel away from the line or supply side, and can "jump" to other conductors if ionized gases are present. Furthermore, Form 4a and Form 4b are specifically designed to allow safe access to a termination zone for maintenance purposes, without interrupting other circuits or risking electric shock.

Method 2: Arc fault containment

It must be noted that the form of separation (as described) cannot guarantee the integrity of the assembly in the event of an arcing fault. Annex ZC and ZD in AS/NZS3439.1:2002 details the additional measures that enhance the switchboard's ability to protect against the effects of internal arcing faults Annex ZC focuses on arc prevention techniques, and Annex ZD specifies the testing process and criteria.

Extract from AS/NZS3439.1:2002, Annex ZC, clearly states:

"Specific objectives cover one or more of the following:

(a) To provide means to reduce the probability of the initiation of an internal arcing fault.

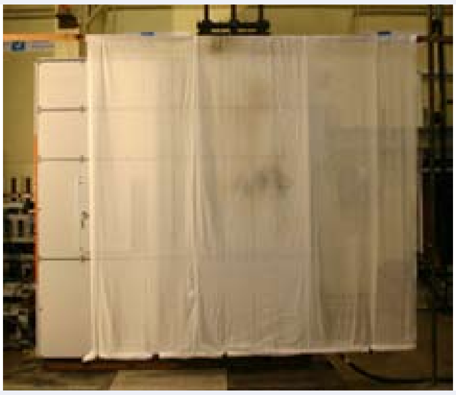
(b) To protect personnel from injury in the event of a fault under the normal operating conditions of the ASSEMBLY.

(c) To limit as far as possible the extent of damage to equipment in the event of a fault."

Annex ZC is quite specific in its description of methods of limiting the ability of an arc to initiate, and thereafter limiting the damage caused by an arc if it does occur. It nominates a combination of any one or more of the following solutions:

1. The use of insulation on all live conductors
2. Arranging functional units with venting to promote rapid extinction of an arc
3. Setting protective devices to interrupt the arc before it can cause damage
4. Using arc detection technology to interrupt the supply
5. Using earth fault detection to interrupt supply

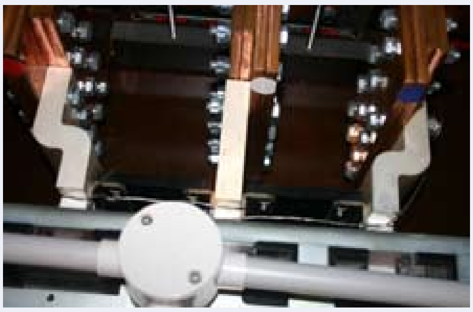
How the switchboard ultimately achieves its aim is captured during the arc fault test as defined in Annex ZD. This is predetermined by the switchboard manufacturer in consultation with the testing authority. The arc fault test is quite specific in its requirement to limit the possibility of personnel injury. A curtain of gauze is placed in front of the switchboard on test. To pass the test, the gauze must not be ignited by an arc and the switchboard must maintain its designed IP rating. No other fittings or fixtures are allowed to be dislodged during the test. Standard load side arc fault tests are specified within the standard. However, it is also possible to construct special tests in consultation with the testing authority, such as line side or unlimited arc fault tests.



THE ARC FAULT TEST IS QUITE SPECIFIC IN ITS REQUIREMENT TO LIMIT THE POSSIBILITY OF PERSONNEL INJURY. A CURTAIN OF GAUZE IS PLACED IN FRONT OF THE SWITCHBOARD ON TEST.

Once the design is established, the test authority needs to initiate the arc within the switchboard. This is an art form in itself. Multiple strands of common fuse wire are fitted across the bus bar within the enclosure, usually at the point closest to the line side within the nominated chamber. This is illustrated in the images below. In some instances, it is possible for the arc to become unstable when the supply current is applied, and it can self extinguish before the arc fault test can take effect. . If this occurs, then the test must be repeated. It is a significant investment to build and test boards for arc faults as defined in AS/NZS3439.

ARC INITIATING FUSE WIRE WRAPPED AROUND BUSBAR CONNECTION PIECE



ARC INITIATING FUSE WIRE ON ACB MAIN TERMINALS

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