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ESTIMATION OF FUNCTIONING QUALITY OF DISTRIBUTIVE ELECTRICAL NETWORKS APPLYING CRITERIAL MODELLING

The given research illustrates application of criterial models for determination of quality criterion of distributive networks functionning for estimation of possible variants of users supply at restoration of its principal sections.

Keywords: *distributive networks, functioning quality, power supply reliability, power quality, Markov process, criterion modelling.*

Introduction

One of conditions of economic development of the country is steady, qualitative power supply of consumers and enterprises. State of electric power industry after considerable period of insufficient investment is characterized by serious deterioration both of generation facilities, and network equipment [1]. Decrease of power supply quality is a result of equipment degradation. State of those electrical networks where energy consumption grows for example, as a result of transition to electric heating requires special attention [2]. Therefore for providing of corresponding level of power supply, reconstruction of electrical networks and electric equipment restoration is necessary.

Because of limited resources of utility companies there is a problem of rational distribution of financial resources for choosing the priority objects of reconstruction and equipment restoration. Decision making concerning measures which are financed should be based on data about functioning quality of power supply sector. Functioning quality of distributive electrical network is set of properties which determine its ability to supply consumers with qualitative electric power [3].

Considerable volume of work to be realized for restoration of network sector is impossible to perform without limitation of power supply of consumers. As distributive networks are mainly of radial type it is necessary to provide variants of additional supply points in case of cut-off. It is possible to realize due to certain functional redundancy in the structure of networks. To solve this problem is possible, after estimation of functional quality of "adjacent" feeders in case of their usage for the supply of the consumers.

The purpose of this paper is construction of the algorithm of additional supply variants estimation on the basis of their comparison by quality functioning criterion.

Criterial model of functioning quality of distributive electrical network

The criterial model obtained on the basis of combining Markov processes theory and criterial method is offered in [3]. General view of criterial model is the following:

$$E = \sum_{i=1}^{m} P_i \prod_{j=1}^{n} x_{*j}^{\nu_{ji}}, \qquad (1)$$

where P_i – similarity criterion which in this case is probability of system stay in state *i* (component, taking into account the reliability of the system); $\prod_{j=1}^{n} x_{*j}^{\nu_{ji}}$ – efficiency index of state *i* (component, taking into account quality of power); x_{*j} – independent parameters which characterize basic properties of system (probability of correspondence of electric power quality indexes to standard documents).

For estimation of functioning quality of distributive electrical network the criterial model will

have the following form:

$$E = \sum_{i=1}^{n} P_i \cdot \frac{1}{P_i\left[A_{min} \le A \le A_{max}\right]^{\nu_{ii}}} \prod_{\substack{j=1 \\ j \ne i}}^{n} P_j\left[A_{min} \le A \le A_{max}\right]^{\nu_{ji}} - \\ - \sum_{i=n+1}^{m} P_i \prod_{j=1}^{n} P_j\left[A_{min} \le A \le A_{max}\right]^{\nu_{ji}}, \quad (2)$$

where m – is total amount of possible states of distributive electrical network, $m=n+k$; n – is amount of operating states; k – is amount of non- operating states; $P_j\left[A_{min} \le A \le A_{max}\right]$ – is probability that quality index of electric energy A is in admissible limits thus, that system is in state j; A – is the value of quality index of electric energy; ν^{ji} – are elements of transitions matrix which are algebraic sums of failures rate λ and restorations rate μ.

For determination of probability of system stay in state i P_i the Markov processes theory [4] is used. Their disadvantage is significant amount of possible states of system which is determined as 2^r where r – is the amount of system elements. Having used elaborations in [5] hierarchical Markov networks and in [6] formulas for determination of failures rate and restorations of groups elements, amount of states can be decreased considerably. Thus error is minor and technique can be used for engineering calculations. General view of state graph taking into account simplifications is presented in Fig. 1.

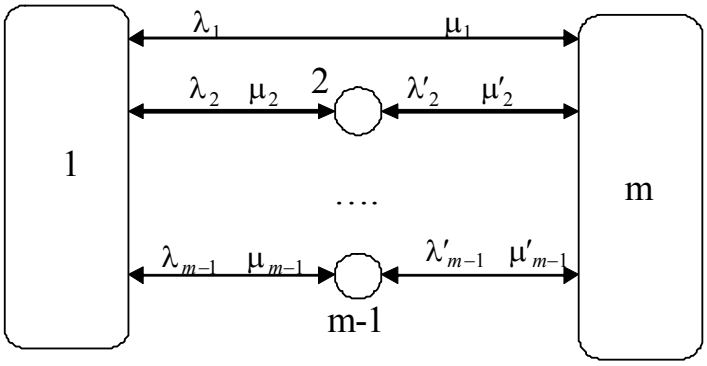

Fig. 1. General view of state graph of distribution network without taking into account switching equipment and relay devices

Probability of correspondence to ГОСТ 13109-97(State Standard) of voltage deviations by technique stated in [7] is determined for account of power quality.

Algorithm of estimation of variants of feeder consumers supply is presented in Fig. 2.

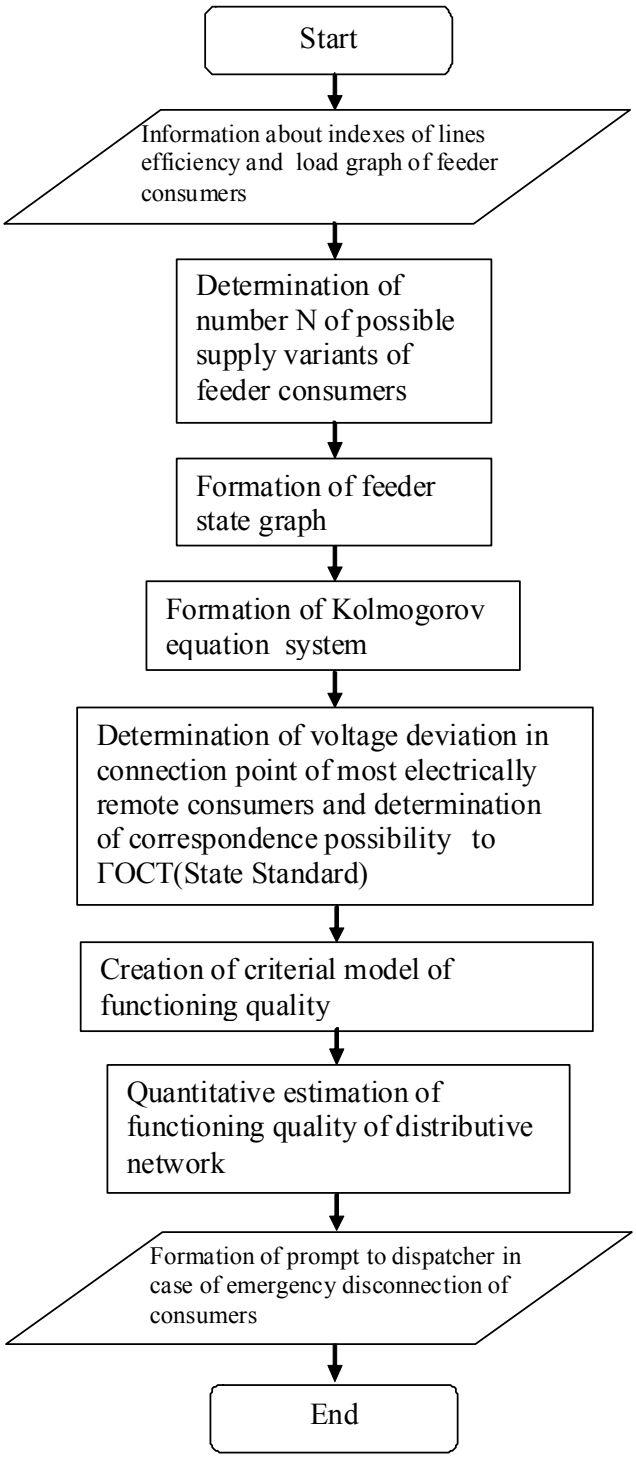

Fig. 2. Algorithm of estimation of supply variants of feeder consumers

Estimation of consumers supply variants by functioning quality criterion

For illustration we use the circuit, shown in Fig. 3. Quality estimation of this system we will perform taking into account voltage deviation in supply node of most electrically remote consumer TS-457.

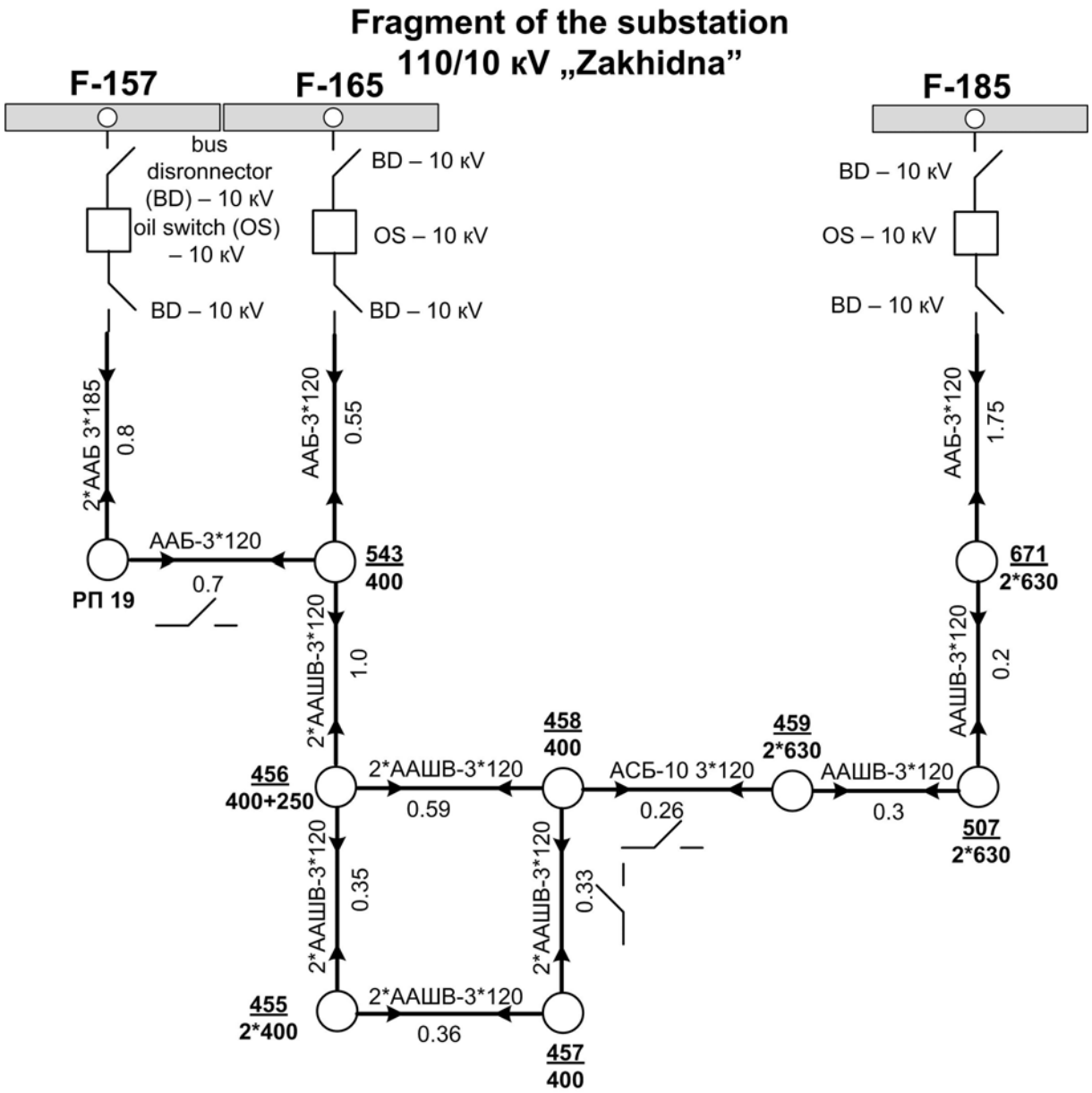

Fig.3. Diagram of feeder 165 with possible supply variants from feeders 157 and 185

Initial data for calculation of functioning quality are given in Table 1.

Table 1

Initial data

	λ (1/year)	μ (1/year)
Cable line	0,0122/km÷7/km	292

While performing calculations reliability of switching equipment and relay protection was not considered. Assumptions regarding simultaneous change of specific value of probability of failures λ for all network sections is accepted.

Calculation results of functioning quality without taking into account power quality are shown in Fig. 4. Analyzing it we can make conclusions about efficiency level at supply from feeder 165 (curve 1) and feeder 157 (curve 2) and from feeder 185 (curve 3).

By the results of calculation (see Fig. 5) which is given taking into account quality of power (voltage deviation), we can see considerable dependence of functioning quality on quality of power.

Depending on criterion of functioning quality sequence is the following: feeder 165 (curve 1); feeder 157 (curve 2); feeder 185 (curve 3).

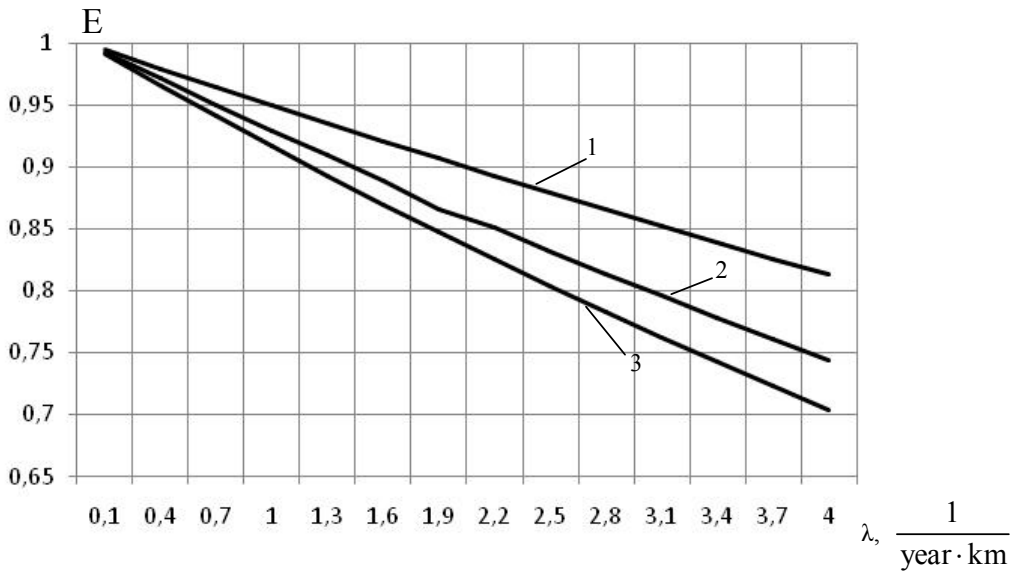

Fig.4.Variation of functioning quality of different supply variants without taking into account quality of power

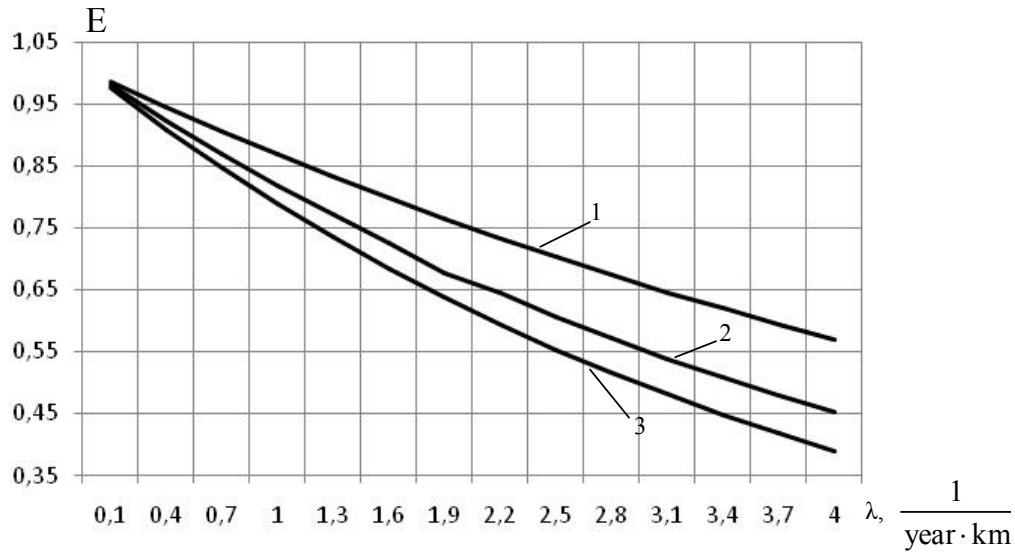

Fig.5.Variation of functioning quality of different supply variants taking into account quality of power

Analysis of computation results shows, that while restoration operations on principal section of feeder 165, consumers should be connected to DU-19 of feeder 157. However, accounting real variation of reliability indexes of considered feeders the feeder 185 can be better.

Conclusions

The obtained criterial model allows to evaluate numerically the quality of functioning of distributive electrical network. Estimation is performed relatively "ideal" system, therefore comparison of different variants of electric-power systems can be carried out without determination of technical-and-economic indexes. Using the obtained results we can elaborate stage-by-stage reconstruction plan of distributive electrical networks which is necessary in case of switch over to electric heating.

REFERENCES

1. Надійне та безпечне електропостачання, розвиток електромереж – під контролем Держенергонагляду [Електронний ресурс] 12 липня 2007. Режим доступу: http://www.ukrenergo.energy.gov.ua/ukrenergo/control/uk/publish/article?art_id=54905&cat_id=35981

2. Ключко В. П. К вопросу о разработке схем развития распределительных электрических сетей энергоснабжающих компаний / В. П. Ключко // Новини енергетики. – 2008. – № 6. – С. 28 – 33.

3. Критерій оцінки якості функціонування розподільних мереж [Електронний ресурс] / Лежнюк П. Д., Комар В. О., Кравцов К. І. // Наукові праці Вінницького національного технічного університету. – № 3. – 2008. Режим доступу до журн.: http://www.nbuv.gov.ua/e-journals/VNTU/2008-3.files/uk/ 08pdlodn_ua.pdf

4. Аналіз якості функціонування складних систем за допомогою критеріальних моделей [Електронний ресурс] / Комар В. О., Тептя В. В. // Наукові праці ВНТУ. – 2007. – №1. Режим доступу до журн.: http://www.nbuv.gov.ua/e-journals/VNTU/2007-1/ukr/07kvoocm.pdf

5. Distribution System Reliability Assessment Using Hierarchical Markov Modeling / Brown R. E., Gupta S., Christie R. D., Venkata S. S., Fletcher R. // IEEE Transactions on Power Delivery, Vol. 11, № 4, October 1996. – P. 1929 – 1934.

6. Биллинтон Р. Оценка надежности электроэнергетических систем / Биллинтон Р., Аллам Р.; пер. с англ. В. А. Туфанова; под ред. Ю. А. Фокина. – М.: Энергоатомиздат, 1988. – 288 с.

7. Кількісна оцінка якості функціонування розподільної електричної мережі за допомогою критеріальної моделі [Електронний ресурс] / Лежнюк П. Д., Лагутін В. М., Комар В. О // Наукові праці Вінницького національного технічного університету. – № 4. – 2008. Режим доступу до журн.: http://www.nbuv.gov.ua/e-journals/VNTU/2008-4.files/uk/ 08pdlhcm_ua.pdf

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