New Technology for Medium Voltage Replacement Breakers

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Outline

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Abstract

For decades, medium voltage circuit breakers have used stored energy spring mechanisms to operate moving contacts for the purpose of electrical power interruption. While the electrical interruption technology has significantly improved over the years (minimum oil to air magnetic to SF^6 to vacuum), circuit breaker operating mechanisms have remained largely unchanged.

Leading edge, magnetically actuated breaker mechanism technology is changing the face of medium voltage circuit breakers, and is the first leap forward in mechanism technology in over 50 years.

The Early Days

Early circuit breakers, whether they were minimum oil or air magnetic, featured solenoid type mechanisms. These mechanisms drew large amounts of current on closing; and in some cases, required current to keep them closed. On the plus side, these older products were designed with loose tolerances. Most were not dependent on lubrication for proper operation.

Stored energy circuit breakers rose to prominence in the 1950's. Although some breakers used hydraulic accumulators to charge and store energy, the vast majority used enormous springs which closed the circuit breaker as they discharged. Closer tolerances made attention to lubrication and periodic maintenance a must.

Solenoid Mechanism

Hydraulic Mechanism

Springs remain the primary source of stored energy for medium voltage circuit breakers. All mechanical parts in these veteran devices move at high energy and velocity during switching operation and are subject to a significant wear over their operating life. Circuit breakers with arc-quenching media such as minimum oil, air, and SF6, require a high amount of stored force for proper switching, especially during fault conditions. The greater the force and energy involved, the greater the stress and wear of the individual mechanism parts. No matter how meticulously the circuit breaker has been designed and manufactured, they still require planned periodic maintenance. This may entail replacing worn parts and lubricating bearings and other moving/sliding surfaces.

The introduction of vacuum circuit breakers improved the interruption process substantially. Reduced contact travel, 75% reduction of contact velocity compared to minimum oil type breakers, and a small moving contact mass are all salient features of vacuum technology. As a result, the modern vacuum circuit breaker requires a significantly smaller, lower energy operating mechanism with subsequent significant reduced wear.

The operating characteristics of the spring stored energy vacuum circuit breaker became the new industry standard for medium voltage circuit breakers and the catalyst for a mechanism to use in replacement breakers for older technology.

Spring Stored Energy

As today's owners of aging medium voltage switchgear struggle with continual system reliability issues, direct roll-in replacement breakers have become a viable option to the high cost and down time associated with complete switchgear replacement.

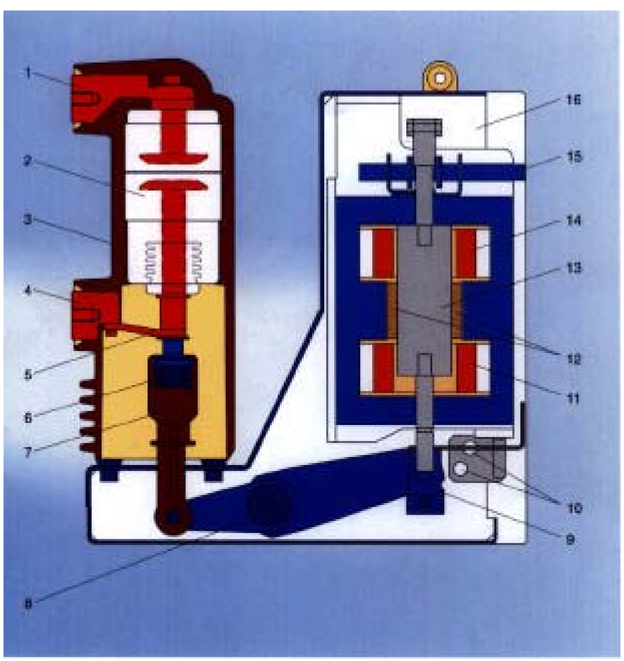
Although today's replacement breakers can provide a solution, most use stored energy spring mechanisms to operate moving contacts for the purpose of electrical power switching and interruption. As noted elsewhere in this paper, this mechanism technology has been around for decades, even though the interrupting medium has seen significant improvement, from minimum oil to air magnetic to SF6 gas to vacuum. Because of the magnitude of moving parts (varies between designs and manufacturers) in these mechanisms, continual maintenance and periodic refurbishment are still required to maintain reliability.

Technology for the Future

Magnetically actuated, 3 cycle replacement circuit breakers offer the first leap forward in mechanism technology in over 50 years. With its simplicity and reduced number of moving parts, this technology offers the cost savings of virtually limitless mechanical endurance with almost no maintenance. As a direct replacement for aging medium voltage circuit breakers, the magnetically actuated mechanism technology meets the demands of the next millennium for highly reliable power distribution.

The Technology

In the magnetically actuated vacuum circuit breaker (Figure 1), a single actuator drives a common jackshaft (8). This jackshaft in turn couples the actuator energy to the moving contacts of the vacuum interrupters (2) on all three poles through insulating pushrods (7). The actuator consists of a bistable magnet system, in which switching of the armature (13) to the relative positions are effected by the magnetic field of two electrically excited coils (11 and 14). The jackshaft is basically the only mechanically stressed part. Wear of parts and its associated required maintenance are therefore considerably reduced. The magnetic latching required to hold contacts together during faults is also quite remarkable. Two permanent magnets (12) hold the magnetic armature in one of the two limit positions corresponding to OPEN and CLOSED. Neither mechanical latching nor a constant electrical current supply is therefore required.



1. Upper Primary Terminal
2. Vacuum Interrupter
3. Epoxy Potting Compound
4. Lower Primary Terminal
5. Flexible Connector
6. Wipe Springs
7. Insulated Pushrod
8. Jackshaft
9. Stroke Adjustment
10. Position Sensors
11. Close Coil
12. Permanent Magnets
13. Armature
14. Open Coil
15. Manual Opening Actuator
16. Mechanism Enclosure

Figure 1: Side View of Magnetically Actuated Circuit Breaker

Actuator Principle

The only moving part (Figure 2) is the central armature. The top illustration shows the upper, latched limit position. The magnetic field lines generated by the two permanent magnets are also shown. The magnetic flux is channeled into the upper area of the actuator by the position of the armature, and increases the adherence of the armature to the upper stop. In this condition, there is no power applied to the coil of the actuator, and the actuator can therefore apply its remaining force for any length of time.

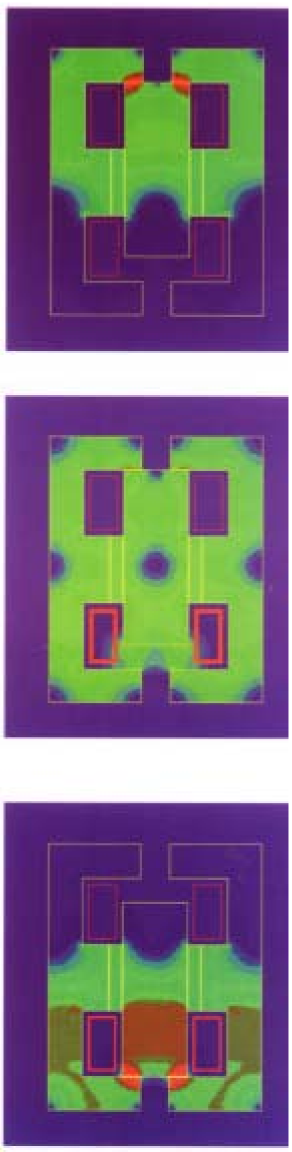


Figure 2: Sequence of Magnetic Operation

The middle illustration shows how the field lines change when current is applied to the lower coil. The magnetic disadvantage of the larger air gap at the bottom is compensated for by the magnetic advantage of the lower coil, causing field lines in the core assembly to move apart. The latching effect is accordingly diminished, and as the current rises, the armature moves downward. The armature will always seek a position in the field where the magnetic field energy in this system is at its minimum.

In the bottom figure, the armature has reached that position. The coil current and permanent magnet now act together and produce a very strong force that draws the armature downwards. For safe latching, however, the action of the permanent magnets alone is sufficient, and the current is therefore switched off when the limit position has been reached. The condition is then a 180° mirror image of the left-hand figure.

Other features of a magnetically actuated circuit breaker significantly reduce auxiliary power requirements and shorten charge time after operation. A single electronic unit controls all input/output functions for the circuit breaker. The auxiliary power required is only a fraction of what a conventional circuit breaker uses. The electrical energy needed for energizing each of the two coils and operation of the breaker is stored in two electrolytic capacitors housed in the circuit breaker.

To recharge the capacitors after operation, the circuit breaker draws less than 1.5A at 120V. The stored energy of the capacitors is capable of performing the standard Open – Close – Open duty cycle common among stored energy spring circuit breakers. Since there are no primary closing springs to charge, the capacitors are charged and ready for operation in less than 2 seconds after a duty cycle operation.

In order to increase the reliability and operational abilities of the magnetically actuated circuit breaker, inductive proximity sensors (10 of Figure 1) are used to detect the OPEN and CLOSED limit positions, thus eliminating the need for standard auxiliary switches.

Magnetic Actuator with Epoxy Pole Pieces

Maintenance

The intent of the magnetically actuated circuit breaker was to produce a virtually maintenance free component for use in distribution systems with reduced life cycle costs. The number of functional components was minimized, and the remaining components were optimized for extended lifetimes.

The magnetic actuator is completely maintenance free over its lifetime. The inductive position sensors have no mechanical interaction with the mechanism, and are therefore also maintenance free. The universal electronic control uses any voltage greater than 80 volts AC or DC; is tested for operational integrity for the extended life of the circuit breaker and consumes only 4W of steady state power. Advanced electrical isolation guarantees EMI proof operation. The unit controls the electrical impulse to the operating coils. Breaker operation can be electronically defeated during racking operation. As an addition standard mechanical racking interlocks this feature further enhancing operator safety.

The following table demonstrates the virtually limitless mechanical properties of magnetically actuated technology:

Table 1: Mechanical properties of Circuit Breakers

ANSI Requirement	Minimum Requirement * (Industry Standard)	Magnetically Actuated Capability (25kA)
No-load mechanical endurance	10,000 no-load operations	100,000 no-load operations
Operations between servicing	2,000 no-load operations	Limited only by operations
Continuous current switching	1,000 load operations	30,000 load operations

* These are the maximum endurance requirements by ANSI for breakers rated at less than 15kV rated voltage, less than 31.5kA symmetrical interruption, and less than 2000A continuous current. Endurance requirements for higher voltage, interruption, and continuous current ratings are considerably lower.