An Innovative Design of Indoor Medium Voltage Vacuum Switchgear

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Abstract

The paper briefly describes the design of MV vacuum switchgear which by means of an innovative rotating mechanical system combines the functionality and many of the advantages of both fixed pattern and withdrawable switchgear. The reasons for this approach and the ways fo achieving it are discussed. The equipment features the use of the latest design of vacuum interrupters allowing for compact design and the use of an extremely reliable proven low energy spring operating mechanism. The reasons for selecting a spring operated mechanism as opposed to other types of mechanisms are discussed. The design and operation of the circuit breaker unit is described and the design features such as provision of separate compartments and internal arc resistant design leading to improved safety of the equipment, with reduced operational consequences in the event of an internal arc. The design of the vacuum interrupters is also briefly discussed together with the arc control technique used to minimise size and maximise performance.

Keywords

Withdrawable, Vacuum, Switchgear, Isolation,

Contact

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1 Introduction

Historically MV vacuum switchgear in the 1970's was originally provided in a fixed pattern format. This reflected the extreme reliability of the then new vacuum interrupter technology together with their zero maintenance requirement. However, after a time, fixed pattern equipment became less popular, and withdrawable vacuum equipment was introduced. This change of direction was not due to any reliability problems with the vacuum equipment, but was instead due to a number of the customers' operational needs, specifically visible isolation, and integral earthing, together with working practices based generally upon withdrawable oil circuit breakers. The introduction of withdrawable vacuum equipment clearly gave visible isolation, and the provision of an earthing truck was relatively simple. In addition it was possible for users to swap circuit breaker trucks if necessary.

However fixed pattern equipment did give a number of advantages to the customer, namely; simplicity of design, compactness, and the use of air as insulation phase-to-phase, and cabling from the front to allow back to back mounting of equipment. For some time, MV switchgear manufacturers have also been taking into consideration increased operator safety

Figure 1. Author with VISAX unit

requirements. They did this by developing internal arc proof units that allow the circuit breaker to be isolated with the front door closed and locked. However, these units generally retained a complex construction due to the isolation and withdrawal of the circuit breaker and the partitioning in three compartments, which lead to a number of disadvantages. In particular these were the length and number of connections in the main circuit, and the amount of insulating material required due to the necessity of the insulating supports to provide mechanical strength to the main circuit. In addition there was the problem of providing robust position indicators for the circuit breakers and the earth switches to comply with international standards; and the unreliable visibility of isolating distances from outside of the unit. The equipment described here was designed to give the advantages of fixed pattern equipment while retaining the flexibility and the other advantages of withdrawable equipment, as well as to overcome the perceived limitations of previous designs.

2 Discussion

In order to achieve this ambitious target a number of innovations were necessary, together with a new concept of operation. It was decided to take advantage of the opportunities the vacuum interrupter technology provide, together with a radical solution to the problems of isolation and simplification of the circuit breaker unit. The small size, short contact travel and relatively low mechanical energy necessary to operate the vacuum interrupters gave us the opportunity to design one module to fulfil both the circuit breaker and the isolator functions, resulting in a unique design of withdrawable switchgear

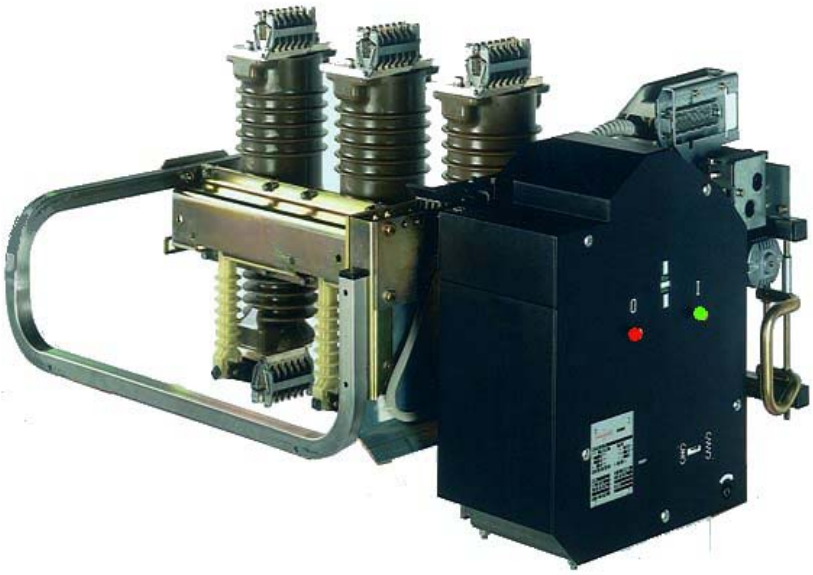


Figure 2. The circuit breaker module with poles in operating (vertical) position.

2.1 The Concept

. Firstly as shown in Figure 2 the phases were aligned in series which significantly simplifies the cabling and busbar connections, as well as allowing for a much simplified drive mechanism. The key components shown are the three synthetic resin poles each with a vacuum interrupter within their upper portion. The three poles are arranged from the front to the back and fixed at their centres on an earthed central metal support. This central metal support also contains the drive mechanical linkage to the poles with the operating mechanism at the front.

Secondly the circuit breaker module together with its drive mechanism are designed to rotate by 90’ to provide visible isolation as shown in Figure 3. This literally revolutionary concept allowed for many other simplifications in the design and manufacture of the circuit breaker, including; a reduced number of support insulators, a much simplified cubicle, and straightforward cabling from the front of the unit, allowing back to back application. A key feature of this design is that isolation of the circuit breaker can be carried out with a remote controlled motor, giving the possibility of full remote operation.

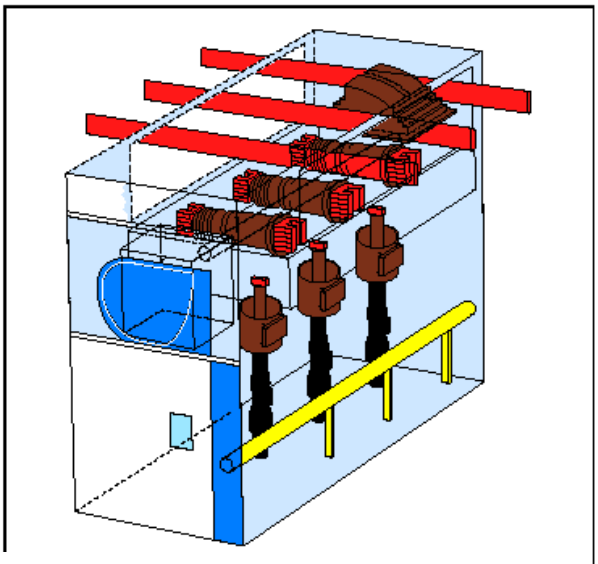


Figure 3. Circuit breaker in isolating (Horizontal) position

2.2 Operation

The module is self-standing and transfers very low reaction forces during operation of the circuit breaker. The ends of the breaker poles are fitted with specially designed isolating contacts seen in Figure 2, which are designed for a rotating movement and engagement. Rotating isolation in itself is not

new and has been used in other switchgear designs, but the key innovation here is that both isolation and circuit breaking functions have been combined in just one piece of apparatus, giving the key benefits of simplicity and reliability.

The isolator circuit breaker module not only combines both of these functions but also includes all necessary interlocking required for operation and isolation. This circuit breaker design has now been fully proven for service voltages of 12 and 24 kV and for short circuit fault levels up to 40 kA. Rotating the circuit breaker around an axis near the central position on its support provides isolation from both the busbar and cable circuits as shown in Figure 3. In
the service position, the circuit breaker poles are vertical and in the isolating position, they are horizontal, after rotation of 90 degrees. For simplicity and extreme reliability, the operating mechanism is arranged to be fixed to the central support of the circuit breaker and the whole assembly rotates together for isolation purposes. The circuit breaker is fixed and supported at its two ends to a frame and rotation of the circuit breaker is carried out by a mechanism in the mechanical cross bar. Because the design combines several different functions in one module, this has enabled us to keep the mass of the circuit breaker module very low. For example the mass of a 12kV, 25kA, 1250A module is less than 100 kg.

2.3 Compartmental modules

The basic design of withdrawable switchgear units has not changed much in the last 50 years. The transition from oil and air to vacuum or SF_6 technology has however made it possible to reduce the size of circuit breakers, and consequently the size of the switchgear units.

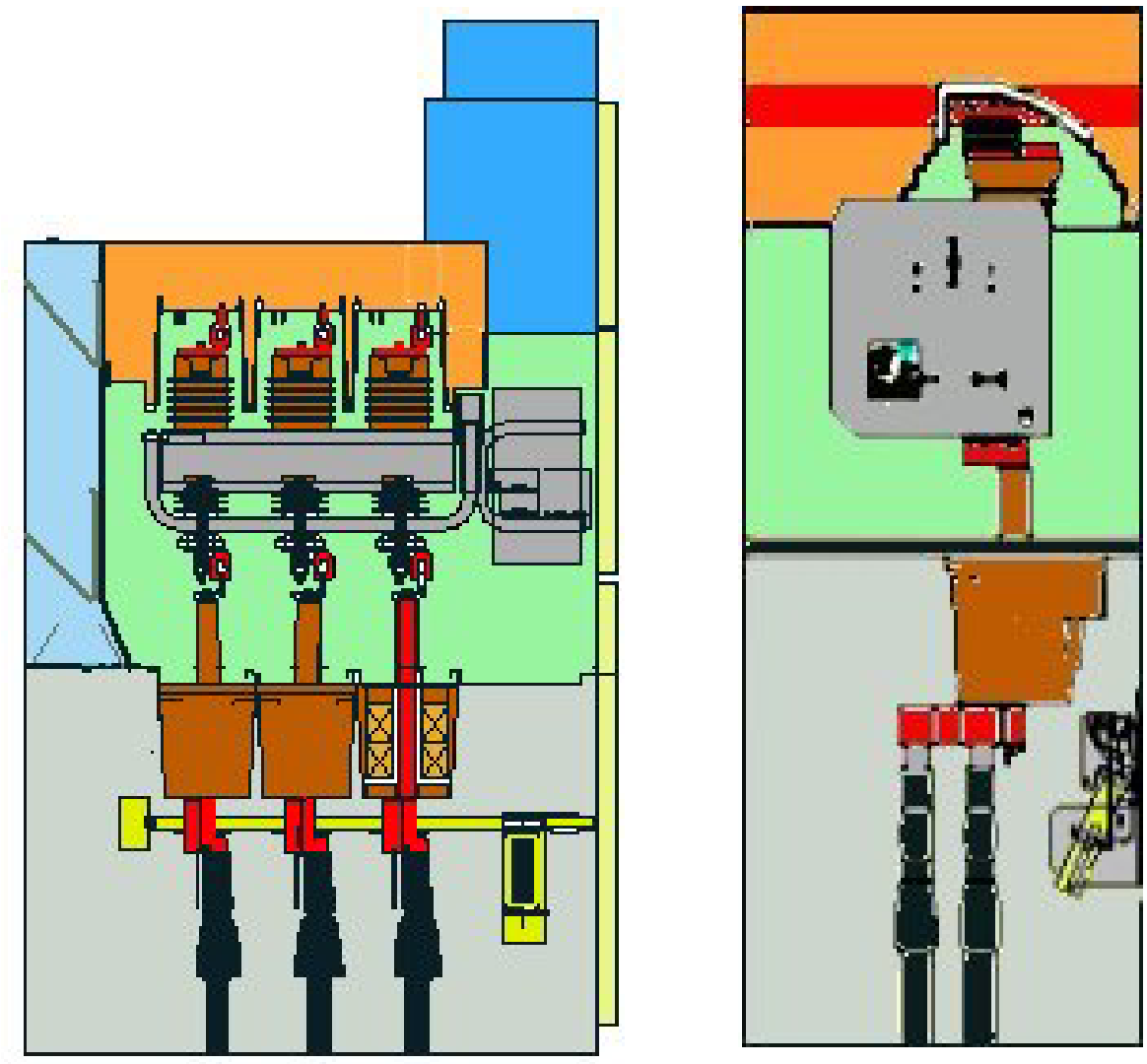


Figure 4. Layout of VISAX Cubicle Showing Left Side and Front elevation

This switchgear has been designed to have three different compartments as shown in Figure 4. The busbar compartment is separated from the circuit breaker compartment by a horizontal metal sheet that also supports the busbar spouts. Isolation of the circuit breaker causes a metal shutter to close, automatically preventing access to the spouts from the

circuit breaker compartment. In the same way, the circuit breaker compartment is separated from the cable compartment by a metallic partition that is bolted to the multipurpose bushing. Before withdrawing the isolator circuit breaker module, a protection screen has to be inserted to prevent the access to the upper contacts of the multipurpose bushing. Contrary to conventional withdrawable switchgear, the front-to-back arrangement allows the same functions to be performed with either two or three compartments. For the two compartment design, the partition between the circuit breaker and the cable compartment is removed. This solution has the advantage of giving excellent CT and power cable access. However, the withdrawal of the isolator circuit breaker module is still safe because of the protection screen inserted between circuit breaker and cable compartments. The only difference with a three compartment design concerns the possible propagation of a fault occurring at the cable terminals. The probability of a fault in this area is nowadays considered to be very small because of the simplicity and the reliability of the cable terminations. However it must be borne in mind that partitioning between the circuit breaker and cable compartments is essential for conventional withdrawable switchgear to allow extraction of the circuit breaker whilst the cables are energised. In addition, by locating the cables beneath the switchgear compartment, it was possible to build units back to back. In this case, instead of standing on the floor, the circuit breaker is held by rails attached to both sides of the fixed housing. The isolation and withdrawal of the circuit breaker is thus independent of the floor condition.

2.4 Latest Generation Vacuum Interrupters

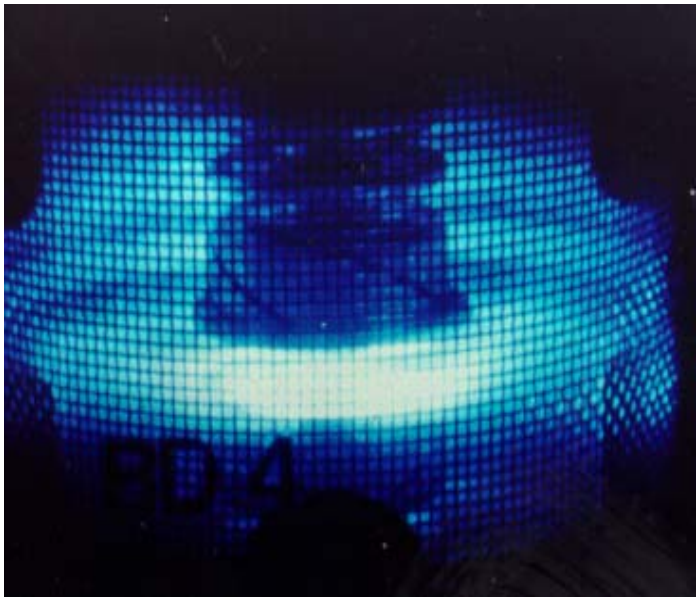
In vacuum switchgear the heart of the equipment is, of course, the vacuum interrupter. The interrupters used in this circuit breaker are from our VG range, and are a new state of the art range of vacuum interrupters designed and manufactured by us to meet today's diverse needs. These interrupters are the culmination of over fifty years experience and research and development in this field [1]. This latest generation includes a very long life, high performance, and small size, as well as a design for the environment approach [2]. The vacuum interrupters are the key to any vacuum switchgear, and these have been carefully engineered to simplify the design of the switchgear. For example all interrupters are the same overall length, same contact stroke, and have the same connection system as shown in Figure 5. This allows us to optimise the general switchgear design for a number of different ratings.

Figure 5. VG Range of Vacuum Interrupters

For fault ratings up to and including 31.5kA the interrupters use our patented "Folded Petal" Radial Magnetic Field (RMF) arc control geometry. The choice of RMF contact as opposed to Axial Magnetic Field (AMF) geometry was made on the basis of performance versus size. For the lower ratings RMF contacts were considered to be more efficient

Figure 6. Folded Petal RMF contacts interrupting a 20kA fault current.

and to allow us to use a smaller contact diameter for a given short circuit rating. Figure 6. shows a still photo of a contact switching taken from a film made in our research laboratories. The film was taken with a high speed camera @ 5,000 pictures per second, and shows a 35mm diameter Folded Petal RMF contact successfully interrupting 20kArms @ 12kVrms. This is an exceptionally efficient contact design, which in combination with our patented Chrome Copper contact material, performs effective interruption of high fault currents with a very small diameter contact. This in turn allows us to design and manufacture small diameter interrupters with a very small moving mass, suitable for compact switchgear with low energy mechanisms.



This is an important design point for the switchgear, as a low energy mechanism with a short contact stroke can be made both simple and extremely reliable. In fact this aspect of the vacuum interrupter design allowed us to optimise the design of the operating mechanism for the vacuum interrupters in order to give maximum benefit in simplicity, size, weight, and endurance.

2.5 High endurance spring operating mechanism

The specially designed motor charged M5S spring mechanism drives the VISAX unit. Based on the approach of a common technical platform, a concept which is widely used in the car industry. This mechanism is also used for a number of other vacuum circuit breakers of our range incorporating the VG vacuum interrupter range; BLV circuit-breaker, HVX circuit-breaker, VOX dead tank circuit-breaker EX and EAX dog-house circuit breakers. The mechanism type M5S benefits from more than10 years of field experience, and is thus considered to be a well proven design. In the interests of extreme reliability it was decided to utilise this proven design rather than introduce a newer unproven solution. In this design the simple single drive shaft arrangement with a spiral spring for closing & tripping provides exceptional reliability & security.

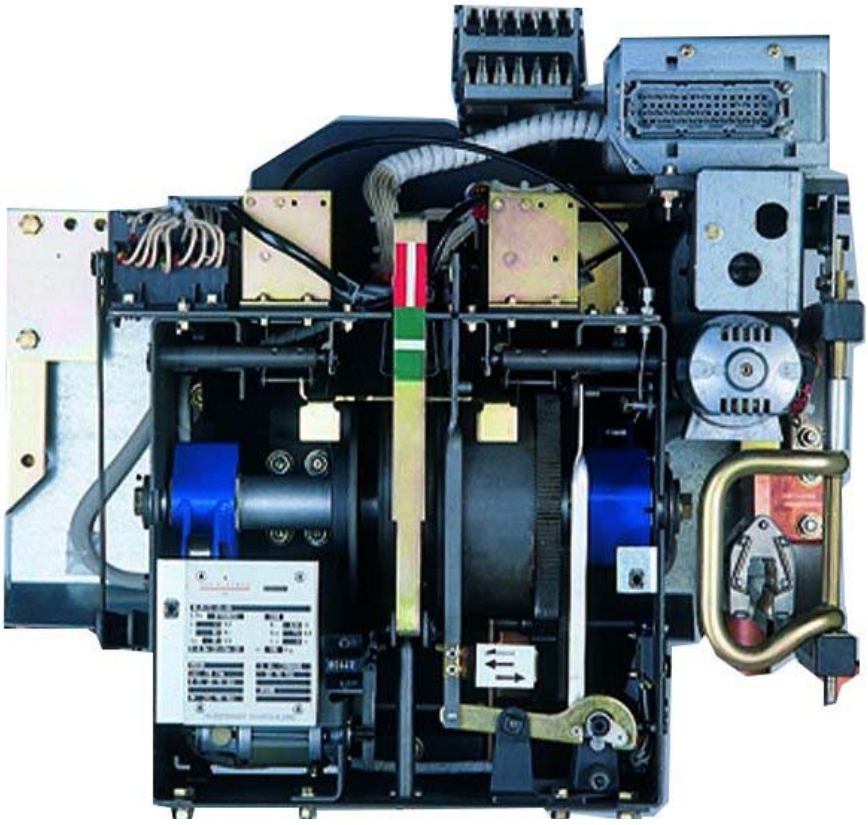


Figure 7. M5S Spring Mechanism

The spiral spring stores the necessary energy to perform a fast O-CO reclosing cycle. It accelerates the main shaft & the cam, which pushes the moving contact of the vacuum interrupter to closing position. Compared to a magnetic actuator, the spring operated mechanism enables us to achieve faster operation, and as a result opening is completed within only 3 cycles of current.

At the end of each closing operation, the spiral spring may be rewound so that the necessary energy to perform a complete reclosing cycle is always available. The standard operating mechanism is equipped with a closing coil, trip coil & an auxiliary contact block for remote indication of circuit breaker operations. The M5S spring mechanism represents

a true technological step, through the reduction of complexity and number of moving parts, compared with a more traditional spring-operating mechanism, and does this without the limitations and constraints of a magnetic actuator. The M5S has been proven for more than 10,000 operations without maintenance.

3 Conclusions

The combination of an innovative design of switchgear allowing the functionality of withdrawable equipment but with the advantages of fixed pattern equipment together with a new generation of optimised high performance vacuum interrupters gives significant advantages over conventional equipment. The innovative design of the rotating isolator circuit breaker module enables maximum simplification of the withdrawable switchgear. In addition due to the front-to-back arrangement of all functions, a straight-line connection can be established between the busbar and power cables, substantially improving reliability. The ease of access to all functions from the front and the reliability and readability of the component position indicators allow operators to provide rapid servicing and significantly reduced risk of operator error, as well as allowing back to back operation of panels. Also the introduction of internal arc resistant compartments and venting into the design, means that in the event of an internal fault operator safety is significantly improved, as well as reducing the consequences of the fault on the equipment and switchboard. The use of a simple, proven spring mechanism made possible by the use of the latest designs of vacuum interrupters enhances both reliability and endurance.

As indicated above, this innovative approach to switchgear offers outstanding reliability and operating safety as well as access to key components, in a compact form.

4 Acknowledgements

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5 References

[1] L. T. Falkingham “Fifty years of Vacuum Interrupter Development in the UK” *Proc. of the XXth International Symposium on Discharges and Electrical Insulation in Vacuum*, Tours, 2002.

[2] L. T. Falkingham and M Schlaug “The Next Generation of Vacuum Interrupters; Using a ″design for the environment″ Approach” *Proc. of CIRED, Barcelona, 2003*