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RESEARCH ARTICLE

ELECTRIC POWER DISTRIBUTION SYSTEM RELIABILITY ASSESSMENT OF ARBA MINCH CITY, ETHIOPIA

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ABSTRACT

Reliability of electric power delivery system is a critical issue in order to make a continuously available sufficient voltage, of satisfactory quality, to meet the consumer's' needs. The paper studies about the reliability analysis of Arba Minch distribution system using different index parameters. In the city electricity is highly affected by a continuous power interruption and outage from the main grid. The reliability indexes such as SAIFI, SAIDI, CAIDI, and ASAI parameters has been analyzed based on power interruption frequency and duration data. The reliability of Arba Minch city is poor so EEPCO should take different mechanisms of improving the power availability hours and reduce interruption frequency and duration.

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INTRODUCTION

Power quality is a part of customer satisfaction and the real measure of a utility's good customer focus. However, many of the other factors contributing to customer satisfaction, such as the quality of billing and response to customer inquiries are generally beyond the venue of the planner. Power quality is also better thought of as voltage quality and deals with any deviation from a perfect sinusoidal voltage source. Reliability planning focuses on reliability, which includes availability as an important element. Aspects of power quality not related to reliability are generally addressed only tangentially, as they normally work out in systems designed to provide sufficient reliability of capacity, as the equipment and units used in the system have been designed so that will occur. In the larger sense, "Power Quality" has different parts such as reliability and availability. Power system reliability is the ability of the power delivery system to make continuously available sufficient voltage, of satisfactory quality, to meet the consumer's' needs (Lee Willis H., 2004). In the context of distribution systems, reliability has historically been associated with sustained customer interruptions (interruptions lasting more than a few minutes).

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Figure 1. Availability is a subset of reliability and reliability is a subset of power quality (Richard E. Brown, 2009)

This is reflected in the predominant use of the reliability indices SAIFI and SAIDI (Wangdee, W. and Billinton, 2005; Richard E. Brown, 2009). These values represent the number of sustained interruptions and the number of interruption hours that an average customer experiences in a given year (the reliability indices ASAI and CAIDI are also widely used, but they can be directly computed from SAIFI and SAIDI and offer no new information). (Brown, 2009) Reliability varies naturally from month to month or year to year. Some years will prove lucky and reliability will be higher than expected. Other years will be unlucky and reliability may be much worse than average. This natural variation in reliability is an important aspect of distribution systems. Reliable utility services are vital to all industrial, commercial and military installations. Loss of electricity, thermal fuels, water, environmental control, or communications systems can bring many operations to an immediate halt resulting in significant economic loss due to unscheduled downtime, loss of life, or threat to national security. These services are delivered by vast, complex networks with many components (Richard E. Brown, 2009). Arba Minch city had got electric power until 1982 EC through Sodo to Arba Minch transmission line. Recently, it receives supply from Gilgel Gibe and MelkaWokena hydropower generator renewable energy; it doesn't have any standby power supply to satisfy its demand and to increase its power quality. Perfect power quality is a perfect sinusoid with constant frequency and amplitude. Less than perfect power quality occurs when a voltage waveform is distorted by transients or harmonics, changes its amplitude, or deviates in frequency. Customer interruptions are power quality concerns since they are a reduction in voltage magnitude to zero.

Reliability is primarily concerned with customer interruptions and is, therefore, a subset of power quality. Sustained interruptions (more than a few minutes) have always been categorized as a reliability issue, but many utilities have classified momentary interruptions (less than a few minutes) as a power quality issue. The reasons are (1) momentary interruptions are the result of intentional operating practices, (2) they did not generate a large number of customer complaints, and (3) they are difficult to measure. Today, momentary interruptions are an important customer issue and most distribution engineers consider them a reliability issue. This paper concerned on sustained and temporal interruptions. Because ArbaMinch substation doesn't gauges any momentary and instantaneous interruptions due to limitation of automatic recording instruments and skilled manpower. Availability is the percentage of time a voltage source is uninterrupted (Wangdee and Billinton, 2005). If the line is interrupted somewhere, power will not be available. And also the system will not be reliable if power is not available. So due to different reasons its power was interrupted always. These power interruptions were happened due to the external fault (transmission line, generating units etc.); maintain the stability of the system; internal fault and abnormality (i.e. Arba Minch city) and for maintenance purpose.

Outage and interruption

Outage is the state of components when it is not available its intended function due to some component that are directly associated with that component. A customer interruption are the losses of service to one or more customers or other facilities and is the result of one or more components outage depending upon system configuration and caused by a wide range of phenomena including equipment failure, animals, trees, severe weather, and human error. Two different aspects of reliability receive attention in any type of power distribution reliability analysis, either of outages or interruptions. These are expressed by frequency (how often something occurs) and duration (how long it lasts). With respect to interruption, frequency refers to the number of times service is interrupted during a period of analysis - once a decade, two times a year, five times a month, or every afternoon. Duration refers to the length of these interruptions; some last only a few cycles, others for hours, even days. Frequency and duration are used with regard to outages, too. (Lee Willis, 2004)

Reliability Indices

Reliability indices are statistical aggregations of reliability data for a well-defined set of loads, components, or customers. Most reliability indices are average values of a particular reliability characteristic for an entire system, operating region, substation service territory, or feeder. System Average Interruption Duration Index (SAIDI) is the average duration of all interruptions per utility customer during the period of analysis. Here, the total customer minutes of interruption are added together and divided by the total number of customers in the system. It is measured in units of time, often minutes or hours. For a fixed number of customers, SAIDI can be improved by reducing the number of interruptions or by reducing the duration of these interruptions. Since both of these reflect reliability improvements, a reduction in SAIDI indicates an improvement in reliability. Customer Average Interruption Duration Index (CAIDI) is the total number of customer hours of interruption divided by the total number of customer interruptions, which yields just the average duration of a customer interruption. It can also be viewed as the average restoration time. CAIDI can be improved by reducing the length of interruptions, but can also be reduced by increasing the number of short interruptions. Consequently, a reduction in CAIDI does not necessarily reflect an improvement in reliability. It is commonly used by electric power utilities. It is related to SAIDI and SAIFI, and is calculated as

$$\mathrm{CAIDI} = \frac{\text{sum of all customer interruption durations}}{\text{total number of customer interruptions}} = \frac{\mathrm{SAIDI}}{\mathrm{SAIFI}}$$

CAIDI is measured in units of time, often minutes or hours. It is usually measured over the course of a year. Momentary Average Interruption Frequency Index (MAIFI) is a reliability indicator used by electric power utilities. MAIFI is the average number of momentary interruptions that a customer would experience during a given period (typically a year). Electric power utilities may define momentary interruptions differently, with some considering a momentary interruption to be an outage of less than 1 minute in duration while others may consider a momentary interruption to be an outage of less than 5 minutes in duration. MAIFI is calculated as

$$\mathrm{MAIFI} = \frac{\text{total number of customer interruptions less than the defined time}}{\text{total number of customers served}}$$

MAIFI has tended to be less reported than other reliability indicators, such as SAIDI, SAIFI, and CAIDI. However, MAIFI is useful for tracking momentary power outages, or "blinks," that can be hidden or misrepresented by an overall outage duration index like SAIDI or SAIFI. Momentary power outages are often caused by transient faults, such as lightning strikes or vegetation contacting a power line, and many utilities use recloses to automatically restore power quickly after a transient fault has cleared. Customer Average Interruption Frequency Index (CAIFI) is a popular index used in electrical reliability analysis (Richard E. Brown, 2009). It is designed to show trends in customers interrupted and helps to show the number of customers affected out of the whole customer base. It is the average number of interruptions experienced by customers who had at least one interruption during the period. System Average Interruption Frequency Index (SAIFI) is commonly used as a reliability indicator by electric power utilities. SAIFI is the average number of interruptions per utility customer during the period of analysis. This is just the total number of customer interruptions that occurred in the year divided by the total number of customers in the system. SAIFI is measured in units of interruptions per customer. It is usually measured over the course of a year. For a fixed number of customers, the only way to improve SAIFI is to reduce the number of sustained interruptions experienced by customers. Average Service Availability Index (ASAI) is the customer-weighted availability of the system and provides the same information as SAIDI. Higher ASAI values reflect higher levels of reliability.

MATERIALS AND METHODS

System reliability can be study in different mechanisms, modeling and methods. In this seminar paper, the paper is used index parameters to investigate power reliability of Arba Minch city via the necessary information and data that collected from Arba Minch district EEPCO and substation offices of different load locations at winter and spring sessions of 2011 GC as shown on Table 1 and 2.

RESULTS

Data's shown below are collected from Arba Minch substation and Arbaminch district EEPCO. The data's are 3 months power interruption frequency and duration information. Such information is not sufficient to make power reliability analysis of Arba Minch city but due to the shortage of recorded data and their poor documentation system, the analysis was done based on monthly information.

As shown in the load curve above, the feeder is loaded more during the day time up to midnight because most customers need a supply. Whereas the industries such as Textile factory andArbaminch University needed a supply throughout a day that is why after midnight load demand is around 1500KW. Unlike Sunday, Load curve of the remaining days of a week is similar to Tuesday's load curve.

Table 1. Arba Minch Distribution system Interruption and Customer Data

Load Area	Frequency			Duration			customer-interruption			Total Pop'n
	February	March	April	February	March	April	February	March	April	
Sechia	25	18	13	67.77	39.97	44.4	267145	171925	153410	2645
Sikella	32	20	14	108.317	52	32.7	355914	228488	263640	4394
Overall Interruptio	12	7	16	60.03	52.3	18.3				
Total	69	45	44	236.133	144.3	95.4	623059	400413	417050	7039

Table 2. Arba Minch Distribution System Customer Power Interruption duration

	Sum of durations of all customer		
	February	March	April
Sechia	179251.65	105720.7	117305.8
Sikella& textile	475944.9	228488	143758.5
Overall Interruption	422551.17	368139.7	128694
(ASAI) reliability-percentage (%)	67.20375	79.9625	86.75694

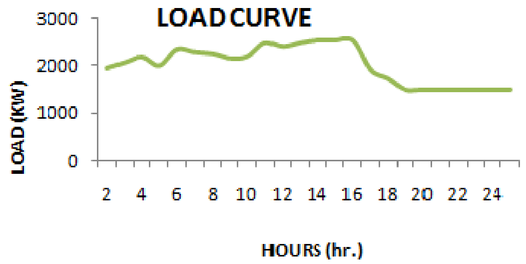
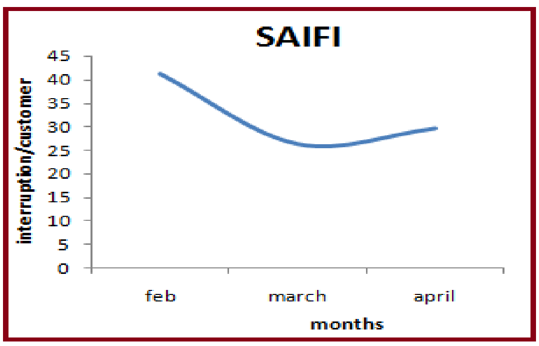
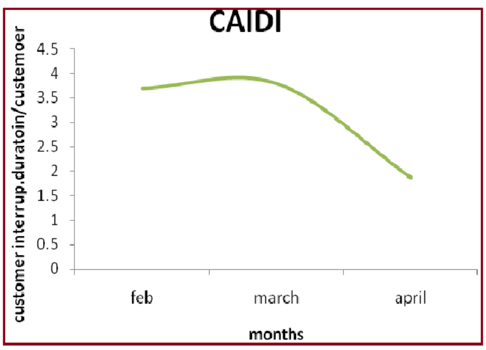


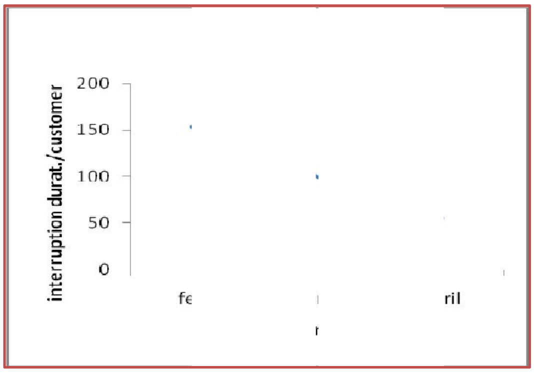
Figure 2. Arba Minch city Tuesday's load curve



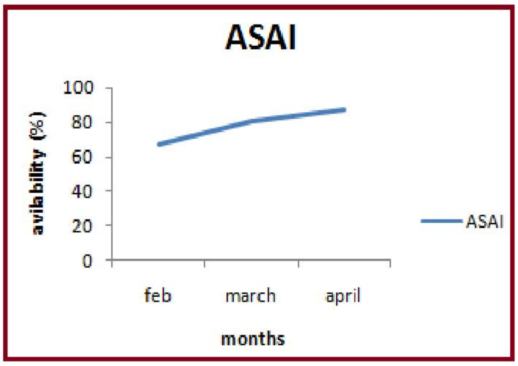
(A)



(B)



(C)



(D)

Figure 3. Reliability Index graph of Arba Minch City

As the above reliability index graphs of figure-3, indicated that average number of interruptions per utility customer and the number of customers affected out of the whole customer base during a month too high. But the index results are improving from month to month due to different mechanisms taken by EEPCO. Even though availability of electric power in Arba Minch city is increasing from time to time, unavailability of supplying power is too high. For example, on April, for 95 hours and 21 minutes power isn't available in the Arba Minch city as shown Figure 3 (D).

Conclusion

Reliability of service is one of the major factors electric consumers weigh in perceiving how well their electric supply system is doing its job. In fact, CAIDI is mathematically equal to SAIDI divided by SAIFI. Therefore, CAIDI will increase if SAIFI improves more quickly than SAIDI. That is, reliability could be improving in both frequency and duration, but CAIDI could be increasing. In summary, SAIDI and SAIFI are generally good measures of reliability, but can potentially bias spending towards areas of the system that may already have adequate reliability. CAIDI is confusing since increasing CAIDI could be either good or bad. Index parameters are a good parameters for studying power system reliability of Arba Minch city and they indicates what are the causes; how can we reduce interruption frequency and duration; by what types of interruption and outage our systems are affected. The reliability of Arba Minch city is poor so EEPCO should take different mechanisms of improving the power availability hours and reduce interruption frequency and duration.

Generally, electric power reliability Arba minch city can be improve by using different ways such as replacing damaged substation transformer by new, installing advanced protection system, good design, using stand by renewable technology etc.

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