

NEW GENERATION OF VACUUM CIRCUIT BREAKERS WITH MONOSTABLE MAGNETIC ACTUATOR

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ABSTRACT

Paper deals with the design and parameters of the new generation of vacuum circuit breakers (VCB) built around novel design of magnetic actuator. Actuator utilizes magnetic system with the serial magnetically hard alloy. The actuator is fixed in closed position by magnetic flux. In the open position it is fixed with the aid of opening spring. Single coil allows providing close and trip actions depending on the direction of the injected current. In each VCB pole separate actuator is installed. These actuators are linked with the synchronizing shaft providing control of auxiliary switches and interlocks. This design allows achieving high mechanical life and maintenance free feature during the entire product lifetime.

INTRODUCTION

Vacuum switching technology provides circuit breaker with the following well-known advantages:

- maintenance-free interrupter design
- high dielectric strength leading to small interrupter size;
- high interrupting capacity (up to 100kA rms) [1];
- comparatively low erosion of contact system providing long electrical life;
- short contact stroke allowing simplification of the actuating mechanism and reduction of the energy required for circuit breaker control

These advantages however did not lead to creation of the maintenance-free VCB during first decades after introduction due to application of old-fashioned motor-spring actuators requiring scheduled maintenance.

At the end of 80-s authors applied single-coil magnetic actuator for VCB [2]. This design though using conventional magnetic materials and bulk iron yoke allowed for the first time ever designing maintenance-free VCB that had entirely changed service concept.

However, this design had limited breaking capacity (20kA) that had been associated with the limiting holding force of the magnetic actuator.

Later an alternative concept of magnetic actuator had been offered [3, 4]. This design allowed providing necessary holding force. However, it required application of rare-earth magnets, laminated yoke and two coils. These peculiarities increased cost of the actuator and complicated its design.

The present paper describes design concept and basic parameters of a new single-coil magnetic actuator applicable for high-current VCB.

ACTUATOR DESIGN

The heart of the actuator is two medium energy magnets – yoke and armature - made of magnetically hard alloy and providing latching forces in excess of 230 kilograms. The yoke houses the single coil that provides the energy to operate the mechanism.

In the closed position the magnetic forces are concentrated at the yoke-armature interface and provide the latching force required to keep the mechanism closed.

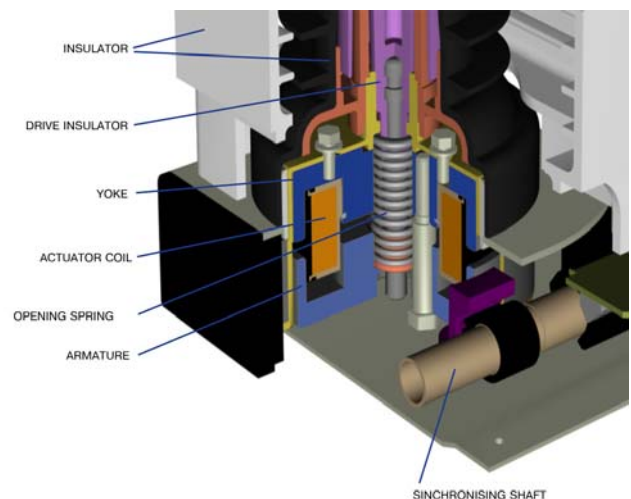


Fig1 Cross-section of new magnetic actuator assembled in VCB pole

PRINCIPLE OF OPERATION

Open position. In the open position actuator fixed with the aid of residual mechanical force (pre-strength) of the opening spring (Fig1). Electrical consumption is absent.

Closing operation (Fig2). Electrical closing command starts the discharge of pre-charged capacitor bank of control module into the actuator coil. When electromagnetic force overcomes force of pre-strength opening spring, armature starts moving (Fig2 b)).

When the contact gap is over, movable contact of VI stops, the armature continues movement and overpasses 2mm of “additional compression gap” compressing the contact pressure spring and opening spring that store the energy for the future opening operation (Fig.2 c)).

At the end of the compression gap the armature latches magnetically to the yoke (Fig.2 d). Since closing of magnetic

system the coil current further increases to produce magnetic field to saturate the magnets and provide the power of the permanent magnets enough to hold the armature in the CLOSED position after the coil current has been cut off by a control module.

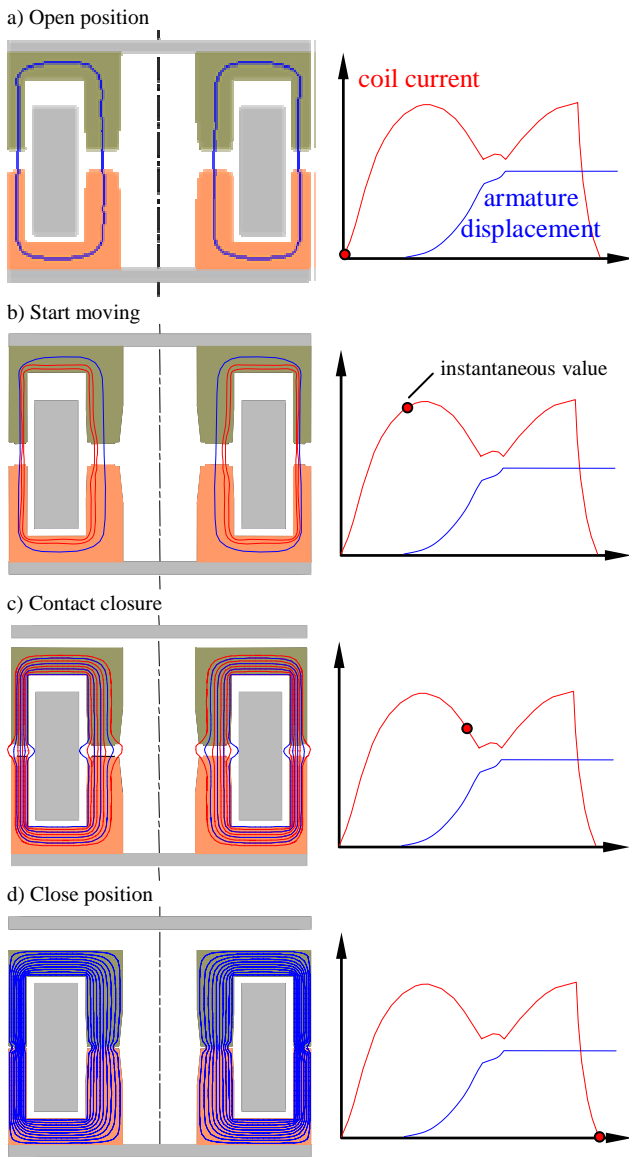


Fig 2 Closing operation

Closed position. The actuator is fixed in closed position by magnetic flux of permanent magnets - yoke and armature.. Magnetic latch force is much more higher than force of opening and contact pressure springs, so the magnetic actuator keep VCB closed in any standard situation (vibration, strong external magnetic field when short circuit current passes through and around) Electrical consumption is absent

Opening operation. To open the breaker the current of opposite polarity, derived from the opening capacitor in the control module, passes through the coil for 15÷20 milliseconds. This current partially de-magnetizes the magnets and reduces the magnetic holding force in the armature. When the summary force of charged opening and contact pressure springs exceeds the magnetic force, the armature releases from yoke (Fig3 b)), rapidly accelerates and tear off the contact of VI (Fig3 c)). The breaker is opened (Fig3 d)).

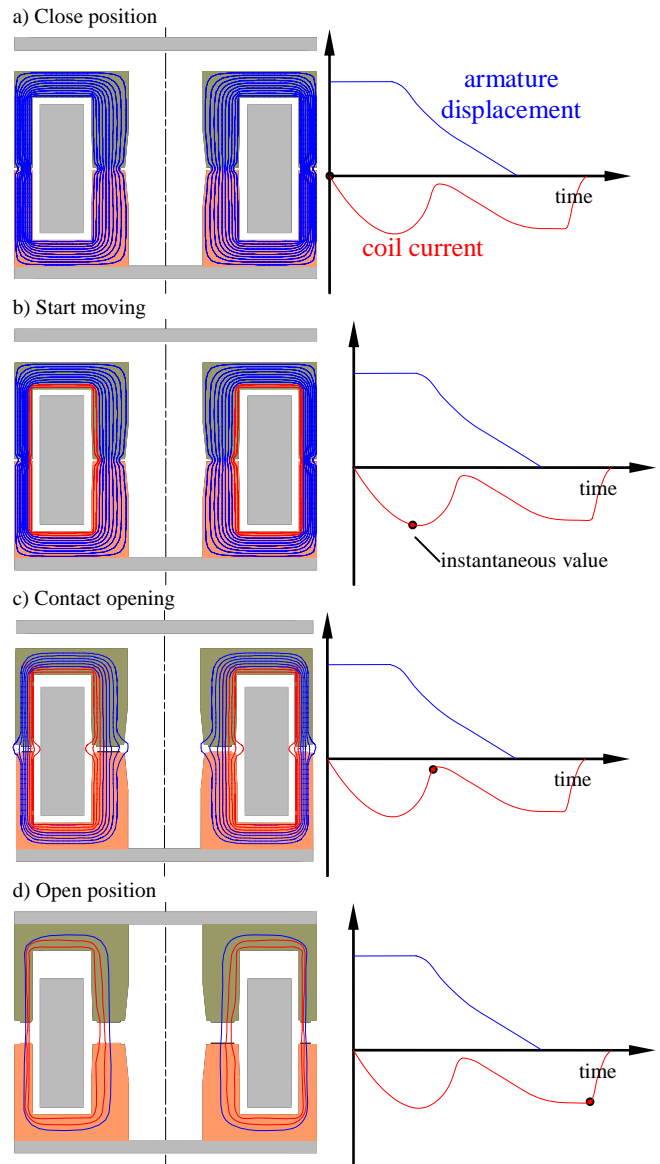


Fig 3 Opening operation

ACTUATOR PARAMETERS

Static condition

Each kg of mass of new actuator produces 850N of magnetic force. It is almost twice higher than for the design described in [2, 5]. This result has been achieved with the aid of finite-elements analysis and optimization of new actuator design (Fig4).

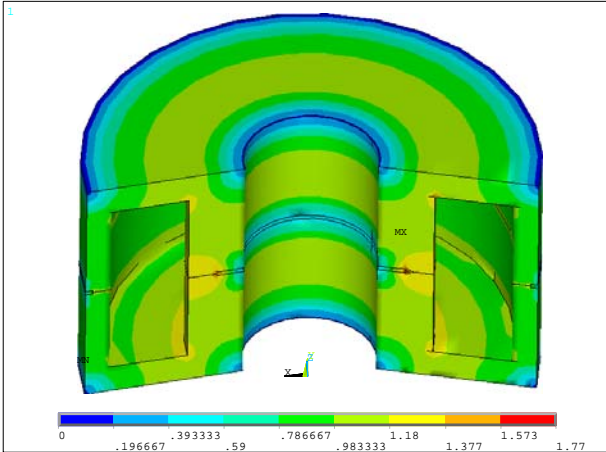


Fig4 Example of 3D FM analyses of magnetic field of new actuator

Opening spring parameters are chosen to satisfy the following requirements:

- 1) High stability of breaker open position at any allowable VCB orientation;
- 2) Minimum power consumption at closing operation.

Dynamic characteristics

The actuator coil parameters – the total square of copper and number of turns – have been optimized to reach minimum power consumption and maximum mechanical life of the vacuum interrupter contact system. Optimization has been made on the basis of experimental working characteristics of actuator (Fig5)

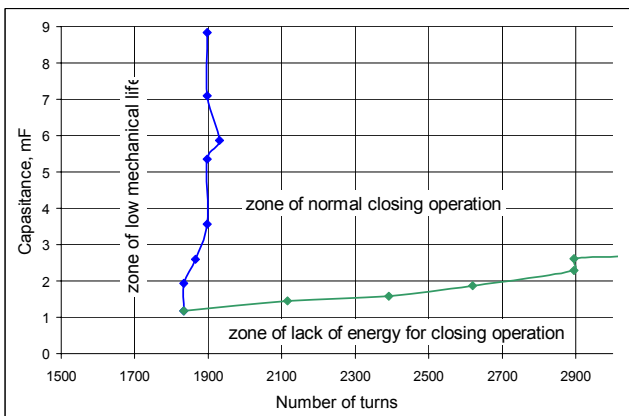


Fig5. Example of working characteristic of new actuator.

As a result of the mentioned optimization energy stored in

capacitor bank required for close-open duty has been reduced to 150 Joules for VCB with rated breaking capacity 31.5kA at 12kV. It is important to note that this energy is sufficient to provide close-open duty within the entire range of technological and temperature variations of the parameters of VCB and control electronics.

NEW GENERATION OF VCB

On the basis of the described actuator new range of high current VCB has been designed.

TABLE1 – VCB performance data

rated voltage	rated current	breaking current
12 kV	800/1000/2000 A	20 /25/31.5 kA
17.5 kV	800/1000/2000 A	16/20/25 kA
24 kV	800/1000 A	16/25 kA

Fig. 6 illustrates appearance of the new VCB.



Fig.6 New VCB appearance.

VCB has separate actuators installed in each pole. These actuators are linked with the aid of synchronizing shaft providing control of auxiliary switches and interlocks. The characteristics of actuator, vacuum interrupter and the characteristics of the rest components of VCB pole have been designed to achieve:

- maintenance-free feature during the entire product lifetime
- low power consumption;
- high mechanical life;
- low dimension and weight

This task has been successfully implemented. Standard mechanical life of the new actuator equals 50000 CO operations. Special versions with the mechanical life 150000 CO operations are also available.

The weight for 12kV/2000A/31.5kA version does not exceed 46kg that is approximately twice lower than for the products available in the market. The same is true with reference to VCB dimensions. Having conventional height and width new

VCB has approximately twice lower depth providing unique possibilities for designing compact switchboards.

CONCLUSION

New concept of the mono-stable single coil magnetic actuator allows extending range of maintenance-free VCB up to 2000A rated current and 31.5kA rated breaking current. At the same time it allows achieving exceptional mechanical life, compactness and low weight.

AKNOWLEDGEMENTS

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