Chapter 1

Network Structures

Definition

Standard IEC 60038 defines voltage ratings as follows:

– *Low voltage (LV):* for a phase-to-phase voltage of between 100 V and 1,000 V, the standard ratings are: 400 V - 690 V - 1,000 V (at 50 Hz).

– *Medium voltage (MV):* for a phase-to-phase voltage between 1,000 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 will look at:

– 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 upon and divided up so that each functional aspect can be considered.

(NC) means that the switch or circuit-breaker is closed in normal conditions.

(NO) means that the switch or circuit-breaker is open in normal conditions.

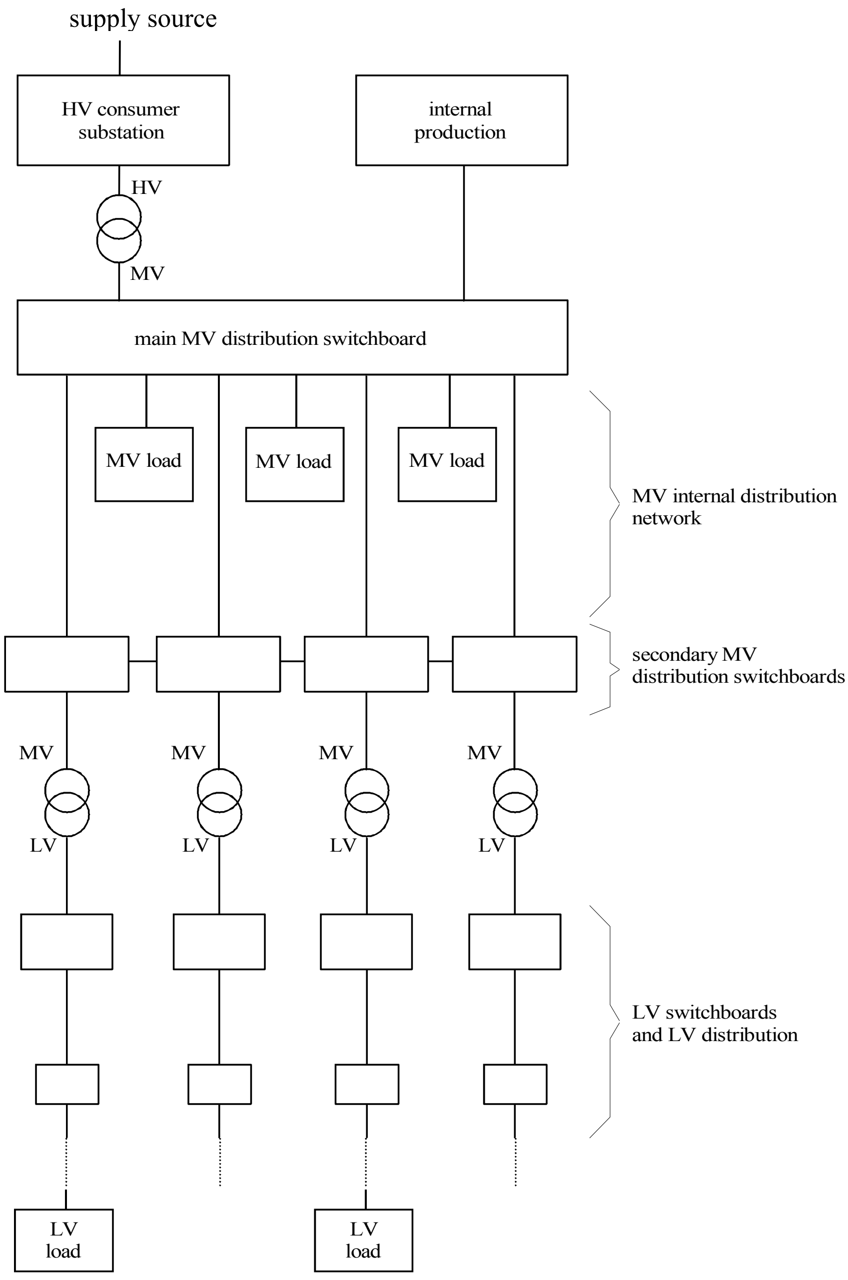

Figure 1-1: *structure of a private distribution network*

1.1. General structure of the private distribution network

Generally, with an HV power supply, a private distribution network comprises (see Figure 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 generation 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.

1.2. The supply source

The power supply of industrial networks can be LV, MV or HV. The voltage rating of the supply source depends on the consumer supply power. The greater the power required, 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 Figure 1-2)

Advantage:

– reduced cost.

Disadvantage:

– low reliability.

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

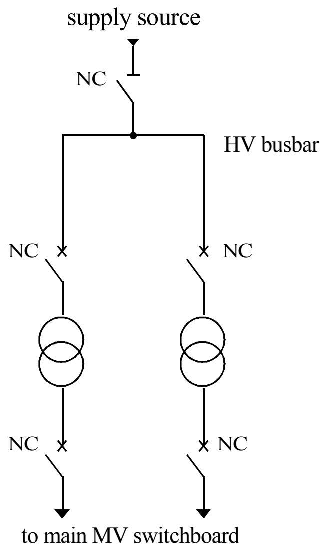

Figure 1-2: *single fed HV consumer substation*

Dual power supply (see Figure 1-3)

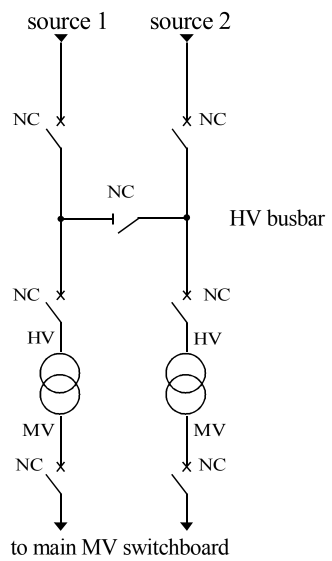

Figure 1-3: *dual fed HV consumer substation*

Operating mode:

– normal:

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

Disadvantages:

– More costly solution.

– Only allows partial operation of the busbar if maintenance is being carried out on it.

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

Dual fed double bus system (see Figure 1-4)

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.

Disadvantage:

– More costly in relation to the single busbar system.

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

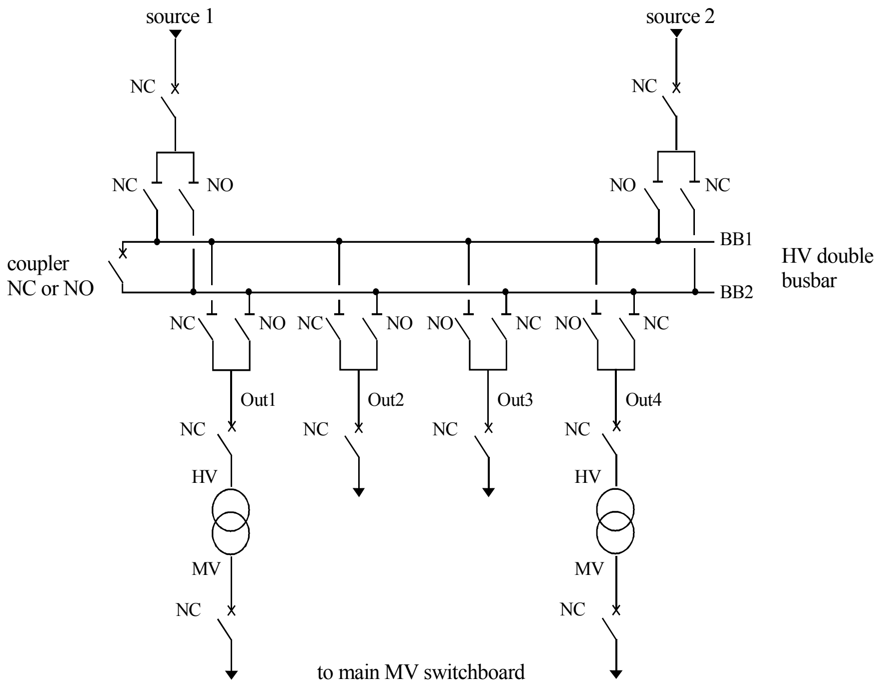

Figure 1-4: *dual fed double bus HV consumer substation*

1.4. MV power supply

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

1.4.1. *Different MV service connections*

Depending on the type of MV network, the following supply arrangements are commonly adopted.

Single line service (see Figure 1-5)

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

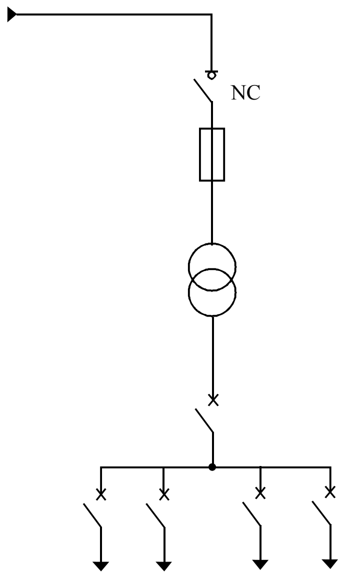

Figure 1-5: *single line service*

Ring main principle (see Figure 1-6)

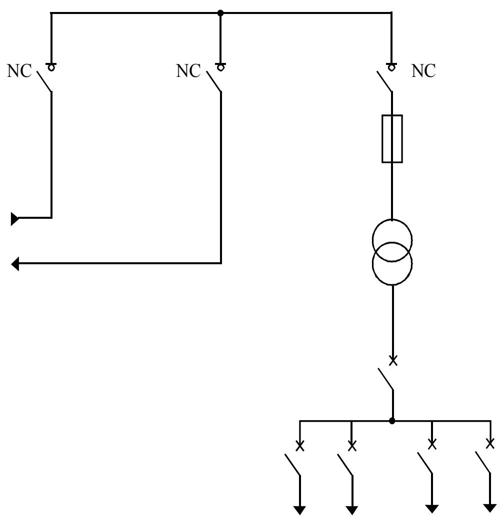

Figure 1-6: *ring main service*

Ring main units (RMU) are normally connected to form an MV ring main or loop (see Figures 1-20a and 1-20b).

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

Parallel feeder (see Figure 1-7)

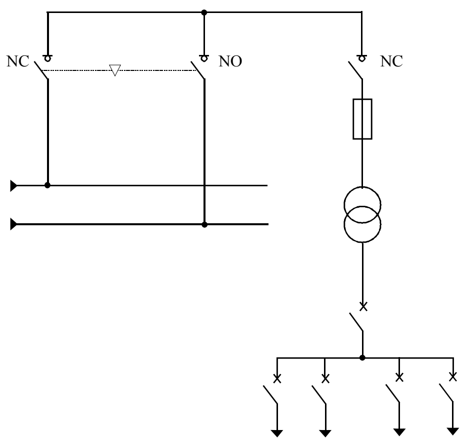

Figure 1-7: *duplicated supply service*

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 (see Figure 1-21).

The main operational difference between this arrangement and that of an RMU is that the two incoming switches are mutually interlocked, in such a way 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 section 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.

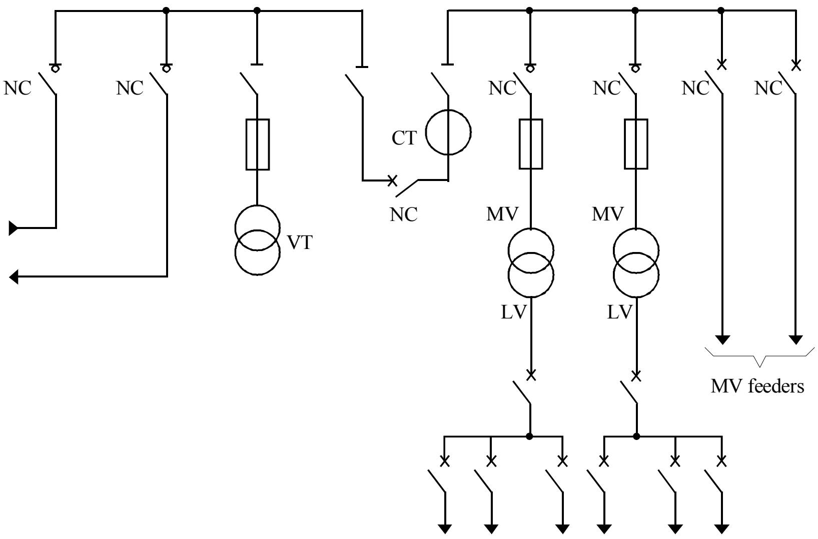

Figure 1-8: *example of MV consumer substation*

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 Figure 1-9)

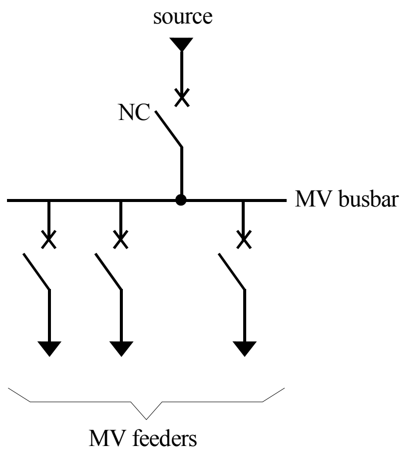

Figure 1-9: *1 busbar, 1 supply source*

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 Figure 1-10)

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.

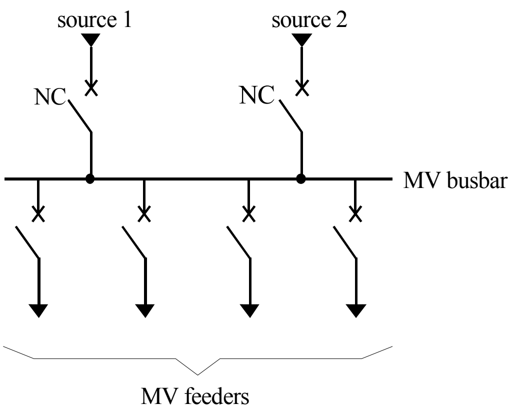

Figure 1-10: *1 busbar with no coupler, 2 supply sources*

2 bus sections with coupler, 2 supply sources (see Figure 1-11)

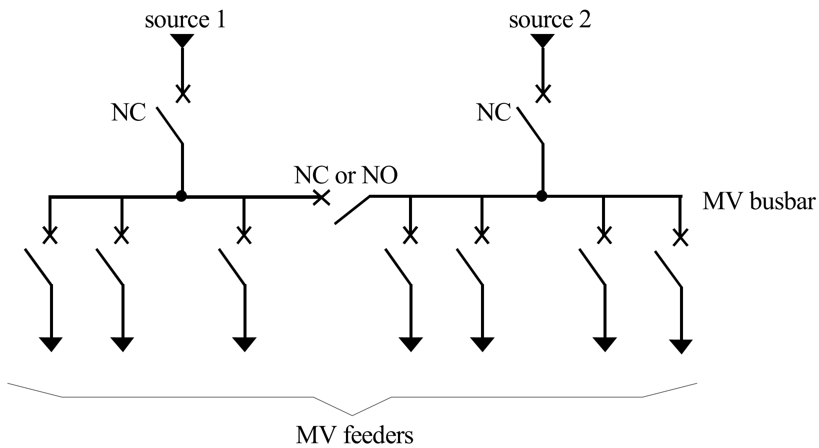

Figure 1-11: *2 bus sections with coupler, 2 supply sources*

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 in 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 Figure 1-12)

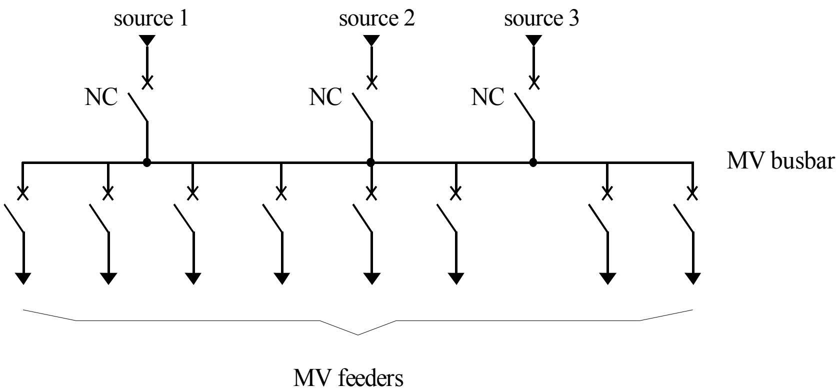

Figure 1-12: *1 busbar with no coupler, 3 supply sources*

Operation: the power supply is normally 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 Figure 1-13)

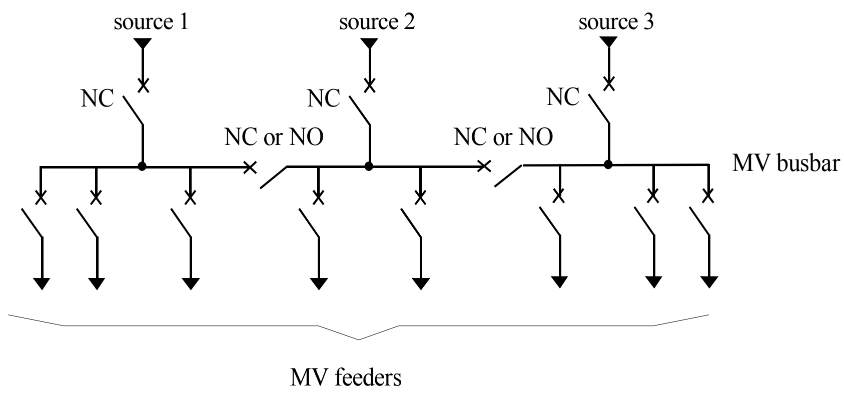

Figure 1-13: *3 bus sections with couplers, 3 supply sources*

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 two 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 Figure 1-14)

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 opened and the other busbar feeds all the outgoing feeders.

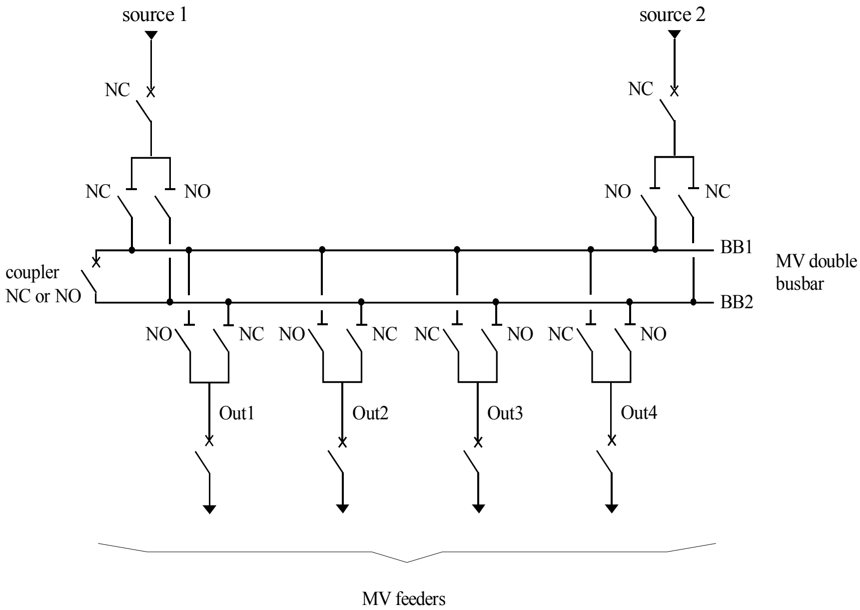

Figure 1-14: *2 busbars, 2 connections per outgoing feeder, 2 supply sources*

2 interconnected double busbars (see Figure 1-15)

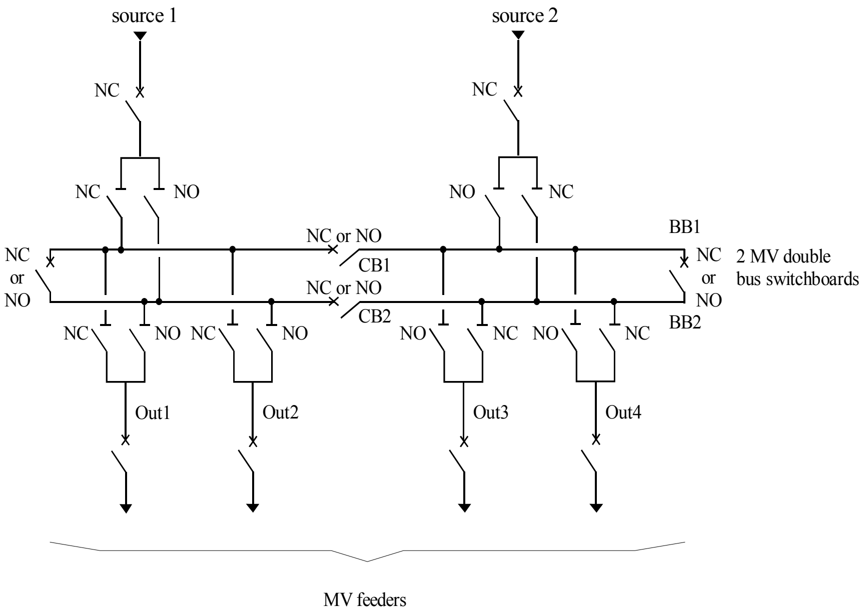

Figure 1-15: *2 interconnected double busbars*

Operation: this arrangement is almost identical to the previous one (two busbars, two connections per feeder, two 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 Figure 1-16)

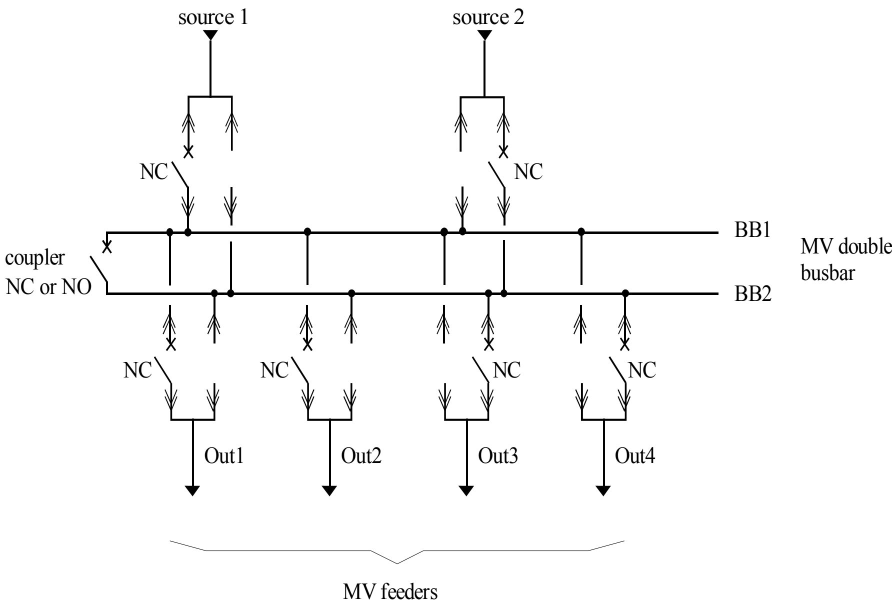

Figure 1-16: *"duplex" distribution system*

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 opened 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.

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 structures 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 Figure 1-17)

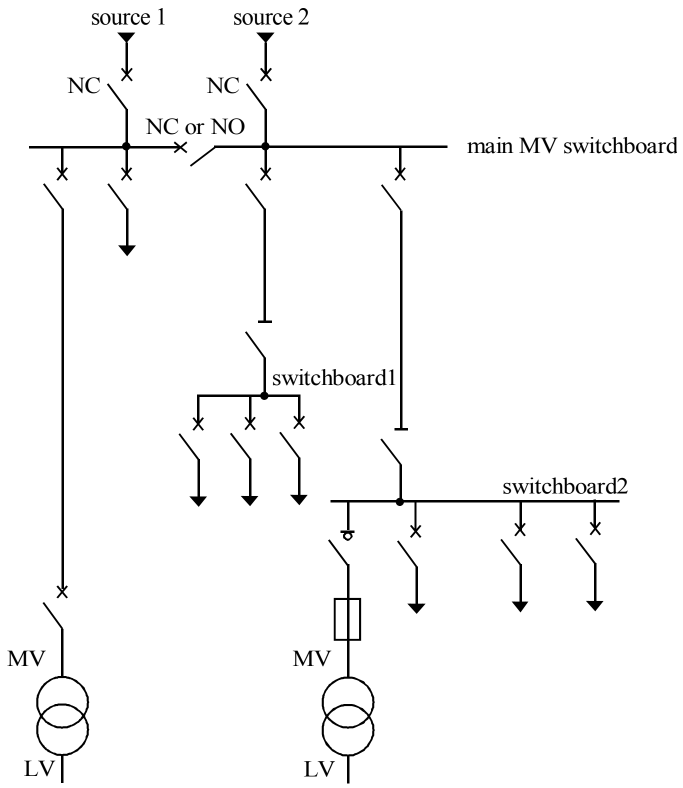

Figure 1-17: *MV single fed radial network*

– 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 vital requirement and it is often adopted for cement works networks.

Dual fed radial network with no coupler (see Figure 1-18)

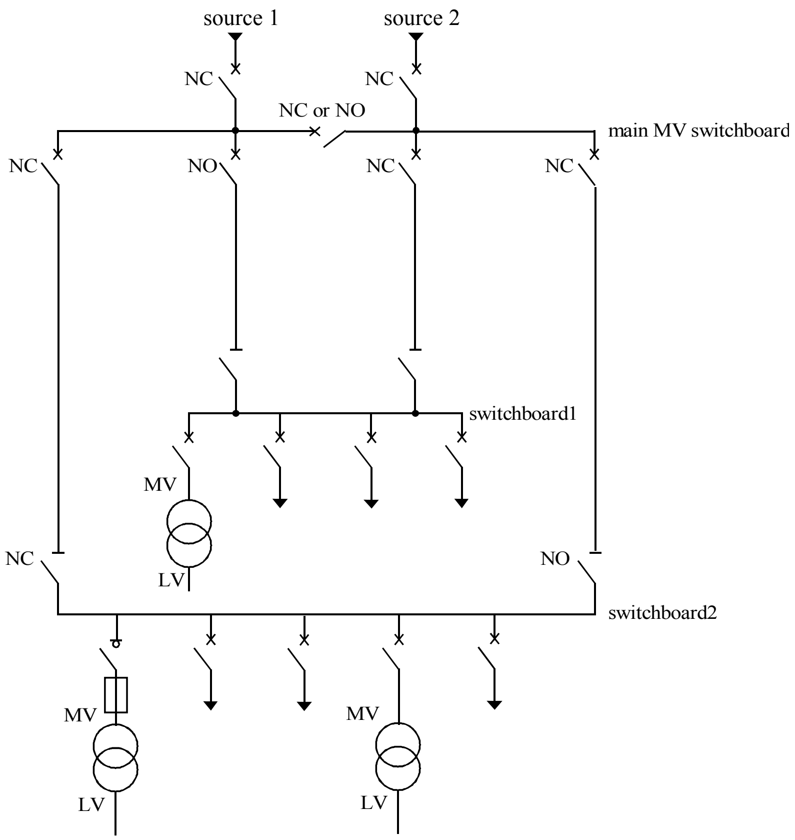

Figure 1-18: *MV dual fed radial network with no coupler*

– The main switchboard is fed by two sources with coupler.

– Switchboards 1 and 2 are fed by two 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 Figure 1-19)

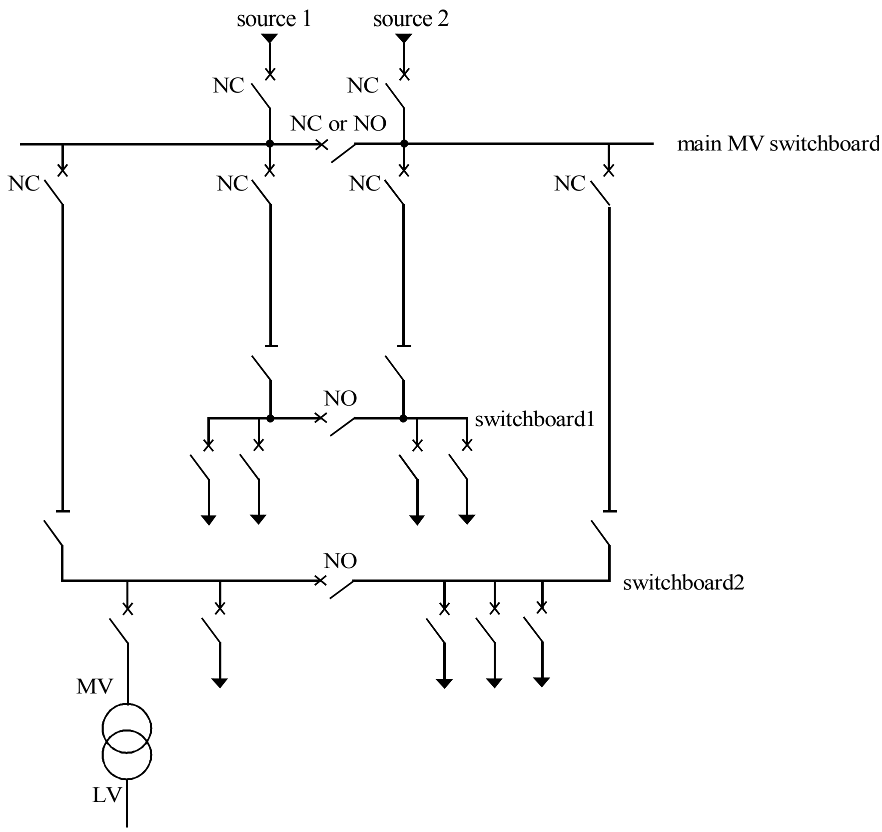

Figure 1-19: *MV dual fed radial network with coupler*

– 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 Figure 1-20a)

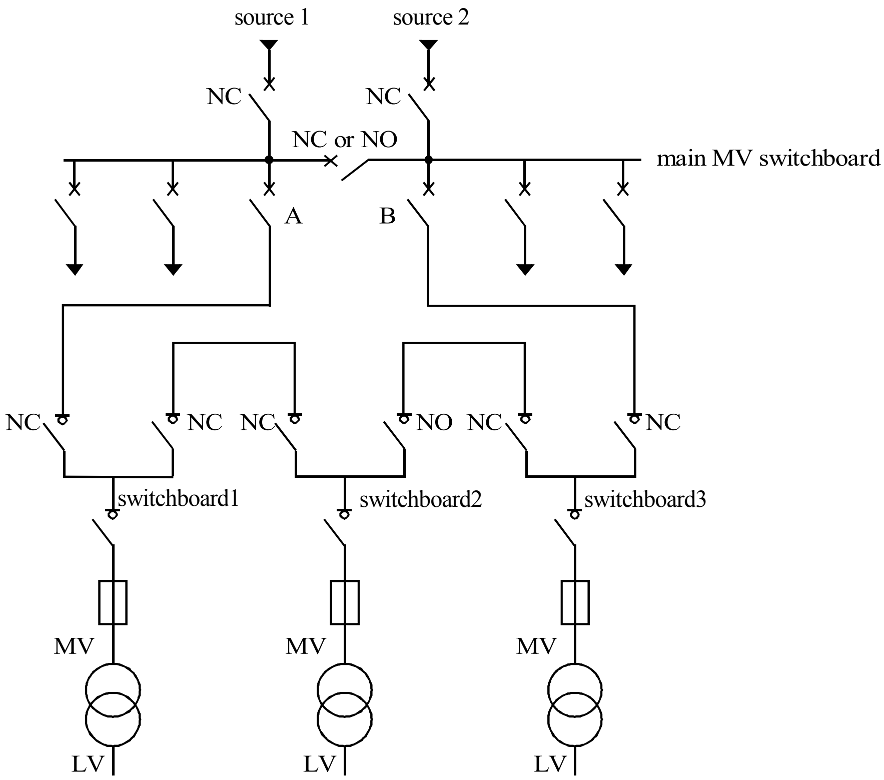

Figure 1-20a: *MV open loop system*

– The main switchboard is fed by two 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* (in 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 section 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 for at least several minutes or dozens of minutes if the loop reconfiguration is carried out manually by operators.

Closed loop (see Figure 1-20b)

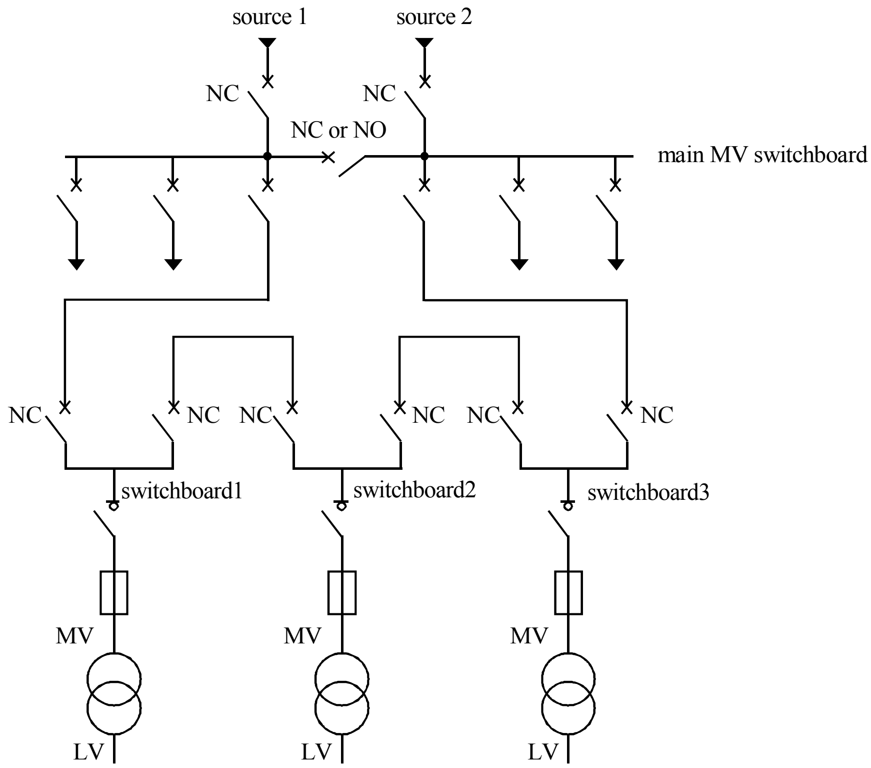

Figure 1-20b: *MV closed loop system*

– 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 caused by a fault (see section 10.1.8).

This system is more efficient than the open loop system because it avoids power cuts. However, it is more costly since it requires circuit-breakers in each switchboard and a complex protection system.

Parallel feeder (see Figure 1-21)

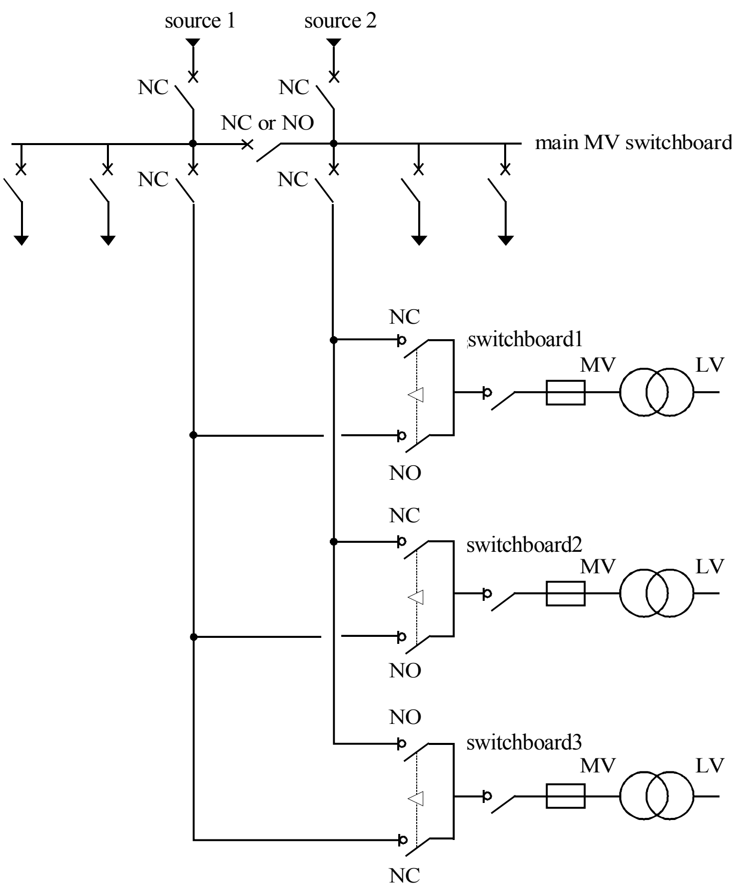

Figure 1-21: *MV parallel feeder network*

– 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 that require good supply continuity.