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Reliability Analysis of Sakarya Area Electricity Distribution System

Adem TAŞIN*[1], Türker Fedai ÇAVUŞ[1]

Abstract

Power system reliability is an important issue for providing minimal loss of service to each user. It is accepted that almost 90% of power outages are caused by failures in the Electricity Distribution System. In this study, the reliability analysis of the Alancuma feeder belonging to the Sakarya distribution system was aimed. The reliability assessment of the feeder was made using the analytical approach, Monte Carlo simulation (MCS) technique and ETAP (Electrical Transient and Analysis Program) software, and the results were observed to be close to each other. The most commonly used SAIFI and SAIDI system indices were evaluated according to the Turkey average and the reasons for the interruption for the feeder were investigated.

Keywords: Reliability, Monte Carlo Method, distribution system.

1. INTRODUCTION

Although there are many definitions of reliability, the widely accepted view is that the device/system will be able to fulfill the purpose expected of it under operating conditions for a certain period of time [1].

Reliability techniques for future design, planning, control and Operation help to evaluate electrical power systems [2].

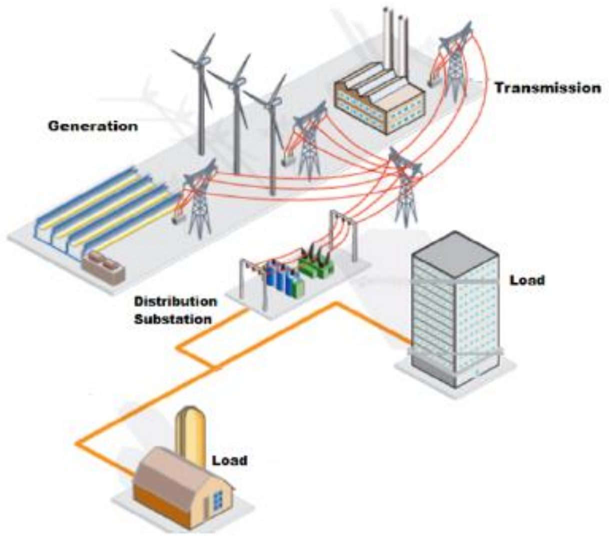

Figure 1 Structure of a Power System

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Considering the electrical energy system as a whole, it can be divided into three basic parts: generation, transmission and distribution [3].

Since electrical energy systems are large and complex, as well as reliability indices and types of failures for each level vary, reliability analysis for the entire system is very difficult

Therefore, electrical energy systems are divided into 3 hierarchical levels at the point of reliability evaluation. The first level is related to the production phase and the ability to meet demand power. The second level examines the situation in which energy can be produced and delivered to the main reducer substations to cover the production and transmission stages. The third level evaluates all stages of generation, transmission and distribution [4-5].

The effect of Index results obtained at the second level on load point indices is explained by statistics that it is around 1%. Therefore, both the impact of indices obtained from the first and second level regions on the analysis of customer load point indices is negligible, as well as the large and complex size of the system, which includes all three levels, when evaluating reliability at the distribution level, the indices of generation and transmission levels are omitted [6].

2. DISTRUBITION SYSTEM RELIABITIY

Distribution system reliability analysis is performed by calculating the necessary indices for user load points. The classic concept uses three basic indices parameters for reliability indices. These indices are commonly referred to in Billiton's book [3] as the average failure rate (λ), the average outage time (r), and the average annual outage time (U). It is also worth noting that these indices are expected or average values, not deterministic values [3].

2.1. Distribution Reliability İndices

In a research project of EPRI (Electric Power Research Institute), it has been determined that customer-indexed reliability indices are the most commonly used indices [4].

In general, these indices in the literature;

1. Customer-oriented indices,
2. Load and energy-oriented indices,
3. Cost-oriented and other indices.

It is divided into groups as [7].

2.1.1. Customer Oriented İndices

SAIFI (System Average Interruption Frequency Index)

$$\text{SAIFI}=\frac{\sum \lambda_i N_i}{\sum N_i} \quad \textit{(Interruption/customer yr.)} \qquad (1)$$

Where λ_i is the failure rate and *Ni* is the number of customers of load point *i*.

SAIDI (System Average Interruption Duration Index)

$$\text{SAIDI}=\frac{\sum U_i N_i}{\sum N_i} \textit{ (hour/customer.year)} \qquad (2)$$

Where U_i is the annual outage time and *Ni* is the number of customers of load point *i*.

CAIDI (Customer Average Interruption Duration Index)

$$\text{CAIDI}=\frac{\sum U_i N_i}{\sum \lambda_i N_i} \quad \textit{(Hour/customer interruption)} \qquad (3)$$

(Hour/customer interruption)

ASAI (Average Service Availability Index)

$$\text{ASAI}=\frac{\sum N_i * 8760-\sum U_i N_i}{\sum N_i * 8760} \textit{ (p.u)} \qquad (4)$$

ASUI (Average Service Un-availability Index)

$$\text{ASUI} = 1 - \text{ASAI}=\frac{\sum U_i N_i}{\sum N_i * 8760} \textit{ (p.u)} \qquad (5)$$

Where 8760 shows the total time (hour) value in a calendar year.

2.1.2. Load and Energy Oriented İndices

ENS (Energy Not Supplied Index)

$$ENS = \sum L_{a(i)} U_i \quad (KWh/yr.) \tag{6}$$

Where $L_{a(i)}$ is the average load connected to load point i.

AENS (Average Energy Not Supplied Index)

$$AENS = \frac{\sum L_{a(i)} U_i}{\sum N_i} \quad (KWh/customer\ yr.) \tag{7}$$

2.2. Methods for Distribution Reliability Analysis

2.2.1. Analytical Approach

In the study, it was accepted that system components are connected to each other in series when calculating indices. In this method, the average failure rate, the average repair time and the average annual outage time indices for each load point are given by the following equations [4].

$$\lambda_s = \sum \lambda_i \tag{8}$$

$$U_s = \sum \lambda_i . r_i \tag{9}$$

$$r_s = \frac{U_s}{\lambda_s} = \frac{\sum \lambda_i . r_i}{\sum \lambda_i} \tag{10}$$

2.2.2. Monte Carlo Simulation (MCS) Method

Monte Carlo simulation method is a simulation technique using probabilistic distributions [8].

This simulation technique is generally based on three basic levels. First, a set of random numbers is created in the specified range, and second, according to the desired method of probabilistic distribution of these numbers (Exponential distribution) probabilistic distribution is made, third, the results are obtained by repeating the targeted number of operations.

For the time-sequential simulation technique, realistic artificial working/repair history of the relevant system elements are needed [11]. This artificial history is generated using the random number generator and the probability distribution of the error and repair parameters of the element. The reliability indices of the system and the probabilistic distribution of these indices are obtained from the artificial history of the system [9].MCS helps in building an artificial history for each component operation for a simulation time, which was set in this work to be 10000 years.

Roy BILLINTON and his team compared the reliability indices results [8] found by applying analytical methods to the RBTs test system with the results found by Monte Carlo simulation method in their study, and showed that he achieved results close to analytical results.

2.2.3. Reliability Assessment Tool in ETAP

ETAP (Electrical Power System Analysis & Operation Software) is a simulation program in which analysis is performed and reported in different modules within the scope of IEC and ANSI standards in electrical power systems [10].

Load flow analysis module, short circuit analysis module, harmonic analysis module, etc. in addition to its modules, there is a reliability assessment module. With the reliability module in the program, the reliability indices of the system created in a one-line diagram can be calculated.

Reliability analysis studies are also available with different software such as ETAP. For example the effect of automatic reclosers on distribution network system was examined using [12] analytical technique. This application is made with DISREL software. And 11kV Karberey-Ramety Feeder-II DIgSILENT software was used for reliability analysis of the electrical power distribution system [13].

3. RESEARCH METHODOLOGY

The purpose of this research work reliability analysis of the Alancuma feeder of the Kozluk (Figure 2) region belonging to the Sakarya distribution system.

First, an analytical calculation of the reliability analysis of the selected feeder is performed, second, a simulation calculation is performed with MCS, and third, the feeder is modeled in the ETAP, and the reliability analysis of the feeder is performed, and then the results found are compared.

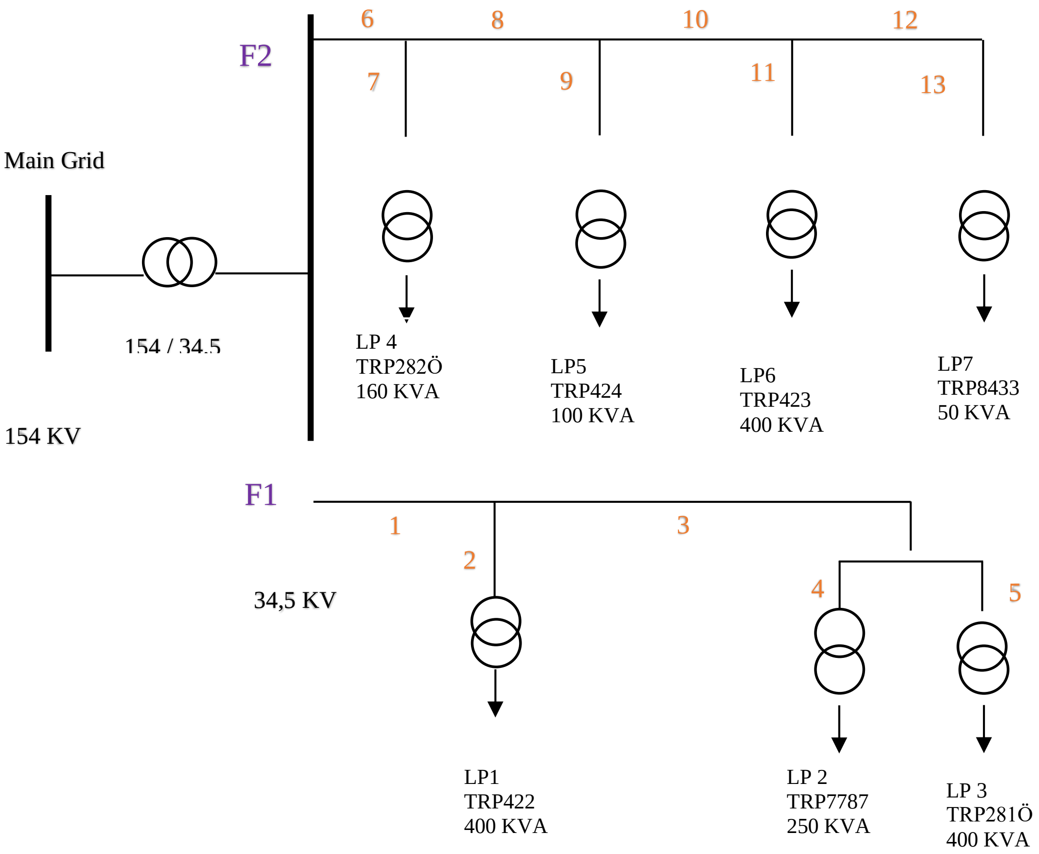

Figure 2 One-Line Diagram of Alancuma Feeder

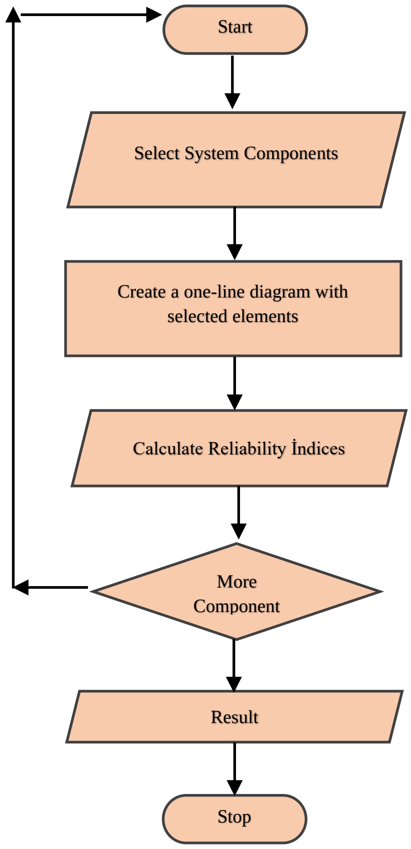

Figure 3 Flow Chart for Calculation of Reliability

Figure 3 shows the flowchart of the feeder in the ETAP software.

From SEDAŞ data [14], the average failure rate, average outage time and average annual unavailability are calculated from the last five-year interruption occurrences and outage durations of Alancuma feeder.

Table 2 shows the average failure rate, average downtime and average annual unavailability indices calculated according to Table 1 and SEDAŞ data [14].

Table 1 Details of the system of Fig. 2

Load Point	Number of Customers	Average load demand (kW)
LP 1	203	368
LP 2	1	225
LP 3	1	372
LP 4	1	139,2
LP 5	112	92
LP 6	20	296
LP 7	7	32,7

Table 2 Reliability parameters for system of Fig. 2

		F1		
Component Section	Length (km)	λ (f/yr)	r (hours)	U (hours/yr)
1	0,0579	0,4016	0,1141	0,0458
2	0,0270	0,1875	0,0533	0,0100
3	0,2073	1,4373	0,4086	0,5873
4	0,0781	0,5416	0,1539	0,0833
5	0,0767	0,5317	0,1511	0,0803
		F2		
Component Section	Length (km)	λ (f/yr)	r (hours)	U (hours/yr)
6	0,2276	1,5782	0,4486	0,7080
7	0,0638	0,4423	0,1257	0,0556
8	0,7743	5,3673	1,5257	8,1892
9	0,0173	0,1200	0,0341	0,0040
10	0,4000	2,7728	0,7882	2,1856
11	0,1361	0,9437	0,2682	0,2532
12	0,6656	4,6137	1,3115	6,0510
13	0,3455	2,3951	0,6808	1,6307

From the indices in Table 1, the complete reliability indices of the system have calculated.

Table 3 shows the reliability indices of the system calculated by analytical, MCS and ETAP.

Table 3 System Indices

System Indices	Analytical	MCS	ETAP
SAIFI	21,33	21,3359	21,3282
SAIDI	19,88	19,8554	19,9023
CAIDI	0,932	0,93061	0,933
ASAI	0,9977	0,99773	0,9977
ASUI	0,0022	0,00226	0,00227
ENS	30322	30277,4	30371
AENS	87,89	87,76	90,7

SAIFI- (interruption/cust.yr)
SAIDI- (hours/cust.yr)
CAIDI- (hours/cust..interp.)
ENS- (kWh/yr)
AENS- (kWh/cust.yr)
ASAI (p.u)

The study showed that analytical, simulation and modeling results are very close to each other.

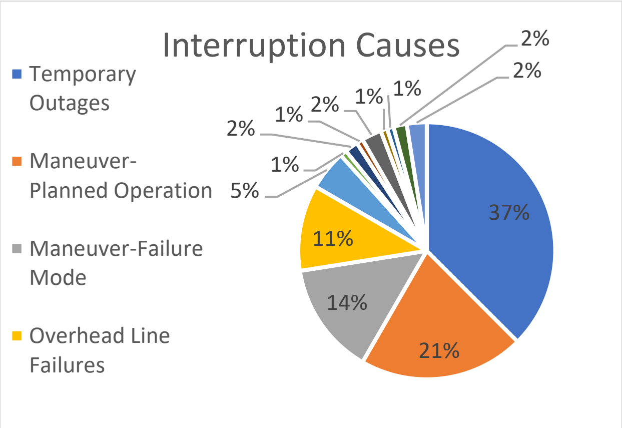

Figure 4 Interruption Causes of Alancuma Feeder

It is seen that the highest reason for interruption is temporary outages with 37%. This is followed by planned maintenance work with 14%.

4. CONCLUSION

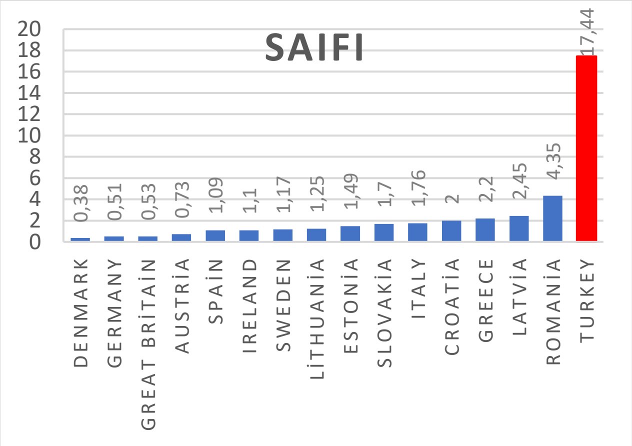

Figure 5 2019 SAIFI values of Turkey and Other Countries [15].

TEDAŞ 2019 activity report [15] on Turkey and other European countries compared SAIFI and SAIDI values. As shown in the Figure 5 and Figure 6, the values of SAIFI and SAIDI which the two most used indices are higher in our country compared to other countries.

It was observed that the SAIFI value of the Alancuma feeder was above the average of Turkey, and the SAIDI value was below the average.

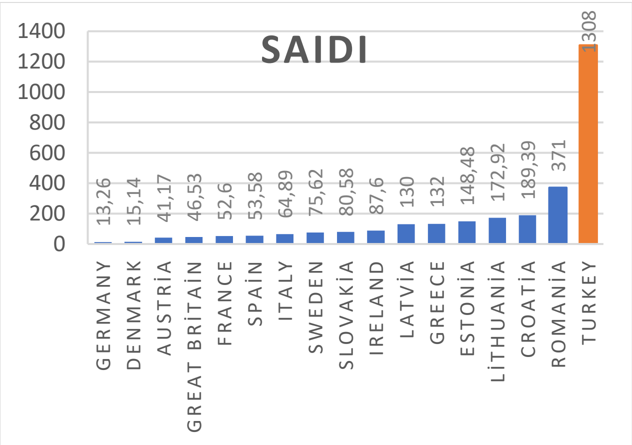

Figure 6 2019 SAIDI (minutes/customer yr.) Values of Turkey and Other Countries [15].

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The Declaration of Conflict of Interest/ Common Interest

No conflict of interest or common interest has been declared by the authors.

The Declaration of Ethics Committee Approval

This study does not require ethics committee permission or any special permission.

The Declaration of Research and Publication Ethics

The authors of the paper declare that they comply with the scientific, ethical and quotation rules of SAUJS in all processes of the paper and that they do not make any falsification on the data collected. In addition, they declare that Sakarya University Journal of Science and its editorial board have no responsibility for any ethical violations that may be encountered, and that this study has not been evaluated in any academic publication environment other than Sakarya University Journal of Science.

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