Chapter 5

Results and Discussions

Based on the algorithm shown in Figure 3.5, a software program has been developed and tested. During the program testing, it was found that the computation time is acceptable when the test system is small and the study period is short. However, the computation time increases with longer study period. If the proposed method is to be applied to an actual system, such as EDL central-I system, for the whole year period then the computation time will be too long and not acceptable. Therefore, the algorithm has been modified to reduce computation time as described below.

Then, comparison of EDL and the proposed method results are carried out for the year 2001, 2002, 2003 and 2004. Hydrology data of each year is assumed to have three possible scenarios i.e. wet or normal or draught year. Therefore, there are 12 study cases. For each case, the objective function is to maximize revenue with given constraints, result of the proposed method is assessed and compared with EDL maintenance schedule. Details of results obtained are given using hydrology data of the year 2001- 2004.

5.1 Reduction on computation time

When the characteristics of hydrology are considered, the capacity, water rate and water level are usually slow changing among days of each month. The generation schedule and revenue calculation results in the same month will be very similar. For these reasons, the possible maintenance window could be reduced to a shorter period.

From Figure 5.1, the key to computation time reducing is how to vary maintenance schedule of unit K. As described before, we assume the beginning of maintenance schedule on different day in the same month is lightly impact to the revenue when compare with on different day in other month. Then the maintenance schedule will be varied from the month to other in the study period. With this principle, the feasible maintenance schedules of unit k will not be more than 12 schedules (months). Hence, the combination of maintenance schedule for generation scheduling and revenue calculating will be reduced. The result of this step is the best month for each generating unit scheduled outage. However, the final schedule on daily basis is still required.

Next the three weeks before and after the maintenance schedule of each unit must be considered because the longest time between considered schedule in the month and neighboring month is about four weeks. It is similar the maintenance allowance window reduces to start at three weeks before the resulted schedule from the first step and to finish at three weeks after the schedule plus maintenance time. With this concept, we will consider almost possible schedule. Similar to the proper month search in the first step, a most proper week will be searched with the algorithm in Figure 5.1 by varying the maintenance schedule from week to other weeks in the new maintenance allowance window. The maximum considered case of each maintenance requirement in this step is not more than 7 cases.

The final maintenance schedule search will use the result schedule from the second step as initial schedule and search the first date of maintenance in boundary 3 days before to 3 days after the initial schedule. It results from an assumption that the neighboring week would be selected if almost days of the week were in maintenance period. Moreover, this step finds the most proper day due to difference in load profile. The Figure 5.2 shows the principal of the 3 search steps. With the three search steps and Visual Basic language software, the computation time of year 2002 normal inflow case that the result will be shown in the next topic when determine the maintenance allowance window whole year is about 50 hours. The computer that computed is Pentium4 3.0 GHz with 1 Giga Bytes RAM.

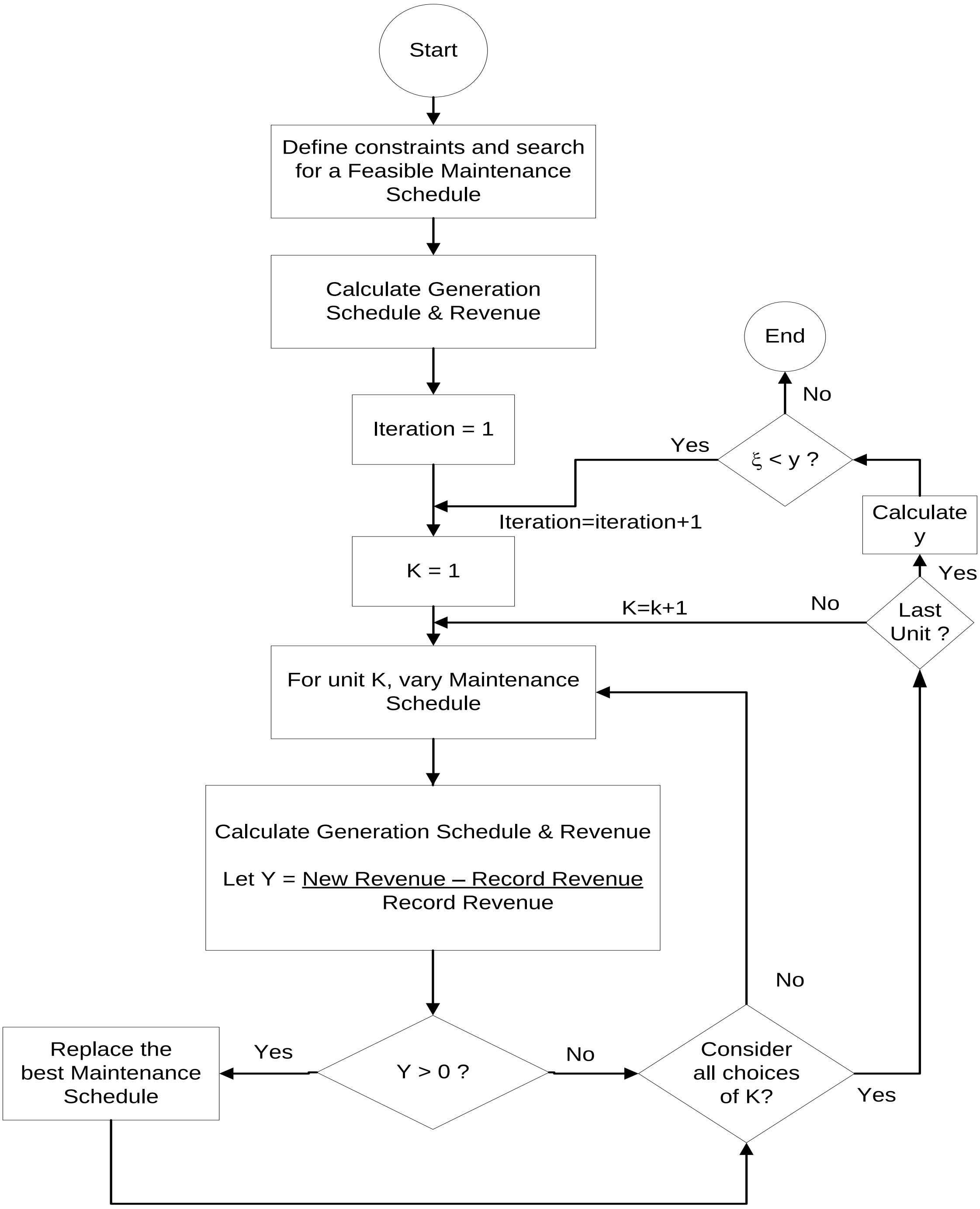

Figure 5.1 Search algorithms from Figure 3.5

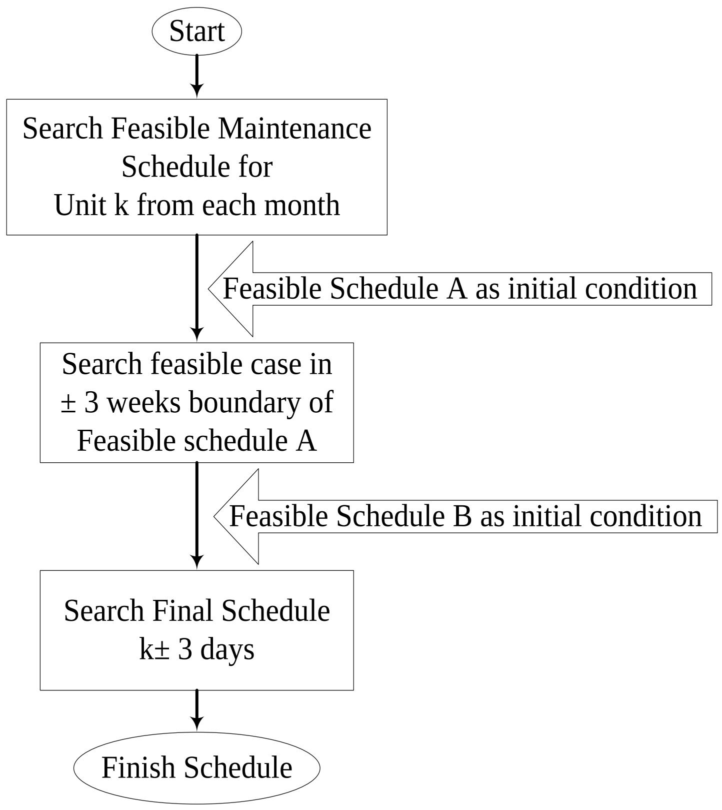

Figure 5.2 Three search steps

5.2 Case Study Results

A computer program of the proposed method provides output information concerning performance data of the power system as follows;

- Hourly import and export power
- Annual net cost (revenue)
- Daily minimum reserve
- Maintenance schedule of each generating unit
- Monthly water release of each reservoir

Test results of year 2002 are presented below as sample of primary data for discussion and further analyses.

5.2.1 Reserve capacity

Daily minimum reserve data obtained from the program for year 2002 is compared with that from EDL as shown in Figure 5.3. The figure shows low reserve capacity from proposed method is during the starting of rainy season (June and July) while EDL schedule is during winter and summer season (January to March) because of EDL existing generation principle is to generate as much as they can after rainy season. Then the water storage will reduce to low level in February or March and generating units will be in maintenance during low storage period while March is the high demand period of the year. The proposed method is different, generators will generate at higher tariff hour. Consider EDL tariff and limited energy, import tariff is higher than export tariff and all generating units have enough water for generate many hours in rainy season but they have less water in summer season especially small reservoir power station. If a generator of large reservoir is in maintenance in summer season, total import energy will be increased and net revenue will be reduced. Then the proposed method suggests to outage generating unit in starting of rainy season. However, the schedules are related to water inflow assumption.

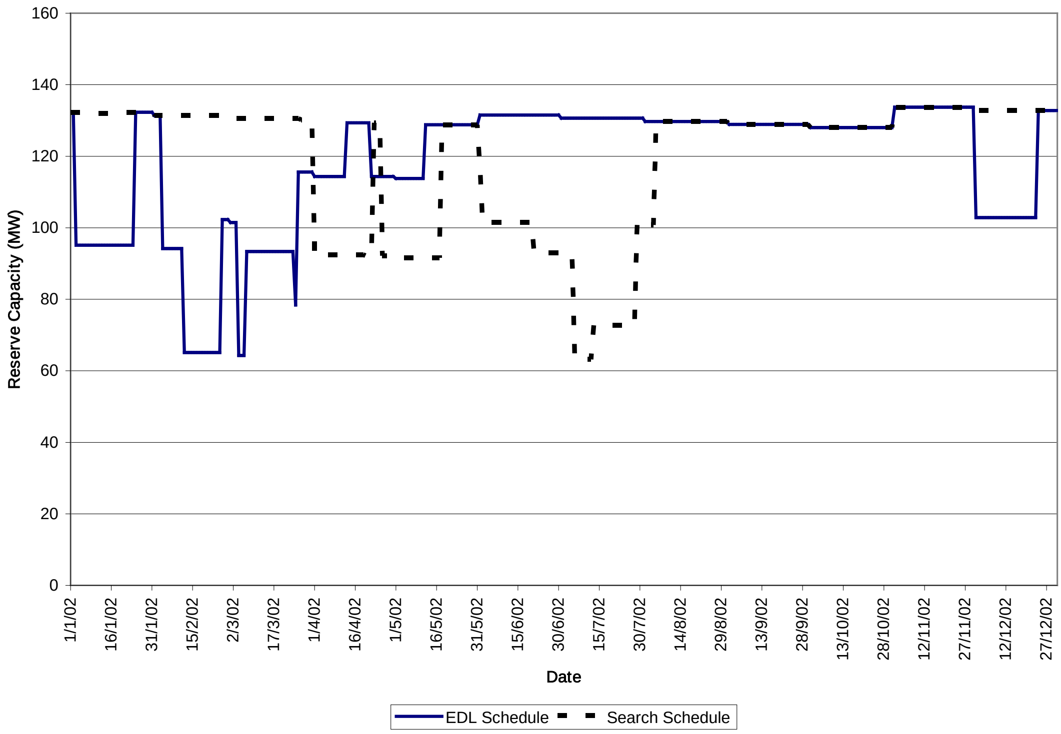

Figure 5.3 Daily minimum reserves

5.2.2 Power Exchange

Difference of power transfer from the proposed schedule compared with EDL schedule for each hour in the year 2002 are obtained from the program as shown in Figure 5.4. If we consider only 7 days, we can see more clearly power flow conditions as in Figure 5.5 below. The figures show import energy of proposed schedule is higher than EDL schedule because of generation planning of the proposed method is not minimize imported energy due to higher tariff but maximize net revenue is the objective function. If the export energy increases more than import energy increases maybe give more revenue and the schedule should be selected. This topic will be discussed again in 5.3.

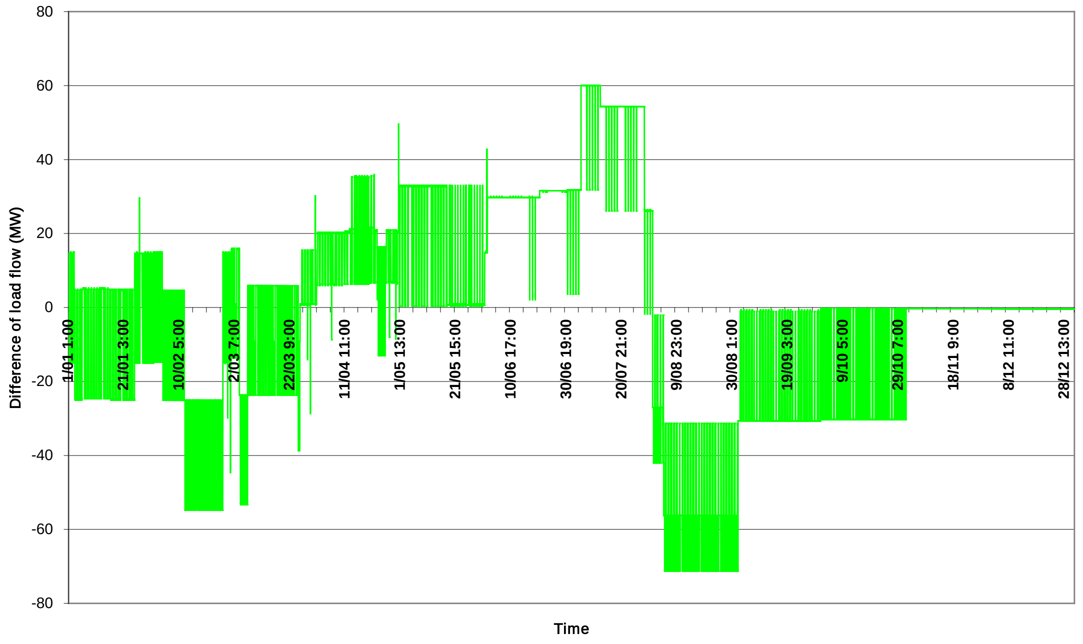

Figure 5.4 Difference of Hourly Power Exchange for the year 2002

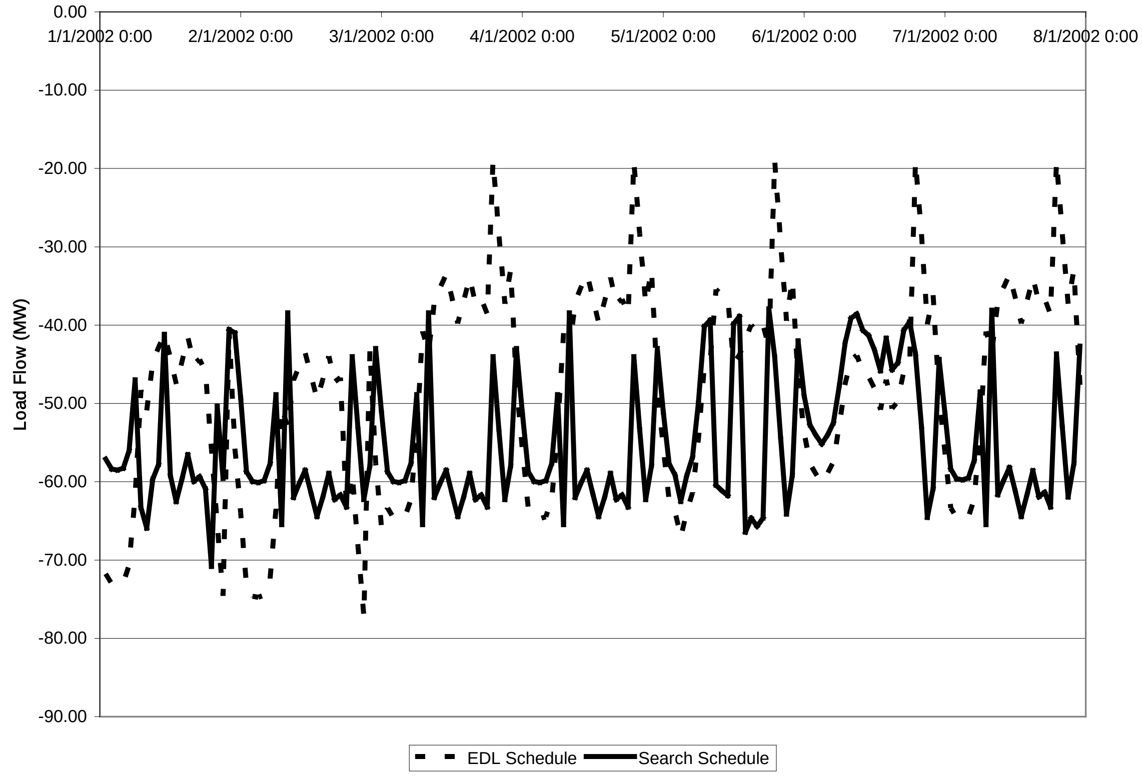

Figure 5.5 Hourly Power Exchange for Jan 1 – 8, 2002

5.3 Analysis of Year 2002 Power System Performance

Performance data, for year 2002 using normal inflow scenario, from the proposed method is compared with EDL's using the same generation planning obtained from the proposed searching process. The reservoir operations, maintenance schedules, revenue, import/export and minimum reserves are compared as detailed below.

The comparisons of reservoir operations are given in Table 5.1, Figure 5.6. For Nam Ngum Dam and Table 5.2, Figure 5.7 for Nam Leuk Dam respectively.

The comparison of maintenance schedules are given Figure 5.8 and comparison of the power exchanges and revenues are given in Table 5.3

The Table 5.3 shows net revenue of proposed schedule is more than EDL schedule 19.9 million baht or 3.6 percents though import energy is increased. Because of import energy is increased 1.6 GWh but export energy is increased 19.6 GWh. The maximum export and import power is higher but are still in the limits, 210 MW maximum export and 50 MW maximum import. The minimum reserve capacity of proposed method is lower but still over the requirement, 40 MW (The largest unit). The daily minimum reserve distribution of proposed method is worse due to more standard deviation. However, the proposed schedule should be selected when compared with EDL schedule because of higher revenue and over minimum reliability requirement.

Table 5.1 Nam Ngum Dam 2002

Month	Inflow	EDL Schedule			Search Schedule		
		Starting Volume	Release	Ending Volume	Starting Volume	Release	Ending Volume
Jan	223	3,600	806	3,004	3,600	904	2,906
Feb	172	3,004	764	2,399	2,906	887	2,177
Mar	151	2,399	864	1,673	2,177	1,007	1,309
Apr	234	1,673	1,085	809	1,309	856	674
May	526	809	865	457	674	718	470
Jun	1,465	457	1,203	706	470	912	1,010
Jul	2,332	706	1,230	1,795	1,010	1,104	2,226
Aug	2,637	1,795	688	3,731	2,226	1,119	3,730
Sep	2,217	3,731	1,039	4,700	3,730	1,039	4,700
Oct	1,102	4,700	1,036	4,700	4,700	1,036	4,700
Nov	555	4,700	800	4,442	4,700	800	4,442
Dec	319	4,442	870	3,878	4,442	870	3,878

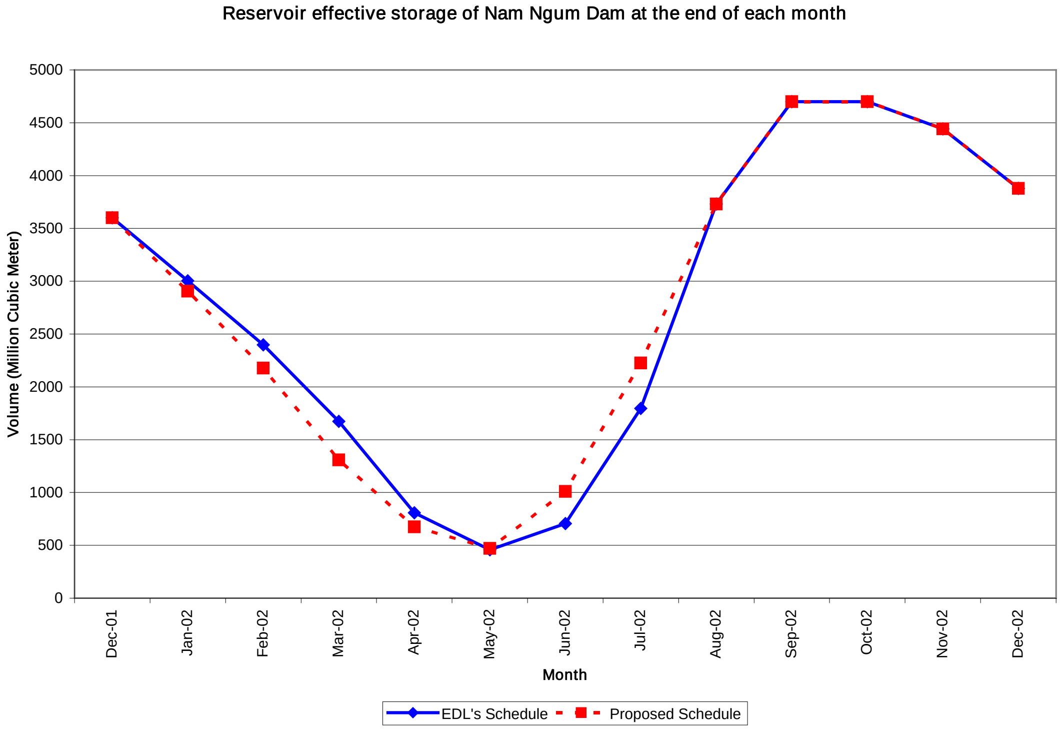

Figure 5.6 The comparison of Nam Ngum reservoir operation

Table 5.2 Nam Leuk Dam 2002

Month	Inflow	EDL Schedule			Search Schedule		
		Starting Volume	Release	Ending Volume	Starting Volume	Release	Ending Volume
Jan	0.85	170.00	35.22	134.72	170.00	25.38	144.56
Feb	0.59	134.72	12.60	121.80	144.56	18.61	125.63
Mar	0.30	121.80	33.28	87.91	125.63	18.11	106.90
Apr	0.29	87.91	23.69	63.60	106.90	42.68	63.60
May	3.91	63.60	46.63	19.97	63.60	46.63	19.97
Jun	56.85	19.97	56.85	19.07	19.97	56.85	19.07
Jul	127.33	19.07	89.38	56.11	19.07	30.08	115.40
Aug	135.25	56.11	93.26	97.19	115.40	87.24	162.50
Sep	112.21	97.19	51.08	157.41	162.50	86.51	187.29
Oct	44.18	157.41	56.14	144.55	187.29	86.04	144.52
Nov	4.05	144.55	0.06	147.63	144.52	0.06	147.60
Dec	1.67	147.63	0.06	148.34	147.60	0.06	148.30

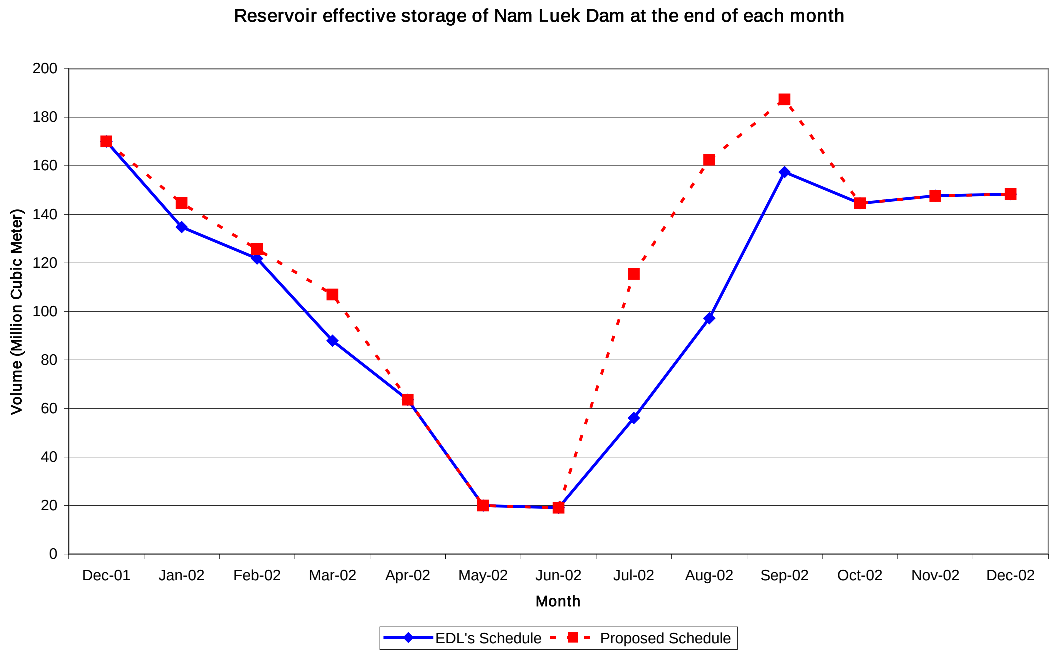

Figure 5.7 The comparison of Nam Luek reservoir operation

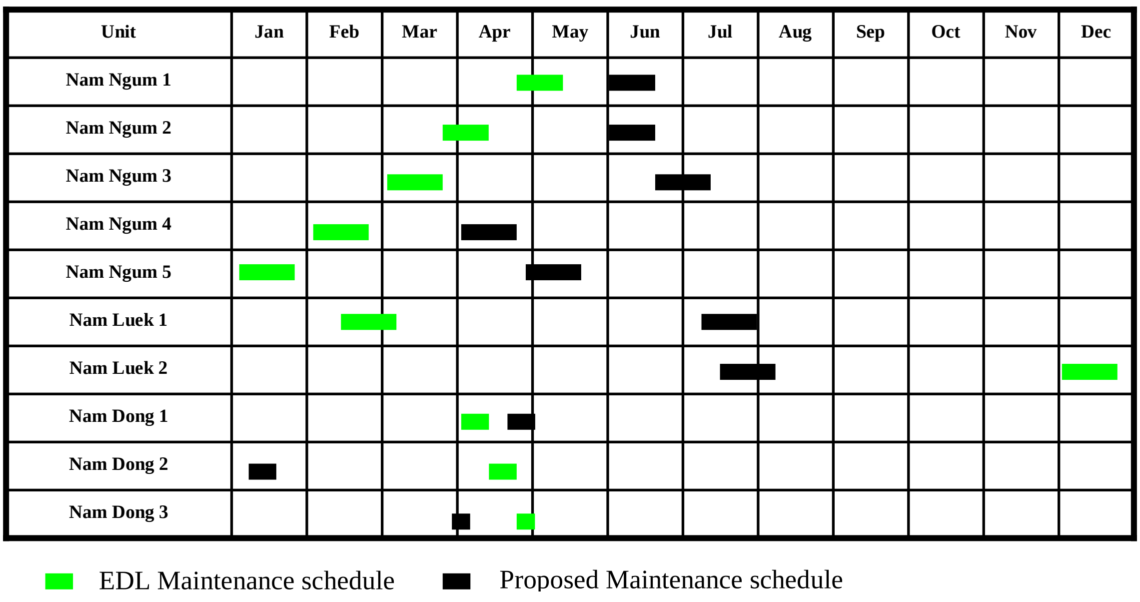

Figure 5.8 comparison of maintenance schedules

Table 5.3 Comparison of the power exchanges and revenues

Schedule	Export Energy	Import Energy	Maximum Export	Maximum Import	Net Revenue	Reserve (MW)	
	(GWh)	(GWh)	(MW)	(MW)	(M.Baht)	Minimum	Deviation
EDL Schedule	488.0	0.8	118.0	16.2	552.4	64.3	18.2
Search Schedule	507.7	2.4	140.9	23.3	572.3	63.2	19.8
Difference	19.6	1.6	22.8	7.1	19.9	-1.1	1.6
Difference (%)	**4.0**	**210.3**	**19.4**	**44.0**	**3.6**	**-1.7**	**9.1**

5.4 Analyses of the 12 Study Cases

Twelve study cases are formulated based on three inflow scenarios for four consecutive year (2001 – 2004). Electricity demand will be assumed increasing every year and the water inflow will be assumed as low, normal and high according to drought, normal and wet weather conditions. Analyses are focused on determining water inflow and load demand influences on generation maintenance scheduling objective (maximize revenue) and constraint (reserve capacity)

5.4.1 Influence of Water Inflow

Comparisons of three water inflow scenarios in each year are carried out to determine effects of water condition on the revenue and reserve capacity. Results are shown in Figure 5.9 -5.10. The figure 5.9 shows maximum revenue increase is normal inflow scenario because of the water release is more than low inflow, then the generation plan to maximize revenue have more limited energy to generation at proper hour. However, it cannot describe when compared with high inflow scenario. The very high water release due to high inflow is enough for generation and avoided import most hours, then the different maintenance schedule effect to the generation plan only movement of generation hour. Consider the revenue increased percentage, 3 of 4 years show the maximum increase percentage is low inflow scenario because of low net revenue.

The reserve capacity of proposed schedule is compared to EDL schedule shown in figure 5.10. The minimum reserve capacity is not related to inflow water, the minimum of them can be occurred on normal, high or low inflow scenario. However, the almost minimum reserve capacity in 2001 and 2002 of proposed schedule are lower than EDL schedule but still higher than minimum requirement, 40 MW. Difference in 2003 and 2004, all reserve capacity of the proposed schedule are higher than EDL schedule because of EDL schedule are not concern to minimum reserve requirement but the proposed method have done.

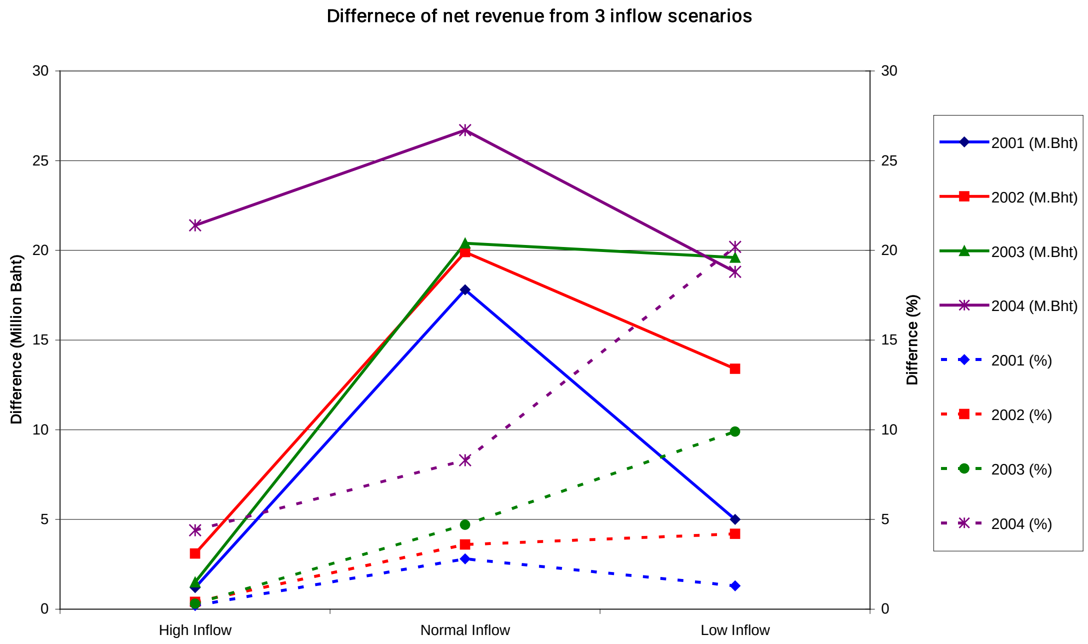

Figure 5.9 Effect of water inflow on revenue

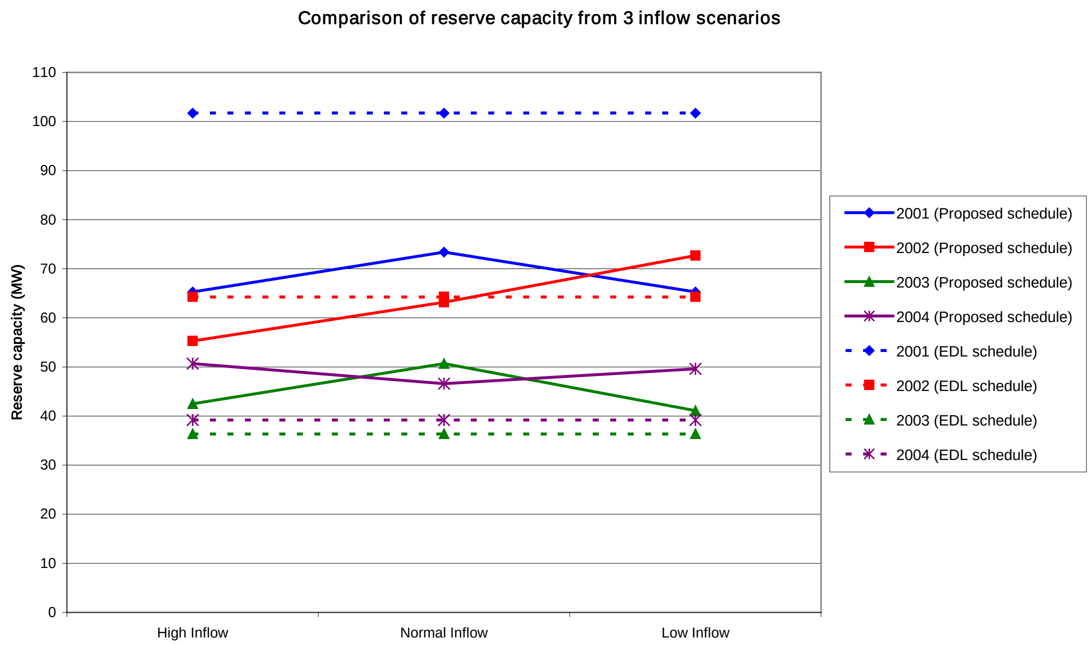

Figure 5.10 Effect of water inflow on minimum reserve capacity

5.4.2 Influence of Load

Comparisons of each water inflow scenario for 2001-2004 periods are carried out to determine effects of load or demand increases on the revenue and reserve capacity. Results are shown in Figure 5.11 and 5.12. The trend of revenue increase is higher when load increases. The maximum revenue increase in 3 of 4 years is 2004 scenario due to highest demand. The percentage of increase strongly confirms. According to lower surplus limited energy when demand growth, the better maintenance schedule will give more chance to get more revenue. Figure 5.12 shows the reserve capacity of the system will reduce when demand growth, but the proposed method concern minimum reserve requirement.

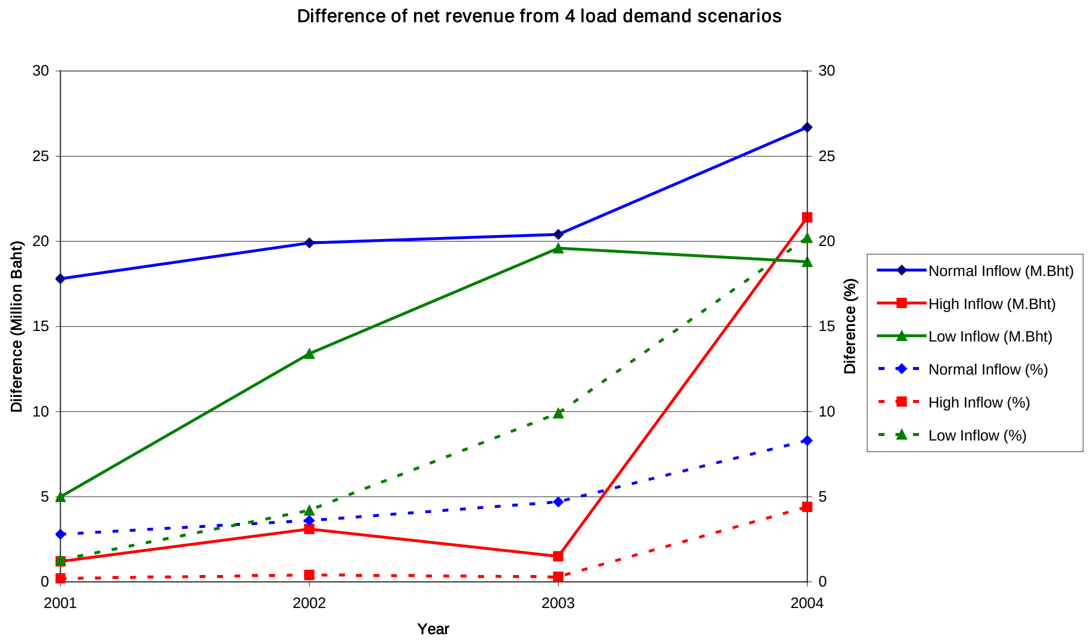

Figure 5.11 Effect of demand on revenue

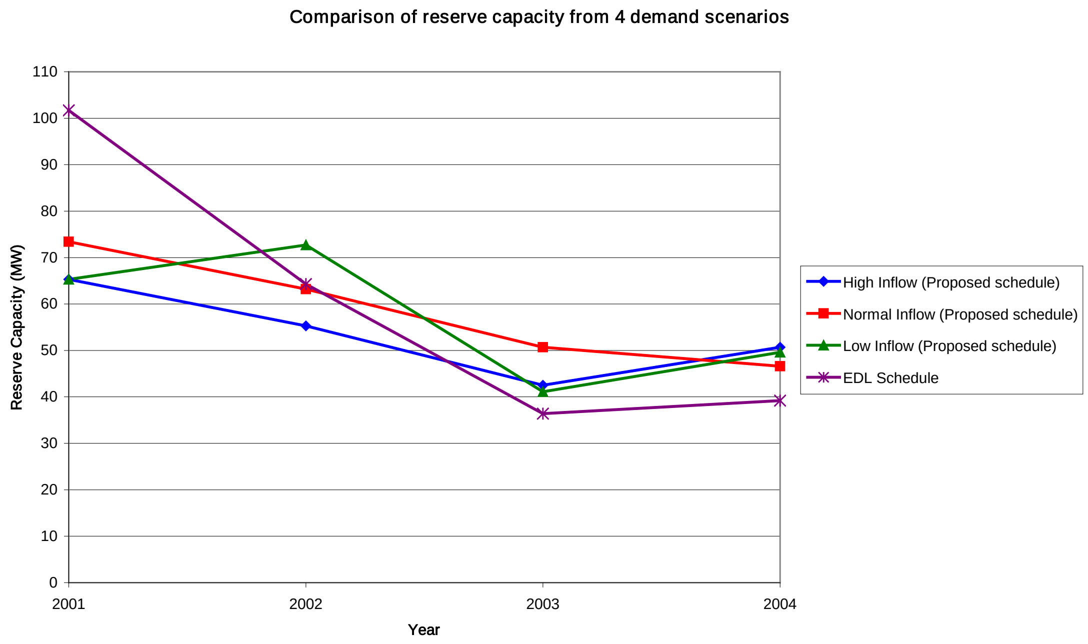

Figure 5.12 Effect of demand on minimum reserve capacity