Scientific Journals
Maritime University of Szczecin

Zeszyty Naukowe
Akademia Morska w Szczecinie

2012, 30(102) pp. 121–125

2012, 30(102) s. 121–125

Techniques of statistic research of power surges in marine power plants

Techniki badania statystycznego skoków napięcia w morskich siłowniach okrętowych

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Key words: marine power plants, fluctuation of power, statistical analysis

Abstract

A general characteristic of power fluctuation as the casual discrete phenomena in marine power plants have been considered. The approach to processing of the statistical information necessary for a substantiation of a technique of voltage failures' statistical research is offered. The software for the statistical analysis of processes power change and definition of a power station operating mode are developed.

Słowa kluczowe: morskie siłownie okrętowe (statkowe), fluktuacja mocy, analiza statystyczna

Abstrakt

Artykuł omawia ogólną charakterystykę wahań zasilania jako przypadkowych, dyskretnych zjawisk w morskich siłowniach okrętowych. Zaproponowano sposób przetwarzania informacji statystycznych niezbędnych do uzasadnienia techniki badania statystycznego awarii napięcia. Opracowano oprogramowanie do analizy statystycznej procesów zmiany zasilania i definicję trybu pracy siłowni.

Introduction

One of the indexes of electric energy quality is voltage failures which appear in numerous cases in autonomous electric power systems including ship's ones. The quantity of electric power influences technological processes greatly. Short-term failures and overvoltages in power supply systems often break the work of electric motors of different mechanisms, microprocessors equipment, automatized production operation systems, systems of telecommunications, and blocks of digital devices.

One of the reasons of voltage failures and overvoltages is change of autonomous power station loading, especially while powerful asynchronous motors starting. Voltage failures can be regarded as random process. Lately great attention is given to the rise of reliability and quality of electric energy in autonomous power stations [1, 2, 3]. However, problems of statistic analysis of the duration and quantity of voltage failures in autonomous electric power systems (AEPS) and the analysis results application in practical systems designing are still unresolved.

Thus, there exist an urgent task of perspective AEPS designing with protection against voltage breaks. The salvation of this scientific task leads to the necessity of probability statistic evaluation receipt of voltage breaks and overvoltages which occur in AEPS occasionally, and which are accepted as initial data for the measures elaboration concerning voltage breaks in perspective AEPS.

The aim of the article consists in the determination of the statistic characteristics of the processes of voltage changes on the basis of daily diagram of the electric power station work, and programme means development for the automatization of the process of electric power station work analysis in different modes.

Research material

The power station contains three synchronic generators, each with the power of 250 kW. Statistic research of the quantity of voltage breaks and overvoltages in AEPS includes:

1) detection of reasons which influence the occurrence of power surges and power breaks (and voltage breaks as a result) in running AEPS;
2) determination of the function of probability distribution $F(x)$;
3) determination of the law of distribution of voltage break probability;
4) determination of the characteristics of the random quantity of voltage break (of the expectation value and dispersion);
5) determination of the total duration of voltage breaks in a definite term.

The data stated above is necessary to elaborate means for the cut (exclusion) of the quantity of voltage breaks in AEPS; to synthesize AEPS structure with protection against voltage breaks what corresponds to the demands of structural system security and to the demands of regular electricity supply.

Every consumer of electrical energy is characterized by its own work diagram which in numerous cases is independent from other consumers' work regimes. The prognostication of consumers' loading work diagram is vital for the valuation of the type of power station loading change. The statistic analysis of the loading diagram is made on the example of the electroenergetic system of the trawler "Nakhodka".

The order of solution of the above stated interrelated problems on the basis of generally known statistic approaches is demonstrated in the figure 1.

Statistic investigation aims at the determination of the law of the distribution and characteristics of the overvoltages and power (voltage) breaks in a definite period of time.

There is a certain method of statistic data gathering which is used for the determination of the quantity of voltage breaks which correspond to the voltage switching on and off. This method is based on the processing of the observations of events leading to voltage breaks. Data gathered in such way are necessary for the determination of the empirical (statistical) distribution of the random quantity (breaks).

Discrete distribution is considered to be theoretically given in case when all possible values of x_i received by the random value, and probability $p(x_i)$ for every case $X = x_i$ on condition that:

$$\sum_i p(x_i) = 1$$

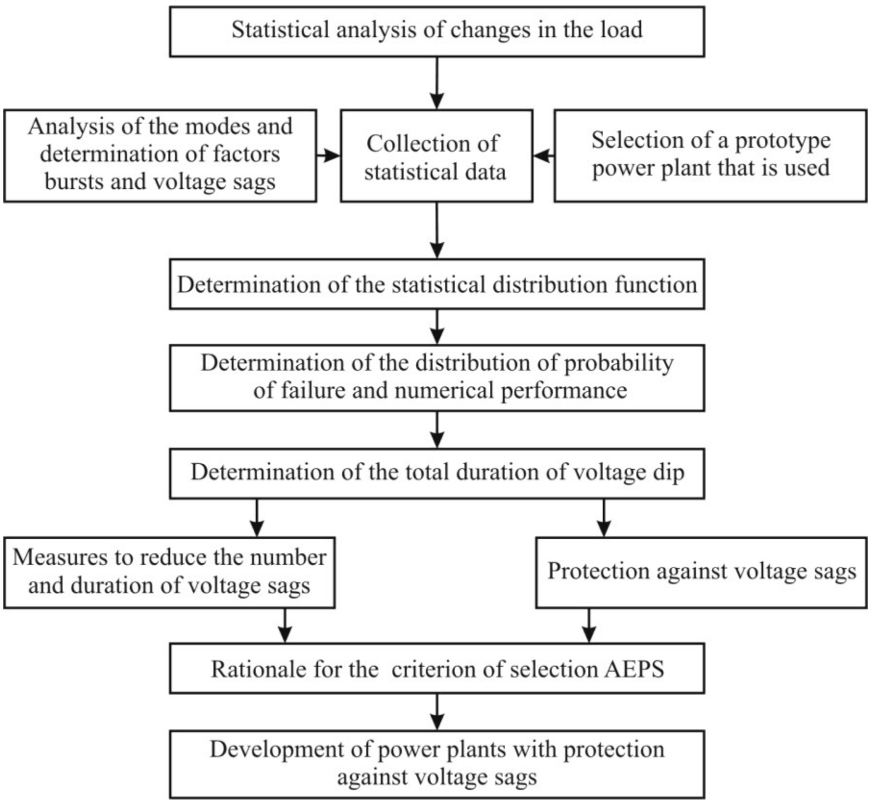

Fig. 1. General order of the research
Rys. 1. Algorytm badań

In case of small number of experiments approximate values of numerical characteristics of distribution may be found.

Alongside, the flattening of the statistic curve of distribution for its presentation with the help of analytical dependencies and its transformation into the form of theoretical distribution of random value is ensured by the previous choice of one of the distribution laws.

For the description of the discrete random values such law of distribution may be used:

a) binominal law of distribution:

$$P(x) = C_n^x p^x q^{m-x} = \frac{n!}{x!(n-x)!} p^x q^{n-x} \tag{1}$$

where:

C_n^x – quantity of combinations from n to x, $n = 0,1,2,\dots$ – integers;

b) Poisson law of distribution:

$$P_m = \frac{a^m}{m!} e^{-a} \tag{2}$$

where:

$m = 0,1,2,...$ – integers;

a – expectation of value X (voltage breaks).

Poisson law is limiting for the binominal distribution in case of bulk of experiments and low probability of events.

Knowing the distribution of breaks probabilities, it is necessary to determine expectation value of breaks:

$$M[X] = \sum_{i=1}^{n} (x_i - m_x) p_i \tag{3}$$

variance of breaks:

$$D[X] = \sum_{i=1}^{n} (x_i - m_x)^2 p_i \tag{4}$$

mean-square deviation of breaks:

$$\sigma[X] = \sqrt{D[X]} \tag{5}$$

For the random value distributed according the Poisson law dispersion is equal to its expectation value. For this reason $M[X]$ and $D[X]$ are to be determined from the experimental data. In case if their values are close, it is possible to make a conclusion in favour of the hypothesis of Poisson distribution.

Having obtained values $M[X]$ and $\sigma[X]$, it is possible to determine a statistical value of voltage breaks on the interval with duration T which is necessary for the determination of the voltage breaks' total duration:

$$Y = M[X] + k\sigma[X]$$

where: k – factor which is typical for the selected distribution (from 0.5 till 3). This value is needed further for the determination of the total voltage breaks duration.

For AEPS voltage breaks durations $\Delta t'_\text{b}$ depend on the protection means fast-acting, and also on the time of starting and receiving the loading by reserve supply sources $\Delta t''_\text{b}$, e.g. by reserve Diesel generator sets:

$$\Delta t'_\text{b} = t_\text{rp} + t_\text{mes} + t_\text{scb}$$

$$\Delta t''_\text{b} = t_\text{rp} + t_\text{mes} + t_\text{rs}$$

where:

t_rp – time of relay protection functioning;

t_mes – time of commutation set cutoff;

t_scb – time of the engaging of the section circuit breaker;

t_rs – time of the reserve supply source starting and its reception of the loading.

Total voltage breaks duration in AEPS can be presented in following expression:

$$\sum \Delta t_\text{b} = (M[X] + k\sigma[X])(\Delta t'_\text{b} + \Delta t''_\text{b})$$

Having such rated characteristics, it is possible to take measures concerning regular power supply by force of the increasing protection means fast-acting, application of reserve power supply sources, use of regular power supply sources or special devices protecting consumers against short-term power supply breaks.

Methods of statistical research of the power splashes in autonomous power stations include automatization of the processing of the results of power energy consumption observations. The later may be done by the force of the programme modules development for automatic output of diagrams and power station work parameters. The flow chart of the program algorithm is represented in the figure 2.

The program developed according to the algorithm stated above allows to determine times and values of maximum and minimum voltage; to calculate power mean value, mean square deviation, value of maximal power of loading, mean value of overvoltages and voltage breaks. Besides, there is a possibility to receive the above stated characteristics in a certain period of time. Power station work mode and percentage of generators loading is chosen according to power being consumed.

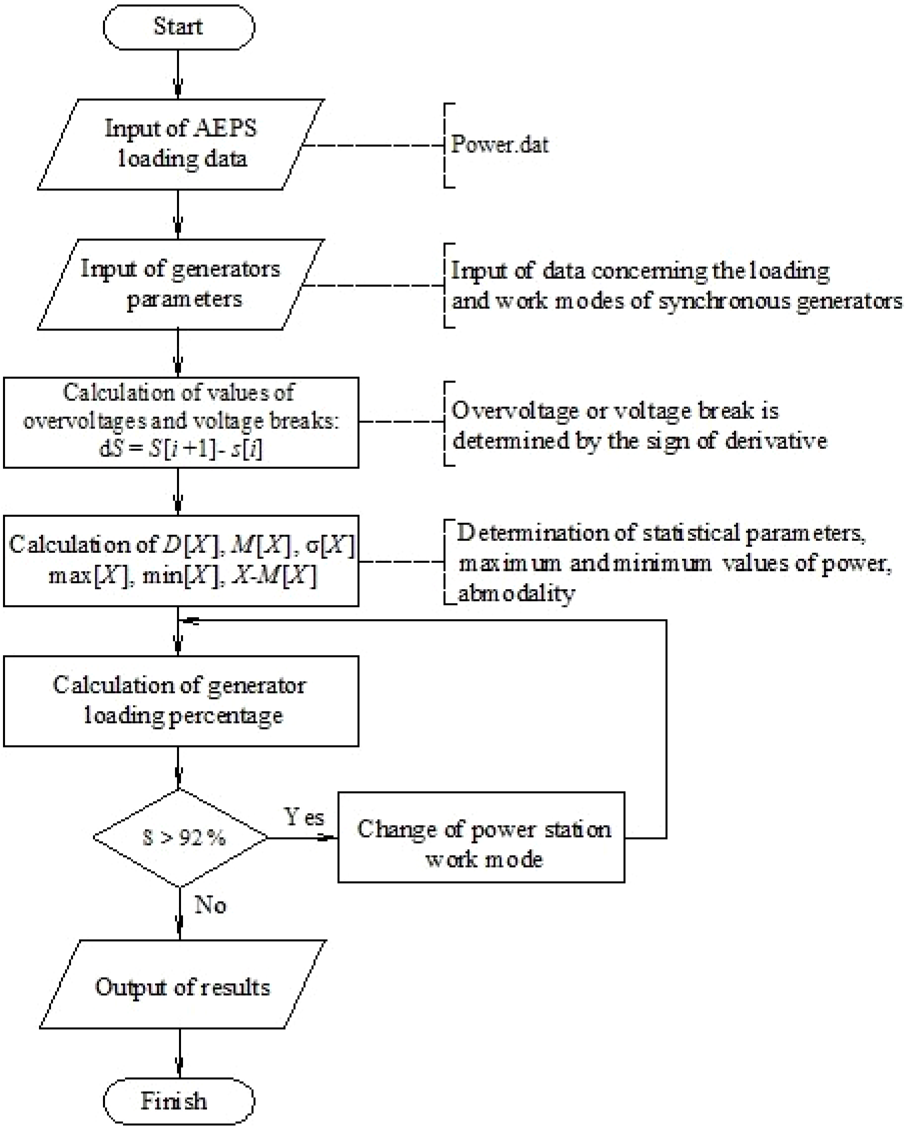

Fig. 2. Flow chart of the program algorithm
Rys. 2. Schemat blokowy algorytmu programowego

The value of the empirical function of distribution $F(x)$ and distribution of frequency of random value X of breaks are presented in table 1.

Table 1. Distribution of voltage breaks probabilities
Tabela 1. Rozkład prawdopodobieństwa spadków napięcia

Observation interval №	Average number of breaks in a certain period	Frequency (probability) of breaks	Cumulative empirical function $F(x)$
1	5	0.11	0.11
2	4	0.09	0.20
3	9	0.20	0.40
4	5	0.11	0.51
5	6	0.13	0.64
6	6	0.13	0.78
7	5	0.11	0.89
8	6	0.13	1.00
Total	46	1.00	–

For the development of protection means against voltage breaks (VB) and its results prevention VB prognosis for a definite AEPS is required. These prognoses can be made on the basis of available statistics or calculations for a definite system. For the registration of VB depth and duration, it is necessary to organize measurements by specialized devices which would give reliable prognoses.

According to the results of empirical function calculation (Table 1), it is possible to construct a diagram of its distribution (Fig. 3).

Substantial structure and configuration of an AEPS along with electrical equipment work mode are to be taken into consideration for the calculation of VB characteristics. A sample of the power station under research must represent the later in detail. It is necessary in order fulfilled calculations to not only give an opportunity to determine required voltage, current, power in units, but also to define this parameters' deviations from typical constant values.

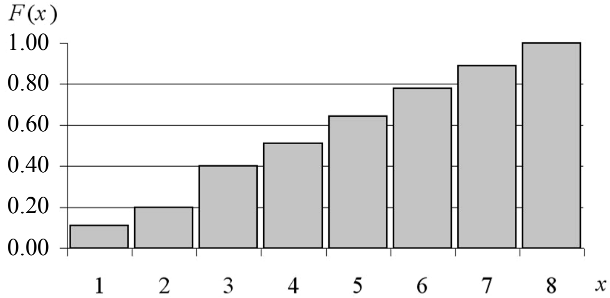

Fig. 3. Statistic function of the distribution of voltage breaks probabilities
Rys. 3. Funkcja statystyczna rozkładu prawdopodobieństwa spadków napięcia

Conclusions

There exists a scientific problem of the development of perspective general-purpose systems of power supply with protection against voltage breaks of random nature. The problem salvation is based upon probabilistic statistical analysis of the quantity of voltage breaks as a result of loading commutations which occur while AEPS running. Authors have achieved the results necessary for the grounding of the methodology of statistic research of voltage breaks considering mode peculiarities of electric power systems. The statistical analysis of voltage breaks considering regime peculiarities of the definite electric power system is a vital aid for the development of technical offers concerning the creation of AEPS with protection against voltage breaks, and for the choice of valuation criteria of the later.

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