

OPTICAL BUS OF CENTRALIZED RELAY PROTECTION AND AUTOMATION SYSTEM OF MEDIUM VOLTAGE SWITCHGEAR FOR DATA COLLECTION AND TRANSMISSION

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Published online: 24 November 2017

ABSTRACT

The article deals with the system of information collection and transfer from a centralized relay protection and automation system for medium voltage electrical units based on a passive optical bus. The issues of electromagnetic compatibility of technical devices are also considered, and the intensity of electromagnetic interference is calculated in the distribution center of medium voltage. Since the electric power industry objects are characterized by a complex electromagnetic environment, including a significant adverse effect on the reliability and full functionality of modern microprocessor relay protection and anti-emergency automatic systems, the solution is considered for a centralized relay protection and automation system based on xPON passive optical network technology.

Key words: centralized system of relay protection and automation, signaling and measurements; distribution point of medium voltage; medium voltage distribution network; electromagnetic interference; conductive low-frequency interference; conductive high-frequency interference; IEC 61850; IEC 61000-2-5-195; IEC 61000-4; Degree of electromagnetic compatibility intensity.

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doi: <http://dx.doi.org/10.4314/jfas.v9i7s.72>



I. INTRODUCTION

The distribution points of 6-35 kV (hereinafter - DP) are an important element of power supply systems for industrial enterprises and medium voltage distribution networks providing direct power supply to high-voltage electricity consumers.

The DP is a sectional electrical unit consisting of bus bars, a certain number of cells and a control corridor. Electrical equipment is located in cells: circuit breakers, current transformers (CT), line and bus disconnectors, fuses, voltage transformers (VT), overvoltage protection devices (arresters or excess-voltage suppressors). Figure 1 shows the DP circuit with the voltage transformation consisting of seven cells:

- two supply lines, each of which is connected to the corresponding bus section;
- two outgoing cable lines;
- one cell with the arrester;
- one cell with the power reducing transformer T and the 0.4 kV assembly;
- one cell with the voltage transformer.

The power transformer T is used for power supply of 0.4 kV consumers. Its presence makes it possible to classify a DP as a distribution transformer substation (DTS).

In addition to high-voltage equipment, the DP also includes relay protection and automation devices, measuring instruments, etc.

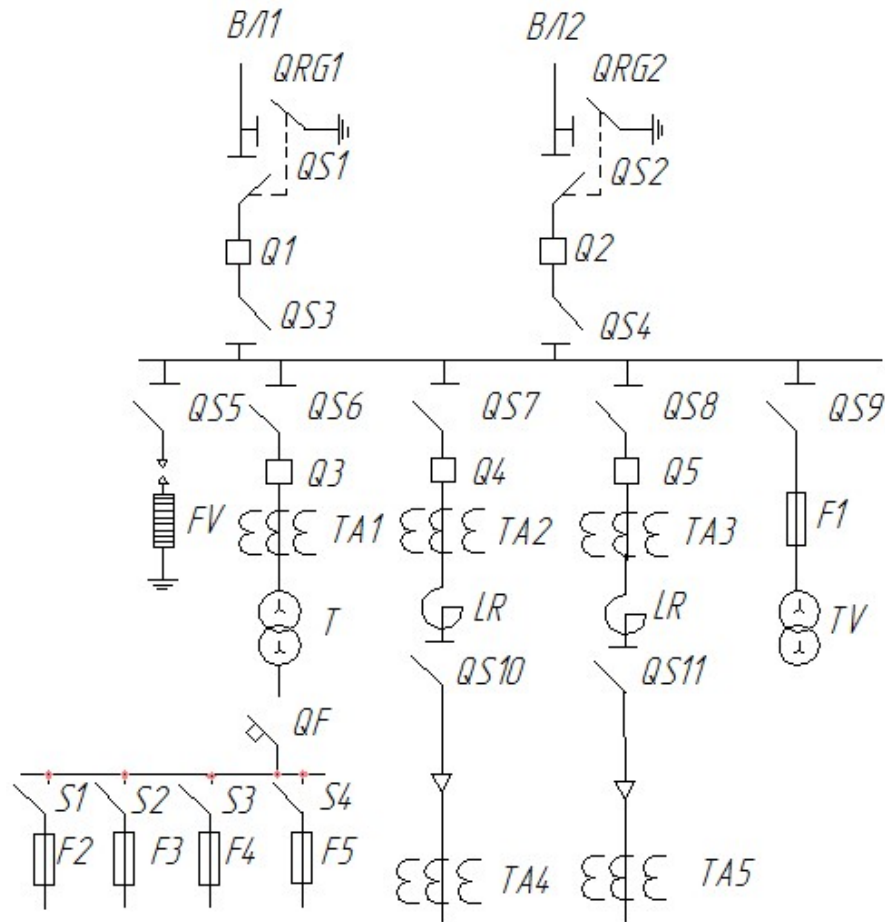


Fig.1. Schematic diagram of the distribution point with seven cells [1]: Q - oil circuit breaker; QS - disconnector; QF - circuit breaker; S - switch; F - fuse; QRG - earthing switch

An electric power system is operated in real time mode - therefore, there are high requirements to ensure reliability, continuity and operation quality, including to relay protection and emergency control systems for individual electrical units and the electric power system as a whole.

The modern level of information technologies and computing facilities, as well as a clearly traced trend towards the digitalization of electrical networks, allow us to reconsider the approaches to the development and the improvement of traditional relay protection functions of electrical units with various voltage classes, primarily of medium voltage, as the most common and, thus, the most significant for end users [1].

When PSP are replaced or reconstructed, the issue of significant financial investments arises, due to which a complete replacement of relay protection systems is a very difficult task for a significant number of medium voltage electrical units.

It should be noted that the development of PSP equipment in the world, the transition to microprocessor-based digital complexes of PSP and the distribution of such international standards as IEC 61850 also revealed the problem of the incompatibility concerning the outdated electromechanical and microelectronic equipment with the new digital PSP systems.

II. Centralized system of relay protection for medium voltage distribution point

In order to solve the problem of economical, functional and reliable replacement of a large number of out-of-date devices of relay protection and automation units in medium voltage networks also from the point of view of electromagnetic compatibility (EMC) a method is proposed and a centralized system of relay protection and automation (Hereinafter referred to as CENTRALIZED RELAY PROTECTION SYSTEM, CRPS) is proposed on the basis of this method, where a passive optical bus can be used as a system for data collection and transfer between interconnection devices and a centralized microprocessor.

CRPS is a multifunctional unit providing the protection of medium voltage power plants (primarily the DP of 6-10 kV) from all types of damage and abnormal operation modes [3], and with the advantage of centralization and complex protection functions, as well as with self-check, remote control and monitoring features, an operative modification and the adjustment of RP algorithms and making them adaptable to the operating modes of an electrical unit.

A communication passive optical bus developed and used in CRPS will provide structured, secured and reliable organization of information networks for data transmission and processing (information collection and transmission systems - ICTS) in CRPS [3].

The peculiarity of CRPS is the transfer of relay protection and automation logic to the central server, and the leaving of PDO (Pairing device with an object) logic on outgoing lines:

- Digitization of analog signals (LFF, ADC units);
- Switch control (logic outputs);
- Passive optical communication interface (communication with the server) (Figure 2).

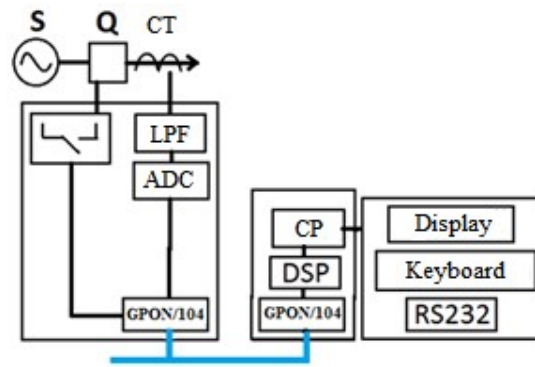
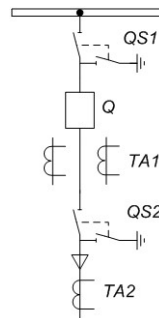


Fig.2. Structural diagram of proposed CRPS; CT-circuit transformer, LPF – Low-pass filter, ADC analog-to-digital converter, CP – central processor, DSP – digital signal processor.

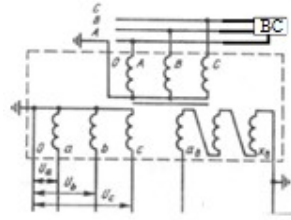
In the proposed centralized system, all the logic of protection and automation is concentrated in one device - the server; An important role in this case is played by the server communication line with the coupling units in the switchgear [3].



a) Output line 6 (10) kV



б) PDO connection to the current transformer, where BC – baycontroller.



b) connection of BC to voltage transformer

Fig.3. Implementation of standard BC connection to measuring transformers in switchgear: a) outgoing line of 6 (10) kV
 b) BC connection to the current transformer in switchgear, c) BC connection to the voltage transformer in switchgear

A communication system must provide the necessary speed of protection and automation, its reliability contributes to the overall reliability of the system with a central server. A communication line should provide speed and reliability of transmission/reception, also from EMC point of view [4].

The device of interface with an object realizes the connection of CRPS with the technical process in an electrical unit. The main elements of PDO are: a filtering unit, a digitizing unit, a communication unit, including the passive optical bus interface GPON/EPON, and a communication unit with a computer to tune with the FEC-RS 232. A passive optical bus in CRPS is built using GPONEPON technology. The network layer is implemented using the protocol IEC 60870-5-104 [4].

The example of a standard PDO connection implementation to measuring transformers [5] in the switchgear cell of 6-10 kV is shown on the following figure (Figure 3).

The main PDO functions [5] in a switchgear, DP and RTP are the quantitative determination of the technological process current state and the conditions of its operation due to the processing of analog current and voltage signals; the performance of input/output functions and the processing of discrete signals and control functions by switching devices; At that the support of various communication channels (RS485, Ethernet, OF) and the use of xPON technology (GPON/IEC 60870-5-104) are provided [6].

Data exchange between a central server (servers) and PDO is performed via communication lines using GPON/IEC 60870-5-104 technology [6].

You can use an industrial SCADA controller (Front-EndController - FEC) or a separately manufactured device (hereinafter a central server) as a central CRPS server [7].

The central server (CS) CRPS performs continuous monitoring of the state [8], protected by DU and determines the triggering conditions in accordance with the analysis of parameter values coming from the measuring transducers (PDO). Also a self-diagnostic module is implemented for diagnostics and signaling, which ensures the self-diagnosis of CS, the control of transmitted data correctness and, if necessary, the transfer of error information (error code) concerning measurements to the upper-level automated control systems (ACS). During receiving/transmission of the measurements received from PDO, they are given time marks obtained with GPS and GLONASS sensors. The communication port serves to transfer the available information to other digital systems (APCS, etc.) (Figure 4).

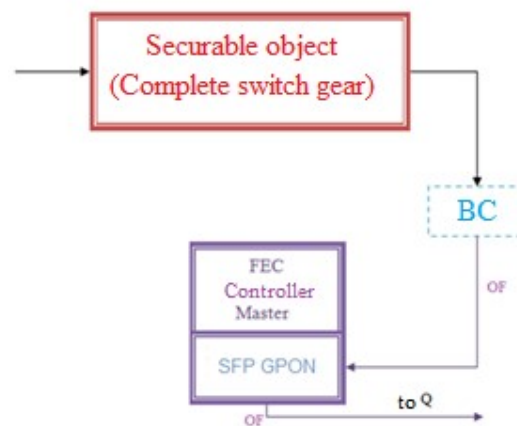


Fig.4. Structural diagram of CRPS: Protected object of DP, BC-bay controller, SFP GPON-SFP module ONTGPON, FEC controller - central server CRPS, Q - switch, OF - OFTS.

Figure 4 shows that the reception and the transmission of teleinformation and signals are carried out using an optical passive bus (OF).

III. The influence of the electromagnetic environment on the operation of centralized relay protection

Electric power facilities are characterized by a complex electromagnetic situation, and in the most unfavorable case, a significant negative impact may take place on relay protection and automation systems [9], APCS, etc., including the communication lines deployed in an electrical device of a communication line, primarily in traditional "copper" lines. External electromagnetic fields [10] induce in communication line circuits, based on copper conductors, interferences, which not only reduce the quality of transmission, but also can

excite large voltages and currents, leading to the destruction of communication lines and the equipment connected to it [11].

According to static data, an incorrect operation of relay protection and automation devices based on microprocessors [12] is caused by insufficient EMC in 10% of cases. The reason is that the sensitivity of traditional microprocessor relay protection devices to electromagnetic interferences is very small and does not meet modern requirements.

IEC 60050 [13] specifies the existing boundaries between an apparatus (a system and an installation) and an electromagnetic environment which provide the same apparatus (a system or an installation) with intrasystem and non-system electromagnetic compatibilities [16], namely, the ability to function satisfactorily in the electromagnetic environment created by system and external sources, without the creation of unacceptable interference to other components. Another aspect of the electromagnetic compatibility is the interference emission monitoring and the provision of adequate noise immunity.

International Standard IEC 61000-2-5-95 classifies electromagnetic interferences as low-frequency ones (the spectrum of electromagnetic radiation is spread in the range up to 9 kHz), high-frequency interference (the spectrum of electromagnetic radiation spreads in the range much higher than 9 kHz) and electromagnetic disturbances generated by electrostatic discharges [15, 16]. The nomenclature specified in the international standard defines certain types of electromagnetic interference: for example, the emitted low-frequency noise is determined by the influence of magnetic and electric fields [17]. The conductive low-frequency electromagnetic disturbances defined in the standard are manifested in an electric network as follows:

- by harmonics and interharmonics of the power supply voltage;
- by the voltages of signals transmitted in power supply systems;
- by power supply voltage fluctuations;
- by dips, short-term interruptions and power voltage emissions;
- by power supply voltage deviations;
- by the asymmetry of voltages in three-phase power supply systems;
- by the changes of supply voltage frequencies;
- by induced low-frequency voltages;
- by permanent components in AC power supply networks.

Inadmissible electromagnetic environment is also determined by non-linear loads, which create the currents of high harmonics of industrial frequency, 50 Hz (2 - 3 kHz). When such currents take place in the high, medium, low voltage power supply system, harmonic

distortion of voltages are created. These distortions can be destructive for a large number of electronic products used in a distribution network.

Moreover, local high-frequency fields created by control, signaling, data transmission devices and other devices used in relay protection, accounting, control and monitoring systems in such installations can be observed at power facilities.

A peculiar special case of electric field undesirable influence [19] on the secondary part of medium voltage distribution network is the discharges of electrostatic charges on conducting parts. Charges are accumulated on dielectric information carriers when passing through the input-output and print devices, as well as on the servicing electric engineering personnel (operators).

IV. Calculation of electromagnetic interference intensity at a medium-voltage substation

In order to determine the degree of an electromagnetic interference intensity, let's consider the effect of conductive high-frequency and low-frequency electromagnetic disturbances, which may be manifested by dips, short-term interruptions and voltage ejections in a DP (Figure 1) at $U_{nom} = 10$ kV.

The occurrence of dips and short-term power interruptions can be associated with the accidents at high-voltage or medium-voltage power lines, short circuits in low-voltage switchgears, and with the switching of high-power loads. The abnormal mode of a medium voltage distribution network operation also does not exclude the possibility of electromagnetic interferences. The networks with isolated neutral can operate in single-phase earth fault mode (SPEF) for a long time. This contributes to the wear of insulation, thereby increasing the risk of multiphase damages [19].

In accordance with the international standard IEC 61000-2-5-95, which establishes the classification of electromagnetic interference and the environment for various locations of electrical, electronic and radio electronic product and equipment placement [15], the MATLAB software simulates a medium voltage distribution network (Figure 5), which includes a distribution point of medium voltage (RTP). During the development of the mathematical model, they used Simulink and SimPowerSystems library units. The mechanism of the of asymmetric electromagnetic interference effect from the power source to secondary devices (equipment or system) with a single-phase earth fault in the network was considered in the mathematical model of the distribution network [18]. That is, when the source of interference originating from the main part of the medium voltage distribution network caused

by a single-phase earth fault acts on the secondary part of the medium voltage distribution network.

The circuit developed in MATLAB represents a complex "bridge" [18]. When the circuit is balanced or symmetrical, the voltage drop caused by the source of interference is not observed on the secondary circuit. However, at a single-phase earth fault (SPEF), the absence of a network symmetry is observed near the source of interference (SPEF point). In an unbalanced and asymmetric circuit, a voltage drop in the secondary circuit U_2 is observed due to the U_1 interference source [18], which distorts the network voltage.

The mathematical model (Figure 5) was developed using the numerical units of MATLAB software such as the generator (Γ); switching devices (B1 and B2); current transformer (CT); measuring units (IB1 and IB2); oscillograms (S1, S2, S3); timer; power lines (L); load (N); short-circuit (K), by the means of which a single-phase earth fault is simulated at the point "A", i.e. in the power part of the medium voltage distribution network. Then let's consider the effect and the consequence of a single-phase earth fault that occurred at point "A" on the secondary circuit of electrical devices in a medium-voltage distribution network. The use of measuring unit 1 and 2 is necessary, since by the means of these units the values of linear and phase currents and voltages are determined automatically and with the help of oscillograms these values are displayed in a graphical form of a value (Fig. 6, Fig. 7).

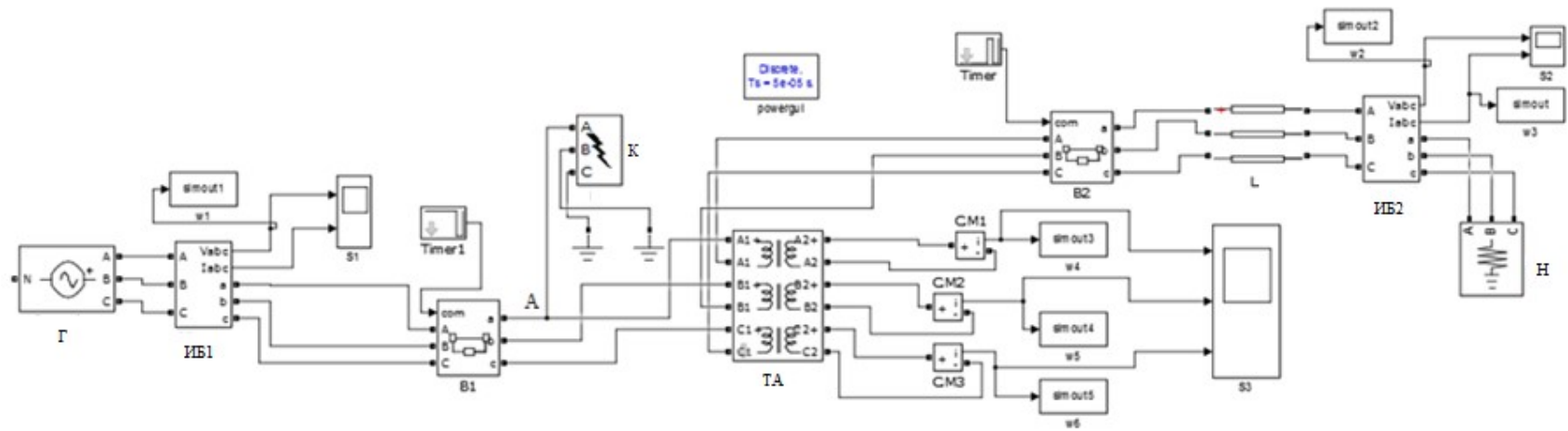


Fig.5. Mathematical model RTP - 10 kV: generator (Г); switching devices (B1 and B2); current transformer (CT); measuring units (IB1 and IB2); oscillograms (S1, S2, S3); timer; power lines (L); load (N); short-circuit (K).

10 kV distribution network operates with an isolated (ungrounded) neutral as a rule. In the normal mode, the network phase voltage (U_A, U_B, U_C) relative to the ground is symmetrical and equal to the phase voltage ($10 / \sqrt{3}$ kV). The value of the single-phase ground fault currents is conditioned to the currents flowing through the distributed capacitances of the phases.

In the international standard IEC 61000-2-5 [14], in case of an unacceptable electromagnetic situation, the voltage change in power supply systems is set with the frequency of 50 Hz ranging from 10% -99% U_{nom} (voltage dips, $[\Delta] U$), as well as short-time power interruptions, at which $[\Delta] U = 100\% U_{nom}$ with the duration from $\frac{T}{2}$ up to a few seconds.

The standard IEC 61000-2-5 states that voltage dips and short-term power interruptions can be caused by accidents on medium-voltage or high-voltage power lines or in other network equipment, accompanied or not accompanied by a re-inclusion (with the duration of 100-600 ms) [14].

In our case, the single-phase short circuit (Figure 6) on the ground lasts:

$$t_{osz} = t_{kon} - t_{nach} = 0,6s - 0,4s = 0,2s \quad (1),$$

there t_{osz} is the duration of a single-phase earth fault; t_{kon} - end time of SPFP; t_{nach} is the initial time of SPFP, which is accompanied by electromagnetic interference.

SPFP (t_{nach} SPFP = 0,4 s) is accompanied by the voltage drop of 100% U_{nom} at phase A, with the duration of 0.2 s, at that the voltage in the remaining phases makes $U'_B \approx 8.56$ kV, $U'_C \approx 8.56$ kV (figure 6). Such a voltage jump on the undamaged phases is explained by the fact that the protection is triggered in the case of SPFP and the switch is switched. At SPFP of the phase-A, the earth's surface at the point of damage acquires the potential of this phase, and the voltages of the undamaged phases relative to the ground, would be equal to the phase-to-phase voltages ideally at 10 kV: $U'_B = U_{BA}$, $U'_C = U_{CA}$, but the occurrence of SPFP is accompanied by electromagnetic interferences, which last 200 mcs in the time range from 0.4 to 0.6 and their influence obviously affects the values of currents and voltages of intact phases B and C, i.e. these values change discontinuously under the influence of electromagnetic interference, in this case, during the analysis of electromagnetic interference effect on the medium voltage distribution network, the voltage values at phases B and C make 8.56 kV, respectively (Figure 7). The long-term high-frequency noise cardinally affects the values of voltages in the undamaged phases B and C and make 8.56 kV. The currents and the voltages of phase A, B and C are determined by the means of unit 1 and 2 measuring.

At that, the interference derivative, which determines the maximum interference voltage on the power part of the distribution network U_{smax} , in this case is equal to:

$$x = \frac{[\delta]x}{[\delta]t} = \frac{8560}{200 \cdot 10^{-6}} = 0,428 \text{ kB}[15] \quad (2),$$

where x is the maximum value of electromagnetic interference amplitude; Δx – s the amplitude of electromagnetic interference change; Δt is the change of time.

I.e. the voltage at the undamaged phases B and C increased by 0.428 kV, which could lead to the heating of conductors, an increased wear of insulation and, subsequently, to an emergency situation.

The frequency of oscillations for a high-frequency electromagnetic interference is:

$$f_0 = \frac{[\omega]_0}{2[\pi]} = \frac{1}{2[\pi] \cdot 10^{-4}} = 1,59 \text{ МГц} \quad (3)$$

With the appearance of a long electromagnetic interference in the distribution network, a pulsed electromagnetic interference is observed, with the duration of 200 mcs (Figure 6, Figure 7).

The power section also has derivative interferences, determined by the maximum interference voltage on the secondary circuit U_{smax} , taking into account that [18] the impulse interference can not be more than 10 V. In the secondary circuits, the values of currents and phase voltages are shown as in the power part using the measuring devices: ammeter and voltmeter. According to the simulation results, the voltage in the secondary circuit increased by 4 V (Figure 7). And the rate of interference change is:

$$x = \frac{[\delta]x}{[\delta]t} = \frac{800}{200 \cdot 10^{-6}} = 4B[17] \quad (4),$$

where x is the maximum value of the electromagnetic interference amplitude; $[\Delta] x$ is the amplitude of electromagnetic interference change; $[\Delta] t$ is the change of time.

Those. The voltage on the undamaged phases B and C increased by 4 V.

And the frequency of impulse interference oscillations is:

$$f = \frac{[\omega]_0}{2[\pi]} = \frac{1}{400 \cdot 10^{-6}} = 1,59 \text{ кГц} \quad (5),$$

The power part of the distribution network at 0.4 s - 0.6 s has the voltage decrease in B and C phases by 20.01%, i.e. $U'_B = 8,56 \text{ kV}$ $U'_C = 8,56 \text{ kV}$. In the secondary circuit, the values determined by measuring units show that the voltage is reduced to $U'_B = 800 \text{ V}$ $U'_C = 800 \text{ V}$

After the circuit breaker triggering in the power section of the 10 kV distribution network, the voltage in all phases becomes equal to 10.3 kV according to the indices of the measuring unit 1 and 2.

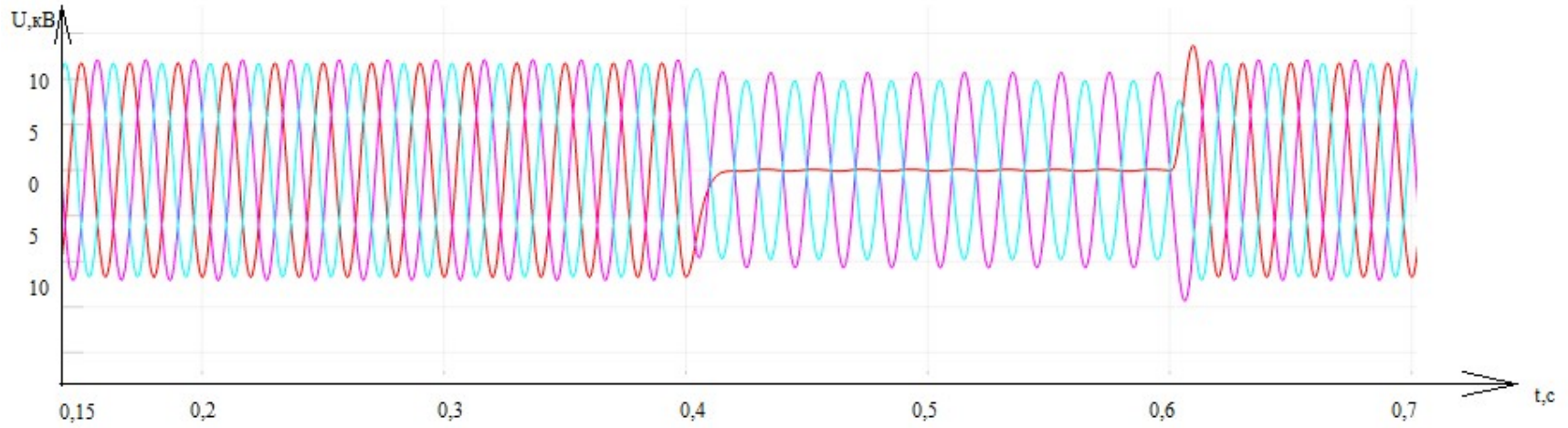


Fig.6. Voltages at SPFP: the values of phase A are marked in red, the values of phase B in pink and the values of phase C in blue

The appearance of electromagnetic interference in the medium voltage distribution network is determined by such parameters as frequency f and amplitude A_m [15], which determine the interference voltage in the secondary circuits. As is known from [18], the range of electromagnetic interference duration makes from tens of nanoseconds to milliseconds at the outputs of secondary device communication line (apparatuses, systems).

The effect of electromagnetic interference extends not only to the power part of the medium voltage distribution network, but also on the secondary part of the distribution network, so that the value of voltage in phase A within the power and the secondary part, according to Figures 6 and 7 is reduced to zero and further - the acquisition of oscillatory character, at that the whole process lasts for 0.2 s, i.e.

- In the power part, the voltages are attenuated in phase A, and the voltages in the undamaged phases B and C increase to the values equal to 8.56 kV,
- The voltages within phase A are attenuated in the secondary circuit, and the voltages in the undamaged phases B and C increase to the values equal to 800 V.

In the power section the voltage fluctuations in phase A are damped after 0.4 s - 0.6 s, and the voltages on the undamaged phases B and C are reduced to the values of 8.9 kV.

In the secondary circuit the phase A voltage is attenuated after 0.4 - 0.6 s, and the voltages in the undamaged phases B and C are reduced to 800 V.

Interference propagates both in general and in differential mode, the first of which is dominant. In the differential mode electromagnetic interference appears between the phases of the power source and is transferred to the equipment, and the source of interference is external interference caused by the damage of an electrical network. In this case, it can be seen from Figures 6 and 7 that the electromagnetic interference caused by the abnormal operation of the distribution network appears on each conductor (phase).

In order to reduce the influence of the device susceptibility [18] (equipment or system), it is necessary to reduce the inductance of the communication line and the secondary power circuits, since the amplitude of the interference voltage depends not only on the rate of interference change, but also on the inductance of the communication line, i.e.

$$U_{smax} = U_1(p)L_n/L \quad (6),$$

where $U_1(p)$ is a single voltage jump in phase A, L_n is the inductance of the secondary circuit line, and L is the inductance of the interference source.

In order to reduce the inductance (L_n) of the communication line, it is necessary to reduce the area of the loop formed by the forward and reverse communication wires, i.e. the use of twisted pairs, coaxial cables, flat cables, in which each communication line has 2 or 3 wires.

In order to reduce the inductance of the secondary power circuits, it is necessary to increase the cross-section and the area occupied by the conductors and conductive surfaces of the secondary supply circuit system.

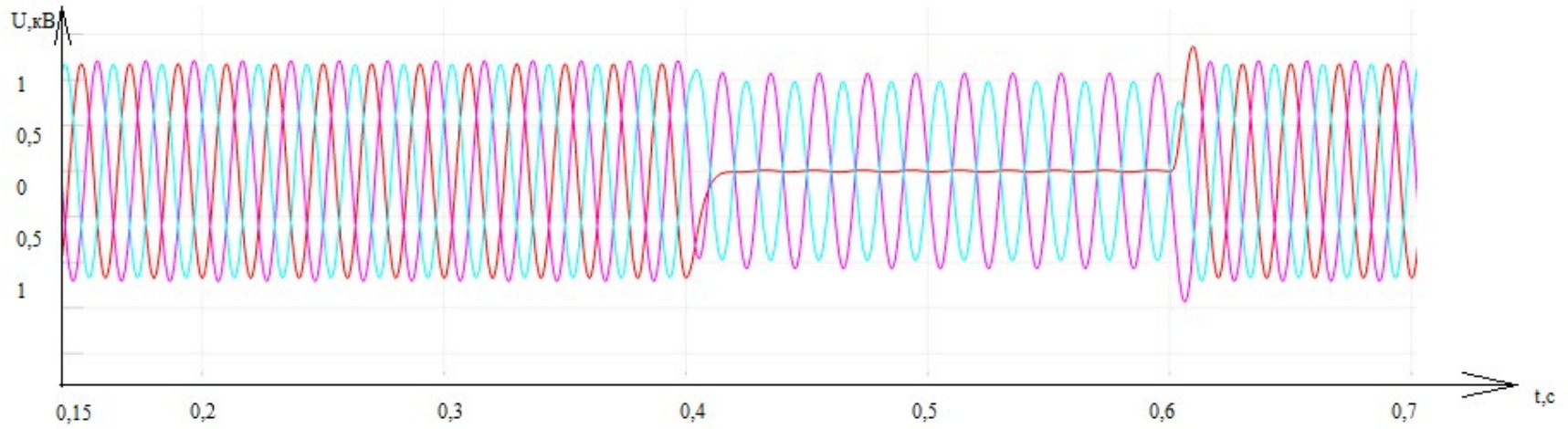


Fig.7. Voltages at SPFP in the secondary circuit of the distribution network: the values of phase A are indicated in red, the values of phase B in pink and the values of phase C in blue

Summarizing the simulation, it can be noted that they determined the influence of electromagnetic low-frequency and high-frequency conductive interference with the predominance of high-frequency conductive interference in the developed mathematical model of the switchgear. Having understood the types of interference, according to the international standard it is necessary to establish the degree of intensity concerning the influence of electromagnetic interference taking into account the frequency, which was calculated in the course of the experiment - 1.59 MHz and 1.59 kHz.

From the technical documents intended for medium-voltage connection protection terminals (for low-frequency and high-frequency interference, respectively) the attestation data are showed [20] according to the requirements of electromagnetic compatibility. From these data it is possible to determine the degree of electromagnetic environment rigidity. Taking into account the received indications (1.59 MHz and 1.59 kHz) and on the basis of the international standard IEC 255-22-4 we determine the degree of rigidity - 3.

According to the interstate standard IEC 61000-4-13: 2002 (GOST 30804.4.13-2013) [14], the development of electromagnetic interference in power supply networks is caused by the appearance of higher harmonic stress components and its oscillations due to the impact of electrical equipment with a nonlinear and time-varying current-voltage characteristic. For example, the transformers and the motors with high inductive load, controlled actuators with electronic regulators, valve converters for electrolysis, gas-discharge lamps, etc. cause non-sinusoidal currents, which along their path to the electrical equipment create non-sinusoidal voltage drops on the full network impedances even with sinusoidal voltage of a network. Voltage drops created by consumer currents lead to the distortion of the mains voltage sinusoidal form at the frequency of 50 Hz and to the appearance of harmonics.

Also, electromagnetic influences can manifest themselves as reversible and irreversible disturbances. Thus, acoustic noises (from 100 MHz), radio interference (10 kHz - 1 GHz), the interference in data collection/transmission can be examples of reversible disturbances, and a failure in the operation of a relay protection system that led to a load removal is the example of irreversible disturbances [20].

The intensity of radio interference is characterized by the vertical component of the electric field strength near the earth's surface (E_2).

The level of radio interference, (dB), is determined by the value [20]:

$$Y = 10 \lg (E_2/E_1) \quad (7)$$

where E_1 is the basic electric field strength, mcV/m,

Y is the level of radio interference, dB.

Usually, $E_1 = 1 \text{ mcV/m}$ is taken as the base value, then

$$Y = 20 \lg E_2/E_1 \quad (8)$$

The estimated frequency is 0.5 MHz, as recommended by the International Committee on Radio Interference. The level of the useful signal at this frequency makes 60 dB approximately.

It was noted in [20-33] that in order to implement a reliable power supply, to increase the efficiency and the service life of equipment, it is necessary to carry out the measures that would reduce the effect of electromagnetic interference. Such measures include: correct implementation of power systems, the observance of necessary measures for grounding the design of relay protection and automation devices, the shielding of communication cables, a correct design of hardware for relay protection and automation device, etc.

V. CONCLUSIONS

In this paper, they simulated the mathematical model of the distribution network, in which they considered the mechanism of unbalanced electromagnetic interference effect from a power source on secondary devices (equipment or system) at a single-phase earth fault in a network. Taking into account the mathematical calculation of electromagnetic interference and graphical components of the mathematical model for the medium voltage distribution network, the degree of electromagnetic compatibility rigidity was determined taking into account the received indications. Taking into account the obtained readings (1.59 MHz and 1.59 kHz) and based on the international standard IEC 255-22-4 they determined the degree of rigidity equal to 3. Also, using the graphically obtained parameters, it can be concluded that in the case of an unbalanced distribution of an electric medium-voltage network with a single-phase ground fault near the source of interference, there is a voltage drop in the power section and in the secondary circuit of electrical installations obtained from the source of interference [18]. In order to reduce the effect of electromagnetic interference on devices (or systems) a FOCL shall be used as communication channels, which eliminate most of the problems associated with interference immunity and a poor quality of transmitted information in traditional copper communication channels at a power plant.

VI. SUMMARY

The main and the cardinal way of interference effect reduction on communication channels in the electrical installations of different voltage classes is the transition to fiber-optic

communication lines and various optical communication systems, including passive ones, for example, according to xPON technology.

An important advantage of xPON technology is that an optic fiber (OF) is used as a physical communication channel, which, among other things, has a high degree of security against unauthorized access, unlike other media.

When a fiber optic is used for the deployment of SSPI for CRPS, the influence of interference on CRPS devices is significantly reduced [4] and the reliability of [10] RPA and ASTCP systems in DP of 10 kV is increased.

Accordingly, the use of xPON technology is proposed to reduce or prevent electromagnetic interference in the centralized relay protection system and the automation of the medium voltage distribution center.

VII. ACKNOWLEDGEMENTS

The work was financially supported by the Russian Federation Ministry of Education and Science within the framework of the federal target program "Research and Development in Priority Areas for the Development of the Russian Science and Technology Complex during 2010-2020", subsidy provision agreement # 14.577.21.0194 - 3rd stage issued on October 27, 2015, the unique identifier of applied scientific research (of the project) is RFMEFI57715X0194.

VIII. REFERENCES

Book

1. Kryukov V.I., 1989. Maintenance and repair of electrical equipment of substations and switchgears: Textbook / V.I. Kryukov. - M.: Higher education. - 367 p.

Official source

2. Position of PJSC "ROSSETI" "On a unified technical policy in the electric grid economy", the protocol of 2013.

Article from the magazine (printed version)

3. Digital hardware and software elements of microprocessor relay protection and automation of power systems / N.I. Ovcharenko M.: NTF "Energoprocess", 2006. 120 p.; II. [Library of electrical engineering, supplement to "Energetik" magazine; Issue 5-6 (89-90)].

Article from the magazine (printed version)

4. Egorshv D.E. Optimization problems for fiber-optic communication networks in the subscriber access area / D.E. Egorshv // T-Comm - Telecommunications and Transport. Issue # 7/2010

Book

5. Kireeva E.A., Tsyruk S.A., 2010. Relay protection and automation of electric power systems: Textbook. - M. Publishing center "Academy", - 288p.

Internet resource

6. <http://www.tsonline.ru/articles2/pronsol/novye-gorizonty-pon>

Internet resource

7. http://www.aipet.kz/student/diplom/2014/frts/aes/aes_ru/20.pdf

Internet resource

8. http://digitrode.ru/computing-devices/mcu_cpu.html

Book

9. L.A. Plaschansky, 2005. The basis of power supply. Section "Relay protection of electrical installations": Textbook. 3rd ed. - Moscow: Publishing house of Moscow State Mining University, - 143 p.

Book

10. Arlilaga J., Bradley D., Bodger P., 1990. Harmonics in electrical systems: Trans. from English / M.: Energoatomizdat, 320 p.

Book

11. Schwab A., 1998. Electromagnetic compatibility. Trans. from German. Mazina V.D. and Spectora S.A. 2nd ed., rev. and add. / Ed. by Kuzhekina. Moscow: Energoatomizdat, 480 p.

Article from the magazine (printed version)

12. Birin D.A. Development and security of passive optical networks / D.A. Birin // T-Comm - Telecommunications and Transport Issue # 7/2011

Official source

13. Interstate Standard IEC 61000-4-13: 2002

Official source

14. IEC 61000-2-5-95

Book

15. Dyakov A.F., Kuzhekin I.P., Maksimov B.K., Temnikov A.G., 2009. Electromagnetic compatibility and lightning protection in the electric power industry: Textbook for

universities /; Ed. by RAS reporter, Doct. of Tech. Sciences, prof. Dyakova A.F. - M.: Publishing house MEI, - 455 p.: Ill.

Book

16. Williams T., Armstrong K., 2004. EMC for systems and installations. M.: Publishing House "Technology", - 508 p.

Book

17. Gurvich I.S., 1975. Protection of computers from external interference. M., "Energy", - 160 p., Ill.

Book

18. Gurvich I.S., 1984. Protection of computer from external interference. - 2nd ed., Revised and add. - Moscow: Energoatomizdat, - 224 p., Ill.

Book

19. Korzhov A.V., 2007. Electromagnetic compatibility in the electric power industry: Textbook / Korzhov A.V. - Chelyabinsk: Publishing house UYUrSU, - 70 p.

Book

20. Harlov N.N., 2007. Electromagnetic compatibility in the electric power industry: Textbook. - Tomsk: Publishing house of TPU, - 207 p.

Article from the magazine (printed version)

21. Safin, A.R. Ivshin, I.V. Misbakhov, R.S.,Tsvetkov, A.N.,Denisova, N.V., /Controlled rectifier simulation model development for reversible reciprocating electrical machine/ International Journal of Pharmacy and Technology. June-2016, Vol. 8, No.2, pp. 14059-14068 June-2016

Article from the magazine (printed version)

22. Safin A.R., Ivshin I.V., Kopylov A.M., Misbakhov R.Sh, Tsvetkov A.N./ Selection And Justification Of Design Parameters For Reversible Reciprocating Electric Machine /International Journal of Applied Engineering Research Volume 10, Number 12 (2015) pp. 31427-31440

Article from the magazine (printed version)

23. Kopylov A.M., Ivshin I.V., Ph.D., Safin A.R., Misbakhov R.Sh., Gibadullin R.R. / Assessment,Calculation And ChoiceOfDesignDataForReversible ReciprocatingElectricMachine/ International Journal of Applied EngineeringResearch Volume 10, Number 12 (2015) pp. 31449-31462.

Article from the magazine (printed version)

24. Reshetnikov A.P., Ivshin I.V., Denisova N.V., Safin A.R., Misbakhov R.Sh., Kopylov A.M./ Optimization Of Reciprocating Linear Generator Parameters /International Journal of Applied Engineering Research Volume 10, Number 12 (2015) pp. 31403-31414

Article from the magazine (printed version)

25. Burganov, R.A., R.S. Misbakhov, V.M. Gureev and Misbakhov, R. and N. Moskalenko, 2015. Simulation of L.R. Mukhametova, 2016. Methodological aspects of the driver of economic growth and energy. Int. Sci. Res. J., 72: 189-195.

Article from the magazine (printed version)

26. Oleg Gennadievich Savelyev, Ibragim Amirovich Murataev, Marat Ferdinandovich Sadykov and Rinat Shaukatovich Misbakhov, 2016. Application of Wireless Data Transfer Facilities in Overhead Power Lines Diagnostics Tasks. Journal of Engineering and Applied Sciences, 11: 1151-1154

Article from the magazine (printed version)

27. Safin, A.R., Ivshin, I.V., Kopylov, A.M., Misbakhov, R.S., Tsvetkov, A.N.2015. Selection and justification of design parameters for reversible reciprocating electric machine.. Source of the DocumentInternational Journal of Applied Engineering Research. 10 (12), pp. 31427-31440

Article from the magazine (printed version)

28. Kopylov, A.M., Ivshin, I.V., Safin, A.R., Misbakhov, R.S., Gibadullin, R.R. 2015.Assessment, calculation and choice of design data for reversible reciprocating electric machine. International Journal of Applied Engineering Research.

Article from the magazine (printed version)

29. Reshetnikov, A.P., Ivshin, I.V., Denisova, N.V., Misbakhov, R.S., Kopylov, A.M.2015. Optimization of reciprocating linear generator parameters. International Journal of Applied Engineering Research

Article from the magazine (printed version)

30. Golenishchev-Kutuzov, A.V., Golenishchev-Kutuzov, V.A., Kalimullin, R.I., Potapov, A.A.2011. Photoinduced decrease in local polarization switching fields in lithium niobate crystals. Physics of the Solid State, 55-60 pp.

Article from the magazine (printed version)

31. Bogdanova, Kh.G., Bulatov, A.R., Golenishchev-Kutuzov, V.A., Golenishchev-Kutuzov, A.V., Kapralov, A.V.2002. Acoustic anomalies near phase transitions in manganite. Acoustical Physics, pp. 75-80

Article from the magazine (printed version)

32. Golenishchev-Kutuzov, A.V., Golenishchev-Kutuzov, V.A., Kalimullin, R.I.2000. Laser generation of acoustic waves at a periodic domain structure in lithium niobate. *Acoustical Physics* 46 (3), pp. 284-286

Article from the magazine (printed version)

33. Batanova, N.L., Golenishchev-Kutuzov, A.V.1997. Acoustic waves in ferro- and piezoelectrics with a periodic electrical relief. *Acoustical Physics* 43 (4), pp. 468-470

How to cite this article:

Lizunov I N, Khuziyakhmetova E A, Ermeev R I, Misbakhov R S. Optical bus of centralized relay protection and automation system of medium voltage switchgear for data collection and transmission. *J. Fundam. Appl. Sci.*, 2017, *9(7S)*, 763-787.