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Information Supply for a Monitoring System of the Distributed Parameters of Power Lines on the Basis of Reflectometers

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1 INTRODUCTION

In the concept of development of electroenergetics the most acute today is the question of construction of a smart grid. The important requirements of construction of such grid are reliability and fail-safety of electro supply. For maintaining reliability of high voltage power lines not only their modernization is necessary, but also duly identification and elimination of deviations of technological parameters. At present finding malfunctions and damages of power lines is conducted by means of their visual inspection by linear brigades, in some cases with getting involved small aircraft what is connected with greater time and material outlays. In this connection, the task of creating a system of remote monitoring of power lines local parameters becomes urgent. Unlike existing devices of fault location the system of monitoring should carry out not only the function of fault location (FL), but also control with preset periodicity deviations of the distributed parameters of a line, possessing at that high sensitivity.

2 BASIC PART

1.1 Principles of construction of a monitoring system

The devices based on methods of active probing – reflectometers can become the basis for development of a system of monitoring power lines parameters. Such devices are capable to fix remotely local deviations of parameters of a long line, uniting the following kinds of damages:

- breakages and short circuits of wires;
- decrease in a level of insulation;
- changes of distance between current-carrying wires of air lines and wood-bush vegetation;
- formation of glaze-clear ice on air power lines.

The automatic fault location finder (ALIMP) is developed for monitoring air power lines (fig.1).



Fig. 1: Appearance of the device ALIMP

The specificity of the reflectometer ALIMP lies in the application of chirps as probing impulses. Application of the complex modulated signals is proved by the necessity to radiate a signal of small power, but at the same time to receive high sensitivity to the changes of power lines parameters with the required measurement accuracy of the distance to the places of damage. The reflected signals are accepted by the receiver and processed by the digital signal processor. As a result a reflectogram is formed which displays levels of the reflected signals from heterogeneities of the power lines.

The examples of reflectograms are presented in fig. 2. In the lower part of the figure the reflectograms with damage (ground short circuit) are shown by a continuous line and without damage – by a dash-dot line. In the upper part of the figure a relative reflectogram is represented, received as a result of subtraction of the first two.

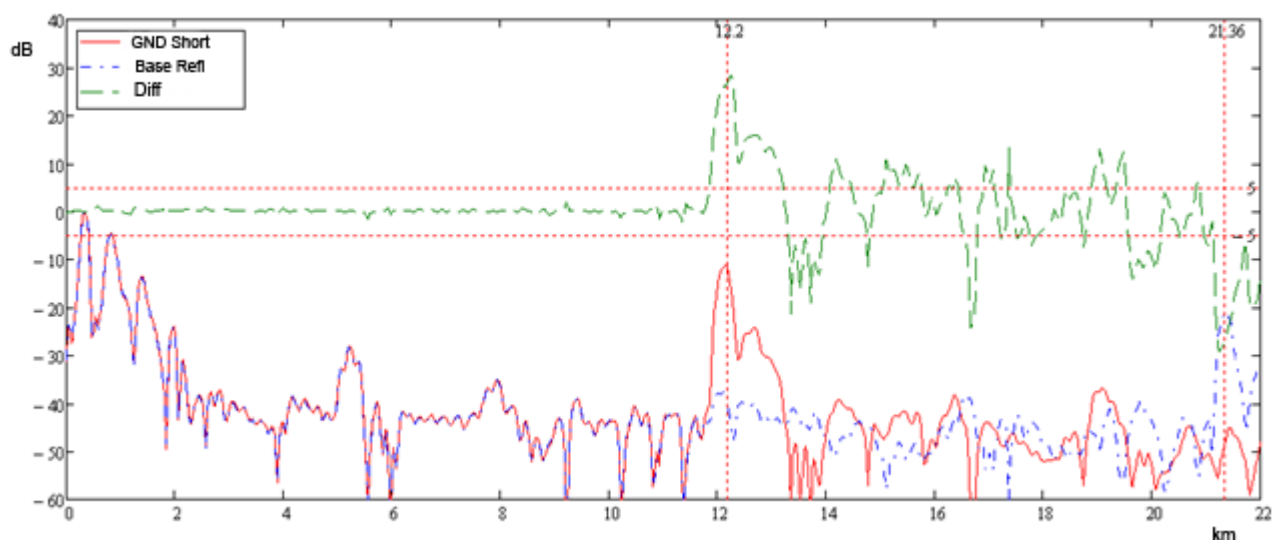


Fig. 2: Dash-dot line below - base reflectogram;
Solid line - ground short circuit of the phase "B";
Dashed line above - difference between the reflectograms

Relative changes of a level of the reflected signal characterize changes of the power line local parameters, such as capacitor, inductive and active resistance. Experimental data [1] show, that the amplitude of the reflected signal to the greatest degree depends on the changes of capacitor parameters of a line reflecting the change of distances between lines and the ground, and also on the change of insulation.

2.2 Algorithms of processing of the information

The generalized algorithm of processing of the received information is shown in fig. 3. In the reflected signal, along with a useful signal corona discharges and noise are included; therefore at formation of the reflectogram it is necessary to have a maximum signal-to-noise ratio. Such condition is carried out by application of the following algorithms of filtering of the received signal:

- the selective frequency filtering – provides rejection of narrow-band signals;
- the matched filtering and accumulation of the received reflectograms from an array of multiple probing – realizes the increase of ratio "a useful signal / noise";
- the selective temporal filtering from an array of probing – carries out the protection from single non-synchronous impulse noise.

The algorithms of filtering listed above are realized on the digital signal processor installed directly in the device.

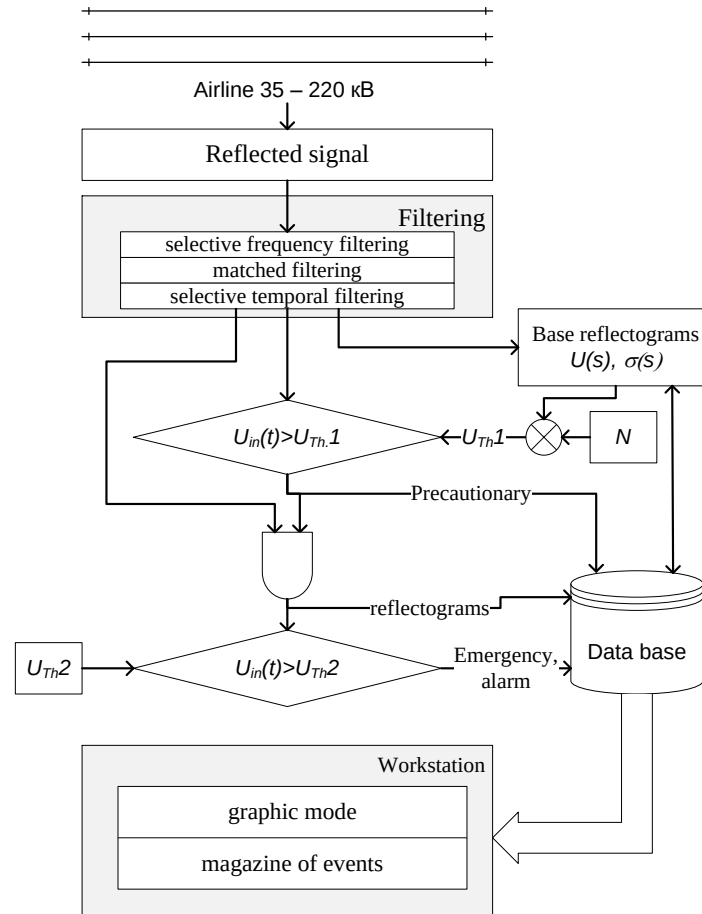


Fig. 3: Algorithm of processing of the information

The final result of work of the device ALIMP is finding a deviation (fault location) of the power line electric parameters, measurement of a level of this deviation and calculation of distance. Presence of noise in a received signal leads to mistakes of measurement. The decision of finding comes to an algorithm of comparison of the received value with the set detection threshold by Neyman-Pearson criterion [2] at maximization of probability of correct detection and the fixed probability of false alarm. For this purpose when probing a basic reflectogram the signal processor by a set of realizations counts up a mean square deviation ($\sigma(s)$) for all local distances of a line. The detection threshold ($U_{Th.1}$) is calculated by multiplication of $\sigma(s)$ by a normalizing factor N which is defined automatically by a calculated program or set manually from the panel of the device. After detection of arisen heterogeneity of the power line parameters the device classifies deviations by a level and duration. Technological deviations are subdivided into emergency (power lines damage) and precautionary ones depending on the set threshold values. For emergency deviations a threshold value $U_{Th.2}$ is set. The distance up to a place of deviation (power line damage) is defined by the distance up to the first local threshold crossing (fig. 2). The results of fixing of damages are transferred to the top levels into a database (DB) or to the industrial control system of a substation. In case of individual work of the operative or relay personnel with an independent device, the result of calculation is displayed on the digital panel of the device.

The system of power lines monitoring can contain one device serving up to 5 air power lines, or can unite a set of the devices ALIMP working in a mode of periodic probing of lines. The block scheme of the system is presented in fig. 4. The basic parts of the system are the devices ALIMP; a database server for storage of reflectograms, precautionary and emergency signals; and a workstation for displaying information.

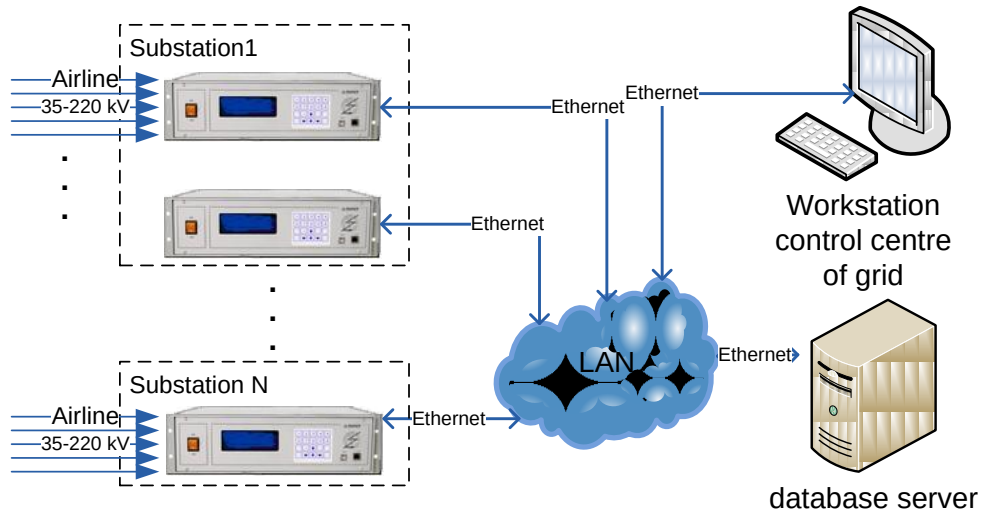


Fig. 4: Block scheme of power lines monitoring on the basis of the devices ALIMP.

The information from devices about the condition of lines in real time is transferred by Ethernet to the interface within the limits of the local computer network of the enterprise and kept in a database server. The access to a database can be executed from any workplace of operative, linear and other services of the enterprise. For an example, a workstation shown in the block scheme, is located in the control centre of grid. At a workstation the software of display of the power lines condition is installed. It includes a magazine of events and a window for the analysis of the power lines condition in a graphic mode.

The example of a display of the daily (for 24 hours) condition of the airline 220 kV, length 36 km is shown left in fig. 5.

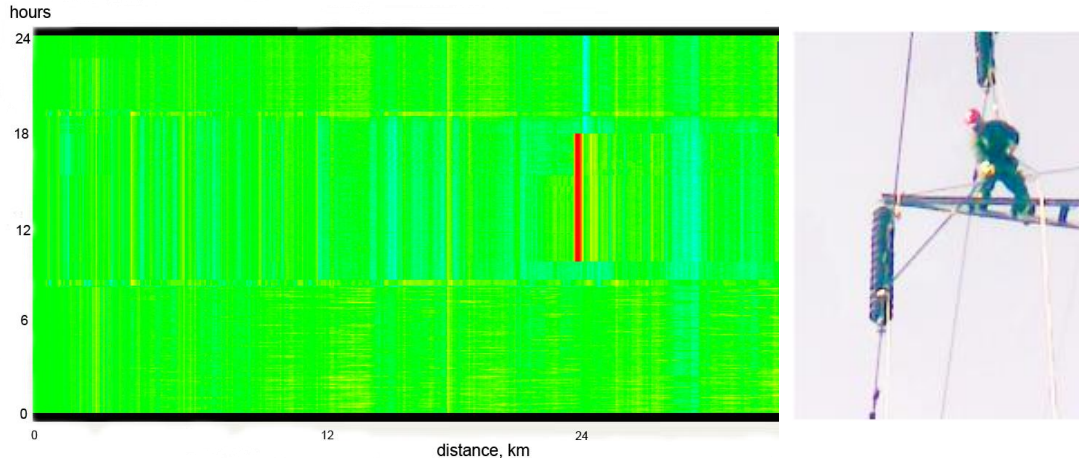


Fig. 5: Photographic representation of relative changes of the power line parameters.
 Work on a line

The axis "X" is presented as distance in km., an axis «Y» as time per hour. A relative deviation of the line parameters proportionally corresponds to the brightness of the image. From the example of this figure it is seen, that at distance of 24 kilometers at 8:30 a.m. there was a sharp change of the power line parameters. Such change has been caused by works on the power line with installation of temporary ground from 8:30 a.m. to 6:00 p.m. (fig. 5, right). The level of relative change has made more than 30 dB.

The example of the definition of trees ignition place under the airline of 200 kV "Etilen – Luch" by the system of power line monitoring is presented in fig. 6.

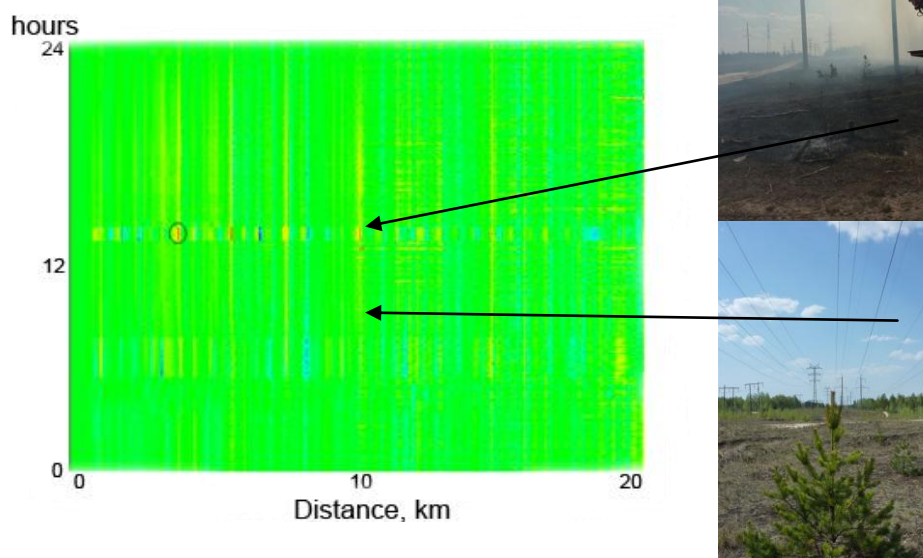


Fig. 6: Photographic representation of relative changes of the power line parameters.
 Definition of a place of ignition

Fixing of inadmissible distance between current-carrying wires of air lines and wood-bush vegetation, as well as the identification of failure of the power line insulation are shown in fig. 7.

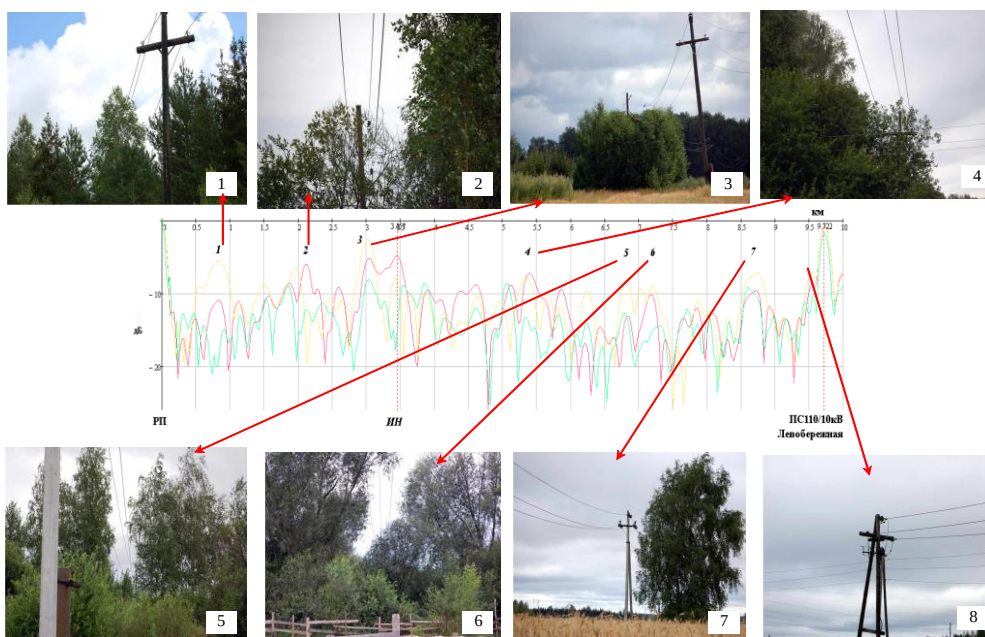


Fig. 7: Remote diagnostics of the power line of 6 kV at the substation 110 kV "Levoberezhnaya".
 The revealed fault and heterogeneity of the power line.

Graphic representation of power lines condition is convenient for the analysis by the service personnel of lines. However for the operative personnel service the most appropriate is to present the information in the form of a magazine of events (fig. 8), related to damages with the inclusion of the following parameters:

- date/time;
- dispatching name of a line;

- substation (an installation site of the device);
- distance up to the place of a technological deviation;
- level or class of alarm.

Depending on a damage rate (a level of a deviation), the program generates precautionary or emergency signals. Great values of deviations, for example, more than 25 dB, are equated to emergency signals with an accompanying sound and a checkback.

In the program of monitoring, installed in a workstation, filters are provided for viewing a magazine of events. To such filters belong: sorting and sample of events according to the set time interval; the substation; the name of a line; a damage rate and the distance.

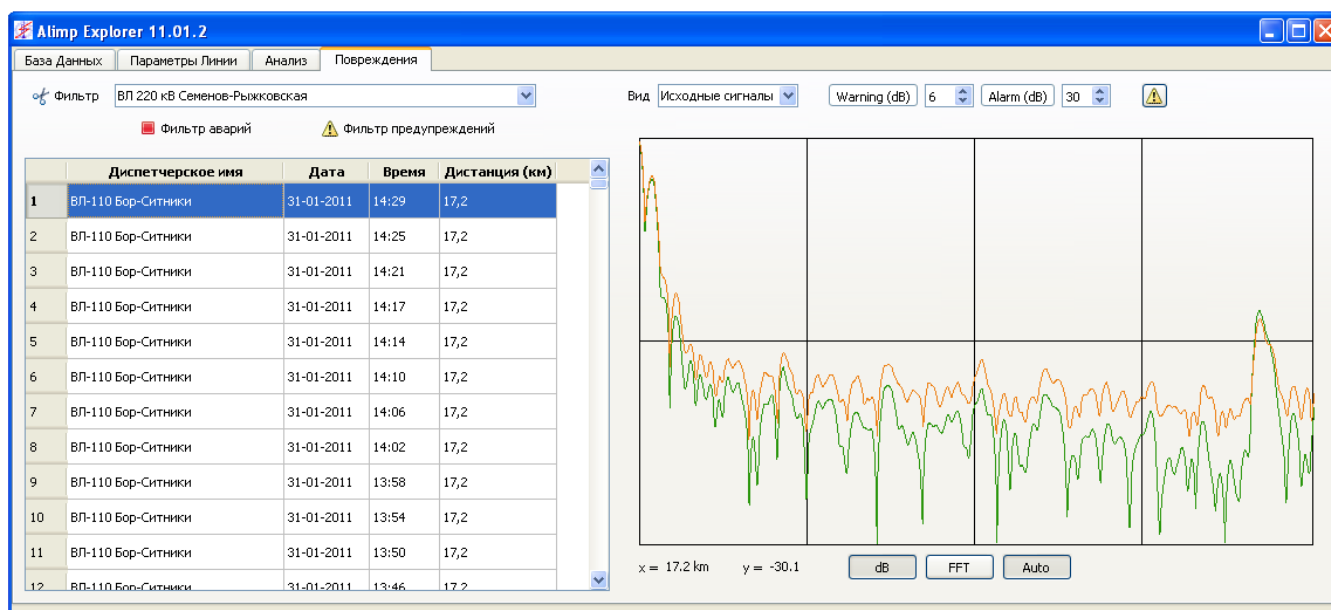


Fig. 8: Example of a magazine of events.

2.3 Integration of the system of monitoring

The modern power complex includes such systems as the industrial control system, the microprocessor terminals of power lines protection, systems of gathering and transfer of the technological information, a security complex, etc.

The integration of the system of power lines monitoring is necessary for uniting and structuring the incoming information in a unified program-technical complex (PTC) of substations, and also for interaction with relay protection and automatics terminals as shown in fig. 9.

The devices ALIMP can cooperate with relay protection and automatics terminals for the realization of an intellectual mode of power lines automatic reclosing (AR). The essence of intellectual AR consists in the following: in case of failure after the operation of relay protection the device ALIMP within the time, not exceeding 30 ms., analyzes the power line condition and generates a signal of sanction or blocking of a mode of automatic reclosing (AR) at detection of damages, at that the resource of switches increases. Integration of the device with terminals of relay protection and automatics can be executed in two variants (fig. 9). In the first variant with terminals which external interface is executed on RS485 with IEC protocol 60870-5-103, additional communications in the form of wire lines are necessary. In the second variant additional communications are not required, as protocol IEC 61850 supports GOOS messages between the devices of the bottom level, ignoring the top one. Variant 2 is most preferable, as it excludes cabling of additional cables and is assigned for work with terminals of protection of last generation.

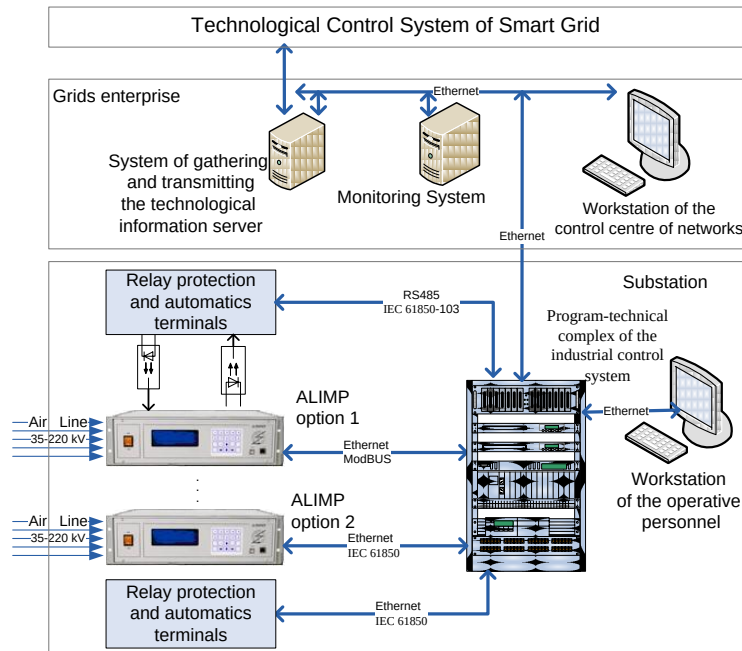


Fig. 9: Scheme of integration of a monitoring system in PTC of substations

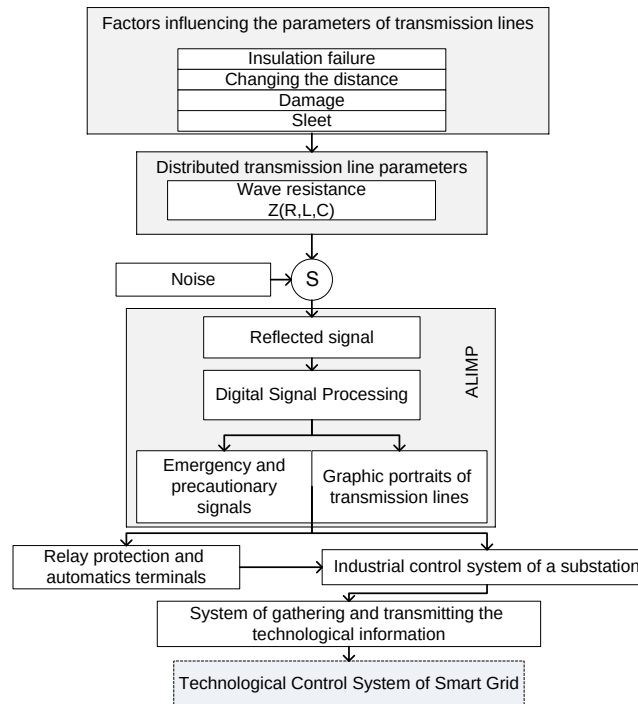


Fig. 10: Block diagram of transformation of the information about the power line condition

By protocol IEC 61850 a system of power lines monitoring can be integrated into the industrial control system of a substation which is the basis for gathering and storage of the technological information. The industrial control system of a substation transmits the received signals and reflectograms to the top levels of hierarchy of the program-technical complex (PTC) through the system of gathering and transmitting the technological information (SGTTI) (fig. 10). Emergency signals from the industrial control system also can be used in the system of security complex of substations with off state power lines.

3 CONCLUSION

Thus, use of the information of a monitoring system of the power lines parameters will allow to expand essentially a diagnostic base of a complex of the electric grids automation systems. Formation and processing of warning signals about threats of power lines insulation failure and places of such threats will find wide application in operative management and operation of an electric grids complex. To conclude, the offered technologies are expedient for using in smart grids.

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