Riga Technical University
Institute of Power Engineering
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ELECTRICAL INSTALLATION OF RESIDENTIAL BUILDINGS

Methodical Guidelines for Practical Works

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These methodological guidelines for practical works have been developed for students of the course "Electrical installation of residential buildings". It is a methodological material containing theoretical descriptions and design methodology for practical assignment as prescribed in the course programme. The study material has been developed for regular, external, and part-time students of electrical power engineering studies.
The material includes the assignments, methodological materials, final examination materials developed and collected by the Department of Electric Supply.

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INTRODUCTION

The task of a practical assignment is to develop wiring for a residential building and to include an auxiliary building in the plan. The feeder link is an overhead or cable line that enters the house from East/West/South/North. Supply voltage: 400/230 V.

Step-by-step plan:

- draw up the general plan;
- draw the electric supply part of the axonometric drawing of the residential house;
- select fixed and mobile power using equipment and include a tankless water heater (17 kW);
- draw up the abridged circuit diagram of the residential building;
- calculate design power for each of the groups of the main switchgear and the house lead;
- select the necessary elements of the wiring system;
- calculate voltage deviation at one of the electrically most distant installation points and assess its admissibility;
- draw wiring plans for all floors of the residential building (in the basement, the wiring shall be installed above the plaster, while on all other floors — under the plaster);
- write down the step-by-step plan for mounting a lamp / socket on a brick/wooden surface.

Additional task: draw connection circuit of a meter.

Figure 1 represents the structure of an electricity supply project of a residential house.

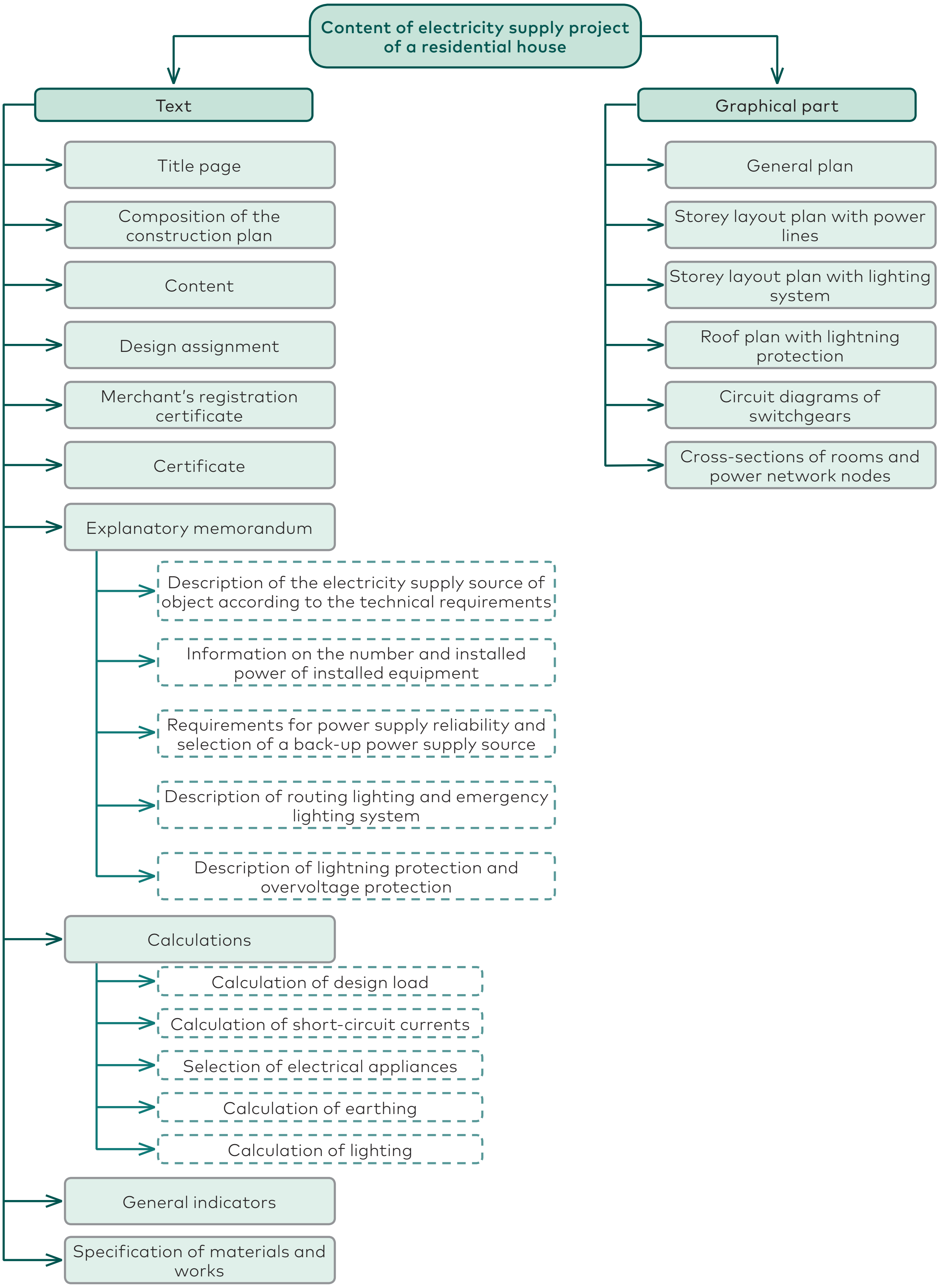


Fig. 1. Optimised structure of an electricity supply project of a residential house.

1. OBJECT STRUCTURE AND ARRANGEMENT IN THE CONSTRUCTION SITE

The explanatory note shall provide information on the following:
1) geographical arrangement of the section;
2) object's address;
3) area of the house;
4) access roads;
5) options of electricity supply;
6) installed electric power P = ….. kW, cosφ = ….., earthing network: TN-C/TN-S/TNC-S;
7) outer walls and partition walls of the building;
8) location of furniture (freely selected).

Functional use of buildings and description of the electric power: power of the fixed and mobile using equipment located in the residential building. The residential building is a one-storey/two-storey building with/without basement. The total usable area of premises: …. m^2. The following electrical appliances are located in the house:

- washing machine: P = …. kW;
- dishwashing machine: P = …. kW;
- small technological kitchen device: …. kW, …. kW, …. kW, …. kW, …. kW;
- refrigerator: P = …. kW;
- electric stove: P = …. kW;
- tankless water heater: P = …. kW;
- electric motor for opening the garage gate: P = …. kW;
- other fixed using equipment: …. kW, …. kW, …. kW, …. kW, …. kW.

Examples of fixed using equipment are given in Table 1.1.

Table 1.1

Possible power of using equipment and location of the equipment in premises

Room No. (explications)	Room type	Using equipment	cos φ	*P*, kW
	Entrance	LED bulbs	0.90	0.012
	Hall	Router	0.65	0.020
		LED bulbs	0.90	0.012
	Auxiliary room	Boiler	1.00	10.000
		Washing machine	0.80	1.000
		LED bulbs	0.90	0.012
	Dining room/kitchen	Teapot	1.00	2.500
		Refrigerator	0.65	1.400
		Coffee machine	0.90	1.500
		Cooker hood	0.75	0.250
		Microwave oven	0.75	1.500
		Electric stove	0.98	9.000
		LED bulbs	0.90	0.012
	Household room	iRobot	0.75	0.600
		LED bulbs	0.90	0.012
	Living room	TV set	0.65	0.150
		DVD	0.65	0.006
		Decoder	0.65	0.006
		Mobile phone charger	0.80	0.005
		LED bulbs	0.90	0.012
	Room	Lamp	0.90	0.008
		Computer	0.65	0.100
		Table lamp	1.00	
		LED bulbs	0.90	0.012
		Table lamp	0.90	0.008
		LED bulb	0.90	0.012
	Bathroom	Hair dryer	0.80	1.700
		Electric razor	0.75	0.015
		LED bulb	0.90	0.012
		Fan	0.75	0.020
	Garage/shed/greenhouse	LED bulb	0.90	0.012

2. GENERAL PLAN OF THE OBJECT

Table 2.1

Explication of buildings and structures

No. in the plan	Name of the structure	Area, m^2	Notes
1	Residential building	……	P_{uzst} = …, cosφ = …
2	Sauna	……	P_{uzst} = …, cosφ = …
3	Garage	……	P_{uzst} = …, cosφ = …
4	Shed	……	P_{uzst} = …, cosφ = …
5	Greenhouse	……	P_{uzst} = …, cosφ = …

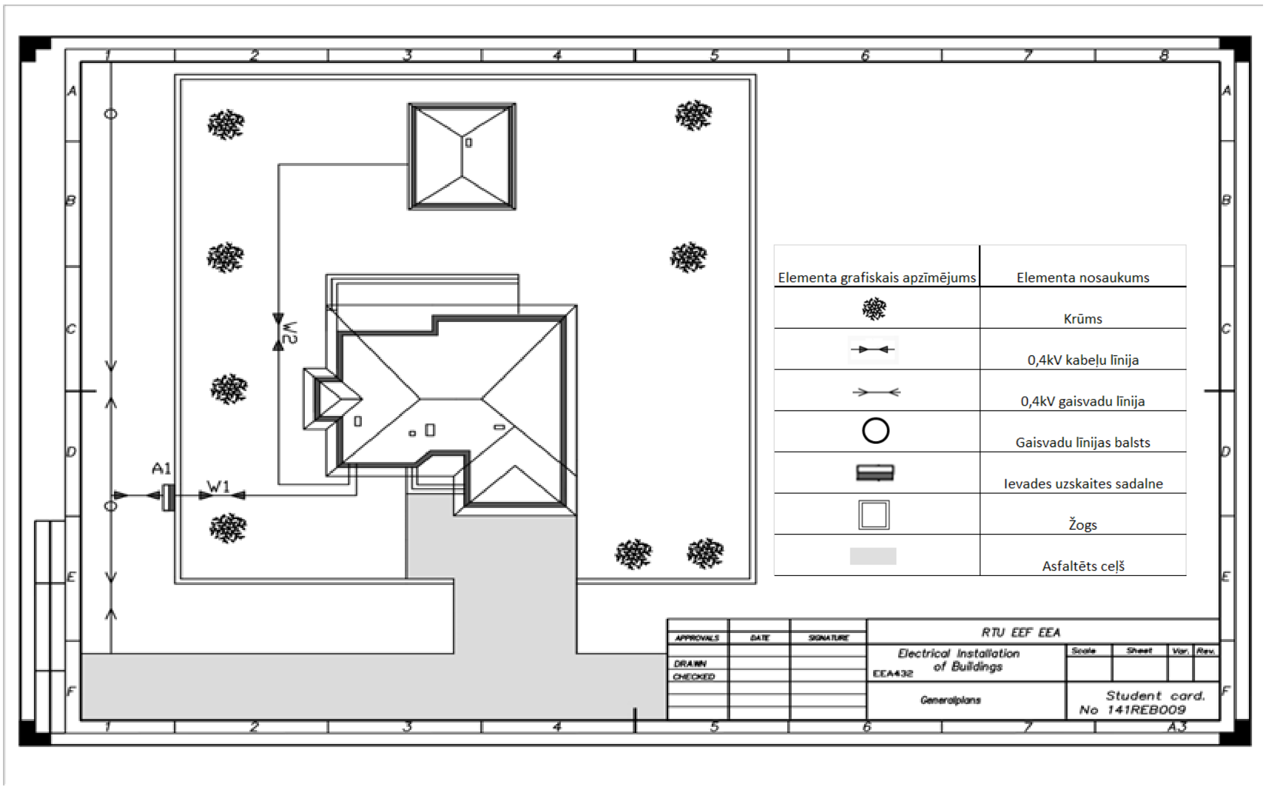


Fig. 2.1. General plan of the object.

3. CIRCUIT DIAGRAMS OF WIRING IN THE RESIDENTIAL BUILDING

A1 switchgear must comply with the requirements of AS Sadales tīkls and must be located outside the object's territory so that it is easy accessible by an inspector. A1 metering switchgear feeds the main switchgear A2 of the house from which the main cables to group switchgears lead according to the assignment variant.

Cable routes shall be installed under the plaster everywhere. Lighting systems and socket network shall be designed to be separate. See an example of the circuit diagram in Annex 2. DESIGN PART

4. DETERMINATION OF THE DESIGN POWER IN A NETWORK WITH UNEVENLY LOADED PHASES

When designing electricity supply to a residential building, design power for both separate groups of the switchgear and the feeding lead in general must be determined, considering the existing or planned using equipment. Three-phase, two-phase, and single-phase using equipment can be connected to three-phase switchgears (Fig. 4.1). The power of single-phase and two-phase using equipment can be divided unevenly. In this case, the equivalent three-phase power in the building lead is calculated using single-phase and two-phase consuming units. Real power is calculated as follows:

$$P_{\text{en}} = 3P_{\text{nmf}}, \tag{4.1}$$

where P_{en} — equivalent real three-phase power from unevenly loaded phases, W;
P_{nmf} — real power of the phase loaded mostly by the using equipment connected to two-phase and single-phase voltage, W.

$$P_{\text{nmf}} = \sum_i P_{\text{f}i} + P_{\text{flin}}, \tag{4.2}$$

where $\sum_i P_{\text{f}i}$ – total power that is connected to the voltage of the maximum loaded phase, W;

P_{flin} – power of the maximum loaded phase that is gained from two-phase using equipment, W. It can be calculated using the following equations (4.3)–(4.5):

$$P_{\text{L1}} = \frac{P_{\text{L1,2}} + P_{\text{L3,1}}}{2}, \tag{4.3}$$

where $P_{\text{L1,2}}$ — power of the two-phase using equipment connected between the phases "1" and "2", W;
$P_{\text{L3,1}}$ — power of the two-phase using equipment connected between the phases "3" and "1", W;

$$P_{\text{L2}} = \frac{P_{\text{L1,2}} + P_{\text{L2,3}}}{2}, \tag{4.4}$$

where $P_{\text{L2,3}}$ — power of the two-phase using equipment connected between the phases "2" and "3", W;

$$P_{\text{L3}} = \frac{P_{\text{L2,3}} + P_{\text{L3,1}}}{2}, \tag{4.5}$$

Calculation of the reactive power is similar to the calculation of the real power.

In practice, the group power should be divided in phases in the switchgear as evenly as possible. If the irregularity of phase power does not exceed 15 % of the total installed power, the power can be regarded as symmetrical.

In Fig. 4.1, both single-phase (L1; L2; L3) and two-phase (L1,2; L3,1; L2,3), and three-phase (L) using equipment are connected to the switchgear:

- P_{L1}, P_{L2}, P_{L3} and Q_{L1}, Q_{L2}, Q_{L3} are the total real and reactive power of the using equipment connected to the corresponding phase;
- $P_{L1,2}$, $P_{L3,1}$, $P_{L2,3}$ and $Q_{L1,2}$, $Q_{L3,1}$, $Q_{L2,3}$ are the total real and reactive power of the two-phase using equipment;
- using equations (4.3)–(4.5), it is possible to change from two-phase loads to single-phase loads and to sum P_{L1}, P_{L2}, P_{L3} and Q_{L1}, Q_{L2}, Q_{L3};
- P_L and Q_L is the real and reactive power of all three-phase groups of a switchgear.

Assuming that the largest power is in phase L1 (Fig. 4.1), the total three-phase apparent power in an unevenly loaded network $S_{3f\Sigma}$ that flows in the cable W feeding switchgear can be established according to (4.6):

$$S_{3f\sum} = \sqrt{\left(3P_{L1} + P_L\right)^2 + \left(3Q_{L1} + Q_L\right)^2}, \quad (4.6)$$

where P_{L1} – total real power of using equipment connected to phase L1, W;
Q_{L1} – total reactive power of using equipment connected to phase L1, var;
P_L – total real power of three-phase using equipment, W;
Q_L – total reactive power of three-phase using equipment, var;

All using equipment are not turned on simultaneously and not all using equipment operate with complete (rated) load; therefore, the actual power (design power) flowing in line W (Fig. 4.1) will be less than calculated according to equation (4.6). Decrease in the power is determined considering the demand factor k_p:

$$S_{3fapl} = k_p S_{3f\sum}, \quad (4.7)$$

where S_{3fapl} – design power flowing in the feeding cable W, VA
k_p – demand factor:

$$k_p = k_v k_n, \quad (4.8)$$

where k_v – coincidence factor (Table 4.1);
k_n – load factor.

Table 4.1

Number of using equipment	2	3	4, 5	6, 7	8–10	11–15
k_v	0.85	0.80	0.75	0.70	0.65	0.60

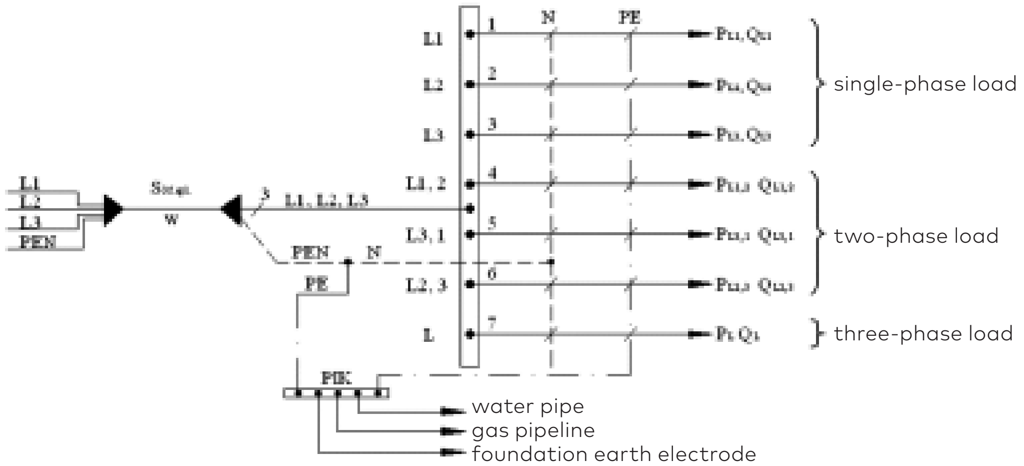


Fig. 4.1. Illustrative drawing for determining the design power in the house lead (not including the switching devices) [122]: W — feeding cable; L1, L2, L3 — phase wires; PEN — protection neutral conductor; PE — protection conductors; N — neutral conductor; PIK — potential equaliser busbar; 1–7 — group numbers in the switchgear.

5. SELECTION OF LOW-VOLTAGE ELECTRICAL INSTALLATIONS

Busbars in low-voltage switchgears must be selected according to the necessary resistance to possible mechanic damage. To order the switchgears, the necessary apparatuses and types thereof must be provided.

5.1. Selection of low-voltage cables

Cable test following thermal impact using the formula (5.1):

$$S \geq S_{\text{th,min}} = \frac{\sqrt{B_{\text{k}}}}{C_{\text{th}}} = \frac{\sqrt{I_{\text{p0}}^2 t_{\text{dros}}}}{C_{\text{th}}}, \tag{5.1}$$

where $S_{\text{th,min}}$ – minimum permitted area of conductor cross-section, mm^2;
$t_{\text{droš}}$ – burn-out time of cable protection fuse, s;
C_{th} – factor for testing thermal resistance of cable insulation, $C_{\text{th}} = 75$;
I_{p0} – effective value of the periodic component of short-circuit current during the first period, A;
B_{k} – heat impulse, A^2 s.

Voltage drop test must be carried out for the selected cables W according to formula (5.2):

$$\Delta U = \sum \frac{(PR_0 + QX_0)L}{U_{\text{t}}}. \tag{5.2}$$

Test for voltage drop in percent:

$\Delta U\ \% \leq 5\ \%.$

The condition is fulfilled if the permitted voltage drop in cable end is less than 5 %, but this voltage drop is not the determinant as the voltage drop at the end user must be evaluated.

Selection of other cables is shown in Table 5.1.

Table 5.1

Test of the selected cables

Cable beginning	Cable end	Cable	S_{apl}, kVA	Cable material	Cable, mm²	$S_{kab} \geq S_{ek}$	$I_{pieļ} \geq I_{apl}$	ΔU, %
1	2	3	4	6	7	8	9	10
US	GS	W						
GS	SS-1	W1						

5.2. Selection of the main switchgear busbar

Design should result in the selection of busbars of the main switchgear (GS). The following parameters shall be established for switchgears (Table 5.2): admissible continuous current, length, width, height, and distance between busbars (this will be observed when selecting the switchgear, or in individual assembly when ordering a switchgear).

Table 5.2

Technical parameters of a busbar

$I_{pieļ}$, A	Length, mm	Width, mm	Height, mm	Distance between busbars, mm

Busbar selection according to continuous duty is done according to formula (5.3):

$$I_{pieļ.fakt} = K_{11} K_{15} I_{pieļ} \geq I_{apl}, \qquad (5.3)$$

where $I_{pieļ.fakt}$ – is the actual admissible current for a busbar according to the operation conditions, A;

K_{15} – the factor according to the busbar location.

Peak withstand current test of a busbar is carried out according to the following conditions:

$$\sigma_{pieļ} \geq \sigma_{apl}, \qquad (5.4)$$

$$\sigma_{apl} = \frac{M}{W}, \qquad (5.5)$$

$$M = \frac{Fl}{k_{st}}, \qquad (5.6)$$

$$W = \frac{bh^2}{6}, \qquad (5.7)$$

$$F = \sqrt{3} k_j i_{tr}^2 = \frac{l}{a}, \qquad (5.8)$$

where $\sigma_{pieļ}$ – admissible bending stress in a busbar, MPa;

σ_{apl} – bending stress caused by electrodynamic force, MPa;

M – bending moment in the busbar span, N m;

W – moment of resistance of busbar cross-section, m^3;

k_{st} – busbar strength factor, k_{st} = 8–12;

F – electrodynamic force acting on the busbar, N;
l – distance between insulator units, m;
a – distance between busbars, m;
b – busbar height, m;
h – busbar width, m.

If results of these tests are satisfactory, the selected busbars may be installed in the main switchgear.

5.3. Selection of current transformers and electricity meters

Current transformers TA with a meter are installed on the main switchgear busbars after transformer T.

Selection of current transformers according to voltage is done according to the following condition (5.9):

$$U_t \leq U_{nom}. \quad (5.9)$$

Selection of current transformers according to rated current is done according to the following condition (5.10):

$$I_{nom} \geq I_{apl}. \quad (5.10)$$

Selection of current transformers according to secondary load is performed according to equations (5.11)–(5.14):

$$Z_{2nom} \geq Z_2, \quad (5.11)$$

$$Z_2 = Z_{sl} + R_{kont} + R_v, \quad (5.12)$$

$$R_v = \rho_{Cu} K_{sh} \frac{l_{vad}}{S_{vad}}, \quad (5.13)$$

$$Z_2 = \frac{S_{skait}}{I^2_{skait}}, \quad (5.14)$$

where Z_{2nom} – rated load of secondary winding of a current transformer, $Z_{2nom} = 0.2\ \Omega$;
Z_2 – resistance of design load in the secondary circuit, Ω;
Z_{sl} – meter resistance, Ω;
R_{kont} – contact resistance, $R_{kont} = 0.1\ \Omega$;
R_v – conductor resistance, Ω;
ρ_{Cu} – copper specific resistance, $\rho_{Cu} = 0l.017\ (\Omega\ mm^2)/m$;
K_{sh} – circuit factor, $K_{sh} = 1$, if the current transformers are connected in a star configuration;
l_{vad} – conductor length, m;
S_{vad} – area of conductor cross-section, mm^2;
S_{skait} – meter power, $S_{skait} = 0.8$ VA;
I_{skait} – rated current of the meter, $I_{skait} = 5$ A.

Determine the meter resistance according to formula (5.15):

$$Z_2 = \frac{S_{skait}}{I^2_{skait}} = \frac{0,8}{5^2} = 0,032\ \Omega. \quad (5.15)$$

Determine resistance in the conductor assuming that it is a copper conductor (2.5 mm^2) with the total length of 3 m:

$$R_v = \rho_{Cu} K_{sh} \frac{l_{vad}}{S_{vad}}. \quad (5.16)$$

Determine design load in the secondary circuit of the current transformer according to the following formula:

$$Z_2 = Z_{sl} + R_{kont} + R_v. \quad (5.17)$$

The condition is tested (5.11):

$$Z_{2nom} \geq Z_2.$$

Selection of current transformer by thermal strength is done according to the following condition:

$$(K_{th} I_{1nom})^2 t_{th} \geq B_k, \quad (5.18)$$

where K_{th} – thermal strength factor of the current transformer, K_{th} = 60;
I_{1nom} – rated current of the primary winding, I_{1nom} = 5 A;
t_{th} – duration of thermal strength t_{th} = 1 s.

Design heat impulse near current transformers is determined using the following formula:

$$B_k = I_{p0}^2 t_k. \quad (5.19)$$

Thermal strength of the current transformer

$$(K_{th} I_{1nom})^2 t_{th} \geq B_k. \quad (5.20)$$

Selection of current transformer by the dynamic endurance is done according to the following condition:

$$I_{dynTA} \geq i_{tr}, \quad (5.21)$$

where I_{dynTA} – dynamic resistance current of the current transformer, kA;
i_{tr} – surge current on the main busbars.

$$I_{dynTA} \geq i_{tr}. \quad (5.22)$$

If all the conditions are fulfilled, the selected current transformer with a specified accuracy class may be used.

5.4. Selection of low-voltage fuses

Fuses as a protection device for equipment and cables may be installed in the main and group switchgears. Fuses must be selected applying the following algorithm.

Selection of fuses according to voltage is done according to the following condition:

$$U_t \leq U_{nom}. \quad (5.23)$$

Selection of fuses according to rated current is done according to the following condition:

$$I_{iel.nom} \geq K_{dr} I_{apl}, \quad (5.24)$$

where $I_{iel.nom}$ – rated current of fuse;
K_{dr} – safety factor, K_{dr} = 1.00–1.25.

Selection of fuses according to technological overload current is done according to the following condition:

$$I_{iel.nom} \geq \frac{I_{sm}}{K_{pārsl}}, \quad (5.25)$$

where $K_{pārsl}$ – empirical overload factor (may be determined within these limits: 1.6–2.5);
I_{sm} – device peak current.

In the case of one motor, the starting current may exceed the motor rated current even by seven times, in case of several motors, the starting current is determined according to formula

$$I_{sm} = i_{sm,max} + I_{apl} - K_{iz} i_{max,nom}, \quad (5.26)$$

where $i_{sm,max}$ – the largest peak current of the given group of consuming units, A;
$i_{max,nom}$ – rated current of the consuming unit with the highest peak current, A;
I_{apl} – design current of a group of consuming units, A;
K_{iz} – characteristic coefficient factor of the consuming unit with the highest peak current.

Test of the protective cable is done according to this condition:

$$I_{pieļ} \geq \frac{I_{iel.nom}}{K_{aizs}}, \quad (5.27)$$

where $I_{pieļ}$ – admissible current in a cable, A;
K_{aizs} – protection factor; if protection is necessary only against short circuit then $K_{aizs} = 3$, if protection is necessary only against continuous overloads then $K_{aizs} = 0.8–1.0$.

Test of fuses according to sensitivity is done according to the following condition:

$$I_k^1 \geq K_j I_{iel.nom}, \quad (5.28)$$

where K_j – sensitivity factor, $K_j = 3$.

Test of fuse in a single-phase short-circuit:

$$I_k^1 \geq K_j I_{iel.nom}.$$

Test of fuses according to breaking capacity is done according to the following condition:

$$I_{atsl.nom} \geq I_{p0}, \quad (5.29)$$

where $I_{atsl.nom}$ – the breaking capacity of fuse short-circuit.

5.5. Selection of protective circuit breaker

Selection of the automatic circuit breaker SF2.10 is similar to fuse selection.

Selection of automatic circuit breakers according to voltage is done according to the following condition:

$$U_t \leq U_{nom}. \quad (5.30)$$

Selection of automatic circuit breakers according to design current is done according to the condition

$$I_{iel.nom} \geq K_{dr} I_{apl}. \quad (5.31)$$

Selection of automatic circuit breakers according to technological overload current is done according to the condition

$$I_{iel.nom} \geq \frac{7 I_{apl}}{K_{pārsl}}. \quad (5.32)$$

Test of the protective cable is done according to the condition (5.33). The mentioned SF2.10 protects motor M-2.10; therefore, W2.10 must be checked. Cable must be protected only against short circuits; therefore, the following is assumed: $K_{aizs} = 3$.

$$I_{pieļ} \geq \frac{I_{iel.nom}}{K_{aizs}}. \quad (5.33)$$

Test of automatic circuit breaker according to sensitivity is done according to the condition

$$I_{\text{k}}^{1} \geq K_{\text{j}} I_{\text{iel.nom}}. \tag{5.34}$$

Test of automatic circuit breaker according to breaking capacity is done according to the condition:

$$I_{\text{atsl.nom}} \geq I_{\text{p0}}. \tag{5.35}$$

5.6. Calculation of three-phase short-circuit current

To be able to select and test electrical apparatuses and conductors, for example in the switchgear cable of a residential building, three-phase short-circuit currents both before 10 kV or 20 kV transformer and after the transformer on the 0.4 kV side must be taken into account in calculations. For the calculation of short-circuit current according to the design circuit diagram (Fig. 5.1 a)), a substitution circuit diagram (Fig. 5.1 b)) must be drawn up. Resistances of electrical apparatuses on the high-voltage side are not taken into account in calculation of short-circuit currents, as they are very small.

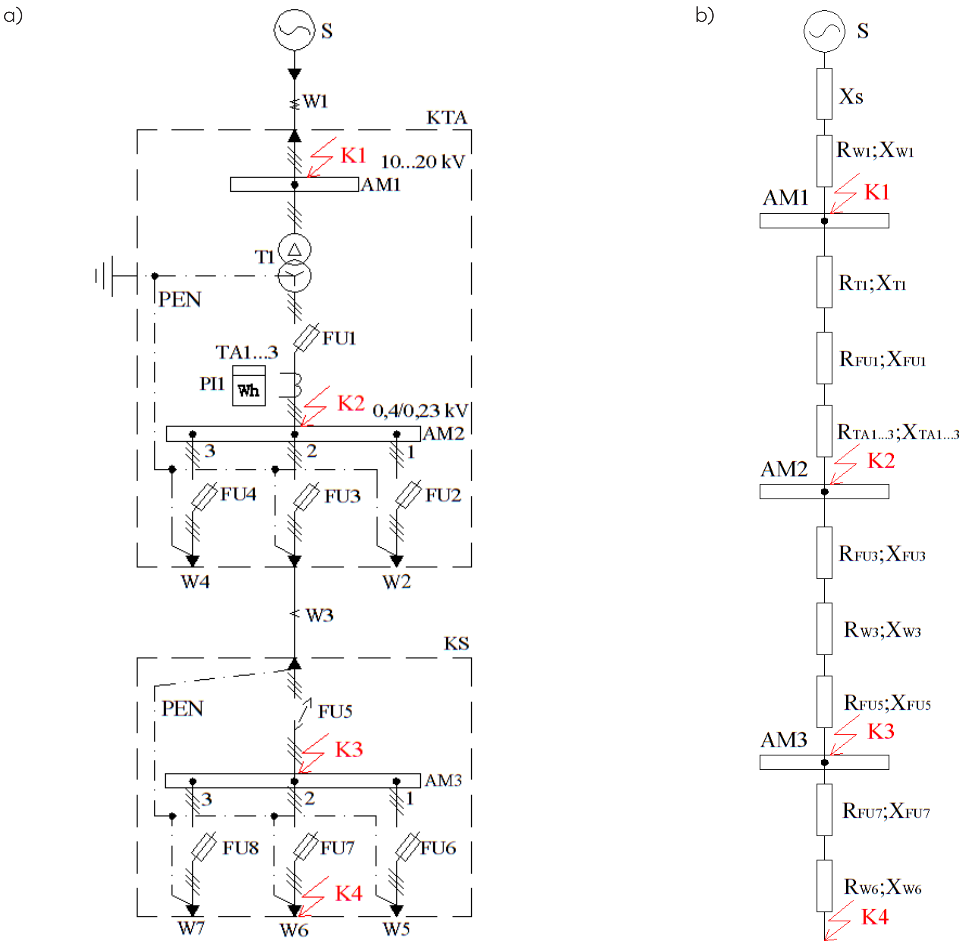


Fig. 5.1. Example of a fragment of electric supply circuit for a residential house: **a**) design circuit; **b**) substitution circuit, where K1–K4 is short-circuit point.

Three-phase short-circuit current is calculated as follows:

$$I_{\text{K}}^{(3)} = \frac{E_{\text{S}}}{\sqrt{3} Z_{\Sigma}}, \tag{5.36}$$

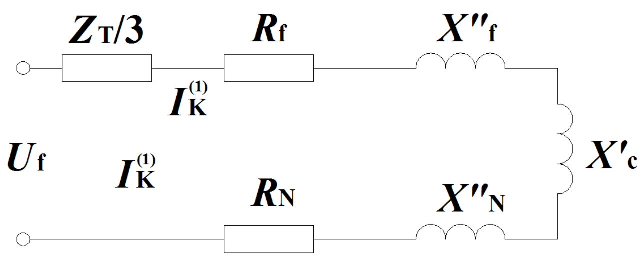
where E_{S} – system electromagnetic force, V;
Z_{Σ} – total impedance, Ω.

See the calculation of resistance of the substitution circuit (Fig. 5.1 **b**) in the Table in Annex 3.

5.7. Calculation of single-phase short-circuit current

Single-phase short-circuit current is calculated to test the sensitivity of electrical apparatuses. It is very important as single-phase short-circuit current may be the decisive one in selecting protective devices in some cases. In practice, when protective devices are selected, one-phase short-circuit currents are often disregarded.

In low-voltage networks with earthed neutral, the symmetrical component method is used in the calculations of single-phase short-circuit current. Figure 4.2 shows shorted loop with resistance values used in the design.



U_f — phase voltage
Z_T — transformer impedance
R_f — resistance of phase wire
X_f'' — internal inductive reactance of phase wire
R_N — resistance of neutral conductor
X_N'' — internal inductive reactance of neutral conductor
X_c' — external inductive reactance of short-circuit loop

Fig. 5.2. Design circuit of one-phase short-circuit loop.

$$I_K^{(1)} = 3I_{K1}^{(1)} = \frac{3U_f}{Z_{\Sigma 1} + Z_{\Sigma 2} + Z_{\Sigma 0}}, \quad (5.37)$$

where $I_{K1}^{(1)}$ – positive sequence component of single-phase short-circuit current, A;
U_f – network phase voltage, V;
$Z_{\Sigma 1}$ – total positive sequence resistance, Ω;
$Z_{\Sigma 2}$ – total negative sequence resistance, Ω;
$Z_{\Sigma 0}$ – total zero sequence resistance, Ω;

In equation (5.37), it is necessary to take into account resistances of the transformer and all network sections (loop):

$$I_K^{(1)} = \frac{3U_f}{Z_{T1} + Z_{T2} + Z_{T0} + Z_{t1} + Z_{t2} + Z_{t0}}, \quad (5.38)$$

where Z_{T1} – transformer positive sequence resistance, Ω;
Z_{T2} – transformer negative sequence resistance, Ω;
Z_{T0} – transformer zero sequence resistance, Ω;
Z_{t1} – network positive sequence resistance, Ω;
Z_{t2} – network negative sequence resistance, Ω;
Z_{t0} – network zero sequence resistance, Ω.

Transformer and network positive and negative sequence resistances are equal: $Z_{T1} = Z_{T2}$, $Z_{t1} = Z_{t2}$. Network zero sequence resistance

$$Z_{t0} = R_f + 3R_N + j(X_L + 2X_M), \quad (5.39)$$

where R_f – resistance of faulted phase, Ω;
R_N – resistance of neutral conductor, Ω;
X_L – inductive reactance of loop, Ω;
X_M – inductive reactance of the mutual inductance of the circuit of unfaulted phases and return wire with short-circuit loop, Ω. If the distance between phase wires is small, then it is assumed that $X_L = X_M$.

According to the external and internal inductive reactance,

$$X_{\mathrm{L}} = X_{\mathrm{c}}' + X_{\mathrm{f}}'' + X_{\mathrm{N}}'', \qquad (5.40)$$

where X_c’ – external inductive reactance of short-circuit loop, Ω;
X_f ”– internal inductive reactance of phase wire, Ω;
X_N” – internal inductive reactance of neutral conductor, Ω.

$$X_{\mathrm{c}}' = 0,29 \lg \frac{D}{\sqrt{r_{\mathrm{f}}\, r_{\mathrm{N}}}}, \qquad (5.41)$$

where r_f – radius of phase wire, m;
r_N – radius of neutral conductor, m;
D – distance between the axis of phase wire and neutral conductor, m.

Network zero sequence resistance

$$Z_{\mathrm{t0}} = R_{\mathrm{f}} + \mathrm{j}3X_{\mathrm{f}}'' + 3(R_{\mathrm{N}} + \mathrm{j}X_{\mathrm{N}}'') + \mathrm{j}3X_{\mathrm{c}}'. \qquad (5.42)$$

According to the connection between positive and negative sequence resistances, equation (5.42) is included in formula (5.38) assuming that $Z_{\mathrm{t1}} = R_{\mathrm{f}} + \mathrm{j}3X_{\mathrm{f}}''$, then

$$I_{\mathrm{K}}^{(1)} = \frac{U_{\mathrm{f}}}{\dfrac{2Z_{\mathrm{T1}} + Z_{\mathrm{T0}}}{3} + Z_{\mathrm{t1}} + R_{\mathrm{N}} + \mathrm{j}X_{\mathrm{N}}'' + \mathrm{j}X_{\mathrm{c}}'}. \qquad (5.43)$$

Network impedance

$$Z_{\mathrm{t}} = R_{\mathrm{f}} + \mathrm{j}X_{\mathrm{f}}'' + R_{\mathrm{N}} + \mathrm{j}X_{\mathrm{N}}'' + \mathrm{j}X_{\mathrm{c}}'. \qquad (5.44)$$

To simplify the calculation of short-circuit current, Z is usually summed up without dividing it in R and X:

Then the single-phase short-circuit current

$$I_{\mathrm{K}}^{(1)} = \frac{U_{\mathrm{f}}}{\dfrac{Z_{\mathrm{T}}}{3} + Z_{\mathrm{t}}}. \qquad (5.45)$$

Value of transformer resistance Z_T can be looked up in the manual. Transformer resistance depends on the type of the transformer, connection group, primary voltage, and transformer rated power.

Network resistance Z_t or the loop phase zero resistance Z_c can be calculated by using (5.46):

$$Z_{\mathrm{c}} = Z_{\mathrm{c.\bar{i}p}}\, l, \qquad (5.46)$$

where $Z_{c.\bar{i}p}$ – a specific resistance of conductor loop that can be looked up in a manual, Ω/km;
l – conductor length, km.

Specific resistance of conductor loop depends on the material and cross-section of the conductor.

Table 5.3

Selection of low-voltage fuses

Desig-nation	I_{apl}	Type	$U_{nom} \geq U_t$	$I_{iel.nom} \geq K_{dr} I_{apl}$	$I_{iel.nom} \geq I_{sm}/K_{pārsl}$	$I_{pieļ} \geq I_{iel.nom}/K_{aizs}$	$I_k^1 \geq K_j I_{iel.nom}$	$I_{atsl.nom.} \geq I_{p0}$
1	2	3	4	5	6	7	8	9
FU2								
FU3								
FU4								
FU5								
FU6								

Table 5.4

Selection of low-voltage protective circuit breakers

Desig-nation	I_{apl}	Type	$U_{nom} \geq U_t$	$I_{iel.nom} \geq K_{dr} I_{apl}$	$I_{iel.nom} \geq I_{sm}/K_{pārsl}$	$I_{pieļ} \geq I_{iel.nom}/K_{aizs}$	$I_k^1 \geq K_j I_{iel.nom}$	$I_{atsl.nom} \geq I_{p0}$
1	2	3	4	5	6	7	8	9
SF1.1								
SF1.2								
SF1.3								
SF1.4								
SF1.5								

5.8. Example of drawing up selectivity chart

Testing of fuses and automatic circuit breakers according to the selectivity is done by drawing up selectivity charts. Figure 5.3 presents a selectivity chart for the possible most complex nodes.

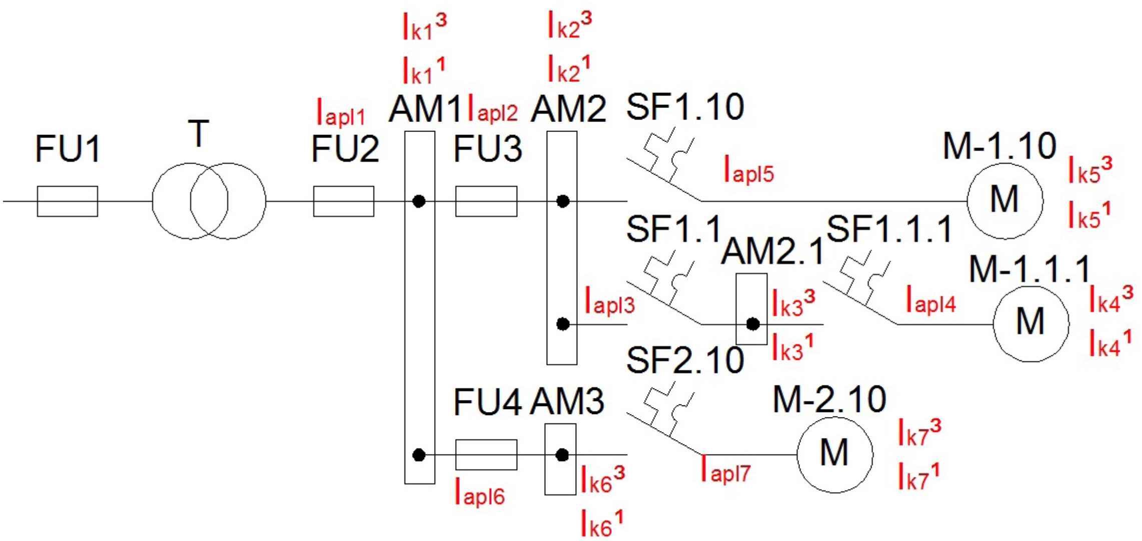


Fig. 5.3. Example of circuit diagram for drawing up a selectivity chart.

Selectivity chart for the branch at the end of which motors *M-1.10*, *M-1.1.1*, and *M-2.10* are installed is shown in Figs. 5.4, 5.5, and 5.6, respectively.

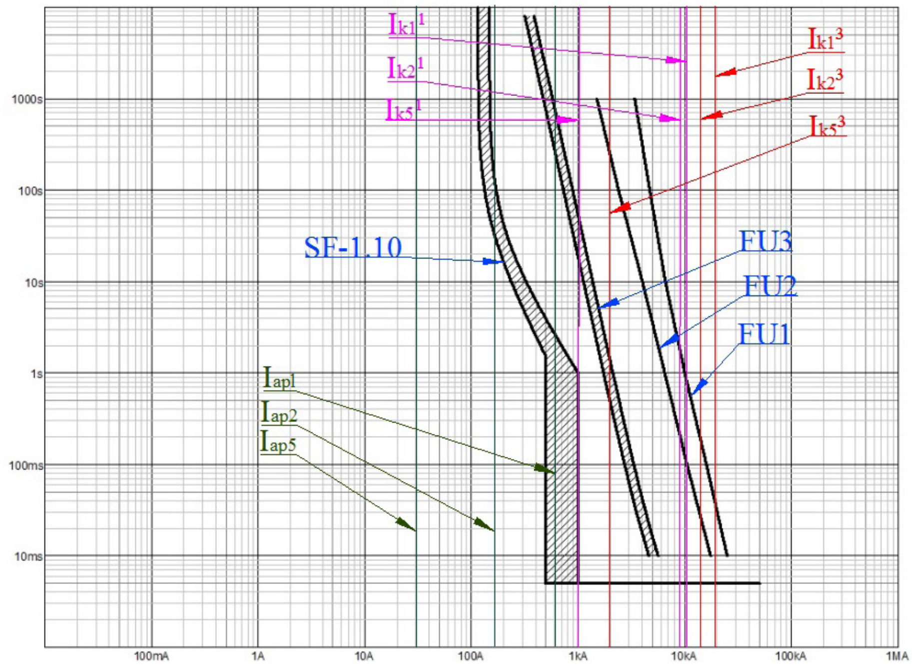


Fig. 5.4. Selectivity chart of motor *M-1.10*.

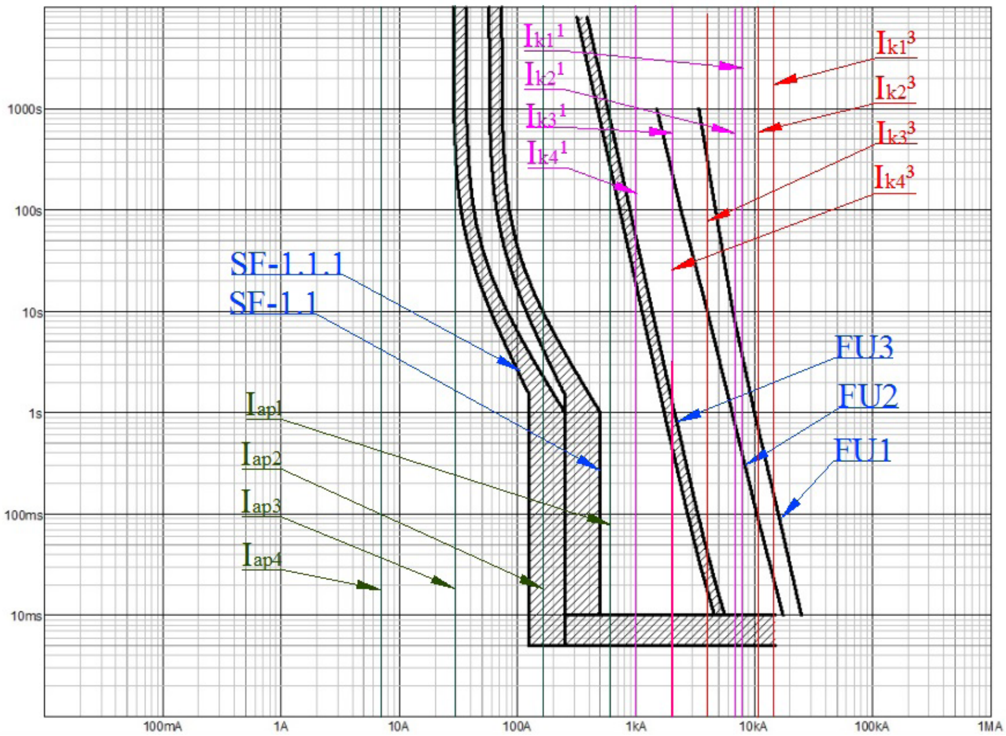


Fig. 5.5. Selectivity chart of motor *M-1.1.1*.

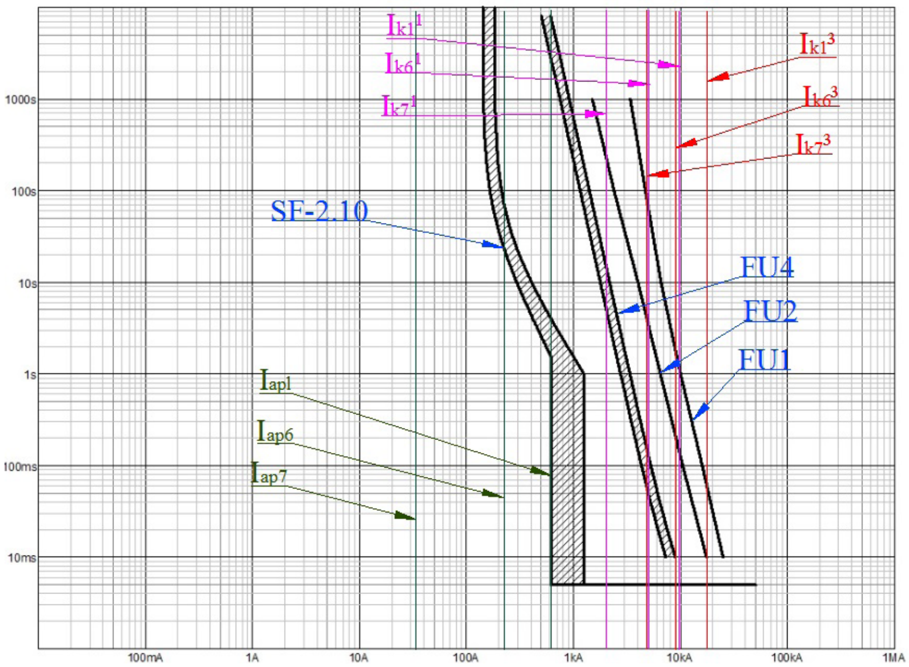


Fig. 5.6. Selectivity chart of motor *M-2.10*.

5.9. Selection of cables

Cables must be selected pursuant to IEC 60287-1-1, LVS EN 50565-1. Voltage deviation is determined according to the standards LVS HD 21.4 S2, LEK 049 LEK 139, LEK 129, and LBN 261-07. Minimum area of cross-section of conducting materials is set according to Table 2 in Annex 4 to the Construction Standard LBN 261-07.

However, in reality cables are often selected only based on the design current by design offices in Latvia. If the type and length of cable and the power flowing through the cable line is known, the voltage deviation can be calculated. In line with LEK 139, the permitted voltage deviation in 1 kV electricity network ranges from 5 % to 10 % of the rated voltage. According to LEK 078, the voltage deviation in 0.4 kV electricity networks of buildings may not exceed 4 % of the rated voltage of the network.

Voltage deviation is determined according to formula (5.47):

$$\Delta U = \frac{\sum \left(P_{\mathrm{W}} R_0 + Q_{\mathrm{W}} X_0\right) l}{U_{\mathrm{t}}}, \qquad (5.47)$$

where P_{W} – real power in the cable line, W;

Q_{W} – reactive power in the cable line, W;

U_{t} – network voltage, V;

l – length of cable line, km;

R_0 – real specific resistance of cable, Ω/km;

X_0 – specific reactance of cable, Ω/km.

Voltage deviation in percent of the rated voltage:

$$\Delta U_{\%} = \frac{\Delta U}{U} \cdot 100, \%. \qquad (5.48)$$

5.10. Selection of low-voltage load switches

Load switch shall be installed in the lead of each switchgear to ensure disconnection of the switchgear to perform maintenance or repair works during operation. Algorithm for selecting load switch is shown hereafter.

Selection of load switches according to voltage is done according to condition

$$U_t \le U_{nom}. \quad (5.49)$$

Selection of load switches according to design current is done according to condition

$$I_{nom} \ge I_{apl}. \quad (5.50)$$

Testing of load switches according to electrodynamic strength is done according to condition:

$$i_{dyn} \ge i_{tr}, \quad (5.51)$$

where i_{dyn} – the current that the device endures without losing the constructive strength, kA;

i_{tr} – the possible largest instantaneous short-circuit current, kA.

$$i_{dyn} \ge i_{tr} = \sqrt{2} I_{p0}^{(3)}. \quad (5.52)$$

Testing of load switches according to thermal strength is done according to condition

$$I_{th}^2 t_{th} \ge B_k, \quad (5.53)$$

$$I_{th}^2 t_{th} \ge B_k = I_{p0}^{(3)} t_k. \quad (5.54)$$

Selection of load switches according to breaking capacity is done according to condition

$$I_{atsl.nom} \ge I_{apl}. \quad (5.55)$$

Selection of other load switches is presented in Table 5.5.

Table 5.5

Selection of load switches (example)

Load switch	I_{apl}, A	Switch	$U_{nom} \ge U_t$	$I_{nom} \ge I_{apl}$	$i_{dyn} \ge i_{tr}$	$I_{th}^2 t_{th} \ge B_k$	$I_{atsl.piel} \ge I_{atsl}$
1	2	3	4	5	6	7	8
QW1							
QW2							
QW3							

5.11. Selection of switches

Switches are selected according to several conditions.

1. Voltage:

$$U_n \ge U_t. \quad (5.56)$$

2. Current:

$$I_n \ge I_m. \quad (5.57)$$

3. Protection against the environmental impact:
   IP XX (0–6; 0–8).
4. Assembly type:
   - under the plaster;
   - above the plaster.
5. Switching circuit:
   - simple single-pole switches;
   - single-pole change-over switches;
   - multiposition switches.

5.12. Selection of sockets

Sockets are selected according to several conditions.

1. Voltage:

$$U_{nom} \geq U_t. \qquad (5.58)$$

2. Protection against the environmental impact (IP): IP2x are mainly sufficient for residential premises, minimum IP44 must be selected for the basement.
3. Place and type of installation: above the plaster in the basement of the residential house and in garage, under the plaster in residential premises.
4. Rated current:

$$I_{nom} \geq I_{apl}. \qquad (5.59)$$

5. Number of phases:
   - single-phase;
   - three-phase.

5.13. Selection of earthing system

Earthing system includes: earth electrode, earth wire, earthing mains and earthing conductors. All protective earth is divided according to the functionality: functional earth and safety earth. Earthing systems are regulated by LVS EN 62305, LVS HD 60364-5-54, LEK 048, LEK 069, and LBN 261-07.

Earth electrodes can be divided into two large groups: natural and artificial earth electrodes. When installing an earthing system, all natural earth electrodes shall be used: water pipes, metallic parts of the building, and the steel reinforcement in foundation that is connected to earth. If the earthing resistance value laid down by regulatory enactments cannot be reached by using the natural earth electrodes, artificial earth electrodes shall be installed.

Feeding of residential buildings with voltage up to 1 kV must be ensured from a power supply with a solidly earthed system using the TN system. TN system is a system in which there is one point that is directly connected with earth and the exposed conductor parts of the device are connected with this point by protection wires. According to the layout of protection wires, three TN system types are distinguished:

1) TN-C is a TN system in which the protective earth (PE wire) and neutral conductor (N wire) are combined in full length;
2) TN-S system is a TN system in which the protective earth and neutral conductor are separate in full length;
3) TN-C-S system is a TN system in which the functions of the protective earth and neutral conductor are combined in one wire only at some part of the line starting from the power source (Fig. 5.7).

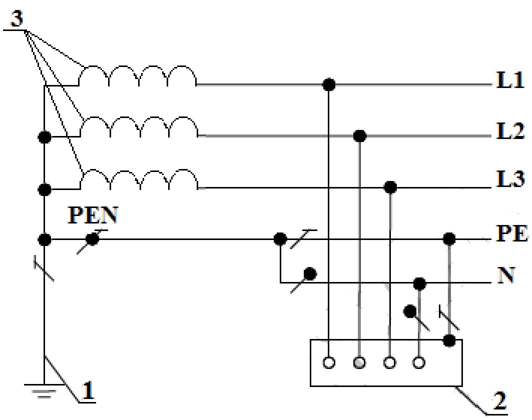


Fig. 5.7. TN-C-S system: 1 – neutral earth of the power source; 2 – exposed conductor parts; 3 – power source.

TN-C, TN-S, and TN-C-S systems for specific electrical installations are selected according to the requirements of power supply standards of these electrical installations. When using a TN system, it is advised to earth PE and PEN wires repeatedly before the lead in the electrical installation and in other accessible places. Natural earth electrodes shall be used first in case of a repeated earth. Exhaust resistance of a repeated earth electrode may not exceed 30 Ω. In large and multi-storey buildings, similar function must be ensured with potential equalisation by connecting protection wire to the main earth busbar.

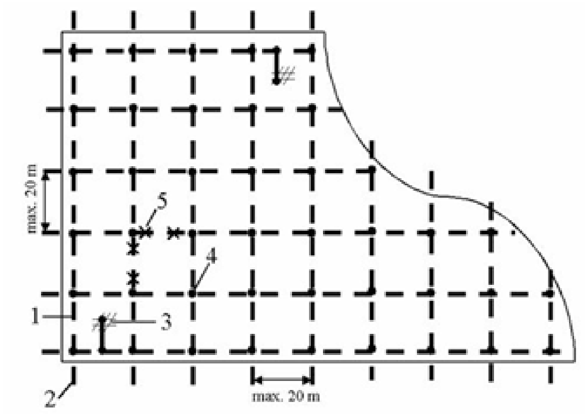
For the protection against indirect connection, automatic protection tripping must be installed in electrical installations. For automatic protection, tripping of the supply automatic circuit breakers that react to overcurrent or leakage circuit can be used. All exposed conductor parts must be connected to solidly earthed system of the power source. If automatic protection tripping of the power source is used, the main potential equalisation system must be installed and, if necessary, also additional potential equalisation system. The main potential equalisation system must interconnect the following conductors in electrical installations with voltage of up to 1 kV.

1. TN system – PE or PEN wire of the feeder link.
2. Earth wire that is connected to a repeated earth at the lead to the building (if there is an earth electrode).
3. Metal pipes of engineering communications in the building (cold and hot water pipes, sewage pipes, gas pipelines, etc.). If there is an insulating bush in the lead of gas pipeline, only the part of the gas pipeline that is located at the same side as the building, if looking from the insulating bush, shall be connected to the main potential equalisation system.
4. Metal parts of building frame and elevator shaft.
5. Metal parts of the central ventilation and conditioning systems. If ventilation and conditioning systems are not centralised, the metal air conduits shall be connected to the PE busbar of the supply switchgear.
6. Earth electrode of the functional earth, if there is such and if there are no restrictions on connecting the functional earth network to the safety earth device.

To connect all the mentioned parts with the main potential equalisation system, these parts shall be connected to the main earth busbar with the wires of potential equalisation system.

Foundation earth electrode is the reinforced concrete or additional conductor that is laid in the concrete foundation of a building and is used as an earth electrode. To ensure good connections, it is suggested to establish an additional metal conductor network that is connected to the reinforced concrete bars in addition to the twin-twisted reinforced concrete bars. Where appropriate, a connection wire shall be led from the reinforced concrete to the external lightning conductor wires or to those building constructions that are used as lightning conductor wires, and to the earthing system installed outside the building.

Reinforced concrete shall cover the foundation earth electrode (Fig. 5.8) with a minimum 50 mm thick layer that ensures good protection against corrosion. The steel bars present in reinforced concrete have equal galvanic potential to the copper laid into ground. This is a good solution for installing earthing system in reinforced concrete buildings, with minimum costs.



1 — foundation earthing wire, for example 40 mm × 4 mm galvanised flat bars
2 — foundation earthing terminal
3 — connection point to reinforced steel
4 — connecting clamp of foundation earth electrode parts
5 — additional connection of foundation earth electrode to steel bars

Fig. 5.8. Location of foundation earth electrodes.

Materials, dimensions, cross-section area of earth electrodes, and minimum cross-section area of protection conductors are determined according to Tables 3 and 4 in Annex 4 to the Construction Standard LBN 261-07, LVS EN 62305-3, and LEK 048. Resistance of earthing devices in 400/230 V electrical grids together with the natural earth electrode must not exceed 4 Ω [55]. If it is not possible to measure the resistance of the natural earth electrode, for example in a newly built building, the natural earth electrode shall not be taken into account.

5.14. Explication of materials

At the end, explication of materials must be drawn up and Table 5.6 must be filled in.

Table 5.6

Explication of materials

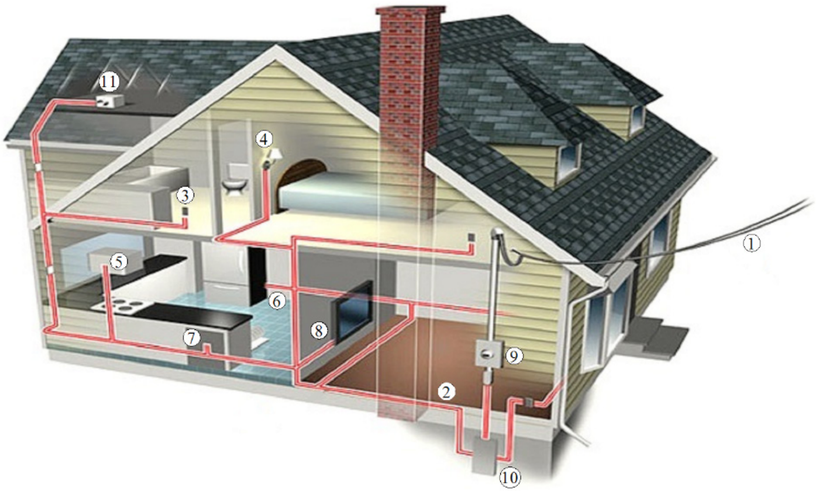
No.	Name	Type, manufacturer	Quantity	Measurement unit	Alphanumeric designation (Annex 1)

6. TYPES OF ELECTRICAL INSTALLATION AND WIRING METHODS

Electrical installation is the totality of low-voltage wires, fixing elements, supports, and other constructions that constitute the lighting network, power system, or electric circuits of control, signalisation, and protective relaying. This chapter introduces the types of electrical installation and general principles of wiring methods, as well as deals with the controversial issue of the height for installing switches and sockets from the floor. Specific principles for selecting conductors and apparatuses are discussed in previous chapters.

Electrical installation can be subdivided in outside and inside wiring. **Outside wiring** ensures supply of electricity to the building. Inside wiring is located within the building. Inside wiring can be either exposed or hidden. Using the exposed wiring (above the plaster), wires are fixed to the surface of walls, ceiling and beams, as well as in metal or plastic ducts, boxes or skirting boards. Hidden wiring (under the plaster) is used in living accommodations as this is the safest option. The main disadvantage of hidden wiring is difficult access to wires. Hidden wiring is installed in walls, floor, lintels, and ceiling. Wires are placed in flexible metal ducts and boxes. There is also a combined wiring option when wires are installed in cable channels. This combines the accessibility of exposed wiring and safety of hidden wiring. Combined wiring method is used in hallways and auxiliary rooms.

Nowadays, channel wiring is another popular type of electrical installation in residential buildings. This is a type of hidden wiring when special channels for electrical installation are placed in walls, floor, or ceiling. This wiring method was not used during the Soviet times.



1 – outside wiring
2 – inside wiring
3 – socket
4 – lamp
5 – cooker hood
6 – refrigerator
7 – dishwashing machine
8 – TV set
9 – metering switchgear (lead switchgear)
10 – main switchgear
11 – electrical installation

Fig. 6.1. Electrical installation of a residential building.

The type of electrical installation and wiring method depend on:

1) the place of installation, for example fire and explosion risk in rooms, buildings, zones;
2) description of the walls or other parts to be built;
3) accessibility of wiring to people and pets;
4) voltage;
5) expected electromechanical loads in case of short-circuit;
6) other tensions, for example mechanical, thermal, or open flame related tensions that may affect the wiring during installation or operation.

Installation height of switches and sockets from the floor is established by the architect or customer, as currently there is no regulatory enactment in Latvia specifying the installation height of switches and sockets from the floor. Usually, sockets are installed 0.3 m from the floor and switches — 0.9 m from the floor. In kitchen, sockets are installed above the worktop (kitchen appliances). Lamps, switches, sockets, and other electrical equipment that is a part of the interior are selected by the designer together with the architect and customer.

Special conditions.
Wiring in basement shall be installed above the plaster. All sockets, switches, branch boxes, and lamps must have more protection from the intrusion of water (IP44), switchgear must be IP65. Wiring on the ground floor can be placed under the plaster, and all switches, sockets, branch boxes, and lamps may be IP20–IP23. In attic, all wiring must be under the plaster.

6.1. Wiring peculiarities

6.1.1. Wiring in bathroom and shower room

Air in a **bathroom and shower room** is humid. Therefore, there are strict requirements for wiring in bathrooms and shower rooms. According to IEC 60364-7-701 [147], bathroom and shower room are divided in separate zones (Fig. 5.2).

- Zone No. 0. In this zone, no sockets may be located, and only home electrical appliances [up to 12 V (AC) and 30 V (DC)] with SELV protection and IPX7 (protection against heavy splashing in all directions) may be used in this zone. The power source of these appliances must be located outside Zones No. 0 and No. 1.
- Zone No. 1. In this zone, home electrical appliances [up to 25 V (AC) and 60 V (DC)] with SELV or PELV protection may be used, but the power source of these appliances must be located outside Zones No. 0 and No. 1. Protection class of electrical installations must be IPX4 (in public bathrooms or shower rooms — IPX5).
- Zone No. 2. Sockets for electric razors and home electrical appliances with SELV or PELV protection may be located in this zone. Protection class of electrical installations must be IPX4 (in public bathrooms or shower rooms — IPX5).
- Zone No. 3. It is allowed to install 230 V sockets in this zone. Sockets must be connected via current leakage relay (leakage protection). Protection class of electrical installations must be IPX1 (in public bathrooms or shower rooms — IPX5).

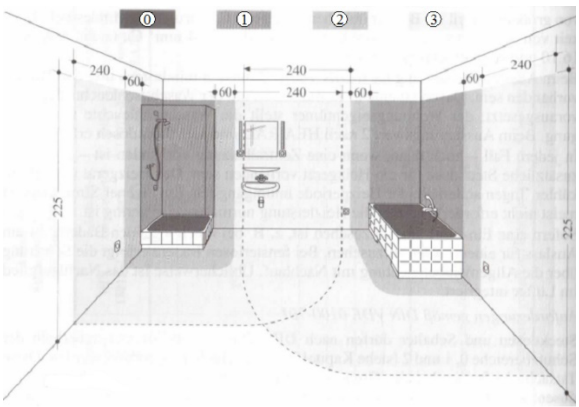


Fig. 6.2. Zones of bathroom and shower room (dimensions in cm).

Division of bathroom and shower room in zones according to IEC 60364-7-701 are especially popular in Australia and Germany.

6.1.2. Wiring heights

Usually, sockets are installed 0.3 m from the floor and switches – 0.9 m from the floor. In kitchen, sockets are installed above the worktop (kitchen appliances). Wiring heights differ in Europe and the world. For example, in Germany switches must be installed 1.05 m from the floor, but sockets – 0.3 m from the floor (Fig. 5.3). In bathroom and shower room, sockets are usually installed at the same height as switches. Nowadays, the installation height of switches and sockets from the floor is often determined by the architect or customer, as it is part of the interior.

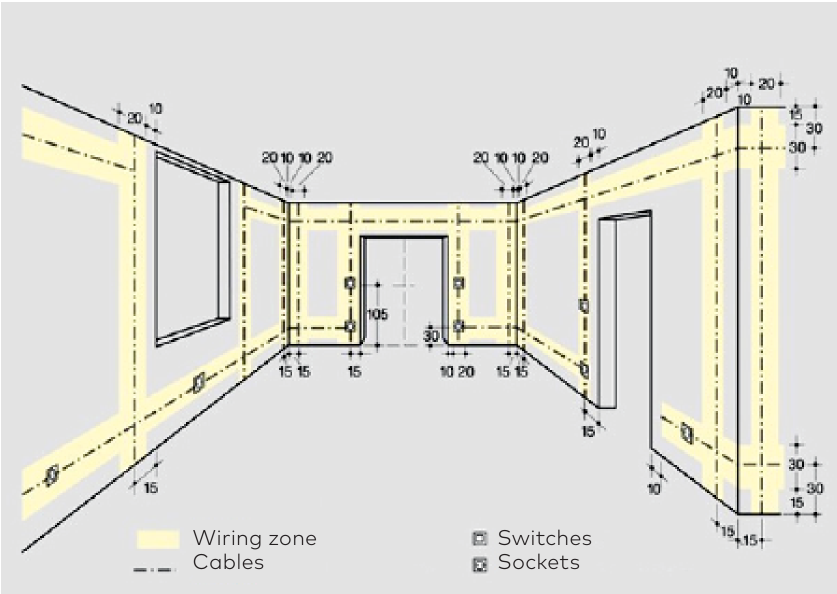
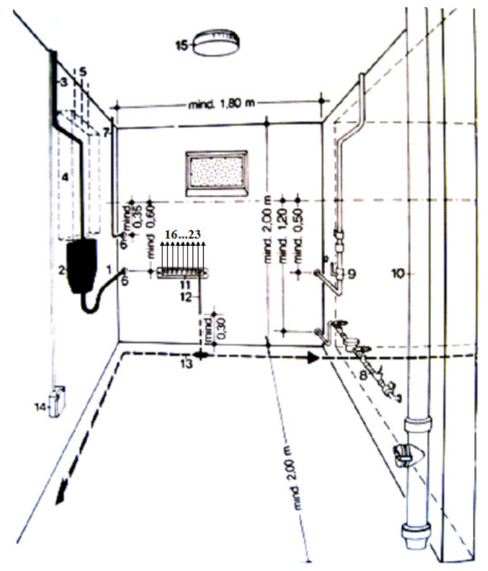


Fig. 6.3. Wiring zones in Germany.

6.1.3. Special room for engineering communication leads

Special room for engineering communication leads is a technical room in which lead switchgear, potential equalisation busbar, electricity meters, etc. are located (Fig. 5.4). Such solution is often found in Europe, including Germany, but currently it is not regulated by regulatory enactments in Latvia. In new residential building designs this solution is becoming more and more popular also in Latvia, and a separate room for engineering communication leads is often provided in the basement or on other floors.



1 — electricity lead from terminal box to potential equalisation busbar and meter
2 — terminal box (lead switchgear)
3 — electricity lead
4 — place for electricity meters
5 — place behind the meter for wires to group switchgears
6 — protective tube for cable feedthrough
7 — telecommunication lead
8 — water pipe inlet and meter
9 — gas inlet and terminal valves
10 — sewage pipe
11 — potential equalisation busbar
12 — foundation earth electrode connection wire
13 — foundation earth electrode
14 — socket
15 — lamp
16 — connection to PEN wire
17 — to water pipe
18 — to sewage system
19 — to heating system
20 — to aerial
21 — to communication device
22 — to lightning protection earthing
23 — to protection wire

Fig. 6.4. Separate room for engineering communication leads [146].

6.1.4. Number of sockets and lamps according to the accommodation type

In Germany, the number of sockets and lamps per each accommodation room (Table 6.1) and the equipment of feeding switchgear are set according to specific comfort levels in line with regulatory enactments and the accommodation type.

Table 6.1

Number of sockets and lamps according to the accommodation type

No.	Room		★[1]		★★[2]		★★★[3]	
			Sockets[4]	Lamps	Sockets[4]	Lamps	Sockets[4]	Lamps
1	Bedroom/living room[5]	≤12 m^2	3	1	5	2	7	3
2		>12 m^2 ≤20 m^2	4	1	7	2	9	3
3		>20 m^2	5	2	9	3	11	4
4	Kitchen		7	2	9	3	11	3
5	Household room		4	1	7	2	9	3
6	Bathroom		3	2	4	3	5	3
7	WC		1	1	2	1	2	2
8	Hallway	≤2,5 m	1	1	1	2	1	3
9		>2,5 m	1	1	2	2	3	3
10	Balcony/loggia/	≤3 m	1	1	1	1	2	1
11	terrace	>3 m	1	1	2	1	3	2
12	Storage room		1	1	2	1	2	1
13	Basement		1	1	2	1	2	1
14	Lounge		3	1	5	2	7	2

1 — accommodation with minimum number of electrical installations, for example social house or summer residence.
2 — standard accommodation with average number of electrical installations, for example a flat in a multi-family building.
3 — accommodation with increased comfort, for example private house for a family or two.
4 — a double socket should be installed in the bedroom near bed. In the table, double socket is indicated as one socket.
5 — the number of sockets in living room should be increased by 1.

7. GRAPHICAL PART

Example of the graphical part is included in Annex 3.

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ANNEX 1

Summary of design methods and electrical installation selection criteria according to the regulatory materials of Western Europe and Latvia

Conditions for design method or selection criteria	Variables used in the equations	Notes
1. Design load		
1. *Analytical methods.* 1.1. Precedence diagram method. 1.2. Statistical method. 2. *Empirical methods.* 2.1. Demand factor method. 2.2. Principle of determining partial design loads. 2.3. Electricity specific consumption method. 2.4. Technological graph method. 2.5. Specific load of unit of area. 2.6. Computer software method.		
2. Resistances for calculation of short-circuit currents		
$X_S = \frac{U_B}{\sqrt{3} I_{kS}^{(3)}}$ (1) $Z_T = \frac{U_{K\%}}{100} \cdot \frac{U_t^2}{S_T}$ (2) $R_T = \Delta P_k \cdot \frac{U_t^2}{S_T^2}$ (3) $X_T = \sqrt{Z_T^2 - R_T^2}$ (4) $X_W = X_0 l$ (5) $R_W = R_0 l$ (6) $Z_\Sigma = \sqrt{R_\Sigma^2 + X_\Sigma^2}$ (7) $Z_\Sigma' = Z_\Sigma \left(\frac{U_Z}{U_V} \right)^2$ (8)	X_s – system resistance, Ω; U_B – base voltage, V; $I_{kS}^{(3)}$ – three-phase short-circuit current of a system, A; Z_T – transformer impedance, Ω; $U_{K\%}$ – transformer short-circuit voltage, %; U_t – network voltage, V; S_T – transformer rated apparent power, VA; R_T – transformer resistance, Ω; P_k – transformer short-circuit power loss, W; X_T – transformer reactance, Ω; X_W – line reactance, Ω; X_0 – line specific reactance, Ω/km; l – length of the line, km; R_W – line resistance, Ω; R_0 – line specific resistance, Ω/km; Z_Σ – total impedance, Ω; R_Σ – total resistance, Ω; X_Σ – total reactance, Ω; Z_Σ' – total impedance in medium-voltage reduced to the 0.4 kV side, Ω; U_Z – voltage in the low-voltage side, V; U_A – voltage in the medium-voltage side, V	

3. Cable		
Selection criteria: 1) rated voltage $U_{\mathrm{kab,n}} \geq U_{\mathrm{t}}$; (9) 2) permitted current under continuous duty $I_{\mathrm{pieļ}} = k_{11} k_{14} k_{15} I_{\mathrm{pieļ,n}} \geq I_{\mathrm{apl}}$; (10) 3) thermal strength $S_{\mathrm{k}} \geq S_{\mathrm{th,min}} = \frac{\sqrt{B_{\mathrm{k}}}}{C_{\mathrm{th}}} = \frac{\sqrt{I_{\mathrm{p0}}^2 \left(t_{\mathrm{k}} + T_{\mathrm{a}}\right)}}{C_{\mathrm{th}}}$ (11)	$U_{\mathrm{kab,n}}$ – cable rated voltage, V; U_{t} – network voltage, V; I_{apl} – design current, A; $I_{\mathrm{pieļ,n}}$ – permitted current in cable, A; k_{11} – correction factor according to the actual ambient temperature; k_{14} – correction factor for observing the actual specific thermal conductivity of soil for cables laid in trenches; k_{15} – correction factor for observing the number of cables in a trench and distance between the cables; S_{k} – area of cable cross-section, mm^2; $S_{\mathrm{th,min}}$ – minimum area of cable cross-section to thermal strength, mm^2; B_{k} – heat impulse, A^2 s. C_{th} – thermal strength factor, $(\mathrm{A\ s}^{0,5})/\mathrm{mm}^2$; I_{p0} – effective value of the periodic component of short-circuit current during the first period, A; t_{k} – duration of short-circuit current flow, s; T_{a} – time constant of short-circuit, s.	Only cables with polyethylene or polyvinyl chloride insulation shall be tested.

4. Fuse		
Selection criteria: 1)rated voltage $U_{dr,n} \geq U_t;$ (12) 2) design current $I_{el,n} \geq k_{dr} I_{apl};$ (13) 3) short-term technological overload current or peak current $I_{el,n} \geq \frac{I_{sm}}{k_{pārsl}}$ (14) where $I_{sm} = i_{sm,max} + I_{apl} - k_{izm} i_{max,n};$ (15) 4) if the fuse protects the feeder link $I_{pieļ} \geq \frac{I_{el,n}}{k_{aizs}};$ (16) 5) selectivity $t_{n+1} \geq k_{izkl} t_n;$ (17) 6) sensitivity $I_K^{(1)} \geq k_j I_{el,n};$ (18) 7) breaking capacity $I_{atsl,n} \geq I_K^{(3)}$ (19)	$U_{dr,n}$ – fuse rated voltage, V; U_t – network voltage, V; $I_{el,n}$ – rated current of the fusible element, A; I_{apl} – design current, A; k_{dr} – safety factor, k_{dr} = 1.00–1.25 [7]; I_{sm} – peak current, A; $k_{pārsl}$ – empirical overload factor, k_{parsl} = 1.6–2.5[7]; $i_{sm,max}$ – the largest peak current of a separate consuming unit of the given group, A; $i_{max,n}$ – rated current of the consuming unit with the highest peak current, A; k_{izm} – characteristic operating ratio of the consuming unit with the highest peak current; k_{aizs} – factor that depends on the room, wire brand, and protection device, k_{aizs} = 0.8–3.0 [7]; $I_{pieļ}$ – actual continuously permitted current for a wire, A; t_{n+1} – time coordinate of the protection closest to power source; t_n – time coordinate of the protection closest to electricity consuming unit; k_{izkl} – leakage factor according to the negative leakage of protection curve closest to the power source and positive leakage of the next protection curve in the direction of consuming unit, k_{izkl} = 1.3–3.0 [7]; $I_K^{(1)}$ – single-phase short-circuit current in the most distant point of the protected network, A; k_j – sensitivity factor, which is 3 for fuses [7]; $I_K^{(3)}$ – three-phase short-circuit current, A; $I_{atsl,n}$ – rated interrupting current of fuse, A	In the case of one motor, peak current (maximum current) equals the starting current of this motor, but in the case of several motors it is determined according to the equation

5. Circuit breaker		
Selection criteria: 1) rated voltage $U_{a,n} \geq U_t$; (20) 2) design current $I_{iest,atk} \geq k_{dr} I_{apl}$; (21) 3) short-term technological overload current or peak current $I_{iest,atk} \geq \frac{I_{sm}}{k_{pārsl}}$ (22) where $I_{sm} = i_{sm,max} + I_{apl} - k_{izm} i_{max,n}$; (23) 4) if the fuse protects the feeder link $I_{pieļ} \geq \frac{I_{iest,atk}}{k_{aizs}}$; (24) 5) selectivity $t_{n+1} \geq k_{izkl} t_n$; (25) 6) sensitivity $I_K^{(1)} \geq k_j I_{iest,atk}$; (26) 7) breaking capacity $I_{atsl,n} \geq I_K^{(3)}$ (27)	$U_{a,n}$ – circuit breaker rated voltage, V; U_t – network voltage, V; $I_{iest,atk}$ – releaser setting current, A; I_{apl} – design current, A; k_{dr} – safety factor, k_{dr} = 1.00–1.25 [7]; I_{sm} – peak current, A; $k_{pārsl}$ – empirical overload factor, k_{parsl} = 1.6–2.5[7]; $i_{sm,max}$ – the largest peak current of a separate consuming unit of the given group, A; $i_{max,n}$ – rated current of the consuming unit with the highest peak current, A; k_{izm} – characteristic operating ratio of the consuming unit with the highest peak current; k_{aizs} – factor that depends on the room, wire brand, and protection device, k_{aizs} = 0.8–3.0 [7]; $I_{pieļ}$ – actual continuously permitted current for a wire, A; t_{n+1} – time coordinate of the protection closest to power source; t_n – time coordinate of the protection closest to electricity consuming unit; k_{izkl} – leakage factor according to the negative leakage of protection curve closest to the power source and positive leakage of the next protection curve in the direction of consuming unit, k_{izkl} = 1.3–3.0 [7]; $I_K^{(1)}$ – single-phase short-circuit current in the most distant point of the protected network, A; k_j – sensitivity factor, which is 1.5 for fuses [7]; $I_K^{(3)}$ – three-phase short-circuit current, A; $I_{atsl,n}$ – rated interrupting current of circuit breaker, A	Selection criteria for circuit breakers with thermal release and magnetic release. In case of one motor, peak current (maximum current) equals the starting current of this motor.

6. Load break switch		
Selection criteria: 1) voltage $U_{sv,n} \geq U_t$; (28) 2) design current under continuous duty $I_{sv,n} \geq I_{apl}$; (29) 3) electrodynamic strength $i_{sv,dyn} \geq i_{tr}$; (30) $i_{tr} = \sqrt{2} I_{p0} k_{tr}$; (31) $k_{tr} = 1 + e^{\frac{-0{,}01}{T_a}}$; (32) $T_a = \frac{X_\Sigma}{\omega R_\Sigma}$; (33) 4) thermal strength $I_{th}^2 t_{th} \geq B_k$; (34) 5) breaking capacity $I_{atsl.pieļ} \geq I_{atsl}$. (35)	$U_{sv,n}$ – rated voltage of load break switch, V; U_t – network voltage, V; $I_{sv,n}$ – rated current of load break switch, A; I_{apl} – design current, A; $i_{sv,dyn}$ – maximum permitted surge current for a load break switch, A; i_{tr} – surge current at short-circuit point, A. I_{p0} – three-phase short-circuit current, A; k_{tr} – surge current factor; T_a – time constant; X_Σ – total inductive reactance from the system to short-circuit point, Ω; R_Σ – total resistance from the system to short-circuit point, Ω; B_k – design heat impulse at the installation point of load break switch, A^2 s; $I^2_{th} t_{th}$ – heat impulse guaranteed by the manufacturer, A^2 s; $I_{atsl.pieļ}$ – permitted interrupting circuit, A; I_{atsl} – actual interrupting circuit, A	
7. Contactor		
Selection criteria: 1) voltage $U_{k,n} \geq U_t$; (36) 2) design current under continuous duty $I_{k,n} \geq I_{apl}$; (37) 3) commutated power $P_{k,n} \geq P_{apl}$ (38)	$U_{k,n}$ – contactor rated voltage in power circuit, V; U_t – network voltage, V; $I_{k,n}$ – contactor rated current in power circuit, A; I_{apl} – design current, A; $P_{k,n}$ – rated real commutated power of contactor, W; P_{apl} – real design power for the group commutated by contactor, W	

8. Current transformer

Selection criteria:

1) rated voltage

$$U_{TA,n} \geq U_t; \tag{39}$$

2) rated current

$$I_{1n} \geq I_{apl}; \tag{40}$$

3) permitted secondary load

$$Z_{2n} \geq Z_2; \tag{41}$$

$$Z_2 = Z_{sl} + R_{kont} + R_V; \tag{42}$$

4) thermal strength

$$\left(k_{th} I_{1n}\right)^2 k_{th} \geq B_k; \tag{43}$$

5) dynamic strength

$$I_{TA,dyn} \geq i_{tr} \tag{44}$$

$U_{TA,n}$ – current transformer rated voltage, V;
U_t – network voltage, V;
I_{1n} – primary rated current of current transformer, A;
I_{apl} – design current, A;
Z_{2n} – rated load for a current transformer with the selected accuracy class, Ω;
Z_2 – resistance of design load in the secondary circuit, Ω;
Z_{sl} – total resistance of apparatuses connected to one current transformer, Ω;
R_{kont} – resistance of contacts in the secondary circuit of a current transformer, Ω;
R_v – resistance of the wires connecting secondary circuit of a current transformer, Ω;
k_{th} – thermal strength factor as provided in the current transformer catalogue;
t_{th} – thermal strength time of a current transformer, s;
B_k – design heat impulse, A^2 s;
$I_{TA,dyn}$ – maximum temporarily permitted current in the primary winding of a current transformer, A;
i_{tr} – surge current at the short-circuit point, A.

9. Earth

Considering the natural earth electrodes, the following condition must be fulfilled:

$$R_m \leq \frac{R_{norm} R_{dab}}{R_{dab} - R_{norm}}. \tag{45}$$

Leakage current resistance of one vertical earth electrode

$$R_{Z,V} = 0,37 \frac{\rho}{l_{el,v}} \cdot \lg \frac{4 l_{el,v}}{d_v}. \tag{46}$$

Leakage current resistance of horizontal earth electrode

$$R_{Z,H} = 0,37 \frac{\rho}{l_{el,h}} \cdot \lg \frac{2}{d_h t}. \tag{47}$$

If all electrodes are connected in parallel, then, for example, total resistance of all vertical earth electrodes

$$R_{Z,V\Sigma} = \frac{R_{Z,V}}{n_v k_i}. \tag{48}$$

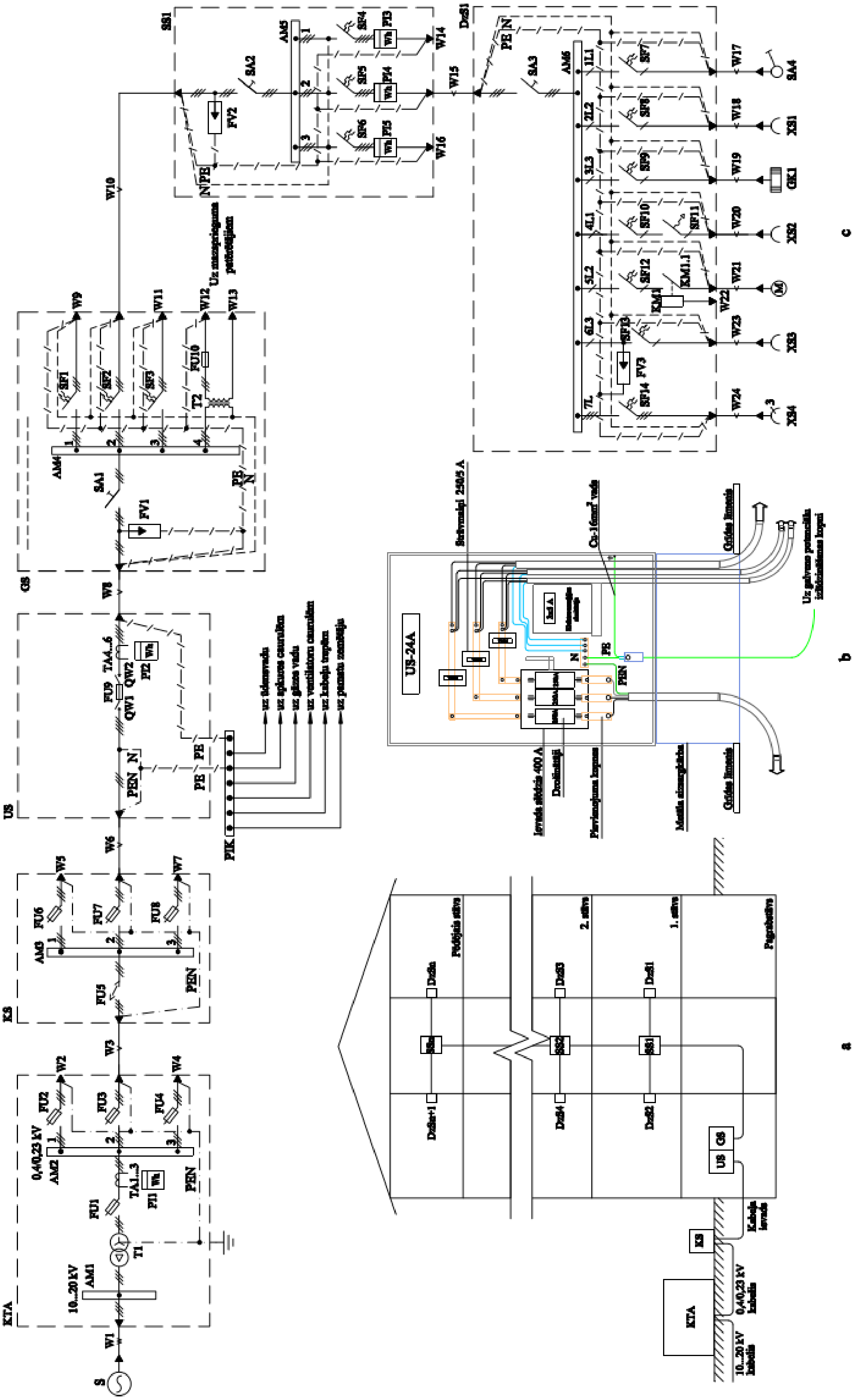
Earth electrode impedance

$$R_{kont} = \frac{R_{Z,V\Sigma} R_{Z,H}}{R_{Z,V\Sigma} - R_{Z,H}}. \tag{49}$$

R_m — resistance of artificial earth, Ω;
R_m — standardised resistance of earth, Ω;
R_{dab} — resistance of natural earth electrode, Ω;
$R_{Z,V}$ — leakage current resistance of vertical earth electrode, Ω;
ρ — soil specific resistance, Ω m;
$l_{el,v}$ — length of vertical electrode, m;
d_v — outside diameter of vertical electrode, m;
$R_{Z,H}$ — leakage current resistance of horizontal earth electrode, Ω;
$l_{el,h}$ — length of horizontal electrode, m;
d_h — diameter of round steel or half of the width of a flat steel sheet, m;
t — depth of laying horizontal electrode, m;
n_v — number of vertical electrodes;
k_i — operating ratio of electrodes for observing the increase in leakage resistance of each electrode due to screening of adjacent electrodes.

ANNEX 2

Example of power supply to a residential building (TN-C-S)



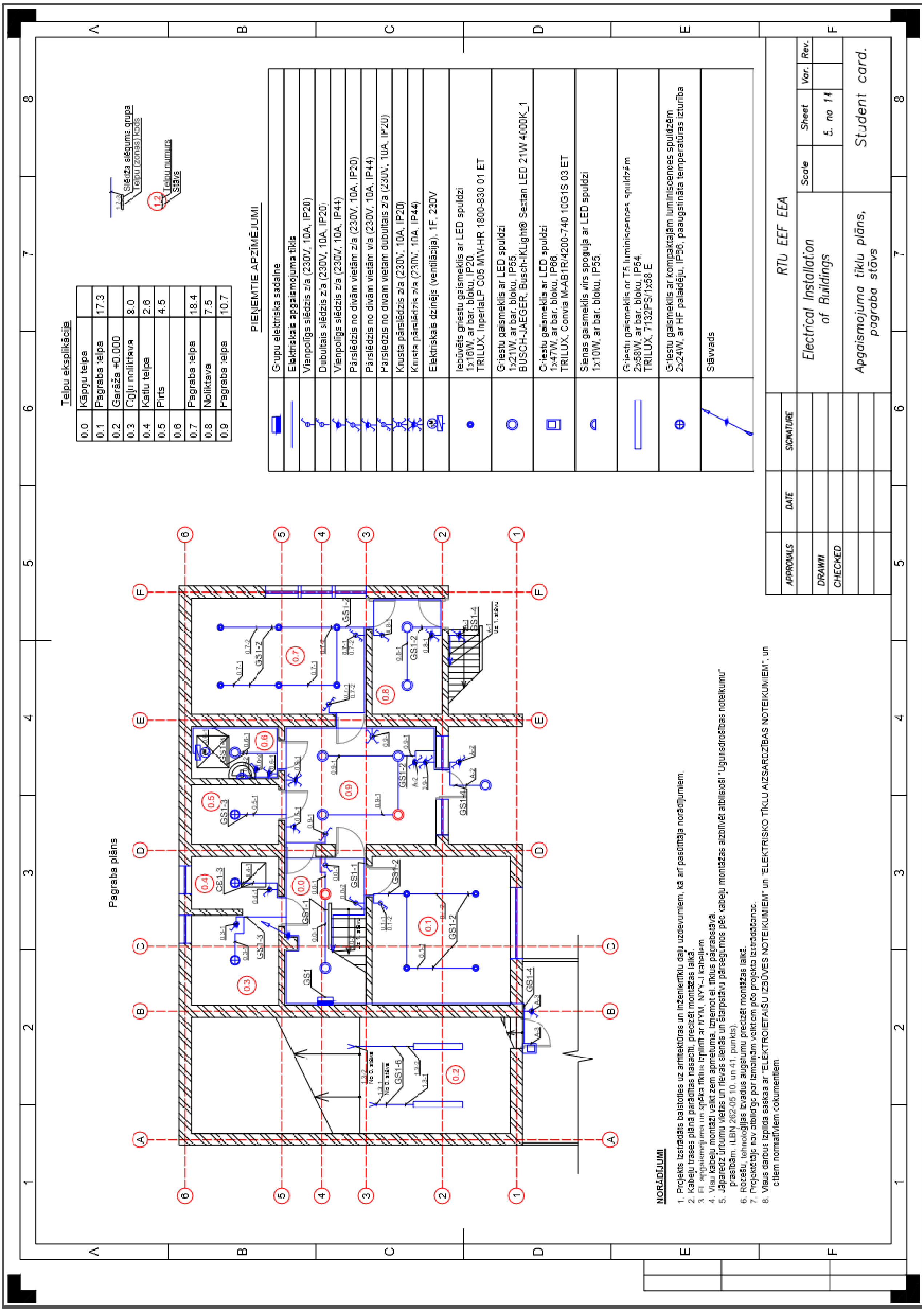
PIEŅEMTIE APZĪMĒJUMI

	Grupu elektriska sadalne
	Elektriskais tīkls
	Vienpolīgs slēdzis z/a (230V, 10A, IP20)
	Dubultais slēdzis z/a (230V, 10A, IP20)
	Vienpolīgs slēdzis z/a (230V, 10A, IP44)
	Pārslēdzis no divām vietām z/a (230V, 10A, IP20)
	Pārslēdzis no divām vietām v/a (230V, 10A, IP44)
	Pārslēdzis no divām vietām dubultais z/a (230V, 10A, IP20)
	Pārslēdzis no divām vietām dubultais z/a (230V, 10A, IP44)
	Krusta pārslēdzis z/a (230V, 10A, IP20)
	Krusta pārslēdzis z/a (230V, 10A, IP44)
	Dimmeris z/a (230V, 10A, IP20)
	Dimmeris z/a (230V, 10A, IP44)
	Elektriskais dzinējs (ventilācija), 1F, 230V
	Iebūvēts griestu gaismeklis ar LED spuldzi 1x16W, ar bar. bloku, IP20, TRILUX, InperlaLP C05 MW-HR 1800-830 01 ET
	Griestu gaismeklis ar LED spuldzi 1x21W, ar bar. bloku, IP55, BUSCH-JAEGER, Busch-IKLight® Sextan LED 21W 4000K_1
	Avarijas griestu gaismeklis ar LED spuldzi 1x21W, ar bar. bloku un bateriju, IP55, BUSCH-JAEGER, Busch-IKLight® Sextan LED 21W 4000K_1
	Griestu gaismeklis ar LED spuldzi 1x47W, ar bar. bloku, IP66, TRILUX, Convia M-AB1R/4200-740 10G1S 03 ET
	Sienas gaismeklis virs spoguļa ar LED spuldzi 1x10W, ar bar. bloku, IP55,
	Griestu gaismeklis or T5 luminiscences spuldzēm 2x58W, ar bar. bloku, IP54, TRILUX, 7132PS/1x58 E
	Griestu gaismeklis ar kompaktajām luminiscences spuldzēm 2x24W, ar HF palaidēju, IP66, paaugstināta temperatūras izturība
	Piekārtais griestu gaismeklis ar LED spuldzi 1x58W, ar bar. bloku, IP44, TRILUX, LateraloP H1 BLGS 6000-830 01 ETDD
	Piekārtais griestu gaismeklis ar LED spuldzi 1x54W, ar bar. bloku, IP20, TRILUX, LateraloR H1 BLGS 6000-840 01 ETDD
	Iebūvēts griestu gaismeklis ar LED spuldzi 1x5W, ar bar. bloku, IP20, BUSCH-JAEGER, 2067_12_U_100+2068_21
	Kontaktligzda (1P+N+E, 16A, 230V, IP20, z/a)
	Kontaktligzda (1P+N+E, 16A, 230V, IP44, z/a)
	Kontaktligzdu bloks 2x(1P+N+E, 16A, 230V, IP20, z/a)
	Kontaktligzdu bloks 2x(1P+N+E, 16A, 230V, IP44, z/a)
	Kontaktligzdu bloks 2x(1P+N+E, 16A, 230V, IP44, v/a)
	Kontaktligzda 3P+N+E (16A, 400V, IP44, v/a)
	El.izvads
	Stāvvads

Rasējumu saraksts

No.	Nosaukums	Piezīmes
1	Vispārīgie rādītāji	
2	Ģenerālais plāns	
3	Aksonometriskais rasējums	
4	Principshēma GS-1	
5	Apgaismojuma tīklu plāns, pagraba stāvs	
6	Apgaismojuma tīklu plāns, 1. stāvs	
7	Apgaismojuma tīklu plāns, mansarda stāvs	
8	Spēka tīklu plāns, pagraba stāvs	
9	Spēka tīklu plāns, 1. stāvs	
10	Spēka tīklu plāns, mansarda stāvs	
11	Stāvvada principshēma	
12	Montāžas operāciju secības apraksts un skices, gaismeklis uz koka	
13	Apgaismojuma vadības shēma no divām vietām ar pārslēdzi	
14	Potenciālu izlīdzināšanas noradījumi	

APPROVALS	DATE	SIGNATURE	RTU EEF EA				
			Electrical Installation of Buildings	Scale	Sheet	Var.	Rev.
DRAWN					1. no 14		
CHECKED			Vispārīgie rādītāji	Student card. No			



Pagraba plāns
Telpu eksplikācija
0.0 Kāpņu telpa
0.1 Pagraba telpa 17.3
0.2 Garāža +0.000
0.3 Ogļu noliktava 8.0
0.4 Katlu telpa 2.6
0.5 Pirts 4.5
0.6
0.7 Pagraba telpa 18.4
0.8 Noliktava 7.5
0.9 Pagraba telpa 10.7
Slēdža slēguma grupa
Telpu (zonas) kods
Telpu numurs
Stāvs
PIEŅEMTIE APZĪMĒJUMI
Grupu elektriska sadalne
Elektriskais apgaismojuma tīkls
Vienpolīgs slēdzis z/a (230V, 10A, IP20)
Dubultais slēdzis z/a (230V, 10A, IP20)
Vienpolīgs slēdzis z/a (230V, 10A, IP44)
Pārslēdzis no divām vietām z/a (230V, 10A, IP20)
Pārslēdzis no divām vietām v/a (230V, 10A, IP44)
Pārslēdzis no divām vietām dubultais z/a (230V, 10A, IP20)
Krusta pārslēdzis z/a (230V, 10A, IP20)
Krusta pārslēdzis z/a (230V, 10A, IP44)
Elektriskais dzinējs (ventilācija), 1F, 230V
Iebūvēts griestu gaismeklis ar LED spuldzi 1x16W, ar bar. bloku, IP20, TRILUX, InperlaLP C05 MW-HR 1800-830 01 ET
Griestu gaismeklis ar LED spuldzi 1x21W, ar bar. bloku, IP55, BUSCH-JAEGER, Busch-IKLight® Sextan LED 21W 4000K_1
Griestu gaismeklis ar LED spuldzi 1x47W, ar bar. bloku, IP66, TRILUX, Convia M-AB1R/4200-740 10G1S 03 ET
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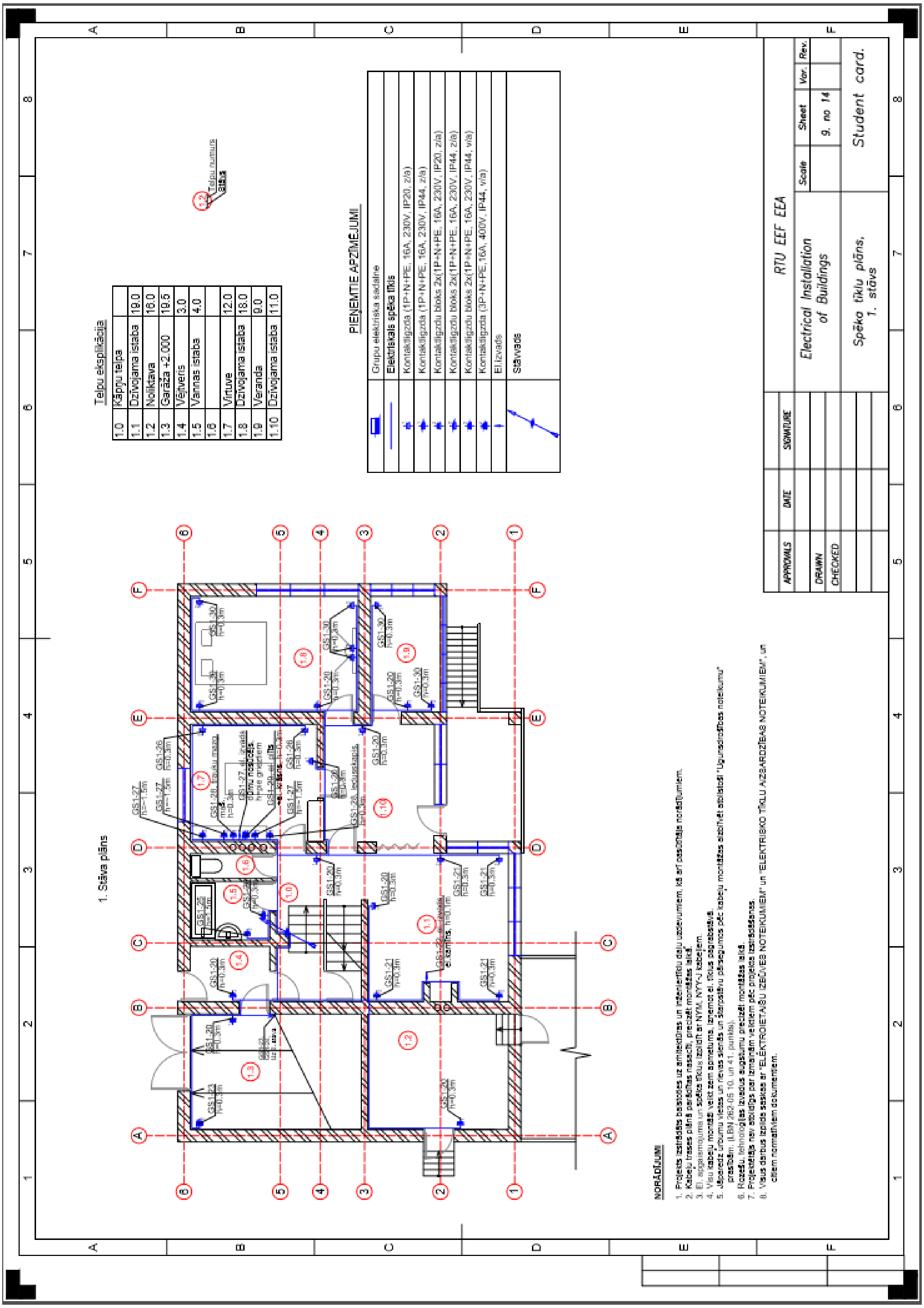
Griestu gaismeklis or T5 luminiscences spuldzēm 2x58W, ar bar. bloku, IP54, TRILUX, 7132PS/1x58 E
Griestu gaismeklis ar kompaktajām luminiscences spuldzēm 2x24W, ar HF palaidēju, IP66, paaugstināta temperatūras izturība
Stāvvads
NORĀDĪJUMI
1. Projekts izstrādāts balstoties uz arhitektūras un inženiertīklu daļu uzdevumiem, kā arī pasūtītāja norādījumiem.
2. Kabeļu trases plānā parādītas nasaoīti, precizēt montāžas laikā.
3. El. apgaismojuma un spēka tīklus izpildīt ar NYM, NYY-J kabeļiem.
4. Visu kabeļu montāži veikt zem apmetuma. Izņemot el. tīklus pagrabstāvā.
5. Jāparedz urbumu vietas un rievas sienās un starpstāvu pārsegumos pēc kabeļu montāžas aizblīvēt atbilstoši "Ugunsdrošības noteikumu" prasībām. (LBN 262-05 10. un 41. punkts).
6. Rozešu, tehnoloģijas izvadus augstumu precizēt montāžas laikā.
7. Projektētājs nav atbildīgs par izmaiņām veiktiem pēc projekta izstrādāšanas.
8. Visus darbus izpilda saskaa ar "ELĒKTROIETAIŠU IZBŪVES NOTEIKUMIEM" un "ELEKTRISKO TĪKLU AIZSARDZĪBAS NOTEIKUMIEM", un citiem normatīviem dokumentiem.
APPROVALS
DATE
SIGNATURE
DRAWN
CHECKED
RTU EEF EEA
Electrical Installation of Buildings
Scale
Sheet
5. no 14
Var.
Rev.
Apgaismojuma tīklu plāns, pagraba stāvs
Student card.


1. Stāva plāns
Telpu eksplikācija
1.0 Kāpņu telpa
1.1 Dzīvojamā istaba 19.0
1.2 Noliktava 16.0
1.3 Garāža +2.000 19.5
1.4 Vējtveris 3.0
1.5 Vannas istaba 4.0
1.6
1.7 Virtuve 12.0
1.8 Dzīvojamā istaba 18.0
1.9 Veranda 9.0
1.10 Dzīvojamā istaba 11.0
Telpu numurs
Stāvs
PIEŅEMTIE APZĪMĒJUMI
Grupu elektriskā sadalne
Elektriskais spēka tīkls
Kontaktligzda (1P+N+PE, 16A, 230V, IP20, z/a)
Kontaktligzda (1P+N+PE, 16A, 230V, IP44, z/a)
Kontaktligzdu bloks 2x(1P+N+PE, 16A, 230V, IP20, z/a)
Kontaktligzdu bloks 2x(1P+N+PE, 16A, 230V, IP44, z/a)
Kontaktligzdu bloks 2x(1P+N+PE, 16A, 230V, IP44, v/a)
Kontaktligzda (3P+N+PE,16A, 400V, IP44, v/a)
El.izvads
Stāvvads
NORĀDĪJUMI
1. Projekts izstrādāts balstoties uz arhitektūras un inženiertīklu daļu uzdevumiem, kā arī pasūtītāja norādījumiem.
2. Kabeļu trases plānā parādītas nosacīti, precizēt montāžas laikā.
3. El. apgaismojuma un spēka tīklus izpildīt ar NYM, NYY-J kabeļiem.
4. Visu kabeļu montāži veikt zem apmetuma, izņemot el. tīklus pagrabstāvā.
5. Jāparedz urbumu vietas un nievas sienās un starpstāvu pārsegumos pēc kabeļu montāžas aizbīvēt atbilstoši "Ugunsdrošības noteikumu" prasībām. (LBN 262-05 10. un 41. punkts).
6. Rozešu, tehnoloģijas izvadus augstumu precizēt montāžas laikā.
7. Projektētājs nav atbildīgs par izmaiņām veiktiem pēc projekta izstrādāšanas.
8. Visus darbus izpilda saskaņā ar "ELEKTROIETAIŠU IZBŪVES NOTEIKUMIEM" un "ELEKTRISKO TĪKLU AIZSARDZĪBAS NOTEIKUMIEM", un citiem normatīviem dokumentiem.
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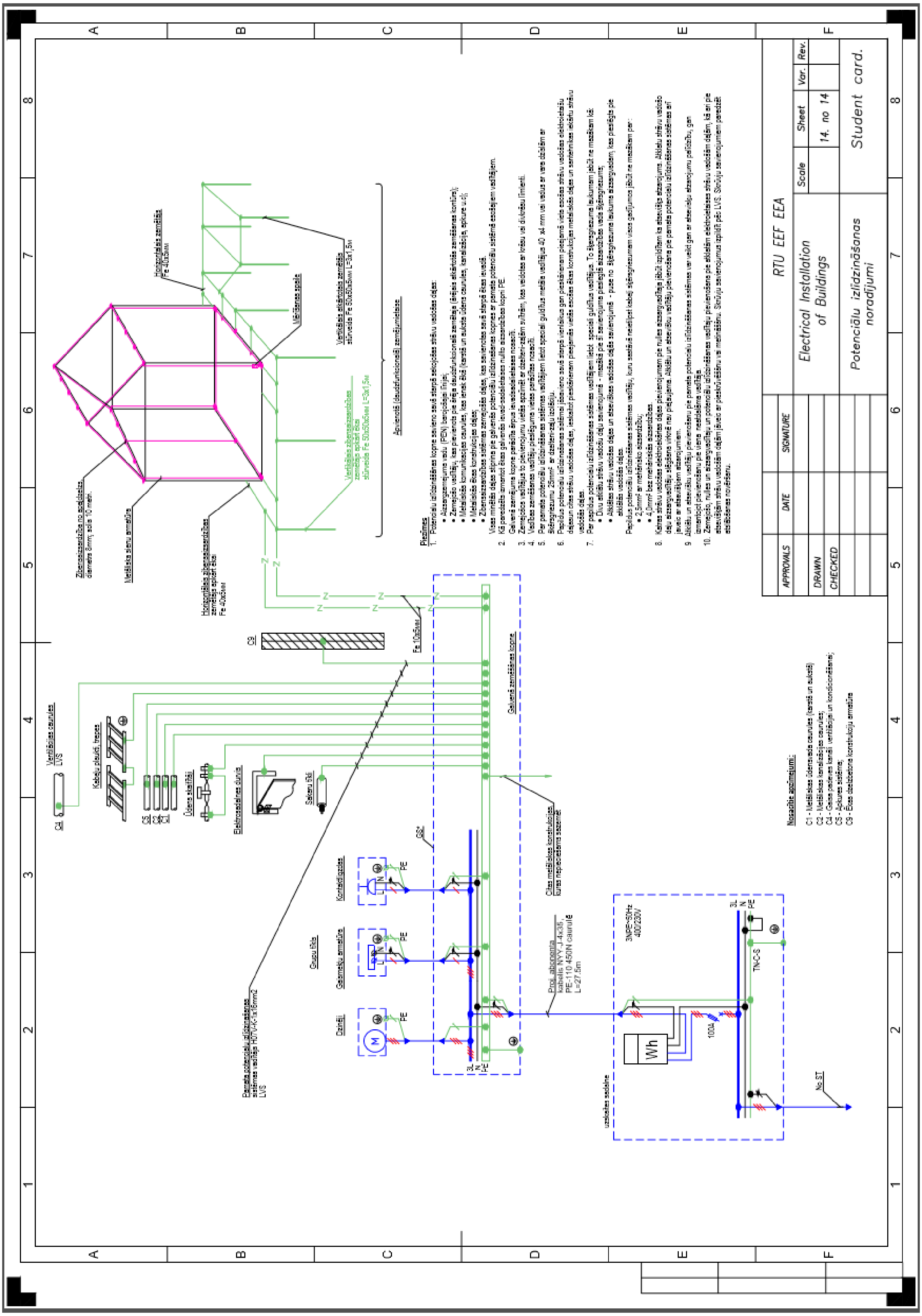
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