METHOD OF INTENSITY ASSESSMENT OF POWER LINES SWINGING

Bekbayev A., Dzhamanbayev M., Akpanbetov D., Karbozova A..
Kazakh National Technical Research University named after K.I Satpayev, the Republic of Kazakhstan

bekbaev_a@mail.ru

Abstract: *On the basis of long-term statistics data of wires swinging accumulated by energy systems of Kazakhstan the swinging intensity linear regressional dependence has been elucidated as a function of wind speed and its direction to the power line, as well as the length of a span and the number of half-waves in the span. Lower and upper limits of regression equations parameters has been estimated.*

Keywords: WIRE SWINGING, REGRESSIONAL DEPENDENCE, SWINGING INTENSITY

In the development of countermeasures for wires swinging and in the design of power lines it is necessary to take into account information about the possible intensity (range) of wires oscillations, depending on the wind speed and the characteristics of power lines. This information can be obtained from the accumulated by energy systems long-term statistical observations of wire swinging during the operation of power lines.

As shows the analysis of statistical data on the wires swinging, which took place in energy systems of West - Kazakhstan region, wires are exposed to swinging regardless of voltage classes, type of lines, effective span and the magnitude of mechanical stresses in wire. Moreover, wires oscillations appear with different number of half-waves in the span [1].

The article is devoted to the establishment of the empirical wind speed, angle of wind flow attack to the lines, span and number of half-wave dependences of swinging intensity. Selected materials cover one half-wave (18 cases), two half-wave (15 cases) and three half-wave (5 cases) swinging. The total number of observations is n = 38. According to the sample material, the minimum span length is 90 m. and the maximum is 367 m..

To establish an empirical dependence, the following variables were introduced:

$$A_P = \begin{pmatrix} A_{P1} \\ \cdot \\ \cdot \\ A_{P38} \end{pmatrix} \qquad X = \begin{pmatrix} 1 & x_1 \\ \cdot & \cdot \\ \cdot & \cdot \\ 1 & x_{38} \end{pmatrix}$$

where A_p - observation vector, dimension (38 × 1), $X = \tilde{\lambda} V_\perp$ - matrix of independent variables, dimension (38 × 2), $\tilde{\lambda} = \frac{\ell}{m}$; (ℓ – span length), x_i – constituting the independent variables X.

Notably, A_p – determines the intensity of swinging, $V_\perp$ – vertical component of the wind speed, $\tilde{\lambda}$ – the length of the half-waves, m – number of half-waves in the span.

b - vector of parameters which are to be evaluated, dimension (2 × 1):

$$b = \begin{pmatrix} b_0 \\ b_1 \end{pmatrix}$$

E - vector of errors (residuals), dimension (38 × 1):

$$E = \begin{pmatrix} e_1 \\ \cdot \\ \cdot \\ e_{38} \end{pmatrix}$$

Model equations represented in matrix form

$$A_p = Xb + E \tag{1}$$

By the least squares method (LSM - method) for evaluation b [2].

$$b = \begin{bmatrix} b_0 \\ b_1 \end{bmatrix} = \left(X^T X \right)^{-1} X^T A_p \tag{2}$$

where "T" - symbol of transposition.

As a result of calculations based on accumulated statistical data we obtain a linear regression model of the first order.

$$A_p = b_0 + b_1 \tilde{\lambda} V_\perp = b_0 + b_1 \frac{\ell}{m} V Sin\alpha \tag{3}$$

where $b_0 = 1{,}785$; $b_1 = 0{,}0011$ - parameters of equation.

Adequacy assessing of regression model is made by F - Fisher criterion. Estimated (actual) value of F according to [3].

$$F_{act} = \frac{\sum_1^n (A^{\mathrm{T}}_{pi} - \overline{A}_p)^2}{s^2} \tag{4}$$

$$s = \sqrt{\frac{\sum_1^n (A_{pi} - A^{\mathrm{T}}_{pi})^2}{n-2}} \; ;$$

$$\overline{A}_p = \frac{1}{n} \sum_1^n A_{pi} ;$$

where A_p - observed value, A^T - theoretical (predicted) value, S - assessment of dispersion adequacy.

Comparison results of actual value $F_{act} = 46.78$ and table $F_{table} = 4.12$ $(F_{act} > F_{table})$ shows the reliability of regression equations. Tabulated values are defined for significance level 0.05 and degree of freedom $n - r = 36$, where r - number of coefficients of the regression equation.

Valuation of b_i coefficients is made by Student's t-test [3].

$$t_{b_0} = \frac{b_0\sqrt{n}}{s}\sqrt{\frac{\sum_1^n (x_i - \bar{x})^2}{\sum_1^n x_i^2}};$$

$$t_{b_1} = \frac{b_1\sqrt{\sum_1^n (x_i - \bar{x})^2}}{s}; \tag{5}$$

where $\bar{x} = \frac{1}{n}\sum_1^n x_i$ (x_i − independent variables).

Calculated values of t-statistics:

Tabular value of tα – criteria, which was calculated for the significance level $\alpha = 0{,}05$ and the number of degrees of freedom 36, equals to $t_\alpha = 2{,}03$. Seeing that $t_{b_0} > t_\alpha$ and $t_{b_1} > t_\alpha$, corresponding coefficients of the regression equation is considered significant.

For confidence interval calculation the marginal error for each indicator is to be defined [3].

$$\Delta b_0 = \frac{t_\alpha s}{\sqrt{n}}\sqrt{\frac{\sum_1^n x_i^2}{\sum_1^n (x_i - \bar{x})^2}};$$

$$\Delta b_1 = t_\alpha \frac{s}{\sqrt{\sum_1^n (x_i - \bar{x})^2}}; \tag{6}$$

The lower and upper limits of regression equations parameters

$$b_0 - \Delta b_0 \le b_0 \le b_0 + \Delta b_0;$$
$$b_1 - \Delta b_1 \le b_1 \le b_1 + \Delta b_1;$$

In view of numerical values $\Delta b_0 = 0{,}5$ and $\Delta b_1 = 0{,}00033$

$$1{,}285 \le b_0 \le 2{,}285; \tag{7}$$
$$0{,}00077 \le b \le 0{,}00143;$$

Analysis of these predictable swinging intensity boundaries shows that the intensity of swinging increases with the length of span, wind flow speed and the number of half-waves in the span.

The regression model (3) will be used in research of power lines swinging phenomena and in the development of methods and means of protection against swinging.

References

1 Murat A. DJAMANBAYEV, (Kazakh National Techn. University – Almaty, Kazakhstan), Alexander A. VINOGRADOV (JSC "Elektrosetjstroyproekt" - Moscow, Russia) OBSERVATIONS OF GALLOPING IN THE NORTHERN PART OF KAZAKHSTAN. – Seventh International Symposium on CABLE DYNAMICS, Vienna (Austria), December 10-13, 2007

2 Dreyper N., Smit G. Prikladnoy regressionnyiy analiz /perevod s angliyskogo/.- M.: «Statistika», 1973. Str. 393

3 Eliseeva I.I., Kuryisheva S.V. i.dr. Praktikum po ekonometrike /uchebnoe posobie/.- M.: «Finansyi i Statistika», 2001. 192 str.