IMPROVING SAFETY ON AGEING SWITCHGEAR

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Synopses

This paper aims to create awareness of the potential dangers associated with ageing switchgear. The different designs of switchgear installed in South Africa are described together with the potential dangers associated with each design.
The factors that influence the safety of switchgear installations are listed and basic recommendations are made to minimise the dangers on older installations.
A number of options are available to improve the safety of ageing switchgear these are discussed and evaluated against a total replacement of the switchgear with new equipment.
When latest health and safety legislation is considered owners of ageing switchgear cannot afford to ignore the risks associated with the equipment and not take the necessary precautionary steps to minimise this risk.

1 Introduction

In general switchgear has a proven record of reliability and performance failures are rare but, where they occur, the results may be catastrophic. Tanks may burst resulting in the ejection of burning oil or hot gasses, causing death or serious injury to persons and major damage to plant and buildings in the vicinity of the failed equipment.
Accident experience has shown that failure usually occurs at, or shortly after, operation of the equipment. Thus the way switchgear is operated its condition and the circumstances existing in the system at the time of operation to a large extent determines, whether the equipment will safely perform its duty.
Switchgear of all types and ratings has been manufactured in accordance with international standards for a period in excess of 50 years. As with most equipment however, current specifications differ totally from those of earlier years, experience and technical developments have shown the previous specifications to be deficient. Examples of differing requirements between earlier and current standards are those relating to operating mechanisms and operator protection during equipment failure.

The health and safety act of 1993 clearly states that the onus is on the employer to take all reasonable precaution to ensure the safety of personnel working with and in the vicinity of electrical plant and machinery. It is thus critical that ageing installations are evaluated and where necessary precautions are taken to minimise the risk to personnel. This may include fault level increases, performance deformation due to worn parts, insulation degradation and lack of maintenance.

2 Potential problems with ageing switchgear

2.1 Outdated designs

2.1.1 Mechanisms

Four basic designs of mechanism exist, these are, Dependant Manual, Independent Manual, Manual Charged Stored Energy and Motorised Stored Energy mechanisms.
With the dependant manual mechanism which is no longer manufactured, the operator closes or opens the switchgear by moving a lever or handle by hand. Movement of the contacts is totally dependent upon the speed and actions of the person operating the levers/handles. Any hesitancy on the part of the operator is likely to lead to a serious and potentially fatal failure of the switchgear. In addition should a lever/handle be closed onto a system fault, the force needed is significantly greater than when closed with normal system load current. In some cases it may be physically impossible to close the circuit breaker under fault conditions which may lead to failure. Old installed manually dependent switchgear is thus for obvious reasons a high safety risk.

Manually independent mechanisms require manual operation but the speed of the contacts on closing and opening is independent of the operator, for this reason the risk is significantly reduced. There is a slightly higher risk due to the fact that the operator must be present during the operation and experience has shown that failure usually occurs during operation. Manually independent mechanisms are still manufactured but are used mainly on isolators.

Switchgear using stored energy mechanisms when fitted with remote electrical closing do not require the operator to be present during the close or open operations, the risk to human life is thus further reduced. Most circuit breakers manufactured currently are of the stored energy type.

2.1.2 Interrupting Medium

Oil circuit breakers have a reputation of reliability and a large portion of all switchgear installed in South Africa uses oil as the interruption medium. Although medium voltage oil circuit breakers are no longer manufactured oil filled ring main units are still popular.

The major risk with oil is that if a failure occurs, the consequences are catastrophic with high risk to plant and personnel in the vicinity of the installation. For this reason and due to the higher maintenance costs of oil circuit breakers, they are no longer manufactured and have been replaced by circuit breakers using SF6 or Vacuum as the interruption medium. See figures 1 and 2.

2.1.3 Internal Arc Fault Rating

The internal arc fault rating was virtually unheard of in South Africa before 1996. Then with safety regulations changing, almost half of all switchgear manufactured currently requires this additional safety feature.
The internal arc fault rating is a feature built into switchgear, which ensures operator safety in the event of switchgear failure. This is achieved by securing all doors and covers and directing dangerous hot gasses away from the front of the switchgear.

2.2 Overstressing of the Switchgear

With continued strengthening of the national power system, the system fault levels at older installations can in some cases now exceed the fault rating of the switchgear.
The switchgear then becomes overstressed during fault conditions and the risk of failure is increased.

2.3 Maintenance

When switchgear is maintained correctly according to the manufacturer's guideline and by trained personnel it will give trouble free service for up to thirty years and beyond. The safety risk increases when simple inexpensive periodic maintenance is ignored or performed by inexperienced personnel and when pirate parts are used.

3 Options to Improve Safety on Ageing Switchgear

3.1 Retrofitting

Retrofitting is defined as adding components to equipment on site so as to achieve additional features or ratings. A number of different retrofitting options are available that will improve the safety of ageing switchgear installations.

3.1.1 Retrofitting Oil circuit breakers with SF6 or Vacuum.

Some switchgear manufacturers have designed modern SF6 or Vacuum circuit breakers that are fully interchangeable with the installed oil circuit breaker enclosures. This allows for increased safety and lifetime extension to be achieved at approximately half the cost of a total replacement of the switchboard with new equipment. In the majority of cases additional features such as motorised mechanisms and higher fault ratings can also be achieved by retrofitting a circuit breaker.
Figure 1 shows the catastrophic nature of an oil circuit breaker failure with figure 2 showing an SF6/Vacuum circuit breaker failure for comparison.

3.1.2 Retrofitting remote switching facility.

Accident experience has proven that the majority of switchgear failures occur during or shortly after an operation. It makes sense to operate old switchgear remotely thus ensuring operator safety. Dependant manual operated switchgear can be retrofitted with remote actuator mechanisms. Remote electrical operation facilities can be wired into existing control schemes.

3.1.3 Retrofitting Internal Arc Rating

The ultimate operator protection is achieved when even during equipment failure the safety of an operator in the substation is ensured.
This feature can be fitted on site to some types of switchgear at a relatively low cost. It must however be noted that due to the catastrophic nature of oil circuit breaker failures, this feature cannot be retrofitted to oil switchgear unless the circuit breaker is changed to SF6 or vacuum. Figure 2 shows how hot gasses are directed away from the operator on arc vented switchgear.

3.1.4 Retrofitting Modern Protection

Fast busbar protection such as arc detection systems can clear faults in a fraction of the time of traditional protection schemes thus limiting danger to personnel and damage to equipment.
Figure 3 shows the results of a test done using the arc detection system. The waveforms clearly show that the fault was detected within 5 ms, with the incoming circuit breaker clearing the fault after 35 ms.

Retrofitting of arc detection protection is an affordable option for all types and ratings of switchgear and has been accepted by Eskom as a national standard**.**

3.2 System studies

All organisations with responsibility for switchgear ought to have available a record of their switchgear. Typical information that is required for each item of equipment is; location, manufacturer and type, installation date, voltage and current rating, certified fault rating, type of operating mechanism, date equipment last maintained, type of protection fitted and details of the settings.

If this information is not available it should be prepared as a matter of urgency as it is essential in risk analysis and planned maintenance programs.

The next stage is to calculate the fault level at the terminals of all equipment and compare it with its certified rating. If the fault level exceeds the fault rating, the equipment must be retrofitted or replaced with switchgear having the correct rating. This will ensure that equipment is not overstressed during faults and become a high safety risk. This is fundamental if responsible persons defined in the OHS act are to avoid prosecution in the event of injury to personnel.

The final stage is to perform protection grading to ensure that the switchgear trips when required. This will prevent both nuisance trips and undue stress due to frequent through faults.

3.3 Planned Maintenance programme

All leading switchgear manufacturers detail maintenance guidelines for their switchgear. If switchgear is maintained according to these guidelines it can be expected to last for over forty years.
Unfortunately the importance of maintenance is, in a lot of cases under estimated until it's too late, that is until a fatal or serious failure occurs.
Some of the reasons for none or poor maintenance are, lack of product knowledge, lack of funds and reluctance to give access to equipment. This problem is compounded by current employment trends that are leading to essential skills in switchgear maintenance departments being lost.
Basic maintenance should include, mechanical and electrical operational tests, contact travel tests, resistance of primary circuit tests, cleaning primary insulation and checking substation batteries.

4 Conclusion

Switchgear has a proven record of reliability and performance failures are rare, but there are precautions that should be taken to ensure the safety of personnel working with or in the vicinity of switchgear.
Older types of switchgear have with time been proven to be deficient in some areas. This together with changing system fault levels and poor or no maintenance can lead to high safety risks to personnel in aged switchgear installations.
This risk can be largely eliminated by performing system studies followed by remedial actions such as retrofitting aged installations with modern circuit breakers, high speed protection systems, remote switching or ultimately the Internal Arc Fault feature.

Figure 1: Shown below is the damaged caused by an 11kV, 20kA oil switchgear failure.

Figure 2: Shown below is a SF6 circuit breaker during a 25 kA internal arc fault certification test. Note how all hot gasses are directed away from the front of the switchpanel.

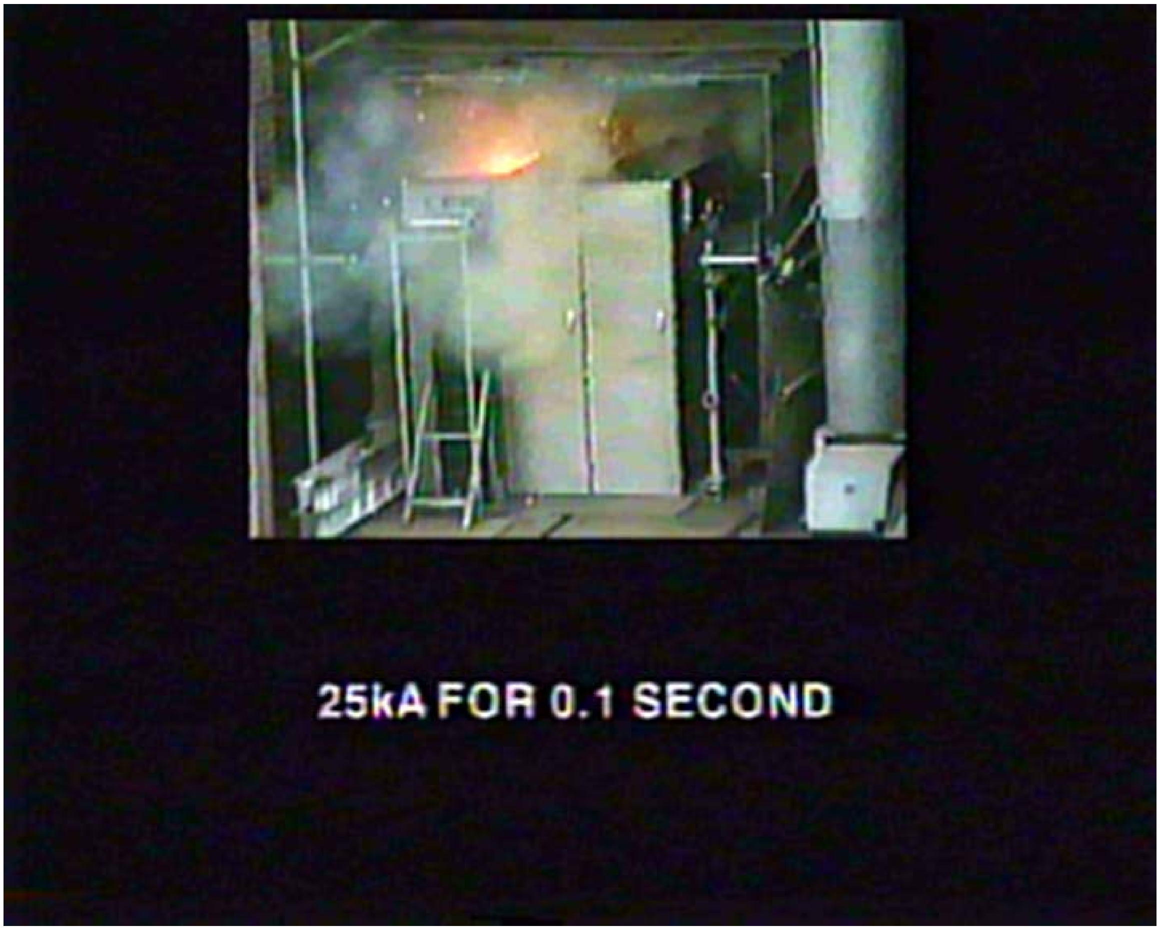
25kA FOR 0.1 SECOND

Figure 3: The traces below show how protection using arc detection can isolate a fault within 30 milliseconds. Traces 1A through to 2C show the fault current and voltage. Trace 4A shows the CT that detected the fault current. Trace 4D shows the status of the relay contact and 4B the status of the incoming circuit breaker main contacts.