

Top Five Switchgear Failure Causes and how to avoid them

Over the years, we have all gained valuable field experiences that provide insight into how and why equipment fails. I have created the following list of top five general causes for switchgear failures and how they can be prevented, based upon my particular experiences. I hope that this information can *spark* creative thinking from our readers to prevent future switchgear failures due to their own unique field observations.

Loose connections

Loose and faulty connections cause an increase of resistance at that localized point. The increased resistance causes increased heat in accordance with Ohm's law, $P = I^2R$. The increase in heat will escalate until complete thermal failure of the connection occurs or the nearby insulation fails resulting in a fault. One major insurance carrier estimates that approximately 25 percent of all electrical failures occur due to loose connections.

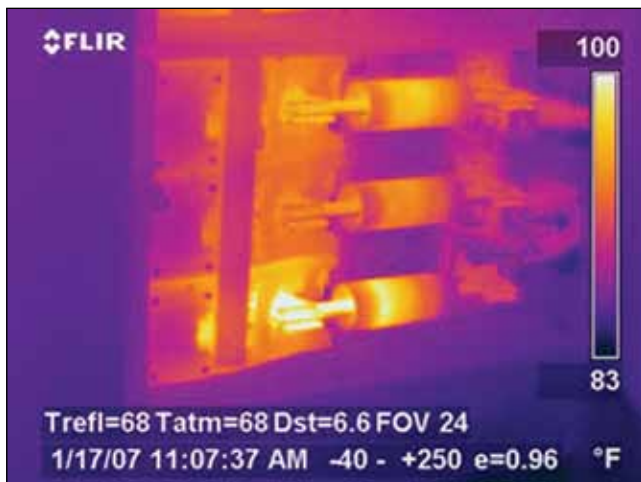


Figure 1 — Hot Fuse Connection

The solution to avoiding these types of failures is to perform regular infrared inspections of all switchgear. Infrared viewing ports should be installed and medium-voltage switchgear should have ports that also pass ultraviolet light so that corona cameras can be used to inspect for corona and surface partial discharge activity. Figure 1 shows a thermal image of a loose switchgear connection that could lead to future failure if not repaired.

Insulation Breakdown

A whole series of articles could be written about these types of problems, but we will focus just on the most common culprits here. Low-voltage insulation is fairly simple and is not subject to the same voltage stresses as medium-



Figure 2 — Unshielded Medium-Voltage Jumper Cable

voltage switchgear insulation. Keeping low-voltage insulation failures in check mostly involves keeping the insulation dry and clean and ensuring clearances are adequate.

Medium-voltage insulation systems are much more complex due to the greater voltage stresses that exist. Areas within the switchgear that are overstressed will initially fail over a small portion of the insulation but will then

escalate over time until complete failure occurs. The most likely areas for these problems to occur are:

- a. Jumper cables – Unshielded jumper cables are used to connect switches to transformers in unit substation design; connect potential transformers, control power transformers, and surge arresters to the bus; and connect transformer coils and taps together. Anytime these cables come in contact with ground, other phases, or even other

types of insulation used to support them, they will likely develop stresses at those points that will lead to future failure (see figure 2).



Figure 3 — Switchgear Bus Support Barrier

- b. Bus – Most switchgear designs use simple insulation barriers to separate compartments and to support the bus. These barriers often have small air gaps between the bus and insulation. The localized voltage stress is great enough to cause the air to break down and this partial breakdown will lead to eventual failure (see figure 3).



Figure 4 — Termination Failure

- c. Cable terminations – Cable terminations are difficult to build properly. These components transition the shielded cable that has nearly perfect inherent voltage stress control to a connection to the bus. Many things can go wrong if great care is not taken during the termination construction, and the proper voltage stress relief details are not realized. Additionally, the portion of the termination nearest to the connection essentially consists of unshielded insulation, so care must be taken to ensure

adequate clearances in that area. All of these locations within the termination can create localized partial insulation breakdown that will lead to failure (see figure 4).

Localized partial insulation failures are known as partial discharges. Fortunately, the partial discharge activity creates detectable signals which are the early warning signs of future complete insulation failure. The solution to preventing medium-voltage switchgear failures begins with utilizing the hand-held partial discharge detector equipped with an ultrasonic sensor to detect surface insulation defects and a transient earth voltage sensor to detect internal insulation defects.

Water

Water intrusion or immersion due to natural disasters or accidents can create instant short circuits, long term insulation damage, and long term metallic component corrosion, among other complications. Medium-voltage switchgear that is exposed to high humidity conditions will absorb moisture, and voltage stresses will attack the hydrophobic insulation surfaces which were designed to inhibit moisture absorption (see figure 5).

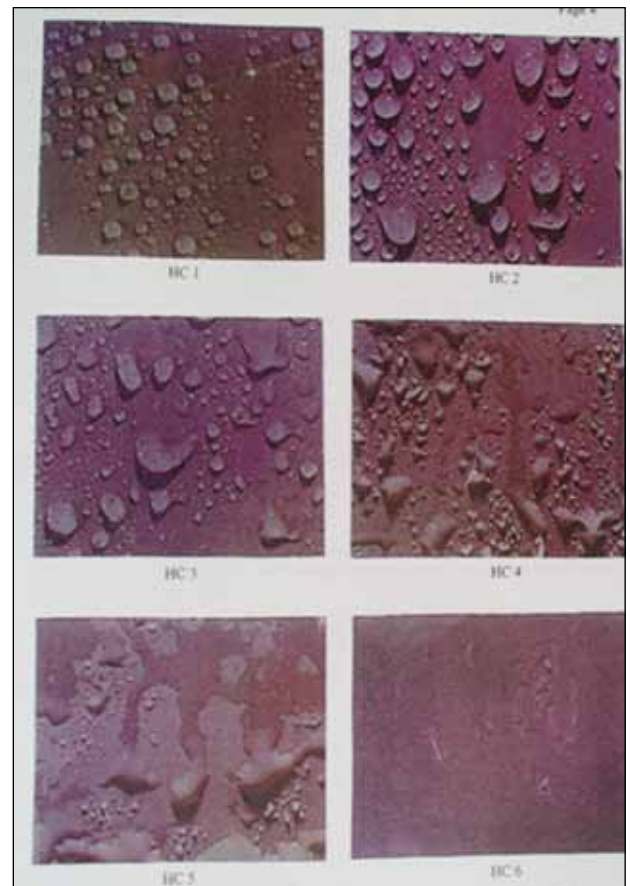


Figure 5 — The upper left photo shows good insulation with hydrophobic surface qualities that progressively worsen until the insulation becomes hydrophilic in the lower right photo due to voltage stresses.

For medium-voltage switchgear, using the partial discharge detector described above will prevent long term moisture-related insulation faults while the infrared camera can detect abnormal heating of corroded connections.

Breaker Racking

Racking in a closed circuit breaker onto an energized bus can quickly cause severe personal injury or death and immediate severe equipment damage (see figure 6). Additionally, the breaker may not always line up properly or may encounter other difficulties as it is being racked, and these problems can cause a sudden severe fault. Unfortunately, the traditional act of breaker racking requires personnel to manually perform this task directly in harm's way.

The solution to this problem is to always make sure that mechanical and electrical interlocks are functional and all breaker and cell components are properly inspected and serviced. To ensure personnel safety, strong consideration should be given to employment of a remote circuit breaker racking device such as shown in figure 6.



Figure 6 — Severe Breaker Damage Caused by Improper Rack-In Operation

Faulty Ground Fault Protection

Unlike the items above, a defective ground fault protective device will not create a fault itself. However, it will not offer protection from an arcing ground fault which is a common failure mode in 480Y/277V solidly-grounded switchgear. These types of faults are very destructive but do not draw high enough currents to trip breakers or cause fuses to open and can persist until catastrophic failure of the switchgear occurs (see figure 7).



Figure 7 — Severe Damage from Arcing Ground Fault

The solution to this problem requires an outage and manually testing the ground fault protection system by current injection. Just as important is to pay close attention to ensure that the equipment is properly installed. Sensor polarities must be tested when applicable and the neutral ground connection must be located in the correct position so that the sensors will detect fault currents properly. A list of recommended test procedures can be found in the NETA ATS and MTS standards.



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