

Ageing electrical switchgear

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Introduction

Continued safe operation of electrical equipment is critical for the safety of all mine personnel, particularly electrical personnel working on or near electrical equipment.

Electrical equipment in mines varies in age and for switching devices, the number of operations. This equipment deteriorates due to:

- age
- the number of operations under normal and fault conditions
- the operating temperatures over an extended time
- the amount of contaminants accumulated in and around the equipment.

Quantifying the extent of deterioration can be difficult due in part to inadequate records. Furthermore it is impossible to monitor for deterioration related to possible failure modes that have not been identified.

The design, construction and commissioning of this equipment often occurred many years prior and records are limited or not available. At installation, the 'whole of life' (in particular the 'disposal' timeframe) may not have been identified. To understand the life span of the equipment, the conditions of operation, number of operations, maintenance procedures employed and loading of the equipment should have been recorded. In some cases the electrical switchgear is over 40 years old and much of the maintenance and original equipment manufacturers (OEMs) information is not available.

High Voltage

Failure of oil filled high voltage electrical switching equipment has been a long standing major concern.

In February 2015 in Western Australia, two workers died and two were severely injured when 11kV ring main units exploded, showing the potential results of failure of ageing equipment (photo 1). Various safety bulletins were issued after that incident, while on UK websites, previous warnings had been issued about this type of equipment.

Oil filled 11kV circuit breakers have failed catastrophically causing injury (photo 2). Again, the internet has information on similar equipment failures.

Oil filled outdoor 66kV circuit breakers in switchyards have failed in service sending projectiles a considerable distance, and current and voltage transformers used for metering and protection functions have also failed in service.

Oil filled ring main units with switch fuse tee offs have failed at some mines. There have been internal failures and cable termination fires (photo 3).

Under fault, equipment has suffered greater damage when relays in protection circuits have failed, and backup protection took longer to operate.

Low voltage

It can be difficult to determine the state of repair of low voltage switchgear, typically 415 volt motor control centres (MCC) with multiple individual cells. While OEMs specify the number of operations of contactors and switches, generally including the number of permissible operations at various interrupting currents, actual number of operations in older MCCs can't be determined.

Due to the age of the equipment, replacement parts may no longer be available, so new components have to be sourced, which in itself can lead to mismatches throughout the MCC, and can also compromise the arc fault containment properties of the installation. The form rating of the panels may not be known or may not meet the current site standards.

The integrity of the arc flash containment often cannot be determined and recently mines have reported incidents where internal arc faults have resulted in doors being blown open or off their hinges.

Sometimes changes made to the circuitry over time have been poorly updated on the drawings, which can mislead anyone working on this equipment using incorrect information.

A catastrophic switchgear failure, where the protection trip time is delayed by inaccurate or faulty relays, can result in total destruction of the switchboard, and recovery afterwards can be delayed due to inaccurate drawings.

In addition, cut off cables in the field have resulted in electrical shocks and potential fatalities, and this becomes more relevant when non armoured cables have been used for installations.

Large distribution switchboards (typically in workshops and administration building) may also pose a significant risk of failure due to ageing.

Recommendations

- Isolate the circuit upstream of the unit, prior to accessing oil filled ring main units (photo 4),
- Operate aged circuit breakers from a remote location if possible, otherwise open/close them with power isolated.

Conduct a power system analysis to include:

- Fault level identification
- Protection setting verification
- Touch and step potential calculation
- Arc flash incident energy level determination

Develop or use an evaluation process for the electrical equipment. Use a recognised risk management tool for

- electrical switchgear to calculate the level of risk to, firstly, the safety of personnel and then to business impacts.

Develop a specific maintenance strategy based on the failure modes of ageing equipment, including failures of primary

- protection relays, failure modes of interrupting equipment and use of back up protection.

Quantifying risk with ageing electrical equipment, including from overseas, requires a continuous review of any safety

- information from incidents and from the manufactures' themselves, monitoring safety bulletins from around the world.
- Check the suppliers' website for potential failure notices.

Ensure all drawings are maintained up to date and if the validity is in doubt, conduct a point to point audit of the

- installation.

If attempting to extend the operating life of ageing electrical equipment, ensure any tests used to justify the extension

- are valid and the reliability of such testing is quantified.

Strategies used in attempting to extend the life of MCCs include thoroughly inspecting bus bar systems and replacing

- main incoming circuit breakers and associated protection relays.

- In individual MCC cells where switching devices have operated frequently, change out the entire cell.
- Consider partial discharge analysis, where applicable, to identify potential catastrophic failure in equipment
Where possible, upgrade MCCs through replacement, otherwise replace the incoming circuit breaker and protection relays. Change out individual cells of the MCCs fitted with all new items.
- For electrical equipment over 30 years old, plan to address all the above identified issues.
Ensure current maintenance systems adequately record data to quantify any deterioration (particularly due to ageing)
- of installed equipment.

References

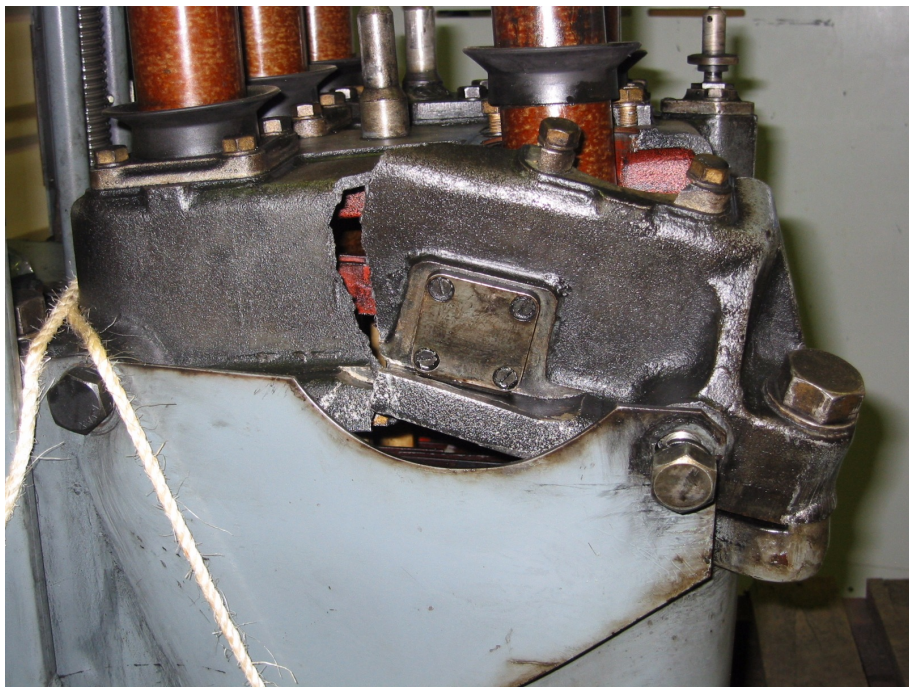
The following alerts and incident report, some relating to ageing equipment and oil filled apparatus, are among items available on <https://www.dnrm.qld.gov.au/mining/safety-and-health/alerts-bulletins-search-tool/alerts-bulletins-search> relating to electrical equipment failure:

- Safety Alert 308 Arc flash and blast when 1000V circuit breaker reset
- Safety Alert 220 Arc flash causes flash burns and equipment damage
- Significant Incident Report 68 Severe burns received from 11kV arc flash explosion
- Safety Alert 149 Oil filled circuit breaker failure
- Safety Alert 82 Failure of an isolation device
- Safety Alert 75 Recent 1000 volt circuit breaker failures
- Safety Alert 20 Look after electrical protection back-up batteries

In Queensland mining safety and health legislation, the *Mining and Quarrying Safety and Health Regulation 2001* includes:

- Section 22 General, which requires that the operator or site senior executive must ensure switchgear at a mine reliably interrupts circuits, under fault conditions, throughout the mine's electrical distribution system; and that each electrical circuit at the mine is protected against overload, short circuit and earth fault under all operating conditions
- Section 100 Selection and design, which requires that the plant must be fit for its intended use, used in its intended work environment, does not fail catastrophically or by common mode or cascade failure; and incorporates appropriate engineering controls to protect the plant operator and other persons

For coal mines, the *Coal Mining Safety and Health Regulation 2001* has mostly similar provisions.







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