АВТОМАТИЗАЦІЯ ТА КОМП'ЮТЕРНО-ІНТЕГРОВАНІ ТЕХНОЛОГІЇ

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Procedure for reliability assessment of electricity distribution systems

The main objective of this study is to establish the level of reliability of electricity distribution systems, which is currently characterized by multiple problems, because, at present, these systems have a complex configuration and are affected by a significant number of refusals, conditioned by various influencing factors. To achieve the proposed objective, the most important indicators were selected, which allow estimating the level of reliability of electricity distribution systems, regardless of structure and configuration. The main results obtained are those related to the application of the proposed reliability assessment procedure for estimating reliability indicators, which are of significant importance for the operation of electricity distribution systems, thus providing the possibility of justified planning of measures to prevent refusals and increase the level of reliability of the examined systems.
reliability indicators, electrical distribution systems, level of reliability, assessment procedure

Introduction. At the current stage, the question of the reliability of the operation of distribution systems is the key issue, to which particular attention must be paid. The reliability of such a system is closely related to its structure and differs from case to case. The safety in operation of a distribution system is an integral characteristic, determined by its components, its design and the operating conditions. At the same time, the operation of distribution systems in the agricultural sector is influenced by a number of factors, both determined and undetermined. These factors are random in nature and their occurrence may be internal or external, objective or subjective. Many researchers in the field have tried to solve these problems, but so far they have not been solved completely and definitively, and the main problem is still being addressed by researchers [1-3].

The electrical distribution systems are currently complex systems that are continuously developing. This is explained by the fact that, due to contemporary socio-economic demands, an increasing number of new electricity consumers are emerging and this leads to the emergence of more load nodes, and the structural schemes of distribution systems are becoming increasingly complex. It is clear that this is beneficial in the development of the agricultural sector, but with it come new requirements and problems in ensuring the reliability of distribution systems.

The continuing increase in the number of components of structural schemes makes the risk of faults and interruptions in the supply of electricity to consumer's increase, causing serious problems [4-10]. Assuring the level of reliability gives the opportunity to bring the mathematical expectation of outages and damage to an acceptable value for both electricity consumers and distribution systems. It is clear that this follows from the determination of the influencing factors, which cause the occurrence of random interruptions, in order to reduce their significant number and ensure the normalized level of reliability.

Materials and methods. In this study, for the solution of the problems formulated for the research, the electrical distribution systems were examined, and the research methodology is based on standard methods of analysis and calculation. The main characteristics of the electrical distribution systems researched are presented in Table 1.

Table 1 – The characteristics of the electrical distribution systems researched

Sector	**The total length of electrical lines, *km***	**Total number of consumers supplied, *consumers***
1	2478	28231
2	3843	42487
3	4156	36128
4	2114	41236
5	2894	23173

Source: developed by the author

Have been used in the study: mathematical modelling; graph and matrix theory; probability theory; methods of statistical analysis and processing of experimental data; theory of linear and non-linear equations; calculation techniques with specialized software, "Microsoft Excel", "EasyFit 5.5 Professional".

Results and discussions. The final result is the calculation of the refusal probability of the analyzed system with respect to the load node, or the probability of operation without refusal (p) (the probability of the diametrically opposite event).

When presenting the scheme in the form of minimum sections the given process can be achieved faster and simpler compared to the presentation of the respective scheme in the form of a minimum graph, but from what has been presented it appears that the process of determining the minimum sections itself is more complex and difficult. The reliability of supply to the load nodes (receivers) of complex schemes is determined by refusals occurring not only in normal operation, but also during planned preventive disconnections of distribution system elements (most often in the process of carrying out planned disconnections for prophylaxis or routine or capital repairs).

The order of the calculation of reliability indicators taking into account the determined preventive planned disconnections is as follows:

- groups of elements are sized, preventive disconnection of which can be overlapped, so elements most often are with series connection between them and disconnection of one of these elements leads to the occurrence of rejection of the respective graph, as such elements can be those with series connection;
- for such cases the planned reliability indicators of these schemes are determined.

Thus for a group of (ρ) real elements with disconnection frequencies $1/\lambda_i, 1/\lambda_2, ..., 1/\lambda_n$ or operating times $T_1, T_2 ..., T_n$ the lowest common multiple $\lambda_1, \lambda_2, ..., \lambda_n$ and the smallest time interval in which an integer number of planned disconnections of each component element T. From the group of elements, choose the element (i) which has a

maximum preventive disconnection time λ_i . The parameter of the flow of planned disconnections (λ) and their average probability [5-10] for the equivalent element (j) will be determined for the analyzed systems.

The analytically obtained reliability indicators of the equivalent element of the investigated scheme are aligned to an integral element of that scheme and all other component elements are given null (0) indicators.

The problem of creating these states often arises in the process of analytical calculation of project schemes, when the schedule of planned disconnections and current repairs of component elements is not known.

In the process of composing the preventive disconnection groups of the component elements the presented relation will be respected, then it means, that the determined time period in the analyzed system will lack states having disconnected elements with a determined preventive planning.

From the above, it appears that the smaller the size of the distribution system under analysis, the higher the probability of the respective states.

In general, considering preventive planned disconnections of component elements of distribution systems [1-8], the probabilities of refusal states can be related to the load node (receiver) and the refusal flow parameter of the respective scheme with respect to the load node, which is determined for the analyzed systems.

The minimal sections in the scheme of the system remaining after excluding element (j) from the searched scheme will be obtained from the sections of the integral scheme of the system after excluding the minimal sections.

In assessing the reliability of distribution systems, it is absolutely necessary to characterize both components, i.e. structural and operational reliability. In aim to facilitate this process, the respective operations need to be carried out according to a well-determined consecutiveness and from all this, the criterion for the assessment of the real level of reliability was composed, on the basis of which the reliability analysis of the investigated systems was carried out.

Therefore, in consideration of the above, in order to simplify the reliability assessment process, the reliability level of distribution systems in the agricultural sector has been assessed on the basis of the following indicators: average duration of refusals (τ); average frequency of occurrence of refusals (λ); average time to restore refusals (μ); average total refusal time (T_{med}). Table 2 shows the reliability indicators of the researched systems, determined on the basis of the developed criterion, for the year 2023.

Table 2 – Reliability indicator values of the systems researched

Indicator	**Seasonal values**			
	Spring	**Summer**	**Autumn**	**Winter**
τ, h	0,89	1,09	1,07	1,12
λ	3,02	2,67	3,01	2,69
μ, h	0,91	1,21	1,15	1,27
Tmed, h	3,84	3,63	3,72	3,69

Source: developed by the author

From the results it appears that the determined indicators differ from one system to another due to several factors, such as:

- specific geographical location conditions;
- the number of agricultural consumers supplied with electricity,
- the summary length of power lines in the systems;
- the configurations and structure graphs of the systems;
- the number and condition of component parts.

Conclusions. Based on the study conducted, it was found that in the process of assessing the reliability of electrical distribution systems, it is absolutely necessary to classify and systematize interruptions in the supply of electricity to consumers, caused by various influencing factors, depending on the season and geographical location of the distribution systems. The results directly depend on the structure of the systems and for this reason it is absolutely necessary to perform calculations, determine the minimum sections and layout graphs of the distribution system, in relation to the component elements.

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Порядок оцінки надійності систем розподілу електроенергії

Основною метою даного дослідження є встановлення рівня надійності систем розподілу електроенергії, який на даний час характеризується множинними проблемами, оскільки в даний час ці системи мають складну конфігурацію та зазнають впливу значної кількості відмов, зумовлених різними факторами впливу.

Для досягнення поставленої мети було обрано найбільш важливі показники, які дозволяють оцінити рівень надійності систем розподілу електроенергії незалежно від структури та конфігурації. Основними отриманими результатами є ті, що пов'язані із застосуванням запропонованої методики оцінки надійності для оцінювання показників надійності, які мають суттєве значення для функціонування систем розподілу електричної енергії, що забезпечує можливість обґрунтованого планування заходів щодо запобігання відмовам та підвищення рівня надійності досліджуваних систем. З метою спрощення процесу оцінки надійності, рівень надійності систем розподілу в аграрному секторі було оцінено на основі таких показників, як: середня тривалість відмов (τ); середня частота виникнення відмов (λ); середній час відновлення відмов (μ); середній сумарний час відмов (T_{med}). Визначені показники відрізняються від системи до системи через декілька факторів, таких як: специфічні умови географічного розташування, кількість сільськогосподарських споживачів, що забезпечуються електроенергією, сумарна довжина ліній електропередачі в системах, конфігурації та структурні схеми систем та кількість та стан складових частин.

На основі проведеного дослідження було встановлено, що в процесі оцінки надійності систем розподілу електроенергії абсолютно необхідною є класифікація та систематизація перерв у постачанні електроенергії споживачам, спричинених різними факторами впливу, в залежності від пори року та географічного розташування розподільчих систем.

показники надійності, системи розподілу електроенергії, рівень надійності, методика оцінювання

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