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Design of Functional Electrical Power Transmission and Networking

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Abstract
The paper consists of designing a network system followed by a technical and economical based solution, which will be characterized by minimal distribution costs fulfilling technical required standards on reliability of the network and the quality of energy distributed. The system is at 110 kV and the loads are at 10kV and the other details like minimum distance, total MVA rating, types of conductors, networking and how to reduce losses etc. are given in detail.
Keywords: Optimal design, Minimal cost, PSAT, Total MVA, Per-unit, MATLAB Simulink

1 Introduction

Nowadays, designing and transmitting an electric power in an optimal way is a mandatory task. So that the power losses will be highly reduced and access of an electricity to all areas will be increased. Hence to design an optimal way of power transmission and configuration, the following requirements are considered in detail.

- Proposing a graph layout by interconnecting the various loads and system with possible grid lines; considering the distance to be covered.
- Determining the cross sectional areas of the conductors;
- Selecting suitable transformers for the loads;
- Determining the losses in the lines and the voltages at the nodes using the load analysis MAT LAB program;
- Showing the detailed layout of the selected network including the conductors, bus bars, isolators, surge diverters and circuit breakers.

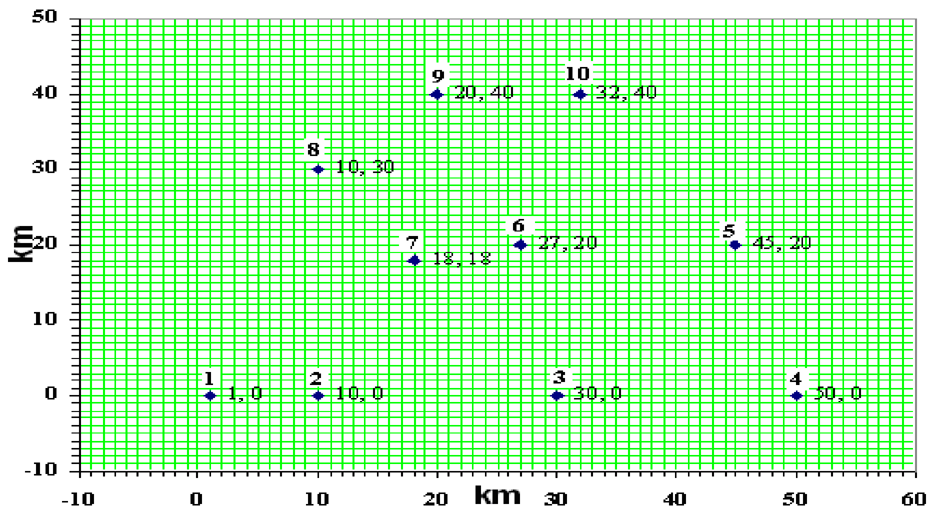

Figure 1: Assumed possible locations for the substations and the generation

Table 1: Power consumption in the Substation (in Megawatts)

Substations	1	**2**	**3**	**4**	**5**	**6**	**7**	8	9	10
Loads, MW	5	**10**	**15**	**25**	**20**	**30**	**35**	15	25	40
Power factor	0.7	**0.65**	**0.8**	**0.9**	**0.6**	**0.8**	**0.75**	0.7	0.7	0.85

NB: The bold substations are considered in this paper with substation 7 as a generation (see table 2 below)

Table 2: Probable supply points

1	2	3	4	5	6	7	8	9	10
-	X	X	X	X	X	G[1]	-	-	-

[1] Substation 7 is both Generation location and it has also loads to consume

Here are some of the possible connections between substations including the generation location.

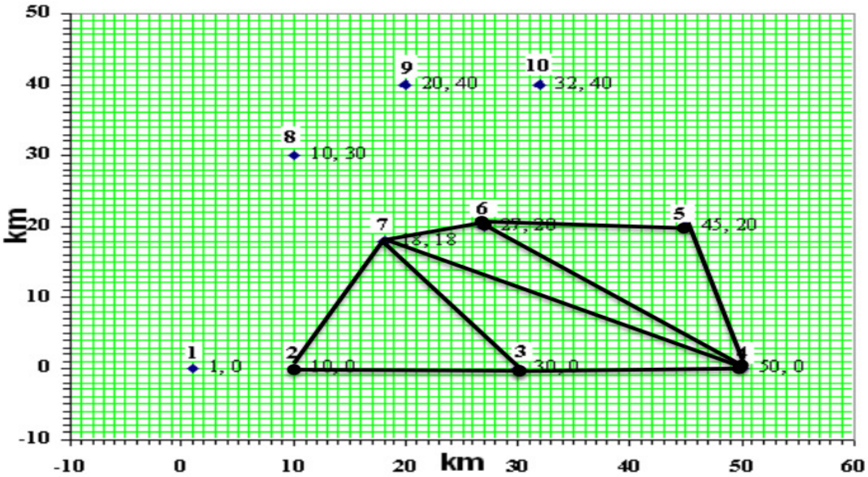

Figure 2: Possible connections between all substations

2 Distances Calculation

Firstly, we have to calculate the shortest distance (path) between each substation so that we can evaluate the economical path for supplying loads. We used figure 1 and figure 2 to compute the distances with the help of distance formula (KREYSZIG, 2011). For a given two coordinate points say (x_1, y_1) and (x_2, y_2) are given points then the distance these coordinate points is given by:

$$D_{12} = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$$

For instance, the distance between point (substation) 7 with coordinate point of (18, 18) and point (substation) 4 with coordinate points of (50, 0) is given by:

$$D_{74} = \sqrt{(18 - 50)^2 + (18 - 0)^2} = \sqrt{1348} = 36.715$$

Hence the distance between substation 7 and 4 is D_{74}=36.715km

Calculating similarly the distance between the other substations is give as follows

$D_{72} = 19.698km$	$D_{73} = 21.633km$	$D_{74} = 36.715km$
$D_{76} = 09.220km$	$D_{23} = 20.000km$	$D_{34} = 20.000km$
$D_{45} = 20.616km$	$D_{65} = 18.000km$	$D_{64} = 30.480km$

3 Selecting the Possible Network

As we can see from figure 2 above there are a lot of possible paths between substation to propose electrical power transmission and networking. But, when we design we must consider the following main criteria to select as which path is to follow which satisfies the given criteria (Sadaat, 1994) (Kothari, 1989).

- Minimal distribution costs fulfilling technical required standards on reliability of the network
- Quality of the energy distributed

Hence based on the criteria the following different cases are considered as initial alternatives.

3.1 Case I

Connecting the network radially in a way that; starting from bus 7(generation or PV bus) to bus 6-bus 5-bus 4-bus 3 and ends with bus 2. Thus the total distance covered in the network connection is $9.22 + 18 + 20.616 + 20 + 20 = 87.836km$. Since it covers small distance compared with other cases to be discussed below it may reduce the transmission line cost, voltage drops and hence power losses. But it is less reliable regarding if one of the line is faulted from the generation side the next substation will not get power totally and hence the quality of energy distribution will be affected more.

3.2 Case II

Connecting bus 7(generator/PV) to bus 3-bus 4-bus 5-bus 6-bus 7-bus 2. The total distance covered in this case is $21.633 + 20 + 20.616 + 18 + 9.220 + 19.698 = 109.167km$. Regarding the reliability this case is better than the case 1, but its transmission distance is longer than the case I. Thus, the transmission line cost, voltage drop and power loss is higher due to maximum length. On top of it, if the line between bus 7 and bus 2 is faulted, the load connected with bus two might not have power at all. In which this reduces the efficiency and power distribution quality.

3.3 Case III

Connecting bus 7(generator/PV) to bus 4-bus 5-bus 6-bus 7-bus 2-bus 3-bus 4. The total distance covered in this case is $36.715 + 20.616 + 18 + 9.220 + 19.698 + 20 + 20 = 144.249km$. Regarding the reliability this case is the best because when a line fault occurs, it has three possible paths for any substation, but its transmission distance is very long. Thus, the transmission line cost, voltage drop and power loss is higher due to maximum length. Hence let's see another case that is case IV for more possible option.

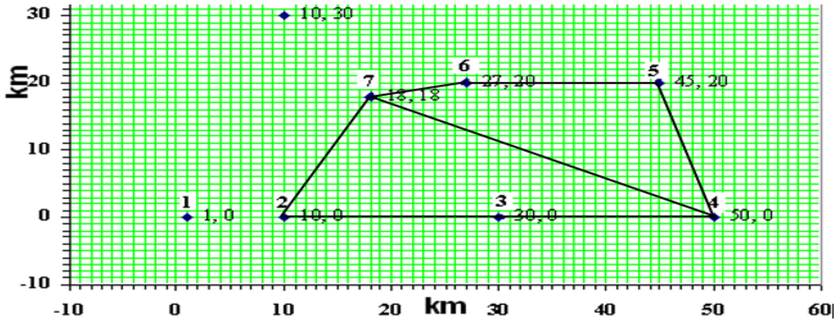

Figure 3: A possible network configuration with more reliability

3.4 Case IV

Connecting bus 7 to bus 6 -bus 5 –bus 4- bus 3-bus 2- and back to bus 7. The total distance of this option is $9.220 + 18 + 20.616 + 20 + 20 + 19.698 = 107.564km$ this option is more reliable than the first two cases and even its distance is shorter than the third and the second cases. Thus, the quality of energy distribution is more reliable that is, it has two possible paths in case any fault occurs in any path of the system. This system is also known as ring system and it is a common practice in many electrical power distribution company (Sadaat, 1994). Therefore, considering those advantages and common engineering practices I used this kind of distribution system as given in figure 4 below. Hence the networking path will follow the pattern of buses as **bus 7-6-5-4-3-2-7.**

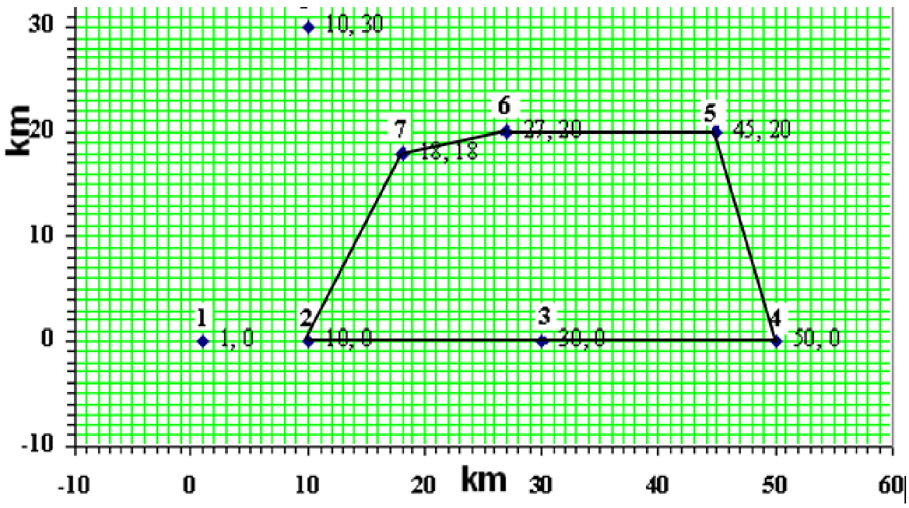

Figure 4: The selected network for power distribution with generation at bus-7 and a load on all substations

4 Total MVA of the Generator

The total MVA of generator is given the summation of total load per power factor. According to energy conservation the summation of total power entering into the node is equal to the power leaving the node. Thus assuming lossless transmission line and the values given in Table 1.

$$S_g = \sum_{i=2}^{7} \frac{P_{Li}}{pf_i} = \frac{P_{L2}}{pf_2} + \frac{P_{L3}}{pf_3} + \frac{P_{L4}}{pf_4} + \frac{P_{L5}}{pf_5} + \frac{P_{L6}}{pf_6} + \frac{P_{L7}}{pf_7}$$

$$= \frac{10}{0.65} + \frac{15}{0.8} + \frac{25}{0.9} + \frac{20}{0.6} + \frac{30}{0.8} + \frac{35}{0.75} = 179.412MVA$$

Then to find out the circuit breaker rating for main entrance; for three phase system;

$$I_b = \frac{S_g}{\sqrt{3}V_{L-L}} = \frac{179.412MVA}{\sqrt{3} * 110kv} = 941.669\text{A}$$

Then from the standard table the current carrying capacity of CB is greater than or equal to I_b and maximum short circuit carrying capacity of generator for standard generator reactance 20% [IEC] is given by

$$I_{sh} = \frac{I}{Z} = \frac{941.669}{0.2} = 4708.345A$$

5 MVA Ratings of Load Transformers

For the six different loads (in all substations) we can follow the same principle and their MVA, circuit protective ratings and conductor area will be given as follows;

$$S_{L2=\frac{10MVA}{0.65}=15.385MVA} \quad S_{L3=\frac{15MVA}{0.8}=18.75MVA} \quad S_{L4=\frac{25MVA}{0.9}=27.778MVA}$$

$$S_{L5=\frac{20MVA}{0.6}=33.333MVA} \quad S_{L6=\frac{30MVA}{0.8}=37.5MVA} \quad S_{L7=\frac{35MVA}{0.75}=46.667MVA}$$

But from standard table the appropriate MVA and reactance of transformers considering calculated values and the standard MVA rating given in Table 12 (in appendix) is given below.

Table 3: Standard transformer MVA and its impedance

Bus no	Calculated transformer MVA	Standard MVA of transformer	Transformer impedance	
			resistance, r	Reactance, x
2	15.385	16	4.38	86.7
3	18.75	25	2.54	55.9
4	27.778	40	1.46	38.4
5	33.333	40	1.46	38.4
6	37.5	40	1.46	38.4
7	46.667	63	0.87	22

6 Transmission Line Parameters

Since all of the line lengths are less than 100km and its KV is 110kv, we are going to use data provided by Table 11[in appendix]. We chose the biggest nominal cross-sectional area in mm^2 (240/32) because as discussed previously, we adopted a nominal current equals to 505A. Since those parameters are given for 100km, we adapted them according to the distances of the line considering that both resistance and reactance are directly proportional to the distance but admittance is inversely proportional to the line distance. For example, for line parameters between substations 5 and 4, the parameters will be calculated as follows:

$$R_{54}(20.616km) = \frac{12\Omega}{100km}x20.616km = 2.474\Omega$$

$$X_{54}(20.616km) = \frac{40.5\Omega}{100km}x20.616km = 8.350\Omega$$

$$Y_{54}(20.616km) = \frac{2.81x10^{-4}\Omega}{20.616km}x100km = 1.363x10^{-3}\text{S}$$

Hence based on this calculation the line parameters are given in the following table.

Table 4: Line Parameters

From line	To line	Distance(km)	R (Ω)	X_L(Ω)	Y (semen)
7	6	9.220	1.106	3.734	$3.048*10^{-3}$
6	5	18.000	2.160	7.290	$1.561*10^{-3}$
5	4	20.616	2.474	8.350	$1.363x10^{-3}$
4	3	20.000	2.400	8.100	$1.405*10^{-3}$
3	2	20.000	2.400	8.100	$1.405*10^{-3}$
2	7	19.698	2.364	7.978	$1.427*10^{-3}$

7 Per Unit Values of Each System.

Since most of the parameters are at different base value it is common practice to use per unit value so that to avoid the effect of transformation ratio on the efficiency of power network.

Let's choose the base values as follows;

- S_{base} = 179.412MVA, (the total MVA)
- V_{base} = 110kv for high voltage side and 10 kv for low voltage side.

Therefore, from the general formula the base impedance for high voltage side is calculated as;

$$Z^{PU}{}_{HV} = \frac{V^2{}_{B(L-L)}}{S_{base}} = \frac{(110kv)^2}{179.412MVA} = 67.443\Omega; \qquad Z^{PU}{}_{lv} = \frac{(10kv)^2}{179.412MVA} = 0.557\Omega$$

- For loads, the per unity value of power is calculated using the following formula

$$P_{Load(pu)} = \frac{P_{Load}}{S_{base}}$$

- For transmission lines and transformers, the per unity values of impedances are calculated using the following formula

$$Z_{pu} = \frac{Z_{actual}}{Z_{base(HV)}}$$

Table 5: Per Unite value of lines parameters, loads and transformers

Line from	Line to	R (pu)	X_l (pu)	Y(pu)	Bus no.	P_L(pu)	Q_L(pu)	Per unit value of Transformer	
								Resistance,r	Reactance,x
7	**6**	0.0164	0.0554	$45.194*10^{-6}$	**7**	0.1951	0.1721	0.0129	0.3262
6	**5**	0.0320	0.1081	$23.145*10^{-6}$	**6**	0.1672	0.1254	0.0216	0.5694
5	**4**	0.0367	0.1238	$20.201*10^{-6}$	**5**	0.1115	0.148632	0.0216	0.5694
4	**3**	0.0356	0.1201	$15.495*10^{-6}$	**4**	0.1393	0.0675	0.0216	0.5694
3	**2**	0.0356	0.1201	$15.495*10^{-6}$	**3**	0.0836	0.0627	0.0377	0.8288
2	**7**	0.0351	0.1183	$21.159*10^{-6}$	**2**	0.0557	0.0652	0.0650	1.2855

8 Nominal Circuit Breaker Ratings

Selecting the nominal circuit breaker ratings, size of conductor and area of conductor for generation, transmission and loads [IEC].

❖ **For generation of standard reactance = 20%**

The rated current, $I_r = \frac{S_g}{\sqrt{3}V_{L-L}} = \frac{179.412MVA}{\sqrt{3}*110kv} = 941.669\text{A}$

- The nominal circuit breaker current is found from Table 13: $I_n = 505A$
- The maximum rating current of conductor and its area without considering correction factors is: 505A and 240/32mm². This area applies for all high voltage side conductors.
- The **braking capacity** and **opening capacity** of circuit breaker is

$I_\infty = \frac{V}{\sqrt{3}*Z_{SH}} = \frac{110kv}{\sqrt{3}*0.2*\frac{V^2base}{S_{base}}} = \frac{110kv}{\sqrt{3}*0.2*\frac{110^2}{179.412}} = 4.708kA$ …. **braking capacity**

For standard multiplier of 2.5 its opening capacity is= $2.5x4.708kA = 11.771kA$

To find out the breaking and opening capacity of breakers the series, parallel and other connection of line parameters are considered.

❖ **For load at bus 7**

The total short circuit impedance up to the point is the summation of generator reactance plus transformer reactance;

$$Z_{CB_7} = Z_{SC_7} = X_G + X_{T_{Sh}} = (0.2 * 67.443\Omega) + (0.0129 + \text{j}0.3262) * 0.557 = 13.4958 + \text{j}0.1817 = 13.4970\Omega$$

- **Breaking current:** $\boldsymbol{I_\infty = \frac{V}{\sqrt{3}*Z_{SC}} = \frac{10kv}{\sqrt{3}*13.4970} = 0.4278kA}$
- **The circuit breaker opening capability=** $\boldsymbol{2.5 * I_\infty = 1.0695kA}$

❖ **For load at bus 6**

$$Z_{Sh6} = X_{Sh6} = Z_g + Z_{7-6} + Z_{TSh}$$

$$(0.2 * 67.443\Omega) + (1.016 + j3.734) + (0.0216 + \text{j}0.5694) * 0.557 = 14.5166 + \text{j}4.0512 = 15.0713$$

- **Breaking current:** $\boldsymbol{I_\infty = \frac{V}{\sqrt{3}*Z_{SC}} = \frac{10kv}{\sqrt{3}*15.0713} = 0.3831kA}$
- **The circuit breaker opening capability=** $\boldsymbol{2.5 * I_\infty = 0.9577kA}$

❖ **For load at bus 5**

The total short circuit impedance up to the point is the summation of generator reactance plus transformer reactance;

$$Z_{CB_5} = Z_{SC_5} = X_G + X_{T_{Sh}} = (0.2 * 67.443\Omega) + (0.0216 + \text{j}0.5694) * 0.557 = 13.5006 + \text{j}0.3172 = 13.5043\Omega$$

- **Breaking current:** $\boldsymbol{I_\infty = \frac{V}{\sqrt{3}*Z_{SC}} = \frac{10kv}{\sqrt{3}*13.5043} = 0.4275kA}$
- The circuit breaker opening capability= $2.5 * \text{I}_\infty = 1.0688\text{kA}$

❖ **For load at bus 2**

$$Z_{Sh6} = X_{Sh6} = Z_g + Z_{7-2} + Z_{TSh}$$

$$(0.2 * 67.443\Omega) + (2.364 + j7.978) + (0.0650 + \text{j}1.2855) * 0.557 = 15.889 + \text{j}8.694 = 18.112$$

- **Breaking current:** $\boldsymbol{I_\infty = \frac{V}{\sqrt{3}*Z_{SC}} = \frac{10kv}{\sqrt{3}*18.112} = 0.3188kA}$
- The circuit breaker opening capability $= 2.5 * \text{I}_\infty = 0.7969\text{kA}$

❖ **For load at bus 3**

The total short circuit impedance up to the point is the summation of generator reactance plus transformer reactance;

$$Z_{CB_5} = Z_{SC_5} = X_G + X_{T_{Sh}} = (0.2 * 67.443\Omega) + (0.0377 + j0.8288) * 0.557 = 13.5095 + j0.4616 = 13.5174\Omega$$

- **Breaking current:** $\boldsymbol{I_\infty} = \frac{\boldsymbol{V}}{\sqrt{3}*\boldsymbol{Z_{SC}}} = \frac{\boldsymbol{10kv}}{\sqrt{3}*13.5174} = \boldsymbol{0.4271kA}$
- The circuit breaker opening capability= $2.5 * I_\infty = 1.0678$kA

❖ **For load at bus 4**

The total short circuit impedance up to the point is the summation of generator reactance plus transformer reactance;

$$Z_{CB_5} = Z_{SC_5} = X_G + X_{T_{Sh}} = (0.2 * 67.443\Omega) + (0.0216 + j0.5694) * 0.557 = 13.5006 + j0.3172 = 13.5043\Omega$$

- **Breaking current:** $\boldsymbol{I_\infty} = \frac{\boldsymbol{V}}{\sqrt{3}*\boldsymbol{Z_{SC}}} = \frac{\boldsymbol{10kv}}{\sqrt{3}*13.5043} = \boldsymbol{0.4275kA}$
- The circuit breaker opening capability= $2.5 * I_\infty = 1.0688$Ka

Hence all the calculations are given in a tabular form in Table 6 as follows

Table 6: Short circuit impedance, Breaking and Opening circuit breaker currents

From	To	$Z_{sh}(\Omega)$	I breaking(kA)	I open(kA)
Generation	Bus 7	13.489	4.708	11.771
Bus 7	Load 7	13.497	0.4278	1.0695
Bus 7	Load 6	15.031	0.3831	0.9577
	Bus 5	13.5043	0.4275	1.0688
Bus 7	Bus 2	18.112	0.3188	0.7969
	Bus 3	13.5174	0.4271	1.0678
	Bus 4	13.5043	0.4275	1.0688

9 Modelling and Simulating the System Using PSAT

The distances in this network lay in short transmission lines (< 100km), therefore, the capacitive effect has been neglected only considering the reactance and resistance. The network that we designed in PSAT or MATLAB Simulink with respect to all parameters I computed above, is shown on figure 5 below (Sadaat, 1994).

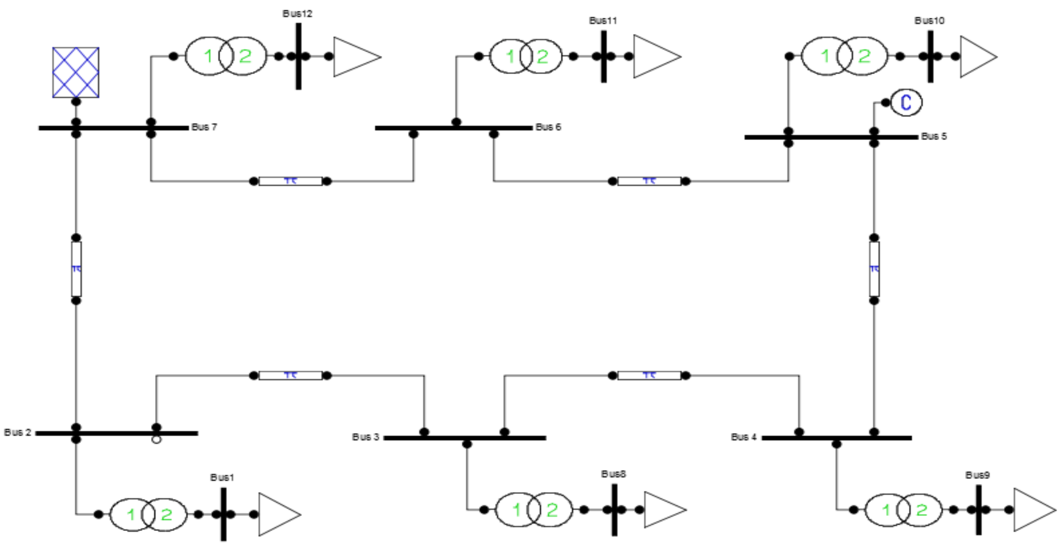

Figure 5: The PSAT Simulink designed model for the system discussed

In the PSAT modeling of figure 5 (above) transformers are used to step-down the 110kv voltage (in the transmission lines) to 10kv at the loads for distribution purpose. Furthermore, inserting static synchronous compensator at the buses highly reduces the losses of the power. Adding the static synchronous compensator, it adds additional initial cost but once it is installed it will always reduce the losses (even it was clearly visible in the simulation results with and without the compensators) hence it is highly recommended to use the static synchronous compensator for minimizing the power losses (Sadaat, 1994) (Sons, 1996).

10 Simulation Results

10.1 Simulink Outputs

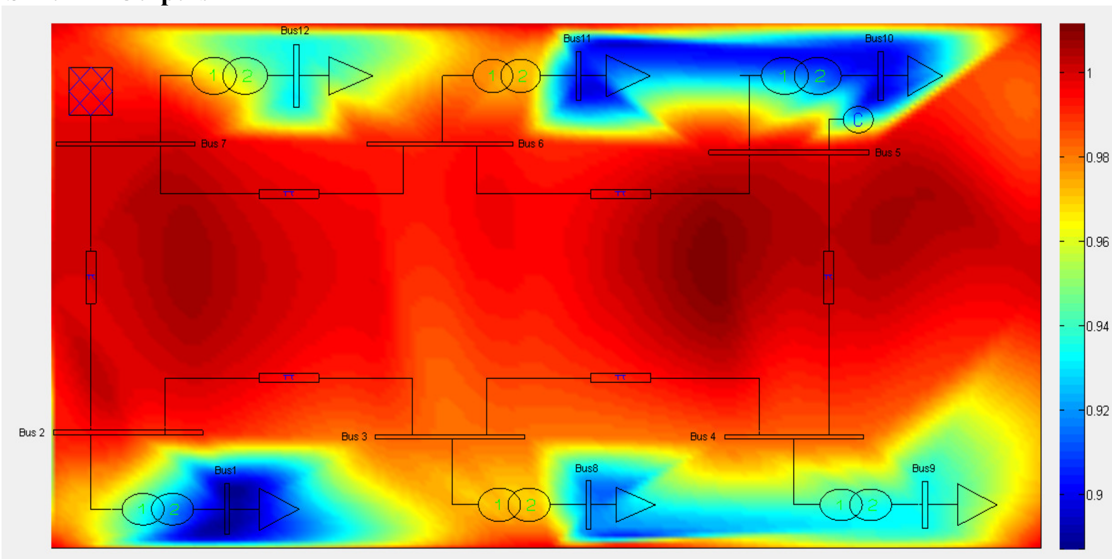

Figure 6: The simulation result for voltage magnitudes

Here in the simulation result all the value of the voltages are in the range of 0.9-1 which is in the required rage of the voltages. Since they are recommended to be close to unity due to the per unit values typically they should be from 0.9-1 voltage magnitudes (Kothari, 1989). Additionally, in some case if it is far away from unity we can adjust using the static synchronous compensator or we can redesign our works in case we may make some calculation errors.

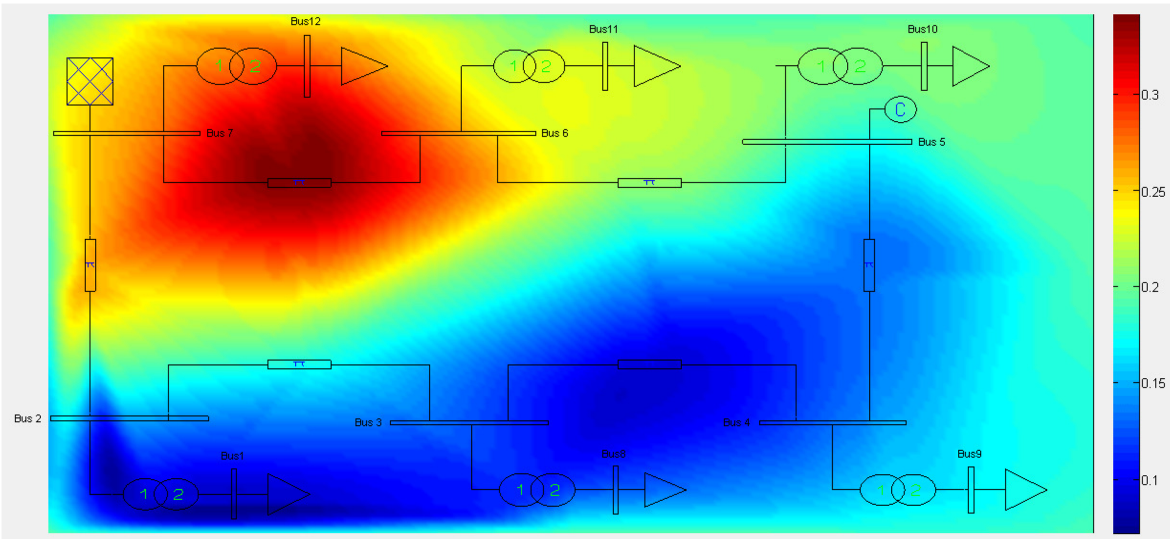

Figure 7: The simulation result for Line Flows

Here in the line from bus 7 to bus 6 has the maximum value, and still it is acceptable because the distance in between these buses is very short(9.22km) and hence its resistance will be very small. Accordingly, it will have less losses than the other lines. In general, the caring capacity in all transmission lines is not overloaded since the simulation result shows as its range is from 0.1-0.3. Hence the transmission line will be healthy since it is safe from being overloaded.

10.2Static Report of the Simulation Output

Table 7: Summery of network statistics and Solution Statics

Date: 17-Aug-2017 20:42:52	
NETWORK STATISTICS	
Buses:	12
Lines:	6
Transformers:	6
Generators:	2
Loads:	6
SOLUTION STATISTICS	
Number of Iterations:	4
Maximum P mismatch [MW]	5.78E-12
Maximum Q mismatch [MVar]	7.82E-12

Table 8: Power flow results

POWER FLOW RESULTS						
Bus	V[kV]	Phase [rad]	P gen [MW]	Q gen[MVar]	P load[MW]	Q load[MVar]
Bus 2	109.2194	-0.0115	-1.6E-12	-2E-13	0	0
Bus 3	107.9988	-0.0312	-4.2E-13	-4.2E-13	0	0
Bus 4	108.1304	-0.04333	-1.8E-13	8.63E-14	0	0
Bus 5	110	-0.04109	-2.6E-13	75.80822	0	0
Bus 6	109.173	-0.01823	-5.4E-12	1.09E-12	0	0
Bus 7	110	0	136.8646	64.31758	0	0
Bus1	8.921134	-0.08734	1.73E-12	2.69E-12	9.957366	11.69049
Bus10	9.011847	-0.10802	4.56E-13	8.86E-13	20.00444	26.66421
Bus11	9.042383	-0.12148	5.78E-12	7.82E-12	29.99769	22.49826
Bus12	9.351522	-0.06573	4.98E-15	2.49E-14	35.00328	30.85886
Bus8	9.191373	-0.10542	3.26E-13	2.79E-13	14.99884	11.24913
Bus9	9.35157	-0.12815	2.04E-13	1.69E-13	24.99927	12.10852

Table 9: Line flow reports

From Bus	To Bus	Line	P Flow [MW]	Q Flow [MVar]	P Loss [MW]	Q Loss [MVar]
Bus 7	Bus 2	1	41.02764	22.01048	0.042411	0.622486
Bus 4	Bus 3	2	-15.5718	6.476556	0.05841	0.194369
Bus 6	Bus 7	3	-60.3139	-5.7783	0.340679	1.142781
Bus 5	Bus 6	4	-29.8188	23.0287	0.290385	0.85121
Bus 5	Bus 4	5	9.649684	21.77306	0.116037	0.387865
Bus 3	Bus 2	6	-30.7165	-6.88903	0.203984	0.685449
Bus 4	Bus9	7	25.10549	14.90864	0.106222	2.800126
Bus 7	Bus12	8	35.18231	35.38602	0.179032	4.52716
Bus 6	Bus11	9	30.20472	27.95579	0.207029	5.457525
Bus 5	Bus10	10	20.16916	31.00645	0.164722	4.342242
Bus 3	Bus8	11	15.08627	13.17122	0.087431	1.922087
Bus 2	Bus1	12	10.06471	13.81351	0.107349	2.123024

Table 10:Global Summery report

GLOBAL SUMMARY REPORT	
TOTAL GENERATION	
REAL POWER [MW]	136.8646
REACTIVE POWER [MVar]	140.1258
TOTAL LOAD	
REAL POWER [MW]	134.9609
REACTIVE POWER [MVar]	115.0695
TOTAL LOSSES	
REAL POWER [MW]	1.90369
REACTIVE POWER [MVar]	25.05632

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Appendix

Table 11: Transmission Line Parameters for 11-150 kV (for 100km)

Nominal cross-sectional area mm^2	r_0, Om (+20ºC)	11kV	110kV			150 kV		
		x_0, Om	x_0, Om	$Y*10^{-4}$, Sm	q_0, Mvar	x_0, Om	$Y*10^{-4}$, Sm	q_0, Mvar
70/11	42.8	43.2	44.4	2.55	3.4	46	2.46	5.5
95/16	30.6	42.1	43.4	2.61	3.5	45	2.52	5.7
120/19	24.9	41.4	42.7	2.66	3.55	44.1	2.56	5.8
150/24	19.8	40.6	42	2.7	3.6	43.4	2.61	5.9
185/29	16.2		41.3	2.75	3.7	42.9	2.64	5.95
240/32	**12**		**40.5**	**2.81**	**3.75**	**42**	**2.7**	**6.1**

Table 12: Three Phase Double Wound Transformer 110 kV rating

	Type	Rated Power, S, MVA	Catalogue details						
			Rated Voltage		Winding losses	Core Losses			
			HV	LV	ΔP_w, kW	ΔP_c, kW	R_t, Om	X_t, Om	ΔQ_x, kvar
1	2500/110	2.5	110	11	22	5.5	42.6	508.2	37.5
2	6300/110	6.3	115	11	44	11.5	14.7	220.4	50.4
3	10000/110	10	115	11	60	14	7.95	139	70
4	16000/110	16	115	11	85	19	4.38	86.7	112
5	25000/110	25	115	10.5	120	27	2.54	55.9	175
6	40000/110	40	121	10.5	160	50	1.46	38.4	260
7	63000/110	63	115	10.5	260	59	0.87	22	410
8	80000/110	80	121	10.5	310	70	0.71	19.2	480
9	125000/110	125	121	10.5	400	120	0.37	12.3	687.5

Table 13: Maximum long-term allowable nominal Power in MW at 25°C

Nominal cross-sectional area mm^2	Nominal current I, A	110kV Power, MW
70/11	210	47.6
95/16	260	59.3
120/19	313	70.1
150/24	365	80.9
185/29	430	93.5
240/32	505	108.8

Table 14: Given parameters for the nominal current, cross-sectional area and other constants

Таблица П9 Длительно допустимые токи и мощности для неизолированных сталеалюминиевых проводов марок АС, АСК, АСКП, АСКС при температуре воздуха +25 °С

Номинальное сечение, мм²	Ток, А		Мощность, МВт, вне помещений при напряжении, кВ					
	вне помещений	внутри помещений	35	110	150	220	330	500
35/6,2	175	135	10	—	—	—	—	—
50/8	210	165	12	—	—	—	—	—
70/11	265	210	15,2	47,6	—	—	—	—
95/16	330	260	18,9	59,3	80,9	—	—	—
120/19	390	313	22,3	70,1	95,6	—	—	—
120/27	375	—	21,5	67,4	92	—	—	—
150/19	450	365	25,7	80,9	110,3	—	—	—
150/24	450	365	25,7	80,9	110,3	—	—	—
150/34	450	—	25,7	80,9	110,3	—	—	—
185/24	520	430	29,7	93,5	127,5	—	—	—
185/29	510	425	29,2	91,7	125,1	—	—	—
185/43	515	—	29,5	92,6	126,3	—	—	—
240/32	605	505	—	108,8	148,4	217	326	—
240/39	610	505	—	109,7	149,6	219	329	—