Chapter 4

Maintenance Scheduling Analysis of EDL Central-I Area Case Study

This chapter describes generator maintenance scheduling of the EDL Central-I Area as a case study. System data consist of generator capacity, reservoir storages, operations, head function and water inflow statistic or probability. In addition system load and power exchange data are also given as well as EDL maintenance schedule, and crew constraints.

A brief description of custom-made software is included and details of the software algorithms are given in Appendix. The software is developed using Visual Basic Programming Language.

Three case studies are carried out using hydrology data of the year 2001, 2002, 2003, and 2004. The result of these studies is discussed in following section, and Testing input data are as follows.

4.1 Generator data

Table 4.1 Generator data

Dam	Unit	Installed Capacity (MW)	k_1	q
Nam Ngum	1,2	15	8.67	57.30
Nam Ngum	3,4,5	40	8.85	117.10
Nam Leuk	1,2	30	8.95	17.41
Nam Dong	1,2,3	0.336	8.49	0.31

Where as:

$$P_1 = k_1 \times q \times H_t \qquad (4.1)$$

P_1 is the generating power of unit 1. (kW)

k_1 is total efficiency provided by manufacturer multiply by velocity. (kJ/m^4)

q is discharge through turbine. (m^3/s)

H_t is net head at time t. (m)

4.2 Reservoir data

4.2.1 Reservoir Storage Data

Table 4.2 Reservoir Storage data

Reservoir	Maximum storage(MCM)	Maximum effective storage(MCM)	Dead storage (MCM)	Average evaporation per month(MCM)
Nam Ngum	7,000	4,700	2,300	12.96
Nam Leuk	200	200	200	0.9072
Nam Dong	0.043	0.043	0.043	0

4.2.2 Reservoir Operation Data

Table 4.3 Reservoir Operation Data

Reservoir	Maximum Tentative Flow ($M.m^3$/month)	Minimum Operation Flow ($M.m^3$/month)	Initial Effective Volume ($M.m^3$)	Ended Effective Volume ($M.m^3$)
Nam Ngum	40.254	23.154	3,600	3,600
Nam Leuk	3.008	0.439	170	170
Nam Dong	0.078	0.011	0.038	0.038

4.2.3 Head Function Data

Head at any time that is used in equation 4.1 has been given as many scatter points between the net head and effective storage by the dam constructor. The function, that is used for calculate the head when Effective Volume given, is simplified to polynomial equation based on least square error method and shown as equation 4.2.

$$H_t = K_a V_t^5 + K_b V_t^4 + K_c V_t^3 + K_d V_t^2 + K_e V_t + K_f \qquad (4.2)$$

Where as:

V_t Effective Volume at time t. (m^3)

K_a, K_b, K_c, K_d, K_e, K_f are the constant values where are shown in table 4.4.

Table 4.4 Constant value for calculate the head

Reservoir	K_a	K_b	K_c	K_d	K_e	K_f
Nam Ngum	1.18×10^{-18}	-3.11×10^{-14}	2.90×10^{-10}	-1.22×10^{-6}	5.39×10^{-3}	28.4
Nam Leuk	7.88×10^{-11}	-5.11×10^{-8}	1.31×10^{-5}	-1.72×10^{-3}	2.08×10^{-1}	176
Nam Dong	0	0	0	0	0	135

4.2.4 Water Inflow Data

The water inflow will be forecasted by using the probability inflow table of each reservoir that is shown in Figure 4.1, 4.2 or appendix B table B 1.1, B 1.2, B 1.3 When the long term weather forecasts are given, the number of probability inflow will be predicted. For Laos Region-I system, the probability inflow prediction is shown in table 4.5

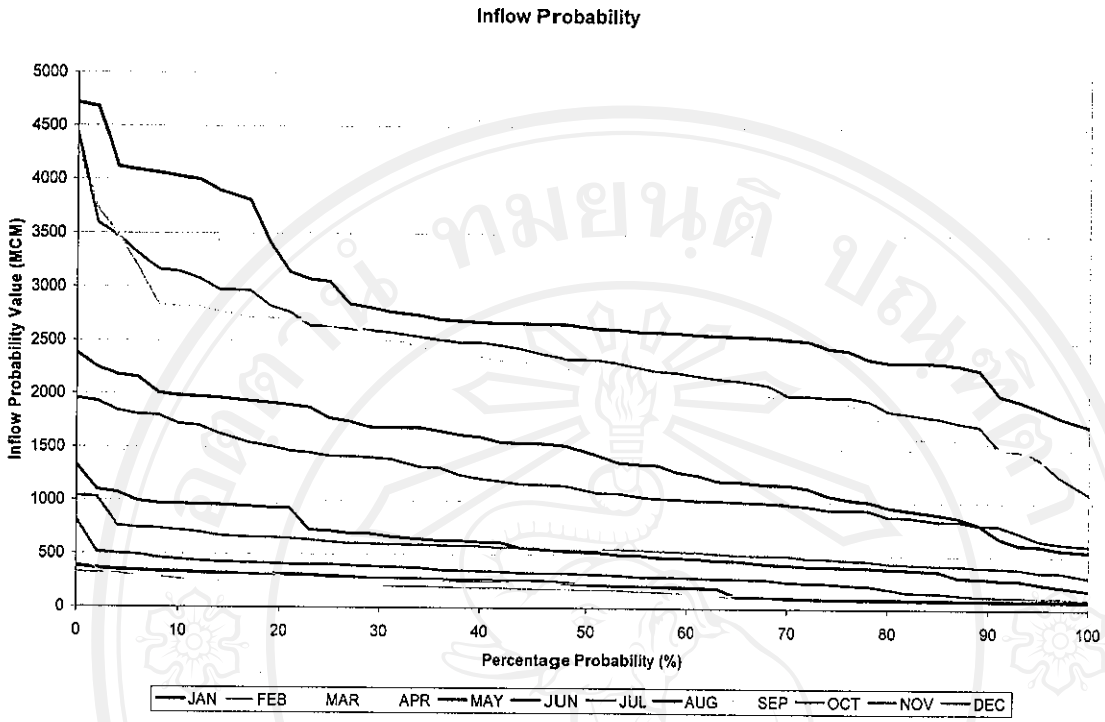

Figure 4.1 Inflow Probability of Nam Ngum Reservoir

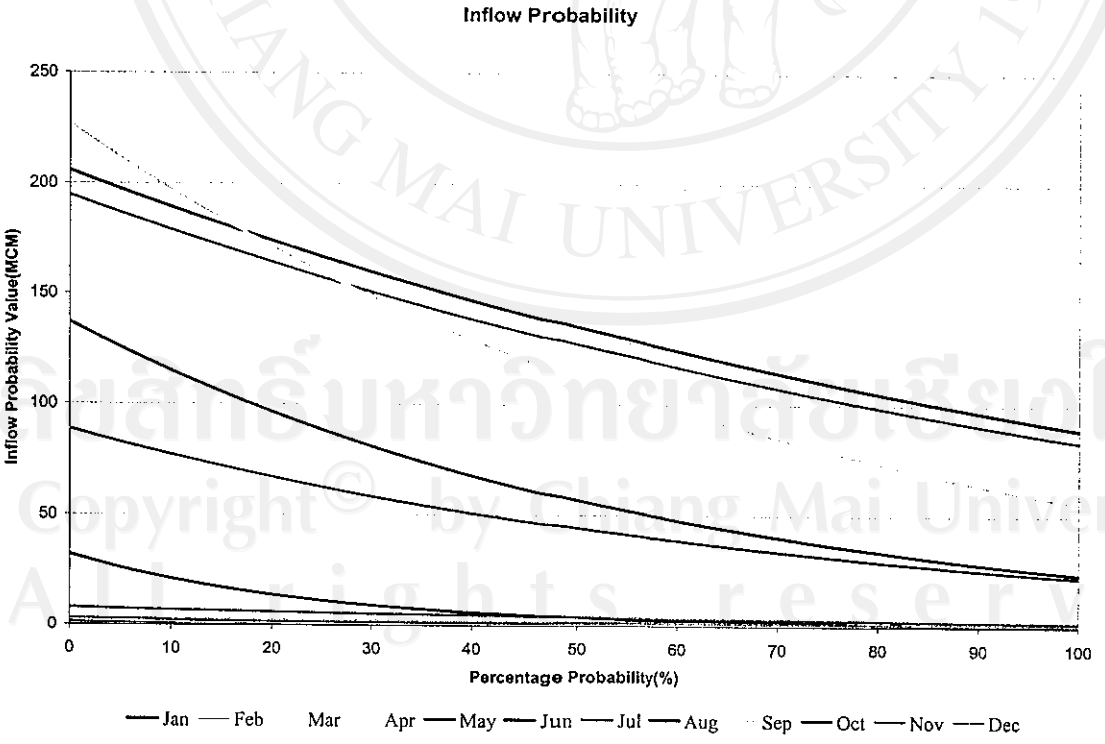

Figure 4.2 Inflow Probability of Nam Leuk Reservoir

Table 4.5 The probability inflow prediction of region-I system

Reservoir	Upper Rule Curve	Lower Rule Curve	Draught	Normal	Wet
Nam Ngum	20%	100%	75%	50%	25%
Nam Leuk	20%	100%	75%	50%	25%
Nam Dong	20%	100%	75%	50%	25%

4.3 System Data

4.3.1 Hourly Load Forecast

Normally, the system planner must forecast the annual peak and monthly peak load. Table 4.6 shows the monthly peak load of Laos region-I system. The hourly load can be calculated from load profile of each typical day and monthly peak load. Load profiles of Laos region-I system are shown in figure 4.3 to 4.14.

Table 4.6 Monthly peak load in MW of Laos region-I system

Month \ Year	2001	2002	2003	2004
January	108.7	118.5	134.1	147.5
February	109.5	119.4	144.1	158.5
March	110.3	120.2	148.1	162.9
April	111.1	121.1	145.6	160.1
May	111.9	122.0	142.0	156.2
June	112.8	122.9	137.9	151.7
July	113.6	123.8	136.3	149.9
August	114.4	124.7	135.2	148.7
September	115.2	125.5	136.0	149.6
October	116.0	126.4	138.6	152.4
November	116.8	127.3	138.5	152.3
December	117.6	128.2	138.0	151.8

4.3.2 Load profile twenty four hours

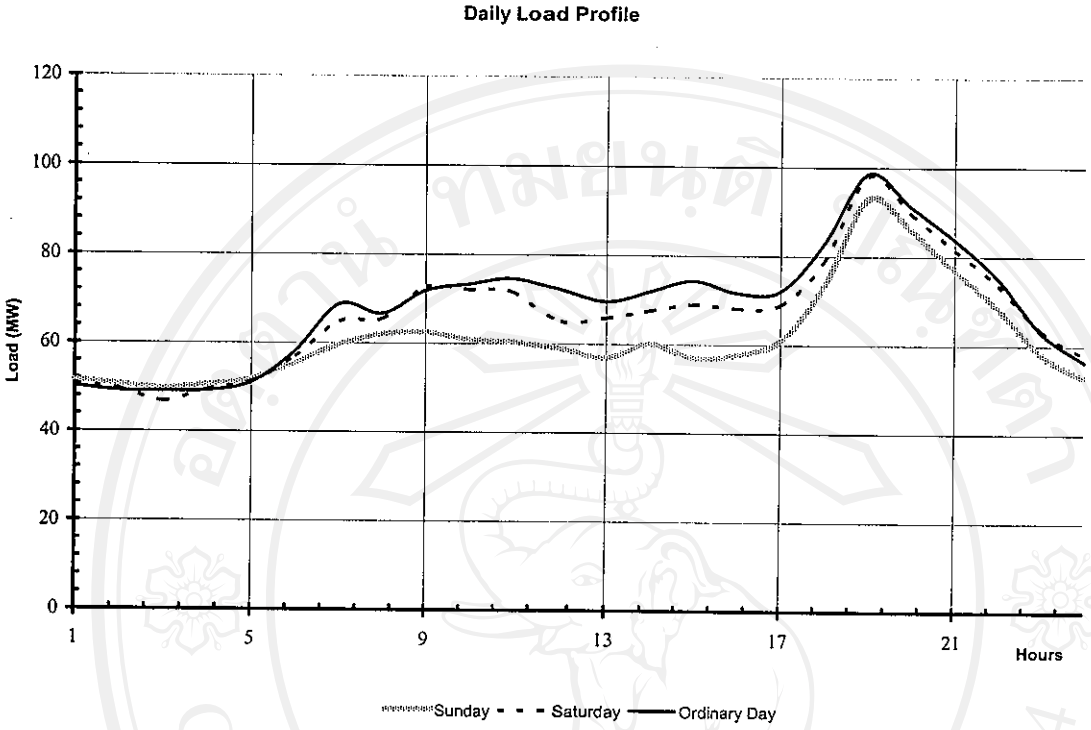

Figure 4.3 Daily Load Profile of EDL Central-I Area for January

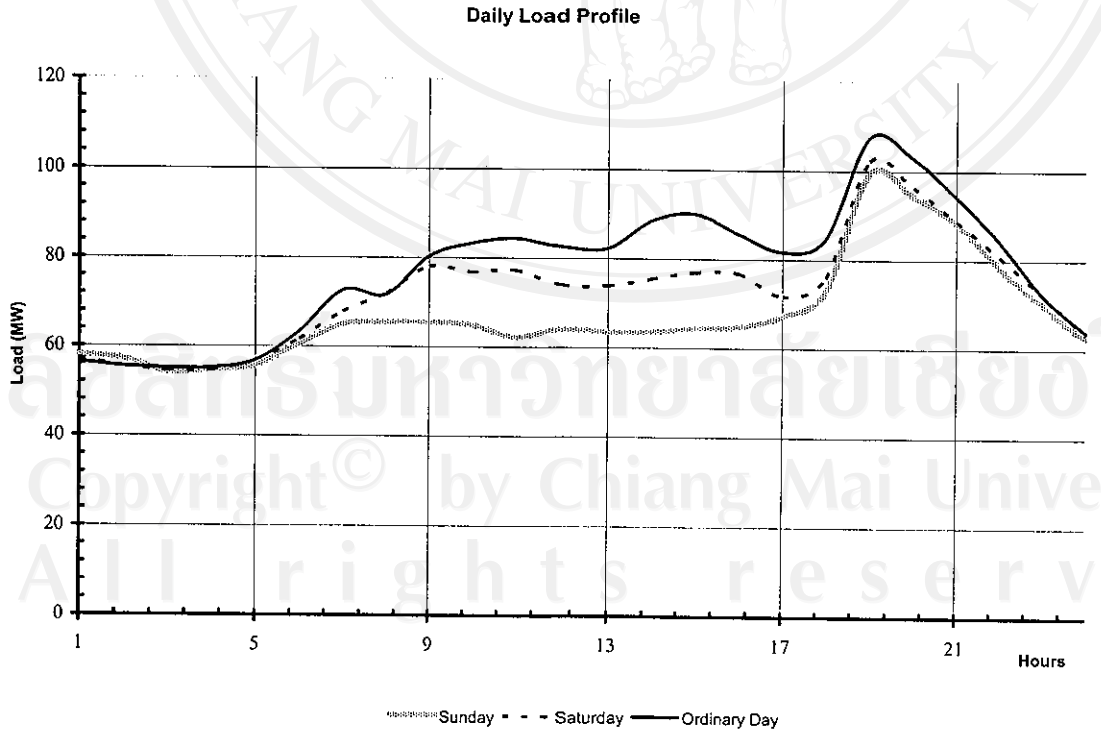

Figure 4.4 Daily Load Profile of EDL Central-I Area for February

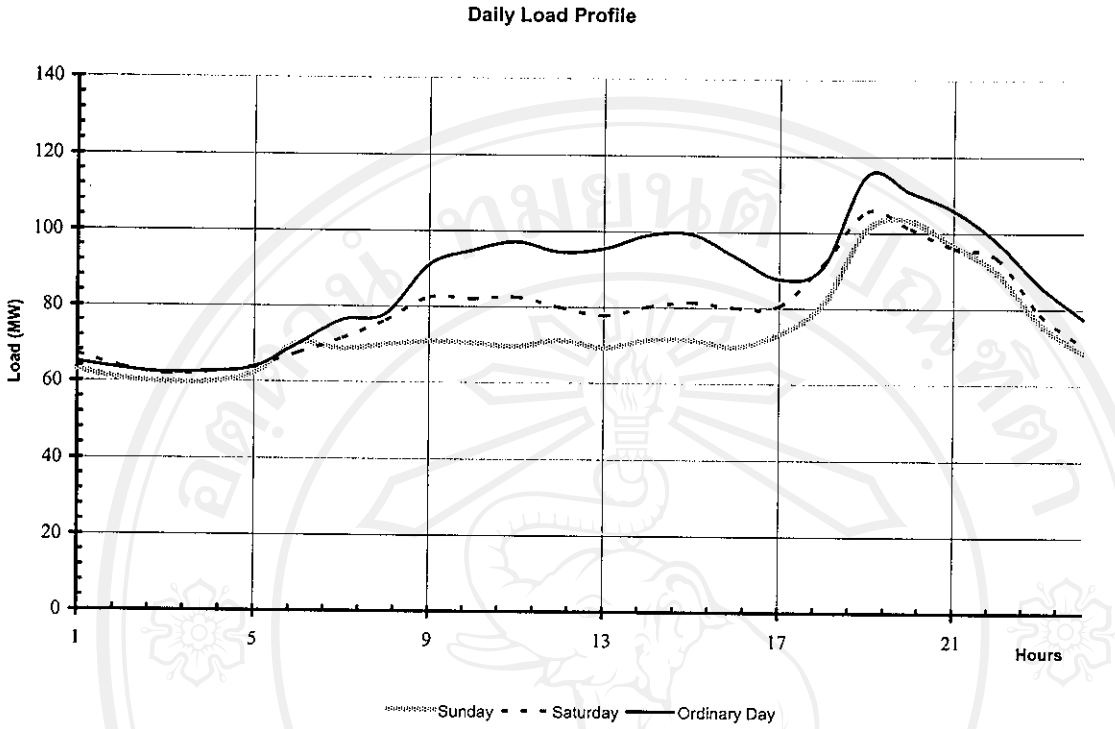

Figure 4.5 Daily Load Profile of EDL Central-I Area for March

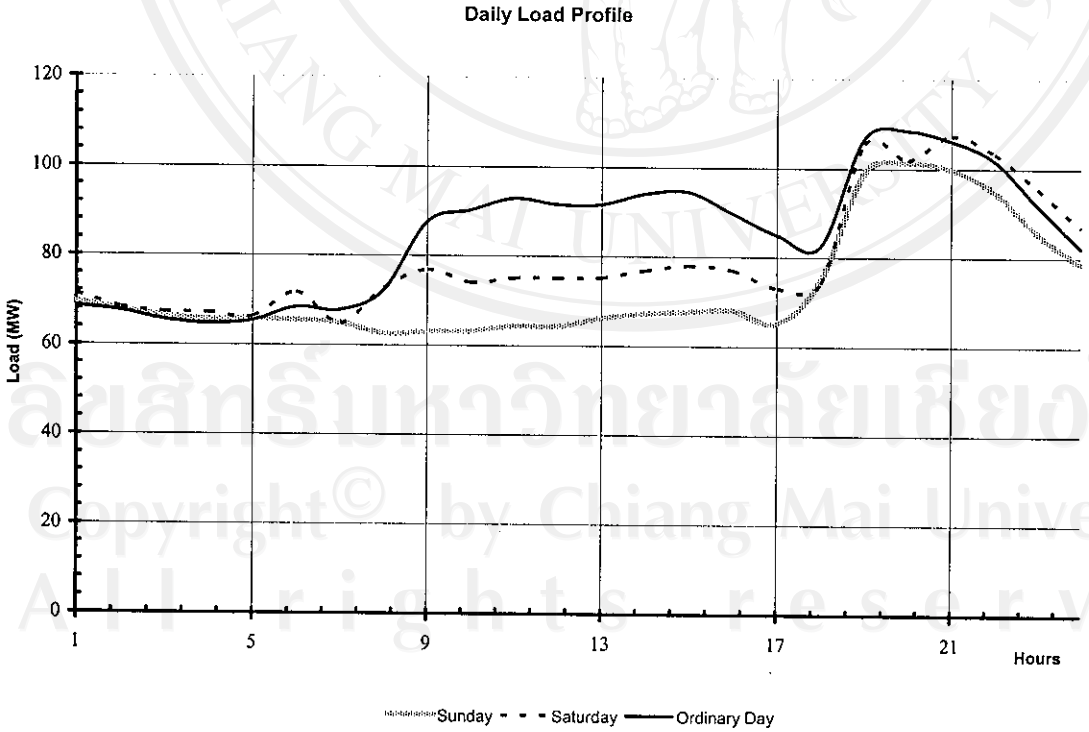

Figure 4.6 Daily Load Profile of EDL Central-I Area for April

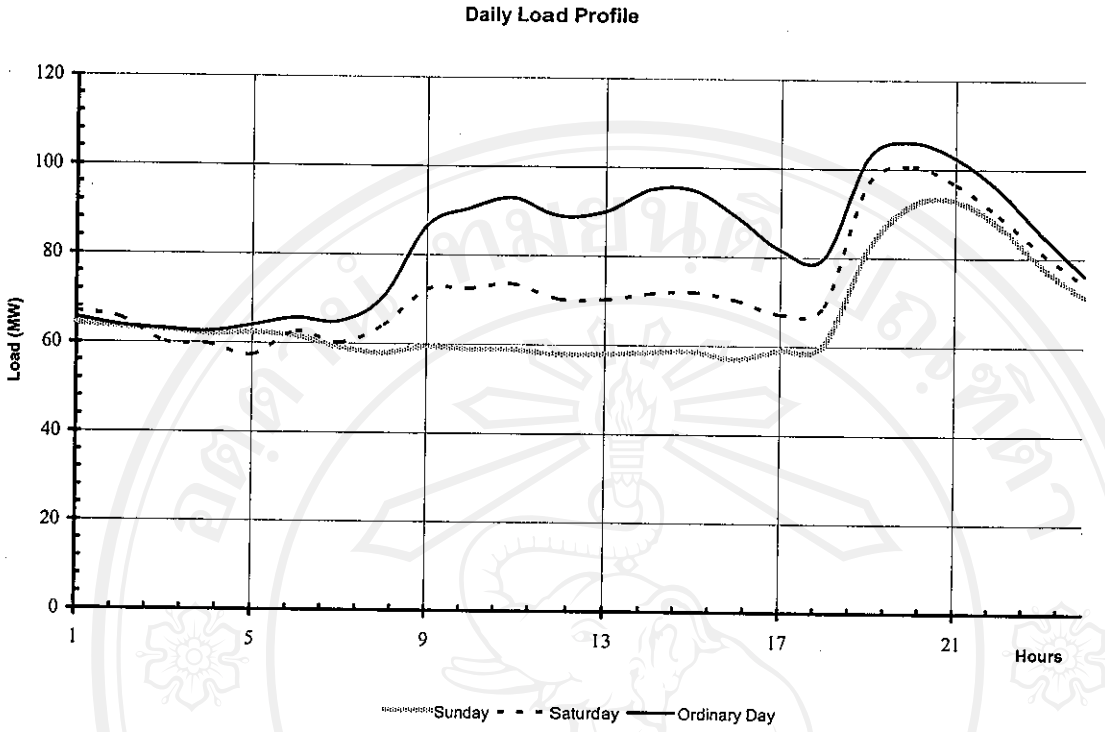

Figure 4.7 Daily Load Profile of EDL Central-I Area for May

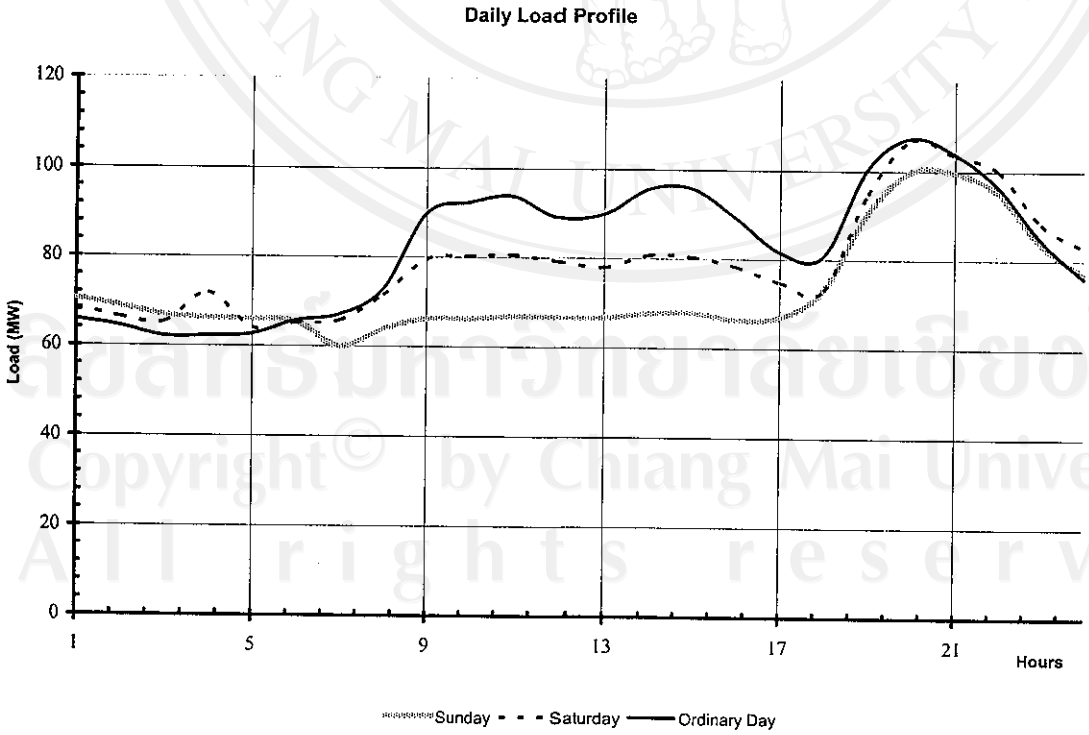

Figure 4.8 Daily Load Profile of EDL Central-I Area for June

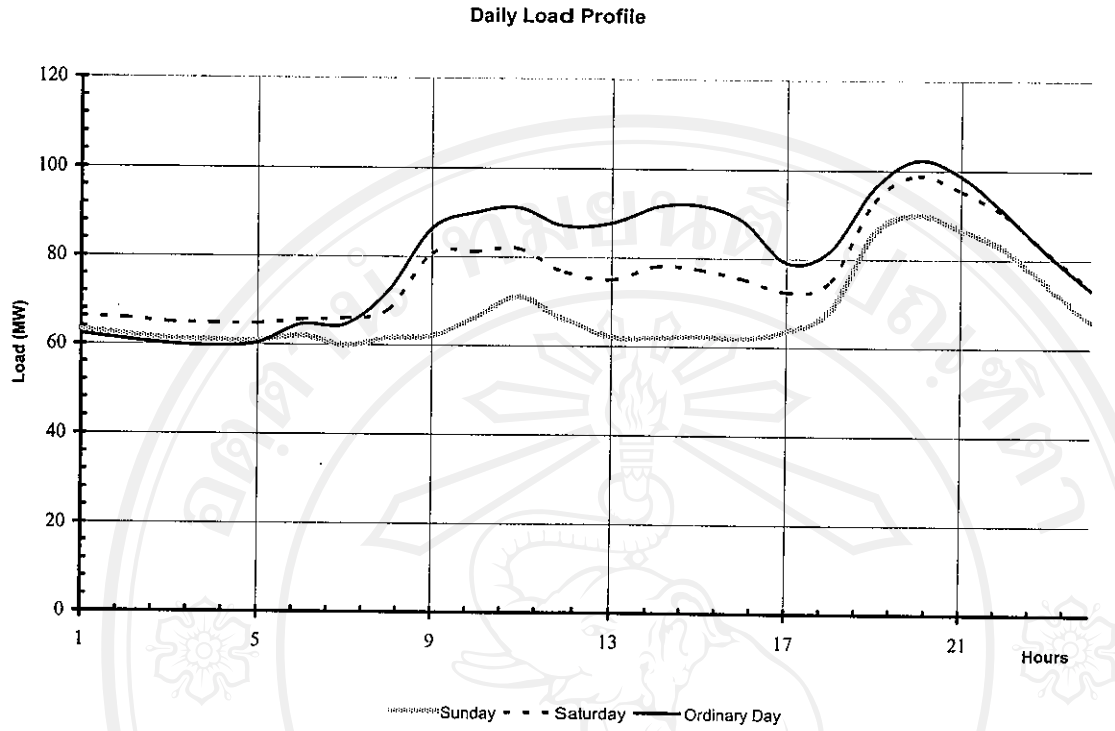

Figure 4.9 Daily Load Profile of EDL Central-I Area for July

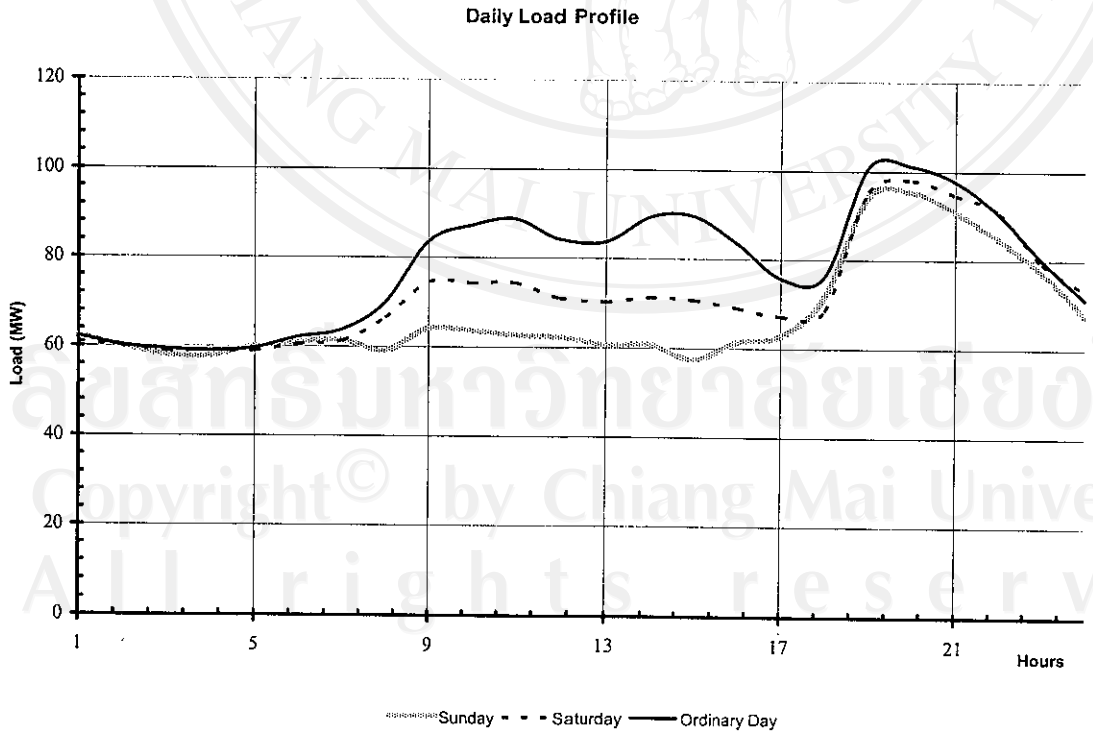

Figure 4.10 Daily Load Profile of EDL Central-I Area for August

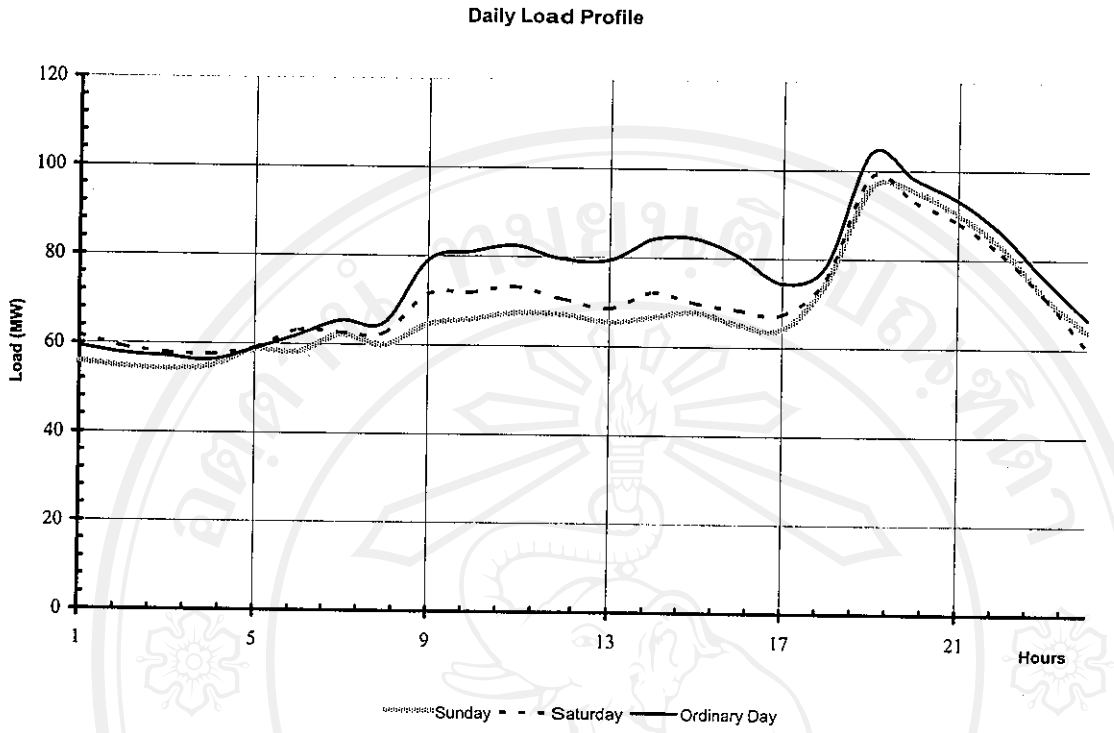

Figure 4.11 Daily Load Profile of EDL Central-I Area for September

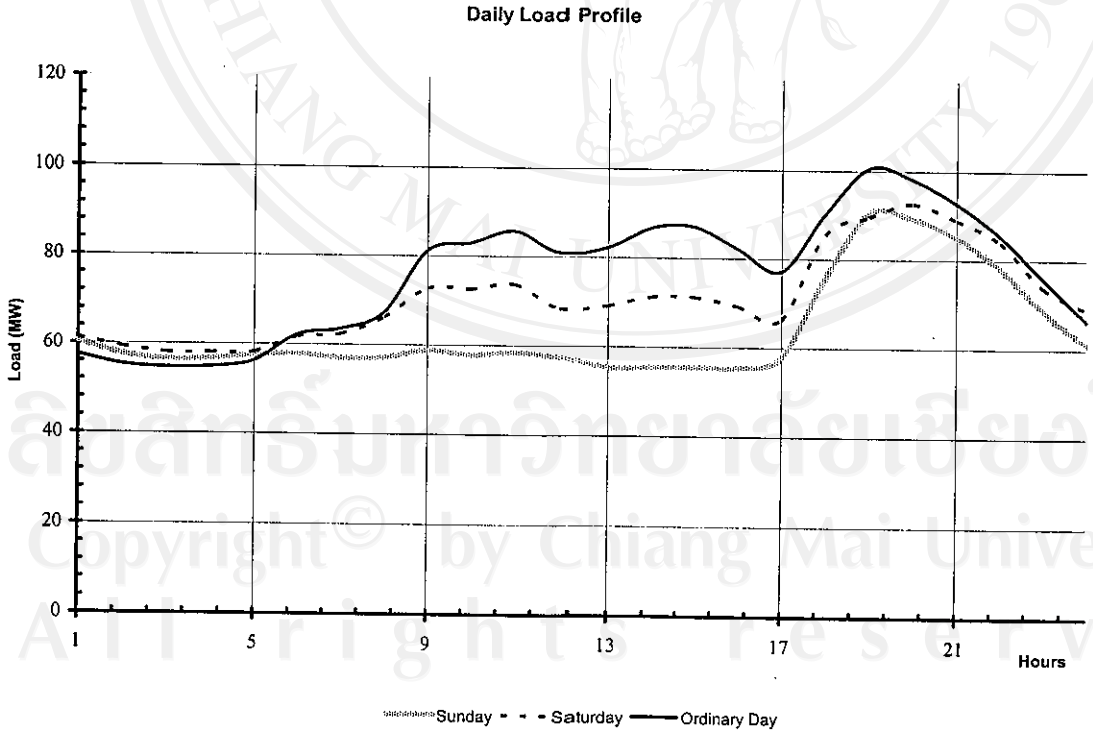

Figure 4.12 Daily Load Profile of EDL Central-I Area for October

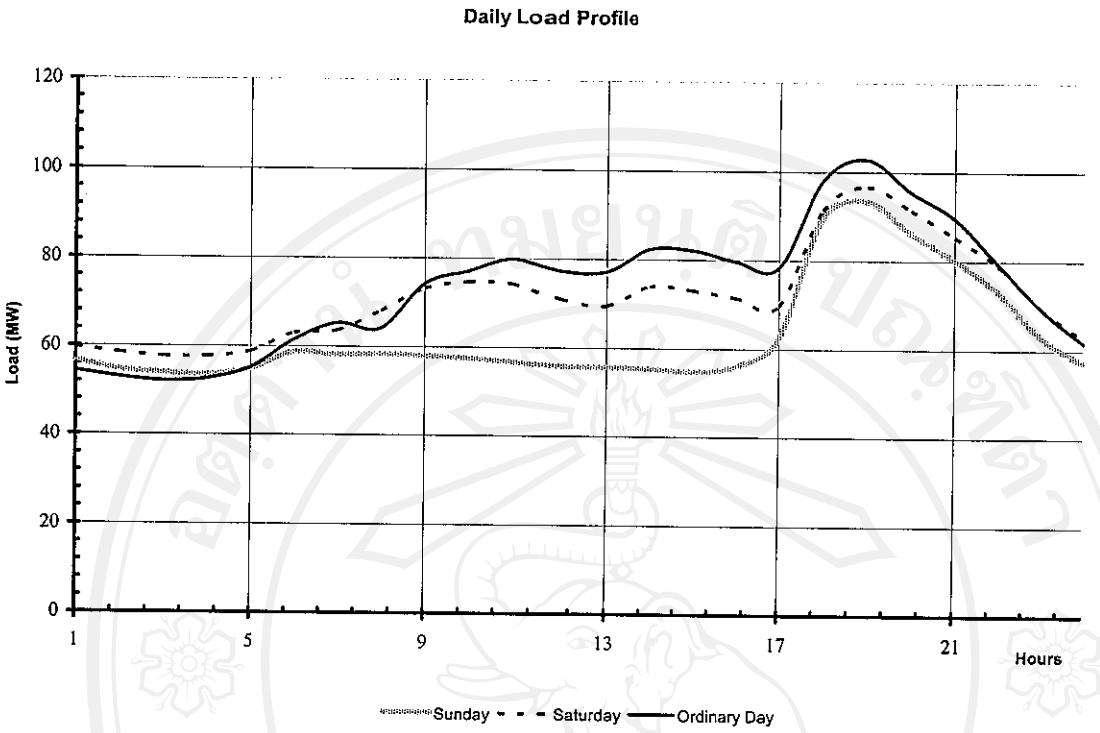

Figure 4.13 Daily Load Profile of EDL Central-I Area for November

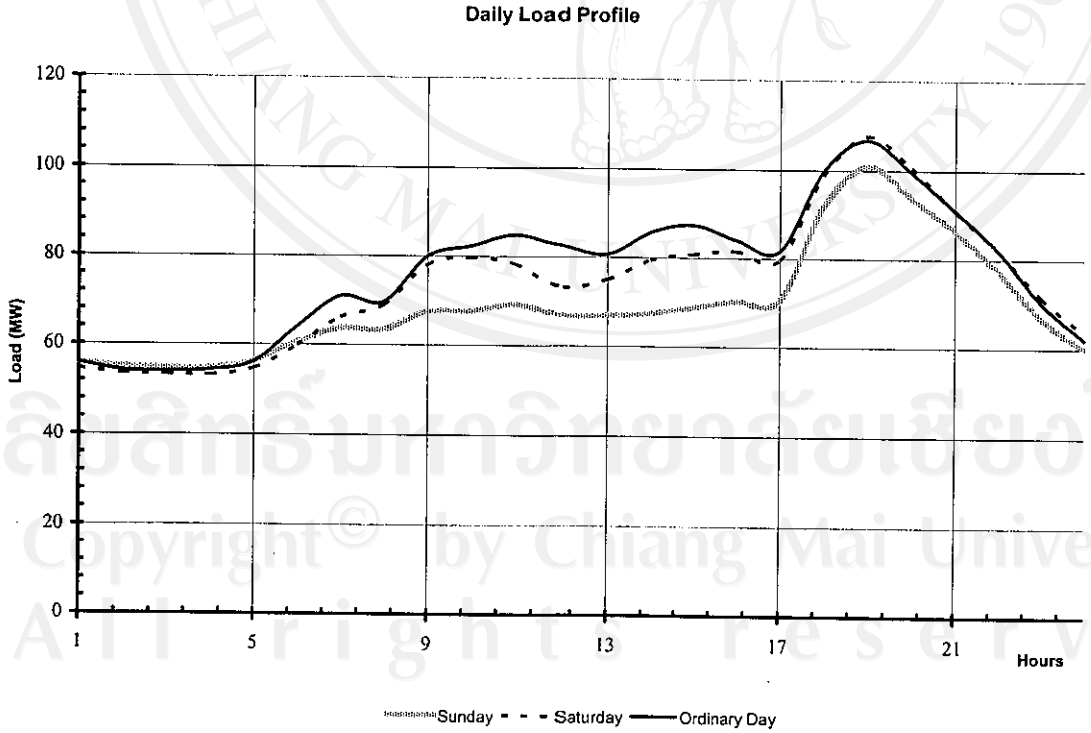

Figure 4.14 Daily Load Profile of EDL Central-I Area for December

4.3.3 Power Exchange Data

Table 4.7 Power Exchange Data

Type	Period	Tariff (Baths/kWh)	Maximum Flow (MW)
Import	Peak	1.41	50
	Off-Peak	1.33	
Export	Peak	1.22	210
	Off-Peak	1.14	

Remarks: Peak – is high demand of local consumption which is started from 18:00 to 21:30 O'clock equal 3.5 hours and others are off-peak equal 20.5 hours.(Except Saturday and Sunday are off-peak 24 hours)

Off-peak – is low demand of local consumption

4.4 Maintenance Data

4.4.1 EDL Maintenance Schedule

Table 4.8 EDL Maintenance Schedule

Unit	2001			2002			2003			2004		
	Start date	Stop date	Total day	Start date	Stop date	Total day	Start date	Stop date	Total day	Start date	Stop date	Total day
NNG1-U1	3 Jan	22 Jan	20	22 Apr	11 May	20	1 Nov	21 Nov	21	1 Jan	21 Jan	21
NNG1-U2	29 Jan	16 Feb	19	25 Mar	12 Apr	19	17 Mar	6 Apr	21	22 Jan	11 Feb	21
NNG1-U3	20 Feb	13 Mar	22	4 Mar	25 Mar	22	6 Jan	31 Jan	26	1 Nov	26 Nov	26
NNG1-U4	20 Mar	10 Apr	22	4 Feb	25 Feb	22	17 Feb	14 Mar	26	1 Dec	26 Dec	26
NNG1-U5	18 Apr	9 May	22	3 Jan	24 Jan	22	22 Apr	17 May	26	1 Jan	26 Jan	26
NL-U1	1 Nov	23 Nov	23	12 Feb	6 Mar	23	12 Feb	6 Mar	23	12 Feb	5 mar	23
NL-U2	1 Dec	23 Dec	23	1 Dec	23 Dec	23	1 Dec	23 Dec	23	1 Dec	23 Dec	23
ND-U1	1 Apr	10 Apr	10	1 Apr	10Apr	10	1 Apr	10 Apr	10	1 Apr	10 Apr	10
ND-U2	11 Apr	20 Apr	10	11 Apr	20 Apr	10	11 Apr	20 Apr	10	11 Apr	20 Apr	10
ND-U3	21 Apr	30 Apr	10	21Apr	30 Apr	10	21 Apr	30 Apr	10	21 Apr	30 Apr	10

4.4.2 Allowable windows for maintenance

Table 4.9 Allowable windows for maintenance

Unit	2001			2002			2003			2004		
	Start date	Stop date	Total day	Start date	Stop date	Total day	Start date	Stop date	Total day	Start date	Stop date	Total day
NNG1-U1	1 Jan	31 Dec	365	1 Jan	31 Dec	365	1 Jan	31 Dec	365	1 Jan	31 Dec	366
NNG1-U2	1 Jan	31 Dec	365	1 Jan	31 Dec	365	1 Jan	31 Dec	365	1 Jan	31 Dec	366
NNG1-U3	1 Jan	31 Dec	365	1 Jan	31 Dec	365	1 Jan	31 Dec	365	1 Jan	31 Dec	366
NNG1-U4	1 Jan	31 Dec	365	1 Jan	31 Dec	365	1 Jan	31 Dec	365	1 Jan	31 Dec	366
NNG1-U5	1 Jan	31 Dec	365	1 Jan	31 Dec	365	1 Jan	31 Dec	365	1 Jan	31 Dec	366
NL-U1	1 Jan	31 Dec	365	1 Jan	31 Dec	365	1 Jan	31 Dec	365	1 Jan	31 Dec	366
NL-U2	1 Jan	31 Dec	365	1 Jan	31 Dec	365	1 Jan	31 Dec	365	1 Jan	31 Dec	366
ND-U1	1 Jan	31 Dec	365	1 Jan	31 Dec	365	1 Jan	31 Dec	365	1 Jan	31 Dec	366
ND-U2	1 Jan	31 Dec	365	1 Jan	31 Dec	365	1 Jan	31 Dec	365	1 Jan	31 Dec	366
ND-U3	1 Jan	31 Dec	365	1 Jan	31 Dec	365	1 Jan	31 Dec	365	1 Jan	31 Dec	366

4.4.3 Maintenance crew constraints

Table 4.10 Maintenance crew constraints

Unit	Crew Requirements			
	2001	2002	2003	2004
NNG1-U1	30	30	30	30
NNG1-U2	30	30	30	30
NNG1-U3	30	30	30	30
NNG1-U4	30	30	30	30
NNG1-U5	30	30	30	30
NL-U1	30	30	30	30
NL-U2	30	30	30	30
ND-U1	30	30	30	30
ND-U2	30	30	30	30
ND-U3	30	30	30	30
Maximum	60	60	60	60