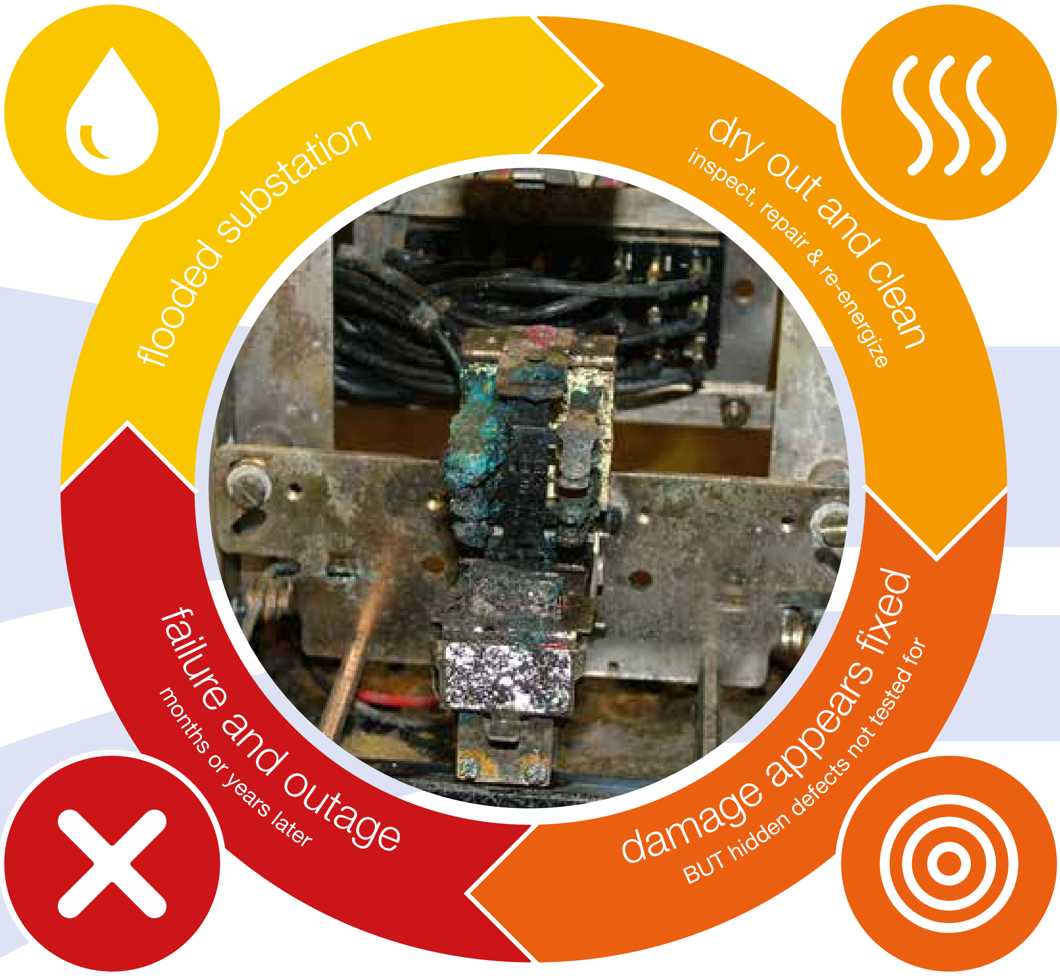

After the flood

How to prevent future failures and outages after the immediate damage is fixed

Averting post-flood failures

Flooding obviously causes immediate failures in many electrical assets, including substations. But even though power can be restored quickly, hidden flaws may have developed which, left undetected, will lead to future problems.

This paper examines the processes that cause flaws to develop in electrical assets after they have been flooded – and the practical steps that can be taken to prevent further failures.

The advice given here is based on EA Technology's wealth of experience dealing with flood damage in power assets across the world, including Hurricane Sandy in October 2012, which caused billions of dollars of damages in the USA and left millions of people without power.

Internal corrosion was visibly developing on this unit, just 24 hours after flooding

General considerations

Water alone can be very harmful to electrical equipment but flood water can be even more harmful as it contains various debris, salts, metals, acids, silt and many other items in solution or suspension. Flooded components will require immediate detailed cleaning followed by dry out. The sooner this can occur, the better. Otherwise the damage will worsen.

Not only is it necessary to dry out the components themselves but it's also necessary to thoroughly dry out the room where the equipment is located or the high humidity conditions can cause the dry components to reabsorb unwanted moisture. Getting the room dry and keeping a low humidity atmosphere in any electrical room is essential.

Let's consider electrical equipment in a simple manner, to address the general considerations for remedial actions due to flood damage. Electrical equipment consists of components that serve simply as conductors or insulators: they are designed to assist or thwart the flow of electrical current. Then we have structural components, which can be strictly for supporting the conductors and insulators, or the insulators themselves can also act as structural components. Finally, we have mechanisms which primarily allow mechanical actions to occur. Each of these component groups should be considered separately. Then we should consider individual groups of equipment separately, in regard to their specific problems.

Conductors

Conductors themselves can generally be addressed in a fairly simple manner by thoroughly cleaning their surfaces and then drying them before any corrosion can take place. Minor surface corrosion can also be carefully removed as long as it's not too deep, but care must be taken to prevent removing any plating. Be sure that the room remains dry or the corrosion can come back. Deeper damage will require disassembly and replating.

Interfaces where conductors meet insulators can present greater challenges. These interfaces can hold contaminants in films or sediment deposits, which can cause future corrosion or insulation damage. Greater voltage gradients exist at these interfaces and for medium voltage equipment, these high stress locations are often where partial discharge activity originates. Care must be taken to ensure these areas are cleaned thoroughly and disassembly may be necessary.

Separable connectors used in medium voltage cable system applications are designed to exclude water, so the termination and splice connections should not be damaged. Cable plugs and sockets should be dismantled and inspected to confirm no contamination has occurred within the interface. If no problems are observed, then these components should be reassembled with fresh grease. If problems are found, then these components should be replaced.

Cable and wire require closer consideration. The open ends of the cables can allow moisture entrance and the moisture can wick throughout the entire length of the cable. In some instances the cable can dry out over time and in more severe cases, purging the cables with nitrogen has been successful. This practice has been previously successful for medium voltage cables where insulation moisture levels are much more critical. Another option for medium voltage cables may be to consider utilising a process that injects the cables with a silicon based fluid. This process has the additional advantage of also potentially improving pre-flood cable insulation defects and extending life. The concern for all cables is the potential long term damage due to corrosion from the residue left behind, since cleaning the internal portion of the cable is very difficult or impossible. In many cases, cable replacement may be the best solution.

Switchgear secondary wiring also requires special examination. Experience has shown that low voltage connection terminals that have been immersed in flood water will continue to corrode even after cleaning, especially those with positive polarity. This has been attributed to the effect on the metal by deposits of acidic materials, which were not removed during washing. The reaction between the acid, metal and air together with electrolytic action has resulted in corrosive salts being produced. This reaction will lead to future problems. Contaminants from flood water will likely propagate throughout stranded copper control wiring by capillary action, which can lead to long term copper corrosion and insulation breakdown. Earthing connections should also be cleaned to prevent future corrosion.

Moisture and contamination can cause problems to develop long after immediately apparent flood damage has been fixed.

Insulators

Since flood water is conductive, it can have a very detrimental effect on insulation. Certain types of insulation, such as porcelain, do not absorb water and simple cleaning to remove residue is all that is needed to get them back in service.

Other types of insulation, such as epoxy, may have a natural glossy finish or be coated with an anti-tracking coating to inhibit moisture entrance. Often, visual inspection can provide a good indication of whether or not the insulation likely absorbed water and a basic insulation resistance test often works well to recognize wet insulation. Good success has been achieved using warm dry circulating air to remove insulation moisture while monitoring insulation resistance improvement. Be sure to reference relevant standards on insulation resistance to ensure minimum acceptable test results are reached before energising.

Cellulose insulation which is found in dry type transformers, many control power transformers and many coils absorbs moisture readily but can also be dried out in the same manner as other insulation. However, the contaminants are likely to be left behind throughout the bulk of the insulation and can create partial discharge activity, which will reduce operating lifetime.


Flood-induced corrosion can continue to develop on many components.

Mechanisms

Mechanisms are the heart of all circuit breakers and optimum mechanical performance is essential for safety and system protection. Mechanisms consist of many moving parts, including bearings, pins, rings, cylinders and latches, all operating in concert to provide quick acceleration of the moving contacts.

If mechanisms have not been immersed in flood water, then they should be thoroughly inspected, keeping in mind that a damp room will be very humid and can lead to corrosion problems also. If mechanisms have been immersed, then they will need to be thoroughly cleaned. However, while this may remove the obvious contamination, it is very difficult to remove all residue and there is a strong possibility that the lubrication which is so critical to proper operation, will be left with traces of silt or sediment. Even small amounts of these contaminants will lead to problems. Complete tear down and reassembly will likely be the only possible solution if this occurs and in the longer term it will probably be necessary to replace the mechanism or the complete apparatus itself.

Protective and control relays, whether electronic or electromechanical, will be very likely be damaged by flood water and will need replacing.

The equipment enclosure must also be examined. Metal clad equipment is designed with protective paint coatings for normal environmental conditions but it is not designed to withstand the corrosive nature of flood water. Any structural metals which are part of the electrical equipment assembly should also be thoroughly cleaned and may need to be repainted. This will likely be required on both internal and external surfaces.


The effects of corrosion (top) on a circuit breaker, 26 months after moisture contamination and (bottom) on relay contacts. Damage is clearly leading to failure.

After energising

Getting power restored is a significant accomplishment in the tedious flood recovery process but the next step should be to employ a range of non-invasive testing strategies to ensure the lights remain on.

Immediately after energising, all medium voltage equipment should be checked for the presence of partial discharge activity, utilising ultrasonic sensors to detect surface problems and TEV sensors to detect internal component or apparatus flaws. A PD survey should be conducted weekly for the first month and quarterly for the first year. For more critical assets consideration should be given to installing permanent monitoring equipment.

While PD testing will go a long way towards ensuring insulation integrity, infrared surveys should be conducted to ensure no conductor related problems are occurring. Ideally, the flood restoration crew would have the opportunity to install infrared viewing ports on enclosure panels, to allow regular thermographic inspections to be performed more efficiently and safely.

Circuit breakers should also be checked regularly, using first trip timing instruments and other technologies to ensure proper operation and to exercise the mechanisms.

An experienced technician has a trained eye to quickly spot signs of early anomalies and regular visual inspections should be introduced to determine if corrosion is taking place on all equipment, including secondary wiring, conductors, structural components and enclosures.

One major consequence of electrical equipment flood damage is that the long term asset lifetime will likely be reduced. This factor will require the owner to accelerate his rebuild or replacement investment planning strategy. In some cases, the remaining asset life has been assessed as half that which would have been used prior to the flooding event.

Ongoing measurement, location, recording and analysis of partial discharge activity will help identify post-flood defects that could escalate into failures.

The UltraTEV Locator™ (top) and UltraTEV Monitor™ (bottom) both measure relative humidity, as well as surface and internal discharges.

This paper formed the basis of an article published in the February 2013 edition of the USA's Electrical Construction & Maintenance magazine.

See the published article at:
www.bdb.im/qdg

Join us on Linked In if you would like to share YOUR experience of why switchgear fails and how to prevent it.

Our Experience

EA Technology has been working with electrical asset operators since 1966 to optimise the safety, reliability and performance of their installations. The advice given here is based on our engineers' experience of working with customers in many countries, including the UK and USA.

Global Footprint

We provide products, services and support for customers in 90 countries, through our offices in Australia, China, Europe, Singapore, UAE and USA, together with more than 40 distribution partners.

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