ANALYSIS OF RELIABILITY OF TYPICAL POWER SUPPLY CIRCUITS

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Abstract

This article is devoted to the analysis of the reliability of typical power supply circuits. The question of what factors have the greatest impact on the reliability of power supply circuits, as well as what methods and tools are used to analyze and improve their reliability is considered. Particular attention is paid to the comparative analysis of various types of power supply schemes and the determination of their advantages and disadvantages in terms of reliability. The article also discusses current trends and developments in the field of increasing the reliability of power supply and possible ways to optimize existing circuits. The results obtained can be useful for specialists in the field of power engineering and electrical engineering in the design, maintenance and modernization of power supply systems.

Keywords: electrical power systems, reliability indicators, cross-section classes, typical circuits.

I. Introduction

In the modern world, electricity supply is a key aspect of ensuring the life of society and the functioning of its economy. The performance of industrial enterprises, the safety of residential complexes, the efficiency of vehicles and much more depend on the reliability of power supply systems. In this regard, analysis and improvement of the reliability of standard power supply circuits is a relevant and important task for specialists in the field of electrical engineering and power engineering.

The purpose of this article is to study the factors affecting the reliability of power supply circuits, as well as to develop methods and tools for their analysis and improvement. It is proposed to consider various types of power supply schemes, analyze their advantages and disadvantages from a reliability point of view, and also consider current trends and developments in the field of increasing the reliability of power supply.

It is important to note that the efficient operation of modern power supply systems requires not only technical competence, but also consideration of various factors such as climatic conditions, technological changes and energy efficiency requirements. Therefore, analysis of the reliability of typical power supply schemes has many practical applications and can become the basis for optimizing existing power supply systems and developing new, more reliable solutions.

II. Formulation of the problem

Determining reliability indicators for modern electric power systems is impossible without the use of appropriate software systems. In our country and abroad today, the following software systems are most widely used, allowing one to model and calculate probabilistic reliability indicators of electric power systems:

1. Software systems "RISK SPECTRUM" (Sweden); "SAPHIRE" (USA), using "fault trees" and "event trees" as initial data.

2. Software package "WINDCHILL RBD" (USA), using a special block diagram of system performance.

3. Domestic software complex "ARBITR" ("ASM SZMA"), using the logical-probabilistic method.

4. Software systems for modeling energy systems: "MATLAB", a software environment that allows you to simulate energy facilities and develop control systems; "ETAR SYSTEMS" (USA), software for electrical power systems, allowing for the design, analysis, and maintenance of electrical power systems; "PSCAD" (Canada), a software package that allows you to simulate the operation of power systems.

The main disadvantage of foreign-made software systems is the high cost and complexity of training personnel to study specialized software systems.

The use of complex and expensive specialized software systems is justified only in those industries where equipment failure can cause catastrophic consequences, for example, in nuclear energy. For projects in which equipment failure does not entail such serious consequences, it is possible to use proprietary software products, for example [1, 6, 8], the cost of which is not comparable with specialized ones, and the limited set of functionality is compensated by the ease of development.

III. Problem solution

Most of the main step-down substations currently being built have a simplified circuit with separators and short circuiters on the high voltage side. Refusal to install an oil or air circuit breaker saves capital and operating costs and reduces the construction time of a substation (Figure 1). Jumpers on the high voltage side increase the maneuverability of switching of dead-end substations, especially if they are equipped with a separator with a double-acting drive. At dead-end substations made in the form of a "radial line – transformer" block, separators need not be installed.

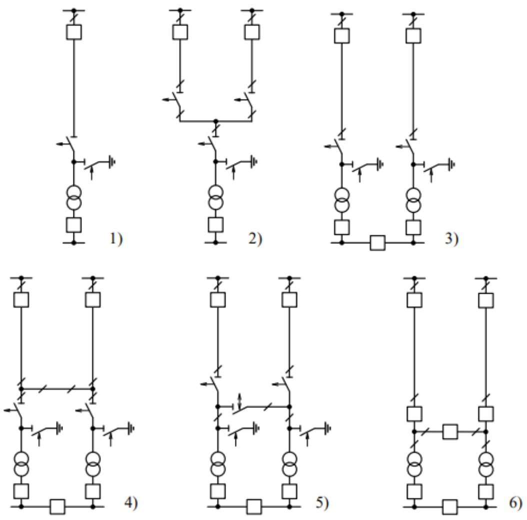

Figure 1: *Comparison of typical external power supply schemes*

During the operation of simplified substations, significant shortcomings were identified in the operation of open-type separators and short circuiters. The high response time of these devices makes it difficult to automatically reclose the main switch and contributes to the development of damage that occurs in the transformer. In addition, turning on the short circuit causes a sharp decrease in voltage at the supply substation. If an air circuit breaker with a voltage of 110–220 kV is used as a main switch, installing a short circuit in a zone of 0.5–6 km is unacceptable due to the kilometer effect. In this zone, the short-circuiter is replaced by various teletrip pulse systems while maintaining the backup function of the short-circuiter. The use of a tele-breaking pulse also avoids the reduction in voltage caused by the activation of the short circuit.

Table 1 shows reliability indicators for the circuits presented in Figure 1.

Table 1: *reliability indicators for the circuits presented in Figure 1.*

Scheme	ω_Σ, year^{-1}	n, year^{-1}	$T_{rec.}$, hour	$K_{rec.}$, p.u.	Conclusion
1	0.401	0.3048	12.5	$5.7 \cdot 10^{-4}$	Best by ω_Σ
2	0.793	0.1160	14.4	$1.8 \cdot 10^{-4}$	-
3	0.802	0.0154	12.0	$0.21 \cdot 10^{-4}$	Best by n
4	0.804	0.0164	10.3	$0.19 \cdot 10^{-4}$	-
5	0.823	0.1660	11.6	$0.22 \cdot 10^{-4}$	-
6	0.758	0.0250	5.6	$0.16 \cdot 10^{-4}$	Best by $T_{rec.}$ and $K_{rec.}$

Analysis of Table 1 allows us to draw the following conclusions. As the number of equipment in the circuit increases, the total failure flow parameter ω_Σ increases. From the point of view of uninterrupted power supply (number of outages n), the most effective is scheme 3. Scheme 6 turns out to be the best in terms of recovery time and emergency downtime coefficient, however, it is approximately 10 times more expensive than the most complex of the simplified schemes - scheme 5. Dead-end substations made according to schemes 3, 4 and 5, are close to the optimal solution both from the point of view of uninterruption and efficiency.

Taking reliability into account when planning the development of power supply systems (PSS) of industrial enterprises (IEs) and when designing its individual links, as well as in operating conditions, is to ensure optimal reliability of power supply to consumers, taking into account the known reliability of system elements.

The main directions for increasing the reliability of power supply to consumers include:

- Creation of rational power supply schemes with an increased degree of reliability.
- Increasing the reliability of PSS elements.
- Improvement or implementation of electrical automation devices and the use of telemechanics.
- Improving the operational maintenance of solar power plants.
- Application of monitoring the technical condition of solar power plant equipment.

In addition to the listed areas, the reliability of PSS is influenced by the following factors:

- Quality of electrical energy.
- Correct choice of neutral mode of electrical networks.
- Optimization of short circuit currents.

Development of rational power supply schemes

The development of efficient power supply schemes is a critical aspect in the planning and operation of energy systems. Optimization of these schemes is aimed at ensuring an uninterrupted and reliable supply of electrical energy to consumers while minimizing economic costs and maximizing operational efficiency. The main parameters that are taken into account when developing circuits are the reliability of system elements, their interaction, as well as possible operating modes in emergency situations.

A critical step in developing sustainable power supply designs is risk assessment and failure analysis of system components. The use of modern modeling and simulation methods makes it possible to predict the behavior of the system in various operational scenarios and minimize the likelihood of failures. This takes into account statistical data on the reliability of components, test and operation results of similar systems, as well as requirements for the quality of power supply.

One of the key areas for optimizing power supply schemes is increasing the degree of redundancy and introducing fault-tolerant technologies. This includes the use of backup lines, automatic transfer switches and intelligent control systems that ensure rapid restoration of power in the event of a major equipment failure. In addition, the use of telemechanical systems and electrical automation devices makes it possible to quickly identify and eliminate faults, which significantly reduces downtime and increases the overall reliability of the system.

Sustainable electricity supply schemes must also take into account economic aspects. This involves analyzing the costs of installing and maintaining equipment, as well as assessing the cost-effectiveness of various circuit options. An important factor is the selection of equipment with an optimal balance of cost and reliability, which allows for a high level of power supply at an acceptable cost.

Increasing the reliability of PSS elements

Increasing the reliability of elements of power supply systems (PSS) is one of the key tasks in the planning and operation of energy systems. The high reliability of individual components can significantly reduce the frequency of emergency situations and ensure a stable power supply to consumers.

One of the main approaches to increasing the reliability of SES elements is the use of high-quality equipment with high performance characteristics. This includes selecting equipment from trusted manufacturers, undergoing rigorous testing and certification, and regularly updating and upgrading obsolete components. The use of innovative materials and technologies, such as intelligent control and monitoring systems, also helps improve reliability indicators.

Regular maintenance and preventive measures play an important role in maintaining the reliability of PSS elements. Routine inspections, diagnostics and replacement of worn parts allow potential problems to be identified and corrected before they develop into serious accidents. The introduction of systems for monitoring the technical condition of equipment, such as vibration sensors, temperature sensors and other parameters, allows you to quickly obtain data on the condition of elements and take measures to maintain them.

Another important aspect is the advanced training and training of personnel responsible for the operation and maintenance of solar power plants. Qualified specialists are able to quickly respond to emerging problems, carry out necessary repairs and ensure correct operation of the equipment. Organizing regular trainings, seminars and advanced training courses helps improve the professional skills and knowledge of employees.

The development of normative and methodological documents regulating the operation and maintenance of solar power plant elements is also important. Standardization of procedures, compliance with technical regulations and recommendations for the operation of equipment make it possible to ensure a uniform level of quality and reliability in all parts of the power supply system.

Application of relay protection and automation devices

The use of relay protection and automation devices plays a key role in modern power supply systems, ensuring the reliability, safety and efficiency of their operation. These technologies are designed to quickly identify and isolate faults in electrical networks, minimize downtime and prevent possible equipment damage. Relay protection provides protection against overloads, short circuits and other anomalies, automatically disconnecting damaged sections of the network to prevent the spread of emergency situations.

Automation devices, in turn, carry out automatic control of power supply, including automatic restart after short-term outages (AR) and automatic switching to backup power supplies

(APS) in the event of failure of the main equipment. This significantly reduces downtime and ensures continuity of power supply for consumers.

Integration of relay protection and automation into power supply control systems allows not only to increase its reliability, but also to significantly improve controllability and operational safety. The use of modern technologies in this area is a prerequisite for the efficient functioning of modern energy systems, where every minute of downtime can have significant economic and social consequences.

Factors influencing the reliability of power supply systems (PSS)

The reliability of power supply systems (PSS) is determined by many factors that affect their ability to provide uninterrupted power supply to consumers. The main aspects affecting the reliability of solar power systems include technical, operational, organizational and economic factors.

Among the technical aspects, the quality and condition of the equipment plays a key role. The choice of modern and reliable technologies, the correct power supply scheme and the use of modern protective devices and automation significantly influence the degree of protection of the system from emergency situations. Regular maintenance and condition checks of equipment also play an important role in preventing possible failures.

Operational aspects include operating mode management, technical condition monitoring and personnel qualifications. Trained and qualified personnel are able to effectively manage the system and quickly respond to possible problems.

Organizational aspects include compliance with standards, risk management and optimization of management and operational processes. Economic factors also play a role: investments in modernization and renewal of equipment help to increase the reliability of solar power plants while optimizing operating costs.

All these aspects are interconnected and require an integrated approach to achieve high reliability indicators. Only systematic management of all factors can ensure stable and efficient operation of power supply systems in the context of modern technological and economic challenges.

IV. Conclusions

Electrical power systems are vital infrastructure that ensures the continued functioning of industrial plants, commercial properties and residential areas. The reliability of these systems plays a critical role in ensuring the stability and security of energy supply for millions of consumers.

An optimal power supply scheme, the use of modern relay protection and automation technologies, as well as an integrated approach to the management and operation of equipment significantly affect the reliability of the system. Effective operating mode management, regular maintenance and qualified personnel are key to minimizing risks and preventing downtime.

Uninterrupted power supply is necessary not only for economic stability, but also to ensure the comfort and safety of people's lives. Investments in modern technologies and continuous improvement of electricity supply systems are strategic priorities that contribute to improving the quality of life and sustainable development of society.

Only an integrated approach to the management, maintenance and modernization of power supply systems allows us to achieve high standards of reliability and ensure sustainable operation in the conditions of modern dynamic economy and technological challenges..

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