The application of type testing to retrofit circuit breakers

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Introduction

Retrofit breakers have been developed in the UK over the last two or three decades to replace old or under-rated air and oil medium voltage circuit breakers and, more recently, some of the early vintage SF6 and vacuum breakers, which are now also reaching the end of their useful lives.

Most of the breakers being replaced were manufactured in the 1960s and 1970s although many were supplied before that. Type test standards have changed radically since this period. Many of the circuit breakers still in service today were tested to British Standard BS 116 dating from 1952 with type test requirements bearing little resemblance to the requirements today.

The latest version of the circuit breaker standard, IEC/BSEN 62271-100 comprises well over 300 pages, with more than three quarters of this devoted to testing.

Generally, new medium voltage indoor switchgear ranges, i.e. the breaker and its cubicle are tested together during their development. IEC62271-1 and IEC 62271-200 are the relevant standards related to IEC 62271-100 mentioned above, which bring the whole switchgear design together. This testing occurs on new ranges of switchgear, developed now by successively fewer but larger organisations as the number of smaller or medium sized UK manufacturers have closed or been bought up and incorporated by the few global switchgear companies who remain. Each of these huge companies has worked to reduce the variety of similar switchgear designs, to reduce development and design support costs and to achieve economies of scale in manufacture. This means although the requirements of type testing have become much broader, more complex and generally much more onerous; and the costs have increased hugely, the number of ranges of similar switchgear they support has reduced.

When it comes to upgrading or replacing existing switchgear there are a number of choices faced by the switchgear owner. In some cases the whole switchgear is replaced with new equipment, tested to the latest standards. However, this can be an extremely and unnecessarily expensive option, when it is possible to simply replace the moveable portion which does all the switching work, since usually only this part is beyond economic repair. In many cases the fixed housing is good for another 25 years life.

Generally, the new switchgear designs mentioned earlier are intended for high volume manufacture, thousands per annum, usually for adoption in several factories to supply to a range of countries worldwide. High development and testing costs are therefore recovered over a large production volume. Retrofit or replacement breakers are aimed at much smaller volumes with some designs aimed at some tens of breaker units and others, at best, a few hundreds.

This leads to the question of what is a sensible approach to type testing circuit breakers being introduced to replace or retrofit the existing designs.

By the nature of the equipment, the breakers are usually replacing designs in switchgear which are obsolete and have been out of manufacture for many years. It is not feasible, either practically, technically or commercially, to fully type test every variant of new circuit breaker in every previous design of cubicle. In many cases it is not possible to obtain a cubicle of the relevant design – and even if one is available there are often subtle and not so subtle variations, within a single switchgear range. Then, even if the equipment is available, the costs of such an exercise would be colossal and, therefore, prohibitively expensive.

So, what is a realistic, experience and engineering judgment led approach for retrofit circuit breakers that still gives a high level of confidence that the new design is satisfactory?

Circuit breaker type testing

The series of type testing required for general purpose medium voltage indoor circuit breakers is prescribed in IEC/BSEN 62271-100.

The following tests would normally be expected to be performed on a breaker in its cubicle for a new development,
Dielectric testing – i.e. Power frequency withstand voltage tests, impulse tests, partial discharge measurements.
Temperature rise tests
Short-time withstand current and peak withstand current tests

Other making and breaking tests, , both short circuit and the many other types of lower current switching tests, while normally performed on a breaker in a cubicle for convenience, are not really affected by the presence of the cubicle and could be performed outside it.

Mechanical endurance tests are usually performed on the circuit breaker without the cubicle.

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P&B Retrofit or Replacement Breaker Designs

P&B Switchgear has developed many dozens of designs and variants of retrofit circuit breaker, investing heavily in type testing these designs and has achieved over 100 type test reports and certificates. The majority are short circuit tests but include temperature rise, dielectric and mechanical endurance testing too. Almost all tests were performed with the circuit breaker in its housing. Most earlier developments were performed as we came across new development requirements for customers and utilised the ABB VD4 range of vacuum breaker. This was either in the refurbished original truck for air break retrofits, or, in the case of bulk oil replacements, completely new breakers.

As the number of bulk oil breaker retrofits increased an approach was made by P&B Switchgear to introduce as far as possible a standard circuit breaker module design, which we could adapt into a series of trucks designed specifically to replicate externally the original breaker and fit into the various manufacturers' switchgear cubicles. The aim was to reduce the repeated design work, reduce the type testing requirement as the range grew and to increase standardisation in manufacture.

P&B Switchgear now offers two types of design to replace bulk oil circuit breakers. One design utilises a complete ABB VD4 VMax motor wound spring type vacuum breaker in a P&B Switchgear designed module, which is then fitted into a vertical isolation truck designed to fit directly into the switchgear housing of the original manufacturer. This is the P&B Switchgear VOR-S range and is available for a limited range of designs.

The second design incorporates a magnetic actuator drive rather than a spring mechanism, designated the VOR-M range of replacement circuit breakers. This breaker range uses resin embedded vacuum interrupter poles from the ABB VD4 breaker range driven by a MagLatch magnetic actuator. Again, the breaker module is identical for any VOR-M breaker of a given rating and, like the VOR-S, is assembled into a truck designed to fit directly into the original switchgear housing.

P&B Switchgear VOR-S
Replacement for Brush VSI / VMV

Type testing the VOR-S range of circuit breakers

P&B Switchgear introduced the ABB VMax breaker to begin the VOR-S retrofit range in 2006. A new isolating contact design was introduced in 2008 and is now used across the range for normal current ratings up to 2000A. P&B Switchgear has performed a range of type tests on the VOR-S circuit breakers in different types of switchgear housings. Further development and type testing has included up-rating existing 25kA switchgear designs to a rating of 31.5kA rms with peak withstand current of 80kA.

The ABB VMax range of breakers have been extensively type tested in ABB switchgear ranges to demonstrate compliance with all the tests required by IEC/BSEN standards, including extended mechanical endurance testing to 10,000 operations. There are many tens of thousands of VMax breakers in service and using this product in the P&B VOR-S means we can offer a high level of confidence in its operation and future reliability.

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P&B Switchgear VOR-M
Replacement for GEC BV17 / VMX

Type testing the VOR-M range of circuit breakers

P&B Switchgear began development of the VOR-M breaker in 2010 with designs to cover GEC BVP17, Brush VSI and SWS C/D range circuit breakers. Since then, more than 20 further breaker types and ratings have been added to the VOR-M range. This range uses resin embedded vacuum interrupter poles manufactured by ABB in Germany which are used in ABB breakers internationally across their MV switchgear range. These devices have been subjected to numerous series of type tests in various ABB switchgear ranges covering all of the IEC / BSEN tests described earlier. This includes the VM1 circuit breaker range, which is the VD4 breaker with the EL spring mechanism replaced by a magnetic actuator.

The P&B VOR-M uses a MagLatch actuator designed and supplied by EPS in Loughborough, UK. The same design of actuator is used by ABB in their VM1 range.

P&B have performed extensive type tests to the latest IEC standards on the VOR-M circuit breaker in representative switchgear housings. These tests include short circuit, dielectric, temperature rise and extended mechanical endurance tests to 10,000 operations.

Again, by employing widely used ABB vacuum interrupters and the well proven MagLatch actuator, we can offer high confidence of excellent service performance and reliability.

Partial discharge measurements, as part of IEC/BS dielectric type testing at independent HV laboratories, have been performed on P&B VOR-M and VOR-S circuit breakers.

Routine tests and other considerations

It is important that any new circuit breakers being offered as retrofit solutions can be shown, by performance of relevant type testing, to be capable of the ratings claimed. It is important that this includes testing of the interface between the new breaker and the old cubicle. At P&B we have performed a huge range of type tests on air and oil breaker designs in original cubicles to demonstrate this.

We have discussed earlier the practical difficulties of testing every arrangement, for a vast array of different, usually obsolete, older switchgear designs. However, we have tested our VOR-M and VOR-S breakers in a range of representative switchgear units which demonstrate that the circuit breaker designs are suitable for even wider use.

It is worth mentioning that during previous short circuit type testing of some LV breaker designs we found the condition of original isolating contacts had deteriorated with age and led to complete failure at currents below the original short circuit ratings. Although some suppliers re-use the existing contacts in their replacement breakers we have introduced a new fully tested, isolating contact design for our VOR breakers and we supply new or refurbished contacts with all other retrofit breakers.

Older designs of circuit breaker required a high degree of maintenance to ensure reliable operation. This includes regular contact and oil changes in bulk oil breakers. However, mechanisms have not always been reliable and required regular servicing. Newer designs of breaker have lower operating forces and thus simpler mechanisms were introduced. Mechanical endurance type testing on modern breakers now require the number of operations to be increased by a factor of 10 compared to the older designs. New magnetic actuators are capable of a further factor of ten operations more than even modern, lightly loaded spring mechanisms. Modern vacuum interrupters have shown they perform excellently in all system switching conditions, their life span is into thousands of load operations, they last 30 years and beyond and the number which fail in service can be counted, virtually, on your fingers.

Control of manufacturing processes and quality systems are also of a different order to those in place in most factories 3 or 4 decades ago.
There is little doubt that the latest generation of circuit breakers are designed and tested to higher standards than those of the products they are replacing.
Many old switchgear designs have seen failures in service caused by various mechanical problems, but some have been caused by gradual increase in partial discharge, leading to dielectric failure and major flashover. International standards require routine factory partial discharge measurement of some components such as bushings. Some customer specifications, such as ENATS in the UK, request partial discharge factory testing of complete switchgear but PD testing of breakers, or complete switchgear units, is not widely performed and is not a required routine test in IEC/BSEN standards.

However, partial discharge checks in the factory can be useful in finding some flaws in the final assembly and at P&B, we have invested in testing facilities to perform detailed PD measurements. Every VOR circuit breaker manufactured undergoes this check as part of our rigorous routine test procedure.

Despite the tests we have introduced, satisfactory long term dielectric performance is better ensured by taking into account the experience gained to date, at the design stage. This is achieved in the design, for example, by avoiding high electric stress forming shapes, ensuring adequate clearances, eliminating small gaps at different potential etc. All these could gradually cause ionisation under prolonged stress at normal voltage.

At P&B we have performed comprehensive electrostatic field analysis of the VOR type isolating contact/bushing/spout design and interface to ensure the design is dielectrically sound.

However, another major factor in the service performance of indoor switchgear is related to the environmental condition in which the equipment is to operate.

Normal conditions for indoor switchgear are defined in the previously mentioned standards and switchgear is designed to operate in these conditions. This assumes ambient air is not significantly polluted by dust, smoke, corrosive and / or flammable gases, vapours or salt. Conditions for humidity are specified, which should result in no more than occasional condensation.

As designers and manufacturers of safety critical switchgear products, we take great efforts to ensure they are designed and tested to meet the requirements of the relevant standards.
Once installed it is important that high levels of humidity and condensation are avoided in the substation to prevent onset of partial discharge, potentially leading to breakdown of solid insulation. If conditions of high humidity and condensation are likely, they can be prevented by suitable substation ventilation and heating of the equipment. Measures such as these should be adopted by the user to ensure long term reliable service performance.

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