Medium Voltage Electro-Mechanical Linear Actuator Breaker

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ABSTRACT

Today's users of medium voltage circuit breakers are expecting their equipment investment to deliver more in the way of greater performance, improved reliability levels, significantly less maintenance, and wider ranges of application, all in the same size or smaller package. Manufacturers have, over time, met a majority of the challenges through technological improvements and advances. Much of this effort over many years centered on the electrical interruption means. Moving from the very early years of minimum oil to air magnetic to vacuum, as the now preferred interruption means has resulted in smaller and more reliable medium voltage circuit breakers requiring less ongoing maintenance. Still the push has continued for medium voltage devices with broader application ranges from an operational nature, significantly reduced maintenance and a longer life cycle. This has led manufacturers to actively investigate other medium voltage circuit breaker design areas that might have the potential to efficiently deliver application and maintenance improvements without sacrificing on the tremendous strides made over the past decades.

One area of the medium voltage circuit breaker not significantly changed over this long and steady period of technological advancement has been the operating mechanism. Generally, these circuit breakers have operated through the use of a stored energy type mechanism. Charged closing springs closed the circuit breaker, and closing of the circuit breaker simultaneously charged the opening springs. Basically, the spring stored energy mechanism includes all the elements necessary for storing the energy, and closing and tripping the circuit breaker. A number of other moving mechanical devices are necessary to provide the motion required to close and open the circuit breaker. There is a significant amount of rather precise manufacturing and maintenance procedures associated with this type of operating mechanism. For a large number of today's applications, this type of mechanism is still used and performs very well as it has for so many years. The stored energy mechanism, although essentially the same through the years, has seen design changes and improvements spurred on primarily by changes in interruption technology. The introduction of vacuum interrupters into the equation not only greatly improved the interruption process, it also opened the door for further investigation into design changes elsewhere within the circuit breaker. Vacuum interrupters brought about a significant reduction in the travel distance for contacts, along with a significant reduction in the amount of energy and velocity associated with breaker operation. The use of vacuum interrupters can certainly take some of the credit for realized design improvements in the traditional spring stored energy mechanism. Vacuum interrupter technology, in addition to its obvious circuit interruption advantages, permitted designers to look into other areas for improvement to meet the continuing demand for broader application possibilities, lower maintenance costs and a longer life cycle.

Linear actuator (magnetically actuated) medium voltage circuit breakers have broken the four-minute mile, so to speak, of the medium voltage circuit breaker mechanism. This is the first major advancement in medium voltage circuit breaker mechanism technology in half a century. Magnetic actuator technology permits the medium voltage circuit breaker to more

easily meet the need for broader application capabilities and minimal maintenance. The simple design centering on far fewer moving parts offers a never before expected mechanical endurance with relatively low maintenance over the breaker's life cycle.

INTRODUCTION

Each generation reflects the best technology available at the time of its introduction, building on the strengths of previous designs, while adding new technology. It is now known that the linear (magnetic) actuated mechanism is capable of far more operations than is the stored energy mechanism without maintenance and/or lubrication. It, therefore, stands to reason that the linear actuator mechanism has specific application advantages over its stored energy counterpart.

Eaton is a world leader in vacuum interrupters and medium voltage vacuum circuit breakers. Experience of over 25 years in vacuum interrupter design and manufacturing experience, coupled with over 70 years of power circuit breaker design and manufacturing experience has resulted in a state-of-the-art linear actuator (magnetically actuated) mechanism. This mechanism is now employed in a space conscious design with both fixed and draw-out configurations. This technology, through the use of far fewer and less complicated individual parts, has significantly elevated the circuit breaker's application flexibility and reliability while drastically reducing maintenance costs, all in the same small space saving footprint. The linear actuator mechanism is capable of up to 100,000 operations due to the small number of moving parts. They can be applied up to 1600 amperes continuous (nominal) current and 25kA short circuit (Isc) current. The linear actuated mechanism is matched with the vacuum interrupters to provide the maximum in required forces and the minimum in required operating energy. They are ideal for applications where space is a premium, a more active operational duty is required and frequent scheduled maintenance programs are not practical. Consider the linear actuated vacuum circuit breaker in a switch, arc furnace, automatic transfer switch or capacitor switching application, just to mention a few. A special capacitor switching version is also available, tested in accordance with table 2 of ANSI C37.09-1999. Certainly, further advances will be made and strides taken in an effort to increase the equipment's life cycle, operational capabilities and further reduce the total installation and operating costs.

Figure 1 – Fixed Circuit Breaker

EATON LINEAR (MAGNETIC) ACTUATOR OPERATION

The linear (magnetic) actuator shown in Figure 2 consists of only one moving part. The linear (magnetic) actuator is comprised of four basic parts, these are the close electromagnet (#1), permanent magnet (#2), open electromagnet (#3) and the actuator (#4). Movement is achieved through the use of electromagnetic forces. One large electromagnet (#1) is used to close the actuator. Capacitors, housed in the

circuit breaker, provide the energy required by the close electromagnet. A permanent magnet (#2) then holds the actuator in the closed position, even in the event of a short circuit. For opening, a small electromagnet (#3) is used and is assisted by the stored energy in a small opening spring. Enough energy is provided by the closing operation to charge the opening spring. A capacitor, also housed in the circuit breaker, provides the energy required by the open electromagnet.

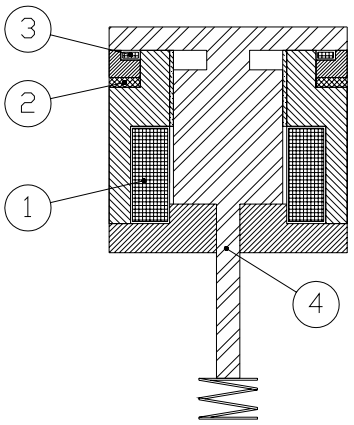

Figure 2 – Linear (Magnetic) Actuator in Closed Position

Figure 2 shows the linear (magnetic) actuator in the closed position. A compressed spring represents the spring energy that is stored for an opening operation.

Figure 3 shows the linear (magnetic) actuator in the open position. As mentioned previously, only a small electromagnet (#3) with an opening spring assist is needed to open the actuator. When the electromagnet is energized, the affect of the permanent magnet (#2) is cancelled. The energy of the charged opening spring is released moving the actuator to the open position.

To close the actuator, the larger electromagnet (#1) is energized, thus providing a powerful force that closes the actuator and charges the opening spring in the same operation.

The single actuator operates a common shaft that uses the energy provided to operate the moving contacts of the vacuum interrupters on all three poles. The shaft itself is the only part that is mechanically stressed.

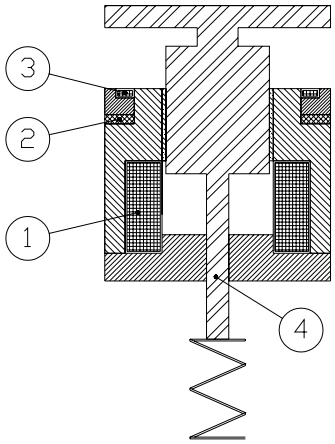

Figure 3 – Linear (Magnetic) Actuator in Open Position

EATON LINEAR (MAGNETIC) ACTUATED CIRCUIT BREAKERS

Draw out type and fixed type medium voltage circuit breakers utilize this very compact linear actuator mechanism. They were tested and proven to ANSI C37.04 and C37.09. They are also UL Listed and CSA witnessed. Because the linear mechanism is quite small, the overall circuit breaker footprint remains compact and perfect for limited space applications (Figure 1).

The linear (magnetic) actuator mechanism is comprised primarily of the linear actuator, the controller and capacitors. As previously discussed, capacitors provide the required energy for the opening and closing operations. The stored energy of the capacitors is capable of performing the standard Open-Close-Open duty cycle closely associated with spring stored energy circuit breakers, thus a high degree of service continuity is provided. The energy stored permits emergency operation in case control power is lost. The single electronic controller regulates all input and output functions for the circuit breaker, and the power supply can utilize a wide range of AC and DC control voltages. It consumes a very small

amount of steady state power. In addition the controller provides user feedback in the form of a "System Healthy" indicator that constantly monitors the condition on the capacitors and the open and close coil circuits.

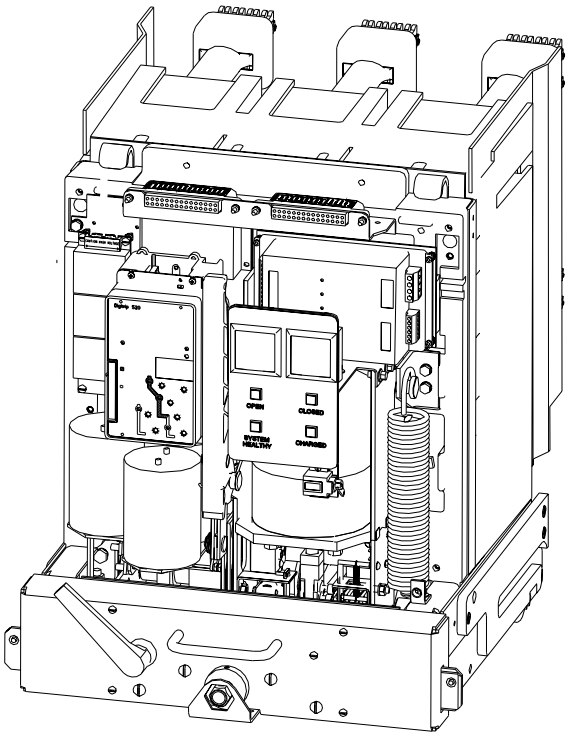

Figure 4 – Draw Out Circuit Breaker (Front Cover Removed)

LINEAR (MAGNETIC) ACTUATED CIRCUIT BREAKER MANUAL OPERATION

While the circuit breaker is powered on, it can be manually closed and opened through the use of front mounted "ON" and "OFF" pushbuttons. In the event that control power is lost, the circuit breaker is capable of performing a manual OPEN operation up to 48 hours after the loss of control power. If the loss of control power is longer than 48 hours, the circuit breaker can be opened utilizing the integral "EMERGENCY OPEN" handle located on the front of the circuit breaker (Figure 5).

Figure 5 – User Interface (Front Close-up)

LINEAR (MAGNETIC) ACTUATED CIRCUIT BREAKER ELECTRICAL OPERATION

While the circuit breaker is powered on, it can be electrically closed and opened. The circuit breaker is capable of performing an electrical OPEN operation up to 48 hours after the loss of control power. The linear actuator circuit breaker does not accept an exterior voltage source to open or close the breaker. A dry contact is used to open or close the circuit breaker remotely. An optional under voltage release device can be used and is mounted separately from the circuit breaker.

MICROPROCESSOR-BASED TRIP UNIT (PROTECTIVE RELAY)

All Eaton type linear actuated circuit breakers are designed to utilize an optional Digitrip microprocessor-based trip unit (protective relay). The electronic trip units are self-powered. When the circuit breaker is closed, no

external power is required to operate their protective systems. The trip unit is wired to the circuit breaker's controller. Under pre-selected conditions, the controller receives a pulse from the trip unit and the controller trips the circuit breaker.

LINEAR (MAGNETIC) ACTUATED CIRCUIT BREAKER SUMMARY

The Eaton linear (magnetic) actuated circuit breaker has taken a huge step in the direction of a medium voltage circuit breaker for use in distribution systems with significantly reduced maintenance, greatly increased operational ratings, and reduced life cycle costs. In addition, it is noticeably smaller and lighter than comparable breakers because of smaller internal components. The result is a highly reliable circuit breaker with mechanism capable of 100,000 operations due to its small number of moving parts.

The linear (magnetic) actuator mechanism is completely maintenance free over its lifetime. Two control voltages are available. A low control voltage range of 36-60 Vac and 36-72 Vdc and a high control voltage range of 100-240 Vac and 100-353 Vdc. The electronic controller was tested for operational integrity for the extended life of the circuit breaker. All normally expected and required safety features previously associated with spring stored energy circuit breakers, such as trip free operation, an anti-pump feature and other safety interlocks are provided.

The loss of control power is of no concern since the circuit breaker can have an OPEN operation performed up to 48 hours after the loss of control power. In addition, the circuit breaker can be opened using its integral front mounted EMERGENCY OPEN handle at any time.

The linear actuated medium voltage circuit breakers and the extra capacity versions are tested to ANSI Standards. The draw-out configuration is a three-position draw out (Disconnect, Test, Connect) device used in conjunction with a fixed draw out cassette. Fixed configuration devices utilize bolted bus or cable connections.

An integrally mounted microprocessor-based Digitrip trip unit (protective relay) can be used to add a large number of sophisticated features to the circuit breaker. These features range from protective features to displays to monitoring and communications.

Finally, the circuit breakers use highly reliable Eaton vacuum interrupters for circuit interruption, certainly the preferred interruption method used today worldwide.