Computerized measurement control system of unauthorized connection to electrical networks and isolation control detection

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Abstract: This article is devoted to the development of computerized information measurement systems that record unauthorized power outages and insulation control in electrical distribution systems. In addition, mathematical models and control programs for the control of unauthorized power interruptions and insulation in electrical distribution systems have been developed and their parameters are based. A current monitoring device was designed for the control of unauthorized interruptions of electricity and insulation in electrical distribution systems, and an experimental copy was developed and test results were obtained.

Keywords: phase, current transformer, model, sumilink, wave, current, voltage, frequency, electrical network

In recent years, small computers, microcontrollers and microprocessors have been widely used as the basis of processing and computing of modern control systems. Modern information technologies and advanced software make it possible to use computerized information and measurement systems to solve problems in the field of electrical measurement and insulation.

In recent years, the automation of electric power systems has led to an increase in technical devices. As a result, a number of problems arose in the distribution of electricity. From these, a number of measurement trends have been developed as a result of the increase in information flows. This has made a significant difference. In order to increase the measurement accuracy, the reliability of the control combined with the universality of the systems that determine many indicators has also been increased.

The new requirements also revealed the shortcomings inherent in modern control and accounting systems. The evolving electricity market places new demands on power system management.

It is very important to ensure high reliability of data when creating information measurement systems for energy efficiency control and calculation. However, recently, the number of failures has increased in proportion to the increase in the volume of data, and the possibility of incorrect signals and control commands has a negative impact on the efficiency of distribution networks.

Based on the above, it can be said that modern computerized information measurement systems, despite their many advantages, do not fully provide the necessary functionality, reliability, accuracy and speed of measurement operations.

The combination of the above shortcomings determines the requirements for the development of a computerized information accounting system for monitoring the insulation condition and accounting for electricity consumption. The operation of the information measurement system requires the development of new control devices, production algorithms and methods of data transmission and exchange in the management and management of distribution networks.

At the present, the computerized measurement control systems in the field of electric power have not been able to perform the following tasks.

1. The computerized information measurement system developed for monitoring distribution power networks can not distinguish between emergency or unauthorized connections of the power network.

2. Now the measurement methods used in the past are sufficiently efficient that they do not allow to record unauthorized connections in advance.

3. Deviations of electrical network and consumption current and power values do not allow to determine the state of unauthorized connection and isolation of electrical networks, as well as to simulate operating modes.

The computerized information measurement system proposed in the scientific article is a device designed for automatic monitoring of the state of electrical networks, and has the ability to receive non-contact information and transmit information with a wide range and sufficiently high accuracy.

At the stage of modeling the interruptions in phase A, the operation of the electric distribution network in the maximum mode and the determinal values of consumer loads are calculated. In this research work, the calculations were made according to the calculation program.

In the modeling of phase interruptions, the values of the active resistance of the earth are taken in the range of 1 - 5 Ohm. The lower limit of the acceptable resistance range is chosen to be off from the standard supply value for high-voltage electrical networks, which is 0.5 Ohm. The upper limit of the measurement range is disabled based on the resistance values of high-power consumers.

Measurement values and calculation results are presented below in Table 1.1 and Figures 1.1, 1.2, 1.3. These numbers show the dependence of the cataclysms calculated from the phase break in the intervals: 1 - 2 in red, 6 - 7 in blue, 12 - 13 in black and 16 - 17 in brown.

As can be seen from Figure 1.1, the overload of phase A of the transformer in the studied mode did not exceed the permissible value for it and its value was equal to 1.4.

The above shows that the phase failure cannot cause the protective device to affect the damaged line, so the unnatural mode of the line, which is dangerous from the point of view of electrical safety, can be used arbitrarily for a long time. Such regimes are particularly dangerous during high wind warning periods in areas with high overall accident rates in power plants.

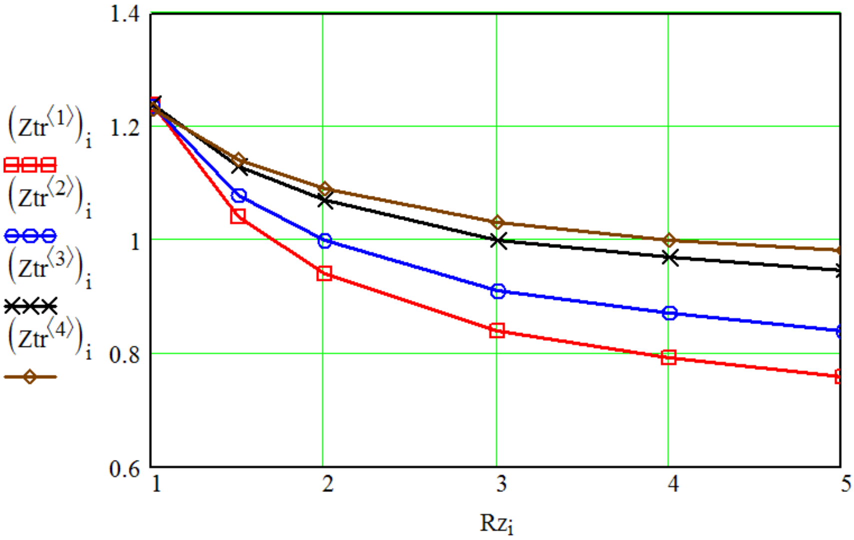


Figure 1.1 - The value of the ground resistance when the phase is broken and when it goes to ground and the dependence on the load of phase A of the step-down transformer

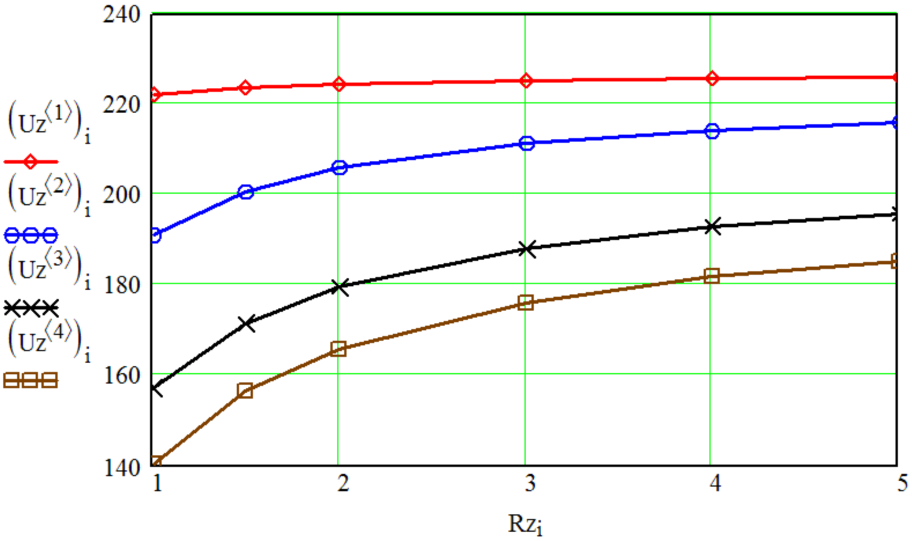


Figure 1.2 - Dependencies of the voltage at the ground connection from the value of the resistance to the ground when the phase is interrupted and falls to the ground

As can be seen from Figure 1.2, the short-circuit voltage to the ground has a maximum value and practically does not change when there is a break in the initial part of the line. When moving away from the beginning of the line, the value of the voltage at the point of phase interruption decreases and it depends more on the resistance of the ground. In all cases, the value of the voltage in the disconnected phase remains high enough and poses an obvious danger to people and animals located near the disconnected phase.

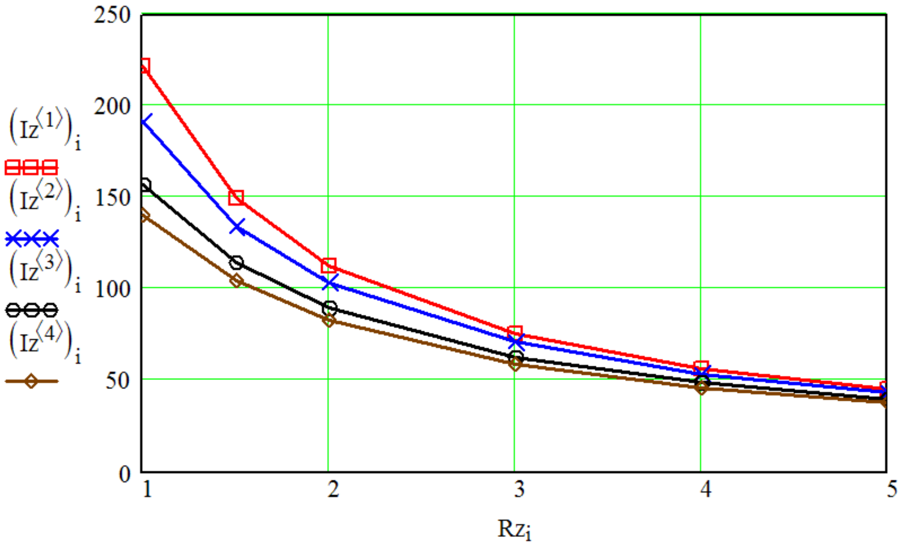


Figure 1.3 - Dependence of the short-circuit current to the ground on the value of the ground resistance in the case of a phase break and its grounding

As can be seen from Figure 1.3, in the case of a phase break in different places of the line, the short-circuit current to the ground has almost the same value and depends on the value of the resistance of the ground. The maximum value of the short-circuit current is when there is a break in the initial part, and the current value decreases as it moves away from the beginning of the line.

Table 1

Values of the parameters of phase failure and short circuit to the ground in different network intervals

The length of the electrical network	1 - 2	6 - 7	12 - 13	16 - 17
	Rer= 1 Ohm			
Izz, A	208,544	189.09	155,529	137,494
Uzz, V	208,446	189.09	155,529	137,494
Ita, A	417,774	451,044	442,134	434,924
Ita / Int	1.2152	1.22265	1.2276	1.2054
	Rer= 1.5 Ohm			
Izz, A	146,118	132,462	113,058	102,116
Uzz, V	167,776	198,693	169,488	153,076
Ita, A	368,088	386,595	403,722	403,956
Ita / Int	1.0192	1.0692	1.1187	1.1172
	Rer= 2 Ohm			
Izz, A	109,956	101,871	88,704	81,144
Uzz, V	219,912	203,841	177,507	162,288
Ita, A	333,004	357,291	381,942	385,728
Ita / Int	0.9212	0.99	1.0593	1.0682
	Rer= 3 Ohm			
Izz, A	73,598	69,696	62,073	57,526
Uzz, V	220,696	209,187	186.12	172.48
Ita, A	297.92	316.8	358,083	365,246
Ita / Int	0.8232	0.9009	0.99	1.0094

	Rer= 4 Ohm			
Izz, A	55,272	52,965	47,718	44,492
Uzz, V	221,088	211,959	190,773	178,066
Ita, A	280,378	310.86	345,411	354,074
Ita / Int	0.7742	0.8613	0.9603	0.98
	Rer= 5 Ohm			
Izz, A	44,296	42,768	38.7387	36,358
Uzz, V	221,382	213,642	193,644	181,496
Ita, A	269,892	301,158	337,491	347,116
Ita / Int	0.7448	0.8316	0.9306	0.9604

Calculation of phase-to-earth short-circuit currents through high resistance allowed to estimate other indicators of typical elementary sections, which allows to enter the difference between high resistance and the maximum possible phase-to-earth short-circuit currents. The current value of unauthorized connection to phases using clamps to ensure reliable power supply is determined. The most recent value of these values is 20 - 40 A.

The results obtained from the model also made it possible to determine the maximum permissible currents for developing sensitivity requirements and evaluating the error of current control devices. When summarizing the results of the model, it was found that the measurement errors do not exceed 2.5%.

Evaluation of TNQ sensitivity of the developed current control device

The value of the information signal at the TNQ output is affected by the following indicators:

the number of packages in the measuring tape;

the size of the air gap in the core;

the value of the current flowing through the conductor.

To analyze the dependence of the information signal in the form of the output voltage on the above parameters, we consider these dependencies separately: u(d), u(w), u(j), where u is the information signal , w is the number of interconnected windings in the measuring coil w2, j is the current in the conductor.

Each parameter was estimated while keeping the others constant. The evaluation was performed at a maximum line current of 80 A for one phase of the overhead line and an air gap of 0.1 mm (0.0001 m) with two air gaps in evaluating the effect of number of windings and current. At a current of 80 A and in the evaluation of the effect of air gaps, it was carried out with the number of windings, constant ho distance and the number of windings in the evaluation of the current effect.

Based on the results of the measurement, we create sensitivity matrices of the absolute values of the main indicators of TNK.

Assessment of the effects of air pollution.

The value of the air gap, mm:

$$d = [0,1; 0,2; 0,3; 0,4; 0,5; 0,6; 0,7; 0,8; 0,9; 1,0$$

depending on u(d):

$$u1 = [5{,}46; 2{,}32; 1{,}80; 1{,}47; 1{,}25; 1{,}08; 0{,}95; 0{,}85; 0{,}71]$$

The interpolation function depends on the informational signal

the interpolation function of the dependence of the information signal on the air gap:

$$u = [108{,}84d^6 - 429{,}92d^5 + 687{,}99d^4 - 574{,}99d^3 + 207{,}09d^2 - 71{,}75d + 10{,}44]$$

Derivative value:

$$f1 = [-32{,}46;\ -13{,}96;\ -6{,}52;\ -3{,}96;\ -2{,}94;\ -2{,}12;\ -1{,}42;\ -1{,}20;\ -1{,}52;\ -1{,}30;]$$

Interpolation error err1=u1-u;

$$errl = [0{,}0014;\ -0{,}0076;\ 0{,}0145;\ -0{,}0091;\ -0{,}0064;\ 0{,}0086;\ 0{,}0043;\ -0{,}113;\ 0{,}0063; -0{,}0013;$$

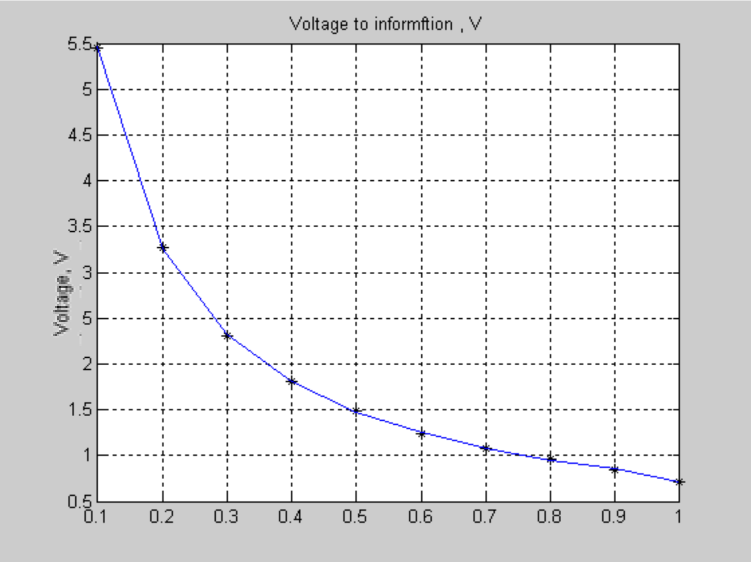


Figure 1.4 - graph of the dependence of the information signal on the size of the air gap

Evaluation of the dependence of the information signal on the number of coils in the coil

Number of chulgams:

$$w = [20; 40; 60; 80; 100; 120; 140; 160; 180; 200]$$

depends on u(w):

$$u2 = [2{,}183; 4{,}366; 6{,}549; 8{,}732; 10{,}915; 13{,}107; 15{,}281; 17{,}464; 19{,}647; 21{,}830]$$

Since the dependence of the signal on the number of windings in the coil is almost directly proportional, the proportionality coefficient k is the value of the first derivative.

$$k = u2/w$$

$$f2 = k = [0{,}1092; 0{,}1091;\ 0{,}1091; 0{,}1091; 0{,}1091; 0{,}1091; 0{,}1091; 0{,}1091; 0{,}1091; 0{,}1091;$$

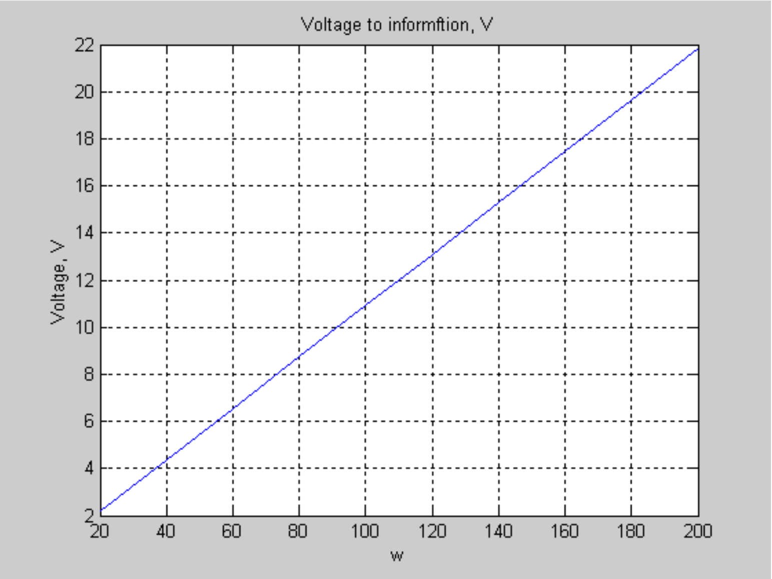


Figure 1.5 - graph of information signal dependence on the number of coils in the coil

Evaluation of the dependence of the information signal on the current flowing from the conductor the flowing through the conductor value:

$$j = [1; 5; 10; 20; 30; 40; 50; 60; 70; 80]\text{V}$$

output information signal:

$$u3 = [2{,}18; 4{,}37; 6{,}55; 8{,}73;\ 10{,}92; 13{,}10; 15{,}29; 17{,}45; 19{,}65; 21{,}83]\ \text{V}$$

primary difference:

$$D = [2{,}182; 2{,}183; 2{,}183; 2{,}182;\ 2{,}183; 2{,}183; 2{,}182; 2{,}183; 2{,}182;]\ \text{V}$$

$$f3 = 2{,}183$$

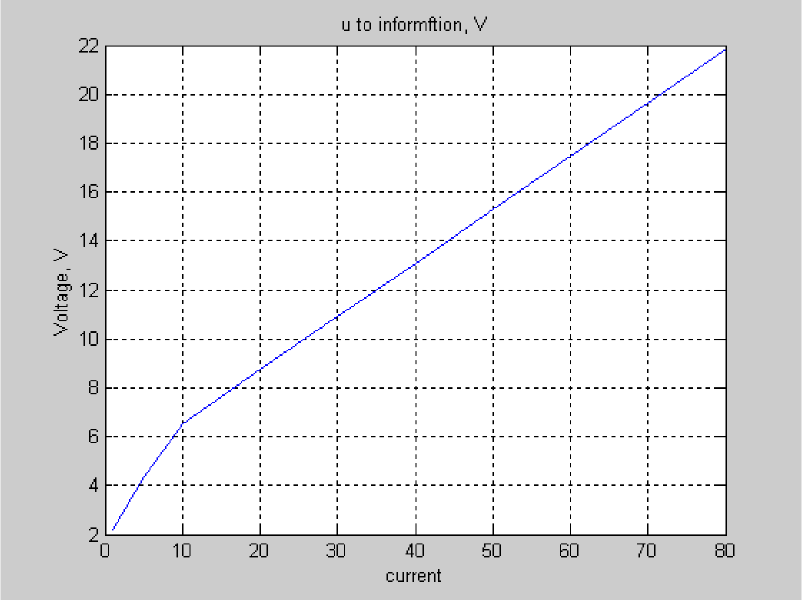


Figure 1.6. Graph of dependence of the information signal at the output on the magnitude of the current flowing from the transformer

Using the information obtained above and the general differential concept, the total value of the information signal at the output is equal to the following.

$$du = \frac{du}{dd}\Delta d + \frac{du}{dw}\Delta w + \frac{du}{dj}\Delta j,$$

$$\text{Here;}\frac{du}{dw} = 0{,}11\frac{du}{dd} = 32{,}44\frac{du}{dj} = 2{,}18$$

Posle podstanovki dannix (maximally absolute production value and significant error parameters) we can open the absolute elimination of the informational signal

After data exchange, we determine the absolute deviation of the signal based on errors as follows.

$$du = 32{,}46 * 0{,}0001 + 0{,}11 * 0{,}11 + 2{,}2 * 0{,}1 = 0{,}233\text{V}$$

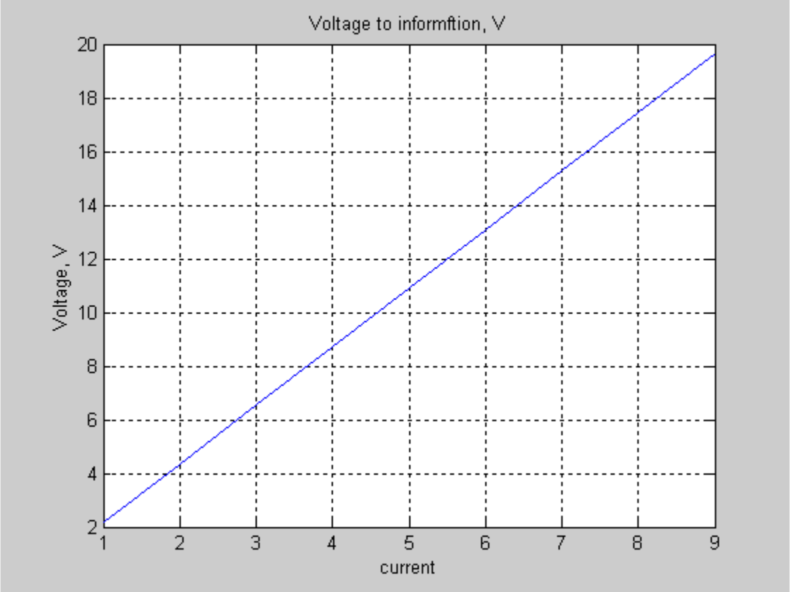


Figure 1.7 is a deviation graph of the linearity of the output signal as a function of the current.

Absolute error is the error of the output signal, taking into account external influences on TNQ

$$du = 32{,}46 * 0{,}0001 + 0{,}11 * 0{,}11 = 0{,}014\text{V}$$

With the help of the sensitivity matrices of the device, it is possible to obtain detailed information about the changes in the output signal for such calculations.

Modeling parts of a single phase of a distribution network in the Electronics Workbench package

The technical capabilities provided by the Electronics Workbench package allow you to develop a model of parts of a real distribution network and to study in this model different operating modes of the network, in particular, normal operation in the presence of an unauthorized connection to the electrical network. In the network, when there is a single-phase earth short circuit, when there is a phase break, this model was built to check its isolation control capability, to identify the emergency modes at the beginning of the network.

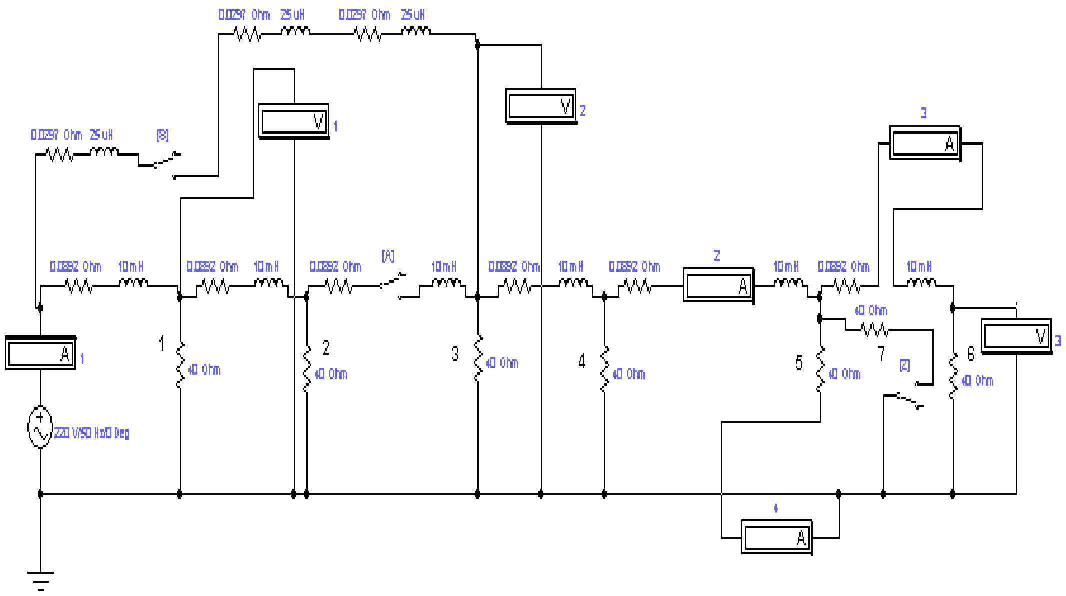


Figure 1.8. A study model of single-phase parts of a distribution network in the Electronics Workbench package

Figure 1.8 shows the model of one phase of the studied network. In the model scheme, elements whose parameters are equal to the real parameters occurring in the network are used.

Simulation of different modes is done with different combinations using B and C keys. Simulation of additional resistances (overload, short circuit to earth and insulation control) is done by turning the C switch on and off. The position of the C button is controlled by pressing the C button. The shunt is connected and disconnected using the S button. .

Sample test results for different modes in the considered network are presented in Table 3.4.

The following conditions were checked:

1. Switches B and C are open, i.e. shunt and unauthorized load off.
2. Button B is on, button C is off, that is, the shunt is on, the switched load is off.
3. Button B is off, button C is on, that is, the false load is on and the shunt is off.
4. Switches B and C are included, meaning both the shunt and the amperage are on.
5. The state of the phase is simulated by pressing the A button (the A button is off - phase failure, the A button is on - the network works in normal mode).

Analysis of the simulation results shows that the phase break is characterized by the absence of readings from ammeters A2, A3 and A4. With switch A turned on (describing the shunt state), the voltage increase at the third consumer is 1.3 V and at the end of the line (V3) is 0.4 V.

Table 1.2

Results of testing the power grid modes in the model

Keys	Status of keys	Network operating modes	Indicators of measuring instruments						
			A1	A2	A3	A4	V1	V2	V3
A	+	There is no phase break	31.98	10.61	5.31	5.31	214.62	213.25	212.27
	-	Phase break	10.76	0.00	0.00	0.00	215.31	0.00	0.00
B	+	A shunt is connected	32.12	10.67	5.34	5.34	215.01	214.42	213.44
	-	The shunt is off	31.98	10.61	5.31	5.31	214.62	213.15	212.27
C	+	There is theft	37,19	15.87	5.29	5.29	214.42	212.76	211.48
	-	No theft	31.98	10.61	5.31	5.31	214.62	213.15	212.27

In the presence of an unauthorized connection (switch C is on), the readings of the ammeters connected to node 5 indicate that Kirchhoff's first law is not fulfilled. In fact, in this case, the expression of Kirchhoff's first law should be similar to the ratio between the device indicators.

$$A2 = A3 + A4 = 5{,}413 + 5{,}42 = 10{,}433$$

The discrepancy in instrument readings is 0.002 A.

In the presence of theft, inconsistency.

$$A2 - (A3 + A4) = 16{,}2 - (5{,}4 + 5{,}4) = 5{,}4A$$

This value is the theft value, which is much larger than the discrepancy in the readings of the ammeters when the switch B is turned off.

The theft value of 0.1 A is more accurately determined, which is 2% of the nominal consumer load of 5 A. The same results were obtained during full-scale tests of the main converter model of the current controller under development. In this case, the ratio of the network current increase to the voltage increase at the output of the primary converter was taken into account.

In a real network, the length of the distance between the consumer connections of one phase is equal to three times the length of one span. In the simulated case, a span length of AC-35 wire of 35 mm2 and 35 m was obtained. In the model, the length of the distance between the connections of single-phase consumers is three times the length of the interval considered above. The obtained results are presented in Table 1.3.

Table 1.3

Results of testing the power grid modes in the model

Keys	Status of keys	Network operating modes	Indicators of measuring instruments						
			A1	A2	A3	A4	V1	V2	V3
A	+	There is no phase break	19.50	6.14	3.26	3.08	176.69	133.87	122.50
	-	Phase break	10.50	0.00	0.00	0.00	210.70	0.00	0.00
B	+	A shunt is connected	30,39	9.78	4.88	4.91	213.64	213.25	195.31
	-	The shunt is off	19.50	6.14	3.06	3.08	176.69	133.87	122.50
C	+	There is theft	19.44	7.76	2.58	2.59	172.87	119.56	103.19

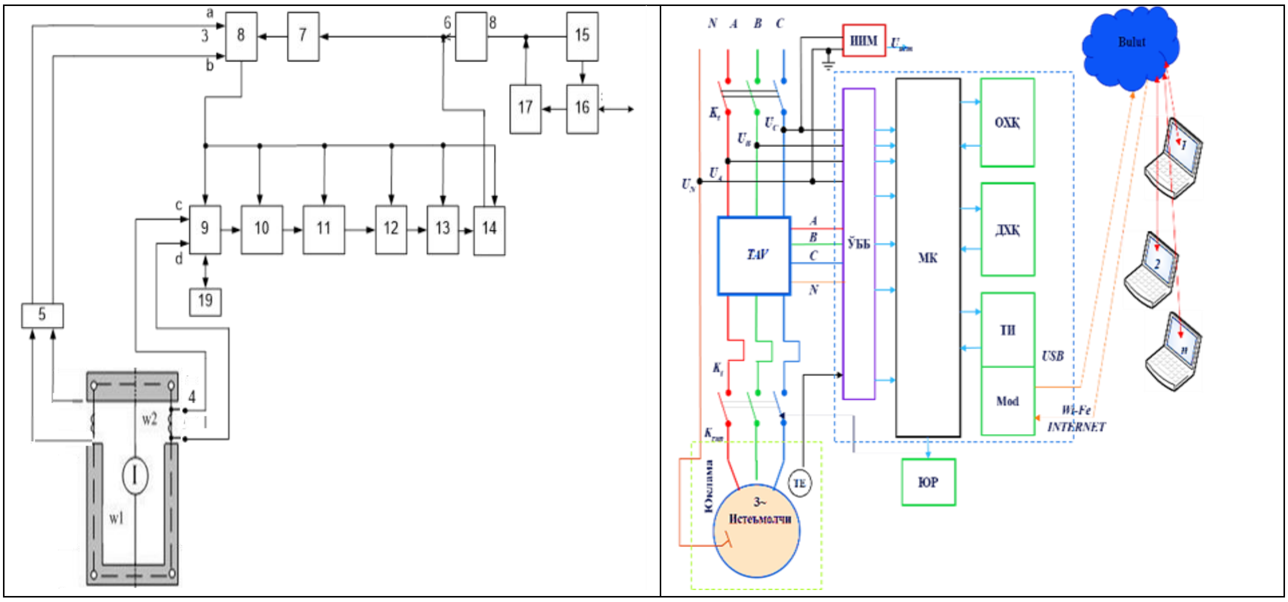
	-	No theft	19.50	6.14	3.06	3.08	176.69	133.87	122.50

The proposed current control device is based on the task of creating improved AC converters designed to operate on the basis of digital signals, for remote transmission of the current value over the Internet in the controlled sections of the transmission line. In this case, it is necessary to use modern components that allow non-contact measurement of currents and transmission of measurement results via a wireless network. The developed device is a converter that converts the current into a voltage signal at the output. Consists of data transmission and reception devices, microcontroller, analog-digital converters, amplifier and non-contact triggers.

The control unit includes transmitting, receiving-transmitting devices, an amplifier whose output is connected to a transmitter, whose output is connected to a transmitting-receiving modem, and a microcontroller. The other output of the microcontroller is connected to the input of the local power network.

The simplified block diagram of the current control device shown in Figure 1.9 shows the following designations:

1 - magnetic core of current transformer; 2 - magnetic switch of the converter; 3-5 DC network; 4 - w2 secondary converter; 5 - rectifier; 6, 18 - data reception and transmission device; 7 - Load receiving device; 8 - current control device; 9 - rectifier; 10 - signal selection, analysis and signal matching blocks; 11 - ARO'; 12 - microcontroller; 13 - modem; 14 - high power amplifier; 15 - device receiving load from the current control device; 16 - data transfer IMS; 17 - high power amplifier, 19 - selective amplifier.



1.9 - picture. A simplified block diagram of a current control device

The circuit diagram of the network data receiver is shown in Figure 1.10.

Let's consider the algorithm of the control and management system of unauthorized connections to the electricity consumption of the distribution network. The following algorithm was developed for the current controller.

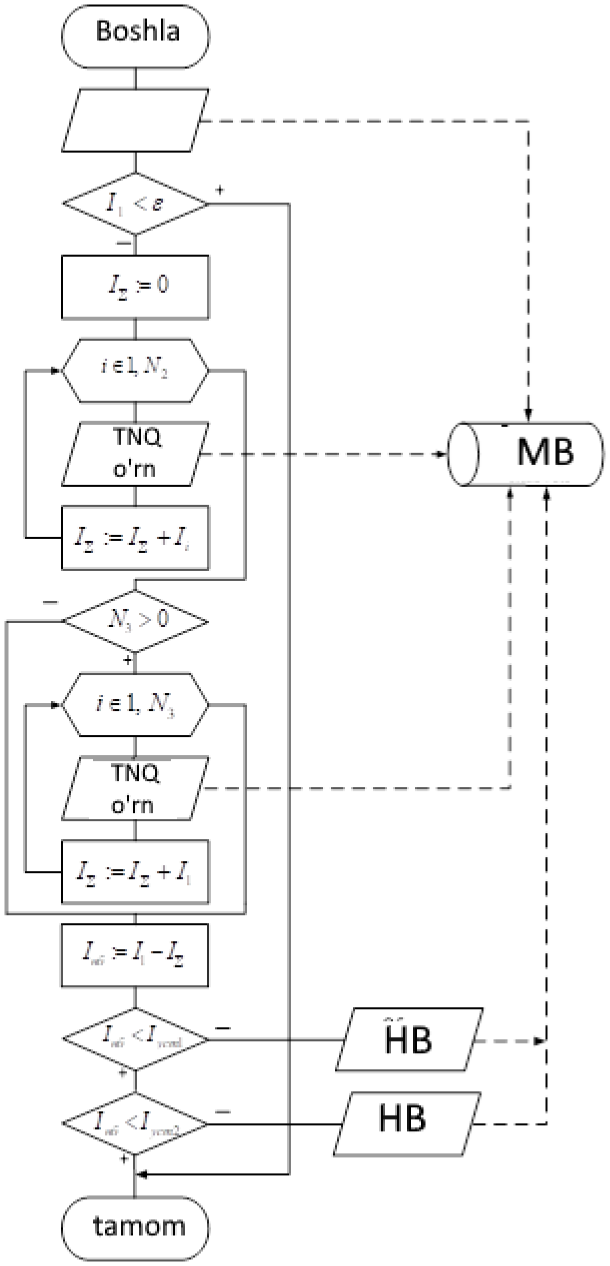


Figure 1.10. Algorithm for determination of power consumption permission connections

In this algorithm, we consider data processing as the usual fundamental parts of the system. We use the principle of differential current comparison to detect unauthorized connections to electricity consumption. In the comparison, a comparison is made between the current values measured by the current controller. For this, we determine the balance between the current at the beginning of the electric power supply of the line and the sum of the currents in all other parts. The current in the presence of unauthorized connections to the consumption of electricity should not be greater than the compared current.

The algorithm performs the following tasks.

e - the value of the minimum current that can be set by the current controller, A;

I1- value of the current i at the input of the fragment of the generalized elements of the amplifier, A;

II- the value of the effective current. The current controller is measured from levels 1 and 2, A;

I∑- The total value of the sum of currents. The current controller is measured from 2 levels, A;

Inb- current imbalance, A;

Iust1- the current is installed. To determine the phase conductor break, this value is obtained from the fragment of generalized elements, A;

Iust2- do not put it on the vine. Summarized elements are extracted from the fragment to detect unauthorized connections

The principle of active power calculation is that energy measurement basically multiplies input voltage and current signals over time to obtain information about power changes over time.

Based on the phase difference and the active power coefficient, the active power is determined as follows:

$$p(t) = Ucos(wt) * Icos(wt + F),$$

$$F = 0 \text{ if so}$$

$$p(t) = \frac{UI}{2}(1 + cos2(wt),$$

$$\text{If there is} F \neq 0$$

$$\begin{aligned} p(t) &= Ucos(wt) * Icos(wt + F) \\ &= Ucos(wt) * [Icoswt) \cos(F) + \ sin(wt)\sin\,(F)] \\ &= \frac{UI}{2}(1 + \cos\,(2wt))\cos(F) + \ UIcos(wt)sin(wt)\sin\,(F) \\ &= \frac{UI}{2}(1 + \cos\,(2wt))\cos(F) + \frac{UI}{2}\sin\,(2wt)\cos(F) \end{aligned}$$

The output frequency of active power is calculated as follows:

$$F = 1721506 * \frac{U * I}{U_{ref}^2},$$

The upper district will not send any signal to the dispatch service level unless there are unauthorized electrical connections and conductor breaks and insulation deterioration. If one of the above situations occurs, the district dispatch service will inform about it from the fragment of generalized elements. The district dispatching service must send him information about the current measured from the part where the current monitoring device works for a detailed analysis of the situation.

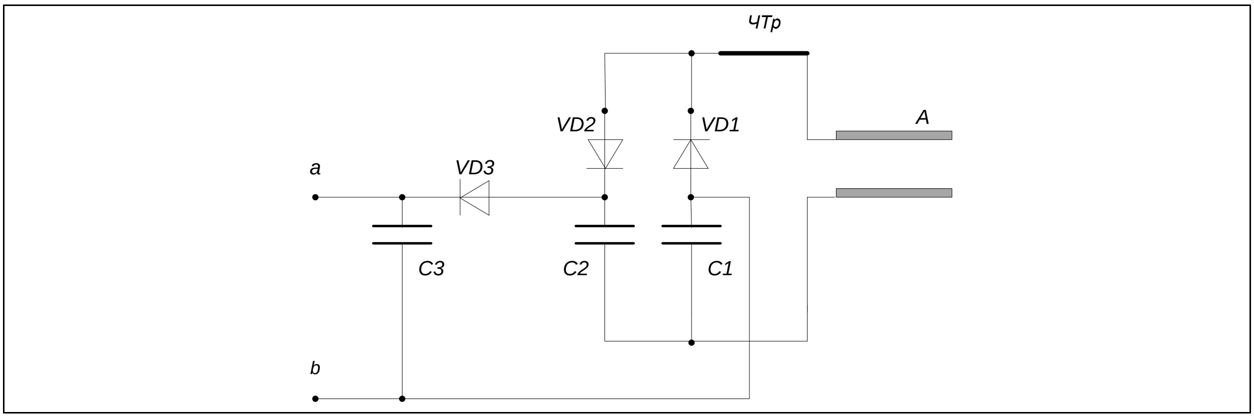


Figure 1.11. Electrical scheme of the network data receiver

In Figure 1.11, the following symbols are accepted: A - antenna; ChTR - half-cycle transformer; VD1÷VD3 - diodes; C1÷C3 - capacitors.

A current transformer J, consisting of a magnetic conductor 2 and a core 1, measures the current. The converter is made up of two coils, with w1 the primary coil running 5 and w2 the second using 9. Rectifiers provide constant current to the entire device circuit with a voltage of 2.5 to 5 V.

The current control device includes 6-data transceiver, 7-control signal receiver, 5-power source, 2-primary transformer, 8-switch, 9-rectifier, 11-ARO', 12 13-microcontroller, 14-UCh power amplifiers included.

The control part of the current control device includes a 6-transmitting device, 16-microcontroller, 17-high-frequency power amplifier and 15-transmitting device.

The case of the device is made removable. It is convenient to install electrical wires in the device. The device is hermetically protected from moisture and precipitation, it works in the temperature range from -60 to +125 ° C.

Any microcontrollers, AROs, data transmission and reception devices with suitable characteristics can be used in the device.

Summary

1. The device for determining the state of unauthorized connection and isolation to electric networks keeps the indicators of electricity monitoring and reports of their consumption costs;

2. Unauthorized connection to electrical networks and the device for determining the state of isolation performs energy efficiency control and internal energy inspection services;

3. It allows to measure the electrical network sizes and determine the state of unauthorized connection and isolation to the electrical networks based on them.

4. As a result of the research, the technical parameters of the device for unauthorized connection to electrical networks, their phase interruptions are the primary voltage 0~260 V, the nominal current and power - 100A/25000 W, the frequency - 45/65 Gs, the measurement accuracy of the device is 0.5 class ensured that.

5. It was confirmed on the basis of research that the amount of output voltage continuously changes up to 7.1634 V when a primary current of up to 100 A flows through the conductor of the device for determining the state of unauthorized connection and insulation. when the criterion is met, the output voltage of the device is within the norm.

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