Application Considerations for Series Combination Overcurrent Protective Devices (OCPD) in New Installations

By GE Specification Engineers
Bill Brownell, PE
Dennis McKeown, PE
Jeff Small

Abstract: Proper applications of series combinations of OCPD are critical to meet minimum reliability and safety considerations.

The application of Series Rated OCPD continues to be one of the most popular and unfortunately most abused methods of electrical project value engineering (VE). Proper due diligence must be performed by the parties applying series ratings. The latest version of applicable building codes should be referenced to ensure minimum safety standard compliance and to meet the Design Professional's electrical system performance criteria. It is a very common occurrence for series ratings to be specified by the design professional in multiple occupancy facilities such as: low, medium- or high-rise condos, time shares, apartments, hotels or strip malls.

Series ratings first began to appear in the marketplace in the late 1970s. In a fully rated system all the OCPD are evaluated individually to ensure that the interrupting (AIC) rating of the OCPD meets (with some safety factor, typically 10%) of the Short Circuit (SC) rating at the equipment bus where the OCPD are installed. In a series rated system, the downstream over-current protective devices have a lower individual rating but the combination of the devices has an interrupting rating at least equal to the available fault current. These combinations can include fuses and circuit breakers and can be in multiple layers.

Device combinations are not limited to those in the same equipment. They can be in different equipment such as a switchboard feeder or a panelboard main vs. panelboard branches. Any distance between devices in different equipment is permitted. The total fault current magnitude must flow through both protectors. The series combination of two protective devices can be in many locations of a large system.

Series ratings are defined as:

A short-circuit interrupting (AIC) rating assigned to a combination of two or more over-current protective devices which are connected in series and in which the rating of the downstream device(s) in the combination is less than the series rating.

It is important to note that the series rating is a short-circuit interrupting rating of the combination of over-current protective devices. There is a misconception that the first, or upstream, device in the series must limit the current to a level not exceeding the interrupting rating of the second, or downstream, device. This is incorrect. The rating is based on the

combination of the series connected devices operating together to safely interrupt the rated fault current without damage to any of the series rated devices. Hence, series combination(s) are ***tested*** to verify performance.

In the past, an analytical method of determining fuse let-through current known as "The Up, Over and Down Method" was utilized. This analysis was based on upstream fuses and downstream circuit breakers as static devices. UL no longer accepts this method. Actual testing documentation is the only currently acceptable series rating certification method by UL.

The National Electric Code (NEC®) is a minimum safety standard, not a design manual. The requirements for series-rated combinations by the NEC are quite clear.

NEC® 2008 *(Actual Code text in blue, Fine Print Notes in red)*

ARTICLE 110 Requirements for Electrical Installations

> **110.9 Interrupting Rating**
> "Equipment intended to interrupt current at fault levels shall have an interrupting rating sufficient for the nominal circuit voltage and the current that is available at the line terminals of the equipment. Equipment intended to interrupt current at other than fault levels shall have an interrupting rating at nominal circuit voltage sufficient for the current that must be interrupted."
>
> **110.10 Circuit Impedance and Other Characteristics**
> "The over-current protective devices, the total impedance, the component short-circuit current ratings, and other characteristics of the circuit to be protected shall be selected and coordinated to permit the circuit-protective devices used to clear a fault to do so without extensive damage to the electrical components of the circuit. This fault shall be assumed to be either between two or more of the circuit conductors or between any circuit conductor and the grounding conductor or enclosing metal raceway. Listed products applied in accordance with their listing shall be considered to meet the requirements of this section."
>
> **110.21 Marking**
> "The manufacturer's name, trademark or other descriptive marking by which the organization responsible for the product can be identified shall be placed on all electrical equipment. Other markings that indicate voltage, current, wattage, or other ratings shall be provided as specified elsewhere in this code. The marking shall be of sufficient durability to withstand the environment involved."

The code requires that equipment ratings be marked on the equipment and that such markings be located so as to be visible or easily accessible during or after installation. The latest revision to the manufacturer's series ratings combination guide should be consulted in addition to the subject panel's marking information to ensure compliance to Article 110-21. If these criteria are not met, the local AHJ may have issues and, with good cause, reject the installation.

> 110.22 Identification of Disconnecting Means

(A) General. Each disconnecting means shall be legibly marked to indicate its purpose unless located and arranged so the purpose is evident. The marking shall be of sufficient durability to withstand the environment involved.

Proper identification needs to be specific. For example, the marking should indicate not simply “motor” but rather “motor, water pump" and not simply “lights” but rather “lights, front lobby.” Consideration also should be given to the form of identification. Marking often fades or is covered by paint after installation.

(B) Engineered Series Combination Systems. Where circuit breakers or fuses are applied in compliance with series combination ratings selected under engineering supervision and marked on the equipment as directed by the engineer, the equipment enclosure(s) shall be legibly marked in the field to indicate the equipment has been applied with a series combination rating. The marking shall be readily visible and state the following:

CAUTION — ENGINEERED SERIES COMBINATION SYSTEM RATED _____ AMPERES.
IDENTIFIED REPLACEMENT COMPONENTS REQUIRED.

FPN: See 240.86(A) for engineered series combination systems.

Section 110.22(B) requires the enclosures of engineered series-rated over-current devices to be legibly marked. A licensed professional engineer determines the ratings and the equipment must have a label, as specified in 110.22(B), to indicate that an engineered series combination rating has been used. It is important that the warnings on replacement components be heeded in order to maintain the level of protection provided by the design.

(C) Tested Series Combination Systems. Where circuit breakers or fuses are applied in compliance with the series combination ratings marked on the equipment by the manufacturer, the equipment enclosure(s) shall be legibly marked in the field to indicate the equipment has been applied with a series combination rating. The marking shall be readily visible and state the following:

CAUTION — SERIES COMBINATION SYSTEM RATED ____ AMPERES.
IDENTIFIED REPLACEMENT COMPONENTS REQUIRED.

FPN: See 240.86(B) for tested series combination systems.

Section 110.22(C) requires the tested series combinations to be legibly marked on the equipment. If the equipment is installed using a marked series combination rating, the equipment must have an additional field applied label, as specified in 110.22, to indicate that a series combination rating has been used.

ARTICLE 240 Overcurrent Protection

240.86 Series Ratings.
Where a circuit breaker is used on a circuit having an available fault current higher than the marked interrupting rating by being connected on the load side of an acceptable over-current protective device having a higher rating, the circuit breaker shall meet the requirements specified in (A) or (B), and (C).

A series-rated system is a combination of circuit breakers or a combination of fuses and circuit breakers that can be applied at available short-circuit levels above the interrupting rating of the load-side circuit breaker but not above that of the main or line-side device. Series-rated systems can consist of fuses that protect circuit breakers or of circuit breakers that protect circuit breakers. The series-rated system can be as specified in 240.86(A) for engineered systems applied to **existing installations** or in 240.86(B) for tested combinations that can be applied in any new or existing installation.

> (A) Selected Under Engineering Supervision in **Existing Installations**. The series-rated combination devices shall be selected by a licensed professional engineer engaged primarily in the design or maintenance of electrical installations. The selection shall be documented and stamped by the professional engineer. This documentation shall be available to those authorized to design, install, inspect, maintain and operate the system. This series combination rating, including identification of the upstream device, shall be field marked on the end-use equipment.
>
> *(New in 2008 NEC)* For calculated applications, the engineer shall ensure that the downstream circuit breaker(s) that are part of the series combination remain passive during the interruption period of the line-side fully rated, current-limiting device.
>
> This provision allows for an engineered solution at existing facilities where an increase in the available fault current results in the existing circuit over-current protection equipment rated below the available fault current in violation of 110.9. The conditions for engineering a solution, however, are quite restrictive. The existing OCPD must remain passive during the operation of the fully rated current-limiting line-side OCPD. In practical terms, this will require low-voltage power circuit breakers with 30-cycle withstand ratings on the load side of a current-limiting fuse. Many power systems will not meet these prerequisites. It is doubtful that the engineered series combination solution will become very popular.
>
> (B) Tested Combinations. The combination of line-side over-current device and load-side circuit breaker(s) is tested and marked on the end use equipment, such as switchboards and panelboards.
>
> FPN to (A) and (B): See 110.22 for marking of series combination systems.

Section 240.86(B) requires that, when a series rating is used, the switchboards, panelboards, and load centers be marked with the series rated combinations that may be used. Therefore, the enclosures must have a label affixed by the equipment manufacturer that provides the series rating of the combination(s). Because there is often not enough room in the equipment to show all the legitimate series rated combinations, UL 67, Standard for Panelboards, allows a bulletin to be referenced and supplied with the panelboard. These bulletins typically provide all the acceptable combinations. Note that the installer of a series rated system also must provide the additional labeling on equipment enclosures required by 110.22, indicating that the equipment has been applied in a series rated system.

(C) Motor Contribution. Series ratings shall not be used where:

(1) Motors are connected on the load side of the higher-rated over-current device and on the line-side of the lower-rated over-current device, and

(2) The sum of the motor full-load currents exceeds 1 percent of the interrupting rating of the lower-rated circuit breaker.

One critical requirement limits the use of series-rated systems in which motors are connected between the line-side (protecting) device and the load-side (protected) circuit breaker. Section 240.86(C) requires that series ratings developed under the parameters of either 240.86(A) or (B) are not to be used where the sum of motor full-load currents exceeds 1 percent of the interrupting rating of the load-side (protected) circuit breaker, as illustrated in Exhibit 240.14.

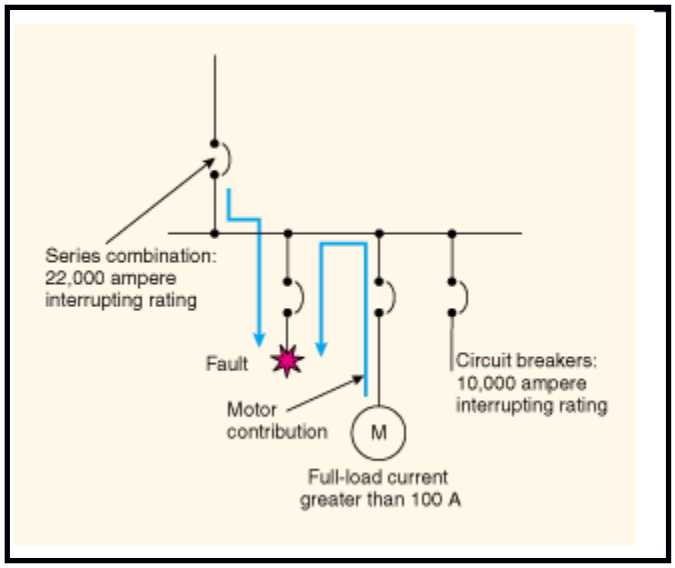

Exhibit 240.14 Example of installation where sum of motor full load currents exceeds 1 percent of interrupting rating for the lowest-rated circuit breaker and this series combination cannot be used.

Local and state codes should also be consulted as specific markets and applications may not allow series ratings. Healthcare power distribution applications are an excellent example of this. In Florida, the Agency for Healthcare Administration (AHCA) will not allow series-rated combinations on essential or normal applications.

Electrical design professionals in the consultant community determine the performance of the electrical power system. The utilization of series-rated combinations is based on a desire to provide the best possible electrical system performance vs. system cost. The electrical system design process carefully evaluates performance risk vs. cost. The decision whether to utilize series ratings may be based on the design professional's experience or the design firm's internal policies may effect the decision to utilize series ratings.

Some equipment in the electrical power distribution system are questionable candidates for utilization of series combination ratings. Switchboard, power panel and mechanical room panel type equipment need close scrutiny. Mechanical panels with multiple motor loads would likely violate the NEC 240.86(C) rule for maximum motor contribution currents and thus

are poor candidates for series ratings. Switchboards are seldom good candidates due to device ampere ratings. As the line-side OCPD gets larger, it is harder to obtain current-limiting behavior. With a line-side device larger than 600A often the available combinations are incomplete. By contrast, with 225A mains the series ratings are excellent for panelboards.

As mentioned previously, critical facilities such as data centers, healthcare facilities and facilities with critical, life safety or other emergency systems may not be good candidates for series rated combinations.

Another area of confusion is the issue of series-rated combinations and selective coordination. At first glance the two electrical system requirements seem to be diametrically opposed. Not necessarily true for a couple of reasons.

- A system study by the design professional would be required to determine, if selective coordination has been achieved.

- After commissioning, most system electrical faults occur in user end use devices. These devices are at the end of branch circuits and the faults are often arcing single line to ground, resulting in greatly reduced currents and much better selectivity.

The design professional determines what methods of short circuit compliance will be used on a project after considering all the relevant factors. With series combination ratings in common usage, if the design professional chooses not to allow series combination ratings, as is their prerogative, this fact should be ***clearly*** communicated to the field on the plans **and** specifications. If the design professional does not communicate that series combination ratings are not allowed, the successful contracting parties are not released from compliance responsibility with the NEC, state and local building codes. If series combination ratings are not specifically disallowed, chances are great that the successful contracting parties will apply series-rated combinations or at least persuade the facility owner to consider the VE savings.

References:

Series Ratings – by the Molded Case Circuit Breaker Section of the National Electrical Manufacturers Association - March/April, 1994 IAEI Journal

NEC® 2008