

Analysis of Reliability Indexes in Air and Ground Distribution Networks (Case Study: Bakhtar)

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Abstract

With respect to power distribution networks, which includes two types of air and ground networks; it is worth noting that the use of the air networks is more economical and therefore dominates the existing air networks. In this paper, the authors have worked on the reliability indexes changes for a month period. As well, the paper's aim is to make a strategy in short-term (monthly) to network management in order to alleviate cutoff number and time, ENS, increasing customer satisfaction from electric distribution companies and comparing the performance of air and ground networks. The paper was done based on a case study sample substation of a network in Bakhtar regional electric company, Iran. Also, simulation results have obtained by CYME PSAF.

1. Introduction

One of the important parameters for identification of power system, study about reliability of the system. In order to separate the different levels, evaluation reliability of power system with regard to the relationship between each of the generation, transmission and distribution system are divided into three levels. As shown in Figure (1), the first level of equipment and generation facilities (HLI), the second level includes generation and transmission facilities (HLII), and the third level includes all equipment power systems, including for generation, transmission and distribution systems (HLIII). Since, the availability of the distribution system is much lower compared to transmission and generation systems (due to its radial structure). This problem indicates necessity to evaluate and improve the reliability in this area power system. [1-7]

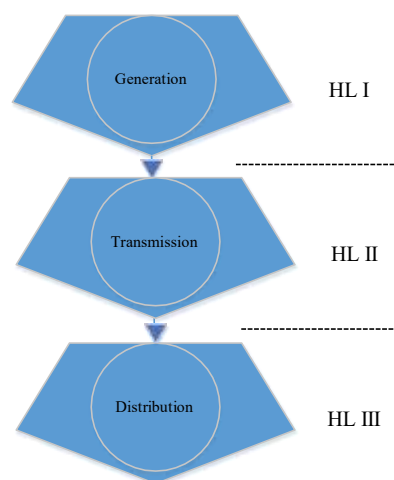


Figure 1: Structure of the Power System in Iran

Assessing the network reliability is one of the most important challenges that system designers face with. In addition, the reliability is one of the most important issues in the design and operation of various systems, because most of the subscribers of the electricity network are connected to the distribution networks and are powered by this network; the distribution network hairs are distributed because distribution companies tend to have their executive planning with maximum risk-taking, the lowest cost and losses, so the importance of checking reliability in the distribution network is more obvious than before. In recent years, the reliability of distribution systems has received more attention due to the increasing importance of generation in energy supply systems, competitive conditions in the electricity market, and reliable and quality energy supply to the customers. In order to measure the reliability in the power distribution network, parameters have been defined, the numerical values of which indicate the level of the reliability. [8-11]

Assess the reliability of the distribution system in the form its quantitative not had a long history and goes back to about the last three decades. Determination of standard criteria reliability by the committee of transmission and distribution engineering of power society (IEEE) in Standard form no.1366 in 1998. Moreover, study of reliability is introduced in a certain range for all companies around the world, has caused the comparison between different networks from the point of view [12-14].

So far, the studies done about the reliability of distribution network in the period of the annual. In this paper, the reliability evaluated in the monthly time period for the Bakhtar regional electric company that is one of the subsidiaries Iran's Tavanir company (Bakhtar regional electric company includes of Lorestan, Hamedan, Markazi, and the centrality is Arak).

This paper, determined the reliability in what months of the year is lower of levels, and thus, improving planning the network reliability in time periods shorter for planners and operators of the system is possible.

The remainder of this paper is organized as follows. Assess the reliability of distribution systems, relationships discussed in this paper, load points indexes, and system indexes is presented in Section 2. Studied distribution network have discussed in section 3. Numerical simulation results with related charts, graphs, and its analysis have been mentioned in section 4. Section 5 concludes this paper.

2. Assess the Reliability of Distribution Network

Evaluation the reliability of the distribution system done by which IEEE standard related indexes introduced them. It is necessary, before introduce these indices be mentioned into three basic parameters which are important in the study of the reliability of distribution systems. These parameters have been defined as load points indexes.

2-1. Load Points Indexes

Radial distribution system is modeled as a series model, then, a series system of equations applies in it [10-14]. Three fundamental parameters of reliability includes average failure rate λ_s , the average time interruption of the system from operation modes r_s and, the average time interruption from operation modes or average of an unavailability in the period of the study U_s .

In this system, aforementioned parameters can be obtained of the following equations.

Equation (1) shows the average failure rate.

$$r_s = \frac{\sum_{i=1}^n \lambda_i r_i}{\sum_{i=1}^n \lambda_i} = \frac{U_s}{\lambda_s} \quad (1)$$

Equation (2) shows the average time interruption from operation mode.

$$\sum_{i=1}^n \lambda_i = \lambda_s \quad (2)$$

Equation (3) shows average time interruption annual from operation mode.

$$U_s = \sum_{i=1}^n \lambda_i r_i = \lambda_s r_s \quad (3)$$

λ_s : Average failure rate (in terms of period time of study/ failure).

r_s : Average time interruption from operation mode (in terms of hour).

U_s : Average time interruption annual from operation mode (in terms of period time of study/ hour).

Which λ_i is failure rate, and r_i is mean time to repair related to parameter i [15, 16]. It is obvious, lonely, these parameters cannot be determine the status and behavior of the system.

Therefore, in order to achieve a better understanding of system behavior have been proposed several standard indices from IEEE- 1366, due to the multiplicity of these indexes, to examine the most important and widely used indices has been provided in order to purpose of this paper [13].

2-1. System Indexes

2-1. System Average Interruption Frequency Index (SAIFI)

In the following equation, system average interruption frequency index is shown.

$$SAIFI = \frac{\sum_{i=1}^n \lambda_i \times N_i}{\sum_{i=1}^n N_i} = \frac{\text{Number of Total Customers Cutoff}}{\text{Number of Total Customers}} \quad (4)$$

λ_i is a failure rate and N_i is number of customers connected to the load point i^{th} . These index, shows that on average, every subscriber in desired time period how many times is interrupted. Equation (4) is presented in terms (Int/ Cust) .

2-2. System Average Interruption During Index (SAIDI)

In the following equation, system average interruption during index is shown.

$$SAIDI = \frac{\sum_{i=1}^n U_i \times N_i}{\sum_{i=1}^n N_i} = \frac{\text{Period Time of Total Customer Cutoff}}{\text{Number of Total Customers}} \quad (5)$$

U_i is interruption during of time and N_i is number of customers connected to the load point i^{th} .

Equation (5) is presented in terms (Hour/ Cust) and, represents the average power cutoff time per customer for the period during of study.

2-3. Customer Average Interruption During Index (CAIDI)

In the following equation, customer average interruption during index is shown.

$$CAIDI = \frac{\sum_{i=1}^n U_i \times N_i}{\sum_{i=1}^n \lambda_i \times N_i} = \frac{\text{Total Time Period of Customer Cutoff}}{\text{Number of Total Customers Cutoff}} \quad (6)$$

In this index, average outage time per customer per time of power cutoff is considered.

Equation (5) is presented in terms (Hour/ Int.Cust) .

2-4. Average Service Unavailability to Electrical Power Index (ASUI)

In the following equation, average service unavailability to electrical power index is shown.

$$ASUI = \frac{\sum_{i=1}^n U_i \times N_i}{\sum_{i=1}^n \lambda_i \times T} = \frac{\text{Total Hour of Electricity Customers Unavailability}}{\text{Total Time Period of the Study for All Customers}} \quad (7)$$

ASUI index describes of customers unavailability amount to electricity as a percentage of the cutoff hours in comparison total hours of a year. ASUI is presented in terms (Hour) .

2-5. Energy Not Supplied Index (ENS)

In the following equation, energy not supplied index is shown.

$$ENS = \sum_{i=1}^n L_i(a) \times U_i = \text{Total of Energy Not Served by System} \quad (8)$$

The amount of $L_i(a)$ is average load of load point (distribution substation). Also, ENS index provides the amount of energy not sold kilowatt hour (Kwh) to customers.

2-6. Average Energy Not Supplied Index (AENS)

In (9), average energy not supplied index is shown.

$$AENS = \frac{\sum_{i=1}^n L_i(a) \times U_i}{\sum_{i=1}^n N_i} = \text{Energy Not Served for Each of Customer} \quad (9)$$

AENS index describes average amount of energy not sold to each customer in terms of kilowatt hours (Kwh).

3. Case Study

Examined distribution network in this paper is distribution network of Saveh in Markazi with radial structure (The authors for the network limitation, do not permit to show pic of the buses and its detail in the paper). This network compared to many distribution network in Iran relatively is better, because of existence networks information and information management. In the paper, in order to more complete and accurate result of study were collected network cutoff information in years of 2010, 2011 and 2012 on a daily basis. As well as, Information on the number of customers and transmission substation feeder load is harvested by Bakhtar regional electric company mechanization software (SIMAP), and loading manuals available at area. Since, the cutoff number and reason in ground and air network are different, therefore in the paper, evaluates reliability indexes for ground feeders (industrial substation feeder no.1 Saveh) and air feeders (industrial substation no.2 Saveh), separately.

With the examining studied on feeders types of faults, they located in the category of transient faults, faults that are not observed after any troubleshooting feeder reconnecting and were classified steady faults. It should be mentioned, reliability indexes can be calculated for each of these faults, separately. In the paper, the feeders steady faults has been studied.

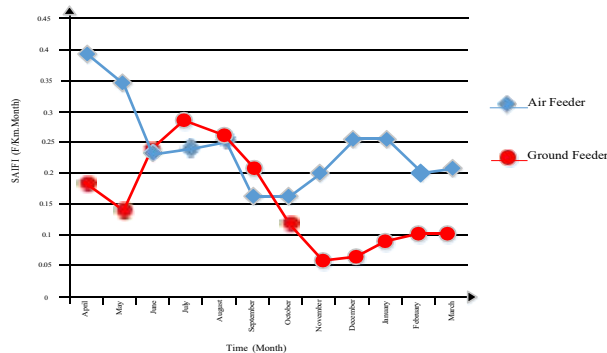


Figure 2: System Average Interruption Frequency Index

3. Simulation Results

Information on the number of customers Information and transmission substation feeder load is harvested and simulated by Bakhtar regional electric company mechanization software (SIMAP), 9 CYME PSAF version of 2.81 R 2.9 and loading manuals available at area.

By apply calculations of the reliability assessment in monthly time period, results in forms system effective indexes (SAIFI, SAIDI, CAIDI, ASAI, ASUI, ENS, and AENS), respectively.

In figures 2- 9 system indexes the system in the form of monthly bar charts are shown in the following.

4-1. System Average Interruption Frequency Index (SAIFI)

This index behaves differently for air and ground feeders. The opening paragraph has no indentation. Figure 2 shows system average interruption frequency index.

According to the graph, number of faults per year for ground feeders are directly linked with the load factor. But, this index for the air feeders in months of beginning of the year due to continuous rains and high winds is higher, significantly. For summer and winter occurrence faults is almost the same at higher levels of the fall season. It means that increasing load in summer and the increase occurrence of faults in the winter have almost equal to role in the air feeders number of faults. It should be noted that, in nearly all months of the year the number of faults overhead lines higher than ground cables, it is natural occurrence due to for different structure of these two networks. According to this index, months of November and December for the ground feeder and October for air feeder are located in higher reliability. As shown in figure 2, July for ground feeder and April for air feeder have a lower level of reliability.

4-2. System Average Interruption Duration Index (SAIDI)

Figure 3 shows the values of λ for studied air and ground feeders in different months of the year. Recorded values for the elimination of occurred feeder faults are related to switching time. This time is approximately 30 minutes.

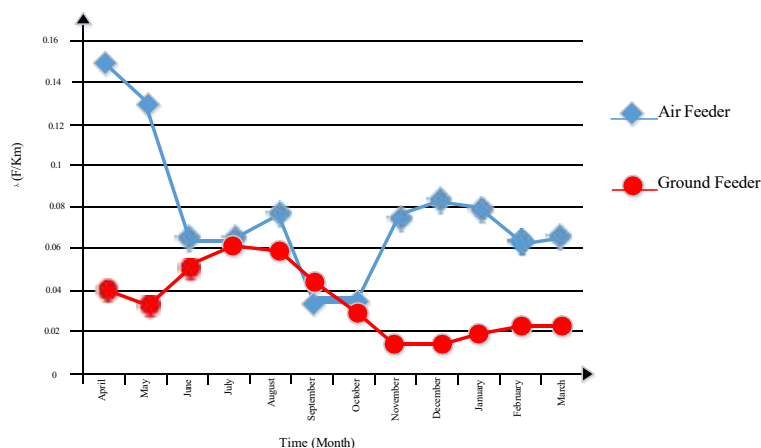


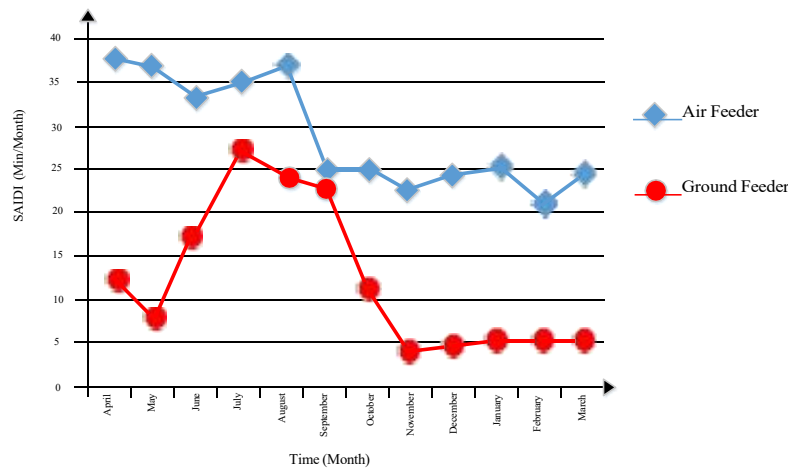
Figure 3: Information of λ Monthly Feeder

Figure 4: Customer Average Interruption Duration Index

By having transmission substation load peak information of area, as well as, receiving information studied peak load feeders in form monthly, monthly peak load of feeders was considered in form the amount of annual peak load. These values are divided in form weighting factor at months of year between the transmission substation. As well as, this calculation has been done for studied feeders that have maneuvering role. Their excess capacity due to main feeders is calculated considering to the amount of their load in different months of year.

With regard to regional load factor (0.6), and apply it to load peak values of substation studied feeders in order to for amount of average load of substation, completely, primary information was achieved for calculation of reliability index.

In ground feeders because it increases the number of faults in the warm months, therefore, repair time and therefore would be more customers cutoff time. But in the air feeders the amount of cutoff time is different depending on the maneuver capacity, appropriate number and place Sectionner, Cut-out and other protective devices. Although, troubleshooting time of air networks faults is considered about half compare with ground networks, but due to the small number of Sectionner and the limited capacity of maneuver, cutoff time tangible increased, especially in the warm months of the studied year. Sometimes, be more than twice of ground network cutoff time. According to this index, in October for ground feeder and February for air feeder are located at higher rank of reliability.

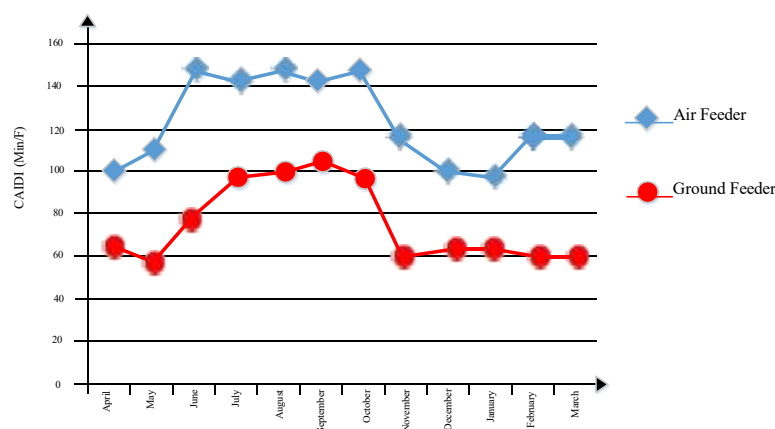


Figure 5: Customer Average Interruption Duration Index

4-3. Customer Average Interruption Duration Index (CAIDI)

Considering that follow the same trend in ground feeder monthly number and cutoff time, The CAIDI index that shows cutoff per fault, the current trend is similar with two index. But in the case air feeder, since, in beginning months cutoff time both of them, are located at higher rank. Figure 7 shows customer average interruption duration index.

Therefore, the fault for each cutoff did not prominent. In general, both of feeders have a similar behavior in terms of this index in the months of year, and increasing cutoff time for each fault is in warm months of year. According to this index, the March and November for ground feeder and April for air feeder are located at higher rank of reliability. Also, September for ground feeder and October for air feeder are located at lower rank of reliability as shown in figure 5.

4-4. Average Service Availability Index (ASAI) and Average Service Unavailability Index (ASUI)

ASUI index is expressed SAIDI index the form of percentage. This subject is similar to the two index aforementioned figures (Figure 6 and 7).

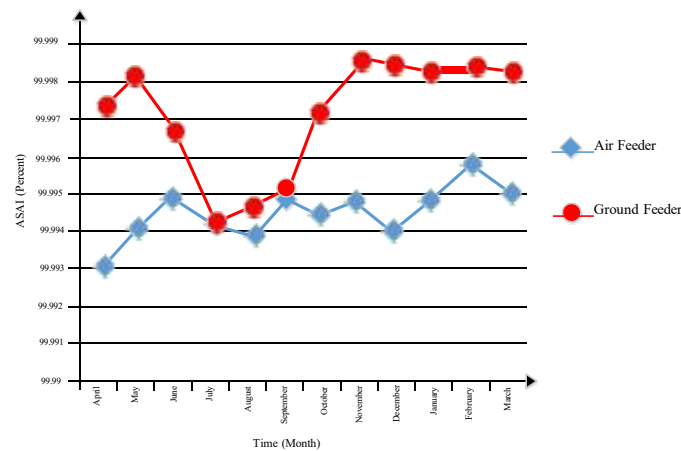


Figure 6: Average Service Availability Index

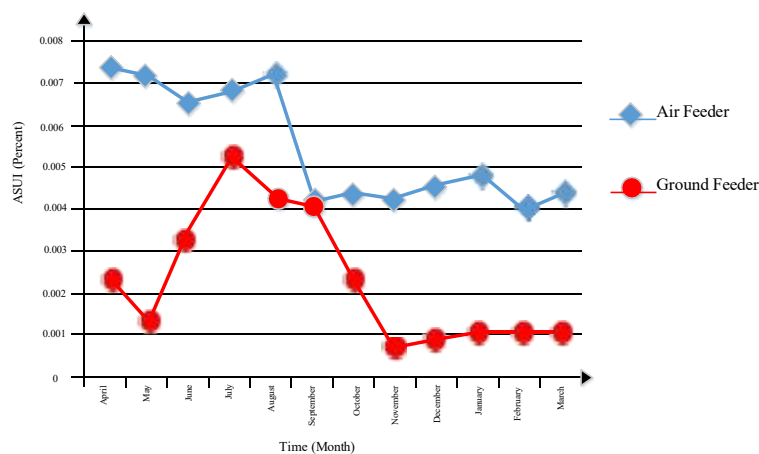


Figure 7: Average Service Unavailability Index

ASAI index expressed as a percentage the amount of service availability to electricity. As well as, customers in both networks in during cold months (December, January and February) have better availability to electricity. According to this index, November for ground feeder and February for air feeder are located at higher rank of reliability. Also, as shown in Figure 6 and 7, the July for ground feeder and April for air feeder are located at lower rank of reliability.

4-5. Energy Not Supplied Index (ENS) and Average Energy Not Supplied Index (AENS)

Figure 8 and 9 shows energy not supplied index (ENS) and average energy not supplied index (AENS).

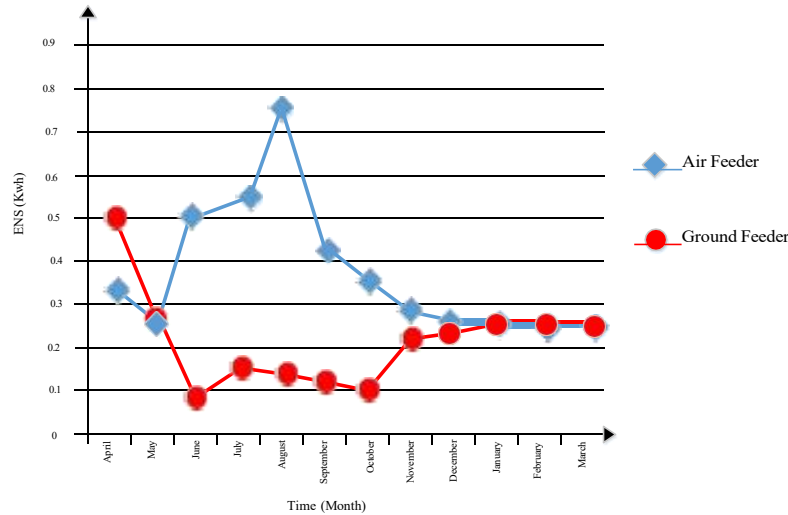


Figure 8: Energy Not Supplied Index

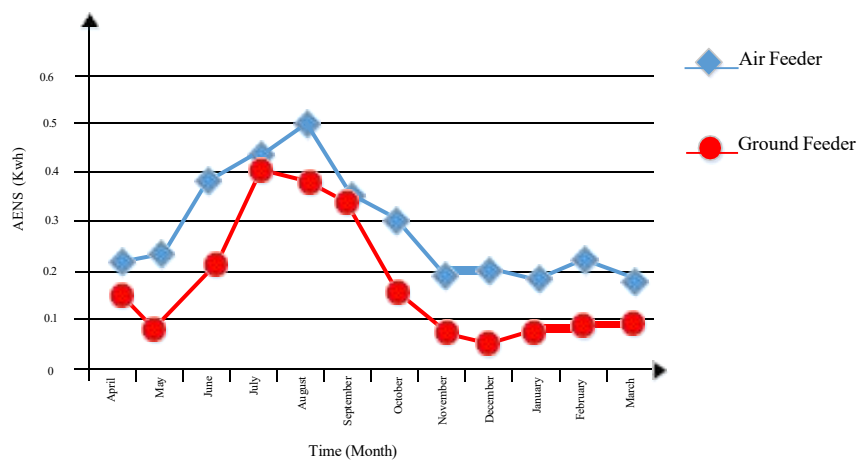


Figure 9: Average Energy Not Supplied Index

After the AENS index has been observed, that total energy not sold to customers in feeder ground, especially in the warm months is much higher than air feeder, however because greater number of the energy not sold to each customer in ground feeder less than air feeder in all months of a year. According to this index, November for ground feeder and January for feeder air are located at higher rank of reliability. As well as, In July for ground feeder and August for air feeder are located at lower rank of reliability as shown in figure 8 and 9.

As shown in figures 4- 9 and analyze the results, faults caused by rising network load in the warm months (June to September) for ground feeders and faults due to rain and wind storm in the beginning months of year (April and May) in air feeders have been allocated largest contribution in reducing the level of reliability. It should be mentioned, that faults have occurred is equal in the warm months of year (due to overload) and cold months of year (due to rainfall) for air feeder. However, this difference was observed for ground feeders. Ground feeder cutoff time in the warm months (June to September) is more than other months of year. In beginning of five months a year has occurred cutoff much greater than other months for air feeder. In warm months of year (June to September) indexes related to the energy and load such as energy not sold to customers (the most important index of sight distribution company disadvantages due to lack of selling electricity) in both the feeders increased greatly.

Since, both of transmission industrial substation supply industrial units mostly, and cutoff occurring in the system causes disadvantages of industrial units, so it can be in order to cutoff reduction by using replacement ground feeder instead of air feeder. To ENS in the months that have reduced rainfall and storms .So, ENS decreases in the cold months (climate with rain and storm). For warm months of year, there are peak load due to an increase temperature, with system optimization that in many research and papers conducted, can be taken to increase the transmission capacity and reliability of the network.

5. Conclusion

As a word, in the paper, information on the number of customers' information and transmission substation feeder load have harvested and simulated by Bakhtar regional electric company mechanization software (SIMAP), CYME PSAF version of 2.81 R 2.9 and loading manuals available at area during a month. The purpose of the paper, present short-term time period strategy (monthly) to network management in order to planning to reduction the cutoff number and cutoff time, finally reducing the amount of energy not sold, increasing in customers' satisfaction from electrical energy distribution companies [17-20] and compare the performance of the air and ground networks.

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