SIEMENS

Ingenuity for life

Arc-fault mitigation in unit substations

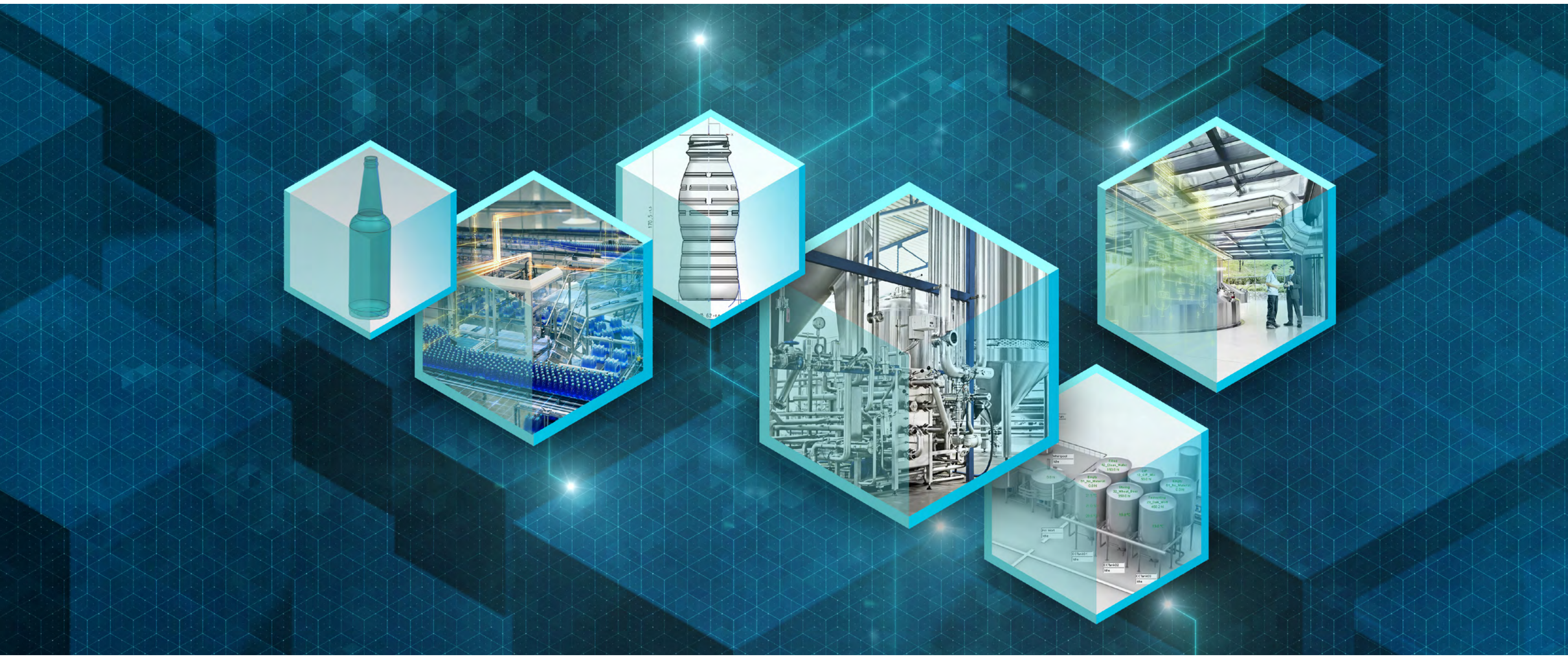
Unit substations present a number of difficulties with respect to reducing the incident energy resulting from an internal arcing event in the low-voltage side of the substation. The commonly considered fault locations are a fault on the load side of a feeder circuit breaker, and a fault on the load side of a main circuit breaker. However, it is important to consider all possible fault locations, including a fault on the line side of the main circuit breaker, or even a fault in the main circuit breaker itself. All of the possible fault locations need to be considered in evaluating alternatives to reduce the energy delivered in the event of an arcing fault.

Users should carefully consider all means to reduce the arc-flash incident energy in substation installations. The advantages of using a primary circuit breaker in unit substations in place of the traditional medium-voltage fused switch readily justify use of a primary circuit breaker.

The preferred approach to reducing incident energy in the event of an arcing fault is to reduce the time needed to remove the fault. Of course, the design of the substation can also be changed to reduce the fault current, but once the substation is installed, this is no longer an option (except for changes in protective settings).

Reduce the time to interrupt the fault current

For a given design, and a given amount of bolted-fault current, the most effective mitigation strategy is to reduce the time to interrupt the fault current.



For a fault in the low-voltage switchgear or switchboard, the time settings of the protective circuit breakers can be reduced, within certain limits. However, in continuous process industrial installations, it is often necessary to use circuit breaker trip devices without an instantaneous function, which restricts the ability to reduce the time to interrupt the fault, and sacrifices a very effective means to reduce arc-flash incident energy.

Shorter operating times

Protective settings can also be changed on modern equipment by the use of a maintenance switch to cause the protective devices to alter their settings to shorter operating times. A maintenance switch can be used when maintenance personnel are in the area of the equipment.

This can be effective, but sacrifices selectivity (protective device settings time coordination) when the maintenance switch is actuated, and depends on the maintenance personnel remembering to use the maintenance switch, and also relies on them to remember to reset the switch when they leave the area. Therefore, the advantage of reduced settings of the protective devices may not always be obtained, and the reduced settings may be left operative after the personnel have left the substation area.

Arc-sensing protective devices

A better choice is to employ arc-sensing protective devices, which typically operate on the detection of the light produced by an arcing fault, and can send an immediate tripping signal to trip the sources of energy to the switchgear or switchboard. This requires that the sources be controlled by electrically-operated circuit breakers, so that they can be tripped by an external signal.

Also, these arc-sensing protective devices often require that substantial current flow accompany the detection of the light emitted by the arcing fault, which demands that current detection be located that can actually sense the fault current.

This can reduce the time to interrupt an arcing fault to a very short time, of the order of 50 ms for low-voltage power circuit breakers, substantially reducing the incident energy produced by the fault.

However, this assumes that the fault is on the load side of the source circuit breakers , e.g., on the load side of a main circuit breaker (and the tie circuit breaker, if there is one). What about a fault that is on the line side of the main circuit breaker, or perhaps in the circuit breaker itself? In this situation, sending a trip command to the main circuit breaker has no effect as the main circuit breaker cannot stop the fault current. In addition, for devices that require the sensing of fault current, the presence of the fault cannot be sensed for a fault on the line side of the current transformers or current sensors.

In that situation, the fault must be removed by the protective device on the primary side of the substation transformer. By far the most common primary protective device is a fuse, either a current-limiting or a noncurrent-limiting fuse, installed in a primary load-interrupter switch unit. Since the fault current on the secondary of a substation transformer is reflected in the primary side of the transformer as a much smaller current, the interrupting time of the primary fuse is generally quite long, so that the incident energy of a secondary fault that lasts until the primary fuse interrupts is quite high.

It has historically been uncommon to have a primary circuit breaker at the substation itself instead of a fused primary switch. However, increasing awareness of the problem of high-incident energy levels in low-voltage switchgear installations for arcing faults on the line side of the main circuit breaker has prompted some users to rethink the practice of using fused primary switches, and to consider the use of a primary circuit breaker instead.

It should be mentioned that some industries have specified low-voltage switchgear without main circuit breakers in order to reduce the purchase cost of the substations. If the substation does not include a main circuit breaker, the desirability of a primary circuit breaker is even more apparent.

Historically, inclusion of a primary circuit breaker connected to the transformer required use of metal-clad switchgear. Metal-clad switchgear is substantially larger than a metal-enclosed interrupter switchgear assembly.

Often, the installation does not have sufficient room available for the installation of metal-clad switchgear, especially when the primary circuit breaker is being installed to replace an existing metal-enclosed interrupter fused switch unit.

SIEBREAK-VCB primary switchgear

Recently, designs of primary metal-enclosed interrupter switchgear have been introduced in which the primary fuses are replaced with a fixed-mounted vacuum circuit breaker, such as the Siemens type SIEBREAK-VCB design. These units require floor space only slightly larger than for traditional fused medium-voltage switches. By including a primary circuit breaker, it becomes possible to initiate tripping of the medium-voltage circuit breaker to remove the secondary fault. This cannot be done with a fused primary load-interrupter switch, as the fault current will almost always be higher than the load-interrupter switch can safety interrupt.

If a primary circuit breaker is installed on the high-voltage side of the substation, control power must be provided for the operation of the circuit breaker. The preferred control power source is a dc battery, which some users prefer to avoid. However, in today's world of communicating devices and remote monitoring and control systems, a dc source is usually available. This is because a major reason for a remote monitoring and control system is to provide information in the event of outages, and if control power is obtained from the ac bus (whether medium voltage or low voltage), the control power would be unavailable when it is most needed.

Scenario	Fault location	Medium-voltage (MV) switching device	Low-voltage (LV) switching device	Device that interrupts arcing fault	Interrupting time (ms)	Incident energy (cal/cm^2)
1	Load side of LV main breaker	MV fused switch	Main breaker	MV fused switch	900 ms	38.3
2	Load side of LV main breaker	MV fused switch	Main breaker	LV main breaker on short-time delay	400 ms	17.0
3	Load side of LV main breaker	MV fused switch	Main breaker	LV main breaker on command from arc-sensing system	35 ms	1.5
4	Load side of LV main breaker	MV fused switch	Main breaker	MV fused switch	900 ms	38.3
5	Load side of LV main breaker	MV circuit breaker	Main breaker	MV circuit breaker phase protection	2,500 ms	106.5
6	Load side of LV main breaker	MV circuit breaker	Main breaker	LV main breaker on short-time delay	400 ms	17.0
7	Load side of LV main breaker	MV circuit breaker	Main breaker	LV main breaker on command from arc-sensing system	35 ms	1.5
8	Load side of LV main breaker	MV circuit breaker	Main breaker	MV circuit breaker on command from arc-sensing system	49 ms	2.1

Table 1

Approximate levels of incident energy for an internal arcing event

What are the approximate levels of incident energy for an internal arcing event in the low-voltage switchgear or switchboard? Let us consider an example of a 2,000 kVA load-center unit substation with primary voltage of 13,800 V, secondary voltage of 480/277 V, and transformer impedance of 5.75 percent. The specific value of incident energy calculated depends on a variety of characteristics as required by the calculation scheme of IEEE Std 1584, so their figures should be considered as examples in the table.

Scenarios 1-4 are for faults where the primary switching device is a fused switch. If the fault is on the load side of the low-voltage main circuit breaker and the fault is interrupted by the primary fuse (scenario 1) the incident energy is 38.3 cal/cm^2. This would be the situation if the protection on the low-voltage main circuit breaker were inoperative, or perhaps set incorrectly. If the protection on the low-voltage main circuit breaker is operational with the trip device having a short-time delay function set for 0.4 s time delay (scenario 2), the incident energy would be cut in half, to 17.0 cal/cm^2. If an arc-sensing system is included in the low-voltage switchgear to send a trip command to the low-voltage main circuit breaker (scenario 3), the incident energy is radically reduced, to 1.5 cal/cm^2. Finally, the worst case is a fault on the line side of the low-voltage main circuit breaker (scenario 4), where the low-voltage main circuit breaker is not able to interrupt the fault, and the incident energy is the extremely high value of 38.3 cal/cm^2, the same as scenario 1.

Scenarios 5-8 show the comparable values for incident energy if the medium-voltage fused switch is replaced with a medium-voltage circuit breaker. Scenario 5 is analogous to scenario 1 except that the overcurrent relay for the medium-voltage circuit breaker typically would allow the fault to exist for a much longer time period, so the incident energy is huge, at 106.5 cal/cm^2.

Scenarios 6 and 7 are identical to scenarios 2 and 3, with the low-voltage main circuit breaker interrupting the fault, so the incident energy values are the same as for scenarios 2 and 3.

The real value of the medium-voltage circuit breaker in reducing the incident energy is seen in scenario 8, where the arc sensing system in the low-voltage switchgear commands the medium-voltage circuit breaker to interrupt the arcing fault and the incident energy is reduced to a relatively mild 2.1 cal/cm^2.

For this example, it is observed the use of a medium-voltage circuit breaker combined with and arc-sensing system in the low-voltage switchgear dramatically reduces the arc-flash incident energy for a fault on the line side of the low-voltage main circuit breaker to about 2 percent of the incident energy of scenario 5.

Also, consider the situation in which there is no low-voltage main circuit breaker, common in certain continuous process industries. In this situation, any arcing fault in the low-voltage switchgear becomes scenario 4 with unacceptable levels of incident energy.

This suggests very strongly that substations that do not have an low-voltage main circuit breaker should always have a medium-voltage circuit breaker and an arc-sensing system in the low-voltage switchgear to send a trip command to the medium-voltage circuit breaker on occurrence of an arcing fault.

Users should carefully consider all means to reduce the arc-flash incident energy in substation installations. The advantages of using a primary circuit breaker in unit substations in place of the traditional medium-voltage fused switch readily justify use of a primary circuit breaker.

Should you have any questions about any of our products, solutions, or services, please contact your local Siemens sales representative for more information.

Published by Siemens Industry, Inc. 2020.

Siemens Industry
7000 Siemens Road
Wendell, North Carolina 27591

For more information, including service or parts, please contact our Customer Support Center. Phone +1 (800) 347-6659

www.usa.siemens.com/techtopics

Order no: SIDS-T40074-00-4AUS

Printed in U.S.A.