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Reliability Evaluation of Al_Mansour 11kV Distribution Network in Baghdad City

Abstract- *Reliability is a key aspect of power system design and planning. This work aims to evaluate and improve the reliability of a power distribution network in Baghdad city. The minimal cut set method has been adopted for reliability evaluation. Evaluating the reliability requires calculating and evaluating a set of reliability indices. In this research, the reliability indices are calculated for Al_Mansour 11kV distribution network in Baghdad city. According to these indices several improvements have been proposed and simulated on the network as follows:*

- *Adding N/C manually switches in the network for isolating fault area and restoring the service to the remaining parts.*
- *Adding N/O manually switches to interconnect feeders and provide alternative supply.*
- *Replacing the manually switches by remotely controlled or fully automated switches with fault indicators to reduce interruption times.*
- *Replacing the overhead lines by underground cables to reduce the fault rates. The software CYMDIST version 7.1 has been used as a tool for the simulation of the distribution network and performing the required analysis.*

Keywords- *Reliability, minimal cut_set method, power system, distribution network, CYMDIST software.*

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1. Introduction

Reliability means "the ability of a system to perform the function it is designed for, under the operating conditions encountered during its expected lifetime". It can be calculated, assessed, planned, and designed into equipment or a system [1, 2]. The majority of distribution systems are radial consisting of main feeders and lateral distributors to supply electric power to consumers [3]. The radial nature of distribution system makes it vulnerable to interruptions in power supply to customers due to fault events. This paper is concerned with the study of reliability of distribution systems. The reliability of a power system is affected by the frequency "number of interruptions during an analysis period", duration "the time of the interruption", and extent of the interruption "how many customer loads are interrupted". From the engineering point of view, reliability assessment depends on determining mathematically the frequency and duration of customer interruptions [4]. The requirements of the power system reliability can be accomplished through optimal planning and lowest cost. The importance of reliability evaluation of power systems is to achieve the most exact and efficient judgment in the planning, operating and maintenance [4].

2. Distribution System Reliability Evaluation

The distribution system mostly affects the supply reliability because it is the weakest link between the source of supply and the customer load points. This paper focuses on the distribution system with the assumption that there is continuously sufficient power provided through the substations. The focus is on the impact of distribution component failures on individual consumer load points.

3. Methods of Distribution System Reliability Evaluation

I. Analytical Methods

Analytical methods represent the system by mathematical models and assess the reliability indices from these models using mathematical solutions. The minimal cut-set method is one of the most common analytical methods, can be applied to systems with simple as well as complex configurations, and is a very suitable technique for the reliability assessment of distribution systems. In this work, the minimal cut set method is used for studying and evaluating the reliability of a distribution system in Baghdad city.

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II. Simulation Methods

Simulation methods or Monte Carlo simulation techniques estimate the reliability indices by simulating the actual process and random behavior of the system. Therefore, the method solves the problem as a series of experiments. The techniques can take into account virtually all aspects and contingencies inherent in the planning, design, and operation of a power system. These include random events such as outages and repairs of components represented by general probability distributions

4. Reliability Indices

The Institute of Electrical and Electronic Engineers (IEEE) has standardized a wide range of reliability indices and reliability calculations for power networks [5]. These indices are a measure of the reliability level of the power system by providing information about the rate and duration of customer interruptions in any given network. Any particular element failed in a power system can cause a partial or even entire system interrupting. The availability of these elements is characterized by failure rate and repair or replacement time.

5. Types of Reliability Indices

I. Load Point Indices

Load point indices are a measure of the reliability level for every load point in the system. These indices include "average failure rate (λ_{lp})", "average outage time (r_{lp})", and "average annual outage time (U_{lp})", at every load point '***lp***'. Load point indices are calculated by using the failure rate (λ_i) and outage time (repair time or failure duration) (r_i) of each component upstream the load point. In this work, the load point indices are computed by the minimal cut_set method using the Reliability Assessment Module (RAM) in CYMDIST software. After computing the load point indices for each load point on the feeder, system indices may then be computed as illustrated by the flowchart in Figure 1.

II. System Indices

System indices are a measure for the reliability of the power system. The important indices are "SAIFI, SAIDI, MAIFI, CAIDI, ASAI, ASUI, ENS, and AENS". In addition, there are other system indices explained in details in reference [5].

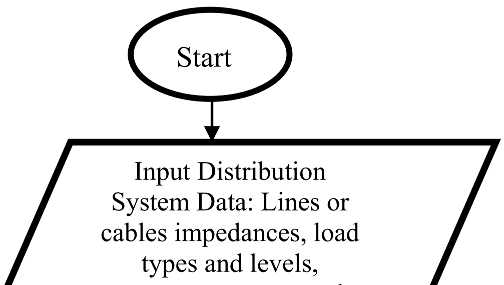

Figure 1: Reliability Assessment Flowchart.

1. SAIFI (System Average Interruption Frequency Index):

SAIFI indicates the average number of sustained interruptions (more than 5 minutes) per customer over a predefined period of time, often expressed as interruption per customer. Year (inter./cust.yr) [5].

$$\text{SAIFI} = \frac{\sum_{lp=1}^{n} \lambda_{lp} * N_{lp}}{N_T} \quad \text{(inter./cust.yr)} \tag{1}$$

Where:

$\boldsymbol{n}$: Total number of load points. $\boldsymbol{N_T}$: Total number of customers of feeder.

$\boldsymbol{N_{lp}}$: Number of customers of load point.

2. SAIDI (System Average Interruption Duration Index):

SAIDI indicates the annual average duration of a sustained outage experienced by a customer. It is commonly measured in hours per customer.year (h/cust.yr).

$$\text{SAIDI} = \frac{\sum_{lp=1}^{n} U_{lp} * N_{lp}}{N_T} \quad \text{(h/cust.yr)} \qquad (2)$$

3. CAIDI (Customer Average Interruption Duration Index):

CAIDI represents the average time required to restore service, often expressed as hour per customer. Interruption (h/cust.inter).

$$\text{CAIDI} = \frac{\text{SAIDI}}{\text{SAIFI}} = \frac{\sum_{lp=1}^{n} U_{lp} * N_{lp}}{\sum_{lp=1}^{n} \lambda_{lp} * N_{lp}} \quad \text{(h/cust.inter)} \qquad (3)$$

4. ASAI (Average Service Availability Index):

ASAI shows the fraction of time that a customer has received power during the reporting period.

$$\text{ASAI} = \frac{\sum_{lp=1}^{n} N_{lp} * 8760 - \sum_{lp=1}^{n} U_{lp} * N_{lp}}{\sum_{lp=1}^{n} N_{lp} * 8760} \qquad (4)$$

Where, $\boldsymbol{8760}$ is the total hours per year.

5. ASUI (Average Service Unavailability Index):

$$\text{ASUI} = 1 - \text{ASAI} \qquad (5)$$

6. ENS (Energy Not Supplied): is the annual total energy not supplied due to interruptions.

$$\text{ENS} = \sum_{lp=1}^{n} (kW)_{lp} * U_{lp} \quad \text{(kWh/yr)} \qquad (6)$$

7. AENS (Average Energy Not Supplied): is the annual average of the total energy not supplied (due to interruptions) per customer.

$$\text{AENS} = \frac{\text{ENS}}{N_T} \quad \text{(kWh/cust.yr)} \qquad (7)$$

6. Minimal Cut_Set Determination for Radial Distribution System

A minimal cut_set represents a group of equipment that has to be removed from operation to cause an interruption. In radial distribution systems, the components between the substation and a load point are connected in series. The average failure rate ($\boldsymbol{\lambda_{lp}}$) for each load point in a radial distribution system is the sum of the failure rates of all the minimal cut_sets to that load point, often expressed as failures per year (**fa/yr**). The average outage time for each load point ($\boldsymbol{r_{lp}}$) is the average of the repair time of the minimal cut_sets, weighted by their failure rates, often expressed as hour per failure (**h/fa**). For $\boldsymbol{m}$ series failure components (minimal cut_sets), the following formulas can be used:

$$\lambda_{lp} = \sum_{k=cs1}^{csm} \lambda_k \quad \text{(fa/yr)} \qquad (8)$$

$$r_{lp} = \frac{\sum_{k=cs1}^{csm} \lambda_k * r_k}{\sum_{k=cs1}^{csm} \lambda_k} \quad \text{(h/fa)} \qquad (9)$$

$$U_{lp} = \sum_{k=cs1}^{csm} \lambda_k * r_k \quad \text{(h/yr)} \qquad (10)$$

Where,

$\boldsymbol{csm}$: The total number of the minimal cut_sets for each load point.

$\boldsymbol{\lambda_k}$: failure rate of the k minimal cut_set. $\boldsymbol{r_k}$: repair time of the k minimal cut_set.

7. Reliability Cost /Worth Evaluation

The utility cost refers to the utility investments to increase reliability to consumers. The reliability worth refers to the benefit received by consumers related with best reliability. The term “consumer interruption costs” is used to evaluate the reliability worth. The total cost of reliability is the utility cost and the consumer interruption cost. The expected “consumer interruption costs” for every load point and for the total system respectively can be calculated as follows:

$$ECOST_j = \sum_{k=cs1}^{csm} \lambda_k \, r_k (kW)_j C_j \qquad (11)$$

$$ECOST = \sum_{j=1}^{n} ECOST_j \qquad (12)$$

Where,

C_j is the interruption cost of load point j associated with an outage cut_set k, $(kW)_j$ is the load power connected at load point j , and n is the no. of load points [6].

8. Reliability Improving

Reliability can be improved by:

1) Replacing overhead lines by underground cables: Underground cables reduce the failure rate of conductors, on other word decrease the SAIFI index. According to the international fault statistics the failure rate of medium voltage overhead lines is usually “3-5 times” greater than medium voltage UGC [7].

2) Providing alternative supply: To improve reliability the network configuration should be considered. The underground cables take long time to repair, so the alternative supply for restoring power rapidly is very essential in urban networks.

3) Sectionalization of feeders: Sectionalization uses equipment that is automatic and nearly instantaneous to isolate faults and malfunctions, and thus minimizes the portion of the feeder circuit that is put out of service.

4) Distribution Automation (DA): It can reduce the interruption duration but does not decrease the failure rate. DA could convert the sustained failure rate to momentary failure rate (less than 5 minutes), or on other ward, decreasing SAIFI index. The consumer time lost can be decreased to 60% when implementing large scale of DA [8].

5) Smart grid: The smart grid will make use of technologies, such as state estimation, to increase fault detection and allow self-healing of the network without intervention of operators. This will ensure more reliable supply of electricity, and reduced vulnerability to natural disasters or attack [9].
6) Addition of fault indicators: Fault indicators sense and indicate the through passing fault current. The number and location of fault indicators influence the improvement of the electricity distribution reliability indices, because it reduces the time needed for fault located

9. Case Study and Discussion

The reliability has been evaluated for Al_Mansour distribution network. The network consists of 14 outgoing feeders from Al_Andulus substation consisting of 2×31.5 MVA, 33/11kV transformers. Five overhead line feeders are considered in this work, these are; Andulus_ (3, 5, 9, 12, and 14). These feeders consist of 159 overhead line sections, 336 nodes, 72 transformers 11/0.4 kV, 72 fuses distributed one for each lateral, 72 load points, and 6 tie lines.

10. Simulation of Al_Mansour Distribution Network

The CYMDIST software (version 7.1) was used to simulate Al_Mansour distribution network (Andulus substation) based on the actual coordination's of the secondary distribution transformers. This coordination's are taken from Iraqi ministry of electricity MOE depending on the global positioning system (GPS). The coordinates are entered to the CYMDist module as x and y coordinates for the nodes (buses) to build the model and specify the actual length of the network sections. Figure 2 shows the one line diagram of this network (overhead line network) which is created using "drag-and-drop" feature by selecting the components from the equipment menu.
The equipment database, shown in Figure 3, contains a set of generic equipment models to be used for simulating the distribution network. Once placed on a network section, the generic equipment may acquire new properties and the original values of some of its parameters can be modified according to the control to be performed. Thus, by feature of its position on the network and its parameters new values, from "generic" the equipment becomes "specific". Consequently, it will acquire a new identity through the equipment number.

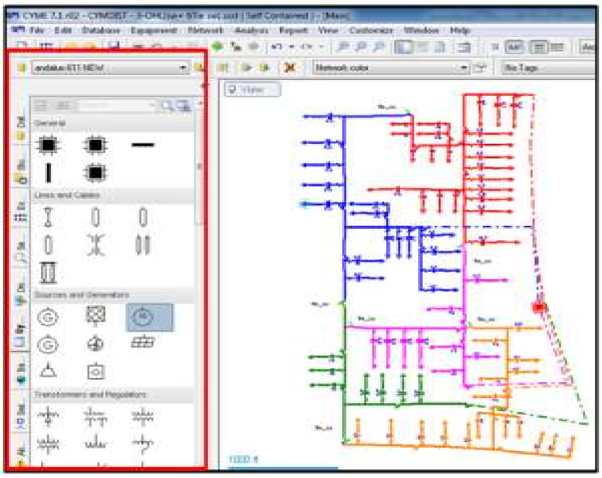

Figure 2: One line diagram of Al_Mansour distribution network.

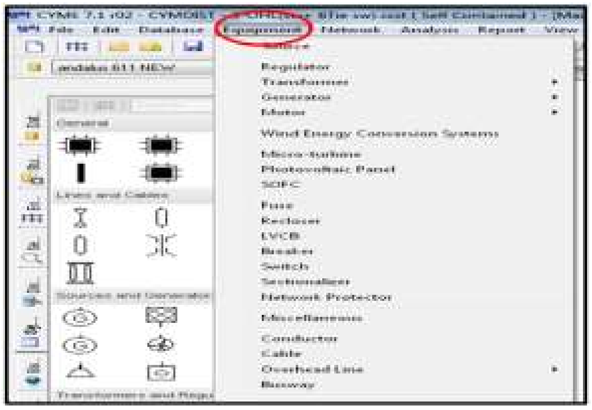

Figure 3: The equipment menu

The analysis menu, shown in Figure 4, provides access to all of the analysis functions such as reliability assessment. It includes all the basic analysis functions available in CYMDIST.
After selecting the reliability assessment analysis, the window shown in Figure 5 is displayed to select the feeders included in the assessment and the type of analysis (predictive or historical).

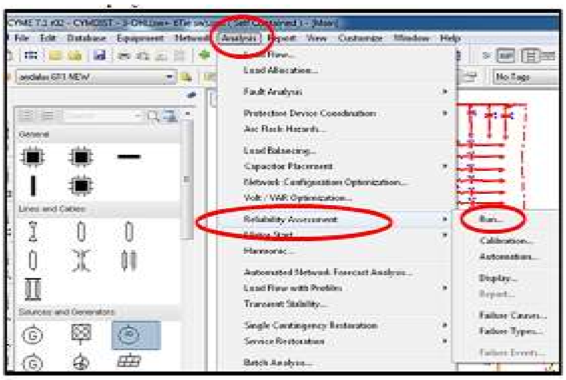

Figure 4: The analysis menu

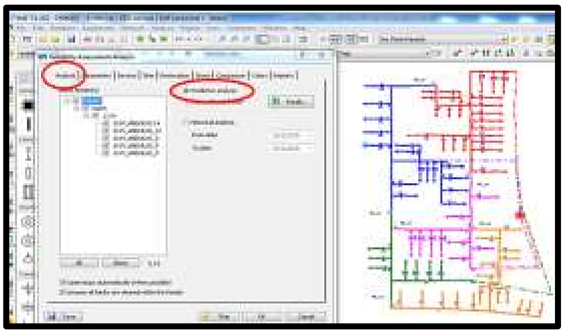

Figure 5: Reliability assessment

In the **Devices** tab, reliability parameters (failure rate and repair time) of the components can be entered as shown in Figure 6. In the **Time** tab, the momentary duration, traveling, inspection, and switching time can be specified as shown in Figure 7.

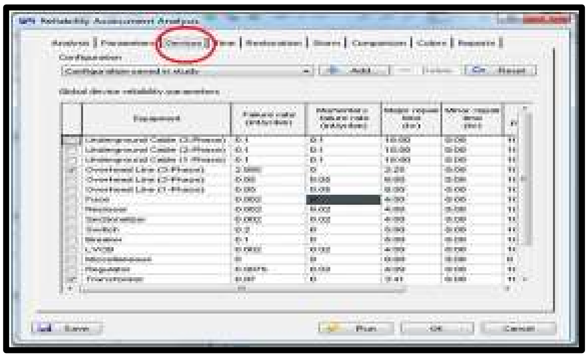

Figure 6: Devices tab

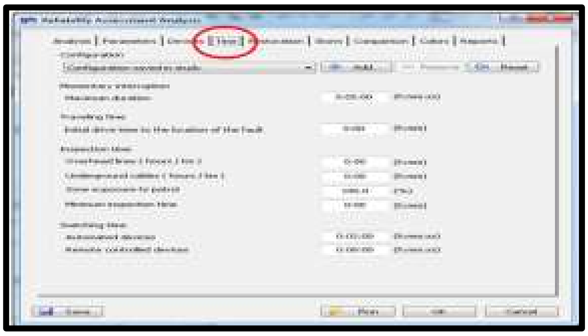

Figure 7: Time tab

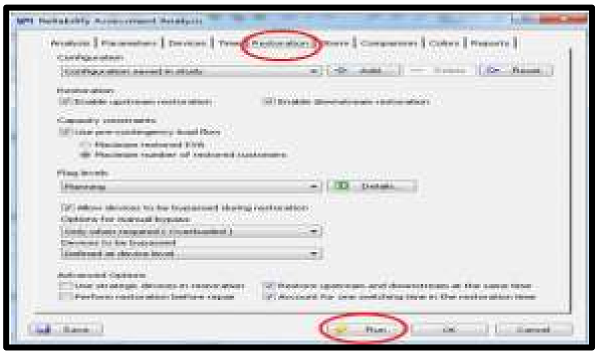

Figure 8: Restoration tab

In the **Restoration** tab, the upstream and downstream restoration can be configured taking into consideration the capacity constraints of the alternative supply as in Figure 8. Then press **Run**. After performing the reliability assessment, the results of the reliability indices can be displayed in tables using **Reports** tab as in Figure 9.
The previous steps can be repeated after replacing overhead lines by underground cables to improve the reliability. Figure 10 shows Al_Mansour distribution network simulation in case of underground cable. Figure 11 shows Al_Mansour distribution network simulation after replacing manual switches by remotely controlled (RC) switches to speed up the restoration.
Figure 12 shows Al_Mansour distribution network simulation after replacing manual switches by fully automated switches. Figure 13 shows the help menu and selecting User Guides**.**

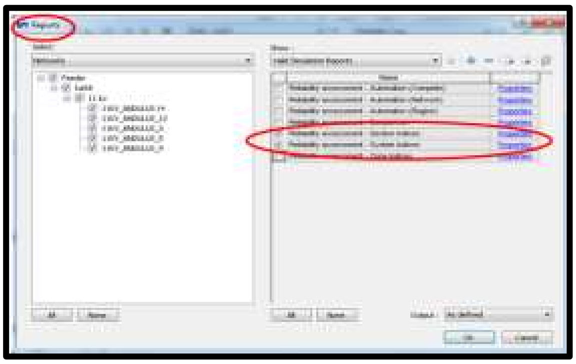

Figure 9: Report tab

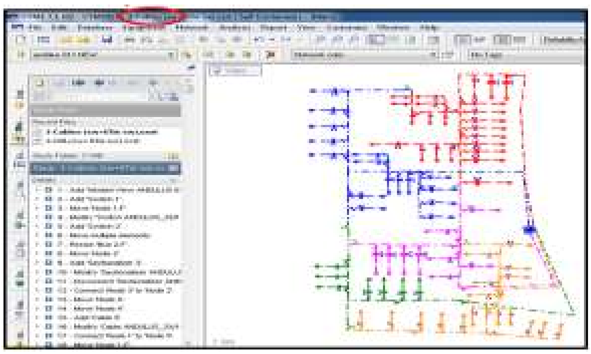

Figure 10: Underground cable network

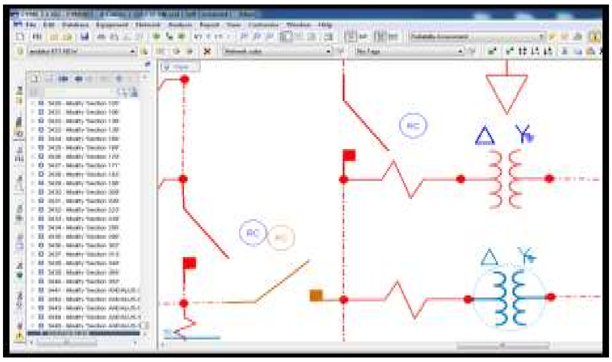

Figure 11: Al_Mansour network Simulation with remotely controlled switches

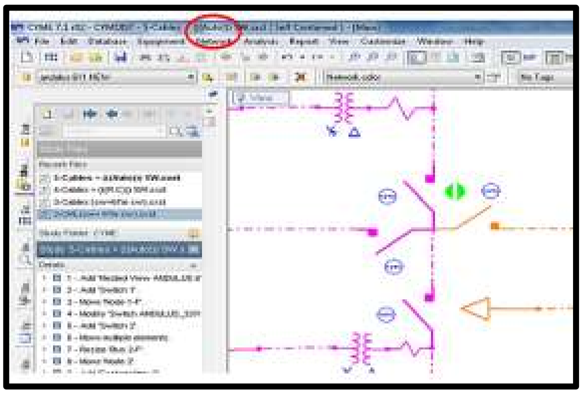

Figure 12: Al_Mansour network Simulation with fully automated switches

Figure 13: Help menu and selecting User Guides

The final model of Al_Andulus network as simulated in CYMDist is shown in Figure 14. Details of network modeling are given in CYME Reference Manual [10].

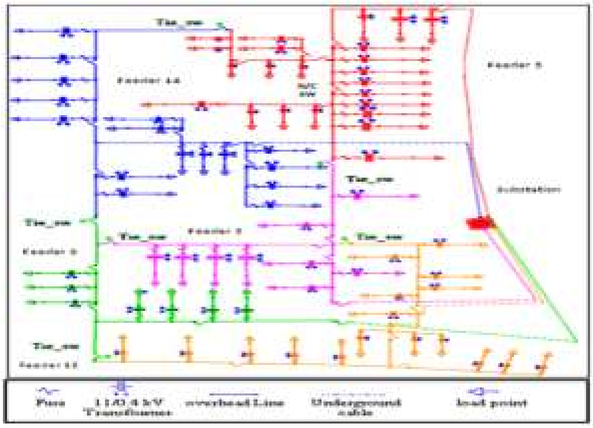

Figure 14: The final model of Al_Andulus distribution network, as simulated in CYMDist, including Al_Andulus substation 33/11 kV and feeders (3, 5, 9, 12 and 14).

11.Reliability Parameters

The reliability parameters include failure rate and repair time or replacement time of the overhead line sections and transformers 11/0.4 kV of Al_Andulus network. These parameters are calculated according to the documentation data and logs of the faults events and maintenance procedures for three years period (2013, 2014, and 2015), as taken from Al_Mansour distribution sector/ MOE (Table 1). The tariff cost (cost of electrical energy) according to MOE is assumed 0.1 $/kWh.

Component Type	Failure rate of a component λ_i (failure/yr)	Repair time r_i (h:mm)	Replacement Time (h:mm)
Transformer 11/0.4 kV	0.07	---	3:41
Overhead Line	2.895	2:25	---
Underground Cable	0.04	30	---

Table 1: Reliability parameters calculated for different network components.

12.Reliability Indices Calculation

The reliability evaluation is simulated on Al_Andulus network as follows: *Case (A): The network in its initial condition (base case)*

Al_Andulus substation 33/11 kV and its 11 kV feeders (3, 5, 9, 12, and 14), shown in Figure 14, in its initial condition are characterized by;

The feeders consist of very old overhead lines, fuses at every lateral are exist, tie lines also exist in some locations but with no tie switches, normally closed (N/C) switches are unavailable (removed). The reliability indices calculated for this network are given in Table 2. The values of reliability indices given in Table 2 are high and not acceptable due to high failure rate and repair time of the components. These indices should be reduced as possible as to approach zero value and consequently increase the system reliability level. The **ASAI** index represents the service availability percent per year and when this index approaches to one, this means increasing in the service availability. *Case (B): Replacing overhead lines by underground cables* After replacing the overhead lines of the network at base case (A) by underground cables, the reliability indices calculated for this network are given in Table 3

Table 2: The Reliability Indices calculated for Al_Andulus network for Case (A)

	Feeder Andulus 3	Feeder Andulus 5	Feeder Andulus 9	Feeder Andulus 12	Feeder Andulus 14
SAIFI (inter/cust.yr)	5.58008	5.95142	3.628	9.20663	6.10171
SAIDI (h/cust.yr)	13.5738	14.4712	8.85635	22.33803	14.83446
CAIDI (h/cust-inter)	2.43256	2.43157	2.44111	2.4263	2.4312
ASAI	0.99845	0.99835	0.99899	0.99745	0.99831
ASUI	0.00155	0.00165	0.00101	0.00255	0.00169
ENS (kWh/yr)	51481.4	26084.1	18154	81125.9	49181.4
AENS(kWh/cust.yr)	111.916	144.911	129.6714	238.6055	153.6918
ECOST ($/year)	5148.14	2608.41	1815.4	8112.59	4918.14

Table 3: The Reliability Indices calculated for Al_Andulus network for Case (B)

	Feeder Andulus 3	Feeder Andulus 5	Feeder Andulus 9	Feeder Andulus 12	Feeder Andulus 14
SAIFI (inter/cust.yr)	0.50793	0.47557	0.37859	0.61709	0.46678
SAIDI (h/cust.yr)	13.3957	12.4250	9.5155	16.6705	12.1612
CAIDI (h/cust-inter)	26.3732	26.1264	25.1341	27.0147	26.0534
ASAI	0.99847	0.99858	0.99891	0.9981	0.99861
ASUI	0.00153	0.00142	0.00109	0.0019	0.00139
ENS (kWh/yr)	50809.5	22413.3	19529	60545.5	40332.5
AENS(kWh/cust.yr)	110.455	124.518	139.492	178.075	126.0391
ECOST ($/year)	5080.95	2241.33	1952.9	6054.55	4033.25

Case (C): Network modification by adding switches

By adding manually, N/C switches on the 11 kV cables. The switches can be used for isolating the faulty sections in order to restore service to the remaining parts of the network. The numbers and locations of these switches are identified through performing contingency analysis, taking into account the minimization of the load outage and capacity constraints of the components. The reliability indices calculated for this network are given in Table 4.

Case (D): Network modification by adding alternative supply

By adding six tie N/O switches to interconnect feeders and provide alternative supply. The reliability indices calculated for this network are given in Table 5.

Case (E): Network modification by using remotely
Controlled switches with fault indicators

The manually switches are replaced by remotely controlled switches with fault indicators. The reliability indices calculated for this network are given in Table 6.

Case (F): Network modification using fully automated switches with fault indicators

The manually switches are replaced by fully automated switches with fault indicators. The switching time for isolating fault and restoring energy is 2 minutes or less. The reliability indices calculated for this network are given in Table 7.

The results of case (F) show significant reduction in SAIFI index (average of the sustained interruption per customer-year) after using fully automated switches. These switches need only minutes or less for switching operation maneuver. The interruption is considered momentary (not sustained) if it takes only 5 minutes or less according to the IEEE standards [5].

Table 4: The Reliability Indices calculated for Al_Andulus network for Case (C)

	Feeder Andulus 3	Feeder Andulus 5	Feeder Andulus 9	Feeder Andulus 12	Feeder Andulus 14
SAIFI (inter/cust.yr)	0.50793	0.47557	0.37859	0.61709	0.46678
SAIDI (h/cust.yr)	8.67408	8.63176	7.79443	9.66682	7.71152
CAIDI (h/cust-inter)	17.07729	18.15022	20.58793	15.66516	16.52065
ASAI	0.99901	0.99902	0.99911	0.9989	0.99912
ASUI	0.00099	0.00098	0.00089	0.0011	0.00088
ENS (kWh/yr)	32251.2	14945.9	16517.5	35375.4	25678.7

AENS(kWh/cust.yr)	70.11126	83.03301	117.98211	104.04525	80.24602
ECOST ($/year)	3225.12	1494.59	1651.75	3537.54	2567.87

Table 5: The Reliability Indices calculated for Al_Andulus network for Case (D)

	Feeder Andulus 3	Feeder Andulus 5	Feeder Andulus 9	Feeder Andulus 12	Feeder Andulus 14
SAIFI (inter/cust.yr)	0.50793	0.47557	0.37859	0.61709	0.46678
SAIDI (h/cust.yr)	2.89844	3.48818	4.65134	3.82045	3.64925
CAIDI (h/cust-inter)	5.70636	7.33468	12.2859	6.19107	7.81791
ASAI	0.99967	0.9996	0.99947	0.99956	0.99958
ASUI	0.00033	0.0004	0.00053	0.00044	0.00042
ENS (kWh/yr)	10157.9	6076.4	10547	14282.5	12217.5
AENS(kWh/cust.yr)	22.08229	33.75758	75.33542	42.00742	38.17975
ECOST ($/year)	1015.79	607.64	1054.7	1428.25	1221.75

Table 6: The Reliability Indices calculated for Al_Andulus network for Case (E)

	Feeder Andulus 3	Feeder Andulus 5	Feeder Andulus 9	Feeder Andulus 12	Feeder Andulus 14
SAIFI (inter/cust.yr)	0.50793	0.47557	0.37859	0.61709	0.46678
SAIDI (h/cust.yr)	2.30555	1.35629	4.28416	3.58466	3.40321
CAIDI (h/cust-inter)	4.5391	2.85189	11.3161	5.80897	7.2916
ASAI	0.99974	0.99985	0.99975	0.99959	0.99976
ASUI	0.00026	0.00015	0.00025	0.00041	0.00024
ENS (kWh/yr)	8035.6	2705.1	9205.3	13848.1	11560.4
AENS(kWh/cust.yr)	17.46874	15.02807	65.7521	40.72978	36.12625
ECOST ($/year)	803.56	270.51	920.53	1384.81	1156.04

The reliability indices for all feeders Andulus (3, 5, 9, 12, and 14) and for all cases (A, B, C, D, E and F) are compared as shown in Figures 15 – 19. The reduction in **SAIFI** index between case A (OHL) and case F (UGC) for all feeders are shown in Table 8.

The reduction in **SAIDI** index between case A (OHL) and case F (UGC) for all feeders are shown in Table 9.

Figure 17 shows increasing in **CAIDI** index of underground cable network due to the variation between the reduction in **SAIDI** index and the reduction in **SAIFI** index.

$$\mathbf{CAIDI} = \frac{\mathbf{SAIDI}}{\mathbf{SAIFI}} \quad \text{(h / cust-inter.)}$$

And the reduction in **SAIFI** index is more than the reduction in **SAIDI** index, but this result does not mean that the system operates with low reliability.

Table 7: The Reliability Indices calculated for Al_Andulus network for Case (F)

	Feeder Andulus 3	Feeder Andulus 5	Feeder Andulus 9	Feeder Andulus 12	Feeder Andulus 14
SAIFI (inter/cust.yr)	0.08789	0.10497	0.09946	0.10135	0.09476
SAIDI (h/cust.yr)	0.79466	1.30687	1.14174	1.19826	1.00074
CAIDI (h/cust-inter)	9.04113	12.4502	11.479	11.82327	10.56041
ASAI	0.99991	0.99985	0.99987	0.99986	0.99989
ASUI	0.00009	0.00015	0.00013	0.00014	0.00011
ENS (kWh/yr)	3260.7	2617.1	2377.8	4238.8	3259.1
AENS(kWh/cust.yr)	7.08848	14.53927	16.98405	12.46713	10.18471
ECOST ($/year)	326.07	261.71	237.78	423.88	325.91

Table 8: Reduction in SAIFI index between case A (OHL) and case F (UGC)

Feeder No.	Case A (OHL)	Case F (UGC)	Reduction %
Andulus_3	5.58008	0.08789	98.42 %
Andulus_5	5.95096	0.10497	98.23 %
Andulus_9	3.628	0.09946	97.25 %
Andulus_12	9.20663	0.10135	98.89 %
Andulus_14	6.10171	0.09476	98.44 %

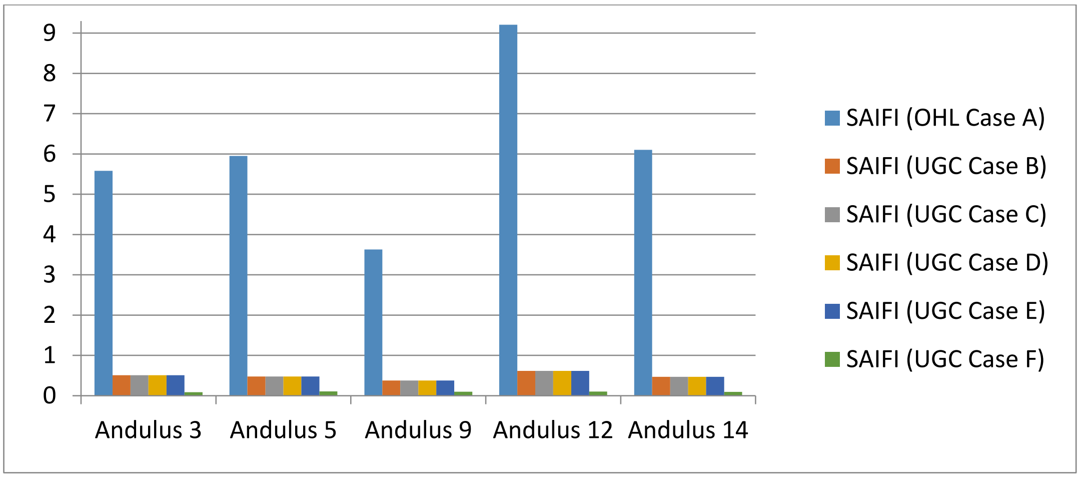

Figure 15: Comparison of SAIFI index results for all cases (A - F).

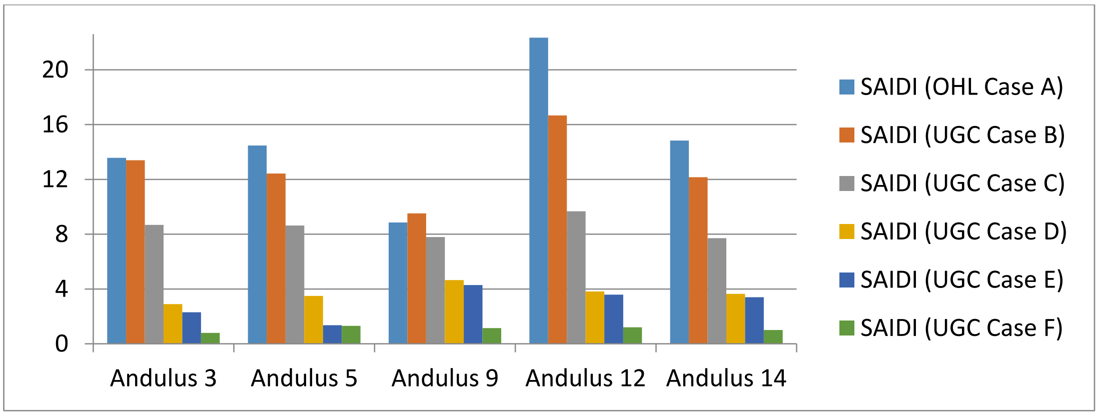

Figure 16: Comparison of SAIDI index results for all cases (A - F).

Table 9: Reduction in SAIDI index between case A (OHL) and case F (UGC)

Feeder No.	Case A (OHL)	Case F (UGC)	Reduction %
Andulus_3	13.57386	0.79466	94.14 %
Andulus_5	14.47126	1.30687	90.96 %
Andulus_9	8.85635	1.14174	87.1 %
Andulus_12	22.33803	1.19826	94.63 %
Andulus_14	14.83446	1.00074	93.25 %

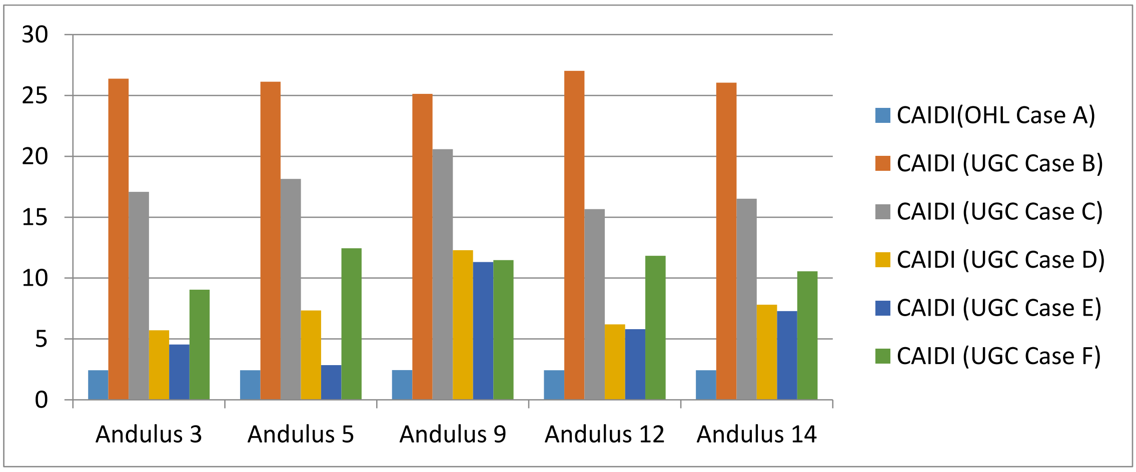

Figure 17: Comparison of CAIDI index results for all cases (A - F).

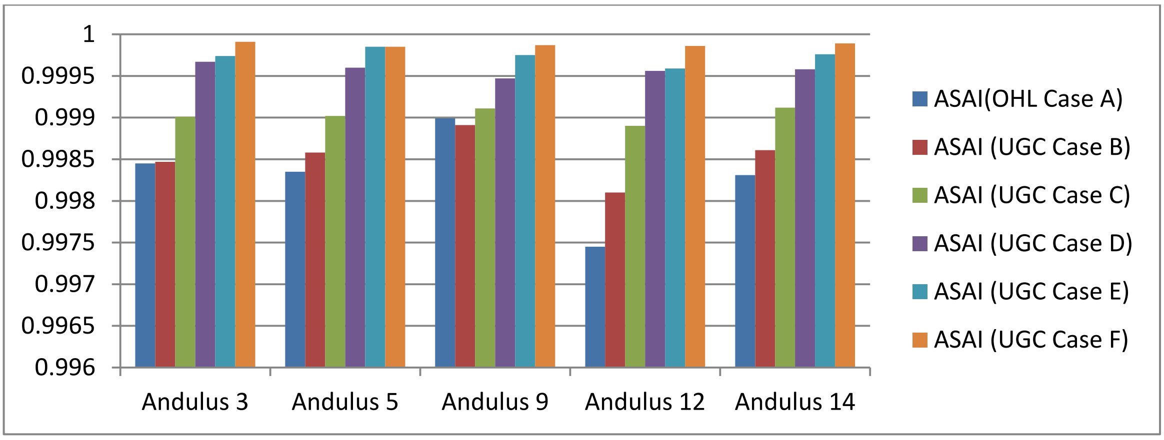

Figure 18: Comparison of ASAI index results for all cases (A - F).

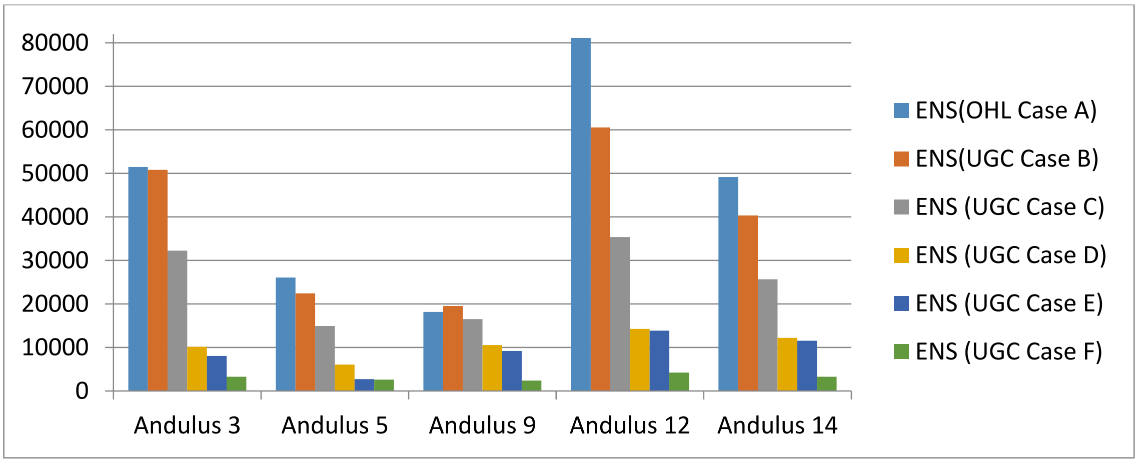

Figure 19: Comparison of ENS index results for all cases (A - F).

Table 10: Reduction in ENS index between case A (OHL) and case E (UGC)

Feeder No.	Case A (OHL)	Case F (UGC)	Reduction %
Andulus_3	51481.4	3260.7	93.66 %
Andulus_5	26084.1	2617.1	89.96 %
Andulus_9	18154	2377.8	86.9 %
Andulus_12	81125.9	4238.8	94.77 %
Andulus_14	49181.4	3259.1	93.37 %

Figure 18 shows increasing in **ASAI** index, for example, in feeder Andulus_3 from only two nines (0.99845) in case A (OHL) to four nines (0.99991) in case F (UGC),which means that the unavailability hours of this feeder reduced from 13.578 hour per year to only 0.7884 hour or 47 minutes. The reduction in **ENS** index between case A (OHL) and case F (UGC) for all feeders are shown in Table 10.

13.Conclusion

The reliability indices were calculated for Al_Mansour distribution network in Baghdad city and the reliability evaluation of the network shows that:

1. When the network (OHL or UGC) was in its initial condition with no fault isolating devices, the network has lowest reliability because there is no alternative power supply to customers.
2. Adding N/C and N/O manually, switches played an important role in decreasing interruption times and consequently reducing SAIDI, ASUI, ENS, AENS and ECOST indices. For example, the decreasing in SAIDI index of feeder Andulus_14 is 75% in case (D) in comparison with case (A).
3. Improving the reliability by replacing manually switches by remotely controlled or fully automated switches, speed up fault isolation and reduced the interruption time, consequently reduce SAIDI, ASUI, ENS, AENS and ECOST indices. For example, the decreasing in SAIDI index of feeder Andulus_3 is 83 % in case (E) in comparison with case (A).

4. Improving the reliability by Replacing OHL by UGC reduces failure rates of components and reduce SAIFI index. For example, the decreasing in SAIFI index of feeder Andulus_12 is 93% in case (B) in comparison with case (A).

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