OPTIMIZATION OF TELECOMMUNICATIONS POWER SUPPLY SYSTEMS BASED ON RELIABILITY CRITERIA

Qodirov Fazliddin Misliddinovich
The leading specialist of the Department of Educational Organization of the University of Management and Future Technologies

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Abstract. *This article presents the optimization of power supply systems in which telecommunication systems are used based on reliability criteria. Parametric-structural analysis was carried out in the optimization of telecommunications power supply systems. Morphological approaches have been developed in optimization.*

Keywords*: electrical energy quality, technical and technological systems, reliability, uninterruptible and guaranteed power supply systems, power supply of the enterprise, reliability indicators, double conversion, autonomous (backup) power supply systems*

Introduction. The current stage of development of technical and technological systems is characterized, in particular, by increasing the requirements of responsible consumers for the quality of electrical energy, reliability and uninterrupted power supply. Responsible consumers are understood as consumers whose power supply disruption leads to the failure of the facility to perform its functions. At present, the problem of ensuring a given level of reliability in the electric power industry of the Republic of Uzbekistan has not been resolved, which leads to a significant increase in the role of autonomous (backup) power supply systems, as well as uninterrupted and guaranteed power supply systems. This necessitates the development of new approaches to the construction of such systems using modern equipment with increased reliability, as well as environmental and technological safety [4].

An integral part of modern autonomous energy complexes are uninterruptible power supply systems (UPS). Such a system is an electrical installation that is designed to provide autonomous power supply to consumers in cases where the quality indicators of electrical energy supplied from the main sources deviate beyond acceptable values. The main functional element of an UPS, which determines its effectiveness, is an uninterruptible power supply (UPS).

To build UPS for responsible consumers, UPS of various types can be used, both static (double conversion) and dynamic (diesel rotary, hybrid, flywheel). The choice of double conversion UPS when constructing the UPS considered in the article is due to a number of their advantages compared to dynamic ones, primarily in terms of reliability [2-5].

With the transition of industrial equipment to digital and information technologies, the requirements for the quality of electrical energy conversion are increasing. To save money on modernizing industrial facilities, it is sufficient to carry out a partial replacement of electrical equipment while maintaining the existing grounding scheme, ventilation system and electrical network structure. When implementing such a project, structural and parametric optimization is carried out.

Formulation of the problem. Reliability indicators depend on the category of power supply of the enterprise. There are three categories of power supply depending on the requirements for reliability and troubleshooting time, while in the first category there is a special group, which includes all the equipment of critical consumers. In this group, it is accepted that the energy system provides the consumer with no more than two sources of power supply, that is, connection provided to no more than two electrical substations; other energy sources are not its objects, but belong to the UPS. The reliability of the UPS includes reliability, durability, maintainability and storage. Quantitative indicators of the reliability of the UPS include: the probability of failure-free operation for a certain time P(t), the average time of failure-free operation T_0 and the availability coefficient K_a. These indicators depend on the probabilistic characteristics of the UPS [8].

To search for the global minimum $\overline{V_{UPS}}$ using the algorithm, it is necessary to calculate the reliability indicators of the synthesized UPS for the selected options. For this purpose, a calculation method has been developed using the method of graphically displaying UPS faults.

Acceptable values of reliability indicators are limited by state, industry and international standards, where the average time between failures (T_0) must be at least 10^6 hours for UPS with AB, the average recovery time (T_r) is no more than 0.5 hours. Ensuring reliable operation of UPS is achieved in various ways circuit designs and the use of special equipment (grounding systems, protection systems, ventilation and air conditioning systems, etc.).

The development and complexity of equipment, including electric power systems, and the variety of architectures of the latter, make it difficult to analyze and assess the reliability indicators of fault-tolerant electric power systems in particular. One reason is the use of "hot standby", where it is difficult to estimate a reasonable number of redundant elements, as well as the failure of significant non-redundant components, which requires replacement of the entire system.

The fault tolerance of the power supply system means the supply of uninterruptible (guaranteed) power with certain quality parameters of the supply voltages. The fault tolerance of the system is directly determined by its operational readiness, which depends on the implementation of planned and repair work. In practice, the decisive factor is the duration of the interruption in the supply of electricity to consumers, therefore, when supplying power to the equipment of an industrial facility, the operational readiness of the power supply system must be higher than the operational readiness of the facility's devices.

According to standards, a quantitative characteristic of reliability is the average time between failures - MTBE (T_o); average downtime - MDT; average operating time - MUT; failure rate - λ; recovery intensity $\mu(\frac{1}{T_r})$. According to [9], the degree of equipment readiness (A) and the reliability (P) of the UPS are determined by the expressions: $A = \frac{MUT}{(MUT+MDT)}$, $P = e^{-\lambda t}$, where t is the time interval at which the reliability is determined. To increase the accuracy of forecasting when assessing the reliability indicators of UPS taking into account subjective errors, it is proposed to use a graphical display of combinations of certain types of violations. The fault tree analysis method was first used in 1962 by Bell Labs for the US Air Force. Later it began to be used to analyze the causes of failures when assessing reliability indicators. To build a fault tree of the synthesized power supply system (Figure 2.5), we highlight the weakest points where the slightest malfunction can lead to unacceptable consequences in the system.

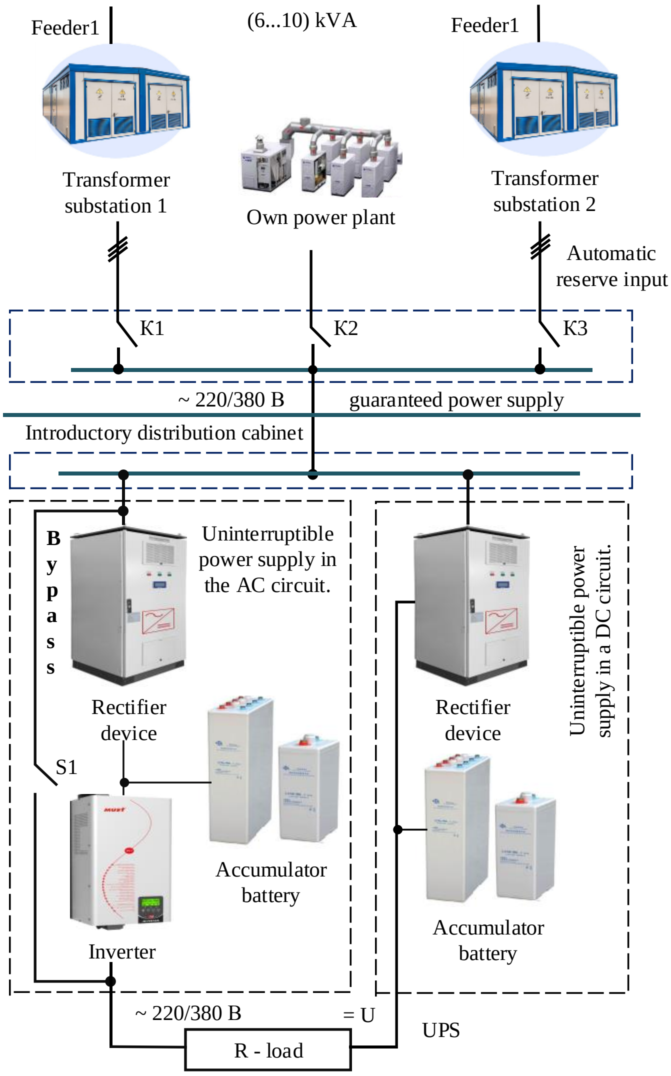

Fig.2.5 - Structural diagram of the synthesized power supply system.

The process of identifying possible system faults, the consequences caused by them and their sorting are partially described in the TEC 812 standard [10]. All faults are assessed by the likelihood of their occurrence and the severity of the consequences for the UPS. Displaying events that can cause certain types of violations in the form of a fault tree will allow you to find the probability of a malfunction or unavailability of the system in hours per year and determine the possible causes of this failure. Violations and the reasons for their occurrence, which are associated with the main event through logical transitions AND/OR, are taken into account. Moreover, all possible options for previous events before the occurrence of the main violation are considered (Figure 2.6).

With a guaranteed power supply, the main events include a power failure at the output of the automatic transfer switch, and the preceding failure at the transformer substation, breakdown of the transformer, failure of the solar cell, etc. Faults located in the lower level of the tree are human errors during installation work, or a malfunction of poor-quality manufacturing of UPS components or parts. In this case, you should use statistical information about possible damage and how to eliminate it. When analyzing a fault tree, a minimum set of combinations is formed, starting with the main events that lead to a failure in the system. Each such set has a significance scale as a percentage of the total unavailability at the ATS output. Fault tree diagrams are very convenient for analyzing complex technical systems.

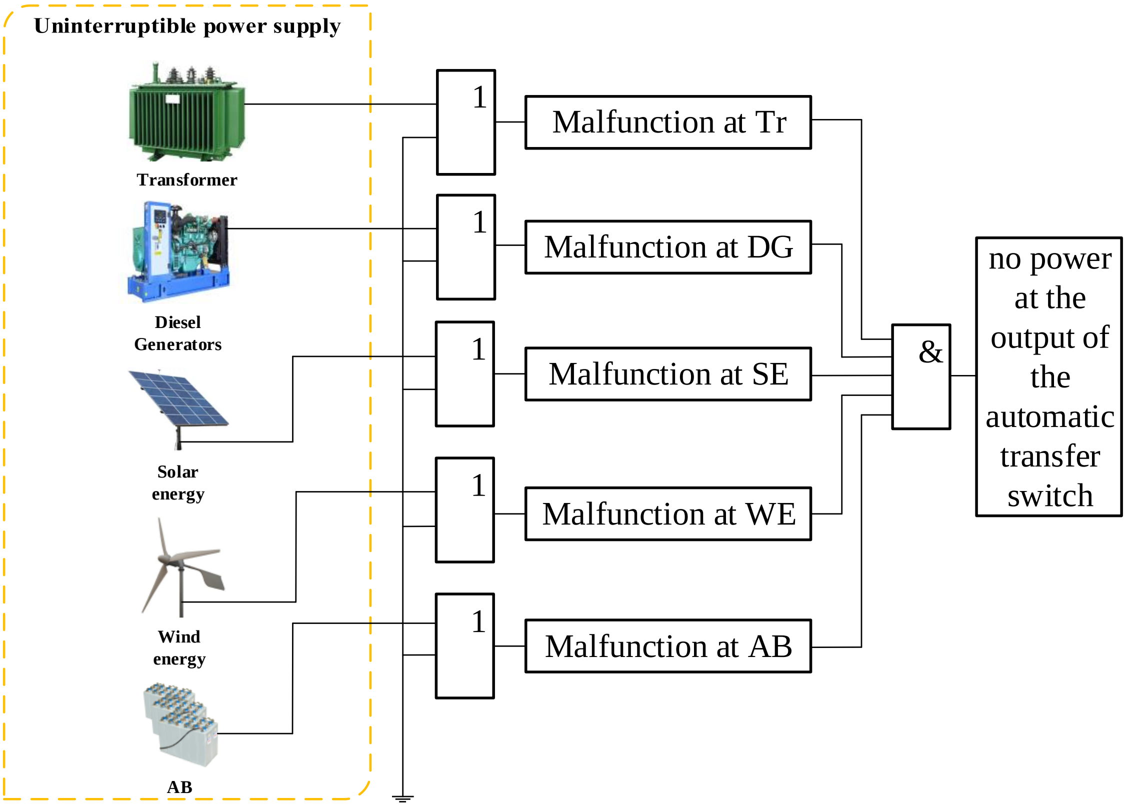

Fig.2.6 - Fault tree.

They make it easy to determine reliability indicators of systems, and especially those for which repair time is not as important as the malfunction itself. The structure of the fault tree determines the logical relationship of blocks and components, and therefore, faults in the UPS.

Table 2.8 - Expressions for calculating reliability indicators

Tree structure	P, where the failure rates of the main and backup elements are different	A, where *i* is an inoperative state
Serial connection.	$exp[-(\lambda_1+\lambda_2)t]$	$\prod_{i=1,n}\mu_i/(\lambda_i+\mu_i)$
Parallel connection	$[\lambda_2\cdot\exp(-\lambda_1 t)-\lambda_1\cdot\exp(-\lambda_2 t)]/(\lambda_2-\lambda_1)$	$1-\prod_{i=1,n}\lambda_i/(\lambda_1+\mu_i)$

The elements of the tree are arranged sequentially (Figure 2.7 a), parallel (Figure 2.7 b), with transitions (Figure 2.7 d) or in the form of equal blocks (Figure 2.7 c) in the “hot standby” mode, when 1 block out of N is constantly functioning. When connecting blocks in series and parallel, reliability indicators are calculated according to the expressions in Table 2.8 [11]. Expressions for calculating the reliability indicators of other connection methods (Figure 2.7, c, d) are reduced to parallel and serial types of connections.

UPSs are constantly evolving, new architectures appear every year, the reliability of individual functional units is increasing, which makes it possible to increase reliability indicators at the stage of their design.

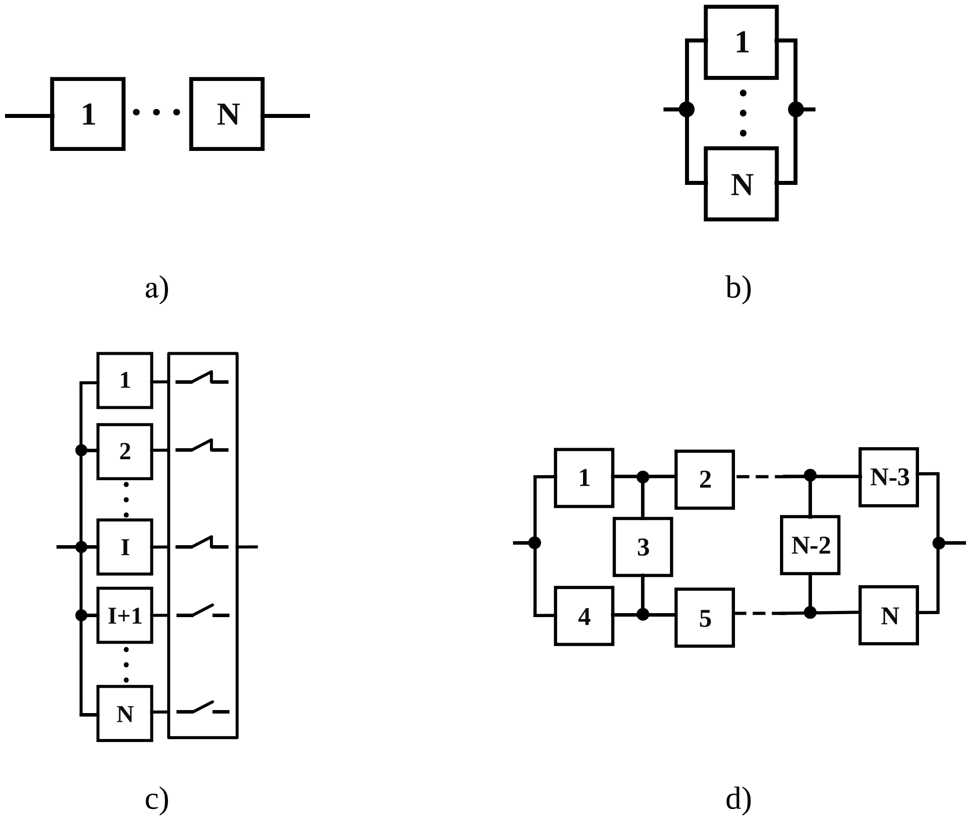

Figure 2.7 - Methods of connecting tree elements.

However, the impact of the human factor on downtime never decreases. This factor is very difficult to control.

Graphic display of combinations of events that can cause certain types of violations provides clarity and allows not only to determine the possible causes of a particular failure, but also to develop measures to effectively eliminate them in the UPS [1].

Conclusions. Optimizing the telecommunications power supply based on reliability criteria requires a number of actions.

To create a computer-aided design system for power supply systems, the following was developed: subgraphs of five levels of the hierarchical structure of power supply systems for selecting elements based on parametric and structural characteristics; routes connecting the vertices of subgraphs (elements) of different levels; external, internal and output parameters of power supply systems (all vertices of subgraphs); four-stage algorithm for the CAD power supply system:

Stage 1 - parametric optimization of the number of vertices of subgraphs at all five hierarchical levels (search for local extrema);

Stage 2 - structural-parametric optimization at all levels of the M1 micromodel, where alternative structures of the synthesized power supply system are selected and local extrema of the objective function are searched for in terms of energy, economic and reliability indicators;

Stage 3 - structural - parametric optimization taking into account all possible routes, which are determined through reachability matrices based on given adjacency matrices, where the object of synthesis is electrical networks;

Stage 4 - parametric optimization based on the results of calculating transient processes and searching for the global extremum of the target function of the power supply system.

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