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Reliability Evaluation of Power Network: A Case Study of Fiji Islands

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***Abstract*— The reliability of electrical power network is the driving force for the development of a country Nowadays most electrical power industries and companies are working for the better satisfaction of the customers while considering the associate cost. Utility companies must have precise information concerning system performance to achieve these goals, consequently guarantee the assets maintenance. The reliability standard of electric power delivered to the customer in Fiji is still in developing stage. Hence it is obvious to have a thorough understanding on the present situation of Fiji islands. In this paper, the performance of electricity delivered being evaluated using commonly used reliability indexes. So that modification and improvement can be done to enhance reliability of Fiji Islands' power network.**

***Index Terms*—Maintenance, Reliability, FEA, SAIFI, CAIDI, SAIDI.**

I. INTRODUCTION

Maintenance is a key issue to enhance the reliability of power generated by utility companies [1]. The ability of delivering uninterrupted power through the network and maintain that power quality level to customers is termed as reliability [2]. Reliability standards in power systems are usually recognized as a sequence of technical requirements to be fulfilled during planning and operation. In general, reliability requirements are met providing a set of services, known as ancillary services [3], which are necessary to protect the integrity of the system and to guarantee the production along with the delivery of electric power throughout the electric grid/network.

In a developing digital world, even the smallest turbulence (i.e. Interruptions and disturbances measuring less than one cycle) in electricity quality can cause loss of information, processes and productivity [4]. The interruptions of power supply and the associated costs are becoming more damaging considering the servers crash, life support machines, intensive care unit, automated microprocessor based devices and industries. These losses can be minimized by ensuring proper maintenance of the power grid/network.

The reliability of Fiji's Electric power is highly important to the economic growth of the nation and for the continuous development. The reliability of Fiji's electric power sector is being challenged as it experiences frequent natural digester and ageing infrastructure. The reliability of Fiji's power network is considered comparatively reliable within the south pacific countries but when comparing it to developed countries such as USA, then it is considered unreliable and indicates that Fiji electric power supply has not reached a standard level yet from the reliability point of view. But so far only handful analysis is being done to justify this situation.

An international assessment has been conducted by Electric Power Research Institution and the U.S. Department of Energy on the global cost of electric outages per year and they have estimated that electric outages cost per year ranges from $26 - $400 billion [5]. Approximately 90% of all customer reliability issues are related to the distribution system [6]. Hence, it is vital to enhance distribution systems reliability to satisfy customer's demands. The idea of power reliability is tremendously large which covers all part of the ability of the system to satisfy the customer's requirements without the overburdening the tariff.

Hence it is a necessity to analyze reliability of the Fiji power system network for further improvement and to ensure sustainable energy production. Nowadays utility companies strive to develop their own strategies to satisfy customer's demands as efficiently as possible at a reasonable service of reliability.

The commonly used reliability indices for distribution systems that most countries use to assess previous performances and predict the next performance of a power system are as follows: *System Average Interruption Frequency Index (SAIFI); Customer Average Interruption Frequency Index (CAIFI); System Average Interruption Duration Index (SAIDI); CAIDI: Customer Average Interruption Duration Index. Average Service Unavailability Index (ASUI) and Average Service Available Index (ASAI).*

Table 1 presents a of scenario of reliability of electrical power system of different countries

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TABLE I: International comparison of reliability indices during the year 2007 [7].

Country	SAIDI	SAIFI
United States	240	1.5
Austria	72	0.9
Denmark	24	0.5
France	62	1.0
Germany	23	0.5
Italy	58	2.2
Netherlands	33	0.3
Spain	104	2.2
UK	90	0.8

However, Fiji Electric Authority (FEA) doesn't use all the aforementioned indices. In this paper the present three indices (i.e. SIIDI, SAIFI and CAIDI) used by FEA has been analyzed; in addition to those one more index (ASUI) has been calculated and compared with the IEEE standards to find the actual scenario of the Fiji electric grid.

II. Reliability Distribution Indices

The major reliability indices for power distribution systems are described below.

SAIFI: This index specifies on how many times the customer experiences a nonstop interruption with a period of time in their respective area. In order to obtain an accurate result, the improvement of SAIFI's index is the fixed number of customers also reducing the number of the continuous interruptions on the system. SAIFI is calculated by using the total number of customer interruptions into total number of customers served, which is shown in Eq. 1. The SAIFI index has units in time inverse.

$$SAIFI = \frac{Total\ number\ of\ customer\ interruption}{Total\ number\ of\ customer\ served} \quad (1)$$

SAIDI: This index is responsible for the average service interruption in the system. SAIDI's purpose is to indicate the total duration of an outage when continuous interruption occurs that result in power loss as shown in Eq. 2; where unit is $h.yr^{-1}$.

$$SAIFI = \frac{Total\ number\ of\ customer\ interruption\ durations}{Total\ number\ of\ customer} \quad (2)$$

CAIDI: The use of this index is to determine the average duration for service restoration to the customer. For further improvements, minimizing the length of the interruption and a faster restoring response rate can be taken into consideration as shown in Eq. 3.

$$CAIDI = \frac{Sum\ of\ customer\ interruption\ duration}{Total\ number\ of\ customer\ Interruptions} = \frac{SAIDI}{SAIFI} \quad (3)$$

III. Fiji Electricity Authority (FEA)

FEA is the main power generation and supply company in the country (Fiji). Fig. 1 shows the power infrastructure of the Fiji Islands served by FEA.

FEA has used three commonly used indices (SAIFI, CAIDI and SAIDI) [8] each year to measure the company power system reliability. In addition, this research has added one more indices (ASUI) for further analysis.

IV. Reliability of FEA

Nearly all electric power industries deliver efficient electricity to its clients keeping track of the reliability indices. So far the most popular indices that used by FEA are SAIFI, CAIDI and SAIDI. IEEE has reviewed the previous standards for the reliability indices. SAIFI is usually measured over the course of a year, and according to IEEE Standard 1366-1998 the median value for North American utilities is approximately 1.10 interruptions per customer [9]. SAIDI is usually measured over the course of a year, and the median value for North American utilities is approximately 1.50 hours [9]. CAIDI is usually measured over the course of a year, and the median value for North American utilities is approximately 1.36 hours [9]. The standard values used in this research for each index provided by the IEEE Standards 1366-1998 [9, 10] are:

- SAIFI: 1.1 (customer/interruptions)
- SAIDI: 1.5hrs
- CAIDI: 1.36hrs

The following section shows the FEA data evaluation results using the aforementioned four reliability indices. Fig. 2 displays the total length of time (shown in %; 1%=102.2 minutes) a customer is without power from years 2005 to 2014. The year 2007 was not kind to FEA due to a flood that occurred in the northern division and a disruption on the 132KV lines resulting power outage to the Central and Western regions. Compared to the year 2008 as the company (FEA) continued to minimize the power outages and distribute efficient adequate power supply. For the years 2013 and 2014, FEA has reduced the values of SAIDI from 511 minutes to 408.8 minutes.

Fig. 3 reflects on the average number of times (shown in %; 1%=1.8) that a customer's power supply is interrupted in a year; ranging from year 2005 to 2014. The year 2006 acquired a value of 27 times (15%) as this was due to faults on line hardware and having a planned maintenance work on overhead and underground lines compared to the year 2007. The value of interruption that occurred in 2007 was 27.8 times (15%) due to major power cuts caused by the 132kV overhead lines at Wailoa hydro power station that again affected the Central and Western Regions. However since 2009; FEA improved their reliability performance.

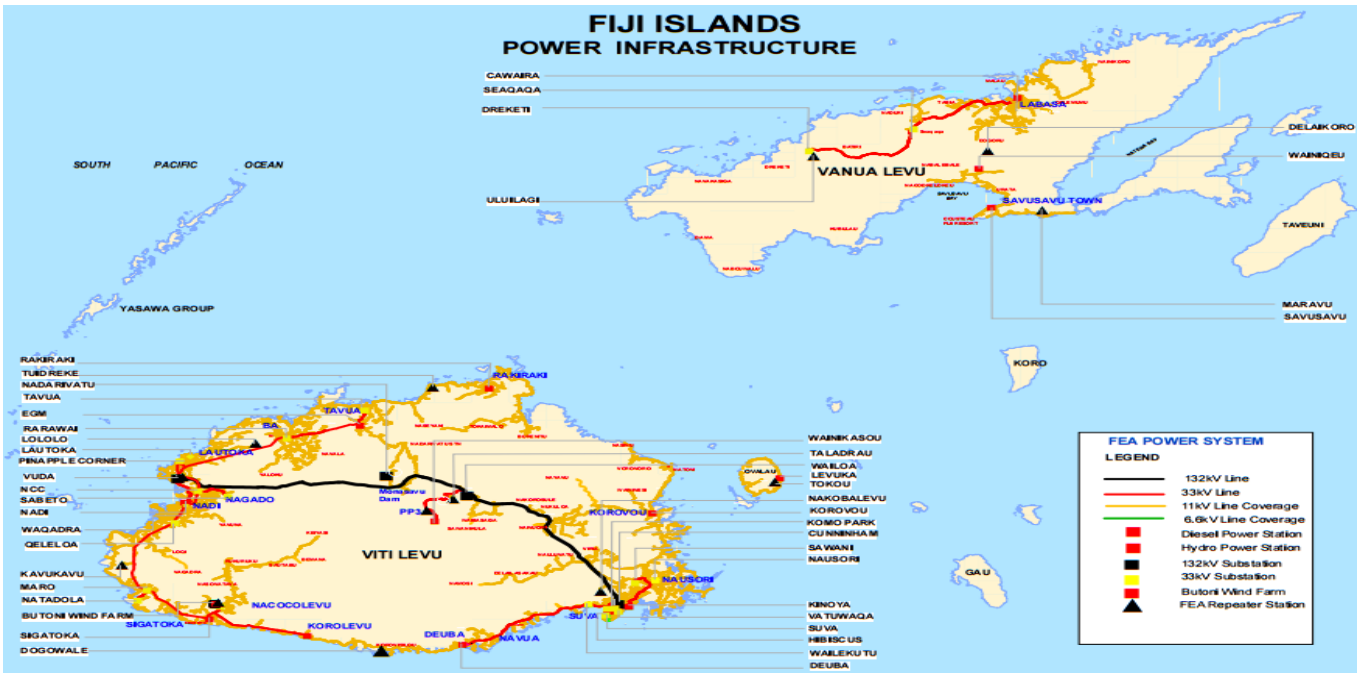

Figure 1: Fiji Power Network by served FEA

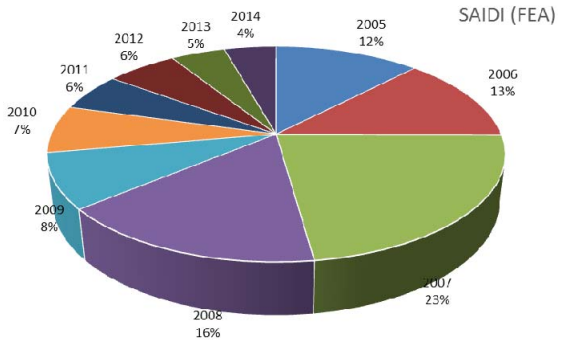

Figure 2: SAIDI for FEA from 2005 to 2014.

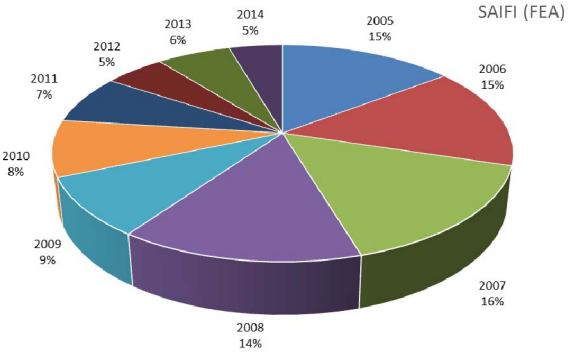

Figure 3: SAIFI for FEA from 2005 to 2014.

Fig. 4 depicts the CAIDI scenario for FEA; including from 9% in 2006 to 15% in 2007, from 9% in 2010 to 12% in 2012 and also from 7% in 2013 to 10% in 2014.

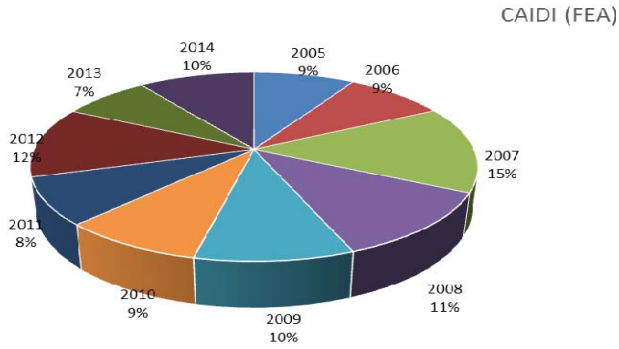

Figure 4: CAIDI for FEA from 2005 to 2014.

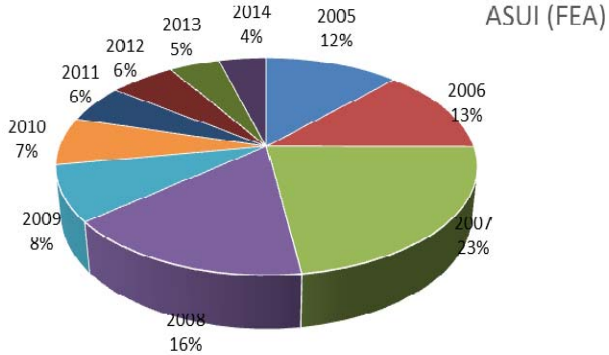

Figure 5: ASUI for FEA from 2005 to 2014.

FEA had the highest ASUI value in 2007 with a value of 0.289610 (23%) shown in Fig 5. Since Fiji had high values for SAIDI in 2007, it also affects the ASUI values exhibited in Fig.5.

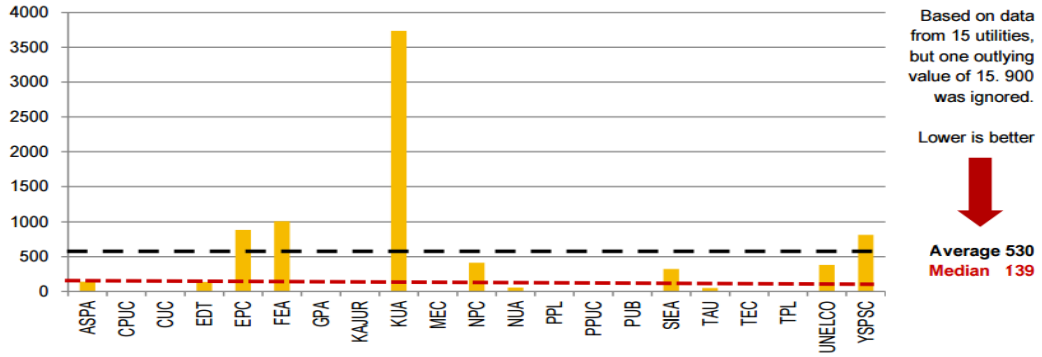

Figure 6: SAIDI interruptions in 2010 (minutes per customer) in the south Pacific Region [11].

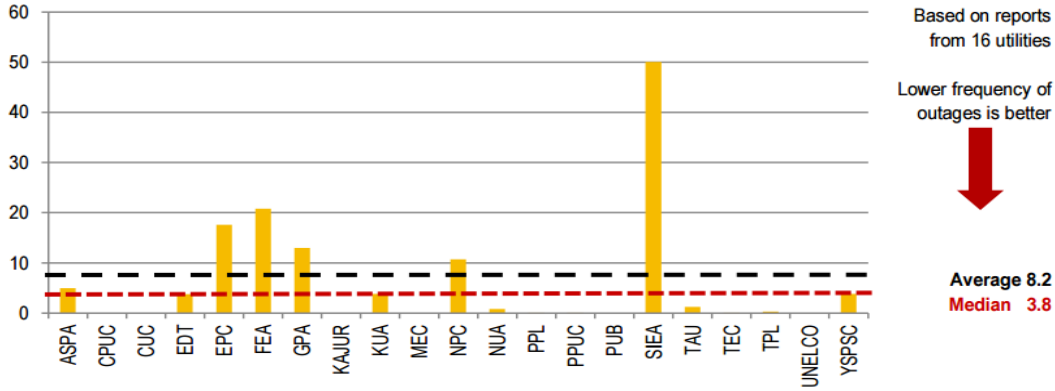

Figure 7: SAIFI: interruption frequency in 2010 (interruptions per customer) in the south Pacific Region. [11]

In the FEA report -2014 [8], SAIDI was considered to be a priority area for improvement considering that current performance is not good (average of 592 minutes per year compared to the Pacific benchmark and customers typically rank reliability of supply as very important. For 2010 (Fig. 6), the reported average was 530 minutes (with one very high value ignored) with a median of only 139 minutes, well within the Pacific goal of 2020.

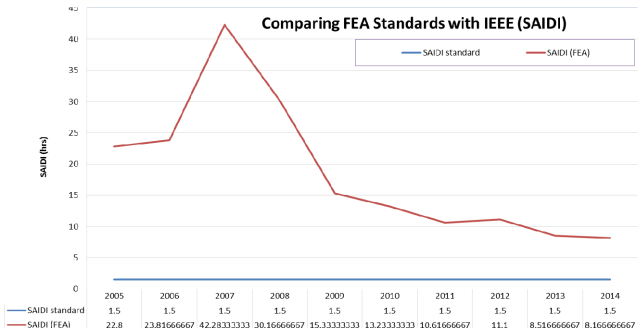

Figure 8: Exhibits the indices being compared along with its standards for SAID of 1.5 hrs.

In year 2010, reported data suggests that SAIFI has dropped to about 8 with a median of less than 4 interruptions per customer per year (Fig. 7). As with SAIDI, SAIFI tends to be estimated by utilities or only partly recorded so the reported improvement may not reflect actual changes in performance.

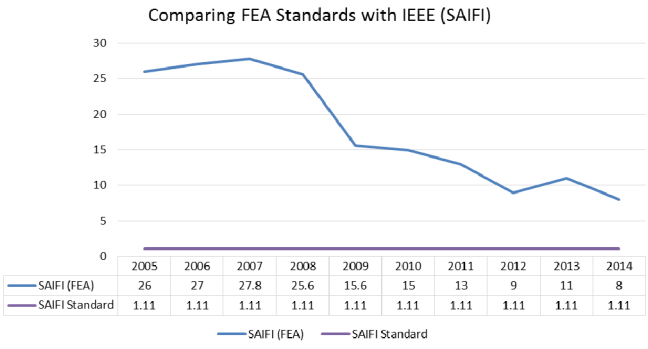

Figure 9: Exhibits the values of SAIFI for all companies being compared with its standard value of 1.11 (customer/interruptions).

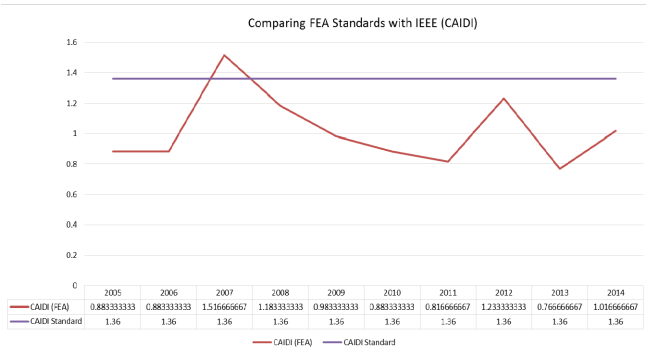

Figure 10: Presents the graph of comparing all CAIDI values with the standard of 1.36 hrs

Fig.8 represents the electric utilities FEA being compared to the standard value of SAIDI at 1.5 hrs. It is evident that during the years 2006, 2007 and 2008 Fiji Electricity Authority (FEA) has acquired values of 23.816667 hrs, 42.283hrs and 30.1667 hrs respectively being the highest due to flooding that occurred in the northern region of Vitilevu and an overhead line rated at 132kV that was linked to Wailoa Hydro plant having numerous outages that also affected the Western and Central regions during the year 2007.

Fig. 9 displays the graph of comparing the standard value of SAIFI at 1.11 (Customer/interruption). FEA being displaced far apart due to its values ranging from 26 – 13 (Customer/interruptions) during the years 2005 to 2011, as the years had passed 2012, 2013 and 2014 had reasonable values of (9.11 and 8) Customer/interruptions.

CAIDI values are simply the ratio of SAIDI by SAIFI. This is viewed as the average restoration period or in other words the time it takes the company to restore power to its customers. As the tides have turned, FEA has remarkably outshined the IEEE CAIDI standards with satisfactory results of 0.8883 hrs during 2005 and 2006 (as shown in Fig. 10). 1.2333 hrs for 2012, 0.7666 hrs and 1.01667 hrs for 2013 and 2014 except for 2007 which had a setback which was discussed earlier that obtained a value of 1.51667 hrs. This is because of the size and population of the Fiji, which is very small nation.

V. Discussion and Conclusion

According to the aforementioned analysis; SAIDI, CAIDI and SAIFI displays high values for FEA in 2007 including ASUI as the values are low in 2007 indicating that the reliability of electric power generated is worse compared to other years.

It has been observed that while comparing FEA's reliability indices with IEEE Standards, FEA has much higher values for all three indices. In order to obtain an optimal index, FEA must review the power outages that were encountered during the years (2005 – 2014).

For FEA to improve the power supply reliability to be in line with international bench mark for power utilities of similar sizes, this research propose that the company may consider the following initiatives to improve the Fiji's power network reliability, consequently ensure the customers have adequate power supply to meet demand at all times.

- Acquire a regular the line–line maintenance. This will increase the life of electrical devices and reduce the equipment costs.
- Continue to develop and install distributed energy generation systems.
- Use technologies that can detect the defects which can be fixed promptly and other relevant equipment that can speed up power restoration.
- To increase the network stability; the 33kV overhead line from Deuba to Korolevu need to be interconnected (please see Fig. 1).

Reliability depends on the maintenance. For electric power companies to achieve the best index value, considering all costs such as maintenance, minimizing power loss in the transmission lines, etc. will help uphold values that produce efficient power. The reliability analysis permits stockholders to determine indices for supplying power to definite customers or to the whole system. The indices also allow the company to compare the previous and actual results which will determine the satisfaction provided towards the customers. Moreover these indices are set as benchmarks that will uphold the companies' expectation to produce better results and FEA still needs improvement after comparing the benchmarks to IEEE standards.

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