CHAPTER FIVE:

IMPROVEMEMT OF RADIAL DISTRIBUTION II KV SYSTEM OF KHARTOUM NORTH CITY

5.1. Introduction:

Due to increase in dependence on electricity and the growth of sensitive loads in all customer sectors(residential, commercial and industrial), the utilities must strive to maximize reliability to ensure that customer requirements are satisfied while incurring the lowest possible cost. Although there is no magic in managing power quality issues, utilities can maximize network performance and better serve customers by diligently addressing trouble prone areas. The first step in maximizing reliability is identifying the root cause of the outages. The main strategy to improve reliability and power quality to customers are to eliminate faults and then to minimize the effect of faults on customers even if it occurs.

5.2. Investigation of radial distribution system (11 KV) of Khartoum North City:

In Khartoum North area there are 22 distribution sub- stations with load 595 MW, 240781 customers , 36 Radial Feeder 33 KV & 121 Radial Feeder 11 KV. (see appendix A) [13,14].The reliability assessment is carried out for 121 radial feeders in 11 KV level for10 months in Khartoum North area (in the period from 1/1/2014 to 31/10/2014) as shown in table 5.1.

Table 5.1: Summarize of Outage duration & Outage freq for Khartoum North distribution network for the period (1.1.2014 - 31.10.2014)

	S/S	LINE NAME	Outage duration (hr)	Outage freq	Interrupted Energy (MWH)
1	SELAITE	Ibrahim Talab	31.13	62	30.19
2		East Soba	0.03	2	0.01
3		Alzerayen	36.28	46	82.53
4		Petrol	57.89	45	77.91
5		Om Doum	29.46	83	48.42
6		Hay Elmustafa	13.98	60	12.41
7	HOFRA	Um Dawanban	45.02	55	118.92
8		El Hofara	13.08	15	3.54
9		El Karnoos	39.82	45	53.73
10		El Mazarea	29.53	101	18.07
11	EID BABEKER	Eid Babeker	48.55	44	83.88
12		El Wadi El Akhdar	14.84	38	15.87
13		Dardoug	25.23	35	51.94
14		El Samra	87.2	68	64.45
15		El Shegla North	13.81	40	19.8
16		Elnaseem	43.08	41	62.86
17		Eltakamul	25.65	31	26.76
18		El Wehdat	3.56	18	4.78
19		El Haj Yousif Agr	29.46	133	35.6
20	NEW KUKU	East Nile Hospital	13.01	19	24.09
21		El Gadesieah	19.25	12	53.93
22		El Soug	16.04	26	20.53
23		El Maygomah	11.37	10	55.9
24		Kuku	16.83	22	35.89
25		El Huda	22.8	36	67.26
26	EL HAJ YOUSIF	Hai El Baraka	23.82	27	65.31
27		El Fayhaa	34.14	35	84.71
28		Souq 6	16	42	36.45
29		El Radmiya	5.5	8	10.06
30		El Ban Gaded	27.21	17	57.68
31		El Saleheen	10.85	17	40.9
32	AWAD GABOR	Kafoury	10.93	55	13.25
33		Gerefat	8.45	11	11.25
34		S Tech. Center	1.23	1	1.85
35		Galab	6.19	12	15.06

36		Dgm	1.24	2	2.81
37		El Safarat	11.12	16	20.59
38	NEW FADUL	El Harareiah	17.15	36	32.93
39		El Maiz	6.88	9	13.6
40		Ami Pharma (Elmasarra)	0.02	1	0.04
41		Adiat	4.92	15	8.24
42		Balsam	6.07	5	13.22
43	OLD FADUL	El Matahen	16.66	12	30.66
44		Bank Elmal	4.86	12	6.71
45		El Waseed	9.78	7	9.2
46		Marhab Oil	34.83	41	64.2
47		New Siga	0.95	1	1.77
48		Weta1	3.65	1	4.75
49		Weta2	7.2	1	0
50	SELAH EL ESHARAH	Miyah Bhri	6.56	14	12.09
51		El Daraga El Talta	5	1	4.42
52		El Deyar El Qatariah	3.2	1	4.48
53		Helat Hamad	7.4	13	14.51
54		Seen	0	0	0
55		El Naeb El Awal	25.35	57	33.67
56		Elmasahha	9.97	14	24.76
57		El Mustawda	1.07	5	0.83
58	SHENDI	M.T.D.	3.6	4	6
59		El Khatmeiah	9.55	17	23.59
60		S/S No. 1	15.33	17	19.06
61		Sudanese Oils	23.93	14	35.85
62		El Bego	14.97	25	29.01
63		M.Stratigic	0	0	0
64	EL GAILI	El Seka Hadeed	40.8	12	8.67
65		Wad Ramli Skne	45.11	66	65.36
66		El Geash	5.93	11	2.11
67		El Kabbashi Agr	23.2	49	18.69
68		El Gaili	8.08	14	6.46
69		El Kabbashi Skne	5.39	4	2.84
70		Wad Ramli Agr	21.22	20	5.02
71		Office	35.25	62	102.39
72	SHAMBAT	El Bayara	10.4	6	21.89
73		Hag El Safy	12.67	54	38.8
74		El Bohoth	19.47	15	34.17
75		Police Tower	13.72	3	3.53

76		El Hadarab	19.03	29	29.66
77		Agri Faculty	20.8	80	33.51
78		El Baraha	16.88	16	28.57
79		El Kubbaneiah	25.41	26	82.93
80	SAAD GISHRAH	El Molid	2.5	4	3.09
81		Bahry Hospital	7.87	15	18.04
82		Ahmed Gasim	1.73	1	0.29
83		Elshabeiah	0.07	2	0.12
84		Elmazad	8.62	23	24.3
85		El Doaly Hospital	3.29	16	5.27
86		Saad Gishrah	0.08	4	0.17
87		El Sababi	31.8	7	43.4
88	EL IZERGAB	El Kadaro	8.44	14	17.17
89		El Faki Hashim	45.58	111	141.12
90		El Salakhanah	22.7	34	61.9
91		El Izergab	10.31	9	17.75
92		El Halfayah	6.88	18	15.02
93		Hay El Rawda	7.72	8	22.09
94		El Samrab	7.87	41	20.24
95		El Kadaro Agri	114.95	117	47.58
96		El Droshab	16.31	15	40.4
97		Nubta	26.99	52	79.11
98		El Mahkama	5.92	18	5.26
99		Sudatel	32.63	70	55.7
100	KHALIL OSMAN	Elsafyah	3.02	6	6.8
101		El Sayfonat	3.72	20	15.02
102		Capo	10.23	6	20.29
103		El Msra	6.63	14	17.32
104		El Safa Oils	26.93	24	29.07
105		Shambat (Hajjar)	8.22	20	7.59
106		Cola	5.57	3	14.89
107	MAHMOUD SHAREEF	Taibat El Ahamda	22.54	32	38.4
108		Beblos Bank	7.56	13	3.58
109		Old Siga	6.77	4	22.95
110		Abrsi	0	0	0
111		Wad Dafeia	2.45	9	5
112		Al Shefa	11.38	28	24.66
113		El Turaa	33.98	44	74.81
114		Gazeera Faculty	2.84	5	2.46
115	MSHROA EL WAHA	El Waha 2	0.08	2	0.07
116		El Waha 1	0	0	0

117		Kutrang	9.14	13	10.13
118		Micoi	17.93	17	18.19
119	EL ELAFON	Elbager	11.37	19	18.65
120		Om Dawanban Old	0	0	0
121		El Elafon	1.06	4	1.78
TOTAL			1,959.52	2,982.00	3,257.06

According to table 5.1 there are 121 radial feeders trips 2,982 times for 1,959.52 hours with 3,257.06 MWH Interrupted Energy in 10 months.

5.3. Improvement of radial distribution system (11 KV) of Khartoum North City:

As seen in table 5.1 (summarize of Outage duration & Outage freq for Khartoum North distribution Network for the period (1.1.2014 - 31.10.2014)) &According to this table it's seen that there are 121 radial feeders trips 2,982 times for 1,959.52 hours with 3,257.06 MWH losses in 10 months. Its need to make these radial feeders more reliable so three scenarios will use which are:

1. By installing auto reclosers & sectionalizers devices in these feeders and connect these devices with load dipatch center by SCADA system.
2. By removing the uninsulated conductor wires of the all radial feeders 11 KV & changing it with insulated wires 11kv.
3. By changing the configuration of the overhead line radial feeders to underground cable system.

5.3.1. Scenario number 1:

Installing auto reclosers & sectionalizers devices in these feeders and connect these devices with load dipatch center by SCADA system as shown below in table 5.2:

Table 5.2: improvement of Khartoum north radial feeders 11 kv by using auto reclosers & sectionalizers

NO	S/S	LINE NAME	AUTO RECLOSER	SECTIONALIZERS	TOTAL COST (SDG)
1	SELAITE	Ibrahim Talab	1	3	650,000.00
2		East Soba	1	3	650,000.00
3		Alzerayen	1	2	500,000.00
4		Petrol	1	3	650,000.00
5		Om Doum	1	3	650,000.00
6		Hay Elmustafa	1	2	500,000.00
7	HOFRA	Um Dawanban	1	3	650,000.00
8		El Hofara	1	2	500,000.00
9		El Karnoos	1	3	650,000.00
10		El Mazarea	1	3	650,000.00
11	EID BABEKER	Eid Babeker	1	4	800,000.00
12		El Wadi El Akhdar	1	2	500,000.00
13		Dardoug	1	3	650,000.00
14		El Samra	1	3	650,000.00
15		El Shegla North	1	3	650,000.00
16		Elnaseem	1	3	650,000.00
17		Eltakamul	1	2	500,000.00
18		El Wehdat	1	2	500,000.00
19		El Haj Yousif Agr	1	3	650,000.00
20	NEW KUKU	East Nile Hospital	1	2	500,000.00
21		El Gadesieah	1	3	650,000.00
22		El Soug	1	2	500,000.00
23		El Maygomah	1	2	500,000.00
24		Kuku	1	2	500,000.00
25		El Huda	1	3	650,000.00
26	EL HAJ YOUSIF	Hai El Baraka	1	3	650,000.00
27		El Fayhaa	1	2	500,000.00
28		Souq 6	1	2	500,000.00
29		El Radmiya	1	2	500,000.00
30		El Ban Gaded	1	3	650,000.00
31		El Saleheen	1	3	650,000.00
32	AWAD GABOR	Kafoury	1	4	800,000.00
33		Gerefat	1	2	500,000.00

34		Galab	1	2	500,000.00
35		Dgm	1	2	500,000.00
36		El Safarat	1	2	500,000.00
37	NEW FADUL	El Harareiah	1	3	650,000.00
38		El Maiz	1	1	350,000.00
39		Adiat	1	2	500,000.00
40		Balsam	1	1	350,000.00
41	OLD FADUL	El Matahen	1	3	650,000.00
42		Bank Elmal	1	2	500,000.00
43		El Waseed	1	2	500,000.00
44		Marhab Oil	1	2	500,000.00
45		New Siga (Shambat)	1	2	500,000.00
46		Weta1	1	2	500,000.00
47		Weta2	1	2	500,000.00
48	SELAH EL ESHARAH	Miyah Bhri	1	1	350,000.00
49		Helat Hamad	1	2	500,000.00
50		El Naeb El Awal	1	2	500,000.00
51		Elmasahha	1	2	500,000.00
52	SHENDI	El Khatmeiah	1	2	500,000.00
53		El Bego	1	2	500,000.00
54	EL GAILI	El Seka Hadeed	1	0	200,000.00
55		Wad Ramli Skne	1	1	350,000.00
56		El Geash	1	2	500,000.00
57		El Kabbashi Agr	1	4	800,000.00
58		El Gaili	1	2	500,000.00
59		El Kabbashi Skne	1	1	350,000.00
60		Wad Ramli Agr	1	3	650,000.00
61		Office	1	2	500,000.00
62	SHAMBAT	El Bayara	1	2	500,000.00
63		Hag El Safy	1	2	500,000.00
64		El Bohoth	1	2	500,000.00
65		El Hadarab	1	3	650,000.00
66		Agri Faculty	1	4	800,000.00
67		El Baraha	1	2	500,000.00
68		El Kubbaneiah	1	2	500,000.00
69	SAAD GISHRAH	El Molid	1	3	650,000.00
70		Bahry Hospital	1	1	350,000.00
71		Ahmed Gasim	1	0	200,000.00
72		Elshabeiah	1	2	500,000.00

73		Elmazad	1	2	500,000.00
74		El Doaly Hospital	1	2	500,000.00
75		Saad Gishrah	1	2	500,000.00
76		El Sababi	1	2	500,000.00
77	EL IZERGAB	El Kadaro	1	2	500,000.00
78		El Faki Hashim	1	3	650,000.00
79		El Salakhanah	1	4	800,000.00
80		El Izergab	1	2	500,000.00
81		El Halfayah	1	2	500,000.00
82		Hay El Rawda	1	2	500,000.00
83		El Samrab	1	2	500,000.00
84		El Kadaro Agri	1	3	650,000.00
85		El Droshab	1	2	500,000.00
86		Nubta	1	3	650,000.00
87		El Mahkama	1	2	500,000.00
88		Sudatel	1	2	500,000.00
89	KHALIL OSMAN	Elsafyah	1	2	500,000.00
90		El Sayfonat	1	1	350,000.00
91		El Msra	1	2	500,000.00
92		Shambat (Hajjar)	1	2	500,000.00
93		Cola	1	1	350,000.00
94	MAHMOUD SHAREEF	Taibat El Ahamda	1	3	650,000.00
95		Beblos Bank	1	1	350,000.00
96		Old Siga	1	1	350,000.00
97		Abrsi	1	0	200,000.00
98		Wad Dafeia	1	2	500,000.00
99		Al Shefa	1	2	500,000.00
100		El Turaa	1	2	500,000.00
101		Gazeera Faculty	1	2	500,000.00
102	MSHROA EL WAHA	El Waha 2	1	1	350,000.00
103		Kutrang	1	1	350,000.00
104		Micoi	1	1	350,000.00
105	EL ELAFON	Elbager	1	2	500,000.00
106		Om Dawanban Old	1	1	350,000.00
107		El Elafon	1	2	500,000.00
TOTAL			107	230	55,900,000.00

As seen in the above table it's need to install 107 auto reclosers with communication and control systems and 230 sectionalizers devices with communication and control systems in all KHARTOUM NORTH distribution network 11 KV radial feeders over head lines & the cost of this scenario is **55,900,000.00 SDG.**

NOTES:

- The unit price of auto recloser with communication & control systems is 200,000 SDG.
- The unit price of sectionalizer with communication & control systems is 150,000 SDG.

By using SCADA system & distribution feeder automation the fault management & system restoration application software which shall provide assistance to the dispatcher for detection the fault by blinking alarm in the control center that tell the dispatcher a fault is occur in radial feeder then localization & isolation the fault by the automated sectionalizing devices which it is also integrated with G.I.S. software and finally restoration of fault by calling the nearest electrical distribution complaints office to repair the located & isolated fault in faster time due to knowing the fault location by the Lockout sectionalizer & blinking fault passage indicators. This is the best way restore the fault in minimum time & decrease the number of interrupted customers.

It will study two situations for 2 radial feeders & the situations are:

1. Existing situation (there is no any auto recloser & sectionalizers).
2. Situation with auto recloser & sectionalizers.

5.3.1.1. Um Dawanban radial feeder

This feeder is from Elhofra sub-station .This feeder is 42.237 km long. It's divided to 10% agricultural load & 90% residential load. This feeder covers

the areas: Umdawanban & Eldebeaba vellages. It will install 1 auto recloser & 3 sectionalizers in this radial feeder. As seen in the Figure 5.1

Table 5.3: summarize reliability data to Um Dawanban radial feeder

LINE NAME	Outage duration (hr)	Outage freq	Customer served	Interrupted Energy (MWH)
Um Dawanban	45.02	55	5105	118.92

The study of this radial feeder has 5 situations:

1- Existing situation (there is no any auto recloser & sectionalizers).
2- Situation with auto recloser & sectionalizers (auto recloser operate).
3- Situation with auto recloser & sectionalizers (sectionalizer no 1 operate).
4- Situation with auto recloser & sectionalizers (sectionalizer no 2 operate).
5- Situation with auto recloser & sectionalizers (sectionalizer no 3 operate).

Table 5.4: The distribution of the customers of Um Dawanban radial feeder

Auto-recloser customers	Sectionalizer No1 customers	Sectionalizer No2 customers	Sectionalizer No3 customers
5105	5105	2341	487

Considering that the line trip for 1:45 hrs & 1 time, reliability indices were simulated with the help of G.I.S. & MATLAB software.

Table 5.5: Reliability results for Um Dawanban radial feeder.

Indices	no any auto recloser & sectionalizers	AUTO-RECLOSER OPERATE	sectionalizer No1 operate	sectionalizer No2 operate	sectionalizer No3 operate
SAIFI (1/yr)	0.021202	0.021202	0.021202	0.009723	0.0020226
SAIDI (min/yr)	0.037103	0.037103	0.037103	0.017014	0.0035395
CAIDI	1.750000	1.750000	1.750000	1.750000	1.7500000

From table 5.5 the better results in terms of improvement of SAIDI & SAIFI with the Situation with auto recloser & sectionalizers, which in turn gives the minimum of SAIDI & SAIFI due to dividing the feeder to sections by adding auto reclosers & sectionalizers. Also. It is very important to place the sectionalizing switches at strategic locations however; it may not be practically true since the location of such switches should be near the motorable roads and the availability of other communication facilities. If it is located at such points, it will facilitate to sectionalize the faulty sections faster and to make the supply available to the unfaulty ones.

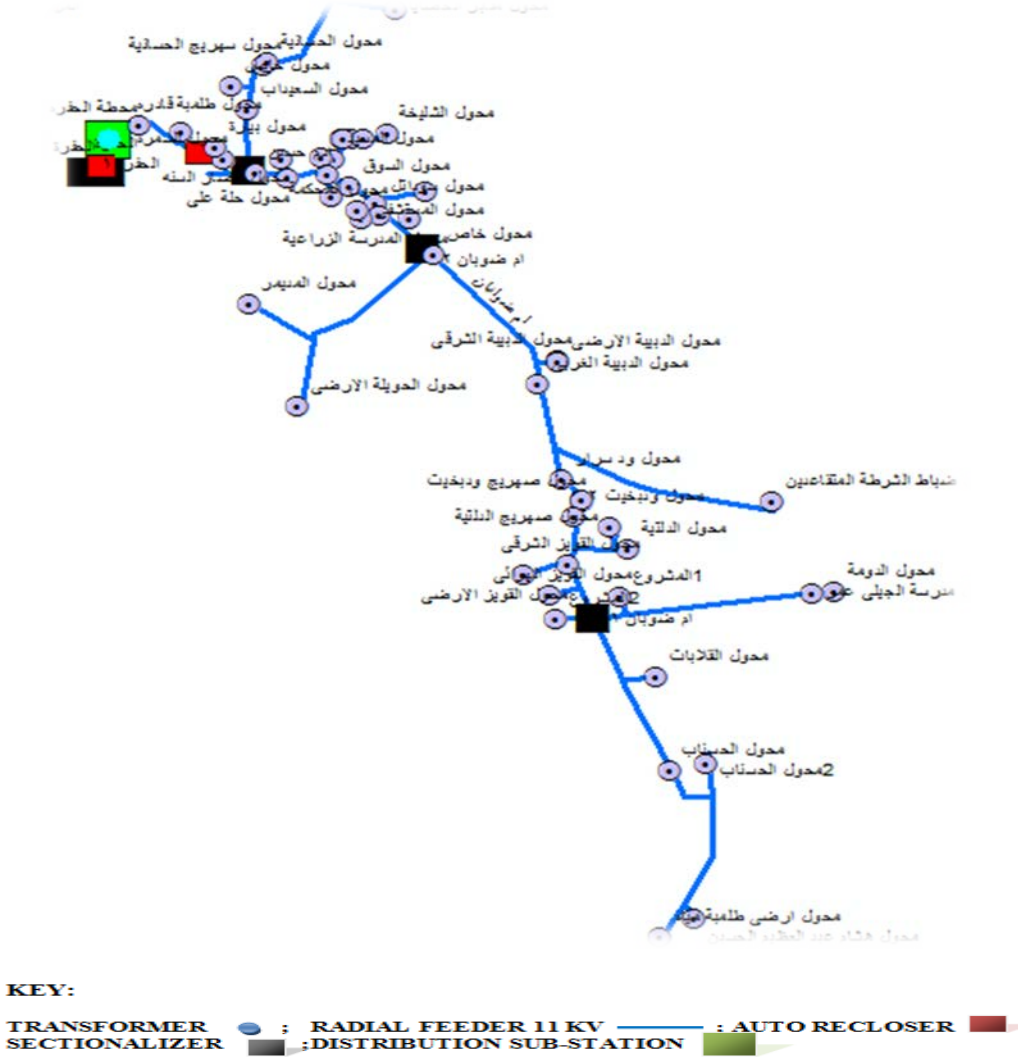

Figure 5.1: UM DAWANBAN radial feeder

5.3.1.2. El Faki Hashim radial feeder

This feeder is from El Izergab sub-station .This feeder is 58.14 km long. It's divided to 35% agricultural load & 65% residential load. This feeder covers the areas: Elzakyab, Elfaki Hashim & Abu Haleama. It will install 1 auto recloser & 3 sectionalizers in this radial feeder. As seen in the Figure 5.2.

Table 5.6: summarize reliability data to EL FAKI HASHIM radial feeder

LINE NAME	Outage duration (hr)	Outage freq	Customer served	Interrupted Energy (MWH)
El Faki Hashim	45.58	111	5601	141.12

The study of this radial feeder has 5 situations:

1- Existing situation (there is no any auto recloser & sectionalizers).
2- Situation with auto recloser & sectionalizers (auto recloser operate).
3- Situation with auto recloser & sectionalizers (sectionalizer no 1 operate).
4- Situation with auto recloser & sectionalizers (sectionalizer no 2 operate).
5- Situation with auto recloser & sectionalizers (sectionalizer no 3 operate).

Table 5.7: The distribution of the customers of El Faki Hashim radial feeder

Auto-recloser customers	Sectionalizer No1 customers	Sectionalizer No2 customers	Sectionalizer No3 customers
5601	298	2368	1371

Considering that the line trip for 1:45 hrs & 1 time, reliability indices were simulated with the help of G.I.S. & MATLAB software.

Table 5.8: Reliability results for El Faki Hashim radial feeder

Indices	no any auto recloser & sectionalizers	AUTO-RECLOSER OPERATE	sectionalizer No1 operate	sectionalizer No2 operate	sectionalizer No3 operate
SAIFI (1/yr)	0.023262	0.023262	0.001238	0.009835	0.0056940
SAIDI (min/yr)	0.040708	0.040708	0.002166	0.017211	0.0099644
CAIDI	1.750000	1.750000	1.750000	1.750000	1.7500000

From table 5.8 the better results in terms of improvement of SAIDI & SAIFI with the Situation with auto recloser & sectionalizers , which inturn gives the minimum of SAIDI & SAIFI due to dividing the feeder to sections by adding auto reclosers & sectionalizers.

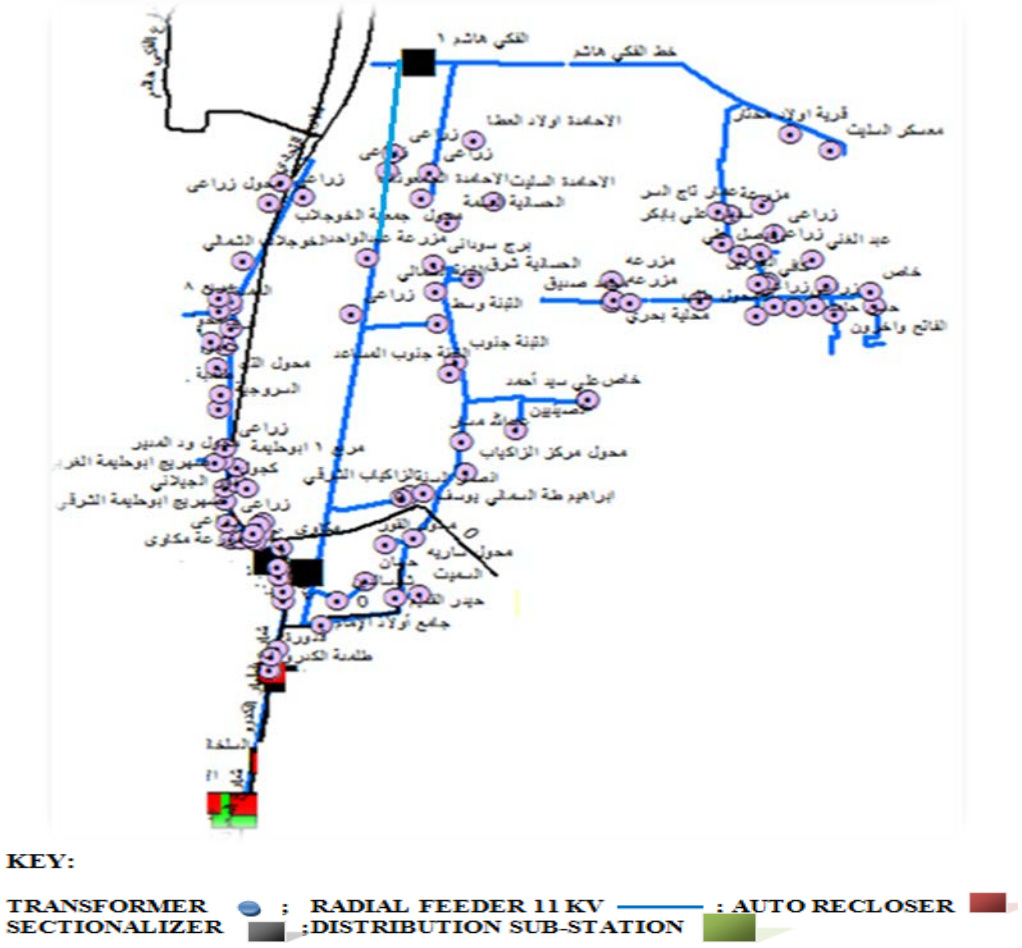

Figure 5.2: EL FAKI HASHIM radial feeder

5.3.1.3. The payback period of this scenario:

Interrupted Energy = 3,257.06 MWH in 10 months

The cost of interrupted energy = 3,257.06 * 260 = 846,835.6 S.D.G.

Where the average tariff in SEDC is 260 SDG for 1MWH

The cost of this scenario = 55,900,000.00 SDG.

$$\text{Payback Period} = \frac{\text{The scenario cost}}{\text{The interrupted energycost}} \times \frac{10 \text{ months}}{12 \text{ months}}$$

$$\text{Payback Period} = \frac{55{,}900{,}000.00}{846{,}835.6} \times \frac{10 \text{ months}}{12 \text{ months}}$$

The payback period = 55 years

5.3.2. Scenario number 2:

Removing the uninsulated conductor wires of the all radial feeders 11 KV & changing it with insulated wires 11KV (Aluminum Conductor Size185 mm2) as shown below in table 5.9:

The advantages of insulated lines include fewer interruptions and lower maintenance costs. Failure rates of overhead lines and underground cables vary widely, but typically underground cable outage rates are about half of their equivalent overhead line types.

Potentially far fewer momentary interruptions occur from animals and tree branches falling on wires which de-energize a circuit and then re-energize it a moment later.

Primary benefits most often cited can be divided into four areas:

A. Potentially-Reduced Maintenance and Operating Costs:

1. Lower storm restoration cost
2. Lower tree-trimming cost

B. Improved Reliability

1. Far fewer momentary interruptions.
2. Improved utility relations regarding tree trimming.

C. Improved Public Safety

1. Reduced live-wire contact injuries.
2. Fewer Fires.

Table 5.9: improvement of Khartoum north feeders 11 kv by changing conductors to insulated wires 11KV

NO	S/S	LINE NAME	O/H LINE LENGTH(m)	TOTAL COST OF REMOVING & CHANGING(SDG)
1	SELAITE	Ibrahim Talab	15249	2,391,043.20
2		East Soba	10609	1,663,491.20
3		Alzerayen	18263	2,863,638.40
4		Petrol	36150	5,668,320.00
5		Om Doum	25511	4,000,124.80
6		Hay Elmustafa	18659	2,925,731.20
7	HOFRA	Um Dawanban	42237	6,622,761.60
8		El Hofara	6783	1,063,574.40
9		El Karnoos	50464	7,912,755.20
10		El Mazarea	22043	3,456,342.40
11	EID BABEKER	Eid Babeker	51168	8,023,142.40
12		El Wadi El Akhdar	14794	2,319,699.20
13		Dardoug	27906	4,375,660.80
14		El Samra	50049	7,847,683.20
15		El Shegla North	19847	3,112,009.60
16		Elnaseem	13613	2,134,518.40
17		Eltakamul	7628	1,196,070.40
18		El Wehdat	9696	1,520,332.80

19		El Haj Yousif Agr	21450	3,363,360.00
20	NEW KUKU	East Nile Hospital	6781	1,063,260.80
21		El Gadesieah	10891	1,707,708.80
22		El Soug	6143	963,222.40
23		El Maygomah	10880	1,705,984.00
24		Kuku	7226	1,133,036.80
25		El Huda	8394	1,316,179.20
26	EL HAJ YOUSIF	Hai El Baraka	12926	2,026,796.80
27		El Fayhaa	6284	985,331.20
28		Souq 6	9160	1,436,288.00
29		El Radmiya	9417	1,476,585.60
30		El Ban Gaded	7329	1,149,187.20
31		El Saleheen	8105	1,270,864.00
32	AWAD GABOR	Kafoury	7242	1,135,545.60
33		Gerefat	3018	473,222.40
34		Galab	8885	1,393,168.00
35		Dgm	2768	434,022.40
36		El Safarat	6408	1,004,774.40
37	NEW FADUL	El Harareiah	5209	816,771.20
38		El Maiz	788	123,558.40
39		Adiat	3275	513,520.00
40		Balsam	740	116,032.00
41	OLD FADUL	El Matahen	3916	614,028.80
42		Bank Elmal	4150	650,720.00
43		El Waseed	3414	535,315.20
44		Marhab Oil	2568	402,662.40
45		New Siga (Shambat)	5326	835,116.80
46		Weta1	1409	220,931.20
47		Weta2	1773	278,006.40
48	SELAH EL ESHARAH	Miyah Bhri	1324	207,603.20
49		Helat Hamad	4365	684,432.00
50		El Naeb El Awal	3883	608,854.40
51		Elmasahha	4117	645,545.60
52	SHENDI	El Khatmeiah	5151	807,676.80
53		El Bego	2494	391,059.20
54	EL GAILI	El Seka Hadeed	1016	159,308.80
55		Wad Ramli Skne	10415	1,633,072.00
56		El Geash	5109	801,091.20
57		El Kabbashi Agr	41997	6,585,129.60
58		El Gaili	5111	801,404.80
59		El Kabbashi Skne	7105	1,114,064.00

60		Wad Ramli Agr	43223	6,777,366.40
61		Office	47154	7,393,747.20
62	SHAMBAT	El Bayara	5169	810,499.20
63		Hag El Safy	4994	783,059.20
64		El Bohoth	8597	1,348,009.60
65		El Hadarab	4950	776,160.00
66		Agri Faculty	18933	2,968,694.40
67		El Baraha	3828	600,230.40
68		El Kubbaneiah	3691	578,748.80
69	SAAD GISHRAH	El Molid	4369	685,059.20
70		Bahry Hospital	1927	302,153.60
71		Ahmed Gasim	160	25,088.00
72		Elshabeiah	2286	358,444.80
73		Elmazad	3167	496,585.60
74		El Doaly Hospital	3887	609,481.60
75		Saad Gishrah	3024	474,163.20
76		El Sababi	3065	480,592.00
77	EL IZERGAB	El Kadaro	9273	1,454,006.40
78		El Faki Hashim	58140	9,116,352.00
79		El Salakhanah	19548	3,065,126.40
80		El Izergab	8468	1,327,782.40
81		El Halfayah	9329	1,462,787.20
82		Hay El Rawda	7013	1,099,638.40
83		El Samrab	10094	1,582,739.20
84		El Kadaro Agri	23603	3,700,950.40
85		El Droshab	8301	1,301,596.80
86		Nubta	19019	2,982,179.20
87		El Mahkama	7698	1,207,046.40
88		Sudatel	11882	1,863,097.60
89	KHALIL OSMAN	Elsafyah	4166	653,228.80
90		El Sayfonat	1204	188,787.20
91		El Msra	2831	443,900.80
92		Shambat (Hajjar)	1888	296,038.40
93		Cola	1132	177,497.60
94	MAHMOUD SHAREEF	Taibat El Ahamda	12369	1,939,459.20
95		Beblos Bank	3242	508,345.60
96		Old Siga	1935	303,408.00
97		Abrsi	1800	282,240.00
98		Wad Dafeia	14699	2,304,803.20
99		Al Shefa	7260	1,138,368.00
100		El Turaa	14179	2,223,267.20

101		Gazeera Faculty	6774	1,062,163.20
102	MSHROA EL WAHA	El Waha 2	14000	2,195,200.00
103		Kutrang	12000	1,881,600.00
104		Micoi	10000	1,568,000.00
105	EL ELAFON	Elbager	19868	3,115,302.40
106		Om Dawanban Old	5779	906,147.20
107		El Elafon	12078	1,893,830.40
TOTAL			1,220,627.00	191,394,313.60

As seen in the above table it's need to remove 1,220,627 meters of uninsulated conductors wires and changing it with insulated wire conductor 11KV in all KHARTOUM NORTH distribution network 11 KV radial feeders over head lines & the cost of this scenario is **191,394,313.60 SDG.**

NOTES:

- The unit price of removing old overhead line by meter 11KV is 5.25 SDG.
- The unit price of changing the meter of insulated wire conductor 11 KV (Aluminum Conductor Size185 mm2) is 35.00 SDG.

5.3.2.1. The payback period of this scenario:

Interrupted Energy = 3,257.06 MWH in 10 months

The cost of interrupted energy = 3,257.06 * 260 = 846,835.6 S.D.G.

Where the average tariff in SEDC is 260 SDG for 1MWH

The cost of this scenario = 191,394,313.60 SDG.

$$\text{Payback Period} = \frac{\text{The scenario cost}}{\text{The interrupted energycost}} \times \frac{10 \text{ months}}{12 \text{ months}}$$

$$\text{Payback Period} = \frac{191{,}394{,}313.60}{846{,}835.6} \times \frac{10 \text{ months}}{12 \text{ months}}$$

The payback period = 188.4 years

5.3.3. Scenario number 3:

Changing the configuration of the overhead line radial feeders to underground cable system. As shown below in table :5.10.

The advantages of underground lines include aesthetics, higher public acceptance, perceived benefits of protection against electromagnetic field radiation (which is still present in underground lines), fewer interruptions, and lower maintenance costs. Failure rates of overhead lines and underground cables vary widely, but typically underground cable outage rates are about half of their equivalent overhead line types.

Potentially far fewer momentary interruptions occur from lightning, animals and tree branches falling on wires which de-energize a circuit and then re-energize it a moment later.

Primary benefits most often cited can be divided into four areas:

A. Potentially-Reduced Maintenance and Operating Costs

1. Lower storm restoration cost
2. Less tree-trimming cost

B. Improved Reliability:

1. Increased reliability during severe weather (wind-related storm damage will be greatly reduced for an underground system, and areas not subjected to flooding and storm surges experience minimal damage and interruption of electric service.
2. Less damage during severe weather.
3. Far fewer momentary interruptions.
4. Improved utility relations regarding tree trimming.

C. Improved Public Safety:

1. Fewer motor vehicle accidents.
2. Reduced live-wire contact injuries.
3. Fewer Fires.

D. Improved Property Values:

1. Improved aesthetics (removal of unsightly poles and wires, enhanced tree canopies)
2. Fewer structures impacting sidewalks.

Table 5.10: Improvement of Khartoum north radial feeders 11 kv by Changing the configuration of the overhead line radial feeders to underground cable system.

NO	S/S	Line Name	O/H Line Length (m)	Total Cost Of Cable Network	Total Cost Of Removing Old Net - Work	TOTAL (SDG)
1	SELAITE	Ibrahim Talab	15249	34,619,709.00	471,041.61	35,090,750.61
2		East Soba	10609	20,923,061.00	327,712.01	21,250,773.01
3		Alzerayen	18263	36,068,893.00	564,144.07	36,633,037.07
4		Petrol	36150	69,796,153.50	1,116,673.50	70,912,827.00
5		Om Doum	25511	49,040,669.50	788,034.79	49,828,704.29
6		Hay Elmustafa	18659	36,340,219.00	576,376.51	36,916,595.51
7	HOFRA	Um Dawanban	42237	82,002,687.00	1,304,700.93	83,307,387.93
8		El Hofara	6783	13,019,359.50	209,526.87	13,228,886.37
9		El Karnoos	50464	94,302,561.50	1,558,832.96	95,861,394.46
10		El Mazarea	22043	46,772,015.50	680,908.27	47,452,923.77
11	EID BABEKER	Eid Babeker	51168	96,460,189.50	1,580,579.52	98,040,769.02
12		El Wadi El Akhdar	14794	29,142,167.00	456,986.66	29,599,153.66
13		Dardoug	27906	55,248,324.00	862,016.34	56,110,340.34
14		El Samra	50049	95,659,893.00	1,546,013.61	97,205,906.61
15		El Shegla North	19847	38,817,149.50	613,073.83	39,430,223.33
16		Elnaseem	13613	27,010,462.00	420,505.57	27,430,967.57
17		Eltakamul	7628	14,433,721.00	235,628.92	14,669,349.92
18		El Wehdat	9696	18,720,778.50	299,509.44	19,020,287.94

19		El Haj Yousif Agr	21450	40,047,612.00	662,590.50	40,710,202.50
20	NEW KUKU	East Nile Hospital	6781	14,789,565.50	209,465.09	14,999,030.59
21		El Gadesieah	10891	22,651,569.50	336,422.99	22,987,992.49
22		El Soug	6143	13,416,248.50	189,757.27	13,606,005.77
23		El Maygomah	10880	22,077,397.00	336,083.20	22,413,480.20
24		Kuku	7226	15,592,790.50	223,211.14	15,816,001.64
25		El Huda	8394	17,811,894.00	259,290.66	18,071,184.66
26	EL HAJ YOUSIF	Hai El Baraka	12926	26,435,608.00	399,284.14	26,834,892.14
27		El Fayhaa	6284	12,562,118.50	194,112.76	12,756,231.26
28		Souq 6	9160	18,307,616.00	282,952.40	18,590,568.40
29		El Radmiya	9417	18,771,501.00	290,891.13	19,062,392.13
30		El Ban Gaded	7329	15,224,388.00	226,392.81	15,450,780.81
31		El Saleheen	8105	16,735,931.50	250,363.45	16,986,294.95
32	AWAD GABOR	Kafoury	7242	14,402,172.00	223,705.38	14,625,877.38
33		Gerefat	3018	6,999,579.00	93,226.02	7,092,805.02
34		Galab	8885	17,478,650.50	274,457.65	17,753,108.15
35		Dgm	2768	7,213,510.00	85,503.52	7,299,013.52
36		El Safarat	6408	13,007,665.50	197,943.12	13,205,608.62
37	NEW FADUL	El Harareiah	5209	16,054,055.00	160,906.01	16,214,961.01
38		El Maiz	788	2,087,521.00	24,341.32	2,111,862.32
39		Adiat	3275	10,900,232.50	101,164.75	11,001,397.25
40		Balsam	740	2,555,198.50	22,858.60	2,578,057.10
41	OLD FADUL	El Matahen	3916	10,394,285.00	120,965.24	10,515,250.24
42		Bank Elmal	4150	12,479,607.50	128,193.50	12,607,801.00
43		El Waseed	3414	6,273,133.50	105,458.46	6,378,591.96
44		Marhab Oil	2568	8,626,326.00	79,325.52	8,705,651.52
45		New Siga (Shambat)	5326	9,835,157.00	164,520.14	9,999,677.14
46		Weta1	1409	2,875,835.50	43,524.01	2,919,359.51
47		Weta2	1773	3,421,992.00	54,767.97	3,476,759.97
48	SELAH EL ESHARAH	Miyah Bhri	1324	4,163,636.00	40,898.36	4,204,534.36
49		Helat Hamad	4365	10,317,822.00	134,834.85	10,452,656.85
50		El Naeb El Awal	3883	8,782,631.00	119,945.87	8,902,576.87
51		Elmasahha	4117	11,200,544.00	127,174.13	11,327,718.13
52	SHENDI	El Khatmeiah	5151	11,514,825.00	159,114.39	11,673,939.39
53		El Bego	2494	7,827,575.00	77,039.66	7,904,614.66
54	EL GAILI	El Seka Hadeed	1016	2,055,607.00	31,384.24	2,086,991.24

55		Wad Ramli Skne	10415	22,568,434.00	321,719.35	22,890,153.35
56		El Geash	5109	10,330,380.00	157,817.01	10,488,197.01
57		El Kabbashi Agr	41997	80,571,715.50	1,297,287.33	81,869,002.83
58		El Gaili	5111	10,555,717.00	157,878.79	10,713,595.79
59		El Kabbashi Skne	7105	20,917,560.50	219,473.45	21,137,033.95
60		Wad Ramli Agr	43223	79,126,150.00	1,335,158.47	80,461,308.47
61		Office	47154	90,656,145.00	1,456,587.06	92,112,732.06
62	SHAMBAT	El Bayara	5169	10,660,407.00	159,670.41	10,820,077.41
63		Hag El Safy	4994	11,120,576.50	154,264.66	11,274,841.16
64		El Bohoth	8597	17,845,718.50	265,561.33	18,111,279.83
65		El Hadarab	4950	10,265,112.00	152,905.50	10,418,017.50
66		Agri Faculty	18933	38,608,605.00	584,840.37	39,193,445.37
67		El Baraha	3828	9,015,946.50	118,246.92	9,134,193.42
68		El Kubbaneiah	3691	8,768,661.50	114,014.99	8,882,676.49
69	SAAD GISHRAH	El Molid	4369	9,216,407.00	134,958.41	9,351,365.41
70		Bahry Hospital	1927	5,584,641.50	59,525.03	5,644,166.53
71		Ahmed Gasim	160	510,527.00	4,942.40	515,469.40
72		Elshabeiah	2286	5,013,138.00	70,614.54	5,083,752.54
73		Elmazad	3167	7,933,705.00	97,828.63	8,031,533.63
74		El Doaly Hospital	3887	9,233,305.00	120,069.43	9,353,374.43
75		Saad Gishrah	3024	6,456,091.50	93,411.36	6,549,502.86
76		El Sababi	3065	7,306,141.00	94,677.85	7,400,818.85
77	EL IZERGAB	El Kadaro	9273	18,844,171.50	286,442.97	19,130,614.47
78		El Faki Hashim	58140	115,807,323.00	1,795,944.60	117,603,267.60
79		El Salakhanah	19548	41,159,905.50	603,837.72	41,763,743.22
80		El Izergab	8468	17,391,146.50	261,576.52	17,652,723.02
81		El Halfayah	9329	18,834,388.00	288,172.81	19,122,560.81
82		Hay El Rawda	7013	14,764,871.50	216,631.57	14,981,503.07
83		El Samrab	10094	21,656,438.50	311,803.66	21,968,242.16
84		El Kadaro Agri	23603	46,372,774.00	729,096.67	47,101,870.67
85		El Droshab	8301	17,311,438.50	256,417.89	17,567,856.39
86		Nubta	19019	34,883,612.50	587,496.91	35,471,109.41
87		El Mahkama	7698	17,996,839.50	237,791.22	18,234,630.72

88		Sudatel	11882	24,772,915.00	367,034.98	25,139,949.98
89	KHALIL OSMAN	Elsafyah	4166	10,623,808.00	128,687.74	10,752,495.74
90		El Sayfonat	1204	2,394,947.00	37,191.56	2,432,138.56
91		El Msra	2831	8,546,723.50	87,449.59	8,634,173.09
92		Shambat	1888	5,292,519.50	58,320.32	5,350,839.82
93		Cola	1132	2,486,714.00	34,967.48	2,521,681.48
94	MAHMOUD SHAREEF	Taibat El Ahamda	12369	25,319,359.50	382,078.41	25,701,437.91
95		Beblos Bank	3242	6,516,991.00	100,145.38	6,617,136.38
96		Old Siga	1935	6,042,535.50	59,772.15	6,102,307.65
97		Abrsi	1800	3,581,590.50	55,602.00	3,637,192.50
98		Wad Dafeia	14699	28,859,828.50	454,052.11	29,313,880.61
99		Al Shefa	7260	15,432,433.50	224,261.40	15,656,694.90
100		El Turaa	14179	27,366,911.00	437,989.31	27,804,900.31
101		Gazeera Faculty	6774	14,887,794.00	209,248.86	15,097,042.86
102	MSHROA EL WAHA	El Waha 2	14000	25,491,727.00	432,460.00	25,924,187.00
103		Kutrang	12000	22,657,771.50	370,680.00	23,028,451.50
104		Micoi	10000	19,380,362.00	308,900.00	19,689,262.00
105	EL ELAFON	Elbager	19868	39,298,508.50	613,722.52	39,912,231.02
106		Om Dawanban Old	5779	10,874,549.00	178,513.31	11,053,062.31
107		El Elafon	12078	24,904,968.00	373,089.42	25,278,057.42
TOTAL			**1,220,627.00**	**2,475,290,764.00**	**37,705,168.03**	**2,512,995,932.03**

As seen in the above table we will need to remove 1,220,627 meters of overhead lines system and changing it with underground cable system 11KV in all KHARTOUM NORTH distribution network 11 KV radial feeders over head lines & the cost of this scenario is **2,512,995,932.03 SDG.**

NOTES:

- The unit price of removing the overhead line system 11KV is 1,544.5 SDG.
- The unit price of changing to underground cable system 11 KV is 1,438 SDG.
- The unit price of cable's terminations & cable's joints 11 KV is 1,500 SDG.
- The unit price of RMU 11 KV is 84,190.80 SDG.

5.3.3.1. The payback period of this scenario:

Interrupted Energy = 3,257.06 MWH in 10 months

The cost of interrupted energy = 3,257.06 * 260 = 846,835.6 S.D.G.

Where the average tariff in SEDC is 260 SDG for 1MWH

The cost of this scenario = 2,512,995,932.03 SDG.

$$\text{Payback Period} = \frac{\text{The scenario cost}}{\text{The interrupted energycost}} \times \frac{10 \text{ months}}{12 \text{ months}}$$

$$\text{Payback Period} = \frac{2{,}512{,}995{,}932.03}{846{,}835.6} \times \frac{10 \text{ months}}{12 \text{ months}}$$

The payback period = 2473 years

5.4. Comparison between the three scenarios:

Table 5.11: comparison between the three scenarios.

	COMPARASION	Installing sectionalizing devices in radial feeders	Removing the uninsulated conductors & changing it with insulated wires	Changing the configuration of the overhead system to underground cable system.
1	**Due to transient faults**	Fault will clear quickly by sectionalizing devices √	The circuit breaker of the line feeder will be tripped	Circuit breaker of the line feeder will be tripped
2	**Due to permanent fault**	Fault will be appeared in a section of the line only √	The circuit breaker of the line feeder will be tripped	The circuit breaker of the line feeder will be tripped
3	**Installing cost**	55,900,000.00 SDG √	191,394,313.60 SDG	2,512,995,932.03 SDG
4	**The operation**	Operation process is done by SCADA system in all over the entire line feeder √	Operation process is done by SCADA system only on the circuit breaker of the feeder in the distribution substation & other process is doing manually	Operation process is done by SCADA system only on the circuit breaker of the feeder in the distribution substation & other process is doing manually
5	**Reliability**	High reliability √	Lowest reliability	Low reliability
6	**Stability**	High stability √	Lowest stability	Low stability
7	**Fault detection**	By SCADA system √	By customer calls	By customer calls
8	**Fault location**	By SCADA system , blocking sectionalizer & blinking fault passage indicators √	Locates by maintenance crew	Locates by maintenance crew
9	**Fault Restoration**	Restoration is done in minimum time due to knowing of fault location √	Restoration will take a lot of time because the working team will search the entire feeder to find the fault after getting complaints from customers	Restoration will take a lot of time because the working team will search the entire feeder to find the fault after getting complaints from customers by using cable fault location car & isolation by R.M.U.S