Chapter 1
Introduction

1.1 Statement and Significance of the Problem

Lao People's Democratic Republic (Lao PDR) is located in Southeast 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 6.2 million in the year 2008. The existing electricity supply to the system in Lao PDR comes from hydro power plants which play an important role on the social-economic development. The energy consumption has been increasing around 13 % annually according to EDL report from 2000-2008. This result comes from the rapid economic growth. Laos has many hydropower resources, approximately 18,000 MW. The Nam Ngum-1 hydropower plant is one in seven hydropower plant is operation by Electricite Du Lao-Generation public company (EDL-Gen) as adopted child of Electricite Du Laos (EDL) is a state-owned utility and responsible for power generation. At present, it has a total installation capacity of 306.5 MW. In Figure 1.1 is shown the location of Nam Ngum-1 hydropower plant [1].

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Figure 1.1 Location of Nam Ngum-1 hydropower plant

Nam Ngum-1 hydropower plant started project has been developed in 3 phases: its power generation with two generators, number 1 & 2 with 30 MW installed capacity. Consequently, it was expanded up to 110 MW with two additional generators of unit 3 & 4 with 40 MW per unit in 1979. Then in 1985, Nam Ngum-1 hydropower plant was expanded to 150 MW, with an additional one generator of unit 5 with 40 MW. Afterward, the annual power generation has been increased due to the increasing of water inflow into the Nam Ngum-1 reservoir from Nam Song diversion in 1996, and diversion water turbine discharge or downstream of Nam Leuk hydropower plant in 2000. As water inflow characteristic is shown in Figure 1.2.

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Furthermore, generators of unit 1 and 2 were rehabilitated during 2003 - 2004 from 15.0 MW per unit to 17.5 MW per unit; hence the total installed capacity of 5 units is 155 MW at present [2].

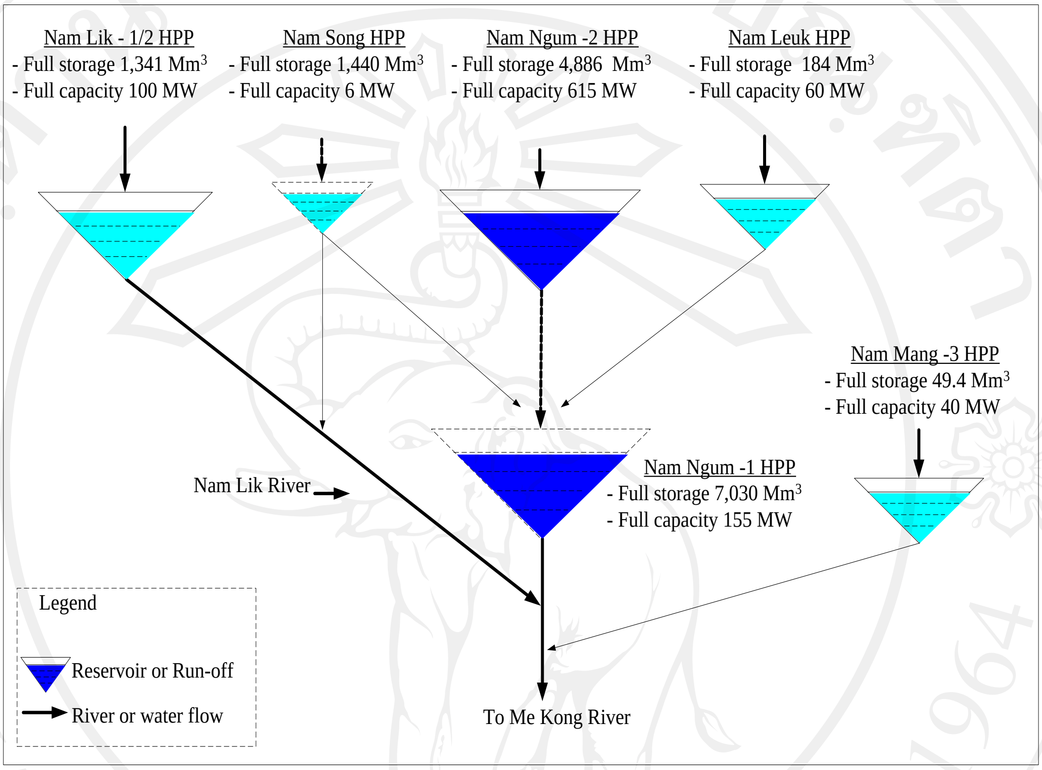

Figure 1.2 Water inflow characteristic into Nam Ngum-1 reservoir

The Nam Ngum-1 reservoir's total capacity has water full supply level of 212.00 m.a.s.l, surface area at 370 km^2. Gross storage capacity is 7,030 million m^3 and water use in power generation or active storage capacity is 4.700 million m^3, and lower water level 196 m.a.s.l at storage 2,296 million m^3 for design but lowdown is about 200 m.a.s.l, some year 198 m.a.s.l. The generators water use is different, for generators of unit 1 and 2 maximum water rate 57.3 m^3/sec, for generators of unit 3, 4 and 5, maximum water rate 117.1 m^3/sec, total water release through turbine is 465.9 m^3/sec the detail is shown in Table 1.1. The Nam Ngum-1 hydropower plant is responsible for the central-1 area to generate power or base load of grid. Therefore, the firm water discharge is the stable available discharge throughout a year for specific water use, i.e., Nam Ngum-1 hydropower plant. The quantity of the firm discharge is an important factor to reservoir management or reservoir operating, the firm discharge is the guaranteed discharge available for 24 hours. As Nam Ngum-1

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hydropower plant is also responsible for peak hour power supply domestic load demand, the water is first allocated 4 hours in the night and 9 hours in the daytime, unless responsible for off-peak domestic load demand hour power supply, the allocation of the water is determined by selecting optimum set point in the water use.[2]

Table 1.1 The principal features of Nam Ngum-1 hydropower plant

Item	Volume	Unit
Annual energy production (average)	1,025	GWh /y
Capacity		
Unit 1 and 2	17.5	MW
Unit 3 , 4 and 5	40	MW
Total Installed Capacity	155	MW
Discharge		
Unit 1 and 2	57.3	m^3/sec
Unit 3 , 4 and 5	117.1	m^3/sec
Total	465.9	m^3/sec
Spill way gate discharge(Radial Gate)		
Width and height 12.5x10 x 4 gates(max 4 m)	3,800	m^3/sec
Storage		
Catchments area	8,460	km^2
Reservoir capacity	7,030	Mm^3
Reservoir area	370	km^2
Annual average inflow	382	m^3/sec
Full supply level	212.30	m.a.s.l
Minimum operating level	196	m.a.s.l
Active storage	4,700	Mm^3
Minimum tail water level (Q = 0 m3/sec)	164	m.a.s.l
Head		
Maximum Net Head	48.3	m
Minimum Net Head	32	m
Nominal Net Head	37	m
Turbine type		
Type	VF-1SR	Francis
Standard	JEC-151-1968	IEC
Speed	176.5 &136.4	rpm

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Table 1.1 The principal features of Nam Ngum-1 hydropower plant (Continue)

Item	Volume	Unit
Dam		
Dam type	Concrete gravity dam	
Dam height	75	m
Crest length	468	m
Dam volume(Concrete)	350,000	m^3

1.2 Literature review

Since this research aims to optimize the operation of many cascaded power plants, the reservoir management is one of the major constraints of the optimization. Therefore, the research is focused on the reservoir operation management. Many researchers reported the benefit and disadvantage from reservoir operation management, many researchers have suggested the principles concerned and some are adopted for this research which can be summarized as follows:

K. R. Sreenivasan and S. Vedula [3]. This paper presents the operation of a multipurpose reservoir system in South India. The operation of a multipurpose reservoir for irrigation and hydropower requires a strategy, the release policy is defined by a chance-constrained linear programming formulation. The objective of the study is to formulate a mathematical programming model to determine, (1) the maximum annual hydropower produced from a multipurpose reservoir while combines the irrigation demands for various specified levels of reliability and (2) rule curve storages for the optimal operation of the reservoir. The model is formulated for a single reservoir serving multiple purposes (irrigation and hydropower). Inflow into the reservoir is considered random and model considers variation in reservoir water level elevation and also the operating range within which the turbine operates. The chance constraint is converted into its deterministic equivalent, using a linear decision rule and inflow probability distribution. The model can be used to determine (1) the maximum annual hydropower that can be produced at different levels of reliability (of meeting the irrigation demands) and (2) the optimal end-of-period storages (rule curve storages) for reservoir operation. Also, the maximum reliability of irrigation associated with a given level of hydropower production can be determined.

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S. Vedula and S. Mohan [4]. In this paper, a real-time operation methodology based on stochastic optimization and inflow forecasting is proposed ,taking an existing multipurpose reservoir system, namely, the Bhadra Reservoir System in Karnataka State, India, as a case. The reservoir is operated for irrigation and hydropower production, irrigation being the primary purpose. The proposed real-time operation methodology consists of three phases of computer modeling. In (1)the first phase, the optimal release policy is determined using Stochastic Dynamic Programming (SDP). Stream flow forecasting using an adaptive Auto Regressive Integrated Moving Average (ARIMA) model constitutes. (2) the second phase. With the forecast inflows and the optimal release policies from the SDP model solution, a real-time simulation model is developed, (3) the third phase. A comparison of the optimal monthly real-time operation with the historical operation of the Bhadra Reservoir System demonstrates the relevance

S. Xiaoyi and H. Qiang [5].This paper presents the cascade hydropower station reservoirs in the upper Hanjiang River of Shiquan, Xihe and Ankang three reservoirs. The problem of long-term optimal operation for the hydropower station reservoirs in the upper Hanjiang River is studied according to the characteristics and main task of the cascade reservoirs. The optimal operation model is established with the target function of maximum cascade power capacity. The model is solved with the combination of successive approximation method of dynamic programming and progressive optimal algorithm. The target functions often used are maximum energy output and maximum energy benefit and maximum cascade storage and so on for optimal operation of reservoirs. The results show that the optimal is better than effects of other algorithms, which the power capacity of hydropower stations and water resources utilization rate increase obviously compared to the results of other algorithms.

M.A. Marino and H.A. Loaicica [6]. Proposed the reservoir management nine-reservoir by using methodology to obtain optimal reservoir operation policies for a large-scale reservoir system. The model maximizes the system annual energy generation. The model incorporates the stochasticity of river flows and keeps future operating schedules up-to-date with the actual realization of those random variables. It yields medium-term (one-year ahead) optimal release. The model is applied to a nine-

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reservoir portion of the California Central Valley Project and the results are compared with those from conventional operation methods currently in use, showing that the use of the model can improve the levels of energy production (about 30 percent increase) while the optimal release policies meet satisfactorily all other functions of the reservoir system.

D. N. Kumar et al [7].This paper presents the reservoir operation of Hirakud Reservoir on Mahanadi River in Orissa State, India, Problem is formulated with the two objectives considered in the study are: (1) Maximization of releases for irrigation and (2) Maximization of hydro power production .The Multi Objective Fuzzy Liner Programming (MOFLP) model is developed for monthly operation of the reservoir, assuming stationary inflows and average monthly demands. Here, the objective functions are considered as fuzzy and the constraints are considered as non-fuzzy. The methodology for fuzzy optimization as explained is applied to the case study, to develop the optimal operating policy. The model can be used to determine the optimal operation policies with these inflows are found out and the maximized satisfaction level and the corresponding maximized values of releases for irrigation and hydro-power produced.

T. Akter and S. P. Simonovic [8].This paper presents the operation of Green Reservoir in Kentucky, USA as a case study, The determination of reservoir release that satisfies various operational needs and restrictions is the main purpose of optimal real-time operation of a reservoir system. Modeling of the uncertain model parameters using fuzzy set theory has been applied in many water resources decision-making problems, including reservoir optimization. Real-time reservoir operation is a continuous decision-making process based on an operating policy. Economic criteria are usually considered for optimization as were considered in this study. A genetic algorithm approach was applied to solve a reservoir system optimization problem with nonlinear penalty functions. Simulation was performed for a known historical inflow scheme with an objective to minimize the total penalty due to the deviations of release and storage from target values. The results obtained are the optimum daily release and storage values considering fuzzy penalty functions and a fuzzy release target. The model also gives the optimum values of the fuzzified parameters along with the decision maker’s optimum level of satisfaction for obtaining those values.

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S. Soares et al. [9]. This paper presents a procedure to optimize the dynamic dispatch of hydro generating units, in the Brazilian electrical power system. The problem, a performance criterion that takes into account variations in tailrace elevation, penstock head losses and turbine-generator efficiencies is considered. The objective of the dynamic dispatch is to calculate a generation scheduling for the next day on an hourly basis, number of generating units in operation and their respective generation outputs are to be determined for all hydro plants and hours of a day. For a hydro system with *N* plants, the problem can be formulated as the following mixed optimization problem. The approach has been tested in a part of the Brazilian power system composing of 9 hydro plants and the results were compared with the verified solution on a typical day. The results show significant savings of around 2.5% which corresponds to more than 33 million dollars per year.

R. Mehta and S. K. Jain [10]. Present paper is aimed to develop operation policy for a multipurpose reservoir using Neuro-Fuzzy technique in an efficient way. Ramganga Reservoir behind Ramganga Dam, Kalagarh, India has been considered as a study reservoir. Determining reservoir operation policy for the efficient management of available water is a complex problem because it involves random hydrologic events. Three Fuzzy Rule Based (FRB) modeling could be a better substitute for the currently-followed operational policies. In this modeling, the human reasoning is easily incorporated in the decision-making process and therefore human operators are better able to apply the results of the model. Fuzzy Rule Based Modeling(FRBM) is the if-then based form. Rule Curve Based policy shown in Table 1 could meet the demands for long period. Using rule curve method, eight categories are defined with different reservoir levels between dead storage level (315 m) to full reservoir level (362.86 m) for monsoon period. For non-monsoon period, these extreme ends have been changed as 315 m to 366 m because there is no need for flood control in this period. Fuzzy Mamdani Models (FMM) and ANFIS-Grid Models (AGM) models are optimized with hybrid method (a mixture of back-propagation and least squares) to give the optimum releases against demands. Trapezoidal (minimum and maximum categories) MF for reservoir levels of flood control is taking care about minimum damages through flood as the reservoir level is above 362 m. Reservoir operating policy in the form of fuzzy “if–then” rules is easy for operators to

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implement. This form of policy is consistent with the human thinking and can include explicit judgments in decision-making process through adequate definition of the membership functions (MF).

C.W. Chih and S.H. Nien [11].This paper develops a generalized multi-reservoir optimization model for basin-scale flood control. The Tanshui River Basin is located in the northern part of Taiwan, having steep terrain and excessive rainfall. The objective for a multipurpose multi reservoir operating system taking into consideration the purposes of controlling flood and regulating storage, in order to determine the optimal hourly releases from reservoirs under the estuary tidal effects during typhoon periods, The model objectives include: preventing the reservoir dam and the downstream river embankment from overtopping, and meeting reservoir target storage at the end of flood. The model constraints include the reservoir operations and the neural-based linear channel level routing. The model constraints include reservoir multipurpose flood control operation and channel routing under tidal effects. This paper presents a neural-based linear channel level routing algorithm developed from artificial neural networks (ANN) for estimating the water level of downstream. In order to formulate a linear channel level routing, the proposed neural-based linear channel level routing algorithm demonstrates a good alternative method in comparison with the Compound Complex Channel (networkor dendritic) system according to the Multimode Method of Characteristics (in short CCCMMOC model).

G.R Dattatray and U.K. Ravindra [12]. This paper develops an uncertainty in reservoir operation parameters such as reservoir storages, releases for irrigation, releases for hydropower production, irrigation demands and power demands are considered by treating them as a fuzzy set. These models are applied to a case study of Jayakwadi Reservoir stage-II, Maharashtra State, India. In this paper, they focus on Fuzzy Linear Programming (FLP) problem for reservoir operation with fuzzy objectives function and fuzzy constraints, the objective of maximization of releases for irrigation and hydropower. Fuzzy set theory is used to model imprecision in various parameters by developing three models. First model considers fuzzy resources, second model is with fuzzy technological coefficients and third model considers both, The two objectives are considered in all the models, viz., max-imization of releases for irrigation (RI) and maximization of releases for

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hydropower production (RP). As explained in methodology, initially the model considers uncertainty involved in resources, *ib*, *i.e.*, irrigation demands, power demands and maximum storage in any time period t in the reservoir are considered as fuzzy resources while technological coefficients are considered crisp in nature.

K. Mohammad et al [13].This paper develops the proposed model which is applied to the Kajoo River in the southeastern part of Iran. Two optimization models are presented. The first model is developed to determine economical combination of permanent and emergency flood control options and the second one is used to determine the optimal crop pattern along a river basin. The river using the genetic algorithm (GA) optimization model. In order to consider the effects of flood control options on hydraulic characteristics of flow, two hydrological routing models for the reservoir and the river are coupled with the optimization model. The results demonstrate an economical integration of permanent and emergency flood control options along the river which include minimum expected value of damages related to floods with different return periods and construction cost of flood control options.

1.3 Objectives of study

The main objectives of this study are as follows:

1. To determine the revised upper and lower operating rule curves of Nam Ngum-1 hydropower plant.

2. To study power production planning based on the optimum rule curve.

1.4 Scopes of study

1. Water inflow into Nam Ngum-1 reservoir will be considered for reservoir operation management.

2. Wet, drought and normal year cases will be considered for reservoir operation management.

3. Affecting factors considered are water released plan of Nam Ngum 2 hydropower plant, Nam Song hydropower plant and Nam Luek hydropower plant.

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