COURSE 7

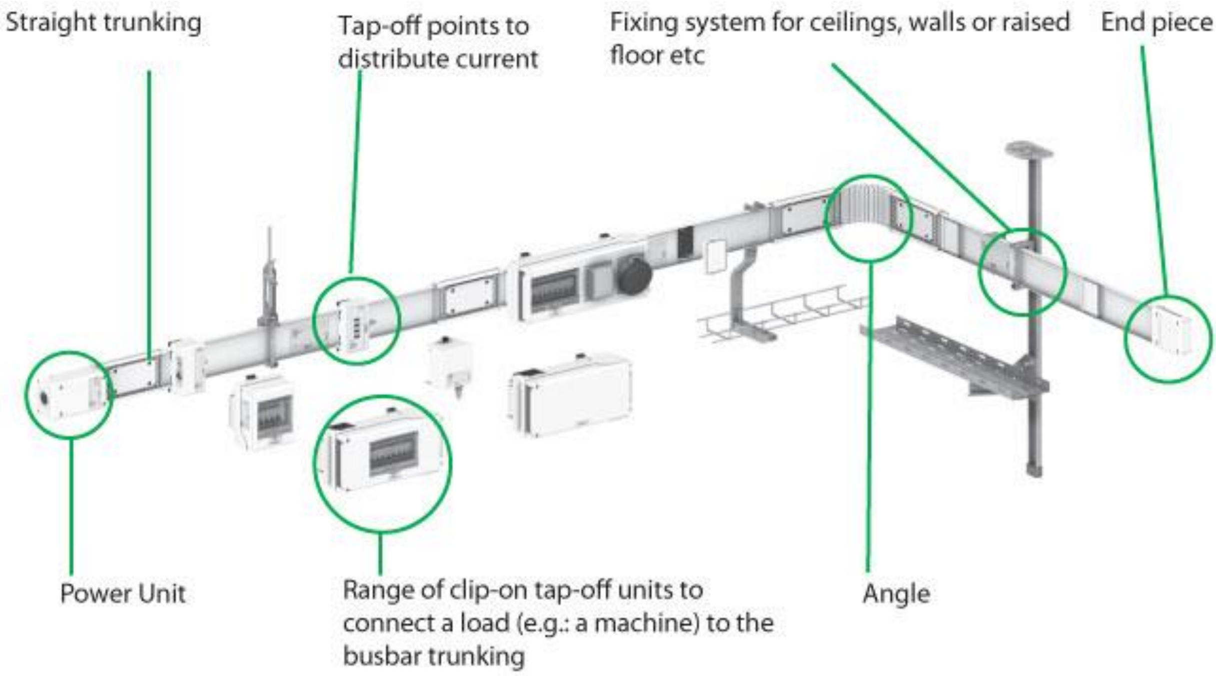
**DIMENSIONING SUPPLY BUS BARS. LOAD AND PEAK CURRENT CALCULATION**

**1. Three-phased bus bars** *(coloane de alimentare)* **for power distribution boards**

A bus bar is a strip or bar of copper, brass or aluminum that conducts electricity within a switchboard, distribution board, substation, battery bank, or other electrical apparatus. Its main purpose is to conduct a substantial current of electricity, and not to function as a structural member.

The cross-sectional size of the bus bar determines the maximum amount of current that can be safely carried. Buss bars can have a cross-sectional area of as little as 10 $mm^2$, but electrical substations may use metal tubes 50 mm in diameter (20 $cm^2$) or more as bus bars.

Busbar Trunking System[1] is a prefabricated electrical distribution system consisting of bus bars in a protective enclosure, including straight lengths, fittings, devices and accessories.




A bus bar can supply one or more electrical distribution boars.

a) the load current for a bus bar supplying a single group of receivers can be estimated with:

- demand coefficients method, according to which:

$$I_{col} = \left(k_c + \frac{1-k_c}{k_a}\right)\frac{P_i}{\sqrt{3}U_n \cos\varphi_m}$$

1. Sistemele de distribuție în **bare capsulate** din Aluminiu sau Cupru, încapsulate în carcase din aluminiu sau oțel cu grad de protecție de la IP00 la IP55 (IP68 pentru aplicații speciale – industria petro-chimică, submersibile etc) se caracterizează prin modularitate. Elementele componente (tronsoane de bare, ferestre de conexiune, cutii de conexiune, unități de alimentare și de închidere, console de suspendare etc) pot fi îmbinate într-o manieră flexibilă, adecvată oricărei aplicații. Fiecare cutie de conexiune poate fi montată/demontată în timp ce sistemul este sub tensiune.

$P_i = \sum_{j=1}^{s} P_{nj}$ is the sum of installed power of all considered receivers [W]

$k_c$ is the average demand coefficient of the group;
*cos* $\phi_m$ is the average power factor of the group;
$k_a$ is an influence coefficient of the number of receivers in the group (extracted from special tables called nomograms).

- Load current coefficients method, according to which:

$$I_{col} = \alpha P_x + \beta P_{s-x}$$

Where α, β, x are tabular given coefficients, depending on the category of receivers;

$P_x = \sum_{j=1}^{x} P_{nj}$ is the sum of rated powers of the first *x* receivers, taken in decreasing order of powers;

$P_{s-x} = \sum_{j=x+1}^{s} P_{nj}$ is the sum of rated powers of remained receivers.

In case of squirrel cage induction motors (when is considered cos $\varphi_m$ = 0.5), the resulting value for $I_{col}$ will increase by 30%. This method is recommended for groups of three-phased receivers - with line voltage of 400 V, so is applicable up to switchboards, not to the substation.

If the considered bus bar supplies several groups of receivers, then the total current required is:

$$I_{ct} = \sum_{j=1}^{k} \left(I_{col}\right)_j \quad [A]$$

b) the peak current $I_{v\ col}$ for a single group with a known number of receivers that simoultaneously start is:

$$I_{v\ col} = \sum_{j=1}^{l} \left(I_{pm}\right)_j + \sum_{j=l+1}^{s} \left(I_{cm}\right)_j \quad [A]$$

And if this number is not known, then:

$$I_{v\ col} = I_c + \left(I_{pm}\right)_{max} - \left(I_{cm}\right)_{max} \quad [A]$$

For „k” groups of receivers, to which the number of receivers simoultaneously starting is known, and the total number of receivers is *„p = k·s”*, the peak total current will be:

$$I_{vt} = \sum_{j=1}^{l} \left(I_{pm}\right)_j + \sum_{j=l+1}^{p} \left(I_{cm}\right)_j \quad [A]$$

And if this numbers is not known, then:

$$I_{vt} = I_{ct} + \left(I_{pm}\right)_{max} - \left(I_{cm}\right)_{max} \quad [A]$$

*Obs.:* Ampacity is defined as the maximum amount of electrical current a conductor or device can carry before sustaining immediate or progressive deterioration. Is a term used only in North America.

### 1.1. Design and placement

Bus bars are typically either flat strips or hollow tubes, as these shapes allow heat to dissipate more efficiently due to their high surface area to cross-sectional area ratio. The skin effect (where an AC bus bar system is concerned, the resistance is increased because current density is increased near the outer surface of the conductor and reduced in the middle) makes 50–60 Hz AC bus bars more than about 8 mm thickness inefficient, so hollow or flat shapes are prevalent in higher current applications.

The current-carrying capacity of a busbar is limited by the maximum acceptable working temperature of the system, taking into account the properties of the conductor material, the materials used for mounting the bars and the limitations of any cables (including their insulation) or devices connected to the bars.

There are two design limits:

- the maximum permitted temperature rise, as defined by switchgear standards
- the maximum temperature rise consistent with lowest lifetime costs - in the vast majority of cases, the maximum temperature dictated by economic considerations will be rather lower than that permitted by standards.

A hollow section has higher stiffness than a solid rod of equivalent current-carrying capacity, which allows a greater span between bus bar supports in outdoor switchyards.

A bus bar must be sufficiently rigid to support its own weight, as well as forces imposed by mechanical vibration and possibly earthquakes, as well as accumulated precipitation in outdoor exposures. In addition, thermal expansion from temperature changes induced by ohmic heating and ambient temperature variations, and magnetic forces induced by large currents must be considered.

Bus bars are typically contained inside switchgear, panel boards, or busway enclosures. Distribution boards split the electrical supply into separate circuits at one location. Busways, or bus ducts, are long busbars with a protective cover. Rather than branching from the main supply at one location, they allow new circuits to branch off anywhere along the route of the busway.

A bus bar may either be supported on insulators, or else insulation may completely surround it. Busbars are protected from accidental contact either by a metal earthed enclosure or by elevation out of normal reach. Power Neutral busbars may also be insulated. Earthing (safety grounding) busbars are typically bare and bolted directly onto any metal chassis of their enclosure. Busbars may be enclosed in a metal housing, in the form of bus duct or busway, segregated-phase bus, or isolated-phase bus.

Busbars may be connected to each other and to electrical apparatus by bolted, clamped, or welded connections. Often, joints between high-current bus sections have precisely-machined matching surfaces that are silver-plated to reduce the contact resistance. At extra high voltages (more than 300 kV) in outdoor buses, corona discharge around the connections becomes a source of radio-frequency interference and power loss, so special connection fittings designed for these voltages are used.

The bus bar cross section area of any given model has been determined by the manufacturer based on:

- The rated current,
- An ambient air temperature equal to 35 °C, for energy-efficiency considerations
- 3 loaded conductors.

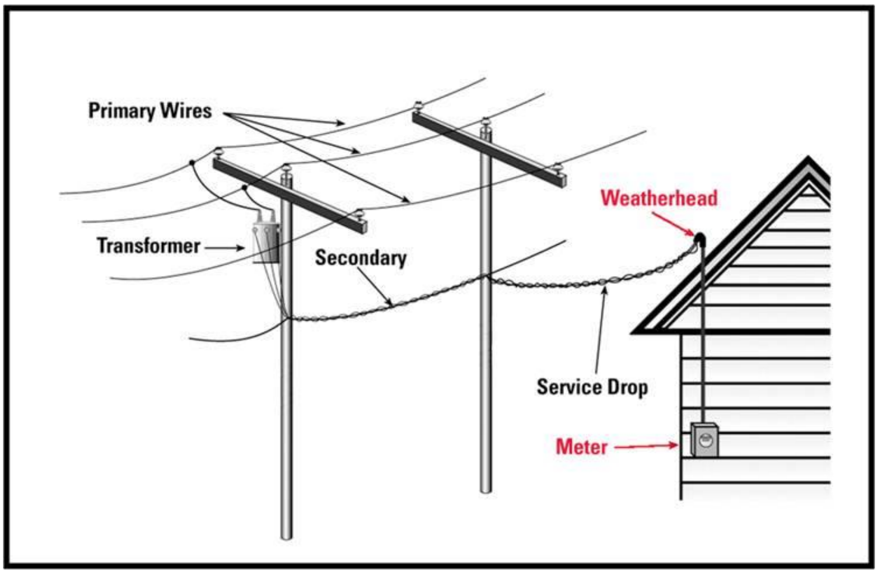
The layout of the bus bar trunking system depends on the position of the current consumers, the location of the power source and the possibilities for fixing the system.

- One single distribution line serves a 4 to 6 meter area
- Protection devices for current consumers are placed in tap-off units, connected directly to usage points.
- One single feeder supplies all current consumers of different powers.

Once the trunking system layout is established, it is possible to calculate the absorbed current $I_{col}$ on the distribution line.

Other terms:

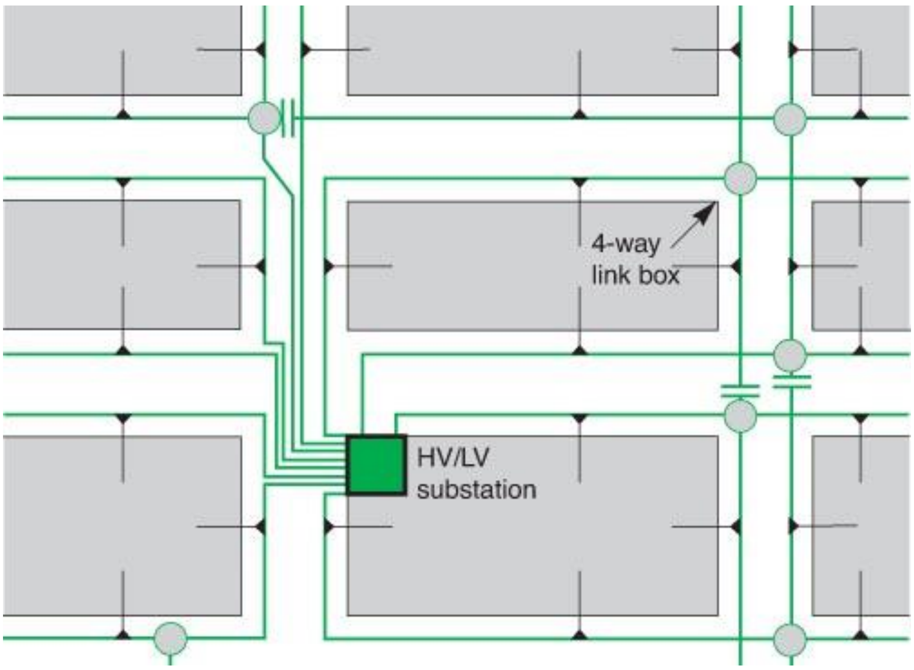
In electric power distribution, a **service drop** is an overhead electrical line running from a utility pole, to a customer's building or other premises. It is the point where electric utilities provide power to their customers. The customer connection to an underground distribution system is usually called a "service lateral". Conductors of a service drop or lateral are owned and maintained by the utility company.




**2. Bus bars from buildings' link boxes** *(firidelor de alimentare din clădiri)*

In densely-loaded areas (cities and large towns), a standard size of distributor is laid to form a network, with (generally) one cable along each pavement and 4-way link boxes located in manholes at street corners, where two cables cross.

Links are inserted in such a way that distributors form radial circuits from the substation with open-ended branches (see Figure). Where a link box unites a distributor from one substation with that from a neighbouring substation, the phase links are omitted or replaced by fuses, but the neutral link remains in place.



Moreover, short lengths of distributor (between two link boxes) can be isolated for fault-location and repair. Recent trends are towards weather-proof cabinets above ground level, either against a wall, or where possible, flush-mounted in the wall.

In the case of bus bars from buildings' link boxes, load current is determined similar to previous calculation (receiver's circuit) only here occurs the simultaneity coefficient:

$$I_{col} = \frac{k_s \cdot P_i}{\sqrt{3} \cdot U_n \cdot cos\varphi_m}$$

A particular case is that bus bars supplying lighting circuits and socket-outlets, where the plugs (outlets) have a comparable power with the light receiver. The particularity lies in the fact that the power factor for lighting circuits is 0.95 or 1, while for socket-outlet circuits the power factor, as well as the yield has a value of 0.8.

Power of circuits is distributed evenly across the phases of three-phased electrical distribution board, but each phase will have a different number of lighting and socket-outlet circuits. The corresponding phase where socket-outlet circuits' power is the greater will be the most required phase, so the size selection will be made according to the current on this phase. In this case, will be determined first the active component $I_{ca}$ and the reactive one $I_{cr}$ of the load current on the most loaded phase:

$$\begin{cases} I_{ca} = \dfrac{P_{iL}}{U} + \dfrac{P_{iP}}{\eta_P U} \\ I_{cr} = \dfrac{P_{iL}}{U} tg\varphi_L + \dfrac{P_{iP}}{\eta_P U} tg\varphi_P \end{cases}$$

Where $P_{iL}$ and $P_{iP}$ represent the installed power on lighting, respectively on socket-outlet circuits of the considered phase. Results that load current of the bus bar will be:

$$I_{col} = \sqrt{I_{ca}^2 + I_{cr}^2}$$

**Substations dimensioning (the third step from the LV dimmensioning procedure) is a MV issue and is not included in the thematic area of the course.**