NEW CONCEPT FOR MEDIUM VOLTAGE GAS INSULATED SWITCHGEAR (GIS)

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This article describes a new series of medium voltage gas insulated switches suitable for use in MV energy supply systems. It was introduced to the market in 1995 and is designed, just as the vacuum circuit breaker which it uses, to be maintenance-free for its lifetime. Its use will increase the reliability, simplify and reduce the costs of operation in public and industrial networks.

This new series, type 8DC, is available with single busbars for rated voltages up to 24 kV, short circuit interruption currents up to 25 kV and rated currents up to 1 250 A. All the most common circuit arrangements are provided. Its operation demands no particular expertise or abnormal procedures.

Historical steps towards total freedom from maintenance in circuit breaker switchgear.

Gas-filled switchgear with maintenance-free HV sections

Nearly 20 years ago, in 1982, the first gas insulated medium voltage switchboard with vacuum circuit breakers was introduced [1]. Compared with air insulated equipment, it had significant advantages:

- hermetic encapsulation of all live parts in SF6 gas filled enclosures
- total exclusion of any influence on the HV parts from pollution, moisture and condensation or small living creatures
- no oxidation of contacts or connections
- no hardening of lubricants
- secondary windings or current transformers totally separated from HV parts
- drive mechanisms accessible at all times

The high voltage parts of this concept are fully maintenance-free but the joints between individual chambers and the mechanical and electrical entries into the chambers are sealed with O-rings and the possibility of a certain leakage rate has to be accepted. The gas pressure is therefore monitored and it is recommended that the gas pressure and quality be checked every 10 years. This is the same interval as for regreasing the drive mechanisms of the circuit breaker. Further maintenance is not required. Operational experience with this concept is extremely good, confirmed by its commercial success. More than 18000 bay-units are in operation throughout the world. Based on the definition of major failures (CIGRE 'Reliability of HV circuit breakers') these units have so far achieved an MTBF of more than 10000 years. This equipment is now available with ratings of up to 40.5 kV, 40 kA and 3 150A and is looked upon as state of the art technology for the upper range of distribution applications.

Ring main units with seam-welded containers which eliminate the gas maintenance

In 1983 the author's company introduced a ring main unit with switches sealed -without any gaskets - into a seam-welded chrome-nickel-steel container. This unit was designed for the many thousands of secondary network substations and is totally maintenance-free: neither the gasfilling nor the drives can or need to be serviced. This concept has also proved to be correct and the use of this unit is widespread.

Vacuum circuit breakers without need for servicing - not even the mechanism. Seven years ago, in 1992, the fully maintenance-free vacuum circuit breaker was introduced [3]. Due to the right combination of material and special lubricant even the drive mechanism became maintenance-free for its lifetime. This new circuit breaker 3AH completed the list of components necessary for maintenance-free switchgear.

The development of GIS

Given these basic components, we were able to introduce, in 1993, a maintenance- free switchboard with line-up circuit breaker and switch disconnector cubicles for currents up to 630 A, with the identification code XDH.

This concept has been extended in the switchboard type 8DC, with circuit breakers up to 1 250 A and improved features.

These new switchboards embody the best characteristics of the previous steps and combine the highest reliability for all operating conditions with freedom from maintenance for life.

What does maintenance-free mean?

Preventative maintenance is that activity which is carried out in accordance with a plan, or after particular occurrences. It comprises:

- lubrication
- fill level checks
- filter changes

Operation dependent items (number of operations, total switched current):

- contact check and replacement
- renewing of arc quenching medium

Environment dependent items:

- cleaning
- corrosion protection renewal

The necessity for these measures cannot be determined remotely. Thus, planned maintenance has previously required that installations be regularly visited and serviced by trained personnel Even the preparatory switching procedures are often extensive and inconvenient to customers. All too often experience has shown that human interference has sown the seeds of future failure. With planned maintenance, one comes into conflict with the, 'if it works don't fix it' principle. A system designed for no maintenance thus avoids:

- implementation and monitoring of the planned maintenance schedule
- employment of maintenance personnel
- stocking of consumable or replacement parts
- switching procedures and network disturbance
- faults caused by maintenance errors

This guarantees the highest reliability with minimum cost. Freedom from maintenance cannot, however, guarantee that every possibility of fault is excluded, so designs must also ensure that unavoidable faults can be quickly and simply overcome. 8DC switchgear is, therefore, so constructed that many important components are accessible whilst the circuit is in operation, for example:

- circuit breaker drive mechanism
- selector switch drive mechanism
- secondary connections

While the busbar is live:

- current transformers
- voltage transformers
- cable terminations

Design requirements

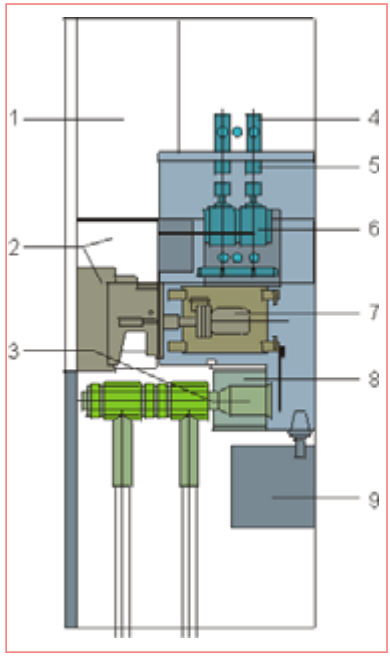

Figure 1. Maintenance-free GIS, type 8DC; section view of circuit rated temperatures.

To create a truly maintenance-free design, particular requirements must be met and special features must be provided. We examine what can be done, using 8DC as an example (Figure 1):

Whilst the pressure stress on the parts of the housing may change, it can never reverse. This significantly minimises stress and increases reliability. Gas is filled after evacuation. In trust in the reliability of the concept, the careful manufacture and quality control, the filling nozzles are pinch-welded after filling is complete.

Nevertheless, an operator can convince himself of the condition before each switching operation: each cubicle has a gas density indicator with a clear, temperature independent display. This indicator has been well-proven in the gas insulated ring main unit 8DJ [2]. Expansion and contraction of a reference volume is transferred magnetically through the container wall without any need for penetration.

To absorb original enclosed moisture from the components, desiccant bags are fitted in each container? Once in operation however, no significant quantity of moisture can enter the container and desiccant renewal is unnecessary.

Features of the conductor entries

Each cubicle and thus each container has at least six high voltage conductor entries (bushings), three for the busbar and three for the cable connections. These are of the external cone type in accordance with CEN HD 50631.

Every high voltage bushing is subject to thorough routine, partial discharge, X-ray and gas-tightness tests before welding in. Each bushing has an integral control electrode in the flange surround. Its connection is brought out. Thus each bushing can be used as part of a voltage indicating system.

Plug-in cable connectors of the external cone system can be plugged directly onto the cable bushings, also for two or three cables per phase, in tandem. These cable connectors also allow direct connection of surge arresters or cable test equipment.

Features of the components

The principles of the vacuum circuit breaker are described in [3]. The circuit breaker is developed out of the known series 3AH. This circuit breaker is maintenance-free for life and can be safely welded, totally gastight into the sealed unit. Due to the arrangement of the drive mechanism to the vacuum tubes, there is only a linear movement inside the gas container. Complicated linkages are unnecessary. The circuit breaker is constructed as a module whose mechanical and electrical behaviour can be tested before welding in.

A three-position selector with the positions ON, OFF and EARTH serves for disconnection and preparation for earthing. Each selector has two drive shafts, one for disconnection, and one for earthing. Both operate a shaft which is concentric with the selector fulcrum. Within the container, no other rods or linkages

are necessary. Neither lever can be inserted whilst the circuit breaker is closed. Between the drives of the breaker and the selector there is an interrogate interlock. To earth the cable connections, the selector is switched to earth and the circuit breaker must be closed, either manually or automatically.

Current transformer secondary windings are always fined outside the containers, in areas of single pole accessibility, for example at the points of transfer to the cable connections or busbars. The transformer secondaries are thus isolated from voltage stresses and undesirable thermal influences of the primary current.

Voltage transformers are excluded from the interior of the enclosures because they are always subject to electrical stress. In 8DC, two solutions are used:

In a feeder circuit, fully insulated, metal enclosed inductive voltage transformers are plugged in from the outside. Within the container, connection is made, through a disconnect switch which is operated from the outside via a gas-tight metal bellows. This allows testing of the switchboard with ac and the cables with dc without having to remove the VT.

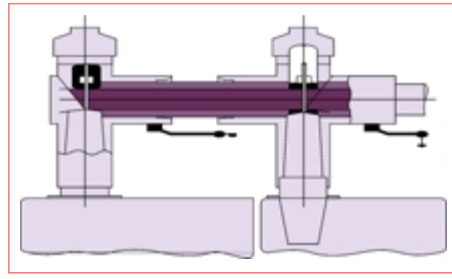

Figure 2. Busbar joints - sectional view.

On the busbars, the fully insulated, metal enclosed vts are plugged onto the cross pieces of the busbar connections. A separate measuring cubicle is unnecessary. The windings and the core of these vts are electrically and magnetically so constructed that the switchboard can be voltage tested without damaging them. This applies to on-site tests at 80% of the rated power frequency withstand voltage. Both solutions are extremely reliable, fulfil operator requirements and, even in the event of fault, hardly affect the switchboard.

The busbars of round copper are outside the containers, as seen in Figure 2.

They are arranged as cubicle-module assemblies, single pole, for attachment to the busbar bushings on each container. Thus any required cubicle combination

can be constructed, altered or extended without gas-working or entry into the containers. Tolerances and expansion or contraction are compensated in the joint cross pieces. The cross pieces and the bars are insulated with high quality, generously dimensioned silicon rubber All external surfaces are conductively coated and earthed. Additionally, they are totally enclosed. The insulation of the bars is thus completely protected against the external influences of climate, pollution and condensation. Altitude-related derating is avoided. The proven, long-life quality of the silicon rubber used guarantees appropriate insulation capability for the life of the equipment.

Features of quality

Reliability, especially for life and without any maintenance, stands or falls with the quality in all respects. In a long-term business, quality demands as set by the user and by the ideals of a responsible manufacturer, are decisive for trust and continuous success.

Total quality management is set out and certified through a QM handbook to ISO9001. This handbook records a wealth of procedural data. In the procurement of materials and safety-relevant parts or assemblies, special quality control agreements are made which comply with those procedures.

The quality of the concept and the design can be seen from the foregoing description.

The quality of testing rests on the long experience of in-house, optimally equipped testing laboratories, accredited to EN 45001. Here the characteristics of the switchgear have been tested and documented to the requirements of the standards and beyond.

Quality of manufacture is in the interest of the manufacturer just as much as the user, In a fully welded construction, any fault which is first discovered in final test or during operation, has serious consequences. This concept, therefore, demands manufacture to the highest quality at every stage. Consequently there is

a comprehensive production control check for each stand-alone assembly, individually documented in the quality record book. It is more important though, that the production team fully understand the importance of the care of their workmanship and its effect on the satisfaction of the user, the success of the company and their own well-being. Regular training, appropriate facilities and incentives guarantee this motivation.

Quality of final test is the last step. It must and does rigorously detect every defect. Correction before dispatch or - when necessary - scrapping and replacement are essential, even when it costs time and money.

Life expectancy

Thirty years was set as the design life, because a commitment to a longer time would be speculative. The gas filling of the enclosure and, therefore the integrity of its insulation - with today's materials, manufacture and test procedures - is theoretically good for about 1 600 years.

Regarding the life of the silicon rubber insulation, some 25 years experience is available (even as outdoor equipment for high voltage). Under the given conditions of use:

- protected from mechanical damage by metal enclosure
- protected from direct effect of sun, rain or snow
- protected from surface discharge by dielectric, earthed screen
- field intensity in the insulation material only a fraction of the breakdown strength

With reliable certainty, a life of more than 30 years can be expected.

Cast resin components, for example insulators and bushings - have been manufactured since 1958 practically without alteration and have impressively proven their durability in this time.

In view of the expected length of life, the three position selectors and their drives are designed for a significantly higher number of operations (2000 cycles) and lubricated for this number and for a lifetime of more than 30 years, circuit breakers for 10 000 operations and more than 30 years [3].

With the advent of this lifelong maintenance-free switchgear, type 8DC, a breakthrough towards highest reliability with lowest operating cost has been achieved. Better planning of asset replacement and confidence in the reliability of supply should result from this concept.

At the end of its useful life, the safe disposal of any equipment should be possible. With 8DC, there is no problem. The insulating gas is unpolluted - because switching takes place in vacuum it can be extracted and prepared for re-use. The metallic parts are not contaminated and are therefore valuable scrap. All other parts, whose material may cause doubts, are identified and easily disposable.

References
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[4] Fleischer L, Hartmann E. 'Extension of use of the maintenance-free VCB into the medium voltage GIS concept'. IEE Conference: 'Reliability of transmission and distribution equipment', University of Warwick, UK. March 1995.