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INDUSTRIAL PLANTS II

Chapter six (part 2): Electrical plants

DOUBLE DEGREE MASTER IN

“PRODUCTION ENGINEERING AND MANAGEMENT”

CAMPUS OF PORDENONE

UNIVERSITY OF TRIESTE

Electrical plants

Design of electrical industrial plants

The **electric plant** is defined as "the set of electrical components, having features coordinates, electrically associated in order to meet specific purposes; they are not part of the electrical plant the user equipments powered by plug sockets, unless they are fixed to the building structure or other fixed structures“.

Electrical plants

Design of electrical industrial plants

The existing regulations (Ministerial Decree 37/2008) it establishes the obligation of the circuit design by a professional writing to professional registers not only for electrical plants of residential units for residential use and condominium services, but for electrical plants of premises used for productive activities (improperly "industrial electrical plants"), commercial and service sector if:

a) when the users are supplied at higher voltage than 1000 V, including the part at BT (users with its own cabin);
b) when the users have power engaged more than 6 kW or when they exceed 200 m^2;
c) when the users located in premises for medical purposes or where there is danger of explosion or fire at greater risk, as well as for installations of lightning protection in building of a volume exceeding 200 m^3.

Decree January 22, 2008, n. 37 - Regulation concerning the implementation of article 11-quaterdecies, paragraph 13 letter (a) of the law n. 248, of 2 December 2005 concerning the reorganization of the provisions relating to activities of installation of the equipment inside buildings - G. U. n. 61, 03.12.2008

Design of electrical industrial plants

As regards the design of the electrical lines, both cable, that the busbars have of inherent characteristics:

the resistance R, the reactance X and the allowable temperatures in the insulation T_i and the sheath T_g. The first two factors affect the voltage drop, which should be contained within the 2.5% to the light lines and 4% for the lines driving force (the total drop from the cabin to the user). The voltage drop ΔV (in V), for a current I (in A) and for a power factor of the load ($\cos\varphi$) is given - approximately - by the formula (valid for $\cos\varphi$ between 0,5 and 0,9):

$$\Delta V = k \cdot \left(R \cdot \cos\varphi + X \cdot sen\varphi \right) \cdot L \cdot I$$

where R and X are expressed in Ω/m, L is the length in m of the line, the line current I in A, k is a coefficient that is assumed equal $\sqrt{3}$ in the three-phase systems, and equal to 2 in the single-phase systems.

Design of industria lplants

Note the current I, the length L and the values of R and X relative to a given conductor, it determines - for that conductor (having a certain section) - the voltage drop and occurs if it is less than or less than the predetermined limit. It should be remembered that the above formula, in addition to being used to calculate the voltage drops of the cables, it is for to calculate the same also for the busbars.

Design of electrical industrial plants

The following tables show the data for some types of cables with copper conductors and frequently used aluminium

a) average voltage: tripolar RG7H10R for rated voltage of 15/20 kV and max working temperature 90°C

Nominal section (mm^2)	Conductor diameter (mm)	Maximum outer diameter (mm)	Cable weight (kg/km)	Current capacity (A)	
				Laying in the air (30°C)	Laying in the ground (20°C)
3x 35	7,0	59,6	4340	178	175
3x 50	8,2	62,7	5000	210	206
3x 70	9,9	66,8	5990	259	251
3x 90	11,6	70,8	7130	315	299
3x120	13,1	74,2	8170	361	341
3x150	14,4	77,5	9260	406	380
3x185	16,1	81,3	10710	467	431
3x240	18,5	87,3	13000	550	497
3x300	21,1	93,6	15490	630	560

Design of electrical industrial plants

The following tables show the data for some types of cables with copper conductors and frequently used aluminium

b) low tension: unipolar FG7R for rated voltage of 0,6/1 kV and max working temperature 90°C

Nominal section (mm^2)	Conductor diameter (mm)	Maximum outer diameter (mm)	Cable weight (kg/km)	Current capacity (A)	
				Laying in the air (30°C)	Laying in the ground (20°C)
1x 1,5	1,5	7,9	50	25	27
1x 2,5	1,9	8,3	60	33	34
1x 4	2,4	9,0	80	43	44
1 x 6	3,0	9,8	100	55	55
1x 10	4,1	10,8	150	76	73
1x 16	5,2	12,2	200	100	93
1x 25	6,3	13,8	300	135	120
1x 35	7,7	15,1	410	169	143
1x 50	9,4	17,1	550	207	168
1x 70	10,9	19,8	780	266	205
1x 95	12,7	22,2	1060	328	245
1x120	14,5	24,2	1300	363	278
1x150	15,6	26,8	1600	444	310
1x185	17,8	29,1	2000	510	351
1x240	20,0	32,2	2500	607	405
1x300	23,1	35,4	3300	703	455
1x400	26,7	39,9	4300	823	514

Design of industrialplants

The following tables show the data for some types of busbars with copper conductors and aluminium frequently used

Construction features and electrical of busbars with degree of protection IP21

Characteristics data	Bars in copper					Bars in aluminum alloy				
Nominal intensity (A) I	800	1350	2000	2500	3000	600	1000	1500	2000	3000
Resistance (mΩ/100m) R	7,1	4,2	2,8	2,2	1,7	13,7	6,4	4,2	3,2	2,1
Reactance (mΩ/100m) X	4,2	2,4	2,1	1,8	1,5	4,2	2,4	2,1	1,8	1,3
Impedance (mΩ/100m) Z	8,3	4,9	3,5	2,8	2,4	14,3	6,9	4,7	3,6	2,5
Rated permissible current of short-time (kA)	33	45	60	75	90	28	40	50	60	90
Rated current of peak permissible (kA)	67	91	129	161	193	57	81	102	129	193
Impedance of the coil of fault (mΩ/100m)	< 73	< 52	< 47	< 44	< 42	< 75	< 49	< 48	< 44	< 41

Design of electrical industrial plants

The following tables show the data for some types of busbars with copper conductors and aluminium frequently used

Construction features and electrical of busbars with degree of protection IP:54

Characteristics data	Bars in copper					Bars in aluminum alloy				
Nominal intensity (A) I	250	350	450	700	900	150	225	320	400	680
Resistance (mΩ/100m) R	23,2	15,4	10,9	8,2	5,4	52,0	27,0	18,2	13,6	8,2
Reactance (mΩ/100m) X	17,4	17,4	17,4	13,4	10,6	17,4	17,4	17,4	13,4	10,5
Impedance (mΩ/100m) Z	29,2	23,5	20,5	16,2	12,3	54,8	32,3	25,2	19,5	13,6
Rated permissible current of short-time (kA)	20	25	25	30	35	15	25	25	30	35
Rated current of peak permissible (kA)	30	51	51	61	71	29	51	51	61	71
Impedance of the coil of fault (mΩ/100m)	< 94	< 84	< 81	< 65	< 56	< 124	< 97	< 91	< 70	< 59

Design of electrical industrial plants

The table shows the main characteristics of low-voltage cables

Nominal section mm^2	Electrical resistance Ω/km at 20°C				Reactance Ω/km at 50 Hz	
	Flexible conductors		Rigid conductors			
	Naked (red copper)	Coated (tinned copper)	Naked (red copper)	Coated (tinned copper)	Unipolar cables	Multipolar Cables
1,5	13,30	13,70	12,10	12,20	0,168	0,118
2,5	7,98	8,21	7,41	7,56	0,155	0,109
4	4,95	5,09	4,61	4,70	0,143	0,101
6	3,30	3,39	3,08	3,11	0,135	0,0955
10	1,91	1,95	1,83	1,84	0,119	0,0861
16	1,21	1,24	1,15	1,16	0,112	0,0817
25	0,780	0,795	0,727	0,734	0,106	0,0813
35	0,554	0,585	0,524	0,529	0,101	0,0783
50	0,386	0,393	0,387	0,391	0,101	0,0779
70	0,272	0,277	0,268	0,270	0,0965	0,0751
95	0,206	0,210	0,193	0,195	0,0,975	0,0762
120	0,161	0,164	0,153	0,154	0,0939	0,0740
150	0,129	0,132	0,124	0,126	0,0928	‘,0745
185	0,106	0,108	0,0991	0,100	0,0908	0,0742
240	0,0801	0,0817	0,0754	0,0762	0,0902	0,0752
300	0,0641	0,0654	0,0601	0,0607	0,0895	0,0750
400	0,0486	0,0495	0,0470	0,0475	0,0876	0,0742
500	0,0384	0,0391	0,0366	0,0369	0,0867	0,0744
630	0,0287	0,0292	0,0283	0,0286	0,0865	0,0749

For conductors with more than 5 cores, the resistance values must be increased by 5%

Design of electrical industrial plants

There is to be noted that the capacities of the cables listed in the previous tables must be multiplied by correction coefficients in order to take into account of the environmental conditions, especially the temperature, the mode of laying and the proximity of other cables.

Design of industria lplants

The table shows the correction coefficients of current capacities in the cables to BT for ambient temperatures other than the reference.

Type of insulation	Type of laying	Temperatures (°C)										
		15	20	25	30	35	40	45	50	55	60	65
PVC	Fixed in the air	1,17	1,13	1,07	1,00	0,92	0,84	0,75	0,65	0,54	0,40	0,20
PVC	Fixed in the ground	1,06	1,00	0,94	0,87	0,80	-	-	-	-	-	-
PVC	Mobile	1,22	1,15	1,08	1,00	0,91	0,82	-	-	-	-	-
Elastomer	Fixed in the air	1,13	1,09	1,05	1,00	0,95	0,90	0,85	0,79	0,74	0,67	0,60
Elastomer	Fixed in the ground	1,05	1,00	0,94	0,88	0,81	-	-	-	-	-	-
Elastomer	Mobile	1,11	1,15	1,08	0,91	0,91	0,82	-	-	-	-	-

Design of electrical industrial plants

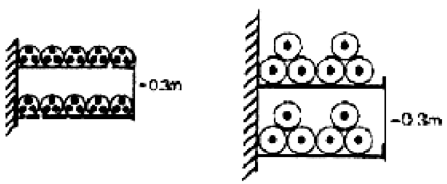
In the figure we report the correction coefficient of current capaciies of as a function of the conditions of installation

Tripolar cables and sets of three unipolar cables laid in air, in contact

In tunnel ventilated

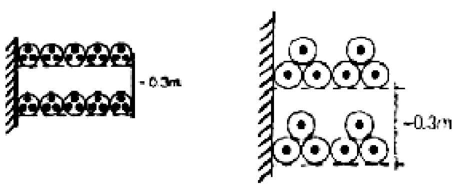
Number of cables and terns				
1	2	3	6	9
0.90	0.84	0.80	0.75	0.73

On duct closed



Number of layers	Number of cables and terns				
	1	2	3	6	9
1	0.95	0.84	0.80	0.75	0.73
2	0.95	0.80	0.76	0.71	0.69
3	0.95	0.78	0.74	0.70	0.68
6	0.95	0.76	0.72	0.68	0.66

On duct open

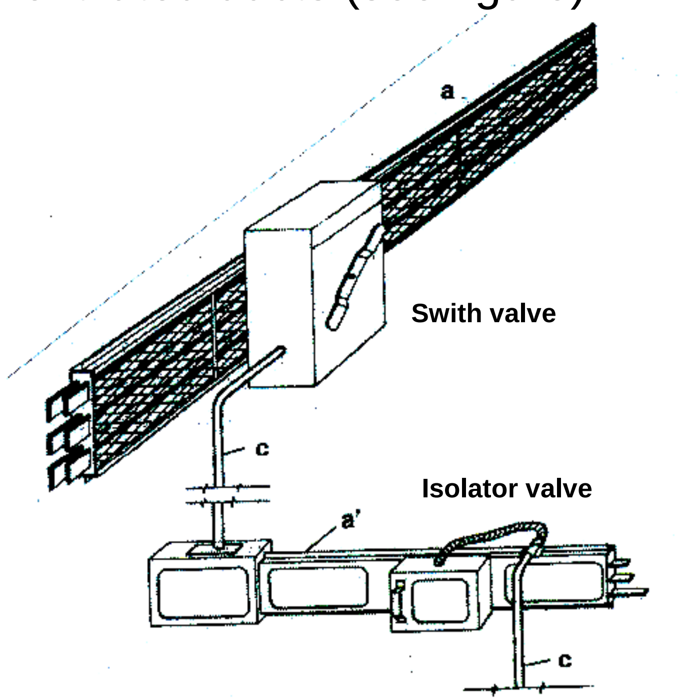


Number of layers	Number of cables and terns				
	1	2	3	6	9
1	0.95	0.84	0.80	0.75	0.73
2	0.95	0.80	0.76	0.71	0.69
3	0.95	0.78	0.74	0.70	0.68
6	0.95	0.76	0.72	0.68	0.66

Design of electrical industrial plants

In the field of flow rates between 1000 and 1500 A are affirmed the busbar to closed covering with bars completely covered with insulating material and closed to pack between them and with the covering.

The heat developed by the Joule effect is transmitted to the outside to conduction, with a transmission coefficient acceptable even if not comparable to that of ventilated ducts (see figure).



Design of electrical industrial plants

In the ducts to closed covering, generally defined it compacts for the smallest encumbrance dimensions, the bus bars and the covering constitute an only body suitable withstanding to particularly elevated electrodynamic short circuit solicitations, which those that develop if more transformers are used in parallel (for example, in the welding equipments).

Design of electrical industrial plants

In the BT cables you must also check the voltage drop, which, usually, should not exceed:

- 2,5% in lighting lines;
- 4% in the lines of the driving force.

The laying of cables can be done in the following ways:

a) laying electric cables insulated, sheathed, underground;
b) laying electric cables, insulated, sheathed, in tunnels practicable;
c) laying electric cables, insulated, sheathed in underground pipes or not, or in tunnels not practicable;
d) laying overhead electrical cables, insulated, sheathed, self-supporting or suspended ropes bearing.

Design of electrical industrial plants

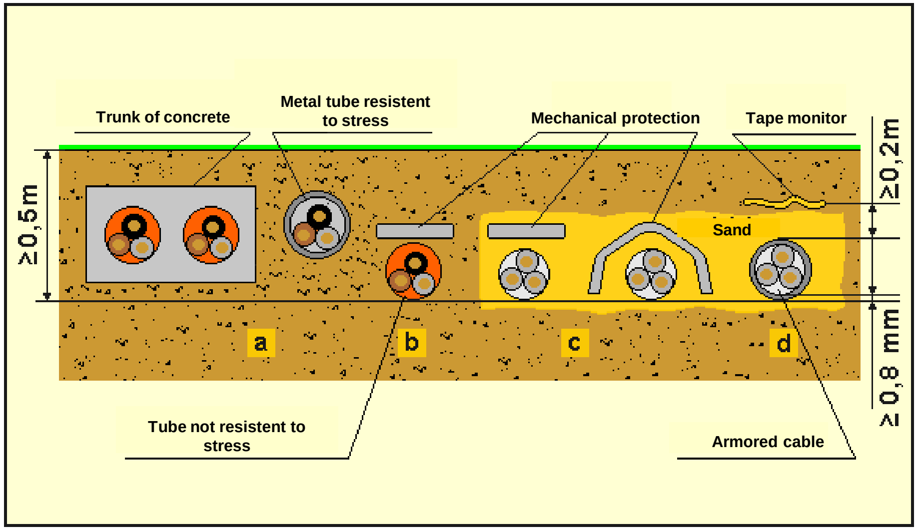
The cables for underground laying must always be equipped with protective sleeve, protected against crushing, where it is foreseen the passage of heavy vehicles, against the damages that can be caused by any excavations manual, but especially from excavations that involve the use of mechanical means.

The sheath must protect the cable from the laying stress and mixes it that composes it must be not hygroscopic, so as can to defend the cores from the contact with water.

They can be buried directly, pipes, tunnels or in concrete ducts with laying mode partly different.

Design of electrical industrial plants

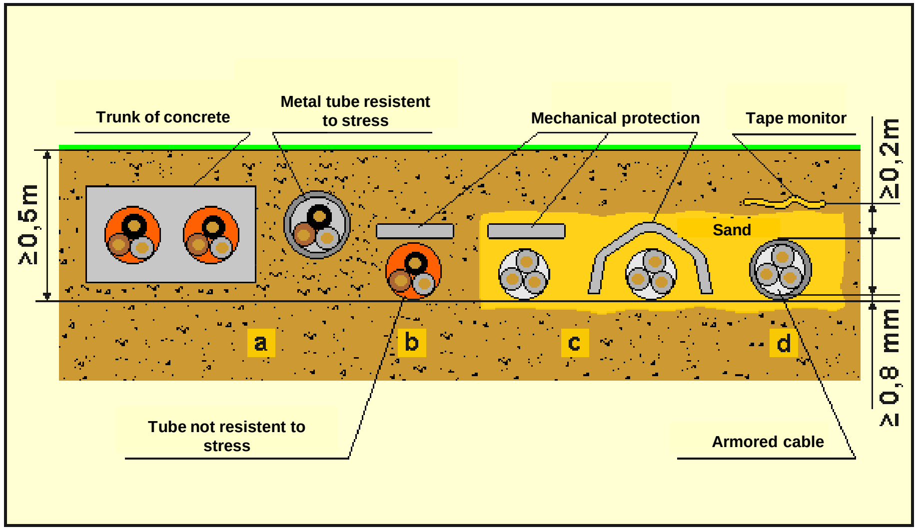
The cables placed directly in the ground, eventually laid on a bed of sand, must be buried at a minimum depth of at least 0.5 m and must possess a metal protection of a thickness of not less than 0.8 mm (figure d) or a additional mechanical protection for its entire length (figure c).
If the cable is armed and posed without any further mechanical protection its position is a good thing that it is marked by a tape monitor (figure d).



Design of electrical industrial plants

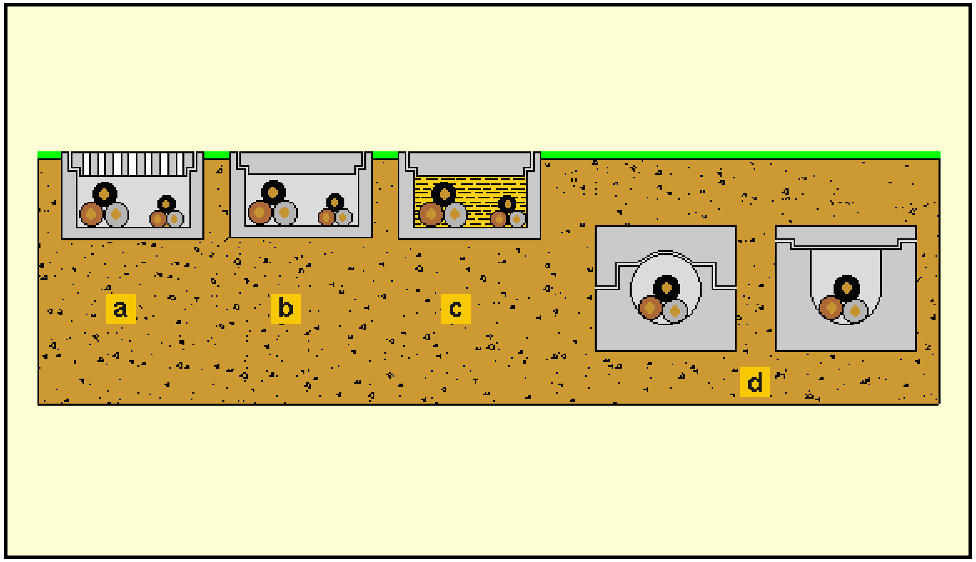
The same requirements as regards laying depth and additional mechanical protection, also apply to the cables laid in pipes which are not resistant to stresses (figure b).

The cables installed in tunnels, in concrete ducts of or in pipes capable of withstanding external stresses (figure a) may, if necessary, be installed at depths less than 0.5 m even without additional protection.



Design of electrical industrial plants

In the design of the foundation is important to determine in advance the position of the tunnels which will have to be obtained for the subsequent laying of electrical pipe lines (figure).



How to lay buried cables in tunnel outcropping and buried
a)ventilated, b) non-aerated, c) non-ventilated with filling, d) openable buried

Electrical plants

<u>Design of electrical industrial plants</u>

All electrical cables that will pass inside the tunnels should be protected with a sheath.

Thanks to total accessibility of the tunnels, which will be of type outcropping in order to be accessible at any time for any possible inspections, the sheathed cables will be laid along the entire tracing.

If it proves necessary vehicle access in the area where the tunnels were built will be necessary to foresee a suitable mechanical seal by filling the same.

Electrical plants

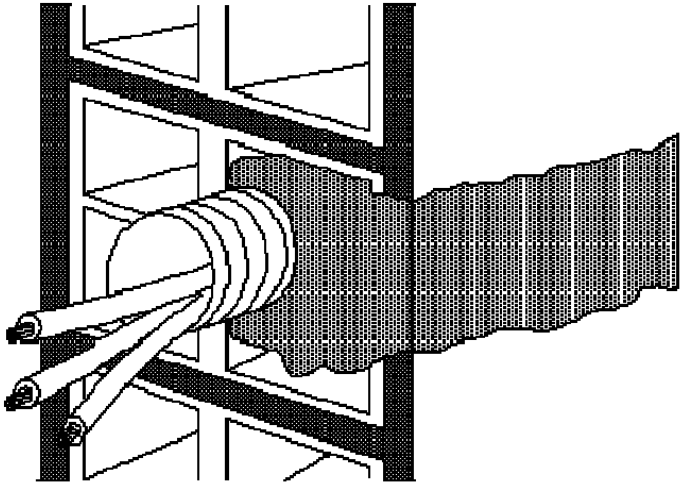
Design of electrical industrial plants

In industrial buildings, be they built with the traditional system or with the prefabricated modular system, the execution of the electrical plant requires the laying of pipe-lines for the protection of conductors and the application to the wall, recessed or protruding, the junction boxes and the boxes within which will be assembled devices (such as circuit breaker, two- way switch,, socket outlets etc.).

The conductors are normally slipped within protective pipes which have the function to safeguard the integrity and give back possible any replacement for unthreading also in the boxed plants.

Design of electrical industrial plants

The protective pipes can be of type diverged according to the type and the place of installation, but, in any case, they must be of such material and construction to withstand no significant permanent deformation without appreciable permanent deformations, particularly without crushing, the mechanical and thermal solicitations which they are subjected during their laying; the types more used are of thermoplastic material based on PVC with elevated degree of self-extinguishing and that do not ignite easily (figure).



Design of industria lplants

Various types of pipes

Electrical plants

<u>Design of electrical industrial plants</u>

The aerial laying of electrical cables, isolated, under sheath self-supporting or suspended or suspended to ropes carriers (figure) it is admitted, only for cables designed to withstanding of operation voltages not exceeding to 1 kV, isolated in conformity, unless it is not about cables for circuits supply for lighting in series or for supply of fluorescent pipes, for which the maximum allowable voltage will be of 6 kV.

Design of electrical industrial plants

With these restrictions of use can occur:

- self-supporting cables to beam with insulation made of cross-linked polyethylene for overhead lines to alternating current according to the norms CEI 20-31;
- cables with steel braid in support embedded in the same insulating sheath;
- cables suspended independent galvanised steel braid ("American" suspension) by means of buckles;
- suspension hooks, properly chosen among commercial types, placed at a distance of not more than 40 cm.

For all these cases collars and shelves of moor will be used, opportunely chosen among the commercial types, for the hold of the cables on the supports, through the above-mentioned steel braids.

Electrical plants

Industrial electrical plants draft projects

During of project of an electrical plant it is necessary first of all to define a few fundamental sizes:

- the supply voltage;
- the distribution voltage, depending on the power consumption, expected load growth and characteristics of energy power supply;
- the network type to be used and the location of cabins;
- the installed power in every department of the factory, broken down by type and nature of the load, namely: machinery for cold working of materials, electric welding machines, electric arc ovens or resistance, pumps, compressors, fans, general and particular lighting, small power users of driving force for offices or otherwise not related to production;

Industrial electrical plants draft projects

During of project of an electrical plant it is necessary first of all to define a few fundamental sizes:

- the size of the individual loads, bearing in mind that over 300-500 kW is mostly convenient direct power at medium voltage (if this does not pass the 20 kV) or with particular transformer;
- the distance of the departments to supply, the possibility of arrangement of the cabins and the degree of security required for the power supply;
- the duration of the working cycles and the possibility to restrict certain absorptions at night hours or to certain months of the year), with the aim to reduce the maximum absorbed power.

Electrical plants

Industrial electrical plants draft projects

You can set a preliminary valuation of the power necessary considering the load density (W/m²) or the energy consumption per unity of product of similar industries, whose immediate references, necessary for the electrical load to do, are the tables.

Load intensity in various types of industries

Industry	Specific load (W/m^2)
Chemical plants	250 – 500
Foundries	250 – 400
Sugar factories	110 – 130
Paper mills	90 – 110
Mechanical processing	80 – 100
Assembling vehicles	60 – 80
Electronic equipment	80 – 70

Energy consumption per unit of production

Tipy of industry	Energy (kWh)	Unit produced
Cars	1000	1 unit
Steel ingots	220	1 ton
rolled steel	300 – 350	1 ton
cast iron	11 – 25	1 ton
oxygen	0,7	1 Nm^3 of O_2
Sugar (beet)	150	1 ton
paper	480	1 ton
Wood pulp	400	1 ton

Industrial electrical plants draft projects

For a more precise valuation of absorptions, in order to establish the position of the transformation cabins, and the tracing of the lines it is necessary to determine the power for the department with the following procedure exposed. The installed power in the g-th department of industrial reality, comprising prevalently similar machines, is given by the sum of the rated power P_j of each machine of the department:

$$P_g = \sum_{1}^{m} P_j \qquad \text{(kW)}$$

The installed power P_t of the entire factory P_t is given by the sum of the installed powers in the various departments (n units):

$$P_t = \sum_{1}^{n} P_g \qquad \text{(kW)}$$

Industrial electrical plants draft projects

The electric power absorbed P_{WG}, that is the power which actually is necessary provide to the g-th department to allow the operation, in the case than the loads of the department (or of the whole company) be represented by electrical motors, is obtained with the following relation:

- active power:

$$P_{Wg} = \frac{P_g \cdot f_n \cdot f_c}{\eta} \quad \text{(kW)}$$

Industrial electrical plants draft projects

The electric power absorbed P_{WG}, that is the power which actually is necessary provide to the g-th department to allow the operation, in the case than the loads of the department (or of the whole company) be represented by electrical motors, is obtained with the following relation:

- apparent power:

$$P_{Ag} = \frac{P_g \cdot f_n \cdot f_c}{\eta \cdot \cos\varphi} \quad \text{(kVA)}$$

where:

f_n= utilization factor of machinery (table)

Type of use	f_u
Lamps	1
Engines from 0,5 to 2 kW	0,7
Engines from 2 to 10 kW	0,75
Engine above 10 kW	0,8
Resistance and induction furnaces	1
Rectifiers	1
Welders	0,7 – 1
Electric stoves	1
Machine tools, conveyors	0,6 – 0,8
Elevators, hoists, lifting equipment	0,8 – 1
Pumps, fans	1

Industrial electrical plants draft projects

The electric power absorbed P_{WG}, that is the power which actually is necessary provide to the g-th department to allow the operation, in the case than the loads of the department (or of the whole company) be represented by electrical motors, is obtained with the following relation:

- apparent power:

$$P_{Ag} = \frac{P_g \cdot f_n \cdot f_c}{\eta \cdot \cos\varphi} \quad \text{(kVA)}$$

where: f_c = comteporaneity factor (table)

Type of use	Number	f_c
Ovens	fino a 10	1
Engines from 0,5 to 2 kW	fino a 10 fino a 20 fino a 50	0,6 0,5 0,4
Engines from 2 to 10 kW	fino a 10 fino a 50	0,7 0,45
Engines from 10 to 30 kW	fino a 5 fino a 10 fino a 50	0,8 0,65 0,5
Engines above 30 kW	fino a 2 fino a 5 fino a 10	0,9 0,7 0,6
Rectifiers	fino a 10	0,8
Electric stoves	fino a 10	0,4
Elevators and hoists in offices and industries	fino a 4 fino a 10	0,75 0,6
Lighting		0,8

Industrial electrical plants draft projects

The electric power absorbed P_{WG}, that is the power which actually is necessary provide to the g-th department to allow the operation, in the case than the loads of the department (or of the whole company) be represented by electrical motors, is obtained with the following relation:

- apparent power:

$$P_{Ag} = \frac{P_g \cdot f_n \cdot f_c}{\eta \cdot \cos\varphi} \quad \text{(kVA)}$$

where:

All these coefficients are <1.

η= average efficiency of the motors, where the valuation rated power is made to the motor axis (table next);

$\cos\varphi$ = average power factor of the load not correct the power factor (table next).

Industrial electrical plants draft projects

cosφ = average power factor of the load not correct the power factor (table).

Features three phase electric motor: $V_n = 380$ V, f = 50 Hz									
P_n (kW)	Nominal yield η_n (%)			Rated power factor $\cos\varphi_n$			Rated current I_n (A)		
	2p = 2	2p = 4	2p = 6	2p = 2	2p = 4	2p = 6	2p = 2	2p = 4	2p = 6
0,55	70	71	70	0,80	0,80	0,73	1,45	1,47	1,63
1,1	77	74	74	0,85	0,81	0,75	2,55	2,8	3,0
2,2	82	78	78	0,85	0,83	0,74	4,8	5,2	5,8
4,0	85	83	83	0,88	0,83	0,76	8,1	8,8	9,5
5,5	85	84	84	0,88	0,85	0,76	11,2	11,7	13,0
7,5	87	86	84	0,88	0,85	0,75	14,9	15,6	18,0
11,0	87	88	88	0,88	0,86	0,78	22,5	22,0	24,3
15,0	89	89	89	0,88	0,88	0,82	30,0	29,0	31,5
18,5	89	89	90	0,88	0,82	0,83	36,0	38,0	37,5
30,0	90	91	91	0,88	0,83	0,84	57,0	60,0	59,0
45,0	92	93	92	0,89	0,85	0,85	83,0	87,0	87,0
90,0	92	94	94	0,89	0,86	0,85	166,0	168,0	172,0

Electrical plants

Industrial electrical plants draft projects

The absorbed total power is given by the sum of the powers of n departments:

- total active power

$$P_{WT} = \sum_{1}^{n} P_{Wg} \qquad \text{(kW)}$$

- total apparent power

$$P_{AT} = \sqrt{\left(\sum_{1}^{n} P_{Wg}\right)^2 + \left[\sum_{1}^{n} \left(P_{Ag} \cdot sen\varphi\right)\right]^2} \qquad \text{(kVA)}$$

Industrial electrical plants draft projects

If the various departments have the same cosφ, the summation of the P_{Ag} is an algebraic sum.

In practice, it is difficult to find accurate and valid coefficients in most cases.

It is therefore a simplified formula of the type:

- total active power

$$P_{Wg} = k \cdot P_g \qquad \text{(kW)}$$

- total apparent power

$$P_{Ag} = \frac{k \cdot P_g}{\cos\varphi} \qquad \text{(kVA)}$$

The value to be attributed to the k coefficient requires a careful examination of machinery used and any expected functional interlocks (which often occurs in robotic welding departments). That coefficient increases to shrink the number of machines considered and tends to 1 (sometimes is k > 1 for one machine, because this can have starting peaks, overloads, etc.).

Electrical plants

Industrial electrical plants draft projects

The most common values of k and cosφ are shown in table

Machinery	k	cosφ
Machine tools	0,25 – 0,4	0,6
Press	0,3 – 0,5	0,6
Resistance welding	0,05 – 0,2	0,4
Compressors and pumps	0,6 – 0,9	0,8
Kneaders, mullers	0,75 – 0,85	0,75
Paint furnaces	0,75 – 0,85	0,75
Resistance furnaces	0,8 – 0,9	1
Arc furnaces	0,7 – 0,9	0,75
Induction furnaces	0,9	0,9
Lighting (fluorescent lamps)	0,9 – 1	0,5

Industrial electrical plants draft projects

When considering special machines, especially those of high power, it is necessary to coordinate the absorption in the time the absorption indicated by the manufacturer of the machine with the other absorptions of the factory to avoid peaks load that may increase the cost of electrical energy.
With the values of P_{Ag} calculated for each corporate department, occurs the power supply line and to the effects of the current capacity, both from the point of view of the voltage drop.
With the value P_{AT} underlying departments reported a transformation cabin sizing ,is carried out of transformers the cabin.

Industrial electrical plants draft projects

In the case of large establishments is advantageous develop dimensioning and testing of electrical networks automatically, using appropriate calculation programs.

The load factor on the transformers should normally be <1 to allow the expansions of the network or the mutuals reserves between transformers or between the cabins.

Usually, the ratio between the power of the load (power factor corrected to cosφ contractual) and the transformers power is chosen in the field between 0,5 and 0,8.

Industrial electrical plants draft projects

The project of the network must be done so that you have:

- balance the loads on the phases;
- low voltage drops in the conductors; these drops must be contained in the following values:
  · for light circuits: less than 3%;
  · for power circuits machinery: smaller 4%;
- the measure of electrical energy absorbed from the loads of the driving force and the light is unique;
- protection devices along the circuits, such as fuses, circuit breakers, voltage drops, insulation, in order to dissect the only circuits in abnormal conditions of operation (overloads, short circuits, voltage reductions, lake of phase, earth faults, etc.) and keep the rest of the plant into service.

<u>Industrial electrical plants draft projects</u>

It is good norm to compare between them some technically acceptable solutions to individuate that one optimal under the economic point of view and practical of operation It is necessary to make then the choice of the section of the cable and the protection against the overload.

The project must meet obviously the specifications inherent to the safety of the workers.

Metalworking industry's electrical plant draft project – Introduction

The company specializes in machining operations for chip removal and work on small and medium series destined for multiple markets, including the automotive market.

The classification ATECOFIN has a 25.62.00 activity code for the work of general mechanics. The company is not classified as unhealthy industry (reference D. M. 5 September 1994).

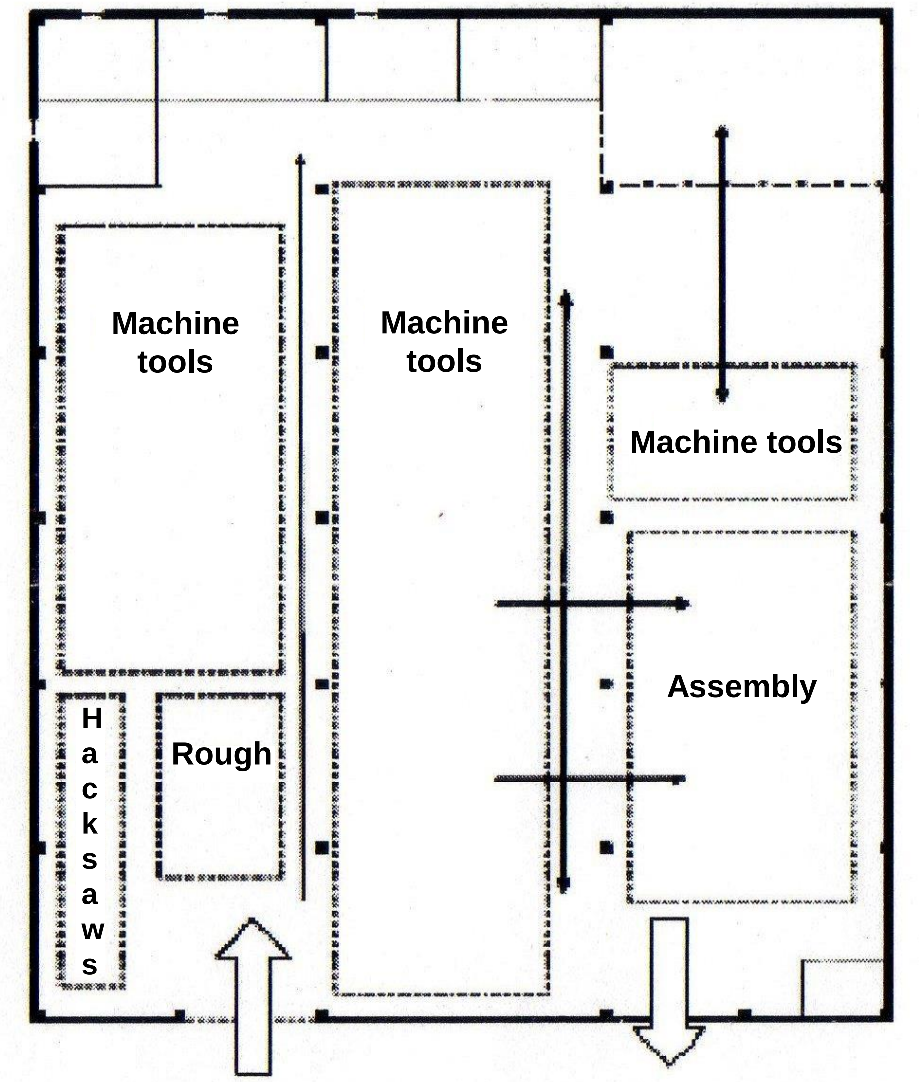
Electrical plants

Metalworking industry’s electrical plant draft project – Introduction

For the construction of the establishment of the land was consolidated with piling.
In the area there is an industrial, commercial and business pole of recent installation, composed of various manufacturing industries.
The municipality is located to seismicity in area 3 and the geological analysis shows that the area where the factory is not affected by phenomena of dejection in case of earthquakes.

Metalworking industry’s electrical plant draft project – Introduction

The planimetry of the site is that one shown in figure



Metalworking industry’s electrical plant draft project – Introduction

The factory employs a workforce of about twenty people, including supervisory personnel.

In the factory are installed:

- two hacksaws: total electrical load of name plate of 1.5 kW;
- five multi pallet horizontal centers and four vertical centers: total electrical load on the name plate 27 kW;
- four lathes and three adjustments: total electrical load overall on name plate of 84 kW;
- a dozen smaller machines tools dedicated to discontinous jobs (drills, moles): total electrical load on the plate 15 kW.

Electrical plants

Metalworking industry’s electrical plant draft project – Introduction

Moreover is to consider the presence of the electrical lighting plant of shed, equal to 45 kW (see calculations executed in the "chapter lighting plants") besides about ten of kW altogether owed the lighting, outside, of the offices and the other ones existing service premises as well as owed the driving force of the auxiliaries power plants.

Auxiliaries plants of industry

1. Telephone plant, 2. anti-intrusion and burglar alarm system , 3. Audio or video entry control system, 4. TV CC: the closed-circuit TV system are typically installed by accesses control in order to increase security against the risks intrusion and are often associated with the anti-intrusion system.The cameras for shooting need electrical power supply, signal line, as well as the line to the command of any motorised zoom,5. Sound diffusion, 6. data transmission systems, the data communication systems or local area network (LAN or Local Area Networks) is intended to interconnect the equipments for data processing (computers, printers, plotters, modem etc.).

Metalworking industry’s electrical plant draft project – Introduction

All processes are organized by lot, the individual workpieces are hardly to exceed 50 kg, never 100 kg, internal movement is organized on pallets and cayssons, there is no need for bridge crane.

The building where you installed the new production occupies an area of 6500 m^2 of which 3500 m^2 covered.

The access to the area leads directly to municipal roads and outside the establishment , on the municipal area there is a large parking lot.

Electrical plant draft project

° *Method of calculation: valuation of maxim of the needed power*

From the introduction is derived the total electrical load installed in industry:

$$1{,}5+27+84+15+45+10 = 182{,}5 \text{ kW} \rightarrow 183 \text{ kW}$$

Electrical plant draft project

I° Method of calculation: valuation of maxim of the needed power

It applies itself all that studied and it is considered the loading density of an industry by mechanical workings like that one analysed, in W/m^2 supplied at the next table, already seen previously

Industry	Specific load (W/m^2)
Chemical plants	250 – 500
Foundries	250 – 400
Sugar factories	110 – 130
Paper mills	90 – 110
Mechanical processing	80 – 100
Assembling vehicles	60 – 80
Electronic equipment	80 – 70

Electrical plant draft project

I° Method of calculation: valuation of maxim of the needed power

The power needed for industry 3500 m2 covered area shall be equal to: :

80÷100 W/m2 x 3500 m2 = 280÷350 kW.

This value, resulting it almost twice the installed load, it seems "a little too approximate" and therefore we proceed with a second method of higher trust.

Electrical plant draft project

II° Calculation method: valuation of the power needed with simplified formulas

For a more precise valuation, in case such as the present case, where you have all machine tools similar to each other (all machine tools), applies the formula already studied:

$$P_t = \sum_{1}^{n} P_g \qquad \text{(kW)}$$

where the installed power P_t of the whole factory is given by the sum of the power installed in various departments (n departments).

Electrical plant draft project

II° Calculation method: valuation of the power needed with simplified formulas

The formula applied to the rated powers of all the company's machines with the exception of 45 kW load relative to shed lighting and 10 kW altogether due to external lighting of offices and other premises of the existing service, as well as other auxiliary plants which will be considered separately.

Developing the calculations is that the installed power in the factory is equal to:

$$P_t = 128 \text{ kW (i.e. } 183 - 55 \text{ kW)}$$

Electrical plant draft project

II° Calculation method: valuation of the power needed with simplified formulas

Using now to the simplified formulas already treated, you can calculate the total active and apparent power of electrical motors that operate all machine tools:

- total active power:

$$P_{Wg} = k \cdot P_g \qquad \text{(kW)}$$

- total apparent power:

$$P_{Ag} = \frac{k \cdot P_g}{\cos\varphi} \qquad \text{(kVA)}$$

where the most common values are given in table already seen previously:

Electrical plant draft project

II° Calculation method: valuation of the power needed with simplified formulas

Machinery	k	cosφ
Machine tools	0,25 – 0,4	0,6
Press	0,3 – 0,5	0,6
Resistance welding	0,05 – 0,2	0,4
Compressors and pumps	0,6 – 0,9	0,8
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Resistance furnaces	0,8 – 0,9	1
Arc furnaces	0,7 – 0,9	0,75
Induction furnaces	0,9	0,9
Lighting (fluorescent lamps)	0,9 – 1	0,5

Electrical plant draft project

II° Calculation method: valuation of the power needed with simplified formulas

Then:

$$P_{Wg} = k \cdot P_g = (0,25 \div 0,40) \times 128 = 32 \div 51,2 \text{ kW} \rightarrow 52 \text{ kW}$$

(value chosen for safety)

$$P_{Ag} = \frac{k \cdot P_g}{\cos\varphi} = \frac{51,2}{0,6} = 85,4 \ kVA \ \rightarrow \ 86 \text{ kVA}$$

(value chosen for safety).

Electrical plant draft project

II° Calculation method: valuation of the power needed with simplified formulas

They now consider the loads of 45 kW relating to lighting of the shed lighting, as well as the 10 kW altogether due to external lighting of offices and other premises of the existing service, and other auxiliary plants equal in total to 55 kW (the simplifying assumption has been made that this load has been corrected to unity power factor).

Adding up the 52 kW active power Pg above obtained to the latter 55 kW, you get in the end required active power equal to 107 kW.

Electrical plant draft project

II° Calculation method: valuation of the power needed with simplified formulas

The Distributor of electrical energy, operating in industrial pole in which is situated industry analyzed, you can then request a connection of electrical energy of the available power of 120 kW (precautionary value) at an voltage 230/400V (BT).

Electrical plant draft project

Observation

In the case in which the active power necessary to the analyzed industry it was found to be higher, for example, near to the 200 kW or, a fortiori, even higher, you would conclude with the Distributor a contract for a supply to 20 kV (MT) of the available power really required, after construction, by industry, the electrical cabin for sorting and processing of which we have previously studied.

Safety information and components of electrical system

It is recalled that it defines the following:

- **plant component**

  Each element used in the production, processing or distribution of electrical energy, as machines, transformers, equipments, measuring instruments, protection devices, pipe lines.

- **user equipment**

  A equipment that converts electrical energy into another form of energy, for example luminous, caloric and mechanical

- **electrical component**

  General term used to describe both the plant components both equipments

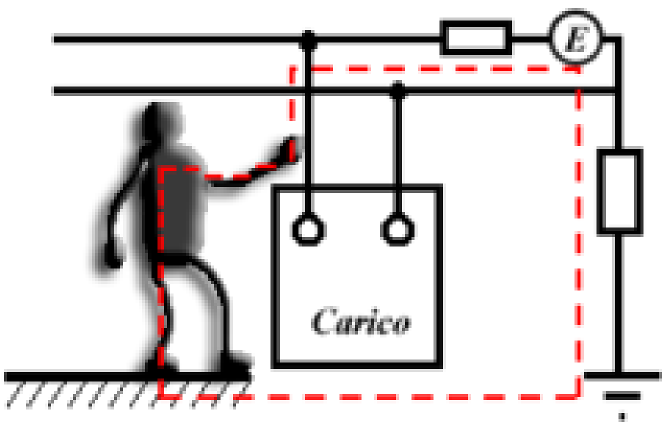
From Standard CEI 64-8 / 2-2007 "Electrical users plants a nominal voltage not exceeding 1000 V alternating current and 1500 V direct current"

Safety information and components of electrical system

A person is subjected to an electrical voltage when it is simultaneously in contact with other potential parties. In the ideal case where all parties are at the same potential, you reaches the "equipotential" condition, which prevents the occurrence of potential differences between the various points. The safety of electrical plants is linked to the presence of two types of risk for:

- ***direct contacts***

  Means the risk of electrocution from an individual as a result of contact with parts of electrical plant which are normally in voltage ("active parts")



Electrical plants

Safety information and components of electrical system

The safety of electrical plants is linked to the presence of two types of risk for:

- ***direct contacts***

  This risk consists of: bare wires, alveolus of electrical sockets, parts not properly insulated and/or protected (figure). The protections against direct contact are linked to the insulation of all active parts of the electrical conductors and their correct installation in under track pipes within raceway and/or external pipes.

Safety information and components of electrical system

The safety of electrical plants is linked to the presence of two types of risk for:

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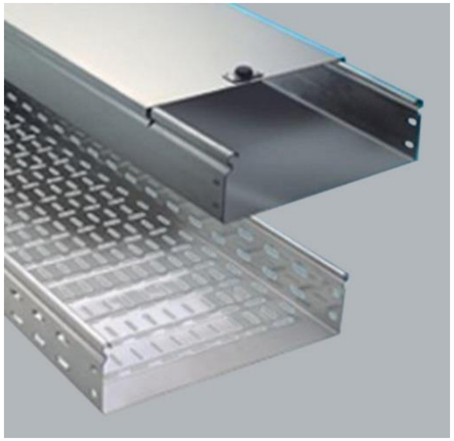


Safety information and components of electrical system

The safety of electrical plants is linked to the presence of two types of risk for:

- ***direct contacts***

  Dangerous interventions may be the prolongation of cables, often improvised by means of connections with electrical tape, replace plug sockets, cables, of two – way switch and / or switches, impaired the use of extension cords and the overhead of multiple electrical socket outlets commonly known as slippers (figure). The dangers are boosted in environments with presence of water and/or moisture.

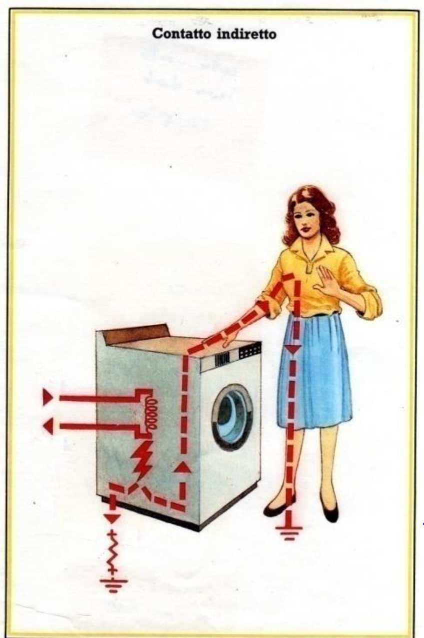
Electrical plants

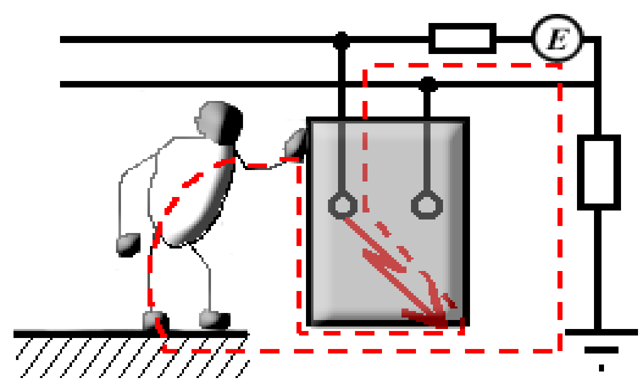
<u>Safety information and components of electrical system</u>

The safety of electrical plants is linked to the presence of two types of risk for:

- ***indirect contacts***

  Means the risk of electrocution from an individual as a result of contact with conductive parts, i.e. active parts, electrical components which, although not normally under voltage (figures), can assume a potential different from zero following an insulation fault.





Safety information and components of electrical system

The safety of electrical plants is linked to the presence of two types of risk for:

- ***indirect contacts***

  Generally, the frames of electrical appliances appliances may go under voltage as a result of anomalies in the operation of these equipments.

  In an electrical plant the ground connection of the grounds is a measure of protection against indirect contact; it is also known as **protection with automatic interruption of the circuit** as it is coordinated with overcurrent circuit breakers or residual current operated circuit breakers , that open the circuit when you are creating a dangerous situation.
  The ground plant with this function are called of protection.

Safety information and components of electrical system

The safety of electrical plants is linked to the presence of two types of risk for:

- ***direct and indirect contacts***

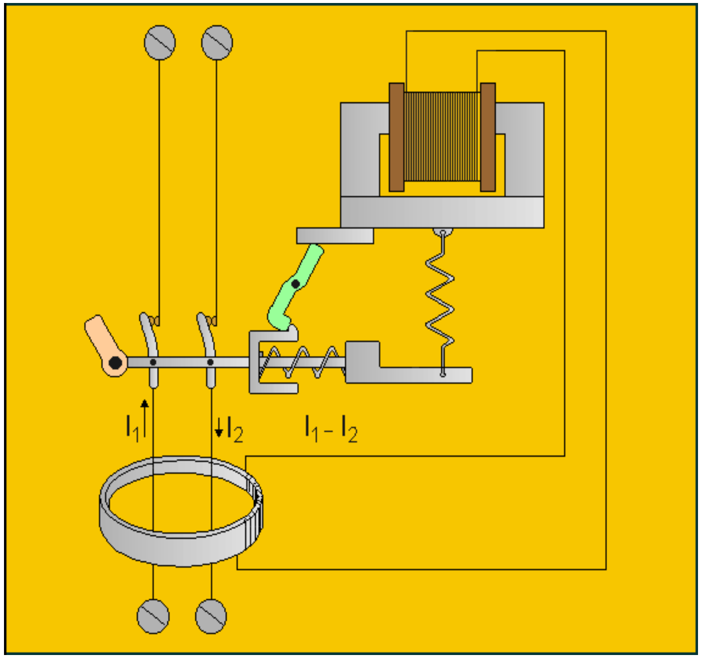
  The residual current operated circuit breaker (figure) to protect against direct or indirect contact is a device capable of opening a circuit when a current difference exceeds a certain limit, following a ground fault.

Safety information and components of electrical system

The safety of electrical plants is linked to the presence of two types of risk for:

- ***direct and indirect contacts***

  The figure shows the operation diagram of a residual current operated circuit breaker.



<u>Safety information and components of electrical system</u>

The safety of electrical plants is linked to the presence of two types of risk for:

- ***direct contacts***

  For the protections from direct contacts are used two distinct types of protection:

  - *total protection* (insulation of the active parts and protection with coverings and barriers);
  - *partial protection* (obstacles or spacing).

<u>Safety information and components of electrical system</u>

The safety of electrical plants is linked to the presence of three types of risk for:

- ***indirect contacts***

  For the protections from indirect contacts are used two distinct types of protection:

  - *protection by automatic interruption of the power supply*;
  - *protection without automatic interruption of the circuit* (double insulation, electrical separation, isolated premises, equipotential premises);
  - *power supply very low voltage*.

Safety information and components of electrical system

Important for a design the knowledge of the **switching devices**, which is a device able to carry out the operations of opening and of closing of a circuit. Generally these operations can be:

- at load, i.e. in the presence of current in the circuit;
- at vacuum, i.e. in the absence of current, being the circuit open in another point.

In addition, the operations can take place:

- in normal working conditions, to connect or disconnect a circuit from the rest of the plant;
- in abnormal operation conditions due to failures in the plant.

Safety information and components of electrical system

In relation to the type of command can be distinguished:

- manual control carried out by the operator;
- automatic control generally determined by the intervention of a protection device or by a control system.

Depending on the operations that are able to perform are distinguished various types of switching devices.

Safety information and components of electrical system

The **switch** (figure) is an device capable of conducting current continuously up to a certain value in normal operation conditions, to open and close the circuit, both under normal conditions and under fault conditions; in the latter case up to certain values of the fault current.

Safety information and components of electrical system

The **switch-disconnector** (figure) is a device able to establish, conduct continuously and to switch currents under normal operation conditions up to a certain value, including any overload conditions specified.

Safety information and components of electrical system

The **disconnector** (figure) is a switching device capable of conducting in a continuous manner a given value of the current normal operation, and for a specified time, a final value of the current in abnormal operation.

Safety information and components of electrical system

The **contactor**, also called a telebreaker (figure), is destined to open and close a circuit under normal conditions up to a certain value of current and possibly in overload conditions.

It is characterized by a high operation frequency and has the only stable position of operation of the main contacts the one of open.

In the closed position can persist only in the presence of control action, generally of the electromagnetic type.

Safety information and components of electrical system

The **circuit breaker** (figure) is a switching device able to establish, conduct and to switch currents under normal conditions and also establish, conduct for a specified duration and to switch automatically currents specified in abnormal conditions, for example in short circuit.

Ground plants

An **ground plant** consists of a conductors system that allow to connect to ground safely certain conductors elements (grounding). This connection can have the following functions:

a) **protective grounding**

:

At ground plant are connected the metallic grounds of equipment that are part of the electrical system; this connection, imposed by the “corrent regulations", keeps the grounds to ground potential during normal operation and limits their voltages with respect to ground in case of fault.

CEI 64-8/2 Grounds: conductive part of an electrical components that can be touched and that is not under voltage in ordinary conditions, but that can go in voltage during fault conditions.

Extraneous grounds: conductive part not part of the electrical plant can introduce a potential, generally the ground potential.

Ground plants

An **ground plant** consists of a conductors system that allow to connect to ground safely certain conductors elements (grounding). This connection can have the following functions:

b) operation grounding

At ground plant can be connected active parts of a plant or of an electrical system.

Important examples are made by the ground connections of the neutrals center of transformer three-phase of power. In other cases the connection allows you to use the ground as conductor of current; examples you have in electric traction railway and also in submarine connections of direct current power with unipolar high-voltage cables in, which use the sea as a second conductor;

Ground plants

An **ground plant** consists of a conductors system that allow to connect to ground safely certain conductors elements (grounding). This connection can have the following functions:

c) grounding to works

When a portion of an electrical system is placed out of service in order to perform the work, it must be disconnected from the part of the plant remains in voltage and connected to the ground in safe and visible way; for the purpose it is connected to the ground plant by means of grounding disconnectors or or provisional connections.

Electrical plants

Ground plants

Each building is equipped with an ground plant; in circuit diagrams the ground connection is indicated with the symbol ⏚ . The elements that constitute an ground plant are:

a) ***ground electrode***: totally immersed in the ground consists of one or more conductor elements connected together;

b) ***ground conductors***: conductors, not in intimate contact with the ground, designed to connect the earth electrodes together and to the collector (or node) main ground;

c) ***grounded collector or main node of ground***: consists of a terminal or a bar is connected both to earth electrode it to the grounds.

Electrical plants

Ground plants

Each building is equipped with an ground plant; in circuit diagrams the ground connection is indicated with the symbol ⏚ . The elements that constitute an ground plant are:

d) ***protective conductors***: said PE, are the conductors that connect the ground conductors to the metal grounds of electrical appliances that can be touched.

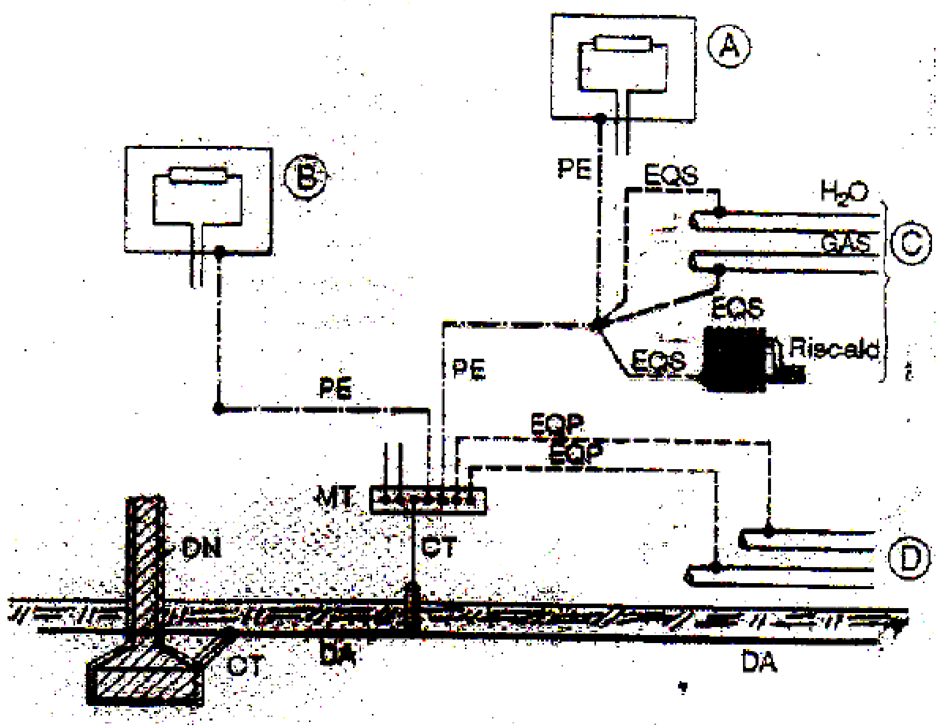
These grounds, in normal conditions, are not in voltage, but can become dangerous in the event of breakdown of the insulation of the conductors inside the equipment;

d) ***equipotential conductors***: are of the conductors having the purpose of ensuring that there are not differences potential dangerous between the metallic grounds still accessible buildings (hydraulic pipings, heating, gas. etc.), to avoid that, in case of faults, parts which can be touched by a person temporarily are located in a different electric potential.

Electrical plants

Ground plants

The elements that constitute an ground plant are visible in the figure.



A,B = grounds – C,D = extraneous grounds – CT = insulated ground conductor – PE = protective conductor – EQP = main equipotential conductor – EQS = supplementary equipotential conductor – MT = grounded collector or node main of ground: – DA = intentional ground electrode – DN = ground electrode of made

Ground plants

Notes of the figure

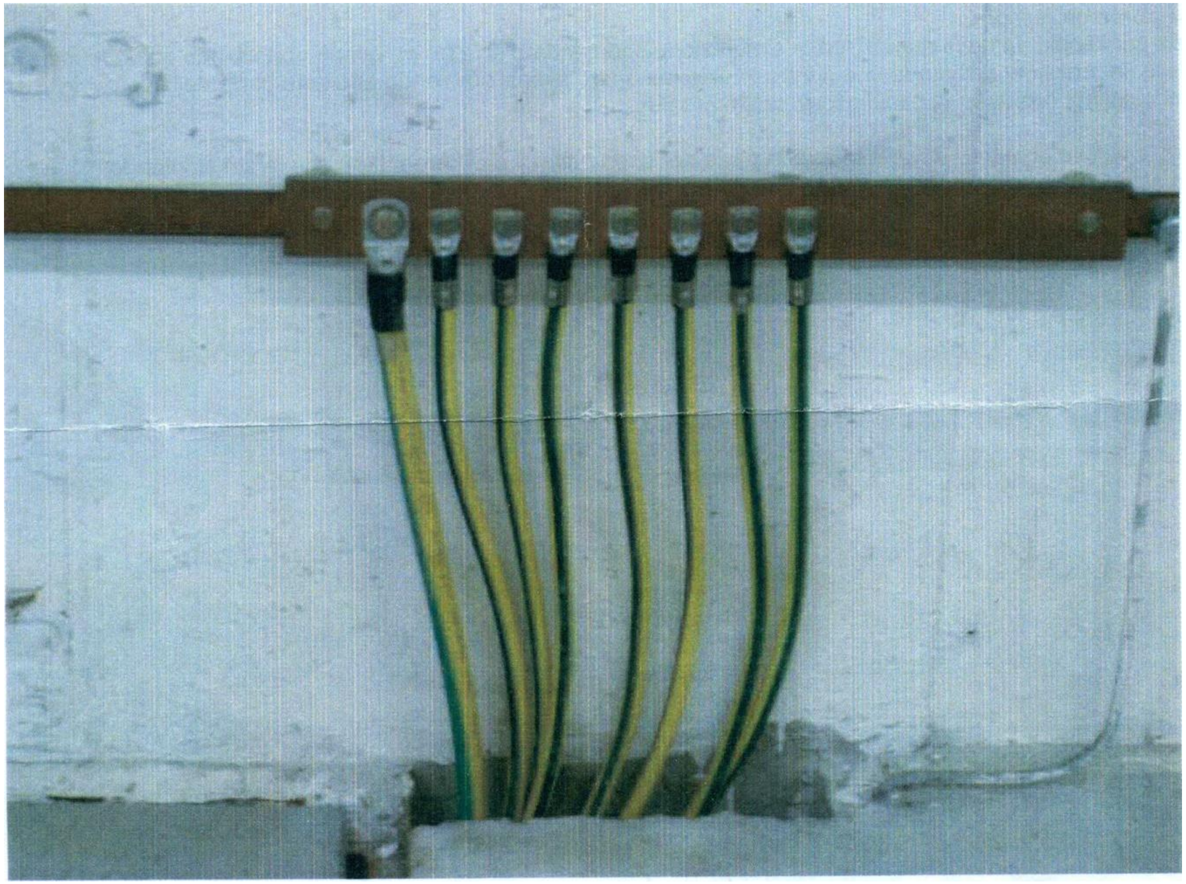
CEI 64-8/2:

The earth electrode is intentional when it is installed only for purposes concerning to the grounding of electric plant (DA).

The earth electrode of made when it is installed for purposes not related to the grounding of an electrical plant (DN).

Ground plants

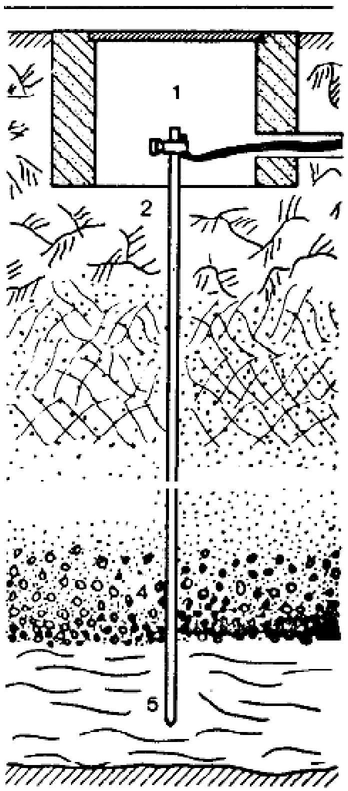
The figure: schematize a grounded collector or main node of ground.



Electrical plants

Ground plants

The figure: schematize a well of grounding.



1 – well, 2 – ground rod, 3 – ground

Ground plants

The position of the earth electrode is signaled by a sign of the type shown in figure.

Electrical plants

Some situations which are contrary to safety

Shining example of design .... integrated

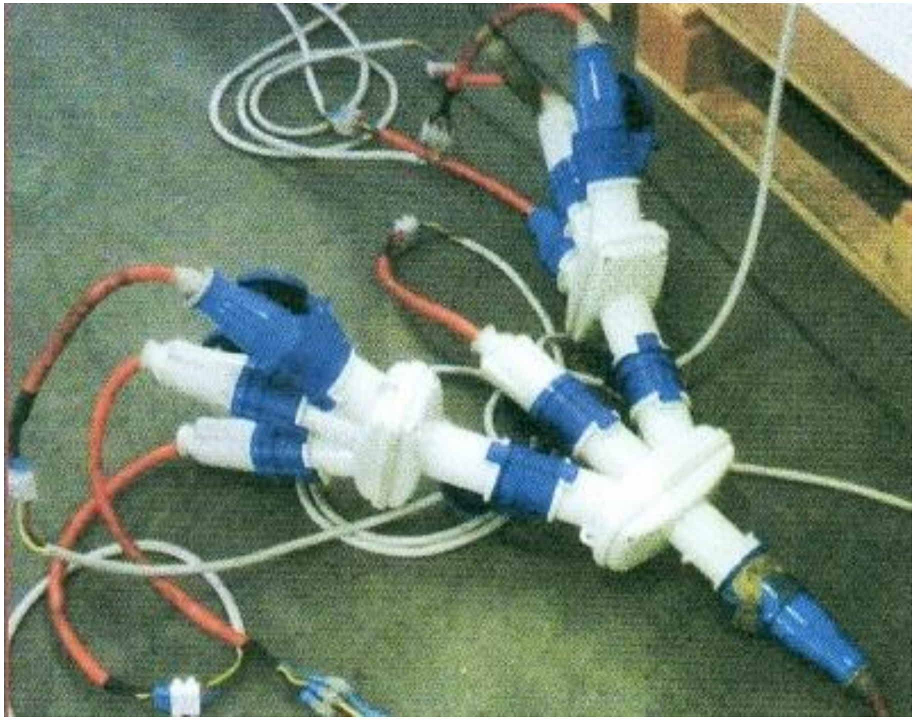
Electrical plants

Some situations which are contrary to safety

Exemple of upper Paleolithic, which still exists area (Verona)

Electrical plants

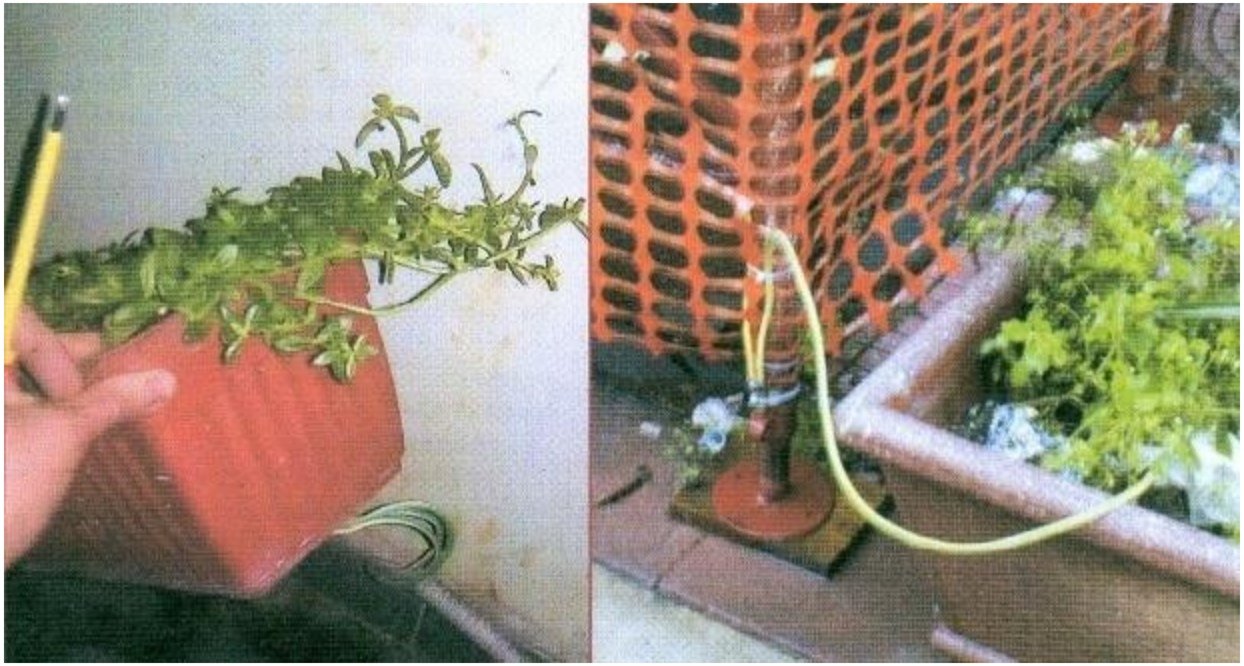
Some situations which are contrary to safety



The "proliferation" of socket and plugs

Electrical plants

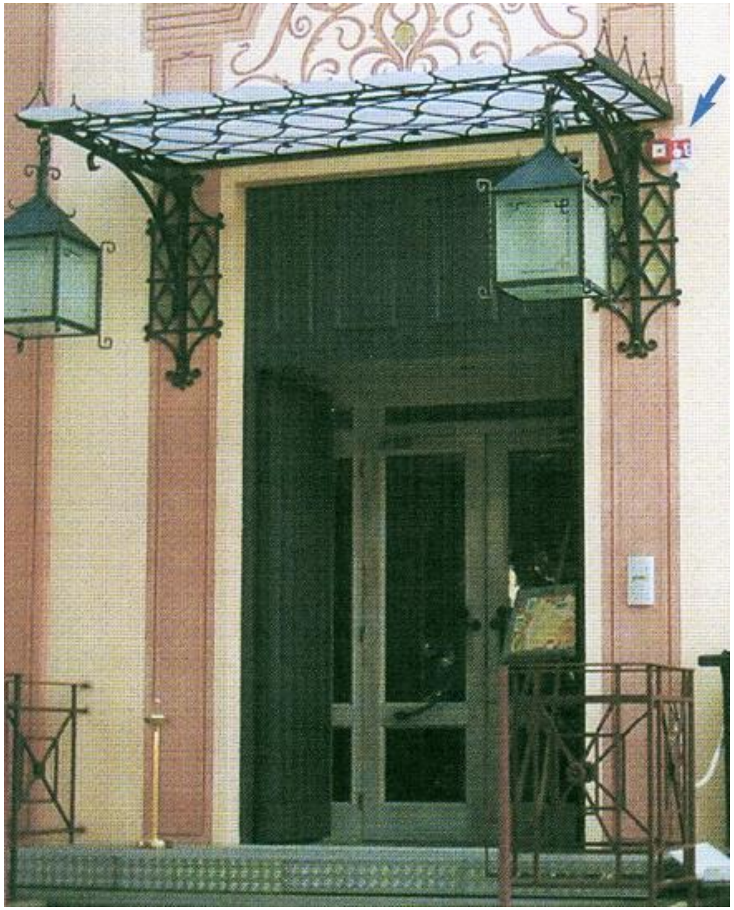
Some situations which are contrary to safety



Two good "grounding"

Electrical plants

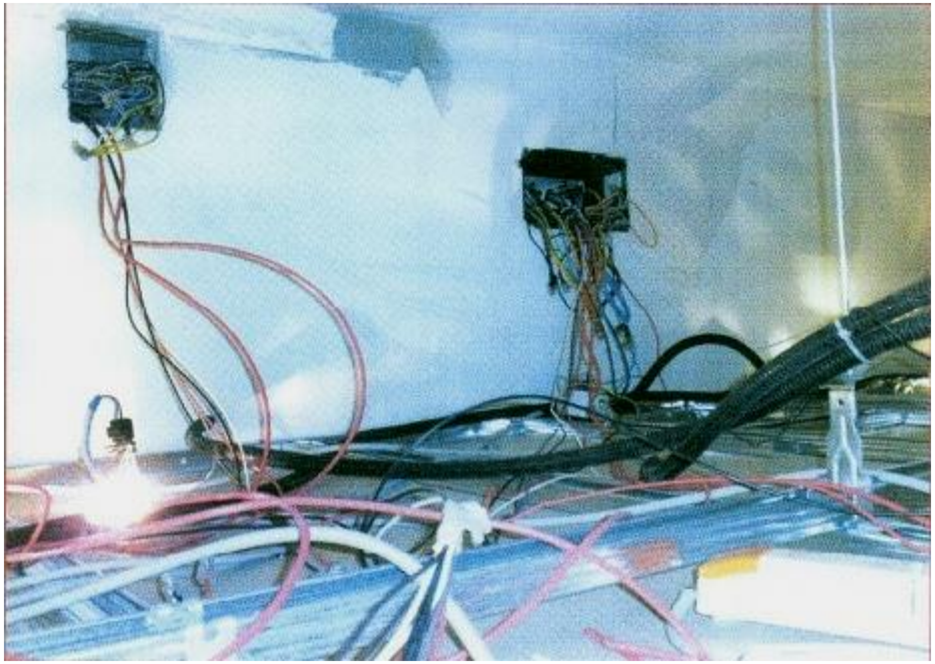
Some situations which are contrary to safety



Emergency command "within reach" from fireman with the scale

Electrical plants

<u>Some situations which are contrary to safety</u>



Suspended ceiling:“plant at workmanlike manner....."