RETROFITTING 11KV CIRCUIT BREAKERS IN PRIMARY SUBSTATIONS

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ABSTRACT

6.6kV/11kV Oil Circuit Breakers of vintage 1950 / 60's are still operating in many utilities today and potentially represent a very high percentage of the total network population. Originally installed circuit breakers may have become unsuitable for a number of reasons; such as their operational requirements, or their asset condition, or they may have a restricted network duty. This paper outlines a number of cost effective solutions to enable older equipment, that is no longer manufactured, to be retrofitted with a modern design. Furthermore, it considers the experiences of one electrical utility after undertaking a retrofit programme of 1,100 circuit breakers. A standardised approach is promoted to replace the many variants and peripheral designs with just a handful of modern products.

INTRODUCTION

In the past decade, a UK Distribution Network Operator (DNO) has retrofitted in excess of one thousand 11kV oil circuit breakers (ocb's) with a Vacuum or SF6 circuit breaker, within one of their regions. The volume represents one third of the total 11kV feeder population. The thrust of replacement was focused on six Original Equipment Manufacturers (OEM) and nineteen variants dating back to the 1960's with differing styles, dimensions and phase centres.

RETROFITTING – THE BUSINESS CASE

There are a number of reasons for retrofitting 11kV switchgear, not least from a technical or strategic viewpoint. Each DNO has slightly differing needs due to historical policies, which results in an extensive range of requirements for any one retrofit. Some technical and strategic reasons are listed below.

Fault Level

A switchboard may be operating above its rated fault level – for a number of reasons including network reinforcement, added generation and paralleling of systems. Fault rating on UK oil switchgear at 11kV is generally 13.1kA (250MVA) and a modern vacuum circuit breaker will be rated at 20kA to 25kA (symmetrical RMS break) at 11kV.

To review the fault level of a circuit breaker a complete fault level analysis is required, which goes beyond simply looking at the fault level ratings stated on equipment rating plates. Feeder fault ratings are published by DNO's and are generally fully assessed at fixed periods unless there are other added influences in the interim, such as generation. Although there appears to be no standard practice or internationally recognised guidelines, it is sensible to review the fault level of circuit breakers when it is within a margin of 5% of any of its key ratings. A more detailed analysis can then be conducted which looks at individual ratings such as peak making current, rms breaking current and circuit time constants/asymmetrical ratings.

In addition, a feeder panel (fixed portion) is always rated at its circuit breaker equivalent, e.g., 13.1kA. When considering increasing the rating of a circuit breaker, there needs to be a parallel reassignment of the switchgear fixed portion. Experience has shown that it may be possible to reassign the fixed portion with a higher fault rating - from values of 18.4kA up to 26.3kA. The process to reassign the fixed portion fault level is subject to another technical procedure (not covered in this paper).

Load Enhancement

A feeder circuit ocb is typically rated at 400A and a modern circuit breaker will be rated at 630A. There may be a requirement to increase a feeder rating above 400A and in this case, a review of the fixed portion current rating is required. The bushings/copper conductors of the original switchboards were manufactured with a range of standardised sizes and are likely to be rated above the value of current stated on the rating plate as, generally speaking, generous tolerances were built into switchgear design in the 1960's. The complete switchgear internals would need to be analysed to determine the maximum thermal rating of individual panel types.

Condition Based

Asset replacement due to age profile, condition assessment, faults or operational restrictions may trigger a need to change a switchboard or to consider the retrofit options available.

Regulatory Pressure

Many older oil circuit breakers had electrical trip and manual closing functionality. With a modern vacuum or SF6 retrofit circuit breaker a remote close operation is possible to restore faulty feeders, without sending personnel to site. The full open/close facility of the source circuit breaker becomes part of the DNO's automation scheme to restore

the majority of customer supplies within a few minutes of the fault occurring. The resultant benefits are reductions in Customer Interruptions (CI) and Customer Minutes Lost (CML) – System Average Interruption Frequency Index (SAIFI) and System Average Interruption Duration Index (SAIDI). This formed the main business case for most of the 1,100 circuit breakers, as mentioned in the introduction to this paper.

Maintenance

Cost benefit and Health Indices (H.I) analysis, by way of assessing the total downtime and maintenance costs, can be a deciding factor. Oil auto-reclosers could be replaced with virtually maintenance free vacuum or SF6 circuit breakers. In addition, those motorised circuit breakers that become spare as a result of the retrofit, and were on fault prone rural feeders, can be swopped to low fault urban feeders to enable a closing feature to be added cheaply to any particular feeder.

Limitations

Not all vintage switchboards are suitable for retrofits due to their style, age and low population. In addition, the fixed portion single bus-bar switchboard types are mostly rated lower than the modern 2000A versions, and this has to be taken into account when reviewing a reinforcement scheme.

Policy

Asset management policy to consider retrofit options continually takes place with a parallel policy of switchboard replacements. Separate policies and standards may be required to replace other components of a switchboard such as protection relays or batteries.

There is also a maturity of policy, whereby after an initial programme to replace circuit breakers that do not have a remote close (at some point this reaches volume saturation), there is a transfer to a policy of asset replacement due to age / condition.

RETROFIT - PRACTICAL SOLUTIONS

The nett effect and requirement for a retrofit design is to reduce the huge array of original equipment size, weight and manufacturer types and variants down to just a few styles. The choices of arc extinction can be either SF6 or Vacuum, and the mechanisms / actuators can be spring charged or magnetic.

For the following figures 1, 2 and 3, each image shows the retained elements of the original oil circuit breaker in blue and the new elements of the retrofit solution in red.

Solution 1 – Complete Roll out & Roll in Unit

This is a fully pre-packaged item of plant requiring minimal on-site mechanical modifications. The circuit breaker generally evolved as a result of the OEM progression of a product range from oil to vacuum or SF6, whereby the fixed portion of switchgear was the same, or very similar. Generally, this succession occurred in the 1980's, thus the vacuum or gas circuit breaker was certified to the older international standards such as BS5311 or IEC56.

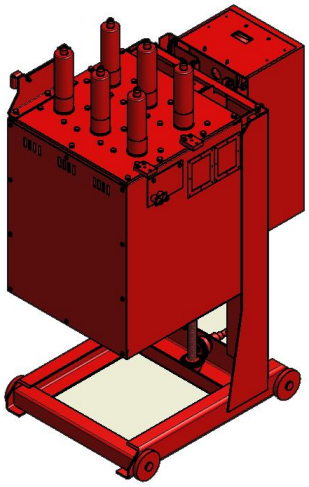

Figure 1: Roll out/Roll in truck (OEM)

Solution 2 – New Circuit Breaker plus original truck

Some circuit breaker retrofits need to utilise the truck / carriage of the old unit. The new breaker and mechanism modules can be fitted onto the truck frame on site, or if the circuit breaker is very large, it may need to be transferred to a factory environment for modification.

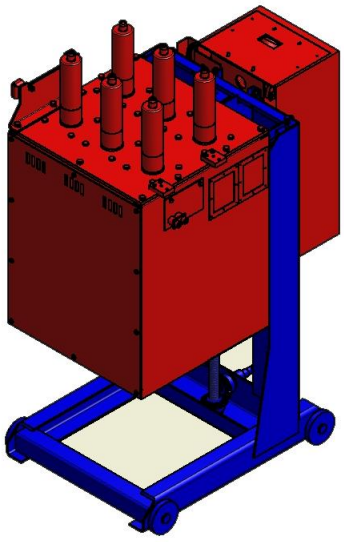

Figure 2: Utilising existing truck

Solution 3 – Hybrid Circuit Breaker with original truck, bushings and top plate

This interesting style of retrofit circuit breaker package comprised a magnetic actuator vacuum auto-reclose circuit breaker fitted beneath the original porcelain bushing top-plate. This is the most onerous retrofit solution and a complex on-site undertaking. The complete ocb internals and mechanism are removed and replaced with the new vcb and a magnetic actuator, complete with its electronic controller. Full routine testing including timing tests have to be undertaken during commissioning. This solution however, removes many of the fears concerned with the primary interface between fixed portion and retrofit circuit breaker.

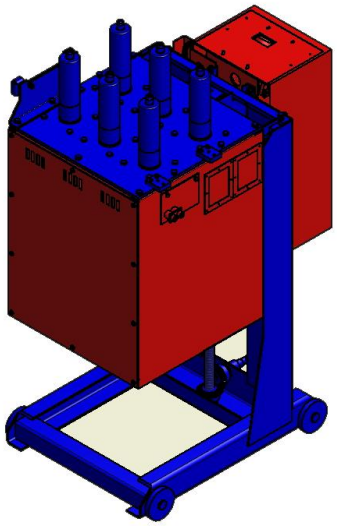

Figure 3: Retention of original truck, primary bushings and ocb top plate

Solution 4 – Bespoke Roll out & Roll In Unit

This is a dedicated and bespoke retrofit solution that has been designed specifically for the higher volume OEM variants, but tested to modern international standards (IEC62271).

This type of solution entails high investment costs, but produces a circuit breaker that can take into account modern design techniques and include additional individual customer requirements or specifications (e.g., ENA Technical Specifications).

The bespoke solution can also take into account the many years of retrofit service and operational experience now gained, thus giving the end user a more advanced technical solution.

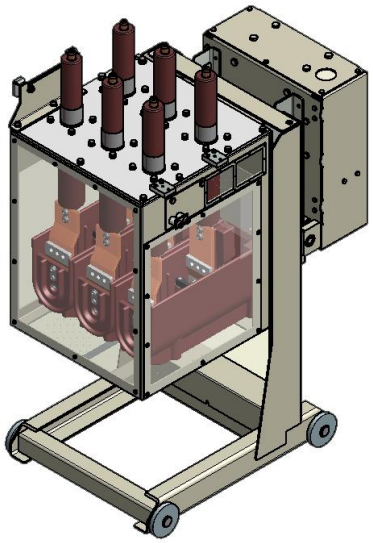

Figure 4: Bespoke Roll out, Roll in solution

Solution 5 – 'One Shot' Remote Control

On some manually charged spring mechanisms it may be possible to install a spring release coil which, when remotely operated, will enable the circuit breaker to have a one shot reclosure (followed by site attendance to manually charge the closing spring in readiness for the next remote operation). This is a simple and cheap method but one that is feasible on only a limited range of switchgear. If a spring release coil is added on old switchgear, there will be no added advantages of savings in maintenance and improved operational performance compared to that of a modern circuit breaker retrofit.

PROCUREMENT

Traditionally, the suppliers of retrofit solutions have been manufacturers with an OEM history. The problem is that the history may go back to great grand-child, and the availability of the original records of the manufacturer could be in question. A global search of manufacturers is sometimes required to enable a satisfactory product to be located, and it is increasingly acceptable for non-OEM manufacturers to offer proven retrofit solutions. It is not economical to design, test and supply 'one-off' circuit breakers or to have small scale retrofit programmes, but experience has shown that larger scale programmes of supply and install provide a very economical solution.

There is the inevitable 'chicken and egg' situation with potential manufacturers as they will not invest without a promised minimum volume and the DNO's will not invest without a certified product. Therefore, bespoke products may only be available for high population types of circuit breaker as design and certification costs for 'one-offs' can

be restrictive.

Whichever route is adopted, switchgear approval and operator safety are mandatory and critical requirements for new equipment.

ANCILLARY REVIEW

There are ancillary checks and reviews that need to be put into place when it has been decided to install a retrofit solution and these form part of a pre-inspection plan.

Analysis is required for all items of plant in a Primary substation that may impact on satisfactory operational duty such as: i) partial discharge checks, ii) review of maintenance and work records for the equipment, iii) internal inspection of representative panels, iv) fault history of the plant type, v) electromechanical protection relay age profiles and functionality, vi) primary batteries capacity and reliability, vii) panel secondary wiring condition, viii) building condition, iv) environmental condition.

To clarify, if a circuit breaker is to be retrofitted, then other parallel and supplementary work may be required, e.g., if electromechanical protection relays were to be changed for microprocessor units and batteries were to be uprated, then additional pre-inspection procedures and company standards may need to be adopted.

CONCLUSION

Many switchboards installed in the 1950/60's are still providing exemplary service and showing no signs of degradation, thereby delaying the need for their replacement. Generally, retrofit solutions are not considered unless a minimum life extension for the original switchboard of at least ten years is being sought – recent retrofit programmes have clearly proven that this is achievable.

Circuit breaker retrofits are undoubtedly a cost effective method of improving and modernising primary substations, subject to the criteria mentioned above. Some modern retrofits have been installed in equipment of 60 years old, posing the question of "how long does a switchboard actually last for ?".

With increasing retrofit volumes and the experience of utilising a variety of manufacturer's products in a large number of product types, some issues have arisen over the 10-year period described, such as discharge on modern bushings, mechanism design issues and product quality control. However, as with all evolving applications, cross-fertilisation and shared product experience between manufacturers and DNO's has been extremely beneficial in helping to ensure that the modern retrofit solution becomes a very economical, robust and technically acceptable solution for many years to come.