Transmission usage cost and loss allocation using AP and MP-AP Method

S. A. Soman, M. S. S. Rao and Rajeev Gajbhiye

Department of Electrical Engineering
Indian Institute of Technology Bombay

October 4, 2010

Outline

Five + Two system

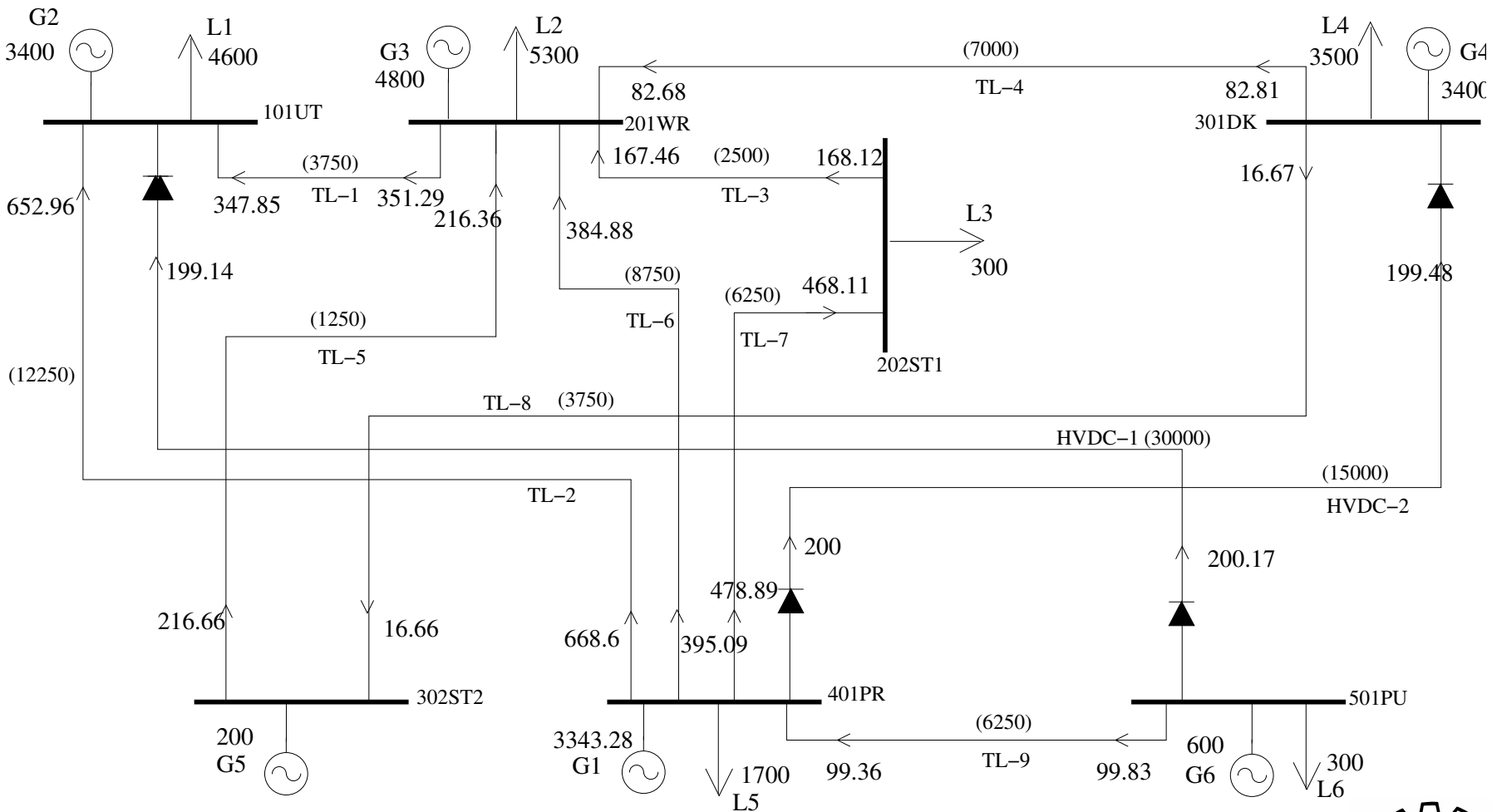

Figure: Five + Two Basic system

Generation Tracing

Starts from the pure source (501PU)

Delete the pure source node, model its contributions to the receipent nodes with generator tags

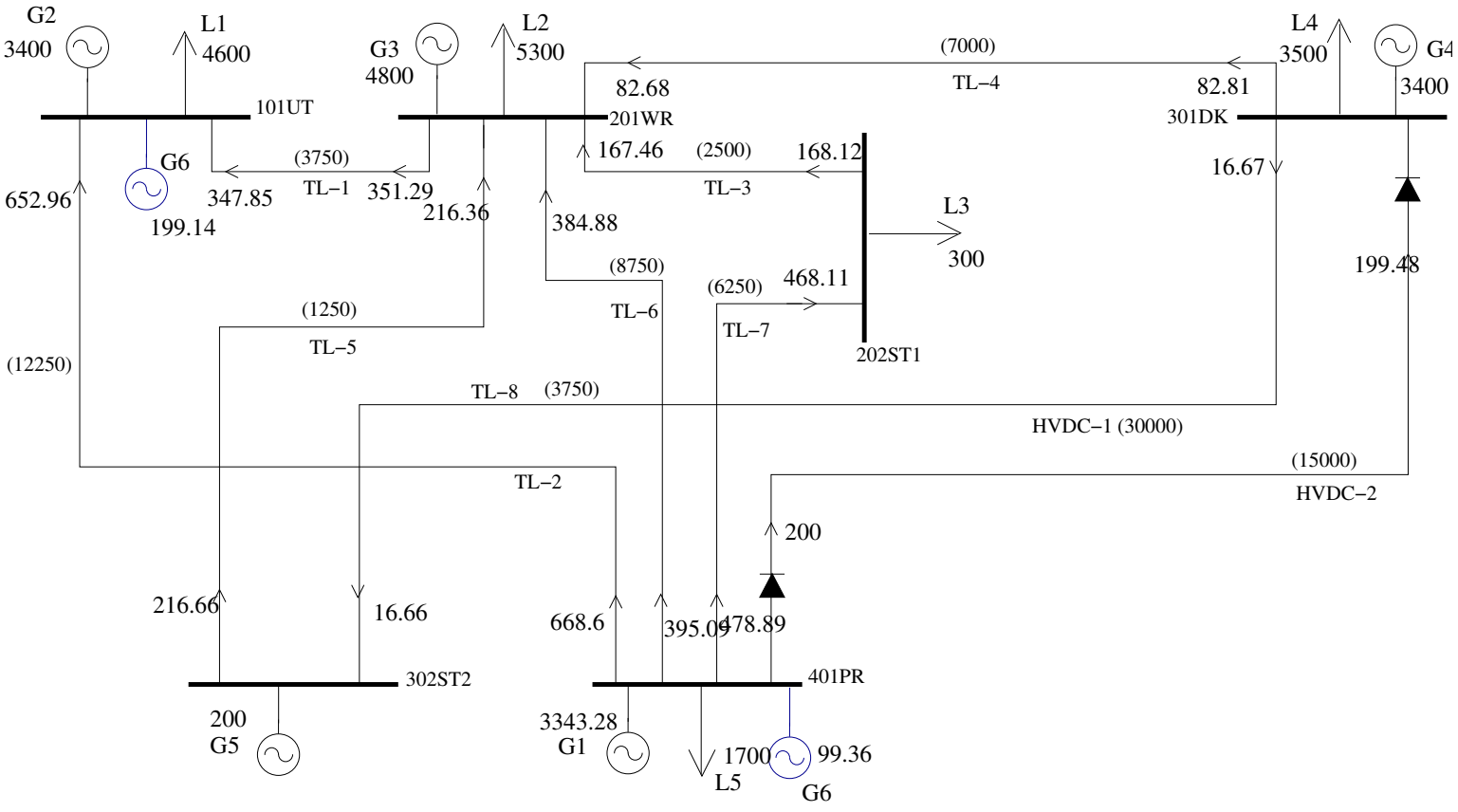

Figure: Elimination of node 501PU

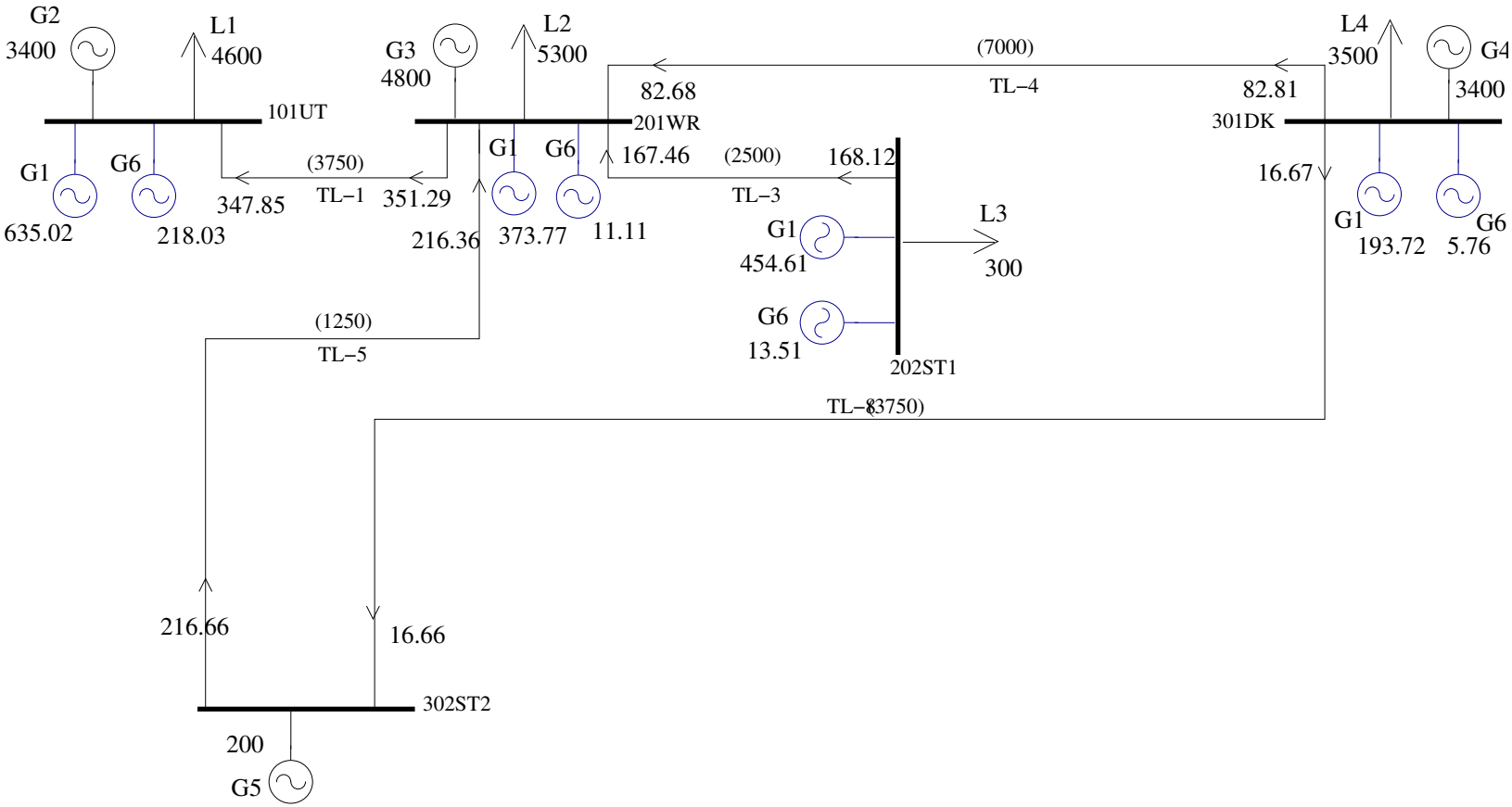

Figure: Elimination of node 401PR

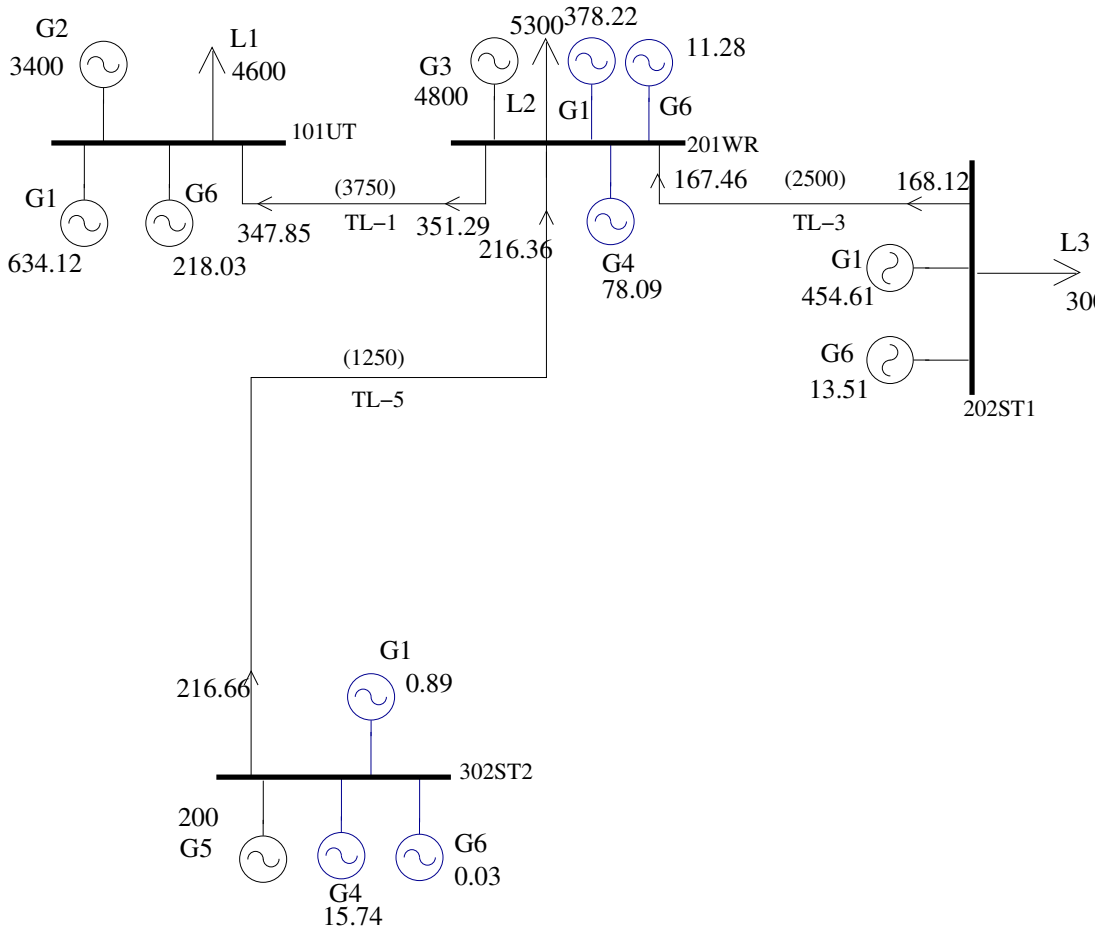

Figure: Elimination of node 301DK

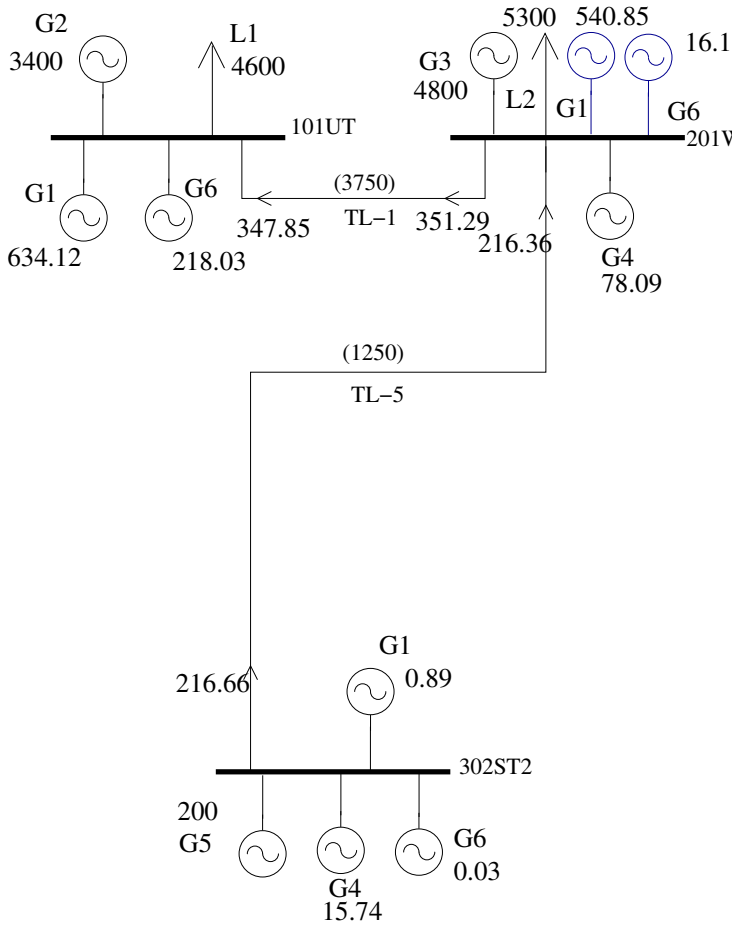

Figure: Elimination of node 202ST1

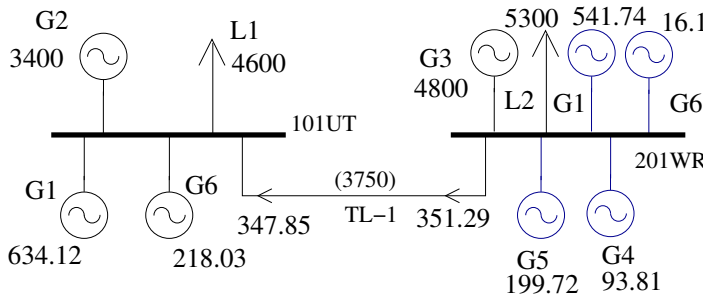

Figure: Elimination of node 302ST2

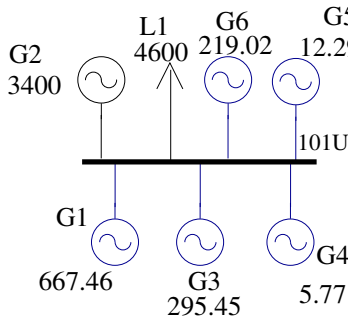

Figure: Elimination of node 201WR

Generation Tracing Results

	L1(4600) 101UT	L2(5300) 201WR	L3(300) 202ST1	L4(3500) 301DK	L5(1700) 401PR	L6(300) 501PU
G1(3343.47) 401PR	667.46	508.05	291.34	188.38	1650.94	
G2(3400) 101UT	3400					
G3(4800) 201WR	295.45	4501.54				
G4(3400) 301Dk	5.77	87.98		3306.01		
G5(200) 302ST2	12.29	187.29		0		
G6(600) 501PU	219.02	15.14	8.66	5.61	49.06	300
Sum	4600	5300	300	3500	1700	300

	G1	G2	G3	G4	G5	G6	Sum
L1	0.145	0.739	0.064	0.001	0.003	0.048	1
L2	0.096	0.000	0.849	0.017	0.035	0.003	1
L3	0.971	0.000	0.000	0.000	0.000	0.029	1
L4	0.054	0.000	0.000	0.945	0.000	0.002	1
L5	0.971	0.000	0.000	0.000	0.000	0.029	1
L6	0.000	0.000	0.000	0.000	0.000	1.000	1

Five + Two system

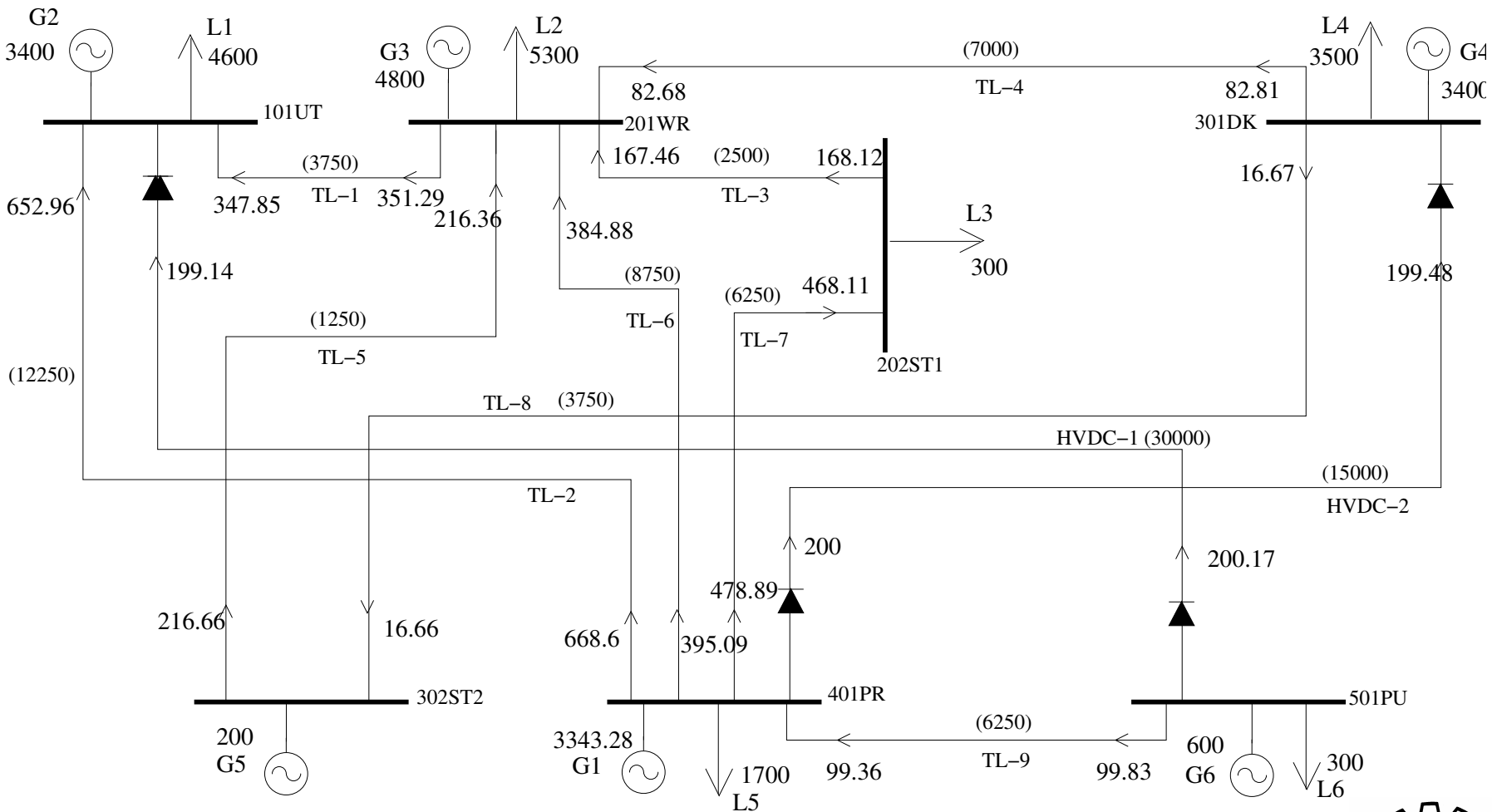

Figure: Five + Two Basic system

Load Tracing

Starts from the pure sink 101UT

Delete the pure sink node, model its contributions to the sender nodes with its load tags

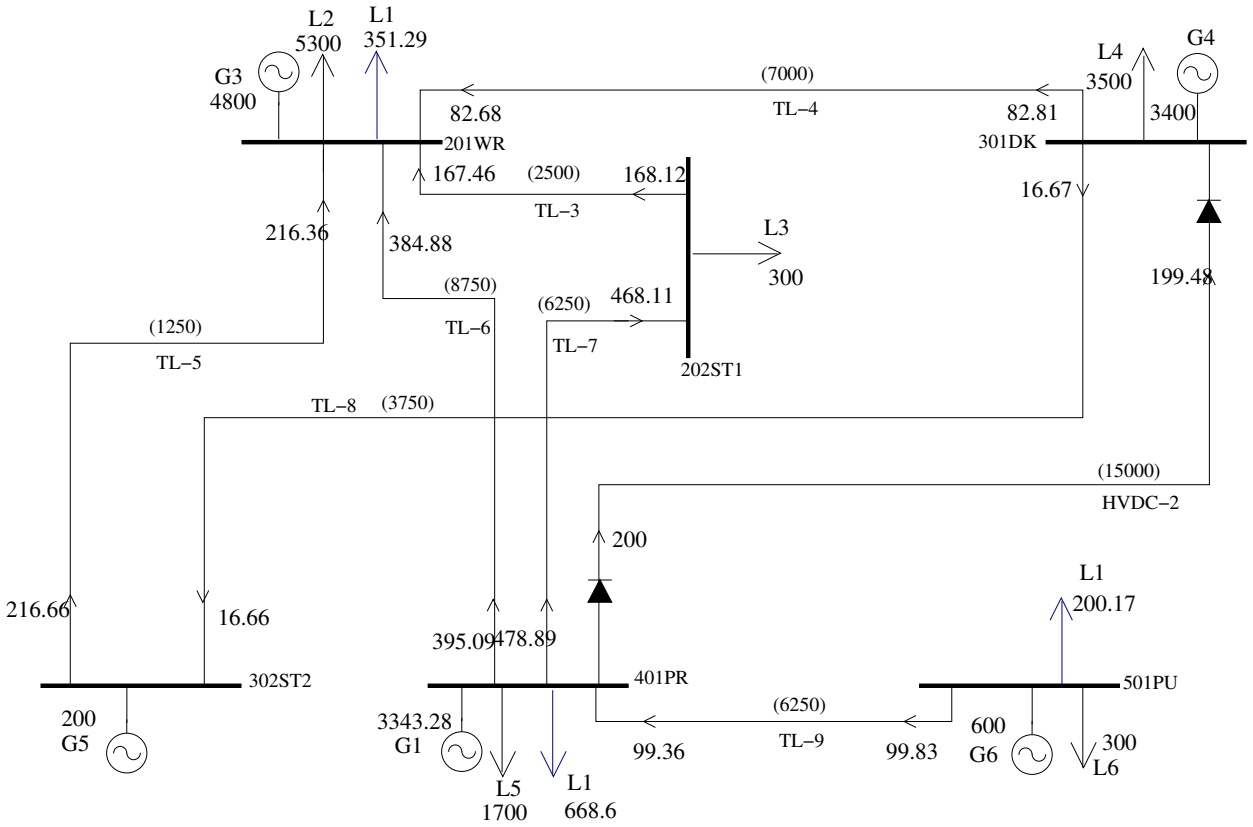

Figure: Elimination of node 101UT

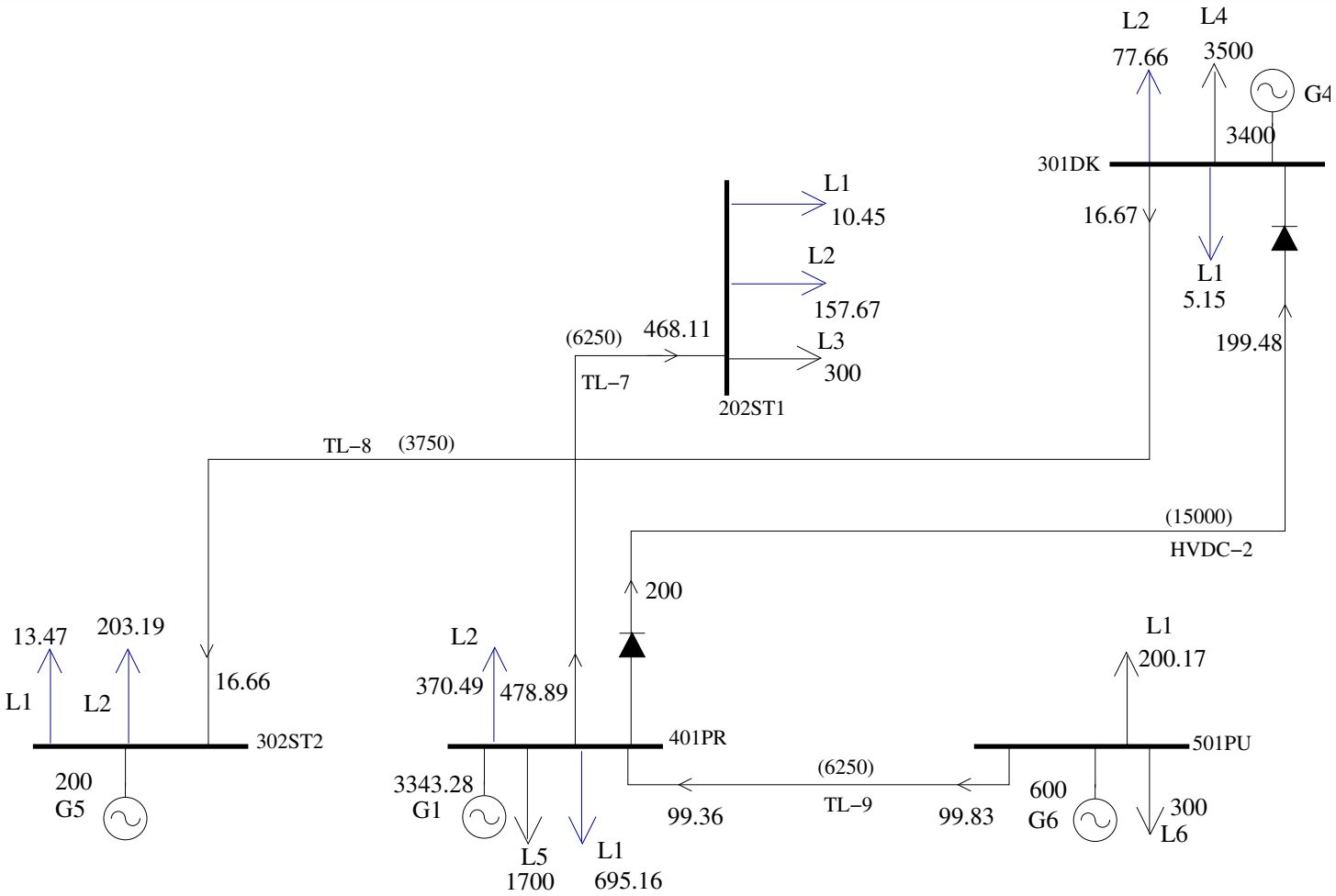

Figure: Elimination of node 201WR

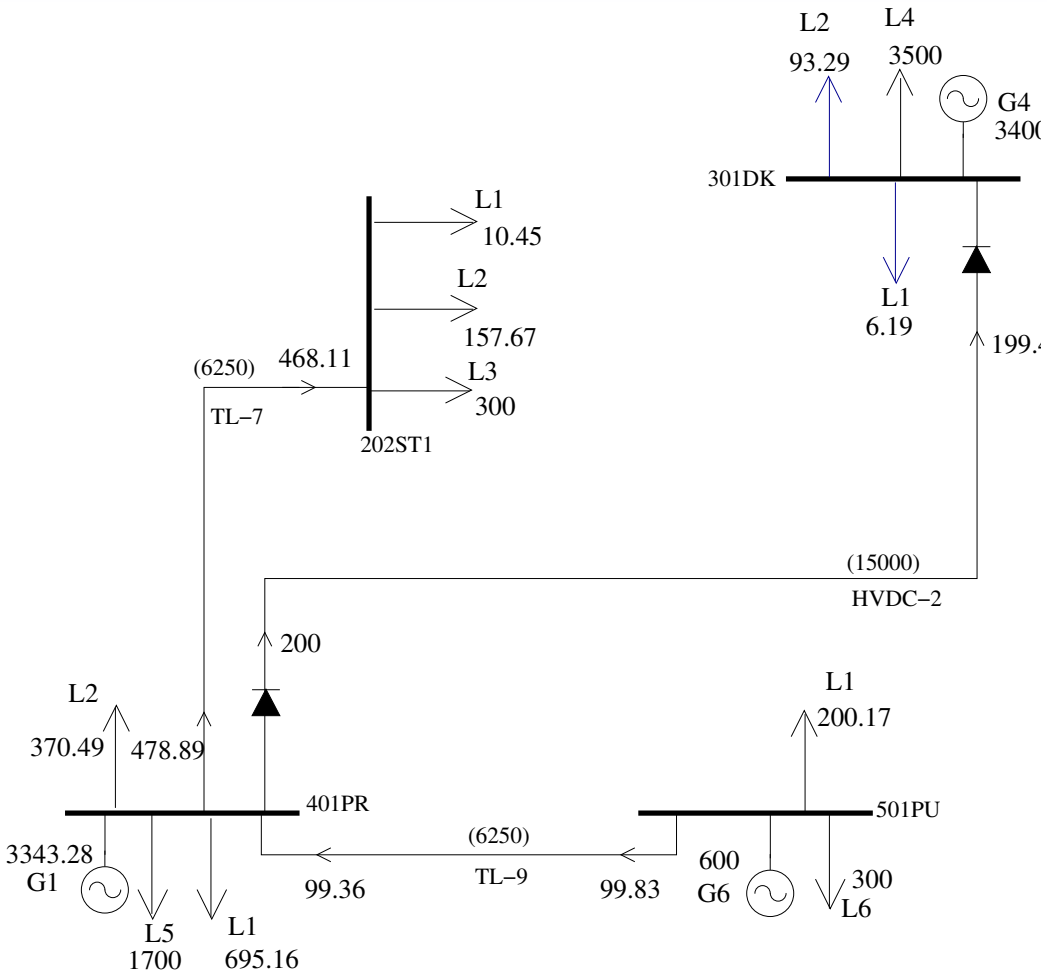

Figure: Elimination of node 302ST2

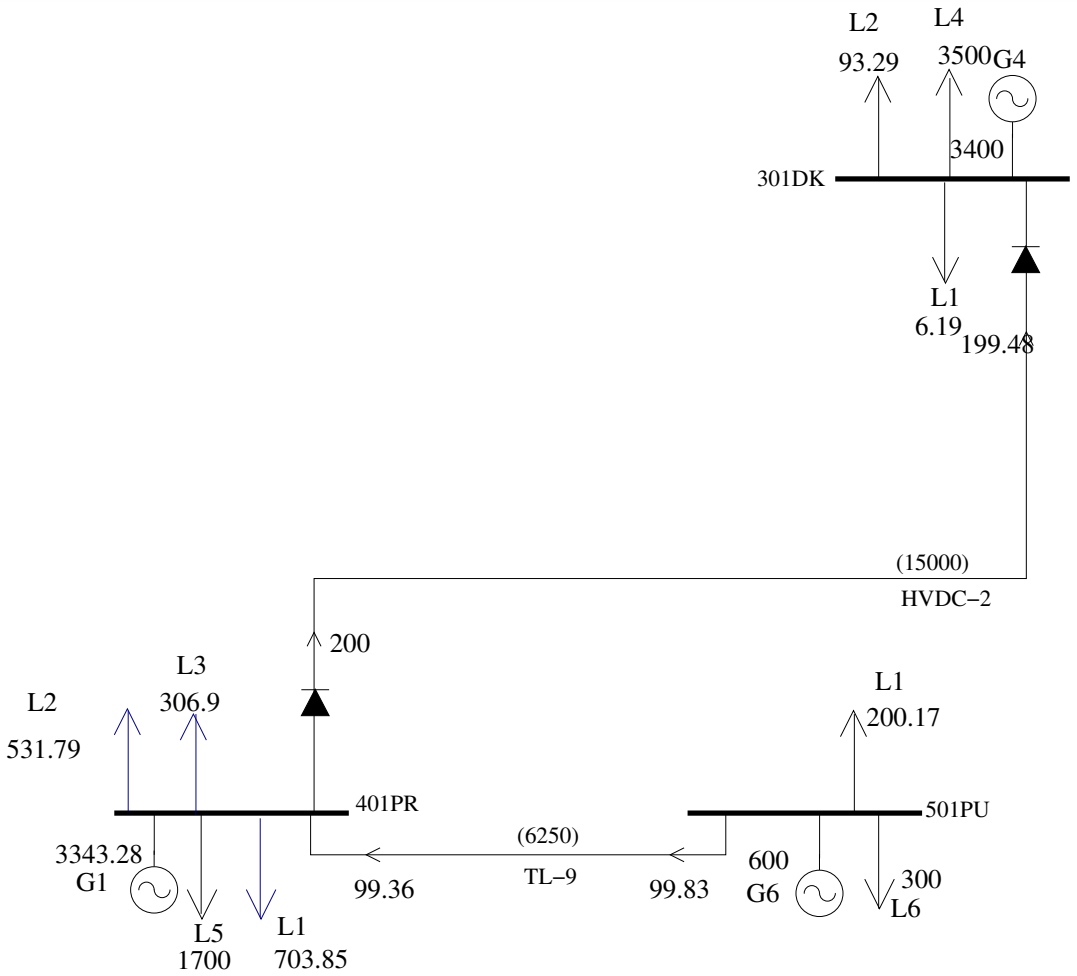

Figure: Elimination of node 202ST1

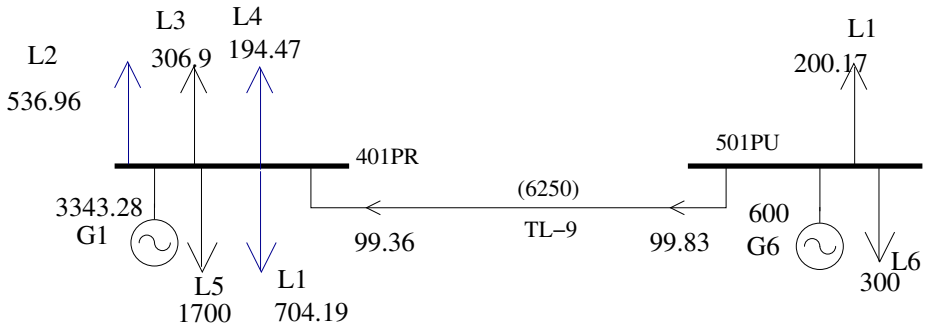

Figure: Elimination of node 301DK

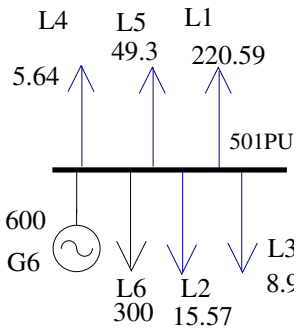

Figure: Elimination of node 401PR

Load tracing Results

	G1(3343.47)	G2(3400)	G3(4800)	G4(3400)	G5(200)	G6(600)
	401PR	101UT	201WR	301DK	302ST2	501PU
L1(4600) 101UT	683.94	3400	298.37	5.85	12.43	220.59
L2(5300) 201WR	521.48		4501.63	88.12	187.57	15.57
L3(300) 202ST1	298.04					8.9
L4(3500) 301DK	188.88			3306.03		5.64
L5(1700) 401PR	1650.94					49.3
L6(300) 501PU						300
	3343.47	3400	4800	3400	200	600

	L1	L2	L3	L4	L5	L6	Sum
G1	0.205	0.156	0.089	0.056	0.494	0.000	1
G2	1.000	0.000	0.000	0.000	0.000	0.000	1
G3	0.062	0.938	0.000	0.000	0.000	0.000	1
G4	0.002	0.026	0.000	0.972	0.000	0.000	1
G5	0.062	0.938	0.000	0.000	0.000	0.000	1
G6	0.368	0.026	0.015	0.009	0.082	0.500	1

Perturbation with G1

	L1	L2	L3	L4	L5	L6
G1	0.202	0.154	0.088	0.057	0.499	0.000

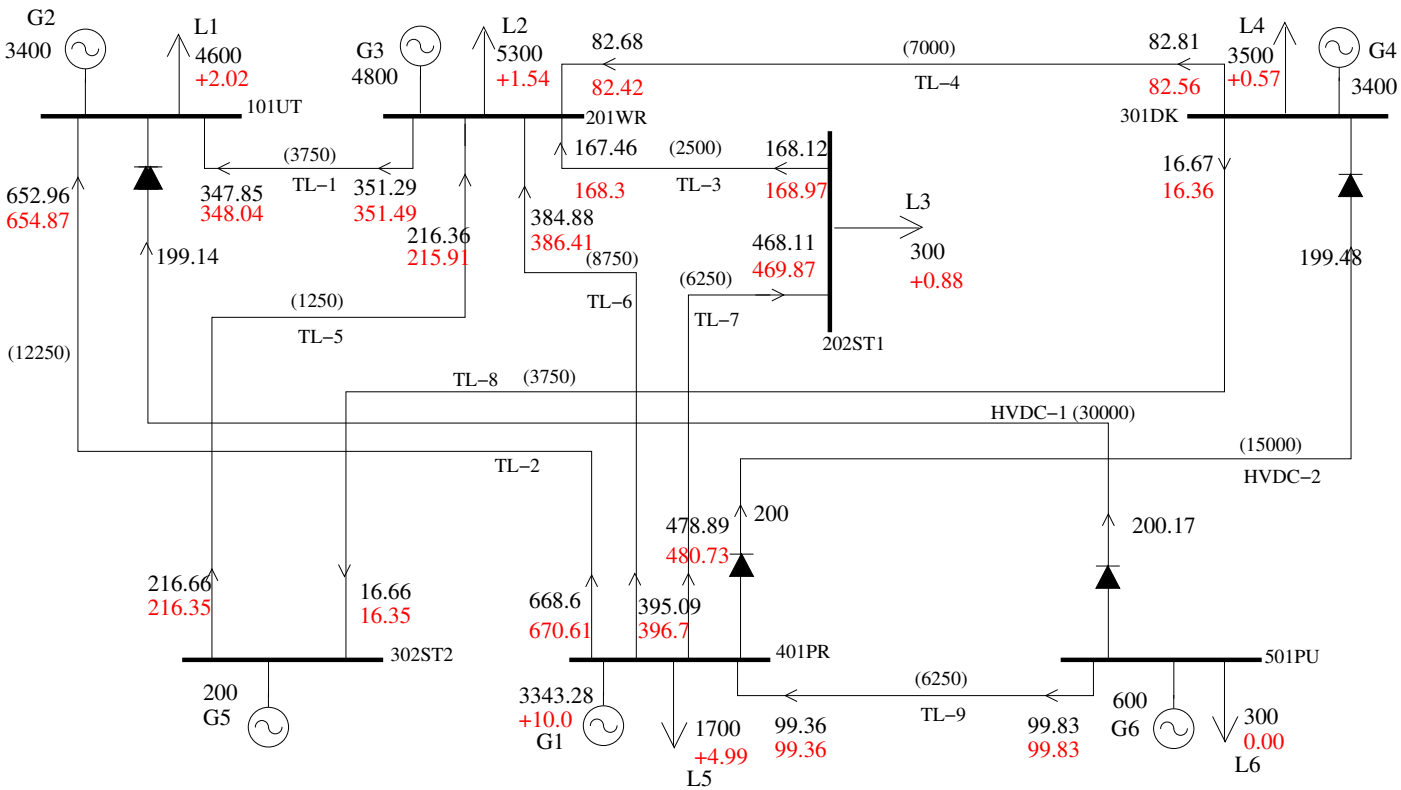

Figure: Perturbation of G1

Marginal Flow Vector:

Entity	Psch	TL-1	TL-2	TL-3	TL-4	TL-5	TL-6	TL-7	TL-8	TL-9
G1	3343.47	0.018	0.196	0.083	-0.031	-0.025	0.157	0.180	-0.025	0.000

Perturbation with G2

	L1	L2	L3	L4	L5	L6
G2	1.000	0.000	0.000	0.000	0.000	0.000

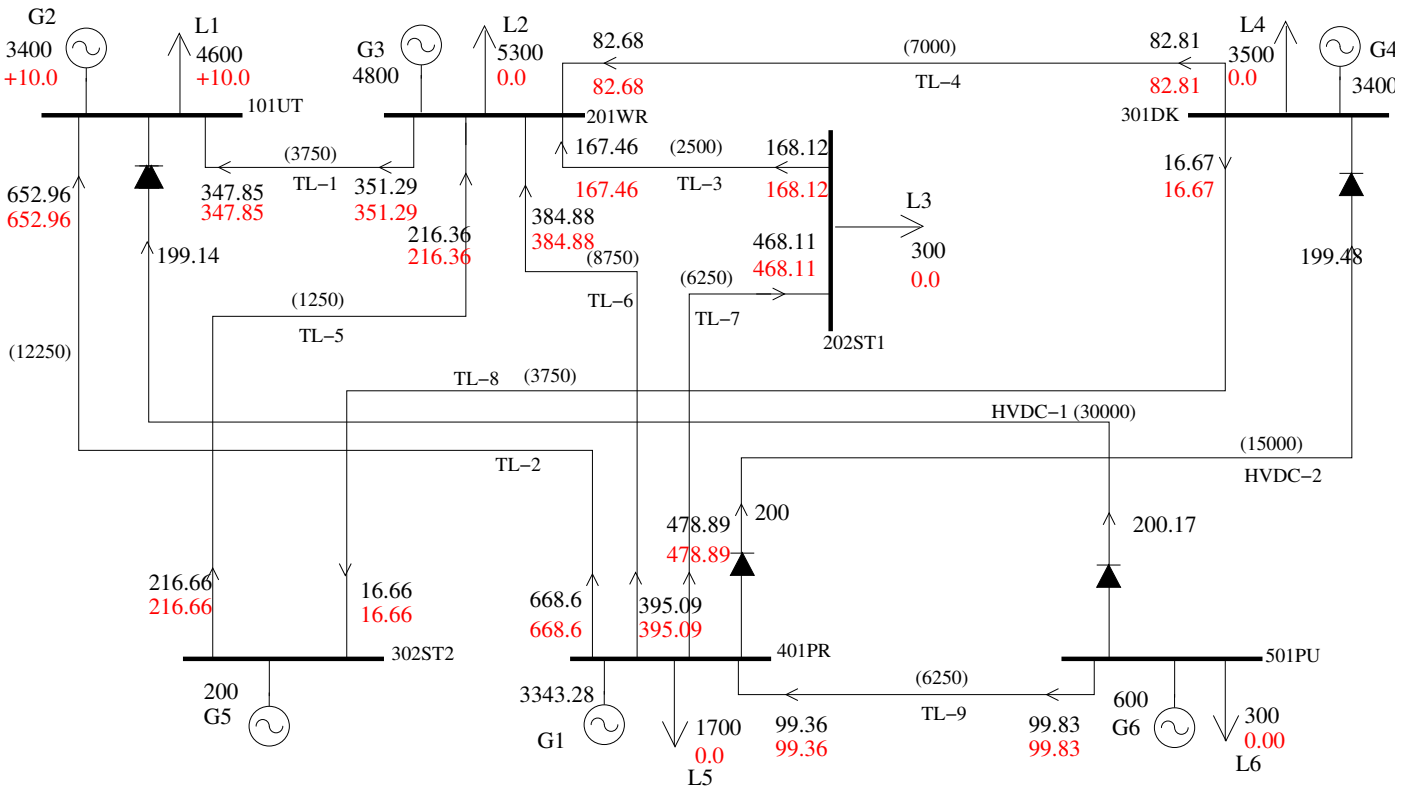

Figure: Perturbation of G2

Marginal Flow Vector:

Entity	Psch	TL-1	TL-2	TL-3	TL-4	TL-5	TL-6	TL-7	TL-8	TL-9
G2	3400	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Perturbation with G3

	L1	L2	L3	L4	L5	L6
G3	0.062	0.938	0.000	0.000	0.000	0.000

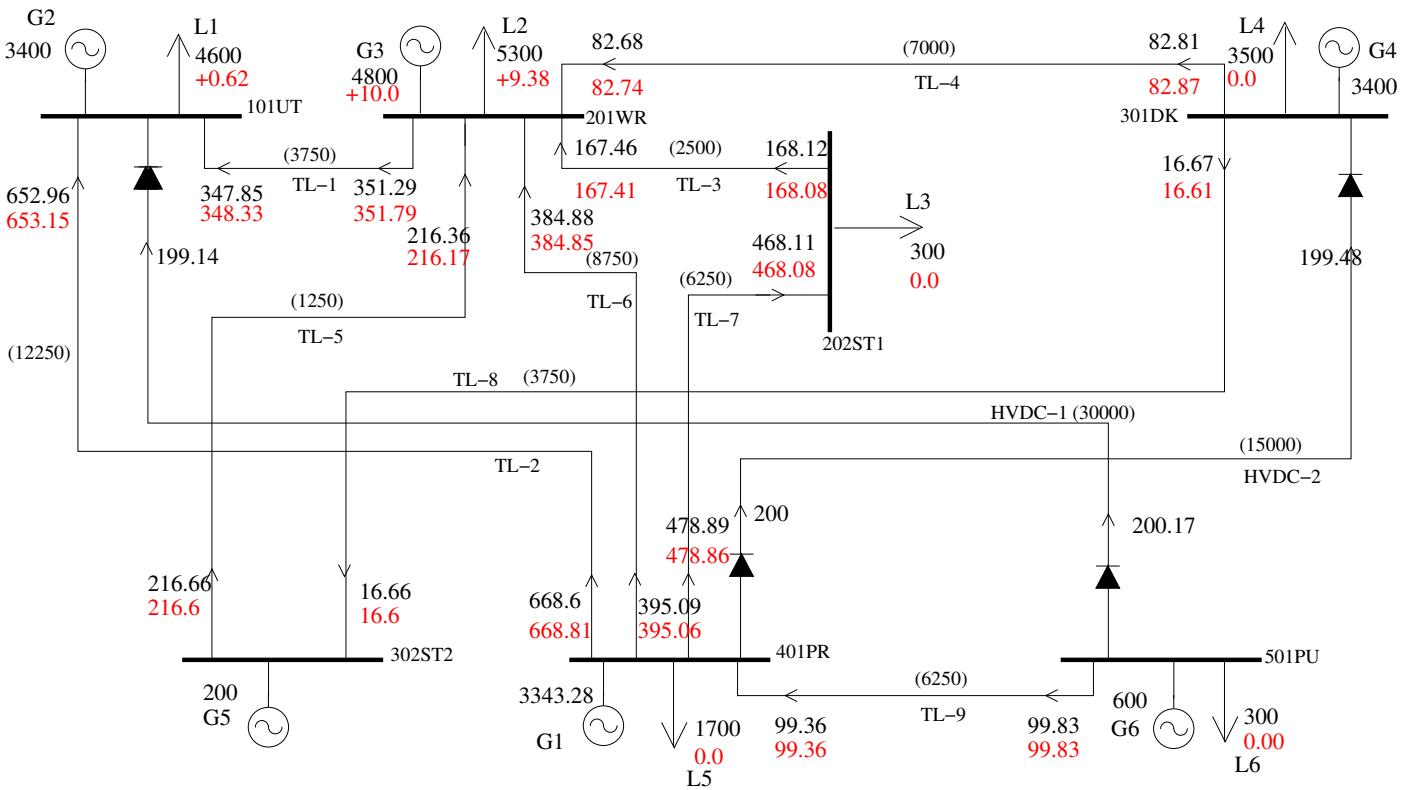

Figure: Perturbation of G3

Marginal Flow Vector:

Entity	Psch	TL-1	TL-2	TL-3	TL-4	TL-5	TL-6	TL-7	TL-8	TL-9
G3	4800	0.048	0.015	-0.007	0.000	0.000	-0.007	-0.007	0.000	0.000

Perturbation with G4

	L1	L2	L3	L4	L5	L6
G4	0.002	0.026	0.000	0.972	0.000	0.000

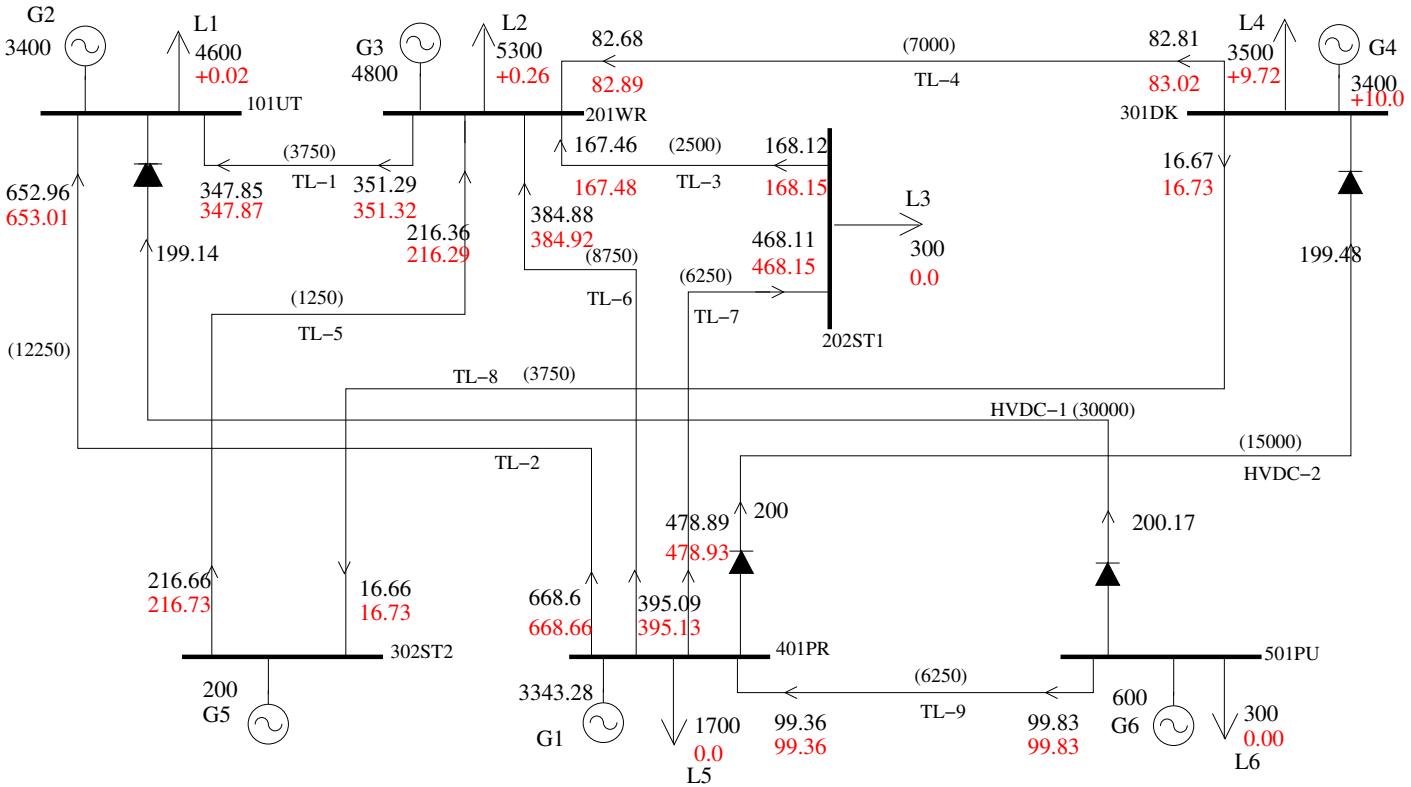

Figure: Perturbation of G4

Marginal Flow Vector:

Entity	Psch	TL-1	TL-2	TL-3	TL-4	TL-5	TL-6	TL-7	TL-8	TL-9
G4	3400	0.001	0.000	0.000	0.015	0.012	0.000	0.000	0.012	0.000

Perturbation with G5

	L1	L2	L3	L4	L5	L6
G5	0.062	0.938	0.000	0.000	0.000	0.000

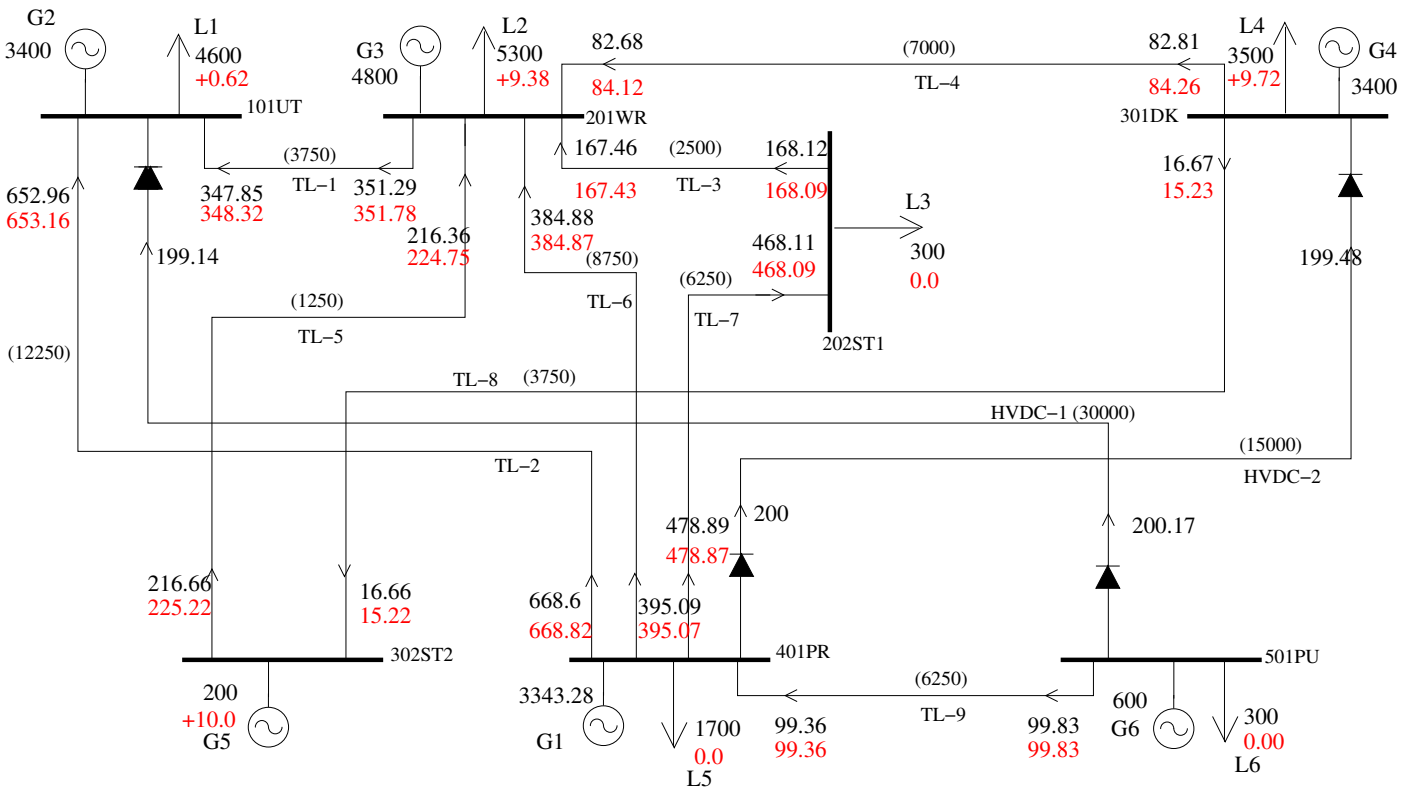

Figure: Perturbation of G5

Marginal Flow Vector:

Entity	Psch	TL-1	TL-2	TL-3	TL-4	TL-5	TL-6	TL-7	TL-8	TL-9
G5	200	0.047	0.017	-0.006	0.138	0.862	-0.006	-0.006	-0.138	0.000

Perturbation with G6

	L1	L2	L3	L4	L5	L6
G6	0.367	0.025	0.014	0.009	0.082	0.502

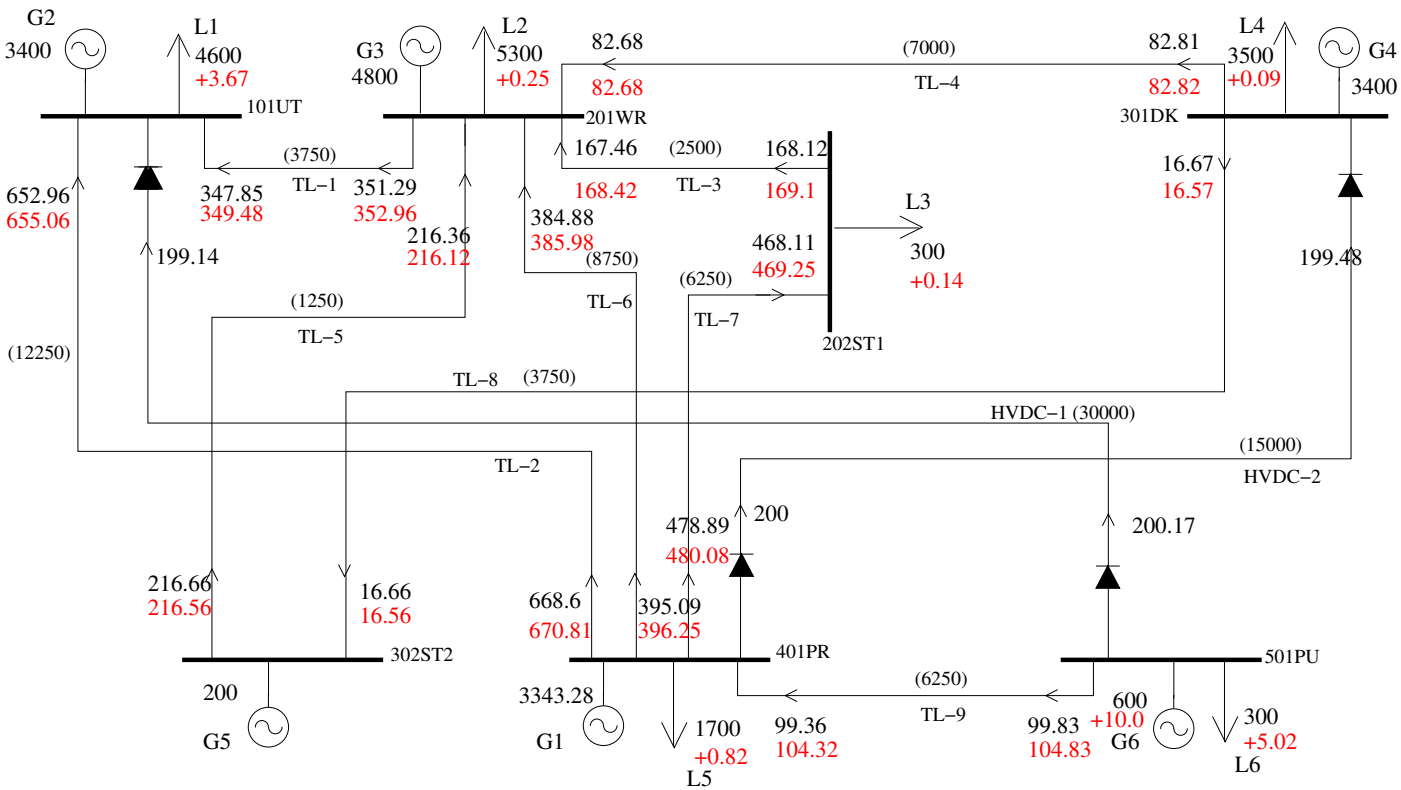

Figure: Perturbation of G6

Marginal Flow Vector:

Entity	Psch	TL-1	TL-2	TL-3	TL-4	TL-5	TL-6	TL-7	TL-8	TL-9
G6	600	0.164	0.216	0.095	-0.005	-0.004	0.112	0.115	-0.004	0.500

Perturbation with L1

	G1	G2	G3	G4	G5	G6
L1	0.148	0.736	0.065	0.001	0.003	0.048

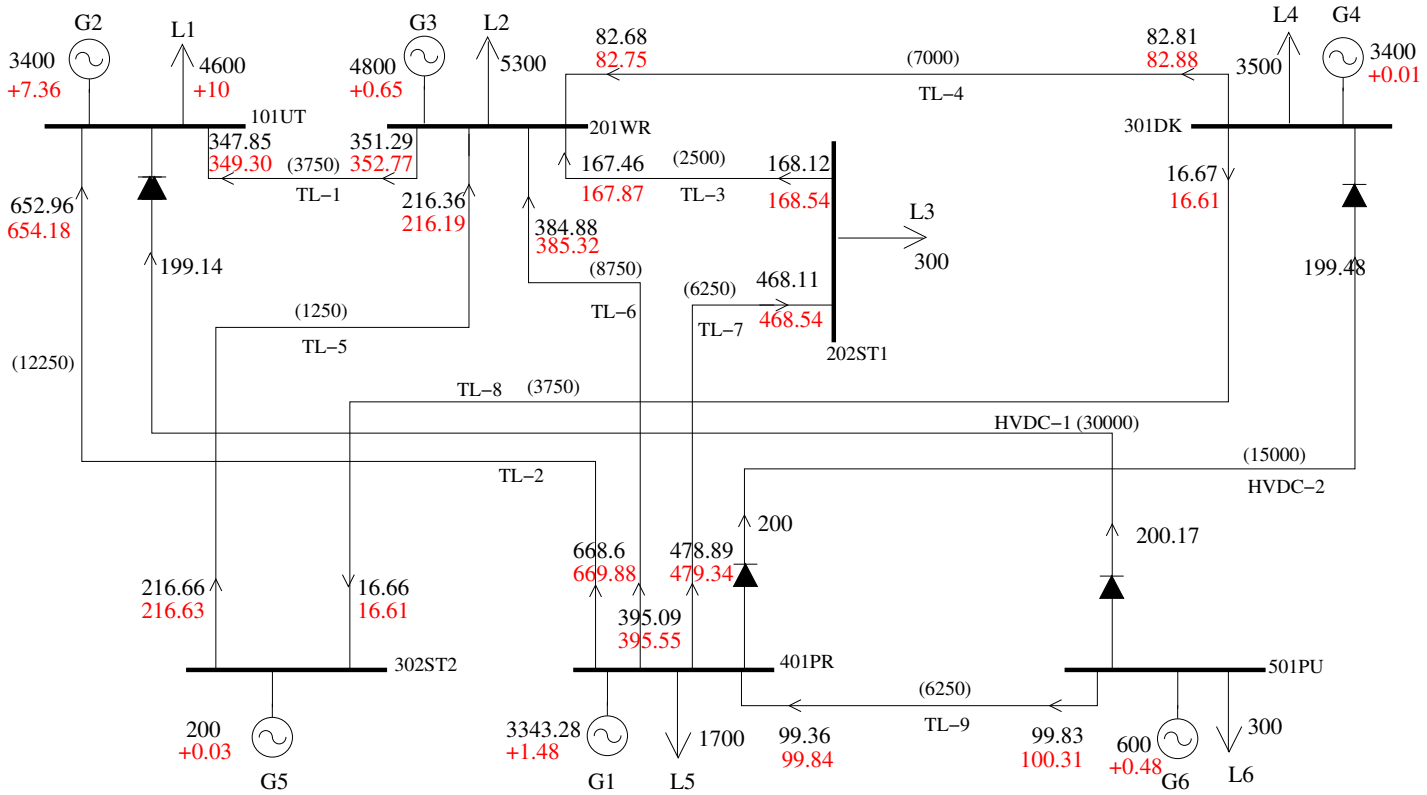

Figure: Perturbation of L1

Marginal Flow Vector:

Entity	Psch	TL-1	TL-2	TL-3	TL-4	TL-5	TL-6	TL-7	TL-8	TL-9
L1	4600	0.146	0.123	0.039	0.001	0.003	0.041	0.041	0.000	0.047

Perturbation with L2

	G1	G2	G3	G4	G5	G6
L2	0.098	0.000	0.847	0.017	0.035	0.003

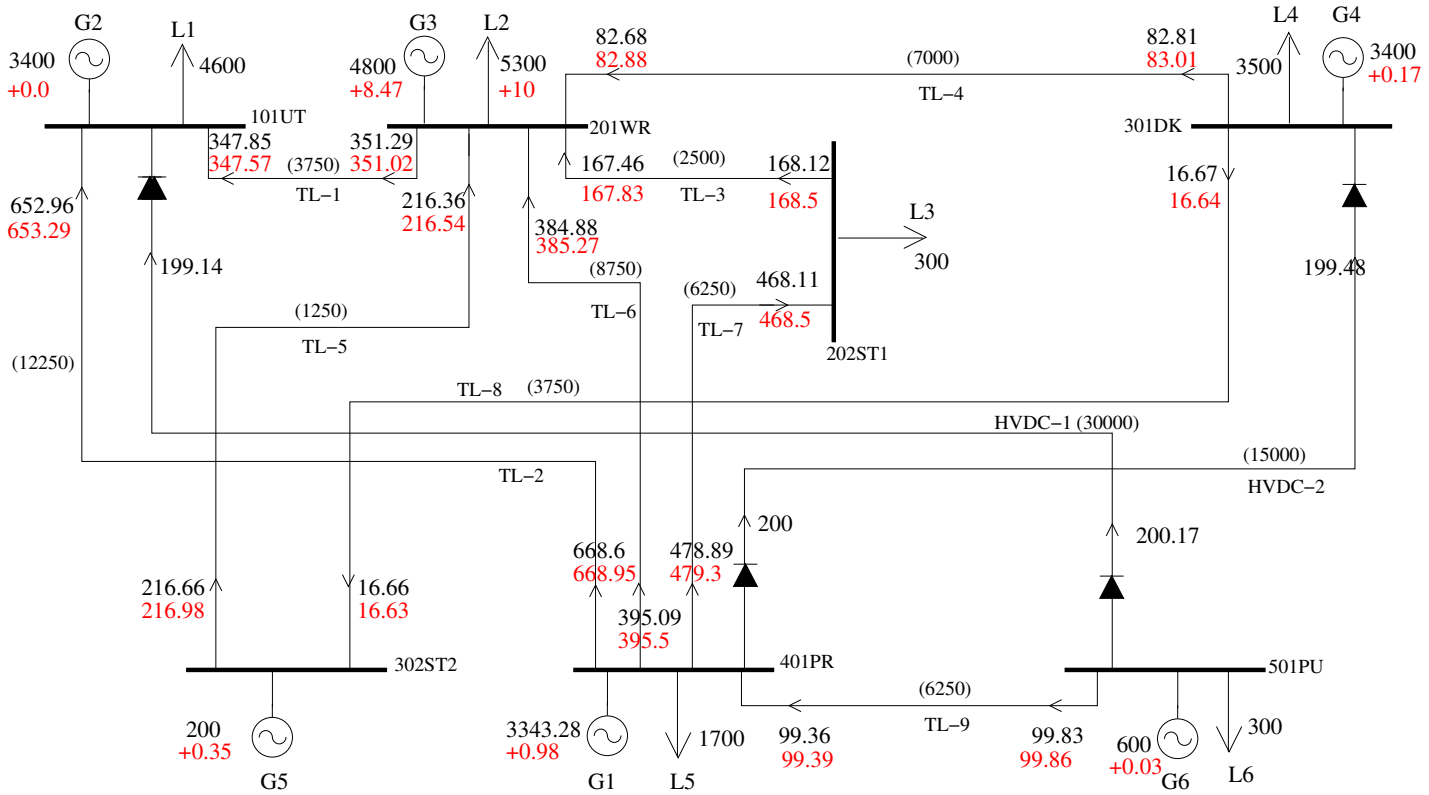

Figure: Perturbation of L2

Marginal Flow Vector:

Entity	Psch	TL-1	TL-2	TL-3	TL-4	TL-5	TL-6	TL-7	TL-8	TL-9
L2	5300	-0.029	0.029	0.035	0.014	0.038	0.037	0.036	0.002	0.003

Perturbation with L3

	G1	G2	G3	G4	G5	G6
L3	0.971	0.000	0.000	0.000	0.000	0.029

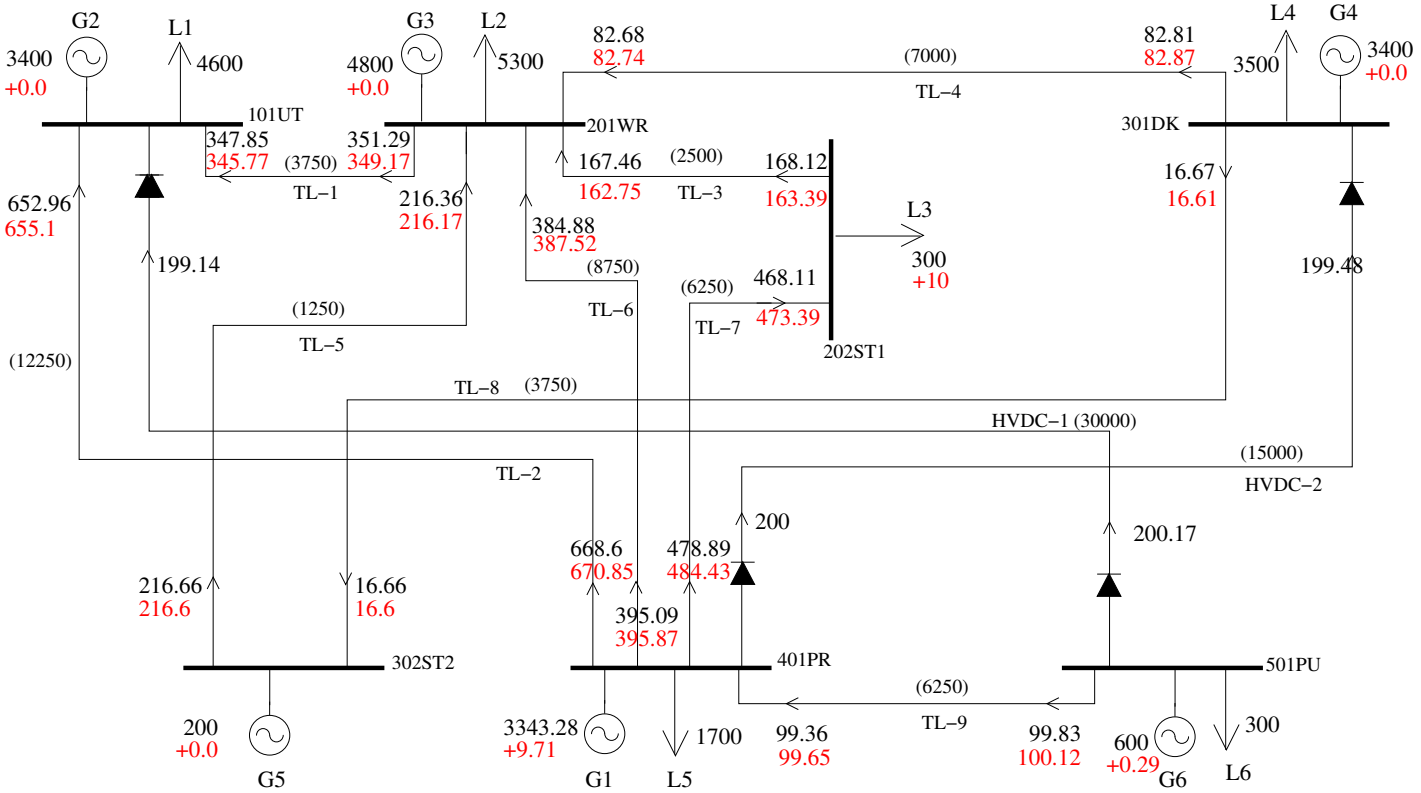

Figure: Perturbation of L3

Marginal Flow Vector:

Entity	Psch	TL-1	TL-2	TL-3	TL-4	TL-5	TL-6	TL-7	TL-8	TL-9
L3	300	-0.214	0.219	-0.476	0.000	0.000	0.274	0.550	0.000	0.029

Perturbation with L4

	G1	G2	G3	G4	G5	G6
L4	0.054	0.000	0.000	0.944	0.000	0.002

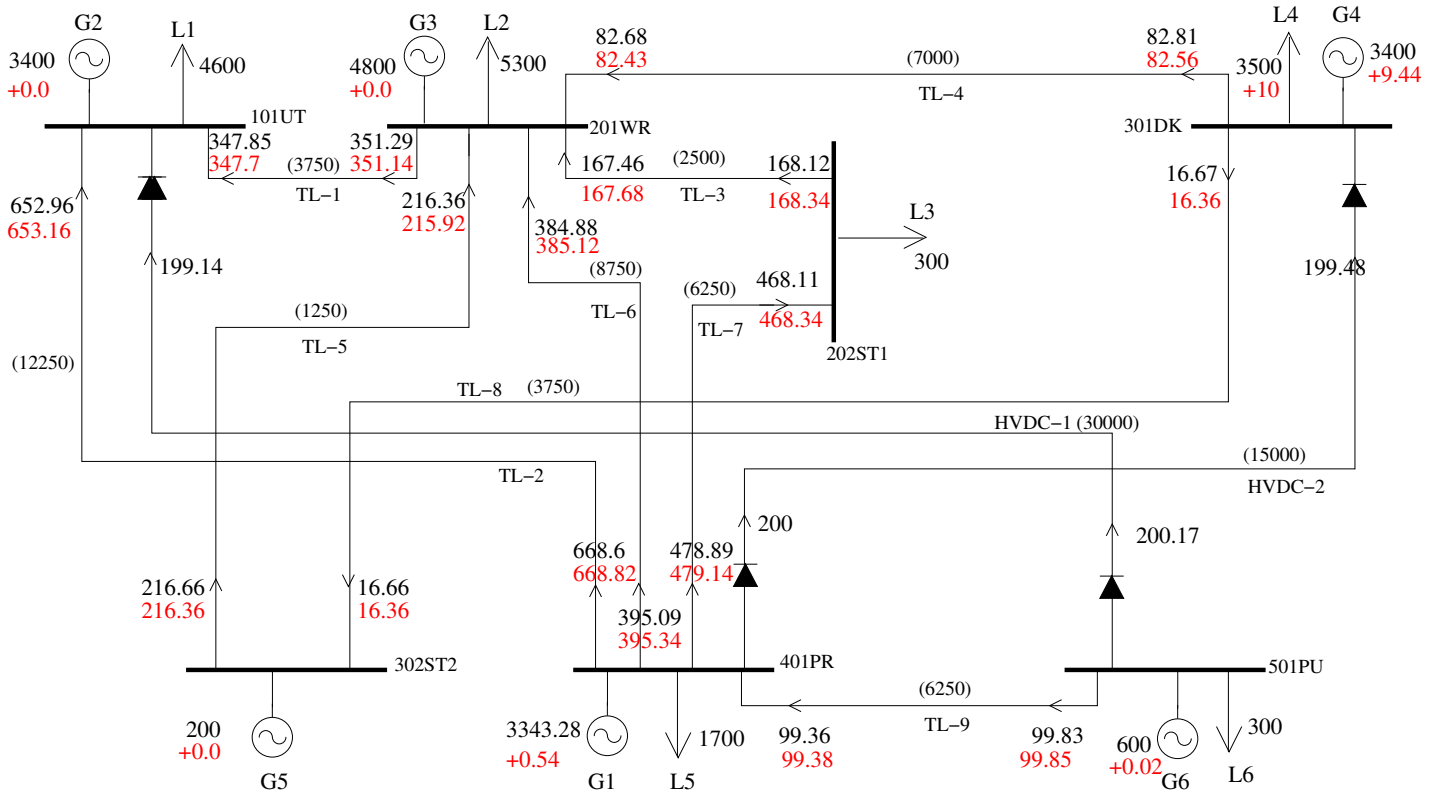

Figure: Perturbation of L4

Marginal Flow Vector:

Entity	Psch	TL-1	TL-2	TL-3	TL-4	TL-5	TL-6	TL-7	TL-8	TL-9
L4	3500	-0.016	0.016	0.019	-0.031	-0.025	0.021	0.020	-0.025	0.002

Perturbation with L5

	G1	G2	G3	G4	G5	G6
L5	0.971	0.000	0.000	0.000	0.000	0.029

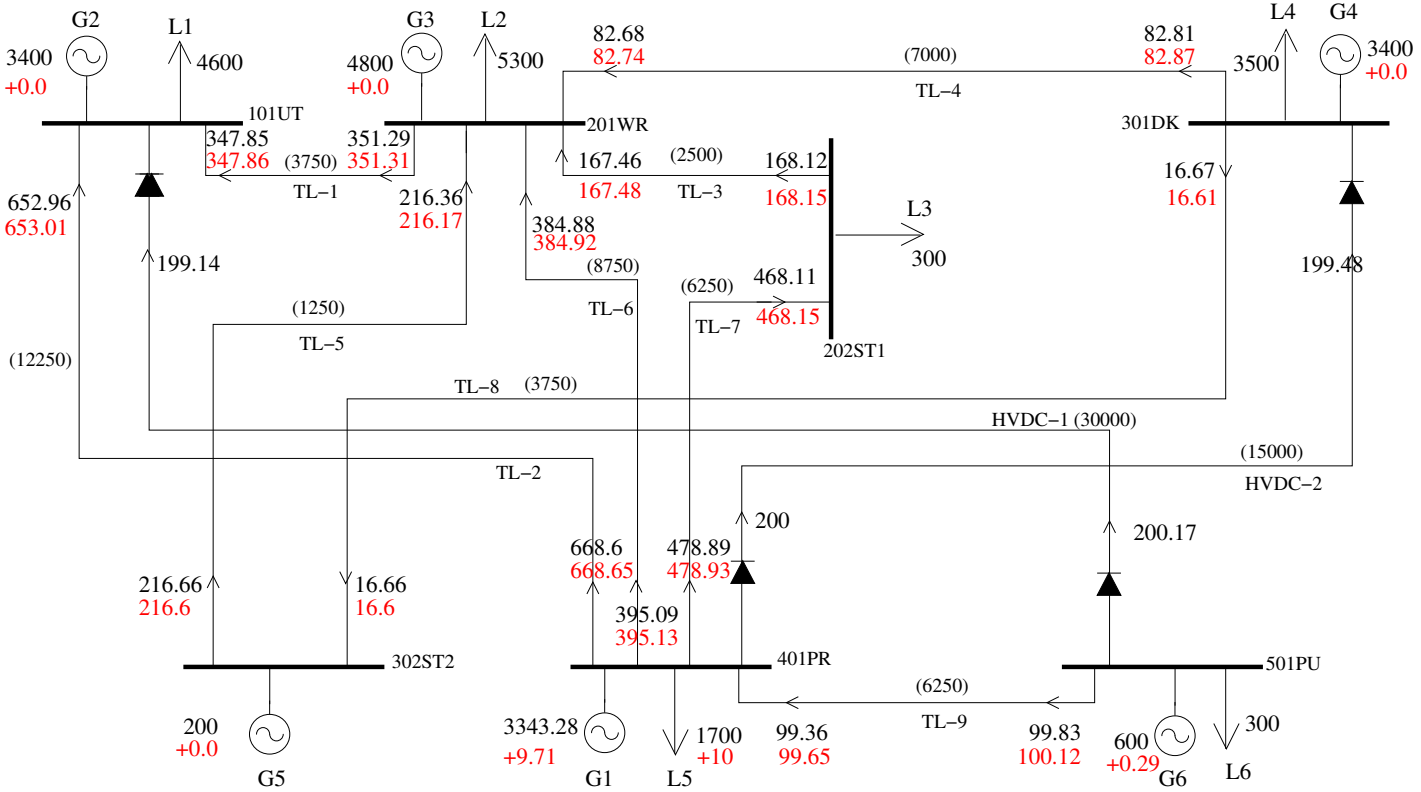

Figure: Perturbation of L5

Marginal Flow Vector:

Entity	Psch	TL-1	TL-2	TL-3	TL-4	TL-5	TL-6	TL-7	TL-8	TL-9
L5	1700	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.029

Perturbation with L6

	G1	G2	G3	G4	G5	G6
L6	0.000	0.000	0.000	0.000	0.000	1.000

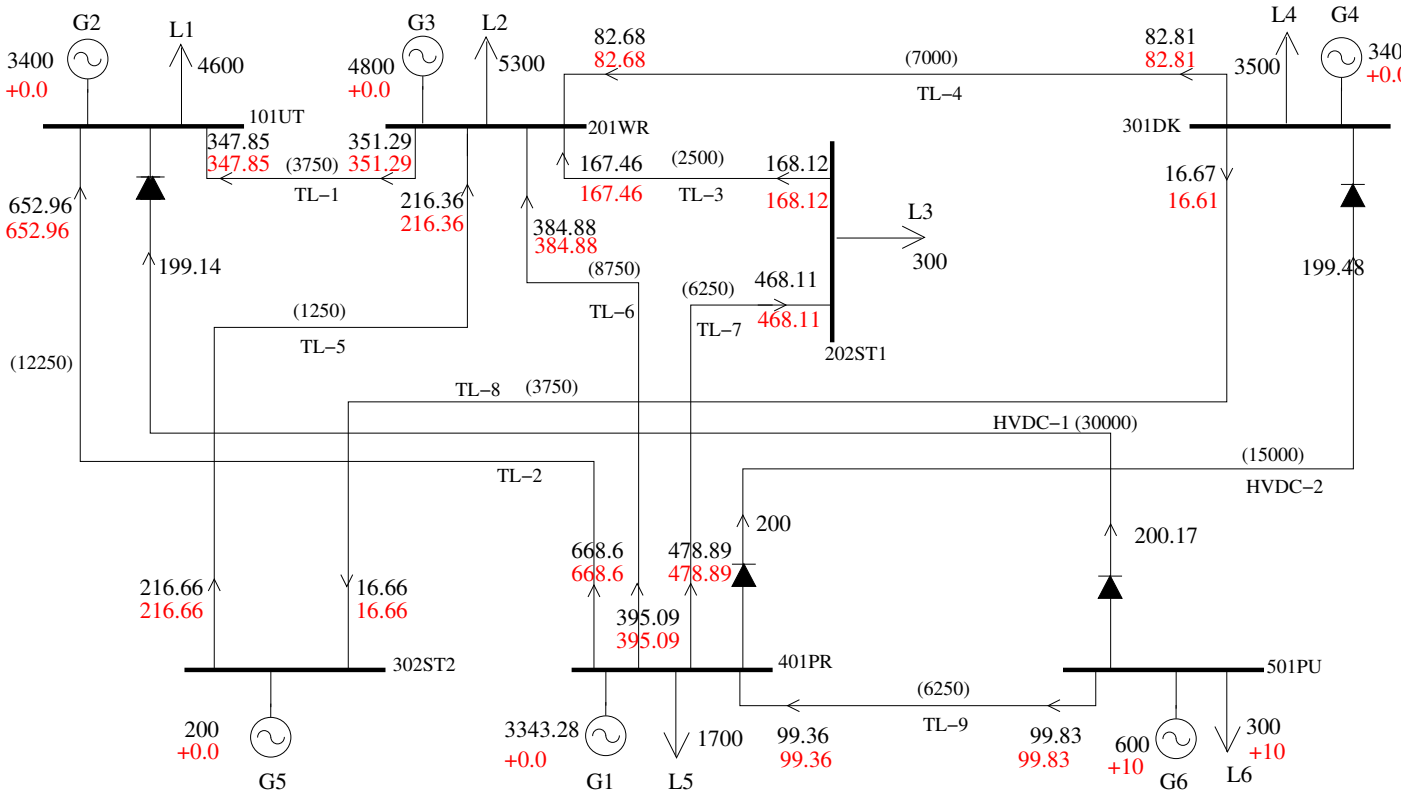

Figure: Perturbation of L6

Marginal Flow Vector:

Entity	Psch	TL-1	TL-2	TL-3	TL-4	TL-5	TL-6	TL-7	TL-8	TL-9
L6	300	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Marginal Flows

Entity	Psch	TL-1	TL-2	TL-3	TL-4	TL-5	TL-6	TL-7	TL-8	TL-9
G1	3343.47	0.018	0.196	0.083	-0.031	-0.025	0.157	0.180	-0.025	0.000
G2	3400	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
G3	4800	0.048	0.015	-0.007	0.000	0.000	-0.007	-0.007	0.000	0.000
G4	3400	0.001	0.000	0.000	0.015	0.012	0.000	0.000	0.012	0.000
G5	200	0.047	0.017	-0.006	0.138	0.862	-0.006	-0.006	-0.138	0.000
G6	600	0.164	0.216	0.095	-0.005	-0.004	0.112	0.115	-0.004	0.500
L1	4600	0.146	0.123	0.039	0.001	0.003	0.041	0.041	0.000	0.047
L2	5300	-0.029	0.029	0.035	0.014	0.038	0.037	0.036	0.002	0.003
L3	300	-0.214	0.219	-0.476	0.000	0.000	0.274	0.550	0.000	0.029
L4	3500	-0.016	0.016	0.019	-0.031	-0.025	0.021	0.020	-0.025	0.002
L5	1700	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.029
L6	300	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Weighted Marginal Flows

Entity	TL-1	TL-2	TL-3	TL-4	TL-5	TL-6	TL-7	TL-8	TL-9
G1	60.85	654.65	275.84	-104.82	-84.26	523.25	601.49	-84.36	0
G2	0	-0.34	-0.34	0	0	-0.34	0	0	0
G3	231.84	73.44	-34.08	-0.29	0	-36	-35.52	-0.19	0
G4	4.42	1.02	-1.02	51.88	41.82	-1.02	-0.68	41.75	0
G5	9.44	3.32	-1.12	27.64	172.38	-1.2	-1.18	-27.65	0
G6	98.64	129.42	56.76	-3.15	-2.52	66.96	68.88	-2.53	300
L1	673.44	565.34	179.86	4.65	12.88	190.44	188.6	0.69	218.5
L2	-153.7	154.76	184.44	74.31	200.34	195.04	192.92	13.09	15.37
L3	-64.05	65.76	-142.71	-0.02	0	82.08	164.88	-0.01	8.73
L4	-56.7	57.05	67.9	-107.66	-86.45	72.1	71.4	-86.66	5.6
L5	-0.17	-0.34	-0.17	-0.1	0	-0.17	-0.17	-0.07	49.47
L6	-0.03	-0.06	-0.03	-0.02	0	-0.03	-0.03	-0.01	0

Neglect Negative Marginal Flow

Entity	TL-1	TL-2	TL-3	TL-4	TL-5	TL-6	TL-7	TL-8	TL-9
G1	60.85	654.65	275.84	0	0	523.25	601.49	0	0
G2	0	0	0	0	0	0	0	0	0
G3	231.84	73.44	0	0	0	0	0	0	0
G4	4.42	1.02	0	51.88	41.82	0	0	41.75	0
G5	9.44	3.32	0	27.64	172.38	0	0	0	0
G6	98.64	129.42	56.76	0	0	66.96	68.88	0	300
L1	673.44	565.34	179.86	4.65	12.88	190.44	188.6	0.69	218.5
L2	0	154.76	184.44	74.31	200.34	195.04	192.92	13.09	15.37
L3	0	65.76	0	0	0	82.08	164.88	0	8.73
L4	0	57.05	67.9	0	0	72.1	71.4	0	5.6
L5	0	0	0	0	0	0	0	0	49.47
L6	0	0	0	0	0	0	0	0	0

Normalization over the line

Entity	TL-1	TL-2	TL-3	TL-4	TL-5	TL-6	TL-7	TL-8	TL-9
G1	0.06	0.38	0.36	0.00	0.00	0.46	0.47	0.00	0.00
G2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G3	0.21	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G4	0.00	0.00	0.00	0.33	0.10	0.00	0.00	0.75	0.00
G5	0.01	0.00	0.00	0.17	0.40	0.00	0.00	0.00	0.00
G6	0.09	0.08	0.07	0.00	0.00	0.06	0.05	0.00	0.50
L1	0.62	0.33	0.24	0.03	0.03	0.17	0.15	0.01	0.37
L2	0.00	0.09	0.24	0.47	0.47	0.17	0.15	0.24	0.03
L3	0.00	0.04	0.00	0.00	0.00	0.07	0.13	0.00	0.01
L4	0.00	0.03	0.09	0.00	0.00	0.06	0.06	0.00	0.01
L5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08
L6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LineCost	3750	12250	2500	7000	1250	8750	6250	3750	6250

Cost allocation of Transmission Lines

Entity	TL-1	TL-2	TL-3	TL-4	TL-5	TL-6	TL-7	TL-8	TL-9
G1	211.56	4704.17	901.67	0.00	0.00	4052.19	2918.34	0.00	0.00
G2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G3	806.02	527.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G4	15.37	7.33	0.00	2291.70	122.30	0.00	0.00	2819.40	0.00
G5	32.82	23.86	0.00	1221.02	504.13	0.00	0.00	0.00	0.00
G6	342.93	929.98	185.54	0.00	0.00	518.55	334.19	0.00	3137.18
L1	2341.30	4062.40	587.93	205.21	37.67	1474.81	915.06	46.59	2284.91
L2	0.00	1112.07	602.91	3282.07	585.90	1510.44	936.02	884.00	160.73
L3	0.00	472.54	0.00	0.00	0.00	635.65	799.97	0.00	91.29
L4	0.00	409.95	221.95	0.00	0.00	558.36	346.42	0.00	58.56
L5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	517.32
L6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Cost allocation of Transmission Lines

Entity	Psch	Cost
G1	3343.47	12787.92
G2	3400	0.00
G3	4800	1333.74
G4	3400	5256.10
G5	200	1781.83
G6	600	5448.39
L1	4600	11955.89
L2	5300	9074.12
L3	300	1999.45
L4	3500	1595.24
L5	1700	517.32
L6	300	0.00

Five + Two system

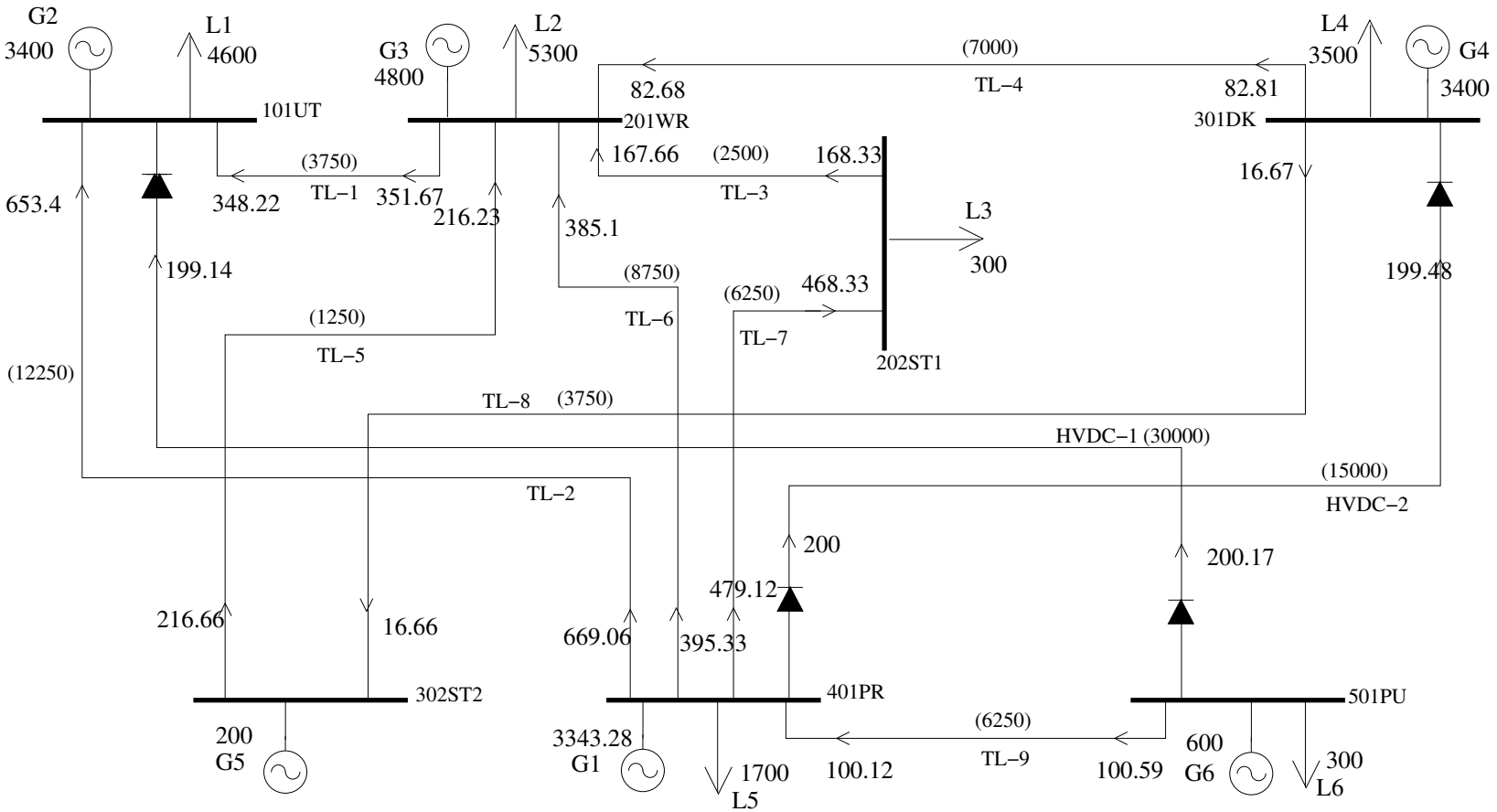

Figure: Five + Two Basic system

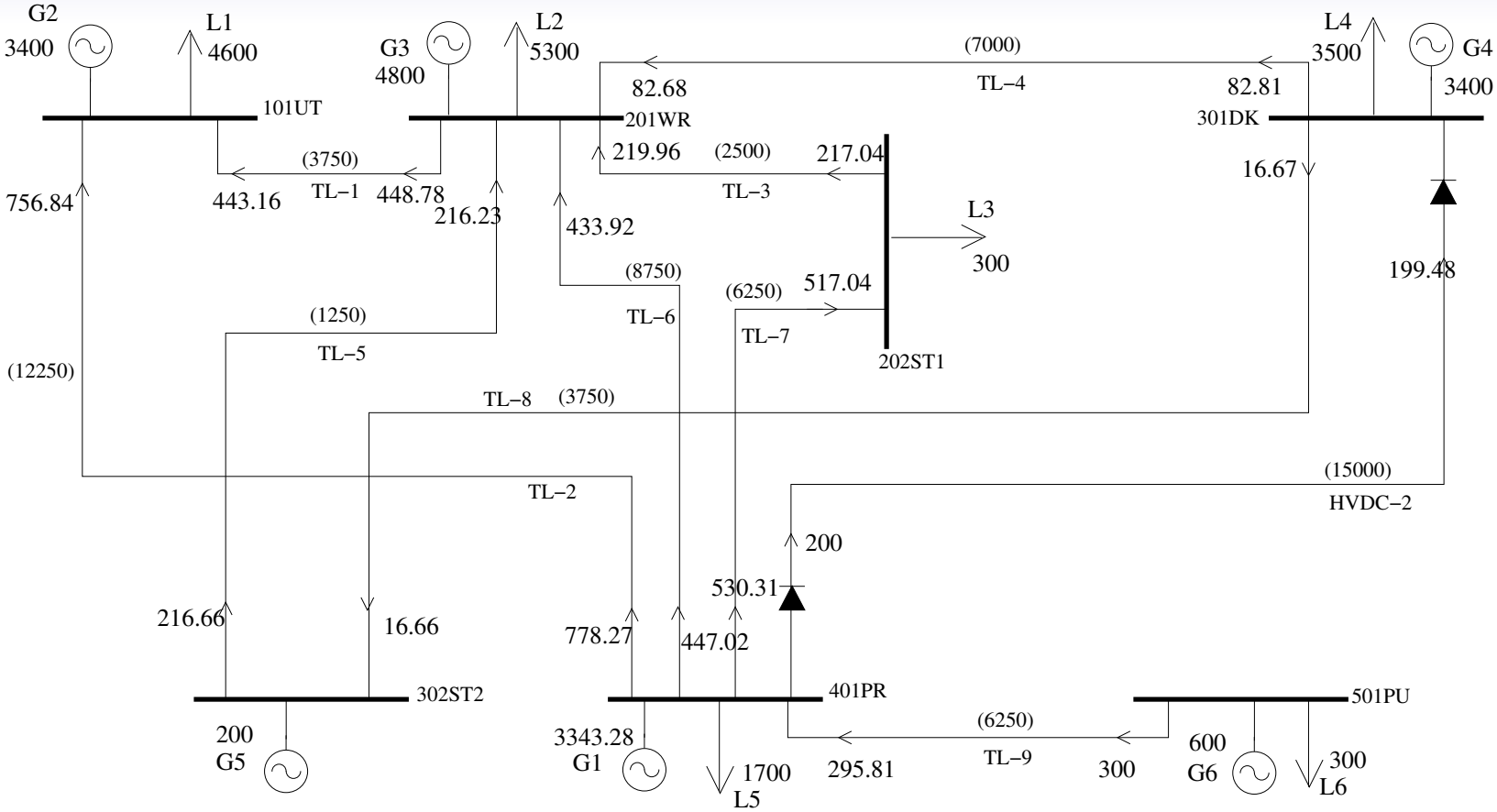

Figure: System without HVDC line 1

repeat the cost allocation for the above network and let the allocated cost vector be *Cost*1

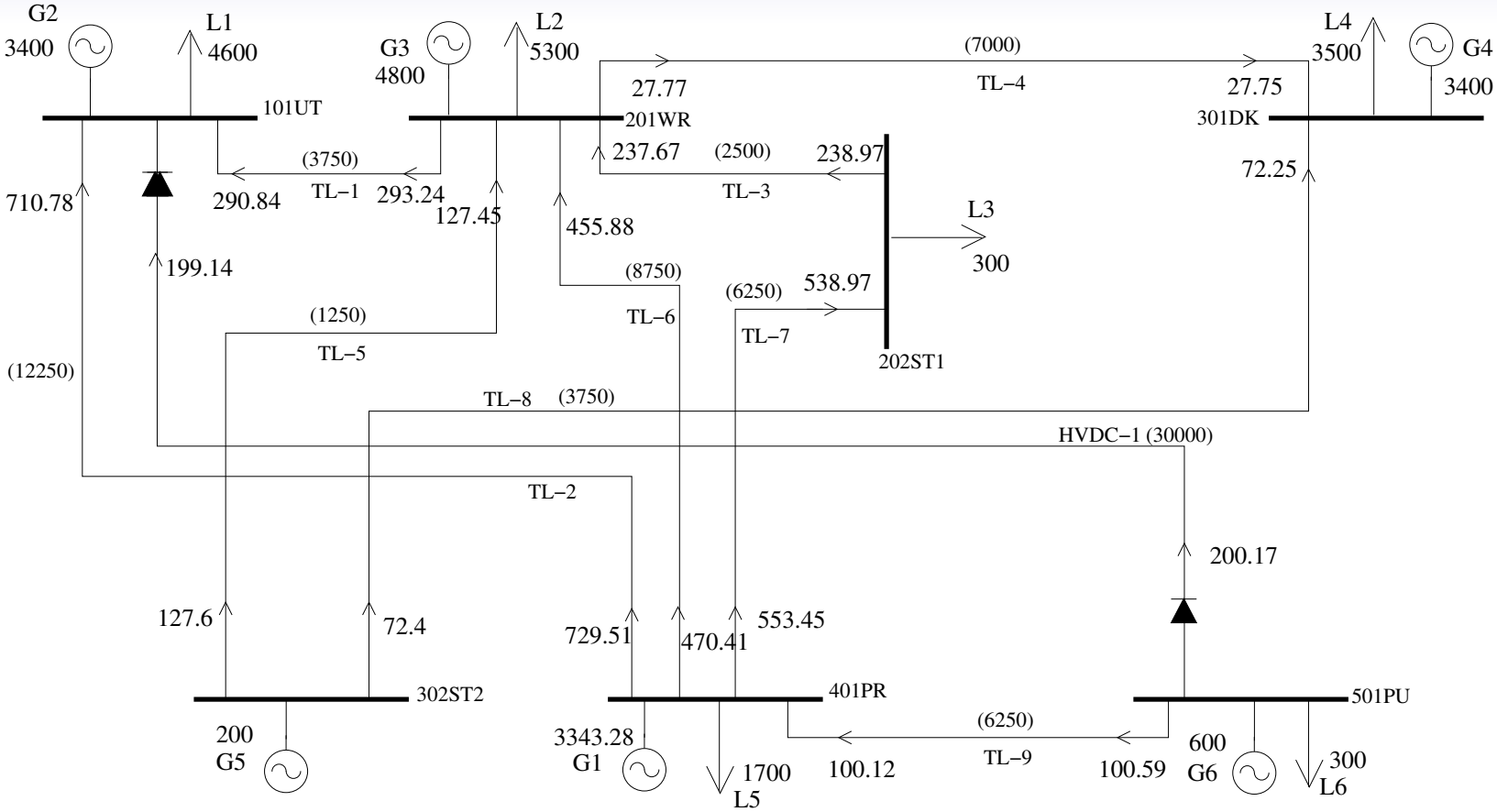

Figure: System without HVDC line 2

repeat the cost allocation for the above network and let the allocated cost vector be *Cost2*

Cost allocation of HVDCLine-1

Assume the allocated cost vector of base network is *Cost*

Entity	Cost	Cost1	Ch_Cost1	N_N_Chng	Normalize	HVDC_Alloc
G1	12787.92	13258.5	470.58	470.58	0.06	881.53
G2	0.00	0	0	0	0	0
G3	1333.74	2652.96	1319.22	1319.22	0.16	2471.25
G4	5256.10	0	-5256.1	0	0	0
G5	1781.83	3474.74	1692.91	1692.91	0.21	3171.27
G6	5448.39	5469.86	21.47	21.47	0	40.23
L1	11955.89	12186.1	230.21	230.21	0.03	431.25
L2	9074.12	6323.75	-2750.37	0	0	0
L3	1999.45	2004.74	5.29	5.29	0	9.92
L4	1595.24	5862.95	4267.71	4267.71	0.53	7994.56
L5	517.32	515.89	-1.43	0	0	0
L6	0.00	0	0	0	0	0
					Sum	15000

Cost allocation of HVDCLine-2

Entity	Cost	Cost2	Ch_Cost1	N_N_Chng	Normalize	HVDC_Alloc
G1	12787.92	13661.9	873.98	873.98	0.27	8228.85
G2	0.00	0	0	0	0	0
G3	1333.74	1637.89	304.15	304.15	0.1	2863.65
G4	5256.10	5260.11	4.01	4.01	0	37.75
G5	1781.83	1795.54	13.71	13.71	0	129.08
G6	5448.39	4389.52	-1058.87	0	0	0
L1	11955.89	9828.52	-2127.37	0	0	0
L2	9074.12	9907.89	833.77	833.77	0.26	7850.22
L3	1999.45	2137.98	138.53	138.53	0.04	1304.35
L4	1595.24	1677.82	82.58	82.58	0.03	777.49
L5	517.32	1452.88	935.56	935.56	0.29	8808.62
L6	0.00	0	0	0	0	0
					Sum	30000

Cost allocation of HVDCLines

Entity	Psch	Cost	HVDC_Alloc1	HVDC_Alloc2	Final_Alloc	POC
G1	3343.4	12787.92	881.53	8228.85	21898.29	6.55
G2	3400	0.00	0	0	0	0.00
G3	4800	1333.74	2471.25	2863.65	6668.64	1.41
G4	3400	5256.10	0	37.75	5293.85	1.58
G5	200	1781.83	3171.27	129.08	5082.19	25.22
G6	600	5448.39	40.23	0	5488.61	9.21
L1	4600	11955.89	431.25	0	12387.14	2.65
L2	5300	9074.12	0	7850.22	16924.34	3.19
L3	300	1999.45	9.92	1304.35	3313.71	11.79
L4	3500	1595.24	7994.56	777.49	10367.29	2.96
L5	1700	517.32	0	8808.62	9325.94	5.35
L6	300	0.00	0	0	0	0.0000

Marginal Loss and Loss Factor

Entity	TL-1	TL-2	TL-3	TL-4	TL-5	TL-6	TL-7	TL-8	TL-9
G1	0.0003	0.0095	0.0007	-0.0001	0.0000	0.0080	0.0082	0.0000	0.0000
G2	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
G3	0.0009	0.0008	-0.0001	0.0000	0.0000	-0.0004	-0.0003	0.0000	0.0000
G4	0.0000	0.0001	0.0000	0.0001	0.0000	0.0000	0.0001	0.0000	0.0000
G5	0.0009	0.0009	0.0000	0.0004	0.0035	-0.0004	-0.0002	-0.0001	0.0000
G6	0.0032	0.0104	0.0007	0.0000	0.0000	0.0058	0.0053	0.0000	0.0048
L1	0.0028	0.0061	0.0002	0.0000	0.0000	0.0021	0.0020	0.0000	0.0005
L2	-0.0006	0.0016	0.0003	0.0001	0.0001	0.0020	0.0018	0.0000	0.0001
L3	-0.0042	0.0107	-0.0026	0.0000	0.0000	0.0143	0.0254	0.0000	0.0003
L4	-0.0004	0.0009	0.0002	-0.0001	-0.0001	0.0011	0.0010	0.0000	0.0000
L5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003
L6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

$$lossfactor = \frac{\partial systemloss}{\partial schedule} \tag{1}$$

Weighted Marginal loss

Entity	Psch	LossFactor	WLF	N-WLF	LossAlloc
G1	3343.28	0.0266	88.831	0.390	17.293
G2	3400	0.0001	0.340	0.001	0.066
G3	4800	0.0009	4.320	0.019	0.841
G4	3400	0.0003	0.884	0.004	0.172
G5	200	0.0050	1.006	0.004	0.196
G6	600	0.0302	18.108	0.080	3.525
L1	4600	0.0137	63.066	0.277	12.278
L2	5300	0.0053	28.355	0.125	5.520
L3	300	0.0439	13.170	0.058	2.564
L4	3500	0.0026	9.030	0.040	1.758
L5	1700	0.0003	0.510	0.002	0.099
L6	300	0.0000	0.000	0.000	0.000

WLF is Weighted Loss Factor

N-WLF is normalized Weighted Loss Factor

Total loss of the system is: 43.32 MW

Discussion!.....

Thank you..