CHAPTER 7

SIMULATION STUDIES

In this chapter, simulation method is presented. The load models proposed in the previous chapters are used in the simulation studies to find load characteristics due to change in voltage and frequency. The proposed models are also compared with the models often used such as constant impedance model.

7.1 Computer simulation method

In order to represent load behaviors during various conditions, a computer programme is developed. The programme is written in FORTRAN on a VAX computer.

The calculation method can be described with a flowchart shown in figure 7.1

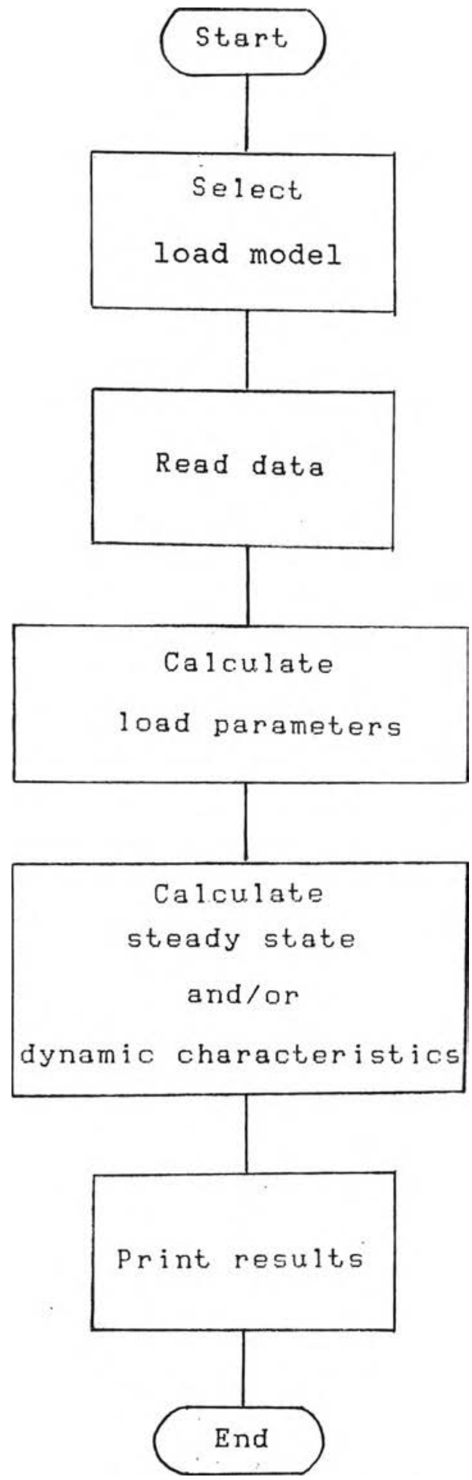

Figure 7.1 Flowchart

7.2 Simulation of exponential model

A simple three buses system with two generators are used to demonstrate the proposed exponential load model. The system is shown in Figure 7.2. Bus 3 is chosen to demonstrate load behavior under steady state and dynamic conditions.

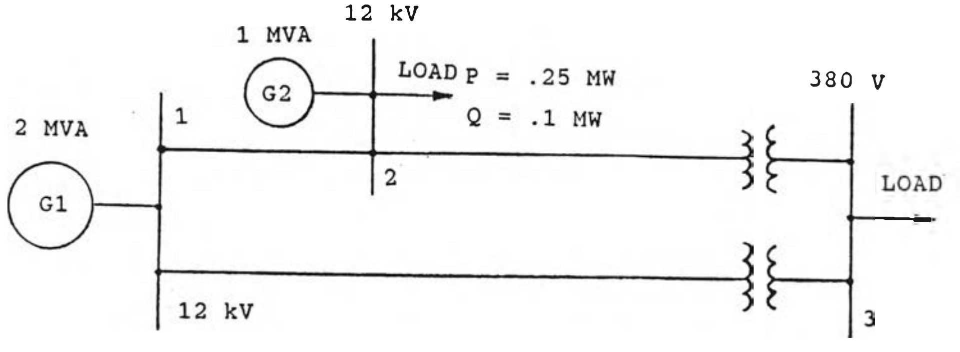

Figure 7.2 Exponential model studied system

The load flow solutions of the system are obtained from SIMPOW, which is a power system simulation programme developed by ABB company, and used as initial conditions for the exponential load model. During disturbances the voltage and frequency at bus 3 are calculated by SIMPOW and used as inputs to the developed programme to derive active and reactive power of loads at bus 3.

There are some studied cases that used voltage and frequency variations provided in the developed programme. The objective is to observe load characteristics against various disturbances that may occur in a real power system.

The results of the proposed model are also compared with SIMPOW and some traditional used model such as constant impedance model.

Table 7.1 presents the simulation results shown in the figures in Appendix 4.

Table 7.1

Simulation results by exponential model

Load case	Description	Figure no.
1	rated condition V = 380 V. P = 940 kW Q = 600 kVAR np = 2.0 nq = 1.4 mp = 1.0 mq = -2.0 Fig. A4.1-A4.2 show steady state characteristics Fig. A4.3 shows voltage and frequency during gen.2 disconnected Fig. A4.4-A4.5 show power of load during gen.2 disconnected Fig. A4.6 shows voltage and frequency during load bus 2 disconnected Fig. A4.7-A4.8 show power of load during load bus 2 disconnected	A4.1-A4.8
2	rated condition V = 380 V. P = 1000 kW Q = 700 kVAR 30 % induction motor np = 0.1 nq = 0.6 mp = 2.8 mq = 1.8 50 % fluorescent	A4.9-A4.20

	np = 1.2 nq = 3.0 mp = -1.0 mq = -2.8 20 % incandescent np = 1.6 Fig. A4.9-A4.10 show steady state voltage characteristics used aggregate and constant impedance model respectively Fig. A4.11-A4.12 show steady state frequency characteristics used aggregate and constant impedance model respectively Fig. A4.13 shows voltage and frequency during gen.2 disconnected Fig. A4.14-A4.15 show power of load during gen.2 disconnected used SIMPOW and developed programme Fig. A4.16 shows power when used constant impedance model Fig. A4.17 shows voltage and frequency during load bus 2 disconnected Fig. A4.18-A4.19 show power of load during load bus 2 disconnected used SIMPOW and developed programme Fig. A4.20 shows power when used constant impedance model	
3	rated condition V = 380 V. P = 3000 kW Q = 2400 kW 60 % air conditioner	A4.21-A4.28

np = 0.0883 nq = 2.51

mp = 0.98 mq = -1.319

20 % fluorescent

20 % incandescent

Fig. A4.21-A4.22 show steady state characteristics used aggregate model

Fig. A4.23 shows voltage and frequency during frequency dip

Fig. A4.24-A4.25 show power of load during frequency dip used aggregate and constant MVA model

Fig. A4.26 shows voltage and frequency during voltage dip

Fig. A4.27-A4.28 show power of load during voltage dip used aggregate and constant current model

7.3 Simulation of induction motor model

The system used for simulation of induction motor model are shown in Figure 7.3

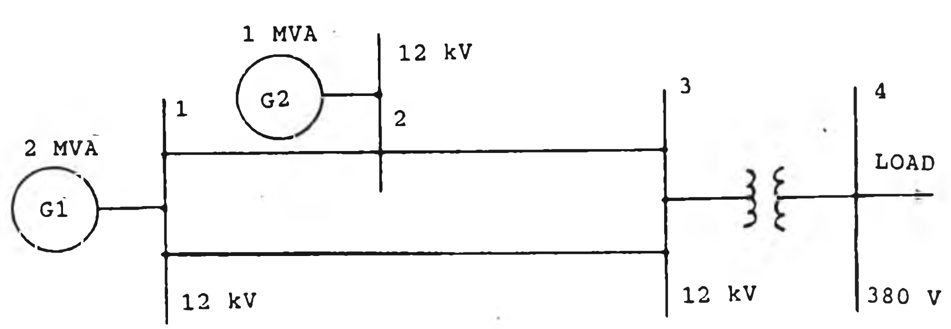

Figure 7.3 Induction motor model studied system

Induction motors are connected at bus 4, voltage and frequency at bus 4 are calculated by SIMPOW as in the cases of exponential model.

Simulation results based on aggregate induction motor model are compared with that based on individual representation. The proposed induction motor model is also compared with the usually used load model (e.g. constant impedance, constant power, etc.)

Table 7.2 presents the simulation results shown in the figures in Appendix 4.

Table 7.2

Simulation results by induction motor model

Load case	Description	Figure no.
1	MOT1 250 kW 380 V.	A4.29 - A4.42
	H = 1.5348 Tm = 1.0	
	Rs = .0414 Xs = .0794	
	Rr = .0169 Xr = .0794	
	Xm = 2.8019	
	MOT2 200 kW 380 V.	
	H = 1.5424 Tm = $0.75*w_r$	
	Rs = .0474 Xs = .0926	
	Rr = .0204 Xr = .0926	
	Xm = 2.5818	
	MOT3 400 kW 380 V.	
	H = .7846 Tm = $0.8*w_r**2$	
	Rs = .0311 Xs = .0781	
	Rr = .0110 Xr = .0781	
	Xm = 2.0309	
	Fig. A4.29-A4.32 show steady state characteristics used aggregate and individual induction motor model	
	Fig. A4.33 shows voltage and frequency during 3 phase fault at bus 3	
	Fig. A4.34-A4.35 show power of load during 3 phase fault used aggregate and individual induction motor model	

	Fig. A4.36-A4.38 show load characteristics when used constant impedance model Fig. A4.39 shows voltage and frequency during gen.2 disconnected Fig. A4.40-A4.42 show power of load when used aggregate and individual motor model and constant current model	
2	3 motors as case 1 and MOT4 355 kW 380 V. H = 2.0392 Tm = 0.8 Rs = .0330 Xs = .0729 Rr = .0104 Xr = .0610 Xm = 2.2189 MOT5 90 kW 380 V. H = .7228 Tm = 0.9*w_r**2 Rs = .0505 Xs = .0701 Rr = .0160 Xr = .0904 Xm = 2.1968 Fig. A4.43-A4.46 show steady state characteristics used aggregate motor model and constant impedance model Fig. A4.47 shows voltage and frequency when gen.1 disconnected Fig. A4.48-A4.50 show power of load used aggregate and individual motor model and constant impedance model	A4.43 - A4.50

7.4 Simulation of composite load

The system used is the same as in figure 7.3, loads are connected at bus 4.

Simulation results based on proposed composite load model are compared with the conventional model (e.g. constant power, etc.)

Table 7.3 presents the simulation results shown in the figures in Appendix 4.

Table 7.3

Simulation results of composite load

Load case	Description	Figure no.
1	MOT1, MOT2, MOT3 P = 200 kW Q = 150 kVAR np = 1.2 nq = 3.0 mp = -1.0 mq = -2.8 Fig. A4.51-A4.54 show steady state characteristics used composite and conventional model Fig. A4.55 shows voltage and frequency during gen.2 disconnected Fig. A4.56-A4.57 show power of load used composite and conventional model	A4.51 - A4.57
2	the same as case 1 and P = 100 kW Q = 300 kVAR np = 1.6 Fig. A4.58 shows voltage and frequency during 3	A4.58 - A4.60

	phase fault at bus 3 Fig. A4.59-A4.60 show power of load used composite and conventional model