CHAPTER 3

RESULTS AND DISCUSSION

In this chapter, the results of the analysis are presented in the following steps.

1. Graphs of daily consumption for each feeder and feeder combined.
2. Summary of the numerical analysis of the daily consumption.
3. Comparison of the means of electricity usage between feeders combined and between days.
4. Correlation analysis between feeder combined.
5. Trend analysis of daily consumption.
6. Comparison of the electricity usage between days.
7. Development of a model of electricity usage by time series.

1. Graphs of daily consumption for each feeder and feeder combined.

The objective of this analysis is to show the graphs of daily consumption for each feeder and feeders combined. The software used for this analysis is MATLAB Version4 (Hanelman & Littlefieled, 1995) and ASP. The results are shown in Figure 3-8.

Figure 3. The daily consumption from feeder 1.

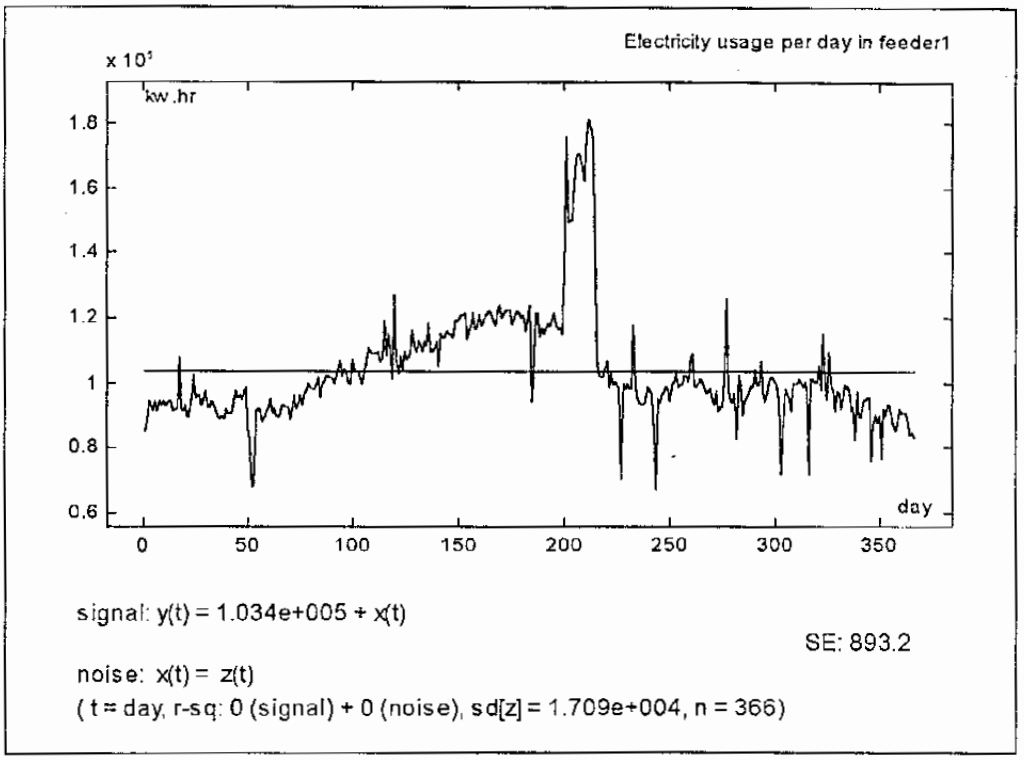


Figure 4. The daily consumption from feeder 2.

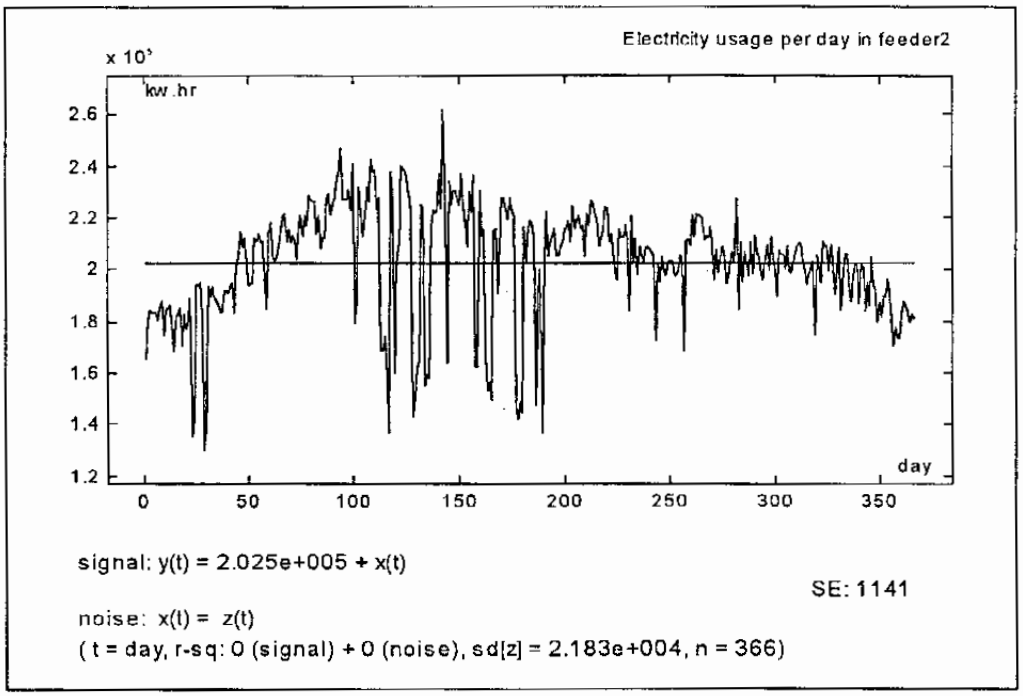


Figure 5. The daily consumption from feeder 3.

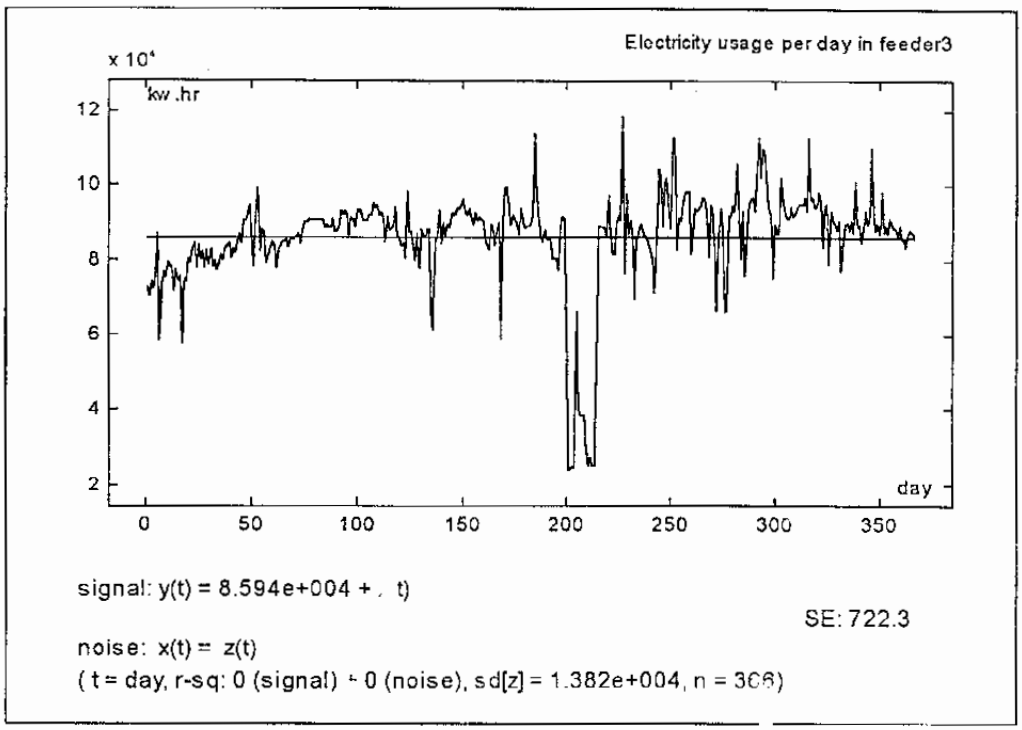


Figure 6. The daily consumption from feeder 6.

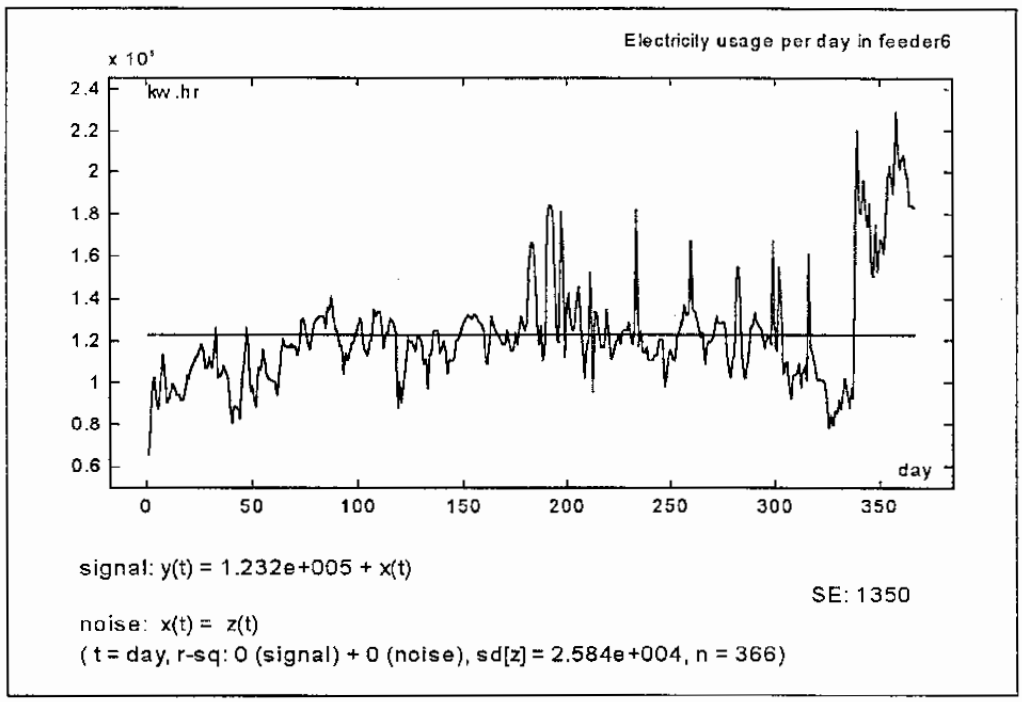


Figure 7. The daily consumption from feeder 7.

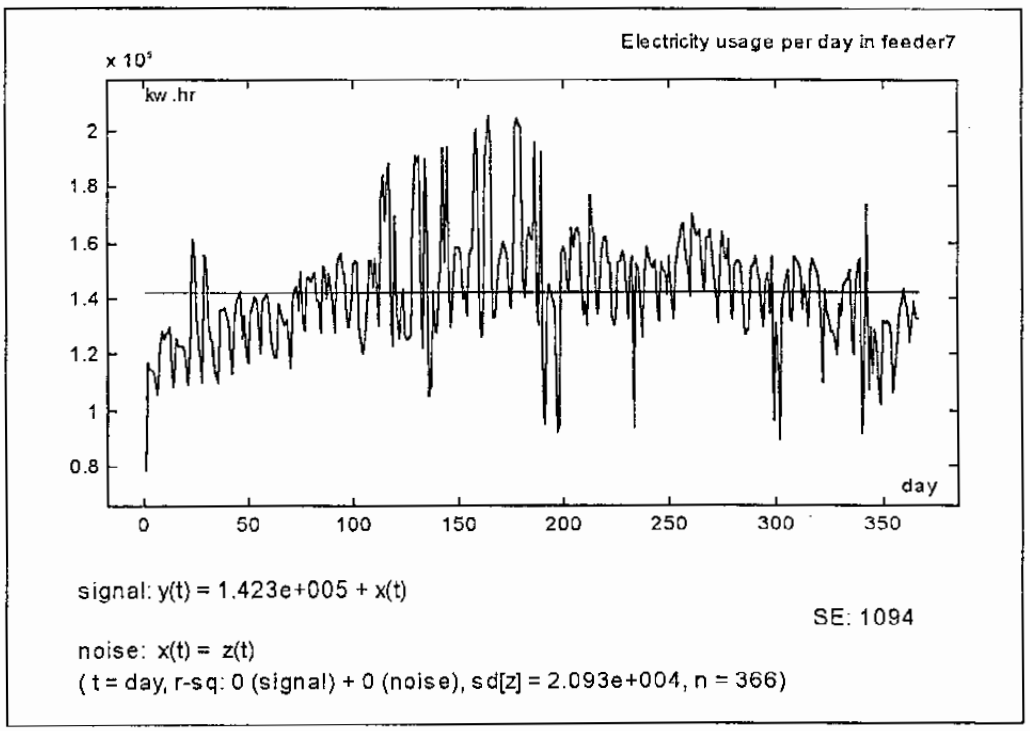
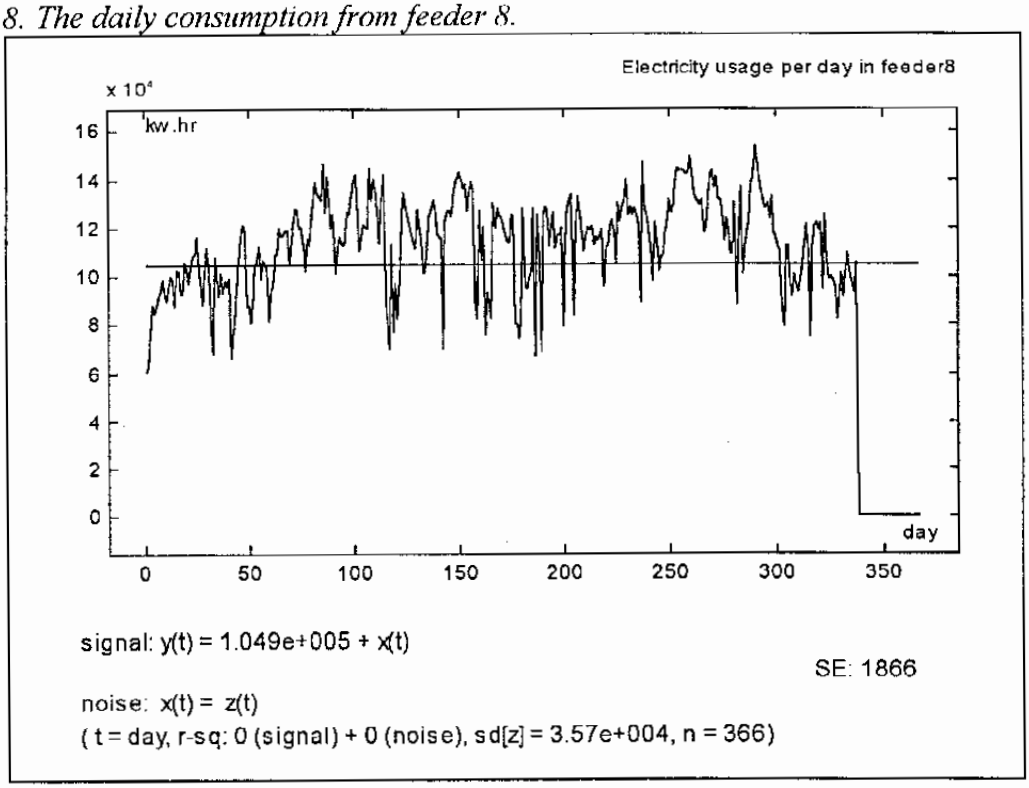


Figure 8. The daily consumption from feeder 8.



Between days 201-216 electricity usage from feeder 1 was very high because some of the electricity was diverted from feeder 3. Between days 104-191 electricity usage from feeder 2 and feeder 7 appear to vibrate conversely. The electricity usage from feeder 8 was combined with the usage from feeder 6 because the meter for feeder 8 was out of order after day 338. Similarly feeders 1 and 3 were combined as well as feeders 2 and 7, together with feeder total for the analysis. The results for these combined feeders are shown in Figure 9-12.

Figure 9. The daily consumption from feeders (1+3).

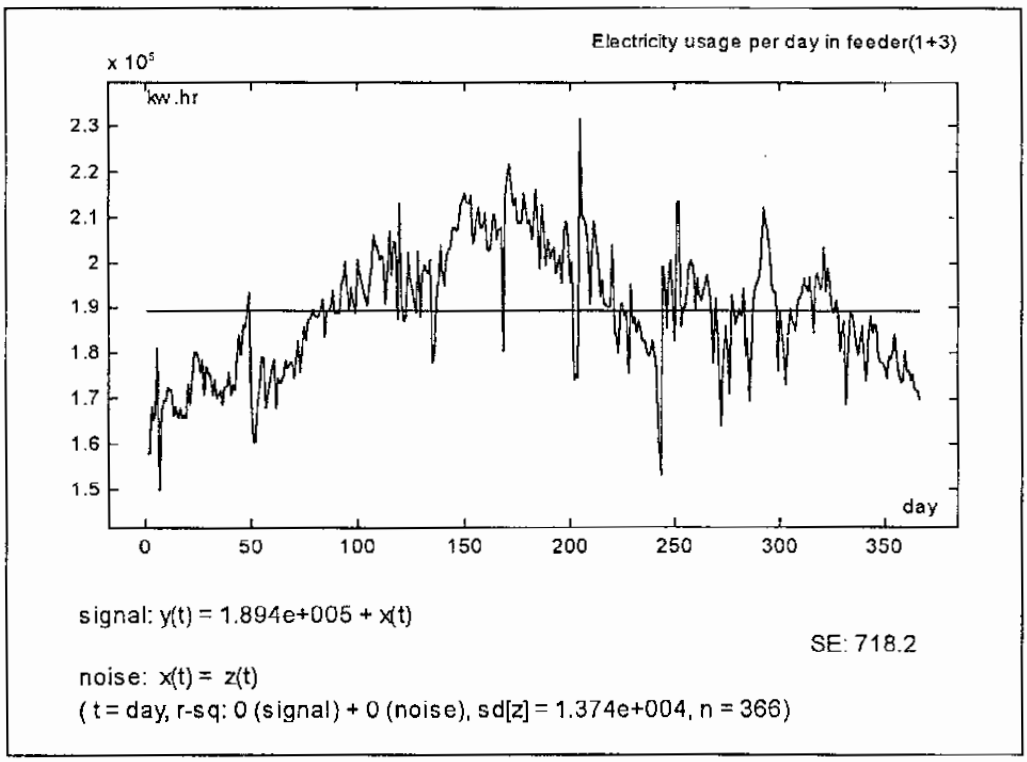


Figure 10. The daily consumption from feeders (2+7).

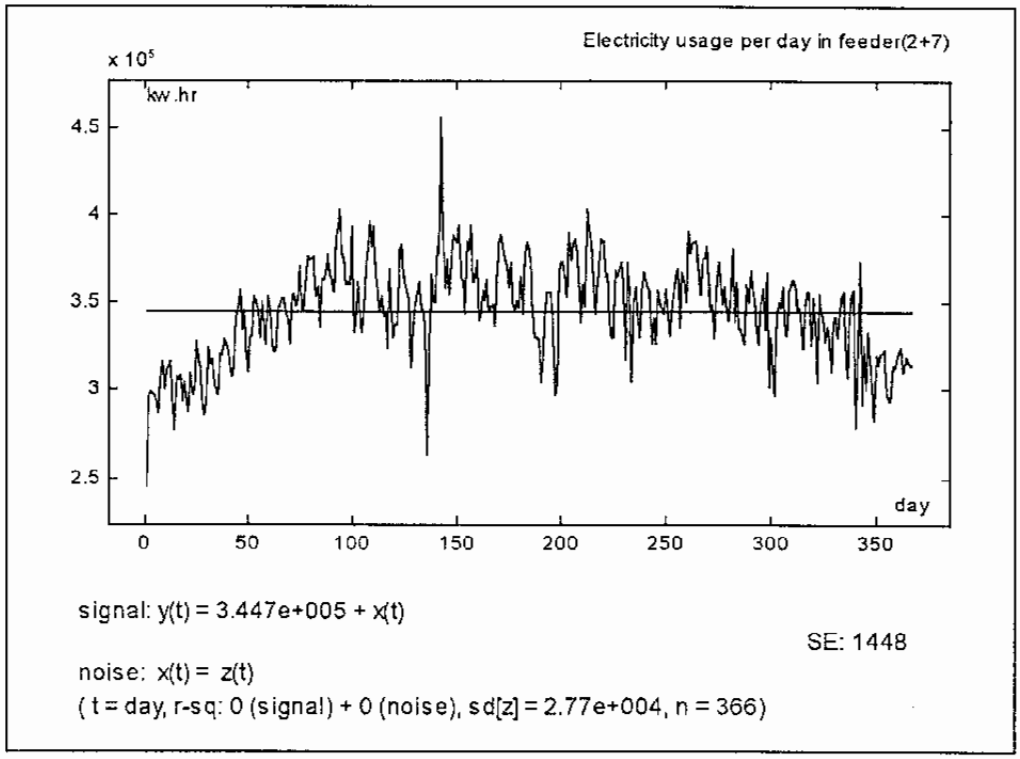


Figure 11. The daily consumption from feeders (6+8).

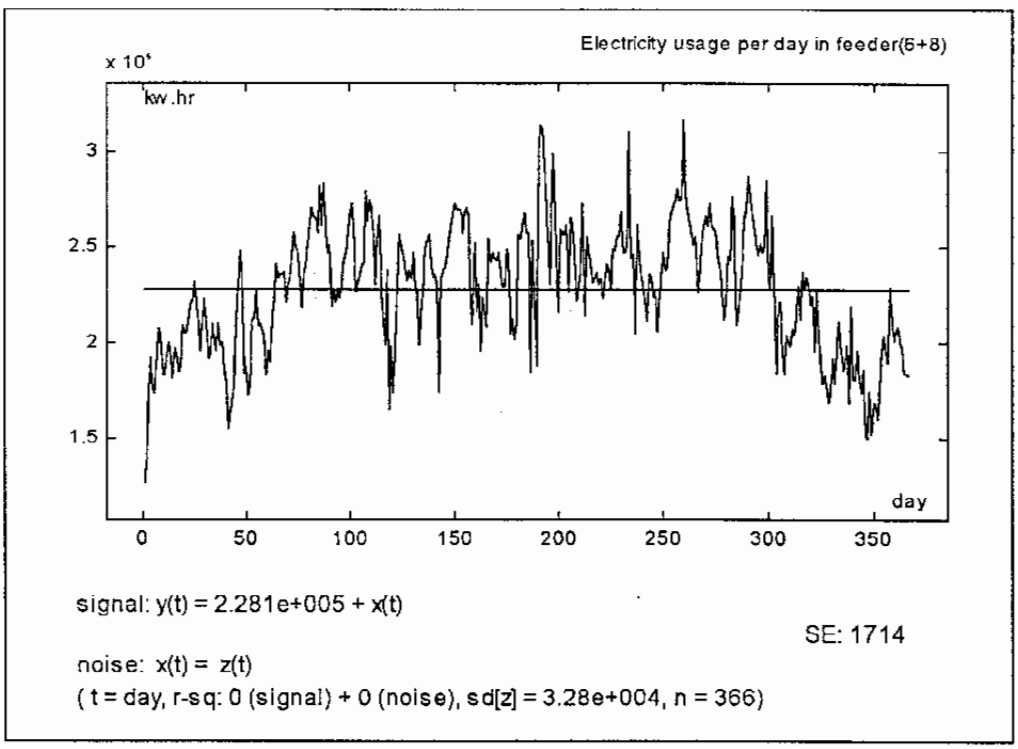
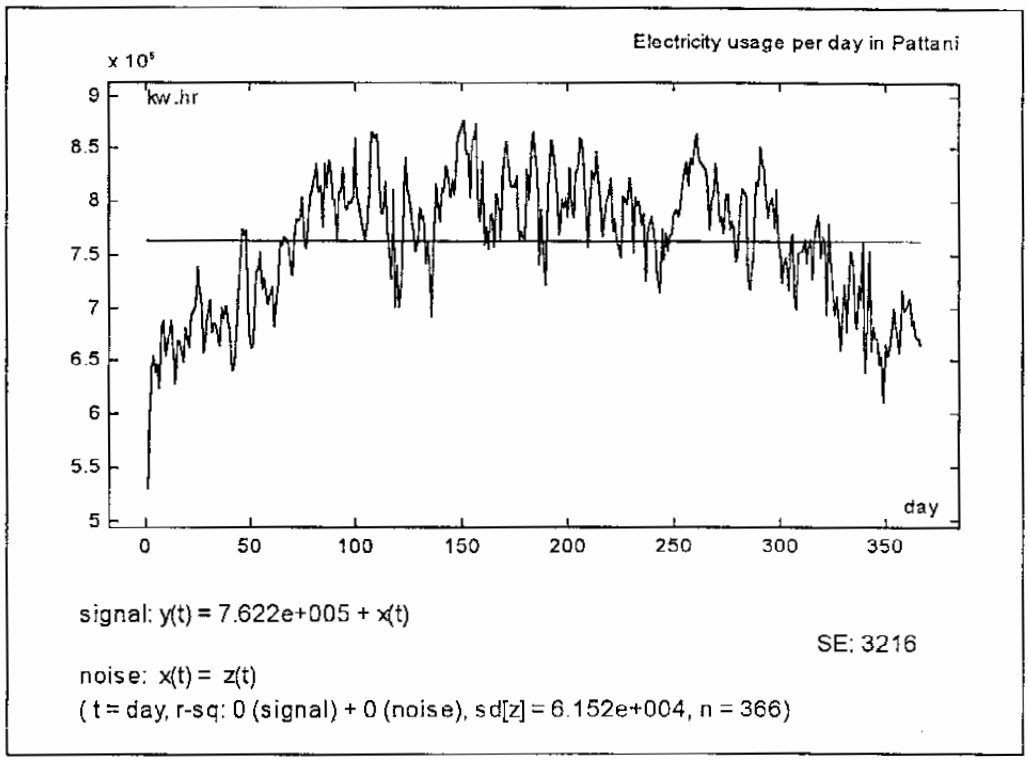


Figure 12. The daily consumption all feeders.

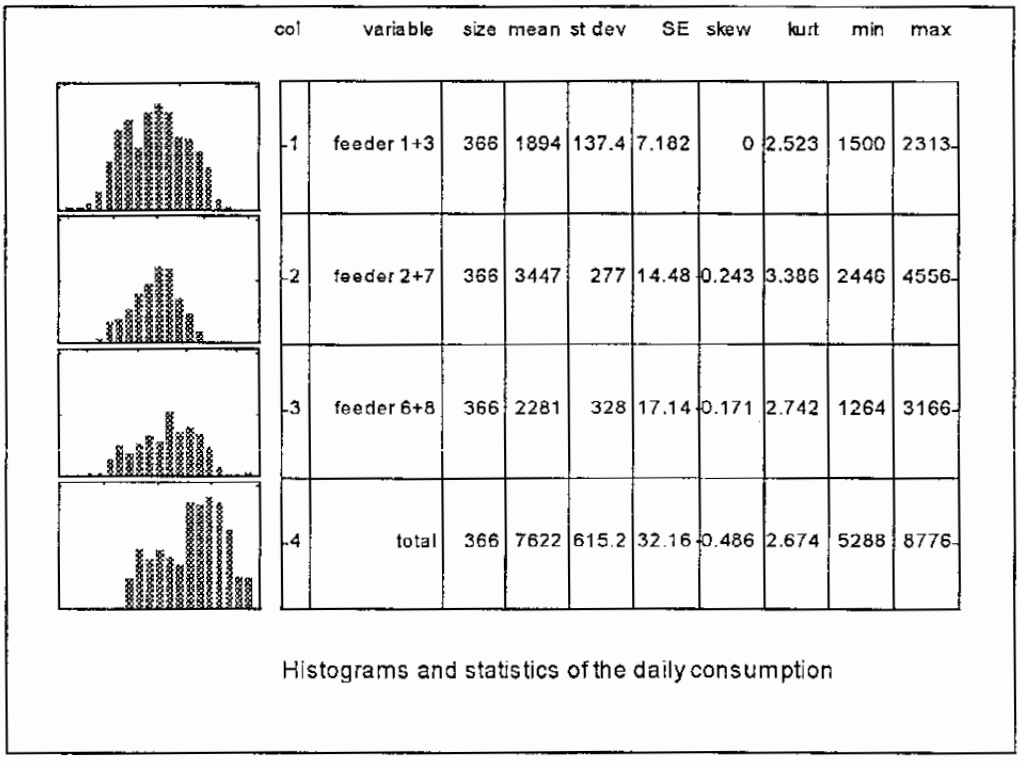


These graphs show that the anomolies seen in the plots of individual feeders have largely disappeared, but some outliers manifested by spikes in the time series remain.

2. Summary of the numerical analysis of the daily consumption.

The objective of this analysis is to show descriptive statistics and the distribution of the data. The software used for this analysis was MATLAB Version 4 (Hanselman & Littlefield, 1995) and ASP. Due to the large size of the numbers, they were reduced by factor of 100. The results of this analysis are shown in Figure 13.

Figure 13. Histrograms and statistics of the daily consumption.



col	variable	size	mean	st dev	SE	skew	kurt	min	max
1	feeder 1+3	366	1894	137.4	7.182	0	2.523	1500	2313
2	feeder 2+7	366	3447	277	14.48	0.243	3.386	2446	4556
3	feeder 6+8	366	2281	328	17.14	0.171	2.742	1264	3166
4	total	366	7622	615.2	32.16	0.486	2.674	5288	8776

Histograms and statistics of the daily consumption

Clearly, the distribution are approximately symmetric and normal. The descriptive statistics show that feeders (2+7) had the highest mean electricity usage with 344,700 units/day. The maximum and minimum electricity usage was 455,600 and 244,600 units/day respectively. The lowest mean electricity usage was in feeders (1+3) with 189,400 units/day. The maximum and minimum electricity usage was 231,300 and 150,000 units/day. In all feeders, the mean electricity usage was 762,200 units/day. The maximum and minimum electricity usage was 877,600 and 528,800 units/day respectively.

3. Comparison of the means of electricity usage between feeders and between days.

The objective of this analysis was to compare the means of electricity usage between feeders and between days. The software used for this analysis was SPIDA Version 6.08. From the analysis, the results was as follows.

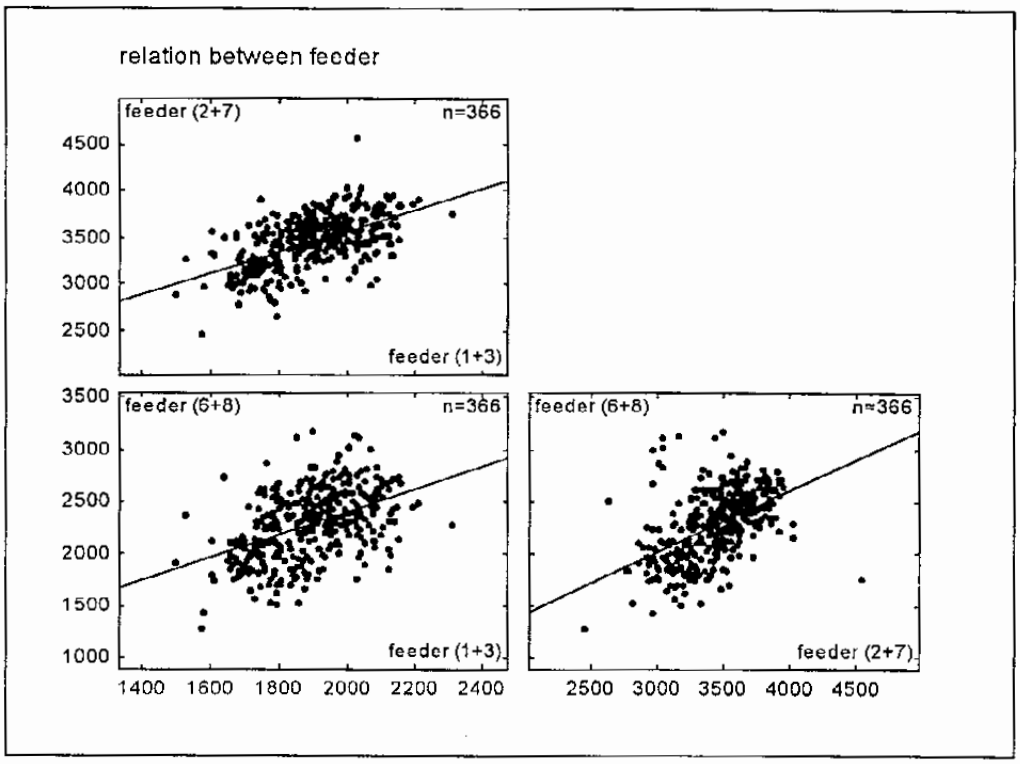
```
Two-way ANOVA - Number of missing values:0

 Effect          Sum of Sq  df          MS      p-value
-------------------------------------------------------
 Row           4.604544e11 365 1261518848            1
 _Row|Column   4.604562e11 365 1261523840            0
 Column|Row    4.788761e12   2 2.39438e12            0
 Residual      2.811892e11 730  385190656 s:19626.275

The overall mean:254056.16
Reliability Total:0.695     Single:0.431
```

There are substantial differences in electricity consumption between the combined feeder and between the days of the years.

4. Correlation analysis between feeder combined

The software used for this analysis was MATLAB Version4 (Hanselman & Littlefield, 1995) and ASP. Due to the large size of the numbers, they were reduced by factor of 100. The results of this analysis are shown in Figure 14.

Figure 14. Graphs of the scatterplot matrices between feeders.



Correlation analysis between feeders.

Pearson's Correlation

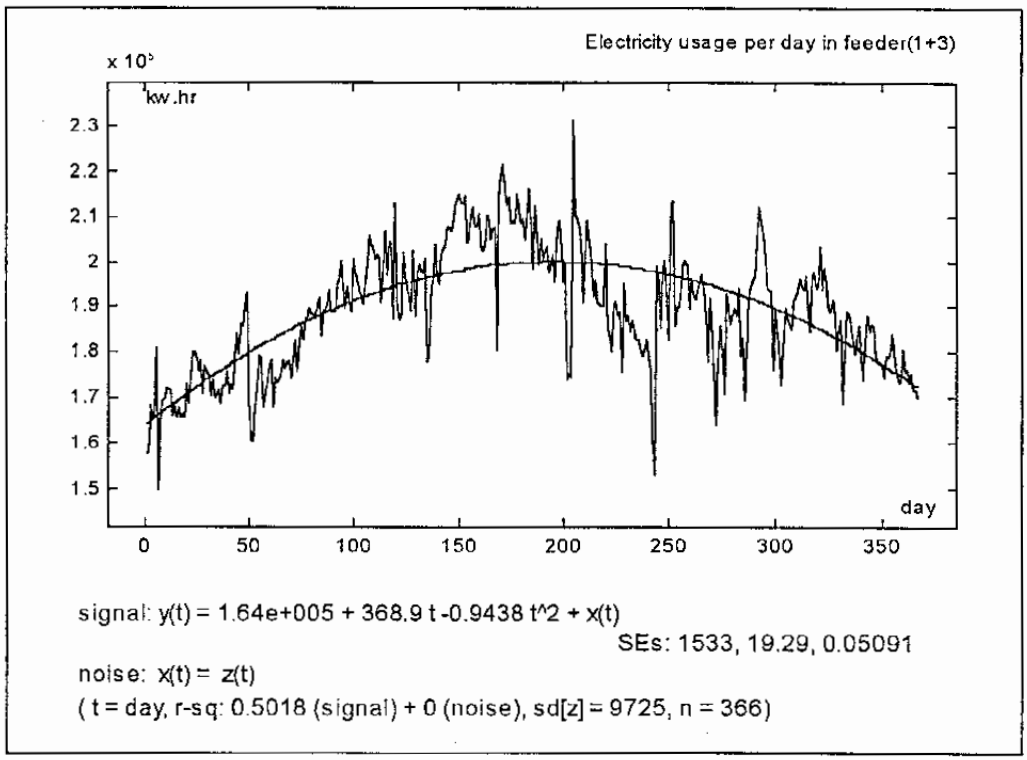
feeder	1+3	2+7	6+8
1+3	1.000	0.565	0.463
2+7	0.565	1.000	0.498
6+8	0.463	0.498	1.000

The results show that, there are positive correlations between all feeders combined. The highest positive correlation occurs between feeders (1+3)-feeders (2+7) and the lowest positive correlation occur between feeders (1+3)-feeders (6+8) with values of 0.565 and 0.463 respectively.

5. Trend analysis of daily consumption.

The objective of this analysis was to construct a model for the trend in electricity usage for each feeder combined and all feeder. The results of the analysis are shown in Figure 15.

Figure 15. The electricity usage trend of feeders (1+3).

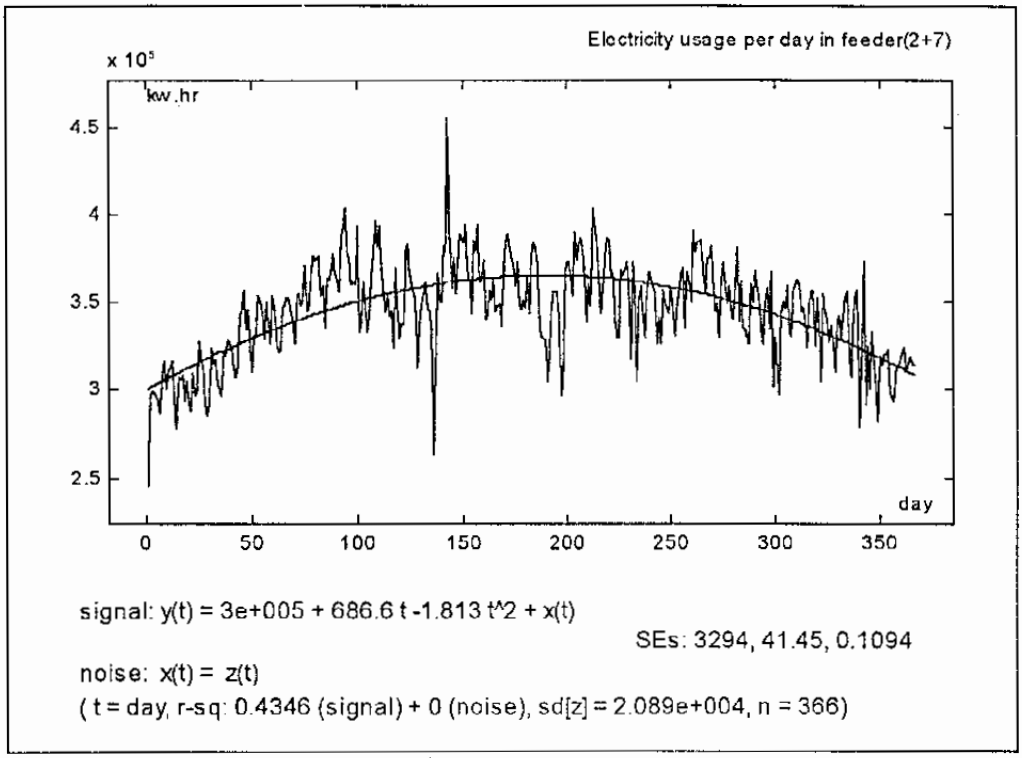


From the analysis, the model for feeders (1+3) are as follows.

$$y(t) = 1.64x10^5 + 368.9t - 0.9438t^2$$

The standard errors of the constant $1.64x10^5$ and the coeffients 368.9 and 0.9438 are 1533, 19.29 and 0.05091 respectively. Thc cfficiency of this model is 50.18 %.From the model of feeders (1+3), which covers the areas of Ramkomut Rd., Yaring District, Panarea District, Yarang District, Mayor District, Tungyangdang District, Maikean District and Kaphor District, the usage increased from early in the year to a peak in July, and then decreased again late in the year. However, the electricity usage late in the year was greater than the usage earlier in the year.

Figure 16. The electricity usage trend of feeders (2+7).

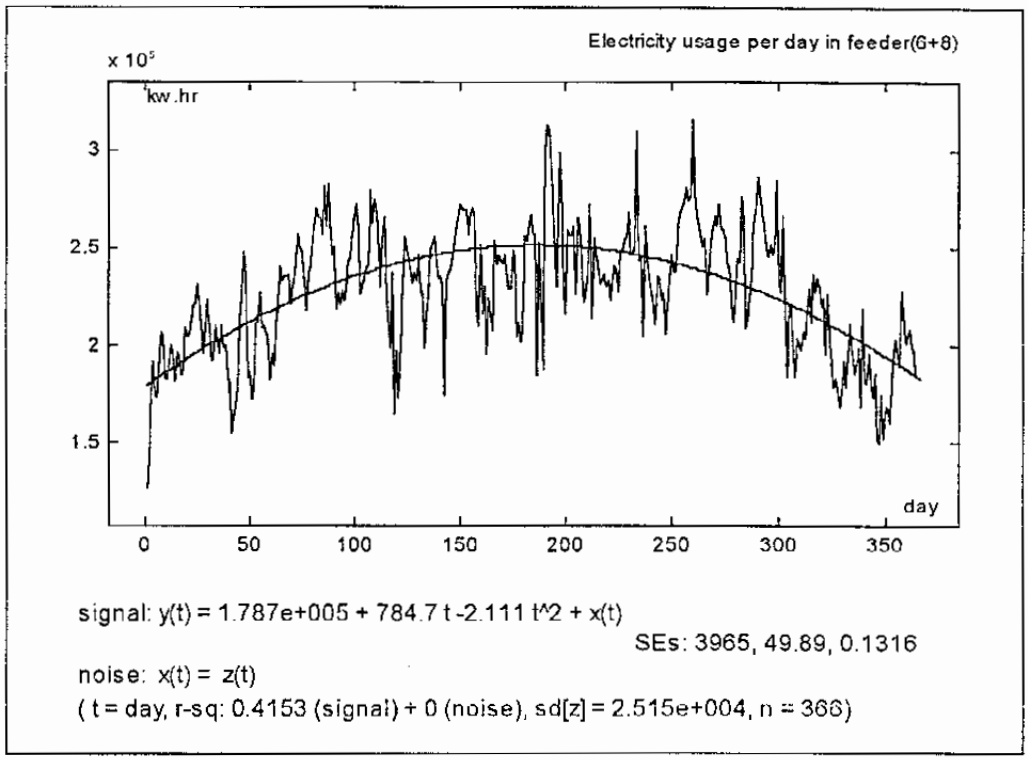


From the analysis, the model for feeders (2+7) is as follows.

$$y(t) = 3x10^5 + 686.6t - 1.813t^2$$

The standard errors of the constant $3x10^5$ and the coefficients 686.6 and 1.813 are 3294, 41.45 and 0.1094 respectively. The efficiency of this model is 43.46%. From the model of feeders (2+7), which covers the areas of Muang District, Pattani Barracks, Kokpho District, Thepa District, Sabayoi District, Lumlong Village, Pattani Airport, Nongchik District and Prince of Songkhla University, the usage increased from early in the year to peak in July, and then decreased again later in the year. However, the electricity usage late in the year was similar to the usage earlier in the year.

Figure 17. The electricity usage trend of feeders (6+8).

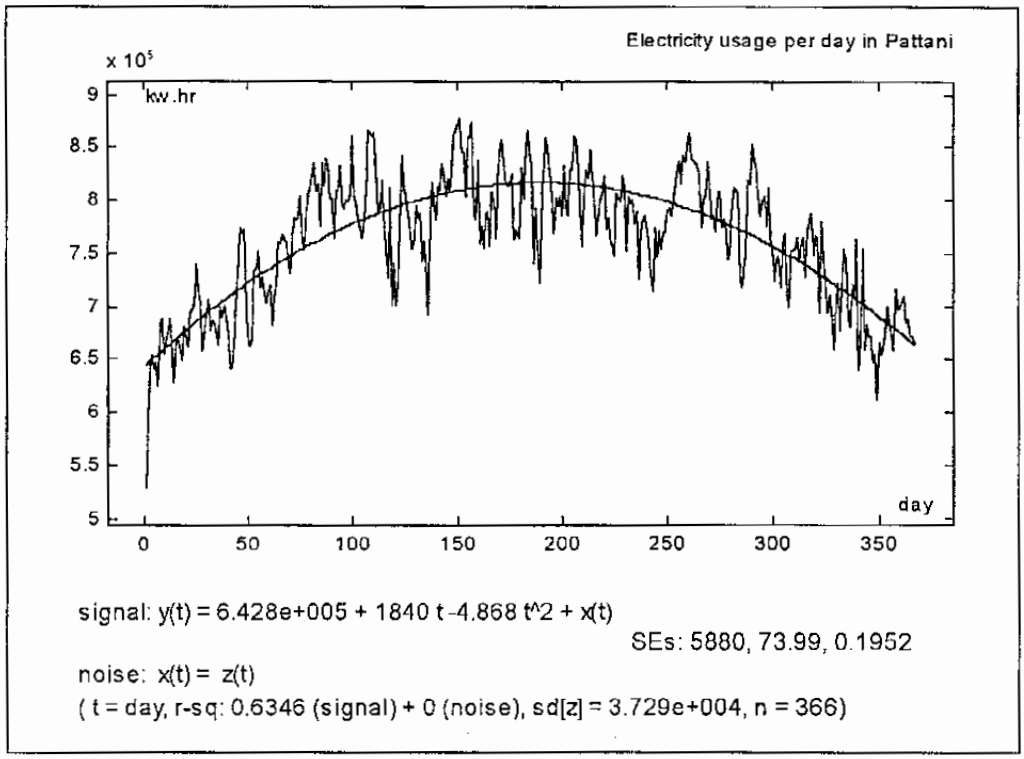


From the analysis, the model for feeders (6+8) is as follows.

$$y(t) = 1.787x10^5 + 784.7t - 2.111t^2$$

The standard errors of the constant $1.787x10^5$ and the coeffients 784.7 and 2.111 are 3965, 49.89 and 0.1316 respectively. The efficiency of this model is 41.53%. This feeder covers areas with a high population density and a lot of industries. The usage very increased from early in the year to peak in July, and then decreased again later in the year. However, the electricity usage late in the year was similar to the usage earlier in the year.

Figure 18. The electricity usage trend of all feeders.



From the analysis, the model for all feeders is as follows.

$$y(t) = 6.428x10^5 + 1840t - 4.868t^2$$

The standard errors of the constant $6.428x10^5$ and the coeffients 1840 and 4.868 are 5880, 73.99 and 0.1952 respectively. The efficiency of this model is 63.46%. From the model of all feeders, the electricity usage very increased from early in the year to peak in July, and then decreased again later in the year. However, the electricity usage late in the year was greater than the usage earlier in the year.

6. Comparison of the electricity usage between days.

The objective of this analysis is to compare the electricity usage for each week in 1996. The data for this analysis included 52 weeks, or 364 values. The first day of 1996 was a Monday, so the remaining days of the years are as follows.

day of year	day of week
1	1(Monday)
2	2(Tuesday)
3	3(Wednesday)
4	4(Thursday)
5	5(Friday)
6	6(Saturday)
7	7(Sunday)
8	1(Monday)
9	2(Tuesday)
10	3(Wednesday)
.....	.....
.....	.....
.....	.....
362	5(Friday)
363	6(Saturday)
364	7(Sunday)

The software used for this analysis was MATLAB Version 4 (Hanselman & Littlefield, 1995) and ASP. The steps of the analysis are as follows.

6.1 Comparison of the electricity usage between days.

6.2 Box plot analysis to check for outliers.

6.3 Comparison of the electricity usage between days after removing the outliers.

An example of the data for this analysis is as follows.

day of year	day of week	feeder (1+3)	(day of year)^2
1	1	157800	1
2	2	158550	2
3	3	168600	9
4	4	165300	16
5	5	167100	25
6	6	180900	36
7	7	150000	49
8	1	167650	64
9	2	169850	81
10	3	169800	100
.....			
.....			
358	1	174300	128164
359	2	180450	128881
360	3	175650	129600
361	4	176100	130321
362	5	174150	131044
363	6	175350	131769
364	7	172050	132496

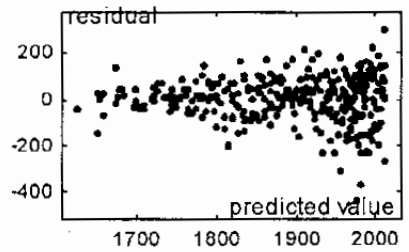
The results of this analysis are shown in Figure 19.

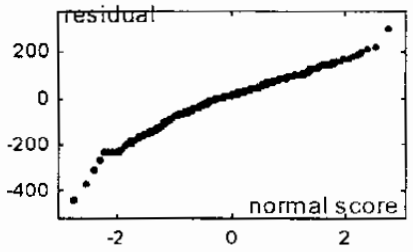
Figure 19. Comparison of the electricity usage between days by raw data for feeders (1+3).

linear regression analysis: response = feeder (1+3)

predictor	coeff	St.Error	p-value
constant	1622	19.83	0
day of year	3.683	0.1954	0
day^2	-0.009416	0.0005184	0
day of week			0.5723
1	(0)		
2	30.4	19.15	0.1285
3	27.46	19.15	0.1584
4	18.47	19.15	0.3357
5	15.87	19.15	0.4081
6	29.51	19.16	0.1358
7	4.626	19.16	0.8093

r-sq: 0.5037 rss: 3.386e+006 df: 355 sd: 97.67 p-value: 0





In feeders (1+3), the order of the days of the week from maximum to minimum electricity usage was Tuesday, Saturday, Wednesday, Thursday, Friday, Sunday and Monday. From observing the quadratic regression analysis results in Figure 19, the p-value showed no significant differences at the 0.05 level of significance between each day's electricity usage.

Figure 20. Box plot of feeder (1+3).

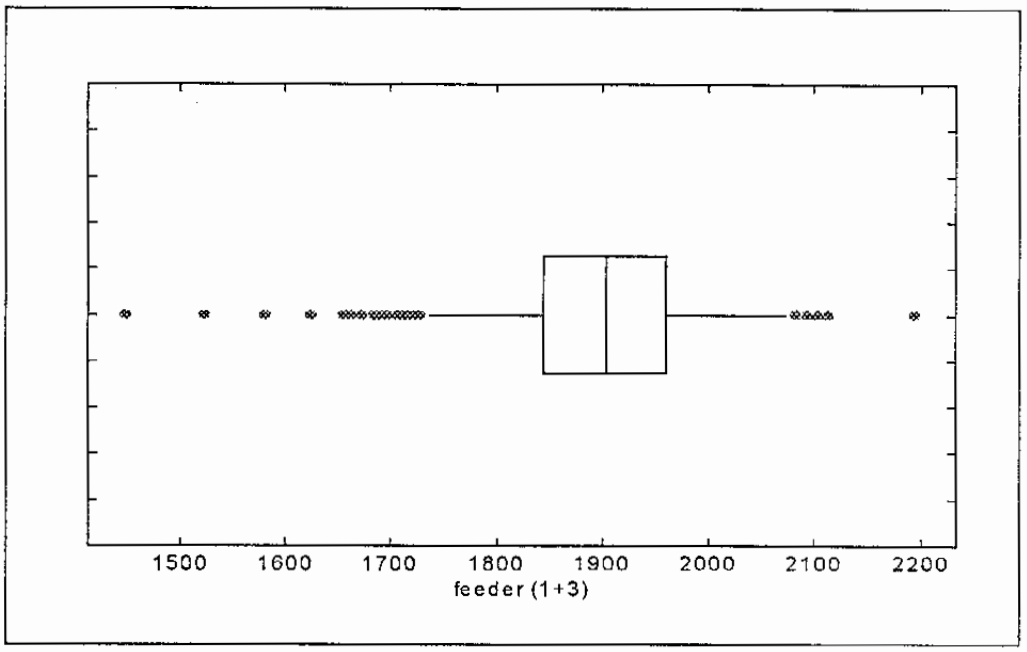
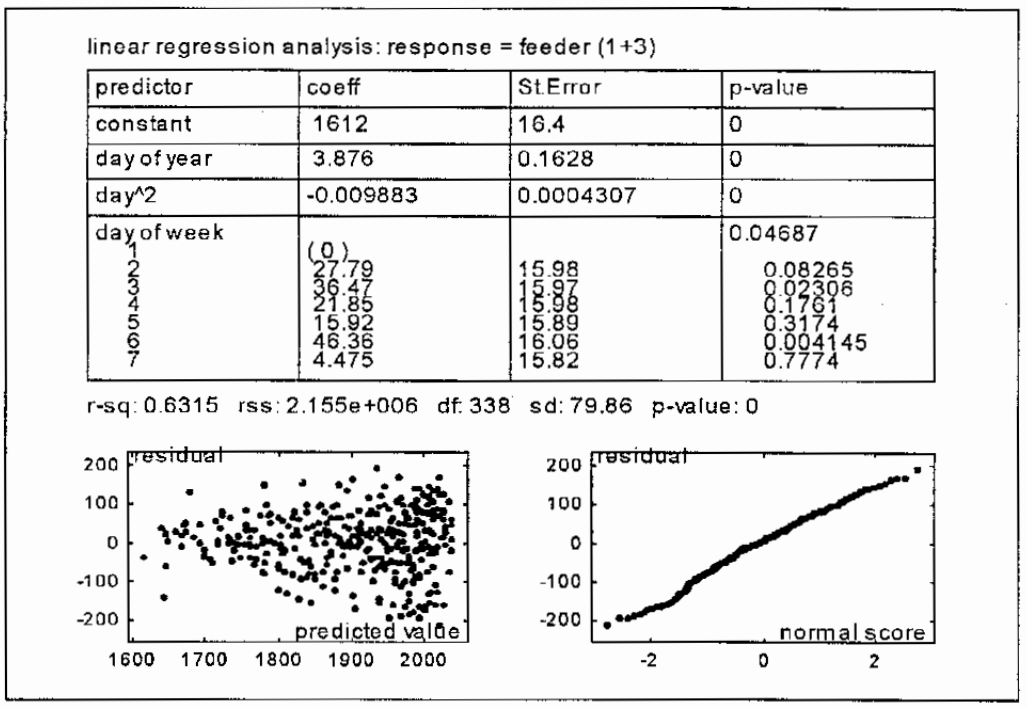


Figure 20 shows the box plot. The outliers of this feeder were more than 208,000 and less than 173,000 units/day and we can use this result for the next step.

Figure 21. Comparison of the electricity usage between days after removing the outliers for feeders (1 + 3).



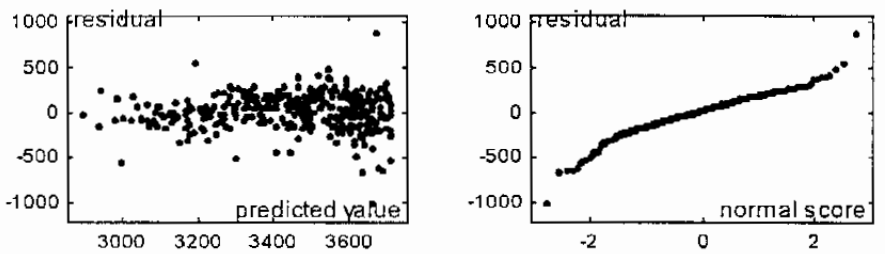
When the outliers are removed the order of the days of the week from maximum to minimum electricity usage become Saturday, Wednesday, Tuesday, Thursday, Friday, Sunday and Monday. The data were found to be normally distributed. From observing the quadratic regression analysis results in figure 21, the p-value showed significant differences at the 0.05 level significance between each day's electricity usage.

Figure 22. Comparison of the electricity usage between days by raw data for feeders (2+7).

linear regression analysis: response = feeder (2+7)

predictor	coeff	St.Error	p-value
constant	2990	40.41	0
day of year	6.894	0.3982	0
day^2	-0.0182	0.001056	0
day of week			1.606e-007
1	(0)		
2	49.48	39.04	0.2058
3	73.52	39.04	0.06048
4	72.02	39.04	0.0659
5	25.5	39.04	0.514
6	-24.33	39.04	0.5336
7	-142	39.04	0.000316

r-sq: 0.4946 rss: 1.407e+007 df: 355 sd: 199 p-value: 0



In feeders (2+7), the order of the days of the week from maximum to minimum electricity usage was Wednesday, Thursday, Tuesday, Friday, Monday, Saturday and Sunday. From observing the quadratic regression analysis results in Figure 22, the p-value showed significant differences at the 0.05 level of significance between each day's electricity usage.

Figure 23. Box plot of feeder (2+7).

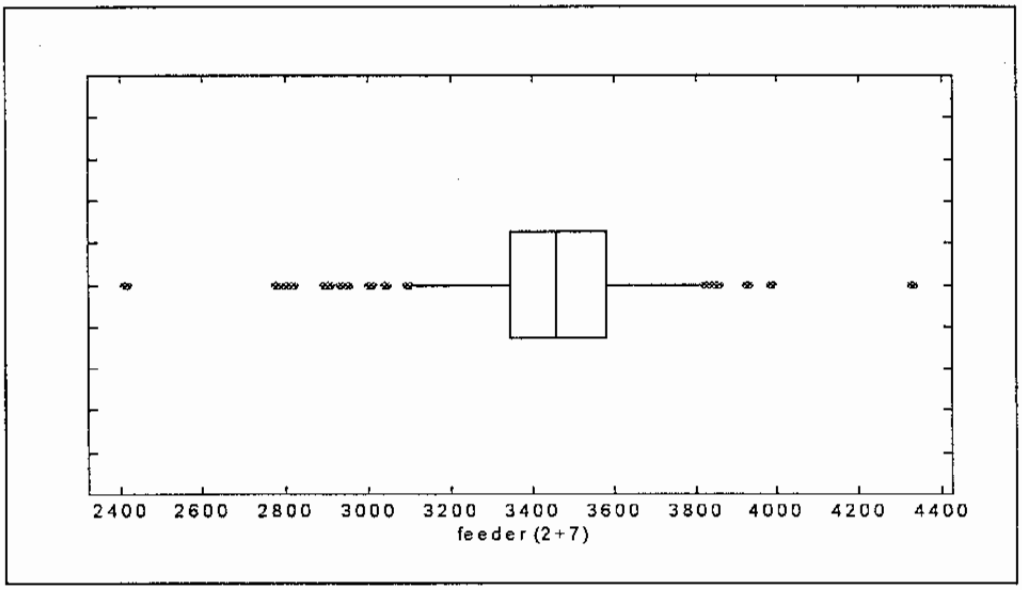
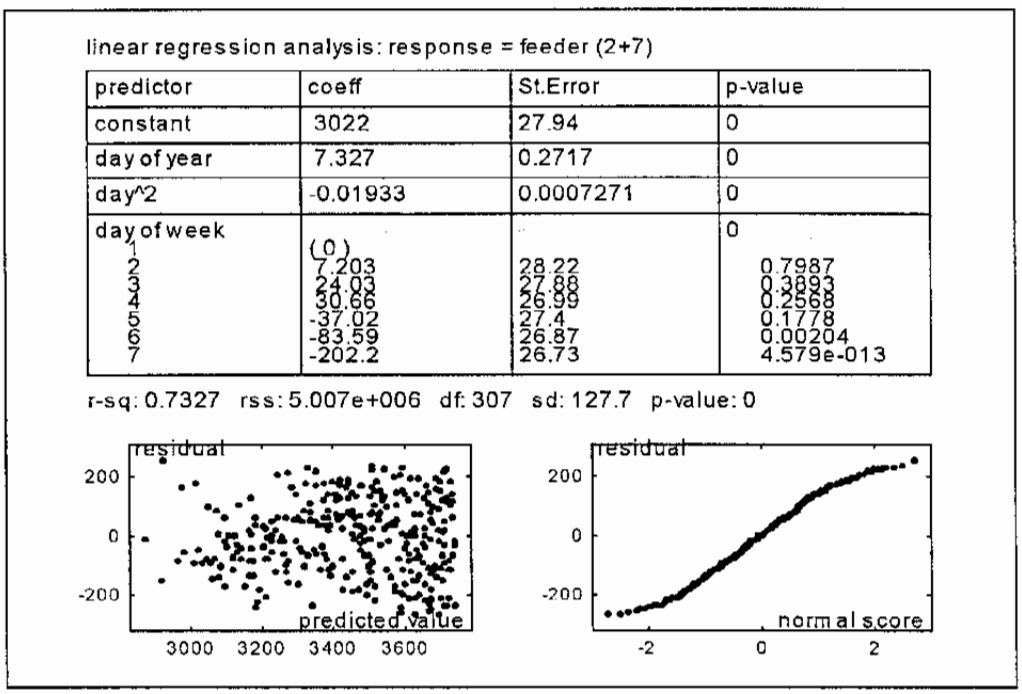


Figure 23 shows the results of the box plot analysis. The outliers of this feeder were more 380,000 and less than 310,000 units/day and we can use this result for the next step.

Figure 24. Comparison of the electricity usage between days after removing the outliers for feeders (2+7).



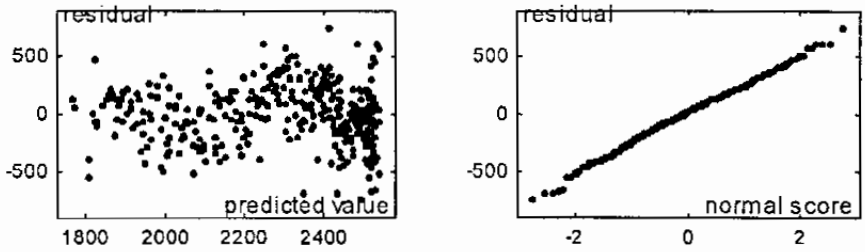
When the outliers are removed the order of the days of the week from maximum to minimum electricity usage become Thursday, Wednesday, Tuesday, Monday, Friday, Saturday and Sunday. From observing the quadratic regression analysis results in Figure 24, the p-value showed significant differences at the 0.05 level significance between each day's electricity usage.

Figure 25. Comparison of the electricity usage between days by raw data for feeders (6+8).

linear regression analysis: response = feeder (6+8)

predictor	coeff	St.Error	p-value
constant	1804	51.24	0
day of year	7.849	0.5049	0
day^2	-0.02111	0.00134	0
day of week			0.5091
1	(0)		
2	-8.698	49.5	0.8606
3	1.025	49.5	0.9835
4	9.303	49.5	0.851
5	-13.09	49.5	0.7916
6	-17.52	49.51	0.7236
7	-88.31	49.51	0.07532

r-sq: 0.4178 rss: 2.262e+007 df: 355 sd: 252.4 p-value: 0



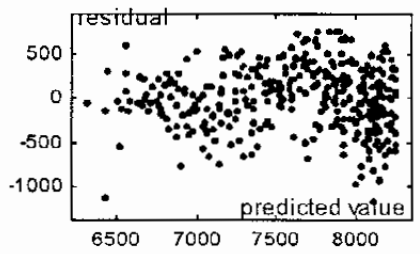
In feeders (6+8), the order of the days of the week from maximum to minimum electricity usage was Thursday, Wednesday, Monday, Tuesday, Friday, Saturday and Sunday. The data was found to be normally distributed. From observing the quadratic regression analysis results in Figure 25, the p-value showed no significant differences at the 0.05 level of significance between each day's electricity usage.

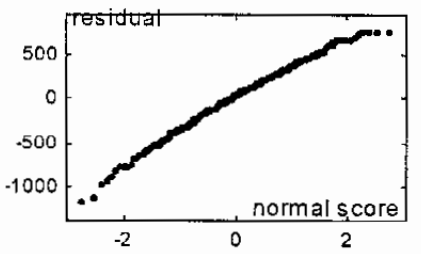
Figure 26. Comparison of the electricity usage between days by raw data for all feeders.

linear regression analysis: response = Pattani

predictor	coeff	St.Error	p-value
constant	6416	73.46	0
day of year	18.43	0.7239	0
day^2	-0.04873	0.001921	0
day of week			0.00005158
1	(0)		
2	71.18	70.97	0.3166
3	102	70.97	0.1516
4	99.79	70.97	0.1606
5	28.28	70.97	0.6906
6	-11.3	70.98	0.8736
7	-225.7	70.98	0.001604

r-sq: 0.6591 rss: 4.649e+007 df: 355 sd: 361.9 p-value: 0





In all feeders, the order of the days of the week from maximum to minimum electricity usage was Wednesday, Thursday, Tuesday, Friday, Monday, Saturday and Sunday. From observing the quadratic regression analysis results in Figure 26, the p-value showed significant differences at the 0.05 level of significance between each day 's electricity usage.

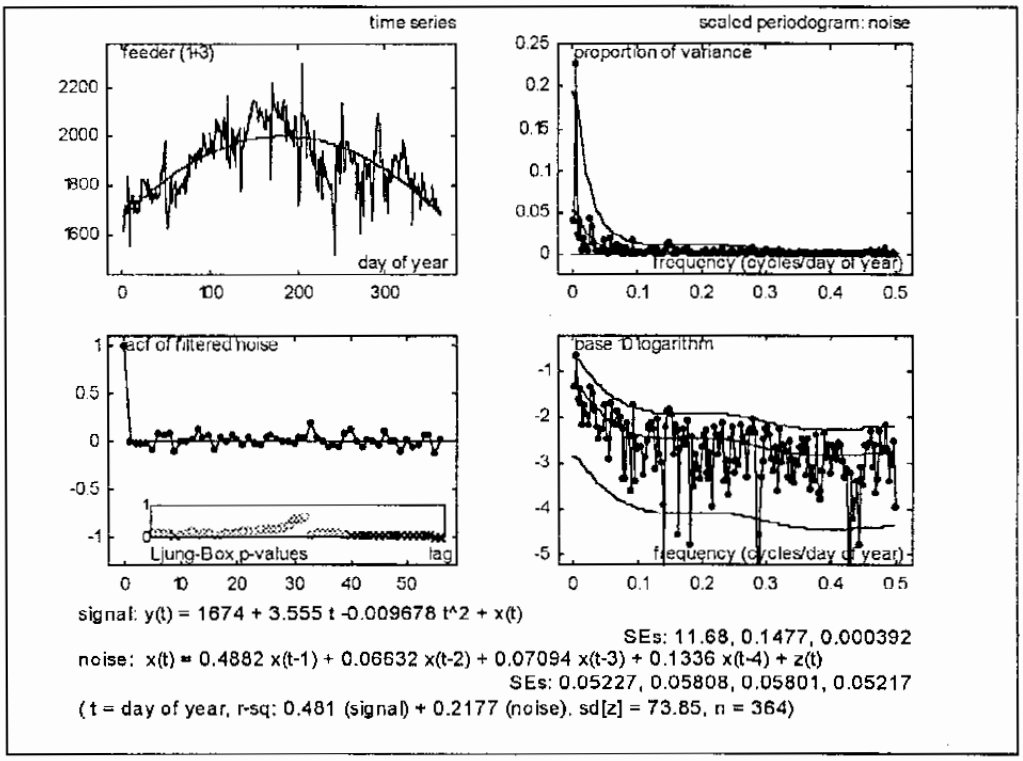
7. Development of a model of electricity usage by time series.

The objective of this analysis was to develop a model of electricity usage using the time series method with an autoregressive process. The steps of this analysis are as follows.

7.1 Development of a model of electricity usage with an autoregressive processes by fitting a quadratic model.

7.2 Development of a model of electricity usage with an autoregressive processes by fitting a time series model.

Figure 27. The quadratic model for feeders (1+3).



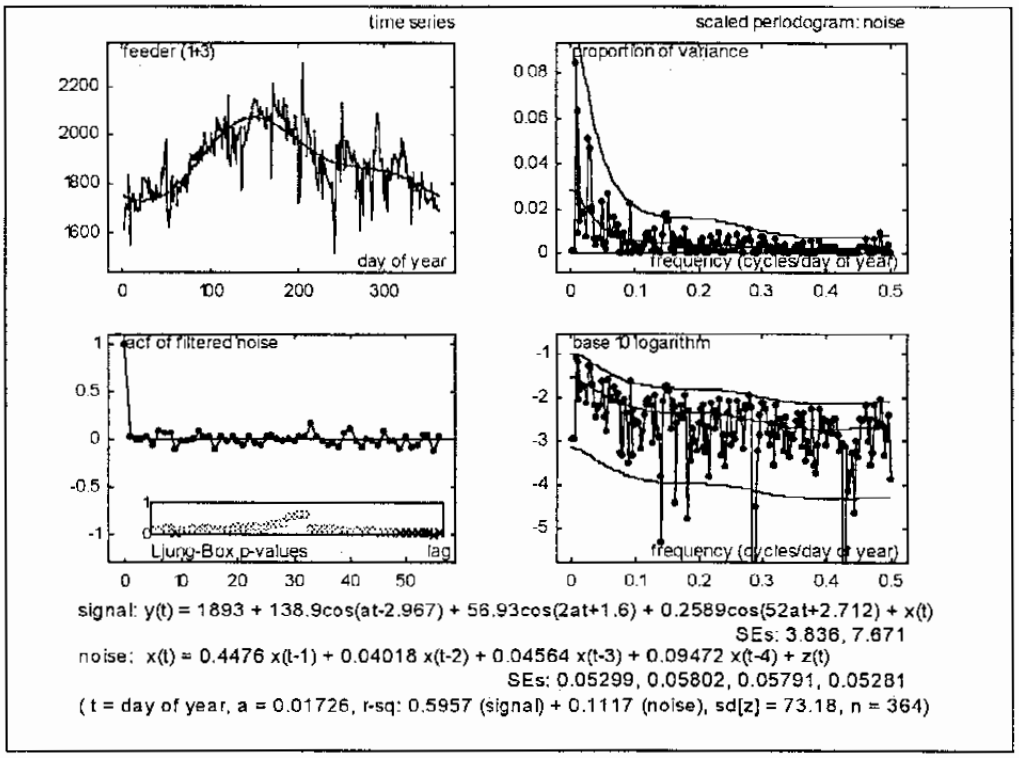
From the analysis, the quadratic model for feeders (1+3) is as follows.

$$y(t) = 1674 + 3.555t - 0.009678t^2$$

The efficiency of this model is 69.87%.

The analysis of electricity usage in feeders (1+3), shows that the usage increased from early in the year to a peak in July, and then decreased again later in the year.

Figure 28. Time series model for feeders (1+3).



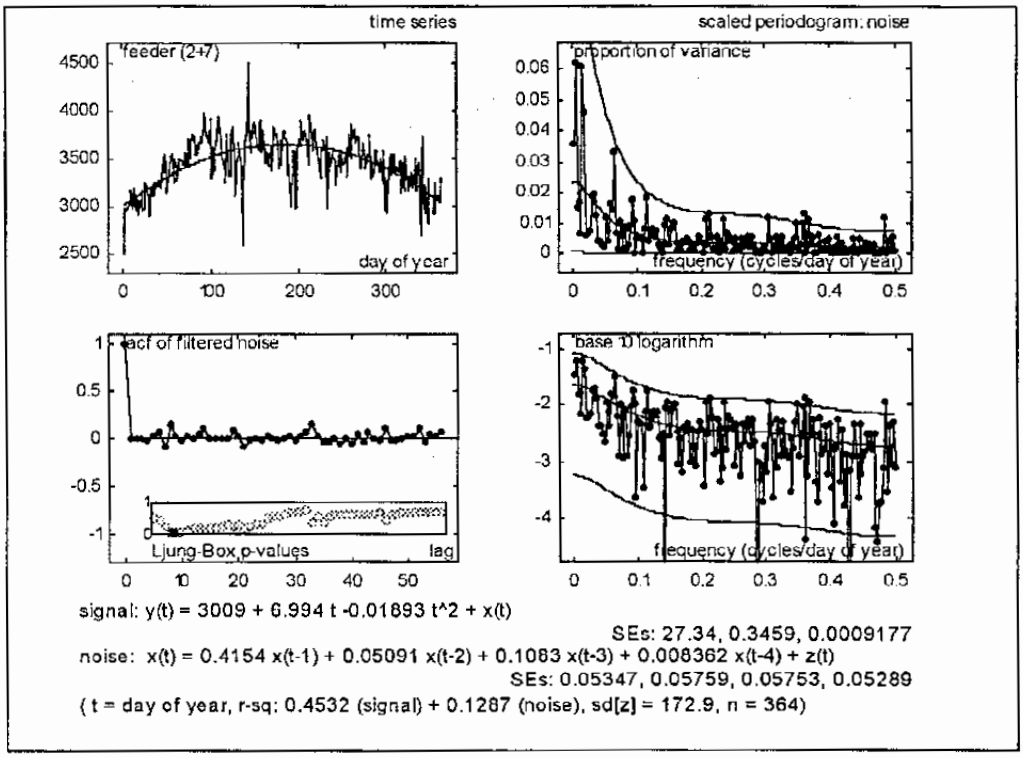
From the analysis, the time series model for feeders (1+3) is as follows.

$$y(t) = 1893+138.9\cos(at-2.967)+56.93\cos(2at+1.6)+0.2589\cos(52at+2.712)$$

The efficiency of this model is 70.74%.

The analysis of electricity usage in feeders (1+3), shows that the usage increased from early in the year to peak in early of June, and then decreased again later in the year. However, the electricity usage late in the year was greater than the usage earlier in the year and electricity usage in March to early of June was very high. The efficiencies of both models are similar.

Figure 29. The quadratic model for feeders (2+7).



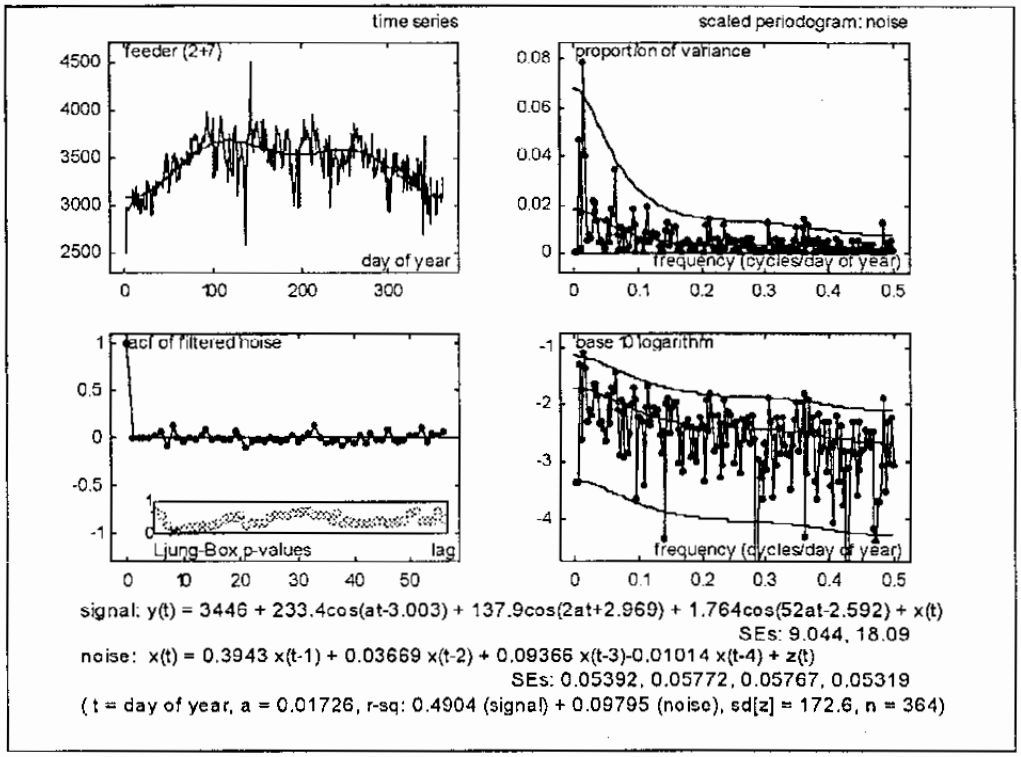
From the analysis, the quadratic model for feeders (2+7) is as follows.

$$y(t) = 3009 + 6.994t - 0.01893t^2$$

The efficiency of this model is 58.19%.

The analysis of electricity usage in feeders (2+7), shows that the usage increased from early in the year to a peak in July, and then decreased again later in the year.

Figure 30. Time series model for feeders (2+7).



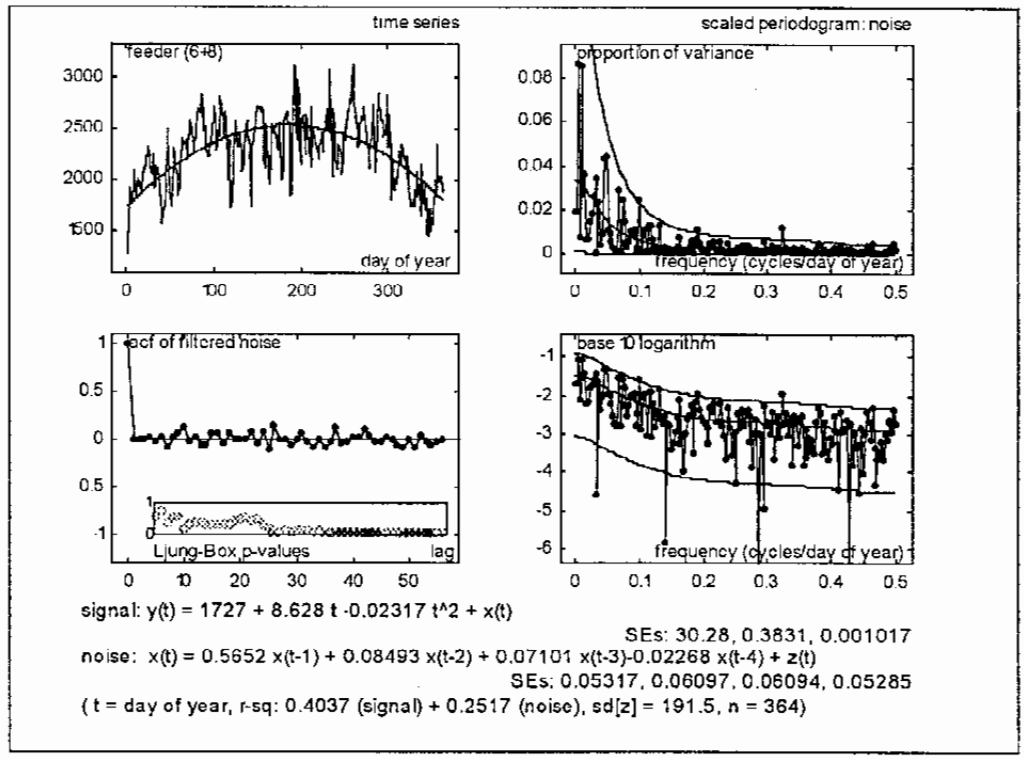
From the analysis, the time series model for feeders (2+7) is as follows.

$$y(t) = 3446+233.4\cos(at-3.003)+137.9\cos(2at+2.969)+1.764\cos(52at-2.592)$$

The efficiency of this model is 58.83%.

The analysis of electricity usage in feeders (2+7), shows that the usage increased from early in the year and to peak on April and September. However, the peak on April more than on September, and then decreased again later in the year. The efficiencies of both models are similar.

Figure 31. The quadratic model for feeders (6+8).



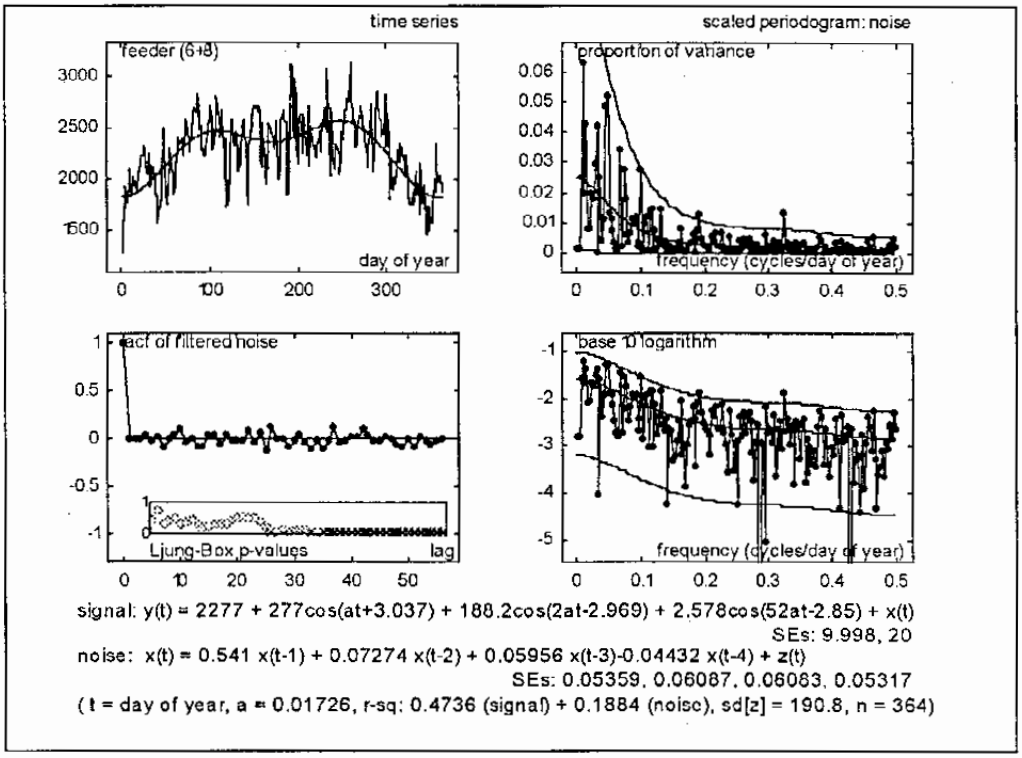
From the analysis, the quadratic model for feeders (6+8) is as follows.

$$y(t) = 1727 + 8.628t - 0.02317t^2$$

The efficiency of this model is 65.54%.

The analysis of electricity usage in feeders (6+8), shows that the usage increased from early in the year to a peak in July, and then decreased again later in the year.

Figure 32. Time series model for feeders (6+8).



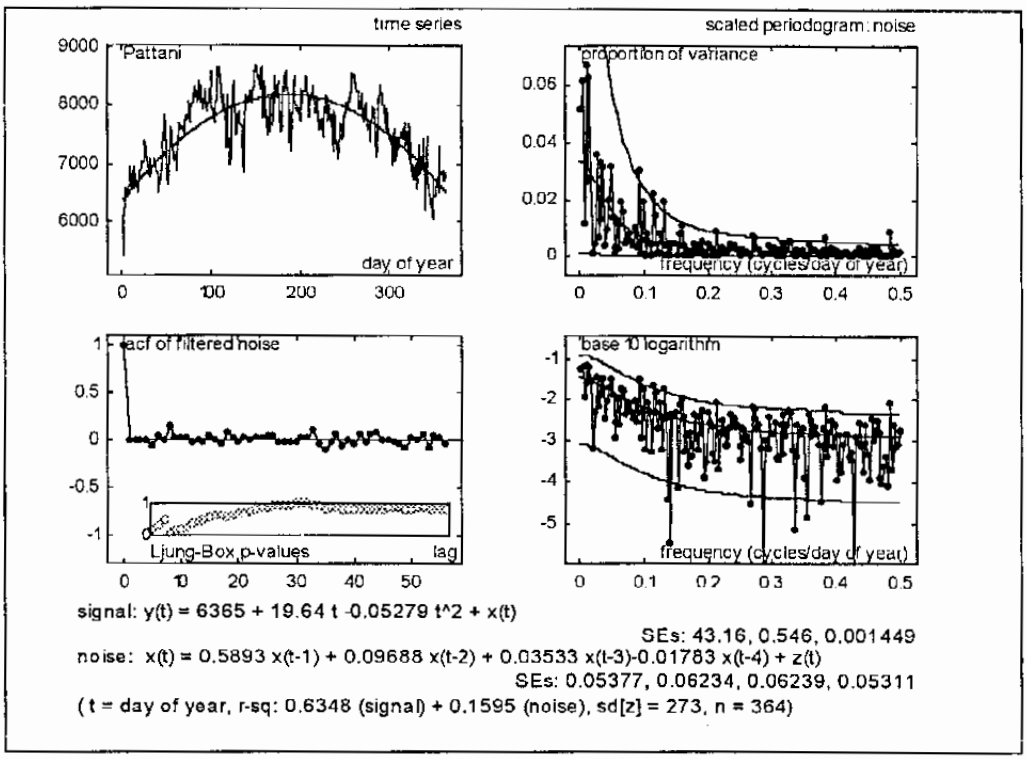
From the analysis, the time series model for feeders (6+8) is as follows.

$$y(t) = 2277+277\cos(at+3.037)+188.2\cos(2at-2.969)+2.578\cos(52at-2.85)$$

The efficiency of this model is 66.20%.

The analysis of electricity usage in feeders (6+8), shows that the usage increased from early on the year and to peak on April and September. However, the peak in September was higher than the peak in April. Electricity usage decreased again later in the year. The efficiencies of both models are similar.

Figure 33. The quadratic model for all feeders.



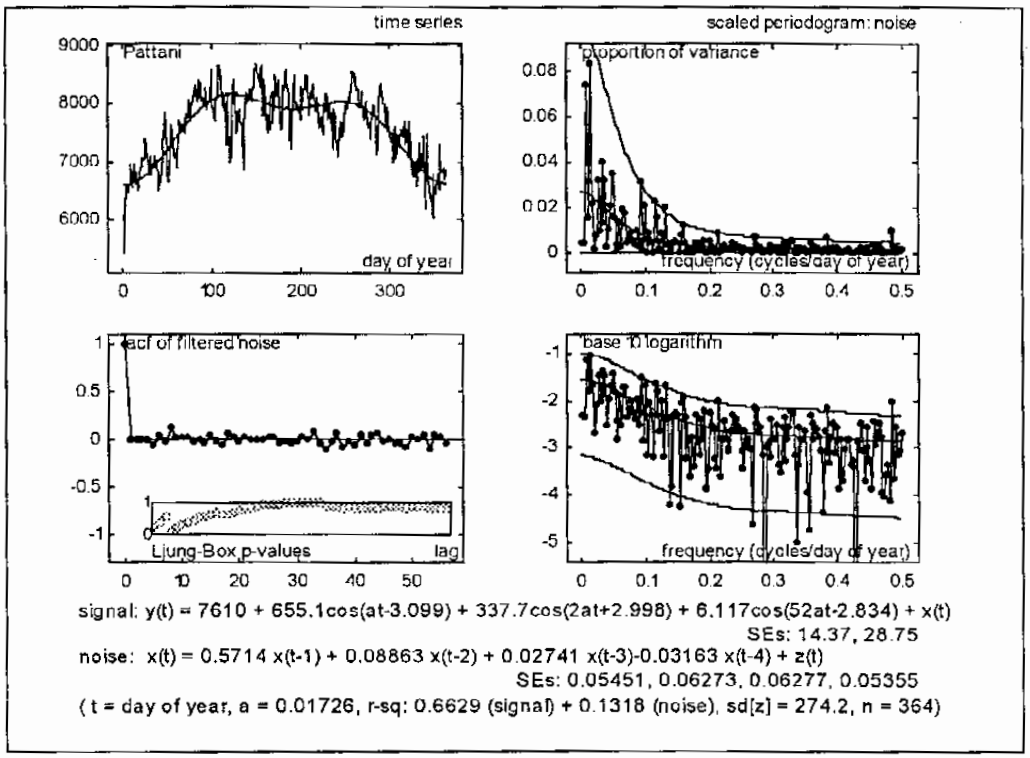
From the analysis, the quadratic model for all feeders is as follows.

$$y(t) = 6365 + 19.64t - 0.05279t^2$$

The efficiency of this model is 79.43%.

The analysis of electricity usage in all feeders, shows that the usage increased from early in the year to a peak on July, and then decreased again later in the year.

Figure 34. Time series model for all feeders.



From the analysis, the time series model for all feeders is as follows.

$$y(t) = 7610 + 655.1\cos(at-3.099) + 337.7\cos(2at+2.998) + 6.117\cos(52at-2.834)$$

The efficiency of this model is 79.47%.

The analysis of electricity usage in all feeders, shows that the usage increased from early in the year and to peak on April and September. However, the peak in April was higher than the peak in September. Electricity usage decreased again later in the year. The efficiencies of both models are similar.