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RELIABILITY EVALUATION AND FAILURE CHARACTERISTICS OF ELECTRIC POWER UTILITY

خصائص حساب قابلية الأداء والانهيار لاستعمالات القوى الكهربية

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الخلاصة – يقدم البحث تحليلا لحساب قابلية الأداء لكميات نظم القوى الكهربية ويشمل وصفا لتحليل أداء النظم . كما يقدم البحث مقارنة بين قابلية الاداء للدوائر الأحادية الوجه والثنائية الوجه مع التعادل الأرضي لمحولات القوى عند شروط مختلفة ، ومقارنة لقابلية الأداء بين ثلاث موصلات لخطوط النقل الهوائية ذات الوجه الواحد وطريقة موصلان – الأرض عند الشروط المختلفه . وتم التوصل الى أن خطوط النقل الهوائية ذات الوجه الواحد تعطي نوعية جديدة للدوائر المختلفة ويمكن استعمالها لكل متطلبات منابع القوى الكهربية – كما أن المعامل الاضطراري البسيط أقل بحوالي من ٣ر١ حتى ٤ مرات للخطوط ذات الدائرتان . ويبين البحث أيضا أن طول الخط يزيد زيادة مباشرة وسريعة مع المعامل الاضطراري البسيط لخط ذو ثلاث موصلات عن نظام موصلان – الأرض .

ABSTRACT- Reliability evaluation fundamentals are necessary for a quantitative reliability evaluation in electric power systems. This paper includes a description of the procedure for system reliability analysis. An important aspect of power system design involves consideration of the service reliability requirements of loads, which are to be supplied and the service reliability, which will be provided by any proposed system.

A knowledge of the reliability of electrical equipment has an important consideration in the design of power system for industrial plants. Ideally, these reliability data should come from a field used of the same type of equipment under similar enviromental conditions and similar stress levels.

In this paper, a comparison between the single-circuit and double circuit reliability working with earthed neutral of power transformer at some variables conditions is given. Also, a reliability comparison between three-conductors of single circuit for overhead transmission line and two-conductors-earth method at various conditions, is introduced. A computer program flow chart is given. Results of calculations are illustrated in curves as well as arranged in tables.

INTRODUCTION- The elementary reserve separation of transmission line (as transformers, single circuit, double circuits and protective devices) and its relation with the reliability will involve heavy capital economic and may worse energy losses of the network [1].

It is well known that, about 85-95% of short circuits on transmission lines are single-phase to ground. Consequently, in order to keep symmetrical voltage of load bus and full transmitted power of three-phase system, the need has arisen to balance the energy transmitted by several techniques [2,7].

One common solution for such problems has been carried out by using the parallel circuits [8].

Accordingly, it is necessary to make a comparison between the technical economics for single-circuit of transmission line and its corresponding double-circuit. The reliability calculation of the transmission line is necessary for estimating the economic damage, which causes source interruption or worsening the quality of electric energy at consumers.

This paper presents, the statistical methods required to investigate the reliability of power supply with single and double circuits. These methods proceed from considering the interval time of flowing limit, and the transmission lines either under operation or under repair [3,4]. The outlays time replacement T_r for damage element with the performance of average restoration as well as the simple forced coefficient after fault is given by:

$$K_f = W \; T_r \qquad \ldots (1)$$

The expected value of economic damage is determined by the following merger equation [4]:-

$$Y = Y_f + Y_p = K_f \cdot \mathcal{E} \cdot \alpha \cdot P_{max} + K_p \cdot \mathcal{E} \cdot B \cdot P_{max}$$
$$= P_{max} \cdot \mathcal{E} \cdot (\alpha K_f + B \; K_p) \; ; \qquad \ldots (2)$$

and the probability of no-failure operation (P_{mo}) is defined by the following equation:

$$P_{mo} = e^{-W} \qquad \ldots (3)$$

1- Comparison between single and double-circuit reliability

Circuits considered in the present study are earthed, comparison includes two varients of electric power substation. The first one is linked in the end of electric power substation with two parallel circuits, and the second has one circuit line as shown in Fig. (1).

1.1 First Varient: Double - circuit lines.

This varient will follow the following cases:

a- Simultaneously failure of two circuits, which can occur after the short

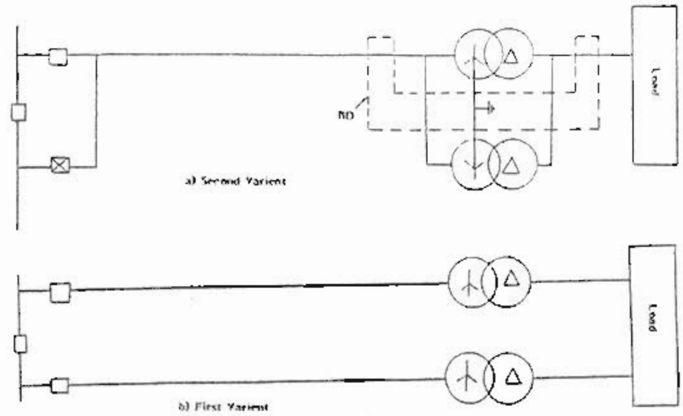


Fig. 1 Electric power circuit of : a) Second Varient : Single Circuit Line;
b) first varient : double-circuit line.

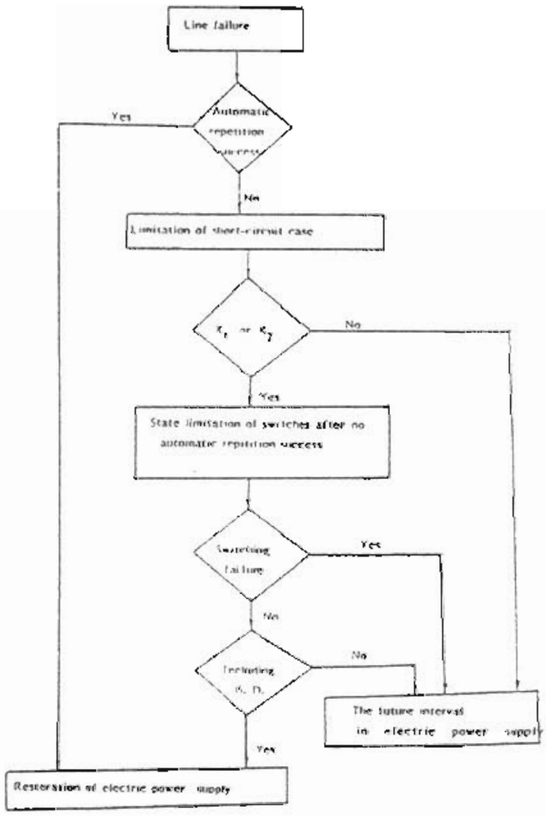


Fig. 2 The block diagram of electric transmission lines.

circuit of one circuit to the other and V. V. , also at falling the support and other accidents. The simple forced coefficient in this is:

$$K_f = W_{\ell} \cdot T_{re} \qquad \ldots (4)$$

b- Superposition failure of one circuit during maintenance plan of the second circuit, it is necessary to determine the simple forced coefficient of first circuit (K_{f21}), existing during the work, and simple plant coefficient (K_{p22}) of second circuit, existing during the maintenance. The simple forced coefficient of first circuit for double-circuit lines (K_{f21}) is determined from the following failures:-

1- Failure of the first circuit (in transmission line), in this case the simple forced coefficient (K_{f21}) will be determined from the following expression:

$$K_{f21} = W_{21} \cdot T_{r21} \qquad \ldots (5)$$

2- Failure of the switches during instability, and also stable of the short-circuit in lines. The failure flow for this case (W_{s21}) is determined by formula:-

$$W_{s21} = K\, W_{21} \cdot W_s + W_{21}\, W_s \qquad \ldots (6)$$

The restoration time of electric power in the case of short circuit instability will determine the active time of switching (T_{sr}), and in the case of short circuit instability will determine the active time of switching (T_{sr}), and in the case of short circuit instability-maintenance time of lines, i.e.

$$K''_{f21} = K\, W_{21}\, W_s\, T_{sr} + W_{21}\, W_s\, T_{r21} \qquad \ldots (7)$$

In comparison of the varients of electric power, it is not neccessary to take into account the simultaneous failure of two transformers, and also the superposition failure of other circuit elements in the maintenance plan of transformers. From the previous, the summation of failure flow (W_{s21}) and simple forced coefficient of first circuit (K_{f21}) will be :

$$w'_{s21} = w_{21} + w_{s21} = w_{21}\,(1 + w_s + k\, w_s) \qquad \ldots (8)$$

$$K'_{F21} = K_{F21} + K''_{F21} = w_{21}\, T_{r21}\,(1 + w_s) + K w_{21}\, w_s\, T_{sr} \qquad \ldots (9)$$

Then, it is necessary to determine the simple plan coefficient of first circuit k_{p22}, in quality which is more specific, from the simple plan coefficient of switches or lines. For circuits of 110 KV and 220 KV agreement, in quality of it 's simple plan coefficient of switches (K_{ps2}), i.e.

$$K_{p22} = K_{ps2} \quad \ldots (10)$$

The failure flow of the first transmission circuit in the suitable time of maintenance plan for second circuit is equal to:

$$W_{p12} = K_{p22} \cdot W'_{s21} \quad \ldots (11)$$

Taking into account that reduction time of electric power during high instruction of failure is more lower than the simple plant coefficient of first-circuit. The simple forced coefficient of first-circuit in the time of maintenance plan of the second-circuit (K_{flps}) is determined by the following expression:-

$$K_{f1p2} = W_{21} \cdot T_{f21} (1 + W_s) \cdot (K_{p22} - 0.5\, T_{f21}) + K\, W_{21}\, W_s \times (K_{p22} - 0.5\, T_{sr})\, T_{sr} \quad \ldots (12)$$

Following that, parameter of failure flow (W_{fp2}) and summation of the simple forced coefficient in the suitable time of the maintenance plan (K_{fp2}) on the whole are equal to:-

$$W_{fp2} = 2\, K_{p22}\, W_{21} (1 + W_s + K\, W_s) \; ; \quad \ldots (13)$$

$$K_{fp2} = 2\, K_{f1p2} \quad \ldots (14)$$

From the part of simultaneous failure of two circuit (part a) and eq ns (12 - 14) received the following equations for calculation of failure flow parameters ($W_{2\Sigma}$) and simple forced coefficient ($K_{f2\Sigma}$) for the electric power with two circuits of transmission lines:

$$W_{2\Sigma} = W_{\ell} + 2\, K_{p22}\, W_{21} (1 + W_s + K\, W_s) \; ; \quad \ldots (15)$$

$$K_{f2\Sigma} = W_{\ell} \cdot T_{re} + 2\, W_{21}\, T_{f21} (1 + W_s) \cdot (K_{p22} - 0.5\, T_{f21}) + 2\, K\, W_{21}\, W_s\, T_{sr} (K_{p22} - 0.5\, T_{sr}) \quad \ldots (16)$$

The analysis show that, the simple forced coefficient in the maintenance plan time (K_{fp2}) is small compared with the simple forced coefficient that arises from failure of two-circuits (K_f), and in the following take into account (K_{fp2} = 1-2% from K_f), i.e.

$$K_{f2\Sigma} = K_f + K_{f2\Sigma} \approx K_f = W_{\ell} \cdot T_{re} \qquad \ldots (17)$$

By receiving the values of $W_{2\Sigma}$ and K_f besides using Eqns (1) , (3) and (2), it is possible to calculate the average time reduction ($T_{re\Sigma}$), the probability of no-failure activity operation (P_{mo}) and the expectation value of economic damage from the interval in electric power (Υ).

1.2- Second varient: Single-Circuit of transmission lines

Figure (2) illustrates the block circuit state of the electric transmission line, where the interval forced in electric power have values in the following cases:-

a- During three-phase and double-phase to ground short-circuits

The failure flow parameter (W_s) and the simple forced coefficient (K_{fs}) in this case can be determined by the following expression

$$W_s = W_{\ell 1} \cdot K_s \; ; \qquad \ldots (18)$$

$$K_{fs} = W_{\ell 1} \cdot K_s \cdot T_{rel} \qquad \ldots (19)$$

b- During the failure of the suitches at power-substation for single-phase (K_1) and double-phase without ground (K_2) short-circuits. The failure flow ($W_{s\ell}$) and the simple forced coefficient ($K_{f\ell}$) in this case can be determined by the following expression [5]:-

$$W_{s\ell} = W_{\ell 1} \cdot W_s (1 - K_s) \; ; \qquad \ldots (20)$$

$$K_{f\ell} = W_{\ell 1} \; W_s \cdot T_{sr} (1 - W_s) \qquad \ldots (21)$$

C- During the failure of the balancing-device for the single-phase to ground fault $K^{`}$ and double-phase without ground short circuit [2]. In this case the failure flow (W_{BD}) and the simple forced coefficient (K_{fBD}) are limited by the formula:

$$W_{BD} = W_{\ell 1} (1 - K_s)(1 - K_{BD}) \; ; \qquad \ldots (22)$$

$$K_{fBD} = W_{\ell 1} (1 - K_{BD})(1 - K_{fBD}) \quad T_{sr} \qquad \ldots (23)$$

Recording that, in the absence of balancing device reliability, while the availability coefficient of the balancing device is assumed equal to 0.9

d- During the superposition failure to the phase-maintenance plan of the circuits. Firstly, determine the simple forced coefficient of electric transmission lines, which work in the unsymmetrical system. Interruption in the electric power for this transmission will be take place in the following cases:-

1- During the damage working in the phase. Intially, from this consideration, that the damage of stability, which call interval in the electric power to consecutive time of maintenance line, and unstable to the time $T^{\vee}$. Consequently, the simple forced coefficient of this case ($K_f^{`}$) is determined by the following expression

$$K_f^{`} = \frac{2}{3} W_{\ell 1} (T_{re1} + K T^{`}) \quad ; \qquad \ldots (24)$$

and the failure flow of this case ($W_1^{`}$) is equal to

$$W_1^{`} = \frac{2}{3} (W_{\ell 1} + K W_{\ell 1}) \qquad \ldots (25)$$

In equations (24) and (25) the multiplier 2/3 takes into account, that only two from three lines is considered in the work.

2- During failure in the same balancing device, in spite of absence of the reliability of balancing device (W_{BD}) is accepted as 0.05, which acts as condensers). The average reduction time of this device is proved to be important and interval practice of electric power after the maintenance plan of one-phase of electric transmission line. In this case the simple forced coefficient (K_{fBD}) possible limited by the expression:

$$K_{fBD} = W_{BD} \cdot K_{P\phi 1} \qquad \ldots (26)$$

It is necessary to calculate the maintenance plan coefficient of electric transmission lines, which requires essential large time compared with planning of the all three-phase simultaneously. This time at the maintenance plan of the all three-phase single-circuit of electric transmission lines is large compared with the maintenance of single-phase, i.e. $K_{pc1} > K_{p\phi 1}$ [6].

Since the normal data of the simple plan coefficients of single-phase for the electric transmission elements be absent, that in working data taking:-

$$(K_{p\phi 1})_i = (K_{pc1})_i \qquad \ldots (27)$$

At this assumption, as in the first varient of electric power for circuits of 110 and 220 KV in quality, which takes the simple plan coefficient:

$$K_{Pl\phi c} = K_{Psl} \qquad \ldots (28)$$

Follows the underline, that the simple plan coefficient of simple and double-circuit switches of electric transmission lines may be different. This stipulation, that in double-circuit varient possible use three-phase switches (oiling), in this time as in single circuit varient used switches with phasing control.

By no means, failure flow parameter ($W'_{lpl\phi}$) and the simple forced coefficient of electric transmission lines ($K'_{fl\phi}$) in the unsymmetrical system, in the time of maintainance plan of single-phase will be limit by the expression.

$$W'_{lpl\phi} = K_{pl\phi c}\left[\frac{2}{3}\left(W_{\ell l} + K\,W_{\ell l}\right) + W_{BD}\right], \qquad \ldots (29)$$

$$K'_{fl\phi} = \frac{2}{3} \cdot W_{\ell l}\, T_{relc} \cdot \left(K_{pl\phi c} - 0.5\,T_{relc}\right) + \frac{2}{3}\, W_{\ell l} \cdot T' \cdot \left(K_{pl\phi c} - 0.5\,T'\right) + 0.5\,K_{pl} \cdot K_{FBD} \qquad \ldots (30)$$

Summation of the failure flow (W_{flc}) and the simple forced coefficient (K_{flc}) in time of the maintenance plan of electric transmission lines which will be equal to:

$$W_{flc} = 3\,W'_{lpl\phi}\ ; \qquad \ldots (31)$$

$$K_{flc} = 3\,K'_{fl\phi} \qquad \ldots (32)$$

Consequently, the failure flow parameter ($W_{\Sigma lc}$) and the simple forced coefficient is limited by the expressions:-

$$W_{\Sigma lc} = W_s + W_{s\ell} + W_{BD} + W_{flc}\ ; \qquad \ldots (33)$$

$$K_{\Sigma lc} = K_{fs} + K_{l\ell} + K_{fBD} + K_{\Sigma lc} \qquad \ldots (34)$$

With calculation E_{qns} (18-23) and (29-32) the equatins take the form

$$W_{\Sigma lc} = W_{\ell l}\left[K_s + W_s(1 - W_s) + (1 - W_s) \cdot (1 - K_{BD}) + K_{FBD}\left[2\,W_{\ell l}(K + 1) + 3\,W_{BD}\right]\right. ; \qquad \ldots (35)$$

$$K_{\Sigma lC} = w_{\ell l} [T_{relc} K_s + T_{sr} w_s (1 - k_s) + T_{sr} (1 - k_s) \times (1 - K_{BD})] + 2w_{\ell l}$$

$$[T_{relc} \cdot (K_{pl\phi c} - 0.5 T_{relc}) + KT^{1}. (K_{pl\phi c} - 0.5 T^{1}) + 1.5 W_{BD} K^2_{pl\phi c}] \quad \ldots (36)$$

By receiving the results of $W_{\Sigma lc}$, $k_{\Sigma lc}$ and using Eq ns (1), (3) and (2), it is possible to get average reduction time ($T_{re\Sigma}$), the probability of nofailure operation of electric transmission lines (P_{mo}) and the expectation value of economic damage (Y_{lc}) from the interval in electric power.

The reliabilities estimation of electric power systems along double-circuits (varient I) and single-circuit (varient II) of lines use the static data [6], in which result in the reliability of electric transmission line elements.

The results of 220 kv circuits are as follow:

Varient 1:

$$w_{2\Sigma} = w_{\ell} + 0.064\ w_{21}, \quad \ldots (37)$$

$$k_{F2\Sigma} = W_{\ell} \cdot T_{re} \quad \ldots (38)$$

Varient 2 :

$$W_{\Sigma lc} = W_{\ell l} \cdot (0.75 K_s + 0.41) + 3 \times 10^{3}; \quad \ldots (39)$$

$$K_{\Sigma lc} = W_{\ell l} \cdot T_{relc} \cdot [(0.9375 K_s + 0.1265) - 1.03 T_{relc}] + 3 \times 10^{5} \quad \ldots (40)$$

Also, for 110 KV circuits , received :

Varient 1:

$$W_{2\Sigma} = W_{\ell} + 0.0\ 28\ W_{21}; \quad \ldots (41)$$

$$K_{F2\Sigma} = W_{\ell} \cdot T_{re} \quad \ldots (42)$$

Varient 2 :

$$W_{\Sigma lc} = W_{\ell l} \cdot (0.8 K_s + 0.28) + 1.5 \times 10^{-3}; \quad \ldots (43)$$

$$K_{\Sigma lc} = W_{\ell l}\, T_{relc} \left[(0.95\, K_s + 0.082) - 1.03\, T_{relc} \right] + 0.75 \times 10^{-5} \qquad \ldots (44)$$

Equation (36) - (41) allow to produce the comparison analysis of reliability varients for the circuits of 220 and 110 KV. Taking into account, that for stable single-phases to ground and double-phases without earthing short-circuit from all stability damage lines, which compose from 75 to 95% for single-circuit calculations to produce at K_s and the values 0.05, 0.15 and 0.25.

The results of calculations illustrate, that the parameter of failure flow for first varient (double-circuit) at 1.5-3 times lower, than for the second varient (Figs. 3.a and 3.b). It follows that the reliability is higher than that firt varient by 1.1-16 times and composes 0.8-95 (Figs. 4.a and 4.b). But the simple forced coefficient for second varient composes only 25-75% from the simple forced coefficient of double-circuit line (Figs. 5.a and 5.b). Therefore, as the middle time composing for second varient at 4-6 times is lower than for first varient.

Also, at decreasing the failure flow of lines, switches and protection relayes at equal conditions of the second varient advantage (single-circuit line) increase, and it's failure flow decreasing to large value, than for second varient in that time, as the relation of the simple forced coefficient is small.

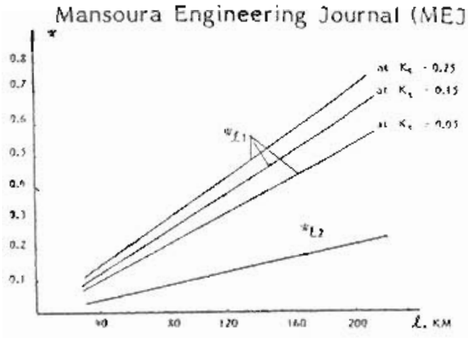
The failure flow parameter ($W_{\Sigma lc}$) and simple forced coefficient for electric transmission line ($K_{\Sigma lc}$) for the three conductors and single-circuit line with balancing device, are calculated by the following formula:-

$$W_{\Sigma lc} = \frac{2}{3} \cdot W_{\ell l} \cdot \left[K_s + W_s (1 - W_s) + (1 - K_s)(1 - K_{BD}) + [2w_s \times (K + 1) + 3W_{BD}\right] \cdot K_{pl\Phi c}\,, \qquad \ldots (45)$$

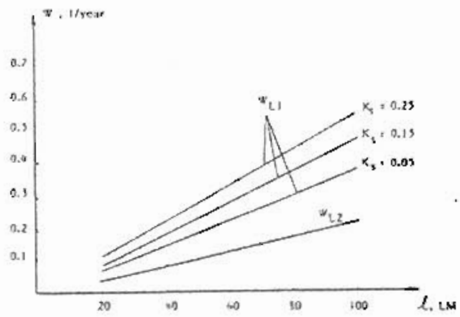
$$K_{\Sigma lc} = \frac{2}{3}\, W_{\ell l} \left[T_{relc} \cdot K_s + T_{sr}\, W_s (1 - K_s) + T_{sr} (1 - K_{BD}) \times (1 - K_s)\right] + 2\, W_{\ell l} \cdot \left[T_{relc} \times (K_{pl\Phi c} - 0.5\, T_{relc}) + KT^{1} \times (K_{pl\Phi c} - 0.5\, T^{1})\right] + 1.5\, W_{BD} \cdot K^2_{pl\Phi c} \qquad \ldots (46)$$

Eqs (45) and (46) can use in the case of phase-maintenance of the lines.

Results of calculation for 35 KV circuits are shown in Figs. (6) and (7), where the relation of the failure flow parameter and the simple forced coefficient depending on the line length for K_s. Figure (8) shows the relation between the reliability of no failure operation and the line length. Also, results illustrate, that in circuits with isolating solid neutral of transformer compared with earthing netural circuits of single-circuit lines (varient 2), have better reliability. For example, for 35 KV circuits, the failure flow parameter for second varient are

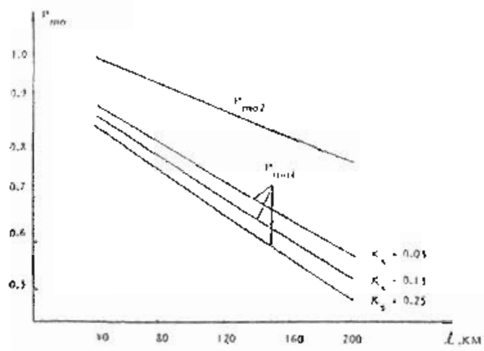


a) For 220 KV of overhead transmission lines

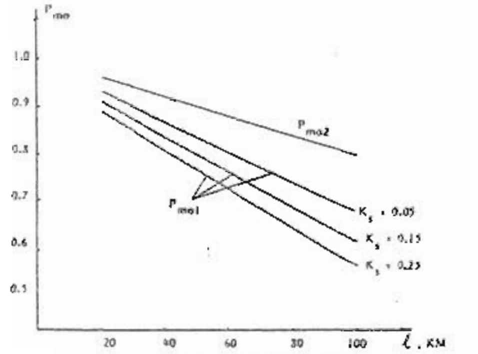


b) For 110 KV of overhead transmission lines

Fig.3 The flow failure parameters of electric transmission lines for single and double-circuit against their length.

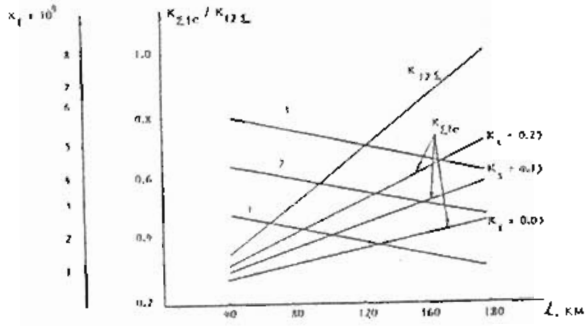


a) For 220 KV of overhead transmission lines

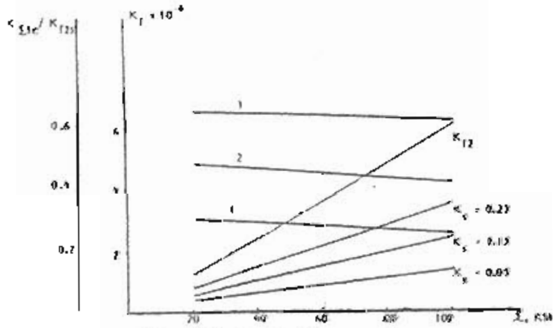


b) For 110 KV of overhead transmission lines.

Fig.4 The probability of no-failure operation for single and double-circuit transmission lines against their lengths.



a) For 220 KV of overhead transmission lines.



b) For 110 KV of overhead transmission lines.

Fig. 5. The simple forced coefficient for first and second varients against their lengths during various value of K_s (curves 1,2 and 3 of $K_{\Sigma 1c}/K_{F2S}$).

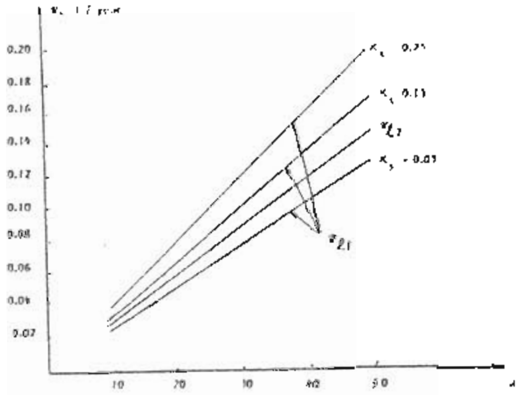


Fig. 6 Flow failure parameters of electric transmission lines of 35 KV (first and second variants) against their lengths.

bigger by 10–35% only (Fig. 6), than the first varient, instead of 150 - 30% in circuits of 220 and 110 KV. In this time, the simple forced coefficient for second varient, is less than the first varient by 2-4 times.

Therefore, in circuits with isolating solid neutral of transformers, as in circuits with earthing neutral of single-circuit line possible fulfil all demands of electric power supply.

Moreover, it is possible to underline that the electric power supply through single-circuit line with phases control and balancing device shows large reliability, than the electric power supply with double-circuit line in single tower circuit.

2. Reliability comparison between three-conductors of single-circuits line and single-circuits with two-conductors-earth

Using two-conductors-earth method for realization needs to small costs at comparison with 3-conductors transmission line. Moreover, allows decreasing the active power lower in electric energy of lines to 25-30% [7].

For reliability comparison of electric power supply by these systems, arise tow varients of electric power supply, the circuit is shown in Fig. 5 (9.a) and (9.b).

2.1-First varient : 3-conductors of transmission lines

The interval of electric power supply in this varient is possible in the following cases:

1. At all cases of short circuit, a time maintainance of line is used, but single-phase to ground short circuit takes alone. In circuits with isolating solid neutral of transformer at single-phase to ground short circuit, allows to work the lines about 2 hours, after that, the circuit, must be disconnected for maintainance.

   The simple forced coefficient for this case is limited by the equation:-

$$K_F^{\lambda} = W_{\ell}\, T_{relc} = W_{\ell} \cdot m.\, T_{relc} + (1 - m)\, W_{\ell}\, T_{relc} = K_{F1}^{\lambda} + K_{F2}^{\lambda} \qquad \ldots (47)$$

2. During failure of switches in sending end substation at all cases of short circuit instability in overhead transmission lines. In this case the simple forced coefficient is equal to :-

$$K_F^{\lambda} = K \cdot W_{\ell} \cdot W_s \qquad \ldots (48)$$

3. During the maintainance plan of overhead transmission lines. For the electric transmission lines in systems with isolating solid neutral of transformers, (6 - 35 KV) in the quality of the simple forced coefficient to take the simple plan coefficient of line, i.e.

$$K_{p1} = K_{p1\ell} \qquad \ldots (49)$$

Then, the summation of the simple forced coefficient of the transmission lines is equal to :

$$K_{\Sigma lc} = \grave{K}_F + K_{F\ell} + K_{pl\ell} = W_\ell (T_{relc} + K T_{sr} W_s) + K_{pl\ell} \qquad \ldots (50)$$

and the effect of damage at the interval of electric power supply can be limited by the following formula :

$$Y = \grave{K}_F \cdot \mathcal{E} \cdot \grave{\alpha} \cdot P_{max} + (\grave{K}_{F2} + \grave{K}_F)\, \mathcal{E} \cdot \alpha \cdot P_{max} + K_{pl} \cdot \mathcal{E} \cdot B \cdot P_{max} =$$

$$[m\, W_\ell T_{relc} \grave{\alpha} + [(1 - m) W_\ell x\, T_{relc} + K W_\ell W_s T_{sr}]\alpha + K_{pl\ell} B] \cdot P_{max} \qquad \ldots (51)$$

The given data of $\grave{\alpha}$ equal to 1.25 times of specific damage plant (i.e. $\grave{\alpha}$ = 1.25 B) .

2.2- Second varient: Single - circuit with two - condutors - earth.

The complete interval in electric power supply for this varient arises in the following cases :

1. During the all stability damage at overhead transmission line. It is necessary to calculate at double-conductor - earth method [7], the simple forced coefficient for this case may be limited by the following equation :

$$K_{DC} = \frac{2}{3} W_\ell T_{DC} \qquad \ldots (52)$$

where: T_{DC} - the mean time of double - conductors earth, which is alawys smaller than T_{relc} for three conductors line by the following :

$$T_{DC} = 0.8\, T_{relc} \qquad \ldots (53)$$

2. During failure of balancing device, the simple forced coefficient for this case can be limited by the equation:

$$K_{BD} = W_{BD} \cdot T_{BD} \qquad \ldots (54)$$

3. During failure of the Switches at sending substation in case of instability of two - conductors - earth, the simple forced coefficient in this case equal:

$$K_F^1 = \frac{2}{3} W_\ell K W_s T_{sr} \qquad \ldots (55)$$

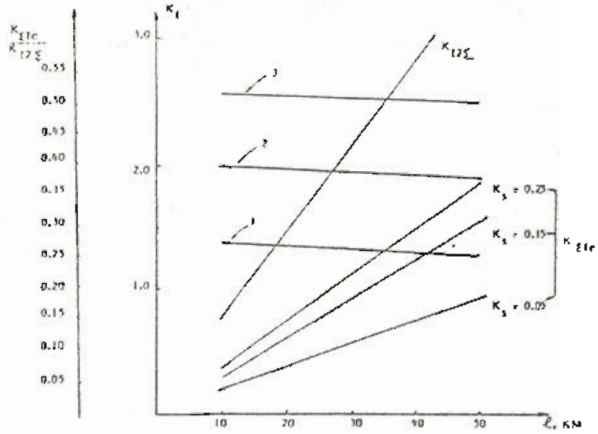


Fig. 7 Simple forced coefficients for first and second variants and their relation with line lengths of 35 KV, curves 1, 2 and 3 of $K_{\Sigma 1c}/K_{12\Sigma}$

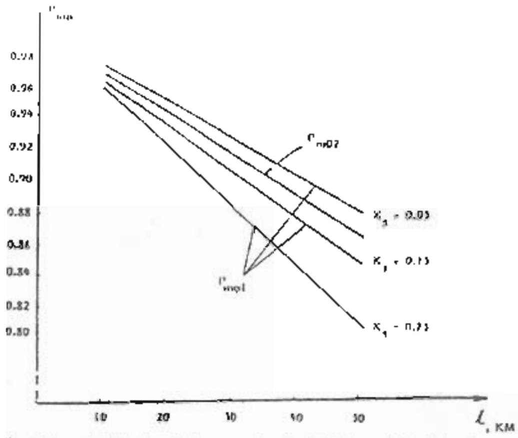
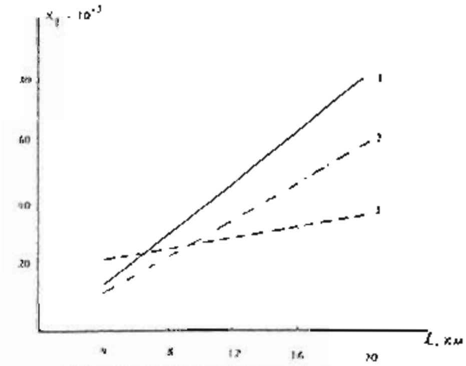
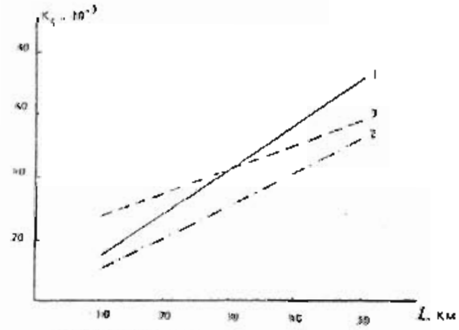


Fig. 8 The probability of no-failure operation of electric transmission lines of 35 KV (first and second variants) against line length.



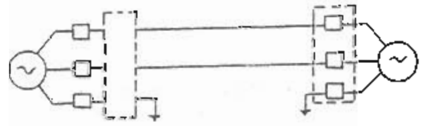
a) For 10 KV of overhead transmission lines



b) For 35 KV of overhead transmission lines.

Fig. 10 The simple forced coefficient against line length (1. K_t for three-conductors of line at m = 0.75 ; 2. K_{t1} for these lines; 3. for two conductors-earth system).

a) Three - Conductors of overhead transmission lines.



b) Two conductors - earth system.

Fig. 9 The circuit of electric transmission line variants.

4. During the maintenance plan of double - conductors earth. The simple plan of transmission coefficient in this case, takes the small value than at three - conductors lines, and is equal to

$$K_{PDC} = (0.66 \div 0.8)\ K_P$$

The summation of the simple electric transmission coefficient can be limited by the equation :-

$$K_{\Sigma DC} = \frac{2}{3} W_{\ell} (T_{DC} + K\ W_s\ T_{sr}) + W_{BD}\ T_{BD} + K_{PDC} \qquad \ldots (56)$$

and the expected value of economic damage is determined by the formula:

$$Y_{DC} = [\frac{2}{3} W_{\ell} (T_{DC} + K\ W_s\ T_{sr}) + W_{BD}\ T_{BD}] \propto + K_{PDC}\ B \Sigma P_{max} \qquad \ldots (57)$$

The analysis of calculations, show that, by increasing the line length, the simple forced coefficient quickly increases for three-conductors line than with two-conductors-earth, as shown in Figs. (10.a) and (10.b)

Conclusions:-

1. Comparitavely, the reliability estimation of electric power supply along single-circuit and double circuit of lines, illustrates that, the single-circuit lines, phase control equipment and balancing device for working in unsymmetrical systems give a new quality of several circuits.

2. Establishing that the electric power supply by these lines is more reliable, than in double-circuit, i.e. the simple forced coefficient at the first case is smaller by 1.3-4 times, than the double-circuit lines. Also, it is illustrated that, it is possible to use the single-circuit overhead transmission line for electric power supply for all demands.

3. Discovering, that for estimating the cost is possible to calculate the costs of varients of electric power, taking into account the values of economic damage not considered before at comparison these varients with economic expenditure.

4. It is shown, that from the values of economic damage follows the calculations of the equal costs varients of electric power by three-conductors of single-circuit transmission line and two-conductors earth of single circuit.

Nomenclature:-

w Failure - flowing / year
T_r Average restoration time, year / failure .

K_F	Simple forced coefficient, relatively the unity.
K_p	Simple plant coefficient, relatively the unity.
Y	Expectation value of economic damage
Y_F, Y_p	Summation of expected damage in resulting of faults and load disconnection planning.
$\propto$, B	Specific expected damage at faults and load disconnection planning.
K_F, K_p	Simple forced and plant coefficients at electric transmission.
$\mathcal{E}$	Degree of load limitation $(o \leqslant \mathcal{E} \leqslant 1)$.
P_{max}	Maximum transmitted power.
P_{mo}	The probability of no-failure operation.
W_{ℓ}	Stream failure of two circuits.
T_{re}	Average reduction time.
$\grave{K}_{F21}$	Simple forced coefficient of first circuit.
K_{P22}	Simple plant coefficient of second circuit during the maintenance.
T_{r21}	Average restoration time during damage of first-circuit for double-circuit transmission line.
W_{21}	The failure flow of first circuit for double-circuit.
K_{F21}	Simple forced coefficient of first circuit for double-circuit.
W_s	Failure flow of switches.
K	Coefficient, indicates that the number of reliability of beginning short circuit instabilities, which changing the stable reliability (for ex. K = 3).
W_{S21}	Failure flow of first circuit switches for double-circuit.
K''_{F21}	Simple forced coefficient of first circuit during maintenance
T_{sr}	The active time of switching
$\grave{w}_{S21}$	$= W'_{21} + W'_{S21}$
K_{PS2}	The simple plant coefficient of switches.
W_{P12}	Failure flow of first circuit in the suitable time of maintenance plant for second .
K_{F1p2}	The simple forced coefficient of 1st. circuit in the time of the maintenance plant of 2nd. circuit.
T_{F21}	The maintenance time of the 2nd circuit.
W_{FP2}	The whole failure flow at maintenance time.
$W_{2\Sigma}$	Failure flow parameters of double-circuit.
$K_{F2\Sigma}$	The simle forced coefficient of double-circuit
K_s	3-phase and double-phase to ground short circuit in line
$W_{\ell 1}$	Failure flow of one-circuit line.

T_{rel} Average reduction time of one circuit line

K_{FBD} Availability coefficient of balancing device.

W_{BD} The failure flow of balancing device.

$K_{P\phi 1}$ Simple plan coefficient of single-phase circuit.

K_{PC1} Simple plan coefficient of single-circuit.

K_{PS1} Simple plan coefficient of single-circuit switches.

m Coefficient, taking into account the single-phaie to earth stability.

$\propto$ The specific damage at discomection of loads for single-phase to ground short-circuit.

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