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LIVE WORKING AS A CONDITION FOR THE IMPROVEMENT OF RELIABILITY PARAMETERS OF MV/LV SUBSTATIONS

The paper presents reliability models of complex electric power facilities i.e. MV/LV pole substations. It provides analysis of failure durations, emergency downtime periods, power supply downtimes as well as the value of electric power not supplied to customers due to substation failures.

1 INTRODUCTION

Pole substations are common for the rural areas. Due to low power consumption, for a number of years, rural networks have been treated as insignificant distribution systems. Therefore, in practice, no research on the issue of quality or reliability of electric power supply for rural customers has been carried out. A major increase in overload of networks in recent years brought about the augmenting number of local MV and LV substation failures. Despite a significant progress in the area of material engineering as well as upgraded manufacturing technology of electric devices, power engineering systems in rural areas are considerably prone to failure. Thus, it is indispensable to carry out complex reliability tests of power engineering systems to determine methods and ways of their operation as well as to identify the most unreliable components of electric power distribution systems.

2 RELIABILITY PARAMETERS OF POLE SUBSTATION

The principal parameter determining the scope of failure is duration of the failure (recovery) t_a. It is defined as the time elapsed from emergence of the failure of the device (substation) to its end i.e. its repair or replacement, and simultaneous restoration of power supply from the respective device [2,6,7]. This parameter first and foremost provides a statistical picture of the quality of failure recovery works organization as well as the scope of failure.

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Another parameter of power engineering systems is the power supply downtime t_p. It is defined as the time elapsed from the loss of power supply by customers to its restoration at the required power capacity [7].

Downtime of a device (substation) due to failure t_{wa} represents time elapsed from the shutdown (either automatic or by maintenance team) of a device as a result of its damage until the restoration of power supply to the device after repair. This value does not correspond to failure duration or power supply downtime. This stems from the fact that preparatory or final works during failure repair may be carried out live.

The researches on unreliability of MV power engineering substations cover the period of 10 years and were on the premises of a large domestic power plant. At the beginning of observations, the facility had 1605 overhead pole stations, while at the end 1657. The observations were performed in two five-year-long periods. In the first period, the power station did not carry out any live working with respect to MV facilities, while in the second period it became the standard of repair and maintenance works. The first period witnessed 182 failures, 174 emergency downtimes and 174 power supply downtimes, while in the second period brought about 179 failures, 167 emergency downtimes and 163 power supply downtimes.

As far the overhead pole stations are concerned, the following reliability parameters have been established: failure duration t_a, emergency downtime periods t_{wa}, power supply downtime t_p, the value of non-supplied electric power per one failure ΔA, reliability parameters q, average failure intensity λ and others. Parametric and non-parametric validation of the results has been carried out. Average values as well as probability density functions for particular reliability parameters have been identified. All analyses have been carried out on the level of confidence $\alpha = 0{,}05$. Values of reliability parameters of pole substations achieved by the author have been presented in Table 1.

3 SUMMARY

The author provided an in-depth reliability analysis of substations on the basis of 10 years of observations of MV substation reliability. The produced results allow to draw the following conclusions:

1. Failure durations fall within a very broad time scope – from several minutes to several days.
2. In relation thereto, it must be articulated that only enhanced organization of repairs can result in a significant reduction of failure duration i.e. major improvement of reliability parameters of MV substations.
3. Emergency downtime periods are shorter than failure durations. This stems first and foremost from increasingly popular live working as well as from the fact that not each failure causes automatic shutdown of a device. If necessary, the device may be shut down by a maintenance team for the time of a failure recovery.
4. Power supply downtimes are also shorter than failure durations. Apart from live working, such state of affairs may develop from operation of backup power supply systems in the case of redundant substations.

Table 1. Reliability Parameters of Pole Substations

Reliability parameters			Prior to introduction of live working	After introduction of live working
Failure duration	$\bar{t}_a$	$[h]$	8,51	7,11
	$\bar{\lambda}$	$\left[\frac{10^{-4}}{a \cdot szt.}\right]$	223,89	216,63
	q	$[10^{-6}]$	21,75	17,58
	Probability distribution and its parameters	---	Log-normal distribution $m = 1,719$ $\sigma = 0,717$	Log-normal distribution $m = 1,543$ $\sigma = 0,720$
Emergency downtime periods	$\bar{t}_{wa}$	$[h]$	6,85	5,73
	$\bar{\lambda}_{wa}$	$\left[\frac{10^{-4}}{a \cdot szt.}\right]$	214,73	202,57
	q_{wa}	$[10^{-6}]$	16,79	13,25
	Probability distribution and its parameters	---	Log-normal distribution $m = 1,492$ $\sigma = 0,738$	Log-normal distribution $m = 1,309$ $\sigma = 0,731$
Power supply downtime	$\bar{t}_p$	$[h]$	4,12	3,39
	$\bar{\lambda}_p$	$\left[\frac{10^{-4}}{a \cdot szt.}\right]$	214,73	197,68
	q_p	$[10^{-6}]$	10,1	7,66
	Probability distribution and its parameters	---	Exponential distribution $\lambda = 0,243$	Log-normal distribution $m = 0,817$ $\sigma = 1,049$
Value of non-supplied energy	$\Delta \bar{A}$	$[MW \cdot h]$	1,27	1,25
	Probability distribution and its parameters	---	Log-normal distribution $m = -0,202$ $\sigma = 1,846$	Log-normal distribution $m = -0,503$ $\sigma = 1,666$

5. Both, the intensity of failure downtimes as well as power supply downtimes are comparatively shorter than failure intensity.
6. To evaluate losses resulting from power supply downtimes for customers as well as power suppliers, authors of publications on reliability of power engineering systems not infrequently refer to failure durations, failure intensity as well as the average expected annual failure duration. As shown in the analysis presented in the paper, it is not the right approach, since parameters depicting failure duration do not corres-

pond to parameters of power supply downtimes for customers;

7. Introduction of live working as a standard for the operation of maintenance teams essentially enhances reliability parameters of electric power distribution systems. Both the intensity of particular conditions as well as average durations show lower values in the case of live working.

4 BIBLIOGRAPHY

1. Chojnacki A.Ł.: *Analiza niezawodności stacji transformatorowo-rozdzielczych SN w warunkach eksploatacji.* Archiwum Energetyki, tom XXXVII (2/2006), s. 147-168.
2. Kowalski Z.: *Niezawodność zasilania odbiorców energii elektrycznej.* Wydawnictwa Politechniki Łódzkiej, Łódź, 1992.
3. Kujszczyk S. i in.: *Elektroenergetyczne sieci rozdzielcze.* PWN, Warszawa, 1994.
4. Paska J.: *Niezawodność systemów elektroenergetycznych.* Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa, 2005.
5. Popczyk J.: *Modele probabilistyczne w sieciach elektroenergetycznych.* WNT, Warszawa, 1991.
6. Sozański J.: *Niezawodność i jakość pracy systemu elektroenergetycznego*. WNT, Warszawa, 1990.
7. Sozański J.: *Niezawodność zasilania energią elektryczną.* WNT, Warszawa, 1982.
8. Stępień J.C.: *Analiza niezawodności eksploatacyjnej linii kablowych 15 kV.* VIII Międzynarodowa Konferencja Naukowa „Aktualne problemy w elektroenergetyce", Gdańsk - Jurata 1997, tom II, s.243 ÷ 250.

PRACE POD NAPIĘCIEM JAKO CZYNNIK POPRAWY PARAMETRÓW NIEZAWODNOŚCIOWYCH STACJI TRANSFORMATOROWO – ROZDZIELCZYCH SN/NN

W referacie przedstawione zostaną modele niezawodnościowe złożonych obiektów elektroenergetycznych, jakimi są słupowe stacje transformatorowo-rozdzielcze SN/nn. Przeprowadzona zostanie analiza czasów trwania awarii, czasów trwania wyłączeń awaryjnych oraz czasów trwania przerw w zasilaniu, a także wartości energii elektrycznej niedostarczonej do odbiorców w wyniku awarii stacji.