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INFORMATIONAL FUNCTION OF DISTURBANCES IN ELECTROMAGNETIC DEVICES

PH.D., D.SC., ENG. KONRAD SKOWRONEK, CSC.

Abstract: The publication considers significance of the disturbances occurring in technological/ electric systems. The classical approach to the theory of information transmission and its new meaning is presented. An attempt is made to determine the unaddressed information. An example of application of the consideration is shown.

Key words: information, technical systems, disturbances in electrical devices

1. INTRODUCTION

The typical methods of research (measurement) of electromagnetic processes in technical systems are a method of deterministic analysis. In most cases useful results are given. Application of more advanced optimization (i.e. reliability calculations) may lead to wrong results. The determination of the place of maximum value of current or voltage gradients makes it possible to realize such aspects of optimization like: durability, reliability, miniaturization and minimization of production and operation costs.

A new problem consists at present in assessment of possible application of the disturbances occurring in the electromagnetic devices to improving operational reliability and performance characteristics of these devices.

2. INFORMATION

Classic information theory was born by Claude E. Shannon. He analysed simple memoryless sources and channels. Information theory can be viewed as simply a branch of applied probability theory, only for transmission. Shannon defined the entropy of a discrete time random process $\{X\}$. The entropy of a process is the amount of information in the process. In real circumstances it is the notion of entropy formulated based on defining the transmission of the information entities.

In many cases observations are made on one process in order to make decisions on another process. The coordinate random processes X and Y might correspond, for example, to the input and output of a communication system.

Shannon introduced the notion of the average mutual information between the two processes:

$$I(X; Y) = H(X) + H(Y)/H(X; Y); \tag{1}$$

the sum of the two self entropies minus the entropy of the pair, and hence

$$I(X; Y) = H(X)/H(XjY) = H(Y)/H(X/Y). \tag{2}$$

Expression (2) describes amount of information on output Y, wich an input provides on it.

Entropy H(x) defined as:

$$H(X) = \int_{-\infty}^{+\infty} f(x) \log f(x) dx \tag{3}$$

where f(x) - probability density function of x(t).

On the other hand the entropy H(X,Y) is:

$$H(X, Y) = \int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} f(x, y) \log f(x, y) dx dy \tag{4}$$

where f(x,y) - probability density function of X(t) and Y(t)).

Ideas related to the information nature evolved in recent years generating the information basis [*sic*] allowing for assessing its amount.

Considerations on semiotics, cybernetics, and philosophy [6,7] appear particularly important. Almost every researcher creates own terms related to information and makes attempts to formulate relationships related thereto.

Nevertheless, until to-day a commonly adopted definition of information and its significance is still missing. Therefore, according to the author, temporary needs related to a definite technological task justify introduction of own denotations, indexes, and methods of their estimation.

In the technological tasks the following forms of information may be specified [5]:

- structural – attributive ones, and
- functional – cybernetic ones.

In the first case the information is related to constitution, structure, properties (inclusive of materials properties), arrangement, etc. In the other – the information embodies functionality, functional significance, a set of properties related to a definite arrangement of the technological system, etc.

For example, according to the opinion of Doede Nauta jr. [6], a cybernetist, solution of the problem of information definition consist in defining the cybernetic meaning of basic semiotic conceptions (a character and its definition, syntactic, semantics, and pragmatics). Thus, the formulation of a general definition of information may be avoided without affecting its possible estimation.

It should be emphasized that a scientist researching the electromagnetic phenomena proceeds in similar way – i.e. by formulating the energy indices at the lowest level of the consideration. One of these indices is represented e.g. by time density of the energy dissipated by a resistor, referred to as active power of the resistor. At the same time, a general definition of energy is missing, that might be noticed at least by reviewing encyclopedias.

The relationship between entropy in the above mentioned sense (3) and the thermodynamical entropy may be proved too. It means that besides the entire complex classification of various entropy conceptions the only important fact is that it defines the degree of the system disorder. Therefore, in the author's opinion, information as an absolute value cannot be defined, as is the case of the energy.

Therefore, only the indices related to its relative transfers may be formulated and probabilistic estimates of its occurrence in definite time and place may be determined. In this sense the Shannon theory provides proper foundations for researching the applications of the notion of entropy H(X) outside the domain of telecommunication.

3. DISTURBANCES AS AN INFORMATION SOURCE

Defining new conceptions and analyzing their possible application should begin from a proposal of distribution of the information in the technological systems, with consideration of unaddressed and unrecognized information (Fig. 1).

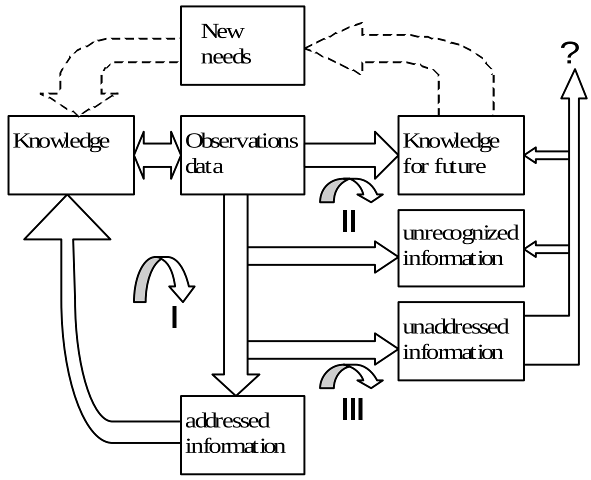

Fig. 1: Proposal of distribution of the information in the technological systems

These two information types enlarge amount of the knowledge that in the future may be adjoined to the knowledge only temporarily used. The cycle I in Fig. 1 presents an information circulation commonly known in the literature (Fig. 2 [9]). It includes, first of all, the temporarily used knowledge inclusive of its acquisition, knowledge activation, problem solving, creation of data files, formulation of their interpretation, their real alphanumeric representations and definition of the transmitted information, inclusive of its selection.

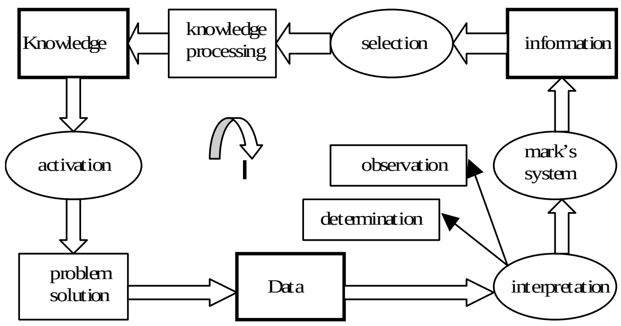

Fig. 2: *Information circulation* [9]

In the cycles II and III most of the above mentioned elements cannot be defined as in the engineer's practice the researcher assumes availability of knowledge of the structure or properties of the considered technological system. This may be, for example, a graph of an electric circuit, pulse answer, distribution of electromagnetic field, etc.

The disturbances generated by the technological system may be an important source of information. The noises and other disturbances of controlled properties are since a long time used in electrical engineering and, in particular, in electronics and telecommunication. Their role usually consists in additive excess of the activation threshold or in enabling division of the electromagnetic spectrum.

In the up to now engineer's practice the uncontrolled noise may be considered as an element belonging to the cycle II.

In case of immeasurable and unexpected disturbances the problem is quite different. There is no method allowing for adapting the control and control-measuring systems to the use of such an unaddressed information (in the cycle III).

The present thesis is the analysis of informational function of disturbances in electromagnetic devices.

We need the most general concept, the thing as a unit in perceptual and conceptual reality. We shouldn't, as often suggested, the concept of the sign as proposed by the semiotician Charles W. Morris [8]. This needs a new interpretation of the semiotic terms syntax, semantics and pragmatics. The good idea can be come from modern neurobiology. The structure of knowledge and the structure of perceived reality come no longer as a surprise.

For example, we can decise, in which form the disturbances in electromagnetic devices are usefull for identification of the parameters of real systems subject to internal (parametric) and external random excitation, as well as the analysis of output signals of the above mentioned systems (including, first of all, estimation of extreme characteristics of output random processes with regard to calculation of reliability factors of the system and its particular parts).

4. EXAMPLE OF INFORMATION REALIZATION

In order to carry out the calculation the input signal model have to be defined as a random process. Thus, input (and output) processes in technology can be most decomposed into two components: a deterministic one and a random one:

$$X_i(t) = m(t) + X(t) \tag{5}$$

where: m(t) - deterministic component (trend), X(t) - centralized random process.

In really conditions all usefully signals are m(t). We assume that the centralized random process X(t) give three forms of information: H_1, H_2, H_3.

The H_1 is the addressed part of full information X(t) (m(x) have not any information!), H_2 – unaddressed and H_3 – unrecognized.

H_1 can be determined as so as possible. With the formula (1) we can have the number of bits in Shannon's theory.

H_2 is not defined – in technology, first of all in electromagnetic devices, we use the security factors for currents, voltages, forces, etc. We should define that H_2 can be described with the formula:

$$H_2(X) = -B\sum_z f(z)\log f(z) \tag{6}$$

where B – the determined function for so far experience, B0 [0; 1], z –structural – attributive and/or functional – cybernetic causal relationship in moment t.

H_3 can be defined in future with (1) – in technology, first of all in electromagnetic devices, we use the interpolation, extrapolation and extraction for currents, voltages, forces, etc.

With H_2 the least information's medium (carrier) der Information is either Bit (as such the element from the least ensamble for selection) or a character (and its definition, syntactic, semantics, and pragmatics) as the least observation's unit. The information's medium is individual object as the construction of brain.

An additional advantage of the assumed linearity of the system is possibility of using probabilistic properties of stochastic processes X). These are unsteady processes of the type:

$$x(t) = A(t)y(t) \tag{7}$$

where: $A(t)$ - determined function, $y(t)$ – stationary realized random process

The determined function $A(t)$ can be have the part

$$B(t) = B = const \tag{7a}$$

Probabilistic parameters of the type (7) processes may be estimated on the ground of a single measurement, similarly as for ergodic processes.

Moreover, if $y(t)$ is a Gaussian process, $x(t)$ is also of the same character.

In the further part of the example analysis it will be assumed, that X(t) is stationary Gaussian process with the mean:

$$E(X) = 0 \tag{7b}$$

and variance

$$\operatorname{var} X(t) = \sigma_X^2 = const \tag{7c}$$

Autocorrelation function is expressed as:

$$K_x(\tau) = B^2 K^2 \sigma_x^2 e^{-\alpha|\tau|} \tag{8}$$

To determine an information $I(Y,X)$ the probability density functions have to be known. To do that only mean and variance are important for gaussian processes.

Thus, we have:

$$E(Y) = 0,$$
$$\operatorname{var} Y(t) = \sigma_Y^2 = \frac{B^2 K \sigma_x^2}{(K+\alpha)}, \tag{9}$$
$$K_{XY} = \frac{\sigma_x^2}{(BK+\alpha)}$$

Finally, we have:

$$I(Y,X) = \frac{1}{2}\ln F(B,K,\alpha), \tag{10}$$

5. CONCLUSIONS

The analysis of informational function of disturbances in electromagnetic devices is still worth studying, because of the growth of importance of random models and methods in present day. The significance of the presented analysis is, that it offers an analytical solutions to the statistical estimation of maximum expected values as well as probabilistic parameters of examining systems.

For example, at present, one could try forecasting, or even controlling reliability of this (or similar) equipment during long-lasting application of the equipment under many-years' operation in random conditions.

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Konrad Skowronek
Poznan University of Technology
Institute of Electrical Engineering and Electronics (IEEE)
Piotrowo 3a, 60-965 Poznan, Poland,
e-mail: konrad.skowronek@put.poznan.pl