INNOVATIVE RETROFIT UPGRADES FOR SAFETY AND RELIABILITY IN AGED SWITCHGEAR

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Abstract - The current economic environment the industry sector and Oil&Gas companies in particular, due to low oil prices, are facing, demands for strong investment's prioritization in electrical assets upgrade.
Installed base may be several decades old, no more supported by the original manufacturer and with questionable reliability due to not available original spare parts and overall obsolescence.
Safety aspect in 20-40plus year old switchgear are often not up to current standards.
Circuit breaker retrofit is a cost-effective modernization solution to address needs in low-budget times.
Retrofit can replace phased-out circuit breakers by current production versions, mechanically and electrically engineered to adapt to the existing switchgear, thus providing a noticeable reliability and performances improvement. Spare parts from active production provides a long service life prospective.
Furthermore an innovative hard-bus retrofill solution is discussed, easily connecting the new breaker to a wide range of existing panels, simplifying design and installation process and providing standardization across installed base.
Retrofill enables the switchgear upgrade when additional constraints are in place:
– other parts than the breaker (shutters, interlocks, etc.) need to be replaced;
– original panel design does not allow to meet today required features and Standards
– budget or operation restrictions make complete SWG renewal not-applicable
Finally EniPower installation example in a major refinery plant describes the original circuit breakers replacement procedure while providing process continuous operation and the upgrade in switchgear features from safety of operation, protection and control and interlocks point-of-view.

I. INTRODUCTION

In today's competitive and cost conscious business environment, companies constantly focus on asset optimization through operating and maintenance cost reduction, while demanding increased reliability and utilization performance. Thus electrical distribution assets operators face the challenge of balancing increasing maintenance costs on aging electrical assets to keep those running as safely and reliably as expected.

Medium voltage switchgear is an asset influencing the plant or network overall reliability and therefore it is a key optimization element to focus on.

In the following the different modernization strategy are compared providing the application boundaries, requirement and impact on process.

II. MODERNIZATION STRATEGIES

Modernization strategies for medium voltage switchgear enable to maintain or even upgrade the reliability and expected performances of the electrical assets in time (Fig. 1) [1].

A. Refurbishment

Refurbishment is the solution for customers not in an immediate need for a complete modernization but wishing for a short to medium term life extension of their assets in order to preserve the original level of reliability.

It typically focuses on the assets that are subjected to the highest mechanical-electrical aging effects, e.g. circuit breakers, contactors and switches.

This solution requires returning the equipment to the manufacturer and therefore it depends on the availability of spare units on site to keep the full plant operational while it applies to limited batches on a rotational basis. This will mean a long refurbishment program to bring all installed base to the same reliability level.

When returned to the manufacturer the equipment is disassembled and checked for wear parts which are replaced, while all components are cleaned and reassembled.

The equipment goes through a routine test sequence and it leaves the factory covered by a new warranty period.

Refurbishment is a viable option for active products or products the original manufacturer still provides main parts of the original interrupting and operation mechanism. Life Cycle information on the legacy products is typically available from major brands.

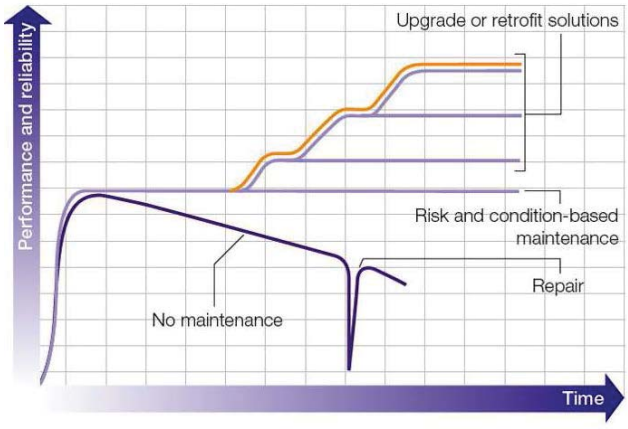

Fig. 1 Reliability decreases with aging equipment

B. Renewal

Switchgear renewal is at the opposite end of the modernization strategy portfolio; it provides the highest benefit in terms of functionality upgrade to state-of-the-art technology and long-term parts availability, aligning the electrical asset to latest international standard.

While technically renewal may be the best option for a long-term reliability, it is often not the chosen solution for a number of reasons:

– highest capital expenditure that may not match the supplied process business plan or operational life expectations [2];

– impact on building, foundations and cable trench due to the size of new switchgear not aligned to the old one;

– physical constraints of the existing site, e.g. accessibility, limit replacement options;

– impact on cables and cable terminations, requiring additional investments, e.g. old cable connections preferred to not disturb;

– requiring the replacement of the complete switchgear line-up and cannot be executed in steps to take in consideration budget or operational priorities;

– long downtime required for dismantling the old switchgear and to install the new one is not process acceptable.

C. Retrofit

Circuit breaker retrofit is a cost-effective switchgear modernization solution to address upgrades needs in low budget times. Retrofit breakers can replace circuit breakers phased out by current production versions, mechanically and electrically engineered to adapt to the existing switchgear. The result is a noticeable improvement on reliability, safety and performances, as the switching devices are the switchgear part mostly subject to electrical and mechanical aging. Retrofit solutions are categorized as shown in Figure 2 depending on the specific extent of the switchgear-renewed portion.

D. Conversion

Conversion consists of replacing the core switching unit while keeping the original truck and connection interface to the switchgear, including primary circuit contact arms and disconnection clusters, shutter operation system and all existing interlocks to the panel.

The main strengths are the possibility to easily engineer the conversion due to the reduced size of state-of-the-art SF6 and vacuum technology switching modules and saving the original interface to the panel, which then does not require a detailed knowledge of the original design.

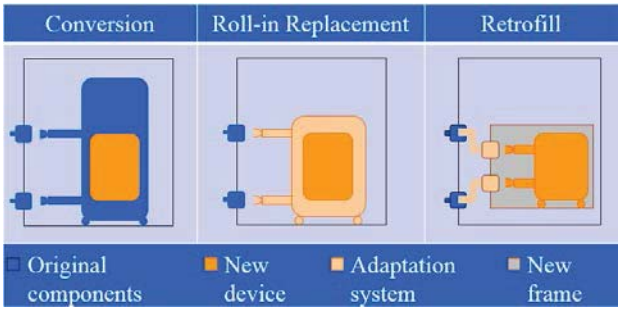

Fig. 2 Retrofit solutions renewal extension

On the backdrop side, the condition of all the original parts not updated can strongly affect the reliability of such a solution. As for refurbishment, conversion applies only to spare units available at site and shall be executed in batches to comply with plant operation.

E. Roll-in Replacement

Roll-in Replacement (RiR) solutions are one-to-one engineered unit exchanges to the original switching device. RiR overcomes the conversion limitations as the complete new unit is manufactured based on a new switching module.

It replicates all interfaces to the panel, providing a higher degree of renovation and higher reliability.

This solution requires a deep knowledge of the original design and interface to panel operation to ensure the new units are interchangeable to the original ones.

There is not limit on the number of units that can be replaced and the full line-up can be updated in one batch or as required by operational priorities.

When a retrofit design is developed, type testing according to the latest standards to verify ratings and ensure safe operation of all expected interlocks is a key requirement.

The original manufacturer can perform testing, as it requires the availability of the original panel or manufacturing drawings. All major manufacturers typically offer RiR solutions for their legacy installed base.

F. Retrofill

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. 2, center) makes the connection to the original bushings on 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.

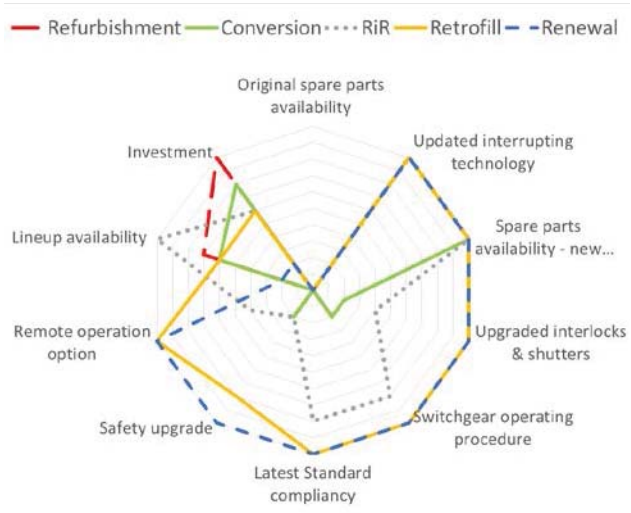

Fig. 3 Comparison scaling of pros/cons of modernization

Retrofill requires a longer bus outage when compared to conversion or RiR direct replacement due to the original switchgear cell modifications needed to accept the hosting frame and new circuit breaker. On the pros side Retrofill requires a limited knowledge of the original design and applies to any manufacturer's switchgear.

G. Safety features

Safety aspects linked to obsolete switching technologies need consideration and can be a driving element when deciding for a modernization. Some safety aspects include:
– fire and explosion hazard: bulk oil and minimum oil CBs used mineral oil as insulation and interruption means; in the event of failure this can greatly increase the consequences of a fire;
– asbestos: air magnetic circuit breakers used such insulating material in the interrupting chambers; while typically stable in operation, it can be released during the circuit breaker arcing-chambers maintenance posing health risk for operators and requiring a specific risk assessment and procedures [3];
– missing interlocks and segregation barriers to high potential parts when opening the switchgear doors and removing the original switching device in obsolete switchgear posing electrocution risks;
– non internal arc (IA) resistant switchgear construction and missing arc gas ducts. Only a few modernization alternatives can provide an IA upgrade, the main limitation being it requires extensive switchgear modifications and the availability of a panel to type test and qualify the solution. Risk mitigation strategies introduced during the modernization process can reduce the IA energy released with active fault detection protections or can provide a safe operating distance to personnel by remote racking and remote operation.

III. INNOVATIVE RETROFILL SOLUTION

The novel retrofill solution presented 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. It simplifies design and installation process by providing a viable solution for the majority of the installed base diversity. In particular retrofill can be the solution for switchgear designs from minor producers no longer on the market, where no drawings or sample ca be easily available.
The adaptation system, supplied in a kit for site installation, allows a completely standard withdrawable switching device to be fitted to the original panel, both for horizontal drawout and vertical lift breaker designs (Fig. 4), thus being able to convert obsolete equipment into new horizontal drawout breakers installations.

A. Design Features

The novel design optimizes the number of standard parts (Fig.4, 4- 9), independently from the original panel design, and supports the design-to-order of the specific parts (Fig4, numbers 2, 3) interfacing directly to original switchgear disconnects to reconstruct the power circuit. Therefore it enables to solidly clamp onto the original disconnects, whatever size and shape, and to provide the new interface accepting the standard circuit breaker.

B. Innovative adaptation system

The core element (patented) of this novel retrofill concept is the adaptation system (Fig. 4, number 2); that provides a reliable connection to the new circuit breaker disconnects. The design of such a part is scaled from a basic parametric design to match the original disconnect size and shape (cylindrical, flat, etc.) on which is clamped during assembly. The original switchgear hot spot becomes a solidly clamped termination, with a higher thermal and mechanical performance. The new bushing and cylindrical connection stud (Fig. 4, number 3) to the new circuit breaker is a standard interface and completely type tested over the applications range.

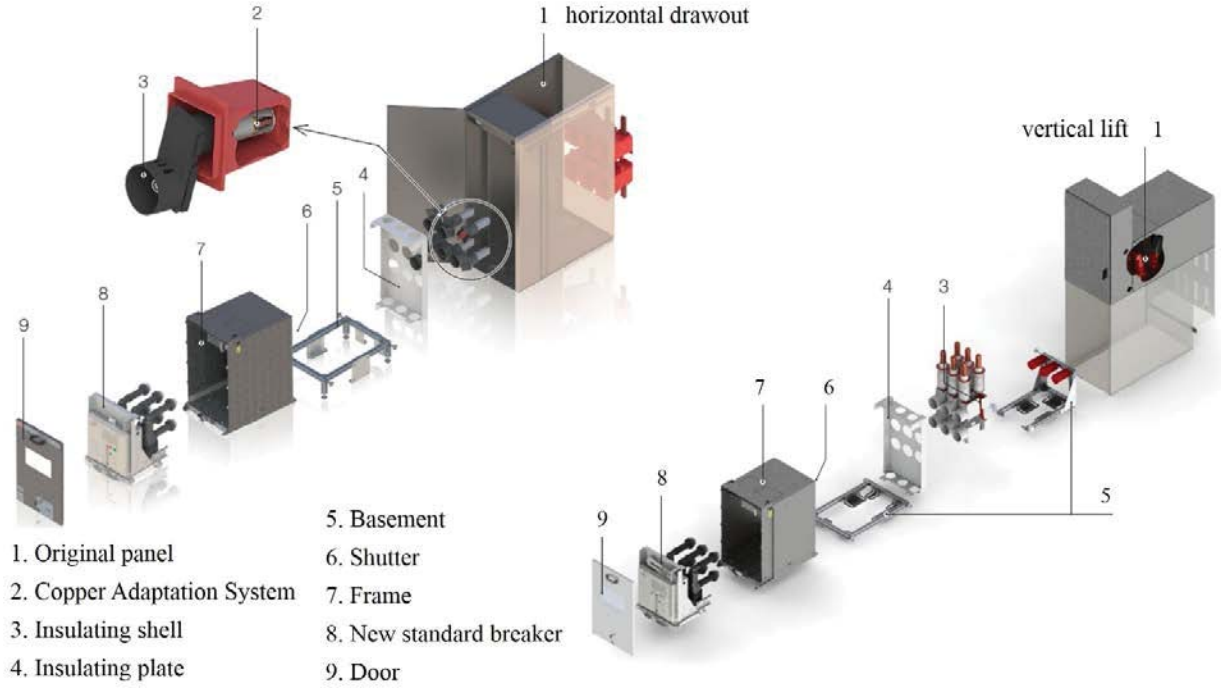

Fig. 4 Innovative retrofill for horizontal drawout and vertical lift original switchgear design components

C. Type tested

A number of common designs for obsolete vertical lift and horizontal drawout panels have been acquired on second-hand market and fully type tested to qualify the retrofill solution according to IEC 62271-200, GB 3906 (China) and ANSI C37.20.2, C39.59. The sum of these different standard requirements ensures the solution provides significant design margins on thermal, dielectric and short circuit dynamic forces performances.
Because the majority of the retrofill solutions are common to different target original switchgear, it is possible to extend power testing type test certificates to new design cases.

D. Installation procedure

This solution balances the need for a modernization with reasonably limited site works and linked outage.
The concept minimises the installation procedure by operating from the original switchgear bushing outward, not requiring rear access. All parts are assembled on site in a sequence starting from the new power circuit and its insulation and only at the end the new frame is positioned inside the original circuit breaker cell, enabling easier access and operation conditions than the old style retrofill that was based on circuit breaker standard compartments.
The concept supports tools for jigging on site the new power circuit and breaker installation and final routine testing to ensure overall solution quality and performances.
Figure 5 shows, from left to right, an obsolete air magnetic circuit breaker in operation, new adaptation system with bushing and basement installed, new frame placing, final unit installed and commissioning and requires 4 working hours per unit.

E. Switchgear revamping option, integral protection and Control upgrade

When the modernization demands extend to the protection and control functions due to age or new requirements, the full switchgear modernization is as easy as the breakers retrofill and a single step achieves both targets.

Current sensors are fully integrated in the frame (Fig.6) with no need for looking at the switchgear arrangement and are ready to be connected to the protection and control device. Sensors bring benefit in project execution with a single type for all applications current range. Sensor's high accuracy and linearity enable the combination of measure and protection classes in one device.
Such solution perfectly fits obsolete circuit breaker with direct action magnetic relays assembled on top of the poles. In such installations there are no CTs in the switchgear and the sensor integration on the frame provide the function without modifications to the power circuit needed for new CTs application.

Fig. 6 Retrofill frame with integrated current sensors

Fig. 5 Retrofill installation sequence

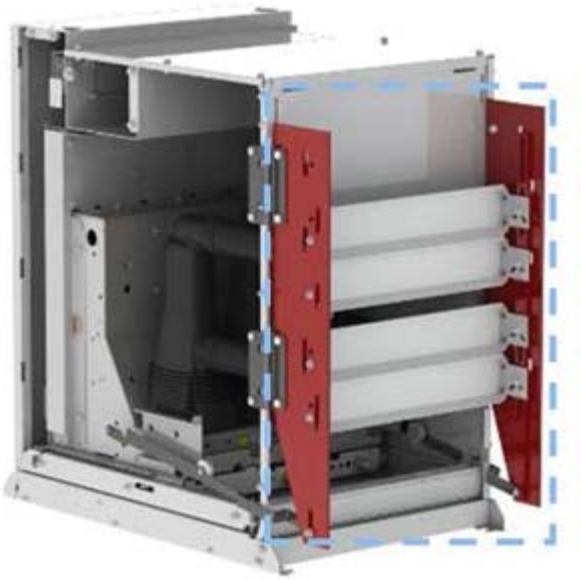

Fig. 7 Retrofill frame ANSI version automatic shutters

F. ANSI version

ANSI application requires additional features and the Retrofill solution can fulfil the demands.
The retrofill frame (Fig. 4, number 7) is equipped with an additional shutter (Fig. 7) that is operated by the Circuit Breaker racking in/out movement, fulfilling IEEE C37 "automatic shutter" requirement.
The solution thus provides both:
- Full metallic segregation during breaker insertion and removal from the frame avoiding accidental electrical-contact injuries.
- Automatically operated insulating shutter during breaker rack-in and out.

It supports also motor operated integral racking, increasing the distance between the operator and any fault incident.
All plastic material components are UL rated (UL 94 rating, equivalent to V0 IEC60695 flammability class).
Finally, the frame enables to host UL approved and ANSI rated magnetic actuated standard vacuum circuit breakers to provide full conformity to such applications.
It can host for the most compelling generator application the mechanical actuated vacuum generator breaker qualified according to dual logo IEC/IEEE 62271-37-013.

G. Retrofill solution benefits

Main benefits provided by the solution are:
– Renewal. It provides new apparatus, a new racking system, an integrated metallic isolating shutter and a state-of-the-art interlocking system, upgrading all mechanical and electrical interfaces from the new circuit breaker to the original panel.
– Integration of protection relay and measuring sensors gives a new life to switchgear with complete equipment revamping.
– Parts availability. The new apparatus embeds standard spare parts with all the benefits in terms of availability and delivery terms. Equipment and spare parts are interchangeable with new switchgear extension panels and additional switchgear in the site.
– Personnel protection increase. The new design overcomes the existing equipment design constraints, providing closed-door racking in-out operational mode to avoid accidental electrical contact injuries (Fig. 8, Fig. 5).
It supports motorized racking in-out circuit breaker operation to further increase personnel safety for the original non-internal arc resistant switchgear.
– Optimised investment. Assets modernization can be included in the maintenance budget (Opex Operating Expenditure) while the long-term strategy can focus on the full switchgear replacement (Capex), porting the standard circuit breaker from the retrofill to new switchgear.

IV. PLANT STANDARDIZATION, A PRACTICAL CASE

In a real-life example common to many process industries demands, a major cement company decided for the electrical network modernization of its main production plant. Due to the growth of the plant over the years, the MT/LV distribution substations added in sequent steps have a number of different manufacturer and technologies, ranging from stationary breakers to floor rolling, from air magnetic to SF6 ones.

The plant electrical operator has applied the novel retrofill solution described, starting from the two incomer circuit breakers in an outdoor shed (Fig. 7), supplying a 5kV ring with a number of MV/LV substations for each production area of the plant.

Figure 8. Retrofill of an air magnetic breaker (original at left)

New standard drawout SF6 breakers, interchangeable to new switchgear installed in the most recent part of the customer network, replaced all the obsolete breakers.
Standardization on one-size-CB-only enables revamping of different original manufactured panels providing the same operational interface and maintenance approach for the original equipment and new panels, as well as the use of spare units throughout the plant and a reduced stock of common spare parts.

V. OIL&GAS REVAMPING APPLICATION

A good example of the Retrofill concept application and its benefit in the Oil&Gas industry is the modernization of a major refinery plant main switchboard, that required the original circuit breakers replacement procedure while providing process continuous operation and the upgrade in switchgear features from safety of operation, protection

and control and interlocks point-of-view. The continuity of operation was possible as the original switchboard has a double busbar and isolation of the circuit breaker compartment by opening the two line disconnectors on the bus-risers enable to operate safely on one panel while the busbar and other feeders are alive and supplying the process.

A. Original Circuit breaker compartment renewal items

The main points addressed from the renewal of the original circuit breaker compartment, in addition to those detailed at chapter N, are shown in Fig. 9 and 10:
– original door (Fig. 9 - Item 1) and racking in procedure with an open door by pushing a several hundreds kg weight air-magnetic CB is replaced by a new door with closed door racking in/out feature. The new vacuum CB is provided with integral motorized racking in/out.
– original insulating shutter system (Fig. 9. Item 2 -PI, partition insulating) is replaced by an integrated metallic shutter (PM, partition metallic) and state-of-the-art interlocking system.
– truck operated (TOC) auxiliary switches (Fig. 9 - Item 3) are replaced by racked in/out auxiliary switches integrated in the CB truck, providing a short mean time to repair (MTTR)
– Circuit breaker auxiliary circuit sockets (Fig. 9 - Item 4) are replaced by new socket integrated in the retrofill frame and matching standard new plug on circuit breaker, providing interlocked auxiliary control circuit function when CB is racked in position according to IEC62271 requirement.
– key based safety and operational logic that were implemented in the original compartment on the earthing switch shaft with different one or two key solutions (Fig. 9 - Item 5) are replaced by new double key integrated in the retrofill frame
– original DC voltage auxiliary supply circuits were not isolated from accidental contacts (Fig. 10 left - Item 6) and in the cell integral revamping have been protected by a polycarbonate insulating shield with tool-based access
– the renewal of the auxiliary compartment door removing all obsolete protection and control equipment, lamps and buttons (Fig. 10 - Item 8) and integration of new multifunctional protection and control processor-based relay (Fig. 10 - Item 9) gives a new life to switchgear with complete equipment revamping.
– new functionality supported from the latest generation relay include advanced communication to SCADA (Fig. 10 - Item 7) by IEC61850 protocol on a digital Ethernet bus to replace the original auxiliary contacts based functionality. Such implementation enables hand-shaking and safety message features providing higher reliability and self-diagnostic of remote control.

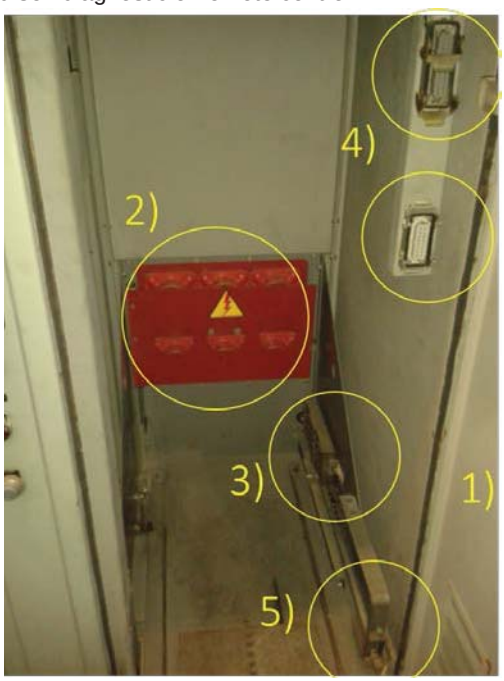

Figure 9. Original CB compartment renewal points


Figure 11. Original switchgear lineup (left) and after retrofill and P&C renewal

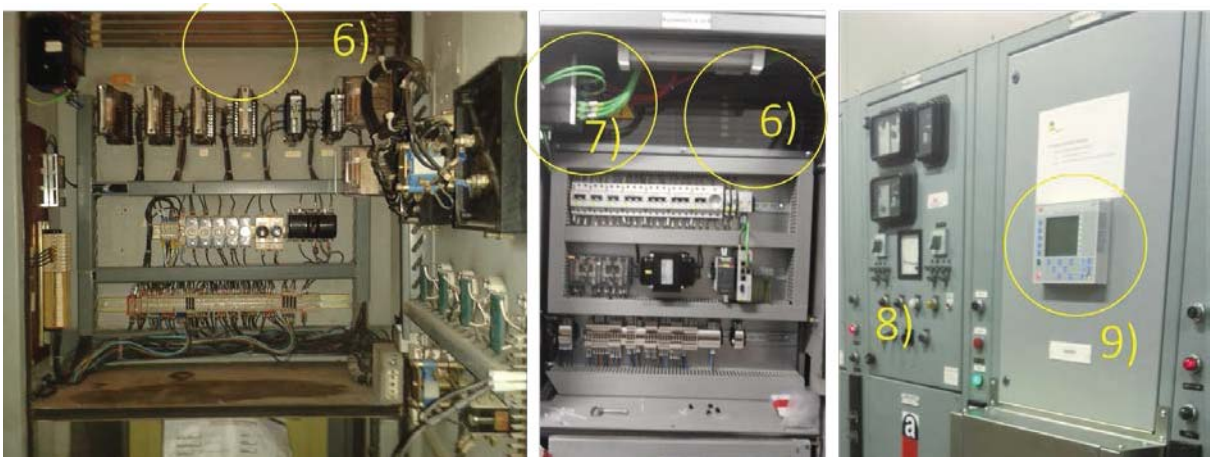

Figure 10. Original Auxiliary circuits' compartment (left) renewal points

VI. CONCLUSIONS

The electrical facility manager's challenge for new installation or maintaining old equipment now has a third option.
The retrofill solution with a standard circuit breaker can extend the plant utilization life for a higher availability and reliability. In a possible future better economic environment, the replacement of the old switchgear toward a new panel could benefit from the reuse the circuit breakers, preserving a significant part of the investment done.
Several industrial and utility sites have benefited from the described novel retrofill solution over a number of different manufacturer switchgear, proving its flexibility to cover a wide range of original designs.
Such a solution, and the different possible modernization strategies discussed, provide a sound technical and economical answer to customer needs, in particular when due to budget limitations or process availability demands renewal is not a viable option, and take active measures towards failure risk reduction and extend the electrical facility safe operational life.

VII. LIST OF ABREVIATIONS

TABLE I

Abbreviation	
IA	Internal Arc
CB	Roll-in-Retrofit
MV/LV	Medium Voltage/Low Voltage
MTTR	Mean Tie To Repair
PI	Partition Insulating
PM	Partition Metallic
RiR	Roll-in-Retrofit
SF6	Sulphur Hexafluoride
SWG	Switchgear
TOC	Truck Operated Contacts

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IX. VITA

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