

INTELLIGENT MEDIUM VOLTAGE CIRCUIT BREAKERS WITH INTEGRAL PROTECTIVE RELAYS

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ABSTRACT

A typical medium voltage circuit breaker is an electrically operated switching device that requires some type of intelligence to direct it as to how and when it will operate. Other closely associated devices, such as relays and sensors are required to detect abnormal conditions and signal the breaker's switching mechanism to operate to protect the system. We can say these devices provide the "brainpower".

Most older protection systems by design provided only single-phase protection using electromechanical relays. These relays are precision built devices with a solid reputation for performance and reliability. Mechanically driven electrical relays were dedicated to one protective function. As the protective system complexity increased, so to did the required number of different electromechanical relays, not to mention instruments, control, extensive wiring and ongoing maintenance.

Individual solid-state relays that followed, usually mounted on the front door of an assembly, were smaller and lighter than their electromechanical counter parts. In general, they were not sensitive to less than desirable environmental conditions and not subject to the wear expected with electromechanical relays.

Today, significant steps have been taken in the direction of microprocessor-based protective relays (trip units) being an integral part of the medium voltage circuit breaker. These integrally mounted devices deliver advanced programmable functions for never before experienced flexibility and capabilities. Their use also significantly reduces installation costs, the overall switchgear assembly footprint, and

equipment maintenance. In short, this technology is a major breakthrough for electrical system protection, along with the latest medium voltage circuit breaker and switchgear assembly design. At a minimum, the microprocessor-based protective relay (trip unit) replaces the normal complement of three or four conventional electromagnetic over current relays, an ammeter, a demand ammeter, and an ammeter switch. Overall, the distinct advantages offered by medium voltage circuit breakers with integrally mounted microprocessor-based protective relays (trip units) and its associated enclosure assembly is recognized today as a very desirable and cost effective approach when considering a new installation or modernization program. Just a quick external visual comparison of two typical medium voltage switchgear assemblies relates a powerful story for those responsible for specifying, manufacturing, installing and maintaining assembled equipment (Figures 1 and 2).

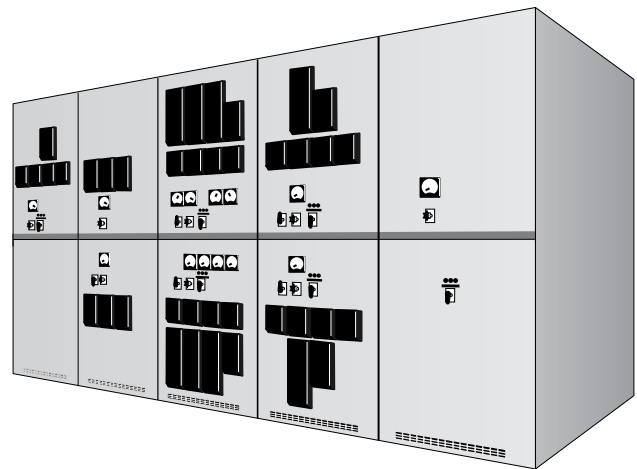


Figure 1 – Typical Switchgear Assembly with Conventional Electromagnetic Protective Relays and Other Devices



Figure 2 – Typical Switchgear Assembly with Microprocessor-based Protective Relays and Other Devices

Obviously, there is far more to it than a visual comparison. Many basic considerations must be reviewed during the selection process based on what was used in the past and what is available today. Design strides taken in recent years have been dramatic relative to the technical capabilities of equipment. What makes the achievements even more noteworthy is that much of the available equipment is now more cost effective and requires far less maintenance than anything previously available.

New complex systems or existing installations being considered for modernization can achieve a degree of functionality not available until the introduction of microprocessor-based protective relays (trip units). The precision offered by these modern protective relays allows for closer system coordination. In addition, the stable electronic circuitry and absence of mechanical motion guarantees the retention of their calibration accuracy for a long time. These microprocessor-based devices have gained a strong position in today's marketplace as experience proves their accuracy, dependability,

versatility, and reliability. Now microprocessor-based devices integrally mounted and functioning in concert with some technologically advanced medium voltage circuit breakers deliver an unbeatable combination for today's medium voltage distribution system. It is a combination that is driving the demand in today's market.

The reliability of the protection system is crucial to the dependable operation of any electrical distribution system. A circuit breaker may not trip or may false trip when a protective relay fails. The consequences can be catastrophic. Much of the traditional reliability depended heavily on the frequency and quality of routine maintenance. Features such as self-testing or status monitoring were not available in the past. Problems could go undetected. Not so today with built-in self-diagnostics.

In the past, manufacturers of protective relays required rather involved annual maintenance procedures. Especially due to the self-test features of modern microprocessor-based protective relays, only simple check-ups are necessary to insure correct circuit breaker operation via the protective relay. This goes hand in hand with vacuum circuit breakers of today which also require significantly less maintenance. This is especially true with some of the latest circuit breaker designs, which are capable of a much higher number of operations.

Today's facilities cannot afford or in some instances will not tolerate unscheduled downtime or costly equipment damage. Older equipment was frequently oversized and used generic over current and ground fault protection regardless of the load. This was, at best, striking a balance or compromise. Often now the expectation is that electrical equipment and its loads must be able to operate at full or even above capacity. The flexibility offered along with a large choice of protection settings and curves with the modern microprocessor-based protective relay eliminates the need for a security margin when planning and coordinating

the system. Coordination is precise because of the wide choice of available curves previously mentioned.

The microprocessor-based protective relay's ability to control and monitor the circuit breaker itself can provide valuable information that can be used to plan the required maintenance schedule for circuit breakers on an individual basis. Information availability combined with the already reduced maintenance requirements of some of today's medium voltage circuit breakers creates a never before experienced positive maintenance environment along with its associated cost savings.

Finally, additional features such as precise system analysis and communications, not available in the electromechanical era, help to make the selection process that much simpler for new equipment and modernization projects. This combined with the fact that extraordinarily capable microprocessor-based protective relays can be supplied as an integral part of some technologically advanced medium voltage circuit breakers is representative of the giant steps taken recently in the area of distribution system protection.

INTRODUCTION

All Cutler-Hammer medium voltage circuit breakers and their associated assembly are available with microprocessor-based protection, monitoring and communications utilizing a variety of front door mounted devices. For the purpose of this paper, however, only microprocessor-based protective relays (trip units) integral to the circuit breaker itself will be discussed. Integrally mounted devices represent another technologically significant step in the direction of a simplified and overall cost improvement picture for the customer.

Every member of the Cutler-Hammer compact family of VCP-T (ANSI) and T-VAC (IEC)

medium voltage vacuum circuit breakers is designed to utilize an integrally mounted, front accessible Digitrip microprocessor based, true RMS sensing protective relay (trip unit). This includes the standard 40kA circuit breaker, the capacitor switching design, and the latest linear (magnetic) actuated design. A tremendous degree of flexibility is offered since both draw out and fixed configurations are available, all configured to utilize the Digitrip protective relay (trip unit) at the time of manufacture or for updating at a later date (Figure 3). These compact, yet powerful, fully integrated and tested circuit breakers with integral protective relays (trip units) provide unique solutions for markets throughout the world, while saving time and money.



Figure 3 – Typical VCP-T Drawout Medium Voltage Circuit Breaker with Integral Digitrip Protective Relay (Trip Unit)

In general, the circuit breakers are tripped automatically on overload and fault current conditions by the combined action of three components:

- 1) Sensors measure the current level.
- 2) The Digitrip Protective Relay (trip unit) provides a tripping signal to a trip actuator or an electronic controller, when current and time delay settings are exceeded.

3) A Low-energy Trip Actuator, in most instances, trips the circuit breaker. Some circuit breakers, such as the linear actuated design, utilize an Electronic Controller.

This arrangement provides a very flexible system covering a wide range of tripping characteristics as described by the time-current curves.

Two protective relay (trip unit) models are available offering a wide range of valuable functions. The entire family of VCP-T (ANSI) and T-VAC (IEC) vacuum circuit breakers can use either of the available models. Present and/or future system requirements will quickly determine the appropriate model. Each protective relay (trip unit) comes in its own plug-in housing and can be easily replaced in the field.

The two Digitrip protective relay (trip unit) models for use with this family of circuit breakers are Model 520V and 1150V covering a range of features from basic protection to advanced protection, metering and communications. An “i” included as part of the model number with the 1150 protective relay, Model 1150Vi for example, indicates the protective relay (trip unit) was designed specifically for IEC applications. Model 1150V provides I^2t , I^4t and IEEE curve selection, while Model 1150Vi provides I^2t , I^4t and IEC curve selection for long delay overload protection. For the rest of this discussion, the protective relays will be generally discussed and the “i” will not be included.

Selecting and operating protective relays is simpler than ever with Digitrip, all without the burden of installation and wiring. Digitrip protective relays are robust with a high immunity to electromagnetic fields and transients. They are designed for harsh environments with a wide range of operating temperatures.

DIGITRIP 520V AND 1150V PROTECTIVE RELAYS (TRIP UNITS)

Both the 520V and 1150V Protective Relays (Trip Units) are self-powered and true RMS sensing. When the circuit breaker is closed, no external power is required to operate their protective systems. Current signal levels and the control power are derived from the current sensors.

A functional local test can be performed through the protective relay’s test receptacle. A small hand held functional test kit is used to check circuitry and mechanical tripping functions. Functional testing of most of the protective relay’s (trip unit’s) electronic circuitry can be performed locally without the need to shut down the circuit.

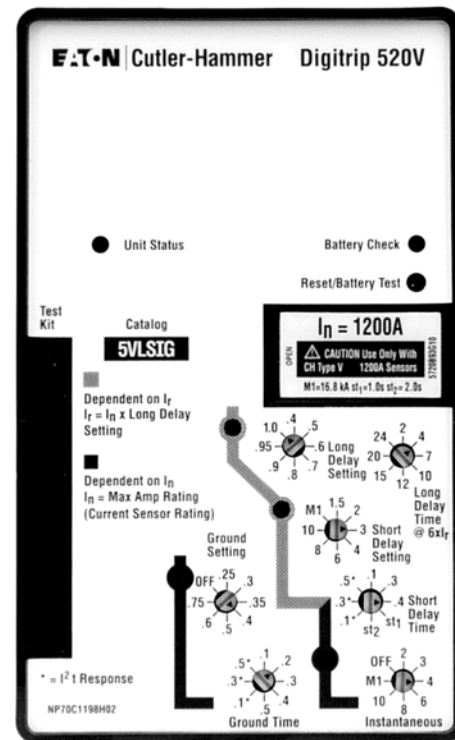


Figure 4 – Typical 520V Digitrip Protective Relay (Trip Unit)

All protective relays (trip units) use a fixed type-rating plug, which matches the current rating of the current sensors. If the rating plug is removed when the circuit breaker is carrying

current, the circuit breaker automatically opens ensuring a safe condition. The rating plug performs several functions:

- 1) It tells the protective relay (trip unit) what the rating is of the current sensors.
- 2) It determines the maximum instantaneous setting which is a function of the current sensor rating.

A visible green light emitting diode (LED) is located on the front of all protective relays (trip units) to indicate present status. Red LEDs indicate conditions such as the “cause of trip” or “trip mode” after an automatic trip operation. A small battery in the protective relay (trip unit) maintains these red indications during a power outage. All protective functions are provided independent of the battery status.

A clear, sealable, tamper-proof Plexiglas cover allows settings to be viewed but not changed, except by authorized personnel.

The protective relay (trip unit) model selected is determined by the overall system requirements and the degree of sophistication needed. Establishing the desired settings or programming the protective relay (trip unit) is simply accomplished from the front of the circuit breaker (Figure 5).

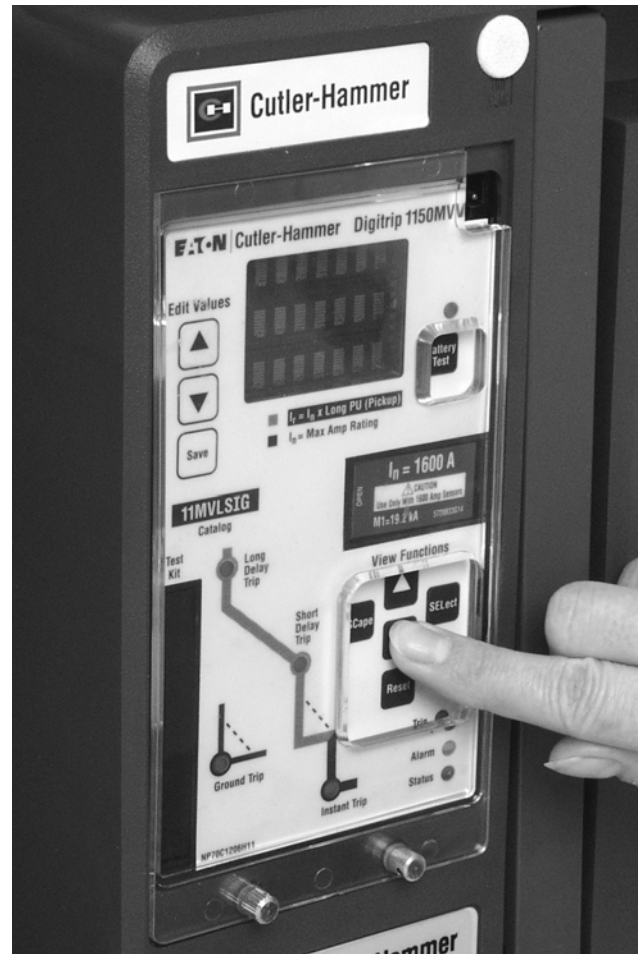


Figure 5 – Programming Integrally Mounted 1150V Digitrip Protective Relay (Trip Unit) in VCP-T Circuit Breaker

The Model 520V provides basic Long Delay (L), Short Delay (S), Instantaneous (I) and Ground (G) levels of protection to cover most applications. Since either the instantaneous or ground elements or both can be disabled, other combinations, such as LSI and LS, are also possible. Five phase and two ground (time-current) curve shaping adjustments are provided. The protection settings are also adjustable. Different curve slope selections are also possible with short delay and ground fault time.

The Model 1150V provides all the features of the 520V model plus advanced protection features, metering and communications to cover the most sophisticated applications. It is

programmable via a keypad on the front of the protective relay (trip unit) or from a remote location over a communications system.

Information about critical parameters, such as power factor, voltage, current, harmonic distortion values and waveform capture, are monitored and can be displayed with a three line LED window on the face of the 1150V protective relay (trip unit).

Five phase and two ground (time-current) curve shaping adjustments are provided. The protection settings are adjustable with numerous selections per function. A wide array of curve selections is available including IEEE and IEC, depending upon the exact 1150 model selected.

VCP-T (ANSI) AND T-VAC (IEC) FAMILY OF MEDIUM VOLTAGE VACUUM CIRCUIT BREAKERS

The Cutler-Hammer compact family of VCP-T (ANSI) and T-VAC (IEC) medium voltage vacuum circuit breakers incorporate many proven design features coupled with over 70 years of power circuit breaker design and manufacturing experience. The circuit breakers have been tested to demonstrate their capabilities beyond what might be considered standard. Since circuit breakers can be called upon for different types of applications, such as capacitance switching or frequent operation, this family of circuit breakers was designed to cover a broad range of applications all within a compact footprint. The use of an integrally mounted protective relay (trip unit) with any member of this circuit breaker family provides the highest degree of sophistication and application flexibility available in the industry.

All of the circuit breakers utilize vacuum interrupters as the interruption means, which is now the preferred interruption means. Cutler-Hammer does not only have a long and respected history in the area of circuit breaker design, it has an equally impressive 25-year

history in vacuum interrupter design and manufacturing.

One compact footprint covers all circuit breakers through all voltages. They are 60% smaller than comparable circuit breakers and 50% lighter. Overall, a reduction of installed space, material, shipping costs, and installation/startup costs is the positive result. The circuit breakers are small without any compromises. They are especially ideal for applications where space is a premium.

VCP-T/VCP-TR AND T-VAC/T-VACR MEDIUM VOLTAGE VACUUM CIRCUIT BREAKER MODELS

VCP-T/VCP-TR circuit breakers are ANSI rated circuit breakers tested to ANSI C37.04 and C37.09. They are UL Listed and CSA witnessed. Ratings are up to 15kV, 40kA and 2500A continuous current.

T-VAC/T-VACR circuit breakers are IEC rated circuit breakers certified to IEC62271-100 for 50 and 60 Hz. They are rated up to 17.5kV, 40kA and 2500A normal current.

In both cases, the “R” in the designation (VCP-TR and T-VACR) means a fixed mounted circuit breaker. The VCP-T and T-VAC designations describe three position drawout circuit breakers utilizing fixed mounted drawout cassettes.

VCP-TC/VCP-TRC AND T-VACC/T-VACRC MEDIUM VOLTAGE VACUUM CIRCUIT BREAKER MODELS

These circuit breakers, identified by a “C” added to the end of each designation, identify circuit breaker with capacitor switching capabilities. Once again the circuit breakers were tested to the same standards and offer the same ratings as just outlined for the VCP-T/VCP-TR and T-VAC/T-VACR models. In addition, they offer capacitor switching capabilities of 250 and 630 amperes (Single

Bank), 250 and 630 amperes (Back to Back) and 25 amperes (Cable Charging).

VCP-TL/VCP-TRL AND T-VACL/T-VACRL MEDIUM VOLTAGE VACUUM CIRCUIT BREAKER MODELS

These circuit breakers are the latest addition to the family of circuit breakers. The “L” in the designation describes state-of-the-art circuit breakers utilizing a linear actuator (magnetically actuated) mechanism. This technology, through the use of far fewer and less complicated individual parts, has elevated the circuit breaker’s application flexibility and reliability. At the same time, maintenance costs are drastically reduced. The linear actuator mechanism is capable of up to 100,000 operations due to the small number of moving parts. Mechanical Close Open endurance is tripled when compared to the same circuit breaker with a stored energy mechanism (Figure 6).



Figure 6 – Typical VCP-TRL Fixed Linear Actuated Circuit Breaker with Integral 1150V Protective Relay (Trip Unit)

Once again, these circuit breakers are tested in keeping with ANSI and IEC Standards as previously described for other members of this family of circuit breakers. They can be applied up to 1600 amperes continuous (nominal) current and 25kA short circuit (Isc) current.

The linear (magnetic) actuator mechanism is comprised primarily of the linear actuator, the electronic controller and capacitors. Three larger capacitors provide the required energy for the closing sequence and one smaller capacitor provides the energy for the opening sequence (Figure 7).

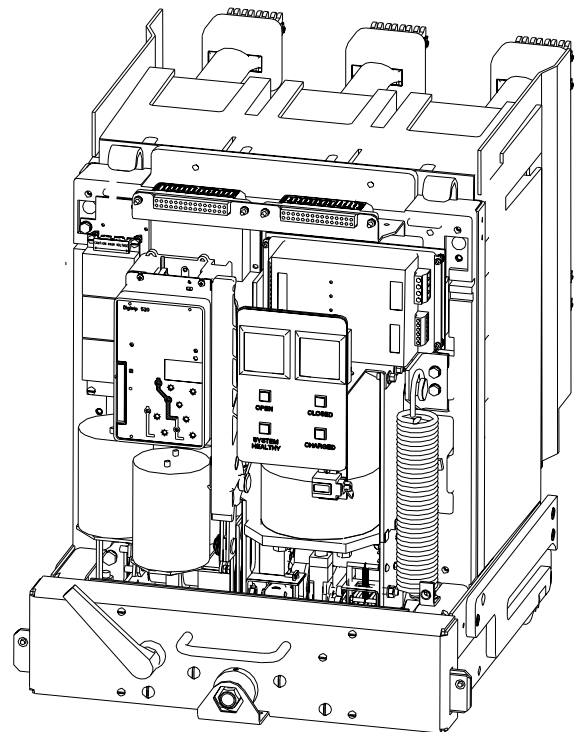


Figure 7 – Typical VCP-TL Draw-Out Linear Actuated Circuit Breaker with Integral Protective Relay and Front Cover Removed

VCP-TL/VCP-TRL and T-VACL/T-VACRL circuit breakers have taken a large step in the direction of significantly reducing maintenance costs, greatly increasing operational ratings, and reducing overall life cycle costs. The linear actuator mechanism itself is completely maintenance free over its lifetime.

These particular circuit breakers are ideal for applications where space is limited, a more active operational duty is required, and frequent scheduled maintenance programs are not practical.

SUMMARY

Microprocessor-based protective relays (trip units) mounted on the front of switchgear assembled equipment, but separate from individual circuit breakers offer distinct and measurable advantages over their electromechanical counterparts, operational, flexibility, initial cost, installation cost, and maintenance cost advantages to mention a few. Today's users of medium voltage protective equipment are, however, expecting more in the way of greater performance, improved reliability, wider ranges of applications, lower maintenance, improvements in overall installed costs, and operational simplification with more sophistication. Medium voltage circuit breakers with integrally mounted protective relays (trip units) take a significant step in this direction. Not only are the features offered unsurpassed, they can be supplied from the beginning as a fully integrated and tested package with each individual circuit breaker.

This modern technological combination is a major breakthrough for the protection of electrical systems. The combination provides unique solutions for markets around the world, while saving time and money. An integrally mounted protective relay (trip unit) is the best and most advanced means for providing the intelligence required by the medium voltage circuit breaker, no matter how sophisticated the requirements. In addition to complete

protection features, an impressive range of communications, monitoring and metering capabilities are available. In short, customers receive no more than they want, but certainly no less than they need. Now more than ever, there is no limit on the amount of emphasis that can be placed on system integration, automation and communications.

Integrally mounted microprocessor-based protective relays (trip unit) have gained a strong and rapidly growing position in the marketplace as experience proves their accuracy, dependability, versatility, and reliability. The precision is unmatched, which allows for much closer system coordination. Circuitry is very stable ensuring calibration accuracy. The upside of such a protective relay (trip unit) integrally mounted in a state-of-the-art medium voltage vacuum circuit breaker is a solid consideration for all new equipment and a significant portion of upgrade possibilities.