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Network Automation and Design Implimintation of 132/11KV Substation

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--***ABSTRACT***--

The aim of this paper is presenting the planning design of a power network which supply the power from a vicinity Distribution Network Operator (DNO) 132KV overhead line through one underground cable terminated to one of the 132KV lattice towers to an industrial state. (It should be mentioned that feeding this high-profile industrial state by one underground cable does not comply firm capacity). The design starts from 132/11KV substation and continues to entire 11KV network up to each factory containing the 400V main circuit breaker on the LV side of the transformer.

It is possible to describe the planning process of an electrical network in several stages.

Key words: *Distribution Network Operator, Overhead line design, Circuit breaker and Transformer.*

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I. Introduction

The quality of the delivered electrical power and the efficiency of power supply system. This paper represents the process of developing the performance of the power transmission system (132 kV/11kV) network Newcastle. The most important developments in the network are focused on reducing the losses of real and reactive power, and reducing the power flow of transmission lines that loaded with electrical loads higher than its rated limits, and control on buses voltages in the network so that its value does not pass accepted values.

It is possible to describe the planning process of an electrical network in several steps Illustrated as follows:

Network Designing Steps: First step should be calculating the total potential load that needs the consideration of losses and diversity factor for this load. This can identify the VA rating of the transformer which has to be used to transfer power to lower voltage that is suitable for this network.

Second step is to estimate number of feeders which is needed to supply all the loads where as the number of feeders depends on their rating value.

Third step is (nodes and loads) draws single line diagram of the network; the diagram contain transformer parameters and nodal demand, cable parameters and proposed route length.

Forth step illustrate troubleshooting such as short circuit studies should be conducted and load flow.

Fifth step it is important to specify normal open point and then check the acceptability of the line flows and voltage levels at undiversified loads, Likewise make check for line flows and voltage drops with an outage of the first cable section out on each of the feeder rings and the normal open point closed.

The final step is performed the necessary troubleshooting and studies if any changes of the network.

System Calculation

STEP 1: Calculate the total potential load and apply a diversity factor:

a) *Load calculation:*

The results illustrated below in Table 1, describe the amount of the load for each of the factories and diversity factor of 0.85 which is applied.

Table 1: *Estimating the Total Potential Load by Group*

Load group item	Number of factory	KW of each	total KW	P.F.	Total KVA
F1	1	1200	1200	0.95	1263.158
F2	1	1100	1100	0.98	1122.449
F3	1	1300	1300	0.95	1368.421
F4 - F8 each	5	800	4000	0.8	5000
F9 - F14 each	5	300	1500	0.8	1875
F15 - F19 each	5	400	2000	0.85	2352.941
Total potential loads			11100		12981.97
All losses	6%		666		778.9181
Total system pot. Load			11766		13760.89
Diversity	85%		10001.1		11696.8
Estimated Peak Load			MW		MVA
			10		12

The table shows the estimated peak load 10 MW and 12MVA of the load. The 132/11KV substation should supply this network with single busbar arrangement and two transformers. According to the Industrial Estate planning, figure (1) shows the 11KV network that supplied two transformers 132/11KV with sustain rating12.5MVA. On the other hand, for 11/0.4KV substations at each factory even though it was possible to use same transformers with high rating, for economical reason, according to the loads, two types of 11/0.4KV transformers with different MVA rating have been employed which is shows below.

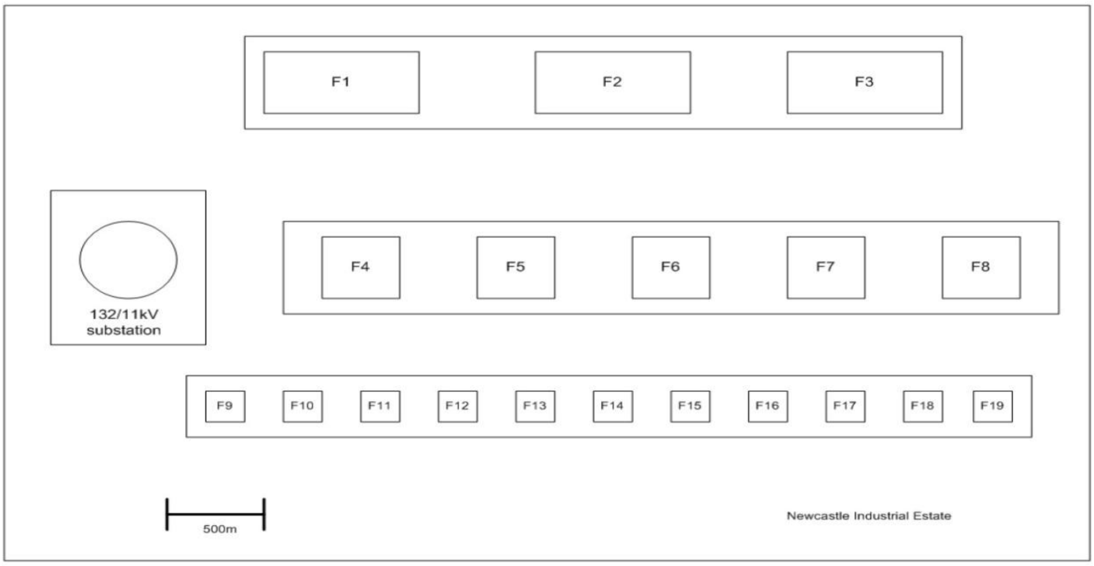

Figure 1: Network Layout

b) *Proposed Transformers characteristics:*

- Two 132/11KV transformers of the following characteristics are proposed to be used in the network:

Type: 3 phase two winding power transformer, Rated capacity (MVA): 12.5, Rated voltage: 132/11KV, Highest system voltage: 145/12KV, Frequency: 50 Hz, Vector group: YNyn0 (no tertiary winding), System of grounding: Solidly grounded, Impedance: 10%, Type of cooling: ONAN, Tapping range: +5 to -15%**,** 16 equal steps each 1.25% on HV side and for HV variation and Type of tap changers: On Load Tap Changer (OLTC)

- 11/0.4KV transformer of the following characteristics are proposed to be used in the network; *In the level 11/0.415 KV, there are several types of transformers that depends on the load in KVA.*

(1): for RMU1:
Type: 3 phase two winding Power transformer. Rated capacity (KVA): 1200, Rated voltage: 11/0.4KV, Highest system voltage: 12/0.435, Frequency: 50 Hz, Vector group: Dyn11 Yyn0, System of grounding: Solidly grounded, Impedance: 4%, Type of cooling: ONAN, Tapping range: +2.5 to -5 % equal steps each 2.5% on HV side and for HV variation, Type of tap changers: NLTC.

(2): for RMU2:
Type: 3 phase two winding Power transformer, Rated capacity (KVA): 1000, Rated voltage: 11/0.4KV, Highest system voltage: 12/0.435, Frequency: 50 Hz, Vector group: Dyn11 Yyn0, System of grounding: Solidly grounded, Impedance: 4%, Type of cooling: ONAN, Tapping range: +2.5 to -5 % equal steps each 2.5% on HV side and for HV variation, Type of tap changers: NLTC.

(3): for RMU3:
Type: 3 phase two winding Power transformer, Rated capacity (KVA): 1200, Rated voltage: 11/0.4KV, Highest system voltage: 12/0.435, Frequency: 50 Hz, Vector group: Dyn11 Yyn0., System of grounding: Solidly grounded, Impedance: 4% , Type of cooling: ONAN, Tapping range: +2.5 to -5 % equal steps each 2.5% on HV side and for HV variation, Type of tap changers: NLTC.

(4): RMU4 to RMU8:
Type: 3 phase two winding Power transformer, Rated capacity (MVA): 1000, Rated voltage: 11/0.4KV, Highest system voltage: 12/0.435, Frequency: 50 Hz, Vector group: Dyn11 Yyn0, System of grounding: Solidly grounded, Impedance: 4%, Type of cooling: ONAN, Tapping range: +2.5 to -5 % equal steps each 2.5% on HV side and for HV variation, Type of tap changers: OFF Load Tap Changer (Resistance Transition Type).

(5): for RMU9 to RMU14:
Type: 3 phase two winding Power transformer, Rated capacity (MVA): 400, Rated voltage: 11/0.4KV, Highest system voltage: 12/0.435, Frequency: 50 Hz, Vector group: Dyn11 Yyn0, System of grounding: Solidly grounded, Impedance: 4%, Type of cooling: ONAN, Tapping range: +2.5 to -5 % equal steps each 2.5% on HV side and for HV variation, Type of tap changers: NLTC.

(6): for RMU14 to RMU19:
Type: 3 phase two winding Power transformer, Rated capacity (MVA): 500, Rated voltage: 11/0.4KV, Highest system voltage: 12/0.435, Frequency: 50 Hz, Vector group: Dyn11 Yyn0, System of grounding: Solidly grounded, Impedance: 4%, Type of cooling: ONAN, Tapping range: +2.5 to -5 % equal steps each 2.5% on HV side and for HV variation, Type of tap changers: NLTC.

c) *Drawing the single busbar layout:*

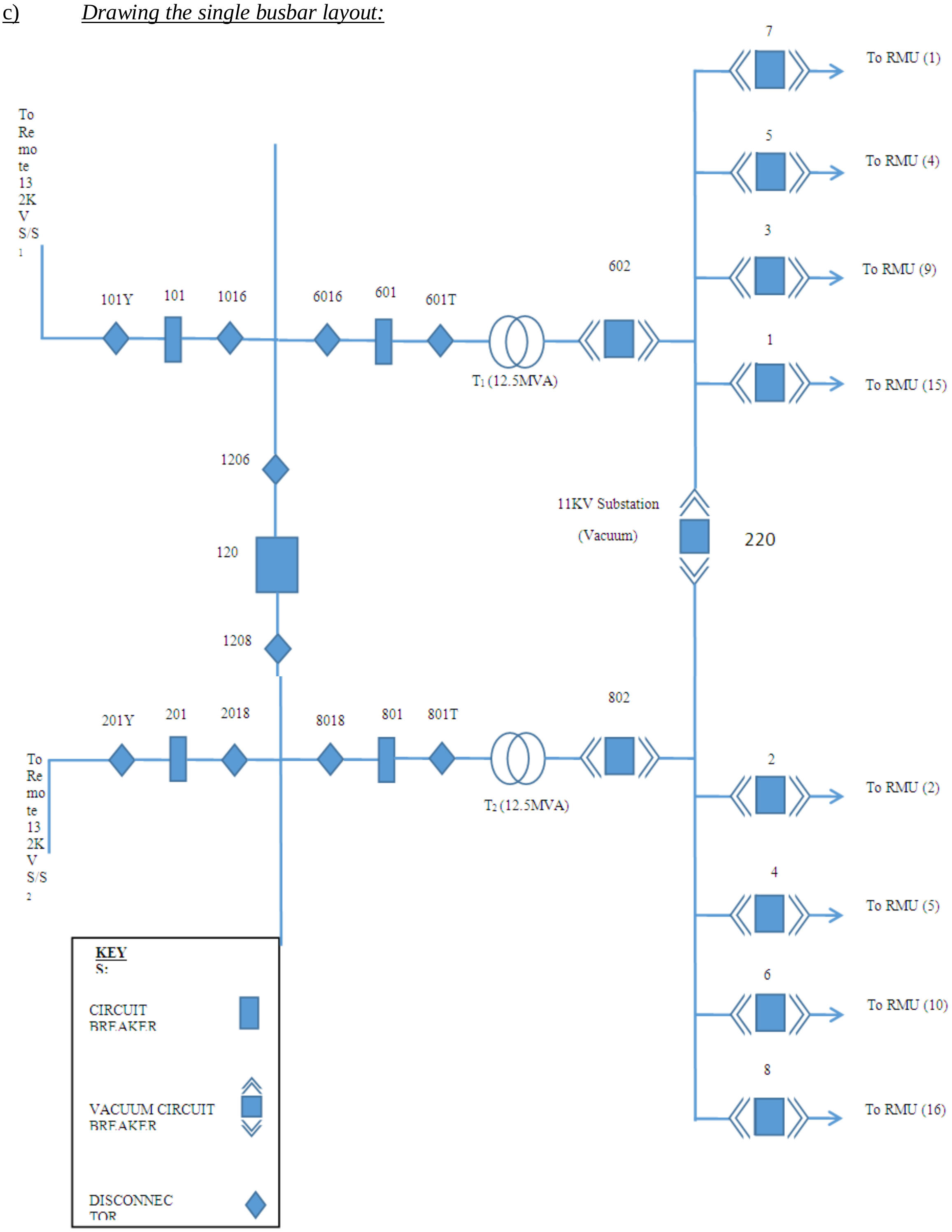

Figure 2: 132/11KV Substation Single Busbar Layout

STEP 2: Design 11 kV feeders for the network:

a) *Cable design:* Examining the summery of Table (1) and utilizing 11KV cables with a current rating (capacity) of 243A, we shall need 8 feeders. This assumes providing security against a loss of the first feeder out on each of the rings. The estimation of 11KV feeders is illustrated in Table (2):

Table 2: Estimating the Number of 11KV Feeders

MVA per feeder	$324 \times 11 \times 10^3 \times \sqrt{3} = 6.17MVA$
Number of feeders	8
Total MVA	49.36
Number of feeders for security	4
4 Feeders in work (firm capacity), Total MVA for 4 feeders	$6.17 \times 4 = 24.68$

From the table, the calculation shows four feeders in work with firm capacity is 24.68 MVA. We going to use eight 11KV feeders, four of them for security.

b) *Cable Specifications: (BS: 6622 IEC 60502-2, REFERENCE GC-11-1-A)*

- *Cable (1):* Single core cable 11KV, XLPE, Armoured Copper conductor, Underground cable, Current Rating Capacity: 243 A, Area of the conductor: 70 seq.mm, Thickness of isolation: 3.4 mm, Thickness of outer sheath: 1.9 mm, Overall diameter: 33.3 mm

Approx. weight: 1870 Kg/Km, Conductor resistance: $R = 0.268\ \Omega/Km\,(at\ 20°C)$, Conductor Reactance: $X = 0.119\ \Omega/Km\,(at\ 50Hz)$, Capacitance: 0.31 $\mu F/Km$

- *Cable (2):* Single core cable 11KV, XLPE, Armoured Copper conductor.

Underground cable, Current Rating Capacity: 288 A, Area of the conductor: 95 seq.mm, Thickness of isolation: 3.4 mm, Thickness of outer sheath: 1.9 mm, Overall diameter: 35.1 mm, Approx. weight: 2210Kg/Km, Conductor resistance: $R = 0.193\ \Omega/Km\,(at\ 20°C)$, Conductor Reactance: $X = 0.112\ \Omega/Km\,(at\ 50Hz)$, Capacitance: 0.34 $\mu F/Km$

For more safe and capacity, design of the network will be with the second cable (Cable 2).

STEP 3: Draw a complete nodal single line diagram. On this diagram note the following:

a) Nodes and loads:

Table 3: Nodes and Loads

Node No.	Title	PF	Load capacity (KVA)	Diversified: 0.85
1	RMU 1	0.95	1263.20	1073.72
2	RMU 2	0.98	1122.50	954.13
3	RMU 3	0.95	1368.00	1162.80
4	RMU 4	0.8	1000.00	850.00
5	RMU 5	0.8	1000.00	850.00
6	RMU 6	0.8	1000.00	850.00
7	RMU 7	0.8	1000.00	850.00
8	RMU 8	0.8	1000.00	850.00
9	RMU 9	0.8	375.00	318.75
10	RMU 10	0.8	375.00	318.75
11	RMU 11	0.8	375.00	318.75
12	RMU 12	0.8	375.00	318.75
13	RMU 13	0.8	375.00	318.75
14	RMU 14	0.8	375.00	318.75
15	RMU 15	0.85	470.60	400.01
16	RMU 16	0.85	470.60	400.01
17	RMU 17	0.85	470.60	400.01
18	RMU 18	0.85	470.60	400.01
19	RMU 19	0.85	470.60	400.01
20	132kv Busbar 1	Source		
21	132kv Busbar 2			
22	11kv Busbar 1			
23	11kv Busbar 2			

b) 11KV RMU configuration:

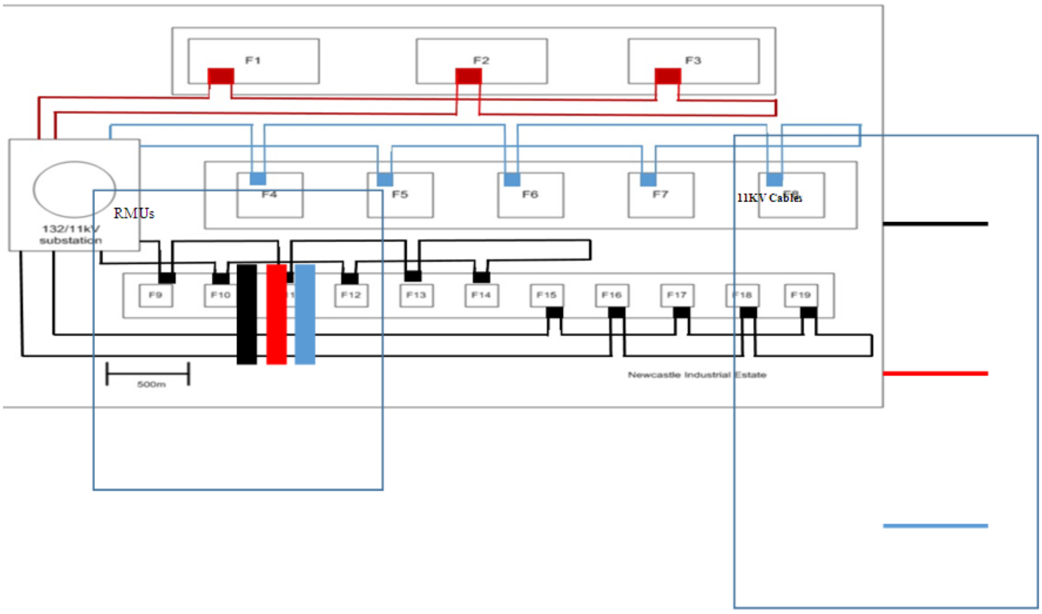

Figure 3: Proposed Industrial 11KV Network

c) Draw a complete nodal single line diagram

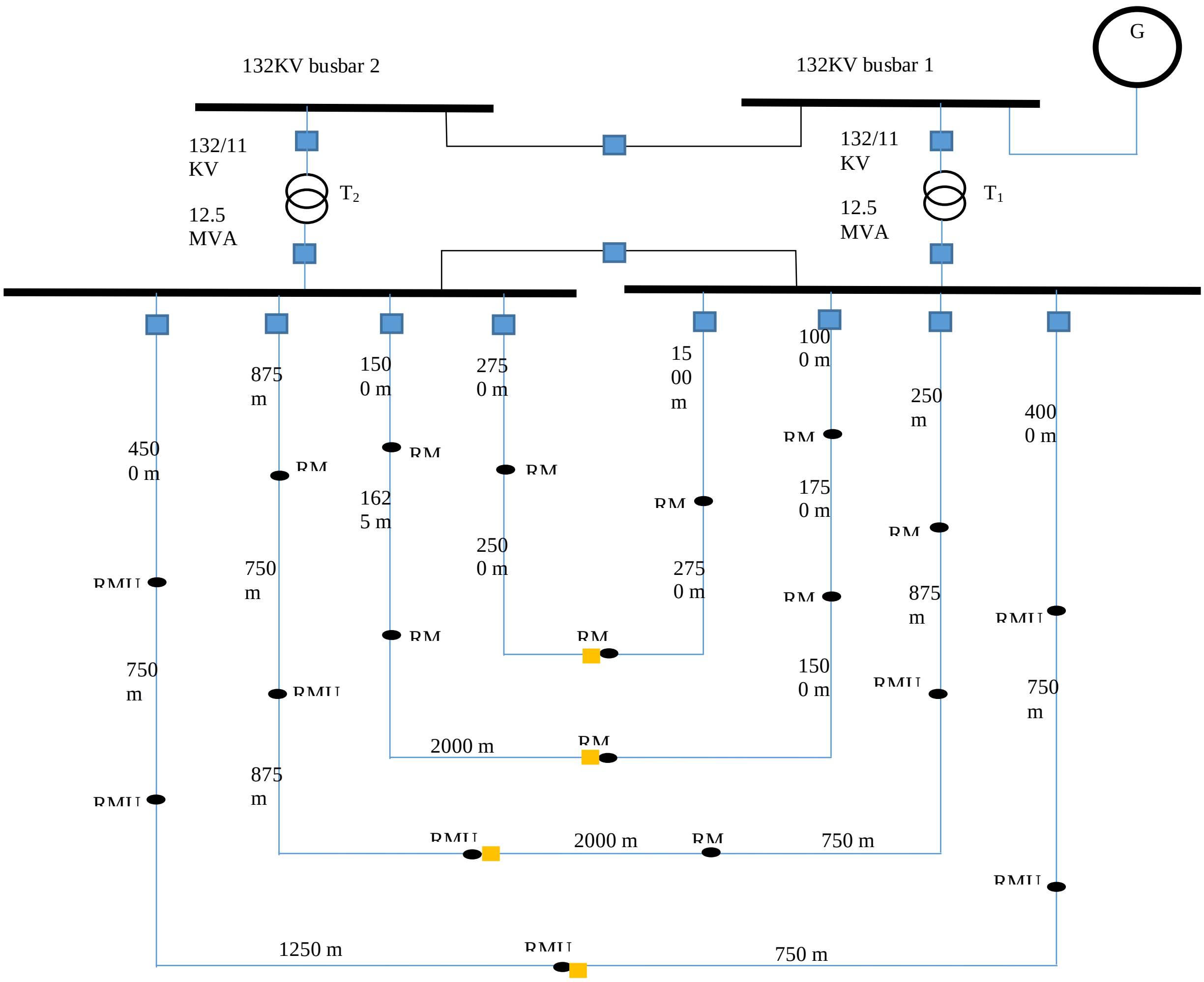

Figure 4: the Proposed Network (cable length in meters)

System Troubleshooting

STEP 4: illustrate short circuit studies calculation:

$$S_{base} = 100MVA$$

$$X_s = X_{p.u.} \times \frac{NewVA_{base}}{OldVA_{base}} = 1 \times \frac{100MVA}{2000MVA} = j0.05 \ \ p.u.$$

$$X_{T1} = X_{T2} = X_{p.u.} \times \frac{NewVA_{base}}{OldVA_{base}} = 0.1 \times \frac{100MVA}{12.5MVA} = j0.8 \ p.u.$$

$$X_{T(parallel)} = \frac{0.8}{2} = j0.4$$

$$Z_{T(p.u.)} = 0.05 + 0.4 = 0.45 \ \ p.u.$$

$$the\ fault\ level = \frac{VA_{base}}{Net\ impedance} = \frac{100MVA}{0.405} = 222.2\ MVA$$

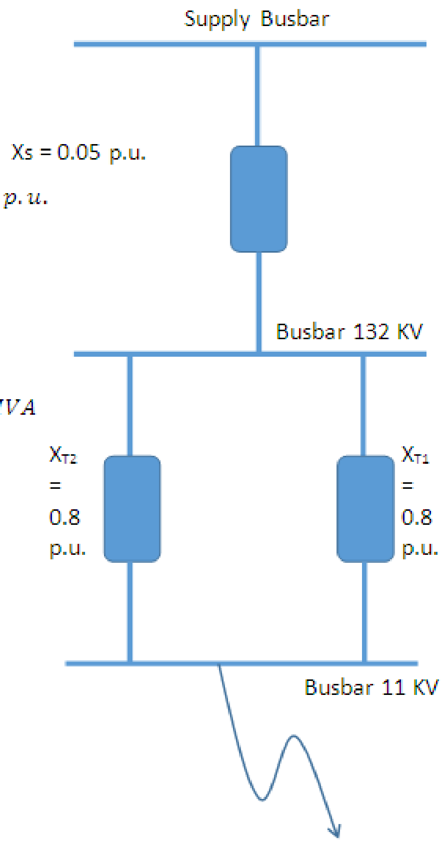

Figure 5: the equivalent

The fault level is 222.2 MVA, it is suitable to use 11KV circuit breakers of fault level 250 MVA (three phase) at the 11KV side of the 132/11KV transformers and at the 11KV feeders. The calculation was the maximum fault level of the network. To be more accurate and secure in selecting circuit breakers for other parts of the network fault and load flow study should be run to determine fault current and current flow at each point and select a CB with appropriate features.

Fault current is 11.66 KA which is almost same as the manual calculated number:

$$the\ fault\ current = \frac{the\ fault\ level}{\sqrt{3}V_{base}} = \frac{222.2MVA}{\sqrt{3} \times 11KV} = 11.66\ \ KA$$

Circuit breakers 250 MVA are appropriate to use at 11KV busbar in the LV side if transformers and also at the 11KV feeders

STEP 5: load flows and voltage drops calculations:

5.1. Design a current continuous and selection of the normal open point position at the feeders:

The selection of the normal open point positions on the rings of the 11KV feeder based on balancing the loads on the feeders.

$$the\ current\ continuous\ on\ the\ feeder = \frac{S}{\sqrt{3}V}$$

5.1.1. Defining normal open point for loop 1:

Table 4: The ring of RMU1-RMU2-RMU3:

Table 4: **Substation**	**Load (KVA)**	**Current (A)**	**Cumulative current (A)**
RMU 1	1263.2	66.3	197
RMU 2	1122.5	58.9	125.2
RMU 3	1368.4	71.8	66.3

Dividing the total current by the two feeders of the ring:$= \frac{197}{2} = 98.5A$

According to the distribution of the loads it is not possible to get balancing. In this case, the highest loads of the three substations at RMU 3, so the normal open point will be selected at the RMU3 towards RMU2.

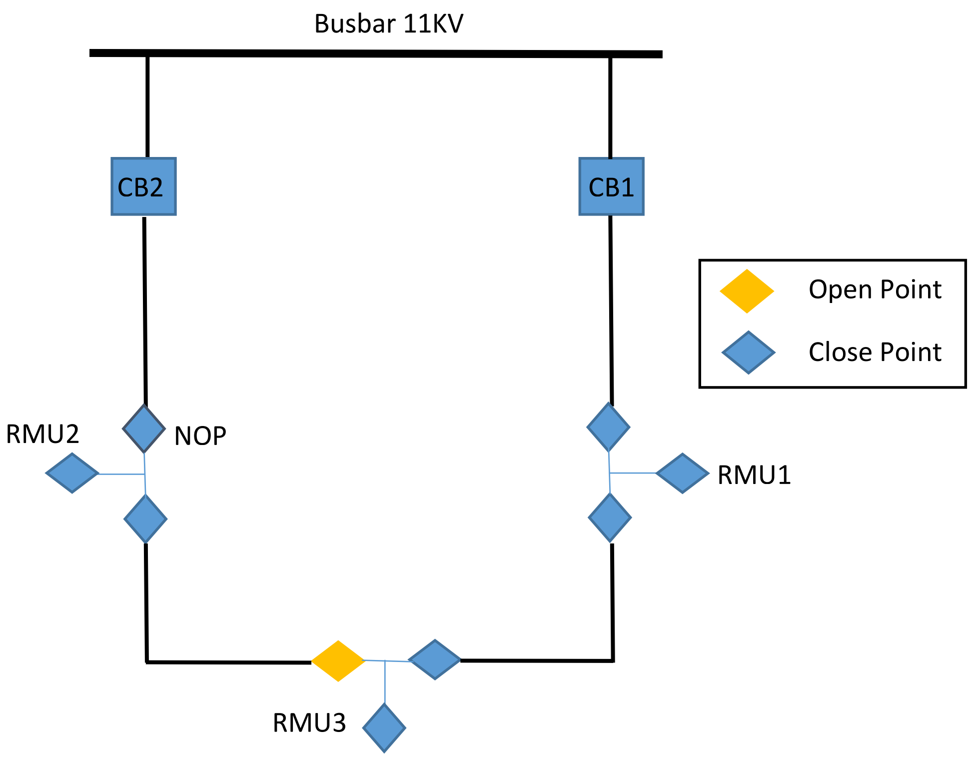

Figure 6: NO point in loop 1

5.1.2. Defining normal open point for loop 2:

Table 5: The ring of RMU4-RMU5-RMU6-RMU7-RMU8:

Substation	Load (KVA)	Current (A)	Cumulative current (A)
RMU 4	1000	52.5	262.5
RMU 6	1000	52.5	210
RMU 8	1000	52.5	157.5
RMU 7	1000	52.5	105
RMU 5	1000	52.5	52.5

Dividing the total current by the two feeders of the ring equal: $\frac{262.5}{2} = 131.25A$

The result shows possible to select the normal open point between RMU6 and RMU8, or between RMU8 and RMU7.

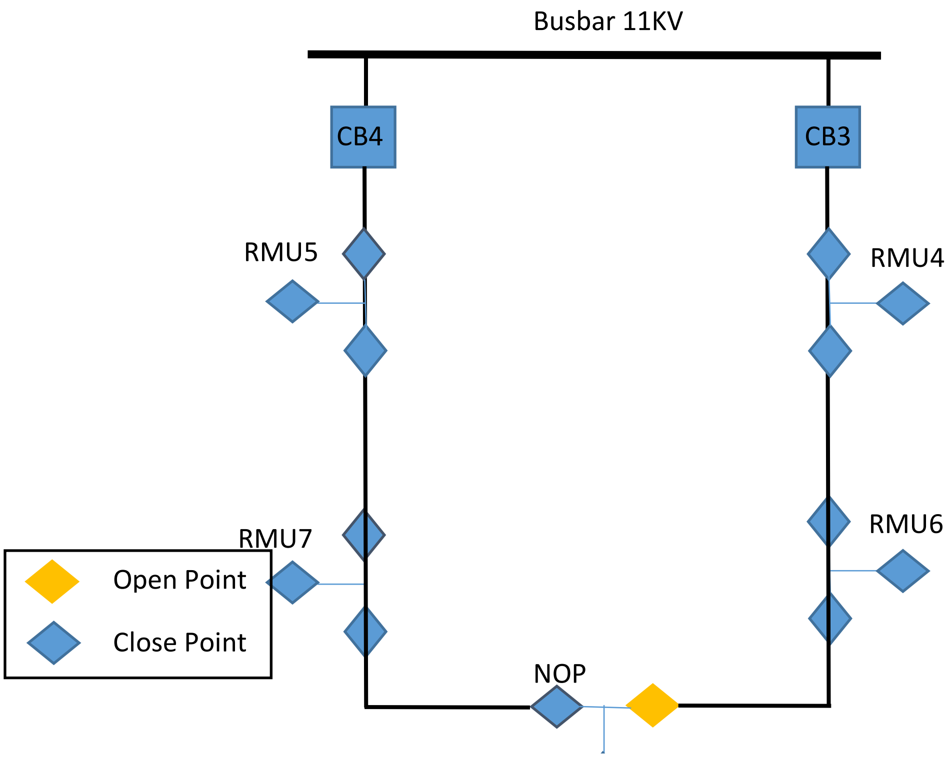

Figure 7: NO point in loop 2

5.1.3. Defining normal open point for loop 3:

Table 6: The ring of RMU9-RMU10-RMU11-RMU12-RMU13-RMU14:

Substation	Load (KVA)	Current (A)	Cumulative current (A)
RMU 9	375	19.7	118.2
RMU 11	375	19.7	98.5
RMU 13	375	19.7	78.8
RMU 14	375	19.7	59.1
RMU 12	375	19.7	39.4
RMU 10	375	19.7	19.7

Dividing the total current by the two feeders of the ring equal: $\frac{118.2}{2} = 59.1A$

The normal open point will be placed at RMU13 towards RMU14.

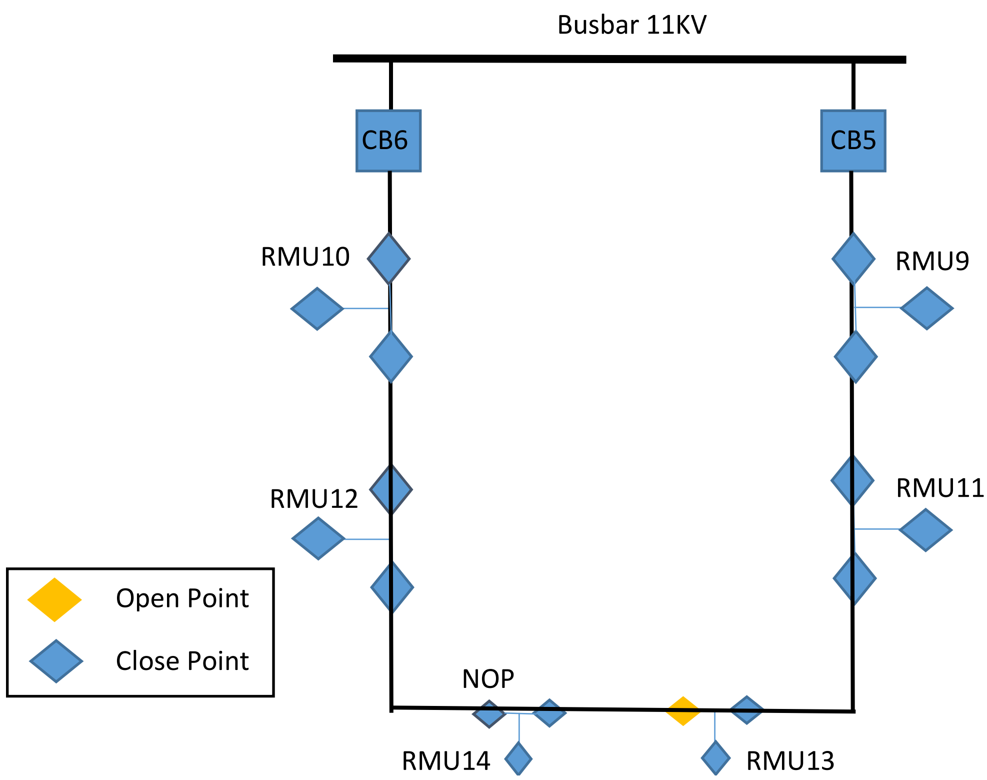

Figure 8: NO point in loop 3

5.1.4. Defining normal open point for loop 4:

Table 7: The ring of RMU15-RMU16-RMU17-RMU18 -RMU19

Substation	Load (KVA)	Current (A)	Cumulative current (A)
RMU 15	470.6	24.7	123.5
RMU 17	470.6	24.7	98.8
RMU 19	470.6	24.7	74.1
RMU 18	470.6	24.7	49.4
RMU 16	470.6	24.7	24.7

Dividing the total current by the two feeders of the ring equal: $\frac{123.5}{2} = 61.75A$

The result shows possible to select the normal open point between RMU17 and RMU19, or RMU18 towards RMU19.

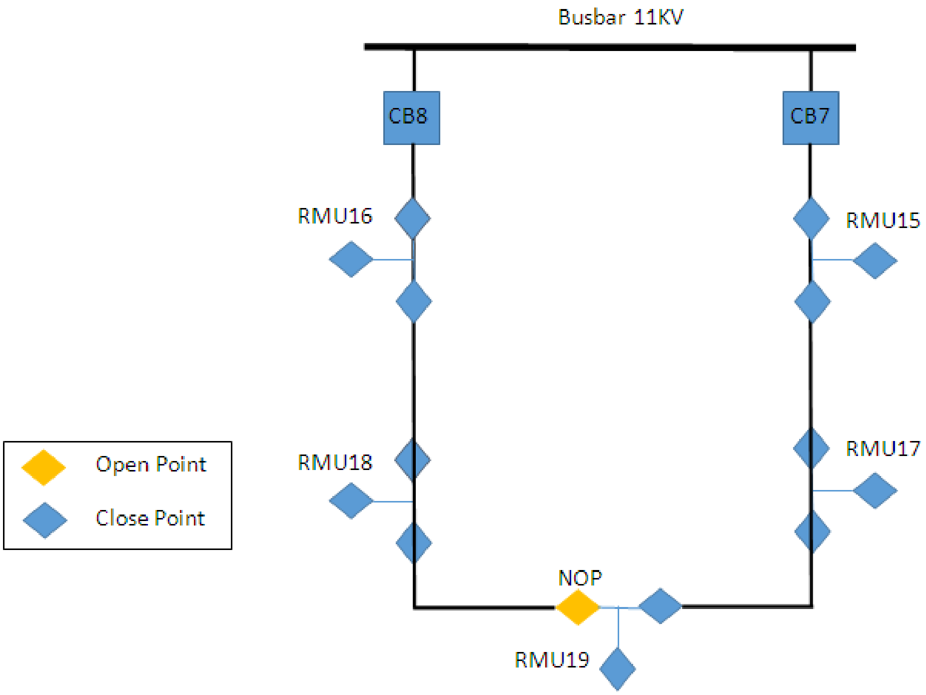

Figure 9: NO point in loop 4

5.2. Check of line flows and voltage drops:
These studies are done with an outage of the first cable section out on each of the feeder rings and the normal points closed.

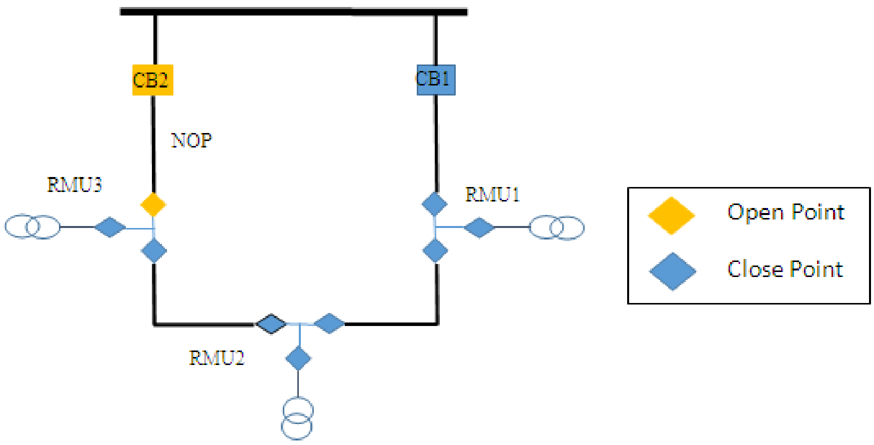

Figure 10: Outage on the first section out of CB1

5.2.1. The ring of RMU1-RMU2-RMU3:

- **Checking of voltage drop:**

$Total\ voltage\ drop = I_1Zl_1 + I_2Zl_2 + I_3Zl_3$
$when\ Z = 0.193 + j0.112 = 0.223[30.13°\ \Omega$
(With neglected the effect of the capacitance of the cable).
$the\ total\ voltage\ drop$

$$= (197 \times [(0.193 \times 0.95) + (0.112 \times 0.31)] \times 1.5) + (125.2 \times [(0.193 \times 0.98) + (0.112 \times 0.2)] \times 2.75) + (66.3 \times [(0.193 \times 0.95) + (0.112 \times 0.31)] \times 2.5) = 173.42\ volt$$

∴The total voltage drop on the ring = 173.42 $volt$

However, the permissible voltage drop $= 0.06 \times \frac{11 \times 10^3}{\sqrt{3}} = 381.05\ volt$

∴The total voltage drop is within the tolerance limits (usually±6%)
The chosen cable is suitable to use at the feeders of the ring of RMU1-RMU2-RMU3.

The cable characteristics are:

(BS: 6622 IEC 60502-2, REFERENCE GC-11-1-A), Single core cable 11KV, XLPE, Armoured Copper conductor, Underground cable, Current Rating Capacity: 288 A, Area of the conductor: 95 seq.mm, Thickness of isolation: 3.4 mm, Thickness of outer sheath: 1.9 mm, Overall diameter: 35.1 mm, Approx. weight: 2210Kg/Km, Conductor resistance: $R = 0.193\ \Omega/Km\ (at\ 20°C)$, Conductor Reactance: $X = 0.112\ \Omega/Km\ (at\ 50Hz)$, Capacitance: $0.34\ \mu F/Km$.

5.2.2. The ring of RMU4-RMU5-RMU6-RMU7-RMU8**:**

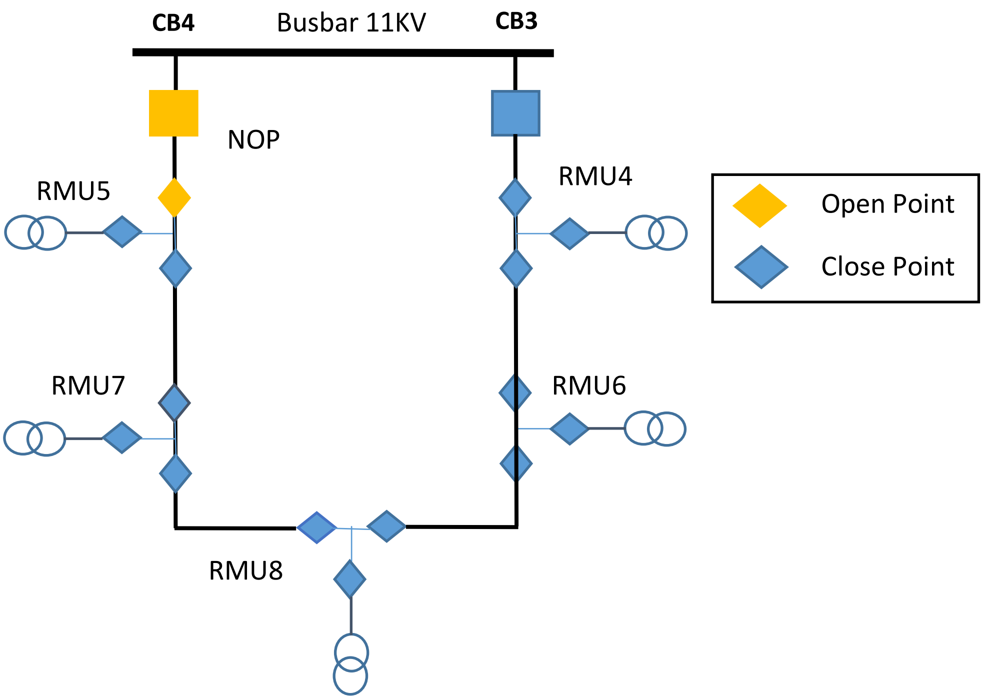

Figure 11: Outage on the first section out of CB4

- **Checking of voltage drop:**

$Total\ voltage\ drop = I_4 Zl_4 + I_5 Zl_5 + I_6 Zl_6 + I_7 Zl_7 + I_8 Zl_8$
$when\ Z = 0.193 + j0.112 = 0.223\lfloor 30.13°\ \Omega$
(With neglected the effect of the capacitance of the cable).
$the\ total\ voltage\ drop$

$$= (262.5 \times [(0.193 \times 0.8) + (0.112 \times 0.6)] \times 1) + (210 \times [(0.193 \times 0.8) + (0.112 \times 0.6)] \times 1.75) + (157.5 \times [(0.193 \times 0.8) + (0.112 \times 0.6)] \times 1.5) + (105 \times [(0.193 \times 0.8) + (0.112 \times 0.6)] \times 2) + (52.5 \times [(0.193 \times 0.8) + (0.112 \times 0.6)] \times 1.625) = 257.41 volt$$

∴The total voltage drop on the ring = $257.41 volt$

However the permissible voltage drop $= 0.06 \times \frac{11 \times 10^3}{\sqrt{3}} = 381.05\ volt$

∴The total voltage drop is within the tolerance limits (usually±6%)
The chosen cable is suitable to use at the feeders of the ring of RMU4-RMU5-RMU6-RMU7-RMU8.

- **The cable characteristics are:**

(BS: 6622 IEC 60502-2, REFERENCE GC-11-1-A), Single core cable 11KV, XLPE, Armoured Copper conductor, Underground cable, Current Rating Capacity: 288 A, Area of the conductor: 95 seq.mm, Thickness of isolation: 3.4 mm, Thickness of outer sheath: 1.9 mm, Overall diameter: 35.1 mm, Approx. weight: 2210Kg/Km, Conductor resistance: $R = 0.193\ \Omega/Km\ (at\ 20°C)$, Conductor Reactance: $X = 0.112\ \Omega/Km\ (at\ 50Hz)$, Capacitance: $0.34\ \mu F/Km$.

5.2.3. The ring of RMU9-RMU10-RMU11-RMU12-RMU13-RMU14:

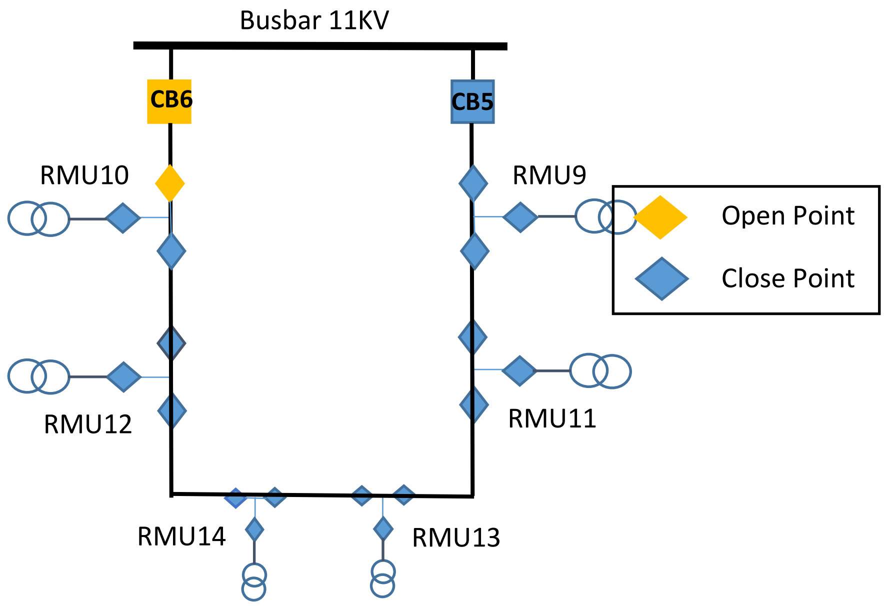

Figure 12: Outage on the first section out of CB6

- **Checking of voltage drop:**

$Total voltage drop = I_9 Zl_9 + I_{11} Zl_{11} + I_{13} Zl_{13} + I_{14} Zl_{14} + I_{12} Zl_{12} + I_{10} Zl_{10}$
$when Z = 0.193 + j0.112 = 0.223\lfloor 30.13° \, \Omega$
(With neglected the effect of the capacitance of the cable).

$$\begin{aligned} \text{the total voltage drop} \\ &= (118.2 \times [(0.193 \times 0.8) + (0.112 \times 0.6)] \times 0.25) \\ &+ (98.5 \times [(0.193 \times 0.8) + (0.112 \times 0.6)] \times 0.875) \\ &+ (78.8 \times [(0.193 \times 0.8) + (0.112 \times 0.6)] \times 0.75) \\ &+ (59.1 \times [(0.193 \times 0.8) + (0.112 \times 0.6)] \times 2) \\ &+ (39.4 \times [(0.193 \times 0.8) + (0.112 \times 0.6)] \times 0.875) \\ &+ (19.7 \times [(0.193 \times 0.8) + (0.112 \times 0.6)] \times 0.75) = 75.8 \, volt \end{aligned}$$

∴The total voltage drop on the ring = 75.8 $volt$

However the permissible voltage drop $= 0.06 \times \frac{11 \times 10^3}{\sqrt{3}} = 381.05 volt$

∴The total voltage drop is within the tolerance limits (usually $\pm$6%)
The chosen cable is suitable to use at the feeders of the ring of RMU4-RMU5-RMU6-RMU7-RMU8.

- **The cable characteristics are:**

(BS: 6622 IEC 60502-2, REFERENCE GC-11-1-A), Single core cable 11KV, XLPE, Armoured Copper conductor, Underground cable, Current Rating Capacity: 288 A, Area of the conductor: 95 seq.mm, Thickness of isolation: 3.4 mm, Thickness of outer sheath: 1.9 mm , Overall diameter: 35.1 mm, Approx. weight: 2210Kg/Km, Conductor resistance: $R = 0.193 \, \Omega/Km \, (at 20°C)$, Conductor Reactance: $X = 0.112 \, \Omega/Km \, (at 50Hz)$, Capacitance: 0.34 $\mu F/Km$.

5.2.4. The ring of RMU15-RMU16-RMU17-RMU18-RMU19**:**

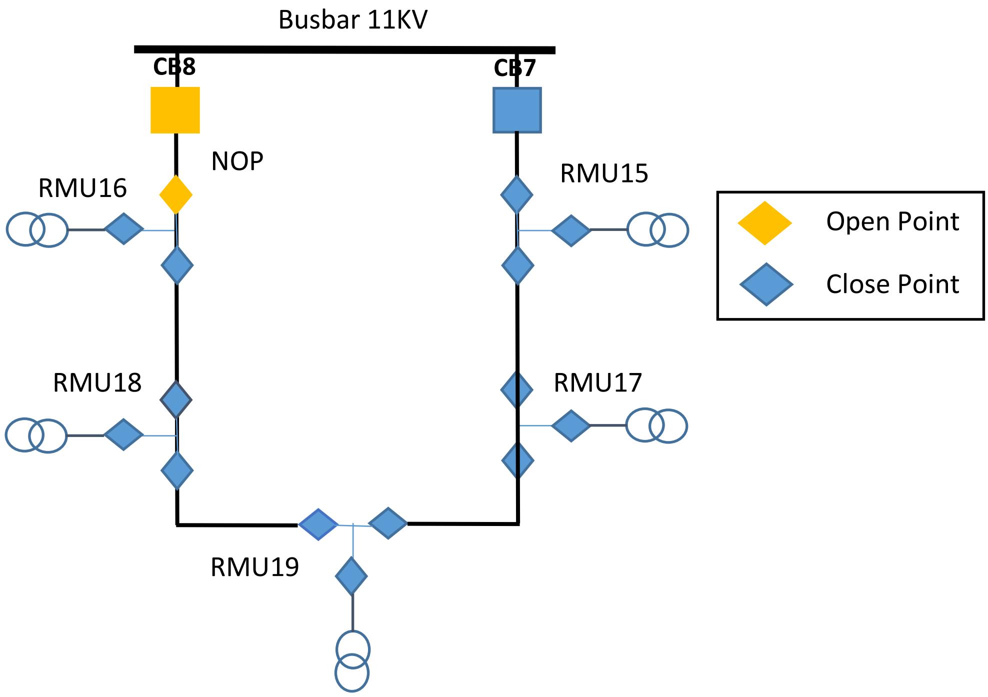

Figure 13: Outage on the first section out of CB6

- **Checking of voltage drop:**

$Total\ voltage\ drop = I_4 Zl_4 + I_5 Zl_5 + I_6 Zl_6 + I_7 Zl_7 + I_8 Zl_8$
$when\ Z = 0.193 + j0.112 = 0.223[30.13° \ \Omega$
(With neglected the effect of the capacitance of the cable).
$the\ total\ voltage\ drop$

$$= (123.5 \times [(0.193 \times 0.85) + (0.112 \times 0.5267)] \times 4) + (98.8 \times [(0.193 \times 0.85) + (0.112 \times 0.5267)] \times 1.75) + (74.1 \times [(0.193 \times 0.85) + (0.112 \times 0.5267)] \times 1.5) + (49.4 \times [(0.193 \times 0.85) + (0.112 \times 0.5267)] \times 2) + (24.7 \times [(0.193 \times 0.85) + (0.112 \times 0.5267)] \times 1.625) = 204.52\ volt$$

∴The total voltage drop on the ring = $204.52\ volt$

However, the permissible voltage drop $= 0.06 \times \frac{11 \times 10^3}{\sqrt{3}} = 381.05\ volt$

∴The total voltage drop is within the tolerance limits (usually$\pm$6%)
The chosen cable is suitable to use at the feeders of the ring of RMU4-RMU5-RMU6-RMU7-RMU8.

- **The cable characteristics:**

(BS: 6622 IEC 60502-2, REFERENCE GC-11-1-A), Single core cable 11KV, XLPE, Armoured Copper conductor, Underground cable, Current Rating Capacity: 288 A, Area of the conductor: 95 seq.mm, Thickness of isolation: 3.4 mm, Thickness of outer sheath: 1.9 mm

Overall diameter: 35.1 mm, Approx. weight: 2210Kg/Km, Conductor resistance: $R = 0.193\ \Omega/Km\ (at\ 20°C)$, Conductor Reactance: $X = 0.112\ \Omega/Km\ (at\ 50Hz)$, Capacitance: $0.34\ \mu F/Km$.

Conclusion

STEP6: Making any necessary changes to the network:

The short circuit and load flow studies results that show the selections of network elements are suitable, so that any necessary changes are not required.

6.1. The current rating of the CBs on the 132KV side:

The current rating of the each transformer $= \frac{12.5MVA}{\sqrt{3} \times 132KV} = 54.67\ A \cong 0.05467\ KA$

6.1.1. The current rating of the CBs 101 and 201 $> 1.3 \times 2 \times 0.05467 = 0.142142\ KA$
Select current rating of CB 101 and CB 201 is 0.2 KA.

- **Two SF6 circuit breakers (101 and 201) of following characteristics:**

a) Nominal system voltage between phases: 132 KV

b) Earthing of neutral at transformers: Solid
c) System Frequency: 50 Hz
d) System highest voltage: 145 KV
e) Fault level: 2000 MVA
f) Current rating: 0.2 KA

6.1.2. The current rating of CBs 120, 601 and 801$> 1.3 \times 0.05467 = 0.071071\ KA$

Select current rating of CBs 120, 601 and 801 is 0.1 KA

- **Three SF6 circuit breakers (120, 601 and 801) of following characteristics:**

g) Nominal system voltage between phases: 132 KV
h) earthling of neutral at transformers: Solid
i) System Frequency: 50 Hz
j) System highest voltage: 145 KV
k) Fault level: 2000 MVA
l) Current rating: 0.1 KA

6.2. The current rating of the CBs on the 11KV side:

The current rating of the each transformer $= \frac{12.5MVA}{\sqrt{3 \times 11KV}} = 656.1A \cong 0.6561\ KA$

6.2.1. The current rating of the CBs 602, 802 and 220 $> 1.3 \times 0.6561 = 0.85293\ KA$

Select current rating of CB 101 and CB 201 is 0.1 KA

- **Three Vacuum Rack-out circuit breakers (602, 802 and 220) of following characteristics:**

m) Nominal system voltage between phases: 11 KV
n) Earthing of neutral at transformers: Solid
o) System Frequency: 50 Hz
p) System highest voltage: 12 KV
q) Fault level: 250MVA
r) Current rating: 1.1 KA

6.2.2. The current rating of feeder circuit breakers CBs 1, 2, 3, 4, 5, 6, 7 and 8 is:

The selection of feeder circuit breaker current ratings is as following:

The highest total load current>Feeder Circuit Breaker Rating>Cable current rating

223 >Feeder Circuit Breaker Rating>288A, Select feeder CBs current rating is 230 A.

- **Eight Vacuum Rack-out circuit breakers (1, 2, 3, 4, 5, 6, 7and 8) of following characteristics:**

s) Nominal system voltage between phases: 11 KV
t) Earthing of neutral at transformers: Solid
u) System Frequency: 50 Hz
v) System highest voltage: 12 KV
w) Fault level: 250MVA
x) Current rating: 0.23 KA

References

[1]. Burke, J. (1994). *Power Distribution Engineering, Fundamentals and Applications.*

[2]. Colin Bayliss and Brian Hardy. (2007). *Transmission and Distribution Electrical Engineering,3rd. Edition.*

[3]. Mohammed Saadi Hasan, Raghad Ali Mejeed, Hayder Salim Hameed. (2019). Analysis of Diyala Power Network for the Distributed Feeders Between Iraq and Iran: 132 kV Baquba-Sarbilzahab. *International Review of Electrical Engineering (IREE)* , (pp. Vol 14, No 5).

[4]. Roger C. Dugan, Surya Santoso. Mark F. McGranaghan, Wayne Beaty. (2003). *Electrical Power System Quality, 2nd Edition,*. McGraw Hill, Professional Engineering.

Indexes

Transformers Reference:

>Techdata of 11KV S11、S11-M series distribution transformer

rated capacity (kVA)	voltage group		connection meghod	impedance voltage	Loss		no-load current(%)	weight (kg)			(LxBxH)(mm) outine dimension			gauge vertica/horizontal
	High-voltage	Low-voltage			no-load	load		machine weight	oil weight	gross weight				
10	11 10.5 10 6.3 6	0.4 0.69	Yyno Dyn11	4	0.65	0.4	3.5	90	55	220	650	450	880	400/350
20					0.08	0.52	3	140	60	270	720	490	950	400/350
30					0.10	0.63/0.6	2.3	185	70	330	750	490	970	450/340
50					0.13	0.91/0.87	2	260	80	430	770	550	1030	450/380
63					0.15	1.09/1.04	1.9	260	85	440	800	600	1040	450/380
80					0.18	1.31/1.25	1.9	320	95	520	790	600	1070	450/430
100					0.20	1.58/1.5	1.8	355	100	570	830	640	1050	550/450
125					0.24	1.89/1.8	1.7	425	115	675	1070	700	1150	550/470
160					0.28	2.31/2.2	1.6	510	130	790	1120	700	1220	550/520
200					0.34	2.73/2.6	1.5	550	145	850	1080	690	1160	550/520
250					0.40	3.2/3.05	1.4	630	165	985	1160	740	1190	650/550
315					0.48	3.83/3.65	1.4	755	190	1155	1230	800	1240	650/550
400					0.57	4.52/4.3	1.3	910	225	1405	1310	860	1250	650/550
500					0.68	5.41/5.15	1.2	1050	240	1600	1370	890	1350	750/600
630				4.5	0.81	6.2	1.1	1250	310	1945	1580	1060	1310	850/660
800					0.96	7.5	1	1540	365	2350	1640	1060	1500	850/660
1000					1.15	10.3	1	1690	405	2645	1720	1060	1540	850/660
1250					1.36	12	0.9	1965	560	3230	1790	1190	1740	850/660
1600					1.64	14.5	0.8	2355	650	3805	1830	1210	1850	850/700
2000					1.96	19.8	0.8	2570	615	4245	2190	1900	1950	820/820
2500					2.31	23	0.7	3130	810	5280	2180	1940	2250	1070/1070

Nonte:tapping range of high-voltage:±5%, ±2x2.5%; frequency:50Hz

Quick Details

Place of Origin:	Zhejiang China (Mainland)	Brand Name:	YUANGUANG	Model Number:	S11-M-10kV
Usage:	Power	Phase:	Three	Coil Structure:	Toroidal
Coil Number:	Autotransformer	Losses:	Low losses	Power transformer:	Distribution transformer
Standards:	IEC,GB,ANSI	Iron core:	Silicon sheet	Windings material:	Copper
Connection Symbol:	Dyn11 Yyn0	Rated power range:	30-2000kVA	High voltage range:	6-11kV
Cooling type:	ONAN	Tap changer:	NLTC		

Cables Reference:

BS 6622
IEC 60502-2
REFERENCE GC-11-1-A

TABLE 6B! SINGLE-CORE 11kV ARMOURED CABLES (COPPER CONDUCTOR)

Nominal Area of Conductors	Thickness of Insula-tion	Thickness of Extruded Bedding	Nominal armour wire diameter	Thickness of Outer Sheath	Overall Diameter	Approx. Weight	Electrical Characteristics					
							Current Rating		Conductor Resistance		Reactance at 50Hz	Capacitance
							In Air at 40°C	In Ground at 25°C	dc at 20°C	50Hz at 90°C		
sq. mm	mm	mm	mm	mm	mm	kg/km	amp	amp	Ω/km	Ω/km	Ω/km	μF/km
50	3.4	1.2	1.6	1.8	31.7	1600	217	198	0.387	0.493	0.126	0.27
70	3.4	1.2	1.6	1.9	33.3	1870	242	243	0.268	0.342	0.119	0.31
95	3.4	1.2	1.6	1.9	35.1	2210	306	288	0.193	0.247	0.112	0.34
120	3.4	1.2	1.6	2.0	36.6	2510	353	324	0.153	0.196	0.108	0.37
150	3.4	1.2	2.0	2.1	38.8	2950	400	369	0.124	0.159	0.106	0.40
185	3.4	1.2	2.0	2.1	40.5	3370	459	414	0.0991	0.128	0.103	0.44
240	3.4	1.2	2.0	2.2	42.8	4030	544	477	0.0754	0.0980	0.099	0.49
300	3.4	1.2	2.0	2.2	45.2	4720	629	540	0.0601	0.0790	0.096	0.54
400	3.4	1.2	2.0	2.4	47.9	5630	714	612	0.0470	0.0633	0.093	0.59
500	3.4	1.3	2.5	2.5	52.0	6990	799	675	0.0366	0.0511	0.090	0.66
630	3.4	1.4	2.5	2.6	55.6	8520	944	752	0.0283	0.0416	0.087	0.74