

## Power Flow and Failure Analysis with Power World Simulator

Ersoy Sena

İstanbul Technical University Electrical-Electronics Faculty  
Elektrik Bölümü  
ersoy20@itu.edu.tr

### Abstract

A transmission system consists of generators, transformers, power transmission lines and loads. Since these transmission system elements cannot be lossless elements in practice, losses, voltage drops or voltage spikes are experienced in the energy transmission system. In this study, the line diagram of the network is designed by entering the power system parameters into Power World. First of all, busbar voltages and load flow are determined for the given system. Then the total power loss is calculated and reduced by connecting a capacitor to the busbars. In addition, 3-phase balanced faults are also examined.

**Keywords:** Power World, Power Flow

### 1. Network Schematic and One Line Flow

Table 1. Data for the transmission lines and the transformers.

Bus - To Bus	R (per unit)	X (per unit)	Y (per unit)	Remarks
Bus 2-Bus 3	0.083	0.372 z	0.00	Line
Bus 3-Bus 5	0.061	0.325 z	0.05	Line
Bus 2-Bus 5	0.045	0.310 z	0.00	Line
Bus 3-Bus 6	0.127	0.410 z	0.10	Line
Bus 5-Bus 6	0.105	0.398 z	0.05	Line
Bus 1-Bus 2	0.000	0.300 z	0.00	Transformer
Bus 3-Bus 4	0.000	0.290 z	0.00	Transformer

Table 2. Data for the generators and loads.

Generation		Load		V (per unit)	Remarks
Bus	P (MW)	Q (MVAR)	P (MW)	Q (MVAR)	
Bus 1	...	...	...	...	1.00 $\angle 0^\circ$ Swing bus
Bus 4	200	30	...	...	Gen. bus
Bus 5	...	...	x	0.2 x	Load bus
Bus 6	...	...	y	0.3 y	Load bus
Bus 3	...	...	50	10	Load bus

The last three digits of the student ID are 434. Accordingly, the parameter values are determined as follows:  $x=217x = 217$ ,  $y=108.5y = 108.5$ , and  $z=0.434z = 0.434$ . All related system values are calculated based on these parameters.

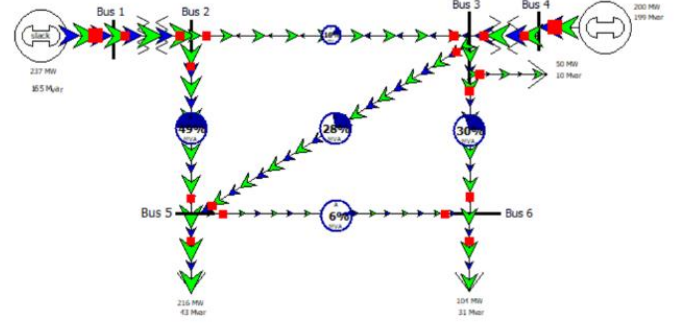


Figure 1. Line Diagram of the Network

	Number	Name	Area Name	Nom kV	PU Volt	Volt (kV)	Angle (Deg)
1	1	Bus 1	Home	138,00	1,00000	138,000	0,00
2	2	Bus 2	Home	138,00	0,97855	135,040	-5,26
3	3	Bus 3	Home	138,00	0,98708	136,217	-5,95
4	4	Bus 4	Home	138,00	1,00000	138,000	-3,37
5	5	Bus 5	Home	138,00	0,91155	125,794	-10,20
6	6	Bus 6	Home	138,00	0,88170	121,675	-10,63

Table 3. Bus voltages and phase angles of the system

Limit MVA that is not visible on the table below is taken as 400.

	Branch Device Type	From Name	To Name	MVA From	MW From	Mvar From
1	Transformer	Bus 1	Bus 2	289,0	237,2	165,1
2	Line	Bus 2	Bus 3	65,7	65,1	-8,9
3	Line	Bus 2	Bus 5	195,2	172,1	92,1
4	Transformer	Bus 3	Bus 4	235,5	-200,1	-124,2
5	Line	Bus 3	Bus 5	111,0	94,9	57,7
6	Line	Bus 3	Bus 6	121,8	115,6	38,4
7	Line	Bus 5	Bus 6	23,6	16,9	16,4

Table 4. Amount of power flow

Case Totals (for in-service devices only)		
	MW	Mvar
Load	369,8	84,3
Generation	437,2	364,3
Shunts	0,0	0,0
Losses	67,3	280,1
Dist Gen	0,0	0,0

Table 5. Total Power Loss

## 2. Reactive Power Compensation

Inductive loads draw reactive power from the system, while capacitive loads supply reactive power to it. Adding shunt capacitors to the buses where inductive loads such as motors are connected allows the reactive power demand of these inductive loads to be met directly through the shunt capacitors instead of the transmission lines. As a result, the reactive power required by the inductive loads is not transmitted over the lines, which reduces power losses in the transmission system. The power rating of the shunt capacitor connected to the bus is selected such that it brings the bus voltage closer to 1 per unit.

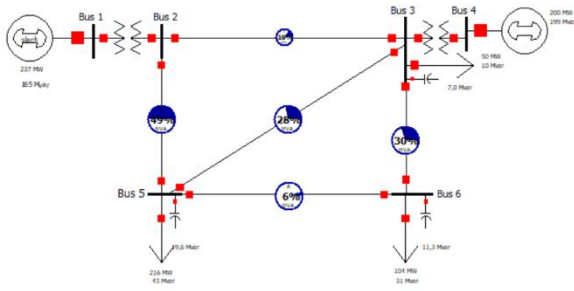


Figure 2. System Schematic after connecting shunt capacitors

When the shunt capacitors are connected to the system, as observed, the load carried by the transmission lines has decreased. In the new condition, the total power loss is:

Case Totals (for in-service devices only)		
	MW	Mvar
Load	375,5	85,9
Generation	422,6	225,1
Shunts	0,0	-51,9
Losses	47,09	191,1
Dist Gen	0,0	0,0

Tablo 6. Total power losses after compensation

## 3. Maximum Load:

It is believed that transmission lines in this part can transmit a maximum of 400 MVA. the maximum load on bus No. 5 will be determined in such a way that it does not exceed the transmission line capacity. Using the trial and error method, it was found that the maximum load voltage that provides the line power carrying capacity is 254 MW. The overload caused an Blackout in the system,

Number	Name	Area Name	Nom kV	PU Volt	Volt (kV)	Angle (Deg)
1	5 Bus 5	Home	138,00	0,76446	105,496	-40,31
2	2 Bus 2	Home	138,00	0,88752	122,478	-20,86
3	3 Bus 3	Home	138,00	0,86955	119,998	-29,11
4	6 Bus 6	Home	138,00	0,70460	97,235	-43,73
5	4 Bus 4	Home	138,00	1,00003	138,004	-12,39
6	1 Bus 1	Home	138,00	1,00000	138,000	0,00

Tablo 7. Bus voltages after blackout

## 4. Fault Analysis

Number	Name	Phase Volt A	Phase Volt B	Phase Volt C
1	1 Bus 1	0,00000	0,00000	0,00000
2	2 Bus 2	0,29576	0,29576	0,29576
3	3 Bus 3	0,55927	0,55927	0,55927
4	4 Bus 4	0,89263	0,89263	0,89263
5	5 Bus 5	0,40901	0,40901	0,40901
6	6 Bus 6	0,43839	0,43839	0,43839

Tablo 8. Phase voltages for 3-phase fault.

Number	Name	Phase Ang A	Phase Ang B	Phase Ang C
1	1 Bus 1	90,00	90,00	90,00
2	2 Bus 2	-19,57	-139,57	100,43
3	5 Bus 5	-33,59	-153,59	86,41
4	6 Bus 6	-35,53	-155,53	84,47
5	3 Bus 3	-24,16	-144,16	95,84
6	4 Bus 4	-5,04	-125,04	114,96

Bus Flows									
BUS	1	Bus 1	138,0	MW	Mvar	MTA	%	1,0000	0,00
GENERATOR	1	97,44	27,79	101,3					
TO	2	Bus 2	1	97,44	27,79	101,3	25	1,0000TA	0,0
BUS	2	Bus 2	138,0	MW	Mvar	MTA	%	0,9786	-5,24
TO	1	Bus 1	1	-97,44	-18,24	99,1	25	1,0000NT	0,0
TO	3	Bus 3	1	3,28	-9,56	10,1	3		
TO	5	Bus 5	1	94,16	27,91	96,2	25		
**** Mismatch ****				-1,24	-9,82				
BUS	3	Bus 3	138,0	MW	Mvar	MTA	%	0,9871	-5,95
LOAD	1	50,00	10,00	51,0	Disten	0,00	0,00	0,0	
TO	2	Bus 2	1	-9,19	9,69	10,2	3		
TO	4	Bus 4	1	-200,00	-52,81	206,9	52	1,0000TA	0,0
TO	5	Bus 5	1	82,84	24,05	86,3	22		
TO	6	Bus 6	1	70,35	9,07	70,9	18		
**** Mismatch ****				-111,64	-46,26				
BUS	4	Bus 4	138,0	MW	Mvar	MTA	%	1,0000	-3,37
GENERATOR	1	200,00	30,008	202,2					
TO	3	Bus 3	1	200,00	62,58	209,4	52	1,0000NT	0,0
**** Mismatch ****				150,00	-9,00				
BUS	5	Bus 5	138,0	MW	Mvar	MTA	%	0,9116	-10,20
LOAD	1	215,50	43,10	219,8	Disten	0,00	0,00	0,0	
TO	2	Bus 2	1	-89,42	-18,34	91,5	23		
TO	3	Bus 3	1	-78,11	-20,80	80,8	20		
TO	6	Bus 6	1	13,73	9,34	14,1	4		
**** Mismatch ****				-103,10	-5,13				
BUS	6	Bus 6	138,0	MW	Mvar	MTA	%	0,8817	-10,43
LOAD	1	136,23	23,10	138,2	Disten	0,00	0,00	0,0	
TO	3	Bus 3	1	-63,64	-11,18	64,6	14		
TO	5	Bus 5	1	-13,36	-11,92	17,9	4		
**** Mismatch ****				-76,39	6,92				

Tablo 9. Phase angles between each phase for 3-phase fault.

The Fault Analysis part did not give any fault currents even though blackout happening. After checking logs etc the problem seemed to be a software issue thus I could not calculate the currents but it can be analyzed from the given tables above.

## 5. Conclusion

In this study, the power flow analysis of the network was performed using the PowerWorld Simulator. Bus voltages were represented in phasor form, and the power flows throughout the system were observed. The total power loss was calculated and then minimized through the addition of appropriately rated shunt capacitors. These capacitors played a crucial role in reducing both active and reactive power losses and in restoring voltage levels at load buses closer to their nominal values. As the load on the system increased, voltage drops occurred at the corresponding buses, leading to potential overloading on the transmission lines supplying those buses. If the line capacity is exceeded, it may result in faults. To analyze this risk, the relationship between the transmission line MVA limits and the maximum allowable load was explored. Finally, the system's response to three-phase balanced faults at each bus was studied. During such faults, the voltages at the affected buses dropped to zero, and the resulting fault currents were equal across all three phases (a, b, c). These scenarios emphasize the importance of both reactive power compensation and fault analysis in ensuring reliable and efficient power system operation.