Security-based Approach for Planning and Design of Electric Supply in Indonesia's New Capital Considering Power Resiliency

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INSTITUT TEKNOLOGI BANDUNG • 1920 •

OUTLINE

1. BACKGROUND

Indonesia is moving its capital.

The most ideal locations of new capital are in parts of Penajam Paser Utara Regency and partly in Kutai Kartanegara Regency, East Kalimantan Province.

- Joko Widodo

A capital is a vital object of a country thus high-quality of electrical energy supplies are needed especially in distribution systems.

2. OBJECTIVES

To determine most reliable power distribution system topology for Indonesia’s new capital.

To determine the number and location of substations needed for Indonesia’s new capital.

To calculate battery capacity & diesel needed for Indonesia’s new capital.

3. METHODOLOGY

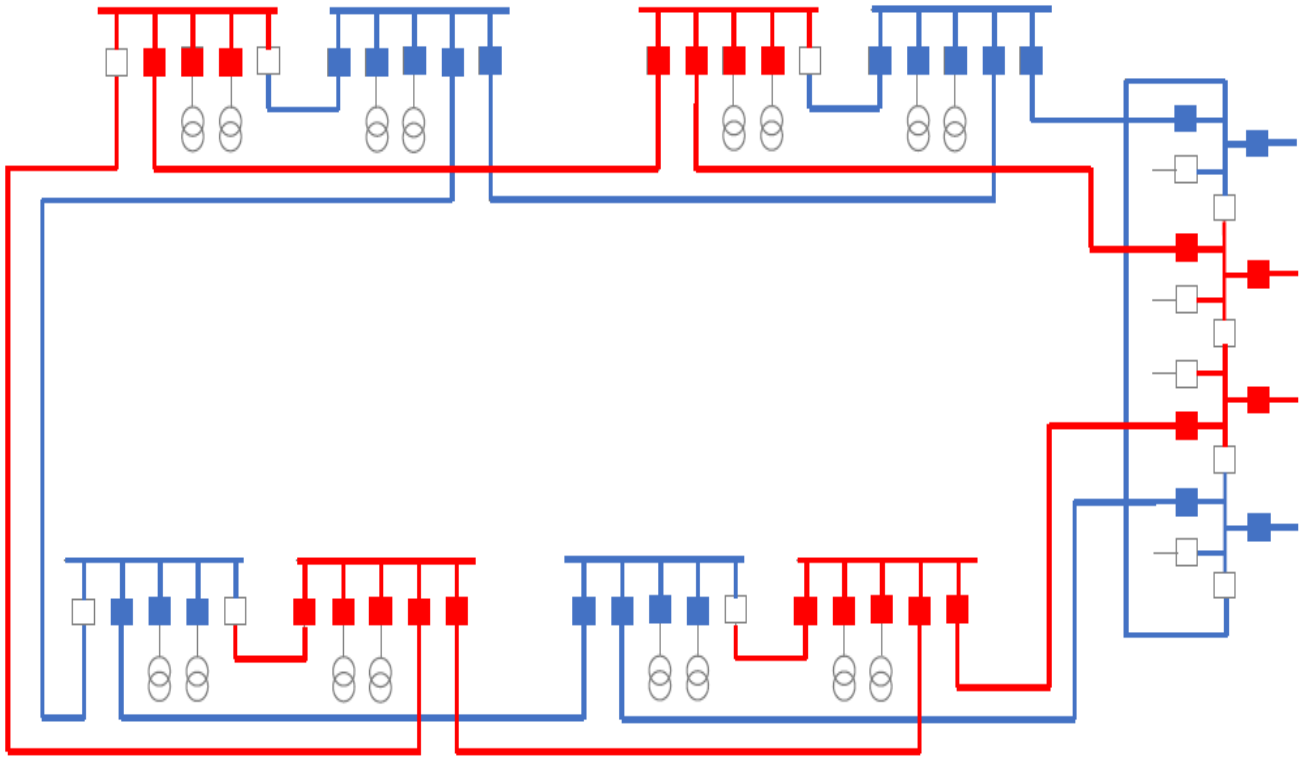
RESEARCH METHOD

1. Collect data of Kalimantan's existing power system.
2. Collect new capital construction planning's data.
3. Create single line diagram of four system topologies.
4. Do the simulation with DIgSILENT PowerFactory.
5. Calculate estimated power demand of new capital.
6. Calculate number of substations and battery capacity needed.

4. RESULTS AND DISCUSSION

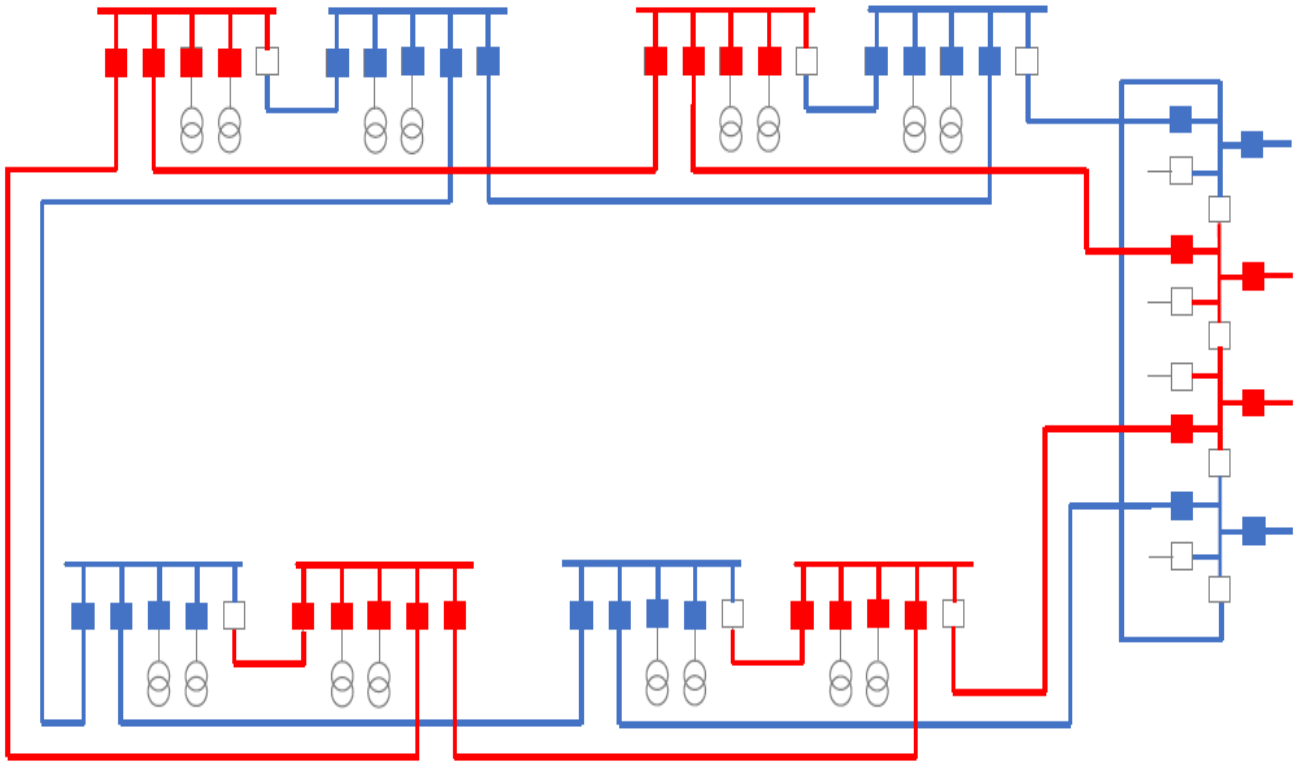
SYSTEM TOPOLOGY PROPOSED

1. Open Loop



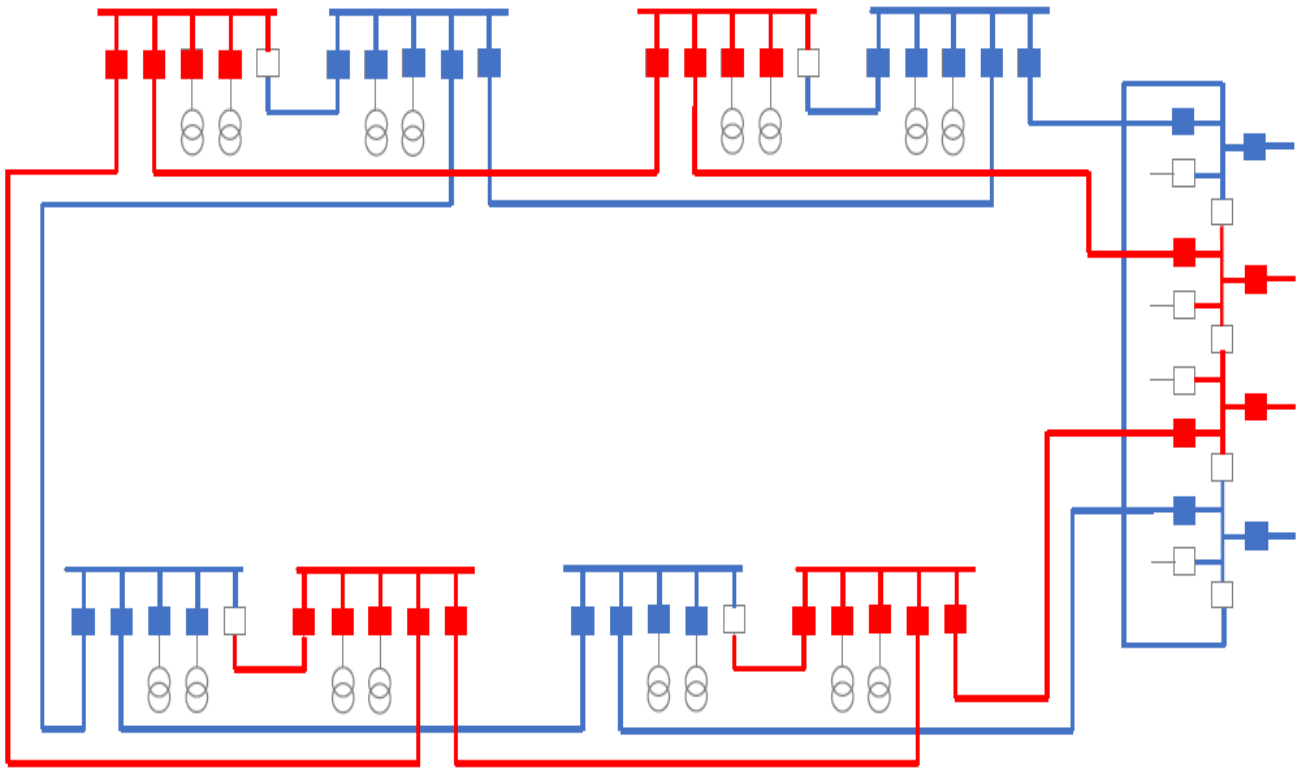
SYSTEM TOPOLOGY PROPOSED

2. Fork (Modification)



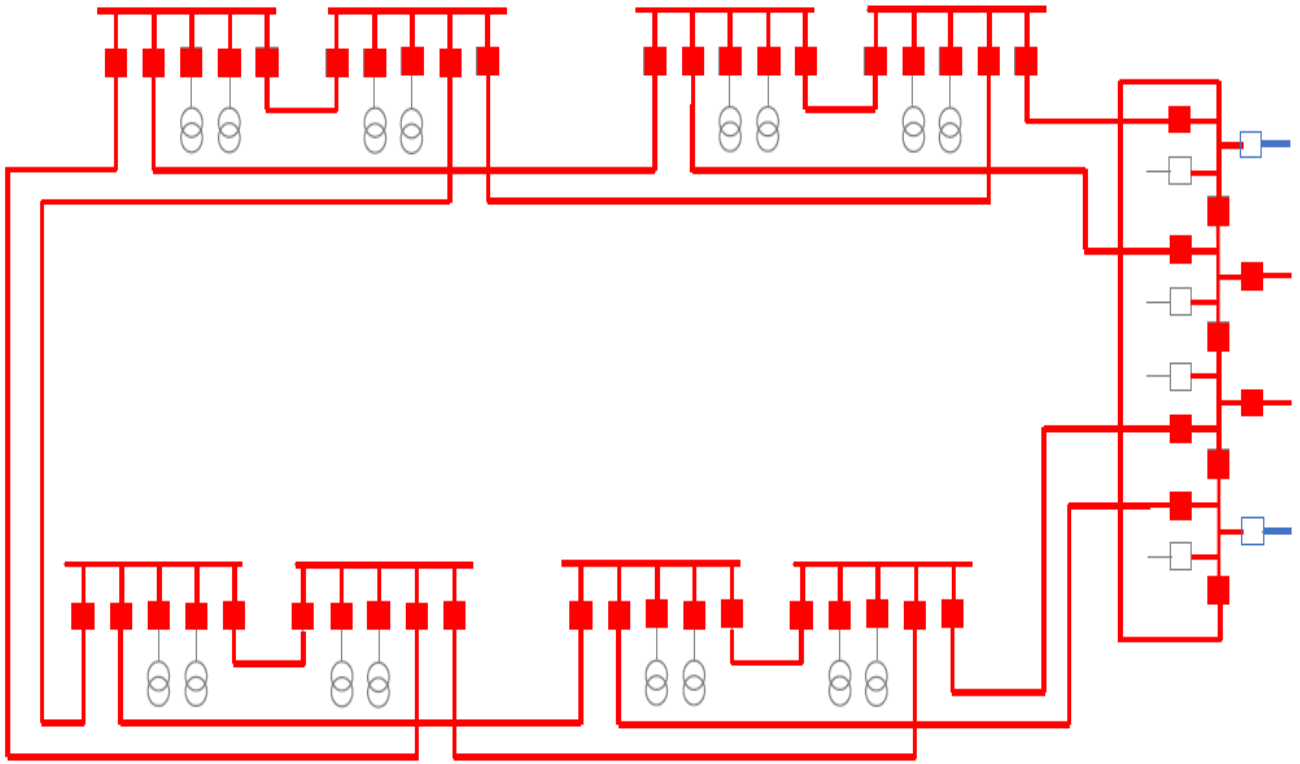
SYSTEM TOPOLOGY PROPOSED

3. Close Loop



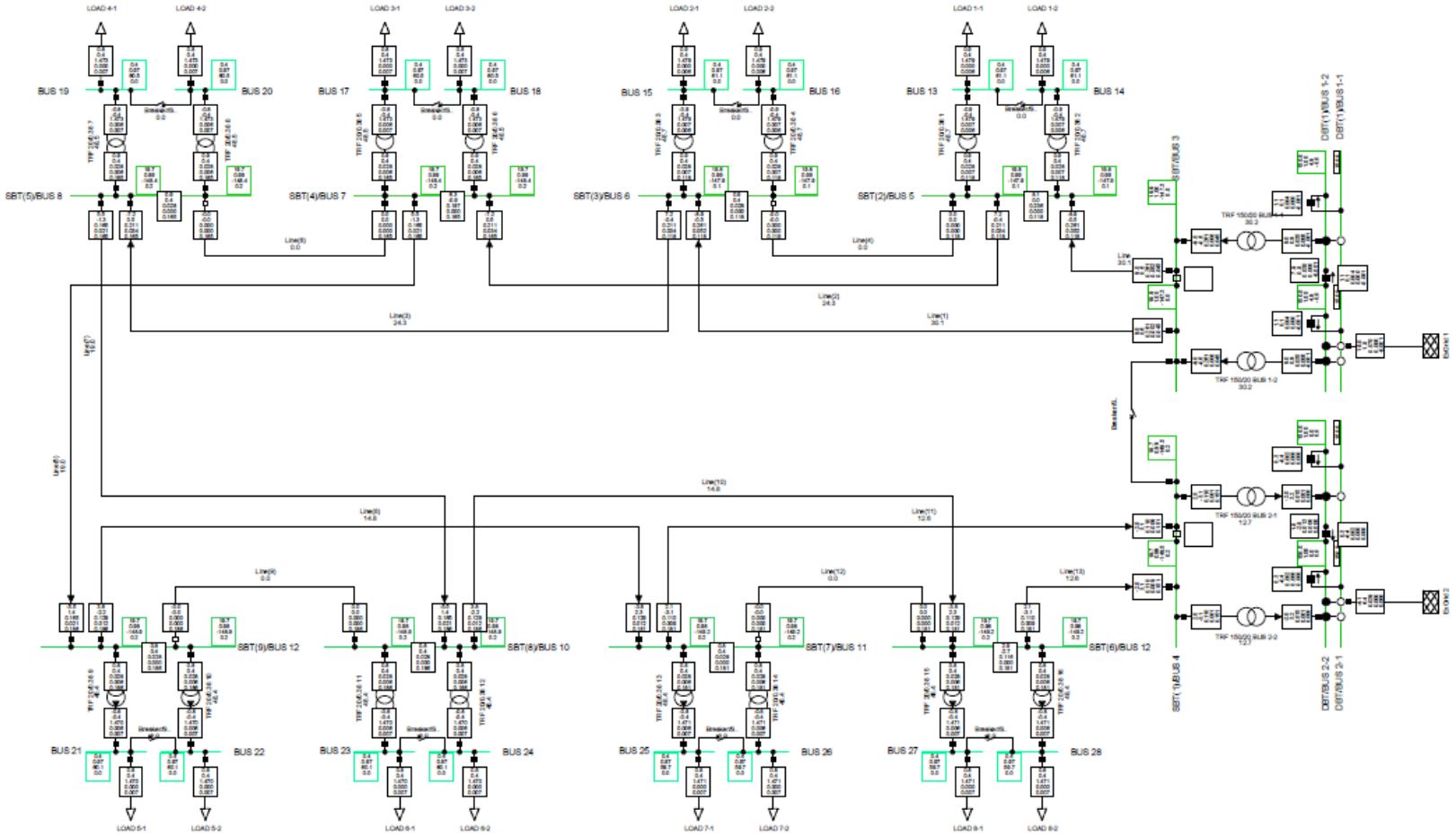
SYSTEM TOPOLOGY PROPOSED

4. Grid

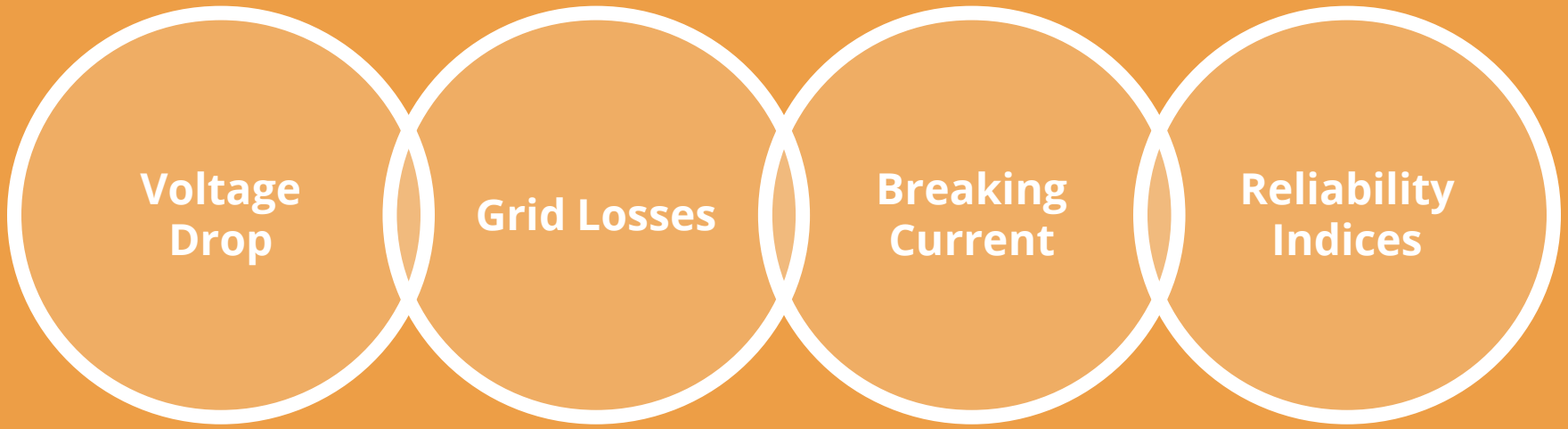


SINGLE LINE DIAGRAM

ex: Open Loop



PARAMETERS TO BE REVIEWED



Load Flow Analysis: Voltage Drop

Name	Nominal Voltage	Maximum Voltage Drop Along Feeder			
	kV	Open Loop (%)	Fork (%)	Close Loop (%)	Grid (%)
BB2	20	0.779033	1.568308	0.389228	0.806225
BB2	20	0.779033	0	1.311215	0.806225
BB2	20	1.212542	3.694545	1.021406	1.239634
BB2	20	1.212542	2.422584	1.021406	1.239634
BB2	20	1.428811	3.483344	1.426453	1.455854
BB2	20	1.428811	3.059989	1.426453	1.455854
BB2	20	1.212542	3.694545	1.569037	1.239634
BB2	20	1.212542	2.422584	1.569037	1.239634
BB2	20	1.428811	3.483344	1.608067	1.455854
BB2.1	150	0	0	0	0
BB2.1	150	0	0	-0.000656	-0.000060
BB2.2	150	0	0	0	0
BB2.2	150	0	0	-0.000656	-0.000060
BUS 1-1	150	0	0	-0.000656	-0.000602
BUS 1-2	150	0	0	-0.000656	-0.000060
BUS 10	20	1.428811	3.483344	1.608067	1.455854
BUS 11	20	1.212542	2.422584	1.569037	1.239634
BUS 12	20	1.212542	3.694545	1.569037	1.239634
BUS 12	20	1.428811	3.059989	1.608067	1.455854
BUS 12-1	20	1.428811	3.059989	1.608067	1.455854
BUS 13	0.38	2.847399	5.287394	2.659542	2.874132
BUS 14	0.38	2.847399	5.287394	2.659542	2.874132
BUS 15	0.38	2.847399	4.036938	2.659542	2.874132
BUS 16	0.38	2.847399	4.036938	2.659542	2.874132
BUS 17	0.38	3.060055	5.079772	3.057834	3.08675
BUS 18	0.38	3.060055	5.079772	3.057834	3.08675
BUS 19	0.38	3.060055	4.663582	3.057834	3.08675
BUS 2-1	150	0	0	0	0
BUS 2-2	150	0	0	0	0
BUS 20	0.38	3.060055	4.663582	3.057834	3.08675
BUS 21	0.38	3.060055	4.663582	3.236418	3.08675
BUS 22	0.38	3.060055	4.663582	3.236418	3.08675
BUS 23	0.38	3.060055	5.079772	3.236418	3.08675
BUS 24	0.38	3.060055	5.079772	3.236418	3.08675
BUS 25	0.38	2.847399	4.036938	3.19804	2.874132
BUS 26	0.38	2.847399	4.036938	3.19804	2.874132
BUS 27	0.38	2.847399	5.287394	3.19804	2.874132
BUS 28	0.38	2.847399	5.287394	3.19804	2.874132
BUS 3	20	0.779033	0	0.389228	0.806225
BUS 4	20	0.779033	1.568308	1.311215	0.806225
BUS 5	20	1.212542	3.694545	1.021406	1.239634
BUS 6	20	1.212542	2.422584	1.021406	1.239634
BUS 7	20	1.428811	3.483344	1.426453	1.455854
BUS 8	20	1.428811	3.059989	1.426453	1.455854

Load Flow Analysis: Grid Losses

Name	Losses (total)			
	Open Loop (MW)	Fork (MW)	Close Loop (MW)	Grid (MW)
Line	0.00949207	0	0.05154282	0.00948721
Line(1)	0.00949207	0.0365471	0.05154282	0.00948721
Line(10)	0.0023678	0.00225901	0.01248868	0.00236659
Line(11)	0.00949207	0.0365471	0.00909116	0.00948721
Line (12)	0	0	0	0
Line (13)	0.00949207	0	0.00909116	0.00948721
Line (2)	0.0023678	0.00225901	0.03365071	0.00236659
Line (3)	0.0023678	0.02045177	0.03365071	0.00236659
Line (4)	0	0	0	0
Line (5)	0	0.00905613	0.02066104	0
Line (6)	0	0	0	0
Line (7)	0	0.00905613	0.02066104	0
Line (8)	0.0023678	0.02045177	0.01248868	0.00236659
Line (9)	0	0	0	0
Grid Losses	0.16	0.25	0.38	0.17

Short Circuit Analysis: Breaking Current

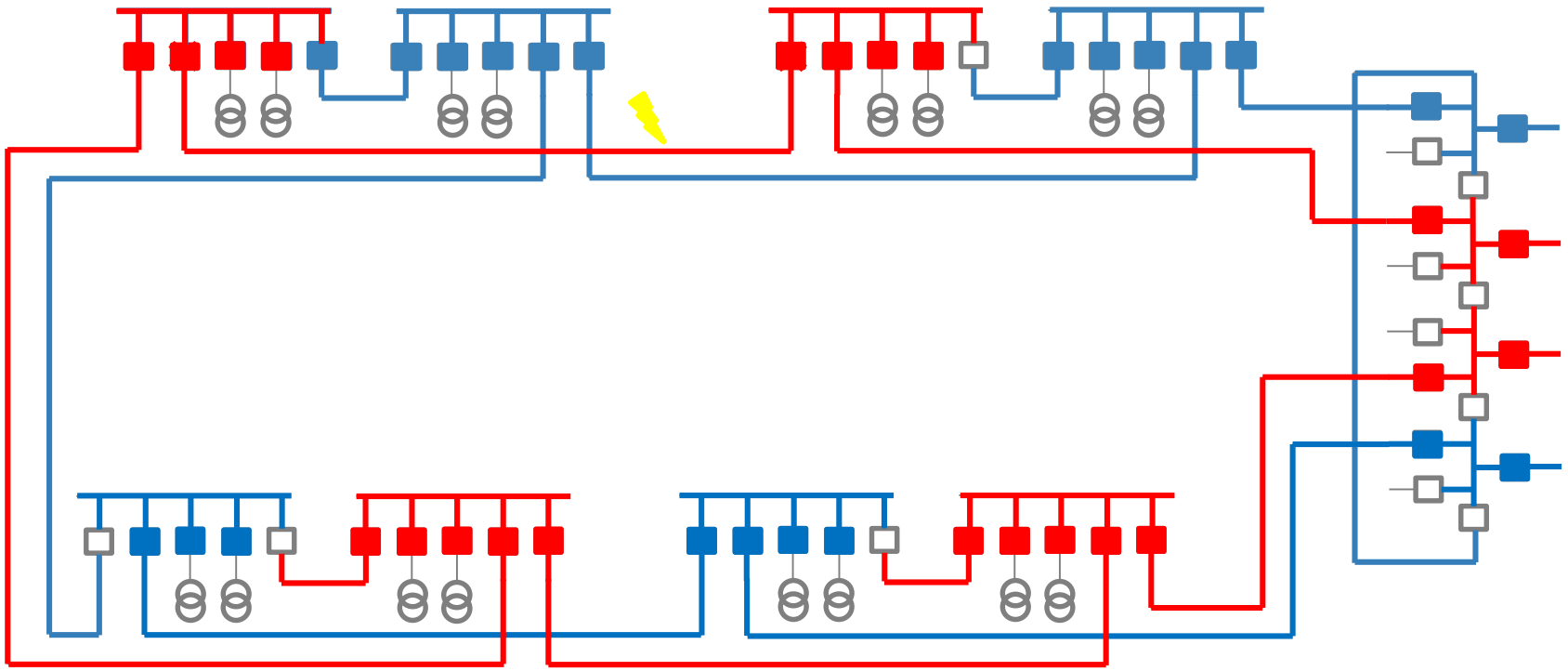
Name	Breaking Current (kA)			
	Open Loop	Fork	Close Loop	Grid
BB2	7.632987	7.632987	10.49606	29.74756
BB2	7.632987	7.632987	10.49606	29.74756
BB2	5.846659	3.370148	9.193918	18.06032
BB2	5.846659	5.846659	9.193918	18.06032
BB2	4.708947	3.931578	8.638289	18.06032
BB2	4.708947	4.708947	8.638289	18.06032
BB2	5.846659	3.370148	9.193918	15.58319
BB2	5.846659	5.846659	9.193918	15.58319
BB2	4.708947	3.931578	8.638289	15.58319
BB2.1	38.49002	38.49002	39.0569	39.50493
BB2.1	38.49002	38.49002	39.0569	39.50493
BB2.2	38.49002	38.49002	39.0569	39.50493
BB2.2	38.49002	38.49002	39.0569	39.50493
BUS 1-1	38.49002	38.49002	39.0569	39.50493
BUS 1-2	38.49002	38.49002	39.0569	39.50493
BUS 10	4.708947	3.931578	8.638289	15.58319
BUS 11	5.846659	5.846659	9.193918	18.06032
BUS 12	5.846659	3.370148	9.193918	18.06032
BUS 12	4.708947	4.708947	8.638289	15.58319
BUS 12-1	4.708947	4.708947	8.638289	15.58319
BUS 13	53.85196	47.39412	57.63398	61.37555
BUS 14	53.85196	47.39412	57.63398	61.37555
BUS 15	53.85196	53.85196	57.63398	61.37555
BUS 16	53.85196	53.85196	57.63398	61.37555
BUS 17	51.5167	49.37135	57.15984	60.71571
BUS 18	51.5167	49.37135	57.15984	60.71571
BUS 19	51.5167	51.5167	57.15984	60.71571
BUS 2-1	38.49002	38.49002	39.0569	39.50493
BUS 2-2	38.49002	38.49002	39.0569	39.50493
BUS 20	51.5167	51.5167	57.15984	60.71571
BUS 21	51.5167	51.5167	57.15984	60.71571
BUS 22	51.5167	51.5167	57.15984	60.71571
BUS 23	51.5167	49.37135	57.15984	60.71571
BUS 24	51.5167	49.37135	57.15984	60.71571
BUS 25	53.85196	53.85196	57.63398	61.37555
BUS 26	53.85196	53.85196	57.63398	61.37555
BUS 27	53.85196	47.39412	57.63398	61.37555
BUS 28	53.85196	47.39412	57.63398	61.37555
BUS 3	7.632987	7.632987	10.49606	29.74756
BUS 4	7.632987	7.632987	10.49606	29.74756
BUS 5	5.846659	3.370148	9.193918	18.06032
BUS 6	5.846659	5.846659	9.193918	18.06032
BUS 7	4.708947	3.931578	8.638289	15.58319
BUS 8	4.708947	4.708947	8.638289	15.58319

Reliability Assessment

Configuration	SAIDI (h/Ca)	SAIFI (1/Ca)
Open Loop	4.396	0.03365
Fork	4.401	0.042363
Close Loop	8.762	0.006913
Grid	8.76	0.002575

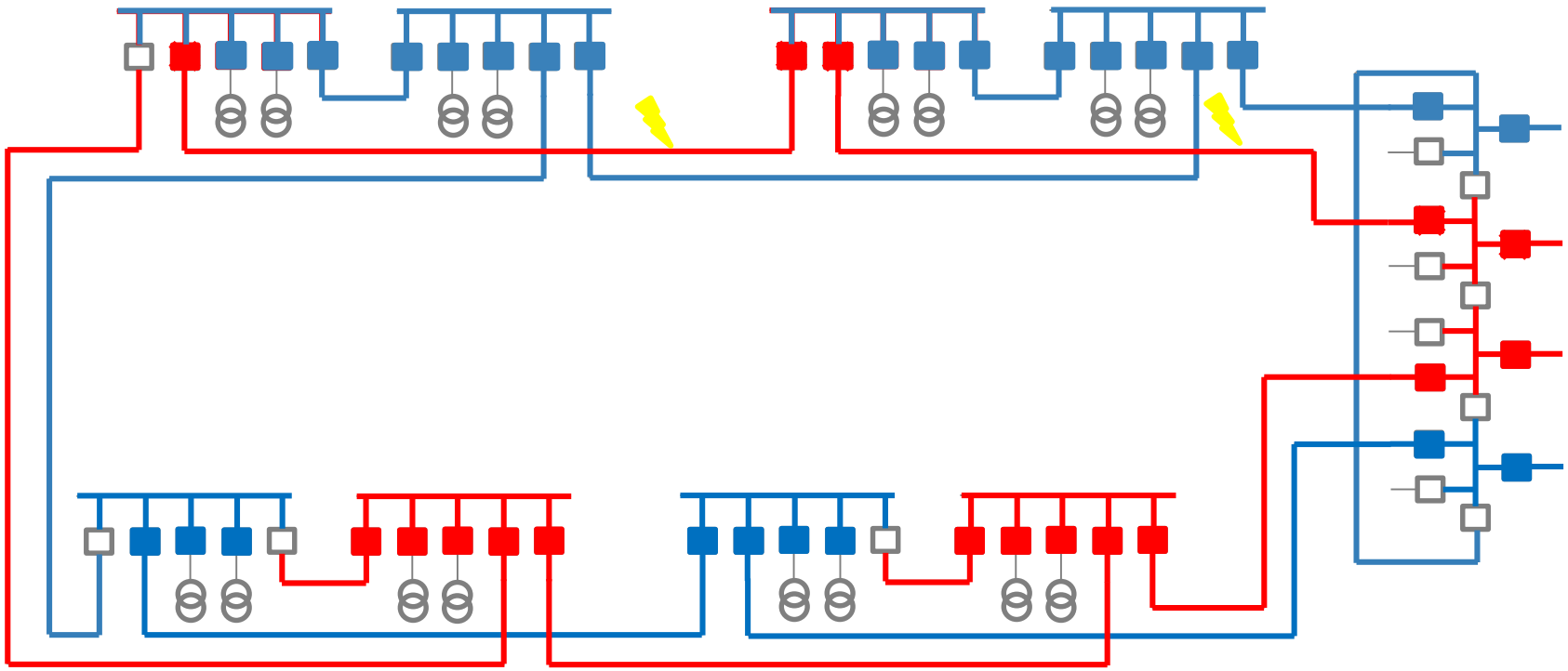
Reliability Animation: Example 1

Open Loop N-1 Criterion

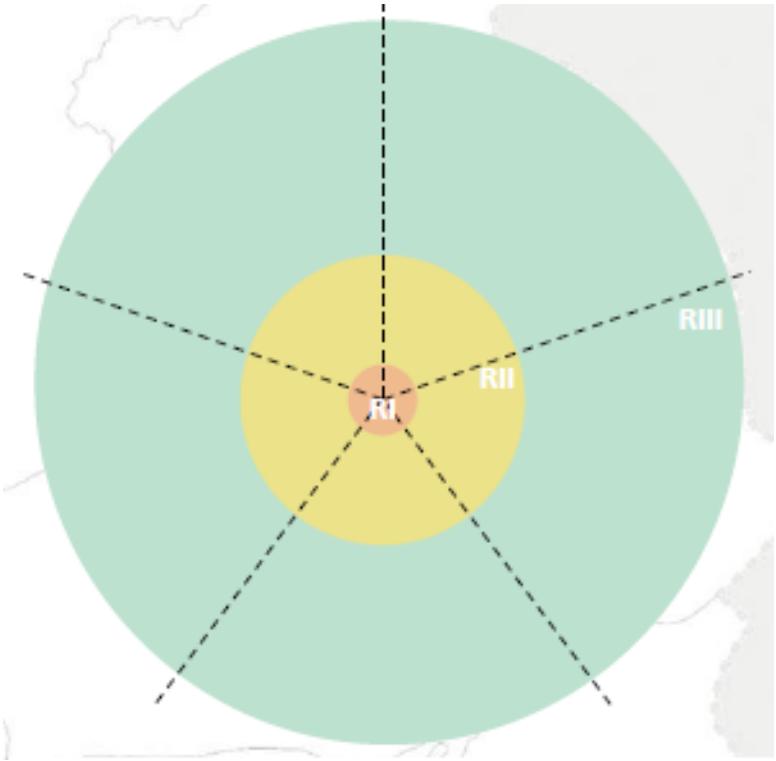


Reliability Animation: Example 2

Open Loop N-2 Criterion



NEW CAPITAL PLANNING CONCEPT



RI:
Kawasan Inti Pusat Pemerintahan (K-IPP), radius ±2,53 km, total area 2.000 Ha;

RII:
Kawasan Ibu Kota Negara (K-IKN), radius ±11,57 km, total area ±40.000 Ha;

RIII:
Kawasan Perluasan Ibu Kota Negara (KP-IKN), radius ±26,58 km, total area ±180.000 Ha.

Power Demand Calculation

$$Pspec = Pmin + (Pmax - Pmin) \cdot ktot$$

where

$$ktot = \frac{(kplc + kstruct + kcomf + kclim + ktech + kBA/TBM}{6}$$

with:

- simultaneity factor: 0.6
- coincidence factor: 0.5

Power Demand Estimation: Ring 1

Bangunan	Bangunan (ha)	Lahan (ha)	Total (ha)	Average Power Demand (W/m2)	Pmin (MW)	Pmax (MW)	Simultaneity factor	kplc	kstruct	kcomf	kclim	ktech	kBA/TM	ktot	Ptot (MW)
Bangunan Gedung Negara	428	213.8	641.8	30 - 50	214	356.6666667	0.6	0.5	0.6	0.7	0.7	0	0	0.4167	273.444444
Perumahan	146.5	114	260.5	10 - 30	36.625	109.875	0.4	0.5	0.1	0.5	0.5	0.29	0.29	0.36333	63.2391667
Prasarana dan Sarana Lingkungan Permukiman di Perkotaan	37.6	37.3	74.9	20 -120	12.5333333	75.2	0.6	0.5	0.6	0.7	0.7	0.22	0.22	0.49	43.24
Fasilitas Kebudayaan	6	3	9	30 - 50	3	5	0.6	0.5	0.4	0.5	0.5	0.33	0.33	0.42667	3.85333333
Fasilitas Pendidikan															
Fasilitas Hubungan Diplomatik															
Fasilitas Pusat Keagamaan	27.6	13.8	41.4	30 - 50	13.8	23	0.6	0.5	0.4	0.5	0.5	0.33	0.33	0.42667	17.7253333
Fasilitas Olahraga dan Rekreasi	30	15	45	70 - 140	35	70	0.6	0.5	0.6	0.6	0.6	0.33	0.33	0.49333	52.2666667
Ruang Terbuka Hijau dan Non-Hijau		900	900												
Infrastruktur Permukiman, Sumber Daya Air, Jalan, Jembatan, dan Transportasi		300	300												
														Total	453.768944

coincidence factor: 0.5

Total Power Demand

$$0.5 \times 463.768944 = 231.8844\ MW$$

Power Demand Estimation: Ring 2

Bangunan	Bangunan	Lahan	Total	Average Power Demand (W/m2)	Pmin (MW)	Pmax (MW)	nultaneity fac	kplc	kstruct	kcomf	kclim	ktech	kBA/TM	ktot	Ptot (MW)
Bangunan Gedung Negara															
Perumahan	1590.9	962.5	2553.4	10 - 30	397.725	1193.175	0.4	0.5	0.1	0.5	0.5	0.29	0.29	0.36333	686.7385
Prasarana dan Sarana Lingkungan Permukiman di Perkotaan	710.8	705.3	1416.1	20 - 120	236.933333	1421.6	0.6	0.5	0.6	0.7	0.7	0.22	0.22	0.49	817.42
Fasilitas Kebudayaan															
Fasilitas Pendidikan	140	70	210	10 - 30	23.3333333	70	0.6	0.5	0.4	0.5	0.5	0.33	0.33	0.42667	43.2444444
Fasilitas Hubungan Diplomatik	87	42.5	129.5	30 -50	43.5	72.5	0.6	0.5	0.4	0.6	0.6	0.33	0.33	0.46	56.84
Fasilitas Pusat Keagamaan															
Fasilitas Olahraga dan Rekreasi	323.5	161.8	485.3	30 - 60	161.75	323.5	0.6	0.5	0.6	0.6	0.6	0.33	0.33	0.49333	241.546667
Ruang Terbuka Hijau dan Non-Hijau		2700	2700												
Infrastruktur Permukiman, Sumber Daya Air, Jalan, Jembatan, dan Transportasi		6000	6000												
														Total	1845.78961

coincidence factor: 0.5

Total Power Demand

$$0.5 \times 1845.78961 = 922.894805\ MW$$

Power Demand Estimation: Ring 3

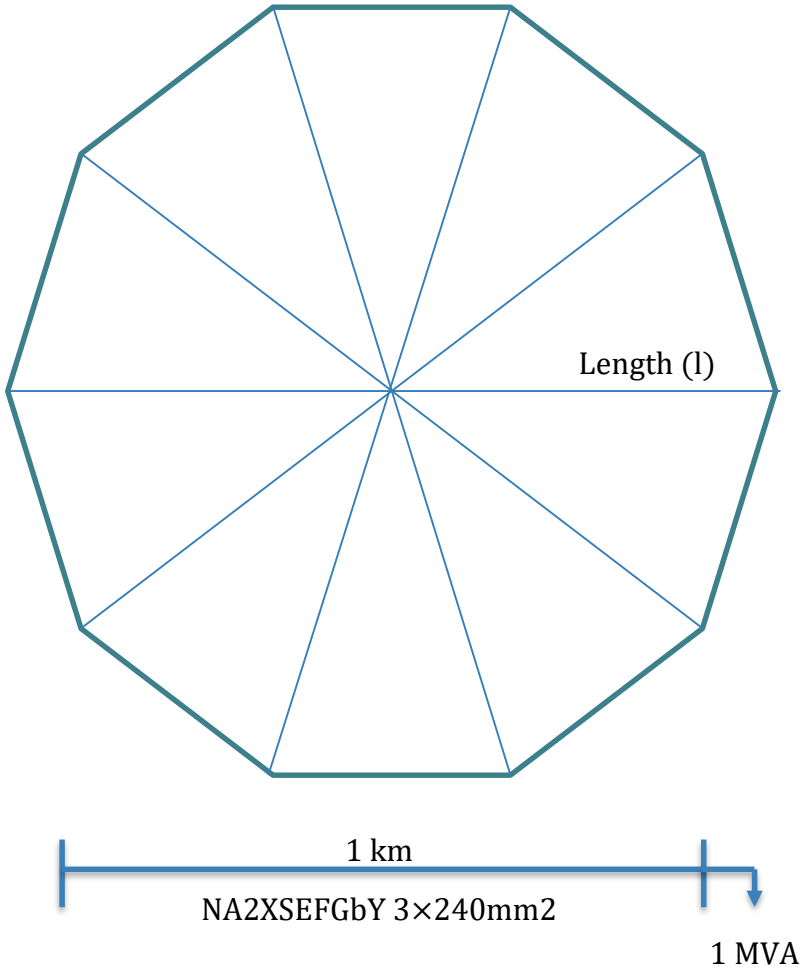
Bangunan	Bangunan	Lahan	Total	Average Power Demand (W/m2)	Pmin (MW)	Pmax (MW)	nultaneity fac	kplc	kstruct	kcomf	kclim	ktech	kBA/TM	ktot	Ptot (MW)
Bangunan Gedung Negara															
Perumahan															
Prasarana dan Sarana Lingkungan Permukiman di Perkotaan	879.5	872.9	1752.4	40 - 70	586.333333	1026.083333	0.6	0.5	0.6	0.7	0.7	0.22	0.22	0.49	801.810833
Fasilitas Kebudayaan															
Fasilitas Pendidikan															
Fasilitas Hubungan Diplomatik															
Fasilitas Pusat Keagamaan															
Fasilitas Olahraga dan Rekreasi															
Ruang Terbuka Hijau dan Non-Hijau		89240	89240												
Infrastruktur Permukiman, Sumber Daya Air, Jalan, Jembatan, dan Transportasi															
														Total	801.810833

coincidence factor: 0.5

Total Power Demand

$$0.5 \times 801.810833 = 400.9054165\ MW$$

Number of Substation Calculation: 150/20 kV



$k = 0.03523\ \%/\ 1MVA, 1m$

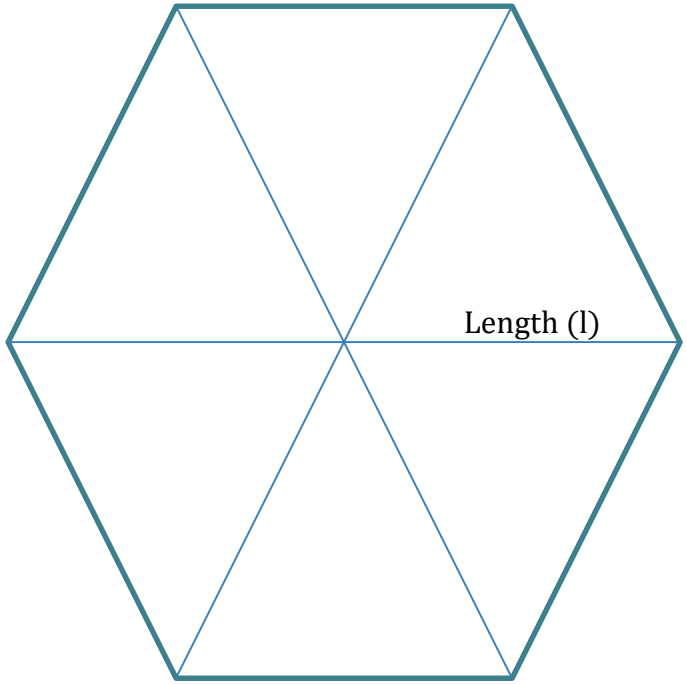
$$\boldsymbol{Area\ per\ feeder} = \frac{1}{2} \times l^2 \times \sin\frac{360}{10} = 0.293893\ l^2\ (\text{km2})$$

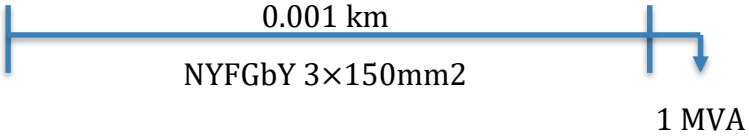
$$\boldsymbol{Area\ per\ substation} = 6 \times 0.4330127\ l^2 = 2.93893\ l^2\ (\text{km2})$$

$$\boldsymbol{S\ per\ feeder} = 6 \times 0.4330127\ l^2 = 0.293893\ l^2\ (\text{MVA})$$

$$\boldsymbol{Total\ Substation} = \frac{Total\ Area}{Area\ per\ substation}$$

Number of Substation Calculation: 20/0.38 kV





k = 0.1157105 %/ 1MVA, 1m

$$\boldsymbol{Area\ per\ feeder} = \frac{1}{2} \times l^2 \times \sin\frac{360}{6} = 0.4330127\ l^2\ (\text{km2})$$

$$\boldsymbol{Area\ per\ substation} = 6 \times 0.4330127\ l^2 = 2.598076211\ l^2\ (\text{km2})$$

$$\boldsymbol{S\ per\ feeder} = 6 \times 0.4330127\ l^2 = 2.598076211\ l^2\ (\text{MVA})$$

$$\boldsymbol{Total\ Substation} = \frac{Total\ Area}{Area\ per\ substation}$$

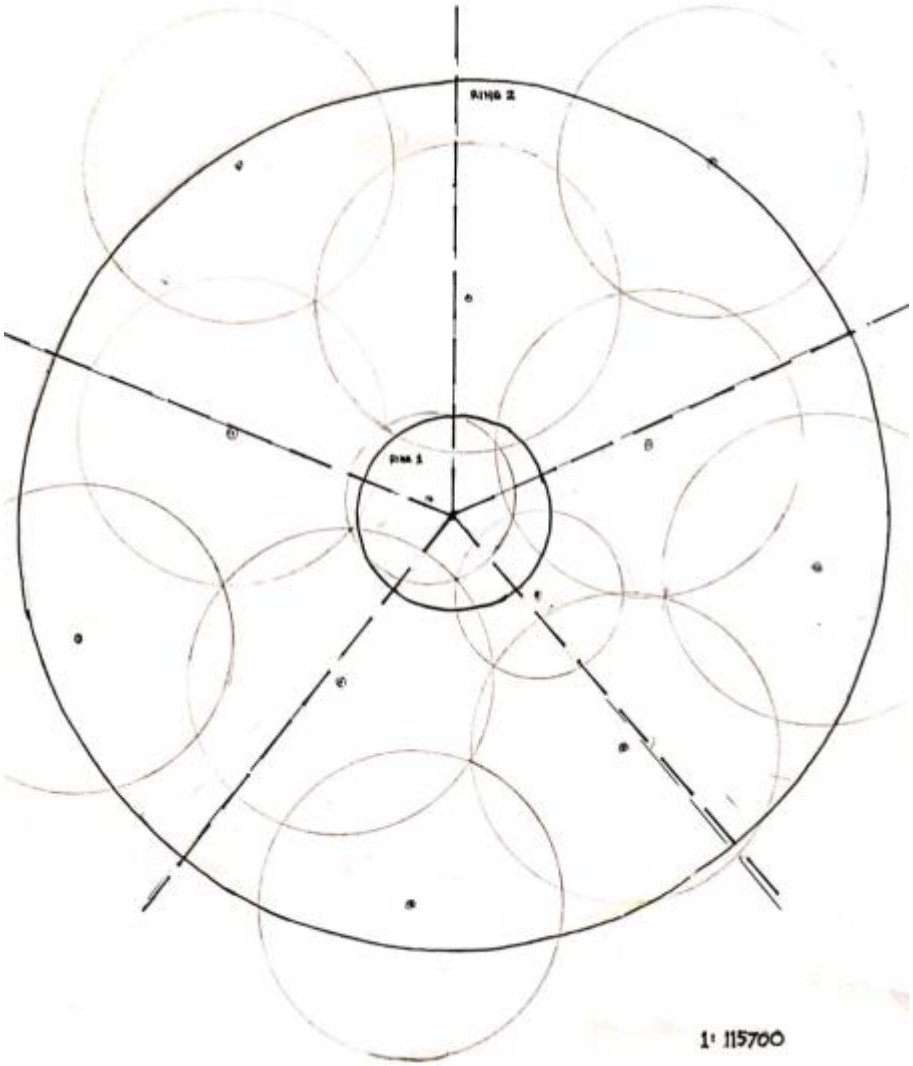
Substation 150/20kV

RING 1					
drop 1%					
Panjang feeder	2.22438304	km			
Jumlah GI	1.382873718	gardu		2	gardu
Kapasitas trafo	182.2970924	MVA	→	113.4422361	MVA
RING 2					
drop 1.5%					
Panjang feeder	4.323542036	km			
Jumlah GI	7.289014297	gardu		8	gardu
Kapasitas trafo	140.6827633	MVA	→	115.3618507	MVA
RING 3					
drop 2.5%					
Panjang feeder	11.16833911	km			
Jumlah GI	4.907481614	gardu		5	gardu
Kapasitas trafo	90.76966517	MVA	→	80.18108333	MVA

Substation 20/0.38kV

RING 1					
drop 5%					
Panjang feeder	224.8756354	m			
Jumlah GI	153.0573613	gardu		154	gardu
Kapasitas trafo	1.64705477	MVA	→	1.473275794	MVA
RING 2					
drop 5%					
Panjang feeder	381.8347305	m			
Jumlah GI	1057.145277	gardu		1058	gardu
Kapasitas trafo	0.970007331	MVA	→	0.872301328	MVA
RING 3					
drop 5%					
Panjang feeder	831.9069468	m			
Jumlah GI	1000.515265	gardu		1001	gardu
Kapasitas trafo	0.445221054	MVA	→	0.400504912	MVA

Location of Substation 150/20kV: Ring 1 & 2



5. CONCLUSION

Open Loop

is the BEST.

Total substations needed:

15 for **150/20 kV**

2213 for **20/0.38 kV**


THANK
YOU