The computational models of measurement parameters for electromechanical energy systems with the application of neurodiagnostics

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Abstract. In paper the influence of space weather on the functioning of electromechanical energy systems are considered. The analysis of geomagnetic activity indices is carried out. The impact analysis was carried out using the example of measurement information from Surgut State District Power Station-1 (Russia) and data on the AE index from the archive (Japan).

1. Introduction
In recent years space weather as a complex and not fully researched concept has been attracting increasing interest among scientists around the world in recent years. This interest is due to the continuous technological progress of mankind on the one hand and the increasing accidents at large industrial facilities, the causes of which may be factors caused by space weather, on the other. The main sources of space weather are associated with solar activity. The sources of cosmic weather are electromagnetic radiation from the Sun, energetic particles and solar plasma flows with a magnetic field which cause a variety of physical phenomena in different geospheres (magnetosphere, ionosphere, and Earth's atmosphere). [1]

The influence of space weather on modern technological systems is described in a large number of literature. Thus, the most frequently mentioned event illustrating the impact of space weather on the technosphere is the accident that occurred in March 1989 in the Canadian city of Quebec. Then during a geomagnetic storm, millions of people were left without electricity for 9 hours due to a break in the power grid. [2]

2. Geo-induced currents
One of the consequences of solar activity on the Earth's surface is the occurrence of geo-induced currents (GIC). GIC are induced in extended metal objects located in the ground, such as pipelines, railway rails, cables, etc. [3] in electric networks, GIC cause saturation of transformers, which leads to distortion and an increase in the excitation current. This, in turn, leads to undesirable relay trips, high reactive power consumption, voltage fluctuations, etc., which ultimately leads to a possible shutdown of the entire system or damage to the transformers. [4]

Geo-induced currents are formed during geomagnetic storms which are caused by a space weather parameter such as a solar wind. The solar wind forms charged particles emitted by the sun. It acts as a geomagnetic field creating a magnetosphere around the earth. The magnetosphere is a complex of plasma physics in connection with the ionosphere. During a storm in space weather the
magnetospheric-ionospheric system becomes severely disrupted, containing intense and rapidly changing flows. There is a so-called auroral zone (auroral electric jet) – an electric current in the area of the auroral oval directed to the west at night and in the morning to the east in the evening. And on the earth’s surface variable cosmic currents manifest themselves as perturbations or storms in the geomagnetic field. According to Faraday’s law of induction, a geo-electric field is induced on the Earth’s surface. This geo-electric field creates a GIC in ground-based technological networks. [4]

GIC monitoring is carried out in the electrical networks of many countries. The observed values of amps in the neutrals of power transformers in a year with an average geomagnetic activity reach 100 A or more and in years with high geomagnetic activity can exceed 200 A. [1] According to [5] the largest recorded value of the geo-induced current was 320 A in the transformer neutral (107 A per phase) in Sweden in April 2000.

In recent years research has been conducted to establish a correlation between variations of the geomagnetic field and the value of the GIC. The most powerful disturbances of the geomagnetic field which lead to the excitation of intense GIC in conducting structures occur in the auroral latitudes (the auroral zone). [6] The Auroral zone is a band of latitudes where the most powerful magnetic disturbances and the brightest auroras are registered. The Aurora zone in Russia and Northern Europe mostly passes over the Arctic ocean, without affecting the areas saturated with technology. Because of this, man-made disasters associated with magnetic storms have not been studied in Russia. [7] However, it has recently been found that dangerous GIC values can also be observed at mid- and low latitudes. [6]

3. Geomagnetic activity indexes
A numerical characteristic that reflects geomagnetic disturbances is the various geomagnetic indexes. Existing geomagnetic activity indexes can be divided into three groups. The first group includes local indexes calculated from the data of a single observatory and indicating the value of local geomagnetic disturbance over the territory: C-, K-indexes. The second group includes indexes that characterize geomagnetic activity throughout the Earth. These are the so-called planetary indexes: Kr, ar, Ar, am, Am, aa, Aa. The third group includes indexes that reflect the intensity of magnetic perturbation from a well-defined source: Dst, AE, and PC. Currently, the most common planetary indices are Kr, AE and Dst. From the point of view of GIT research, the AE index is of the greatest interest. This index characterizes the intensity of auroral currents, the so-called "auroral electric jets", which represent the most important part of magnetic disturbances in the planetary scale. The AE index is determined by a network of 12 magnetic observatories in the polar zone with a resolution of 1 minute. The leading organization for calculating the AE index is the World data center in Japan. [8-9]

4. The influence of geomagnetic index AE on the work of cyclic mechanisms on the example of Surgut state district power station-1
In this article the analysis of measurement information was performed to determine the relationship between the functioning of electromechanical systems and geomagnetic disturbances. As initial data we used the measurement information obtained using the phase-chronometric system at Surgut SDPS-1, and the data archive of the index values of the AE World data center in Japan.

It is necessary to make a convolution of the chronograms in order to be able to assess the degree of correlation of the rotation chronogram of the Surgut SDPS-1 turbine with the geomagnetic activity index. The convolution was performed using four parameters: arithmetic mean, median, standard deviation, and span. As a result of this work the following data table (see table 1) is obtained:
| №  | Mean     | Median   | Std  | R       | AE_Index |
|----|----------|----------|------|---------|----------|
| 1  | 2399992  | 2399988  | 457  | 3353    | 262      |
| 2  | 2399908  | 2399982  | 555  | 3224    | 200      |
| 3  | 2399737  | 2399815  | 681  | 4224    | 200      |
| 4  | 2400577  | 2400616  | 705  | 4417    | 50       |
| 5  | 2400179  | 2400176  | 633  | 3639    | 43       |
| 6  | 2400104  | 2400066  | 556  | 3760    | 44       |
| 7  | 2399954  | 2400010  | 563  | 4136    | 83       |
| 8  | 2399885  | 2399889  | 475  | 3599    | 33       |
| 9  | 2399501  | 2399536  | 604  | 4055    | 86       |
| 10 | 2400035  | 2400087  | 646  | 6627    | 76       |
| 11 | 2400338  | 2400333  | 545  | 3489    | 98       |
| 12 | 2400053  | 2400073  | 536  | 3798    | 147      |
| 13 | 2399607  | 2399627  | 620  | 4058    | 117      |
| 14 | 2400209  | 2400247  | 674  | 4006    | 109      |
| 15 | 2400254  | 2400129  | 837  | 4948    | 152      |
| 16 | 2400210  | 2400223  | 506  | 4142    | 351      |
| 17 | 2400240  | 2400243  | 576  | 6567    | 97       |
| 18 | 2400235  | 2400213  | 613  | 3745    | 135      |
| 19 | 2399877  | 2399994  | 714  | 4086    | 585      |
| 20 | 2399789  | 2399860  | 576  | 3517    | 680      |
| 21 | 2399981  | 2399967  | 561  | 3265    | 346      |
| 22 | 2400007  | 2399977  | 477  | 3466    | 332      |
| 23 | 2399980  | 2399994  | 484  | 3348    | 477      |
| 24 | 2400000  | 2400041  | 484  | 3052    | 740      |
| 25 | 2399950  | 2399955  | 516  | 3702    | 403      |
| 26 | 2400041  | 2399988  | 597  | 3660    | 70       |
| 27 | 2400079  | 2400078  | 441  | 3001    | 415      |
| 28 | 2400053  | 2400048  | 412  | 3108    | 92       |
| 29 | 2400039  | 2400000  | 430  | 2726    | 573      |
| 30 | 2399510  | 2399573  | 793  | 3969    | 352      |
| 31 | 2399874  | 2399876  | 553  | 3491    | 43       |
| 32 | 2400100  | 2400071  | 498  | 3404    | 217      |
| 33 | 2400045  | 2400091  | 720  | 4169    | 470      |
| 34 | 2400059  | 2400056  | 459  | 3239    | 356      |
| 35 | 2400066  | 2400096  | 547  | 3335    | 132      |
| 36 | 2399920  | 2399841  | 686  | 4770    | 53       |
| 37 | 2400162  | 2400157  | 577  | 3544    | 54       |
| 38 | 2400022  | 2400052  | 556  | 3355    | 43       |
| 39 | 2399937  | 2399928  | 400  | 3278    | 58       |
| 40 | 2400468  | 2400498  | 543  | 3538    | 193      |
Histograms of the distribution are constructed for each parameter in order to evaluate the law (figure 1 – 5). The knowledge of the distribution law is necessary for the correct selection of criteria for evaluating the degree of correlation.

From the obtained graphs it can be seen that only histograms for the arithmetic mean and median have a distribution close to normal. This means that the Pearson correlation will not work, since it requires a normal distribution for both values under consideration. [10] In this case rank correlation should be applied. In this article nonparametric Spearman and Kendall criteria are applied. [11] Let the significance level $\alpha = 0.05$ be set, then the hypothesis $H_0$ (the hypothesis of uncorrelated data) will be rejected if the calculation results $p < \alpha$. The calculation results are shown below:
The arithmetic mean:
Spearman correlation coefficient $\text{coef} = -0.139$;
Kendall correlation coefficient $\text{coef} = -0.091$;
Spearman data is uncorrelated $p = 0.394$;
Kendall data is uncorrelated $p = 0.408$.

Median:
Spearman correlation coefficient $\text{coef} = -0.102$;
Kendall correlation coefficient $\text{coef} = -0.072$;
Spearman data is uncorrelated $p = 0.530$;
Kendall data is uncorrelated $p = 0.514$.

Standard deviation:
Spearman correlation coefficient $\text{coef} = -0.177$;
Kendall correlation coefficient $\text{coef} = -0.140$;
Spearman data is uncorrelated $p = 0.273$;
Kendall data is uncorrelated $p = 0.204$.

Range:
Spearman correlation coefficient $\text{coef} = -0.272$;
Kendall correlation coefficient $\text{coef} = -0.188$;
Spearman data is uncorrelated $p = 0.089$;
Kendall data is uncorrelated $p = 0.089$.

At the significance level $\alpha = 0.05$ it can be argued that geomagnetic activity does not affect the operation of cyclic machines as can be seen in the example of Surgut SDPS-1. However, if you change the significance level of $\alpha$ to 0.1, it can be argued that there is a weak negative correlation with the span parameter $R$, i.e., when the AE index decreases the span of the chronogram increases and, conversely, when the AE index increases the span of the chronogram decreases.

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