

# Programming Project : Admittance Matrix and Power/Load-Flow

EE 581

April 19, 2012

## 1 Introduction

This project will be to develop your own power-flow (also known as load-flow) solver to study balanced, three-phase power systems in sinusoidal steady-state. The program will read in data from three files (bus, line and transformer) to construct the power system's admittance matrix and then utilize the Newton-Raphson method to solve for the system's power-flow. Your project will be demonstrated on two power systems (5-bus and 9-bus) to verify operation.

## 2 Input Specifications

The desired format of your input and power system description is three sets (to be three sections of one input file, or three files) of data. The three sets of data are listed below.

1. bus data (in per unit where applicable) - number, type (slack, PV or PQ), magnitude and phase angle of voltage at bus, and average and reactive power injected by generator and load into bus
  - (a) note some values will be constants (knowns) in solution process and others will be initial conditions for the solver
  - (b) this table will look like Table 6.1 (without  $Q_{Gmax}, Q_{Gmin}$ ) of the text and Table 7.1 of the handout where unknowns will be initial guesses
2. line data (in per unit where applicable) - from bus, to bus, series resistance and reactance, shunt conductance and susceptance, thermal limit represented by apparent power, and practical stability limit represented by average power
  - (a) this table will look like Table 6.2 of the text with the addition of a column for practical line loadability
3. transformer data (in per unit where applicable) - from bus, to bus, series resistance and reactance, shunt conductance and susceptance, apparent power rating
  - (a) this table will look like Table 6.3 of the text without "Maximum TAP"

### 3 Output Specifications

The desired output of your project is the following.

1. formatted display of the full admittance matrix
2. bus table of the same form as the input data except with initial, unknown values replaced with solutions from the Newton-Raphson algorithm
  - (a) this table will look like Table 6.6 of the text and Table 7.1 of the handout
3. line power table that provides average, reactive and apparent power transferred; and what percent they are of their thermal (VApu) and practical loadability (Wpu) limits
  - (a) this table will look like Table 6.7 of the text with the addition of columns for percent of thermal and practical loadability limits
4. transformer power table that provides average, reactive and apparent power transferred; and what percent they are of their apparent power (VApu) rating
  - (a) this table will look like Table 6.8 of the text with the addition of a column for percent of apparent power rating

### 4 Test Systems

#### 4.1 5-bus

The 5-bus system is shown in Figure 6.2 of the text with specific data labeled on the diagram and given in Tables 6.1-6.4. Assume a base power of  $S_B = 100$  MVA, thermal limit of  $|S_{therm}| = 11$  VApu for each line, and practical loadability limits of  $|P_{prac}| = 4.7, 9.5, 19.0$  Wpu for lines 2-4, 2-5, 4-5, respectively.

Check your project using the admittance matrix given in Figure 6-3 and power-flow results given in Tables 6.6-6.8.

#### 4.2 9-bus

The 9-bus system is shown in Figure 7.4 of the handout with specific data labeled on the diagram (note impedances and admittances are given in pu). Assume a base power of  $S_B = 100$  MVA, thermal limit of  $|S_{therm}| = 145$  MVA for each line, practical loadability limits of  $|P_{prac}| = 176, 162, 88, 83, 210, 147$  MW for lines 4-5, 4-6, 5-7, 6-9, 7-8, 8-9, respectively, and 160 MVA rating for all transformers. You will need to create input tables of the same form as described above and used for the 5-bus system.

Check your project using the admittance matrix given in Table 7.2 of the handout and power-flow results given in Table 7.1 of the handout.

### 5 Results

Write a short report that summarizes your approach/program, data files and test systems, and presents results (tables) for the two test cases. Include input data files and power-flow program in appendices.

In addition, mail a copy of your program and data files to the instructor, so they can be ran and tested.

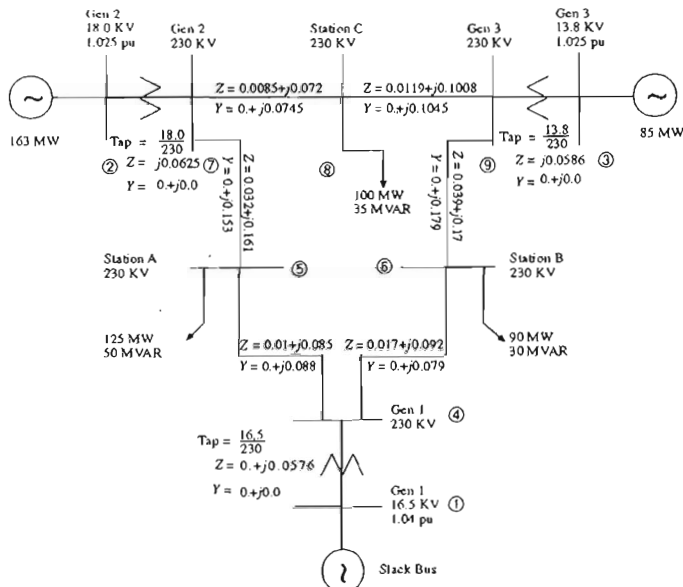


Figure 7.4: WSCC 3-machine, 9-bus system; the value of  $Y$  is half the line charging (Copyright 1977. Electric Power Research Institute. EPRI EL-0484. Power System Dynamic Analysis, Phase I. Reprinted with Permission.).

Table 7.1: Load-Flow Results of the WSCC 3-Machine, 9-Bus System

	Bus #	Voltage (pu)	$P_G$ (pu)	$Q_G$ (pu)	$-P_L$ (pu)	$-Q_L$ (pu)
	1 (swing)	1.04	0.716	0.27	-	-
	2 (P-V)	1.025 $\angle$ 9.3°	1.63	0.067	-	-
	3 (P-V)	1.025 $\angle$ 4.7°	0.85	-0.109	-	-
	4 (P-Q)	1.026 $\angle$ -2.2°	-	-	-	-
	5 (")	0.996 $\angle$ -4.0°	-	-	1.25	0.5
	6 (")	1.013 $\angle$ -3.7°	-	-	0.9	0.3
	7 (")	1.026 $\angle$ 3.7°	-	-	-	-
	8 (")	1.016 $\angle$ 0.7°	-	-	1.00	0.35
	9 (")	1.032 $\angle$ 2.0°	-	-	-	-

Table 7.2:  $\bar{Y}_N$  for the Network in Figure 7.4

	1	2	3	4	5	6	7	8	9
1	$-j17.361$	0	0	$j17.361$	0	0	0	0	0
2	0	$-j16$	0	0	0	0	$j16$	0	0
3	0	0	$-j17.065$	0	0	0	0	0	$j17.065$
4	$j17.361$	0	0	3.307	-1.365	-1.942	0	0	0
5	0	0	0	$-j39.309$	$+j11.604$	$+j10.511$	0	0	0
6	0	0	0	-1.365	2.553	0	-1.188	0	0
7	0	0	0	$+j11.604$	$-j17.338$	0	$+j5.975$	0	0
8	0	0	0	-1.942	0	3.224	0	0	-1.282
9	0	0	$j17.065$	$+j10.511$	0	$-j15.841$	0	0	$+j5.588$
1	0	$j16$	0	0	-1.188	0	2.805	-1.617	0
2	0	0	0	0	$+j5.975$	0	$-j35.4460$	$+j13.698$	0
3	0	0	0	0	0	0	-1.617	2.772	-1.155
4	0	0	0	0	0	0	$+j13.698$	$-j23.303$	$+j9.784$
5	0	0	0	0	0	-1.282	0	-1.155	2.437
6	0	0	0	0	0	$+j5.588$	0	$+j9.784$	$-j32.1540$