Fast - Acting Current Limiter

1.Short - circuit fault current can be limited within 1 ms.
2.Effectively solve the problem of excessive short - circuit capacity of the system.
3.The maximum breaking capacity can reach 210 kA of the prospective short - circuit current.

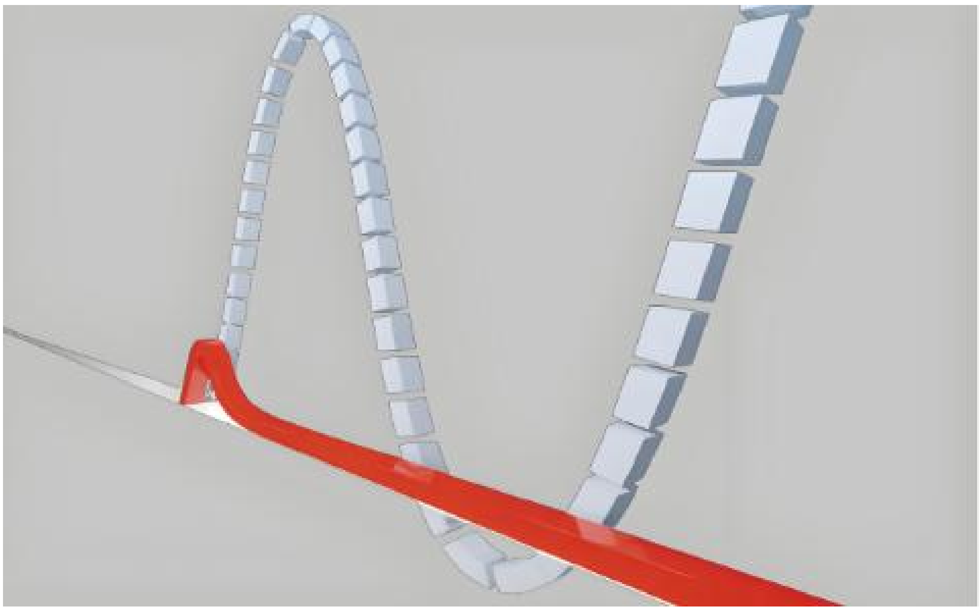
Table of Contents

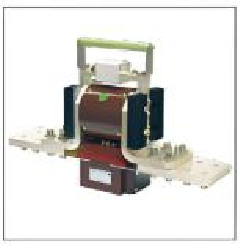
Overview

A switching device with extremely fast breaking speed

Reduce the investment in substations

1. Solve the short-circuit current problems encountered during the construction of new substations and the expansion of existing substations.
2. When paralleled with reactors, it is the most economical and effective way to limit short-circuit currents.
3. An ideal method for interconnecting switch cabinets and substations.
4. The only technical solution in most cases.
5. Reliability has been verified in the operation of thousands of engineering projects.
6. Has been put into use worldwide.
7. The short-circuit current will never reach the maximum expected peak value.
8. The short-circuit current is restricted during the initial rising stage.







Fast Current Limiter

What if the short - circuit current is too large?

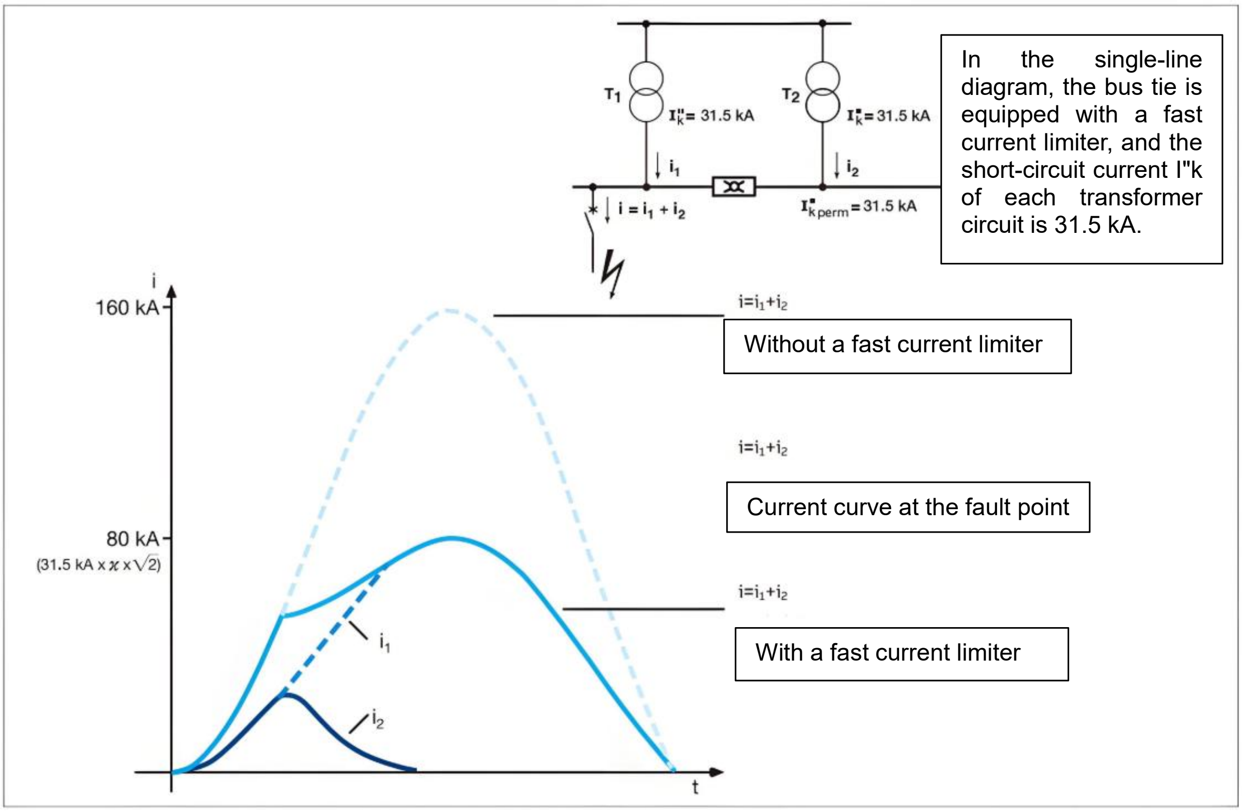
The fast current limiter can interrupt the short-circuit current in an extremely short time, helping you solve this problem.

If a short-circuit fault occurs downstream of a feeder circuit, its first half-wave curve is shown in the figure below.

Each transformer has a short-circuit current of up to 31.5 kA flowing to the fault point, and the maximum short-circuit current through the fault point reaches 63 kA, which is twice the rated value of the equipment.

In this example, the current flowing through the fast current limiter is i_2. It can be seen that through the fast current limiter, the current i_2 is quickly limited. The peak value of the short-circuit current i_1 + i_2 flowing to the short-circuit point does not include the contribution of the short-circuit current from transformer T_2. Therefore, the switchgear with a rated short-circuit current of 31.5 kA can fully meet the requirements of the system's parallel operation.

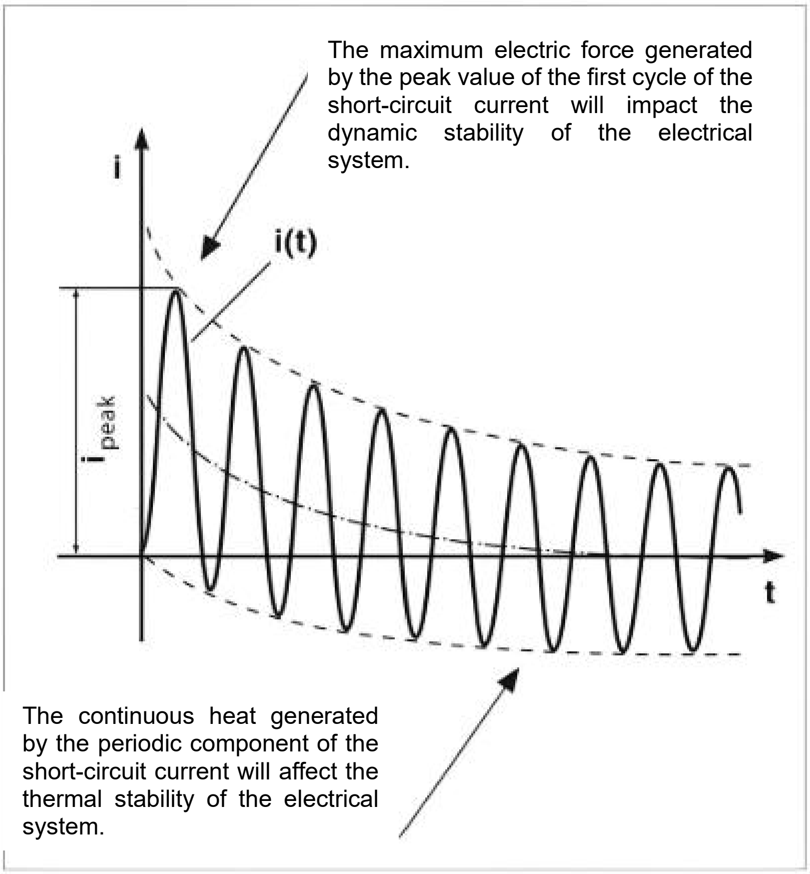
Current at the fault point:i = i1 + i2



Q&A

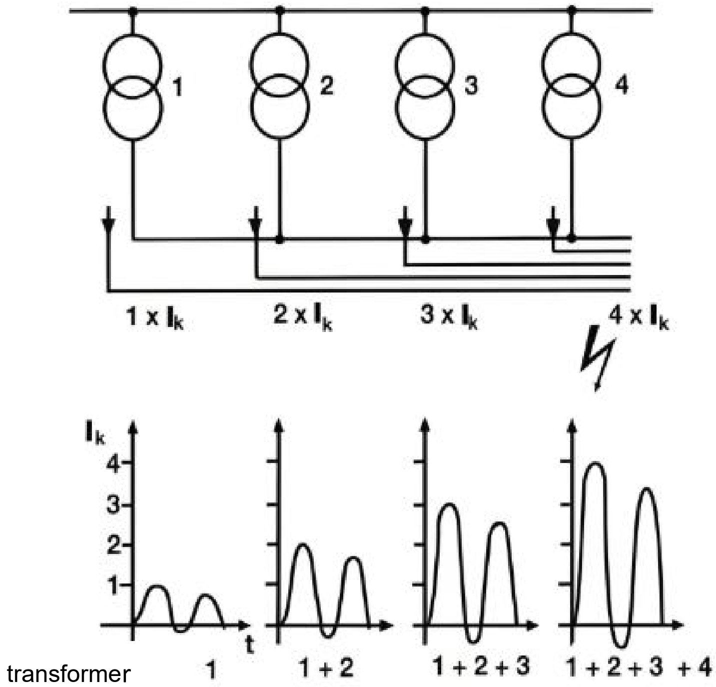
1.What is the short-circuit peak current?

The short-circuit peak current I_{peak} is the maximum instantaneous value in the first cycle of the current, which is formed by the superposition of the periodic component and the aperiodic component of the short-circuit current after a short circuit occurs.



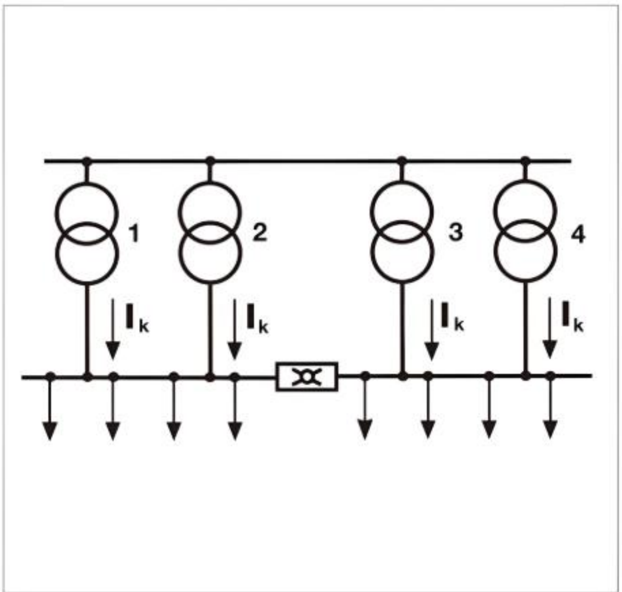
2.Why is it necessary to limit the short-circuit peak current?

A short-circuit peak current that exceeds the rated parameters of the equipment will generate electric force that can damage switchgear, switches, current transformers, and cables.



3.For a set of switchgear that can only withstand a short-circuit current of 2Ik, how to use it in a system with 4 parallel-operated transformers (where the maximum short-circuit current can reach 4Ik) without the risk of excessive short-circuit current and additional losses?

This can be achieved by installing fast current limiters between busbars 1-2 and 3-4 (this is only one of the application schemes of fast current limiters).

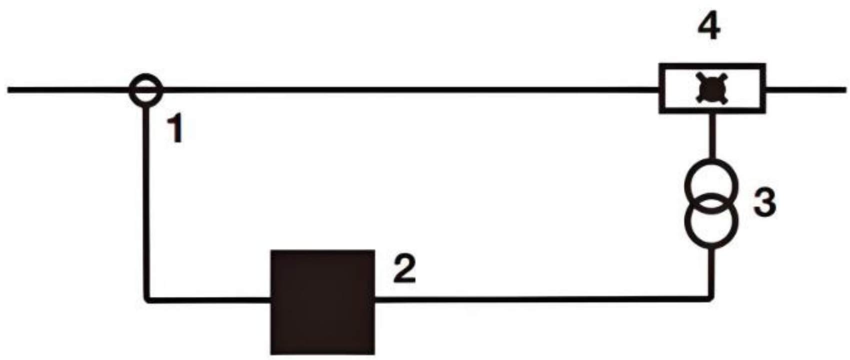


4.What is the working principle of the fast current limiter?

The fast current limiter consists of two parallel conductive circuits. The conductive core can withstand the normal rated current (maximum 5000 A). After the conductive core acts to disconnect the main circuit, the parallel fuse limits the short-circuit current at the initial stage of its rise (within 1 ms).

5.How is the main circuit disconnected within 1 ms?

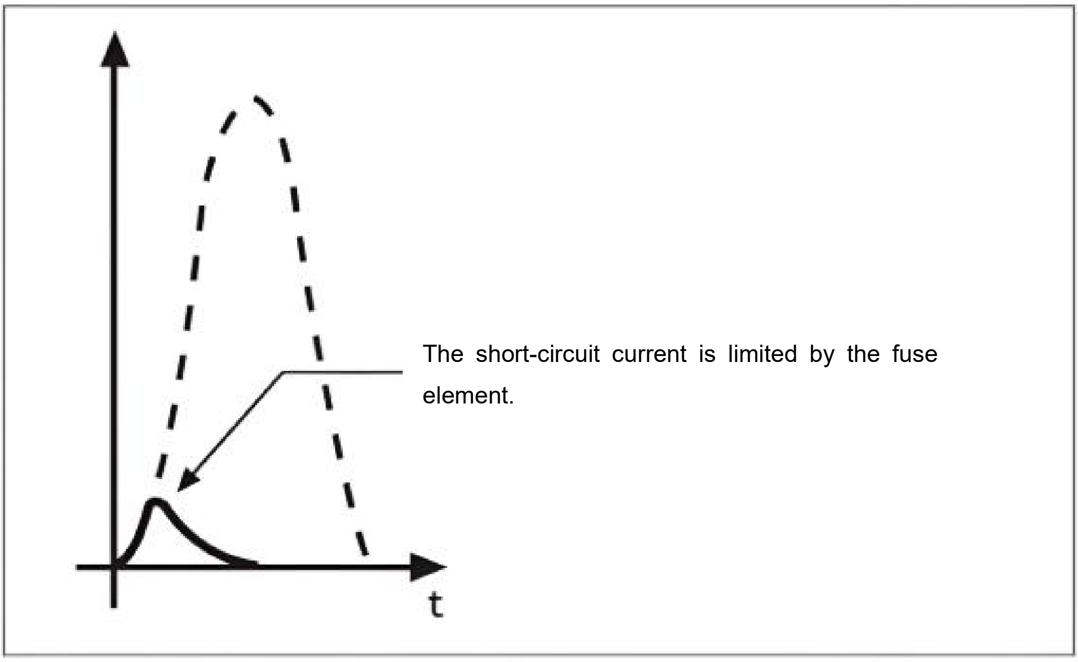
Mechanical energy storage switchgear with a high rated short-circuit current cannot disconnect the main circuit in such a short time. Therefore, we use a special inductive filler.



1.Matching current transformer (for detecting short-circuit current)
2.Measuring and control device (judges whether the current reaches the set value and provides tripping energy)
3.Pulse transformer (converts the tripping pulse to bus potential)
4.Conductive bridge and mounting base (withstands normal operating current and limits short-circuit current)

6.What level of overvoltage will be caused by the instantaneous interruption of current?

When the conductive core of the main circuit is interrupted instantaneously, it will not affect the current of the entire circuit. At the moment the conductive core is interrupted, the current will flow to the parallel fuse, and the fault current will eventually be cut off by the fuse. The overvoltage level generated by the fuse cutting off the current will be lower than the allowable value required by IEC/VDE standards (such as IEC 60282-1/VDE 0670 Part 4). After interruption, the main circuit conductor, parallel fuse and inductive filler will be replaced, while other parts can still be reused.



7.After interrupting the short-circuit current, can the conductive bridge of the fast current limiter be repaired?

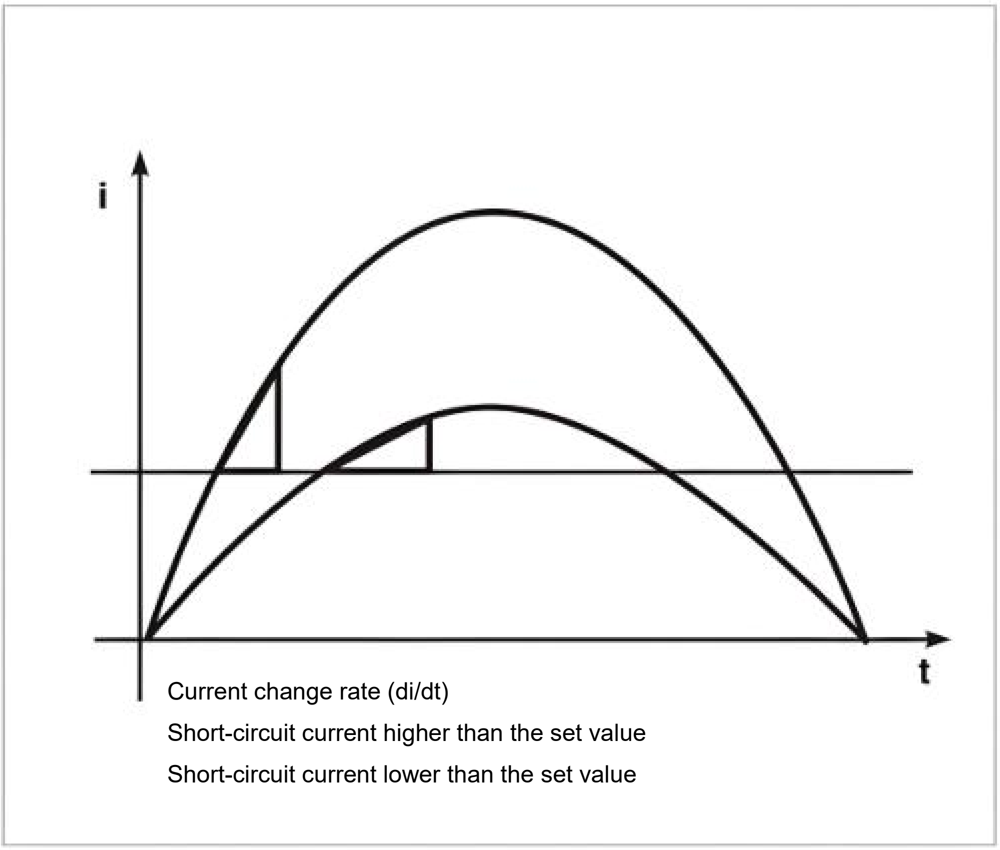
Of course! The manufacturer can repair the actuated conductive bridge. The conductive core, inductive filler and parallel fuses will be replaced, while other components can continue to be used, so repairing the conductive bridge is more economical.

8.Does the fast current limiter interrupt the current in every short-circuit fault?

No! The fast current limiter only interrupts the short-circuit current that is harmful to the system (exceeding the set value), while the short-circuit current below the set value will be cleared by the circuit breaker.

9.How does the fast current limiter judge the severity of a short-circuit fault?

The measuring and control device of the fast current limiter detects both the instantaneous value of the current and the current change rate. Only when both reach the set values will the fast current limiter trip.



10.What is the operational track record of fast current limiters?

Since ABB Calor Emag invented the fast current limiter in 1955, thousands of units have been effectively used in both AC and DC systems. Looking back at 60 years of global operational experience, an increasing number of users have chosen fast current limiters as a solution to address issues such as safely limiting system short-circuit capacity and economically expanding electrical systems and distribution networks.

11.How frequently do fast current limiters operate?

Based on global operational experience, they operate on average once every 4 years (statistics based on the operation of nearly 4,000 fast current limiters).

12.What is the maximum short-circuit current that a fast current limiter can interrupt?

According to test results from the KEMA test station:

12 kV: up to 210 kARMS

17.5 kV: up to 210 kARMS

24 kV: up to 140 kARMS

36/40.5 kV: up to 140 kARMS

The following will illustrate the working principle and application scope of fast current limiters through typical application schemes. Please join us in discussing the challenges of system short-circuit capacity—we can always find technically feasible and economically reasonable solutions using fast current limiters.

Functions

With the growth in global energy demand, there is a need for higher-power power supplies, additional transformers and generators, and increased interconnection between independent power grids. This often leads to short-circuit currents exceeding the allowable values of equipment, resulting in dynamic and thermal damage to the equipment.

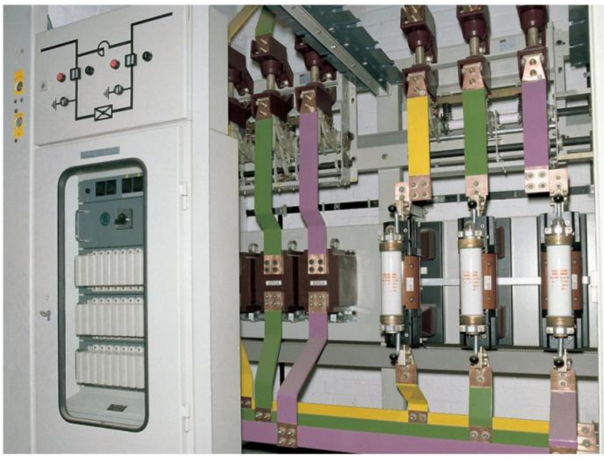
Replacing existing switchgear and cable connections with new equipment that has a higher short-circuit current withstand capacity is usually technically infeasible or uneconomical for users. However, using fast current limiters to reduce short-circuit currents in new or existing systems not only solves the short-circuit capacity problem but also saves investment.

Due to their slow operation, circuit breakers cannot provide protection against the excessive peak value of the first half-cycle of short-circuit currents in the system. Only fast current limiters can detect and limit the short-circuit current at the initial stage of its rise (within 1 ms), so that the maximum instantaneous value of the actual short-circuit current flowing through is much lower than the expected peak value.

Compared with complex conventional solutions, fast current limiters applied in transformer or generator feeder circuits, whether as bus connections or bypass current-limiting reactors, have technical advantages and economic benefits.

In power plants, large industrial facilities, and grid substations, fast current limiters are ideal switchgear in all aspects for solving short-circuit current problems.

Fast current limiter bypass reactor — fixed installation mode



Structural Design

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Composition of Fast Current Limiter for Three-Phase AC Systems

• Three conductive bridge bridge bases

• Three conductive bridges

• Three matching current transformers

• One measurement and control unit

Conductive Bridge Base

Components of the conductive bridge base:

• Mounting plate 1

• Insulator 2

• Pulse transformer 6 and telescopic contact 5

• Connection terminal 3 with quick connector for connecting to the conductive bridge

The quick connector's clamping device is lever-type. For conductive bridges with a rated current Ir ≥ 2500 A and a rated voltage of 12/17.5 kV, bolted connections are used.

Pulse Transformer

The installation position of the pulse transformer depends on the rated voltage:

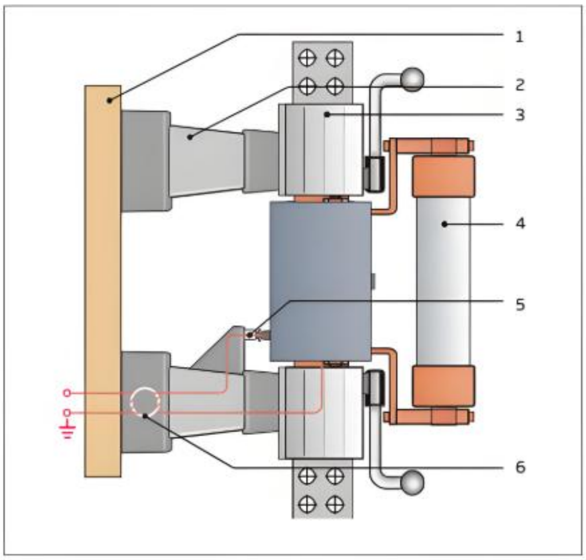
• For rated voltage ≤ 17.5 kV, it is installed only at the lower insulator.

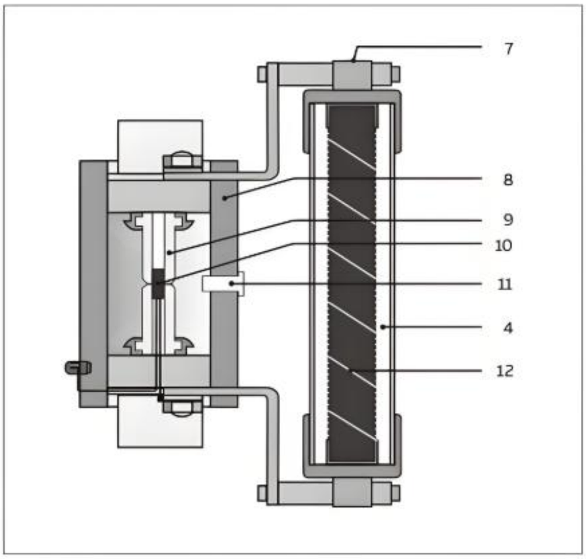
• For rated voltage of 24/36 kV, it is installed at both the upper and lower insulators.

The pulse transformer transmits the tripping pulse from the measurement and control unit (Figure 3) to the inductive filler 10 of the conductive bridge. Meanwhile, it provides electrical isolation between the measurement and control unit (secondary circuit) and the inductive filler, which is at the same potential as the primary circuit, ensuring system safety.

Conductive Bridge

The conductive bridge is a switching element. Inside a robust insulating cover 8, it contains a conductive core and is designed as a conductive connecting bridge body 9 that encapsulates the inductive filler 10. During tripping, the inductive filler is activated, and the conductive core is separated at the pre-cut position.





1 Base
2 Insulating support
3 Connection terminal with clamping device
4 Fuse
5 Trigger terminal
6 Insulating support with pulse transformer

7 Fuse indicator
8 Insulating tube
9 Conductive core
10 Inductive filler
11 Conductive core indicator
12 Fuse element

The current is transferred to the parallel high-breaking-capacity fuse 4, and the fuse element 12 melts, restricting the further increase of the short-circuit current. The current is interrupted at the next voltage zero crossing.

Supporting Current Transformer

The current transformer is used to detect the current flowing through the fast current limiter and is directly connected in series with the fast current limiter.

The supporting current transformer is a special type, which has the same appearance as a conventional current transformer, being of bushing type or block type. Its notable features are as follows:

Extraordinarily high overcurrent coefficient.

The iron core is a low-residual magnetism iron core with an air gap.

There is a low-impedance shielding layer for isolation between the primary and secondary windings.

Measurement and Control Device

The measurement and control device is installed in the control panel (Figure 3) or the low-voltage compartment of the fast current limiter cabinet.

The control panel or low-voltage compartment is composed of functional groups, each of which is installed in a chassis and can be replaced.

Composition of the Measurement and Control Device

• A set of power supplies, which provide the necessary DC auxiliary power for the device; a selector switch that can put the control system into operation or take it out of service at any time; and an additional monitoring component

• A control unit for each phase, which monitors the current flowing through the phase in real time and provides triggering energy for the inductive filler in the corresponding phase's conductive bridge during tripping

• An indicator unit with 5 drop-down relays:

One tripping action indicator for each phase

One drop-down relay for monitoring whether the device is ready

One drop-down relay for monitoring whether the control power supply is normal

• An anti-interference unit, which can protect the measurement and control device from external interference and prevent misoperation. All wiring from the measurement and control device to the current transformers, conductive bridge bases, and AC power supplies will pass through the anti-interference unit

Figure 3: Measurement and Control Device

Working Principle

Composition of the fast current limiter: An extremely fast switch capable of carrying high rated current but with low breaking capacity, paralleled with a fuse having high interrupting capacity. To achieve an extremely short inherent opening time, inductive filler is used here to store the energy required for opening the switch (conductive core).

After the conductive core separates, the current flows through the parallel fuse, which limits the current within 0.5 ms and finally interrupts it at the next voltage zero crossing.

The current flowing through the fast current limiter is monitored in real time by the measurement and control device, which can accurately predict whether the fast current limiter needs to trip at the initial stage of short-circuit current rise. To achieve this predictive function, the device continuously detects the instantaneous value of the flowing current and the current change rate. The fast current limiter operates when both set values are reached or exceeded simultaneously. The three phases of the fast current limiter work independently without interfering with each other.

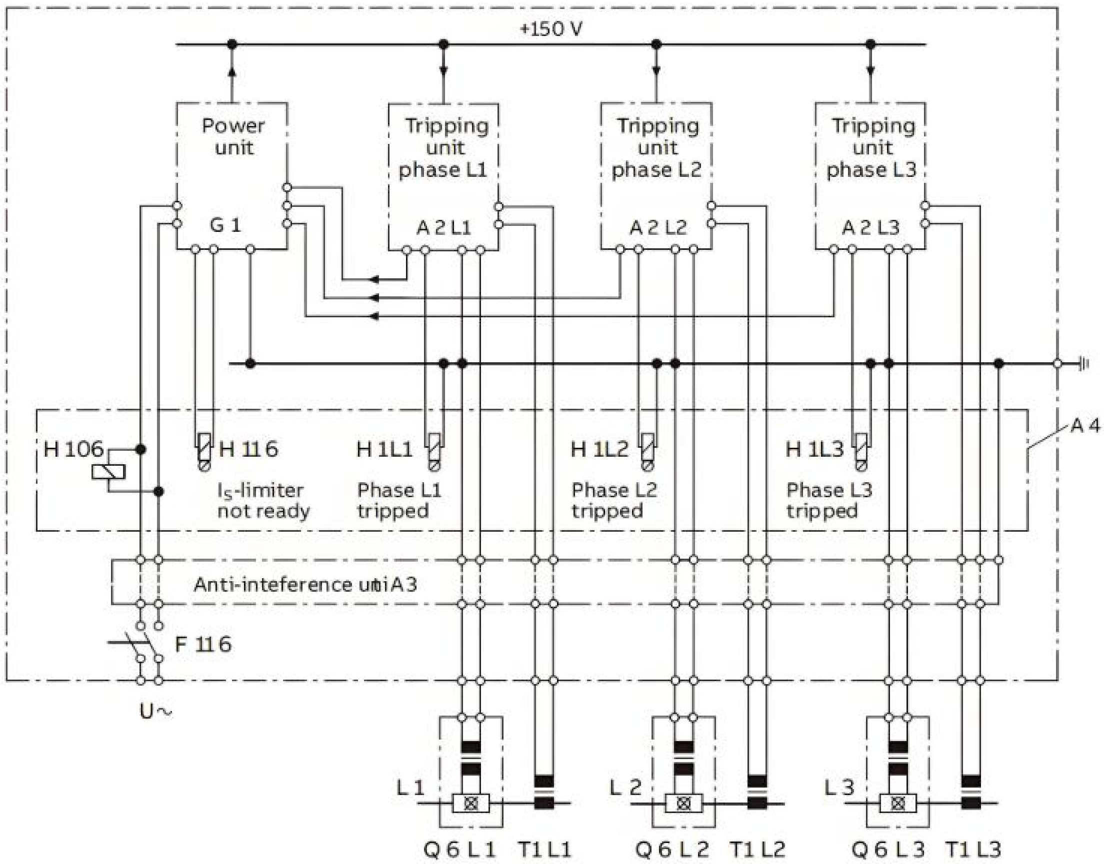
On one hand, the fast current limiter can carry large load currents without loss; on the other hand, it can limit short-circuit fault currents at the initial stage of their rise. Compared with current-limiting reactors, the fast current limiter avoids voltage drops and prevents the expected peak value of short-circuit fault currents from occurring.

To ensure that all three-phase circuits are disconnected, it is necessary to connect a circuit breaker in series with the fast current limiter.

Power Supply Unit

A set of DC 150 V power supplies is used for the charging voltage of the tripping capacitor and also serves as the power supply for the device's electronic components. If required, these two types of power supplies can be separated and installed in different independent modules. The power supply unit has a built-in watchdog that continuously monitors the important functions of the three-phase tripping control unit.

Figure 4: Control Schematic Diagram of the Fast Current Limiter



G1 Power Supply

A2 Tripping Control Unit

A3 Anti-Interference Unit

A4 Indicator Unit

F116 Control Power Supply MCB (Miniature Circuit Breaker)

Q6 Fast Current Limiter (conductive bridge base and conductive bridge)

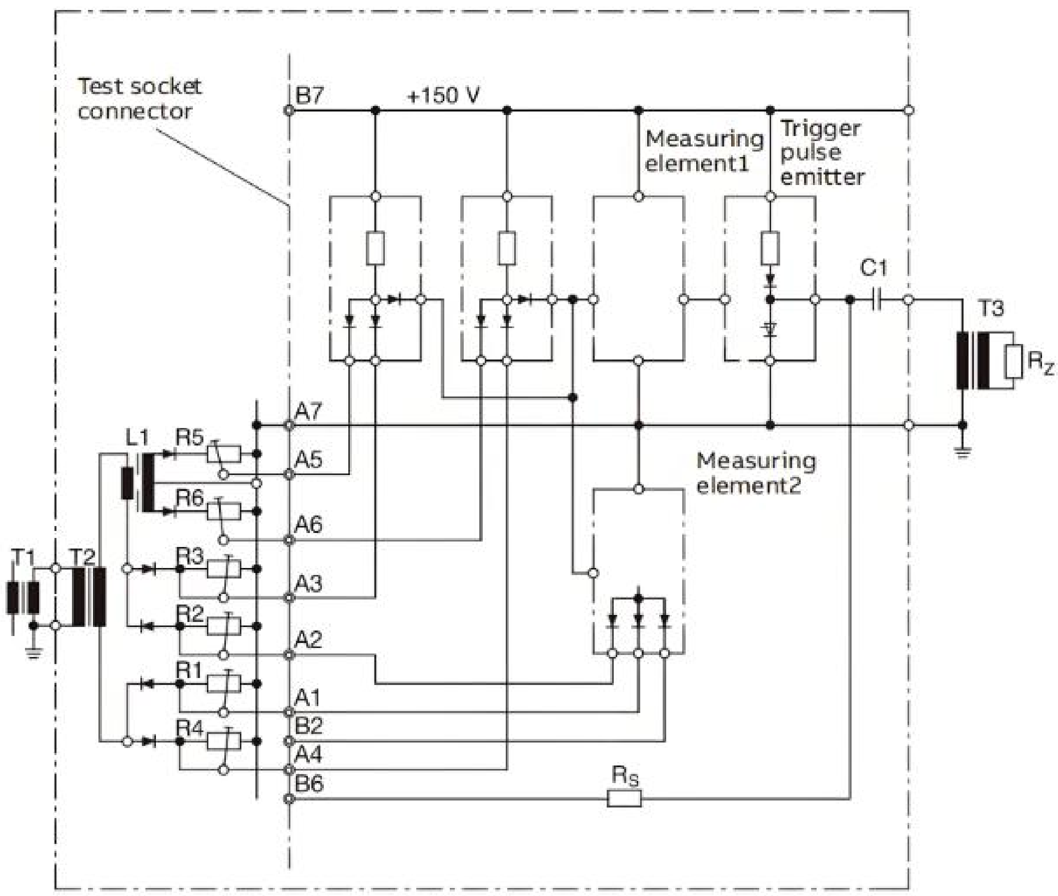
T1 Current Transformer Matching the Fast Current Limiter

Tripping Control Unit

The tripping control unit continuously monitors the current flowing through the matching current transformer, and the three-phase tripping control units work independently. There are two tripping criteria: the instantaneous current value and the current change rate.

These two variables—the instantaneous current value and the current change rate—are proportionally converted into voltage signals, which are sent to the electronic measuring component through a logic gate circuit. When both the instantaneous current value and the current change rate reach their set values, the measuring component outputs a signal. The output signal of the measuring component triggers the semiconductor switching element, which controls the discharge of the tripping capacitor. The discharge pulse triggers the action of the inductive filler in the conductive bridge through the pulse transformer. At the same time, the discharge of the tripping capacitor drives the drop-down relay to act, outputting the "fast current limiter tripped" signal.

Figure 5: Schematic Diagram of the Measurement and Control Device



T1 Current Transformer Matching the Fast Current Limiter

T2 Internal Intermediate Transformer of the Device

T3 Pulse Transformer

L1 Measuring Inductor

R1...R6 Adjustable Resistors

C1 Tripping Trigger Capacitor

RS Discharging Resistor

RZ Inductive Filler

Commissioning

—

Like other protection devices, fast current limiters also require regular inspection. Inspection work can be carried out by the user or ABB. To facilitate testing, we have developed special testing equipment, which consists of test instruments or test plugs and simulators.

Test plugs are used to detect the output voltage and function of the tripping device. Test instruments feature a user-friendly interface, making operation more convenient.

During inspection, the actual conductive bridge must be replaced with a simulator. The simulator has a built-in neon indicator light, which illuminates when a tripping pulse is received.

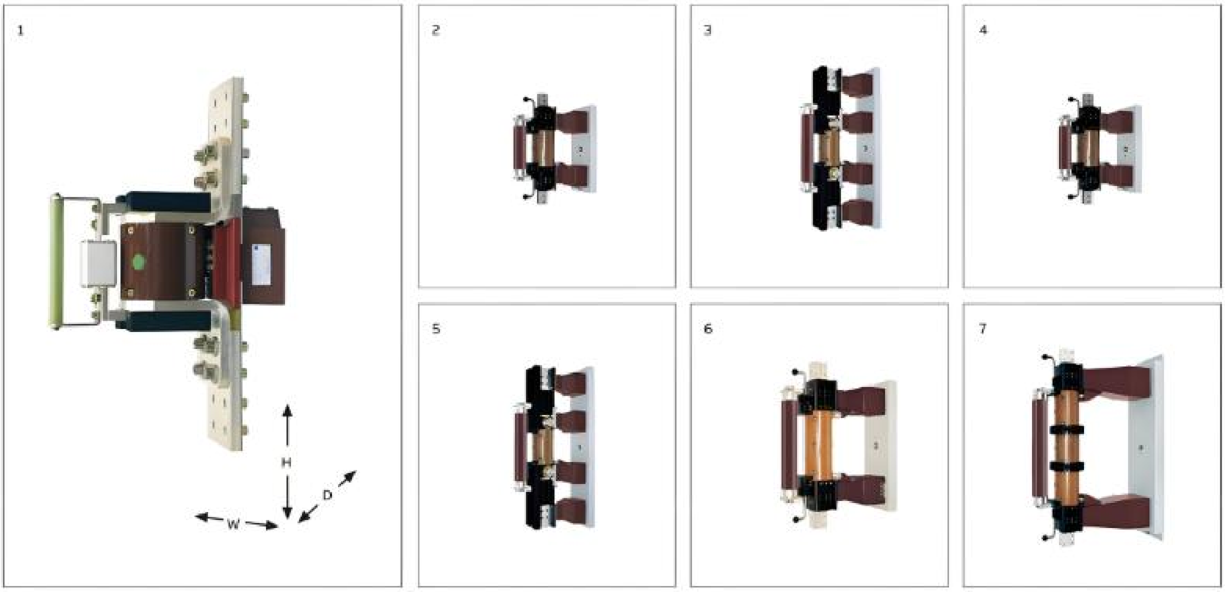
Figure 6:

1 Conductive Bridge and Simulator of the Fast Current Limiter

2 Test Plug

3 Test Instrument

Scope of Supply



A. Fast current limiter supplied as discrete components

In this case, the conductive bridge bases, conductive bridges, and matching current transformers will be installed in the existing switchgear cabinet.

The supplied equipment generally includes:

• Three conductive bridge bases

• Three conductive bridges

• Three matching current transformers

• One measurement and control device (Figure 3)

Technical Parameters	Unit	1	2	3	4	5	6	7
Rated Voltage	V	750	12000	12000	17500	17500	24000	36000/40500
Rated Current	A	1250 2000 3000 4500¹) 5000¹)	1250 2000	2500 3000 4000¹)	1250 2000	2500 3000 4000¹)	1250 1600 2000 3000¹)	1250 2000 2500¹)
Rated Power Frequency Withstand Voltage	kV	3	28	28	38	38	50	75
Rated Lightning Impulse Withstand Voltage	kV	-	75	75	95	95	125	200
Rated Short - Circuit Breaking Current	kA RMS	Up to 140	Up to 210	Up to 210	Up to 210	Up to 210	Up to 140	Up to 140
Conductive Bridge Base	kg	10.5	27.5	65	27.5	65	27/31.5/33	60
Conductive Bridge	kg	17.0	12.5	15.5	14.5	17.5	19/19.5/24	42
Conductive Bridge Base and	Width	148	180	180	180	180	180	240

Technical Parameters	Unit	1	2	3	4	5	6	7
Conductive Bridge	mm							
	Height mm	554	651	951	651	951	740/754/837	1016
	Depth mm	384	510	509	510	509	553/560/560	695

1. With forced air cooling.

Frequency: 50/60 Hz. For higher rated current requirements, the conductive bridge bases and conductive bridges can be used in parallel.

B. Truck-Type Fast Current Limiter Cabinet

Matching the metal-clad switchgear, the three conductive bridge bases and conductive bridges of the fast current limiter can be installed on a truck. The movable truck has the function of an isolating switch. The three matching current transformers are fixedly installed in the cabinet, and the measurement and control device is installed in the low-voltage compartment of the switchgear.

C. Fixed-Mounting Fast Current Limiter Cabinet

Fast current limiters for low voltage, 12 kV, 17.5 kV, and 24 kV can also be fixedly installed in metal-clad switchgear. The three conductive bridge bases, conductive bridges, and matching current transformers are all fixedly installed in the switchgear, and the measurement and control device is installed in the low-voltage compartment.

For 36 kV/40.5 kV systems, only fixed-mounting fast current limiter cabinets are available. Similar to the discrete component supply mode, the measurement and control device is installed in a separate control box (Figure 3).

All fixed-mounting fast current limiter cabinets have the same electrical parameters as those supplied with discrete components.

Truck-Type Fast Current Limiter Cabinet

Typical Dimensions of Truck-Type Fast Current Limiter Cabinet

RatedVoltage (kV)	RatedCurrent (A)	RatedPowerFrequency WithstandVoltage(kV)	RatedLightningImpulse WithstandVoltage(kV)	Height (mm)	Width (mm)	Depth (mm)	Weight (IncludingFastCurrentLimiterTruck)(kg)
12	1250	28	75	2200	1000 2)	1634	1200
	2000						
	2500						
	3000						
	4000 1)						
17.5	1250	38	95	2200	1000 2)	1634	1200
	2000						
	3000						
	4000 1)						
24	1250	50	125	2325	1000	1560	1300
	1600						
	2000						
	2500 1)						

1.Forced air cooling.

3.An additional connection adaptation with a width of 200 mm is required.

For higher rated current requirements, the conductive bridge bases and conductive bridges can be used in parallel.

Application

Fast current limiters are used for parallel operation of systems

For parallel operation between systems or bus sections, when using circuit breakers, the short-circuit current will exceed the equipment parameters, and fast current limiters can usually be used to solve this problem. Each subsystem has at least one incoming power line. After the fast current limiter trips, each subsystem still has power supply (Figure 9). The parallel operation of systems using fast current limiters has the following advantages:

1.Reduce the impedance of the series network, significantly reducing the voltage drop caused by impact loads (such as large motor starting)

2.Improve the load distribution of transformers

3.Reduce the load loss of transformers

4.Improve power supply reliability. When one transformer fails, the load can be transferred to another transformer without interruption

5.Save costs caused by the need for equipment with higher rated short-circuit current parameters

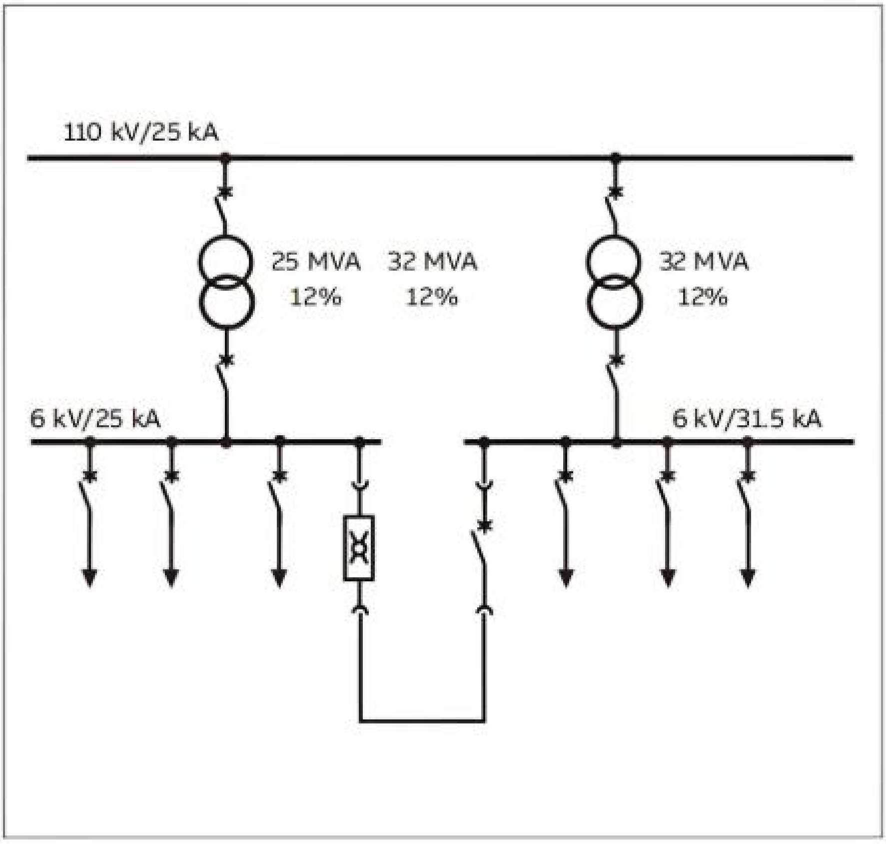
When a short-circuit fault occurs in a subsystem or a certain outgoing feeder, the fast current limiter operates at the initial stage of the short-circuit current rise. Before the instantaneous current value reaches the withstand limit, the bus system is divided into two sections.

After the fast current limiter is opened, the short-circuit fault current is only supplied by the transformer in this section, and can be selectively opened by the circuit breaker of the corresponding circuit.

A significant advantage of the fast current limiter is that the voltage of the part of the system not affected by the short-circuit fault only drops within 1 ms, and even the most sensitive loads (such as computers) are not affected at this time.

For this reason, fast current limiters can be used as switchgear to improve system reliability, suitable for interconnection between "protected system" equipment and "non-protected system" equipment.

Figure 9: Application of Connection Between Bus Sections



Fast Current Limiter as an Interconnection Switch Between the Public Power Grid and the User's Self-provided Power Generation Source

The benefits brought by grid connection make users with self-provided power generation sources willing to connect to the public power grid. However, the short-circuit current contribution of the generator will cause the short-circuit current of the public power grid after grid connection to exceed the allowable value of the original equipment. The most reasonable solution, and usually the only solution, is to install a fast current limiter at the connection between the public power grid and the self-provided power generation (Figure 10).

If necessary, a directional tripping function can be added to the fast current limiter. This requires installing 3 current transformers at the neutral point of the generator. When the generator is in operation, the fast current limiter will only trip when a short-circuit fault occurs in the public power grid.

Fast Current Limiter Bypassing the Current-limiting Reactor

The fast current limiter bypasses the current-limiting reactor (Figure 11). When a short-circuit fault occurs after the current-limiting reactor, the fast current limiter opens at the initial stage of the short-circuit current rise, and the current will be transferred to the current-limiting reactor, and the reactor will limit the short-circuit current to an allowable level.

During normal operation, the fast current limiter bypasses the reactor winding, which can avoid:

1.Copper losses related to load current and reactive equivalent losses caused by the reactor

2.Voltage drops of the reactor related to the load, especially the troubles caused by such voltage drops when large motors downstream are started

3.Generator regulation problems

Figure 10: Application of Connection Between Public Power Grid and Self-provided Power Generation

Figure 11: Application of Bypassing Current-limiting Reactor

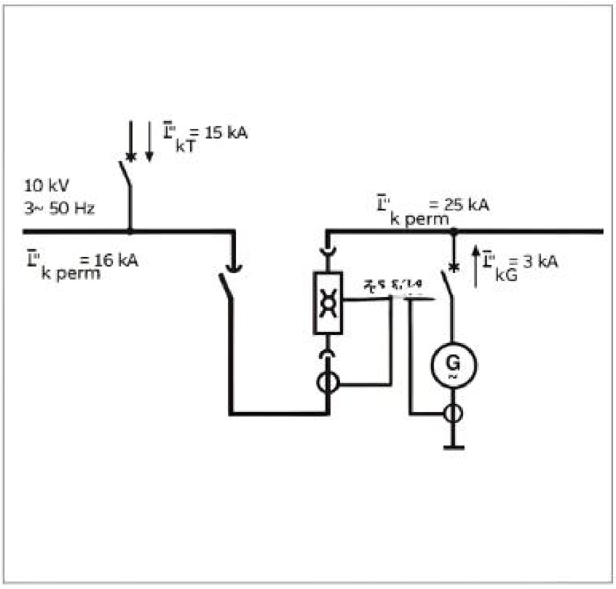


Figure 10

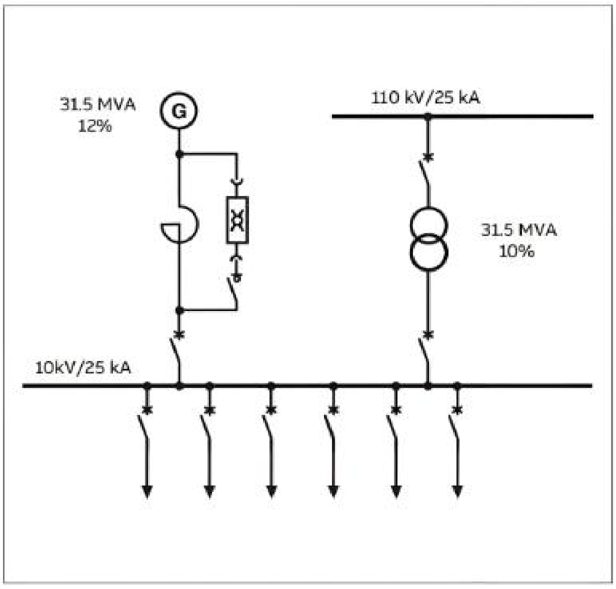


Figure 11

Application of Multiple Fast Current Limiters with Selectivity

In cases where two or more fast current limiters are installed in one or multiple rows of switchgear, additional operating conditions such as current vector sum, differential current, or current comparison are often required to achieve operational selectivity.

If two fast current limiters are installed in a bus section and selective tripping is required, full current detection is necessary:

1.For a short circuit in section A

Only the 1# fast current limiter operates

2.For a short circuit in section B

Both 1# and 2# fast current limiters operate

3.For a short circuit in section C

Only the 2# fast current limiter operates

To measure the full current, current transformers must be installed at the outlet terminals of the transformers.

Total current I_{sum1} equals the current flowing through transformer T1 (I^{T1}) plus the current flowing through the 1# fast current limiter (I_{is-1}).

Total current I_{sum2} equals the current flowing through transformer T1 (I^{T2}) plus the currents flowing through both 1# and 2# fast current limiters.

Total current I_{sum3} equals the current flowing through transformer T1 (I^{T3}) plus the current flowing through the 2# fast current limiter.

The tripping criterion of the fast current limiter follows the "AND" logic function. In bus section A, if both the current of the 1# fast current limiter and the total current I_{sum} reach or exceed their set values, the 1# fast current limiter trips. The same applies to bus section C. In the event of a short-circuit fault in bus section B, both 1# and 2# fast current limiters will trip.

The current vector sum principle corresponds to the current synthesis principle in bus protection systems, with the only difference being that no current transformers need to be installed in the feeder circuit, thus eliminating related costs. Using the same principle, up to 5 transformers can be paralleled with only 4 fast current limiters. This principle ensures that only the fast current limiter(s) closest to the short-circuit point will trip.

Figure 12: Schematic Diagram of Current Vector Sum Function of Fast Current Limiter

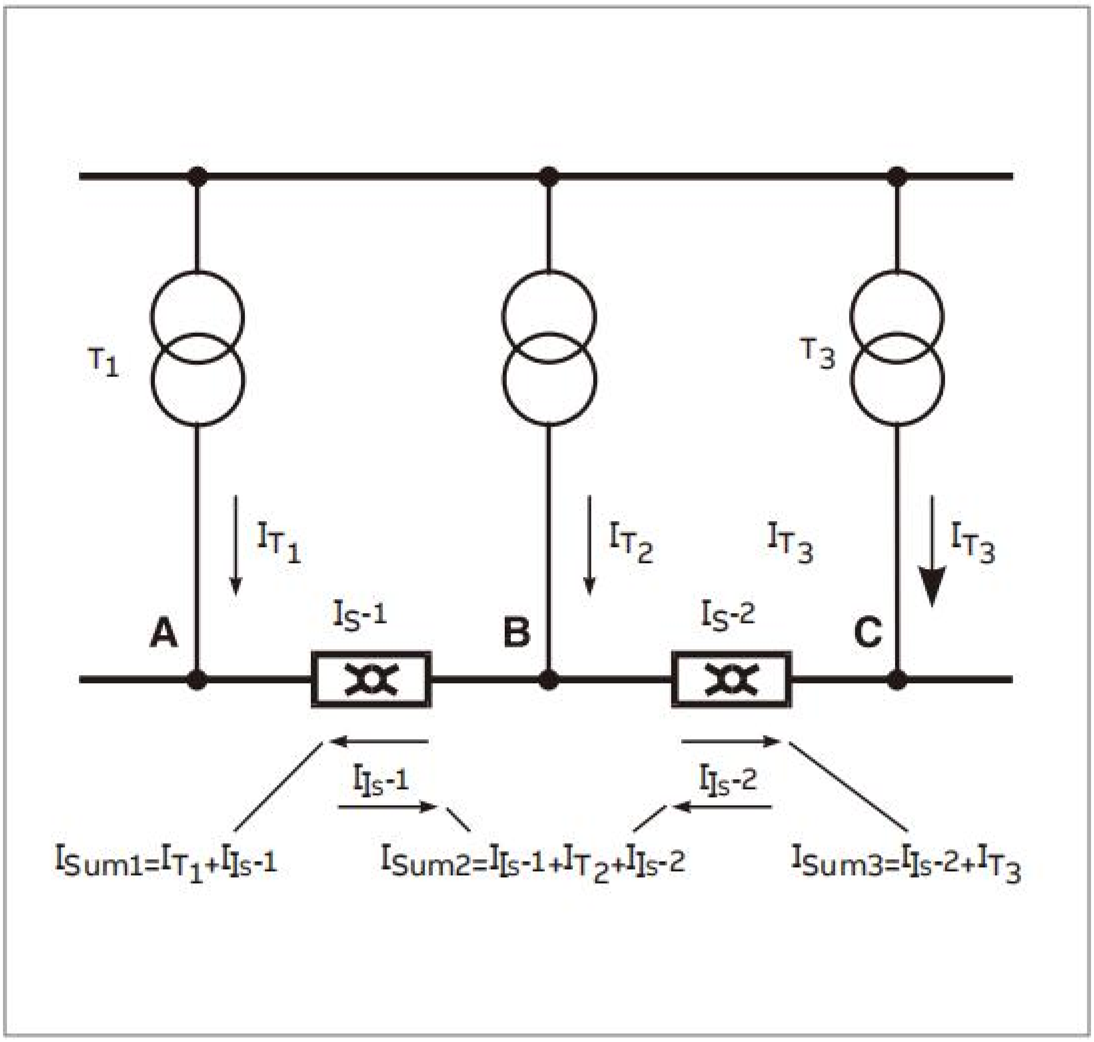


Figure 12