or no equations associated with each bus. The corrections are left in memory for the variable updating routine. Note that as control variables hit limits, the control may be relaxed and afterward reinstated.

NEWVAR

This function updates the independent variables (voltage magnitude and angle) by applying the corrections calculated by the solution subroutine. The corrected variables are then used to build the next iteration's Jacobian matrix and calculate the new mismatch vector.

6.15 EXAMPLE 6A: AC POWER FLOW CASE

The six-bus network shown in Figure 6.18 will be used to demonstrate several aspects of power flows here and in other chapters of this book.

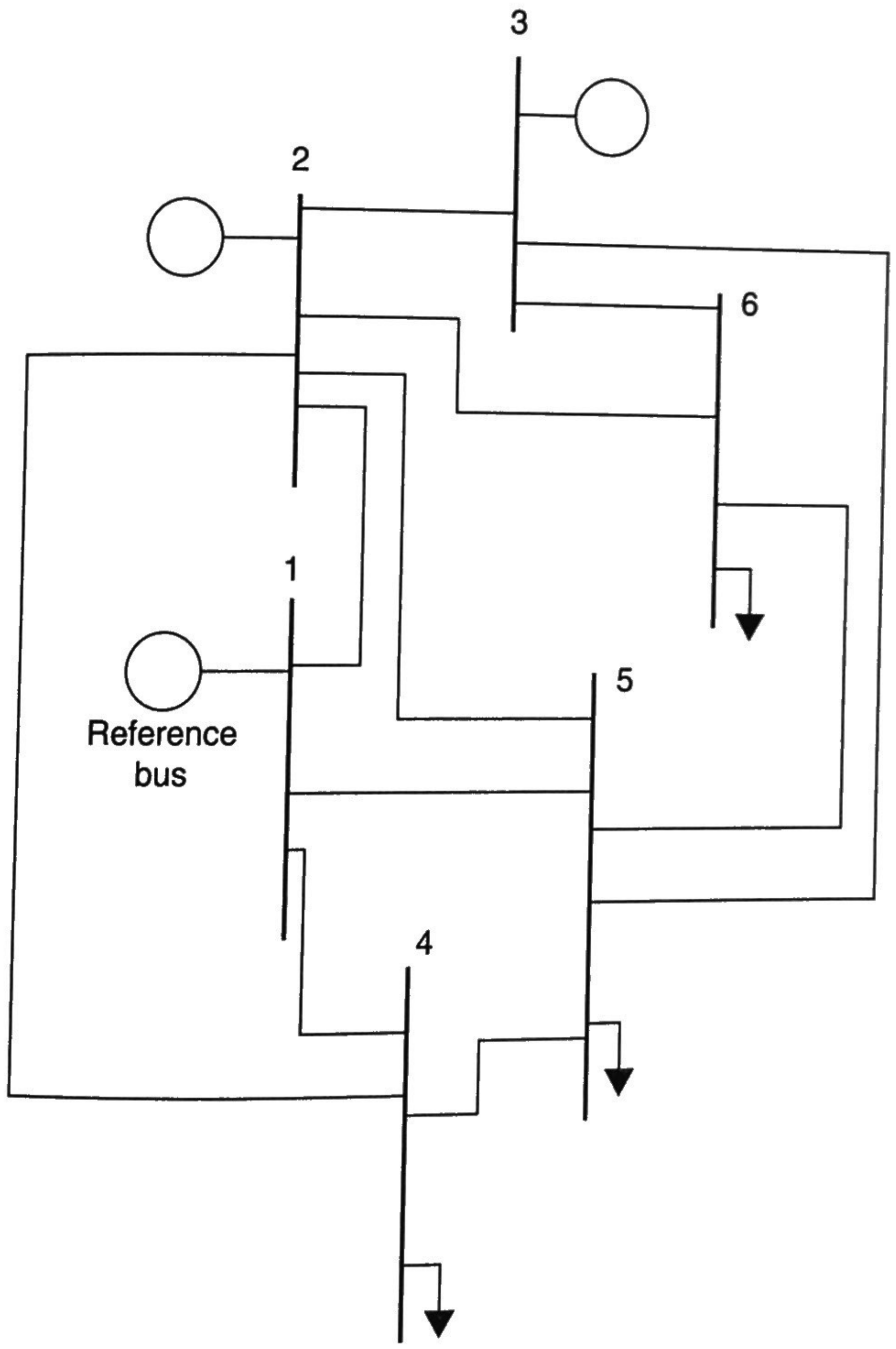

FIGURE 6.18 Six-bus sample system.

This example has a "base case" of 300 MW and 45 MVAR total load. The impedance values and other data for this system are shown here:

Bus Data

Bus Number	Type	P_{load}	Q_{load}	G_s	B_s	Area	V_{mag}	θ	baseKV	Zone	V_{max}	V_{min}
1	3	0	0	0	0	1	1	0	230	1	1.07	0.95
2	2	0	0	0	0	1	1	0	230	1	1.07	0.95
3	2	0	0	0	0	1	1	0	230	1	1.07	0.95
4	1	100	15	0	0	1	1	0	230	1	1.07	0.95
5	1	100	15	0	0	1	1	0	230	1	1.07	0.95
6	1	100	15	0	0	1	1	0	230	1	1.07	0.95

Type 3 = swing bus, type 2 = generator bus, type 1 = load bus

Generator Data

Bus	P_{gen}	Q_{gen}	Q_{max}	Q_{min}	V_{gen}	MVABase	Status	P_{max}	P_{min}
1	110	0	150	−100	1.07	100	1	200	50
2	50	0	150	−100	1.05	100	1	150	37.5
3	50	0	120	−100	1.05	100	1	180	45

Branch Data

Frombus	Tobus	r	x	b	rateA	rateB	rateC	Ratio	Angle	Status
1	2	0.1	0.2	0.04	100	0	0	0	0	1
1	4	0.05	0.2	0.04	100	0	0	0	0	1
1	5	0.08	0.3	0.06	100	0	0	0	0	1
2	3	0.05	0.25	0.06	60	0	0	0	0	1
2	4	0.05	0.1	0.02	60	0	0	0	0	1
2	5	0.1	0.3	0.04	60	0	0	0	0	1
2	6	0.07	0.2	0.05	60	0	0	0	0	1
3	5	0.12	0.26	0.05	60	0	0	0	0	1
3	6	0.02	0.1	0.02	60	0	0	0	0	1
4	5	0.2	0.4	0.08	60	0	0	0	0	1
5	6	0.1	0.3	0.06	60	0	0	0	0	1

Generator Cost Function Data

CostCurveType	StartUp	ShutDown	NumCoeff	c	b	a
2	0	0	3	0.00533	11.669	213.1
2	0	0	3	0.00889	10.333	200
2	0	0	3	0.00741	10.833	240

Power Flow Execution Results

Voltages are all within their limits of 0.95–1.07 pu; the reference bus is scheduled at 1.07 pu and is therefore labeled as UL for upper limit.

All reactive power limits are being met and all line flows are within their MW limits.
All loads are at the base case value of 100 MW and 15 MVAR.
The real and reactive power losses are small.

```
Newton Raphson Convergence Steps
Iter  MAXDP     MAXDPbus  MAXDQ     MAXDQbus  NumVARlim  NumVlim
1     0.825895  6         0.618486  6         0          1
2     0.097117  2         0.142304  5         0          1
3     0.001265  2         0.002313  5         0          1

POWER FLOW RESULTS

Total Pgen     =   328.58  MW     Total Qgen     =   67.74  MVAR
Total PLoad    =   300.00  MW     Total Qload    =   45.00  MVAR
Total PLosses  =    28.58  MW     Total QLosses  =   22.74  MVAR
```

Bus	Pmin MW	Pgen MW	Pmax MW	Qmin MVAR	Qgen MVAR	Qmax MVAR	Pload MW	Qload MVAR	Vmin pu	Vbus pu	Vbus kV	Vmax pu
1	50.0	228.6	450.0	-100.0	-32.2	150.0	0.0	0.0	0.95	1.07 UL	246.1	1.07
2	37.5	50.0	150.0	-100.0	75.7	150.0	0.0	0.0	0.95	1.05	241.5	1.07
3	45.0	50.0	180.0	-100.0	24.2	120.0	0.0	0.0	0.95	1.05	241.5	1.07
4							100.0	15.0	0.95	0.99	228.0	1.07
5							100.0	15.0	0.95	1.01	233.3	1.07
6							100.0	15.0	0.95	1.02	235.4	1.07

Bus	Vmag kV	angle deg	Pgen MW	Qgen MVAR	Pload MW	Qload MW	To Bus	Pline MW	Qline MVAR		Max Flow MW
1	246.1	0.00	228.58	-32.18	0.00	0.00					
							2	123.57	-35.59	UL	100
							5	105.01	3.42	UL	100
2	241.5	-14.46	50.00	75.71	0.00	0.00					
							1	-109.27	59.71	UL	100
							3	11.35	-5.42		60
							4	93.09	17.20	UL	60
							5	15.60	5.30		60
							6	39.22	-1.07		60
3	241.5	-15.99	50.00	24.20	0.00	0.00					
							2	-11.29	-0.89		60
							5	8.92	7.52		60
							6	52.37	17.57		60
4	228.0	-19.08			100.00	15.00					
							2	-89.01	-11.12	UL	60
							5	-10.99	-3.88		60
5	233.3	-16.57			100.00	15.00					
							1	-97.27	19.08		100
							2	-15.33	-8.74		60
							3	-8.72	-12.41		60
							4	11.23	-3.68		60
							6	10.08	-9.24		60
6	235.4	-18.58			100.00	15.00					
							2	-38.25	-1.51		60
							3	-51.81	-16.91		60
							5	-9.95	3.42		60

limits_indicator

Bus	Pgen	Qgen	Vgen
1	228.58	-32.18	1.0700 UL
2	50.00	75.71	1.0500
3	50.00	24.20	1.0500

```
Symbols: UL = Upper Limit Reached or exceeded
         pu = per unit
```

6.16 THE DECOUPLED POWER FLOW

The Newton power flow is the most robust power flow algorithm used in practice. However, one drawback to its use is the fact that the terms in the Jacobian matrix must be recalculated each iteration and then the entire set of linear equations in Equation 6.27 must also be resolved each iteration.

Since thousands of complete power flows are often run for a planning or operations study, ways to speed up this process were sought. One way to speed up the calculation is to use a technique known as the "fast decoupled power flow" (it is often referred to as the "Stott decoupled power flow," in reference to its first author).