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IMPACT OF LIVE WORKING AND STRUCTURAL MODIFICATIONS ON RELIABILITY PARAMETERS IN SELECTED EQUIPMENT OPERATED IN MV/LV DISTRIBUTION SYSTEMS

The paper presents valid reliability parameters of selected substation equipment. The work attempts to answer the question how live working as well as progress in materials engineering and manufacture technology of electrical power engineering devices promoted the improvement of reliability parameters.

1 INTRODUCTION

The most recent complex analysis of reliability issues with respect to devices of MV substations was carried out on the basis of data from 1960s and 1970s by J. Sozański from the Technical University of Kielce. The results have been published in 1974 [5]. In relation to progress in the field of materials engineering, power engineering equipment manufacture technology as well as in the wake of the changes in the manner of maintenance and operation, the indicators presented therein do not reflect actual reliability parameters of currently operated power engineering devices.

2 LIVE WORKING AND MODERN DESIGN OF MV DEVICES

Live working is a method of operation of power engineering equipment allowing to perform maintenance and repair works without cutting off power supply from devices, thus without reducing power transmission and disturbance of electric power distribution.

The impact of live working on substantial improvement of continuity of electric power supplies is obvious, since maintenance of efficiency of power engineering devices and facilities, without cutting off power supply, allows uninterrupted power supply for customers. Furthermore, repair of failure entirely or partially live reduces or eliminates power supply downtime for customers. Live working has also other, not immediate effects for the continuity of electric power supplies. The preventive nature of works allows to repair immediately faults identified during inspections. These works foster maintenance of efficiency of substations devices, thus improving reliability of the entire power

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engineering network. Therefore, live working not only contributes to reduction of the number of downtimes resulting from maintenance works and alleviation of results thereof but first and foremost to reduction of downtimes caused by failures [4].

For a few recent decades, MV power engineering devices have been considerably upgraded, which in connection with the progress in materials engineering technologies, allowed to achieve more effective technical parameters as well as improved reliability and functionality. Owing to the limited size of the article, only the most vital changes in mains transformers and circuit breakers have been indicated.

The most important changes in the construction of transformers include: the use of cold-rolled steel sheets of reduced thickness and improved crystallographic orientation for transformer cores, introduction of CTC conduits as well as the use of modern insulation systems based on plastics and liquid synthetic materials. At present, the research works on the common use of gas insulation (mainly SF6) and superconductor transformers are being carried out. Nevertheless, it is crucial that the majority of new transformers are continued to be produced with the use of tested technologies ensuring long-term trouble-free operation of the equipment.

At the beginning of 1920s, the first low-oil circuit breaker, which ensured clear-cut shutdown of short-circuit currents, was developed. Approximately at the same time, works on other types of circuit breakers i.e. pneumatic and magnetic blow out circuit-breakers were initiated. The first circuit-breakers with sulphur hexafluoride acting as arc-quenching medium were brought onto the market by an American company Westinghouse in 1960. The most recent researches focus on vacuum circuit-breakers, improvement of power shut-down capacity, design modifications and principle of operation of drives as well as introduction of auxiliary devices facilitating increase of the number of functions fulfilled by circuit-breakers [2].

3 RELIABILITY PARAMETERS OF MV EQUIPMENT

Author’s researches on reliability of MV substations cover the period of 10 years and were conducted on the premises of two large domestic power plants. At the beginning of the observations, both plants had 5906 overhead pole substations and 2594 compartment substations. At the end of the observations, a decade later, the numbers were 6761 and 2877 for overhead pole substations and compartment substations respectively.

The conducted research allowed to established reliability parameters of MV substation devices. Comparison of reliability parameters of selected devices carried out on the basis of bibliographical research as well as the author’s own current research has been presented in Table 1.

Table 1. Values of reliability parameters pertaining to failure (recovery) duration of the selected substation devices [3,5]

Devices	*Type of research*	*Average damage intensity*	*Average recovery duration*	*Failure coefficient (Reliability parameters)*
---	---	$\left[\frac{1}{a \cdot szt.}\right]$	$[h]$	---
Transformers	*bibliographical*	$470 \cdot 10^{-4}$	*27,3*	$146{,}45 \cdot 10^{-6}$
	author's own	$65{,}1 \cdot 10^{-4}$	*8,22*	$6{,}11 \cdot 10^{-6}$
Circuit-breakers	*bibliographical*	$98 \cdot 10^{-4}$	*7,4*	$8{,}28 \cdot 10^{-6}$
	author's own	$85{,}95 \cdot 10^{-4}$	*15,0*	$14{,}72 \cdot 10^{-6}$
Disconnectors	*bibliographical*	$54{,}5 \cdot 10^{-4}$	*8,75*	$5{,}44 \cdot 10^{-6}$
	author's own	$25{,}13 \cdot 10^{-4}$	*10,92*	$3{,}13 \cdot 10^{-6}$
Lightning arresters	*bibliographical*	$8{,}3 \cdot 10^{-4}$	*27,3*	$2{,}59 \cdot 10^{-6}$
	author's own	$29{,}27 \cdot 10^{-4}$	*5,86*	$1{,}96 \cdot 10^{-6}$
Cable heads	*bibliographical*	$17{,}11 \cdot 10^{-4}$	*28,40*	$5{,}55 \cdot 10^{-6}$
	author's own	$8{,}46 \cdot 10^{-4}$	*17,42*	$1{,}68 \cdot 10^{-6}$
Insulators	*bibliographical*	$7{,}75 \cdot 10^{-4}$	*17,3*	$1{,}53 \cdot 10^{-6}$
	author's own	$5{,}35 \cdot 10^{-4}$	*9,69*	$0{,}59 \cdot 10^{-6}$

While making a comparison between reliability parameters, one may notice that the average intensity of failure for a majority of substation devices is substantially lower than presented in technical publications and based on empirical research from 1960s-1980s, which may imply that the currently manufactured devices are less prone to failure.

Failure duration for some devices such as transformers, lightning arresters, cable heads, insulators is shorter, while for other (such as circuit-breakers, disconnectors) longer than provided by authors of various publications. Changes in manufacturing of devices as well as progress in materials engineering exert only slight impact on failure duration which is one of the reliability parameters. The above stems from the fact that the duration is not only an effect of technical properties of devices but also depends on their location and function in the system or even on the manner of system operation.

At present, the failure coefficient is lower for all devices except for circuit-breakers than for the devices operated within four last decades of the previous century.

To provide an ample description of reliability properties of power engineering devices currently in use in MV systems, the author conducted an analysis of mortality of power engineering devices (failure duration, emergency downtime periods, power supply downtimes). The designated values of selected parameters have been contained in Table 2. Full results of the analysis have been presented in [1].

Table 2. Reliability Parameters of Analysed Substation Devices [1]

Devices	*Emergency downtime periods*			*Power supply downtimes*			*Value of non-supplied energy*
	Average intensity	*Average values*	*Reliability parameters*	*Average intensity*	*Average values*	*Reliability parameters*	
---	$\left[\frac{1}{a \cdot szt.}\right]$	$[h]$	---	$\left[\frac{1}{a \cdot szt.}\right]$	$[h]$	---	$[MW \cdot h]$
Transformers	$62,1 \cdot 10^{-4}$	7,97	$5,65 \cdot 10^{-6}$	$58,60 \cdot 10^{-4}$	4,71	$3,15 \cdot 10^{-6}$	0,94
Circuit-breakers	$71,15 \cdot 10^{-4}$	14,27	$11,59 \cdot 10^{-6}$	$54,95 \cdot 10^{-4}$	2,04	$1,28 \cdot 10^{-6}$	1,82
Disconnectors	$23,67 \cdot 10^{-4}$	8,89	$2,4 \cdot 10^{-6}$	$22,91 \cdot 10^{-4}$	1,89	$0,49 \cdot 10^{-6}$	1,20
Lightning arresters	$27,78 \cdot 10^{-4}$	4,24	$1,34 \cdot 10^{-6}$	$26,29 \cdot 10^{-4}$	4,18	$1,25 \cdot 10^{-6}$	2,63
Cable heads	$8,17 \cdot 10^{-4}$	16,08	$1,50 \cdot 10^{-6}$	$7,88 \cdot 10^{-4}$	2,38	$0,21 \cdot 10^{-6}$	1,59
Insulators	$5,09 \cdot 10^{-4}$	7,20	$0,42 \cdot 10^{-6}$	$4,59 \cdot 10^{-4}$	2,25	$0,12 \cdot 10^{-6}$	1,45

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WPŁYW PRAC POD NAPIĘCIEM ORAZ ZMIAN KONSTRUKCYJNYCH NA PARAMETRY NIEZAWODNOŚCIOWE WYBRANYCH URZĄDZEŃ EKSPLOATOWANYCH W UKŁADACH DYSTRYBUCYJNYCH SN/NN

W referacie przedstawione zostały aktualne parametry niezawodnościowe wybranych urządzeń stacyjnych. Podjęto próbę odpowiedzi na pytanie, w jakim stopniu wprowadzenie techniki prac pod napięciem oraz zmiany w dziedzinie inżynierii materiałowej i technologii wytwarzania urządzeń elektroenergetycznych wpłynęły na poprawę parametrów niezawodnościowych.