

have reservoirs that are usually daily regulated, are mainly determined by the transit flow of the Nurek HPP. With this ratio, the regulating capacity of these HPPs in the energy system is extremely small.

Therefore, in winter, the limited flow of water in the rivers results in a electricity deficit in covering the load demand. Thus, at present, the magnitude of this winter deficit for the Tajikistan energy system is 2 - 4 billion kWh [2]. The Tajikistan energy system has a surplus of 3 to 7.5 billion kWh of electricity in summer, depending on the water availability of the year. Due to the isolated operation of Tajikistan's energy system, this surplus is not exported to neighbouring countries, so huge amounts of water are wasted.

Due to the aforementioned characteristics of HPPs operation, there are a number of peculiarities in the operation of the Tajikistan energy system, which includes a large number of such generating sources. As HPPs are currently the only renewable energy source in Tajikistan's energy system capable of generating electricity on an industrial scale, there is a need to make the best possible use of their hydrological potential. In order to achieve this objective, it is necessary to clearly plan electricity generation, optimise planned electrical and hydraulic regimes, and solve the issue of correct control of the power system, incorporating both stand-alone and cascade operation of HPPs.

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## APPLICATION OF DIGSILENT POWERFACTORY SOFTWARE AND COMPUTING COMPLEX FOR RELIABILITY ANALYSIS OF ELECTRICAL NETWORKS

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The reliability of any power supply company and the quality of the power supply to consumers depend on the technical condition of the equipment that ensures the transmission of electrical energy. Every year, the percentage of equipment in the world that has a working life that is reaching the end of its useful life increases, but it

is not always possible to renew it. In this connection, the energy industry faces the task of assessing the technical condition of power network equipment and determining the composition of equipment that requires repair and modernisation in the first place. In order to effectively solve this task, it is necessary to analyse the reliability of electricity networks, which is an important and actual task.

A large number of software packages such as Energy CS, RastrWin, PSS®E, EUROSTAG, NEPLAN, DIgSILENT PowerFactory and others are used to carry out studies to calculate and analyse the reliability of electrical networks worldwide [1]. Comparison of the results of calculations indicates different accuracy and simplification, which are used in the algorithms of these software and computing complexes [2].

Today, the software and computing complex DIgSILENT PowerFactory is actively used for research, as it is the most accurate and makes it possible to determine 15 reliability indicators for electrical networks and load units [3], among which: SAIFI (System Average Interruption Frequency Index), CAIFI (Customer Average Interruption Frequency Index), SAIDI (System Average Interruption Duration Index), CAIDI (Customer Average Interruption Duration Index), ASAI (Average Service Availability Index), ASUI (Average Service Unavailability Index), ENS (Energy Not Supplied), AENS (Average Energy Not Supplied), ACCI (Average Customer Curtailment Index), EIC (Expected Interruption Cost), IEAR (Interrupted Energy Assessment Rate), SES (System energy shed), ASIFI (Average System Interruption Frequency Index), ASIDI (Average System Interruption Duration Index), MAIFI (Momentary Average Interruption Frequency Index). The advantages of the software and computing complex DIgSILENT PowerFactory include a user-friendly interface and presentation of the calculation results (Fig. 1).

The reliability analysis in this software and computing complex is based on the following parameters: failure frequency, repair duration and frequency of unstable damage. The reliability indicators are defined using analytical and statistical expressions according to [4], the expressions for reliability indicators calculation and their main characteristics are presented in Table 1.

In Table 1  $C_i$  – number of consumers powered by the  $i$ -th load node;  $A_i$  – number of users of the  $i$ -th load node affected by a power outage;  $Fr_k$  – frequency of emergency situation  $k$ ;  $pr_k$  – probability of occurrence of an emergency situation  $k$ ;  $C$  – number of customers;  $A$  – number of consumers affected by a power outage;  $L_m$  – total deenergized connected capacity (kVA), for each power interruption  $m$ ;  $r_m$  – the duration of each interruption of power supply,  $m$ ;  $L_T$  – total serviced connected capacity (kVA);  $i$  – load node index;  $Pd_i$  – average weighted cut-off power;  $Ps_i$  – weighted average power dissipated at the load node  $i$ ;  $LPEIC_{i,k}$  – average cost of power outages for load node  $i$  and emergency situation  $k$ ;  $k$  – emergency index;  $frac_{i,k}$  – share of deenergized load in the  $i$ -th load node in the  $k$ -th emergency situation.

Table 1 - Main criteria for reliability calculation using the DIgSILENT PowerFactory software and computing complex

System reliability indicators			Indicators of frequency and duration of power supply to the load node		
Criterion	Formula	Dimension	Criterion	Formula	Dimension
SAIFI	$\frac{\sum ACIF_i \cdot C_i}{\sum C_i}$	1/C/a	ACIF <sub>i</sub>	$\sum_k Fr_k \cdot frac_{i,k}$	1/a
CAIFI	$\frac{\sum ACIF_i \cdot C_i}{\sum A_i}$	1/A/a	ACIT <sub>i</sub>	$\sum_k Pr_k \cdot frac_{i,k}$	h/a
ASIFI	$\frac{\sum L_m}{L_T}$	1/a	LPIF <sub>i</sub>	$ACIF_i \cdot C_i$	1/a
SAIDI	$\frac{\sum ACIT_i \cdot C_i}{\sum C_i}$	h/Ca	LPIT <sub>i</sub>	$ACIT_i \cdot C_i$	h/a
CAIDI	$\frac{SAIDI}{SAIFI}$	h	AID <sub>i</sub>	$\frac{ACIT_i}{ACIF_i}$	relative units
ASIDI	$\frac{\sum(r_m \cdot L_m)}{L_T}$	h/a	Energy indicators for the reliability of the load nodes		
ASAI	$1 - ASUI$	relative units	LPENS <sub>i</sub>	$ACIT_i \cdot (\widehat{P}d_i + \widehat{P}s_i)$	MWh/a
ASUI	$\frac{\sum ACIT_i \cdot C_i}{8760 \cdot \sum C_i}$	relative units	LPES <sub>i</sub>	$ACIT_i \cdot \widehat{P}s_i$	MWh/a
MAIFI	$\frac{\sum IM_i \cdot N_{mi}}{\sum N_{mi}}$	1/Ca			
Energy indicators for system reliability					
ENS	$\sum LPENS_i$	MWh/a	AENS	$\frac{ENS}{\sum C_i}$	MWh/Ca
SES	$\sum LPES_i$	MWh/a	ACCI	$\frac{ENS}{\sum A_i}$	MWh/Ca
Costs of interruptions in power supply to the load node			Costs of interruptions to the power supply to the system		
LPEIC <sub>i</sub>	$\sum LPEIC_{i,k}$	\$/a	EIC	$\sum LPEIC_i$	M\$/a
			IEAR	$\frac{EIC}{ENS}$	\$/kWh

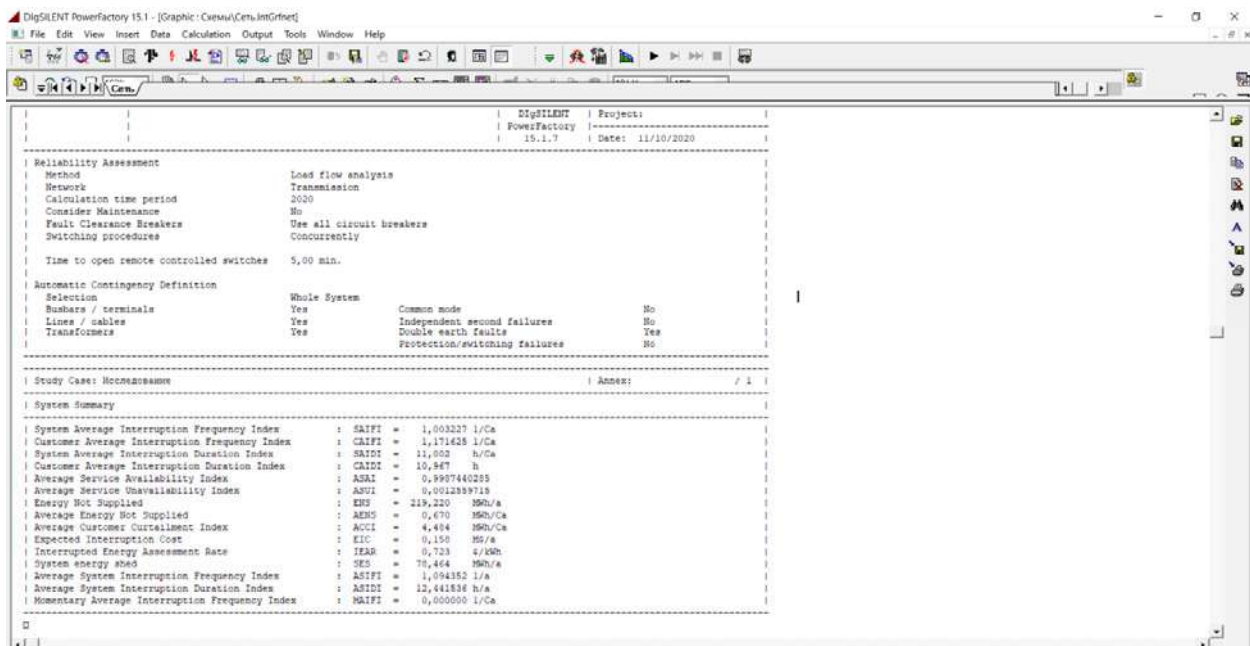


Figure 1 - Presentation of the results of reliability indicators calculation using the DIGSILENT PowerFactory software and computing complex

Thus, the using of the DIGSILENT PowerFactory software and computing complex for calculating reliability indicators for electrical systems makes it possible to analyse the state of the power system under consideration as a whole and its individual elements with high precision in order to solve practical problems of the current state and forecast development prospects.

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