1. Network structures

1. NETWORK CONFIGURATIONS

■ definition

Standard IEC 38 defines voltage ratings as follows:

- Low voltage (LV)

For a phase-to-phase voltage between 100 V and 1000 V. The standard ratings are: 400 V - 690 V - 1000 V (at 50 Hz)

- Medium voltage (MV)

For a phase-to-phase voltage between 1000 V and 35 kV. The standard ratings are: 3.3 kV - 6.6 kV - 11 kV - 22 kV - 33 kV

- High voltage (HV)

For a phase-to-phase voltage between 35 kV and 230 kV. The standard ratings are: 45 kV - 66 kV - 110 kV - 132 kV - 150 kV - 220 kV.

In this chapter we shall look at:

- different supply voltage ratings
- types of HV and MV consumer substations
- structure of MV networks inside a site
- structure of LV networks inside a site
- structure of systems with a back-up power supply

Six standard examples of industrial network structures are given at the end of the chapter.

Each structure is commented and divided up so that each functional aspect can be studied.

1.1. General structure of the private distribution network

Generally, with an HV power supply, a private distribution network comprises (see fig. 1-1):

- an HV consumer substation fed by one or more sources and made up of one or more busbars and circuit-breakers
- an internal production source
- one or more HV/MV transformers
- a main MV switchboard made up of one or more busbars
- an internal MV network feeding secondary switchboards or MV/LV substations
- MV loads
- MV/LV transformers
- low voltage switchboards and networks
- low voltage loads.

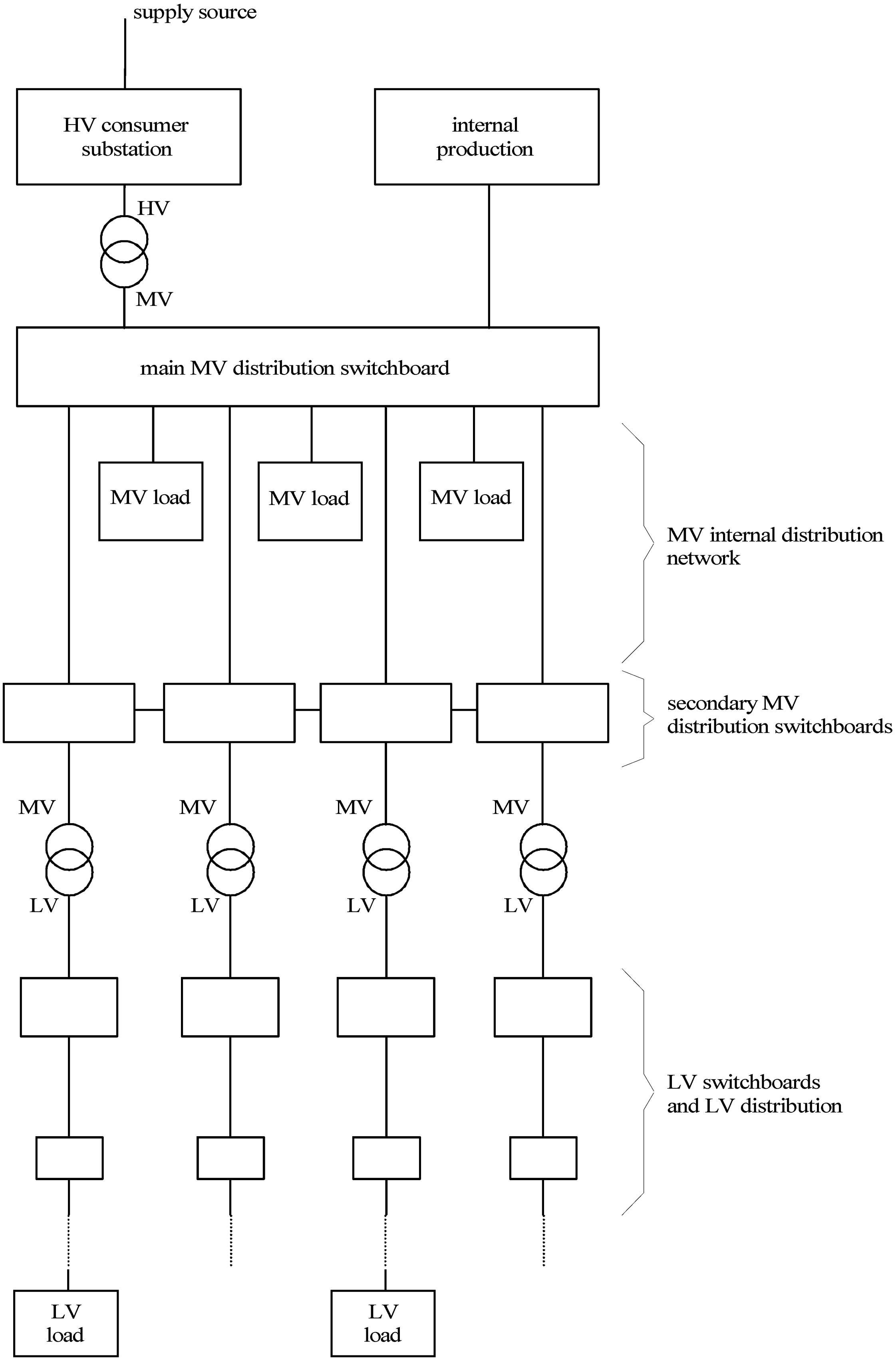


Figure 1-1: general structure of a private distribution network

1.2. The supply source

The power supply of industrial networks can be in LV, MV or HV. The voltage rating of the supply source depends on the consumer supply power. The greater the power, the higher the voltage must be.

1.3. HV consumer substations

The most usual supply arrangements adopted in HV consumer substations are:

- **single power supply** (see fig. 1-2)

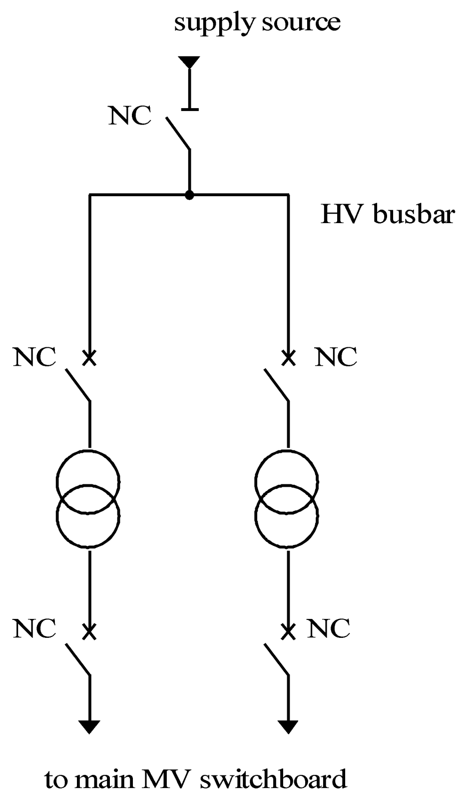


Figure 1-2: single fed HV consumer substation

advantage: Reduced cost
drawback: Low reliability

N.B.: the isolators associated with the HV circuit-breakers have not been shown.

■ **dual power supply** (see fig. 1-3)

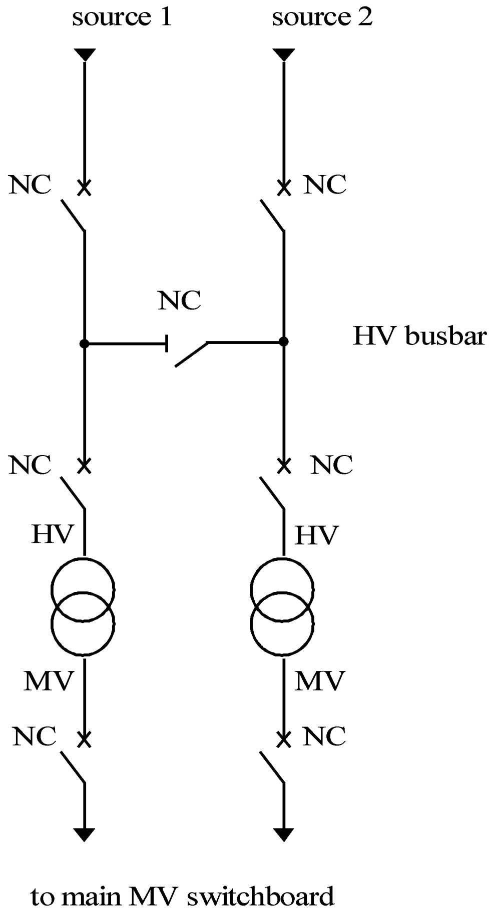


Figure 1-3: dual fed HV consumer substation

operating mode:

- normal: Both incoming circuit-breakers are closed, as well as the coupler isolator. The transformers are thus simultaneously fed by 2 sources.

- disturbed: If one source is lost, the other provides the total power supply.

advantages:
- very reliable in that each source has a total network capacity
- maintenance of the busbar possible while it is still partially operating

drawbacks:
- more costly solution
- only allows partial operation of the busbar if maintenance is being carried out on it

N.B.: the isolators associated with the HV circuit-breakers have not been shown.

■ **dual fed double bus system** (see fig. 1-4)

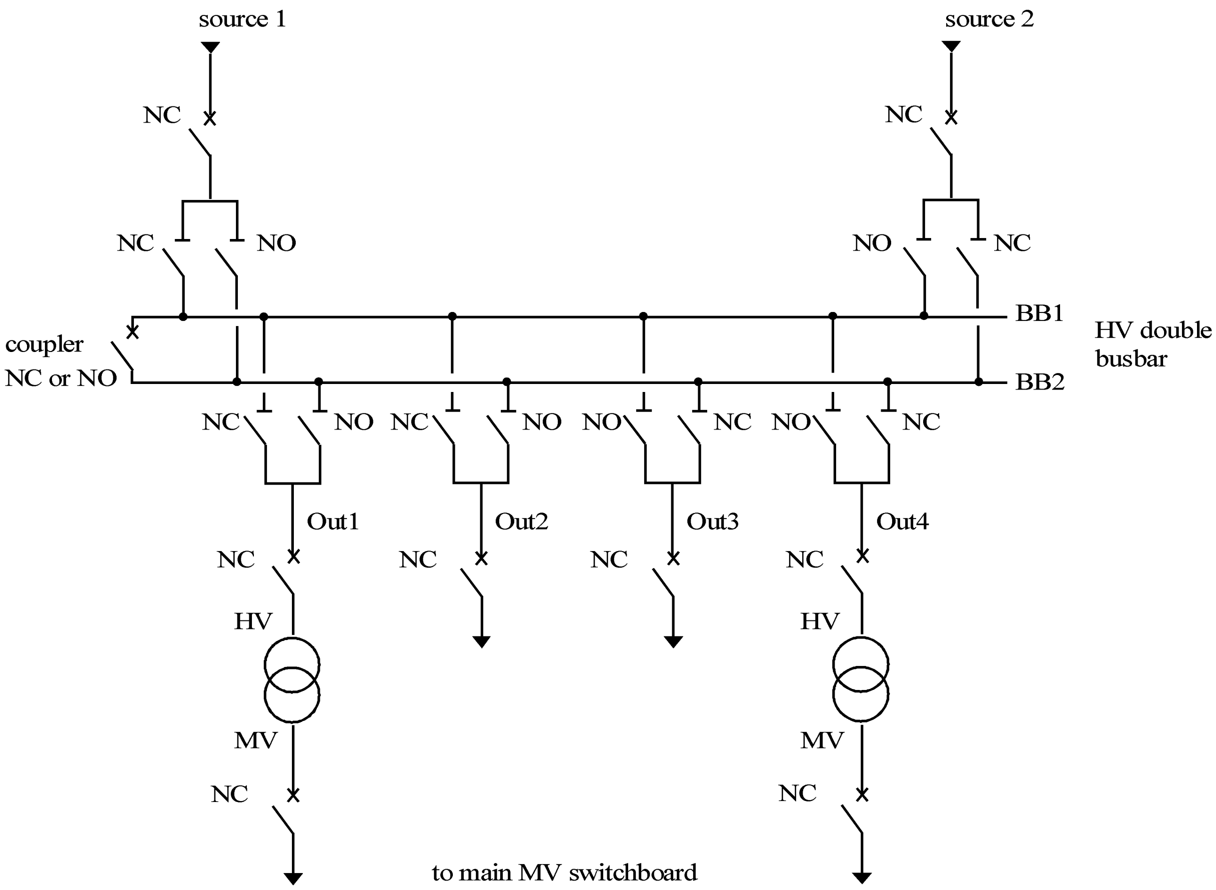


Figure 1-4: dual fed double bus HV consumer substation

operating mode:

- normal: Source 1 feeds busbar BB1 and feeders Out1 and Out2.
  Source 2 feeds busbar BB2 and feeders Out3 and Out4.
  The bus coupler circuit-breaker can be kept closed or open.

- disturbed: If one source is lost the other provides the total power supply.
  If a fault occurs on a busbar (or maintenance is carried out on it), the bus coupler circuit-breaker is tripped and the other busbar feeds all the outgoing lines.

advantages :
- reliable power supply
- highly flexible use for the attribution of sources and loads and for busbar maintenance
- busbar transfer possible without interruption

drawback:
- more costly in relation to the single busbar system

N.B.: the isolators associated with the HV circuit-breakers have not been shown.

1.4. MV power supply

We shall first look at the different MV service connections and then the MV consumer substation.

1.4.1. Different MV service connections

According to the type of MV network, the following supply arrangements are commonly adopted.

- **single line service** (see fig. 1-5)

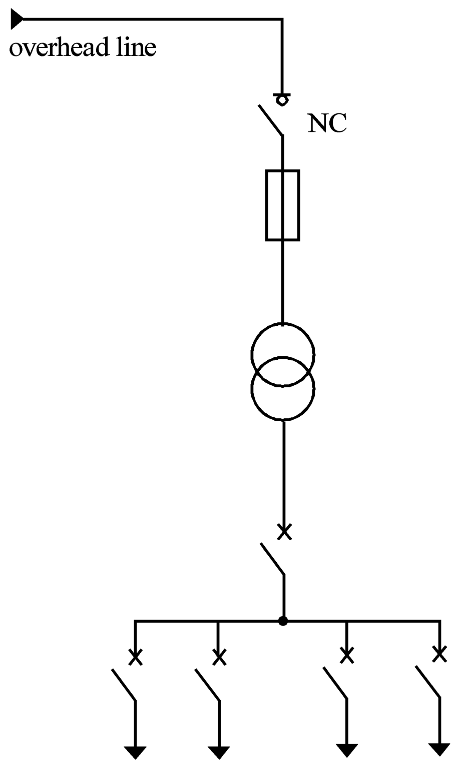


Figure 1-5: single line service

The substation is fed by a single circuit tee-off from an MV distribution (cable or line). Up to transformer ratings of 160 kVA this type of MV service is very common in rural areas. It has one supply source via the utility.

■ **ring main principle** (see fig. 1-6)

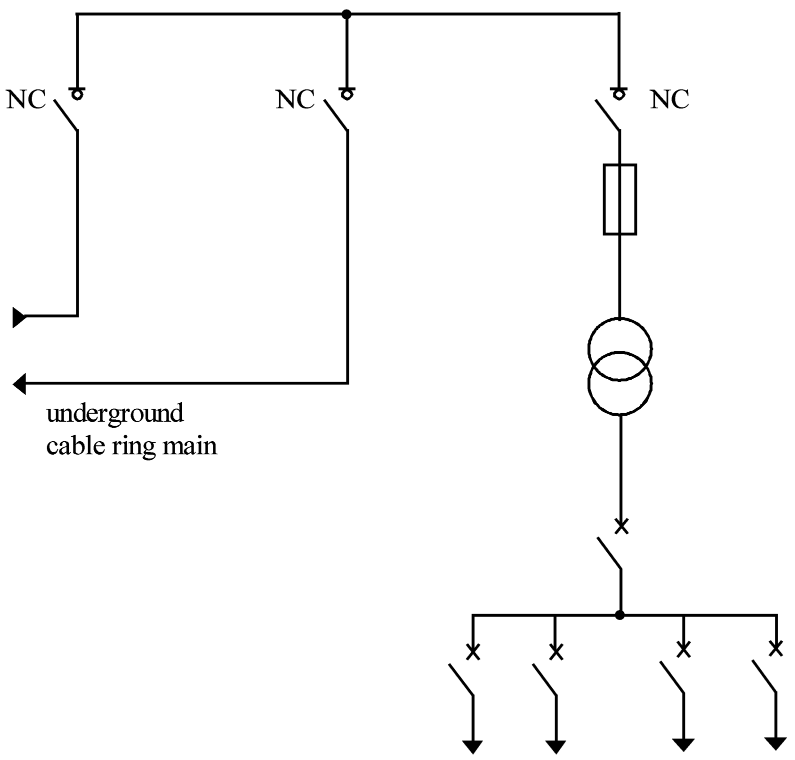


Figure 1-6: ring main service

Ring main units (RMU) are normally connected to form an MV ring main or interconnector-distributor, such that the RMU busbars carry the full ring main or interconnector current.

This arrangement provides the user with a two-source supply, thereby reducing considerably any interruption of service due to system faults or operational manoeuvres by the supply authority. The main application for RMU's is in public-supply MV underground cable networks in urban areas.

■ **parallel feeder** (see fig. 1-7)

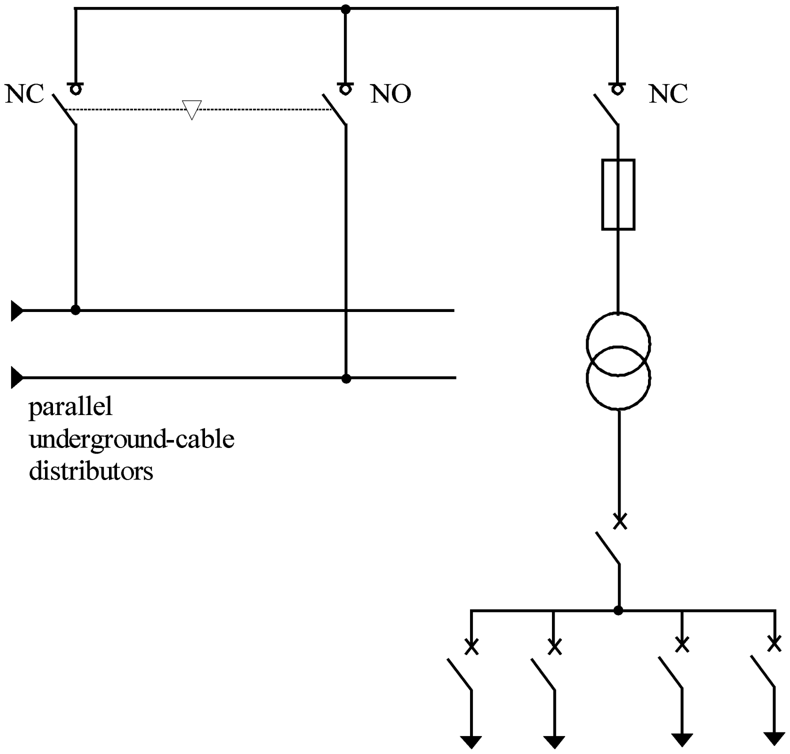


Figure 1-7: duplicated supply service

When an MV supply connection to two lines or cables originating from the same busbar of a substation is possible, a similar MV switchboard to that of an RMU is commonly used.

The main operational difference between this arrangement and that of an RMU is that the two incoming panels are mutually interlocked, such that only one incoming switch can be closed at a time, i.e. its closure prevents that of the other.

On loss of power supply, the closed incoming switch must be opened and the (formerly open) switch can then be closed. The sequence may be carried out manually or automatically. This type of switchboard is used particularly in networks of high load density and in rapidly expanding urban areas supplied by MV underground cable systems.

1.4.2. MV consumer substations

The MV consumer substation may comprise several MV transformers and outgoing feeders. The power supply may be a single line service, ring main principle or parallel feeder (see § 1.4.1).

Figure 1.8 shows the arrangement of an MV consumer substation using a ring main supply with MV transformers and outgoing feeders

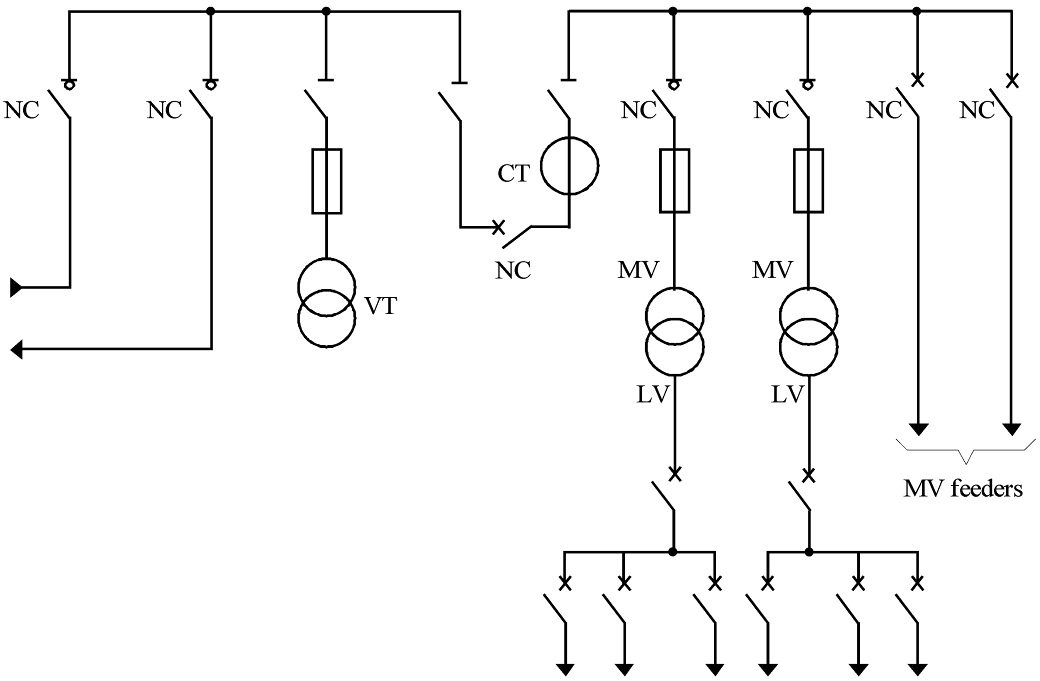


Figure 1-8: MV consumer substation

1.5. MV networks inside the site

MV networks are made up of switchboards and the connections feeding them. We shall first of all look at the different supply modes of these switchboards, then the different network structures allowing them to be fed.

1.5.1. MV switchboard power supply modes

We shall start with the main power supply solutions of an MV switchboard, regardless of its place in the network.

The number of sources and the complexity of the switchboard differ according to the level of power supply security required.

■ **1 busbar, 1 supply source** (see fig. 1-9)

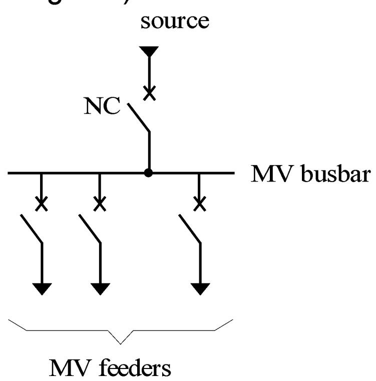


Figure 1-9: 1 busbar, 1 supply source

operation: if the supply source is lost, the busbar is put out of service until the fault is repaired.

■ **1 busbar with no coupler, 2 supply sources** (see fig. 1-10)

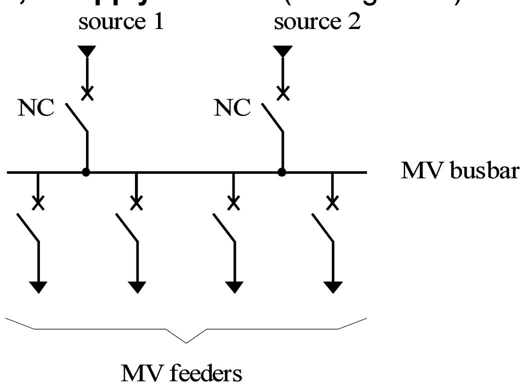


Figure 1-10: 1 busbar with no coupler, 2 supply sources

operation: one source feeds the busbar, the other provides a back-up supply. If a fault occurs on the busbar (or maintenance is carried out on it), the outgoing feeders are no longer fed.

■ **2 bus sections with coupler, 2 supply sources** (see fig. 1-11)

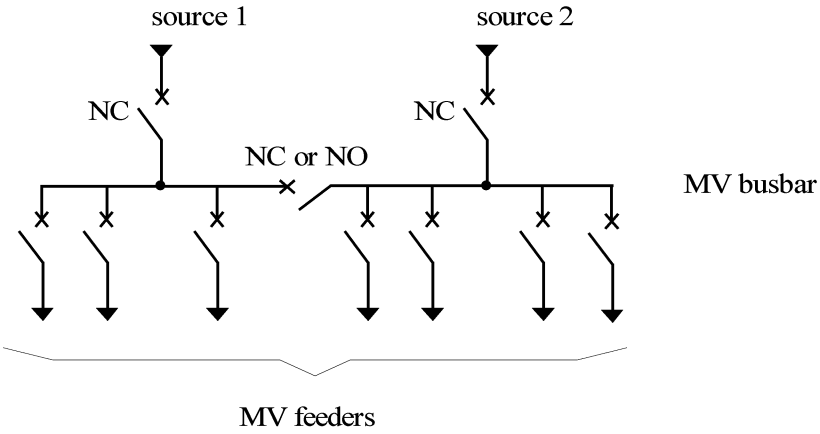


Figure 1-11: 2 bus sections with coupler, 2 supply sources

operation: each source feeds one bus section. The bus coupler circuit-breaker can be kept closed or open. If one source is lost, the coupler circuit-breaker is closed and the other source feeds both bus sections.
If a fault occurs on a bus section (or maintenance is carried out on it), only one part of the outgoing feeders is no longer fed.

■ **1 busbar with no coupler, 3 supply sources** (see fig. 1-12)

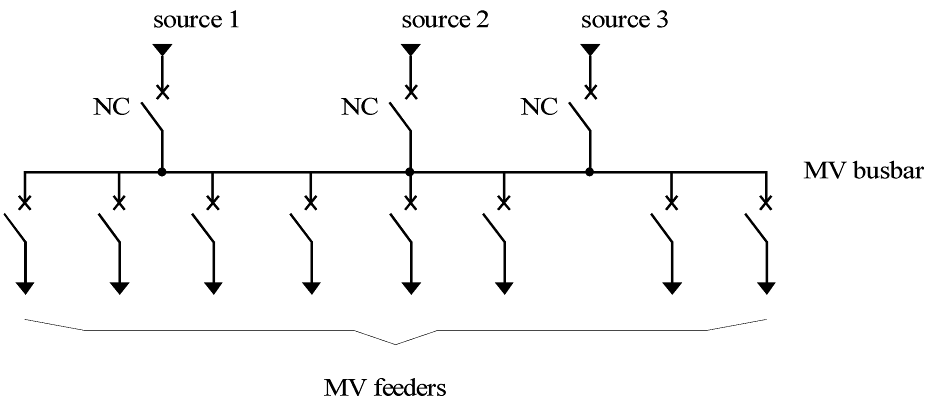


Figure 1-12: 1 busbar with no coupler, 3 supply sources

operation: the power supply is provided by two parallel-connected sources. If one of these two sources is lost, the third provides a back-up supply. If a fault occurs on the busbar (or maintenance is carried out on it), the outgoing feeders are no longer fed.

■ **3 bus sections with couplers, 3 supply sources** (see fig. 1-13)

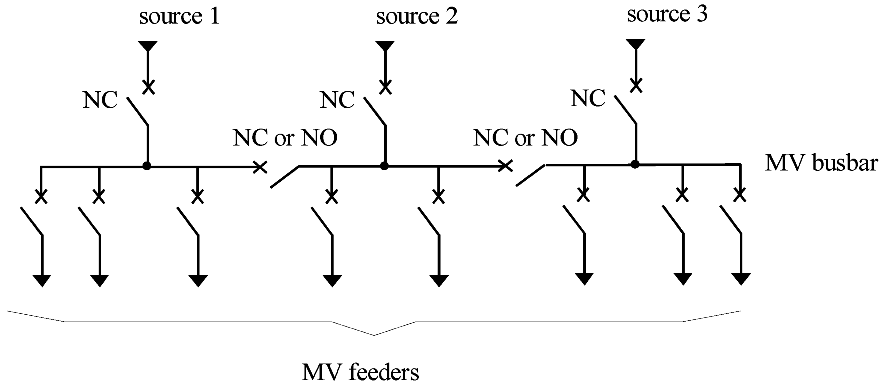


Figure 1-13: 3 bus sections with couplers, 3 supply sources

operation: both bus coupler circuit-breakers can be kept open or closed. Each supply source feeds its own bus section. If one source is lost, the associated coupler circuit-breaker is closed, one source feeds 2 bus sections and the other feeds one bus section.
If a fault occurs on one bus section (or if maintenance is carried out on it), only one part of the outgoing feeders is no longer fed.

■ **2 busbars, 2 connections per outgoing feeder, 2 supply sources** (see fig. 1-14)

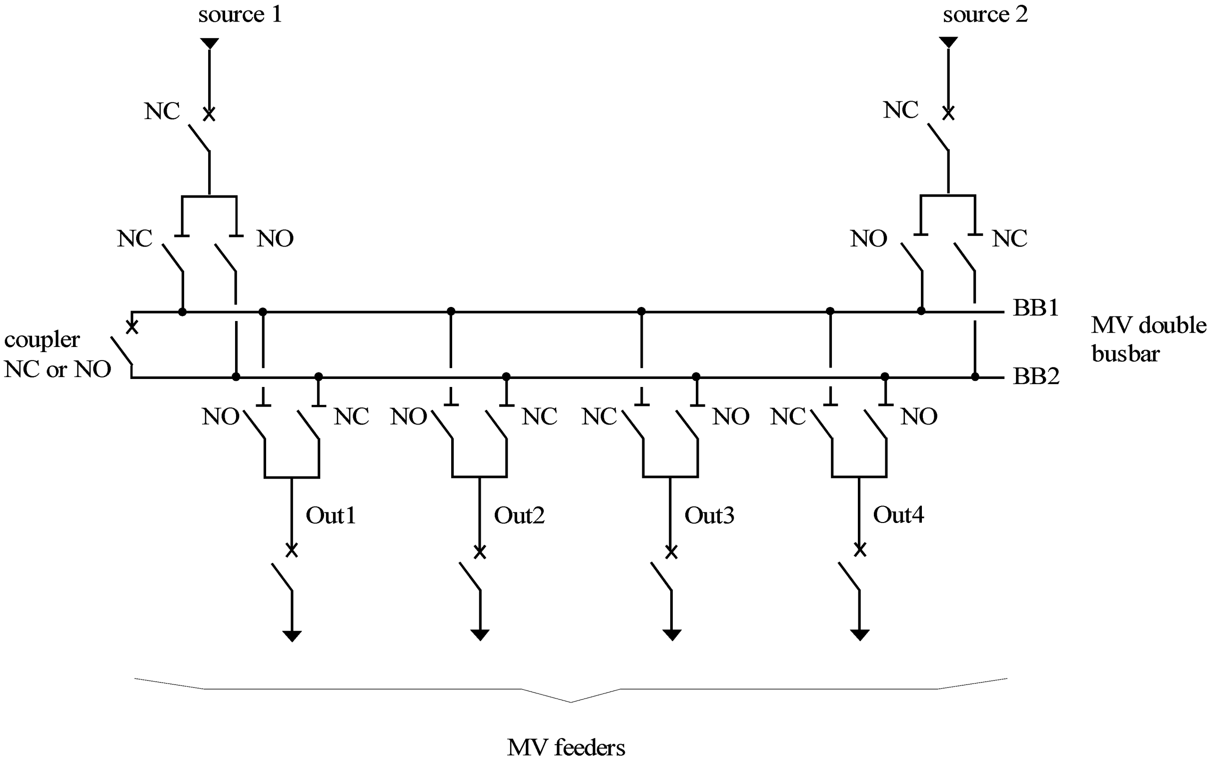


Figure 1-14: 2 busbars, 2 connections per outgoing feeder, 2 supply sources

operation: each outgoing feeder can be fed by one or other of the busbars depending on the state of the isolators which are associated with it and only one isolator per outgoing feeder must be closed.

For example, source 1 feeds busbar BB1 and feeders Out1 and Out2.
Source 2 feeds busbar BB2 and feeders Out3 and Out4.
The bus coupler circuit-breaker can be kept closed or open during normal operation.
If one source is lost, the other source takes over the total power supply.

If a fault occurs on a busbar (or maintenance is carried out on it), the coupler circuit-breaker is tripped and the other busbar feeds all the outgoing feeders.

■ **2 interconnected double busbars** (see fig. 1-15)

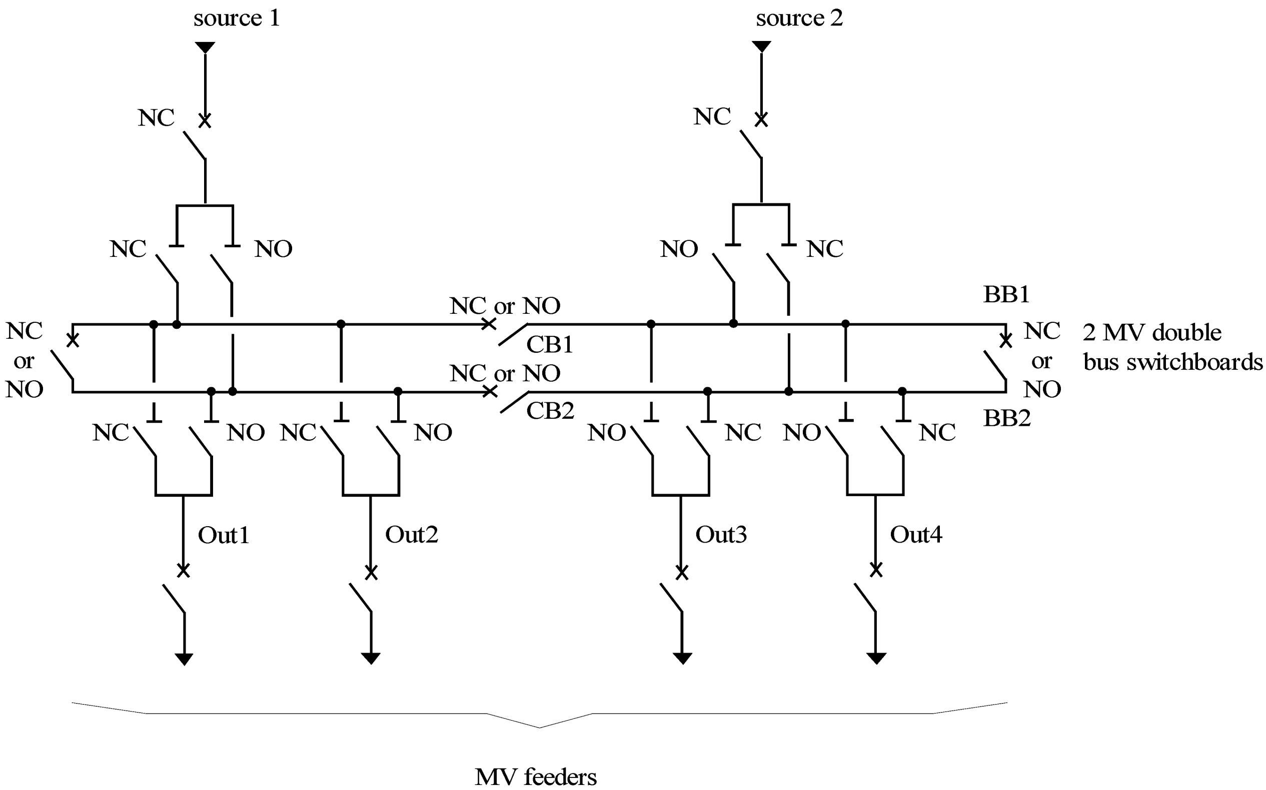


Figure 1-15: 2 interconnected double busbars

operation: this arrangement is almost identical to the previous one (2 busbars, 2 connections per feeder, 2 supply sources). The splitting up of the double busbars into two switchboards with coupler (via CB1 and CB2) provides greater operating flexibility. Each busbar feeds a smaller number of feeders during normal operation .

■ **"duplex" distribution system** (see fig. 1-16)

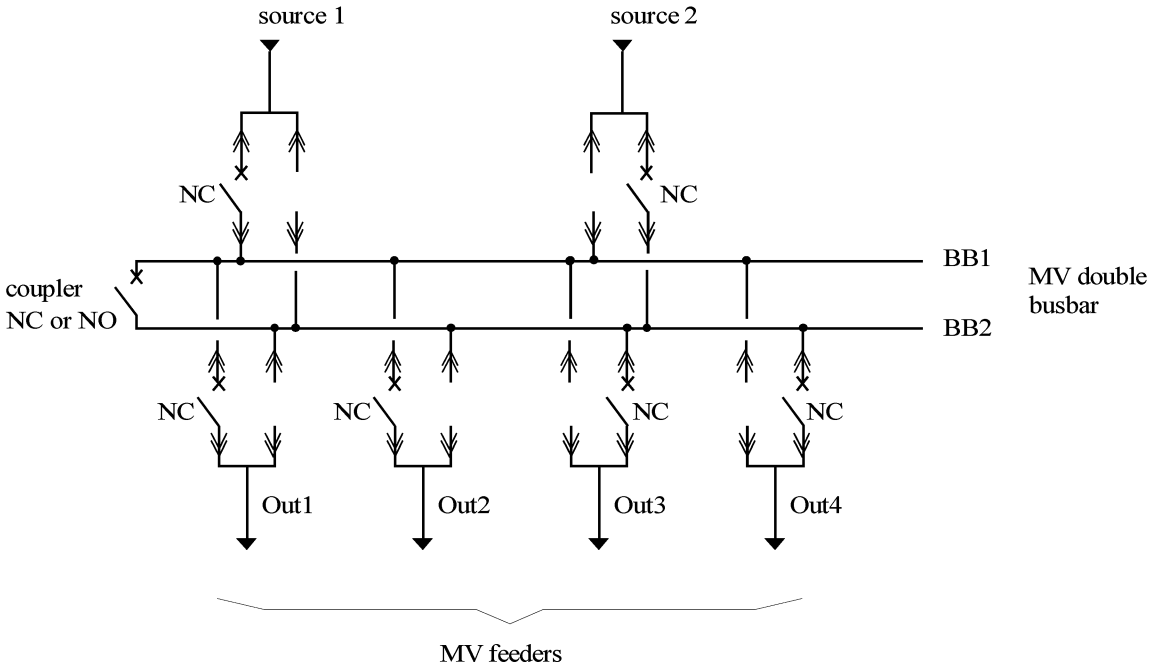


Figure 1-16: "duplex" distribution system

operation: each source can feed one or other of the busbars via its two drawout circuit-breaker cubicles. For economic reasons, there is only one circuit-breaker for the two drawout cubicles which are installed alongside one another. It is thus easy to move the circuit-breaker from one cubicle to the other.
Thus, if source 1 is to feed busbar BB2, the circuit-breaker is moved into the other cubicle associated with source 1.

The same principle is used for the outgoing feeders. Thus, there are two drawout cubicles and only one circuit-breaker associated with each outgoing feeder.
Each outgoing feeder can be fed by one or other of the busbars depending on where the circuit-breaker is positioned.

For example, source 1 feeds busbar BB1 and feeders Out1 and Out2.
Source 2 feeds busbar BB2 and feeders Out3 and Out4.

The bus coupler circuit-breaker can be kept closed or open during normal operation.

If one source is lost, the other source provides the total power supply.
If maintenance is carried out on one of the busbars, the coupler circuit-breaker is tripped and each circuit-breaker is placed on the busbar in service, so that all the outgoing feeders are fed.
If a fault occurs on a busbar, it is put out of service and the circuit-breaker is tripped.

1.5.2. MV network structures

We shall now look at the main MV network structures used to feed secondary switchboards and MV/LV transformers. The complexity of the structure differs depending on the level of power supply security required.
The following MV network supply arrangements are the ones most commonly adopted:

- **single fed radial network** (see fig. 1-17)

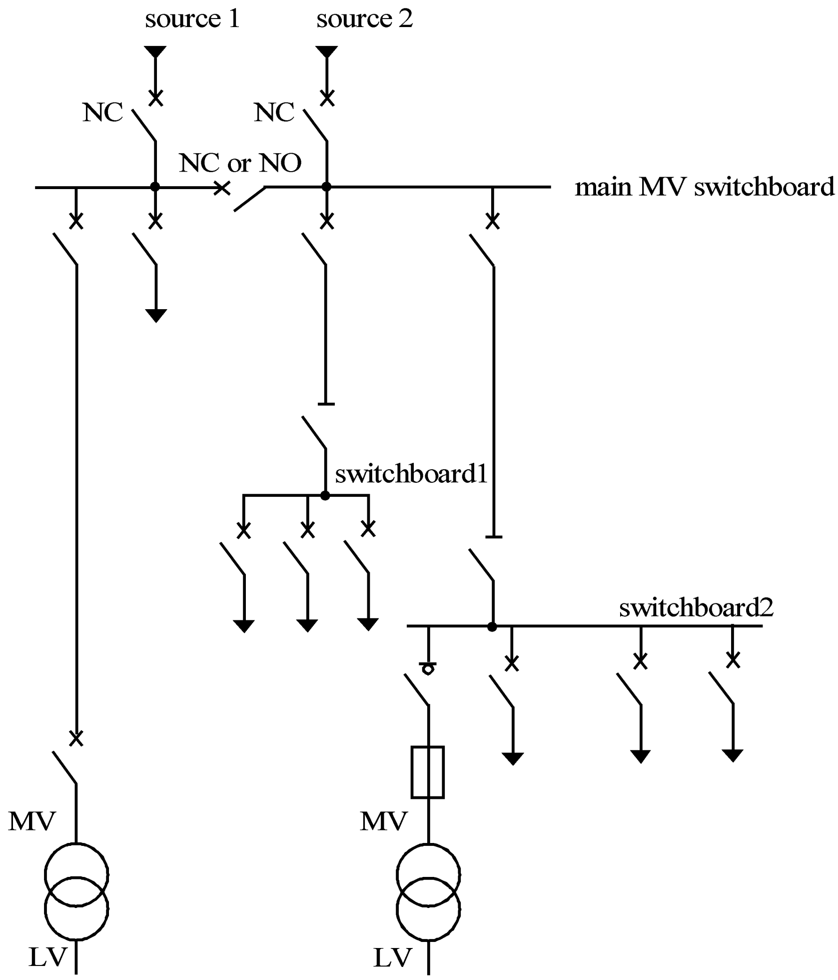


Figure 1-17: MV single fed radial network

- the main switchboard is fed by 2 sources with coupler
- switchboards 1 and 2 are fed by a single source, and there is no emergency back-up supply
- this structure should be used when service continuity is not a high requirement and it is often adopted for cement works networks.

■ **dual fed radial network with no coupler** (see fig. 1-18)

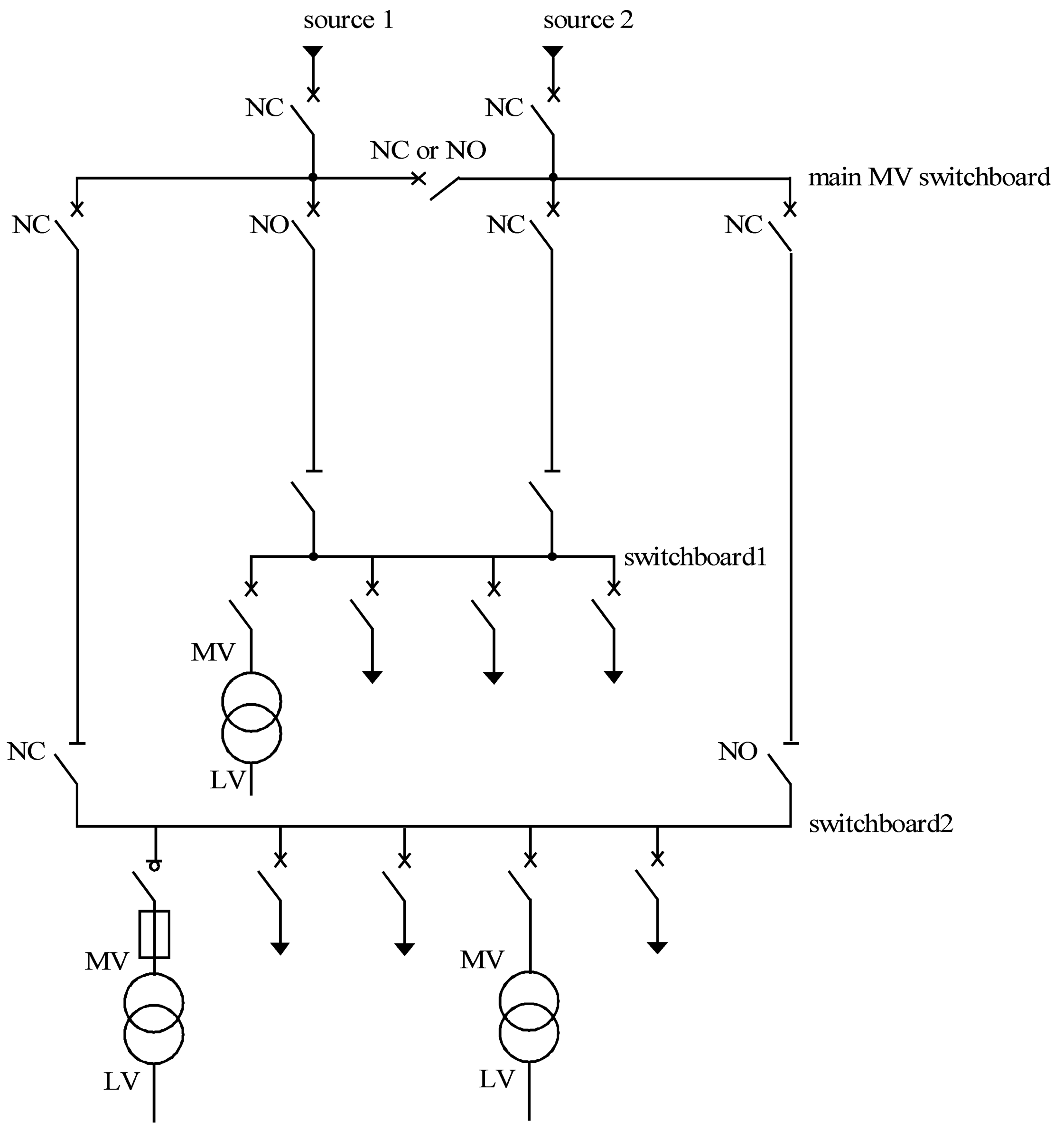


Figure 1-18: MV dual fed radial network with no coupler

- the main switchboard is fed by two sources with coupler.
- switchboards 1 and 2 are fed by 2 sources with no coupler, the one backing up the other.
- service continuity is good, the fact that there is no source coupler for switchboards 1 and 2 means that the network is less flexible to use.

■ **dual fed radial network with coupler** (see fig. 1-19)

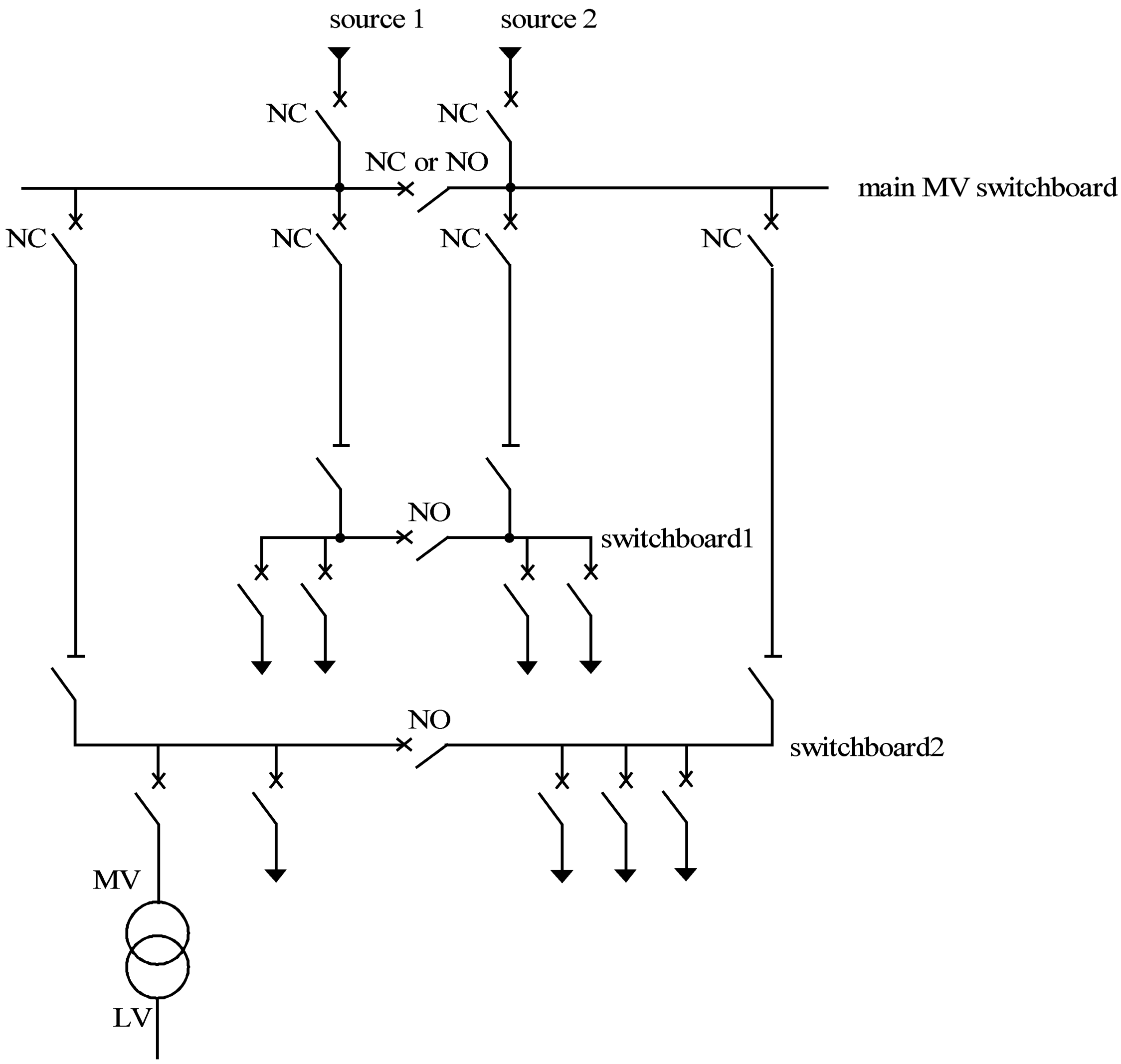


Figure 1-19: MV dual fed radial network with coupler

- the main switchboard is fed by two sources with coupler.

Switchboards 1 and 2 are fed by 2 sources with coupler. During normal operation, the bus coupler circuit-breakers are open.

- each bus section can be backed up and fed by one or other of the sources
- this structure should be used when good service continuity is required and it is often adopted in the iron and steel and petrochemical industries.

■ **loop system**

This system should be used for widespread networks with large future extensions.

There are two types depending on whether the loop is open or closed during normal operation.

☐ **open loop** (see fig. 1-20 a)

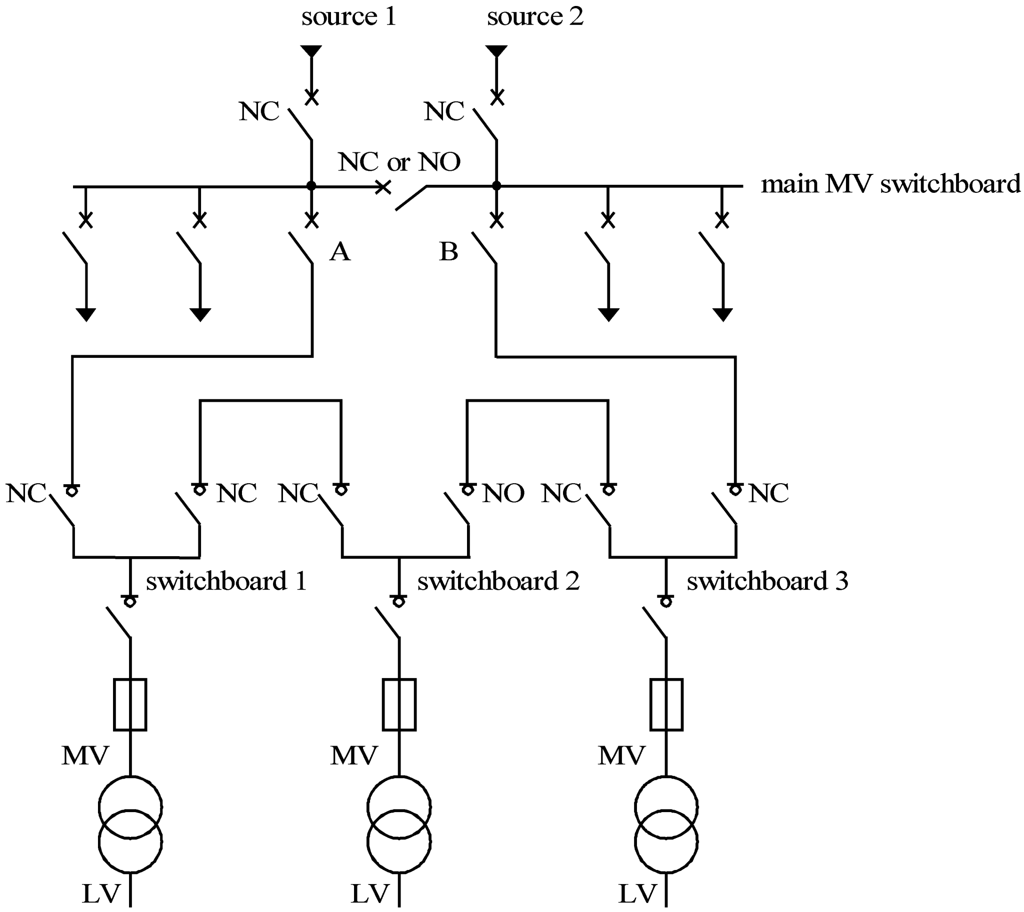


Figure 1-20 a: MV open loop system

- the main switchboard is fed by 2 sources with coupler.
- the loop heads in A and B are fitted with circuit-breakers.

- switchboards 1, 2 and 3 are fitted with switches.
- during normal operation, the loop is **open** (on the figure it is normally open at switchboard 2).
- the switchboards can be fed by one or other of the sources.
- reconfiguration of the loop enables the supply to be restored upon occurrence of a fault or loss of a source (see § 10.1.7.1).
- this reconfiguration causes a power cut of several seconds if an automatic loop reconfiguration control has been installed. The cut lasts at least several minutes or dozens of minutes if the loop reconfiguration is carried out manually by operators.

☐ **closed loop** (see fig. 1-20 b)

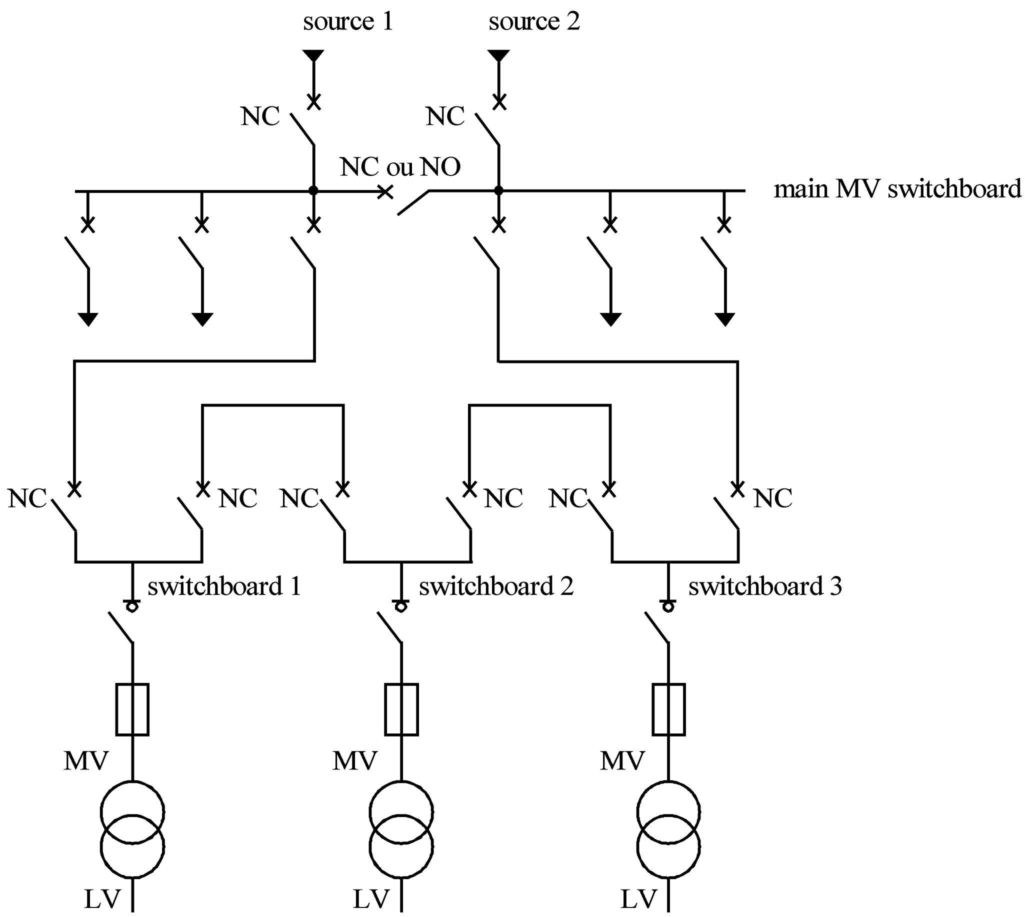


Figure 1-20 b: MV closed loop system

- the main switchboard is fed by two sources with coupler.
- all the loop switching devices are circuit-breakers.
- during normal operation, the loop is **closed**.
- the protection system ensures against power cuts due to a fault (see § 10.1.8).

This system is more efficient than the open loop since it avoids power cuts.

On the other hand, it is more costly since it requires circuit-breakers in each switchboard and a complex protection system.

■ **parallel feeder** (see fig. 1-21)

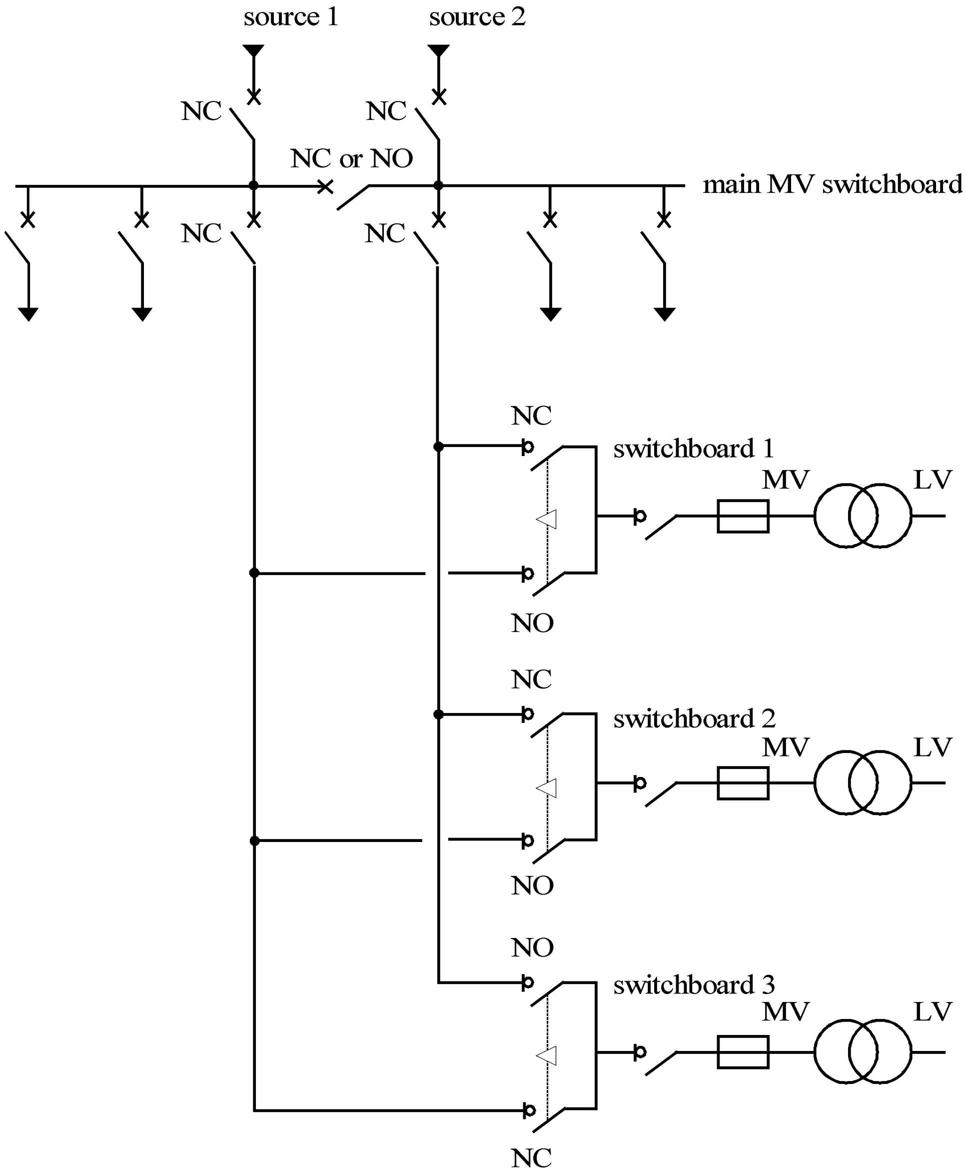


Figure 1-21: MV parallel feeder network

- switchboards 1, 2 and 3 can be backed up and fed by one or other of the sources independently.
- the main switchboard is fed by two sources with coupler.
- this structure should be used for widespread networks with limited future extensions and which require good supply continuity.

1.6. LV networks inside the site

We shall first of all study the different low voltage switchboard supply modes. Next, we shall look at the supply schemes for switchboards backed up by generators or an uninterruptible power supply.

1.6.1. LV switchboard supply modes

We are now going to study the main supply arrangements for an LV switchboard, regardless of its place in the network. The number of supply sources possible and the complexity of the switchboard differ according to the level of supply security required.

■ single fed LV switchboards

example (see fig. 1-22) :

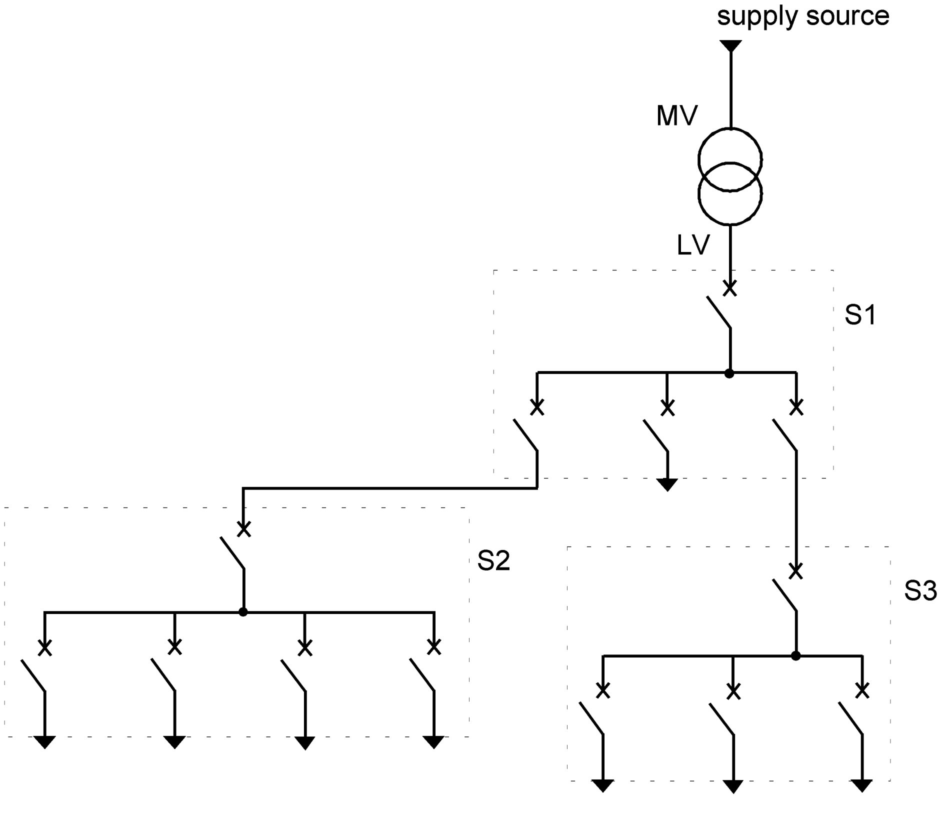


Figure 1-22: single fed LV switchboards

Switchboards S1, S2 and S3 have only one supply source. The network is said to be of the arborescent radial type.
If a switchboard supply source is lost, the switchboard is put out of service until the supply is restored.

■ dual fed LV switchboards with no coupler

example (see fig. 1-23):

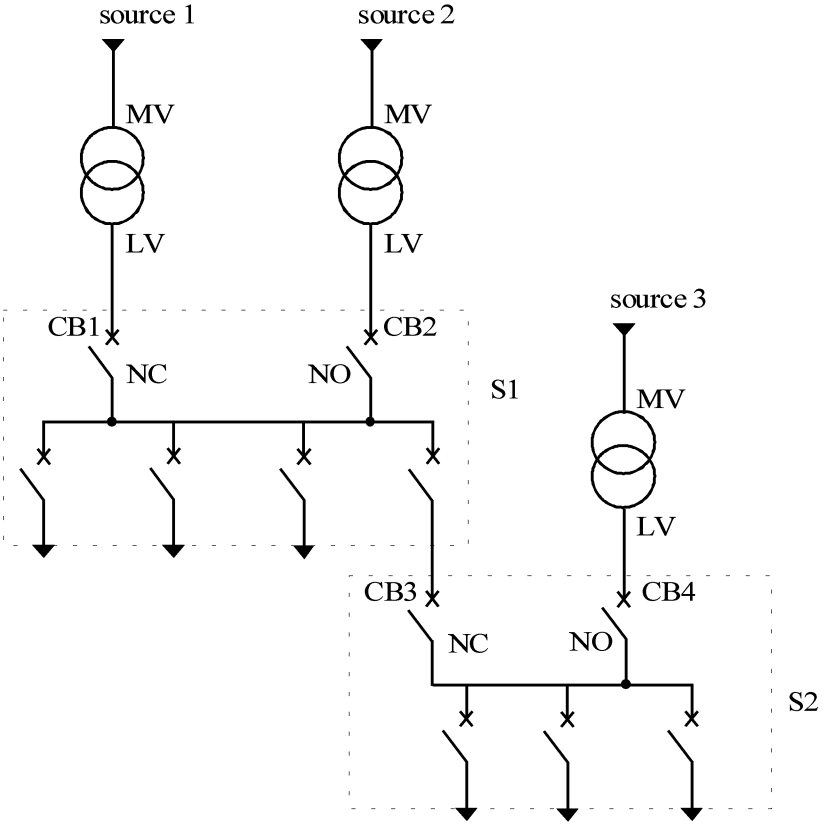


Figure 1-23: dual fed LV switchboards with no coupler

Switchboard S1 has a dual power supply with no coupler via 2 MV/LV transformers.

Operation of the S1 power supply :
- one source feeds switchboard S1 and the second provides a back-up supply.
- during normal operation only one circuit-breaker is closed (CB1 or CB2).

Switchboard S2 has a dual power supply with no coupler via an MV/LV transformer and outgoing feeder coming from another LV switchboard.

Operation of the S2 power supply:
- one source feeds switchboard S2 and the second provides a back-up supply.
- during normal operation only one circuit-breaker is closed (CB3 or CB4)

■ dual fed LV switchboards with coupler

example (see fig. 1-24):

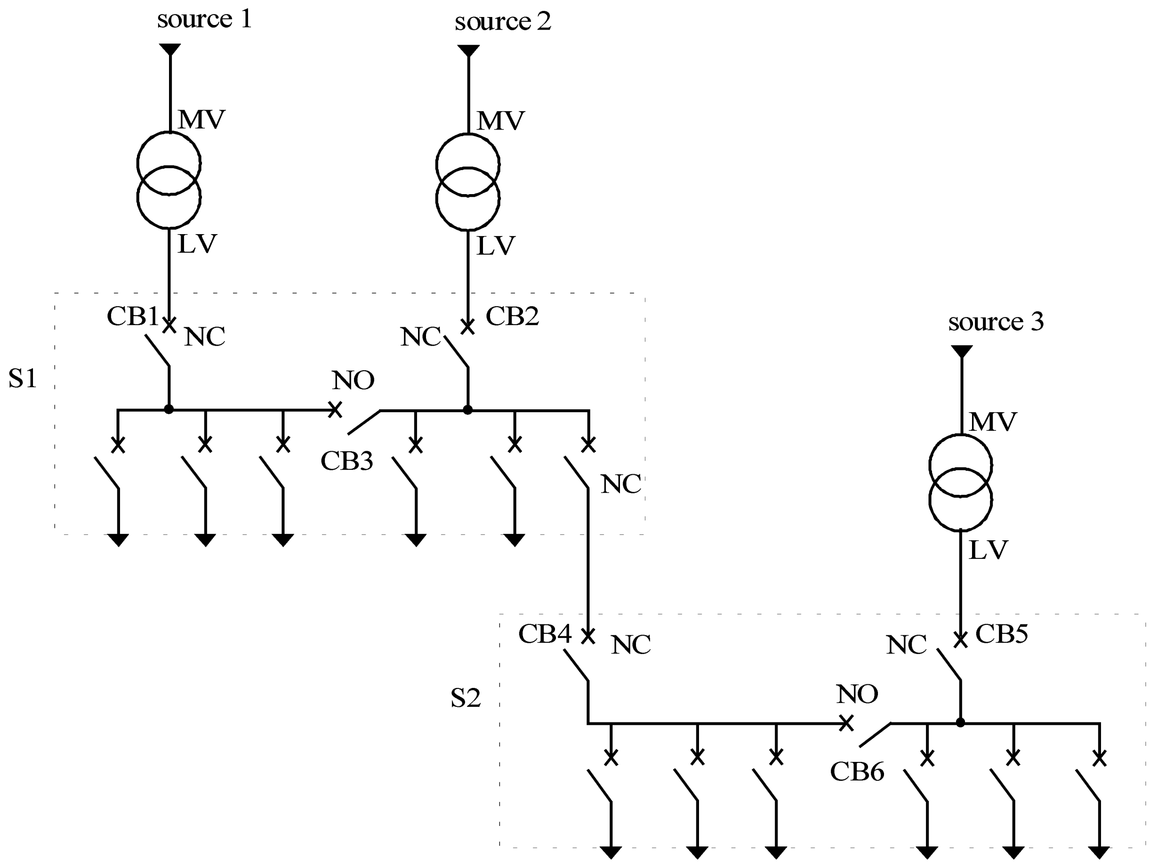


Figure 1-24: dual fed LV switchboards with coupler

Switchboard S1 has a dual power supply with coupler via 2 MV/LV transformers.
Operation of the S1 power supply: during normal operation, the coupler circuit-breaker CB3 is open. Each transformer feeds a part of S1. If a supply source is lost, the circuit-breaker CB3 is closed and a single transformer feeds all of S1.

Switchboard S2 has a dual power supply with coupler via an MV/LV transformer and an outgoing feeder coming from another LV switchboard.

Operation of the S2 power supply: during normal operation, the circuit-breaker CB6 is open. Each source feeds part of S2. If a source is lost, the coupler circuit-breaker is closed and a single source feeds all of S2.

■ triple fed LV switchboards with no coupler

example (see fig. 1-25):

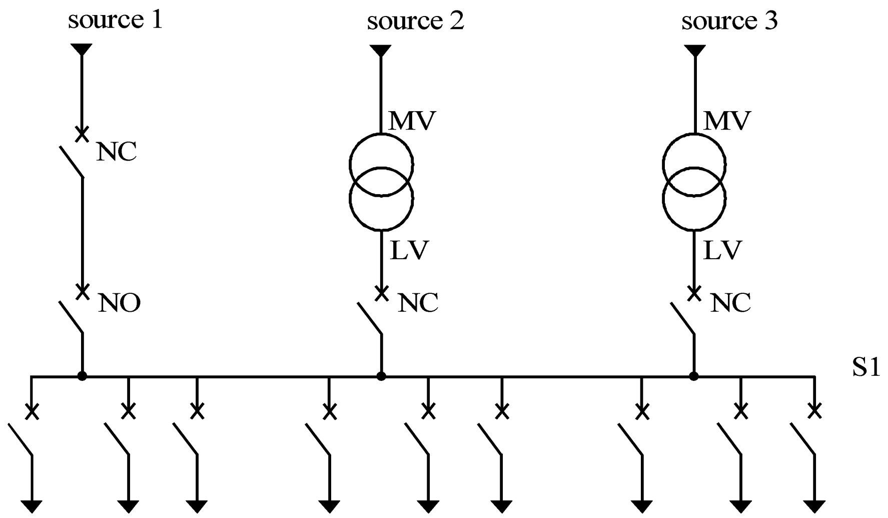


Figure 1-25: triple fed LV switchboards with no coupler

Switchboard S1 has a triple power supply with no coupler via 2 MV/LV transformers and an outgoing feeder coming from another LV switchboard.

During normal operation, the switchboard is fed by 2 transformers in parallel. If one or both of the transformers fail, switchboard S1 is fed by the outgoing feeder coming from another switchboard.

■ **triple fed switchboards with coupler**

example (see fig. 1-26):

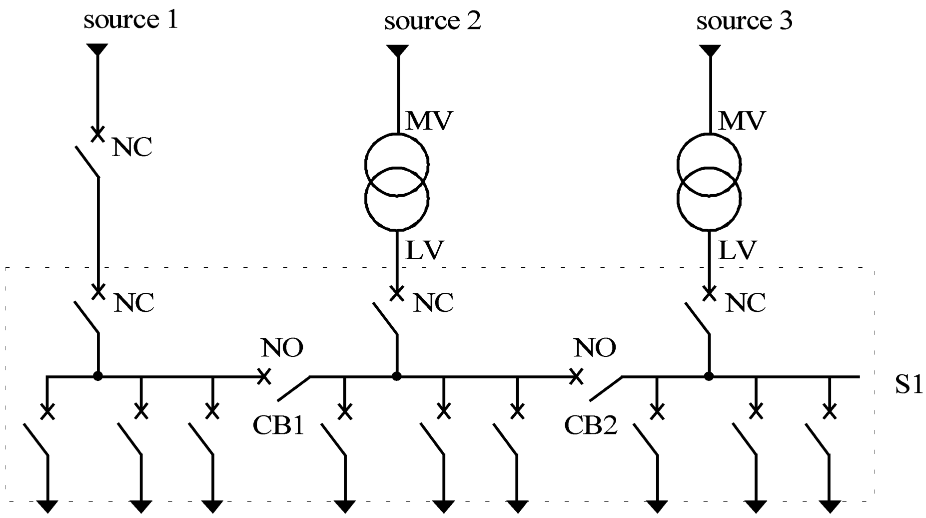


Figure 1-26: triple fed LV switchboards with coupler

Switchboard S1 has a triple power supply with coupler via 2 MV/LV transformers and an outgoing feeder coming from another LV switchboard.

During normal operation, the two coupler circuit-breakers are open and switchboard S1 is fed by 3 supply sources.

If one source fails, the circuit-breaker of the associated source is closed and the incoming circuit-breaker of the source that has been lost is tripped.

1.6.2. LV switchboards backed up by generators

■ **example 1: 1 transformer and 1 generator** (see fig. 1-27)

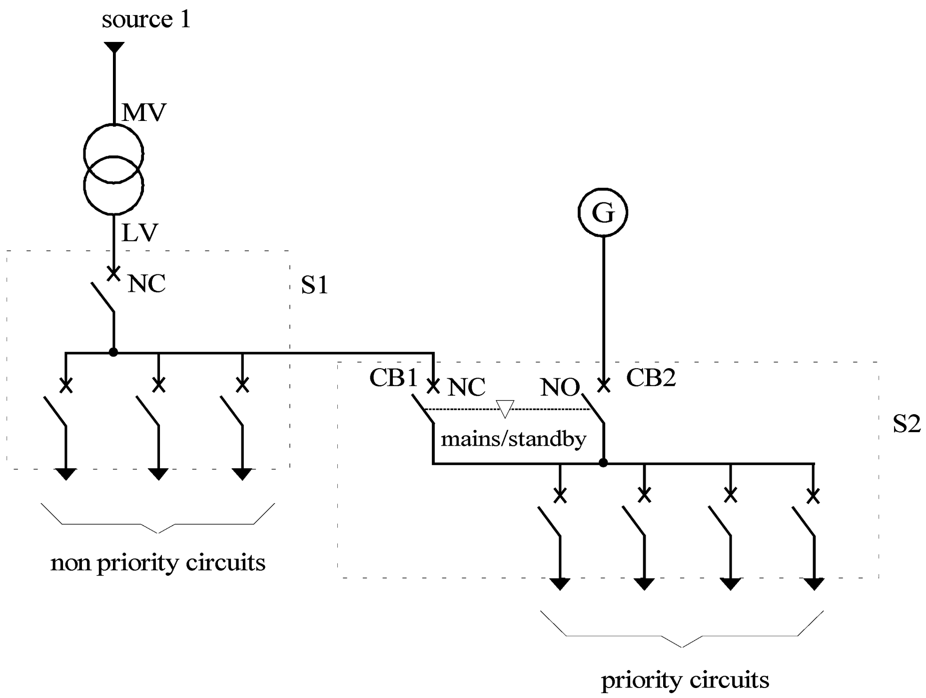


Figure 1-27: 1 transformer and 1 generator

During normal operation CB1 is closed and CB2 open. Switchboard S2 is fed by the transformer. If the main source is lost, the following steps are carried out:

1. The mains/standby changeover switch is operated and CB1 is tripped.

2. Load shedding if necessary of part of the loads on the priority circuit in order to facilitate start-up of the generator.

3. Start-up of the generator.

4. CB2 is closed when the frequency and voltage of the generator are within the required ranges.

5. Reloading of loads which may have been shed during step 2.

Once the main source has been restored, the generator is stopped and the mains/standby changeover device switches the S2 supply to the mains.

■ **example 2: 2 transformers and 2 generators** (see fig. 1-28)

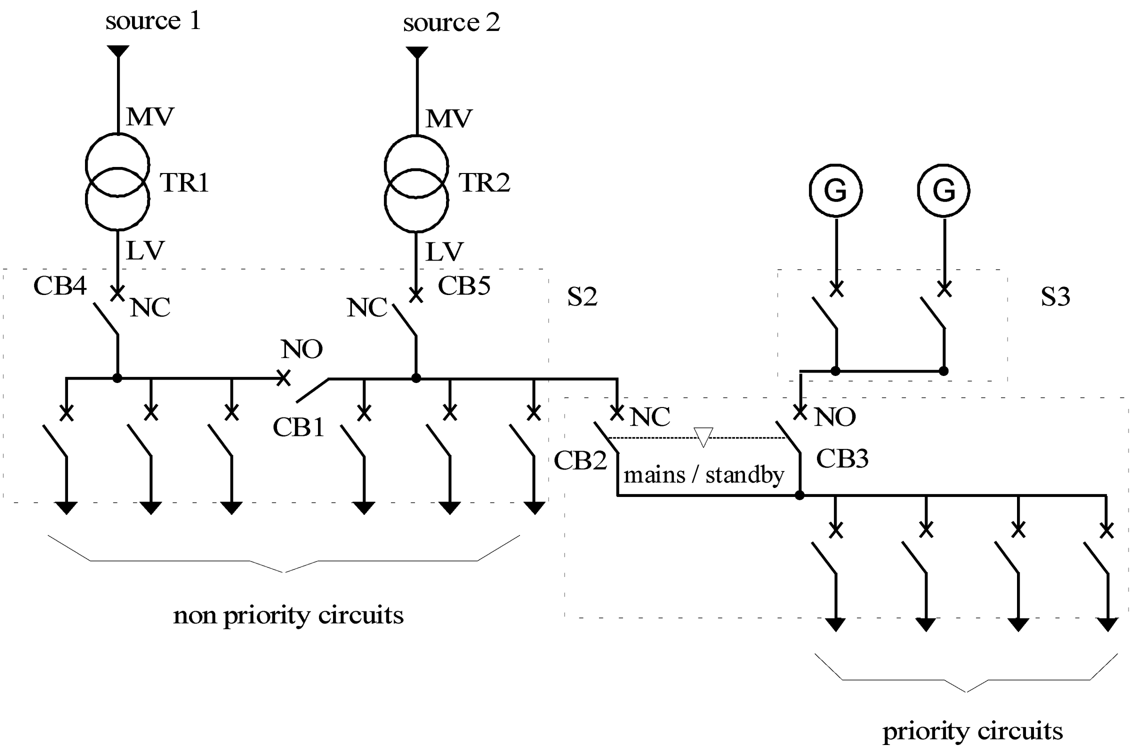


Figure 1-28: 2 transformers and 2 generators

During normal operation, the coupler circuit-breaker CB1 is open and the mains/standby changeover device is in position CB2 closed and CB3 open. Switchboard S1 is fed by transformer TR2.

If source 2 is lost or there is a breakdown on TR2, the S1 (and part of S2) standby supply is given priority by transformer TR1, after reclosing of the coupler circuit-breaker CB1.

The generators are only started-up after the loss of the 2 main supply sources.
The steps for saving the priority circuit supply are carried out in the same way as in example 1.

1.6.3. LV switchboards backed up by an uninterruptible power supply (UPS)

The main devices making up a UPS system are shown in figure 1-29 and table 1-2.

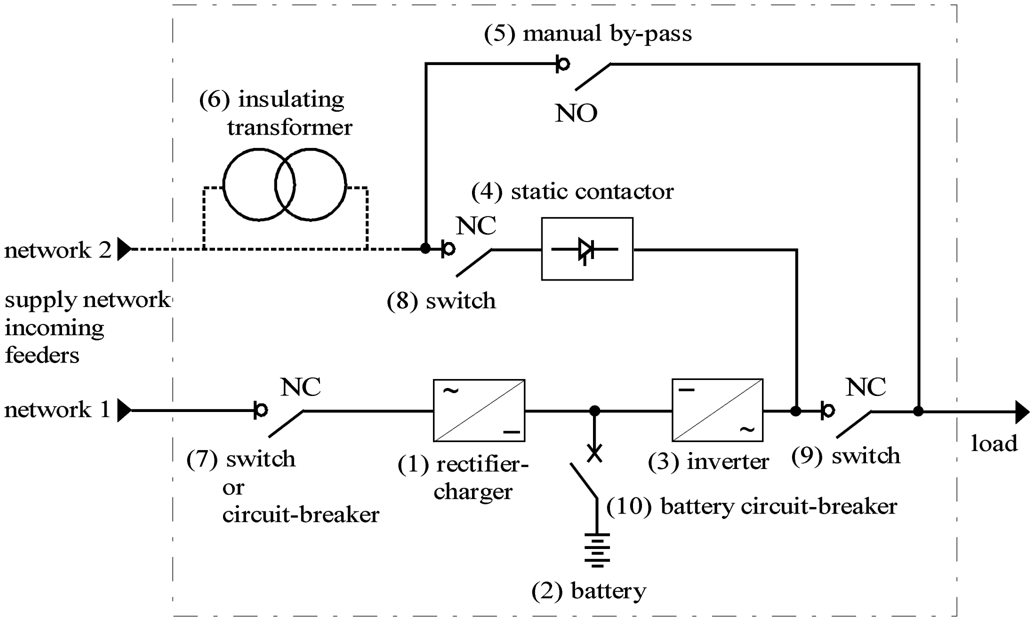


Figure 1-29: uninterruptible power supply system

Device name	Ref. n°	Function
Rectifier-charger	(1)	Transforms the alternating voltage of a supply network into a direct voltage which will: - feed the inverter on the one hand, - continually provide the charge of the storage battery on the other
Storage battery	(2)	Provides a back-up supply to feed the inverter in case: - the supply network disappears (power cut), - the supply network is disturbed (disturbances leading to insufficient quality).
Inverter	(3)	Transforms the direct voltage from the rectifier-charger or storage battery into three-phase alternating voltage with more severe tolerances than those of the network (supplies an alternating current close to the theoretical sine curve).
Static contactor	(4)	Switches over the load supply from the inverter to network 2 (standby) without interruption (no cut due to mechanical switching device changeover time - the switchover is carried out using electronic components in a time < 1 ms). This switchover is performed if the inverter stops working for one of the following reasons: - switched off, - overload beyond the limiting capacities of the inverter, - internal anomaly.
Manual by-pass	(5)	Manual switch which allows the user to be fed by network 2 (standby), while maintenance is being carried out. Its presence is indispensable when the network frequencies upstream and downstream of the UPS are identical.
Insulating transformer	(6)	Provides upstream and downstream insulation when the supply is via network 2. It is especially used when the upstream and downstream earthing systems are different
Manual switches Battery circuit-breakers	(7) (8) (9) (10)	Provides insulation of the different parts when maintenance is being carried out

Tableau 1-2: function of different devices making up an uninterruptible power supply system

network incoming feeder(s)

The terms network 1 and network 2 designate two independent incoming feeders on the same network:

- network 1 (or mains) designates the incoming feeder usually supplying the rectifier-charger,
- network 2 (or standby) is said to be a back-up feeder.

The inverter's frequency is synchronised with network 2 thereby allowing the load to be instantaneously fed by network 1 (in a time < 1 ms) via the static contactor.

The connection of a UPS system to a second independent network is recommended since it increases the reliability of the system. It is nevertheless possible to have only one common incoming feeder.

- **example 1**: LV switchboard backed up by an inverter, with a generator to eliminate the problem of the limited autonomy of the battery (usually about 15 mn) (see fig. 1-30)

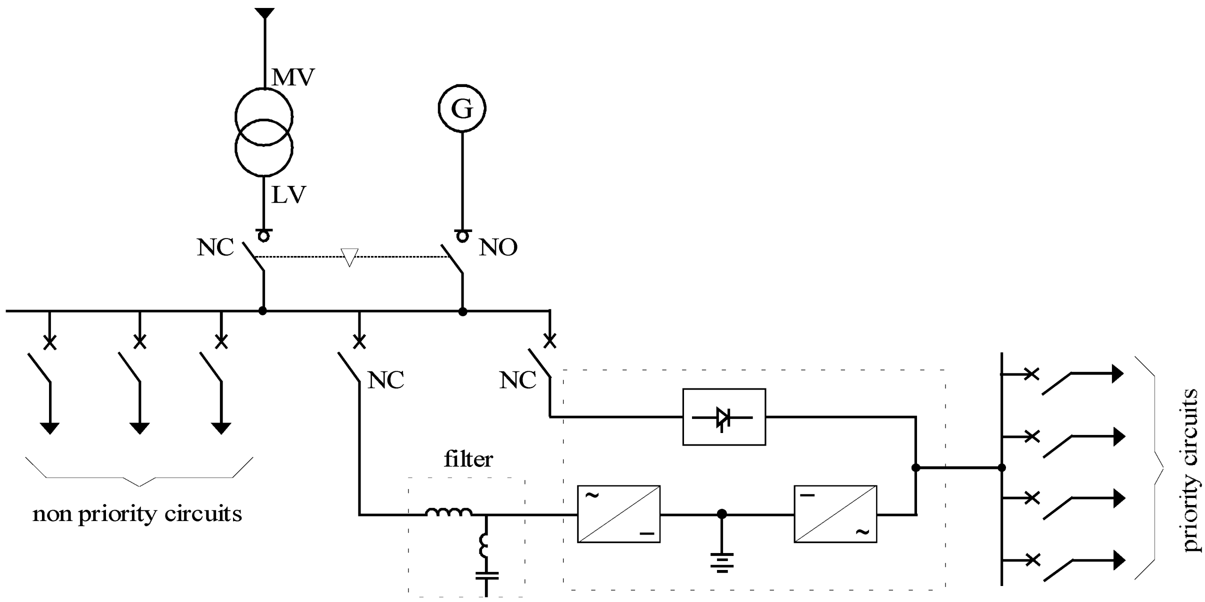


Figure 1-30: LV switchboard backed up by an inverter

The filter allows harmonic currents travelling up the supply network to be reduced.

- **example 2**: LV switchboard backed up by 2 inverters in parallel with no redundancy (voir fig. 1-31)

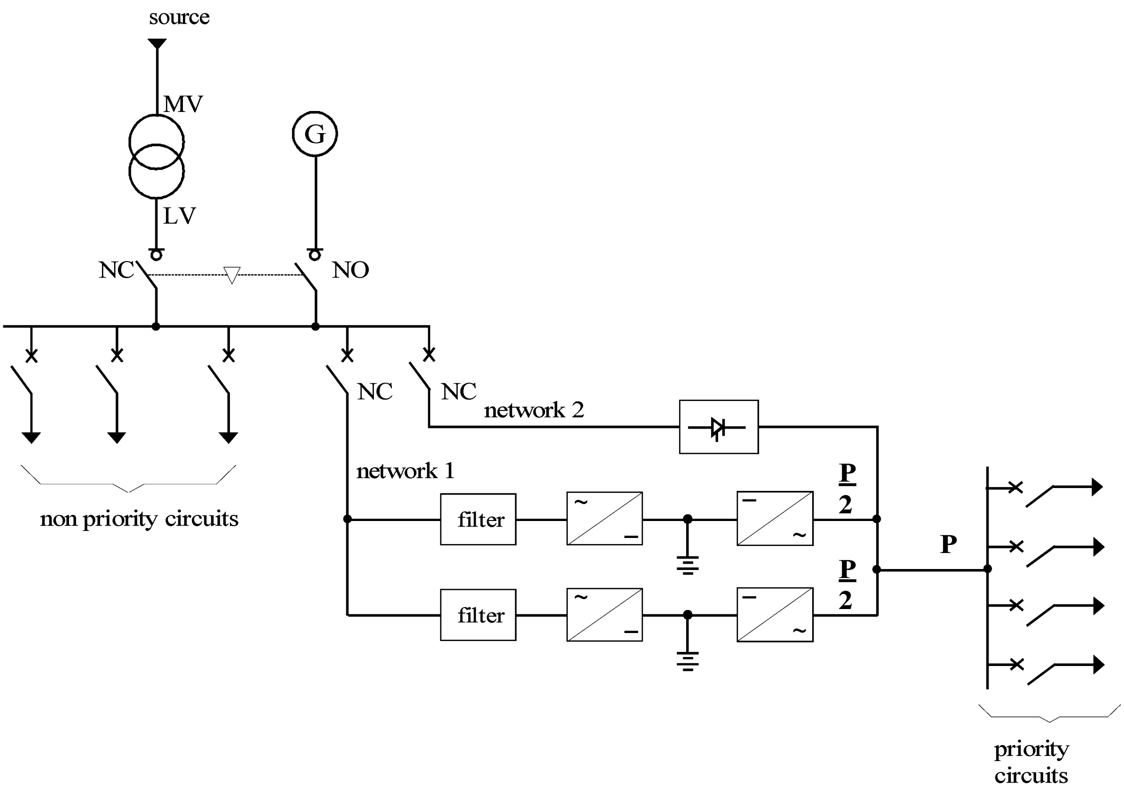


Figure 1-31: LV switchboard backed up by 2 inverters in parallel with no redundancy

This configuration only allows an overall power capacity above that of a single rectifier/inverter unit.
The power P to be supplied is also divided between the 2 inverters.
A fault in one of the units leads to the load being switched to network 2 without interruption, except if the network is beyond its tolerance level.

- **example 3**: LV switchboard backed up by 3 inverters one of which is actively redundant (see fig. 1-32)

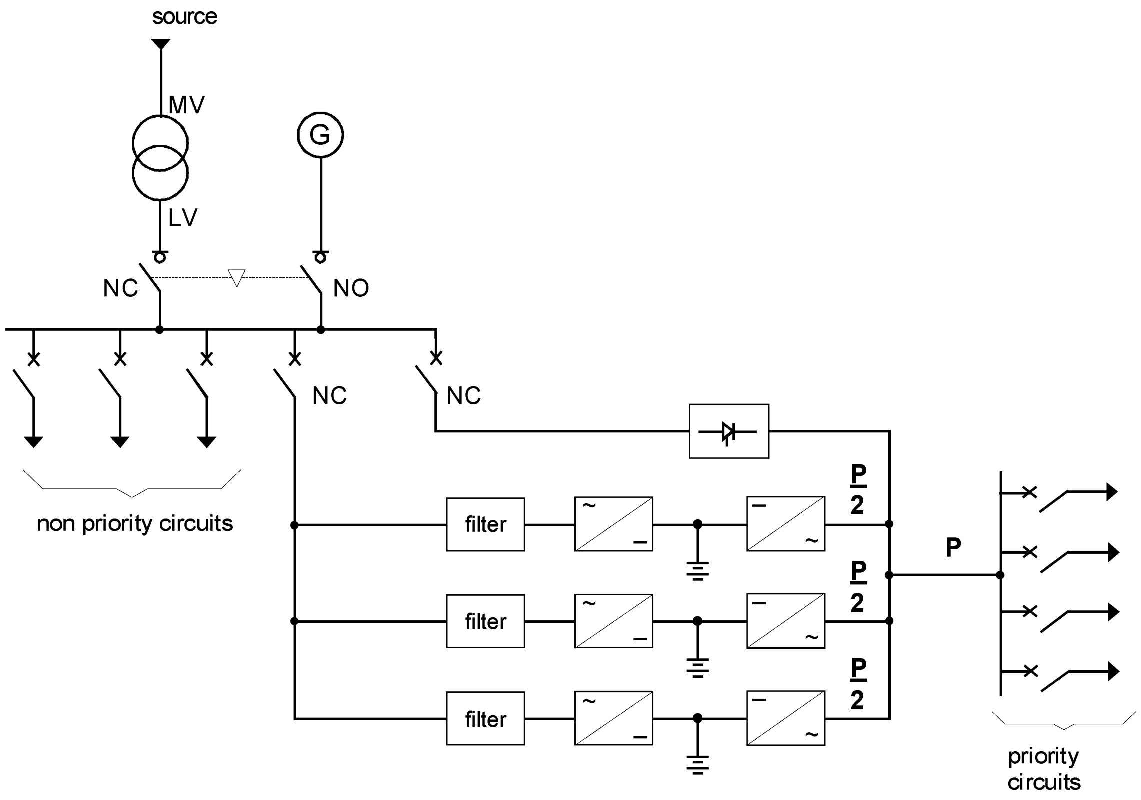


Figure 1-32: LV switchboard backed up by 3 inverters one of which is actively redundant

Let P be the maximum load rating of the priority circuit.
Each inverter has a rated power of $\frac{P}{2}$, which means that when one inverter breaks down, the other two inverters provide the total load power supply.
This is referred to as a parallel-connected unit with 1/3 active redundancy.

■ **example 4**: LV switchboard backed up by 3 inverters one of which is on standby redundancy (see fig. 1-33)

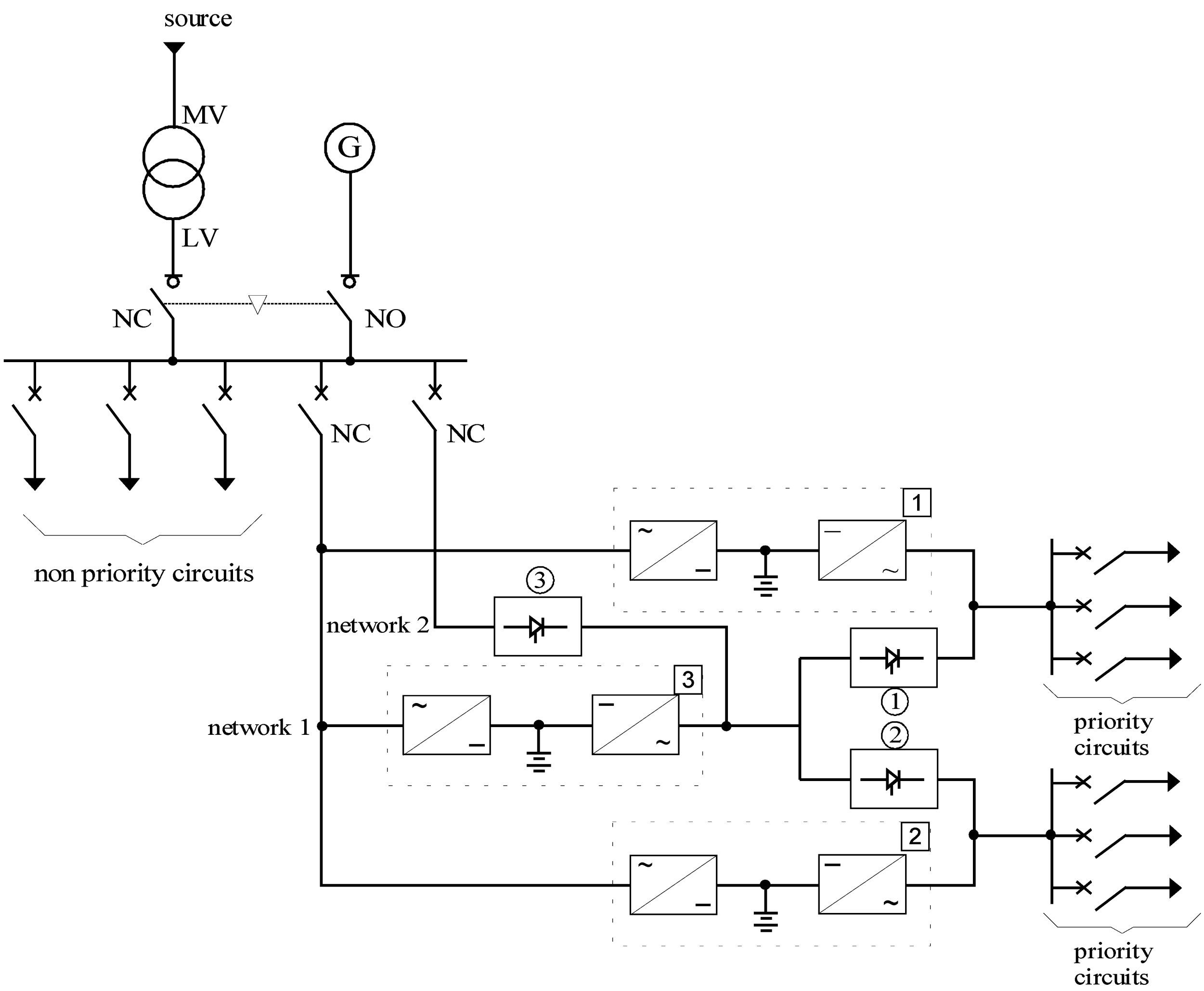


Figure 1-33: LV switchboard backed up by 3 inverters one of which is on standby redundancy

Inverter [3] is not charged, it is on standby ready to back up inverters [1] or [2].
There is no power cut during switchover due to static contactors ① and ②.
Static contactor ③ provides back-up via network 2 in case there is a failure on network 1, or the 2 inverters break down.

This is referred to as a parallel-connected unit with standby redundancy.

1.7. Industrial networks with internal production

example (see fig. 1-34) :

Network structure:

- MV consumer substation
- the main MV switchboard is fed by the internal production station
- some MV outgoing feeders are fed by the utility and cannot be backed up by the internal production station
- an MV loop system and some outgoing feeders are fed during normal operation by the internal production station. If the production station breaks down, this loop system and its outgoing feeders can be fed by the utility.

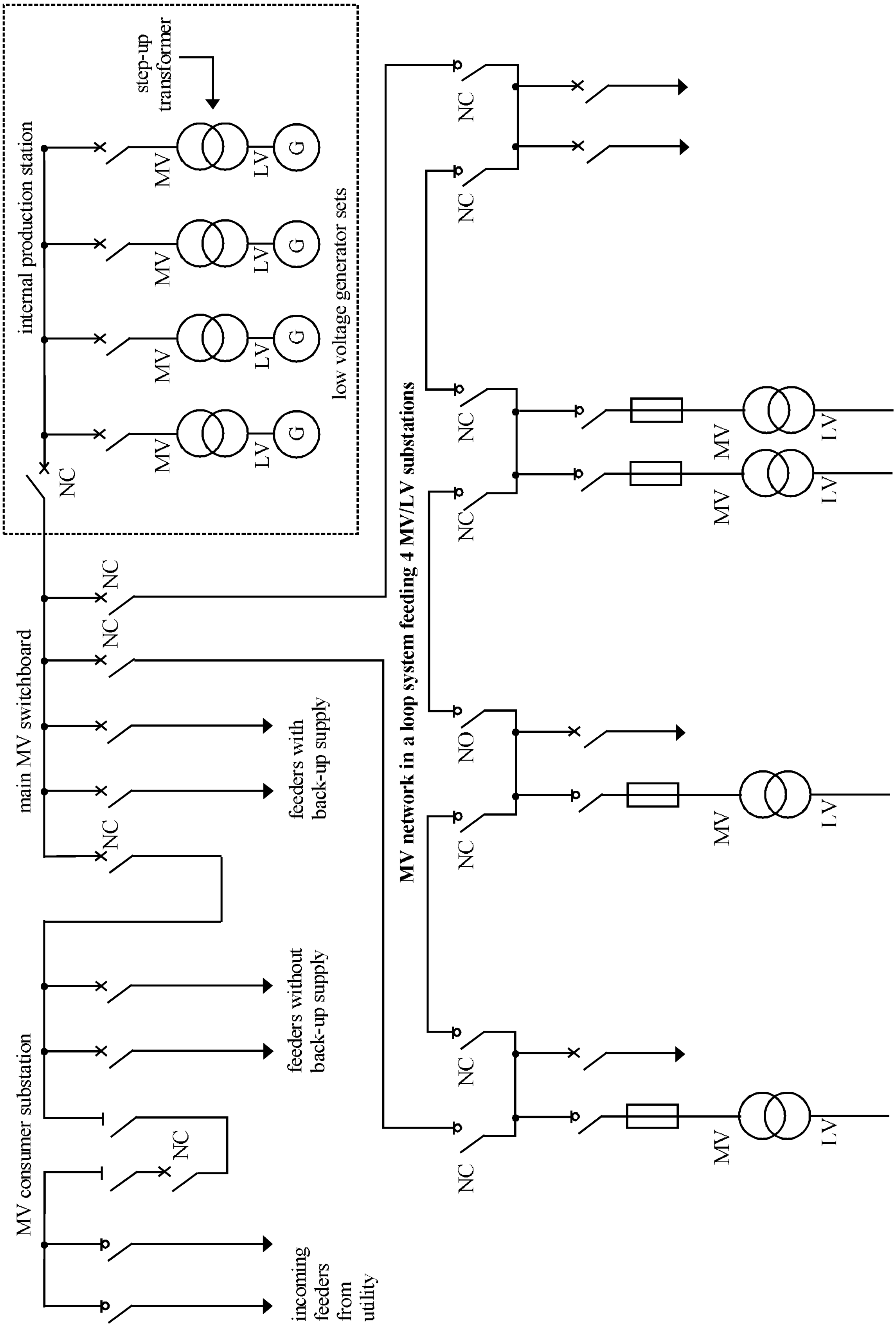


Figure 1-34: industrial network with internal production

1.8. Examples of standard networks

■ **example 1** (see fig. 1-35)

Network structure:

- MV consumer substation in a ring main system with two incoming feeders
- main low voltage switchboard backed up by a generator
- a priority switchboard fed by an uninterruptible power supply
- the low voltage network is the arborescent radial type and the secondary switchboard and terminal boxes are fed by a single source.

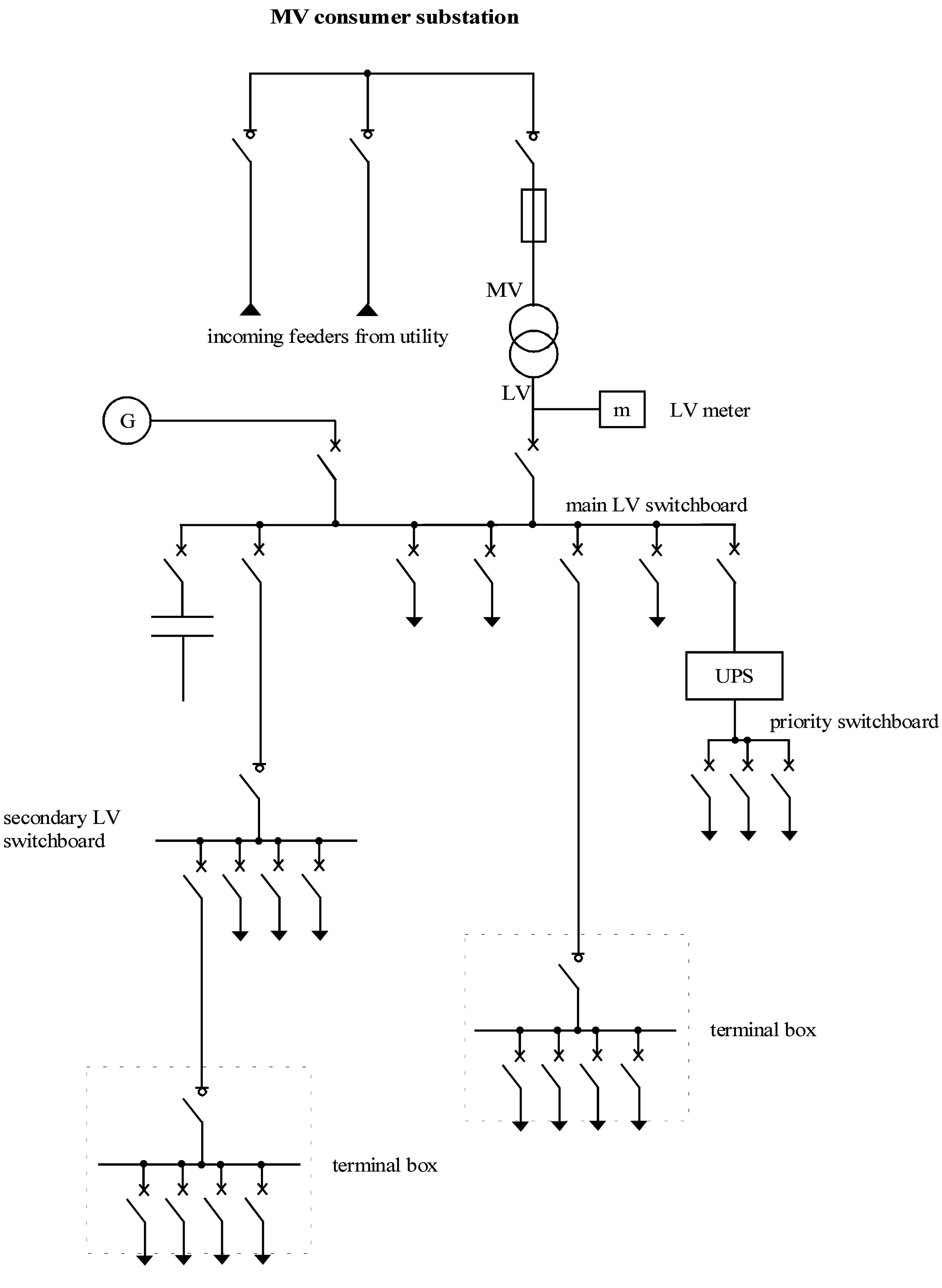


Figure 1-35: example 1

■ **example 2** (see fig. 1-36)

Network structure:

- MV consumer substation
- the main MV switchboard can be backed up by a generator set and it feeds 3 transformers
- the main low voltage switchboards MLVS1, MLVS2 and MLVS3 are independent and each one has an outgoing feeder to an uninterruptible power supply feeding a priority circuit
- the low voltage network is the arborescent radial type and the motor control centres and terminal boxes are fed by a single source.

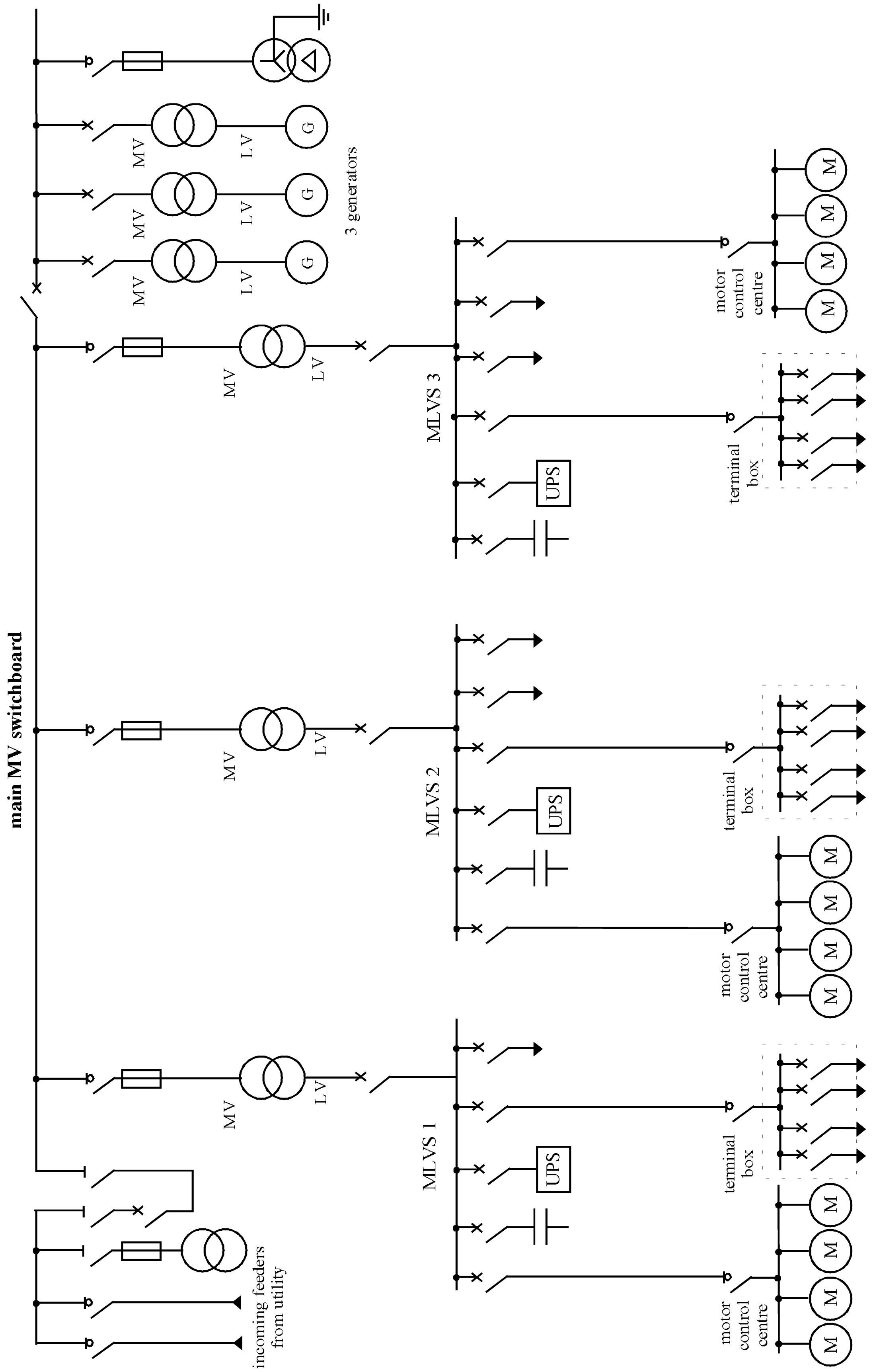


Figure 1-36: example 2

■ **example 3** (see fig. 1-37)

Network structure:

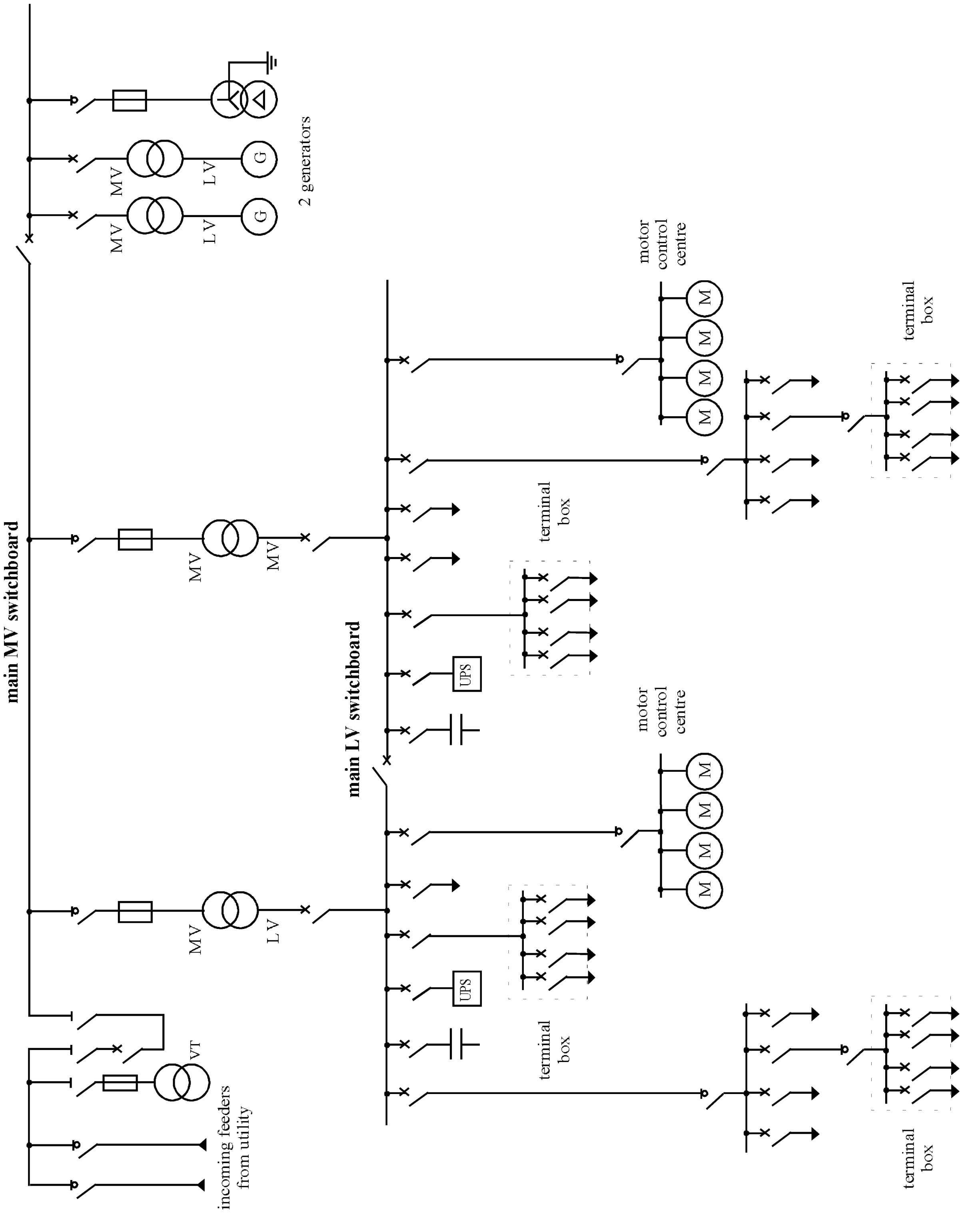
- MV consumer substation

- the main MV switchboard can be backed up by a generator set and it feeds 2 MV/LV transformers

- the main low voltage switchboard has a dual power supply with coupler

- each bus section of the main low voltage switchboard has a UPS system feeding a priority circuit

- the secondary switchboards, terminal boxes and motor control centres are fed by a single source



Dual fed switchboard with 2/3 type transfer

Figure 1-37: example 3

■ **example 4** (see fig. 1-38)

Network structure:

- MV consumer substation

- the main MV switchboard can be backed up by a generator set. It feeds two MV/LV transformers in a single line supply system, 4 MV secondary switchboards in a loop system and a secondary MV switchboard in a single line supply system

- the low voltage network is the arborescent radial type

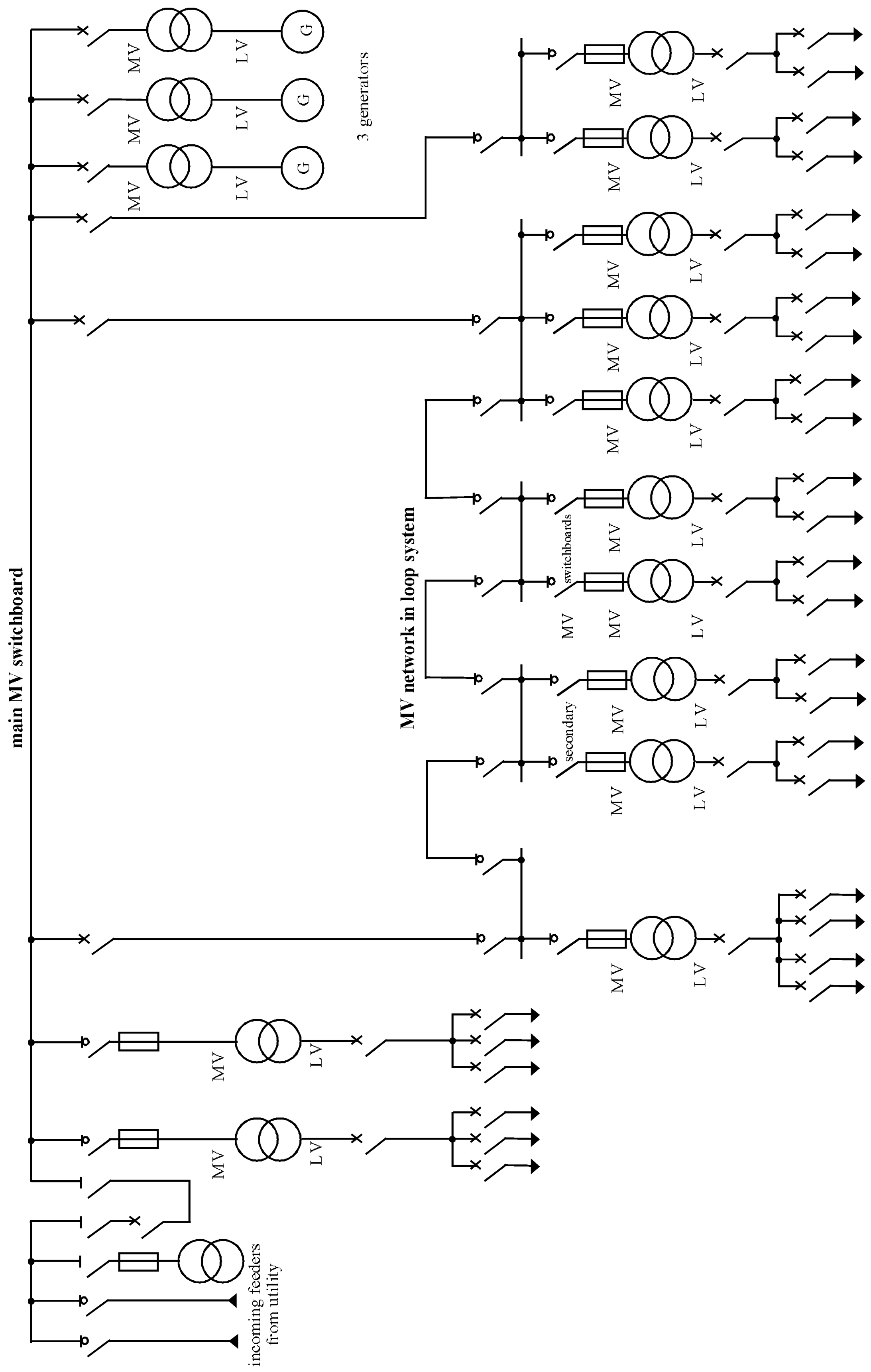


Figure 1-38: example 4

■ **example 5** (see fig. 1-39)

Network structure:

- MV consumer substation.
- two MV ratings: 20 kV and 6 kV.
- the main MV switchboard fed in 20 kV can be backed up by a set of 4 generators.

  It feeds:
  - an MV 20 kV network in a loop system comprising 3 secondary switchboards MV4, MV5 and MV6
  - two 20 kV/6kV transormers in a single line supply system

- the MV main switchboard is made up 2 bus sections fed in 6 kV by 2 sources with coupler. It feeds 3 MV secondary switchboards and two 6 kV/LV transformers in a single line supply system.
- the secondary switchboard MV2 is fed by 2 sources with coupler and is made up of 2 bus sections. It feeds two 6 kV motors and two 6kV/LV transformers in a single line supply system.
- the secondary switchboards MV1 and MV3 are fed by a single source. Each feeds a 6 kV/LV transformer and a 6 kV motor.
- the main low voltage switchboard MLVS1 can be backed up by a generator.
- the main low voltage switchboard MLVS2 is fed by 2 sources with coupler.
- the main low voltage switchboard MLVS3 is fed by a single source.
- the motor control centres 1 and 3 are fed by a single source.
- the motor control centre 2 is fed by 2 sources with no coupler.

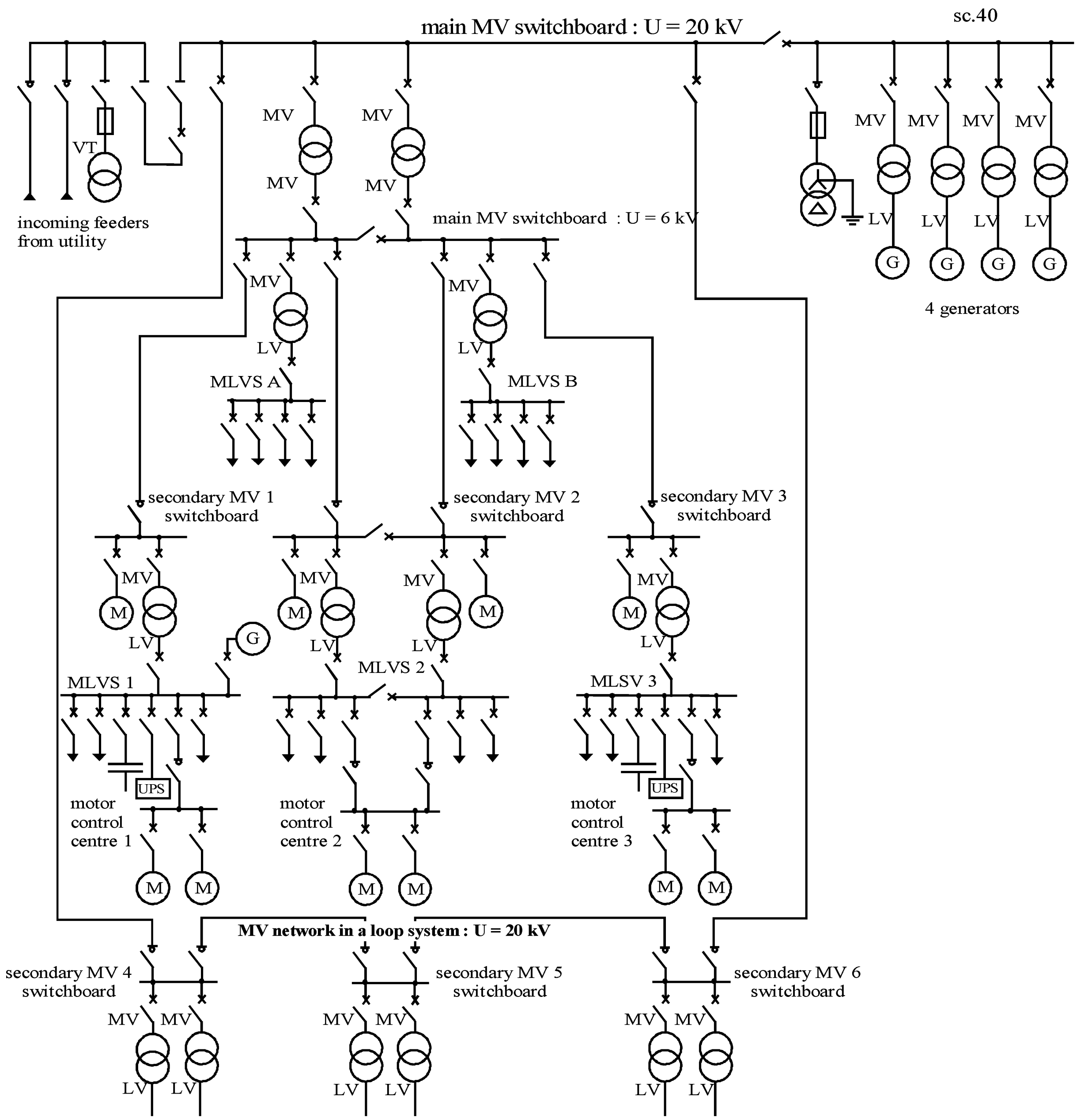


Figure 1-39: example 5

■ **example 6** (see fig. 1-40)

Network structure:

- HV consumer substation fed in 90 kV by 2 HV sources with no coupler (isolators ISO1 and ISO2 cannot operate when loaded and are in closed position during normal operation).

- the central HV/MV transformer is used as back-up. The transformers can be connected on the MV side via the circuit-breakers (moreover, the on-load tap changers allow the currents supplied by each transformer to be balanced).

- the network has two MV ratings: 20 kV and 6 kV.

- the main MV switchboard is fed in 20 kV by 3 sources with coupler. It is made up of 3 bus sections.

- the secondary switchboards MV1, MV2 and MV3 are fed in 6 kV by 2 sources (transformers) with coupler coming from 2 different busbars.

- the main low voltage switchboards MLVS1, MLVS2, MLVS3 and MLVS4 are fed by 2 sources with coupler.

- the motor control centres 1, 2, 3, and 4 are fed by 2 sources with no coupler.

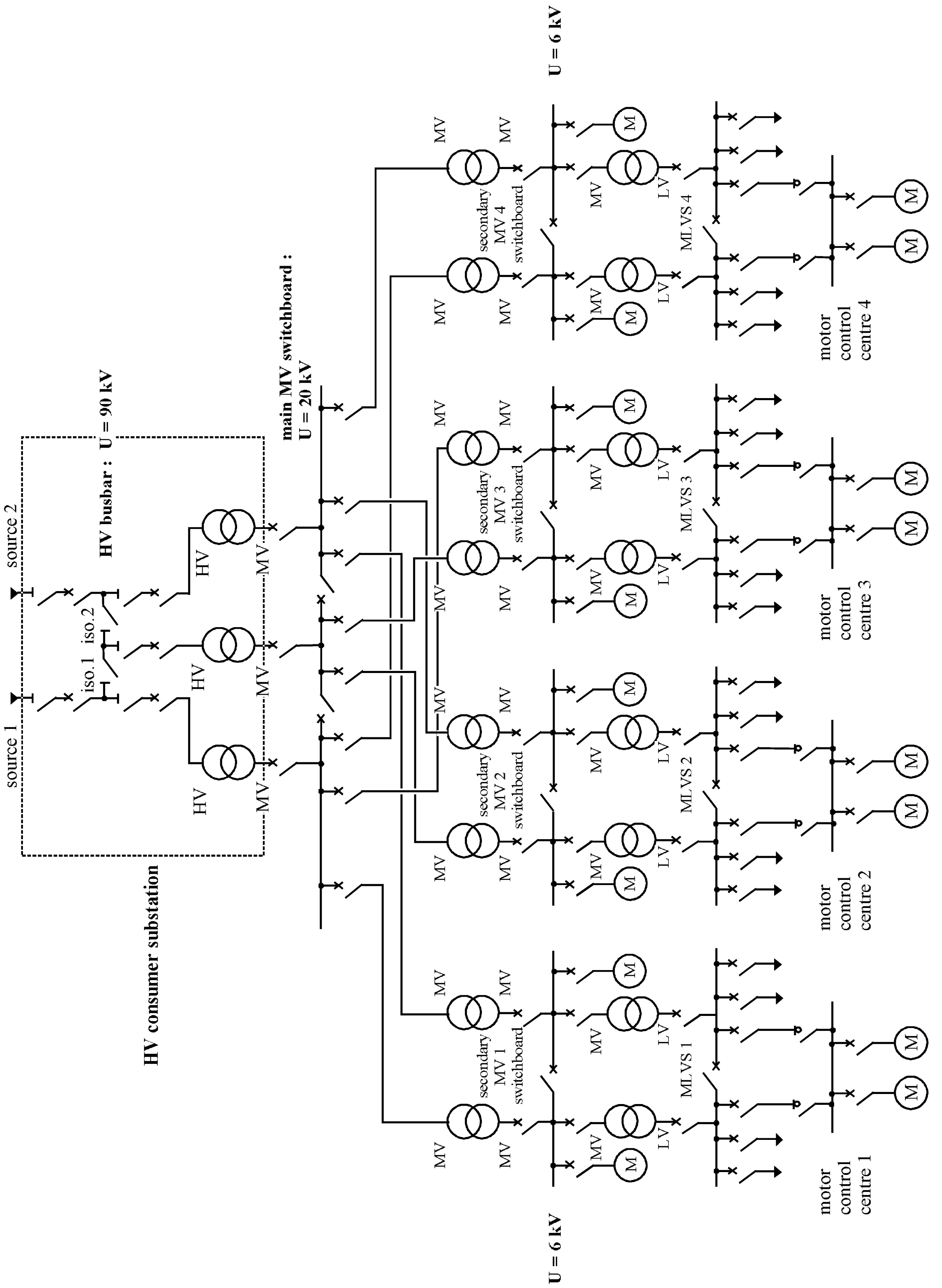


Figure 1-40: example 6

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