

Method of calculation of 0.4 kV input distribution devices

Ivan Bandurin^{1*}, Vladimir Ivanov¹, Alexandr Kakurin¹, Igor Kozyrev¹, Vladimir Korobov¹, Alexey Khaimin¹, Sergey Trashchenkov¹.

¹Pskov State University, Institute of Engineering Sciences, 180000, Russia, Pskov, Lenin Square, 2

Abstract. The article proposes an authorial algorithm allowing the selection of the input distribution device. The mathematical model of the algorithm is constructed in the Microsoft Excel environment. An example is given. Keywords: input switching device, power calculation, automatic switches, protection devices, differential current automatic switch, current transformer, conductor.

Introduction

The solution of various problems of calculation of parameters and selection of equipment of power supply systems by means of Microsoft Excel is fairly widely described in the literature. For example, in work [1] proposes to automate the calculation of the electrical loads of a microdistrict by determining the required capacity of individual buildings and substations. As a result of the automated calculation, the authors get the recommended values of the number of input distribution devices of individual buildings, the nominal power of transformers for two-transformer substations feeding the buildings.

The calculation of the parameters of the electric power supply system of an industrial enterprise is the subject of publication [2]. It shows the calculation algorithm in Excel, which includes determination of the capacity of the workstations, the area of the workrooms, the specific density of the calculated electrical power of the workshops, the nominal power of the workshop transformers. In addition, calculations for reactive power compensation and for the selection of conductor sections are also given.

Another example of the use of Excel in power supply is Article [3], where the author proposes to use Visual Basic for Applications to determine discounted costs for urban, rural and industrial networks at different voltage levels.

The authors of all these works emphasize minimization of labor and time costs due to automation of the design process, minimization of the chance to make an error compared to manual calculations. The typical nature of such calculations makes it easy to algorithmize the design process with Excel, and the versatility and distribution of this table processor makes it competitive with highly specialized electrical systems design products such as Winelso [4], Revit MEP Electrician [5] and many others.

This work focuses on the use of Microsoft Excel to calculate and select low-voltage input distribution devices (IDD) by the author's algorithm.

1 Method of selection and calculation of automatic switches and fuses

The choice of automatic switches is based on the calculation of the load of the waste lines. The formula used to define it, known from electrotechnical techniques, is three-phase or one-phase current. After calculating the calculated value of the current of the group, an automatic switch is selected based on the standard series of current values.

It is important to coordinate the protection devices and the chosen conductors. According to GOST 30331.5-95, the following conditions must be met:

- $i_{CALC.CURRENT} \leq i_{NOM} \leq i_{P.CURRENT}$,
- $i_{DEF.CURRENT} \leq i_{P.CURRENT}$,

where $i_{CALC.CURRENT}$ - is the calculated current of a section of the network;

i_{NOM} - current of the apparatus (nominal);

$i_{P.CURRENT}$ - is the permissible long-term current for the conductor;

$i_{DEF.CURRENT}$ - is a defensive current.

Also, the selected protective device is checked for protection of the network against short circuit current (CC). According to the Rules for arrangement of electrical installations (PUE), protective devices must be protected against CC and must be activated as quickly as possible. The PUE specifies the conditions for selecting machines for this parameter. The conditions are as follows:

- $6 I_{N.C.} \leq i_{ICC}$ - for automatic switches,
- $4 I_{R.C.} \leq i_{ICC}$ - for fuses,

where $I_{N.C.}$ - is the nominal current of the fuse;

$I_{R.C.}$ - is the rated current of the automatic switch;

i_{ICC} - is a single-phase short circuit current.

According to the PUE, paragraph 3.1.8., the time taken to disable the automatic switch in the TN system shall not exceed the following values:

- 0.4 seconds in group networks,
- 5 seconds in the distribution grid.

Automatic switches are divided by response characteristics into 6 categories. The 0.4 kV BP requires only 2: B and C. Automatic switches with the time

* Corresponding author: bandurin_ivan@mail.ru

characteristic C are installed as input devices to protect the network. Category B machines are selected to protect the waste lines of loads.

2 Method of selection and calculation of the devices for the protective disablement

Depending on the power of the connected equipment, the presence of intermediate protective devices and the length of the wiring, the residual current device (RCD) with different differential current limits is used.

The most common protective devices are 10 mA, 30 mA and 100 mA. These devices are sufficient to protect most residential and office premises.

The selection of the protective disablement device shall be made according to the following parameters:

- 1) Operating voltage: 220V or 380V, combined versions are available;
- 2) Type of current: In case of alternating leakage current, the TC type shall be switched off, in case of type A, the TC shall be switched off at a constant and alternating leakage current;
- 3) Number of poles: bipolar or quadripolar;
- 4) Energy dependence. Power-off capability without operating voltage;
- 5) Structural design: the installation is carried out on a DIN-rack, the mounting is in the form of a socket which is portable and is fixed to a wall;
- 6) Type of relay: electromechanical and electronic. The former shall be broken by mechanical means, the others by means of a semiconductor circuit;
- 7) Operating speed: instantaneous and selective;
- 8) Additional functions: for example, a RCD with short circuit or RCD without network overload protection.

The protective switch-off device operates at a certain level of differential current occurring between the strands of the electric cable. The following formula is used to calculate the differential current of the RCD

$$I_{\Delta} = \frac{0,4I_{CALC} \cdot 0,01L_{WIRE}}{1000} \text{ (mA)} \quad (1)$$

where I_{CALC} - is the calculated current on a given stretch of the chain, A; L_{WIRE} - is the estimated length of the wire, m.

It should be taken into account that the threshold current of the apparatus must be 3 times higher:

$$I_{THRESHOLD} = 3I_{\Delta} \quad (2)$$

3 Method of selecting differential current automata

The automatic differential current switch combines the functions of two devices for the protection of an automatic switch and a protective switch.-

Calculate the nominal current value of the differential automaton in the same way as for the automatic switches. According to the standard nominal values of the diffusers, choose the appropriate one. The next step is a check for the leakage current according to formula (2) and a check for the time-current characteristics of the switch.

4 Method of selecting an electrical energy meter

When choosing an electrical energy meter, it is necessary to take into account the phase of the power grid, whether single-phase or three-phase. The electric meter must be installed after the input switch, as the meter must be protected against short circuit current.

The meter is selected on the basis of the parameters specified in the passport.

From the currently available electronic and induction counters, we select the electronic one at the request of the power supply organization. The current selection is based on the base and maximum values. The basic values are 5 and 10 A, the most popular 60 and 100 A for the maximum current. If the current exceeds the maximum current values, then measuring current transformers should be used to connect the current.

The counter can record both active energy and reactive energy. In the counter's passport, accuracy classes are represented as fractions: the first meaning corresponds to the accuracy class for active energy, the second value corresponds to the accuracy class for reactive energy.

The meters are divided by the number of tariffs. There are single rates and multi-rates. The parameters are selected at the request of the customer and are agreed with the energy service provider.

5 Method of selection of measuring current transformers

The electric power with the supply current of more than 100 A is recorded with the connection of measuring transformers. In order to select a current transformer, it is necessary to know the value of the maximum current running on the supply network. The nominal current of the primary winding of the transformer determines the transformation coefficient.

The transformation coefficient should be selected according to the calculated load, taking into account emergency operation. Current transformers with an oversized transformation factor (electrodynamical and thermal resistance or tire protection) are allowed according to PUE if, at the maximum load of the connection, the current in the secondary winding of the current transformer is not less than 40% of the nominal current of the meter, and at the minimum workload not less than 5%.

The class of accuracy is also important when choosing current transformers. For the conditions considered, there are 4 accuracy classes: 0.5; 0.5s; 1; 2.

6 Method of selection of conductor sections

The cross-section of the conductor shall be selected on the basis of the following parameters:

- 1) Calculated total power of the receivers, kW;
- 2) Calculated operating current of the group of receivers, A;

- 3) Type of supply voltage: single-phase, three-phase;
- 4) Conductor material: copper or aluminum;
- 5) How the wiring works: open, hidden.

The calculated power and current of the group is determined by the formulas known from electrical engineering.

The type of voltage depends on the project, but it is recommended that for loads above 11 kW the input should be three-phase.

The materials of the conductors are selected on the basis of the specification. Copper conductors are more reliable and durable, capable of greater cross-section capacity than aluminum conductors, but more expensive.

7 0.4 kV IDD program

The program to calculate the IDD for a private apartment building is executed in the Microsoft Excel environment. In the program, estimates and reference values are presented in tabular form. The external and structural form of the table is based on a questionnaire at the BPR of a residential building. The questionnaire is presented in figure 1.

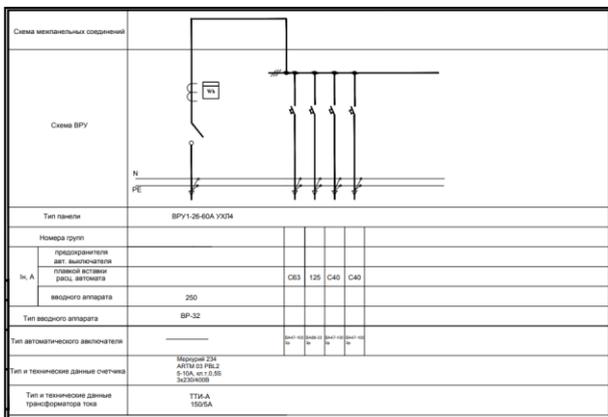


Fig. 1. BPR questionnaire

The table for calculation in Excel consists of a list of parameters such as: the number of the group of receivers, the calculated power, the voltage of the network, the calculated current, the nominal current to select the defense apparatus.

The program displays the selected protection devices for the group: automatic switches, protective switches, automatic differential current switches. The selected conductor cross-section value, the wire material and the type of the liner are also displayed. Part of the table is shown in figure 2.

3	Условное обозначение				
4	№ группы	1	2	3	4
5	Расчетная мощность, кВт	11,72	1,58	2,21	2,21
6	Напряжение, В	380	380	380	380
7	Ток, А	21,35	6,46	8,12	8,12
8	Ток аппарата, А	25	8	10	10
9	Выбираемый автоматический выключатель	ВА47-100 3р 25А (С)	ВА47-100 3р 10А (С)	ВА47-100 3р 10А (С)	ВА47-100 3р 10А (С)
10	Выбираемый дифф.автомат	АВДТ34 С25	АВДТ34 С10	АВДТ34 С10	АВДТ34 С10
11	Выбираемое УЗО	ВД1-63 4р 32А	ВД1-63 4р 16А	ВД1-63 4р 16А	ВД1-63 4р 16А
12	Материал жил проводов	медные	алюминитые	медные	медные
13	Метод прокладки провода	открытая	открытая	открытая	открытая
14	Сечение кабеля, мм2	2,5	2,5	1,5	1,5
15	Цена выключателя				
16					

Fig. 2. Type of calculation table and selected parameters

In the table, cells are assigned a color for convenience. The blue cells correspond to the calculated value, the green cells are selected.

Determine the calculated power and the full load value. The table for calculating the load to be consumed is shown in figure 3.

24	Расчет группы 1								
25	Параметр	Установленная мощность, кВт	Коэффициент спроса	Коэффициент использования	cos φ	Расчетная мощность, кВт	Полная мощность, кВт		
26	Потребитель 1	30	0,8	0,9	0,9	7,2	8		
27	Потребитель 2	2	0,9	0,8	0,9	1,45	1,6		
28	Потребитель 3	4	0,6	0,75	0,7	1,8	2,37		
29	Потребитель 4	3	0,4	0,6	0,7	1,2	1,71		
30	Потребитель 5	0,6	0,2	0,7	0,5	0,08	0,18		
31	Потребитель 6	30				1	0		
32	Потребитель 7					1	0		
33	Потребитель 8					1	0		
34	Потребитель 9					1	0		
35	Потребитель 10					1	0		
36		95,6			0,835	11,72	14,04		

Fig. 3. Table for determining the calculated power of the group

Red cells are needed for manual data entry by the user. The table is designed for 10 consumers and corresponds to one group of electrical receivers. There are up to 20 groups in the program.

To determine the calculated power, it is necessary to enter data on the installed power of the receiver, or the consumer. Demand ratio, utilization ratio and power ratio are to be entered on the basis of the background data.

The total installed power of all consumers or receivers is determined by summing up the cell data. The definition of the calculated power is shown in figure 4.

Fig. 4. Determination of calculated power

This calculation is performed for the entire column. The data from the whole column is then summed and the full power is determined. The program also determines the overall power factor of the group of consumers or receivers.

Calculation of parameters and protective devices of consumer groups. The user then selects the rated voltage and therefore the network type (single-phase or three-phase), figure 5.

3	Условное обозначение	
4	№ группы	1
5	Расчетная мощность, кВт	11,72
6	Напряжение, В	380
7	Ток, А	220
8	Ток аппарата, А	25

Fig. 5. Part of the voltage selection table

Based on the selected working voltage, the calculated current is determined. The table for determining the calculated current is shown in figure 6.

B7		=ОКРУГЛ(ЕСЛИ(В6=220;В5*1000/(В6*F36);В5*1000/(380*1,73*F36));2)			
2	A	B	C	D	E
3	Условное обозначение				
4	№ группы	1	2	3	4
5	Расчетная мощность, кВт	11,72	1,58	2,21	2,21
6	Напряжение, В	380	380	380	380
7	Ток, А	21,35	6,46	8,12	8,12

Fig. 6. Calculation of the operating current

Once the current is calculated in the next cell, the nearest nominal value of the security apparatus is selected. The nominal values of the protection apparatus are shown in figure 7.

B8		=ЕСЛИ(И(В7>0;В7<=1);1;ЕСЛИ(И(В7>1;В7<=2);2;ЕСЛИ(И(В7>2;В7<=3);3;ЕСЛИ(И(В7>3;В7<=10);10;ЕСЛИ(И(В7>10;В7<=16);16;ЕСЛИ(И(В7>16;В7<=20);20;ЕСЛИ(И(В7>20;ЕСЛИ(И(В7>50;ЕСЛИ(И(В7>50;В7<=63);63;ЕСЛИ(И(В7>63;В7<=80);80;ЕСЛИ(И(В7>80;В7<=100			
2	A	B	C	D	E
3	Условное обозначение				
4	№ группы	1	2	3	4
5	Расчетная мощность, кВт	11,72	1,58	2,21	2,21
6	Напряжение, В	380	380	380	380
7	Ток, А	21,35	6,46	8,12	8,12
8	Ток аппарата, А	25	8	10	10

Fig. 7. Implementation of nominal current selection of the protection apparatus

According to the nominal current of the protection apparatus, automatic switches, differential automates, safety devices shall be selected (figure 8).

The RCD is selected on the condition that it is one nominal value greater than the automatic switch. The selected protection devices are given to the user for selection with the specification. That is, the user has the choice to use only an automatic switch to protect the group, or an automatic switch with a protective switch or an automatic differential current switch.

3	Условное обозначение		
4	№ группы	1	2
5	Расчетная мощность, кВт	11,72	1,58
6	Напряжение, В	380	380
7	Ток, А	21,35	6,46
8	Ток аппарата, А	25	8
9	Выбираемый автоматический выключатель	ВА47-100 3р 25А (С)	ВА47-100 3р 10А (С)
10	Выбираемый дифф. автомат	ВДТ34 С25	ВДТ34 С10
11	Выбираемое УЗО	ВД1-63 4р 32А	ВД1-63 4р 16А

Fig. 8. Implementation of fixing of protective devices

In the following cells, the user selects the parameters of the conductors:

- Conductor material copper/aluminum
- Pad type - open/hidden.

The cross-section of the conductor is selected from the selected parameters of the conductors, considering the selected network type (figure 9).

Fig. 9. Arranging Conductor Section

Figure 10 shows a table for calculating the input automaton.

16	Установленная мощность всех потребителей,кВт	73,74
17	Напряжение,В	380
18	Коэффициент спроса для уст. мощности	0,45
19	Расчётный ток на вводе,А	50,48
20	Выбираемый вводной автомат	ВА88-32 3р 50А
21		
22		

Fig. 10 Selection of an introductory dispenser

In the cell «voltage» a condition is included, if the installed power is greater than 11 kW, then working voltage 380 V is set, since the type of network is three-phase.

Conclusion

The program can be used both for calculating the distribution boards of small buildings and for IDD of apartment buildings. It can also be used to calculate individual panels in IDD.

Simplicity of modification and use of the program allows to use it as a specialized «calculator» for current calculations and check.

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