Protective Relaying Issues in Low Voltage Systems for the High and Medium Voltage Engineer

David Beach, John Horak
Basler Electric

Presented before the
60th Annual Georgia Tech
Protective Relay Conference
May 2-5, 2006

This page intentionally left blank.

Protective Relaying Issues in Low Voltage Systems for the High and Medium Voltage Engineer

David Beach, John Horak
Basler Electric

This paper provides some background on low voltage (LV) design practices, as mentioned in the National Electric Code (NEC), and especially for the protection engineer whom normally only works in high voltage (HV) and medium voltage (MV) systems. Such engineers may never have a reason to work with low voltage systems and may never pick up the NEC and be quite unaware of its content. Hence, when asked for guidance on a LV application, may simply extrapolate HV/MV practices to the LV system and give inappropriate advice. The background information herein may assist such engineers in having some basic ideas on major differences faced in protection of LV systems.

The paper will address the topic of low voltage systems from the perspective of the National Electric Code (NEC), for voltages not over 600V. The NEC has different requirements for over 600V, but they will not be addressed in this paper.

Low Voltage Protection Practices That Vary from HV/MV Practices

While there is a large difference between the protection of HV/MV systems and LV systems, there might be some tendency to extrapolate HV/MV practices to LV protection. The topics below discuss some areas where this extrapolation does not hold well. These will be the talking points for the balance of the paper:

1) Definition of Low Voltage
   - The NEC makes a distinction between circuits not over 600V and circuits over 600V rather than using the IEEE definitions that place the break between Low Voltage and Medium Voltage at 1000V
2) Conductor protection
   - For circuits not over 600V, the NEC concentrates on providing protection against overload by basing protection on the ampacity of the conductor. For most types of circuits, the rules tie the load size to minimum conductor size; for branch circuits the overcurrent protection also is tied to the load size, for feeders to the conductor size. For motor circuits, the conductor protection is provided by the motor overload device rather than the overcurrent protective device.
3) Five wire systems
   - In LV systems, Neutral and Ground are carried on separate conductors, where in HV/MV systems, the neutral and ground are effectively the same and one cannot separate ground current from neutral current. Ground fault sensing on LV systems with neutrals must include the neutral current in the sensing.
4) Different requirements for different types of load and equipment
5) Mandatory ground fault sensing for certain circuits
   - For low impedance grounded systems, 480V, on feeders >= 1000A, the NEC requires ground fault protection in a manner that creates coordination difficulties.
   - For most circuits, ground fault protection is provided by phase devices as phase overcurrent.
6) Low Voltage Breakers Design is Much Different than HV/MV Breaker Design
   While not a protection issue directly; the HV/MV protection engineer needs to have some concepts on how HV/MV and LV breakers differ from one another.
   - There are various LV breaker designs (MCCB, ICCB, LVPCB, and designs within each of these categories)
   - 80% rated breakers vs. 100% rated breakers
   - Interruption rating is not what it might appear at first.

Prepared for presentation to the
Georgia Tech Protective Relay Conference, May 2006
02/15/06. Comments: info@basler.com

- The common LV MCCB breaker lacks features that an HV/MV engineer might expect to be included without asking, such as trip and close coils, mounting provisions for CTs, auxiliary status contacts, and draw out construction. The ICCB and LVPCB may or may not have these features.
- The overcurrent response of LV breakers is much different than anything seen on HV/MV system designs.
- In almost all LV breakers there is a high set magnetic instantaneous current level that cannot be overridden, which prevents coordination at these current levels.

7) Load vs. Fault Current Range in LV Systems
   - The ranges of fault current, especially compared to load level currents, can be much greater in LV systems
   - In some applications where load current and fault current are extremely different, CT based current monitoring becomes ineffective, so overload and fault sensing with a classical relay may produce difficulties.
   - Similarly, sensitive ground fault systems can be compromised by high phase faults.

8) LV Systems Tend to Use MCCBs and ICCBs with Standard Trip Units
   - An LV engineer might tend to use a MCCB/ICCB where a HV/MV engineer would apply a protective relay.
   - The NEC is aimed at the mainstream radial overcurrent protection concepts. It does not directly address the niche issues where a protective relay is required.
   - The NEC makes little attempt at addressing generator protection.
   - The NEC makes little attempt at addressing issues associated with IPPs that have islanded and are at risk of back-feeding the utility
   - The NEC does not address advanced concepts in protection such as negative sequence voltage or current monitoring for phase loss detection
   - The NEC does not discuss methods for ground fault detection on impedance grounded systems.
   - The NEC does not discuss advanced motor protection schemes found in modern motor protection packages, and simply requires overload protection.

1. Definition of Low Voltage

The NEC distinguishes between two power system voltage levels, the principal level is 600V and less, and the higher voltage level is greater than 600V. Lower voltages are mentioned in reference to signal and control systems. The term low voltage has a variety of uses in the NEC; in 110.26(A)(1)(b) low voltage is used to refer to not greater than 30V rms for working space requirements; in 110.34(B), dealing with work space around and guarding of systems above 600V refers to low voltage as 600V and below. Article 490 defines High Voltage as above 600V for the purposes of that article and then allows low voltage to be everything else. In Article 517, dealing with Health Care Facilities, 517.64 defines low voltage as being below 10 volts, while 517.78, dealing with X-Ray equipment uses the terms high- and low-voltage without specifically defining either, but seeming to use the 600V distinction from the context. Article 551, dealing with recreational vehicles, defines low voltage as 24 volts or less. In Article 620 for Elevators and related equipment, low voltage is 30 volts or less. Article 680 about swimming pools uses low voltage in a way that implies something much less that 120V, but does not define the term.

While the code panels responsible for writing the NEC cannot seem to agree on a definition of low voltage, this paper will assume low voltage as being 600V and less. The difference between this definition and the IEEE's definition of low voltage being less than 1000V is of minor importance as there is very little that falls in the 600V – 1000V area.

2. Conductor Protection

Typical utility practice in protection is intended to protect against immediate conductor failure. Load management and planning are used to avoid prolonged overloads. Where protection is set depends on the utility, from fairly tight to "Protection shall not load limit." On the other hand, the requirements of the NEC are intended to limit overloads and trip circuits on sustained overloads, often at 125% of full load.

For the most part, the NEC rules on phase overcurrent protection tie back to equipment ratings. The code rules for various types of equipment specify the ampacity of the conductor feeding the load; and the rules for protection of conductors set the overcurrent protection to the conductor rating. The NEC makes a distinction between continuous and noncontinuous loads and has differing rules for the two. In the NEC, a continuous load is one likely to continue for three hours or more. Typically continuous loads are taken at 125% while noncontinuous loads are taken at 100%, although ratings of the overcurrent device can affect this distinction. This will be further explored below under the topic of 80% vs. 100% rated breakers.

3. Five Wire Systems

For the most part, 3-phase low voltage systems under NEC requirements are 5-wire systems with neutral and ground as two separate conductors and each intended for separate use. The utility engineer will be familiar with systems where a neutral conductor is included, particularly in distribution systems. However, that neutral conductor also will be grounded at multiple locations and serves as the return conductor for ground faults. In the NEC world, the neutral is grounded at one location only and carries all unbalanced currents from phase-neutral loads. Some systems covered by the NEC, having no phase-neutral loads, omit the neutral conductor. The NEC also allows for high impedance grounded systems and ungrounded systems under certain conditions, neither of which will have neutral conductors.

The presence of separate neutral and ground conductors simultaneously complicates and simplifies ground fault protection. The neutral conductor complicates ground fault protection in that current in the neutral has to be sensed and included in the determination of the ground fault current. Using window CTs this means an additional conductor through the window; using individual CTs in a residual connection this means a matching CT on the neutral connected into the residual connection and that residual connection measured by the protective device. If relays are being used, the residual calculation from the three phase CTs is not a complete accounting of the residual ground current.

The neutral also simplifies ground fault protection in that all load current can be accounted for and it is not necessary to set ground elements above the maximum possible allowable unbalance. When properly connected, all current seen by the ground elements should be fault current and none of it load current. CT performance issues and coordination with phase only devices do not enter into the consideration of minimum ground fault settings.

One implication of this use of the neutral can be seen in figure 1. Considering this system as a small DG system behind a wye-wye transformer, it should be noted that a line to ground fault on the high side of the transformer will produce fault current that will return to the generator on the neutral conductor and will not be seen as ground fault current by a ground element using sensing as shown by the 51G. The more traditional, utility, configuration would use the 51N connection, which would see the high-side fault as ground fault current, but would be sensitive to phase-to-neutral loads. In many cases, the utility will supply a wye-wye transformer with an internal bond between H0 and X0 which creates a second neutral ground point.

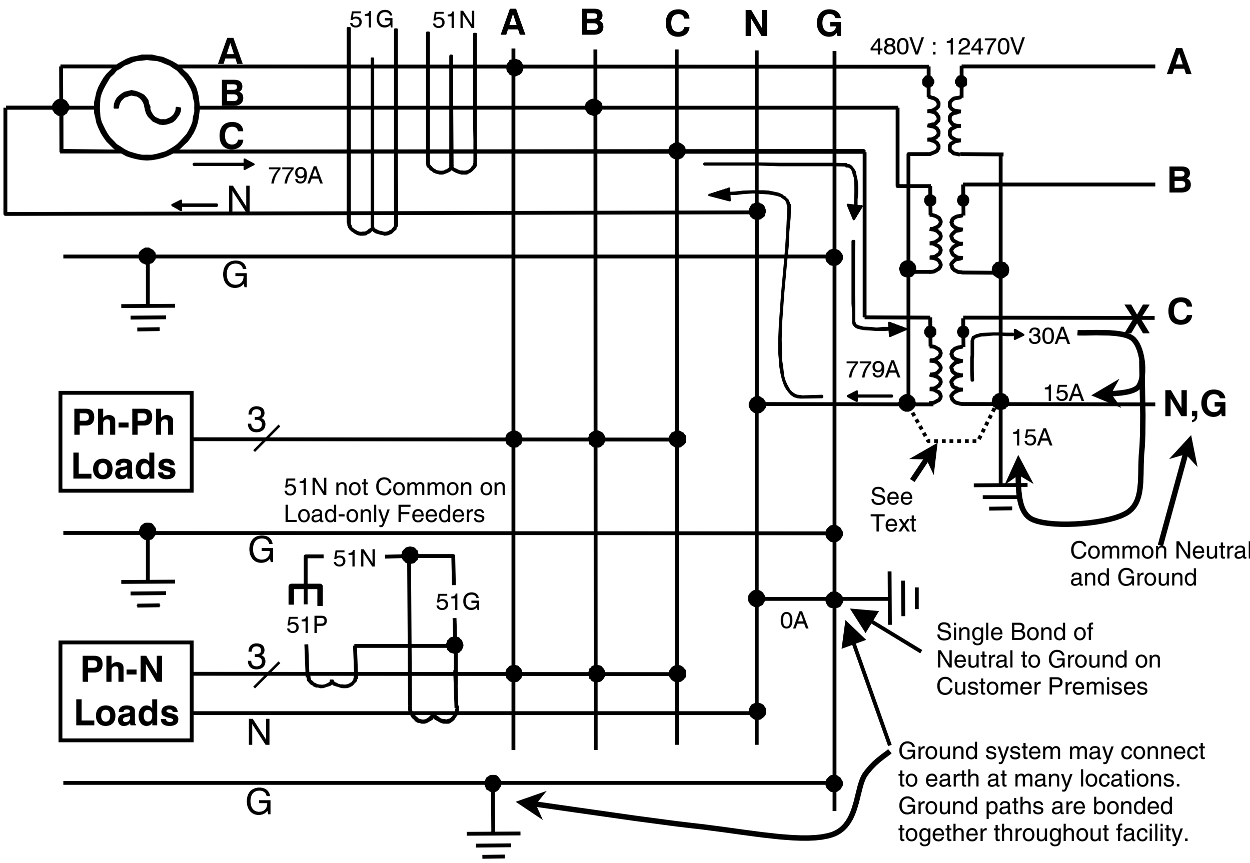


Figure 1 – 5-Wire System with Utility Ground Fault

4. Different requirements for different types of equipment

The NEC is divided into four main sections. The first three chapters are general in nature and apply in all circumstances unless specifically changed by other provisions. The next four chapters deal with specific equipment, occupancies and conditions. The third section is for communications systems and generally stands alone. The final section is tables, most of which are related to the general chapters.

Chapter 2, Wiring and Protection, covers circuits from the branch circuit to the service, overcurrent protection, plus grounding and bonding. Chapter 3 covers conductors and wiring methods, it is here that the ampacity tables are found.

Chapters 4 through 7 of the NEC are a series of Articles giving rules for various types of equipment, occupancies, and conditions. The equipment rules cover things from lights and receptacles to panels and switchboards to motors, transformers, and generators to appliances and heating equipment as well as others. The occupancy requirements deal with hazardous area, assembly and entertainment areas, agricultural buildings, and other specialized buildings. The special condition requirements deal with things like on site generation and control and alarm systems.

Of particular interest to someone who normally works on utility systems would be the following articles:

- 240 – Overcurrent Protection
- 250 – Grounding and Bonding;
- 310 – Conductors for General Wiring (essentially all power wiring would fall under general wiring)
- 408 – Switchboards and Panelboards
- 430 – Motors, Motor Circuits, and Controllers
- 445 – Generators

- 450 – Transformers and Transformer Vaults (Including secondary Ties)
- 700 – Emergency Systems
- 701 – Legally Required Standby Systems
- 702 – Optional Standby Systems
- 705 – Interconnected Electric Power Production Sources.

5. Mandatory ground fault sensing for certain circuits

The NEC has ground fault protection requirements for protection of personnel and for protection of equipment. The ground fault protection for personnel is provided by Ground Fault Circuit Interrupter (GFCI) devices, typically receptacles but occasionally branch circuit breakers. These requirements typically apply to small circuits (15A and 20A, 120V). There are two classes of ground fault protection for equipment (typically GFP). One of these two is for heat tracing applications. The other GFP application pertains to the topics of this paper.

NEC 215.10 for feeders and NEC 230.95 for services have very similar requirements for circuits 1000A and above for solidly grounded 480V and 600V grounded-wye systems. With exceptions for certain continuous industrial processes and fire pumps, each circuit disconnecting means rated 1000A or above shall be provided with ground fault protection, although that protection is allowed to be further upstream in the customer's system. This ground fault protection may not be set higher than 1200A and for currents of 3000A or greater the fault must be interrupted within one second. Interestingly, this ground fault protection is the only portion of the protection system required by code to be tested. The only other field testing requirements in the NEC are for Emergency and Standby generation.

Once the 215.10/230.95 GFP requirements have been met, there may be additional levels of ground fault protection, but in general, ground fault protection of low voltage systems is provided by the phase protection device. It is this reliance on phase devices for ground fault protection that drive the NEC requirements for low impedance equipment grounding means to allow high fault currents to flow. To ensure the low impedance equipment grounding path, the NEC devotes more space to grounding and bonding than to any other portion of the code.

6. Low Voltage Breakers Design is Much Different than HV/MV Breaker Design

The NEC does not offer standards on breaker design; it simply says that it must be able to interrupt current in the environment in which it is applied. There are many design variations in LV breakers and a good description of the various types of LV circuit breakers may be found in IEEE 1015, the "Blue Book" [2]. The standards that describe breaker design are UL-489 (NEMA AB-1) [3], applicable to Molded Case Circuit Breakers (MCCB) and Insulated Case Circuit Breakers (ICCB); and IEEE C37.13 [4], applicable to Low Voltage Power Circuit Breakers (LVPCB). Below is a comparison of these classifications, largely taken from table 4-2 of [2], but with a few extra pieces of information that reflect modern design.

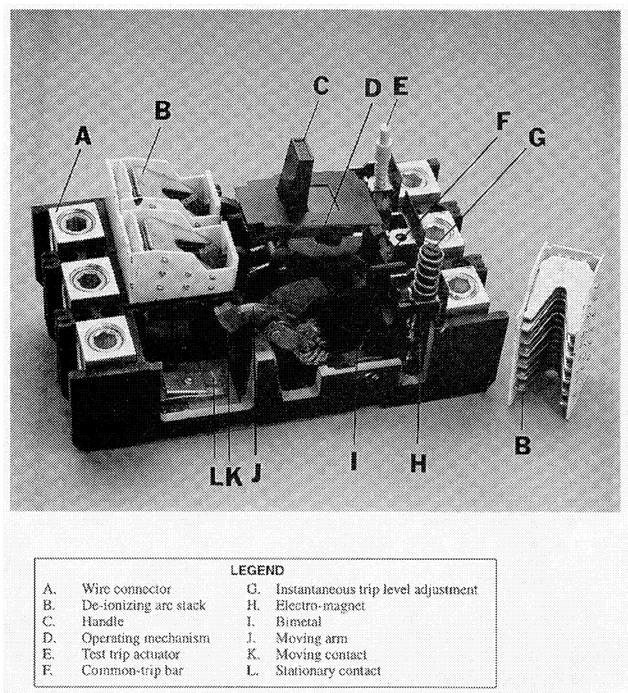
A caveat, though; the line between LVPCBs and ICCBs is becoming increasingly blurred. Some manufacturers are producing products that it appears almost as if the only difference between the two products is the nameplate.

LVPCB	ICCB	MCCB
Maintainable; Solid state trip units; Always 100% rated; 90^0C lugs; PU Tol. ~105%-125%; Rated at V_{MAX}; One or two styles per Mfr. 30cycle short time rating on some designs	Possibly maintainable; Solid state trip units; Usually 100% rated; 75^0C lugs; PU Tol. ~105%-125%; Rated at $V_{NOMINAL}$; Limited styles available; High end MCCB or low end LVPCB	Sealed package, not maintainable; Thermal/magnetic tripping or solid state trip units; Usually 80% rated; 60^0C or 75^0C lugs; PU Tol. ~105%-125%; Rated at $V_{NOMINAL}$ Many styles available
Types of operators: mechanically operated, two-step stored energy, and electrical two-step stored energy	Types of operators: mechanically operated, two-step stored energy, and electrical two-step stored energy	Types of operators: mechanically operated, over-center toggle. External motor operator may be available
Selective trip over full range of fault currents up to interrupting rating	Selective trip over partial range of fault currents within interrupting rating	Selective trip over a smaller range of fault currents within interrupting rating
Remote trip and close coils standard	Trip and close coils generally available	Shunt trip available option for most designs
Aux status (52a, 52b) contacts standard	Aux status (52a, 52b) contacts available	Aux status (52a, 52b) optional for some lines
Friendly to adding CTs in breaker cabinet	Friendly to adding CTs in breaker cabinet	Cabinet designs usually make adding CTs an issue.
Standards require draw-out construction; permitting racking to a distinct “test position” and removal for maintenance	Available in draw-out construction permitting racking to a distinct “test position” and removal for maintenance	Some are available in plug-in design allowing removal for inspection or replacement Large frame sizes may be available in draw-out construction
Operation counter is available	Operation counter may be available	Operation counter is not available
Interrupting duty at 480Vac; 22-100kA without fuses and up to 200kA with integral fuses. More recent designs offer 200kA without fuses.	Interrupting duty at 480Vac; 22-200kA	Interrupting duty at 480Vac; 22-65kA without fuses and up to 200kA with integral fuses or for current-limiting type
Current limiting available only with fuses	Current limiting with fuses long available; recently current limiting without fuses has become available	Current limiting available with and without fuses
Usually most costly	Usually mid-range cost, but depends on the enclosure selected	Usually least costly
Small number of frame sizes available	Small number of frame sizes available	Large number of frame sizes available
Extensive maintenance possible on all frame sizes	“Not Maintainable” per UL standards	Not maintainable
Used in switchgear	Used in enclosures and switchboards	Used in enclosures, panelboards, and switchboards
Not available in series ratings	Not available in series ratings	Available in series ratings
100% continuous-current rated in its enclosure	80% continuous-current rated unless specifically stated to be rated 100% in an enclosure	80% continuous-current rated unless specifically stated to be rated 100% in an enclosure
IEEE Std. C37.13	UL 489	UL 489

Table 1: Comparison of LV Breaker Features

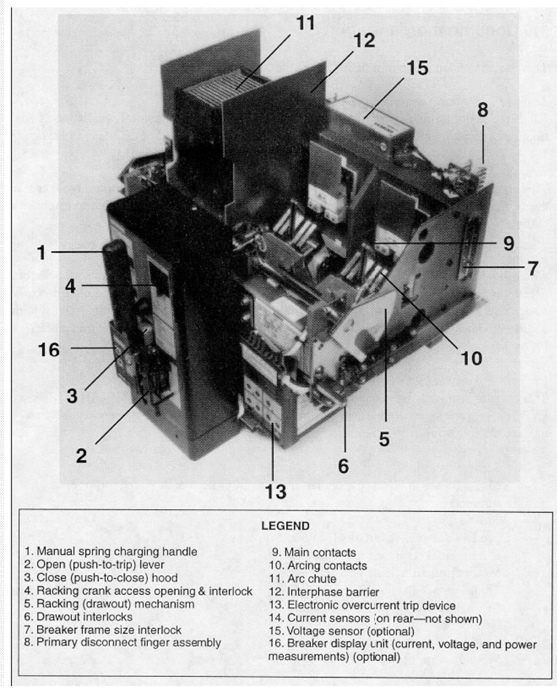
.

The MCCB is the mainstream breaker found in standard practice. These breakers are hard plastic boxes that cannot be disassembled after construction and tend to have very limited functionality or flexibility. They typically are thermal-magnetic trip devices, but may have solid-state trip units. The ICCB is an upgraded version of the MCCB that makes the device somewhat field maintainable and adds the ability to have more complex trip units and features such as trip coils and close coils. The LVPCB is a high amperage full feature breaker, except it lacks certain current limiting features that can be obtained in small molded case breakers.



Source: Square D Company.

Figure 1-1—Cutaway view of a typical MCCB



Source: Siemens Energy & Automation, Inc.

Figure 1-2—Low-voltage ac power circuit breaker—drawout type (shown partially disassembled to show internal features)

Figure 2a, 2b. Circuit Breaker Cutaway [2]

The figures above are from IEEE 1015, the “Blue Book” [2], offering some comparison of the breaker types. The figure numbers are as found in this source.

The continuous rating of MCCBs and ICCBs is not exactly what one would expect at first glance. These breakers are rated to continuously carry only 80% of their nameplate current, unless a 100% rated device is purchased. The NEC’s “Breaker FLA is based on 125% of continuous load current" and the UL489’s “breaker continuous duty is 80% of nameplate" are “two sides of the same coin." Once one reaches the high-end products associated with ICCBs, 100% ratings become more common. LVPCBs are always 100% rated. This distinction is driven by the need for the breaker to dissipate the heat developed by these higher currents, particularly in breakers with thermal-magnetic trip units. Nearly all 100% rated breakers have solid-state trip units as these produce less heat to be dissipated than thermal magnetic trips.

In HV/MV systems, an engineer would never install a breaker rated to interrupt less current than the available current. However, in LV systems, an MCCB breaker, or a fuse, can be applied in applications where the available short circuit current is higher than the rating of the breaker or fuse, if the underrated device is in series with an approved MCCB breaker or fuse that can interrupt the available fault current. Series rated MCCB/MCCB, fuse/MCCB, and fuse/fuse combinations must be tested and listed in accordance with UL489. Series ratings of MCCB/MCCB are always within one manufacturer, but fuse/MCCB and fuse/fuse combinations will cross manufacturer lines. The fuse in series ratings is always a current limiting type. Only breakers with thermal-magnetic trip units are included in listed series ratings.

There is one common misconception surrounding series rated combinations; because a series rating relies on both devices tripping to interrupt the fault, there is an implication that use of fully rated combinations avoids this miscoordination. Fully rated does not mean selectively coordinated, in many cases the trip characteristics of the devices in a fully rated combination will be identical with the trip characteristics of a comparable series rated combinations; identical to the point of coming from the same published trip curves.

The interrupting rating of low voltage circuit breakers is not as straightforward as an HV/MV engineer might expect. The interrupting capability tests of MCCBs and ICCBs, use a voltage source capable of producing the stated current, but are connected to the source via a stated length of cable. The cable adds impedance to the circuit. Because a voltage source is used rather than a current source, the increase impedance reduces the net current to the breaker during the test. Per [5], for example, a 22kA circuit breaker is actually only tested to 9,900A.

Another typical practice that might be strange to a HV/MV engineer is the use of integral fuse/breaker combinations to obtain increased fault interruption ratings. To achieve high interrupting capacity, LVPCBs and current limiting MCCBs have traditionally relied on integral fuses designed to clear the highest-level fault currents. In the larger frame sizes of LVPCBs the limiter would usually be a separate assembly paired with the breaker. As low voltage circuit breaker design has progressed, options have become available for high interrupting ratings without the need for fuses. Current limiting circuit breakers relying on the magnetic forces of the fault current to “blow apart” the contact were the first high-interrupting breakers without fuses. The latest generation of LVPCBs and ICCBs has produced non-current limiting breakers with interrupting ratings as high as 200kA.

An engineer accustomed to working with HV/MV breakers may be surprised to find many features that are normal on HV/MV breakers become a costly or unavailable adder on an LV breaker, especially when working with MCCBs. If these features are required, the design may need to graduate from MCCBs to ICCBs and a major price increase will be seen. The typical MCCB is just an overcurrent sensing and tripping device. It has

- no trip coil without the addition of an accessory shunt trip coil
- no close coils (motor operators that operate the breaker handle can be obtained on some models)
- no allowance for CTs
- no auxiliary status contacts without the addition of accessory contacts
- cannot be drawn out as a means to completely isolate downstream equipment
- no operations counter

These features can be obtained in ICCBs and LVPCBs, usually as options at additional cost on ICCBs and more likely to be standard features on LVPCBs.

The HV/MV engineer is accustomed to inverse-time response overcurrent elements that trace their roots back to electromechanical induction disk relays. The low-budget mainstream LV circuit breaker is based on the thermal (long time) and magnetic (instantaneous) response characteristics. Using solid state trip units, available as options for some MCCBs and standard in ICCBs and LVPCBs, one has a wider curve shaping control, but the response is still different than the response to which the engineer may be accustomed.

Below are typical curves seen in the trip units contained in MCCB, ICCB, and LVPCBs. While these curves tend to be generic, they are essentially redrafts of curves seen in [6], IEEE 242, the Buff book. One manufacturer does provide options for Medium Inverse, Very Inverse, and Extremely Inverse in the long time delay portion of the breaker curve. Another replaces the Long Time Pickup and Long Time Delay portions with a single, curved, segment that looks like a Very or Extremely Inverse curve

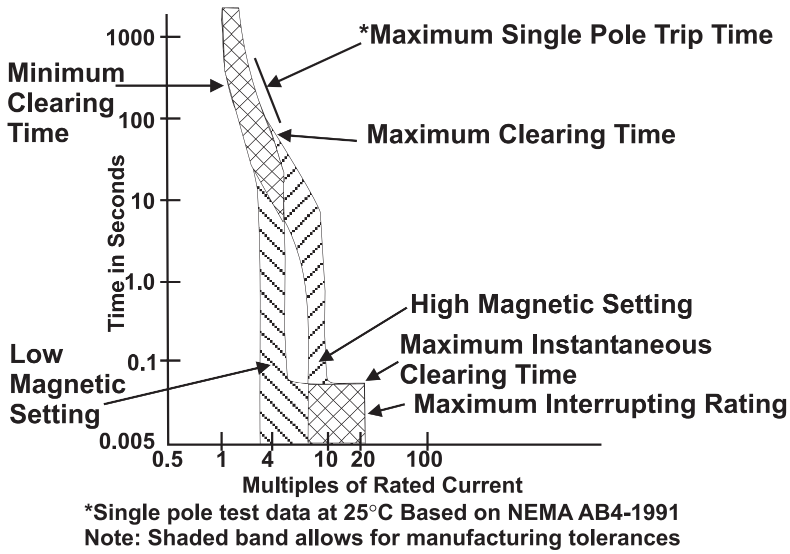


Figure 3 - MCCB with Adjustable Magnetic Trip Inst., Fixes Thermal Long Time [6]

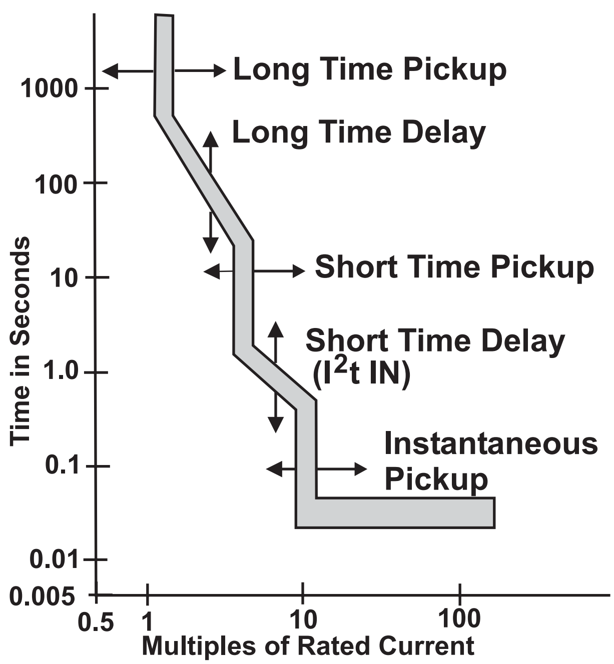


Figure 4 - Typical TCC Curve for Electronic Trip Circuit Breaker, (I^2t IN) [6]

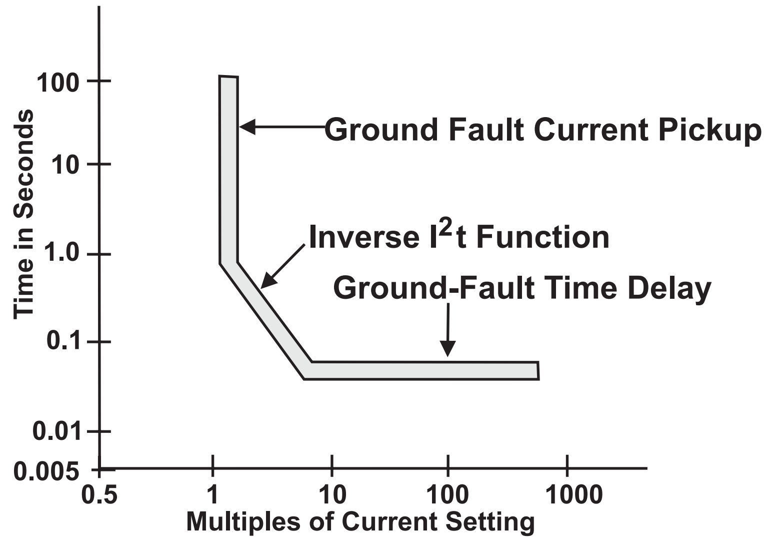


Figure 5 - Ground-fault TCC curve (I^2t IN) for Electronic Trip Circuit Breaker [6]

Typically on MCCBs and ICCBs there is a level of current where the breakers will always trip with no time delay. This feature is needed so the breakers can be self-protecting. This feature is not always shown in electronic trip-unit response curves, such as seen in section 3.d above, but it is generally there. For currents above this fixed instantaneous current level, there is no coordination with downstream overcurrent devices. In the majority of cases, the instantaneous trip current is high enough that the current level will not be reached in actual practice, but the problem of a possible miscoordination is still there. Per the standard, LVPCBs have a 30-cycle withstand rating, which is often the same as the interrupting rating. It is possible for LVPCBs to have a higher interrupting rating and an instantaneous override, but to gain the principal benefits of the LVPCB it is not used above its withstand rating.

7. Load vs. Fault Current Range in LV Systems

An engineer accustomed to working in HV/MV systems may be a bit surprised at the high fault currents and high dynamic range of currents that are experienced in LV systems. In HV/MV distribution systems maximum load currents for both distribution substations and transmission lines likely will be in the range of 200-3000A, though of course values outside this range are found. The fault duty typically will be on the order of 5,000 to 30,000A, in most applications. While these ranges are large, fault currents, in general, often are less than 30 times load current. This has ramifications on CT selection; if the CT ratio is selected so that secondary current during peak load is 5A, the peak current during faults is a manageable 150A, but usually much less. While 150A is a high amount of current for a CT to push, it is doable, and in most applications, the current is lower.

In LV systems the load current range can be considerably wider. Low voltage circuits can range from 15A to 6000A, although 4000A is a more typical upper end. To achieve good voltage regulation, transformer impedances are very low, possibly fed from transformers oversized for the facility's true power needs, or from a network of transformers. The result can be very high fault duties. Fault currents approaching 200kA are reported in networked systems. The more common designs with a single moderately sized (<1MVA) transformer will have fault duties less than 50kA. Also, the dynamic range of currents that can be seen in LV systems is very high. A 200A breaker fed from a 2000A bus, which in turn has 50kA fault duty, means the breaker will see fault current that is 250 times its rating. Even if the breaker were rated 1000A, a fault would push 50 times its rating through the breaker. The situation serves to make a point on CT sensing. Classical CTs cannot respond well to such dynamic range. It might only put out blips of current at each zero crossing. When a CT saturates, it does not simply put out a maximum current, and no more; the output becomes so distorted that the relay starts to see less current the more the actual current rises. This puts a handicap on classic protective relaying. One may need the trip units that are supplied with such breakers to respond to the highest currents, even if a protective relay is installed.

8. LV Systems Tend to Use MCCBs and ICCBs with Standard Trip Units

The great majority of work in LV systems only involves overcurrent monitoring where an MCCB, ICCB, or at times an LVPCB, is sufficient. When applications arise where the advanced techniques of a protective relay may actually be more appropriate, the system design, lack of guidance from the NEC, and lack of experience of the engineer tends to limit the protective relay option from immediate consideration.

The NEC does not offer much guidance for application usually assumed to require relays, such as generators, IPP interconnects, phase loss detection, and schemes to detect ground faults on high impedance grounded systems

- The NEC requires only minimal generator protection, that the generator shall be protected against overload.
- The interconnection of a generator with the serving utility system is addressed in Article 705. Here it says overcurrent protection is required, that the system must shut down on loss of the primary source (utility).
- The NEC only lightly touches on ground fault detection processes in high impedance grounded systems.
- The NEC does not directly address that application of negative sequence current or voltage and the advances that can give for system protection.
- The NEC does not discuss advance motor protection schemes found in modern motor protection packages, and simply requires overload protection.

Each of these schemes could use a protective relay. Given the breaker designs described above, the relay could be incorporated into a low voltage network by:

- Obtain an ICCB or LVPCB with the lowest cost possible trip unit. (An MCCB without a trip unit (molded case switch) with a shunt trip is possible too). These breakers cannot be bought without at least a basic trip unit. Obtain a breaker model with a trip coil and a close coil and the appropriate CT placement. It is likely that you will obtain CTs mounted loose/separate from the breaker. Install a relay to monitor the CTs. The basic trip unit will be needed for the case where the current rises to extreme fault levels, where a CT might not be able to perform, but we will allow the relay to do the other tripping functions, still maintaining conductor protection per the NEC.
- Install a protective relay. Not all 480V panel boards have space to mount a relay, but some relays are smaller than others and available in a variety of case sizes.
- Allow the protective relay to add all the myriad of features, yet still perform the overcurrent protection as called for by the NEC. The average relay can do many things the typical 480V trip unit cannot.

The cost differential of the most basic trip unit, without ground protection, and the approach above, is likely in favor of installing the relay, and one obtains more functions than the most capable trip unit.

Conclusion

The paper’s intent was to let the HV/MV engineer become more aware of a few important aspects LV design that differ from HV/MV design, including some concepts out of the NEC, a few critical concepts on LV system design practices, and some concepts of where classical protective relaying fits into this environment. This breadth of this topic will not be gained entirely from this paper, but the concepts herein are important building blocks that must be part of one’s work in the LV environment.

References

1. The National Electric Code, NFPA 70, 2005 Edition
2. IEEE Standard 1015, IEEE Recommended Practice for Applying Low-Voltage Circuit Breakers Used in Industrial and Commercial Power Systems ("Blue Book")
3. UL 489 (NEMA AB1), Molded-Case Circuit Breakers, Molded Case Switches, and Circuit-Breaker Enclosures
4. IEEE Standard C37.13, IEEE Standard for Low-Voltage AC Power Circuit Breakers Used in Enclosures
5. Cooper Bussmann, "Fuseology", available at http://www.bussmann.com/apen/pubs/spd/index.asp
6. IEEE Standard 242, IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems ("Buff Book")
7. David Beach, Negative Sequence Relaying Applications in Ungrounded and High Impedance Grounded Industrial Systems, Western Protective Relay Conference, October 2005; available at http://www.basler.com

Biography

David Beach received a BS degree in Electrical Engineering from California State University, Fresno in December of 1982 (and is presently progressing toward an MSEE from Idaho State University). Since that time, David has become a Registered Professional Engineer, licensed in the states of California, Oregon, and Washington. David worked in the Consulting Engineering business until February 2005 when he joined Basler Electric Company as a Senior Application Engineer. David is a Senior Member of the IEEE, a member of the Industrial Applications Society and the Power Engineering Society of IEEE, and represents Basler on the work groups extending IEEE Standard 1547.

John Horak received BSEE degree from the University of Houston in 1988 and his MSEE degree, specializing in power system analysis, from the University of Colorado, Denver, in 1995. He worked ten years with Stone and Webster Engineering and was on assignment for six years in the System Protection Engineering offices of Public Service Company of Colorado. Previous employers include Houston Light and Power and Chevron. John joined Basler Electric in 1997 and is a Senior Application Engineer. John is a member of IEEE-IAS and -PES and has P.E. licenses in Colorado and California.

www.basler.com

Highland, Illinois USA
Tel: +1 618.654.2341
Fax: +1 618.654.2351
email: info@basler.com

Suzhou, P.R. China
Tel: +86 512.8227.2888
Fax: +86 512.8227.2887
email: chinainfo@basler.com