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## Reliability of Distribution Network Components Based on Failure Databases

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### Abstract

The paper deals with the computation of distribution network components reliability parameters. Knowledge of the component reliability parameters in power networks is necessary for the reliability computation and also for reliability-centered maintenance system. Component reliability parameters are possible to retrieve only with accurate databases of distribution companies. Such a database includes records of outages and interruptions in power networks. It is impossible to retrieve reliability parameters from this data in a direct way because of heterogeneity. In this paper, we introduce some results of databases calculations. We apply this framework for the retrieving of parameters from outage data in the Czech and Slovak republics. There are also actual results.

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*Keywords:* Component reliability; distribution network; failure database; failure rate; failure duration

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### 1. Introduction

Data on failures and scheduled outages in power supply enable calculation of global reliability indices of power supply and reliability of important components of power distribution networks. Unified outage monitoring in the former Czechoslovakia started in 1975 according to regulations [1]. These regulations unified interruptions, outages and damaged equipment monitoring options for all distribution companies in Czechoslovakia. Unfortunately, database building has ceased since 1990 because of political and social changes. Later the expert group, CIRED Czech, has introduced a discussion on reliability issues. The first calls for integration of particular outage databases were already claimed at the first meeting of this group in

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1997. In 1999, distributors opted for unified monitoring of global reliability indices and the reliability of selected pieces of equipment. Up-to-date method for component reliability evaluation in distribution networks draws upon grid code [2].

A statistical significance of an outage database depends on the number of records in the database. The broader the database on operation and component failures is, the more reliable data can be acquired, provided we know the extent of the equipment studied. Therefore, it is necessary to merge databases of various distributors and distribution areas. The main problem of the merging is the heterogeneity feature: databases of various distributors differ from one another, because they have different database systems and also different approaches for evaluation of outages and interruptions in their networks. A common way of addressing the problem is to develop a common relation scheme and different data transform into the relation. It enables querying and analysis. We have selected 31 attributes [3]. For monitoring certain equipment the following list of entries has to be completed:

- Outage Identification - unique code of event
- Outage Type - accidental, planned or forced
- Voltage of network and equipment
- Outage Cause - foreign influences, causes before starting operation...
- Equipment Type - overhead line, underground line...
- Failed Equipment - specific device - conductor, switch, pole, fuse...
- Failed Equipment Type - further specification - wooden pole, steely pole...
- Amount of Failed Equipments
- Producer of the equipment
- Production Year - age of the component
- Date and time of outage beginning
- Date and time of beginning and end of manipulations determining failure
- End of outage - date and time of a restoration of power supply in the area affected by failure
- End of equipment failure - date and time of the device failure termination
- Installed capacity, number of distribution transformers and customers at the beginning and end of outage
- Failure Type - with or without equipment damage

We need to have also knowledge of the power network itself. For example, we must know the number of pieces of equipment for a set type, the total length of a line type, voltage level and so on. These are basic data which are fully sufficient for reliability computation.

## 2. Current State of Database

Since the beginning of year 2000, data on failures and outages have been collected at the Department of Electrical Power Engineering, VŠB-TU Ostrava. The final database comprises sub-databases of different companies (areas). Distributors have delivered their data in xls files twice a year. Today database contains more than 400 thousand records on voltage levels 110 kV, MV and partially LV. Seven distribution areas of the Czech Republic and one in Slovakia contributed their data into our database. The structures of databases vary therefore different approaches to conversion and assessment has to be applied. In [4] there is introduced a framework that makes it possible to retrieve parameters from these various databases. This idea is developed and new results are shown bellow.

### 3. Results of Component Reliability

The basic reliability data of particular elements may be computed from the database of outages and interruptions stored at the VSB - TU Ostrava. In this paper, the equipment reliability is given by failure rate and the mean time to repair [5]. Values in the included figures are anonymous because the data are sensitive and calculation criteria may not be suitable for objective comparison. So far the documentation concerning the number of pieces of equipment in distribution areas in 2011 are not available. Therefore, to compute component reliability, the latest available data were used and the documentation will be verified subsequently. The results of component reliability may be revised in the course of verification.

The results of component reliability in this paper are based on the following structure:

Level I - Reliability of equipment

- Type of equipment
- Network voltage, equipment voltage

Level II - Component reliability

- Damaged equipment
- Network voltage, equipment voltage
- Specific type
- Manufacturer
- Year of production

Events of 3-minute to one-month duration are included in calculations. The following figures in REAS3 - REAS11 abbreviations give anonymous comparison of component reliability in different distribution areas in the Czech and Slovak republics [6,7]. Abbreviation REAS gives component reliability evaluation for all selected areas together.

From the significant differences in particular years it is possible to observe the contribution of our analyses. The divergence of reliability indices is eliminated during long-term observation. These parameters could update reliability indices from old regulations [1].

An example of component reliability of one component type (level II) is given in next four figures. The resulting data obtained by monitoring one region in 2000-2011 (the whole time of monitoring) are illustrated in bar graphs - Fig. 1 shows failure rate and Fig. 2 shows mean time to repair.

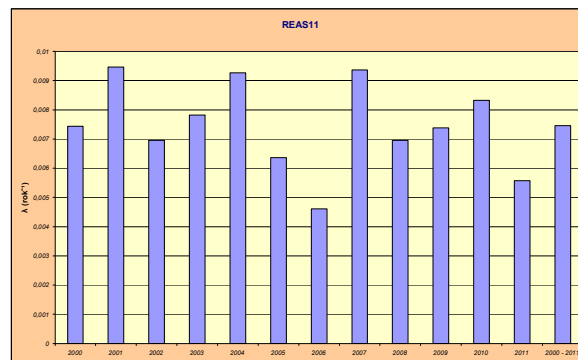


Fig. 1. Failure rate - 22 kV conductor, one region

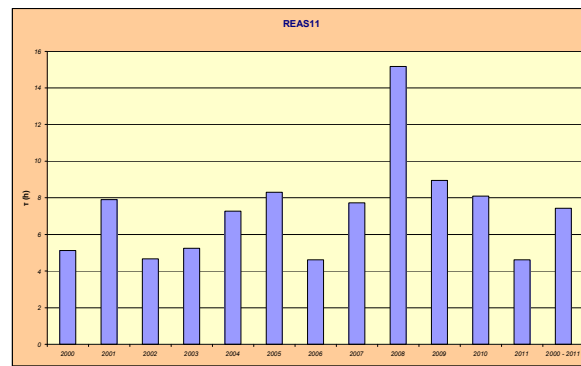


Fig. 2. Mean time to repair - 22 kV conductor, one region

It is possible to provide also comparison of distribution regions. The Energy Regulatory Office could find these results useful for justifying of renewal costs among distribution system operators. The resulting data obtained by monitoring all regions in 2000-2011 are illustrated in bar graphs - Fig. 3 and Fig. 4.

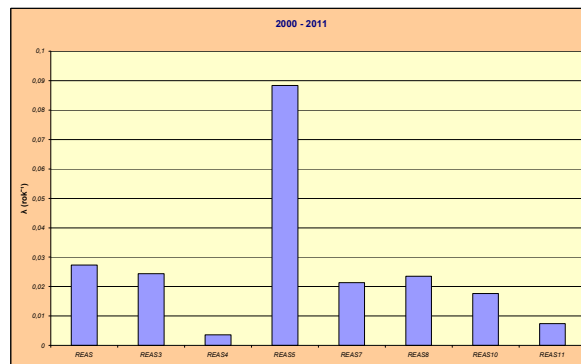


Fig. 3. Failure rate - 22 kV conductor, all regions

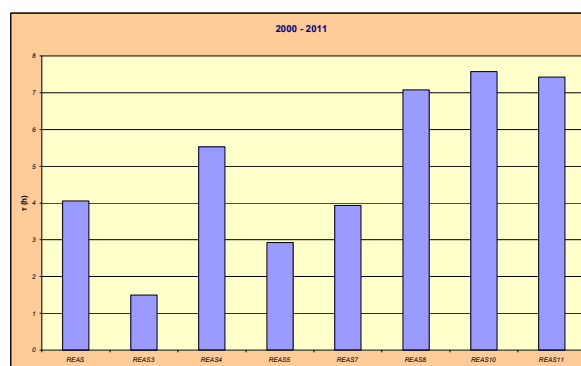


Fig. 4. Mean time to repair - 22 kV conductor, all regions

#### 4. Effect of Long-term Failures

Analysis of failure durations proved that most significant failure rates are caused by mismanaged service and operation. The effect of these failures on reliability was calculated for all components. The method used here is similar to that from the previous chapter with one difference - time to repair used for computation is not limited to 1 month.

Long-term failure can seriously affect the mean time to repair. For example, 21 failures of 22 kV conductor in REAS8 area measured in years 2000-2011 caused increase in average value of time to repair from 4 h (Fig. 4, REAS entry) to 18 h after including all the data into calculation. The effect on failure rate is less significant – increase from 0.02727 to 0.02728.

An analysis of event durations was carried out for comparison. The example of resulting data is illustrated in the bar chart Fig. 5 for all regions and data. The most of outages are longer than 1 hour and shorter than 1 month. But it is not true for all particular regions [8]. It depends on the range of their networks.

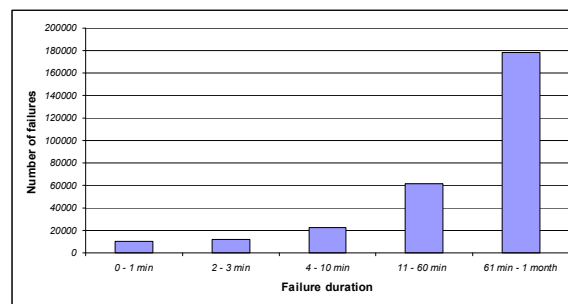


Fig. 5. Number of outages distributed according to their duration

#### 5. Failures Classification Depending on the Cause

One of the results of analyses is classification of failures depending on their cause. The pie chart in Fig. 6 illustrates the first level of failure classification. All the types of equipment in areas monitored in years 2000 - 2011 were included in the process.

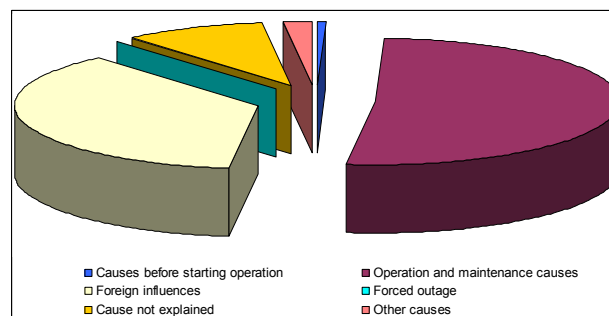


Fig. 6. First level of classification of failures depending on the cause

The most common cause of outages is “Operation and maintenance causes”.

## 6. Conclusion

This paper describes the results of reliability evaluation of equipment in distribution networks. These results were acquired by processing data on failures and outages from different distribution areas collected during years 2000 - 2011. The current condition of the database is described as well. The data used in this paper is anonymous as the results concerning reliability of networks can be published only if the particular company cannot be identified.

The data was processed by means of internet application developed by the Department of Electrical Power Engineering in cooperation with the Department of Computer Science, VŠB-TU Ostrava. The results of reliability are given for only one component - 22 kV conductor; the complete results are available in the internet application.

Furthermore, the paper elaborates on the failure duration frequency and failure causes. We can also obtain other information important for operators, such as the faulty equipment series from a specific producer, areas of the greatest amounts of unsupplied energy, etc.

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