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Methods of Recognition and Identification of Disturbances in High-Voltage Power Lines

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Abstract - **In this paper the methods of integral differential-difference recognition of signals and square-pulse transformation of harmonic signals for detecting transients in power systems are described. The object of this work is the theory of signal processing disturbances in power lines when a leaps and short circuits occur.**

Keywords - **Harmonic signal, integrated differential-difference recognition, square-pulse conversion, the conversion process, leap, short circuit.**

I. Introduction

The actual problem in creating modern information systems for controlling power settings and creating a special processor for power quality control is to develop a theoretical framework for correlative processing of harmonic signals that describe the technological parameters of objects [1]. Especially important task of harmonic signal's recognition is the identification of distortions in high-power systems in the event of short circuit, leading to changes in their correlation and spectral characteristics. Successful completion of this task can be accomplished based on developed methods of integrated differential-difference signal's recognition and neural processor's square-pulse signal's conversion.

II. Research of Signal Distortion When Leaps and Short Circuit Appears in Power Lines

Leap's type changes of amplitude characteristics of amperage and voltage in the power line occur when switching modes of power (Fig. 1). This may occur increasing of amperage in several times. This is especially seen in the sharp rise in the neutral voltage.

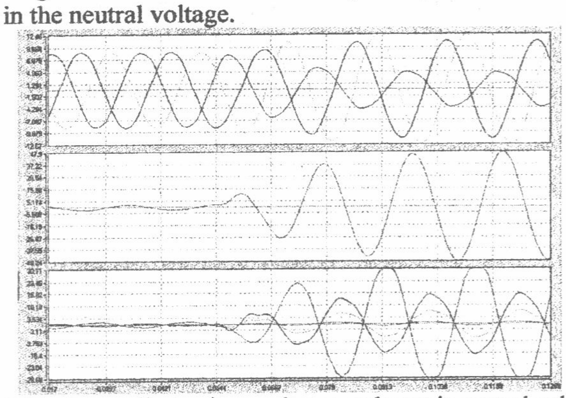
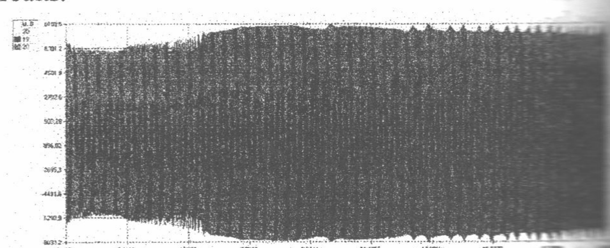


Fig.1 Charts coordinate phase voltages, voltages in neutral voltages and amperage when switching modes of operation of power systems

Research transients currents and voltages shows that one type of accident often develops and becomes another [2]. Each species of accident has a characteristic type of transition process. However, to date there are no methods and tools for automated determination of the type of failure and the place of injury or damaged equipment.

Experimental digigrams of leap in electrical networks with the successful launch of powerful electric motors (Figs. 2) show the growth characteristics of amperage in which there is no negative exponential component characteristic of short circuits.



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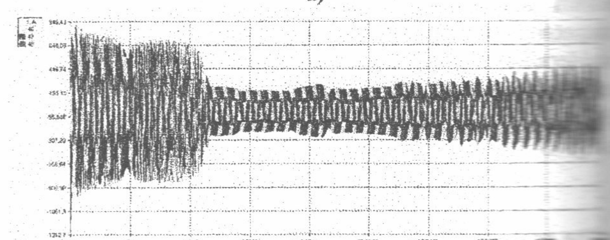

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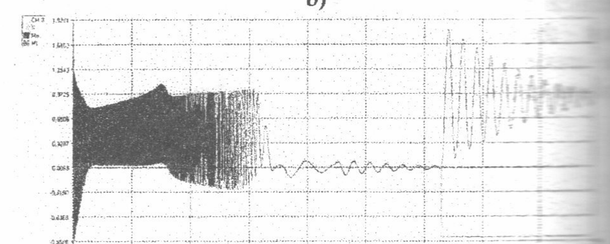
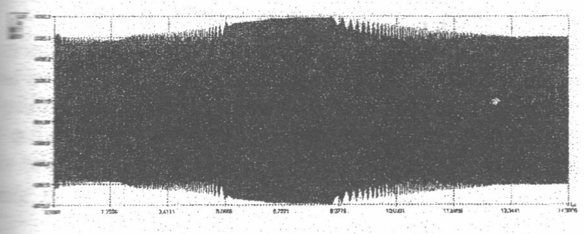


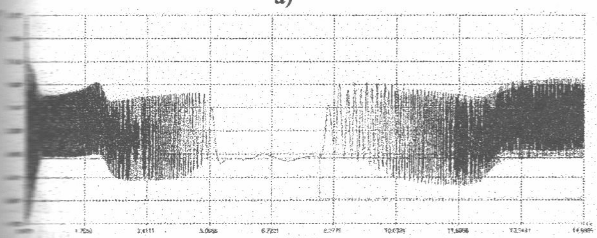
c)

Fig. 2 Experimental digigrams of leap in electrical networks

Figures 3 show the experimental digigrams of leap in electrical networks when launch of powerful electric motors is unsuccessful, which are accompanied by exponential characteristics changing of amperage in the electrical motors at the appropriate time.



a)



b)

Fig. 3 Experimental digigrams of leap in electrical networks

In the event of interphase circuits in high power lines ...ing of amperage arise, but it doesn't lead to significant ...tion of harmonic signals,. The recognition of this type ... circuits can be essentially performed in the range of ...2 periods of industrial frequency when the three-phase ...it occurs, that is shown in Figure 4.

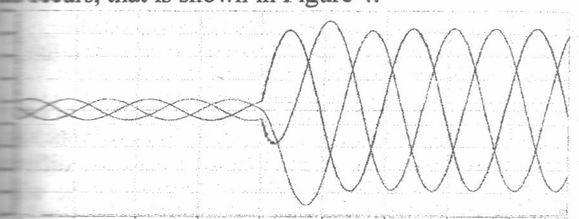
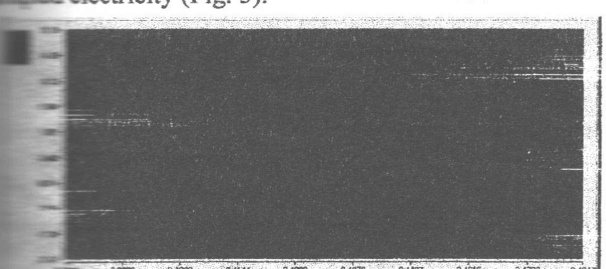


Fig. 4 Three-phase short circuit

Ground fault in distributed networks 6 - 35 kV 50 Hz ...er frequency is approximately 75% of the total damage. ...etworks with isolated neutral circuit of one phase on the ...und is not an accident [3]. However, because of the length ... power grid increases their capacity, thus increasing ...erage to the ground. The amperage on the ground give ...much heat damage, destroying the conductive equipment ... insulation. Experience shows that single-phase circuit ... a short period of time, and sometimes even instantly ... into two-phase or three- phase circuit and consequently ...pted electricity (Fig. 5).



...5 Charts phase voltages and voltage in neutral when going to ...gle-phase circuit two-phase with the emergence of electric arc.

...ure 6 shows that in case of short circuits there is a ...ficant distortion of harmonic signals, amplitude spike ...erage decrease exponentially in the development of a ...rt circuit.

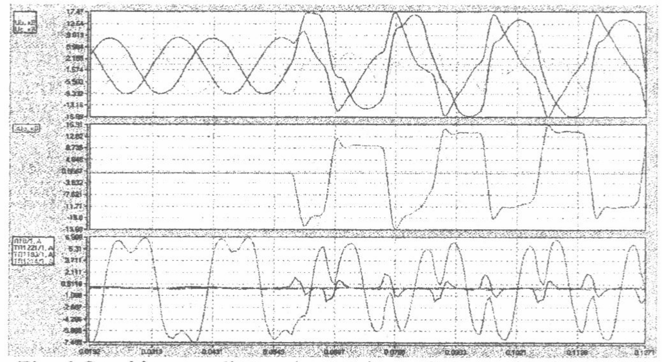


Fig. 6 Graphics coordinate phase voltages in neutral voltages and amperage in the transition to the normal operation of the two polar curve

Our researches show [3-5] that the proposed methods of recognition of transients in the power system is highly integrated method of differential-difference recognition and identification of disturbances and leaps in high-voltage network and a method neural processor square- pulse transformation of harmonic signals conversion.

III. METHOD OF INTEGRAL DIFFERENTIAL-DIFFERENCE SIGNAL RECOGNITION

Let's look at the model of the leap in high-voltage network (Fig. 7).

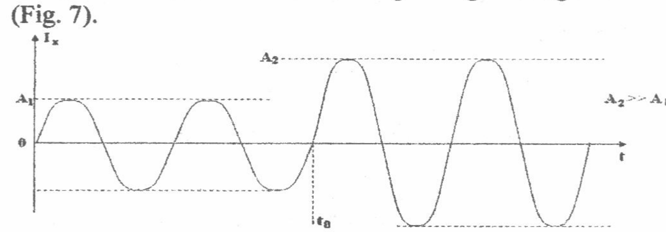


Fig. 7 The model of the leap at the moment (t_0) when high power consumer is switching on

Main features of leap are [3, 6]:

1. Permanence of quality characteristics of harmonic signal if $t < t_0$ and $t \geq t_0$;

2. The jump of amperage in any time from value A_1 (t<t0) to the value A_2 (t>t0) (this jump can be 1-2 orders of magnitude more than the initial value).

3. Leap or decline load amperage amplitude-MIB is constant, i.e.

- Leap $A_1 = const$; $A_2 = const$; $A_1 << A_2$;
- Decline $A_1 = const$; $A_2 = const$; $A_1 >> A_2$.

The problem of recognition of the disturbance in the transmission line can be successfully resolved by digital processing of harmonic signals $X_i = A_i \cos \omega_0 t$ according to the following algorithm (Fig. 8):

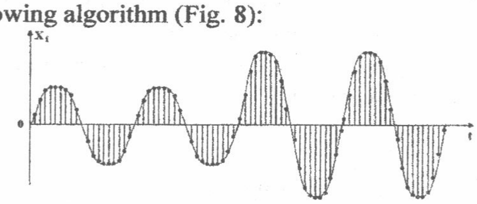


Fig. 8 Model of leap with taking into account the sampling amplitude of harmonic signal when $\Delta t = const$, $\delta = const$

As a result, the ADC output at the interval of one period of harmonic signal centered the flow a digital readout $(\dot{x}_1, \dot{x}_2, ...\dot{x}_i......\dot{x}_n)$ where $M_x = \frac{1}{n}\sum_{i=1}^{n}\dot{x}_i = 0$; $-A \le x_i \le A$.

In order to simplify the solution of the problem present $\dot{x}$ in the form $|\dot{x}|$, i.e. it can be done at the ADC output by discarding the sign or the ADC input by straightening harmonic signal $|\dot{x}|$ (Fig. 9).

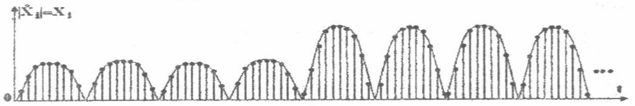


Fig. 9 Modular characteristic of leap's model of harmonic signal

Data processing algorithm of this model is done in increments $\Delta t = \pi/2$, i.e. sliding mode through the half-life harmonic signal.

To perform square-pulse difference method digital samples x_i should be saved recurrence (in stack mode) in memory register $x_i \to x_{i-1} \to x_{i-2} ... \to x_{i-j} ... \to x_{i-n}$ and compare these values to current memorized reference x_i under the scheme $\to x_i \to x_{i-1} \to x_{i-2} ... \to x_{i-j} ... \to x_{i-n} \Rightarrow x_i - x_{i-n}$.

This means that the subtraction operation will be performed on the data harmonic signal shifted to the following points $\pi/2$ (Fig. 10).

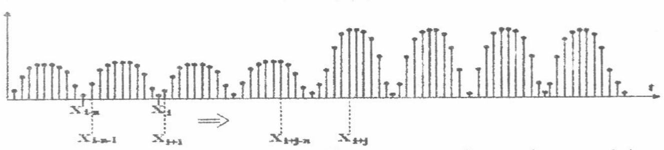


Fig. 10 Model of formation of differences ongoing and memorizing values of harmonic signal

As a result of such transactions in sliding mode with increments Δt we obtain next: $Z_i = |x_i - x_{i-n}|$,

where modular operation takes into account changes in the symmetry of the amplitudes of the amperage in the direction of growth and decay in leaps at discharge load sources.

Schedule changes of Z_i during time when leap occurs shown in Fig. 11.

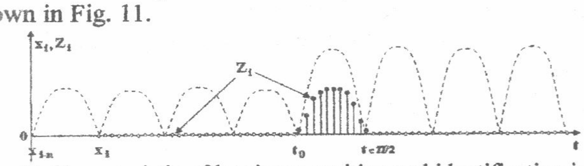


Fig. 11 Characteristic of leap's recognition and identification in the electrical network

Figure 11 shows that the response of the processor will have a change in amperage amplitude at the time of the jump: $A_1 \to A_2$; $A_1 << A_2$ at the half-period interval, but is invariant to possible other more or less amperage amplitude jumps in other moments, i.e.

$$Z_i = \begin{cases} 0, t \le t_0; \\ (A_2 - A_1)\sin \omega t, t_0 \le t \le t + \pi/2. \\ 0, t > t_0 + \pi/2. \end{cases}$$

Consider the problem of recognition and identification of short circuit in the electrical network.

Experimental researches and registration of disturbances in electrical networks using devices "Altra" and their variants show that in case of short circuits of different nature is observed approaching to the exponential attenuation and distortion of harmonic signal at several periods of the sine wave amperage at the time interval $t > t_0$. In this case, short circuit discrete model has the form shown in Fig. 12.

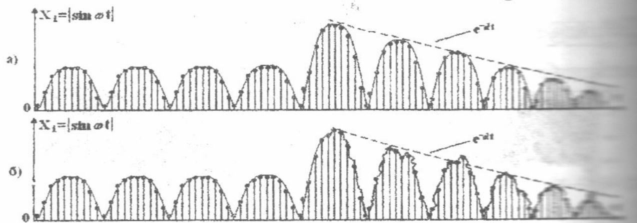


Fig. 12 Discrete models of short circuits in electrical networks with exponential decline of amperage (a) and simultaneous harmonic signal distortion (b)

In case of disturbance in the electrical network as a result of difference-pulse processing of harmonic signals at the time t_0 we get a graph shown in Figure 13 (model of Fig.12 (a)).

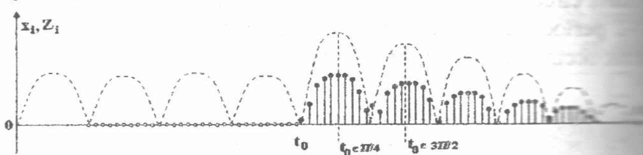


Fig. 13 Characteristic of recognition and identification of a short circuit in electrical network without distortion of harmonic signal

Thus on the basis of the proposed modular-difference method fact of disturbances in electrical network will be registered in the interval of time $t_0 + \pi/2$ or even at the interval $t_0 + \pi/4$.

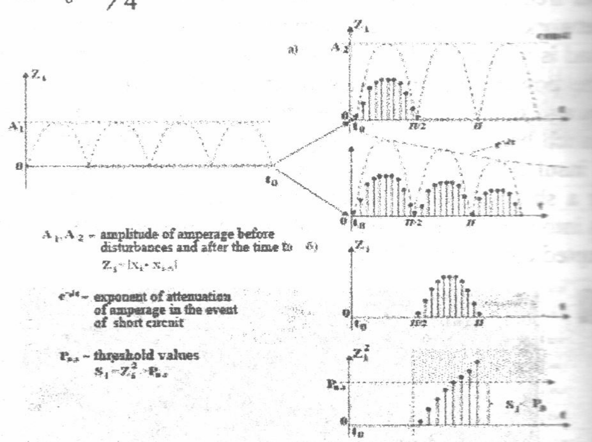


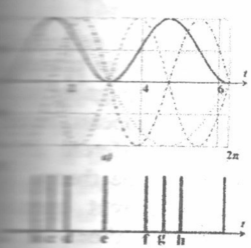
Fig. 14 Time production model of detection, recognition and identification of disturbances in electric networks like leap's type and short circuit

As it is shown in Fig. 14, in the event of a short circuit according to the developed method, it is possible to identify it at the time interval $t_0 + \pi/4 < t_0 + \pi/2 < t_0 + \pi$. That is in the range of a quarter or half a period after registration perturbation in electric network.

...ULSE SIGNAL'S CONVERSION

...mentally established that primary sensory neurons ... sensitive about harmonic signals $Asinx$ and $Asin^2x$ ... Therefore, the square-pulse harmonic signal ...sion, which ensures the formation of flow pulses ... to the specific points of the sampling step, became ... of the proposed method.

...ig. 15 shows the implementation of the proposed method ...-pulse harmonic signal threshold conversion.



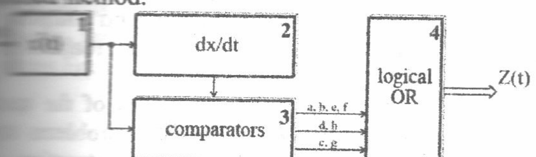
a,e – $x(t) = 0$;

b,d,f,h – $x(t) = \frac{dx(t)}{dt}$;

c,g – $x(t) = \max$.

...ig. 15 Implementation of method square-pulse harmonic signal threshold conversion

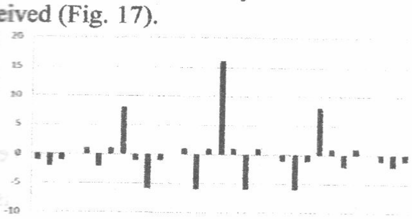
...ig. 16 shows the functional scheme that implements the ...posed method.



...ig. 16 Functional scheme of neural associative processor's ...ponent that implements a square-pulse transformation of harmonic signal in a pulse stream

...is functional scheme includes: 1 - module of elevation to ...quare of the input signal, 2 - differentiation module ,3 – ...dule of comparators, which form the outputs respectively ...al signals a,b,e,f,d,h,c,g, acting on logic element inputs ...4, the output of which is formed by pulsed flow Z(t).

...s a result of processing of pulse flow signal formed by ...essor with the structure of dynamic neuron signal pulse ...e is received (Fig. 17).



...ig. 17 Result of convolution code, which is formed by correlation neural processor

...aracteristics of this pulse flow approaching the ...aracteristics of noise signals, which are widely used in data ...ems based on the M- signal and Barker code and are ...aracterized by improved detection and recognition ...perties of modulated and manipulated signals. These ...perties can be effectively used for processing harmonic ...nals in high voltage power supply networks of oil and gas ...ustry and recognition of their damage in the event of short ...cuits and other transients.

...e convolution of signal code, shown in Fig. 17, obtained ...m the processing of harmonic signal by dynamic neuron ...ic model of neuron. As a result of research aimed at improving the performance of discrete square-pulse harmonic signal conversion by selecting the most appropriate weighting coefficients, the results are shown in Fig. 18 (a).

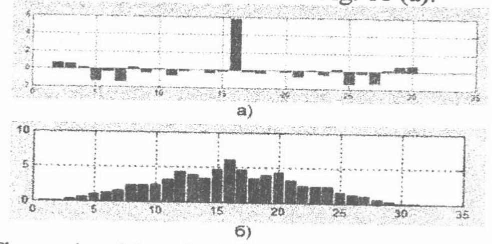


Fig. 18 The results of the selection of optimal weighting coefficients α_i (a) and convolution of signal received by a short circuit in high-voltage power network.

Fig. 18 (b) shows the convolution of signal as the result of a short circuit on the high-voltage power network received by correlation neural processor recognition harmonic signals based on the dynamic model of a neuron. It differs significantly from the standard convolution of harmonic signals, enabling identification of a short circuit.

V. CONCLUSION

Researches of disturbances in high-voltage networks like leap's type and short circuits revealed that recognition of distortion harmonic signals in power line algorithm must be implemented in real time in the interval 1-2 periods of industrial frequency, provided the two developed methods - integral differential-difference recognition and square-pulse harmonic signal conversion. The methods can effectively detect abnormal situations in high voltage electrical networks and can be widely applied in other cases of recognition of distortion of harmonic signals.

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