CHAPTER 1

Introduction and Literature Review

1.1 Statement and Significance of Problem

Lao People's Democratic Republic (Lao PDR) is located in South East Asia at the center of Indochina peninsula between latitude 13-23 degree north and longitude 100-108 degree east. Laos has an eastern border of 1,957 km with the Socialist Republic of Vietnam, a western border of 1,730 km with the Kingdom of Thailand, a southern border of 492 km with the Kingdom of Cambodia, a northern border of 416 km with the People's Republic of China and northwestern border of 230 km with the Union of Myanmar. Total area of Laos is 236,800 square kilometers and the population was about 6.4 million in the year 2015. Laos have many rivers, which is appropriately topography for hydropower construction as well as many hydropower plants can be constructed in the same river. All hydropower plants are under responsibility of Electricite Du Laos (EDL) and Independent Power Producer (IPP). Presently, EDL is facing problems in operation and control reservoir management. These problems cause from many hydropower plants which are not belong to the same owners. Operation management for electricity production of cascading reservoirs in the same river are very difficult due to theseconstraints. These make EDL loses the opportunity to get the optimum the electricity production. Namkhan 2 and 3 hydropower plants are directly responsibility of EDL. Therefore, these hydropower plants can manage for optimal electricity production and water regulation. All of above reasons cause this study.[1]

The existing electricity supplies of power system in Laos comes from hydropower plants which has an important role in the social-economic development. The energy consumption has been increasing around 15 % annually, according to EDL 2016 report, which causes from the rapid economic growth. Laos has many hydropower resources of approximately 18,125 MW in 2025. Both hydropower plants, Namkhan 2 and 3 are operated by Electricite Du Laos-Generation Public Company (EDL-Gen). EDL-Gen is subsidiary company of EDL. EDL-Gen is a state-owned utility and responsibility for power generation. Namkhan 2 and Namkhan 3 hydro power projects are owned by Lao's government, operated by EDL. Both projects are constructed by Sinohydro corporation Co., LTD, surveyed and designed by Hydrochina Guiyang Engineering Corporation. Namkhan 2 and 3 hydropower plants are located at Xienggnuen district Luangprabang province. The location of Namkhan 2 and 3 hydropower plants are shown in the figure 1.1 as below.

Namkhan river is located in the northern Laos, at north of latitude 20°19'- 19°21' and east longitude of 103°43'- 101°57'. The Namkhan river is a first level tributary at the left bank of Mekong river, and it originates from the southwest part of Houa Phan province in Laos. The highest point in the Namkhan river basin is 2257 masl (meter above sea level). Namkhan river generally flows from east to west, which merge with Mekong river in Laungprabang district. The water surface elevation at confluence is about 270 masl and drainage area is 7,620 km^2. Furthermore, Namming river is a big river branch of the Namkhan river and it flows into the Mekong river. [2]

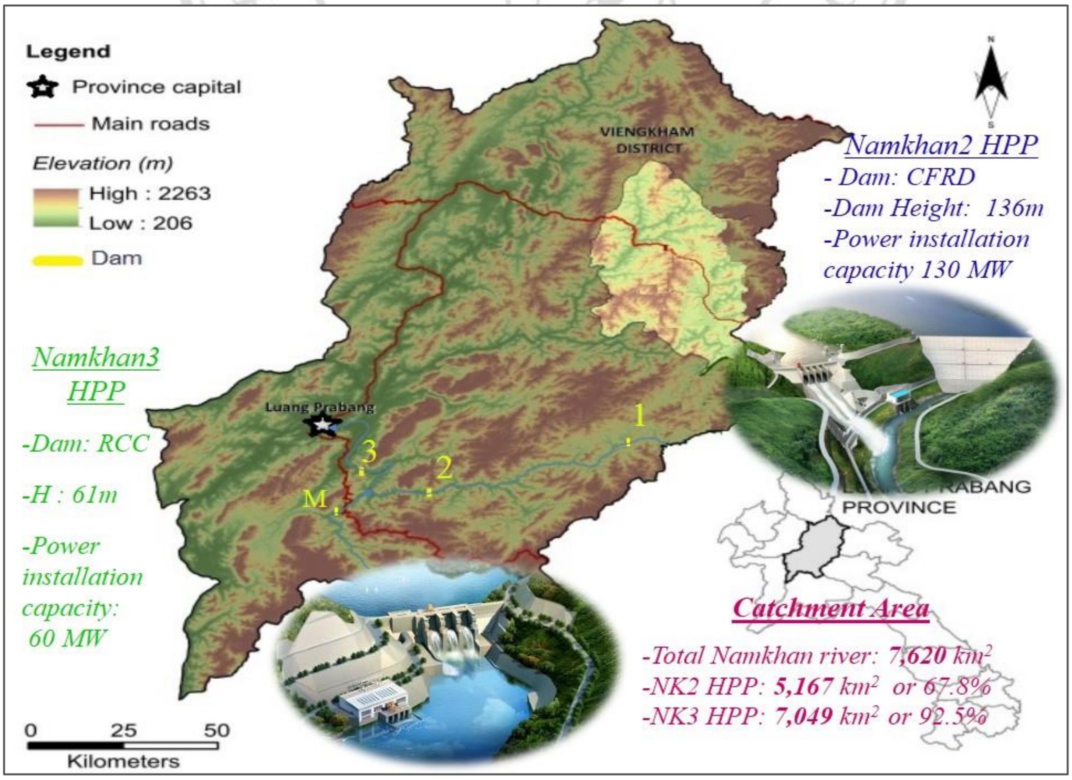

Figure 1.1 Location of Namkhan 2 and 3 HPP in Luangphabang province.

The Namkhan 2 hydropower plant (HPP) is located about 75 km from the river mouth and about 35 km from the 13th North national road. This hydropower plant was constucted in early 2011 and the project completed on September 2015. The Namkhan 3 hydropower plant is located about 43 km from the river mouth and about 6 km from the 13th North national road. The project started the construction in mid 2012 and completed in June 2016. Also, Namming hydro power project is under servey and construction, which is small hydropower. Furthermore, Namkhan 1 hydropower project is located at the upstream of Namkhan 2 HPP, had finished survey. The development of Namkhan 1 HPP is under future planning. Figure 1.2 shows all hydropower plants characteristic development in Namkhan basin.

Namkhan 2 and 3 hydropower plants can be provided energy generation for the consumption in the northern region of Laos. The peak load demand is during 4 hours (17h:00-21h:00) during in each day, which has energy demand in dry season. This is an important factor for managing reservoir operation and to guarantee power supply whole year. That is all of reason cause this study.

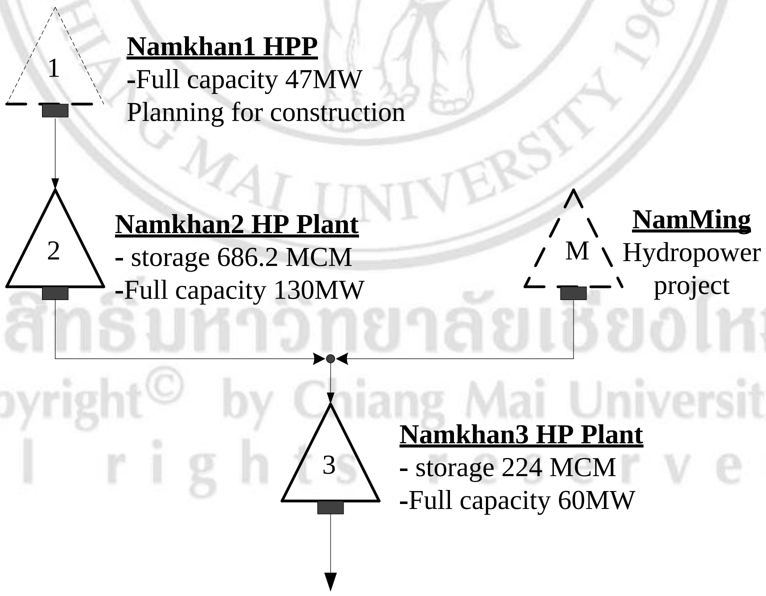

Figure 1.2 Characteristic of Namkhan basin.

The basin area is situated in the mountain area and cover with forest, crops and vegetation along both banks. The river valley develops with a gentle slope at both banks. Hydrological data collected from two hydrology stations: Banmout and Pakbak stations.

These data were established on Namkhan river, which cover the basin area of 7,321 km^2 and 7,049 km^2 of Banmoout and Pakbak stations, respectively. The Namkhan 2 hydropower plant has storage capacity at 686.2 million cubic meter (MCM). Surface reservoir area is 30 km^2. Water normal level of pool elevation is 475 masl. Water used for operating electricity production is 229.1 MCM. Dead storage capacity is 457.1 MCM. Dead storage elevation is 465 masl. The water discharge turbine is 67 cubic meter per second (m^3/s) per unit and total discharge turbine is 134 m^3/s (two units).

The Namkhan 3 hydropower plant has water storage capacity at 224 MCM. Surface reservoir area is 7.05 km^2. Water normal level of pool elevation is 348 masl. Water used for producing electric is 48 MCM. Dead storage capacity is 17.6 MCM. Dead storage elevation is 343 masl. Water discharge turbine is 88 m^3/s per unit and total discharge turbine is 176 m^3/s (two units). Table 1.1 shown the principal features of Namkhan 2 and 3 hydropower plants. [3]

Table 1.1 The principal features of Namkhan 2 and 3 hydropower plants

Description	Unit	NK 2 HPP	NK 3 HPP
Hydrology data			
Catchment area of dam site	km^2	5,167	7,049
Average annual inflow	m^3/s	67	92.1
Design peak flow (0.1%)	m^3/s	8,640	9,410
Index of engineering benefit			
Annual energy generation	GWh/y	558	240
Installed capacity (2 Units)	MW	130	60
Water discharge turbine	m^3/s	135	176
Annual utilization hours	hour	4,294	4,000
Spillway gate discharge (Radial Gate)			
Amount of spillway gate	channel	4	3
Maximum discharge	m^3/s	9,974	5,710
Dimension of spillway (WxH)	m	13.5 x 21	13.5 x 21
Rate head			
Maximum net head	m	119.18	41.50
Minimum net head	m	104.58	36.50

Table 1.1 The principal features of Namkhan 2 and 3 hydropower plants (Cont)

Description	Unit	NK 2 HPP	NK 3 HPP
Data of reservoir storage			
Reservoir area	km^2	30.57	7.07
Full supply level	m.a.s.l	477.86	349.06
Reservoir full capacity	MCM	686.2	224
Dead storage level	m.a.s.l	465	343
Reservoir dead storgae capacity	MCM	457.1	176
Regulation storage capacity	MCM	229.1	48
Rate head			
Mean rated head	m	111	39
Tailrace flood level	m.a.s.l	355.58	304.22
Tailrace check flood level	m.a.s.l	357.30	306.09
Turbine			
Number of turbine	set	Two	Two
Turbine type	type	Francis	Francis
Rated speed	R/min	273	157.9
Dam			
Type of the dam	Type	CFRD	RCC
Height of the dam body	m	136	61
Crest Length	m	365	156
Foundation width	m	397.67	57
Dam crest elevation	m.a.s.l	481	353
Empty tunnel			
Intake elevation of empty tunnel	m.a.s.l	415	311
Dimension of tunnel body (WxH)	m	5x9	3x5
Maximum discharge	m^3/s	719.31	229.77
Main electromechanical equipments			
Generator unit capacity	MW/MVA	65/81.25	30/36
Main power transformer	set	2	2
Rated capacity of power transformer	kVA	90,0000	36,000
Specification crane in the plant	ton	250/50/10	160/50/10
Power transmission line voltage	kV	115	115
Number of circuits	circuit	2	1
Length of transmission line	km	23.792	6.86
Economic indication			
Total static engineering investment	USD	308,500,870	127,767,028
Time for construction project	Month	54	42
Project completed date	dd/mm/yy	25/09/2015	25/06/2016

1.2 Literature Review

Many researchers have pointed out the concerns and principles adopted for this research. The details are as follows.

J. Zhang, *et al* [4] have presented about the improved model of reservoir management optimization. Case study is multi-reservoir at the Minjiang basin in Fujian province, China. The purposes is to optimal generation and scheduling of multi-reservoir system management to best suitable. In this paper has used four algorithm totals: improved particle swarm optimization (IPSO) algorithm, particle swarm optimization (PSO) algorithm, Genetic algorithm (GA), dynamic programming successive approximation (DPSA) algorithm. These algorithm are used to solve the problem of reservoir operation, which under many conditions of river. This paper is shown the process of research method and result of all algorithms. Then, all results will be compared between four algorithms such as: nonlinear numerical function optimization, comparison of annual electricity generation. Conclusions, IPSO algorithm was applied to optimize the long-term multi-reservoir system operation, guarantee energy output to be optimizing. The results from compared scheduling indicated that IPSO to outperform PSO, GA, DPSA. Therefore, IPSO can be improved efficiency and suitability for solution the optimal energy generation of the multi-reservoir system.

R. U. kamodkar and D. G. regulwar [5] have presented the reservoir system operation. Case study is the Jayakwadi stage II, Maharashtra state, in India. This paper considers two objectives: first objective is to release water for maximizing irrigation. The second objective is to release water for maximizing hydroelectric generation. This paper was solved the problems in single reservoir operation, which under the conditions of power plant. The reservoir operation is considered benefits of irrigation and hydroelectric generation, which release to efficient and satisfy of both objectives. The methods used is fuzzy methods for reservoir operation model. The results will be compared between water requirement and water resource in Jayakwadi river. The planning of reservoir management is supplied in water requirement for managing the irrigation and hydroelectric generation to suitable objectives. However, the model may be extended to the fully fuzzy linear programming model (FFLP) of water resource.

B. Lu, *et al* [6] have presented the multi-purpose of reservoir designed for the hydropower generation at Xiushui watershed in Jiangxi province, China. The target of this research is to economic benefits from the hydropower generation. Algorithm used in this study case is included progressive optimization algorithm (POA), particle swarm optimization algorithm (PSO) and genetic algorithm(GA). This study is analyzed the reservoir operation, which will be evaluated the possible improvement to optimize benefits. The paper demonstrates the usefulness of optimization procedures to improve the operation for a real-life reservoir system of hydropower generation system. Three algorithms have been shown to produce more superior results for scheduling of hydropower generation.

Q. Chen, *et al* [7] have presented the reservoir operation to benefit of river ecosystem. The case study is Qingshitan reservoir at the Lijiang river in China. The purposes is to consider the irrigation, the cruise navigation and the water supply aspects. This paper shows the development methods of the optimization model to explore a trade-off solution. The development model is depended on the social-economic interests and the nature flow maintenance-base. Conclusion, this research was regulated for maintaining natural flows, which is fundamental to conserve the river ecosystem. The development method can be applied the reservoir operation for the demonstration under the optimal operation scheme. This case study is indicated the propose approach to promise and efficiency. Therefore, it is a choose way for optimizing hydraulic structures to operate in the ecological and the economical.

Q. Cui, et al [8] This paper has presented the improved Thomas-Fiering(FT) and wavelet neural network models for the cumulative errors reduction in the reservoir inflow forecasted. Objective is to obtain enhanced accuracy for forecasting the reservoir inflow and to find the suitable parameters of the data series for forecasting in the errors' reduction. Furthermore, a wavelet neural network (WNN) model was utilized to represent a learning approach for the model parameter training to timely, which adjust input parameters by according to the errors, so as to reduce overall forecast errors as much as possible.

H. Fang, *et al* [9] have presented about an optimal simulation model to solves the operational problems between water demand and water transfer-supply. This study case is multi-reservoir system in Liaoning China. The purpose is a new storage allocation and the rule based on a target storage curve. The operation rule curve included the water diversion rule, amount a period, a hedging rule based on an aggregate reservoir to determine the total released from reservoirs. A simulation of optimization model is established to optimal the water released curves and the target storaged curves. Algorithm used is IPSO algorithm. The main objective is the water transfer to alleviates water shortaged in recipient region. The optimal simulation model used is the heuristic algorithm for improved particle swarm optimization. Conclusion, the important target is to build a new model for optimizing operation joint, so to alleviate water shortages in region northern china.

M.H Afsharb [10] has presented the efficiency operation of multi-reservoir system, which used the decision variables for solving the problems in the storaged or released volume. The algorithm used is the PSO algorithm, which used to operate the system analysis of multi-reservoir case. The methods solved the problems of hydropower generation in multi - reservoir system and it shown to be more effective in each location or solutions optimal. This paper is shown the small and medium scales, due to most used dynamic programming. Large scale problems of the reservoir operation discipline has attempted by linear programming methods. The optimal solution for solving problems of reservoir operation and storage volume are the decision variables of the problems. The paper is shown excellent performance, particularly with released volume, taken as decision variable of the yielding optimal solution.

B. Malekmohammadi, ***et al*** **[12]** have presented about ranking the optimal solution of reservoir management by Electric-TRI method, NON-dominated sorting genetic algorithm II model (NSGA-II). Bathtiari reservoir is located in southwestern Iran. The multi-objective solution of reservoir operation was to give the water balance between water demand and water resource. The purposes is to build new model to minimize from flood damage and the association with deficits in supplying water demand (agricultural). In this case was controlled the water flow for operating multi-objective and support water demand. The planning can be helped for decising in short term and long term operational. Conclusion, the solution by Electric-TRI is optimal model for operating multi-objective and provides a suitable for considering the preferences of decision making (DMs).

D. Sounantthalath [13] has presented the reservoir management of Nam Ngum-1 hydropower plant for optimum electricity production, in Vientiane province, Laos PDR. The objective of study is to determines and revises the upper, lower switching cures of reservoir management. The planning of electricity production is based for operating the hydropower plant. The research methodology is reviewing the operation methodology, which can be applied with plants in countries. The collected data is used for operating reservoir and plan analysis. The modeling of reservoir operation used the linear programming, which under conditions such as: water inflow and selection appropriate variable. The benefits are attain the reservoir management approach for electrical product optimization in Namngum-1 hydropower plant, to attain the operation model, to manage for combinating many hydropower plants in the same river. The research can be obtain the electric production planning of dam.

F. Change, et al [14] This paper has presented the watershed rainfall forecasting using neuro-fuzzy networks with the assimilation of multi-sensor information. The purpose is to analyze the rainfall sources that complex of rainfall coupled with physiographic context for great challenge in the development of accurate rainfall forecasts. Rainfall forecast was carried out by using the adaptive network-based fuzzy inference system (ANFIS). The results demonstrated that the ANFIS fed with the assimilated precipitation provided reliable and stable forecasts with the correlation coefficients higher. The obtained forecast results are very valuable information for the flood warning in the study watershed during typhoon periods.

M. Rockwood [15] has presented the application of streamflow synthesis and reservoir regulation (SSARR) program to the lower Mekong river. It recognized that question of availability of basic data for studies making and analysis, which was fundamental. One of the major deficiencies in basic data is the streamflow data that enough: record-length to constitute an adequate sample for analyzing projects. Theories are to recognize the further of generalized approach for analyzing and developing hydrologic such as: the rainfall-runoff relationship, the stremflow routing, the design flood determination, the reservoir regulation studies, and the streamflow forcrasting techniques, computer techniques application, would be an important adjunct to train the system analysis. However, the methods is operational for deriving extended periods (15-

20 years) of streamflow records synthetically from available rainfall data. Such analysis could also be used for designing floods, various types of flow routing and reservoir regulation study.

1.3 Objective of Study

1.3.1 To maximize the electricity production of Namkhan 2 and 3 hydropower plants using multi-reservoir optimization technique.

1.3.2 To manage the reservoir operation for water requirements for downstream and energy demand in the dry season, flood control in rainy season and electricity production for efficiency and sustainability.

1.4 Scope of Study

1.4.1 Reservoir operation management will study and research especially of Namkhan 2 and 3 hydropower plants.

1.4.2 The planning for electricity production of the Namkhan 2 and 3 hydropower plants, which consider five cases as: wet year, average wet year, normal year, average dry year and dry year.

1.4.3 Analysis and considering the reservoirs management of among water inflow, water discharge, water storage and energy generation of both hydropower plants to appropriately operational.

1.5 Benefit of Study

1.5.1 To attain the management methodology of hydropower generation that appropriates of both hydropower plants.

1.5.2 Be able to meet the downstream water and electricity demand in the dry season and to protect the risk causing a flood on downstream in the rainy season of both dams.

1.5.3 To attain the reservoir management and environmental protection for producing electric power to efficiency and sustainability.

1.5.4 Can be applied the such methodology with other hydropower plants that same cases in each rivers, Laos.