APPLICATION NOTE

Continuous Power for Main Distribution Boards in Data Centers

IEC

To achieve reliable and continuous operation in Data Centers, electrical system design is undoubtedly critical.
But choosing the right protection system for the electrical installation is essential if the correct economic and functional service of the entire plant is to be guaranteed and to minimize problems caused by abnormal service conditions or actual faults.

What is Continuous Power?
Continuous Power is everything in terms of products and functionalities inside installations tasked with supplying energy, protecting people and loads. ABB cutting edge solutions achieve fast coordination between devices, thus avoiding stress and damage to the electrical distribution system by excluding only the minimum zone affected by the fault.

Why you need Continuous Power solutions
Data Centers, which are one of today's most critical infrastructures, should never be mistaken for installations where a set of commercial components is merely brought together. Data Centers are, in fact, coordinated, optimized facilities built as intelligent, highly efficient and highly reliable systems.
Selectivity is the key to establishing a good system in facilities that cannot tolerate power cuts in their Data Centers. This is because selective systems isolate faults within the shortest time, with the minimum damage and ensure that the least number of unrelated loads is affected by the fault.
In this application note explains how ABB solutions are designed to guarantee continuity of service while safekeeping the whole installation.

Main benefits

Speed
60% less commissioning time than conventional cabling

Maximize Safety and Reliability
Keep your installation running safely and reliably in every condition

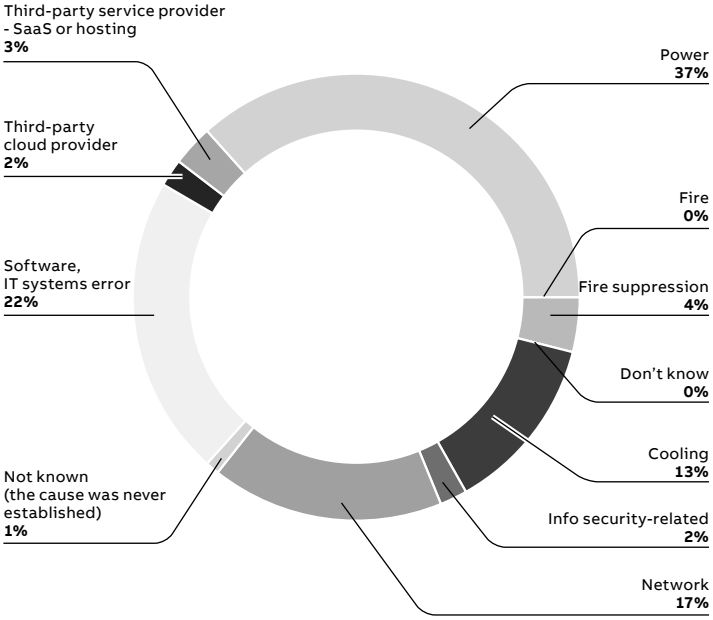
Close to the customers' needs
3 types of coordination bundles to meet all customer needs

Introduction

According to the survey performed by the Uptime Institute, on-site power failure is still the biggest cause of serious outages, accounting for 37%.
It is also important to note that the cost of outages in 2020 increased and that 56% of them cost more than $100,000 [1].

On-site power issues caused over a third of the most recent significant outages

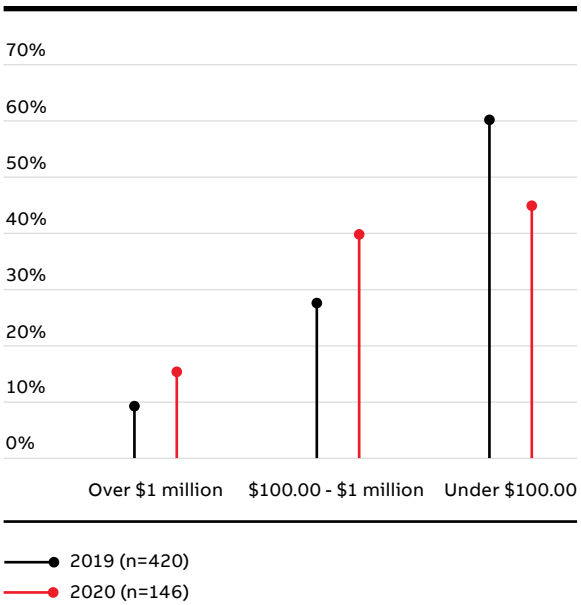
What was the primary cause of the most recent significant incident or outage in your organization?



Outage costs are rising

Estimate the total cost of the downtime incident (from outage to full recovery) sustained by your organization, including direct, opportunity and reputation costs.*

*All figures in US dollars



The Main Distribution Board

Selectivity is certainly needed in every part of the Data Center installation, but there is one part where proper coordination is of paramount importance: the main distribution board.
The short circuit currents and energies are significant in this part of the installation. That is why a proper coordination chain among all the devices has to be in place.
The main distribution board in usually designed in the same way in every Data Center project: there can be just one if redundancy is not required or several if shared redundant Data Center topologies are considered. However, the devices and the loads that each switchboard has to supply are always the same.

Thus the aim of this Application Note is to guide the customer through the best choices in terms of coordination strategies and the features of every Data Center project, no matter what the size. Only coordination techniques that ensure high level selectivity between devices, such as energy and zone selectivity, will be considered.
This can be done thanks to the high levels of selectivity achieved among ABB circuit breakers and the unique features of these devices, which are based on integrated communication capabilities.

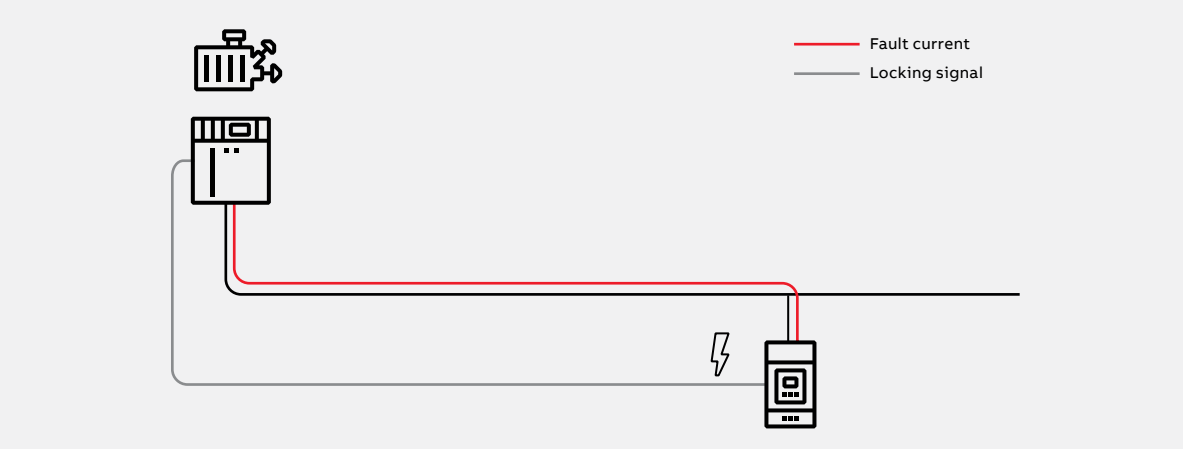
Energy Selectivity and Zone Selectivity behavior with ABB low voltage circuit breakers

SOC

Energy selectivity is a particular type of selectivity that makes the most out of the current-limiting characteristics of moulded-case circuit-breakers, the break-time of which is short enough to prevent the short-circuit current from reaching its otherwise attainable peak value. Under short-circuit conditions, these circuit-breakers are extremely fast (trip times in the range of a few milliseconds) and open in the presence of a strong asymmetrical component.

These phenomena are mainly dynamic and are strongly dependent on the interaction between the two devices in series. Thus manufacturers provide tables, slide-rules and calculation programs defined by theoretically integrating the results of tests carried out in compliance with the provisions in IEC 60947-2. The results are given in the ABB tool Selected Optimize Coordination (SOC).

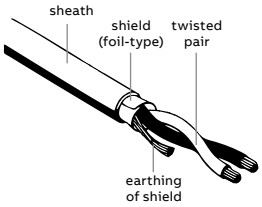
In many ways, zone selectivity can be considered the premium answer to Data Center continuity of service. First of all, by leveraging on communication among circuit breakers, it is easy to detect the exact point in the electrical system where the fault is located, thereby ensuring that the closest circuit breaker trips.
In addition, trip time is reduced to its minimum, thereby limiting the damage that a short circuit can cause to the equipment.



Easy to install and highly customizable, thus able to suit the needs of every installation, zone selectivity can be achieved by means of three different communication possibilities:

- Hardwire connections for 24 V signal exchange. In this case, auxiliary power supply and 3 different cables are required to build the system. More information is available in the Annex.
- Ekip Link, the ABB proprietary Ethernet communication protocol, simplifies the system to a great extent since only one cable does the job of the 3 cables required for hardwire connection. In addition, there is no more need for in and out connection as in hardwire systems since the cables of each circuit breaker are collected by Ethernet switches and the logic is ensured by setting and programming the system correctly.
- The IEC 61850 internationally recognized protocol extends the boundaries of zone selectivity still further by enabling low voltage devices with medium voltage relays to be integrated. The speed of this protocol is incomparable thanks to horizontal communication between devices. For additional information about designing and commissioning zone selectivity systems using the IEC 61850 communication protocol, please read the User Guide “Implementing Zone Selectivity in low voltage devices using IEC61850”.

A brief comparison of these three possible communication methods is given in the table below.

Hardwire 24V	Ekip link	IEC 61850
		
24 V signal exchange	ABB proprietary communication protocol	Internationally recognized communication protocol
Hardwire connections depending on related logic. In this case, auxiliary power supply and 3 different cables are required to build the system.	Only one Ethernet cable. There is no longer any need for in and out connection as in hardwire systems since the cables of each circuit breaker are collected by Ethernet switches and the logic is ensured by setting and programming the system correctly. Easy to install. Real time connection and transmission supervision.	Only the Ethernet cable is required. Up to 3 different clients. One module for both supervision and ZSI.
	60% less commissioning time	LV-MV coordination
Fast communication	Faster communication	Extremely fast due to horizontal communication
	Continuous checks made of communication health status	
	Dual settings?	

Auto diagnosis and supervision of the system itself are other important aspects: Ekip Link and IEC 61850 modules continuously check the health status of the communication, thereby enabling the circuit breakers to react properly if disconnections or malfunctions are detected.
This feature is not available for the 24 V hardwire connection method.

Another further degree of zone selectivity flexibility provided by ABB circuit breakers is having all three types of communication working at the same time in the installation (or just a couple of them) in order to meet the highest reliability standards. This is enabled by the fact that the 3 communication systems exchange messages at different speeds (IEC 61850 is the fastest, Ekip Link follows and while 24V hardwire is slower).
The behavior of circuit breakers in the main distribution board without zone selectivity communication, is explained in the next paragraph.

Adaptive Protection function: “Dual Settings”

If a fault is detected at communication level (this is actually a remote event, but when it comes to system reliability, nothing can be excluded), the event can be used as input for the trip unit, which reacts and changes the protection settings in order to guarantee that selectivity remains in place.
One (or several) circuit breaker/s can change their protection settings simultaneously according to where the fault is located is or through specific installation requests.
This adaptive protection function is called Dual Settings and is available for all circuit breakers equipped with Ekip Hi- Touch /Ekip G Hi-Touch trip units or with Ekip Touch/ Ekip G Touch upgraded by the Adaptive Protection bundle from the ABB Ability™ Marketplace.
Another important use of the Dual Settings function concerns the management of generators: in Data Centers they are usually provided with a panel with their protection and a controller, tasked with controlling their operation, the ramp up stage and when, or when not, to disconnect them.

This is important because zone selectivity logics overlap those of the controller:

- When the Data Center is fed by the utility grid, zone selectivity will be up and running;
- If the primary source is lost, the generator starts and will supply the system until the grid is restored. When this happens, the controller sends a signal to the circuit breakers which triggers a preset programmable status that recognizes this signal as input to pass from zone selectivity to the second set of protections, thereby ensuring that energy selectivity is in place.
- Once the grid is able to supply again, another signal from the controller triggers a different programmable status which switches from the second set of protections to the first one, again with zone selectivity.

This way of managing the electrical installation of a Data Center ensures high reliability and continuity of service. This is because the generator usually contributes with a lower subtransient short circuit component, thus enhancing the coordination of devices when energy selectivity is in place.

The Main Distribution Board

As explained in the previous paragraphs, there can be many solutions able to guarantee safety and continuity of service depending on installation needs and how “critical” a certain Data Center is.

The figures below propose three different levels for the purpose of providing scalable and reliable solutions for ABB customers.

Essential
- Energy selectivity (either total or partial)

Enhanced
- Zone selectivity
- Dual settings

Advanced
- Zone selectivity with IEC 61850 communication protocol
- Dual settings
- Protocol Redundancy
- Integration with MV relays

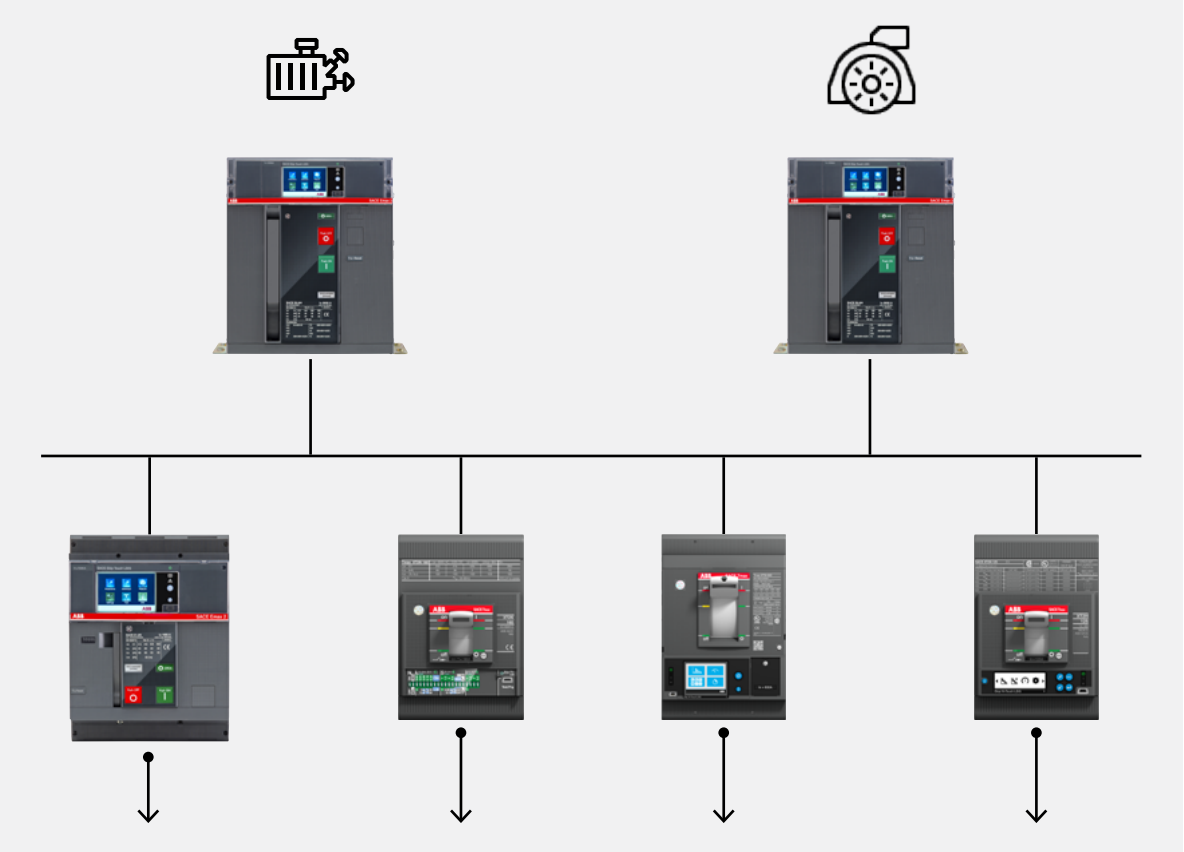
The three levels proposed in the figures above are: “Essential”, Enhanced” and “Advanced”.
In the first (“Essential”), energy selectivity is chosen as a coordination strategy between devices. Energy selectivity is a good solution when the system is composed of several “small” loads, which can be protected by moulded case circuit breakers (MCCBs). These circuit breakers are then part of of a selectivity chain in the main distribution system with larger MCCBs (> 1000 A) or air circuit breakers (ACBs).

This type of installation ensures total selectivity. However, it does not work very well when the difference in size of the circuit breakers in the coordination chain decreases: since both the MCCBs have peak current and let-through energy limiting capabilities, the more similar they are the more similar are their limiting characteristics.

Technology										
						Technology		ACB		
						PR		Emax 2		
						Series		E 2.2		
						Version	B	N	S	H
						Relay		EL		
						Iu	1600...2000	800...2500	250...2500	800...2500
Technology	PR	Series	Version	Relay	Iu/Icu	Icw	42	66	66	85
MCCB	Tmax XT	XT4	N	EL	160.250	36	T	T	T	T
				TM		36	T	T	T	T
			S	EL		50	42	T	T	T
				TM		50	42	T	T	T
			H	EL		70	42	66	66	T
				TM		70	42	66	66	T
			L	EL		120	42	66	66	85
				TM		120	42	66	66	85
			V	EL		150	42	66	66	85
				TM		150	42	66	66	85

Another application scenario for this bundle is when the reliability requirements of the system are not so high and even only partial selectivity in some parts of the installation is acceptable.
The “Enhanced” coordination bundle functions alongside the “Essential” one by introducing Zone Selectivity to the system. This enables the sizes of the circuit breakers in the electrical distribution system to be generally reduced because coordination is no longer managed by timing or let through energy differences, but by messages between devices.
However, as mentioned previously, the mechanical capability of the Tmax XT MCCB range to limit peak current suggests that they are not the best users of zone selectivity coordination since their characteristic cannot be switched off. Once a short circuit current is in the range of their instantaneous protection threshold they will trip, despite their having received one or more locking signals.

The “Advanced” bundle is the most reliable solution available on the market: 2 or 3 communication protocols ensure that zone selectivity is always present. If used as primary communication protocol, IEC 61850 not only enables ZSI logic, but can also be used to integrate the electrical distribution devices into a SCADA system for monitoring and control.
Last but not least, coordination with the relays on the MV side of the transformer ensures and upgrades safety in the event of abnormal operating conditions.
All these considerations refer to a main distribution board with one incomer from the transformer, one from the generator and several outgoers. An example is given in the figure below.



“Essential” coordination: technical information

Information on how to built a main distribution switchboard inside a Data Center while guaranteeing total selectivity between the circuit breaker that protects the transformers and the outgoing feeder ones is given below.

The table is based on the following assumption:

- System Voltage: 415V
- Vdc% of the transformers according to IEC 60076-5 Table 1
- No losses due to cables.

Transformer Power [kVA]	In Transformer [A]	SCC [kA]	Circuit Breaker	Circuit Breaker for Outgoing feeders
250	348	9	XT5N 630 Ekip Dip In=400A	XT2N 160 Ekip Dip
315	438	11	XT5N 630 Ekip Dip In=630A	XT2N 160 Ekip Dip
400	556	14	XT5N 630 Ekip Dip In=630A	XT2N 160 Ekip Dip
630	876	22	XT7S M 1000 In= 1000A	XT5N 400 Ekip DiP
800	1.113	22	XT7S M 1250 In= 1250A	XT5N 630 Ekip Dip
1000	1.391	28	XT7S M 1600 In= 1600A	XT5N 630 Ekip Dip
1250	1.739	35	E2.2N 2000 In=2000A	XT7S M Ekip DIP
1600	2.226	37	E2.2N 2500 In=2500A	XT7S M Ekip DIP
2000	2.782	46	E4.2N 3200 In=3200A	XT7S M Ekip DIP
2500	3.478	58	E6.2S 4000 In=4000A	XT7H M Ekip DIP
3000	4.174	60	E6.2H 5000 In=5000A	XT7H M Ekip DIP

From left to right: transformer apparent power and current on low voltage side, short circuit current due to transformer contribution, the recommended circuit breaker, minimum trip unit required to achieve total selectivity and the maximum circuit breaker for outgoing feeders with total selectivity provided (except last row).

Regarding the minimum trip unit recommendation, the Ekip DIP series suggested here can be considered an entry level trip unit able to meet the selectivity requirements for applications such as Data Centers. However, since Data Centers usually require supervision systems or SCADA, the best choice is to at least equip the circuit breakers in the list with Ekip Touch trip units.

“Enhanced” coordination: technical information

As mentioned previously, the “Enhanced” coordination bundle introduces zone selectivity discrimination within the electrical system.

Transformer Power [kVA]	In Transformer [A]	SCC [kA]	Circuit Breaker	Circuit Breaker for Outgoings
250	348	9	XT5N 630 Ekip Dip In=400A	XT2N 160 Ekip Dip
315	438	11	XT5N 630 Ekip Dip In=630A	XT2N 160 Ekip Dip
400	556	14	XT5N 630 Ekip Dip In=630A	XT2N 160 Ekip Dip
630	876	22	XT7S M 1000 Ekip Dip In= 1000A	XT5N 400 Ekip DiP
800	1.113	22	XT7S M 1250 Ekip Dip In= 1250A	XT5N 630 Ekip Dip
1000	1.391	28	XT7S M 1600 Ekip Dip In= 1600A	XT5N 630 Ekip Dip
1250	1.739	35	E2.2N 2000 Ekip Hi-touch In=2000A	Any ABB ACB or MCCB with min. Ekip Touch
1600	2.226	37	E2.2N 2500 Ekip Hi-touch In=2500A	Any ABB ACB or MCCB with min. Ekip Touch
2000	2.782	46	E4.2N 3200 Ekip Hi-touch In=3200A	Any ABB ACB or MCCB with min. Ekip Touch
2500	3.478	58	E6.2S 4000 Ekip Hi-touch In=4000A	Any ABB ACB or MCCB with min. Ekip Touch
3000	4.174	60	E6.2H 5000 Ekip Hi-touch In=5000A	Any ABB ACB or MCCB with min. Ekip Touch

This bundle is applicable for transformer ratings that require the protection of an ACB circuit breaker. Additional accessories are required to enable it:

- in common with all three methods of designing zone selectivity, auxiliary power supply able to ensure a stable signaling system is required. This is easily achieved thanks to the plug-and-play Ekip Supply module (either 24-48 V DC or 120-240V AC/DC can be used for Rmax 2 circuit breakers).
- Belden 3105 cables are recommended if hardwire connection is included in the project.
- Zone Selectivity with Ekip Link and IEC 61850 needs communication modules that can be easily installed in the circuit breaker cartridge. These modules are Ekip Link and Ekip Com IEC 61850.

The Ekip Hi – Touch series (or Ekip Touch with Adaptive protection module upgrade) is the trip unit suggested for this system since it enables zone selectivity as well as the possibility of having Double Setting functions for no-main supply conditions.

Ekip Supply

Ekip Link

Ekip Com

“Advanced” coordination: technical information

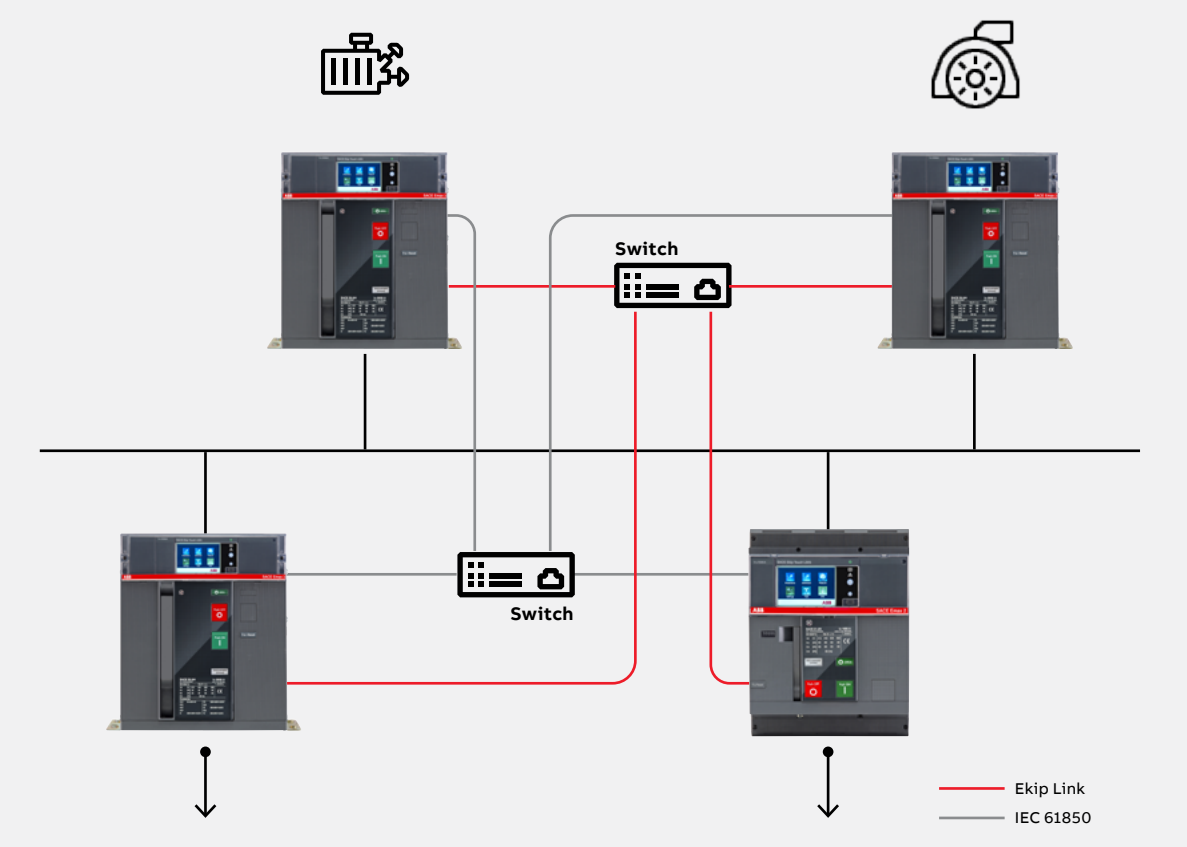
The considerations made for the Enhanced coordination bundle can also be applied to the Advanced version.

Transformer Power [kVA]	In Transformer [A]	SCC [kA]	Circuit Breaker	Circuit Breaker for Outgoings
250	348	9	XT5N 630 Ekip Dip In=400A	XT2N 160 Ekip Dip
315	438	11	XT5N 630 Ekip Dip In=630A	XT2N 160 Ekip Dip
400	556	14	XT5N 630 Ekip Dip In=630A	XT2N 160 Ekip Dip
630	876	22	XT7S M 1000 Ekip Dip In= 1000A	XT5N 400 Ekip DiP
800	1.113	22	XT7S M 1250 Ekip Dip In= 1250A	XT5N 630 Ekip Dip
1000	1.391	28	XT7S M 1600 Ekip Dip In= 1600A	XT5N 630 Ekip Dip
1250	1.739	35	E2.2N 2000 Ekip Hi-touch In=2000A	Any ABB ACB or MCCB with min. Ekip Touch
1600	2.226	37	E2.2N 2500 Ekip Hi-touch In=2500A	Any ABB ACB or MCCB with min. Ekip Touch
2000	2.782	46	E4.2N 3200 Ekip Hi-touch In=3200A	Any ABB ACB or MCCB with min. Ekip Touch
2500	3.478	58	E6.2S 4000 Ekip Hi-touch In=4000A	Any ABB ACB or MCCB with min. Ekip Touch
3000	4.174	60	E6.2H 5000 Ekip Hi-touch In=5000A	Any ABB ACB or MCCB with min. Ekip Touch

The table is the same but, as already explained, the accessories change:

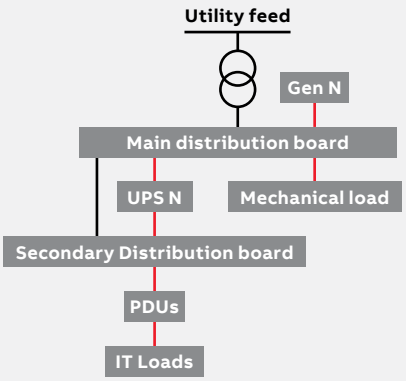
- The IEC 61850 protocol must be used to benefit from communication continuity ranging from low to medium voltage.
- One, between Ekip Link and the hardwire communication, can be used as a backup communication should the IEC 61850 one fail or disconnect.

This bundle is designed for the purpose of providing another layer of redundancy, thus increasing the reliability of the system.



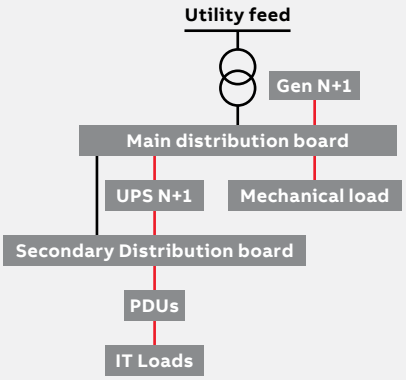
Coordination bundles to suit Data Center electrical system design

Having grouped the selectivity features of ABB circuit breakers into three different coordination bundles, the next step is to guide customers to choosing the bundles best suited to their project designs. A good way to classify the electrical installations of Data Centers is according to their fault sensitivity:



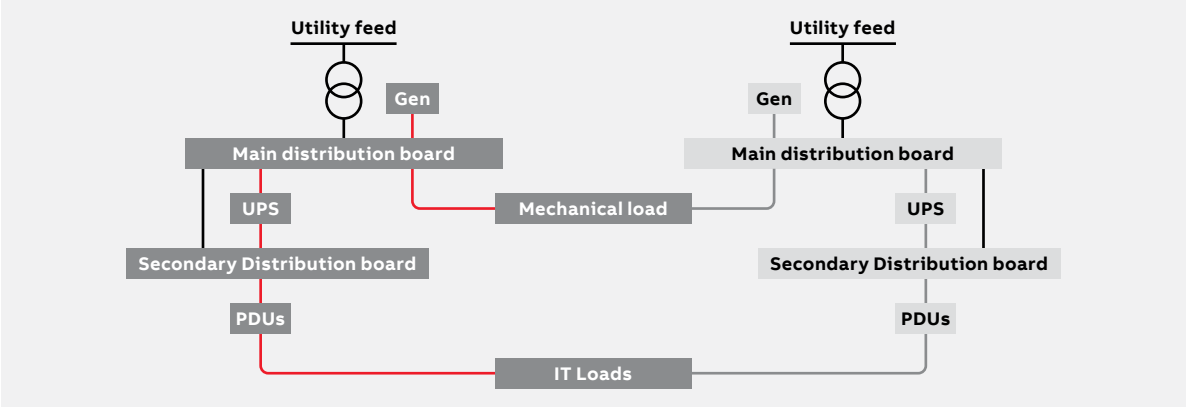
A **Very Fault Sensitive** Data Center is the basic capacity level with infrastructure to support information technology for office settings and beyond. This design protects against disruptions due to human error, but not unexpected failure or outage.

The facility has to shut down completely in the case of failures or maintenance and to do so increases the risk of unplanned disruptions and severe consequences from system failure.

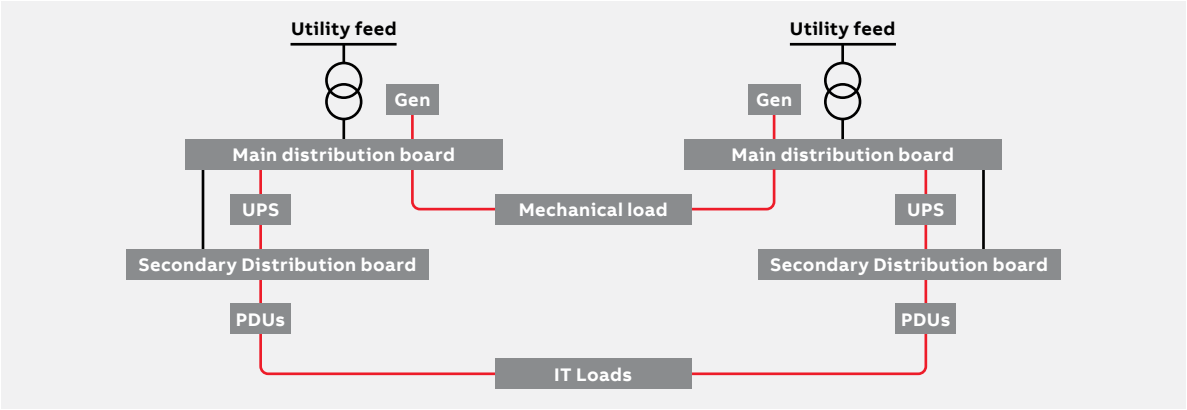


A **Redundant Design** facility covers supplementary capacity components for power and cooling that provide better maintenance opportunities and safety against disruptions.

The components can be removed without shutting down the facility. Similarly to a Very Fault Sensitive facility, unexpected shut-down of a Redundant design Data Center will affect the system.



A **Concurrently Maintainable** Data Center creates opportunity for simultaneous maintenance with redundant components such as a key differentiator as well as redundant distribution paths to serve the critical environment. The Tier III components add to those of Tier II so that any part can be shut down without impacting IT operation.



A **Fault Tolerant** Data Center has several independent and physically isolated systems that act as redundant capacity components and distribution paths. Separation is necessary to prevent an event from compromising both systems. The environment will not be affected by a disruption from planned or unplanned events. This type of facility adds fault tolerance to the Concurrently Maintainable topology. IT operations will not be affected if a piece of equipment fails or there is an interruption in the distribution path.

The choices made in terms of fault tolerance when the electricity distribution system is designed actually reveal parallelism with the choice of selectivity method. Just as one is not expected to invest in an advanced selectivity system for a system with high fault tolerance, a basic level of selectivity selection is not expected in a redundant system with very high fault tolerance.
Thus the best way to design Data Center coordination according to the fault tolerance of the system is shown in the following table.

	Coordination bundles		
Data Center Type	**Essential**	**Enhanced**	**Advanced**
Very fault sensitive	●	-	-
Redundant design	●	-	-
Concurrently maintainable	-	●	●
Fault tolerant	-	●	●

Choice of the required Data Center redundancy and, thus, reliability, strongly impacts the costs of the project itself. All these decisions should be supported by correct considerations about the most suitable selectivity systems.
In installations where no, or few, redundancies are foreseen, an Enhanced or Advanced coordination bundle will not add much in terms of reliability because the system will still be weak from the major failure viewpoint (IT loads or utility side).

Parallelly, designing a fault tolerant system by relying on standard selectivity techniques alone could still cause unwanted outages due to insufficient selectivity logic.

Annex

Main definitions of selectivity
Selectivity is defined by Standard IEC 60947-1 “Low voltage equipment - Part 1: General rules for low voltage equipment”.

Over-current discrimination: Coordination of the operating characteristics of two or more over-current protective devices such that, on the incidence of over-currents within stated limits, the device intended to operate within these limits does so, while the others do not operate. There is therefore selectivity between two circuit breakers in series when, for an over-current which passes through both, the load-side circuit-breaker opens thereby protecting the circuit, whereas the supply-side one remains closed guaranteeing power supply to the rest of the installation. The definitions of total selectivity and partial selectivity are, on the other hand, given in Part 2 of the same Standard IEC 60947-2 “Low voltage Equipment - Part 2: Circuit-breakers”.

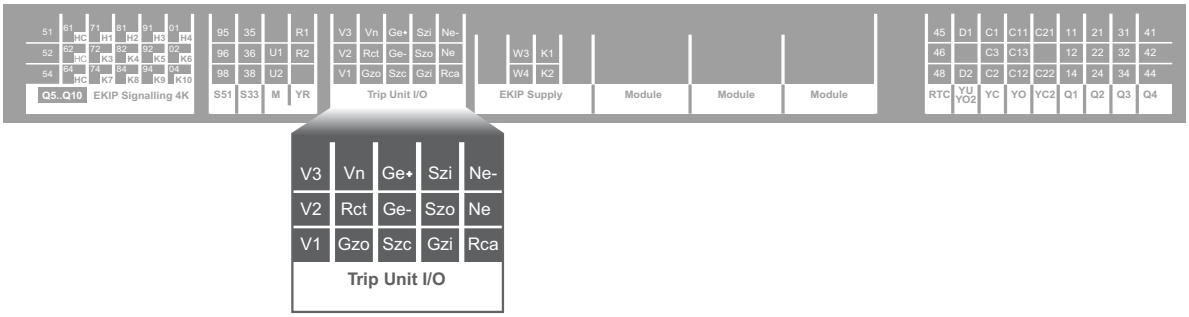
Total discrimination (total selectivity): Over-current discrimination where, in the presence of two over-current protective devices in series, the protective device on the load side effects the protection without causing the other protective device to operate.

Partial discrimination (partial selectivity): Over-current discrimination where, in the presence of two over-current protective devices in series, the protective device on the load side effects the protection up to a given level of over-current, without causing the other protective device to operate.

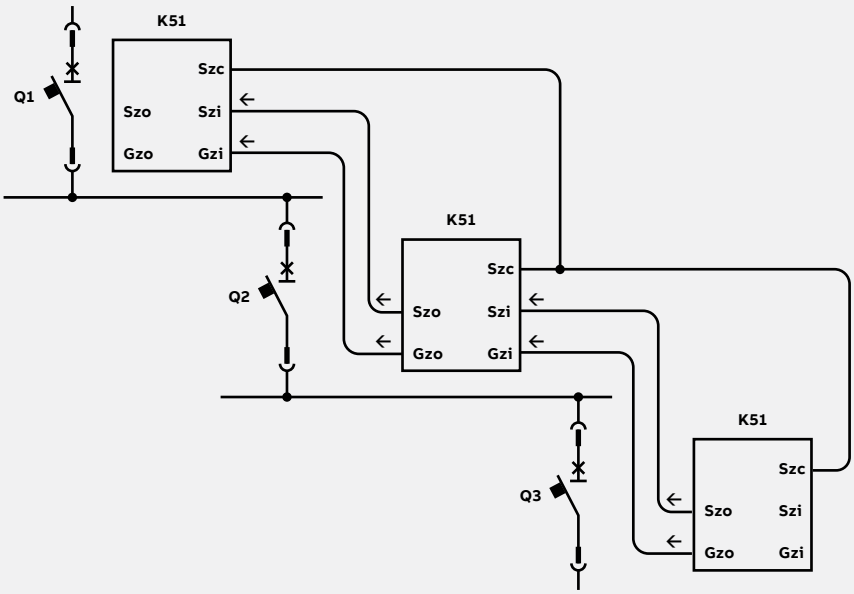
One can speak of **total selectivity** when there is selectivity for any over-current value possible in the installation. Between a pair of circuit-breakers, one speaks of total selectivity when there is selectivity up to the lesser of the Icu values of the two circuit-breakers, since the maximum prospective short-circuit current of the installation will in any case be less or equal to the smallest of the Icu values of the two circuit-breakers.

One speaks of **partial selectivity** when there is only selectivity up to a certain Is current value (ultimate selectivity value). If the current exceeds this value, selectivity between the two circuit-breakers will no longer be guaranteed. Between a pair of circuit-breakers, one speaks of partial selectivity when there is selectivity up to a certain Is value below the Icu values of the two circuit-breakers. If the maximum prospective short-circuit current of the installation is lower than or equal to the Is selectivity value, one can still speak of total selectivity.
For more detailed information about selectivity please visit special website.

ZSI (Zone Selective Interlocking) with Hardwire Connection.
24V auxiliary power supply and proper cabling (use of Belden 3105 cables is recommended) within the circuit breaker system is required for this type of zone selectivity.
The I/O available for Emax 2 circuit breakers and the largest size of Tmax XT moulded case family XT7 are shown in the figure below.
When It comes to zone selectivity the relevant inputs are SZI and GZI, while the outputs are SZO and GZO. As well as these, common connection SZC is also mandatory.



Example of an application diagram (among 3 circuit-breakers)



After having connected all the cables correctly, the system is ready to be configured by ABB Ekip Connect 3 software.

Additional information is available in the following document (24V ZONE INTERLOCKING SYSTEM), with in depth analysis of a Main - Tie – Main system and how the system behaves in every possible fault location.

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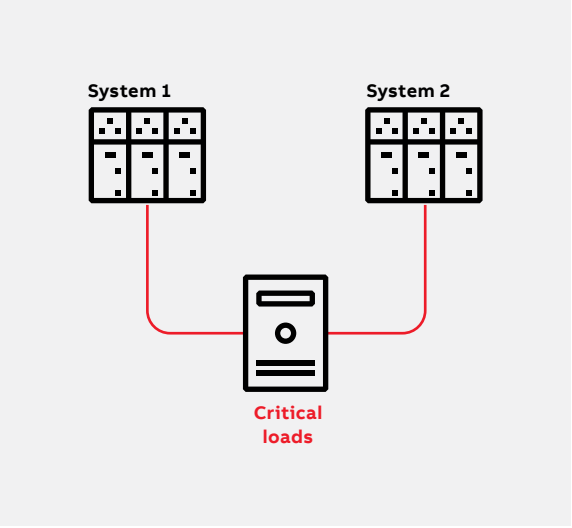
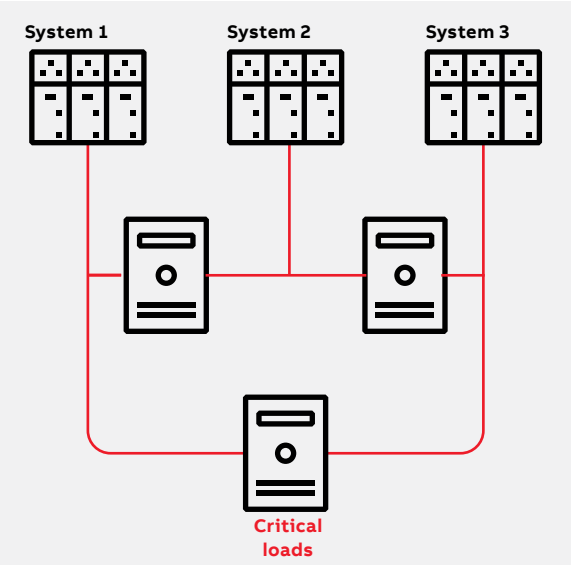
Ekip Connect

Standardized and Optimized System Topologies for Data Center Power Distribution
The below listed Data Center topologies are where the coordination bundles can be applied; for other topologies please contact ABB.



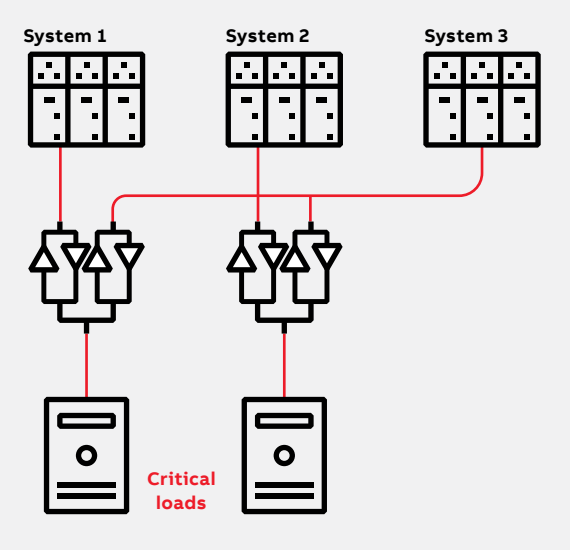
System Plus System
System plus System (aka 2N) topology utilizes two completely independent systems to feed the critical load. The design is based on the customer deploying IT equipment with redundant power supplies sometimes referred to as dual corded loads.
The System plus System design possesses proven reliability but is expensive, since 50% is the maximum utilization of assets possible.
A variant of this topology is System + Utility. "System" has N+1 UPS while Utility does not have UPS.

- Enterprise Data Centers
- Financial Data Centers
- Government Data Centers
- Colocation Data Centers



Shared redundant
Shared redundant is similar to System plus System but uses multiple systems to reduce cost by increasing utilization. The shared redundant design is normally referred to by number of systems over number of loads – 3N/2, 4N/3, etc. For example, using 1 MW block of IT load, a 3N/2 system would have 3 MW of capacity feeding 2 MW of IT load.
This increases utilization to 66%. 4N/3 increases utilization to 75%.
While Shared redundant improves utilization, the loads need to be monitored to ensure redundancy is maintained.

- Cloud Data Centers
- Colocation Data Centers



Block redundant
Block redundant, also known as a catcher topology, utilizes a static transfer switch (STS) to transfer the critical load from the primary or active system to the reserve or catcher system. The active UPS can be loaded to full capacity. The reserve UPS has no load during normal operation. The reserve system can be larger than the active systems. Block redundant utilization can be as high as 80%.
Block Redundant can be applied with single cord or dual corded IT loads. When using single corded IT loads, the STS is a single point of failure.

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