

The Application of Circuit Breakers to Reduce Downtime in Datacentres

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Abstract

Circuit breakers fulfil several functions in the electrical distribution systems of datacentres:

- To protect plant (transformers, generators, UPS, cables) from damage in the event of overcurrents
- To provide a route for power from the source of electrical energy to the data processing racks
- To provide a means of isolation for all or part of the electrical distribution system, thereby facilitating maintenance
- To prevent electrical shock
- To prevent fire

Every Watt of power used by data processing racks is transmitted through several circuit breakers in series. Their selection, co-ordination and operation are therefore critical for the operation of the datacentre.

This paper will describe circuit breaker selection methods and available circuit breaker technology which can contribute to reduced downtime in datacentres. It is divided into issues related to topology (or system layout) and sustainability (performance over time).

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Topology

The topology of an electrical system is determined by the layout of its elements and interconnections. The choice of circuit breaker and at various points can influence the system topology and vice versa.

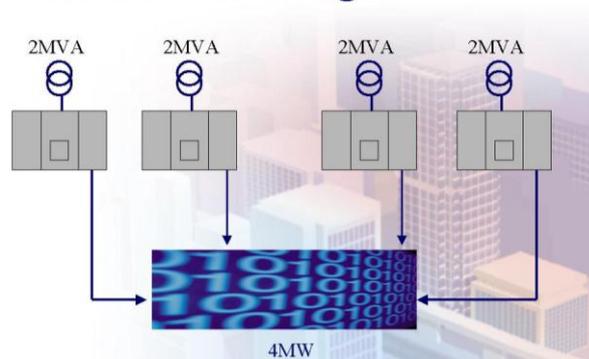
Fault Level

A circuit breaker must be able to interrupt the maximum prospective short-circuit fault level (I_{psc}) at its point of installation. Until now, this has restricted the topology of the distribution system as most engineers have designed layouts which restrict the maximum I_{psc} to the levels of commonly available switchgear and circuit breakers (50 to 65kA). This is usually achieved by limiting the power fed through each main low-voltage switchboard, therefore requiring a higher number of switchboards and feeder cables to service a given load.

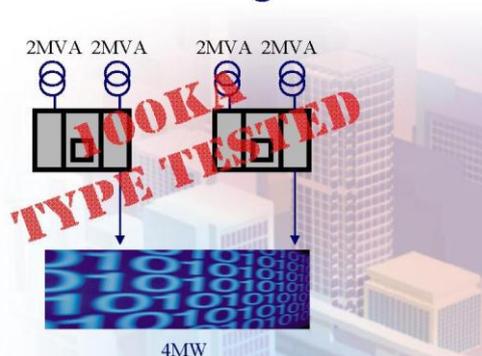
The topology of distribution systems for large loads can be simplified by feeding more power through low-voltage switchboards and circuit breakers, provided they can perform correctly at the correspondingly higher fault levels.

In the example shown below, the topology of system supplying 4MW of processing load is simplified by using a switchboard and circuit breakers rated for a fault level of 100kA.

Standard Switchgear



High-Fault Switchgear



If the system was for a tier III or tier IV datacentre, the switchboard and circuit breakers are simply duplicated to maintain “system + system”. Tier classifications also require that switchboards and circuit breakers are type-tested for the fault levels at which they are intended.¹

The photograph below illustrates an assembly which was been independently type-tested at 100kA.



Control Circuit Redundancy

The concept of redundancy is familiar to designers of datacentres. The use of redundant components in a system increases its resilience. Redundancy is commonly applied at the level of Uninterruptable Power Supply (UPS) selection, and for the selection of backup diesel generation to ensure that failure of a single UPS or generator does not cause downtime.

The operation (closing and opening) of main circuit breakers is usually controlled by the activation of internal closing and opening coils by external control signals. In fact the signal to bring a redundant UPS or generator which cost tens of thousands of pounds online can depend on something as trivial as closing coil in an Air Circuit Breaker (ACB) costing as little as forty pounds. It makes sense therefore, for circuit breakers switching expensive and critical plant, to include redundant closing and opening coils which facilitate duplication of control circuits. Some ACB manufacturers offer double closing and opening coils as an option.ⁱⁱ The addition of an extra closing coil could ensure that a UPS module or diesel generator gets switched into circuit despite a failure in the normal control circuit.

Discrimination

A circuit breaker is, by definition, a device which *opens* electric circuits in the event of overcurrents. However in a datacentre, it is important to maintain the supply of electricity to the load for as great a proportion of time as possible; in other words, circuits should *remain closed* where possible. How can these apparently conflicting requirements be resolved?

If a circuit is overloaded or contains a short-circuit, it is essential that the supply of electricity is removed, otherwise fire or explosion may occur within a short time (seconds, minutes or hours for overloads, depending on their magnitude, and milliseconds for short-circuits). However, by employing the correct selection of circuit breakers, and carefully co-ordinating their characteristics and settings, a designer can ensure that only the circuit breaker directly upstream of the fault or overload opens. Circuit breakers further upstream should be unaffected, remaining closed and continuing to supply their remaining loads. If two circuit breakers in series are co-ordinated in this manner, they are said to exhibit discrimination, or selectivity.

Discrimination between series circuit breakers on overload faults can usually be established by comparing their tripping characteristics graphically.

Discrimination between Moulded Case Circuit Breakers (MCCBs) on short-circuit faults depends on the minimum interruption times and breaker unlatching currents, which are more problematic for the engineer to obtain and analyse. It is therefore usually necessary to consult

data from manufacturers to confirm if series devices will discriminate at a particular I_{psc} . This analysis and consultation should take place early in the design process, as it may be necessary to use breakers of varying physical size to achieve short-circuit discrimination. This cannot take place after the switchboard has been manufactured without incurring cost.

Discrimination between circuit breakers where an ACB is the upstream device is easier to establish, provided the ACB has a short-time withstand (I_{cw}) rating of at least I_{psc} . In other words, the ACB must be capable of passing, or withstanding, the maximum potential through-fault current for long enough to allow the downstream device to open. This means that in the example of the 100kA switchgear described under the heading “Fault Level”, full discrimination is possible if the upstream ACBs have an I_{cw} rating of 100kA. If the ACB has an I_{cw} rating lower than I_{psc} , discrimination with downstream devices is not guaranteed.

Zone Interlocking

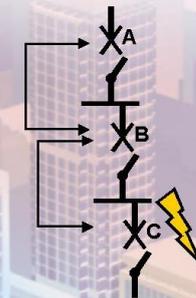
The method of discrimination between ACBs described above relies on upstream ACBs having longer short-circuit trip time delays than downstream ACBs. In consequence, the furthest upstream, or incoming, ACB requires the longest time delay. Although necessary for discrimination, this is not always desirable. In the case of a short-circuit fault directly downstream of the incoming ACB, the I_{psc} will be greater than for a fault anywhere else in the system, and it would be beneficial to interrupt it as quickly as possible.

Zone interlocking provides a solution to the dilemma described above. It is a method of providing short-circuit discrimination without introduced time delays. Rather than forcing upstream breakers to delay opening for all faults, it allows the incoming breaker to trip immediately for a fault directly downstream, but inhibits it from tripping for a through fault on a part of the circuit protected by another breaker. The logic of its operation is as follows:

If the fault is on a part of the circuit protected by a downstream breaker, the downstream breaker trips with no intentional time delay, while sending a “fault-present” signal to all upstream ACBs. On receipt of a “fault-present” signal, an upstream ACB is inhibited from tripping, and only the downstream ACB opens. If the fault is directly downstream of the incoming ACB (not present in any downstream ACBs), no “fault-present” signal is received, and the incoming ACB trips immediately, overriding any time delay.

Zone Interlocking

- A & B detect the fault
- B sends a “fault present” signal to A to prevent A tripping
- B trips without an introduced time delay



The adoption of a zone interlocking scheme enables total discrimination between ACBs, while limiting the exposure of the switchboard to short-circuit faults directly downstream of the incoming ACB.

Sustainability

Sustainability is a measure of the resilience of a system throughout its operational lifetime. Factors which affect sustainability include:

- Maintain-ability
- Susceptibility of the system and components to human error
- Procedures
- Training

It is notable that these factors all involve the interaction of human beings with the system. This is in contrast to the topology, which is an inherent function of the system layout.

Research shows that problems related to sustainability are more likely (70%) to cause downtime in datacentres than problems related to topology (30%).

Overheating

Prevention of overheating in low-voltage switchgear is commonly attempted by including a thermal imaging survey in the maintenance regime. Thermal imaging relies on human intervention in several aspects:

- Operators must perform and interpret the survey correctly
- The maintenance procedure must include thermal imaging surveys often enough to reduce the likelihood of overheating between surveys
- The maintenance procedure must be followed

It is apparent that a failing in any one of these aspects could lead to an undetected overheating problem.

Some modern circuit breakers allow for a form of condition-based temperature monitoring to be achieved. For example, the temperature of the main contacts of the circuit breaker may be monitored by sensors which provide an alarm via the protection relay if a temperature threshold is exceeded.

This can be seen either as an improvement on, or a complement to thermal imaging surveys, that is, real-time, continuous temperature monitoring is achieved without reliance on human intervention.

Fire Risk

Fire is one of the few events which can cause downtime in even the most well-designed and best-run datacentres. Wiring regulations in the UK state that a Residual Current Device (RCD) with a residual current trip setting of not more than 300 milliamperes can be effective in preventing fire caused by leakage currents to earth.ⁱⁱⁱ

A very efficient means of providing this level of protection on distribution circuits is to use a Circuit Breaker with Residual current protection (CBR). The most modern types of CBR have the residual current protection included within the standard frame of a Moulded Case Circuit Breaker (MCCB). No additional RCDs are therefore required, which simplifies the design of the switchgear systems. Indeed, CBRs can provide great flexibility, allowing for wide setting ranges for residual current tripping, adjustable time delays and even alarm-only non-trip settings for critical loads.^{iv}

Maintain-ability

A tier IV data centre with a “system-plus-system” configuration must allow for concurrent maintenance, that is, it should be possible for any path or component to be taken out of service for maintenance or repair with no disruption to the load. An elevated risk of disruption is permitted during maintenance, but it is obviously desirable that this risk should exist for the shortest possible time.

An example is shown below of a design innovation which inherently and obviously improves repair-ability and maintain-ability of ACBs.

All withdrawable ACBs include a set of connections which carry current from the chassis (fixed part) to the body (withdrawable part). The connections always take the form of a sprung contact-cluster assembly, which, as an important current-carrying connection, may need maintenance or repair. Traditional ACB designs have the sprung contact-cluster mounted on the chassis part. As the supply-side connections will be live, maintenance or close inspection requires a full shutdown of the host switchboard by upstream isolation.

Conversely, if the sprung contact-clusters are mounted on the body, they can be easily and quickly maintained or repaired on withdrawal of the body, with the rest of the switchboard remaining in service.



Circuit Monitoring

Prompt and effective operational decisions must be informed by accurate information. In an electrical circuit which is critical to the operation of a datacentre, the measurement and recording of the following parameters provides essential information:

- Voltage
- Current
- Energy
- Power Factor

It is possible to use circuit breakers rather than separate instruments to measure, record and transmit these parameters. Circuit breakers with microprocessor-based protection relays have current and voltage sensors built-in, and only require additional data processing capability to function as multimeters and energy analysers. Many models also offer very advanced functionality such as fault data recording, harmonic analysis and transmission of data over communications networks.

Conclusions

Knowledgeable application of circuit breakers in a datacentre electrical distribution system can ensure not only that equipment is protected from overcurrents, but that it is less likely to incur downtime. Furthermore, downtime can be minimised by careful consideration of products relating to their maintainability.

It is important that designers of electrical systems for datacentres not only understand the theoretical evaluation of switchgear, but that they visit and talk to manufacturers to find out how to better apply their products.

References

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- ⁱ Tier Classifications Define Site Infrastructure Performance. W. Pitt Turner IV, John H. Seader, P.E., and Kenneth G. Brill. The Uptime Institute.
- ⁱⁱ TemPower 2 ACB Double Breaker – Two Steps Ahead No. 08-I55E. Terasaki Electric (Europe) Ltd.
- ⁱⁱⁱ BS 7671: 2008 IEE Wiring Regulations 17th Edition
- ^{iv} TemBreak 2 CBR, Circuit Breaker with Residual Current Protection. No. 08-P41E. Terasaki Electric (Europe) Ltd.