SWITCHGEAR OPERATING PERSONNEL SAFETY UPGRADE SOLUTIONS FOR AGED INSTALLED BASE

Carlo GEMME
ABB - Italy
carlo.gemme@it.abb.com

Paola BASSI
ABB - Italy
paola.bassi@it.abb.com

Giorgio MAGNO
ABB - Italy
giorgio.magno@it.abb.com

ABSTRACT

The paper presents novel solutions and risk mitigation strategies to reduce internal arc (IA) and accidental electrical contact injuries hazard and health consequences. Motorized closed-door racking in-out operational mode enables to modernize the installed base equipment and to keep personnel at a safe distance: by an innovative hard-bus retrofill design concept, enabling to install a standard motorized-racking withdrawable new breaker into a wide range of existing panels or by adding on existing panels an external motorization system applicable to roll-in retrofit. Both solutions improve operational procedure safety on installed base, keeping personnel out of arc flash boundaries and reducing personal protection equipment (PPE) requirements.

INTRODUCTION

The current economic environment limits or demands a strong prioritization to investments in the electrical assets upgrade. The decision for a major capital investment for complete switchgear renewal could stay therefore on hold for years. Electric network installed base may already be several decades old and in general with questionable reliability due to original manufacturer spare parts and specialized maintenance non-availability, leading to overall installation obsolescence.

In this scenario safety aspects for 20-40plus year old switchgear are often not up-to-the today-expected state of the art. The switchgear is often not internal arc classified or in any case missing internal arc resistant construction and gas ducts, requiring open door operation for circuit breaker racking in/out procedures, exposing the operation personnel to potential risks.

Specific safety regulations and standards [1, 2] address electrical safety requirements and require the evaluation of the arc flash boundary, incidence energy and personnel to wear appropriate PPE accordingly (fig.1). Such protection requirement, especially in hot season, may be significantly uncomfortable and rise the effort of the operational procedures, inducing different risks due to hurry, lower caution and dehydration.

In many cases the absence of proper exhaust gas ducts, even with IA classified switchgear will cause the release of smoke, limiting visibility, and toxic combustion by-products to the room, making reaching the room escape route difficult.

Figure 1. Open-door circuit breaker racking-in operation

Only a few modernization alternatives [3, 4] can provide an IA upgrade, the main limitation being it requires extensive switchgear modifications and the availability of an original panel to type test and qualify the solution.

OPERATIONAL HAZARD

The process of racking a circuit breaker into and out of the connected position is one of the most frequent exercises that expose an operator to risk, when performing breaker compartment physical inspection, breaker swapping or scheduled maintenance, often at one-two years' time intervals. Older breakers and original panel breaker interfaces, for example shutter-operation mechanism, are more complex and vulnerable to mechanical failures that create safety problems.

Racking in-out operation shall rank as a high-risk site operation. It requires moving original breaker, typically in several hundred-kilogram range, contemporary operating the mechanical links coordinating shutter opening and closing on an energized-busbar switchgear.

Operating a circuit breaker to the connected position with designs requiring to manoeuvre an on-board lever (fig. 1) or by a racket insertion lever (fig. 2) demands the operator to access the breaker compartment with an open door.

Figure 2. Open-door racket lever circuit breaker racking-in operation

Later designs with screw type hand-crank racking method may operate through a closed door but typically with non-IA resistant design. In all cases, the operator stands right in front of the equipment in potentially unsafe proximity.

SAFETY UPGRADE BY MOTORIZED RACKING

Increased focus on operator safety has caused switchgear owners to question the adequacy of prior switchgear designs that require the cell door to be open and/or the operator to be in near proximity to the equipment in order to manually connect or disconnect the primary circuit. A malfunction during this operation has the potential for catastrophic consequences to equipment and personnel.

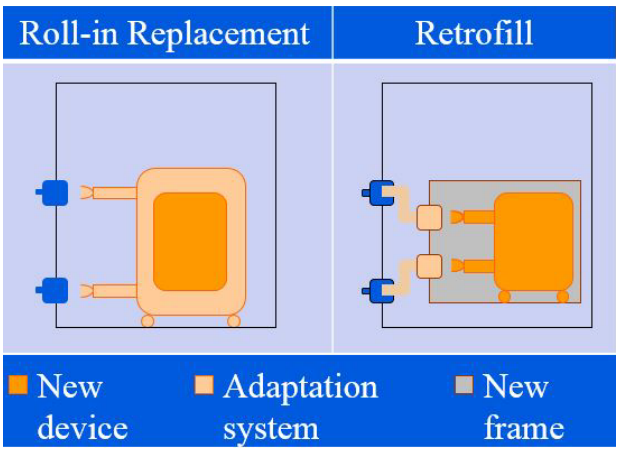

Figure 3. Retrofit solutions for switchgear upgrade

Remote racking provides a safer operating environment for personnel through the proven method of adding distance between the operator and arc flash incident energy at the switchgear site, bringing operation of power circuit breakers to a new level of safety.

INSTALLED BASE APPLICABILITY

Two solutions may apply to existing installed base to move from original manual operation to the new remote racking motorized solution. Those depends on the type of modernization solution adopted in the switchgear, as categorised depending on the specific extent of the switchgear-renewed portion in fig. 3 [4].

Roll-in-Replacement upgrade

Roll-in Replacement (RiR) solutions can replace obsolete circuit breakers by current production versions, mechanically and electrically engineered to adapt to the existing switchgear. It replicates all interfaces to the panel, providing a significant degree of renovation and higher reliability, ensuring the new units are fully interchangeable to the original ones.
Racking motorization can be supplied as a switchgear upgrade together with the RiR breakers. The functional components of fig.4 provide the safety upgrade solution.

Remote console
It provides the controls and position indications to actuate the breaker operation and racking operation. The cable length enables the personnel to be at a safe distance from the breaker for all required switching and racking operations. Only one controller is required for a switchgear line-up.

Portable driver
It actuates the racking operation to/from connected position, providing linear translation for racket type operated breakers or rotational operation for hand-crank breakers. It must provide limit position control and stop in case of emergency or excessive load, detecting a potential jamming condition. Only one driver is required.

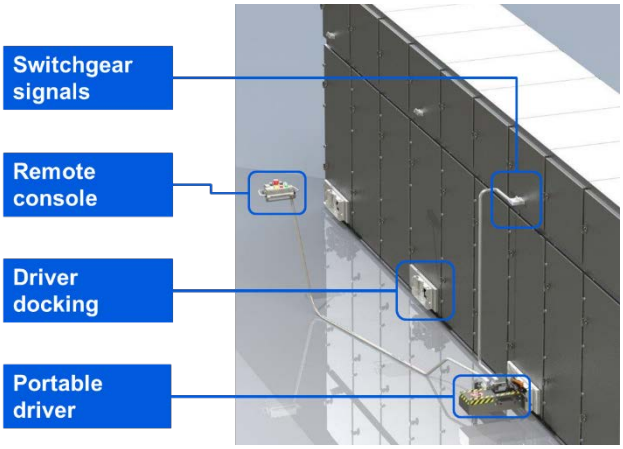

Figure 4. RiR motorization upgrade scheme

Driver docking

Depending on the original racking interface and operational method, a specific docking may be required to hook the portable driver to the unit door.

In particular, for racket type breakers with linear movement the driver provides the force to win initial friction and insertion forces at power disconnects mating/un-mating of a several hundred kilograms breaker and the docking unit must reinforce the door to provide proper resistance to reaction forces.

In some original designs the door, hinges and latching method may not be appropriate to such forces, requiring a new door design.

One driver docking for each motorized breaker compartment of the switchgear line-up is required.

Rotational hand-crank operated breakers may require a simpler interface, often providing only the access hole for the driver shaft if the breaker was open door operated or any modification of the existing door at all. A magnetic driver docking solution enables in that case to make the driver installation extremely simple and the motorization ready-to-go. Only one driver docking is than required for a switchgear line-up.

Switchgear signals

The portable driver controls the breaker connected or disconnected limit position is reached. Optionally a full closed loop control of the breaker racking position may be implemented reading truck operated contacts (TOC) in the switchgear secondary compartment. Additionally power supply of the unit and interlocks operation according to specific design can be controlled through this interface to the switchgear.

Switchgear signal port is optional, in case it is used one for each motorized breaker compartment of the switchgear line-up is required.

Retrofill upgrade

Retrofill is a switchgear modernization process that includes the replacement of the original circuit breaker with a standard withdrawable circuit breaker by installing in the existing switchgear a fixed frame that provides the new circuit breaker interface.

An additional power circuit or adaptation system (fig. 3, fig. 4 components 2 and 3) provides the connection to the original primary disconnect elements.

Such a solution is applicable when the existing switchgear is in serviceable condition. It can greatly upgrade the switchgear safety performances as it replaces a significant number of the original panel parts, like the shutter and shutter operation system and all relevant interlocks in addition to the circuit breaker. It requires a longer bus outage when compared to RiR direct replacement due to the original switchgear cell modifications needed to accept the hosting frame and new circuit breaker.

Retrofill requires a limited knowledge of the original design and applies to any manufacturer's switchgear.

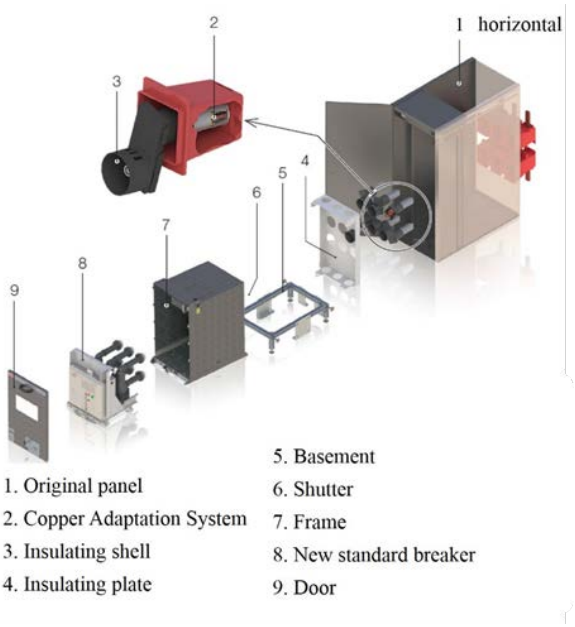

Figure 4. Retrofill components

The retrofill solution presented [4] addresses the modernization needs with an innovative hard-bus retrofill design concept, making it easy to connect the new breaker to a wide range of existing panels and providing a viable solution for the majority of the installed base diversity, in particular for switchgear designs from minor producers no longer on the market.

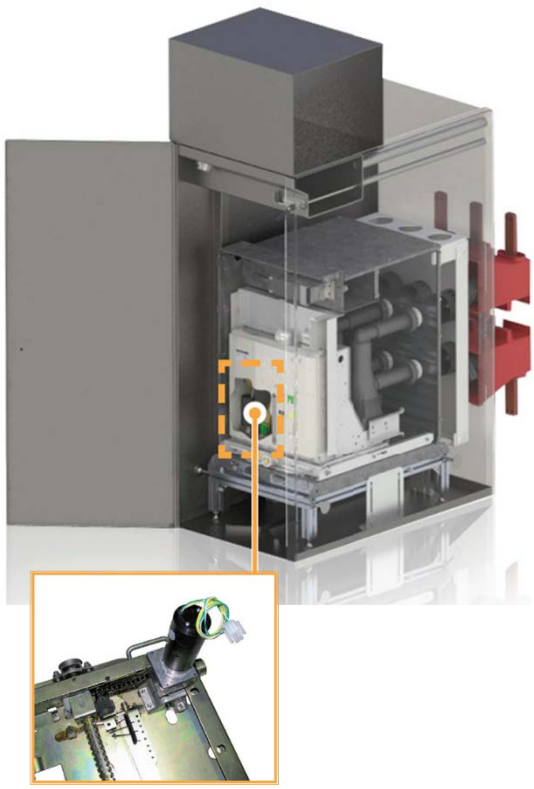

Figure 6. Retrofill motorization upgrade scheme

It converts horizontal drawout and vertical-lift designs obsolete equipment into new horizontal drawout breakers installations.
A completely standard withdrawable switching device fits to the original panel. Referring to fig.6 the new breaker truck hosts a standard truck motor accessory, providing the driver function, and truck connected/disconnected contacts. By using a remote controller personnel can operate the system at a safe distance.

PRACTICAL CASES

Real-life examples show for both the options described in the above chapters the solutions implementation.

Roll-in-Replacement upgrade in a NPP

A nuclear power plant (NPP) operator decided for a modernization of its main 7.2kV, 50kA switchboard.
The original switchboard is not IA resistant and no gas ducts are installed, therefore the adoption of a solution addressing operators safety has been required.
The motorization solution with an external portable driver of the RiR breakers supplied to replace the original air magnetic one from the 80's fulfils the demand.

Figure 7 shows, from left to right,
Original obsolete air-magnetic circuit breaker
The original obsolete air-magnetic circuit breaker is in operation in the switchgear in connected position.
The door is open for the racking out procedure and on the floor the rack interface to the racket operating level is visible for manual operation. The original panel door has two (top and bottom) hinges and one latch, no structural beams.

New Roll-in-Replacement breaker
The new RiR breaker, based on a current production SF6 module is one to one interchangeable to original CB in the switchboard. The breaker has same interface to racket lever (red circled) to enable emergency manual operation.
The panel door has been upgraded to provide proper reaction to driver operating forces, adding several hinges, latches and beams on the door panel.

The new door in closed position.
During normal operation, after breaker racking the portable driver is removed and driver docking in the lower part is closed, providing full metallic segregation. The door is locked in position and only tool-based accessible (IEC 62271-2005.102.2).

Portable driver and driver docking on the panel door
Portable driver is installed in the driver docking on the panel door when racking in/out is required. The remote control is connected to portable driver for the operator to stay at safety distance from the unit while racking. An additional wiring to switchgear auxiliary compartments signal port is connected during operation to provide the signals from truck-operated contacts for redundant position closed-loop control.

The modernization by new circuit breakers roll-in-retrofits, based on production modules, providing availability of spare parts and specialized maintenance, extends the operational life to the system.
The new door and latching upgrade provides a more robust containment system front side in case of internal arc event, even if such solutions are very seldom IA qualified, due to lack of original panel to execute the IA testing.
This gives additional protection to personnel when accessing the switchgear room, for example for preparation of the racking operation.
The motorization solution effectively protects operators during the breaker racking that is the higher probability cause of an IA event. Thanks to the remote control cable extension the operator can stay nearby the rom exit, fully outside the arc flash boundary, therefore with no need of specific PPE. When accessing the breaker compartment for maintenance proper PPE shall be used.

Figure 7. RiR motorization upgrade for a racket type air-magnetic breaker with linear operation

Figure 8. Retrofill motorization upgrade for minimum oil breaker

Retrofill upgrade in a power station

The new retrofill solution is applied for the modernization of a 7.2kV not IA resistant switchboard in a thermal generation power plant from late 70's.
The floor rolling original minimum oil breaker from a local manufacturer acts as the breaker compartment door when in connected position and there are no gas ducts.

Figure 8 shows, from left to right,

Original obsolete minimum-oil circuit breaker

The original obsolete breaker is in disconnected position and therefore outside of the breaker compartment. The original shutter provides a metal segregation in the breaker compartment but this is otherwise accessible when breaker is removed.

New retrofill CB compartment

The retrofill compartment is shown during installation, with metal shatter open for commissioning routine tests. It provides the interface to a current standard production withdrawable vacuum breaker. The remote control interfaces a dedicated signal port (red circled) on auxiliary compartment to enable remote operation.

The new door and breaker in disconnected position.

During normal operation, the station personnel hooks the remote controller to signal port and commands the CB motor truck racking from disconnected position, visible in the door window, to connected position. The new CB frame door provides metal segregation to the breaker compartment in both connected and disconnected position and closed-door racking in-out operational mode to avoid accidental electrical contact injuries. Manual hand-crank operation is possible as an emergency operation while motorized racking in-out as normal breaker operation increases personnel safety for the original non-internal arc resistant switchgear.
The solution enables extensive renewal of all critical components, new breaker, a new racking system, an integrated metallic shutter and a state-of-the-art interlocking system, upgrading all mechanical and electrical interfaces from the new circuit breaker to the original panel.

REFERENCES

[1] 1970-2004, OSHA's regulations, 29 CFR 1910 Occupational Safety and Health Administration, subpart S Electrical

[2] 2015, NFPA 70E, Standard for Electrical Safety in the Workplace

[3] S. Pearce, 2013, "New life for old switchgear", *ABB Review special report* 30-34.

[4] C. Gemme et al, 2015, "Innovative retrofit solution brings safety and reliability upgrade to aged switchgear installed base", *Proceedings CIRED conference*