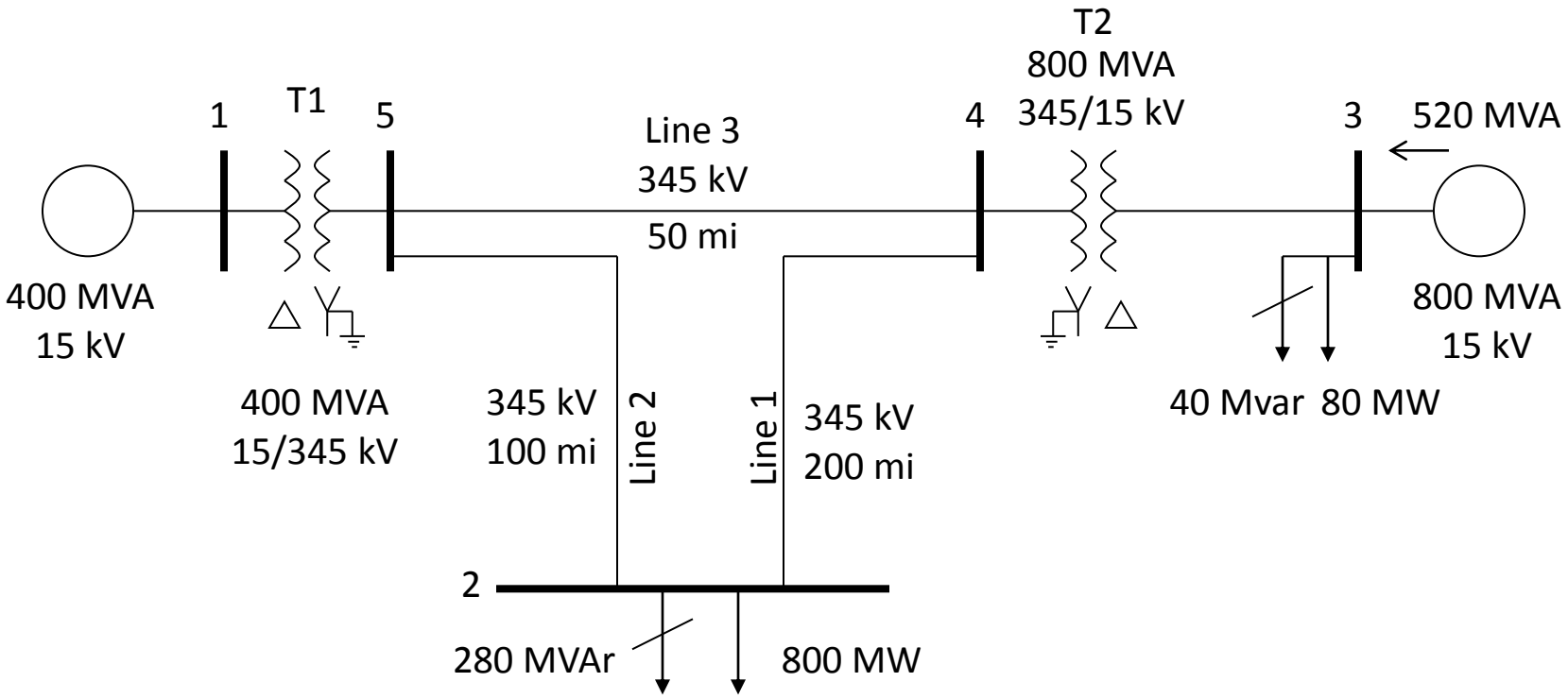
Lecture 1

The N-R Power Flow: 5-bus Example



Single-line diagram

The N-R Power Flow: 5-bus Example

Table 1. Bus input data

Bus	Type	|V| per unit	θ degrees	P_G per unit	Q_G per unit	P_L per unit	Q_L per unit	Q_{Gmax} per unit	Q_{Gmin} per unit
1	Slack	1.0	0	—	—	0	0	—	—
2	Load	—	—	0	0	8.0	2.8	—	—
3	Constant voltage	1.05	—	5.2	—	0.8	0.4	4.0	-2.8
4	Load	—	—	0	0	0	0	—	—
5	Load	—	—	0	0	0	0	—	—

Table 2. Line input data

Bus-to-Bus	R per unit	X per unit	G per unit	B per unit	Maximum MVA per unit
2-4	0.0090	0.100	0	1.72	12.0
2-5	0.0045	0.050	0	0.88	12.0
4-5	0.00225	0.025	0	0.44	12.0

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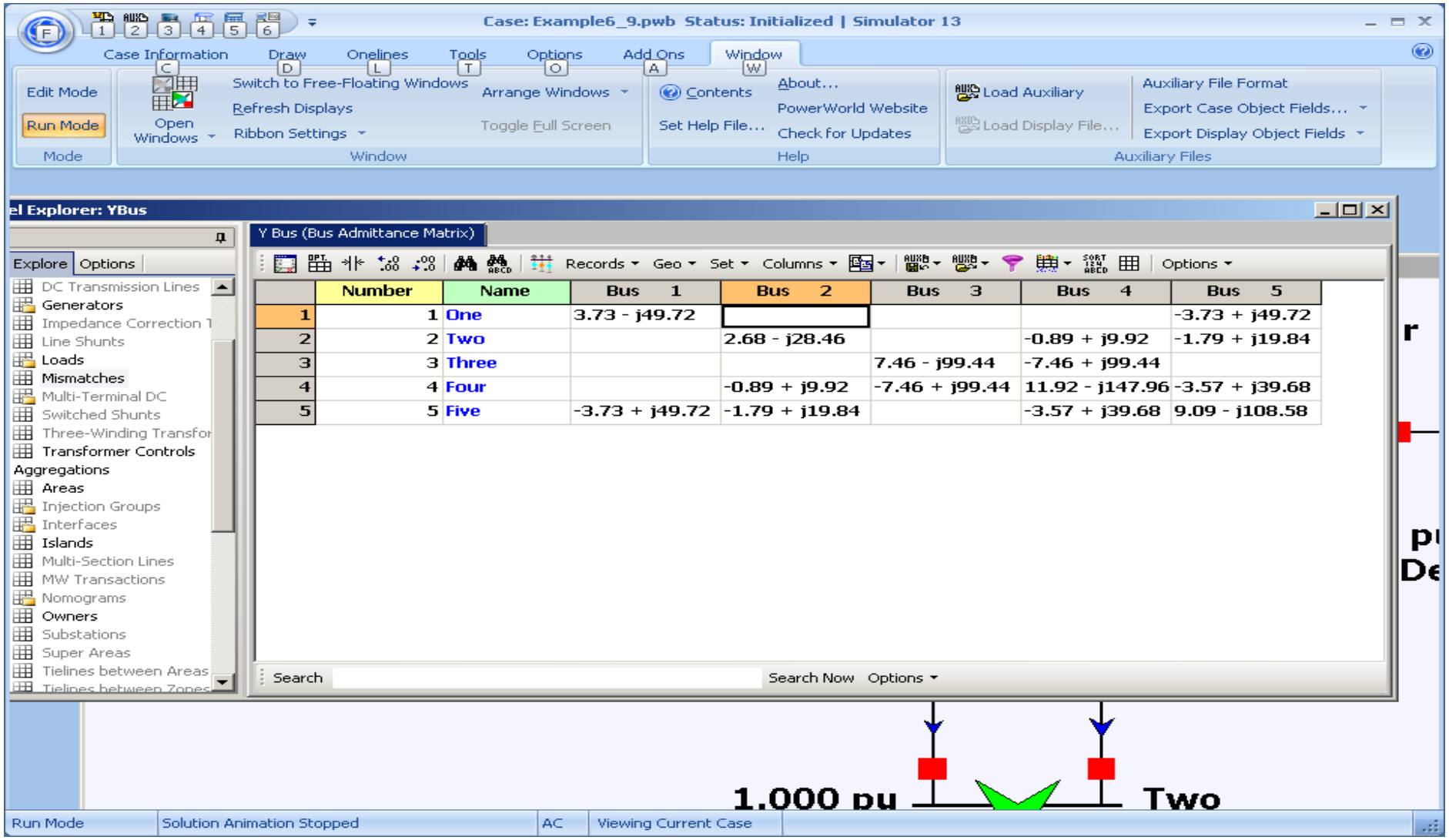
Table 3. Transformer input data

Bus-to-Bus	R per unit	X per unit	G_c per unit	B_m per unit	Maximum MVA per unit	Maximum TAP Setting per unit
1-5	0.00150	0.02	0	0	6.0	—
3-4	0.00075	0.01	0	0	10.0	—

Table 4. Input data and unknowns

Bus	Input Data	Unknowns
1	$\|V_1\| = 1.0$, $\theta_1 = 0$	P_1, Q_1
2	$P_2 = P_{G2} - P_{L2} = -8$ $Q_2 = Q_{G2} - Q_{L2} = -2.8$	$\|V_2\|$, θ_2
3	$\|V_3\| = 1.05$ $P_3 = P_{G3} - P_{L3} = 4.4$	Q_3, θ_3
4	$P_4 = 0$, $Q_4 = 0$	$\|V_4\|$, θ_4
5	$P_5 = 0$, $Q_5 = 0$	$\|V_5\|$, θ_5

Let the Computer Do the Calculations! (Ybus Shown)



	Number	Name	Bus 1	Bus 2	Bus 3	Bus 4	Bus 5
1	1	One	3.73 - j49.72				-3.73 + j49.72
2	2	Two		2.68 - j28.46		-0.89 + j9.92	-1.79 + j19.84
3	3	Three			7.46 - j99.44	-7.46 + j99.44	
4	4	Four		-0.89 + j9.92	-7.46 + j99.44	11.92 - j147.96	-3.57 + j39.68
5	5	Five	-3.73 + j49.72	-1.79 + j19.84		-3.57 + j39.68	9.09 - j108.58

Ybus Details

Elements of Y_{bus} connected to bus 2

$$Y_{21} = Y_{23} = 0$$

$$Y_{24} = \frac{-1}{R_{24} + jX_{24}} = \frac{-1}{0.009 + j0.1} = -0.89276 + j9.91964 \quad per \quad unit$$

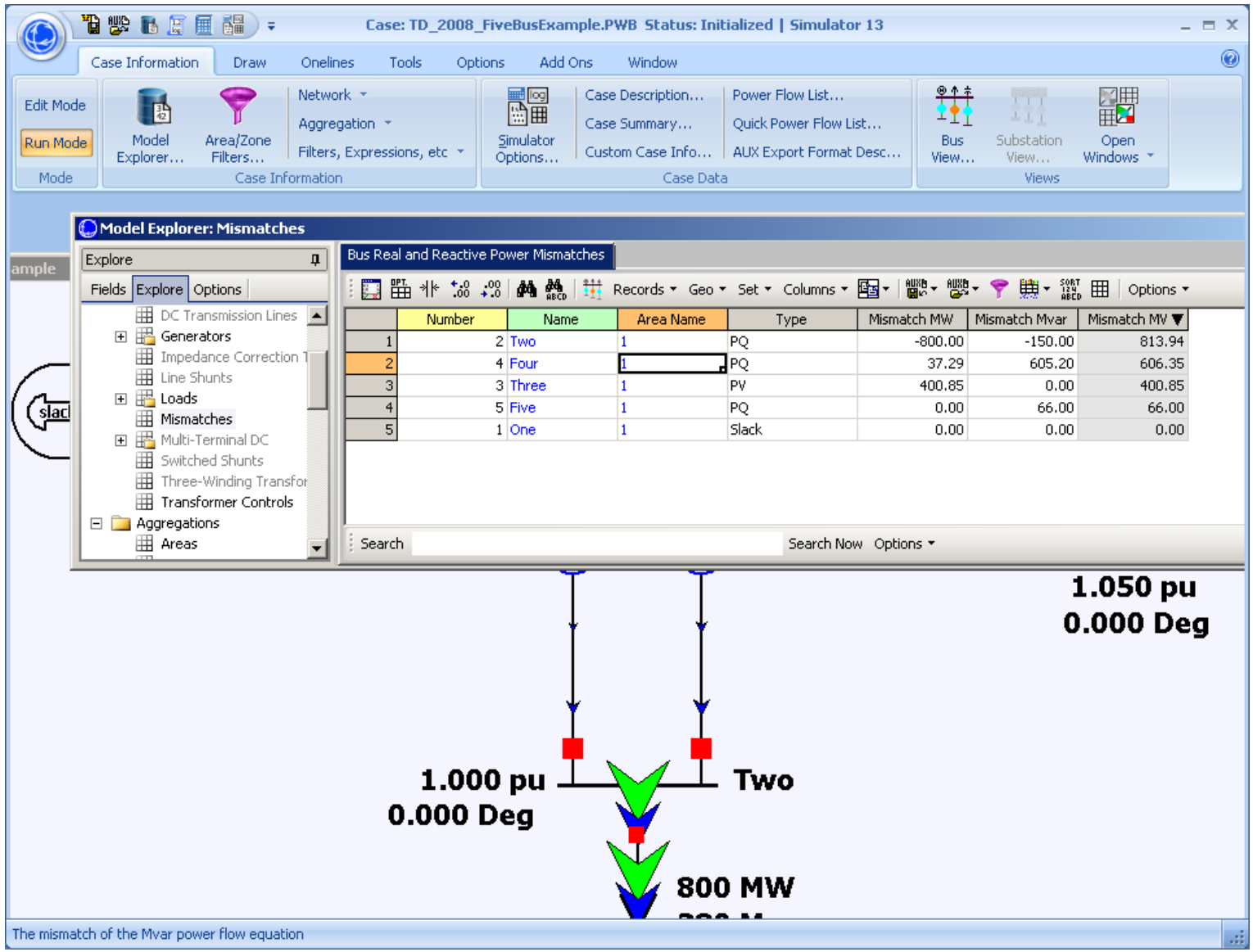
$$Y_{25} = \frac{-1}{R_{25} + jX_{25}} = \frac{-1}{0.0045 + j0.05} = -1.78552 + j19.83932 \quad per \quad unit$$

$$Y_{22} = \frac{1}{R_{24} + jX_{24}} + \frac{1}{R_{25} + jX_{25}} + j\frac{B_{24}}{2} + j\frac{B_{25}}{2}$$

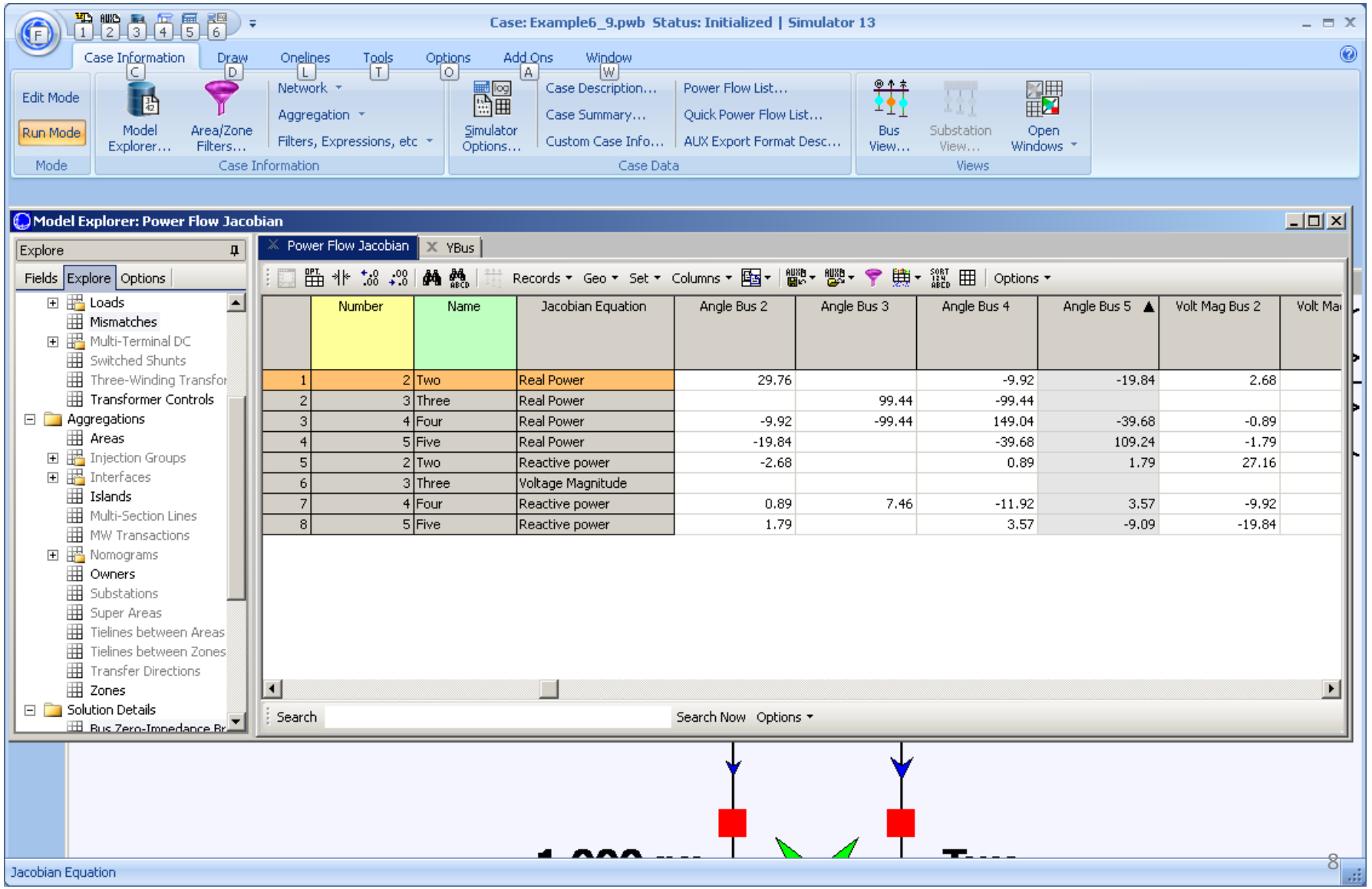
$$= (0.89276 - j9.91964) + (1.78552 - j19.83932) + j\frac{1.72}{2} + j\frac{0.88}{2}$$

$$= 2.67828 - j28.4590 = 28.5847\angle -84.624^\circ \ per \ unit$$

Here are the Initial Bus Mismatches



And the Initial Power Flow Jacobian



	Number	Name	Jacobian Equation	Angle Bus 2	Angle Bus 3	Angle Bus 4	Angle Bus 5	Volt Mag Bus 2	Volt Ma
1	2	Two	Real Power	29.76		-9.92	-19.84	2.68	
2	3	Three	Real Power		99.44	-99.44			
3	4	Four	Real Power	-9.92	-99.44	149.04	-39.68	-0.89	
4	5	Five	Real Power	-19.84		-39.68	109.24	-1.79	
5	2	Two	Reactive power	-2.68		0.89	1.79	27.16	
6	3	Three	Voltage Magnitude						
7	4	Four	Reactive power	0.89	7.46	-11.92	3.57	-9.92	
8	5	Five	Reactive power	1.79		3.57	-9.09	-19.84	

Five Bus Power System Solved