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LayerZero Power Systems

Circuit Breaker Selective Trip Coordination in 225A and 400A Distribution Panelboards

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With the increase of transformer size in the data center, much higher levels of available fault current are being seen. The use of “zero-crossing” circuit breakers to handle these faults, often in the range of 16,000 to 30,000 amps, is not advisable. All too often, the main circuit breaker trips in addition to the branch. This paper analyzes the use of fast-acting circuit breakers to achieve selective tripping.

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Introduction

A properly designed electrical distribution system coordinates all circuit breakers for circuit breaker selective tripping. Selective tripping is defined as: When a fault occurs anywhere in the distribution system, one and only one breaker will trip. That breaker should always be situated upstream and closest to the fault. There should be no other circuit breakers between the tripped breaker and the fault.

In data center distribution panelboards, the Main Circuit Breaker (MCB) feeds up to 42 branch circuit breakers. Each branch circuit breaker feeds its own customer-defined item of mission critical load. MCBs are rated 225A or 400A, whereas branch circuit breakers are typically rated from 10A to 100A. As outlined above, in a properly coordinated system for selective tripping, if a fault occurs on the load side of the branch breaker, it is expected that the branch circuit breaker will open and clear the fault before the MCB opens. (See Figure 1.)

High Speed Branch Circuit Breakers With Selective Tripping

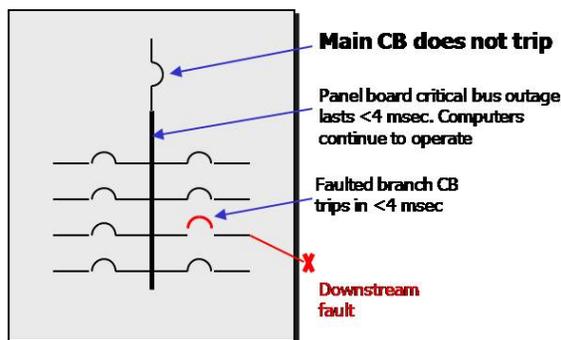


Fig. 1. An example of selective trip coordination

History: A Change In Transformers Affects Mission Critical Systems

During the '80s, '90s and early 2000's, power distribution transformers in the data center were generally rated up to 125kVA. The downstream circuit breakers coordinated properly and there were no coordination problems. By 2005, the use of high power density loads created a demand for more power. The result was the introduction of 225kVA and 300kVA transformers on the data center floor.

A consequence of this introduction is that main circuit breakers trip instead of or in addition to the branch breaker feeding the downstream fault. (See Figure 2.) The higher

rated transformers have disrupted the selective trip coordination that was trouble free for many years.

Not Designed for Selective Tripping

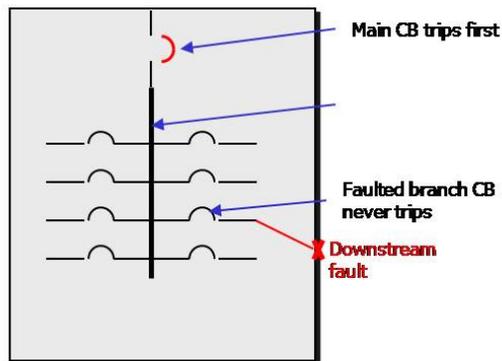


Fig. 2. An example of a circuit without selective-trip coordination

Recognizing The Problem: Circuit Breakers Are Not Coordinated Properly

To understand why tripping selectivity has been lost under the conditions described above, we must examine the respective fault conditions and responses to that fault. The phase-to-ground short circuit current sourced by a 125kVA, 3.5 percent impedance transformer with a 208V secondary is

$$I_k = \frac{125000}{0.035\sqrt{3} \cdot 208} = 9925 \text{ Amps, so}$$

the available fault current is therefore 9,925 amps.

All thermal-magnetic circuit breakers have two ratings: overload and instantaneous. It is the instantaneous rating that must handle the 9,925A of available fault current. Once the available fault current is calculated, a coordination study needs to be initiated so the circuit breaker closest to the fault will 1) be able to withstand the fault, and 2) open the circuit before any upstream circuit breaker opens. Using a branch breaker with an instantaneous rating of 10,000Amps Interrupting Capacity (AIC) was sufficient for the past 30 years.

Today, a 300kVA transformer with 3.5 percent impedance rating has replaced the 125kVA model. Using the same calculations, this transformer has the ability to sustain 23,820 amps of fault current on its secondary side. All downstream circuit breakers must therefore be able to clear a 23,820 amp fault. However, the branch breakers being supplied are still of the 10,000AIC design, clearly not

capable of clearing a fault of this magnitude. There is room for significant confusion here. Manufacturers state that the main breaker (225A or 400A) is rated for 22 kAIC and that the branch breakers are **series-rated** for 22kAIC. A **series-rating**, as described, is for *safety* only. A series safety-rating means that the main breaker will protect the branch breakers in the event that the branch breaker cannot handle the available fault current. In this case, the main breaker will trip open to protect the branch breaker from fire or explosion. A series rating for safety does not state anything about the ability to selectively trip when the fault occurs downstream of the branch breaker.

Zero-crossing Circuit Breaker Design Is Not Sufficient

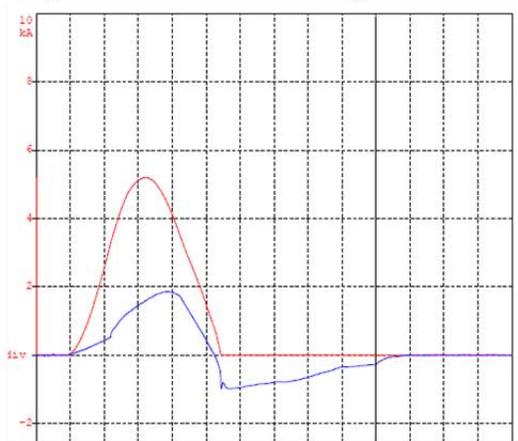
In a thermal-magnetic circuit breaker, a bimetal, temperature-operative element is used to react to slow overloads and an instantaneous magnetic coil is used to react to fault currents. There is no means to extinguish current flow through the arc that begins when the contacts separate and the next current zero crossing. Hence the term: “Zero-Crossing Breaker”; it has to sit there and look at the

The longer a branch circuit breaker is required to conduct a fault current, all of the other branch breakers on the panelboard and their critical loads experience equivalent electrical quality effects. It is imperative that the branch circuit breaker interrupt the fault current as fast as possible.

Solution

The use of a current-limiting branch circuit breaker is the clear solution to this design dilemma. A current-limiting branch circuit breaker does not require waiting 8-9 milli seconds (ms) until the fault current goes to zero. It is engineered to selectively trip up to 35kAIC. Instead of wrapping the instantaneous coil around the bimetal, the two components are separated. (See Figure 4.) A linear magnetic motor opens a set of contacts within 1ms. The resulting ionized gasses are vented through arc chutes and the fault current is reduced and cleared in approximately 2 ms. (See Figure 5.)

Fig. 3. Conventional Zero-Crossing circuit breaker under fault condition



- Zero-Crossing 30A CB
- Each hash-mark is 2ms
- MCB and branch interrupted in 8.5ms
- Tested at 9kA fault current

Red: Current
Blue: Voltage

fault until it extinguishes itself. It has been reported that a zero-crossing branch circuit breaker rated at 10,000 AIC, in series with the MCB, will be able to provide selectivity of tripping if the available fault current is less than about 6,000A. If the fault current is 6,000A or below, the branch breaker will successfully open before the MCB and be coordinated for selective tripping. However, if the available fault current is above 6,000A, the main circuit breaker will trip before the branch to successfully protect it (and avoid a fire or explosion). However, this operation results in loss of power to the entire panel board load. (See Figure 3.)

Fig. 4. A 20A Current Limiting thermal-magnetic circuit breaker

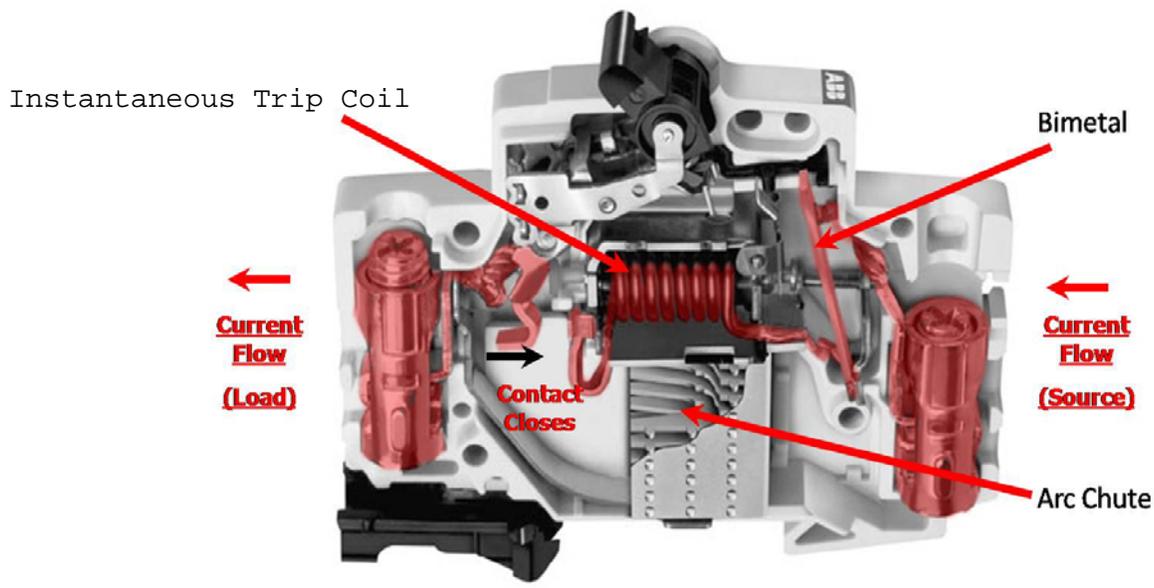
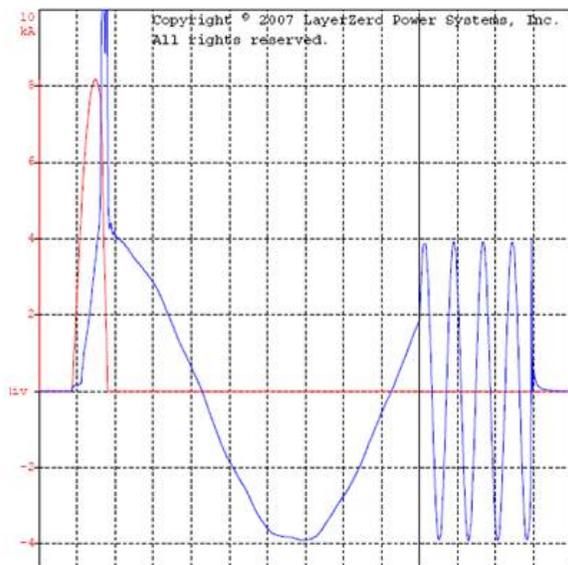


Fig. 5. Current Limiting circuit breaker under fault condition



- **Current Limiting 30A branch**
- **Each hash-mark is 2ms**
- **Only Branch CB Interrupted in 2ms**
- **Tested at 26.8kA fault current**
- **True series rating for selective tripping**

Red: Current
Blue: Voltage

Conclusion

The trend toward higher power density designs in modern data centers has created new difficulties in establishing proper circuit breaker coordination. Higher capacity power distribution transformers with lower per-unit impedance

place increasing coordination pressure on all downstream protective devices.

When prospective fault current levels reach 6,000 Amps root-mean-squared (A_{RMS}) symmetrical, it becomes nearly impossible to design effective coordination through the

panelboard branch circuit protective devices using traditional circuit breakers. The central dilemma is that traditional branch circuit breakers allow too much fault current to flow before disconnecting the fault. This excessive fault current does not permit proper coordination with the $225A_{RMS}$ or $400A_{RMS}$ upstream panelboard main or subfeed distribution circuit breakers.

Selective trip operation via proper coordination is achievable at very high prospective fault current levels by using current limiting (fast acting) branch circuit breakers. These protective components provide the necessary limitation of equivalent normalized energy to remove the fault from the system before the upstream panel board main or subfeed distribution circuit breakers reach the inside boundary of their instantaneous trip range. This fast action reduces the amount of time that all critical circuits (up to 42) on the mission critical bus are exposed to the problem. Current limiting branch circuit breakers substantially ease the coordination design process, improve overall system reliability and yield measurable uptime improvement for the mission critical facility end user.

About the Author

Anthony Pinkey is Vice-President of Sales for LayerZero Power Systems, Inc. Born, raised and educated in New York City, he holds a bachelor's degree in Electrical and Electronics Engineering in the Nuclear Science Sequence from Manhattan College.

Over 25 years in the mission critical power distribution industry, he has held various positions in product management, sales, and marketing. Anthony has represented the United States playing rugby in 10 countries.

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About LayerZero Power Systems

Founded in 2001, LayerZero Power Systems, Inc. is built on the vision of creating outstanding value and transferring this value to its mission critical customers; its talented employees; and its resourceful suppliers. LayerZero has established an industry leadership position in providing products with four salient attributes: Operator Safety; Critical Load Reliability; Information Centricity; and Ethernet based Open Connectivity.

LayerZero's STS; PDU and RPP products lead the industry with innovations like Waveform Capture; Triple Modular Redundancy; Inrush Mitigation; Finger Safe distribution panel boards; and Selective Trip Coordination.

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