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Reliability Analysis and Redesign of Power Distribution System (Case Study of Nazareth Distribution System)

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Abstract: -Low Electrical Power Reliability is a serious problem in our country. System reliability problems are caused by interruptions of power distribution system which leads to damage of electrical and electronics equipment and affecting the production time of the customers. This paper attempts to analyze reliability of existing Nazareth distribution system, identify the problems of low system reliability, and give the solutions to reduce the interruptions and redesign of power distribution system to increase the system reliability. The Reliability Analysis of existing system carried out by Analytical methods and simulation using the data collected from the distribution substation and utility service sectors as input. Distribution reliability indices such as SAIFI, SAIDI and ASAI have been analyzed thoroughly on power distribution system and the analyzed distribution reliability indices values have been compared with standard benchmark values and comparison indicates that Nazareth distribution system is unreliable. To improve the reliability of the network, proper maintenance strategy and redesign of distribution system is necessitated. In this paper redesigning of existing 15kV/2×25MVA power distribution system has been made and replaced by 33kV/5×50MVA one and the result of simulated redesigned distribution system indices of SAIFI in numbers per customer year, SAIDI in hours per customer year and ASAI in % in year improved from 956.33, 923.3, and 89.46% to 2.75, 38.72 and 99.56 respectively. Using Electrical Transient and Analysis Program (ETAP) software, the reliability analysis of the redesigned distribution system and the existing system has been simulated and compared and the result obtained reveals that the reliability of the system is improved and its marginal difference with benchmarked one reduced significantly.

Keywords*: - *Distribution System, Reliability Analysis, Reliability indices, Distribution System Design, ETAP.

I. INTRODUCTION

The power distribution system is made up of sub-transmission lines, power transformers, 33kV lines, 15kV lines, distribution transformers, LV Lines, etc. Currently Ethiopian Electric Power system has 400kV, 230kV, 132 kV primary transmission systems and 66kV, 45kV as sub transmission system and 33kV and 15kV as distribution system. At all the 66 or 45kV substations power transformers of various ratings like 25 /12 /6.3/3MVA are installed for step down of voltage to 15kV for feeding to Distribution Transformers. Once the voltage has been lowered at the distribution substation, the electricity flows to industrial, commercial, and residential centers through the distribution system. Conductors called feeders reach out from the distribution substation to carry electricity to customers. Customers require higher quality service due to more sensitive electrical and electronic equipment. The effectiveness of a power distribution system is measured in terms of efficiency, service continuity or reliability, service quality in terms of voltage profile and stability and power distribution system performance [10].

In Ethiopia, electric power interruption is becoming a day to day phenomenon. Even there are times that electric power interruption occurs several times a day, not only at the low voltage but also at the medium voltage distribution systems. The drop of the voltage, especially at the residential loads, is causing early failure of equipment's, blackening of light bulbs, and decreased efficiency and performance of high-power appliances. Damage of electronic devices and burning of light bulbs have also occurred due to over voltages [9].

The continuity of energy supply can be increased by improved system structure, increased investment during the planning phase, operating phase or both. Power distribution system standards and design guidelines are the minimums acceptable criteria for the design of efficient, economical, durable, maintainable, and reliable electrical power supply and distribution systems. Clarifications of baseline design criteria, standards, policy, and guidelines are provided by Institute of Electrical and Electronics Engineers (IEEE),

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International Electro-Technical Commission (IEC), National Electrical Code (NEC). [8]

II. LITERATURE REVIEW

The research indicated that users were utilizing a wide variety of tools and techniques with different analysis results. These analytical approaches are applied to the IEEE Gold Book standard network in a series of papers to determine the accuracy of their results and how closely they can verify operational anomalies [1]. The two main approaches used are analytical and simulation. The vast majority of techniques have been analytically based and simulation techniques have taken minor role in specialized applications. The main reason for this is because simulation generally requires large amount of computing time, and analytical models and techniques have been sufficient to provide planners and designers with results needed to make objective decisions. Analytical techniques represent the system by a mathematical model and evaluate the reliability indices from this model using direct numerical solutions. They generally provide expectations indices in a relatively short computing time [2].

Analytical methods of reliability analysis used in this paper, which represents the system by mathematical model and evaluates the reliability indices from this model using direct numerical solutions. After the reliability analyzed by analytical methods it is evaluated again by using Electrical Transient and Analysis (ETAP) software to check whether analytical methods work properly.

III. BLOCK DIAGRAM

Single Line Diagram of Nazareth Distribution System (Existing).

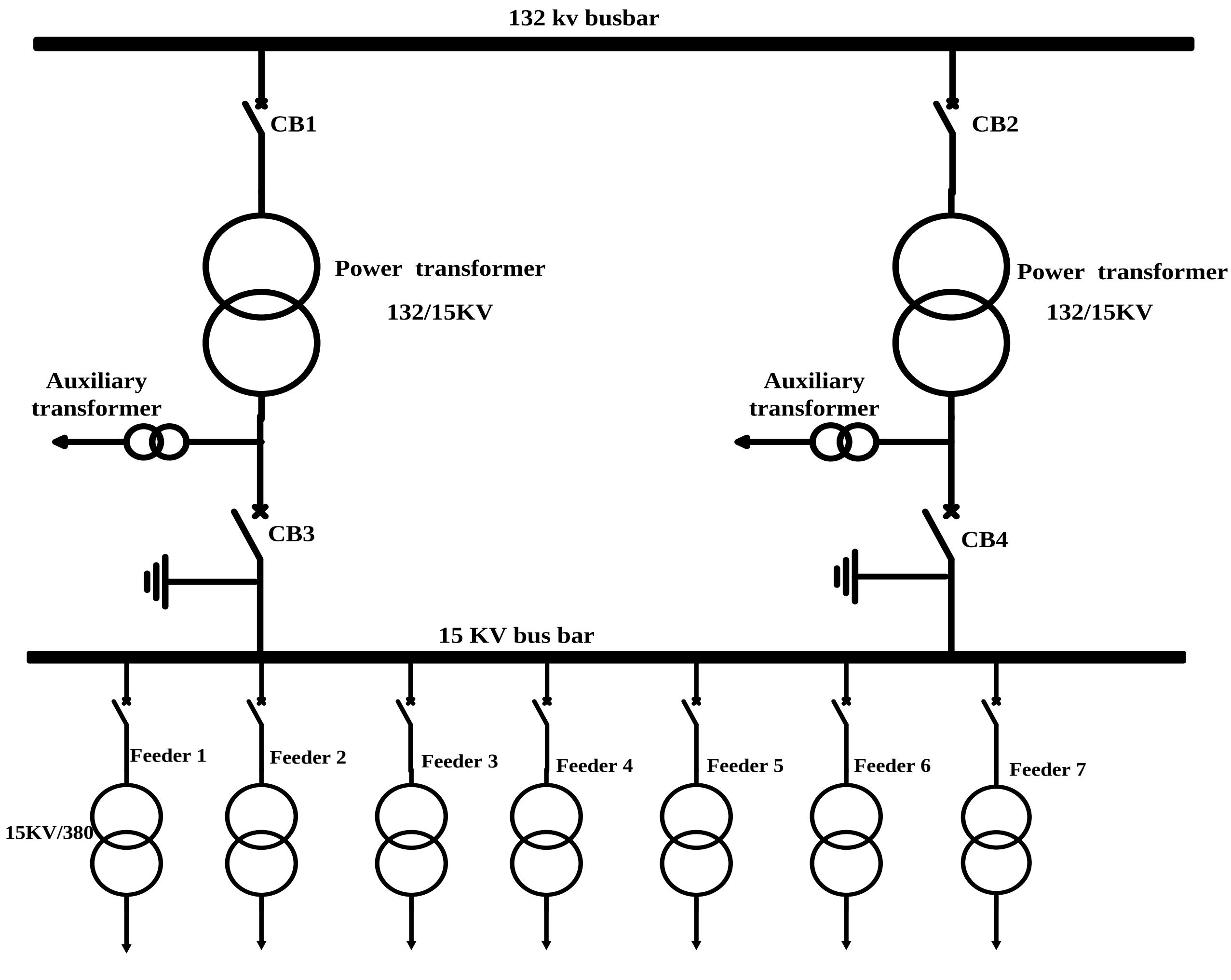

Fig 1:- Single Line Diagram of Nazareth Distribution System

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Feeder	Total number of distribution transformer	Number of customer on feeders (N_i)	Interruption frequency λ_i in (N_o)	Duration of interruption r_i in hours	Load interrupted in (MW) per year
1	34	9104	562	418.95	2806.3
2	69	11588	390	475.95	2296.7
3	84	13056	434	451.60	2679.4
4	73	11713	378	364.80	2214.5
5	5	1	68	35.53	230
6	2	3745	319	248.37	464.8
7	7	4797	406	476.97	2223.9

Table 1:- Interruption Frequencies, Duration of Interruption and Load Interrupted from 01/01/2008 to 30/12/2008 E.C [44].

Type of faults or cause of interruption	**Feeders**						
	1	**2**	**3**	**4**	**5**	**6**	**7**
Earth fault	96	51	54	60	23	51	91
Short circuit fault	86	76	69	59	9	68	90
Over loads	23	25	28	15	0	12	0
Request (Load Dispatch Centre or Request of Emergency Office)	348	238	288	244	36	188	217
Under frequency	9	0	0	6	0	0	0
Total	562	390	434	378	68	319	406

Table 2:- Summary of Causes of Interruptions in Nazareth Distribution Substation

Load type	**Total number of customer per load**
Domestic or residential	43184
Commercial	9062
Industrial	734
Others	1024
Total	54004

Table 3:- Load Types and Total Number of Customers on the Load Type [43].

Nazareth 15KV feeder data								
S.N$_O$	Name of substation	Voltage ratio	Power capacity N_o×MVA	Name of feeder	Total number of DT feeder	Total capacity of DT KVA	Total length of feeder in KM	Conductor size
1	Nazareth	132/15	2×25	Line1	34	7880	13.51	AAC 50mm^2
2	>>	>>	>>	Line2	69	26457	39.23	>>
3	>>	>>	>>	Line3	84	25515	23.52	>>
4	>>	>>	>>	Line4	73	17510	30.85	>>
5	>>	>>	>>	Line5	5		5.2	>>
6	>>	>>	>>	Line6	2	3915	25	>>
7	>>	>>	>>	Line7	7	5930	12.47	>>

Table 4:- Nazareth 15kv Feeder Data [43]

Feeder	Interruption frequency in λ_t (N_o)	Duration of interruption r_t in hours
1	1631	1214.955
2	1131	1380.255
3	1259	1309.64
4	1096	1057.92
5	197	103.37
6	925	720.273
7	1177	1383.213

Table 5:- Total Frequency of Interruption and Duration of Interruption

Current peak load (MW)	Annual load growth in % (EEP) data		Design and planning of future load demand in period (year)			Annual load growth in % (world bank) data
	Growing area	Saturated area	Short term	Medium term	Long term	
44	5	2	5	10	25	6

Table 6:- Data Used for Forecasting, Design and Planning Of Distribution System and Components [24].

Fig 2:- Interruption Frequency of Distribution System from 01/01/2008 to 30/12/2008

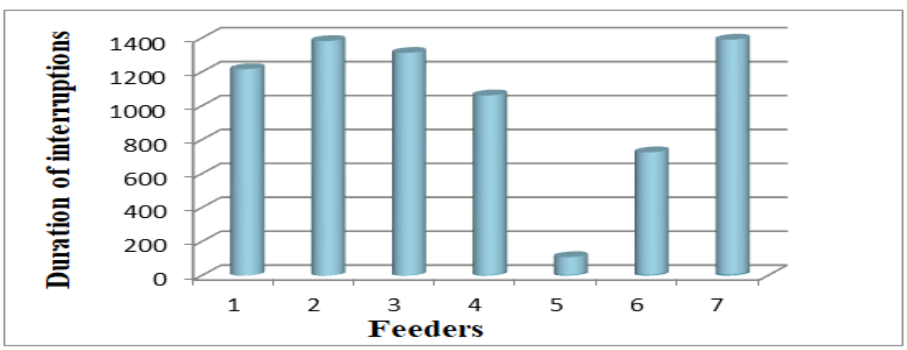

Fig 3:- Duration of Interruption from 01/01/2008 to 30/12/2008 E.C

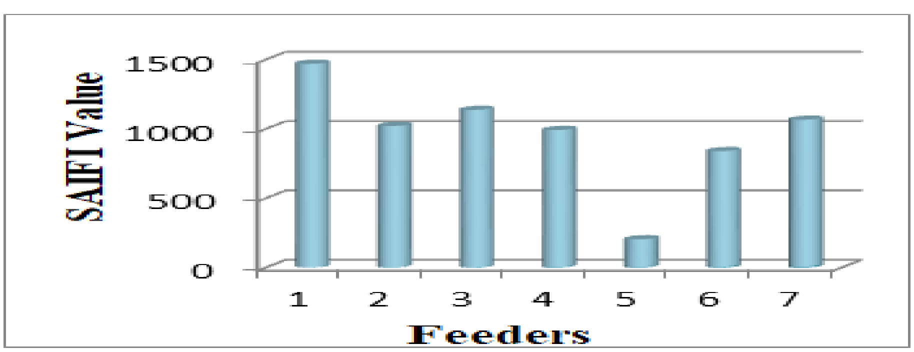

Fig 4:- SAIFI Value from 01/01/2008 to 30/12/2008 E.C for each Distribution Feeder.

Fig 5:- SAIDI Value from 01/01/2008 to 30/12/2008 E.C for each Distribution Feeder.

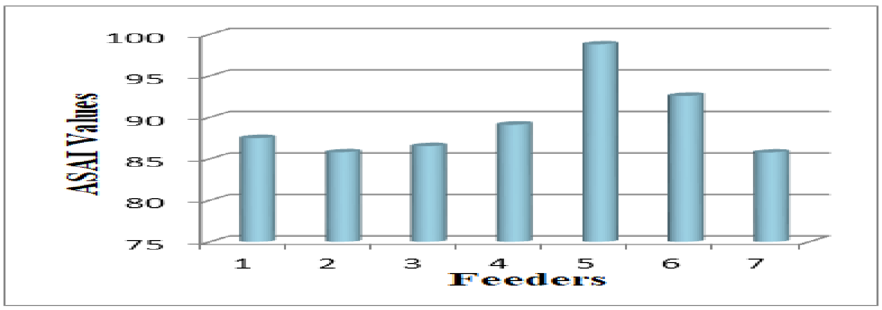

Fig 6:- ASAI Value from 01/01/2008 to 30/12/2008 E.C for each Distribution Feeder.

No	Country	SAIDI (hours/year)	SAIFI (Interruptions/Customer year)	ASAI (%)
1	United States	4	1.5	99.91
2	Austria	1.2	0.9	99.97
3	Denmark	0.4	0.5	99.981
4	France	1.033	1	99.91
5	Germany	0.383	0.5	99.9999
6	Italy	0.967	2.2	99.9991
7	Netherlands	0.55	0.3	99.97
8	Spain	1.733	2.2	99.968
9	UK	1.5	0.8	99.964
10	Ethiopia (Nazareth)	923.3	956.33	89.46

Table 7:- Benchmarks for Reliability Indices

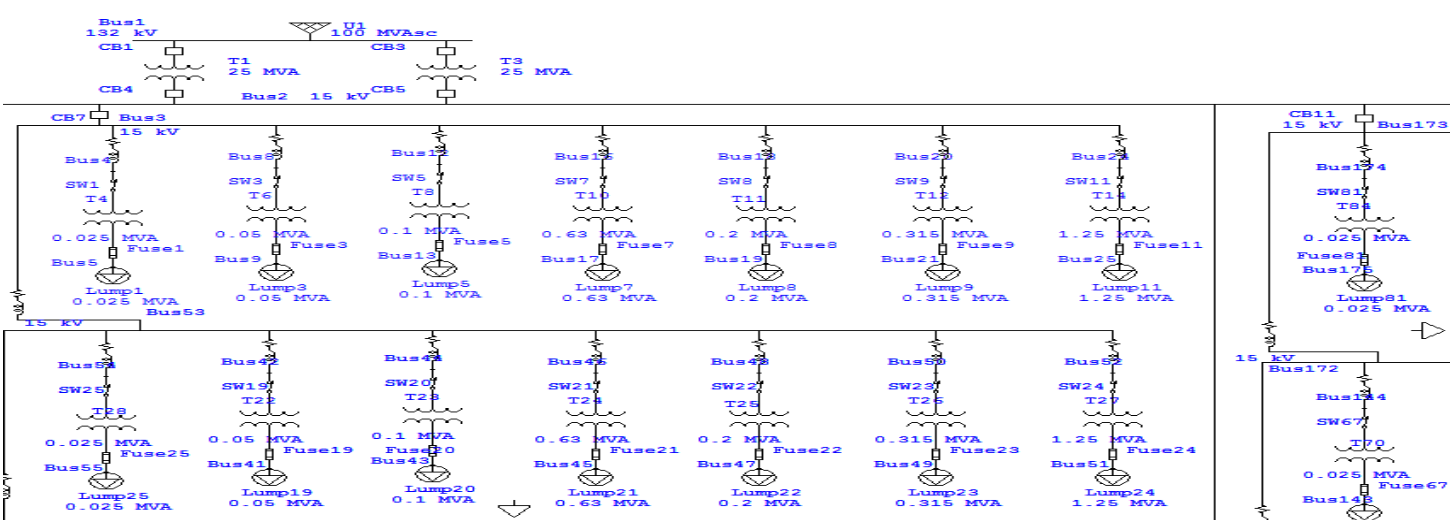
Fig 7:- Nazareth Distribution Systems (Existing)

Indexes	SAIFI (N_o)	SAIDI (hours)	ASAI (%)
Values	956.3372	923.314	89.46%

Table 8:- Simulation Result of Existing Nazareth Distribution System

IV. DESIGN AND SIMULATION RESULT

The main objective of redesign and selection is at the present distribution system cannot meet the customer demand, it is also growing area in which new industries put their footstone for construction and commercial sectors increases from time to time that is why improving the capacity of power distribution system is necessitated.

The planning and design of LV distribution system works for Ethiopian Electric Power is carried out by the help of the following Tables. In the LV design and planning the following factors are considered:

- Saturated areas will have an annual load growth of 2% per annum [24]
- Growing areas will have an annual load growth of 5% per annum [24]

A. Power Distribution System Redesign Summary

- The present 50MVA power distribution system capacity replaced by 250MVA by forecasting of future load demand of customers over 25 years horizon
- The total customers on the present power distribution system including domestic, commercial, industrial and others is 54004
- Customers on redesigned power distribution system increases from this figure in the future as the load demand increases 6% per annum and it is also for growing area which indicates that the number of customers increases from year to year.
- Power distribution substation equipment's and power distribution system equipment's (equipment's after substation) are redesigned and selected based on future load demand of 250MVA

B. Simulation Result by ETAP

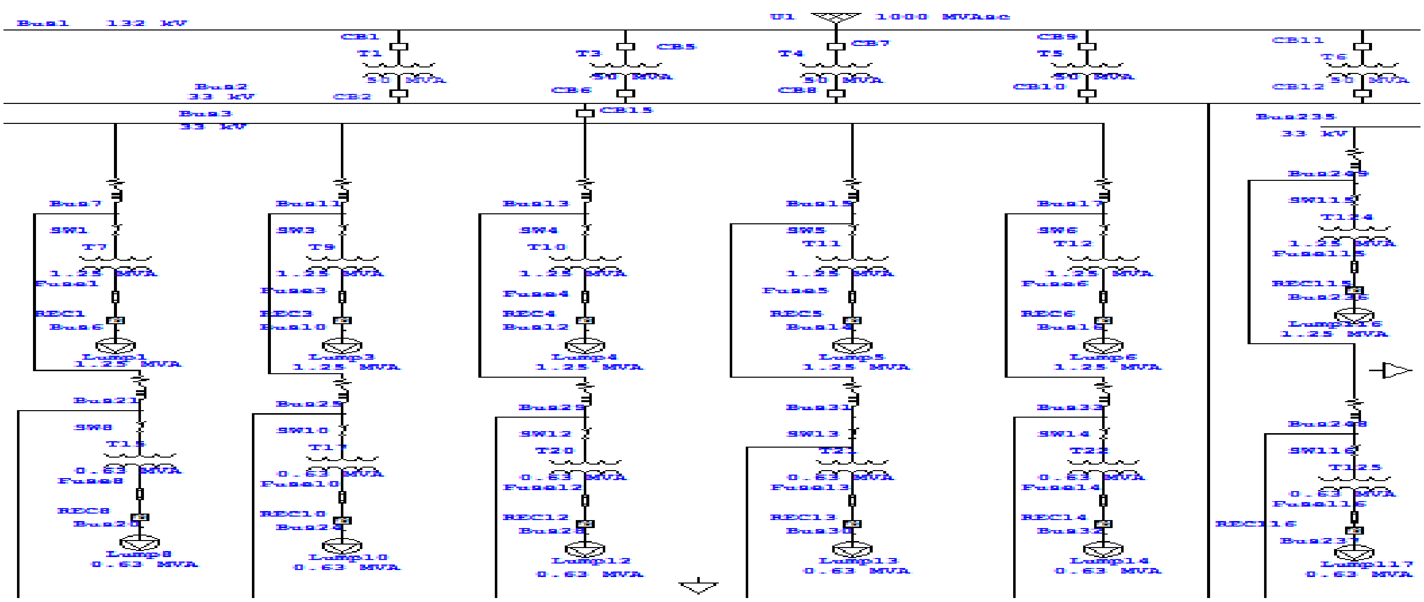

Fig 8:- Partial of Designed Power Distribution System

Indexes	SAIFI (f/customer year)	SAIDI (hr/customer year)	ASAI (%)
Values	2.75	38.72	99.56%

Table 9:- Simulation Result of Redesigned Power Distribution System

V. CONCLUSION

In this thesis, the data collected from power distribution substation and utility service center has been used to evaluate the reliability indices of existing distribution system using analytical and simulation methods and redesign of power distribution system to improve system reliability.

Comparing of reliability index of existing power distribution system with benchmark shows that reliability of the system is not up to the level or standard demanded by customers. Reliability improvement techniques are identified to reduce frequency and duration of an interruption Low system reliability index of existing Nazareth power distribution system has been improved by redesigned of existing 15KV/2×25MVA to 33KV/5×50MVA by considering overloaded of present distribution system and future load forecast over 25 years horizon. The reliability index of redesigned power distribution system has been analyzed using ETAP software and the result of SAIFI interruption per customer year, SAIDI hours per customer year and ASAI in % after design changes from 956.33, 923.3 and 89.46 to 2.75, 38.72 and 99.56 respectively. The reliability index of redesigned power distribution system compared with existing one and standard benchmark. The results obtained reveal that by using proper maintenance strategy especially preventive one and redesign of power distribution system has improve system reliability indices.

REFERENCES

[1]. Temitope Adefarati, Reliability Evaluation of Ayede 330/132KV Substation, International Journal of Engineering and Innovative Technology (IJEIT) Volume 4, Issue 4, October 2014
[2]. Tempa Dorji Electrical Power Engineering, Reliability Assessment of Distribution Systems Including a case study on Wangdue Distribution System in Bhutan
[3]. Michael J.Sullivan, B.Noland Suddet, Terry Vardella, Ali Vojdani, Interruption costs customer satisfaction and expectations for service reliability, IEEE Transactions on power system Vol.11,No,2 May 1996
[4]. R.E.Brown, S-Gupta, R.D Christie , s.s venkata, R Fletcher Distribution system Reliability assessment using Hierarchical Markov Modeling, IEEE Transactions on power delivery, Vol. 11, No,4 October 1996
[5]. Gerd kjolle, kjell sand, RELRAD An analytical approach for distribution system Reliability assessment, IEEE Transactions on power delivery, vol.7, No 2, April 1991
[6]. Roy Billinton, Kenneth Bollinger, Transmission System reliability evaluation using Markov process IEEE. Trans. Power Apparatus system, vol. PAS-87 No 2, PP.538-547
[7]. Binendra shakya, Repair duration effects on distribution system reliability indices and customer outages costs, MSc thesis, department of electrical and computer engineering, University of Saskatchewan Saskatoon, Saskatchewan, Canada 2012
[8]. Transmission and distribution committee, IEEE Guide for Electric Power distribution Reliability indices , IEEE Std 1366TM- 2003 the institute of Electrical and Electronics Engineers Inc.,spark Avenue ,New york, NY 10016-5997,USA,2004
[9]. http://www.eep.gov.et/
[10]. http://www.diva-portal.org/smash/get/diva 2:34874/Full text 01 pdf
[11]. http://www.diva-portal.org/smash/get/diva2:23876/dissertation_v6.pdf