Chapter 1
Introduction

1.1 Statement and significance of the problem

Electricity is one of many forms of energy used in industry, homes, businesses, irrigation and transportation. It has many desirable features, it is clean (particularly at the point of use), convenient, relatively easy to transport from point of source to point of use. And it is highly flexible in its use. In some cases it is an irreplaceable source of energy [1]. Electricity is destined for a major role in development of the country, in progressive industrialization, modernization of agriculture, including extension of irrigated farming, exploitation of forestry resources, and most importantly contributing to living standard improvement for the entire population. In promoting national economy, the Lao's government has emphasized on the development of hydropower energy and the hydroelectric policy has encouraged the growth of investment in hydroelectric energy. In 2004, the total installation capacity of hydro and diesel engine was 630.07 MW of which 270.07 MW, including diesel engine of 9.07 MW, was operated by Electricité du Laos (EDL). And 360 MW were joint-venture projects [14]. The above capacity is not included micro hydro and diesel engine which is in responsible of local authorities. The hydropower system of the Lao People's Democratic Republic is shown in figure 1.1.

EDL is Lao's state enterprise which is responsible for generation, transmission, and distribution of electricity to end users. It also carries out network expansion aiming to meet and servicing the needs of the society, as well as export electricity to Thailand. EDL is also responsible operation and maintenance of country's power system. The power system central-I area (region-I) is the largest power system in Lao PDR and is selected as a case study. It is located in the central part of Laos included Vientiane, the capital city of Lao PDR. The region is interconnected to the Electricity Generating Authority of Thailand (EGAT) system at Nong Khai, Udonthani I and Bung Kan substation but isolated from the rest of Laos. The system is supplied by 3 hydropower stations with a total capacity of 211 MW and diesel generators of 9.07 MW. The technical specification is shown in table 1.1.

In response to the government's ten year Social and Economic Development plan (2001-2010), EDL has planned that the whole country shall be linked by 115 kV network. The generation capacity will increase on base case by 441 MW, and low case by 266 MW. The reserve margin will be not less than 25% [15] as detailed in table 1.2. The system is expected to have power quality and reliability available to meet customer demand. It is also expected that the production and distribution of power will be accomplished at minimum cost.

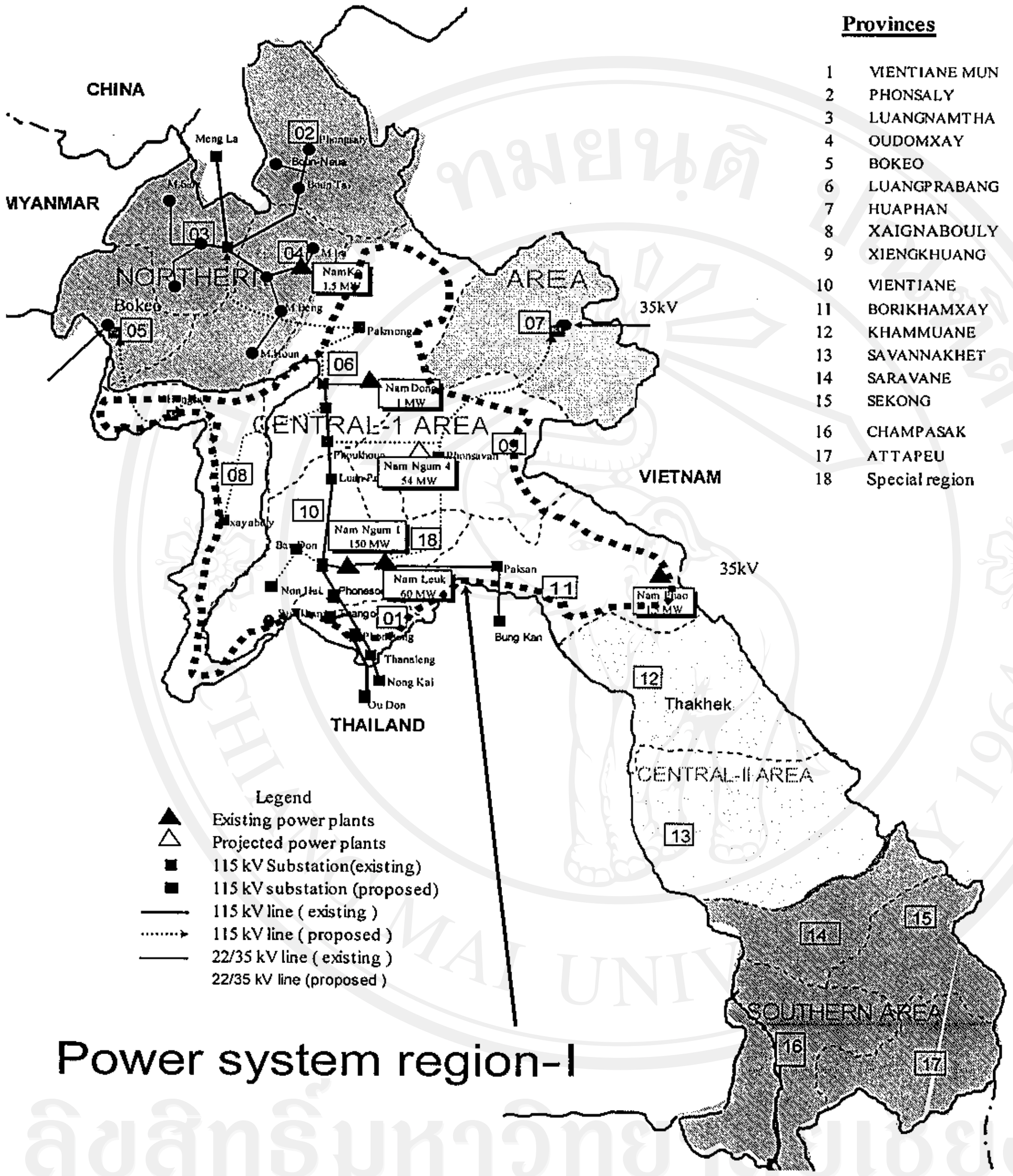

Figure 1.1 Hydro power systems in Lao PDR

Table 1.1, Technical specification of hydropower station in region-I

Item	Project name	No. of generators and capacity	Total capacity (MW)	Maximum head (m)
1	Nam Ngum-I Hydropower plant	(2×15)+(3×40)	150	45
2	Nam Leuk Hydropower Plant.,	(2×30)	60	182.9
3	Nam Dong Hydropower Plant	(3×0.336)	1	136.5
4	Diesel Engines: -Vientiane Municipality -Luangprabang Province	(4×2) (2×0.325)+(1×0.255)+(1×0.125)+(1×0.045)	8 1.07	
	Total	19	220.07	

Sources: Annual report 2000 of EDL.

Up to now, according to the existing power system and hydropower plants, EDL has applied independent operation and maintenance teams or perfect hierarchical organization to each plant permanently. Production and maintenance planning or scheduling of EDL's power system has not yet been co-operated by all plants. Especially, the region-I has not had a master plan for maintenance scheduling. Each hydropower plant has its own independent maintenance crew, maintenance scheduling and production plan. In implementing the above mentioned work, each hydropower plant has been very independent without considering overall system reliability and economic evaluation except for reservoir optimization operation. These conditions may cause high production cost, low reliability and overlap outages in maintenance scheduling.

Generator Maintenance Scheduling (GMS) is the first step in generation operation planning. If generators in a system are shutdown improperly, the system reliabilities will be low and the system economic indices will be poor too. Many methodologies are proposed to solve the generator maintenance scheduling problem; high reliability and low production cost are normally expected in the plan. Most generators are considered as unlimited energy units and have their individual cost.

In Lao PDR, most generators are hydro power stations that the energy production is related to inflow which is an uncontrollable factor. Other generations are small emergency diesel. At present, Electricité du Laos (EDL), who is Lao PDR electricity utility, exports the excess electricity energy to the EGAT system. With high growth of electricity consumption in Lao PDR due to economic growth and expansion of the electricity system, EDL has changed from exporter only to both exporter and importer. The import and export tariffs are time varying according to demand-supply principle. EDL needs a systematic methodology to efficiently plan generation and maintenance scheduling. The methodology must consider the characteristic of hydro power station, e.g. the variation of capacity, the different inflow in each period of year and limitation of energy supply etc.

This thesis presents a development of methodology for daily generator maintenance scheduling on a yearly basis. It will firstly describe the production planning with hydro station characteristics. The detail of maintenance scheduling search will be described in the following sections. Next, the large scale power system constraints and information in the maintenance scheduling problem will be described. Then, 2001, 2002, 2003 and 2004 EDL region-I system test results are shown and compared with the maintenance schedule by EDL. The test results would show the effectiveness of the proposed method which can be appropriately applied to a major hydro power system.

Table 1.2, Power System Development Plan

No	Project	Installation Capacity (MW)	Average Energy/ Year (GWh)	Investment (MUSD)	Source of Fund	Coming Year
01	Nam Mang 3	35	133.5	63	CWE(China) 80% EdL20%	2002-04
02	Xeset 2	76	309	87.9	NORAD5% EdL15% NORINCO (China)80%	2005-09
03	Xepon	75	338	139.2	GoL/Vietnam	2006-10
04	Nam Ngum 5	100	430	128	CMEC(China) 80% EdL20%	2005-07
05	Nam Theun 2 Domestic	75	275	(50)	NamTeun-2-Coorp	2004-09
06	Xeset 3	20	85	28.6	NORAD5% EdL15% NORINCO (China)80%	2009-11
07	Huay Lamphanh Ghai	60	354	102	ADB35% JBIC40% NDF5% EdL20%	2008-10
	Total	441	1,924.5	548.7		

1.2 Literature review

Many researches have suggested modified version of the conventional maintenance scheduling methods for solving the objective maintenance scheduling problems. Recently researches have paid much attention a solution on measuring the impact generation maintenance strategies on the system reliability and on the associated costs and others such as:

Leite de Silva, et al. [3] had focused on cost related measures for maintenance scheduling of generating equipment in power systems. The proposed methodology captures all chronological aspects of the maintenance procedures through a Monte Carlo simulation algorithm. A set of generating maintenance requests can be compared on a cost basis, and if necessary, reliability criteria may also be included in the decision making process.

Mantawy, et al. [4] introduce a new efficient algorithm to solve the long term hydro-scheduling problem (LTHSP). The algorithm is based on using the short-term memory of the Tabu search (TS) approach to solve the nonlinear optimization problem in continuous variable of the LTHSP. The proposed algorithm introduces three new innovations: new rules for randomly generating feasible trial solutions, an efficient Tabu list (TL) for such type of problems, and a method for variable discretization. These result in a significant reduction in the number of the objective function evaluations, and consequently require less number of iterations to reach the optimal solution. The proposed Tabu search algorithm is applied successfully to solve a problem involving four series cascaded reservoirs hydro-electric power system.

Chattopadhyay, et al. [5] presented a system approach to obtain a least-cost maintenance schedule using a Mixed Integer Programming Model. The model provides an integrated framework to formulate plans for fuel production, fuel transportation, maintenance scheduling, and generation scheduling and inter-utility transfers. The method has been applied to two interconnected Indian utilities.

The impact of fuel supply constraints and hydro energy availability on maintenance schedule has been examined in detail. The systems approach adopted in the present study ensures optimal utilization of hydro energy, the production capacity of mines and transportation linkages.

A centralized maintenance schedule for an interconnected system is significantly different from the schedules obtained for the individual utilities without considering interconnections. It is shown that the interconnected mode of operation can lead to substantial changes in fuel supply decisions and the overall system operating costs are significantly reduced.

Quan Chen [6] presented a comparative study of the reliability evaluation of generation systems with energy limited units. The F&D (Frequency & Duration) method can always reflect the operating target that all the hydro energy allotted for the time period should be consumed. From this point of view, F&D is better than FOR (Force Outage Rate) modification method. For energy limited system, LOLP (Loss of Load Probability) alone does not appear to be a sufficient index for the reliability evaluation. Several indices LOLP, F&D and EUE (Expected Unnerved Energy) taken together may give a more complete picture.

Rattanachuen [7] studied and developed a practical daily maintenance scheduling method for a large-scale power system. Several constraints are taken into account including several energy limited units. With the proposed method, an appropriate generator maintenance plan can be obtained. The proposed method first employs the total production cost to decrease the size of problem and to obtain initial solution. Then, the Levelized Loss of Load Probability LOLP) method taking into account reliability index as an objective function is used to search for a generator maintenance plan. The effect of energy limited units which are included in the reliability indices and probabilistic production cost calculation are solved by the peak shaving method.

A computer program has also been developed and tested with the IEEE-RST (IEEE reliability test system) and the EGAT (Electricity Generating Authority of Thailand) system. The results show that the computational time by the proposed method is less than that of conventional methods. The reliability indices and total production cost of the plan obtained from the method are close to or slightly better than the indices and costs of the plans obtained from the conventional methods.

Ramos, et al. [8] presented a combined Primal-Dual Logarithmic-Barrier Interior Point and Genetic Algorithm (GA) for Short-term Hydro-thermal coordination. Several results are presented of the application of a combined GA+ED (Economic Dispatch) algorithm to the short-term hydro-thermal coordination problem. The genetic algorithm is used to compute the optimal on/off status of thermal units, while the economic dispatch module uses an interior point algorithm to deal with the optional solution of the hydraulically-coupled short-term scheduling of thermal and hydro units. Inter-temporal constraints both due to cascaded reservoirs and maximum up and down ramps of thermal units are included in the letter module.

Dahal and McDonald [9] proposed a Genetic Algorithm (GA) for generator maintenance scheduling (GMS) problems in order to overcome some of the limitations of the conventional methods. The results presented that the GA is a robust and stable technique for the solution of GMS problems for real-sized systems. Good solution of the problem can be found if an appropriate problem encoding, GA approach, evaluation function and GA parameters are selected for the problem. Although GAs are not guaranteed to find the global optimal solution, it is a significant achievement to obtain a good solution to a complex problem like GMS in a reasonable time.

As the GSM problem variables are integer, representing them directly as integers in a genetic structure has many advantages. The most significant of these is the great reduction in the GA search space. Furthermore, this type of representation is obvious and easy for decoding and a meaningful crossover and mutation operator can be applied. The integer GA is very robust for GMS problems and can find good solution with a wide range of variations of the GA parameters in a comparatively short time, using traditional operators.

Mromliński [10] introduced the use of linear integer programming method. In the problem of generating units maintenance scheduling the consideration of uncertainty condition is necessary. The input data is divided into two groups: -the power balance of a system and its components which are of probabilistic character, -values characterizing the generating units properties; their expected values should be determined from long-term analysis of units operation. A reliability of energy generation (expressed e.g. as a risk power shortage) should be kept constant throughout the planning period. The level of reliability of power generation has a direct effect on shape of maintenance envelope. Consideration of these factors leads the maintenance schedules different from the schedules obtained with the deterministic approach.

Marwali and Shahidehpour [11] proposed to decompose the global generator transmission scheduling problems using Benders decomposition. This research presents a decomposition approach based on the duality theory for generation/transmission maintenance scheduling with network constraints. The test results demonstrate that the limits on transmission line capacity affect the loading of units and increase the generation by expensive and inefficient units, resulting in an increase in the overall cost of operation. The extension of the generation maintenance scheduling to include transmission maintenance and network constraints is applicable to the problem of maintenance with probabilistic data. Using the proposed decomposition method, additional complex constraints are imposed on the maintenance scheduling problem.

Chen and Toyoda [12] described two new proposals for the optimal maintenance problem of isolated system without network constraints and multi-area system with network constraints. First, a simple and useful method is presented for the generating unit's maintenance problem of the isolated system by means of Linear Programming and Branch-And-Bound technique. Second, a new composition technique based on virtual load is proposed in order to solve the complicated multi-area generating unit's maintenance problem. Efficiency and simplicity of the proposed approach were illustrated by utilizing a sample example which gives the calculation and the interpretation of the algorithm. The proposed algorithm was applied to a practical system of five areas and twenty five maintenance units. The results showed that their approach has higher reliability and remarkably saves more computation time than the conventional approaches, and is very powerful and efficient for multi-area power system with network constraints.

1.3 Objective

This thesis has the following objectives,

- To develop a methodology for daily generator maintenance scheduling suitable for EDL region-I hydro power system.
- To develop software package based on the algorithms described in chapter 3.

1.4 Scope of work

This study will firstly determine the production planning taking into account hydrology of the power stations. The detail of maintenance scheduling search will be described later. Next, the large scale power system constraints and information in the maintenance scheduling problem will be described. Finally, 2001, 2002, 2003 and 2004 EDL region-I system test results are shown and compared with the maintenance schedule used by EDL. The test results should illustrate the effectiveness of the proposed method and can be appropriately applied to a major hydro power system.