New Results of the Reliability Computation in 2011

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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. The main problem for an analysis of these databases is the heterogeneity feature: databases of various distributors differ from one another. It is impossible to retrieve reliability parameters from this data in a direct way. In this paper, we introduce a framework which enables the retrieval of parameters from various databases. We apply this framework for the retrieving of parameters from outage data in the Czech and Slovak republics. There are also actual results.

Key Words: Component reliability, distribution network, and outage database

1 Introduction

This work deals with the component reliability. It is necessary to observe outages and interruptions in the transmission and distribution of electrical energy for retrieving the component reliability [1]. Furthermore, electrical energy unsupplied to consumers is possible to compute. A statistical significance of an outage database depends on the number of records in the database. A larger database would describe the real condition of network equipment more accurately. 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.

In [2] 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 here.

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2 History of Outage Monitoring

Component failure rates tend to vary with a component work life. A bathtub curve is commonly applied to represent the time-dependent failure rate changes of a component. Many parameters in the field of reliability vary for a specific component and the condition in which a component works. These random variables are represented by probability distribution functions [3], [4], [5], [6].

Failure rates of overhead distribution equipment are, in general, very system specific due to their dependence on geography, weather, animals and other factors [7]. Typical reliability values for pieces of distribution equipment have been introduced in [8], [9], [10], [11], [12], [13].

Outage monitoring in the former Czechoslovakia started in 1975 according to regulations 2/74 [14]. 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. 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 1997. In 1999, distributors opted for unified monitoring of global reliability indices and the reliability of selected pieces of equipment [15]. Data for the reliability computation is centrally processed and analyzed at the Technical University of Ostrava. This data has been handled and processed since the year 2000.

3 Reliability Analyses

A majority of reliability computations is performed in the following way. The reliability computation of the whole system is executed on the basis of components reliability that is included in the system. That is the reason why the reliability is computed in two phases. The first phase represents the retrieving of component reliability parameters and the second phase is the reliability computation itself. Other phases may include the evaluation of computed results and an improvement of the supply quality.

In virtue of experience, it is necessary to state that in most cases, the retrieving reliability parameter is far more complicated than the reliability computation itself.

3.2 Input Data for Computations

There are various methods for input data retrieval which are based on the type of an examined object, available data of an examined object, etc. Reliability is divided into two basic groups in compliance with the method of input data retrieval:

- Empirical reliability – input data for the reliability computation is retrieved from data on equipment, or similar equipment operating under similar conditions
- Predetermined reliability – the probability of outage-free operation is expressed on the basis of knowledge about component status.

Obviously, incorrect input data leads to poor results, even when a correct computation method is applied. Moreover, in many cases of reliability computations in electrical power engineering, we face the problem of insufficient data size for a component, e.g. an insufficient number of historical records.

3.3 Reliability Computation

In the case of empirical reliability, we need data on operations and outages of components occurring in the reliability diagram, or data on components of the same type operating under similar operating conditions. The more extensive the database, the more reliable the results are. In the case of power system components, data must be available for outages of breakers, disconnectors, transformers, lines, etc. for a set type and voltage level. Moreover, there is another type of data necessary for the reliability computation. We need to have 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.

Consequently, retrieval of the failure rate for a power system is the basis of the empirical reliability computation. This method is mostly employed in retrieving reliability parameters for the reliability computation because the application of predetermined methods requires different approaches to each power system component.

On the other hand, empirical methods require accurate records of outages. Consequently, for statistically significant results of reliability computations, data on outages dating back to many years in the past is required. It is possible to compute basic reliability parameters of particular components from this database - annual failure rate and time to repair.

The number of outages per period is retrieved from the database. The period is usually defined depending on requirements concerning the reliability computation. An additional value necessary for the failure rate computation is the number of components for a set type and area. This value is possible to retrieve from the equipment owner (usually system operator). As the numbers of components change in the real power network during a period, we update it annually. Other important information is possible to retrieve in more detailed databases, e.g. the most frequent cause of outages, areas of the greatest amounts of undelivered energy, etc.

Regulations 2/74 include reliability parameters for basic equipment. These parameters were set in 1980 and are very outdated. It is necessary to update these parameters using an analysis of outage databases.

3.4 Heterogeneous Outage Data

In the case of electrical power networks, each distributor produces incompatible outage data. Although a data model of this data may be the same (e.g. relational data model), such data is not necessarily compatible. For example, sets of relations for two distributors belong to different relation schemes. Moreover, each scheme includes different attributes expressing the same feature of an entity type.

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 [16]. For the component reliability only few attributes are necessary:

- Distribution Company - anonymous code of distributor
- Outage Identification - unique code of event
- Outage Type - accidental, planned or forced
- Equipment Voltage - 0.4 kV, 22 kV...
- 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 - Siemens, ABB...
- Production Year - age of the component
- Beginning of outage
- End of outage - time of restoration of supply to all consumers
- End of equipment failure - time of repair of the device
- Failure Type - with or without equipment damage

Some other attributes are included for continuity of supply analyses and some for future expansion purposes.

6. Results

The basic reliability data of particular elements may be computed from the database of outages and interruptions stored at the VSB – Technical University of Ostrava. The results include the rates and mean durations of equipment outages.

6.1 Database Range

The actual data collection includes outage data from distributors from the Czech Republic and one from the Slovak Republic. We have retrieved data from eight distribution areas (Table 1).

Distributors have delivered their data in xls files twice a year. Today database contains more than 400 thousand records (from 2000 to 2011) on voltage levels 110 kV, MV and partially LV.

Table 1. Database range

	Region1	Region2	Region3	Region4	Region5	Region6	Region7	Region8
2000	-	-	-	1 - 12	-	-	1 - 12	1 - 12
2001	1 - 12	-	1 - 12	1 - 12	-	1 - 12	1 - 12	1 - 12
2002	1 - 12	-	1 - 12	1 - 12	-	1 - 12	1 - 12	1 - 12
2003	1 - 12	-	1 - 12	1 - 12	-	1 - 12	1 - 12	1 - 12
2004	1 - 12	-	1 - 12	1 - 12	1 - 12	1 - 12	1 - 12	1 - 12
2005	-	-	1 - 12	1 - 12	1 - 12	1 - 12	1 - 12	1 - 12
2006	-	1 - 12	1 - 12	1 - 12	1 - 12	1 - 12	1 - 12	1 - 12
2007	-	1 - 12	1 - 12	1 - 12	1 - 12	1 - 12	1 - 12	1 - 12
2008	-	1 - 12	1 - 12	1 - 12	1 - 12	1 - 12	1 - 12	1 - 12
2009	-	1 - 12	1 - 12	1 - 12	1 - 12	1 - 12	1 - 12	1 - 12
2010	-	1 - 12	1 - 12	1 - 12	1 - 12	1 - 12	1 - 12	1 - 12
2011	-	1 - 6	1 - 6	1 - 6	1 - 6	1 - 6	1 - 6	1 - 6

6.2 Framework Results

The graphic representation of all distribution regions reliability indices from the above-mentioned data for the 22 kV cable is given in Fig. 1. 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.

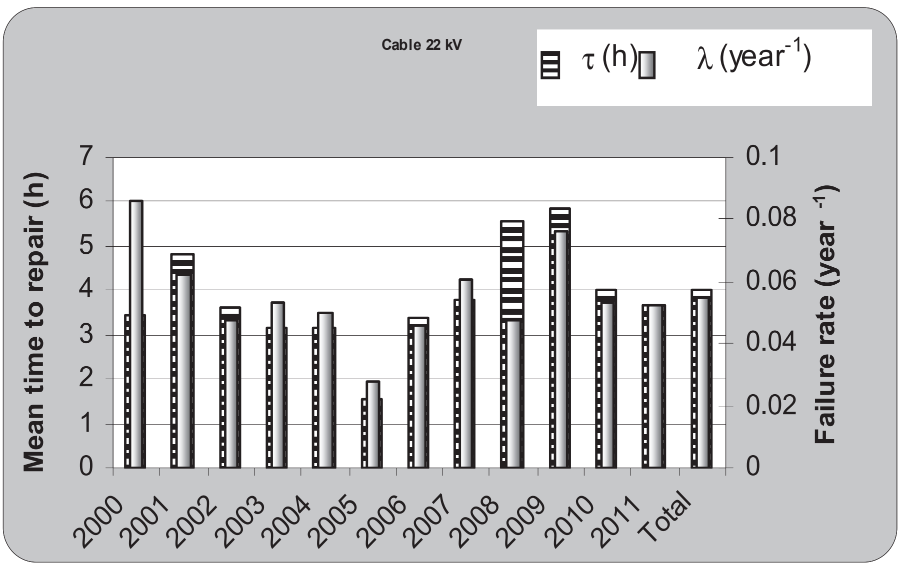

Fig. 1. The value tendency of reliability indices of the 22 kV cable

These parameters could update reliability indices from old Regulations 2/74 [14]. There is a comparison of both databases, 1975 - 1990 and 2000 - 2011, in Table 2.

Table 2. Comparison of results

Equipment		ČEZ 22/80	2000 - 2011
22 kV cable	λ (year^{-1})	14.5	5.274
	τ (h)	215	3.700
22 kV overhead line	λ (year^{-1})	14	2.711
	τ (h)	3	4.108
110 kV overhead line	λ (year^{-1})	5.2	0.324
	τ (h)	3.5	4.244
MV/LV transformer	λ (year^{-1})	0.03	0.006
	τ (h)	2500	4.764
110 kV/MV transformer	λ (year^{-1})	0.04	0.059
	τ (h)	1300	0.480
22 kV circuit breaker	λ (year^{-1})	0.015	0.007
	τ (h)	30	19.443
110 kV circuit breaker	λ (year^{-1})	0.01	0.016
	τ (h)	100	57.125

In Table 2, we can observe that the current reliability indices are rather more superior.

One of the results of analyses is structuring failures according to their causes (Fig. 2). The most common cause of outages is “Operation and maintenance causes”.

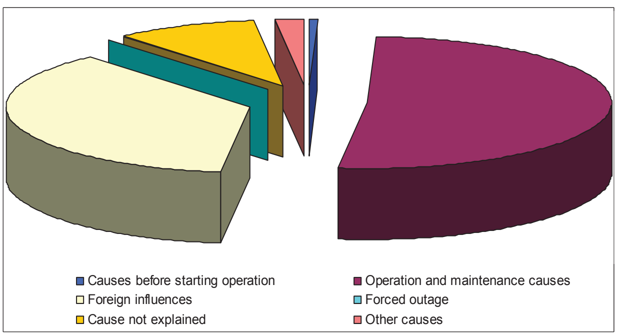

Fig. 2. Structuring outages according to their causes

It is possible to provide also comparison of distribution regions - REAS (Fig. 3). The Energy Regulatory Office could find these results useful for justifying of renewal costs among distribution system operators.

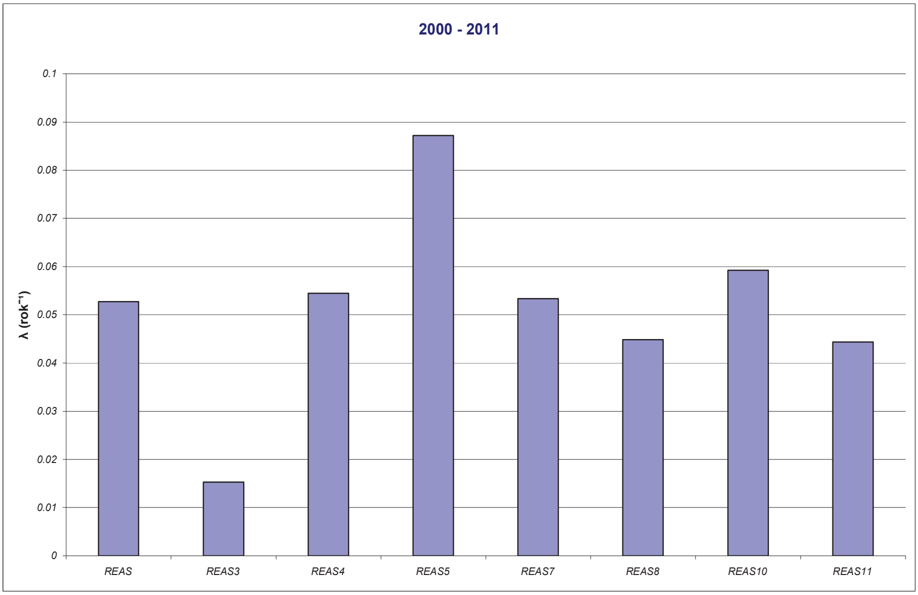

Fig. 3. Comparison of distribution regions

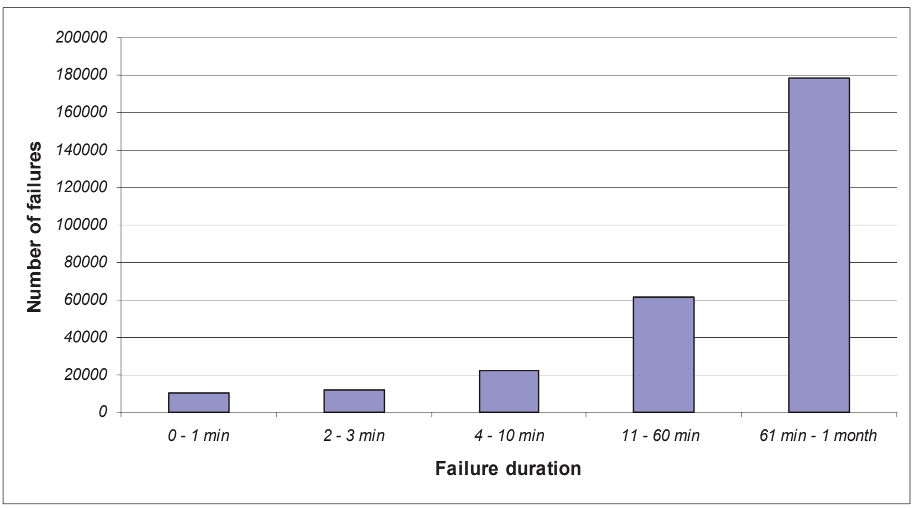

Fig. 4. Number of outages distributed according to their duration

Fig. 4 shows distribution of outages according to their duration. The most of outages are longer than 1 hour and shorter than 1 month.

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.

7. Conclusion

A statistical significance of an outage database depends on the number of records in the database. A larger database would describe the real condition of the network equipment more accurately. Therefore, it is necessary to merge databases of various distributors. The main problem of the fusion is the heterogeneity feature: databases of various distributors differ from one another.

The framework result may include the rates and mean durations of equipment outages. We can also obtain other significant information for operators. The result proves the framework is appropriate for analyzing such data. We compared the new results to the original results in this paper.

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