COURSE 4

The function of a LV “mains” distributor is to provide service connections (underground cable or overhead line) to a number of consumers along its route.
The current-rating requirements of distributors are estimated from the number of consumers to be connected and an average demand per consumer.
The two principal limiting parameters of a distributor are:

- The maximum current which it is capable of carrying indefinitely, and
- The maximum length of cable which, when carrying its maximum current, will not exceed the statutory voltage-drop limit

The characteristics at the point of supply that are provided to the customer are not the same as those characteristics used in the installation design process. Under abnormal running or fault conditions the operating conditions and the supply characteristics may change.

1. Determination of circulating powers in LV installations

The installed capacity of a power system is the total nominal active power of all the system’s station generators (the same definition is applicable to the installed capacity of all the electric power stations in a given country).

The installed power is the sum of the nominal powers of all power-consuming devices in the installation, at at rated voltage and frequency. This is not the power to be actually supplied in practice. The installed power (the nominal active power of the consumer specified in the wiring diagram, in the rating plate or in receivers’ technical book) is:

$$P_n = S_n \cdot \cos\varphi_n \qquad \text{- For electric oven's transformes} \qquad (1)$$

For receivers having an intermittent periodically operating mode, rated power under short-term refers to the long-term operation:

$$P_n = P_{n/p} \cdot \sqrt{DA} \qquad (2)$$

where $P_{n/p}$ is the rated power under intermittent periodically operating mode and DA - subunitary – is the relative active duration of the cycle.
For welding transformers, rated power relative to long-term regime has the expression:

$$P_n = S_n \cdot \cos\varphi_n \cdot DA \qquad (3)$$

For electric motors, power in kW stated on the plate is the mechanical shaft power (electrical power drawn from the grid is obtained by dividing nominal power to nominal yield). The input power consumption will evidently be greater:

$$P_{el}=P_n/\eta_n \qquad (4)$$

The installed power for a group of receivers is the sum of all rated powers related to the long-term regime (DA=1) of all the receivers that can simultaneously operate:

$$P_i = \sum_{k=1}^{n} P_{ik} \qquad (5)$$

When determining of the installed power, monophase receivers uniformly distributed on phases are considered three-phased. In the case when the loading of one phase exceeds with 15% the loading of other phases, the three-phase power input of the network is calculated from the relation:

$$P_i^{(3)} = 3 \cdot P_{i\max}^{(1)} \quad (6)$$

Where $P^{(1)}_{i\ max}$ is the installed power on the highest loaded phase. There are not considered the powers of receivers mounted in reserve installations (backup systems) or powers of equipments with incidental operating (eg fire pumps).

Determination of absorbed power is essential for designing economical and safe operation of electrical systems, within the correct limits of heating and voltage drop. It depends on a **factor of maximum utilization** (ku) and on a **factor of simultaneity** (ks), according to relation:

$$k_s = \frac{P_{sim}}{P_i} \text{ și } k_u = \frac{P_{real}}{P_i} \quad (7)$$

Where P_{sim} is power consumption in simultaneously operation of receivers and P_{real} is the metered consumed power.

House structure	Installed power	ku	ks
one room apartment (and outbuildings)	8 kW	0.65	1
2-3 rooms apartment (and outbuildings)	12kW	0.5	1
4-5 rooms apartment (and outbuildings)	20kW	0.3-0.5	1
House with more than 5 rooms (and outbuildings)	25kW	0.6	0.9
House with more than 5 rooms (and outbuildings) with self providing electric hot water and cooking	30kW	0.65	0.9
House with more than 5 rooms (and outbuildings) with self providing electric hot water, heating and cooking	35kW	0.65	0.83

Factor of maximum utilization must be applied to each individual load, with particular attention to electric motors, which are very rarely operated at full load. In an industrial installation this factor may be estimated on an average at 0.75 for motors. For lighting installations, ku=1.

As there is always some degree of diversity of receivers, is taken into account a simultaneity factor for estimating purposes. ks is applied to each group of loads (e.g. being supplied from a distribution or sub-distribution board). The determination of these factors is the responsibility of the designer, since it requires a detailed knowledge of the installation and the conditions in which the individual circuits are to be exploited. For this reason, it is not possible to give precise values for general application.

Number of downstream consumers	Factor of simultaneity (ks)
2 to 4	1
5 to 9	0.78
10 to 14	0.63
15 to 19	0.53
20 to 24	0.49
25 to 29	0.46
30 to 34	0.44
35 to 39	0.42
40 to 49	0.41
50 and more	0.40

If there is a distribution board supplying a number of circuits for which there is no indication of the manner in which the total load divides between them, hypothetical values of ks are:

Number of circuits	Factor of simultaneity (ks)
2 and 3	0.9
4 and 5	0.8
6 to 9	0.7
10 and more	0.6

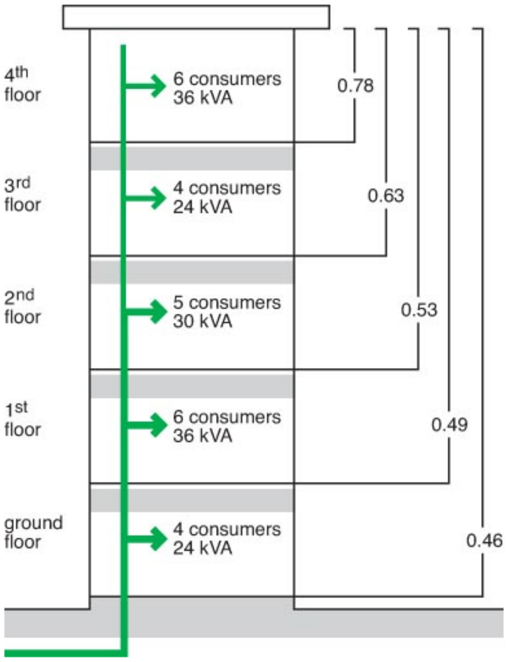


Figure 1 - Application of the factor of simultaneity (ks) to an apartment block of 5 storeys

Factors ku and ks allow the determination of the maximum power and apparent power demand required to dimension the electrical grid. In the case of consumers using electrical heat-storage units for space heating, a factor of 0.8 is recommended, regardless of the number of consumers.

Absorbed power (consumed power) for households is determined by the relation (8) and for industrial customers (including commercial buildings, socio-cultural and administrative) with equation (9):

$$P_a = P_i \cdot k_u \cdot k_s \quad (8) \qquad \text{and} \qquad P_a = P_i \cdot k_u \quad (9)$$

The power demand (kW) is necessary to choose the rated power of a generating set or battery, and where the requirements of a prime motor have to be considered.

For a power supply from a LV public-supply network, or through a MV/LV transformer, the significant quantity is the apparent power in kVA.

The installed apparent power is commonly assumed to be the arithmetical sum of the kVA of individual loads. The maximum estimated kVA to be supplied however is not equal to the total installed kVA.

The apparent-power demand of a load (which might be a single appliance) is obtained from its nominal power rating (corrected if necessary, as noted above for motors, etc.) and the application of the following coefficients:

η = the per-unit efficiency = output kW / input kW

cos φ = the power factor = kW / kVA

COURSE 5

2. Electrical installation design methodology

In order to design an installation, the actual maximum load demand likely to be imposed on the power-supply system must be assessed. To base the design simply on the arithmetic sum of all the loads existing in the installation would be extravagantly uneconomical, and bad engineering practice.

The aim of this chapter is to show how some factors taking into account the diversity (non simultaneous operation of all appliances of a given group) and utilization (e.g. an electric motor is not generally operated at its full-load capability, etc.) of all existing and projected loads can be assessed.

In addition to provide basic installation-design data on individual circuits, the results will provide a global value for the installation, from which the requirements of a supply system (distribution network, MV/LV transformer, or generating set) can be specified.

The main methods of determining the required power in the design phase are:

- Method of demand coefficients, applicable at any level, and especially for large groups of receivers, representing a sector or a company;
- Binomial formula method (which gives results coveringing a small group of receivers with powers far different between them) is recommended to calculate the power demand especially on the switchboards (=distribution boards);
- Direct analysis method, applicable to a small number of receivers, at the level of distribution panels with fewer outgoing circuits, with known operating diagrams and loading charts of all receivers;
- Methods based on specific reporting consumption per unit of product or productive unit area - have reduced precision;
- Methods based on average power and indicators of load curves, recommended to determine the power required at higher levels, from bars of low voltage transformer stations to jonction with high voltage network.

In existing installations, the power required (load demand) is determined based on load curves.

The choice of **distribution architecture** has a decisive impact on installation performance throughout its lifecycle:

- right from the construction phase, choices can greatly influence the installation time, possibilities of work rate, required competencies of installation teams, etc.
- there will also be an impact on performance during the operation phase in terms of quality and continuity of power supply to sensitive loads, power losses in power supply circuits,
- and lastly, there will be an impact on the proportion of the installation that can be recycled in the end-of-life phase.

The process of choosing the proper architecture is rendered below:

1. establish the installation characteristics:

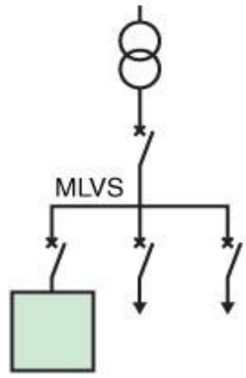
- Main economic activity carried out
- Architectural characteristic of the building(s), taking account of the number of buildings, number of floors, and of the surface area of each floor (=Site topology).
- Constraints in terms of the layout of the electrical equipment in the building
- The ability of a power system to meet its supply function under stated conditions for a specified period of time. (=realiability)

- Features input during design to limit the impact of maintenance actions on the operation of the whole or part of the installation (=maintainability)
- Possibility of easily moving electricity delivery points within the installation, or to easily increase the power supplied at certain points. Flexibility is a criterion which also appears due to the uncertainty of the building during the pre-project summary stage (=flexibility)
- The maximum power which can be consumed at a given time for the installation, with the possibility of limited overloads that are of short duration (power demand - kVA).
- The uniformity of load distribution (in kVA / m²) over an area or throughout the building (load distribution).
- Power interruption and disturbance sensitivity (critical consumers)
- The ability of a circuit to disturb the operation of surrounding circuits due to phenomena such as: harmonics, in-rush current, imbalance, High Frequency currents, electromagnetic radiation, etc. (disturbance capability of circuits);
- Other constrains of environment or claims of the beneficiary.

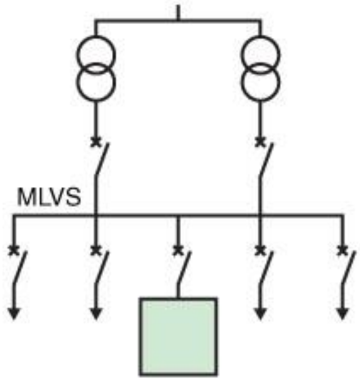
2. establish the architecture details:

This involves defining the electrical installation in more detail. It is based on the results of the previous step, as well as on satisfying criteria relative to implementation and operation of the installation. The process loops back into step1 if the criteria are not satisfied. An iterative process allows several assessment criteria combinations to be analyzed. At the end of this step, we have a detailed single-line diagram. The main possible configurations of LV installations are:

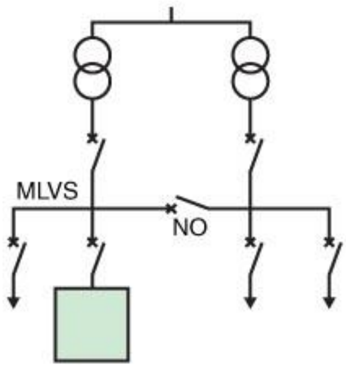
- Radial single feeder configuration: This is the reference configuration and the most simple. A load is connected to only one single source. This configuration provides a minimum level of availability, since there is no redundancy in case of power source failure.



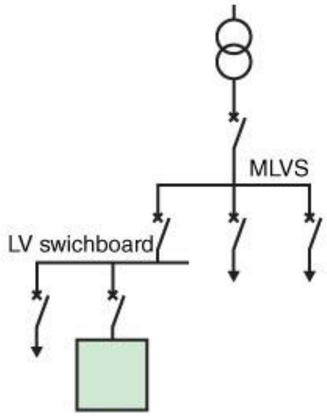
- Two-pole configuration: The power supply is provided by 2 transformers, connected to the same MV line. When the transformers are close, they are generally connected in parallel to the same MLVS= Main Low Voltage Switchboard.



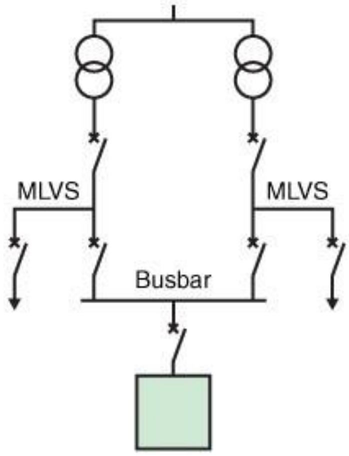
- Variant: two-pole with two ½ MLVS: In order to increase the availability in case of failure of the busbars or authorize maintenance on one of the transformers, it is possible to split the



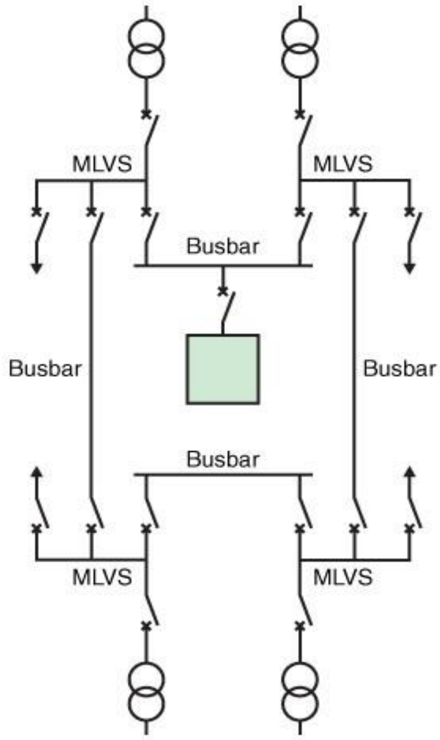
MLVS into 2 parts, with a normally open link (NO). This configuration generally requires an Automatic Transfer Switch, (ATS).



- Shedable switchboard (simple disconnectable attachment): A series of shedable circuits can be connected to a dedicated switchboard. The connection to the MLVS is interrupted when needed (overload, generator operation, etc).



- Interconnected switchboards: If transformers are physically distant from one another, they may be connected by a bus bar trunking. A critical load can be supplied by one or other of the transformers. The availability of power is therefore improved, since the load can always be supplied in the case of failure of one of the sources.
  The redundancy can be:
  - Total: each transformer being capable of supplying all of the installation,
  - Partial: each transformer only being able to supply part of the installation. In this case, part of the loads must be disconnected (load-shedding) in the case of one of the transformers failing.

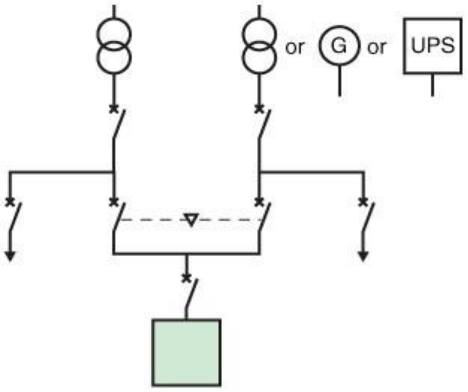


- Ring configuration: This configuration can be considered as an extension of the configuration with interconnection between switchboards. Typically, 4 transformers connected to the same MV line, supply a ring using busbar trunking. A given load is then supplied power by several clustered transformers. This configuration is well suited to extended installations, with a high load density (in kVA/m^2). If all of the loads can be supplied by 3 transformers, there is total redundancy in the case of failure of one of the transformers. In fact, each busbar can be fed power by one or other of its ends. Otherwise, downgraded operation must be considered (with partial load shedding). This configuration requires special design of the protection plan in order to ensure discrimination in all of the fault circumstances.

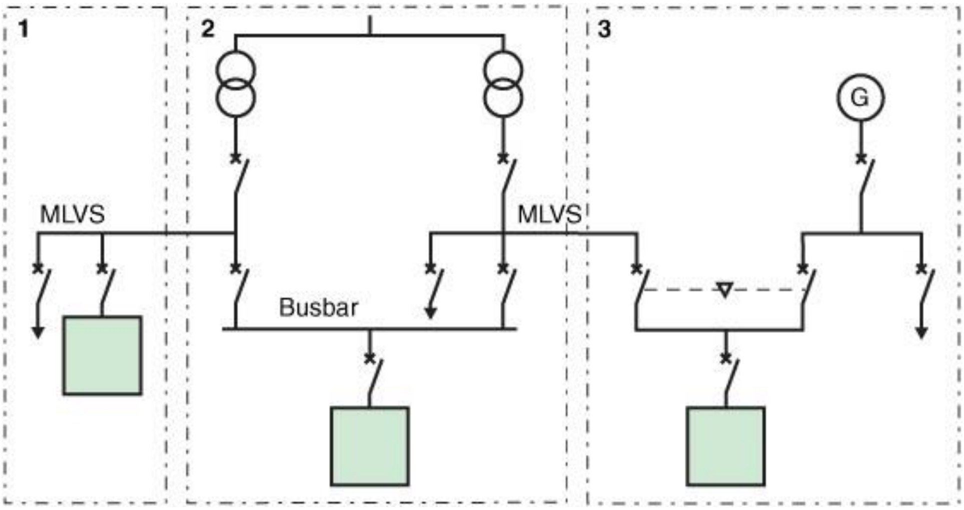
- Double-ended power supply: This configuration is implemented in cases where maximum availability is required. The principle involves having 2 independent power sources, e.g.:
  - 2 transformers supplied by different MV lines,

- 1 transformer and 1 generator,
- 1 transformer and 1 UPS.

An automatic transfer switch (ATS) is used to avoid the sources being parallel connected. This configuration allows preventive and curative maintenance to be carried out on all of the electrical distribution system upstream without interrupting the power supply.



- Configuration combinations: An installation can be made up of several sub-asssemblies with different configurations, according to requirements for the availability of the different types of load. E.g.: generator unit and UPS, choice by sectors (some sectors supplied by cables and others by busbar trunking).



1: Single feeder, 2: Switchboard interconnection, 3: Double-ended

3. establish the equipment:

The choice of equipment to be implemented is carried out in this stage, and results from the choice of architecture. The choices are made from the manufacturer catalogues, in order to satisfy certain criteria. This stage is looped back into step 2 if the characteristics are not satisfied.

4. assessment:

This assessment step allows the Engineering Office to have figures as a basis for discussions with the customer and other players.