Emax 2 and Arc Guard System™ TVOC-2 mitigate electric arc flash

An electric arc flash is an extremely dangerous and undesirable event in an electrical enclosure. ABB’s Arc Guard System TVOC-2 teamed up with ABB Emax 2 circuit breakers creates the foundation for a very effective arc flash damage mitigation strategy for electrical installations.

With temperatures of up to 20,000 °C and violent overpressure waves, an electric arc flash is an extremely dangerous and undesirable event in an electrical enclosure. Arc flashes are usually caused by human error, a defective connection or failure to put measures in place to exclude the entry of small animals into the electrical enclosure. Much work has been conducted over the years to mitigate the effects of arc flash and ABB has had effective countermeasure products on the market for some decades. The Arc Guard System TVOC-2 is ABB’s latest generation of such a product. By combining TVOC-2 with ABB’s Emax 2 circuit breakers, electrical designers can create a system that greatly diminishes the effects of arc flash. The TVOC-2/Emax 2 combination can be deployed in various ways so that not only are arc flash events contained, but facility downtime is minimized.

Most arcing accidents in electrical equipment are caused by human error (65 percent occur with an operator working on the equipment), faulty connections or the intrusion of animals. Most often, the accident occurs when personnel are performing switchgear maintenance or installation and the cabinet door is open. With the door open, the frontline defense of arc-proofed switchgear design – strong doors – is neutralized.

Fortunately, accidents are relatively rare but when they occur, injuries can be serious or even fatal and damage to equipment extensive. Replacing and repairing the equipment can lead to long downtimes, so an arc flash event can be expensive as well as tragic.

For this reason, it is essential to avoid arc flashes at all costs. If they cannot be avoided, their effects must be minimized. An arc guard system is, therefore, a necessary part of a modern switchgear design. ABB’s Arc Guard TVOC-2 – the new version of a well-established arc guard system that has been protecting people and electrical equipment

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from dangerous electrical arcs for over 35 years – is a device that uses a configuration of optical sensors to detect an electric arc. The TVOC-2 interfaces perfectly with ABB Emax 2 circuit breakers to provide a fast-response active protection system that limits the effects of internal arcing.
Electric arc phenomena
An electric arc is a phenomenon that takes place as a consequence of a discharge. A discharge occurs when the voltage between two points exceeds the insulation strength of the interposed gas. Gases, which are good insulators under normal conditions, may become current conductors as a consequence of a change in their chemical-physical properties. Under suitable conditions, a plasma can be generated that carries the electric current until the opening of the protective device on the supply side.

Besides thermal ionization, there is also electron emission from the cathodic pole of the arc due to a thermionic effect: Ions, formed in the gas by collisions caused by the very high temperature, are accelerated by the electric field. They strike the cathode and release energy, thus causing a localized heating that generates electron emission.

The high fault current that arises during an arcing event causes overheating in the cables or circuit busbars, up to their melting point. As soon as a conductor melts, conditions arise that are similar to those present during a circuit opening: An electric arc is created that lasts either until the protection devices intervene or until the conditions necessary for its stability subside. The arc results in an intense ionization of the ambient gas, a drop of the anodic and cathodic voltage and very high current density in the middle of the column (of the order of 100 A/cm²). There are also very high temperatures (thousands of degrees centigrade) in the middle of the current column and – in low-voltage situations – across a distance of some microns to some centimeters.

An electric arc can easily reach 7,000 to 8,000 °C; 20,000 °C can be reached in some cases.
Effects of the electric arc inside electrical assemblies
The first instants of arc formation inside a cubicle can be divided into four phases:
• Compression phase: In this phase, the air volume occupied by the arc is overheated due to the continuous supply of energy delivered into it by the power supply. Due to convection and radiation, the remaining volume of air inside the cubicle warms up. Initially, temperature and pressure are nonhomogeneous.
• Expansion phase: From the first instants of internal pressure increase, a hole will most likely be formed in the enclosure through which the overheated air begins to flow out. In this phase, the pressure reaches its maximum value and then starts to decrease as hot air egresses the cabinet.
• Emission phase: In this phase, due to the continuous contribution of energy by the arc, nearly all the air is forced out of the enclosure.
• Thermal phase: After the expulsion of the air, the temperature inside the switchgear almost reaches that of the electric arc. In this final phase, which lasts until the arc is quenched, materials that come into contact with the arc undergo erosion, with the associated production of gases, fumes and molten material particles.

Should the electric arc occur in an open configuration, some of these phases will not occur or will have less effect. However, there will still be a pressure wave and a rise in the temperature in the arc zone.

Effects of the electric arc on humans
The effects manifested in the vicinity of an electric arc make it a dangerous place:
• Pressure: It has been estimated that at a distance of 60 cm from an electric arc associated with a 20 kA arcing fault, a person is subject to a force of 225 kg over their body area. The pressure wave may cause permanent injuries to the eardrum.
• Temperature: An electric arc can easily reach 7,000 to 8,000 °C; 20,000 °C can be reached in some cases.
• Sound: Sound levels can reach 160 dB (a shotgun blast is only 130 dB) and can damage hearing.
• Ejecta: High-velocity shrapnel poses an obvious danger, especially to the eyes.
• Radiation: Ultraviolet and infrared radiation can injure the cornea and the retina.
• Toxic gases: The fumes produced by burnt insulating materials and by molten or vaporized metals can be toxic.

In other words, the effects of an arc blast are similar to those of an explosion.

Passive and active protection
There are three assembly design philosophies that ensure operator and installation safety in the event of arcing inside low-voltage (LV) switchgear:
• Assemblies mechanically capable of withstanding the electric arc (passive protection)
• Assemblies equipped with devices limiting the effects of internal arcing (active protection)
• Assemblies equipped with current-limiting circuit breakers

These three solutions (and combinations thereof) have been successfully applied by the main manufacturers of LV switchgear and controlgear assemblies. ABB’s TVOC-2/Emax 2 combination is an active protection approach. There are two main approaches to using active protection to limit the destructive effects of the arc:
Pressure sensors that detect the overpressure wave
Sensors can be used to signal the pressure peak associated with the arc ignition. This signal operates on the supply circuit breaker without waiting for the trip time of the selectivity protection to elapse, which is, necessarily, longer. Delay time is about 10 to 15 ms.

Such a system does not need any electronic processing device since it acts directly on the shunt opening release (SOR) of the supply circuit breaker. Obviously, it is essential that the device is set at a fixed trip threshold. However, it is not easy to define in advance what this threshold should be as the value of overpressure generated by an arc fault inside a switchboard is nondeterministic.

Light detectors
The second possibility is to install detectors that sense the light flux associated with the electric arc phenomenon and that send a tripping signal to the circuit breaker. In this case, the reaction time of the detection is about 1 ms. This principle is the basis of the Arc Guard System TVOC-2.

ABB’s Arc Guard TVOC-2 is a device that uses a configuration of optical sensors to detect an electric arc.

To avoid false tripping due to camera flashes or sunlight, the arc monitor can be combined with a current sensor and set to activate only when an overcurrent is also registered. Further interference immunity is conferred by the use of fiber-optic cables, which are not only fast but impervious to the electromagnetic interference that will certainly accompany an arc fault.

Complementing the TVOC-2 is the Emax 2 circuit breaker. The Emax 2 is rated up to 6,300 A and contains a protection trip relay with an integrated power controller that measures and evaluates energy consumption, managing the loads to maintain or reduce the peak power usage. The circuit breaker is easy to use and its advanced connectivity abilities mean it is simple to integrate into smart grids, buildings and industrial plants. These characteristics mean it is easy to connect it to the TVOC-2 to create a fast-acting arc mitigation partnership.

Working with the circuit breaker
One possible configuration is an Arc Guard System formed by TVOC-2 and Emax 2 with an SOR. However, a much shorter breaking time can be achieved using the capabilities of Ekip Touch/Hi-Touch trip units for the Emax 2 along with an Ekip signaling 2K module.
Ekip Touch/Hi-Touch are a new generation of protection trip units that are easy to program and read. The module can be programmed via its MMI (man-machine interface) or using Ekip Connect software running on a laptop. The Ekip Touch/Hi-Touch trip units measure power and energy with precision and save the most recent alarms, events and measurements in order to prevent faults to the installation and trip effectively when necessary. This arrangement allows the total breaking times to be significantly reduced since they no longer depend on the SOR, but on the opening directly commanded by the electronic unit.

**Examples of manageable operation logic**

A TVOC-2 can individually command three different output contacts (each can have multiple breakers connected). Each of the three contacts can be associated with a particular set of light sensor inputs. This selectivity allows discernment as far as circuit breaker tripping is concerned: Instead of shutting down the entire plant in the event of an arc, only sections adversely impacted by the arc are isolated. For simplification, only five of the 30 possible light sensors are shown in the figures.

**Essential arc protection**

Arc protection systems have become an essential element of electrical cabinet design. Indeed, because they reduce downtime cost and damage, some insurance companies will reduce premiums when they are used. Also, protection against arcing accidents is increasingly becoming enshrined in legislation. For example, the Low Voltage Directive of the European Union stipulates that measures to prevent damage by excessive heat, caused by arc flashes, for example, are to be taken.

Combined with the Emax 2 circuit breaker, the TVOC-2 ensures the safety of personnel even when the cabinet door is open and provides all-round, comprehensive arc protection.