Supplement brief to 1VGA672001 – Rev F

UniGear ZVC
Internal Arc Containment, Resistance And Arc Flash Mitigation

Electrical Big Bang

Arc fault is the most catastrophic event that can occur in electrical enclosure. When arc fault occurs, thermal energy up to five times the surface temperature of the sun (20,000°C) is released.

The temperature heats up and expands the air in the enclosure. Pressure inside the enclosure increases and can exceed the explosion limit. If the overpressure is not contained, the enclosure will fail catastrophically; expel hot gases and particles into the surrounding atmosphere. Amount of arc energy released is dependent on the duration of bolted fault before upstream protection system clears the fault.

For extended internal arc fault durations, it is difficult to construct enclosure with sufficient mechanical strength to contain the pressure generated. Most enclosures are designed to withstand 0.5 to 1 second arc proof duration.

Internal Arc

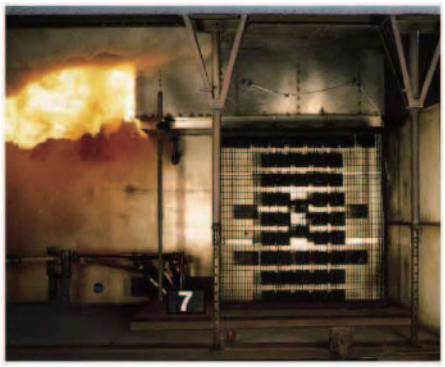
Arc Proof metal-clad switchgear and controlgear is designed and manufactured to prevent the occurrence of internal faults.

If the switchgear and controlgear is installed, operated and maintained following the instructions of the manufacturer, there should be little probability that an internal arc occurs during its entire service life, but it cannot be completely disregarded for hazard risk assessment.

An internal arc fault, which constitutes a hazard, if operators are present, though extremely rare might occur due to reasons such as failure of insulation, contacts due to ageing, overvoltages in system because of switching or lightning surges, pollution due to environmental conditions, mal-operation or insufficient maintenance.

Engineers and site managers have a legislated “duty of care” to make proper equipment selection, operating procedures and service conditions. The effectiveness of the selection, at providing the prescribed level of protection of operators in case of an internal arc, can be verified by type testing.

Designs which have been successfully type tested qualify as IAC classified. This classification is intended to offer a tested level of protection to operators in the vicinity of the equipment in normal operating conditions and with the switchgear and controlgear in normal service position, in the event of internal arc.



Other enhanced measures may be adopted to provide the highest possible level of protection to operators in case of an internal arc. These best practices measures are aimed to limit the external consequences of internal arc;

a) Rapid fault-clearance times initiated by arc detect sensors or by a busbar protection.
b) Application of fault current limiting fuses to limit the let-through current and fault duration.
c) Fast elimination of arc by diverting it to metallic short circuit by means of fast sensing and fast closing devices (arc terminator).
d) Remote control to allow operators to stay outside arc flash boundary.
e) Pressure relief device.
f) All operations behind type tested arc proof doors.

Normal operating conditions means the conditions of metal-clad switchgear and controlgear required to carry out operations such as opening or closing HV switching devices, connecting and disconnecting withdrawable parts, reading of measuring instruments and monitoring equipment, etc. Therefore, if to perform any of such operations any cover has to be removed and/or any door has to be opened, the test shall be carried out with the cover and/or door removed.

Removing or replacing active components (for example, HV fuses or any other removable component) are not considered to be normal operations, neither those required to carry out maintenance works.

The Internal Arc Classification IAC makes allowance for internal overpressure acting on covers, doors, inspection windows, ventilation openings, etc. It also takes into consideration the thermal effects of the arc or its roots on the enclosure and of ejected hot gases and glowing particles, but not damage to internal partition and shutters not being accessible in normal operating conditions.

The Technology

ABB Australia has designed and type tested UniGear ZVC metal-clad switchgear and controlgear to withstand the effects of internal arc faults. International standards IEC 62271-200 and ANSI C37.20.7 guidelines are different but the objectives are the same, i.e. defining minimum safety level for operators. The terms Internal Arc Containment and Arc Resistance are used interchangeably.

Compartments:

A. Busbar compartment
B. Contactor and HRC fuses compartment
C. Cable compartment
D. Low voltage compartment

Main Components

1. Busbars
2. Withdrawable fused contactor's contacts
3. Vacuum contactor
4. HRC fuses
5. Instruments current transformer
6. Earthing switch
7. Auxiliary voltage transformer
8. Cable connection terminals

ZVC deal with internal arcs on two levels:

(i) In the event of an internal arc the panel construction takes control of the situation and keep arc effects zone contained thus provides minimum downtime and maximum operators safety

(ii) Optional "Intelligent MCC" system with IEDs and fast acting arc sensor devices to continuously predict and minimise the damage of arc fault.

The Physical Phenomena

To understand the effects of an internal fault one has to consider the physical process in detail.

1st phase (compression) starts with the arc ignition and ends after reaching the maximum pressure in the corresponding compartment. The enclosed air in the compartment will be heated depending on the arc energy with the pressure relief flaps closed. The pressure in the compartment rises directly proportionally to arc fault current and the length of the arc, and indirectly proportional to the volume of the chamber in which the fault occurs. The duration of the compression phase and the maximum pressure rise depends on arc energy (arc fault current and arc voltage) and the volume of the chamber containing the fault and also other factors such as the place and position of ignition, and also air circulation openings.

2nd phase (expansion) is when maximum pressure peak is reached and the pressure relief system operates to relieve the pressure. In this phase the compressed gas is ejected from the segregated compartment through a special duct

3rd third phase (emission) the remaining air will be heated further and ejected with the pressure relief flaps open. In this stage the remaining air in the compartment will reach the arc temperature. In this stage almost all of the air in the compartment is expelled.

4th and final phase (thermal) in the process now lasts up to the end of arc current duration. In this stage the arc energy is applied completely towards the fixed parts inside the compartment. This results in melting and vaporisation of copper connections, feeders, switching devices, metal parts of the enclosure as well as any plastic and insulating materials. The erosion of material depends mainly on the duration of this period and is also dependent on arc current value, specific thermal characteristic of material used as well as the distance of the switching equipment from the arc source.

The complete process of internal arc inflicts two heavy stresses on the equipment:

- Mechanical stress
  The pressure rise affects the compartment in which the fault occurs in bending of the main and partition walls. The fixing elements as bolts and nuts or the hinges or the fixing of doors or covers or flaps are stressed for strain or shearing. To tackle this problem specially and carefully chosen materials and special bending forms of sheet metal are necessary which will withstand these stresses without undue damage or deformation.
- Thermal stress
  For the whole duration of the fault material will be eroded, vaporised and melted at the arc source and vicinity; thus allowing hot gases to escape outside. It is important that the material should be selected so that they do not continue to burn after the extinction of arc and also that they do not release any toxic or corrosive elements which may increase the indirect damages.

The Design

UniGear ZVC switchgear and controlgear has to manage the internal arc faults and keep the effects of arc confined in the place of occurrence in order to thus provide continuous operation of the remaining functions not associated with the fault.

To fulfil the demand of different standards special measures have to be taken and the switchgear has to be conceived with separate segregated compartments for each function. Special attention has to be given to the design of the doors and the covers which will withstand severe stresses and cannot allow any damaging effects outside.

Care also has to be taken to design the pressure relief flaps of fused contactor and busbar compartments so that when the flap of compartment opens it will not contaminate adjacent compartments. Apart from this, measures have to be taken to avoid any burn through in order to provide ultimate safety in the accessible parts. Moreover the inspection windows require special care in design. Measures also have to be taken not to allow any part or piece of the equipment to fly away during such a fault. Such design has to be available with walkways on front, rear or on sides as required.

UniGear ZVC developed by ABB Australia incorporating these best practices and can fulfil the requirements of IEC and ANSI standards giving the maximum possible safety for the operators.

Arc Flash Mitigation

The most effective means to protect workers from an arc flash hazard is to de-energize the circuit before attempting to work on or near exposed conductors. However, there are some tasks where work must be performed on energized circuits, such as when troubleshooting and testing circuits. International standards recognise these exceptions and require that an electrical hazard analysis be conducted if work is to be performed on or near energized conductors.

Best Practices Engineering Design to reduce Arc Flash Hazard

Consider the following as a means for reducing and optimizing arc flash energy levels:

1. Specify and use arc resistant switchgear and controlgear. Arc resistant switchgear is tested to withstand an internal arcing fault and ensure that operators are not exposed to the arc hazard.

2. Specify and use Insulated Bus. Use of insulated bus for equipment such as motor control centers, switchboards, switchgear, etc. This will reduce the chance that an arc fault may occur. In addition, it increases the probability that an arc fault will self-extinguish.

3. Use Current Limiting Fuses. Current limiting fuses will generally reduce arc flash incident energy levels at downstream locations.

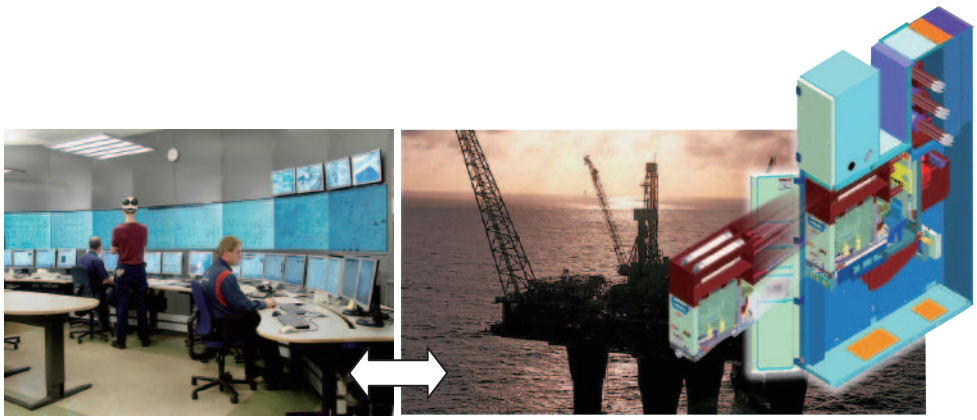
4. Add Current Limiting Fuses. Adding a fuse to an existing power system can decrease fault clearing time. Existing non-fused primary circuit breaker for transformers and motors are locations where this retrofit may apply.

5. Use remote motorised HV isolation racking. The remote motorised HV isolation feature reduces operator risk to arc flash incident by working outside the arc flash boundary when equipment is utilised outside its defined operating range, exposed to pollution or severe environmental conditions, mal-operation or insufficient maintenance.

6. Implement fast speed arc detection and termination scheme. This feature provides fast trip and extinguish time for faults between the main and feeder.

7. Size Protective Devices Low as Possible. Size the current-limiting branch circuit overcurrent protective devices as low as possible. Typically, the lower the ampere rating, the greater the degree of current-limitation provided by the device.

Switchgear Integrated Remote Motorised HV Isolation



Control room operates remote motorised HV isolation. Common applications: remote and unmanned plants.

Non-Integrated after-market motorised HV Isolation hardware

Operator in PPE4 “moonsuit”.

After-market tools

Arc Flash on non IAC type tested switchboard

Protection against Arc Flash. Are We Serious?

We most definitely are!. Unfortunately some people have been subjected to the full forces of an Arc Flash. The outcome is never good. You don't have to ever experience this, but you've got to make the right decisions at the front end.

High fault levels and questionable operating techniques are a DANGEROUS MIX, a waiting time bomb. Can you gamble with safety of operators and plant? Without all the safety requirements being legislated you may regret the outcome. With UniGear ZVC switchgear system, it really is the three inherent design features to ensure maximum safety when you really need it.

1. Stay outside arc flash boundary. Perform remotely – switch power off and isolate HV equipment. Local equipment interfacing when necessary is done with compartment doors closed and fully interlocked.
2. Containment of arc flash. Importance of metal-clad and block construction. All four functional zones are fully segregated to ensure Arc Flash does not transfer to adjacent block or compartments.
3. Arc flash relief system. All blocks are equipped with separate overpressure vents, common arc resistance duct (plenum) and outdoor arc flash relief device venting safely away from operators.

IEC 62271-200 lists five separate criteria for successfully passing an Arc Fault test procedure. If the equipment design does not incorporate the three inherent design features above, the integrity of the original test should be seriously questioned.

The centre of excellent team in Australia can provide calculated incident energy, arc flash boundary and PPE requirements on UniGear ZVC switchboard, following the NFPA 70E and IEEE 1584 standards. The above studies are performed using SKM software.

No. 1 – Stay out of harms way

With UniGear ZVC switchgear system, protection against Arc Flash is maintained because it does not require the operator to interface with the equipment whilst the front door is open. All compartment doors are closed during the following dangerous operating conditions:

- Whilst withdrawing the moving portion from service to isolated position.
- Whilst switching the device OPEN or CLOSED.
- Whilst applying or removing the integral earthing switch.
- Interlocks are also provided between switching device and earthing switch to prevent mal-operation.

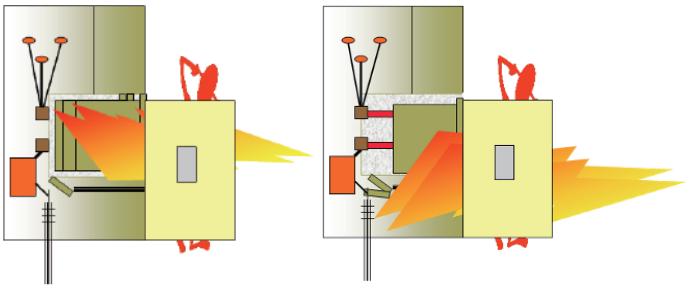
With your switchgear are Compartment Doors required to be open for isolation or insertion procedures, what if something is not quite right?

If your switchgear necessitates being operated with compartment doors open, you cannot rely on being protected by pressure relief vents, they won't operate. With UniGear ZVC switchgear system, we are with you all the way!

Maximum Operator Safety at all times:

- Remote Switching and Isolation of HV equipment in central control room (Outside of arc flash boundary).
- Local Switching and Isolation performed behind closed doors (Doors act as arc proof barrier).

With your switchgear are Compartment Doors required to be open for earthing procedures, what if something is not quite right?



No. 2 – Contain arc flash to that zone

With UniGear ZVC switchgear system, protection against Arc Flash propagation is maintained because all compartments are block segregated and can contain generated arc energy to respective zone. The four zones/blocks are:

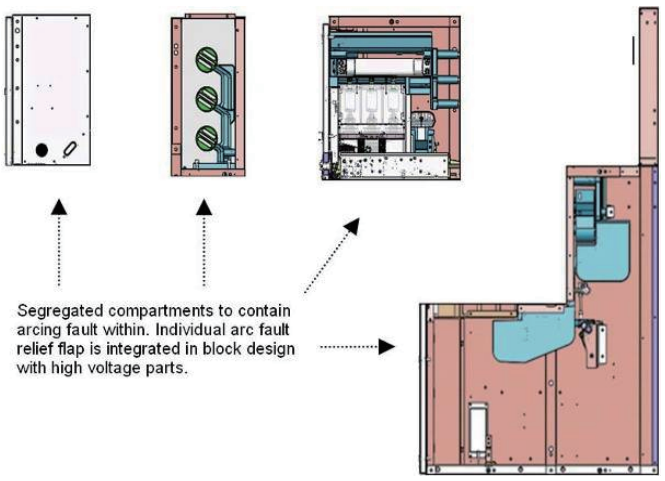
- Main bus compartment.
- Fused contactor compartment.
- Power cable compartment.
- Low voltage compartment.

Are your switchgear panel Compartments segregated to contain an arc flash incident, what if something is not quite right? Are the compartments type tested for arc flash energy, kCal/cm^2?

If your switchgear is of metal-enclosed design or non segregated construction then an arc flash occurrence can propagate within the housing, you cannot rely on being protected by pressure relief vents, they won't operate. With UniGear ZVC switchgear system, we are with you all the way!

Maximum Operator Safety at all times:

- Metal-clad block design to contain arc flash.
- Complete segregation between compartments with individual pressure relief vent.



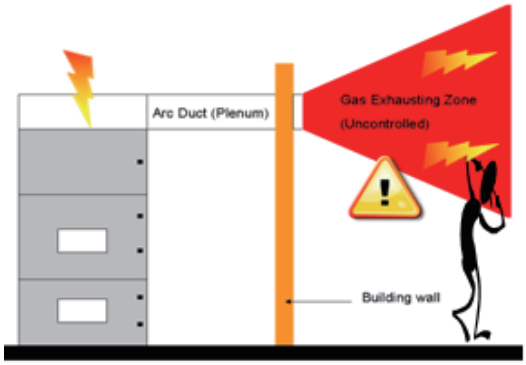
No. 3 – Divert arc flash away to “REALLY” safe area

Arc flash relief system can have a significant safety and financial impact on your business. We understand that safety is the number one priority and arc flash relief system is a specialised field. Our expertise and experience in this field will ensure safe operating limits of your process.

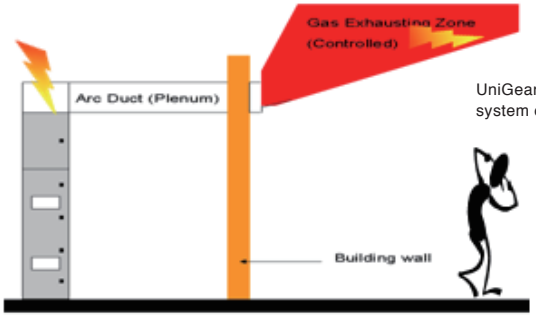
Arc flash energy must be controlled and its hazardous materials contained to ensure safety of operators and equipment. Hazardous materials generated by arc flash are shock waves, hot gasses and burning particles. Therefore correctly designed and installed arc flash relief systems are critical to business performance – plant safety and production availability.

UniGear ZVC standard type tested relief system provides a satisfactory method to deal with arc flash. Sometimes real situations are too complex for the standard method and in these situations calculation modelling can provide valuable insights into the behaviour of the relief system.

UniGear ZVC switchgear system employs a sophisticated relief device design where arcing flash is diverted upwards away from operator, walkway, transformer, other equipment or surrounding building.



Passing the buck design



UniGear ZVC switchgear system design

Executive Summary

The tests show that the metal housing of the UniGear ZVC switchboard is able to protect personnel operating near the switchboard in the case of a fault which evolves as far as striking an internal arc. An internal arc is among the most unlikely of faults, although it can theoretically be caused by various factors, such as:

- Insulation defects due to quality deterioration of the components. As an example the causes can be adverse environmental conditions and a highly polluted atmosphere.
- Overvoltages of atmospheric origin or generated by operation of switchgear element.
- Incorrect operations due to not respecting the procedures or to inadequate training of the personnel in charge of the installation.
- Breakage or tampering of the safety interlocks.
- Overheating of the contact area, due to the presence of corrosive agents or when the connections are not sufficiently tightened.
- Entry of small vermin/insects in the switchgear.
- Material left behind inside the switchboard during maintenance operations.

The characteristics of the UniGear ZVC switchboard notably reduce the incidence of these causes in generating faults, but some of them cannot be eliminated completely. The energy produced by the internal arc causes the following phenomena:

- Increase in the internal pressure
- Increase in temperature
- Visual and acoustic effects
- Mechanical stresses on the switchboard structure
- Melting, decomposition and vaporising of materials

Unless suitably controlled, these can have very serious consequences for the operators, such as wounds (due to the shock wave, flying parts and the doors opening) and burns (due to emission of hot gases).

The test checks that the compartment doors remain closed and that no components are ejected from the switchgear even when subjected to very high pressures, flames or incandescent gases do not cause fires, thereby ensuring the physical safety of the personnel operating near the switchboard. Moreover that no holes are produced in the external, freely accessible parts, of the housing and finally that all the connections to the earthing circuit remain effective to guarantee the safety of personnel who access to the switchboard after the fault.

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