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The Effect of Maximum Probability Value of The Maximum Short Circuit Current on The Possibility of Increasing The Period of The Invested Electrical Equipment Service

Dr. George Isber •

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□ ABSTRACT □

It is known that the electric networks develop with time. This leads to the increase of electrical loads; consequently, malfunction currents become larger. Therefore, the invested electrical equipment, such as circuits, is not sufficient for the required purpose. They are supposed to be replaced; however, this leads to additional expenses which could hardly be borne immediately. Taking into consideration the little probability of the occurrence of greater intensity of malfunction currents, we can be patient with exchanging this equipment gradually. At the same time, this may expose us to the probability of risk due to the insufficiency of these equipments capacity for the load development.

Key word: short circuit current, electrical equipment, probability

•**Professor, Department of Electrical Power Engineering, Faculty of Mechanical & Electrical engineering, Tishreen University, Lattakia, Syria.**

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تأثير القيمة الاحتمالية لتيار القصر الأعظمي على إمكانية زيادة فترة خدمة الأجهزة الكهربائية

الدكتور جورج اسبر*

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□ ملخّص □

من المعروف أن الشبكات الكهربائية تتطور مع الزمن، وهذا يؤدي إلى ازدياد الأحمال الكهربائية، وبالتالي زيادة تيارات القصر (تيارات الأعطال). لذلك فإن المعدات الكهربائية المستثمرة كالقواطع لا تفي بالغرض، ومن المفروض استبدالها، مما يؤدي إلى نفقات إضافية قد لا يمكن تحملها بشكل فوري. فإذا أخذنا بالاعتبار الاحتمال القليل لحدوث الحالة الأكثر شدة لتيارات العطل، فإننا نستطيع التريث بتبديل هذه المعدات بحيث يتم تبديلها تدريجياً. وفي الوقت نفسه قد تتعرض الأجهزة الكهربائية لاحتمال المخاطرة بعدم كفاية استطاعة هذه المعدات لتطور الحمل.

الكلمات المفتاحية: تيار القصر، الأجهزة الكهربائية، الاحتمالات

* أستاذ – قسم هندسة الطاقة الكهربائية – كلية الهندسة الميكانيكية والكهربائية – جامعة تشرين – اللاذقية – سورية.

Introduction:

The traditional method followed for calculating the value of the short-circuit currents leads us to the necessity of finding the maximum value of these currents when all conditions are available, though in practical life, the experiment of investing electrical plants shows us that the value of short-circuit currents in electrical networks possesses a probability quality. And not taking this aspect into consideration will lead to the increase of electrical equipment determinants, and from the economic point, this is unsuitable.

Aims and importance of the research:

In this research, we state a mathematical pattern of an electrical circuit allowing us to find the probability value of the impact current (highest value of the short-circuit current).

- The necessity of moving to the mathematical patterns for calculating the short-circuit currents depends on the following:

1- Choosing the electrical equipment we usually set off from the highest value of the short-circuit current and the hardest conditions.

2- Shortness occurs directly after the studied element. This means that we provide a big uneconomical reserve.

- It is known that any electrical network develops in time; this leads to increasing the loads and the short-circuit currents grow big. Therefore, the invested electrical equipment is insufficient and should be substituted. This requires great expenses which cannot be immediately borne.

If we take into consideration the little probability of the intenser case of the short-circuit current, we can be patient with changing the electrical equipment so that they might be substituted gradually. This in turn could expose us to the possibility of the risk of the insufficient capacity of electrical equipment to response to the load development.

Method of research and the materials used:

The thought of the seriousness of this work leads us to refer to the technical economic solution to compare the expenses resulting from the increased reserve in the chosen electrical equipment caused by big breakdowns (this is a little probability). To do this work, it is necessary to obtain information about the possibility of distributing the cases of short-circuits currents.

- Before doing anything, we analyze the concept of the failures incident (the short circuit) and without any doubt, on calculating the short-circuit currents, it is necessary to take into consideration the short circuit resistance, phase angle and the time of the short-circuit current appearance in the circuit. In the first case, we can consider the short circuit as a complicated event consisting of three independent events:

- In the first incident, the short-circuit current occurred.

In the second incident, the short time occurred in a definite phase Ψ within the limits of the time current alternation.

The short-circuit current occurred in the third incident at a definite point along with the line.

- In the second case, we may regard the last two incidents as defining the probability quality of the short-circuit current, and for knowing the possibility of the short-circuit current appearance, it is necessary to study the short currents during the period of investing the chosen equipment, though in this supposition the various incidents are determined:

The time period between two incidents of the short-circuit current may happen during separate intervals and the occurrence of shortness in phase during parts of the second. Therefore, we should study the second case which considers that the shortness incident appeared with a probability amounting to (1) one.

At the beginning we study a simple case when the consumer is fed by one line that is (L) long and has a resistance of $R_0 = 0$. Here we should distinguish between inductive impedances of the short circuit where X_1 the inductive impedance up to the feeding source, X_2 the inductive impedance of the short circuit at the line and X the inductive resistance up to the occurrence of the short circuit on the line (figure No.1).

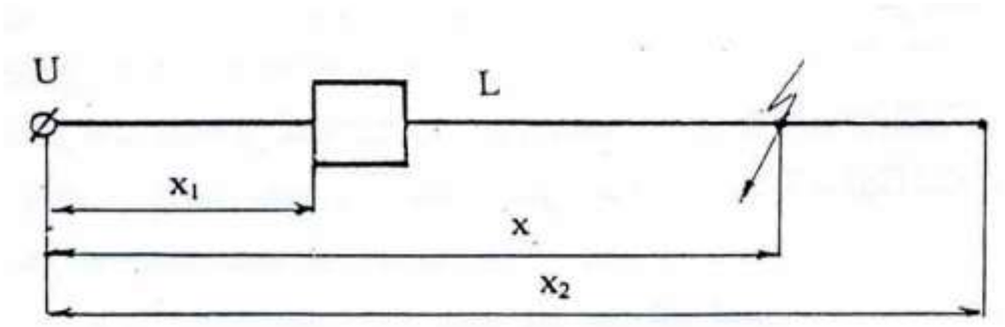


Figure (1)- the computing circuit for finding the short current

- The impact current could be calculated from the following relation (1):

$$i_y = \frac{U_M}{\sqrt{3}x}\left(1+\left|\cos\Psi\right|\right), \quad (1)$$

Where:

- U_M maximum value of voltage;
- Ψ phase angle.

The short circuit could occur at any interval and at any point along the line. Therefore, the possibility of distributing the phase angle Ψ and the impedance X, may be considered as regular in the range from zero to 2π and from X_1 to X_2 [1].

$$f(\Psi) = \frac{1}{2\pi} \rightarrow 0 \le \Psi \le 2\pi \quad (2)$$

$$f(x) = \frac{1}{\chi} = \frac{1}{x_2 - x_1} \rightarrow x_1 \le x \le x_2 \quad (3)$$

Consequently, the distribution density becomes (for both independent elements) equal to their density multiplication.

$$f(x,\psi) = \frac{1}{2\pi\chi} \quad (4)$$

where: $0 \le \psi \le 2\psi$ at $x_1 \le x \le x_2$

According to the relation (1) it demands finding the probability distribution of the impact current in accordance with the distribution density given in relation (4). For this purpose we have to use the famous relation in the theory of probabilities theory for transforming the function of two random values [1]. Upon this we find the distributive function [2].

$$F(i_y) = \iint_G f(x,\psi)\,dx\,d\psi \quad (5)$$

The main difficulty for using the relation (5) is to find the integration range G. This will be done by the phase angle Ψ, and by drawing the function of X(Ψ), taking into consideration the impact current i_y from the relation (1) the value of function X(Ψ) becomes as follows:

$$x = \frac{U_M}{\sqrt{3}i_y}\left(1 + |\cos\psi|\right) \qquad (6)$$

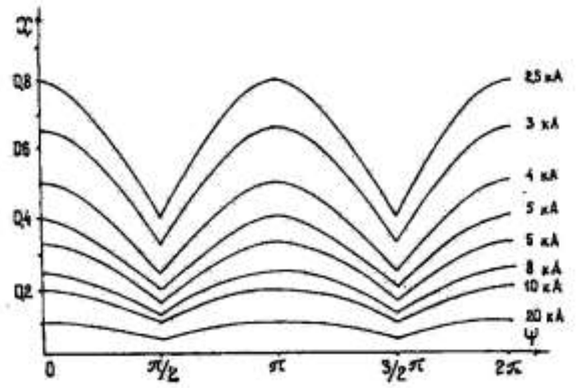


Figure (2) – curves for finding the integration ranges on calculating the probability distribution of the impact current

Suppose that ....$x_2 \geq 2x_1$ here there is a possibility of the following cases are illustrated in figure (2). We are satisfied by the integration in the range $0 \leq \psi \leq \pi/2$ for after this an example from curve No.(2) will be repeated in table (1) where we get two prisms figure (3).

Thus the general relation (5) gives us the following cases for the distribution function:

On :

$$0 \leq i_y \leq \frac{U_M}{\sqrt{3}x_2}$$

$$F(i_y) = 0; \qquad (7)$$

on :

$$\frac{U_M}{\sqrt{3}x_2} \leq i_y \leq \frac{2U_M}{\sqrt{3}x_2}$$

$$F(i_y) = 4\int_{\psi_2}^{\pi/2} d\psi \int_{\frac{U_M}{\sqrt{3}i_y}}^{x_2} dx \frac{1}{2\pi\chi} = \frac{2}{\pi\chi}\left[\left(x_2 - \frac{U_M}{\sqrt{3}i_y}\right)\left(\frac{\pi}{2} - \psi_2\right) - \frac{U_M}{\sqrt{3}i_y}\left(1 - \sin\psi_2\right)\right] \qquad (8)$$

and on:

$$\frac{2U_M}{\sqrt{3}x_2} \leq i_y \leq \frac{U_M}{\sqrt{3}x_2}$$

therefore:

$$F(i_y) = 4\int_0^{\pi/2} d\psi \int_{\frac{U_M}{\sqrt{3}i_y}(1+\sin\psi)}^{x_a} \frac{1}{2\pi\chi}dx + 4(x_2 - x_a)\frac{\pi}{2}\cdot\frac{1}{2\pi\chi} = \frac{2}{\pi\chi}\left(\left(\frac{\pi}{2}x_2 - \frac{U_M}{\sqrt{3}i_y} - \frac{\pi}{2}\cdot\frac{U_M}{\sqrt{3}i_y}\right)\right) \quad (9)$$

where :

$$x_a = \frac{2U_M}{\sqrt{3}i_y}$$

And on:

$$\frac{U_M}{\sqrt{3}x_1} \le i_y \le \frac{2U_M}{\sqrt{3}x_1}$$

Therefore:

$$F(i_y) = 4\int_0^{\psi} d\psi \int_{\frac{U_M}{\sqrt{3}i_y}(1+\cos\psi)}^{x_2} dx\frac{1}{2\pi\chi} - 4(x_2 - x_a)\psi_1\frac{1}{2\pi\chi} + 4 = \frac{2}{\pi\chi}\left(\frac{\pi}{2} - \psi_1\right)x\frac{1}{2\pi\chi} =$$

$$= \frac{2}{\pi\chi}\left[\left(\psi_1 x_1 + \frac{\pi}{2}\chi - \frac{U_M}{\sqrt{3}i_y}(\psi_1 + \sin\psi_1)\right)\right] \quad (10)$$

The elements entered in the two relations (10 and 8) Ψ_1 and Ψ_2 are illustrated in table (1).

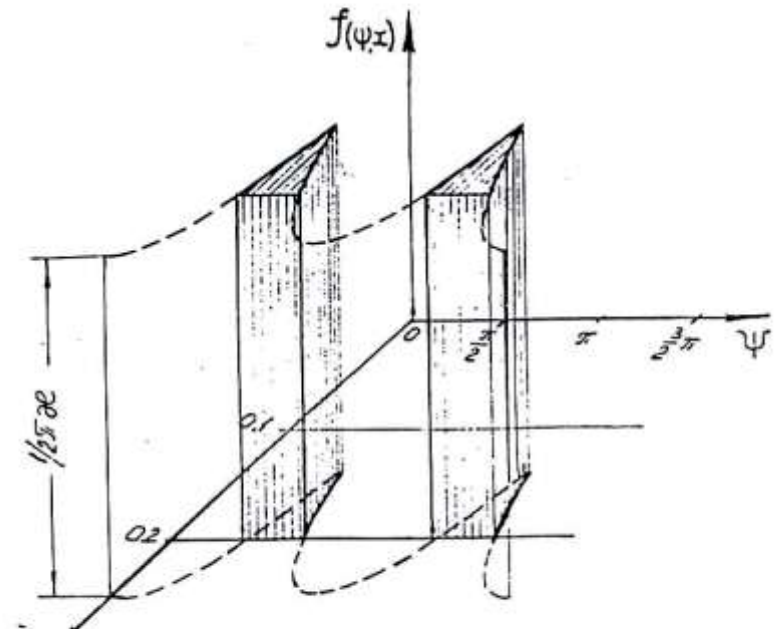


Figure (3)- Finding prism volume on integration

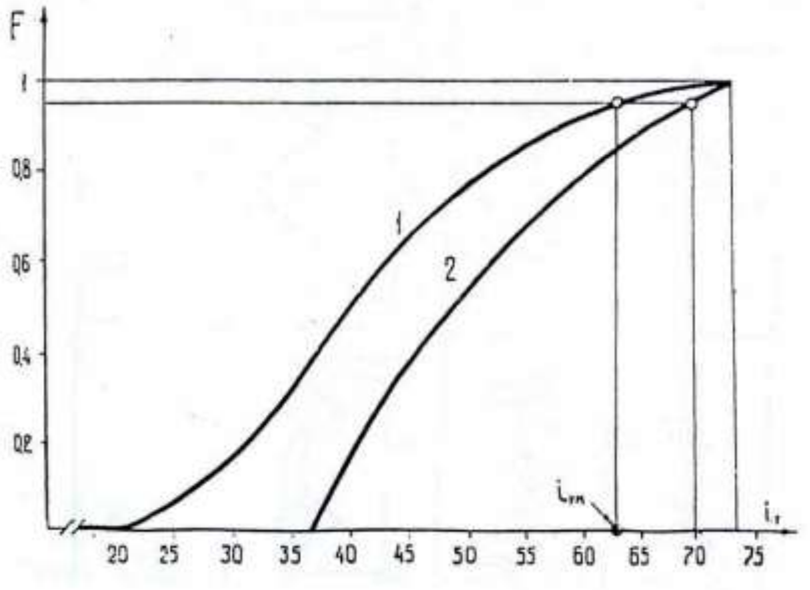


Figure (4)- Finding the arithmatic values of the impact current (i_y)
1- By using the accurate relation,
3- By using the approximate relation (24)

Movement to the case where $x_2 \le 2x_1$ illustrates the possibility of knowing the ranges of integration as in table (2) which confirms to the relation (5), where we get:

And on:

$$0 \le i_y \le \frac{U_m}{\sqrt{3}x_2}$$

$$F(i_y) = 0; \qquad (11)$$

And on :

$$\frac{U_M}{\sqrt{3}x_2} \le i_y \le \frac{U_M}{\sqrt{3}x_1}$$

$$F(i_y) = \frac{2}{\pi\chi}\left[\left(x_2 - \frac{U_m}{\sqrt{3}i_y}\right)\left(\frac{\pi}{2} - \psi_2\right) - \frac{U_m}{\sqrt{3}i_y}(1 - \sin\psi_2)\right] \qquad (12)$$

And on:

$$\frac{U_m}{\sqrt{3}x_1} \le i_y \le \frac{2U_m}{\sqrt{3}x_2}$$

Then:

$$F(i_y) = 4\int_{\psi_2}^{\psi_1} d\psi \int_{\frac{U_M}{\sqrt{3}i_y}(1+\cos\psi)}^{x_2} dx \frac{1}{2\pi\chi} + \left(\frac{\pi}{2} - \psi_1\right)\chi =$$

$$= \frac{2}{\pi\chi}\left[x_2(\psi_1 - \psi_2) - \frac{U_m}{\sqrt{3}i_y}(\psi_1 - \psi_2) + (\sin\psi_1 - \sin\psi_2) + \left(\frac{\pi}{2} - \psi_1\right)\chi\right] \qquad (13)$$

And on:

$$\frac{2U_m}{\sqrt{3}x_2} \le i_y \le \frac{2U_m}{\sqrt{3}x_1}$$

Then:

$$F(i_y) = \frac{2}{\pi\chi}\left\{\psi_1 x_1 + \frac{\pi}{2}\chi - \frac{U_m}{\sqrt{3}i_y}[\psi_1 + \sin\psi_1]\right\} \qquad (14)$$

We get the distribution density through performing the differentiation of the former relation by pointing i_y and according to the principle of reliability [2,4] the former maximum values of the grand impact current i_{ym} are calculated on the basis of the probable value E_X from the following case:

$$F(i_{ym}) = 1 - E_x \qquad (15)$$

Table (1): Curves for the integration ranges

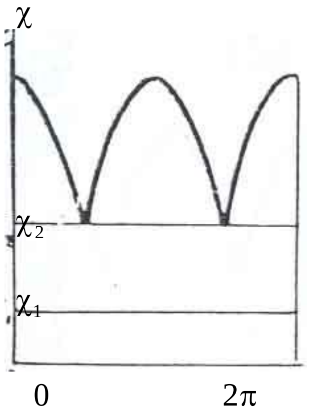
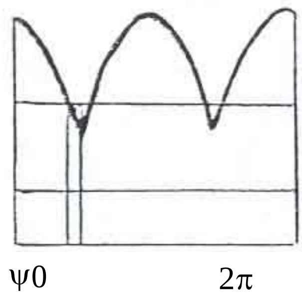
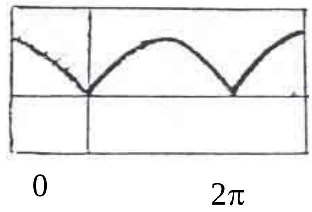
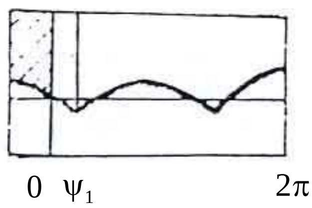
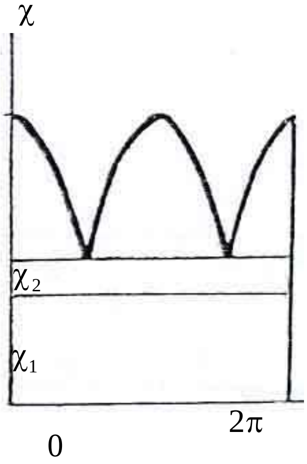
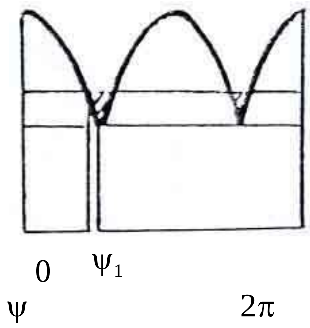
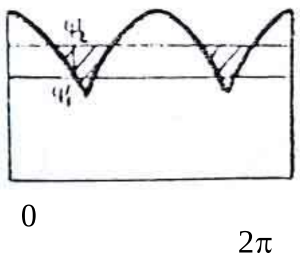
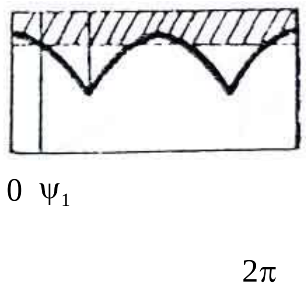
	2.5KA	3KA	6KA	10KA
Curves				
Ranges	$0 \le j_y \le \frac{U_M}{\sqrt{3}\chi_2}$	$\frac{U_M}{\sqrt{3}\chi_2} \le j_y \le \frac{2U_M}{\sqrt{3}\chi_1}$	$\frac{2U_M}{\sqrt{3}\chi_1} \le j_y \le \frac{U_M}{\sqrt{3}\chi_1}$	$\frac{U_M}{\sqrt{3}\chi_1} \le j_y \le \frac{2U_M}{\sqrt{3}\chi_1}$
Value of phase angle	$\psi = \pi/2$	$\pi/2 \le \psi_2 \le 0$	$0 \le \psi_1 \le \pi/2$	$\pi/2 \le \psi_1 \le 0$

Table (2): Curves for the integration ranges

	2.5KA	3KA	4KA	6KA
Curves				
Ranges	$0 \le j_y \le \frac{U_M}{\sqrt{3}\chi_2}$	$\frac{U_M}{\sqrt{3}\chi_2} \le j_y \le \frac{U_M}{\sqrt{3}\chi_1}$	$\frac{U_M}{\sqrt{3}\chi_1} \le j_y \le \frac{2U_M}{\sqrt{3}\chi_1}$	$\frac{2U_M}{\sqrt{3}\chi_1} \le j_y \le \frac{2U_M}{\sqrt{3}\chi_1}$
Value of phase angle	$\psi_1 = \pi/2$	$\arccos\left(\frac{\chi_2}{\chi_1}\right) \le \psi_2 \le \pi/2$	$\arccos\left(\frac{\chi_2}{\chi_1}\right) \le \psi_1 \le \pi/2$	$\arccos\left(\frac{2\chi_1}{\chi_2} - 1\right) \le \psi_1 \le 0$

We find the current through the diagrammatic distribution curve figure (4) curve (1).

Consequently, we see that the greater the loss value resulting from the electrical equipment stopping to work on taking into consideration the little probability of the short current. Therefore, the less the probability E_X, the greater the voltage is and on $E_x \approx 0$ the probability methods give us a result similar to that of the traditional methods.

We move to evaluating the effect of the phase angle of the impact current value on the stability of the impedance value X. In this case the impact current will be dependent on a random (haphazard) value of the phase angle.

- The distribution density of the impact current $f(i_y)$ may be found by the general relation of the theory of probabilities for the random distribution function [5].

- To find the required density, we use the geometrical probability concept. As it is clear from the function $i_y(\Psi)$ shown on figure (5), the probability E_y is bigger than the impact current level, and it suffices us to calculate the increase over the impact current level which could be calculated from the relation:

$$\psi_{y_1} = \arccos\left(i_y / j_M - 1\right)$$

where: $j_M = U_M / \sqrt{3}x$

where:

$$E_y = \frac{4\psi_{y_1}}{2\pi} = \frac{2}{\pi} arc\cos\left(i_y / I_m - 1\right) \qquad (16)$$

and dependency for

$$f\left(i_y / x\right) = / \frac{d}{di_y}\left(1 - E_y\right) / = \frac{2}{\pi j_M \sqrt{1 - \left(i_y / I_m - 1\right)^2}} \qquad (17)$$

The impact current is situated within the ranges $1 \le i_y / I_M \le 2$.

It is clear that the probability distribution density of the phase angle, is subject to Law arcos, which gives us:

$$F\left(i_y / x\right) = 1 - E_y = 1 - \frac{2}{\pi} arc\cos\left(i_y / I_m - 1\right) \qquad (18)$$

According to relation (15) and by changing the value in relation (18) which is $1 - E_x$, we get:

$$i_{yM}\big|_x = \left(1 + \cos\frac{\pi}{2} E_x\right)\frac{U_M}{\sqrt{3}x} \qquad (19)$$

The probability range value 05 is usually taken and less than (2).

By applying this to the relation (20), we can get an important value, for the phase angle which does not practically affect the maximum current value.

This allows the occurrence of a little mistake which is considering the phase angle value equal ($\psi = 0$), thus the relation becomes as follows:

$$i_{yM}\big|_x \approx \frac{2U_M}{\sqrt{3}x} \qquad (20)$$

By comparison with relation (14) the biggest mistake in the calculation when using relation (20) on the probability $E_x = 0.05$, does not exceed 0.1%. Therefore we can get an important application result which happens when making probability enter short currents. It is then possible to neglect the phase angle value, to that we get the following:

$$\tilde{i}_y \approx \frac{2U_M}{\sqrt{3}x} \qquad (21)$$

Where the signal ~ belongs to the case when the value $\psi = 0$ and i_y the impact current.

According to the theory of probabilities distribution (of the reflexive function), we find that:

$$f\left(\tilde{i}_y\right) = \frac{\sqrt{3}x^2}{2U_M} f_x\left(\frac{2U_M}{\sqrt{3}\tilde{i}_y}\right) \qquad (22)$$

On regular impedance, when $f_x(x) = \frac{1}{\chi}$ we get:

$$f\left(\tilde{i}_y\right)=\frac{2U_M}{\sqrt{3}\chi\tilde{i}^{2}_{y}} \qquad (23)$$

And the distribution density:

$$F\left(\tilde{i}_y\right)=\frac{1}{\chi}\left(x_2-\frac{2U_M}{\sqrt{3}\tilde{i}_y}\right) \qquad (24)$$

From the relation (24), the maximum arithmetic value of impact current taking into consideration E_X, we get the following relation:

$$I_{ym}\approx\frac{2U_M}{\sqrt{3}\left[x_2-\chi\left(1-E_x\right)\right]} \qquad (25)$$

This is a new relation for calculating the maximum impact current of the failure current taking into consideration E_X.

By drawing the approximate diagrammatic distribution curve according to relation (24) figure (4) and comparing it with the real curve, we find that it gives us a reserve in the maximum impact current value. It is clear that the mistake in the maximum relation calculated by the approximate relation (24) by comparison with the relations (7 and 10), relates to the numerical values of the network impedances.

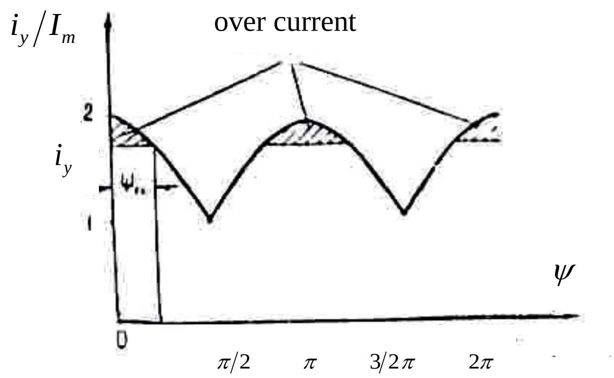
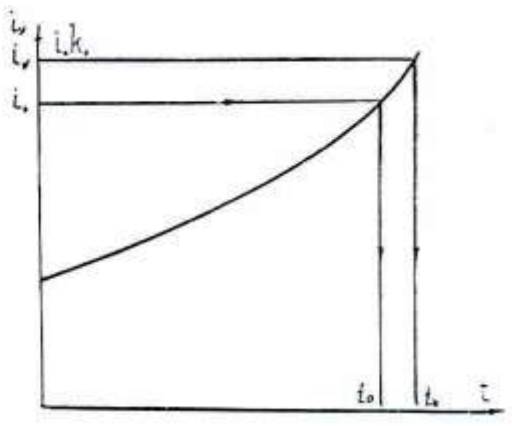


Figure (5)- finding the probabilities of a current occurrence exceeding the impact current



$$K_{\circ}=\frac{2U_m}{\sqrt{3}x_1 i_{ym}}$$

Figure.(6)- Finding the time of secant work on the network development

The obtained result allows us to evaluate the possibility of the electrical equipment to keep working, even if the loads exceed the capacity of this equipment, for example the capacity of secants. If the short-circuit current occurred at the beginning of the feeding line, this equipment would be unstable. Therefore, it is necessary to know the possibility of predicting the replacement time. For example, figure (4) illustrates that the separation current 10 of the secant was calculated on the basis of the maximum value of impact current occurring at the beginning of the line and equal to $2U_M / \sqrt{3}x_1$ that is, $E_x = 0$ then and after an interval t_X it is difficult to invest the secant figure (6). But the possibility of the shortness occurrence at the beginning of the line is little. Therefore, with the possibility of taking into consideration, the probability E_X it could be permitted to elongate the period of investing the electrical equipment and stopping its work until the moment t_X which conforms to the current value that increases the value of separation current I_0.

4- Example:

The following table (3) includes the induction resistance values for a 66 K.V. net, which feeds (electrically supplies) the oil pipes lines of the eastern Syrian region. It indicates that the obtained error in the calculated impact current (after applying the accurate and approximate method) -as we found – does not, exceeds 8% as a maximum.

Percentage error between the accurate and a proximate method in calculating impact current	The induction resistance in starting of & end line as in fig. (1)		Net length KM	Net section name
	X_1 (ohm)	X_2 (ohm)		
7.5	76	100	58	Hama-Salamie
7.3	100	126	62	Salamie-Asria
7.4	126	150	57	Asria-AlRasafi
7.8	150	178	67	Alrasafi-Rakka
7.7	178	206	68	Rakka-Sabah-Alkher
8.1	206	238	76	Sabah-alkher-Khasaka

5- Result:

1) A probable mathematical pattern was assumed to calculate the impact currents in the short-circuit currents.

2) A new relation was assumed to calculate the impact currents according to the theory of probability.

3) A task result has been shown, that it is possible to continue the investment of electrical equipment even after the network-development and considering the probability of the impact current appearance at the value $E_x = 1 - 0.05 = 0.95$ instead of 1.

Conclusion and recommendation:

The obtained result allows us to evaluate the possibility of the electrical equipment to keep working, even if the loads exceed the capacity of this equipment, for example the capacity of secants. If the short-circuit current occurred at the beginning of the feeding line, this equipment would be unstable. Therefore, it is necessary to know the possibility of predicting the replacement time.

Therefore, with the possibility of taking into consideration, the probability E_X could be permitted to elongate the period of investing the electrical equipment and stopping its work until the moment t_X, which conforms to the current value that increases the value of separation current I_0. Figure (6).

References:

1- VENTSEL, E.C., *Teoria veraiatnosti* – Izdatestva Nayka. Moscow, Ru. 1979, 576.
2- KOURENNYL, E.G., PETROSOV, V.A., *Squaring and smoothing in EMC models*: Statistical Solution – Fifteenth International Wroclaw Symposium and Exhibition: Electromagnetic Compability 2000, Wroclaw National institute of Tilicommunications. Poland, 2000. part 1 – 322-325.
3- KOURENNYL, E.G. *Electromagnetic compatibility, (EMC). Nordpublisher,* Donetsk, Ukr. 2005, 247.
4- VENIXOV, V.A.; AHURALEV, V.; FILEPPOVA, T., *optimal operation of plants and electronic systomcs. Mirpublisher*, Moscow, 1994, 195.
5- KHAIN, M.; KLAZONOV, A.A. *Vibor economicheski tselisopraznikh rachutnickh znachii tokov korotkova zamikania v sistemakh electrosnapgenia – electroichistva* Moscow, Ru.. N-2 – 1995,11-15.