n° 161

automatic transfering of power supplies in HV and LV networks

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automatic transfering of power supplies in HV and LV networks

Nowadays even temporary loss of electrical power is a major handicap for firms whose production processes brook no interruption as well as for high-rise buildings whose safety circuits must be operational at all times.

Consequently, transfering of main supply sources onto replacement or emergency sources has proved to be a function used with increasing regularity in electrical distribution, public and private alike.

This «Cahier Technique» begins with an examination of the difficulties of implementing such switching devices, together with the possible technical solutions. This section is followed by a presentation of the various switching types backed up by practical examples. Finally, a table summarises the above and gives the main areas of application.

contents

1. introduction

The purpose of installing source switching devices is to guarantee the continuity of power supply of certain priority loads, for example to ensure protection of persons or to maintain production cycles. Such devices are put into operation either by failure of the main power supply or by voluntary operator action.

Switching devices are particularly used:
■ to supply:
□ computers,
□ high-rise buildings,
□ lighting and safety systems: airfield lighting, premises receiving general public, etc,
□ main auxiliaries of thermal power plants,
□ complete manufacturing lines whose process brooks no interruption, even temporary, of any element in the line (iron and steel, petrochemical, etc...);
■ in medium voltage public distribution for:
□ switching of HV lines and transformers in source substations,
□ supply of HVA/LV-HV level A (U ⩽ 50 kV)/Low Voltage (U ⩽ 1 kV) dual incomer substations.

The devices using these power transfers are highly varied. For example, in power circuits, switching devices are electromechnical or static contactors, circuit-breakers and switches, in high and low voltage alike.

These devices can be operated:
■ manually: such devices are the most elementary and economic. They require intervention of an operator, and the time needed to change from the defective source to the replacement or backup source can be very long (the operator has to move place);
■ automatically: these devices are the fastest and the most commonly used.

Nevertheless the basic configuration can, in most cases, be simply a main power supply, a replacement or backup source and a busbar which is the point common to both sources from which the loads are supplied.

2. various types of transfer schemes

There are three main source switching types, namely:

■ synchronous:
transfer time: zero
(e.g. generator coupling);

■ interrupted circuit transfer
transfer time: 0.2 to 30 s
(e.g. main/emergency function in LV);

■ pseudo-synchronous
transfer time: 100 to 300 ms
(e.g. reacceleration of asynchronous motors).

For switching, a certain number of prior conditions must be met, some of which call for special precautions.

problems presented by switching and precautions to be taken

To construct an installation containing source transfers complying with the continuity of service requirements of its users, a number of factors, calling for special precautions, must be examined in the design stage:
■ presence of a fault on the downstream network;
■ characteristics of the replacement source;
■ preparing the switching orders;
■ voltage loss during switching (for non-synchronous switching);
■ mechanical interlocking of switching devices in LV and HV;
■ dielectric withstand of switching devices (in HV).

presence of a fault on the downstream network

When failure of the main power supply is caused by a fault downstream of the supply transfer location, we recommend you do not switch the supply sources. Rather, the circuit controlling the switching device should be blocked by an order from the downstream network protection system.

characteristics of the replacement source

The rated power, short-circuit power, connection impedances and earthing system of the replacement source may vary considerably from the main source. Thus, for example, the main source may be an 800 kVA, 380 V, 50 Hz, Isc = 20 kA transformer, where as the replacement source is an 200 kVA generator set, having a transient short circuit current of 1 kA.
The devices protecting against phase-to-phase and phase-earth faults in the backed-up network may thus cease to function in certain conditions when this network is supplied by the replacement (or backup) source.
Extreme care must be taken when choosing and setting the protective devices in order to find a protection system compatible with the electrical characteristics and the operating and maintenance modes of both supply sources. Two cases should be emphasised at this point: the reacceleration of certain motors and the resumption of supply of several loaded step-down transformers:

■ the network load includes a number of motors. When the replacement source is a low power one, after the main source has switched to the replacement source, the inrush current and the permanent working current must be limited by:
□ partially shedding loads,
□ staggering restarting of priority motors in the event of an interruption.
If these measures are not taken, in view of the low power replacement source, voltage drops would be extremely serious and motor reacceleration impossible (driving torque less than mechanical load torque).

■ energising of a number of step-down transformers in the distribution network. When switching takes place in HV, allowance must be made for the inrush currents of HV/LV transformers which are some 10 to 15 times their rated current. In actual fact, if the replacement source is an LV generator set, its generator cannot supply currents that high at rated voltage and acts as though it were supplying a short-circuit. It thus delivers a very low voltage for the first few moments after switching which does not simplify motor restarting. Consequently, it is preferable to trip all the step-down transformers on the HV side before switching, and then to re-energise them one after the other.

preparing the switching orders

The input for these orders comes from voltage monitoring:
■ if the replacement source is a generator set: loss of voltage on the main power supply to initiate startup of its motor;
■ presence of stabilised voltage of replacement source to authorize transfer to the replacement source;
■ presence of voltage on the main supply source to return to the normal position.

The switching orders

■ to transfer from the main to the replacement source.
Loss of or drop in main supply voltage may be:
□ permanent, due to:
- tripping of the upstream protective device,
- excessive overloading of the network causing a large voltage drop,
- etc,
□ but also temporary, due to:
- operation of the rapid or slow reclosing controllers of the electricity board’s overhead lines,
- a short-circuit between phases, normally eliminated by the protection devices,
- etc.

The action of the main source undervoltage detector will thus generally be delayed so as not to switch sources due to temporary drop in or loss of voltage. Moreover, if the replacement source is a generator set whose starting order is given by loss of main source voltage, the set’s voltage must first stabilise before a switching order is given (a few seconds).

■ to transfer from the replacement to the main source.
Resumption of the main supply may be preceded by attempts to re-energise the main line, in order to:
□ locate a fault,
□ perform source looping further to an incident,
□ carry out tests following repair or modification of the main line.

The action of the main source voltage presence detector will thus be amply delayed (a few dozen seconds to a few minutes).

Note:
a) devices used to switch from the main to the replacement source without returning to the main source when it is once more present, are normally known as changeover switches;
b) devices automatically returning to the main source are known as main/ emergency changeover switches.

The difficulties in detecting loss of main supply voltage

■ residual distribution network voltage on loss of supply source.
Although the supply source has failed, distribution network voltage can be sustained by:
□ the residual voltage generated by asynchronous motors during deceleration for a period of approximately 0.3 to 1 s,
□ the voltage induced at the terminals of synchronous motors during deceleration,
□ the voltage due to discharging of capacitors connected to the network.
In the case of rapid source switching, this sustained voltage prevents rapid detection of loss of main supply voltage by ordinary conventional devices such as threshold voltage relays.

■ temporary loss of voltage during which the transfer must be blocked. These voltage losses are caused by network controllers such as rapid and/or slow reclosers and switching of HV transformers or lines in HV transformer substations, etc.

The same applies to network undervoltage due to excessive voltage drops caused by transient overcurrents (phase-to-phase or phase-to-earth fault eliminated by discriminating network protection devices, startup of large motors, etc...).

■ choice and cabling of detectors with:

□ one single-phase relay

Normally, only one single-phase detection relay is connected between two phases of the main incomer.
In this case, the third phase may fail without being «seen» by the relay. Switching therefore will not take place, and power supply to the loads remains defective.
This system is satisfactory only if the three-phase power supply is unable to operate for any length of time with two phases only. This calls for the use of protective devices such as three-pole circuit-breakers or fuses with striking-pin delivering a multi-pole breaking order. Otherwise, to prevent this problem, either two relays connected between different phases or three relays in a delta connection must be fitted.

□ three single-phase relays

The above connection (three relays in a delta connection) may however prove tricky when relay thresholds are set between 20 and 30 % of rated voltage. In point of fact, if only one phase fails, the two relays with a terminal connected to this phase are then series-connected and are supplied by the two remaining sound phases. The voltage at the terminals of these two relays equals half their rated voltage, a voltage greater than the setting value (0.2 Un). No switching order is then sent. For this reason it is preferable to use three star-connected relays or three delta-connected relays which are set to 60 % of Un or, better still, a rotating field three-phase voltage relay.

□ a single three-phase voltage relay

This type of relay does not allow detection of supply phase failure at busbar level if the consumer network contains asynchronous three-phase motors, since these motors sustain the voltage of the broken phase at busbar level. A three-phase rotating field overcurrent relay must then be connected to the main incomer.

■ detector mounting

Instantaneous electromagnetic relays are vulnerable to impacts which cause their contacts to bounce and to send false switching orders. This is particularly true when relays are mounted on doors; particular care must thus be taken with this type of mounting to avoid all vibrations likely to interfere with equipment operation.

voltage loss during non-synchronous switching

Such voltage loss, although temporary, is normally quite sufficient to de-energise all the contactors whose coils are supplied by the power circuit. Automatic transfer systems may lose their efficiency to a large extent since the loads controlled by these contactors, now open, cease to be supplied. However, manual staggered resumption of motor operation is possible using the «on» push buttons.
In preference to manual resumption, contactor coils can be supplied by a reliable auxiliary source (battery or rotating set with an inertia flywheel), or a slow release relay can be used.
Another possibility is a capacitor connected in parallel with the coil and charged by the power supply via a rectifier. In this case, the energy required to keep the contactor in the closed position is provided by the capacitor for the brief instant of voltage loss. However, to avoid stretching the capacity of the «buffer» capacitor, the undervoltage time must be relatively short (a few hundred milliseconds) and coil consumption low.
Note that if these solutions are to be implemented, the replacement source must be able to take up all the loads and particularly all the motors in the reacceleration.

Note:
When a coil control circuit opens, the high voltages induced at the coil terminals must be withstood by the rectifier and the capacitor.

mechanical interlocking of switching devices in LV and HV

With the exception of synchronous switching devices for which the two switching elements (main and replacement source) may be simultaneously closed, mechanical interlocking of the devices and electrical interlocking preventing simultaneous supply of the two devices control circuits are recommended in all installations and are normally a standard requirement of electricity boards.

dielectric withstand of switching devices in HV

The dielectric withstand of the switching device of the replacement source used in such synchronous and pseudo-synchronous switching systems must be particularly appropriate. In point of fact, during coupling conditions, the poles of these devices may be submitted, between input and output, to twice the phase-to-neutral voltage of the network (voltage of the two sources to be coupled in opposition of phases).

3. synchronous switching

Both the main source and the replacement source can be synchronized, namely:

■ their voltage vectors are in phase;

■ and their frequency and amplitudes are identical.

The possibilities offered by this switching type are numerous in that source changeover takes place **before voltage loss** of the source in operation; a major advantage is that loads experience no loss of power supply.

The following examples illustrate this type of transfer.

example n° 1 (see fig. 1)

Operating an EHV/HV interconnection substation with double busbar.

The 2 busbars are supplied by the EHV transmission lines of the interconnection network, the coupling circuit-breaker is open and the two busbars are synchronized. The line and transformer feeders are connected to either busbar **A** or **B**. To change the supply of a feeder (changing the busbar), assuming that it is currently supplied from **A**, simply:

■ close the bus coupling circuit-breaker 1 without checking coupling conditions as both busbars are synchronized;

■ close the second disconnecting switch 2b for the feeder in question;

■ open the first disconnecting switch 2a ;

■ open the bus coupling circuit-breaker 1 .

The feeder is then supplied by the other busbar **B.**

Note:

Throughout switching all incomers are connected in parallel on the two coupled busbars; short-circuit power is then high, and the equipment's electrical characteristics must be sufficient for this mode of operation if the likelihood of a fault occurring during the transfer is not negligible.

example n° 2

Substitution of a generator in operation by a standby device in a self-powered electricity producing plant consisting of generator sets.

These generator sets require frequent periodical servicing; the plant is run with n - 1 sets, the nth being either on standby or undergoing servicing.

A set in operation is replaced by the standby set as follows: the generator of the standby set is brought up to synchronous speed and to rated voltage; the circuit-breaker's energising order is sent once coupling conditions have been checked (frequency is equal, voltages have same magnitude and are in phase).

In order to obtain such conditions for coupling and to maintain them after coupling, the generator and the thermal motor are equipped with a voltage and speed regulator, respectively.

The coupling conditions are obtained:

■ either by intervention of an operator giving, according to readings on the differential voltmeter and frequency meter and on the synchroscope, the ± speed orders to the speed regulator, the ± excitation orders to the voltage regulator and the energising order to the circuit-breaker when coupling conditions are met.

In this case a controller, known as a coupler, can be used. This device is designed to check coupling conditions and to give the energising order; regulators are always ajusted manually.

■ or using a synchrocoupler which is a special controller associated with a voltage regulator. It sends the ± speed orders to the motor and the energising order to the generator circuit-breaker.

The regulator sends the ± excitation orders to the generator.

Coupling is then fully automatic.

After coupling, the set to be placed out of operation is discharged (using the speed regulator) and disconnected from the network by opening its coupling circuit-breaker. Substitution is thus completed without disturbing the distribution network and without voltage loss.

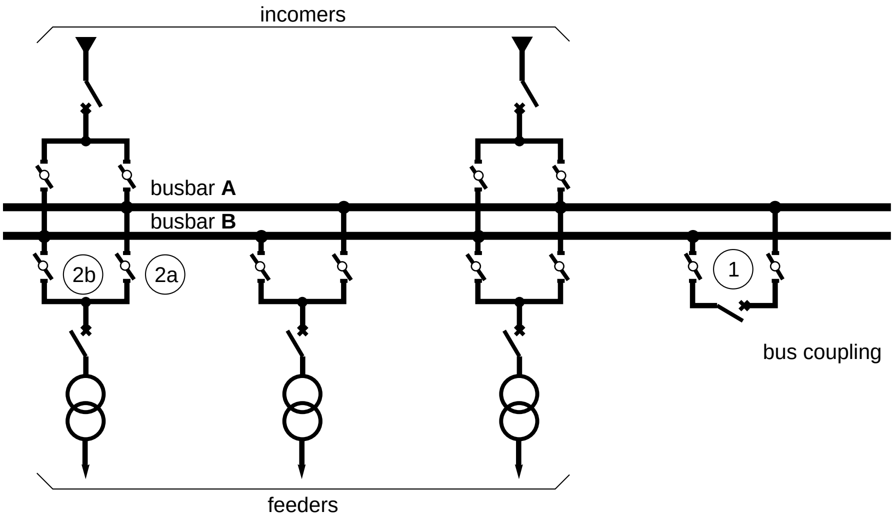


fig. 1: diagram showing an EHV/HV interconnection substation with double busbar.

example n° 3 (see fig. 2)

Automatic no break transfer without breaking of an UPS (Uninterruptible Power Supply) on the public network (or mains) using an SS (Static Switch).

This requirement is a common one: supply of computers, computer management centres, measurement, process control, etc.

The SS is a device enabling the mains to be used to back up the UPS. It stands out by the fact that no voltage loss, even transient, occurs on disappearance (accidental or deliberate) of UPS voltage.
To obtain this result, the UPS permanently ensures its voltage is in phase with the mains voltage.
However, switching is only possible if the mains voltage level is correct.

The operating sequences are as follows:
■ the UPS, its voltage regulated, its frequency controlled and in phase with the mains, supplies the load. The SS is open and the mains delivers no power;
■ the UPS-mains changeover takes place:
□ on an UPS shutdown:
- either due to an internal fault,
- or operator-initiated,
□ on detection of an overload.
The switching order always instantaneously closes the static switch. In the case of overload, the two sources run for a short instant in parallel before the UPS is disconnected.
■ the mains-UPS changeover is operator-initiated.

Following UPS startup, the automatic cycle is as follows:
□ the UPS is synchronised with the mains,
□ the mains and the UPS are connected in parallel,
□ the static switch opens,
□ the UPS is then permanently synchronised on the mains and alone supplies the load.

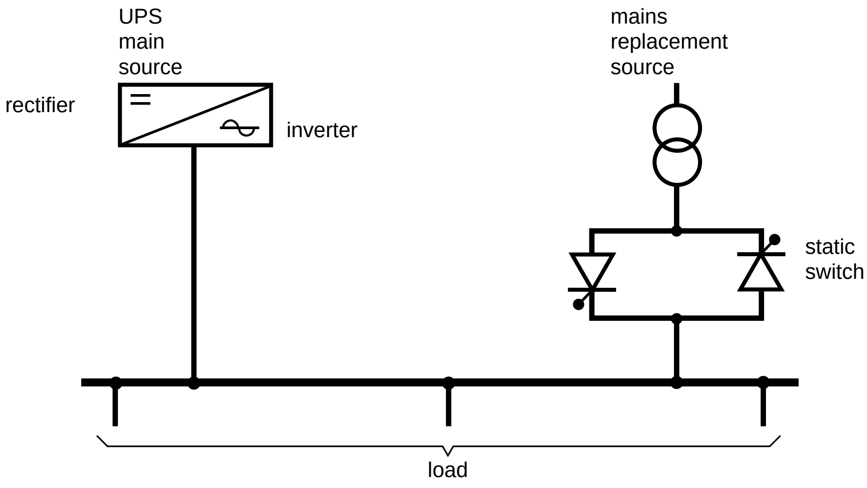


fig. 2: diagram showing a circuit supplied by two sources with automatic no break switching using a static switch.

Importance of the static switch

The ac SS ensures:
■ permanent supply of the load, comparable in terms of reliability to the solution with two parallel-connected UPS, one backing up the other, but at lesser cost;
■ in the event of overload, an ultra-rapid device controls the static switch connecting the mains in parallel to the UPS.
The mains's short-circuit power can thus be profitably used to eliminate the «downstream» faults without taking any special precautions other than standard discrimination rules.

4. interrupted circuit transfer

This type of source switching is the most common, in LV and HV alike, with an area of application extending from industry to the service sector. Switching times normally vary from 0.5 to 30 seconds, while not ruling out lower values for special cases.

in low voltage

Devices must be extremely simple as the electricians operating the LV networks are normally not specialists.

Switchgear

The type of switching device chosen depends on switching frequency:

■ large number of switchings: contactor;

■ small number of switchings (one a week): circuit-breaker.

Control circuit

The control circuits of switching devices are supplied either by a backed-up auxiliary source (e.g. battery) or directly by the power circuit of the device to be controlled.

Power supply

The main supply source is normally the Low Voltage public distribution network (or mains) or a private Low Voltage network from an HV/LV transformer supplied on the HV side by the public distribution network.

The replacement source may be:

■ a second LV network separate from the first;

■ a no-break generator set for rapid resumption of operation;

■ a generator set with manual or automatic startup on undervoltage at the main source;

■ an UPS;

■ etc.

These various replacement sources, in most cases far less powerful than the main source, have a limited backup time. When the backed-up network is supplied by the replacement source, it is thus often wise and sometimes even vital to shed some loads and to restart only ultra-priority motors (see chapter 2).

example

Diagram

The most common diagram for Low Voltage source switching with automatic load shedding is presented in figure 3.

Operating principle

Neither source can be coupled, and circuit-breakers Jn and Jr are mechanically locked: their electrical control mechanism is interlocked in such a manner that a closing order sent simultaneously to both circuit-breakers will only close one of them.

A three-position selector controls the device:

position 1 = off,

position 2 = automatic,

position 3 = voluntary closing of the replacement source circuit breaker and tripping of the coupling circuit-breaker.

■ position 1 = off

All the control circuits are de-energised and all the circuit-breakers are open.

■ position 2 = automatic

□ main network voltage is present, and the corresponding circuit-breaker and coupling circuit-breaker are closed,

□ for a voltage loss exceeding 0.4 second (up to 10 s), the switching controller sends tripping orders to the main and coupling circuit-breakers, and a starting order to the generator set,

□ on receipt of the message «gen set voltage OK», the controller sends an energising order to the circuit-breaker of the replacement source;

□ on resumption of main voltage, and after a time delay of 10 to 180 seconds:

- circuit-breaker Jr opens,
- circuit-breaker Jn closes,
- the set receives a stopping order,
- circuit-breaker Jc closes;

■ position 3 = voluntary energising

This allows voluntary tripping of the coupling circuit-breaker, with the backed-up network supplied by the replacement source.

A special case: reacceleration of LV motors

A controller for restarting motors should be provided when the backed-up network supplies a large proportion of motors which must be reaccelerated as quickly as possible after loss of the main supply. This common need is particularly required by the process and safety of persons and property. In actual fact, on loss of the main source, if no special measures have been taken, all contactors will open. When the supply is resumed, none of the contactor-controlled loads are supplied. On the other hand, if the motors are

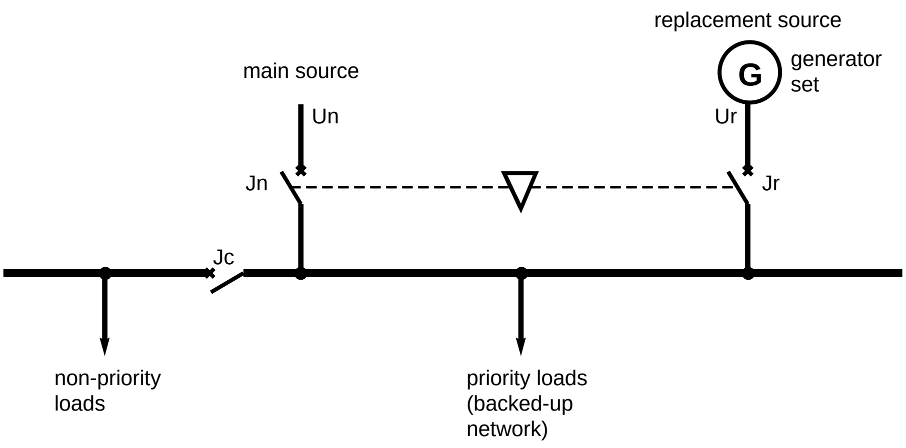


fig. 3: diagram for low voltage source switching with automatic load shedding.

protected and controlled by circuit-breakers, they will simultaneously restart when voltage is restored. If the contactor coils of the motor feeders are supplied by the ac network, use of slow release relays (see chapter 1) also enables their operating order to be maintained during voltage loss.

Residual voltages of asynchronous motors during deceleration normally present no risk on resumption of power supply, since at that moment (t = + 500 ms), the amplitude of these voltages is less than 20 % of Un, a value tolerated by manufacturers for resumption of supply in phase opposition. However the main (overcurrent) protection device of the distribution network may be tripped by the sum of the motor restarting currents.

in high voltage

Source switching taking place at high voltage involves very high powers and, as such, must offer still greater guarantees as to the overall operational dependability of the device.

HV switching is particularly used when there is a large number of priority loads or when these loads are not supplied by a distribution sub-switchboard.

The switching device control orders are prepared by standard electronic controllers.

The two examples given below illustrate this switching type.

example n° 1

«Main-Emergency» device

These devices have one switching device per incomer and an RCV420 type controller (see fig. 4)

Principle

The controller manages the operations. Its function is to detect voltage loss on the main source and to automatically control switching of the load to a replacement source when the following two conditions have been met:

■ voltage is present on the replacement source; and

■ there are no faults in the installation.

Operation

The controller has two high impedance inputs: a «Main» input, connected to a capacitive divider connected between one of the main network's phases and the earth, and an «Emergency» input connected in like manner to one of the phases of the replacement or emergency network.

Voltage loss on the «Main» input controls a time delay relay ,
t_1 (0.1 s to 1 s) which, at the end of the cycle, sends a temporary opening order to the main network switching device and a temporary closing order to the replacement (emergency) source switching device.
If voltage is lost on the replacement (emergency) source, the t_1 time delay relay is locked by the «Emergency» input and switching cannot take place.

Note that the RCV420 controller has a second «Emergency» input in the form of a loop in which the contact of an external voltage relay can be inserted to prevent switching when it is open.
If voltage is restored on the «Main» network, a second time delay relay,
t_2 (10 to 100 s) is energized and, at the end of the cycle, sends a temporary opening order to the «Emergency» network switching device and a temporary closing order to the «Main» network switching device.

Faults in the installation must be detected by an external device fitted with a closing contact which prevents switching using the «fault» input of the controller.

example n° 2

«Dual incomer» device

This device is extremely popular in France for the dual incomer supply of HV/LV transformer substations directly connected to the HV public distribution network. It consists of:

■ one switching device per incomer (HV switch);

■ one electronic controller of the RVH type (see fig. 5).

Principle

A dual incomer assembly (see fig. 6) can be supplied by either incomer as the system is completely reversible.

Detection of voltage presence or loss is identical to the «Main-Emergency» device.

Detection of phase-earth or phase-to-phase faults on the load network is performed by the controller informed by toroids current transformers (three toroids per incomer).

In normal operation, switching is dependent on certain electrical conditions and is performed after certain manual or automatic operations described below:

■ manual switching

The operator manually opens switch **A** then closes switch **B**, having first checked that the following conditions are met:

□ no voltage on circuit **A**,

□ voltage present on circuit **B**,

□ no faults in the substation (downstream network).

The conditions for resumption of the main supply are:

□ checking there are no faults in the substation,

□ manual opening of switch **B**,

□ manual closing of switch **A**.

■ automatic switching

The controller opens switch **A**, then closes switch **B** if the following conditions are met:

□ no voltage on circuit **A,**

□ voltage present on circuit **B**,

□ no faults in the substation,

□ presence of this information for 5 or 30 consecutive seconds. The main purpose of these 30 seconds is to wait for the end of the cycles of the automatic reclosers used on overhead networks.

Restoration of voltage on circuit **A** does not automatically cause switching from circuit **B** to **A**, although manual tripping by the operator is possible.

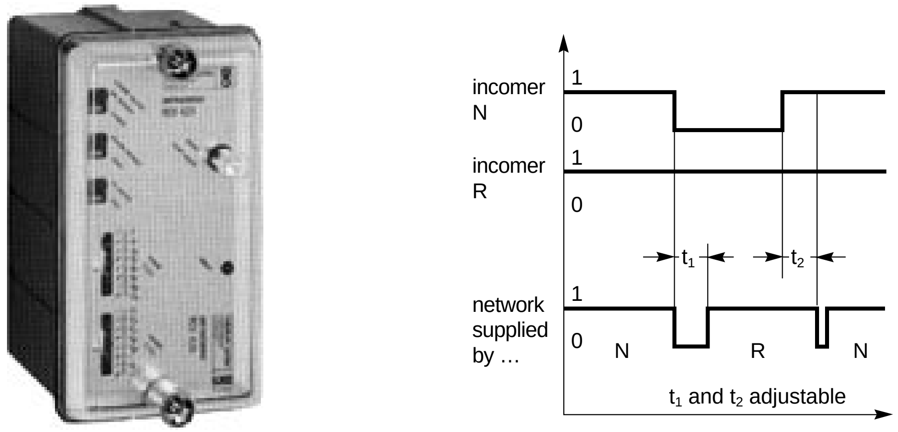


fig. 4: «Main-Emergency» RCV420 controller and its operating sequence (Merlin Gerin).

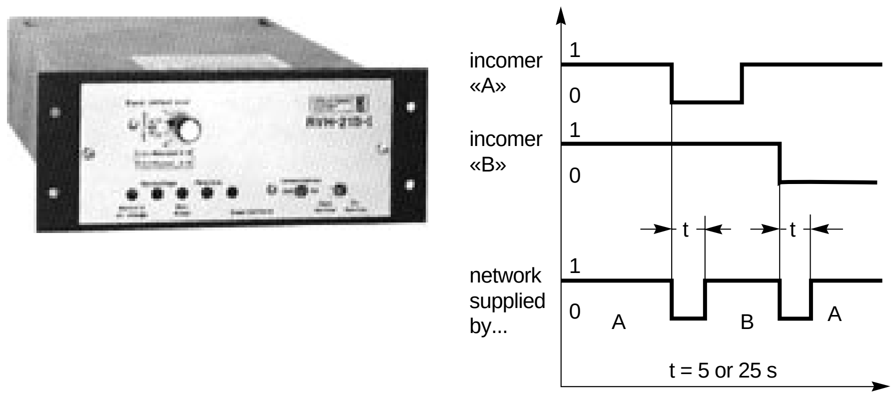
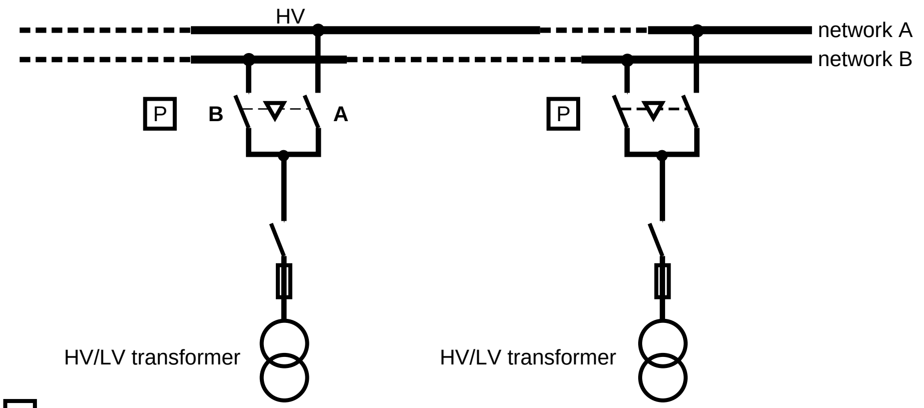


fig. 5: «Dual incomer» RVH215 controller and its operating sequence (Merlin Gerin).



P = changeover switch

fig. 6: diagram showing dual incomer distribution.

5. pseudo-synchronous switching

principle

This type of source switching lasts roughly 150 ms.

The most common diagram is shown in figure 7.

In normal operation, the two half-busbars are supplied by the two incomers respectively: the tie circuit-breaker is open.

Failure of either source triggers startup of the rapid switching device which, in under conditions, sends two orders:

■ a closing order to the tie circuit-breaker;

■ an opening order to the circuit-breaker of the faulty source.

The half busbar of the faulty source is thus re-energised.

area of application

The standard case is that of an installation connected to two HV sources and mainly consisting of asynchronous motors. The operating imperatives of the machines driven by the motors mean the latter cannot afford to stop, even temporarily, or slow down during transfer from the main to the replacement source.

This switching type is especially popular in chemical and oil plants and, more generally, in industries whose manufacturing processes brook no interruption, even temporary, of an element in the line. It is also used to supply thermal power plant auxiliaries.

difficulties

The main problem of this switching type is that a three-phase asynchronous motor sustains at its terminals, during deceleration on loss of power, a three-phase ac voltage with decreasing frequency and amplitude induced by the motor's residual flux.

The maximum amplitude of this residual voltage decreases exponentially as a function of time, with a time constant depending on:

■ motor power;

■ operating state of the stator connections:

□ open stator, case of a three-phase supply failure,

□ short-circuited stator, case of a three-phase fault on the supply.

On the other hand, the rated supply voltage of the motor only slightly modifies the value of the time constant.

The table in figure 8 provides the approximate values of the time constants for extinguishing the residual flow for medium cage asynchronous motors.

If no special precautions are taken, rapid resumption of motor power supply during deceleration may lead to coupling in phase opposition between the replacement source and the load network whose voltage is maintained by the asynchronous motors.

Only high voltage epoxy resin insulated motors can support resumption of supply in phase opposition. Note, however, that in this case the peak current equals roughly 3 times motor starting current, i.e. 15 to 20 In, with the result that the entire distribution network is seriously disturbed:

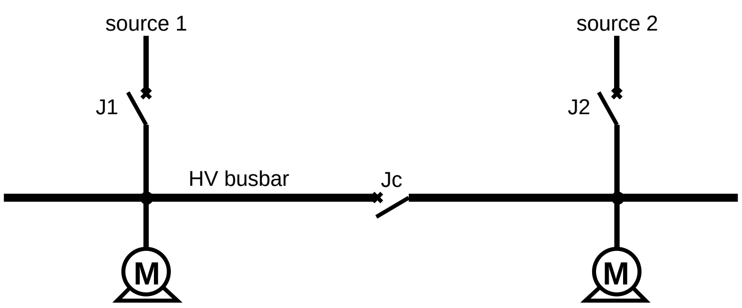
■ voltage drop and large, repetitive electrodynamic forces;

■ nuisance tripping of circuit-breakers by full short-circuit protection;

■ etc.

For these reasons, ultra-rapid resumption of motor supply should not be done without a prior comparison of the phases of the source voltage with residual voltage. Using a voltage phase shift comparison device, however, allows ultra-rapid switching.

A brief description of a phase comparator is given in the appendix.



M: asynchronous motors

fig. 7: diagram usually applied for pseudo-synchronous switching.

motor power	10 kW	100 kW	200 kW	400 kW	800 kW
time constant, short-circuited stator	0.02 s	0.03 s	0.04 s	0.06 s	0.1 s
time constant open stator	0.3 s	0.4 s	0.6 s	1.1 s	1.5 s

fig. 8: time constants for extinguishing residual flux for medium cage asynchronous motors.

ultra-rapid switching with phase shift monitoring

The ultra-rapid switching operations, which are possible, are shown in the three diagrams in figure 9.

Sequence A:

The switching order trips separator circuit-breaker J1 or J2; after opening, the phase comparator is put into operation and, when switching conditions are favourable, sends an energising order to the tie circuit-breaker Jc.

Sequence B:

The switching order trips separator circuit-breaker J1 or J2 and energizes the phase comparator. When switching conditions are favourable, the phase comparator sends an energising order to the tie circuit-breaker Jc.

Sequence C:

The switching order energizes the phase comparator. When switching conditions are favourable, the comparator simultaneously sends an energising order to the tie circuit-breaker Jc and a tripping order to separator circuit-breaker J1 or J2.

Note:

a) sequence C is the one normally chosen as switching times are shortest.

b) certain problems may arise when preparing the switching order, such as:

- detection of real loss of main supply voltage in presence of residual voltage;
- relay speed;
- etc.

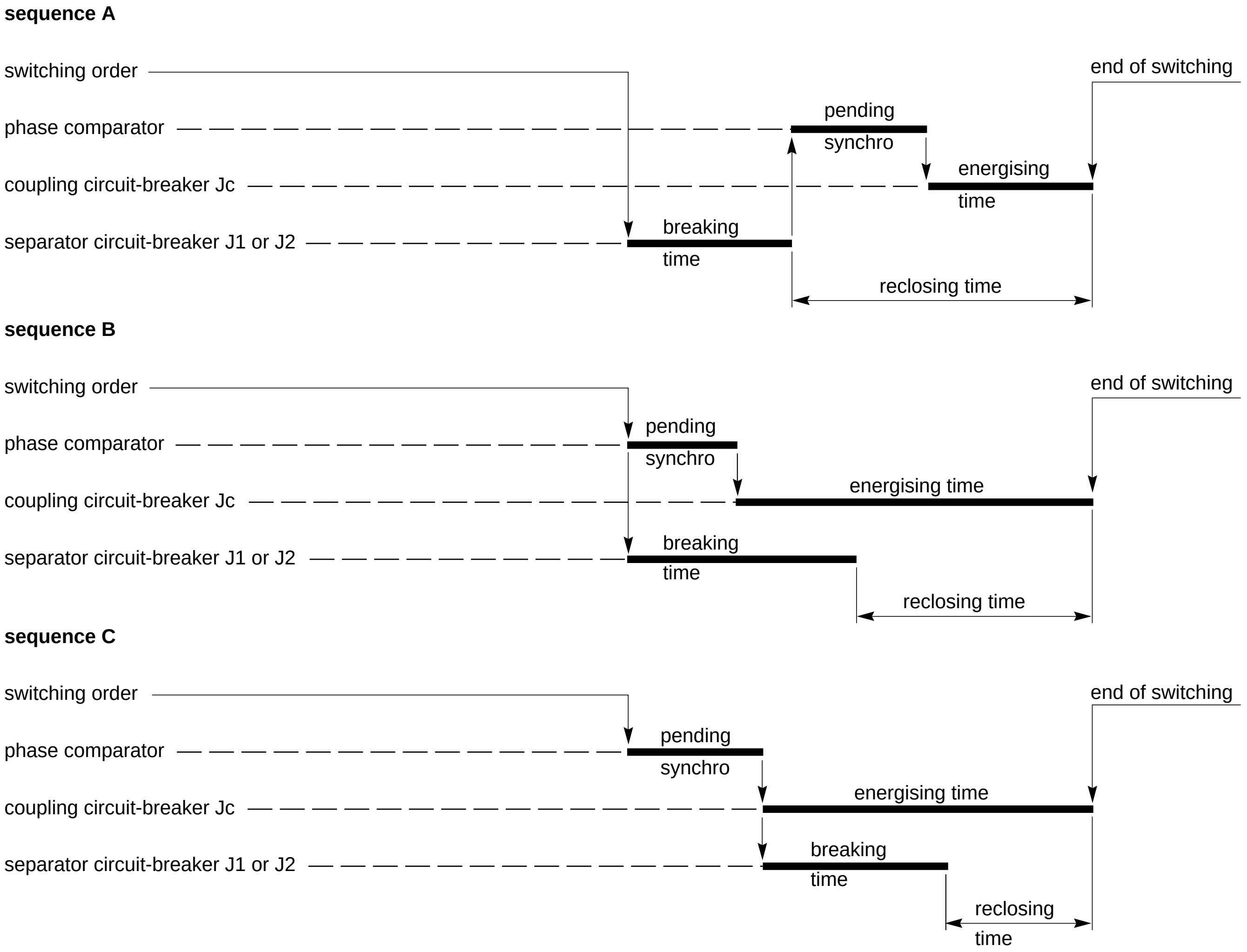


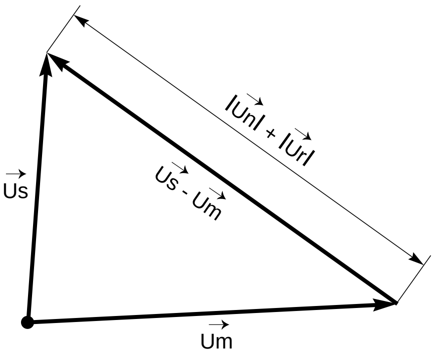
fig. 9: possible ultra-rapid switching operations.

Conditions be met by the network for rapid coupling

The first condition to be met when coupling actually takes place is expressed by the inequation:

$|\vec{Us} - \vec{Um}| < |\vec{Un}| + |\vec{Ur}|$

(see fig. 10)



$\vec{Us}$ = voltage of source resupplying motors (replacement source).

$\vec{Um}$ = voltage at motor terminals after separation of their first source (residual voltage).

$\vec{Un}$ = rated voltage of motor.

$\vec{Ur}$ = acceptable residual voltage of motor.

$|\vec{\mathbf{Us}} - \vec{\mathbf{Um}}| < |\vec{\mathbf{Un}}| + |\vec{\mathbf{Ur}}|$

fig. 10: electrical variables and inequation conditioning success of rapid coupling.

As a rule motors can support a coupling in phase opposition, after separation of their first source, provided that residual voltage at their terminals does not exceed the value Ur equal to 25 % Un.

This initial condition, although necessary, is not sufficient to ensure successful reacceleration of motors. In point of fact, despite monitored coupling meeting this inequation, the speed of all motors is less than their rated speed, meaning motors absorb a current exceeding their rated current.

To increase chances for successful resumption of motor supply on rapid switching, the following conditions are thus required:

■ the speed reached by motors, on resumption of supply, must be as high as possible. Speed depends on:

□ length of undervoltage time,

□ inertia of rotating masses,

□ load torque during deceleration;

■ the supply network voltage drop must be slight. This drop depends on:

□ impedance of the electrical circuits,

□ the current absorbed by the motors,

□ the number of motors reaccelerated;

■ the value of the driving torque during resumption must be (far) greater than load torque.

Driving torque depends on:

□ rated value of driving torque on full voltage,

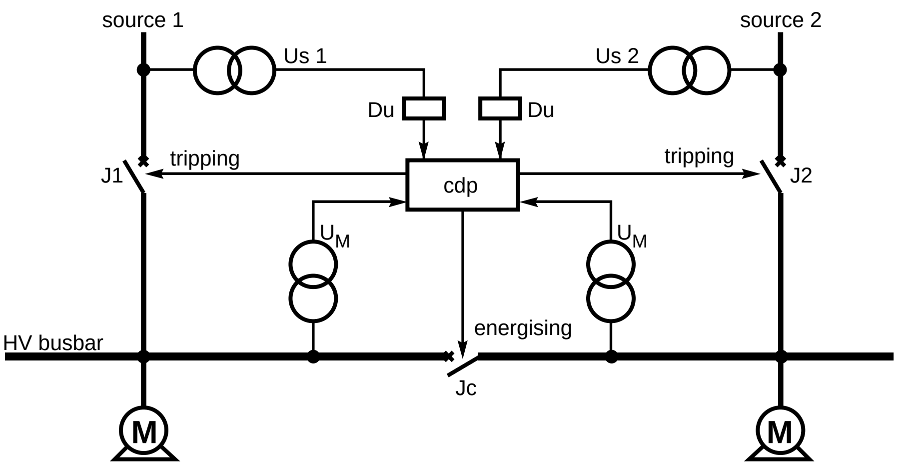
□ the form of torque in the speed range between speed at which resumption takes place and rated speed,

□ the voltage applied at the motor terminals.

Note that if motor slip is considerable on resumption of power supply, throughout the restart period, the current absorbed by the motors is constant and approaches, in an initial approximation, starting current (the curve of current absorbed by an asynchronous motor as a function of rotation speed, is relatively flat).

Diagram showing the rapid switching device

(see fig. 11)



Du: undervoltage detector

cdp: phase comparator

M: asynchronous motors

fig. 11: diagram showing the rapid switching device to supply to MV networks.

6. summarising table

	switching type			
	synchronous	**interrupted circuit transfer**		**pseudo-synchronous**
		LV	**HV**	
application examples	- busbar switching, - substitution of one generator by another, - switching an UPS to the mains	from industry to service sector: - supply of pumps, - supply of auxiliary circuits of a transformer substation, - supply of hypermarkets, - etc	- supply with 2 switchable HV incomers, - supply by one main source and one replacement source	reacceleration of asynchronous motors
switching time	zero	0.5 to 10 s	1 to 30 s	0.06 to 0.3 s
devices used (examples of Merlin Gerin equipment)	- coupler, - synchrocoupler, - UPS unit with static switch (EPS 2000 and 5000)	- automatic source changeover switch with circuit-breaker (Compact and Masterpact)	- cubicle assembly with changeover switch (VM6, DDM and NSM)	rapid HV circuit-breaker associated with a phase comparator
observations	switching must take place before main source voltage is completely lost			difficulties in preparing switching orders (presence of residual voltage)

7. conclusion

This description of operating conditions to be met and technical requirements to be considered leads us to the following practical conclusion.

Before choosing a switching device, it is preferable and indeed vital to know:

■ the quality of the main and replacement sources:

□ amplitude, duration and frequency of voltage drops,

□ duration and frequency of voltage loss (whether or not service resumption controllers are present upstream, e.g. rapid or slow reclosers),

□ available power;

■ load requirements as regards continuity of supply:

□ no supply failure tolerated,

□ voltage loss tolerated (0.3 s, 1 s, 30 s, etc).

appendix: brief description of a phase comparator

The phase shift of the two sources is measured by subtracting the two voltage vectors, Us and Um, i.e.:

$\vec{Us} - \vec{Um} = \vec{U}$

Where

$\vec{Us} = Us \sin\omega_1 t$

(replacement source voltage)

$\vec{Um} = Um \sin\omega_2 t$

(residual voltage)

Note: the writing

$|Us| = |Um| = |Ua|$

simplifies calculations

Using the trigonometric formula

$$\sin\alpha - \sin\beta = 2\cos\frac{\alpha+\beta}{2}\sin\frac{\alpha-\beta}{2}$$

the following can be written:

$$\vec{Us} - \vec{Um}$$

$$= 2\,Ua\cos\frac{\omega_1+\omega_2}{2}t\,\sin\frac{\omega_1-\omega_2}{2}t = \vec{U}$$

The pulsation voltage envelope

$\frac{\omega_1+\omega_2}{2}$ has a pulsation beat

$\frac{\omega_1+\omega_2}{2}$ expressing phase shift evolution in time between $\vec{Us}$ and $\vec{Um}$ (see fig. 12).

The voltage $\vec{Us} - \vec{Um}$ is rectified and filtered. The instantaneous values of the envelope curve voltage, or beating voltage, thus obtained are used to determine phase shift between the two sinusoidal voltages to be compared: there is a zero phase shift for the minimum instantaneous value.

When the envelope curve voltage drops below a set threshold, the comparator sends a switching order until the envelope curve voltage once again exceeds the threshold value.

If there is a great difference between the two frequencies, the comparator prevents switching since, in this case, the conditions for ultra-rapid switching are not favourable.

However, if residual voltage is less than a preset value (e.g. 0.20 to 0.60 Un), switching takes place despite a large difference in frequency.

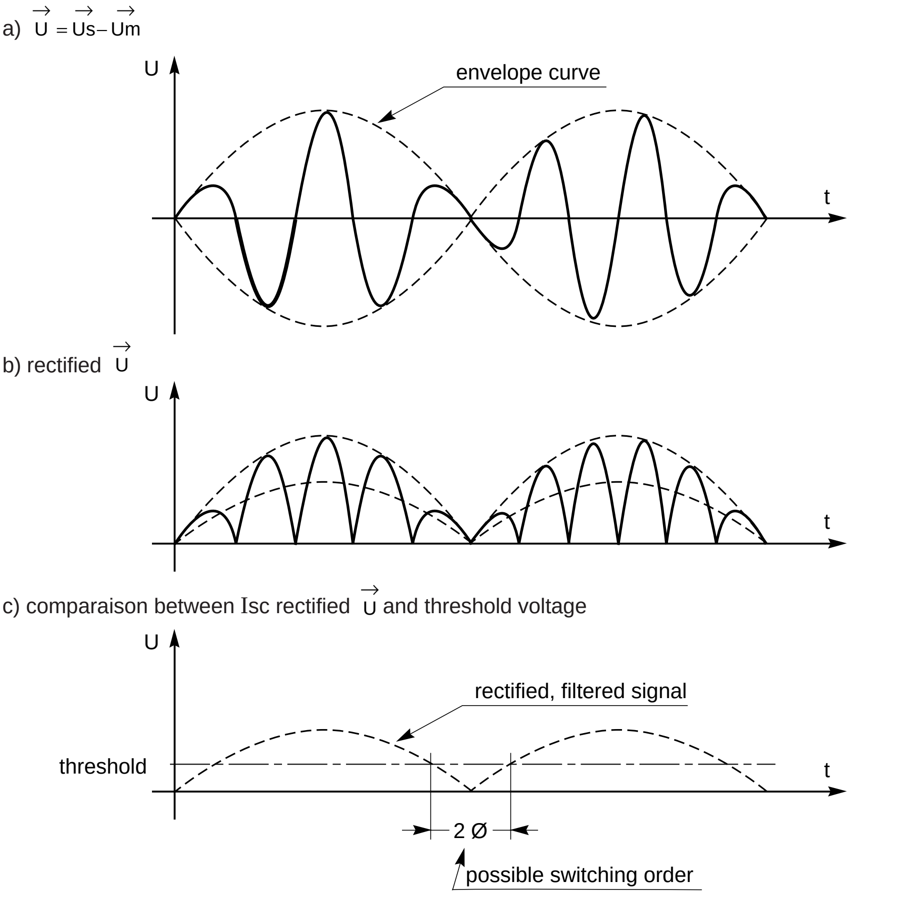


fig. 12: phase comparator analysis between two voltages: $\vec{Us}$ and $\vec{Um}$.

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