

# Valuation of Reliability Assessment for Power Systems in Terms of Distribution System, A Case Study

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**Abstract**— Supplying electrical energy to the load on demand, economically and with acceptable levels of reliability and service quality is the main task of a distribution system. Energy distribution reliability is important in the competition conditions in electricity markets because consumers directly supply energy. Therefore, it is not enough to estimate how reliable the distribution system is at present and to estimate the future reliability change in order to make optimum planning decisions, but also to provide the necessary amount of spinning reserve. The past reliability performance of distribution system can be quantified using a wide range of indices. This study is concerned with evaluating the reliability indices for only part of a network. Even though this study is limited due to unavailability as well as the inaccessibility of full and correct data over a sufficient period for analysis, it can give a clue and motive for further evaluation of the reliability of network.

**Keywords**—Reliability Assessment; Distribution System; Reliability Indices; Spinning Reserve.

## I. INTRODUCTION

The power system reliability is defined as the probability that the system performs its assigned task of supplying the load for a given period of time under the operating conditions faced [1,2]. Reliability can be divided in two basic aspects; System adequacy and System Security. Sufficiency come to the capacity of the power system in correlation to energy need and security come to the dynamic response of the power system to failure. Until now distribution power systems are rarely loaded close their border, power system proficiency is of comparatively minor interest and reliability accent on system security [3, 4].

Actual the deregulated electric power utilities are asset restructured and set as diverse generation, distribution and transmission firms and the accountability of keeping reliability of the all power system is divide by all related firms in place of by a one electric utility [5]. The majority of discontinuities that

customers observe are due to failures in the distribution system. Reliability objectives and means of attaining them should be based on customer needs and desire to pay for a desired level of reliability; thus reducing the total cost [6], e.g. power supply cost plus customer interruption costs as shown in Figure 1.

In the unexpected case, the possibility of electricity interruption experienced by consumers may be decreased by the capital goods in the planning process, the operating process or both. The cost function is directly related to the level of reliability; it is necessary to make financial investments on a large scale in order to obtain a good result at the reliability level and in the opposite case the reliability level is low and it causes an excessive cost to the consumers due to interruptions. It is also most important that service providers set up a balance between the cost of enhancing reliability and quality in terms of service and the economic benefits that advancement brings to consumers [7]. In the face of the disruption experienced by the consumers, there will be a price charged by the consumers to live off-line and this amount is called "reliable customer cost". In addition, this value can be defined as Value of Lost Load (VOLL) in literature. VOLL should be willing to pay the average consumer to pay for the loss in order to avoid additional electricity without electricity. VOLL is a measure for decrees regarding the total capacity of a power source. [8] This value cannot be applied to a different country because the VOLL estimate of an individual country generally reflects the preferences of consumers in that country. This is especially true for countries where electricity supply is rapidly expanding and restructured, and there is a possibility of supply tightness [9-12]. In order to maximize reliability in a system, the reliability development costs of services and the cost of damage to consumers must be balanced. Hence, the best level of reliability is achieved when the sum of the cost of utility for the supplied electricity and the cost of the consumer is at a minimum.

There are reserves in power systems that are used to ensure energy sustainability along with reliability indices. This reserve is defined as spinning reserve (SR), which was introduced in unexpected events to provide production and consumption balance [13]. SR is a requirement to resolve situations that occur during the production or transmission interruptions in the power system grid [14]. This reserve is kept below the nominal level and is provided by the capacity separated by production units in response to a specific need. The increased amount of the existing reserve increases the quality of the system and the reliability of the system when the system production cost rises, while the low amount on the other side causes the system to load [15, 16]. In addition, the voltage and frequency stability is achieved by the power balancing technique by load and load change methods [17].

For this reason, there are some indices to include and measure the costs or losses that occur in the service program and the consumer side as a result of the power outage, and this should be considered in planning and operations. Network reliability analysis Generates load point and system indexes. These indices are divided into energy indices and frequency / expectation indices.

- System Average Interruption Frequency Index (SAIFI),
- The Average Service Availability Index (ASAI),
- Customer Average Interruption Duration Index (CAIDI),
- Customer Interrupted per Interruption Index (CIII) evaluated for part of Bosphorus Electricity Distribution Incorporation (BEDAŞ) network shown in Figure 2.

All utilities would have the data available to calculate all the reliability indices. The record data found was from 1.1.2012 to 24.5.2013 and sufficiently enough to make generalizations about the reliability of all of the BEDAŞ network. But it can indicate the performance of the network over the period. In addition, it can be used for further studies.

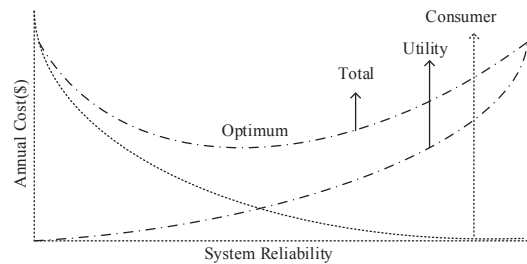


Fig.1. Total cost of reliability

In this work load point indices such as [18];

- System Average Interruption Duration Index (SAIDI),

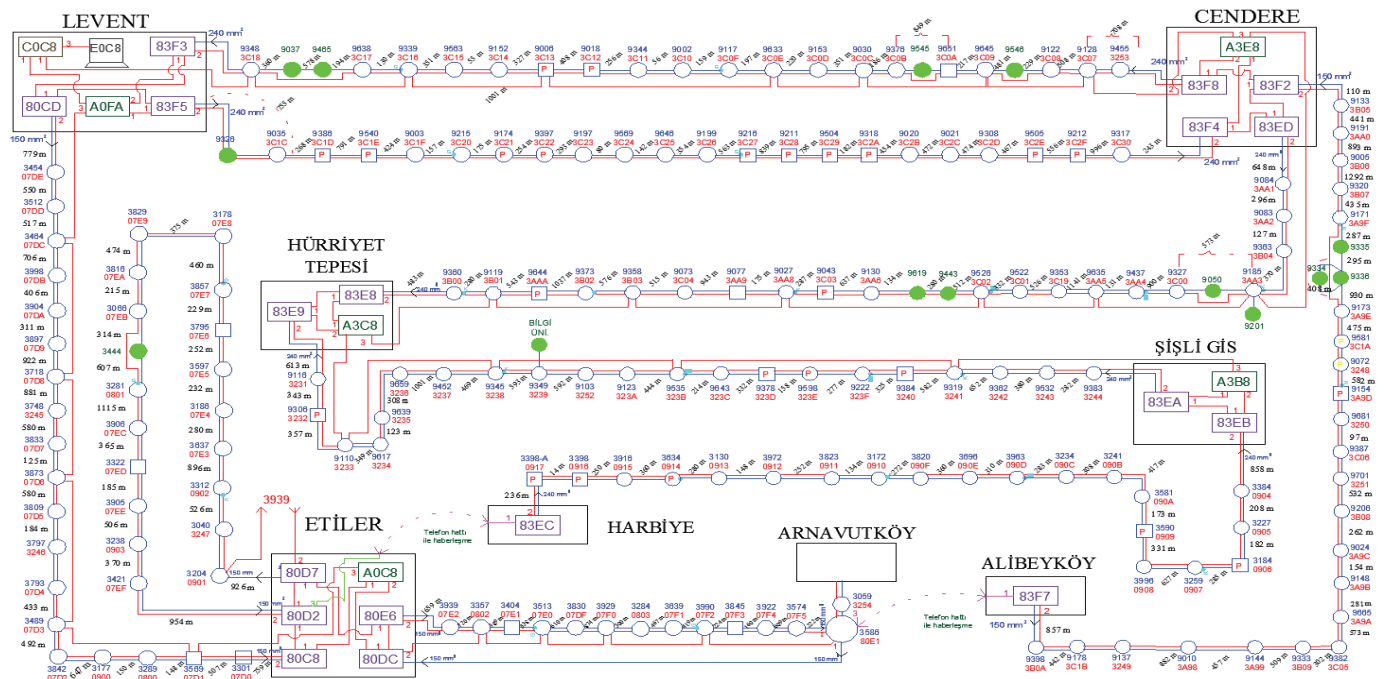


Fig.2. The Network under the study

## II. THE INDICES OF RELIABILITY

In general, network connection standards are made to a greater extent in increasing the reliability, efficiency and cost of the power system [19]. The evaluation of the quantitative

reliability of the distribution system in the electrical grid can basically be divided into two parts; prediction of performance for the future and measurement of performance for the past. In order to evaluate the reliability performance of the distribution systems, two sets of reliability index, system

indexes and customer load point index were established [20]. The Institute of Electrical and Electronics Engineers (IEEE), whose standard number is P1366, refers to the generally accepted reliability indices as "Electricity Distribution Reliability Index Guidelines" [21]. In the following sections, some of these indices between customer-based ones are briefly described.

#### A. System Average Interruption Frequency Index

SAIFI is designed over a predefined area to provide information on the frequency of continuous interruption per customer.

$$SAIFI = \frac{\text{Total number of customer interruptions}}{\text{Total number of customers served}} = \frac{\sum \lambda_i N_i}{\sum N_i} \quad (1)$$

Where  $N_i$  is the number of customers and  $\lambda_i$  is the failure rate to load point  $i$ .

#### B. System Average Interruption Duration Index

SAIDI is designed to provide information about the average amount of time a customer has been paused, and is widely known to be minutes of customer outages or customer hours.

$$SAIDI = \frac{\text{Sum of customer interruption durations}}{\text{Total number of customers served}} = \frac{\sum U_i N_i}{\sum N_i} \quad (2)$$

Where  $N_i$  is the number of customers and  $U_i$  is the annual outage time of load point  $i$ .

#### C. Customer Average Interruption Duration Index

CAIDI refers to the average time required to restore

$$CAIDI = \frac{\text{Sum of customer interruption durations}}{\text{Total number of customer Interruptions}} = \frac{\sum U_i N_i}{\sum \lambda_i N_i} = \frac{SAIDI}{SAIFI} \quad (3)$$

Where,  $U_i$  is the annual outage time,  $N_i$  is the number of customers and  $\lambda_i$  is the failure rate of load point  $i$ .

#### D. Customer Average Interruption Frequency Index

CAIFI was designed to help show the number of customers affected by discontinuities across the entire customer base and to show that customers are cutting their trends.

$$CAIFI = \frac{\text{Total Number of customers interrupted}}{\text{Total number of customers served}} = \frac{\sum N_o}{\sum N_i} \quad (4)$$

#### E. Average Service Availability Index

$$AIFI = \frac{\text{Customer hours of available service}}{\text{Customer hours demanded}} = \frac{\sum N_i \times 8760 - \sum U_i N_i}{\sum N_i \times 8760} \quad (5)$$

The total number of hours in a year is expressed as 8760.

In addition, other indices may be found for the electrical distribution reliability indices in the IEEE guidelines.

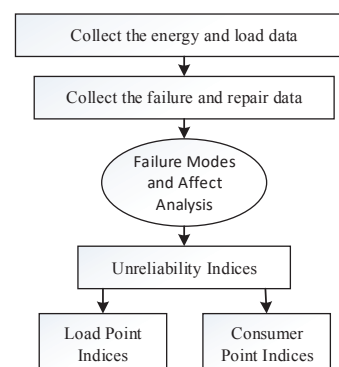


Fig.3. Steps are followed for estimating the reliability indices

### III. CALCULATION AND ANALYSIS OF INDICES FOR THE GRID UNDER STUDY

The following steps describe the path followed to estimate the reliability indices of the given system (Fig. 3):

- The failure data of the components are collected.
- The outage and switching time data for every component is collected.
- Average load and energy at each load point is estimated using substation data.
- Numbers of consumers connected at every load point are estimated.
- The length of HT and LT cables is estimated.
- Finally, customer-centric indices are estimated using load point indices.

However, in this study the data used were the tripping time of the relay due to faults in the feeder, the reconnection time of the feeder and number of customers at distribution centers. Number of all customers interrupted, which are included in the grid is found by summing the customers at the downside of the interrupted feeders [22]. Based on the data the total number of customers is 119842. This data is summarized in Table 1 below.

TABLE I. SUMMARY OF THE COLLECTED DATA (FROM 1.1.2012 TO 24.5.2013)

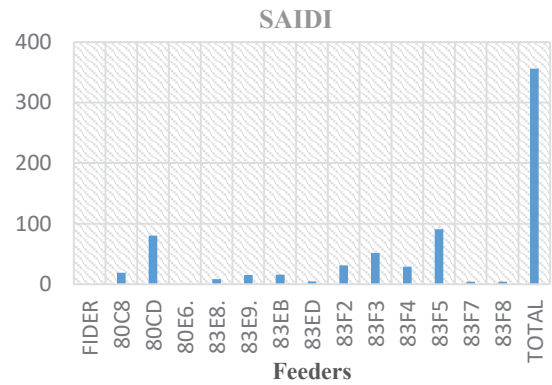
Area	Feeder	Interruption Frequency	Customers Interrupted	Interruption Duration (minutes)
Etiler	80C8	7	19908,00	771,62
	80E6	1	685,00	102,17
Hürriyet	83E9	4	33038,00	218,28
	83E8	1	8048,00	124,42
Şişli Gis	83EB	2	14287,00	288,10
	83F3	8	54131,00	831,02
Levent	83F5	7	189447,00	372,08
	80CD	2	12504,00	514,77
	83F8	1	8978,00	56,55
Cendere	83ED	2	14433,00	78,18
	83F4	3	41393,00	173,95
	83F2	6	25953,00	906,85
Alibeyköy	83F7	2	13209,00	256,60
TOTAL		46,00	436014,00	4694,58

Among the indices of reliability SAIDI, CAIDI, SAIFI, ASAI and CIII are calculated for network under study respectively. The summary and descriptions are shown in table 2. In addition, the indices are calculated for the feeders and the results are shown in Fig.4. In order for indices to be meaningful, it is necessary to have a standard data method. It is easy to apply the indices routinely. The problem is how the utility programs should distinguish large events from routine events. Almost all regulators allow utilities to distinguish large events from normal failures. However, an important event needs to be identified. Conventionally, public services have implemented very simple measures to define important events. Precautionary case "every event in which more than 10% of service customers are out of service for 24 hours is an important event". Another definition in the literature is "15% of the customers during the storm" [23]. Since regulators in the system want to relate performance to reliability, utility programs are looking for a better-defined approach when an abnormality occurs in the system. According to IEEE Standard 1366, a "major event" is defined as a disastrous event that exceeds the design limits of the power system. Utilities are allowed to expect significant cases when computing their indices. The IEEE working group proposed a method known as the Beta method to define Major Event Day (MED) is any day that exceeds a day's SAIDI threshold and is called  $T_{MED}$ . Daily SAIDI values for the last five years can be used to obtain the  $T_{MED}$  value. Since the data this study is only from 1.1.2012 to 24.5.2013,  $T_{MED}$  is not calculated.

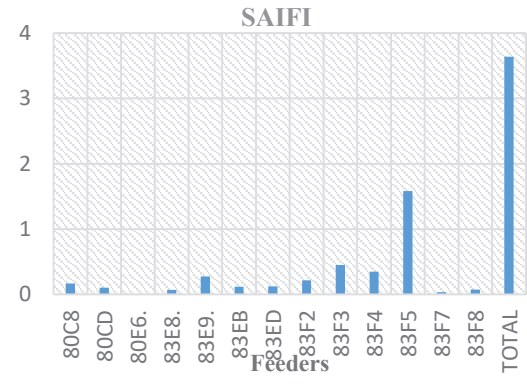
***Insert feeder's reliability indices and their graphs***

TABLE II. SUMMARY OF INDICES FOR THE NETWORK UNDER STUDY

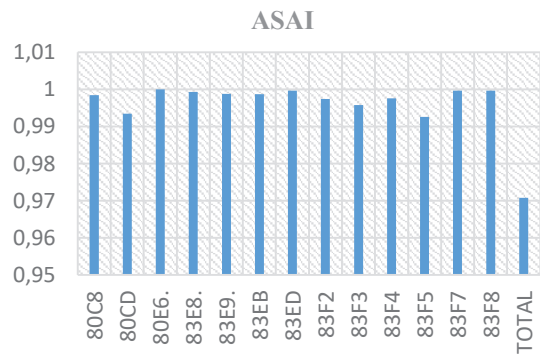
Index	Value	Unit	Description
Customer Minute Total Number of interrupted	44102345,9		
SAIDI	368,004088	Min.	The average customer was out of service for 355.9828 minutes over the period
CAIDI	101,148922	Min.	On average any customer was out of service for 97.8447 minutes over the period The customer had 3.63824 probabilities of experiencing power outage over the period
SAIFI	3,63824035		Average usability value of the system during the period 99.965%
ASAI	96,982%		
CIII	10139,8605		On average 10139.8605 customers are interrupted



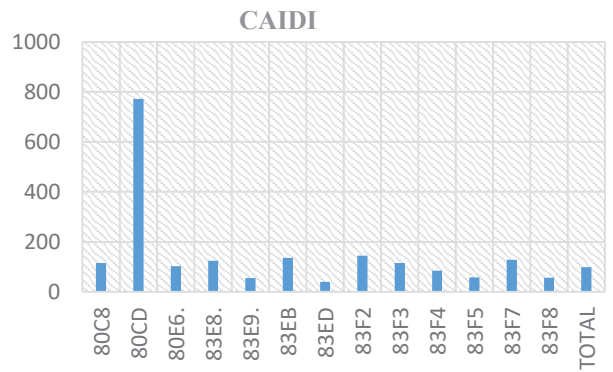
(a)



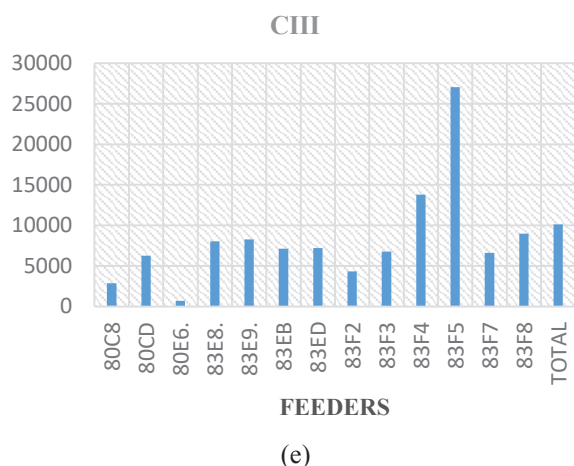
(b)



(c)



(d)



(e)

Fig.4. Reliability indices for the Feeders and the network understudy from 1.1.2012 to 24.5.2013 (a) SAIDI (b) SAIFI (c) ASAI (d) CAIDI (e) CIII.

#### IV. CONCLUSION

To measure the reliability of a power distribution system, the first step is to understand how you will implement the IEEE standard reliability indices. The main events for the deterioration of reliability measures and should be removed. The data in this study are, without excluding the major event due to shortage of duration under study. From the result the feeders that are found in Etiler have high SAIDI, CAIDI, SAIFI, CIII values. ASAI values show small variation among the feeders. The results also show that most of the outages are concentrated around Etiler, Levent and Cendere Feeders.

As a further work, data over sufficient periods can be collected and analyzed, major event can be excluded and all indices of reliability including load point and energy indices can be calculated. The outage costs can also be estimated. Along with all these, the effects on the reliability of the reserves used in power systems can be examined.

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