Making Standard Switchgear Arc Resistant With Relays and Sensors

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Making the workplace safer is a goal for most manufacturers. For at least the past 20 years a great deal of effort has been placed on examining arcing faults. Arc fault safety is discussed in NFPA 70E and the incident energy can be calculated using IEEE 1584, but neither of these documents covers the entire issue. Most of the emphasis for arc fault protection is placed on procedures that reduce the risk of starting a fault or what protection is required in the event the fault happens. And to a degree you could argue that even if we do everything possible to prevent an accident, accidents are by definition still going to occur. So what can be done? The solution for new installations is to install equipment that has met the requirements of an arc fault test like IEEE C37.20.7 using either mechanical strength or fast acting electronic sensing and protective devices or a combination of both.

But how do you address an installed base of standard switchgear? Equipment owners are looking for ways to make their installed base of standard equipment perform more favorably in the event of an internal arcing fault without having to replace it with an arc resistant design. Can sensors and fast acting relays and other devices that are designed to limit the fault be used to make standard switchgear perform like arc resistant switchgear? And the answer is, maybe, but only if you do it correctly.

Is this an argument against protective devices? Absolutely not. It is an argument for understanding what these devices do for your equipment and where they may not be able to help. It is unfortunate that there are advertisements stating that these new sensors and protective devices make arc resistant switchgear obsolete. This is a marketing oversimplification that should be clarified by this document.

Here are some of the devices with a brief description of how they work and where there are potential issues if not properly applied. Remember, no form of protection is 100% fail-proof unless you completely de-energize the equipment; and even that won't prevent mechanical injuries.

Protective Relay Schemes

Differential relay schemes provide fast response to a number of different fault conditions; arcing faults being one of them. Any fault inside the protected zone results in an immediate signal to the primary circuit breaker feeding the fault location. Typical operating time using a bus differential is less than 1.5 cycles plus the operating time for the circuit breaker. Using a 3-cycle breaker, the fault will clear in less than 80ms. This means the arc fault current will reach its peak value. The arc will vaporize the solid material it strikes and the expanding gases combined with the radiated heat will overpressure the enclosure. It is very likely there will be significant equipment damage when using standard switchgear. By contrast, the limited duration will significantly lower the incident energy calculation.

Additionally, there are switches that can be used to select instantaneous trip settings with lower current set points. Often called Maintenance Switches, they are manually set to lower current trip points for the instantaneous setting and reduce the incident energy of the fault while an operator has access to the equipment. This method still requires time to detect the current and signal the circuit breaker to trip. The time to trip is approximately the same as is described above; 1.5 cycles plus circuit breaker operating time.

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Sensors

There are numerous devices on the market to “look” for the indications of arcing and signal a device to clear the circuit. The most common technique is to sense light. An arc, even a very small arc, has a large magnitude light signal. Light sensors can detect the presence of an arc or the presence of a light source so there must be some differentiator to confirm arcing activity. Typically, the light sensor will be coordinated with current sensing in the protection relay or in a separate module to provide security of tripping on arc fault. Current monitoring for unexpected current flow is a key point. A protective system using a light sensor was most likely tested at maximum fault current because that is the requirement in the test guides for proving the equipment is arc resistant. This does not take into account how the sensor behaves with the presence of light accompanied by lower levels of current flow. Many light sensing systems use adjustable light sensitivity and adjustable current coordination level. These are typically recommended to be set high such that ambient light sources including direct solar input and full current flow will not cause an inadvertent trip. The correct test point is unexpected current flow.

There are sensors that detect noise. An arcing fault in the insulation system usually begins as insulation breakdown over time, and this can be observed as a partial discharge (PD) event. This means you can detect the initiation of an arcing event with PD sensors focused on a specific set of frequencies associated with arcing. Where PD sensing is used, it may be possible to detect and clear the fault before it escalates into an arcing overpressure event. Arcing detection via PD can be combined with ultrasonic level detections which will be high as the arc starts to evolve through air when it is still a relatively high impedance path.

There are sensors that can be focused on fast rising pressure and trigger a protective device when rapid changes in pressure are detected. Sensing pressure means the fault has already occurred and the protective device is only limiting the fault duration to lower the incident energy.

Sensors that detect heat tend to be slower in response and are not used often in switchgear arc fault protection.

Protective Devices

The sensing devices described above are used to signal a device designed to interrupt or commutate the fault current. There are many different types of protective devices that will perform this function. There are other devices that are self-contained, requiring no external triggering sensor.

The first of which is the current-limiting fuse. The beauty of a current-limiting fuse is that it is self-contained. It is its own sensor and interrupting device. When placed in-line with the incoming supply it will limit the peak let-through current and clear the fault before the internal arcing overpressure event can reach a level that damages the downstream equipment. The current-limiting circuit breaker performs in much the same way except it uses internal current sensors to initiate the trip action.

The down side to these types of devices is their basic ratings. As the voltage rating goes up, the rated continuous current typically goes down, making their use in MV switchgear difficult. These devices are

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well suited for LV switchgear. They will require some type of mechanical protection for a fault occurring on the incoming terminals as those would be unprotected. A typical arrangement would use an arc resistant section to house the fuses or current-limiting circuit breaker and standard switchgear downstream under the protection of those devices. There are other types of fuses that are electronic and operate using an explosive charge. These are very effective in interrupting an arc fault quickly and can be use in MV switchgear. These devices require a separate section of switchgear to house them and like other protective devices, have no protection on their incoming terminals.

Overall, the most common method of stopping an arcing fault after detection is to open the circuit via a circuit breaker. This design typically utilizes a sensing device that determines the presence of an arc fault by one of several methods described earlier and signals the main breaker on the line-up or the up-stream device feeding the circuit.

The same sensing techniques can be coupled with commutating devices that redirect the current flow away from the arc. Most of these devices create a bolted fault on the bus (often called a crowbar device). Some devices transfer the current to a controlled arcing event within a protective chamber. The bolted fault, created by a high speed switch or by a fast-acting circuit breaker, is available on both low-voltage and medium-voltage equipment. The controlled arcing event device is relatively new and has primarily been applied to low-voltage equipment. The fault current flows until an upstream circuit breaker trips the circuit for either design. The upstream breaker must trip within a specified time or the protective device can fail.

There are pluses and minuses to all of these techniques. Using a fast-acting sensor or relay scheme to trip a circuit breaker works very well when the fault is detected before it escalates. After the fault escalates, the overpressure event has occurred and the protective scheme is just limiting the damage. When coupled with arc resistant switchgear, this is very effective protection. The AR switchgear will contain and redirect the overpressure and the protection will clear the fault with limited damage to the equipment.

Using a commutating device can provide a faster response, but there are side effects that must be considered. Commutating to a controlled arc event in a different compartment is an effective way to move the energy away from the equipment fault with minimal impact to the equipment. It is a relatively gentle transfer of the fault current. Other commutating devices provide a transfer from an arcing event to a bolted fault event and wait until back-up protection clears the circuit. This is a very effective method of getting the incident energy away from the operator, but in doing so creates a very harsh condition for the equipment.

A bolted fault on switchgear bus creates both mechanical and thermal stress on the equipment that can do serious damage to the attached components like transformers and motors. When the main bus is faulted, all of the connected components back feed into the bus. Motors become generators and transformer windings will move and expand on their supports. These devices are not necessarily designed to withstand the same short-circuit or short-time levels as the switchgear. Even when the back-up protection is coordinated with the switchgear ratings, the connected equipment could easily be damaged. Should the back-up protection go beyond the equipment ratings, the fault may reoccur. This is especially true for the controlled arcing devices where exceeding the rating for current flow will transfer

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the arc from its original location to the location of the protective device, but now with no back-up protection.

Additionally, faults occurring on the incoming circuit breaker are not covered by any protective device in the switchgear. Incoming protection comes from the upstream protection unless it is an arc resistant enclosure.

So can standard switchgear be adequately protected by sensors and protective devices? Perform a thorough evaluation of the protective device and sensor system to assure it meets the operational requirements for fault protection for both personnel and equipment. Evaluate the incoming terminals for a method of protection. Evaluate the potential issues created by the system such as the effect of a bolted fault on any connected equipment. Consider how the switchgear protective equipment timing and operation coordinates with your normal operation protective scheme. If you can find a satisfactory answer to these issues, then you have a solution for improving arc fault protection in your existing equipment.

Note that these improvements do not allow the equipment to be called arc resistant unless they are tested to IEEE C37.20.7-2017 on the specific equipment type.

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