Oil circuit breaker retrofit and switchgear safety solutions

by Richard Blakeley, RPS Switchgear

Oil has been employed as an insulating and arc-extinguishing medium in high voltage switchgear since the earliest switchgear was designed at the end of the 19th century. It has been extensively used in the development of switchgear at both transmission and distribution levels over the past 100 years and generally has a proven record of reliability and performance.

The risks of oil in high voltage switchgear

There are however, significant risks associated with the use of oil in electrical switchgear and these range from environmental to operational to financial and of course not least, safety. It is important to recognise that, because of the energies involved, failure of an oil switch or a circuit breaker to work correctly, particularly under short circuit fault conditions can lead to a catastrophic explosion and subsequent oil fire.

Failures are rare, but where they involve the ignition of oil the results are usually catastrophic. Ignition of the oil often results in a rupture of the switch oil chamber, resulting in the ejection of burning oil and gas clouds, causing death or serious injury to persons and major damage to plant and buildings in the vicinity of the failed equipment.

Sadly, there are too many examples of where the failure of 11 kV oil switchgear has resulted in explosions and oil fires that have caused injury or death to personnel and destroyed entire switch-rooms, often causing significant damage to adjacent plant as in the case illustrated here.

Fig. 1 shows a view of the 11kV substation building and grid transformers ablaze, shortly after the failure of one oil circuit breaker.

Fig. 2 shows a view of the interior of 11 kV switch room showing the damage after the resultant oil fire.

Switchgear of all types and ratings has been manufactured in accordance with British and other international standards for a period in excess of 60 years. As is the case with most equipment manufactured over many decades however, current specifications bear little resemblance to those of the earlier years, particularly reflecting the present day demands for operation, environment and safety.

Accident experience over the past decades has shown that failure usually occurs at, or shortly after, operation or maintenance of the equipment. Human involvement is absolutely key in ensuring safety in substations. Thus, the way switchgear is operated and maintained, its condition and the network configuration at the time of operation, to a large extent, determines whether the equipment will continue to safely perform its duty.

Each country has its own set of laws, regulations and health and safety legislation, but in most countries it is a legal requirement for all owners and operators of electrical equipment to
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risk that elderly oil switchgear brings, it is
likely that there will be initiatives put in
place during the next few years by many
of the regulatory authorities, to ensure
that network owners and operators are
underway with programmes to remove
elderly oil-filled switchgear from electricity
supply networks.

Circuit breaker retrofit
One very effective, proven option for
the replacement of elderly oil-filled
switchgear is to replace the existing oil-
filled circuit breaker trucks with modern
vacuum equivalent units. This process is
generally known as ‘Retrofit’ and, because
only the circuit breaker is changed, the
implementation does not involve any
lengthy outages or work on the high
voltage cables which would be the
case of course if the entire switchboard
was being replaced. The principle of
switchgear retrofit was developed many
years ago and has now become popular
and universally accepted.

The important aspect of retrofit is that it
replaces only the “dynamic” parts of the
switchboard, i.e. the parts that wear out.
RPS Switchgear has been replacing the
Reynolle LMT oil circuit breakers with their
vacuum truck for almost 40 years, with
more than 5000 units in service worldwide.

Retrofit advantages
The advantages of switchgear retrofit as
an asset replacement option are:

- The RPS Retrofit vacuum breaker has
  the same design heritage as the
  original switchgear, which ensures
  that it is a direct replacement for the
  old oil circuit breaker, with all critical
dimensions and operational features
  being the same as the original LMT
  breakers.

- The removal of oil significantly improves
  safety in the substation.

- In most cases only an individual circuit
  outage is required to complete the
  work (busbars remain “live”).

- Less than 1 day per circuit is required
  to complete the work; therefore
  minimal system disruption and minimal
  involvement is required by customers
  site staff.

- Retrofitting can allow the short circuit
  withstand rating of the switchboard
to be increased, (RPS has Type
Certification evidence to support this).

- Retrofitting replaces the oil circuit
  breaker with long life, low maintenance
  unit. Typically maintenance frequencies
  for the new circuit RPS retrofit breakers
  are three times longer than those for
  the old oil circuit breakers.

- The new VCB uses either the existing
  secondary isolating contacts or a
  new higher integrity plug and socket
  connection for the control and auxiliary
  supplies.

- Retrofit is very cost effective compared
  with switchboard replacement, (<25%)
  of the true costs of switchboard
  replacement.

- The design is a complete, fully tested
  assembly, (to 62271-100), which
does not use any recovered or
refurbished parts, all parts are new and
manufactured to the latest standards.

Switchboard safety to modern standards
The retrofit of the oil circuit breaker with
the RPS vacuum unit obviously results in
a significant improvement in operator
safety and business risk, by removing
old oil-filled circuit breakers from the
substation. However there are other
important, (tested), safety enhancements
that we believe are needed and that RPS
can install onto existing LMT switchboards
to bring the old switchgear fixed portions
into compliance with the latest standards
for Internal Arc Safety.

The first and most important of these is to
protect people in front of the switchgear,
which is the essential operational side
of the switchboard. It is the area in the
switch-room where local operations are
conducted as well as the area where most
maintenance work and routine inspection
is undertaken.

Clearly the element of the switchboard
that not only has the biggest influence
on safety at the front of the switchboard,
but also contains the dynamic part is the
circuit breaker compartment.

Retrofitting of an arc-proof front door –
racking and operating behind a closed
door.

As stated above, a very important
operational area for people in the
switch-room is the region in front of the
switchgear: this is where operators spend
more than 95% of their time and where
most accidents have occurred.

More than 10 years ago short circuit
testing was undertaken on existing LM
switchgear to show the consequences of
an internal arc fault in the circuit breaker
chamber, with a vacuum circuit breaker
installed but with the standard cubicle
door. These tests involved creating a
250 MVA arc fault in the VCB chamber for
a 1 s duration.
**APPLICATION**

500 MVA, 1 s internal arc tests on standard LMT switchgear.

These tests were then repeated in early 2010, but at a higher level of 500 MVA for 1 s, to demonstrate what happens with a standard panel at 25 kA fault level. In both cases the results were very dramatic, showing that, even with a VCB installed, an internal arc fault in the breaker compartment results in the breaker cubicle door blowing open allowing the arc explosion to exit the front of the switchboard where an operator would be standing. (see Figs. 4 to 8).

These tests demonstrated that, although oil has been removed from the switchboard, thereby removing the risk of an oil explosion and catastrophic damage, an internal arc fault in the VCB chamber still presents significant danger to personnel in the front of the switchboard.

It has also been recognised that another activity where the operator is potentially exposed is when the breaker is being racked in and out of service, because with the existing switchboard the cubicle door must be open to rack the breaker. Retrofit arc-proof front doors are now available for existing switchboards. These have been tested in accordance with the latest standard, (IEC 62271-200) to protect the operator for an internal arc fault in the circuit breaker chamber for 25 kA for duration of 1 s with roof heights down to 2.8 m.

The arc-proof front door also allows the operator to rack the breaker into and out of service without opening the cubicle door, thereby maintaining safety for the operator during all racking operations. The arc-proof front door also allows the circuit breaker to be inserted into the “Bus bar Earth” position with the cubicle door closed, thereby maintaining the arc withstand ability at the front of the switchboard during this operation. This is not possible with the existing doors.

In addition the existing bus-bar chamber and current transformer chamber covers can be replaced with “pressure relief” covers, allowing these chambers to vent safely to the rear of the switchboard. Removable “blast shields” can be fitted to each end of the existing switchboard to ensure safety at the ends of the switchgear. And a containment and deflector system can be fitted to the top of the switchboard to further ensure safety for the operator at the front and sides of the switchboard should an internal arc-fault occur.

**High speed internal arc protection**

First and foremost, it is important to have strong certified switchgear to withstand the pressures and stresses caused by an internal arc.

With both elderly and new switchboards however, this can be further supplemented to improve safety by the addition of high speed arc protection.

The fast removal of the fault will reduce damage to switchgear and also significantly reduce the repair and return-to-service time following an internal arc event.

**Conclusions**

The increasing risks of ownership of ageing, (oil-filled) switchgear should not be ignored. The quiescent operating regime of most switchgear often makes the assessment of the true condition of the equipment difficult, but to perform its most important functions switchgear must be able to operate under short circuit conditions at the top of its design envelope. The chances of an internal arc failure are thankfully very small, but the consequences of such a failure are disproportionately high due to the energies involved and, as the age of the circuit breaker and its insulation and arc-interrupting systems approach the end of their design life the chances of such a failure will increase.

This editorial concludes that the experiences of designing new switchgear to the latest arc-withstand standard can be successfully applied to existing switchboards to bring them in line with the latest safety requirements. Significant safety improvements can now be made by retrofitting key components to existing oil-filled switchboards to bring them in line with the latest 62271-200 standard for internal arc withstand safety, without having to implement costly switchboard replacement strategies.

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