CHAPTER 4

EXPONENTIAL MODEL

In this chapter, exponential model is described in detail. Method for grouping load components at a load bus is presented.

4.1 Mathematical formulation

There are many expressions for exponential model (i.e. $P = P_o * V^n$, $P = P_o * V^n * (1+b * \Delta f)$), the expression chosen here is similar to that used in ref.[7]. The active and reactive power demand of loads are assumed to be represented by the following equation :

$$P(t) = P_o * (V(t)/V_o)^{np} * (f(t)/f_o)^{mp}$$

$$Q(t) = Q_o * (V(t)/V_o)^{nq} * (f(t)/f_o)^{mq}$$

where the subscript o refers to nominal values.
np, mp, nq, mq are load characteristic parameters.

4.2 Load characteristic parameters

To use exponential model, it is necessary to know the load characteristic parameters. The characteristics of many load elements are well known, for example, fluorescent lamps, incandescent lamps. If they are not known, they may be found from theorectical analysis or experiment.

Many works concerning load models have published these parameters, some typical values of them are presented in Table 4.1

Table 4.1

Load parameters for exponential model

Load type	np	nq	mp	mq	Ref.
Fluorescent lamp	1.0	-	-	-	1
	1.2	3.0	-1.0	-2.8	7
Incandescent lamp	1.6	-	-	-	1
	1.5-2	-	-	-	4
	1.6	0	0	0	7
Heating	2.0	-	-	-	1
	2.0	0	0	0	7
Induction motor					
full load	0.1	0.6	2.8	1.8	7
half load	0.2	1.6	1.5	-0.3	7
Air conditioner	0.5	2.5	0.6	-2.8	8
Residential	1.5-2	3-4	-	-	18
	1.9	1.6	-	-	23
Industrial	0.2	0.6	-	-	23

From Table 4.1, the load characteristic parameters for load components usually vary from 0-3.0 in magnitude. A difference between residential loads and industrial loads can be observed. The value of parameter np of residential loads is about 2.0, shows that the load contains a major portion of constant impedance load components.

As a matter of fact, the load characteristic parameters of composite loads are not constant. They may change in a day and in a year due to qualitative change of system loads. For example, in summer air conditioner loads are greater than in winter.

In a real power system, it is not easy to find the adequate numerical values of load parameters. However, this problem is not deal with here.

In this work, a method is derived how to find a model of a composite load when the percentage of the different components of the load are known e.g. lamps, heaters etc.

4.3 Grouping load at a load bus

To build a load model at a load bus, it is necessary to combine several load components together to one equivalent model.

The data required for this purpose are :

- load characteristics data, which present load element characteristics
- load composition data, which describe the demand of each load components.

To find aggregate load parameters, the method presented in ref.[7] is used. If there are k load components connected to the bus, the aggregate load parameters are calculated by the following equations :

$$np = \sum_{i=1}^{k} np_i * P_i / P_o$$

$$mp = \sum_{i=1}^{k} mp_i * P_i / P_o$$

$$nq = \sum_{i=1}^{k} nq_i * Q_i / Q_o$$

$$mq = \sum_{i=1}^{k} mq_i * Q_i / Q_o$$

$$P_o = \sum_{i=1}^{k} P_i$$

$$Q_o = \sum_{i=1}^{k} Q_i$$

4.4 Example

Suppose the bus bar A connected to a number of loads as shown in Fig. 4.1

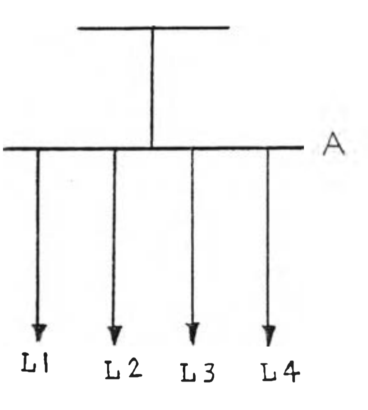

Figure 4.1 Example system

The data of each load are given in Table 4.2

Table 4.2

Load characteristic parameters

Load	P	Q	np	nq	mp	mq
L1	0.3	0.24	2.0	0	0	0
L2	0.2	0.18	1.4	3.0	1.5	-1.8
L3	0.25	0.20	1.0	1.1	2.5	-1.0
L4	0.12	0.10	0.2	0.6	3.3	-2.2

P, Q are per unit values.

For this example

$$P_o = 0.3 + 0.2 + 0.25 + 0.12$$

$$= 0.87$$

$$Q_o = 0.24 + 0.18 + 0.20 + 0.10$$

$$= 0.72$$

The aggregate np is calculated by

$$np = [(0.3*2) + (0.2*1.4) + (0.25*1.0) + (0.12*0.2)]/0.87$$

$$= 1.326$$

Calculate in the same way for the remaining parameters will give :

$$nq = 1.139$$

$$mp = 1.518$$

$mq = -1.033$

Thus, the equivalent load model at bus A are :

$$P = 0.87 * V^{1.326} * f^{1.518}$$

$$Q = 0.72 * V^{1.139} * f^{-1.033}$$

4.5 Conclusions

The exponential model is quite general. It relates changes in active and reactive power of loads to changes in voltage and frequency by the load characteristic parameters.

If the data of load components are known, the aggregate load parameters can be determined for a composite load. An example is presented which shows the method for grouping loads together.