OPTIMAL NETWORK FLOW RATE FOR INSTALLATION OF SMALL HYDRO POWER PLANTS: A CASE STUDY XEDON RIVER BASIN, LAOS

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โครงข่ายอัตราการไหลที่เหมาะสมสำหรับการติดตั้งโรงไฟฟ้า
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มหาวิทยาลัยเทคโนโลยีสุรนารี

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิศวกรรมศาสตรดุษฎีบัณฑิต

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ปีการศึกษา 2560

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Suranaree University of Technology has approved this thesis submitted in partial fulfillment of the requirements for the Degree of Doctor of Engineering.

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ดวงตะวัน คำแก้ว : โครงข่ายอัตราการไหลที่เหมาะสมสำหรับการติดตั้งโรงไฟฟ้ากำลังน้ำขนาดเล็ก, กรณีศึกษาลุ่มน้ำเซโดน ส.ป.ป. ลาว (OPTIMAL NETWORK FLOW RATE FOR INSTALLATION OF SMALL HYDRO POWER PLANTS: A CASE STUDY XEDON RIVER BASIN, LAOS) อาจารย์ที่ปรึกษา : รองศาสตราจารย์ ดร.อนันท์ อุ่นศิวิไลย์, 264 หน้า.

วิทยานิพนธ์นี้นำเสนอวิธีการเพิ่มประสิทธิภาพของโครงข่ายพลังงานไฟฟ้าในสาธารณรัฐประชาธิปไตยประชาชนลาว โดยการประเมินศักยภาพของลุ่มน้ำสาขา XEDON ซึ่งในการประเมินนั้นขึ้นอยู่กับความสัมพันธ์ระหว่างอัตราการไหลเฉลี่ยต่อปีกับพื้นที่เก็บกักปริมาณน้ำฝน เป็นการประเมินค่าอัตราการไหลระหว่างสถานีวัดน้ำในลุ่มน้ำสาขา XEDON โดยวิธีการประมาณค่ากำลังสองน้อยที่สุด (least-squares estimation method) เพื่อใช้เป็นข้อมูลสำหรับวางแผนการผลิตพลังงานไฟฟ้าของโรงไฟฟ้าพลังน้ำขนาดเล็กร่วมกับโรงผลิตน้ำเพื่อการประปา โดยพิจารณารวมถึงการสูญเสียพลังงานภายในระบบท่อด้วย นอกจากนี้วิจัยนี้ยังมีวัตถุประสงค์เพื่อลดกำลังสูญเสียรวมของระบบให้ต่ำสุดในระบบโครงข่ายไฟฟ้าในสาธารณรัฐประชาธิปไตยประชาชนลาว ด้วยเทคนิคการหาค่าที่เหมาะสมที่สุดแบบฝูงอนุภาค (PSO) และได้ทำการทดสอบกับระบบ 16 บัส ที่ตั้งอยู่ภาคใต้ของลาว

ผลการประเมินค่าอัตราการไหลของน้ำในเครือข่ายท่อน้ำประปาจำนวน 7 ท่อค่าที่เหมาะสมที่สุดในแต่ละท่อมีค่าดังนี้ 0.0025441 ลูกบาศก์เมตร/ชั่วโมง, 0.004497 ลูกบาศก์เมตร/ชั่วโมง, 0.030503 ลูกบาศก์เมตร/ชั่วโมง, 0.040503 ลูกบาศก์เมตร/ชั่วโมง, 0.097456 ลูกบาศก์เมตร/ชั่วโมง, 0.032544 ลูกบาศก์เมตร/ชั่วโมง, 0.041953 ลูกบาศก์เมตร/ชั่วโมง และแรงดันน้ำบริเวณข้อต่อจุดต่างๆจำนวน 6 จุด มีค่าที่เหมาะสมที่สุดดังนี้ 152.97 กิโลปาสคาล, 146.99 กิโลปาสคาล, 138 กิโลปาสคาล, 157.91 กิโลปาสคาล, 169.79 กิโลปาสคาล, 178.14 กิโลปาสคาล นอกจากนี้การสูญเสียระดับความสูงของหัวน้ำต่ำสุดของระบบรวมมีค่าเพียง 10.513 เมตร

ผลการลดกำลังสูญเสียต่ำสุดของระบบโครงข่ายไฟฟ้า 16 บัส ก่อนที่จะเชื่อมต่อกับโรงไฟฟ้าพลังน้ำขนาดเล็กคือ 31.1208 เมกะวัตต์/ชั่วโมง และผลการลดกำลังสูญเสียต่ำสุดหลังจากเชื่อมต่อกับโรงไฟฟ้าพลังน้ำขนาดเล็กที่ตั้งอยู่บริเวณจุดที่มีศักยภาพจุดต่างๆ 5 จุด ดังนี้ 1.9071 เมกะวัตต์/ชั่วโมง, 1.2266 เมกะวัตต์/ชั่วโมง, 0.1710 เมกะวัตต์/ชั่วโมง, 0.3282 เมกะวัตต์/ชั่วโมง, และ 0.7650 เมกะวัตต์/ชั่วโมง

จากผลการลดกำลังสูญเสียต่ำสุดของระบบโครงข่ายไฟฟ้า 16 บัส ที่ตั้งอยู่ภาคใต้ของลาวหลังจากเชื่อมต่อกับโรงไฟฟ้าพลังน้ำขนาดเล็กที่ตั้งอยู่บริเวณจุดที่มีศักยภาพจุดต่างๆ 5 จุด จะถูก

ค่าการสูญเสียพลังงานต่ำสุดหลังจากการเชื่อมต่อกับโรงไฟฟ้าพลังน้ำขนาดเล็ก พบว่า สาขาลุ่มน้ำ HOUAY CHAMPI เป็นจุดที่เหมาะสมที่สุดในการติดตั้งโรงไฟฟ้าพลังน้ำขนาดเล็กสำหรับโครงข่ายพลังงานไฟฟ้าในสาธารณรัฐประชาธิปไตยประชาชนลาว

มหาวิทยาลัยเทคโนโลยีสุรนารี

สาขาวิชา วิศวกรรมไฟฟ้า
ปีการศึกษา 2560

ลายมือชื่อนักศึกษา ____________
ลายมือชื่ออาจารย์ที่ปรึกษา ____________

DOUANGTAVANH KHAMKEO : OPTIMAL NETWORK FLOW RATE FOR INSTALLATION OF SMALL HYDRO POWER PLANTS: A CASE STUDY XEDON RIVER BASIN, LAOS. THESIS ADVISOR : ASSOC. PROF. ANANT OONSIVILAI, Ph.D., 264 PP.

NETWORK FLOW/CO-OPTIMIZATION OPTIMAL/POWER AND WATER ANALYSIS/NETWORK MODEL

This thesis presents the concept of increasing the optimization of the power network in the Lao People's Democratic Republic. The evaluation of the potential point in the XEDON river basin is based on the relationship between the annual average flow rate and the rainfall catchment area, it is estimated the value between the gauging station in the XEDON river basin. By the least-squares estimation method to be used as the data for the planning of generation plants of the small hydropower plants and the water production plants for water supply, it includes the loss in the system. Moreover, the objective of this research is improvements in the power network are including the minimum of the total loss of systems. The optimization to improve the total loss of systems is using particle swarm optimization (PSO) and it also the particle swarm optimization is tested to power networks with 16 bus systems in southern Laos.

And the results are the best obtained for water flow rate balance in pipe water networks are the best obtained 0.0025441m^3/h, 0.004497m^3/h, 0.030503m^3/h, 0.040503m^3/h, 0.097456m^3/h, 0.032544m^3/h, 0.041953m^3/h. Parallel, the water pressure at the nodes in the best-obtained 152.97kPa, 146.99kPa, 138kPa, 157.91kPa,

169.79kPa, 178.14kPa. Moreover, the best obtained for water networks include minimum total head loss of systems was 10.513m.

Therefore, the results are obtained for the minimum loss in the power system network 16 bus before connecting with the small hydropower plants is 31.1208 MW/h and the results are obtained for the minimum loss in the power system network 16 bus after connecting with the small hydropower plants at the potential points are 1.9071 MW/h, 1.2266 MW/h, 0.1710 MW/h, 0.3282 MW/h, and 0.7650 MW/h. Besides, it also able to the results utilizing the proposed approach was compared between to five cases after association with 16 bus system in southern Laos to select the location of the potential point for the installation of small hydropower plants. Hence, through the test results, both cases received for the minimum loss in the system before and after the connection to the small hydroelectric power plant at the potential point. When it was compared, it was found that after the connection with the small hydroelectric power plant at the potential point, it was the case that the optimal minimum loss value was obtained.

Finally, we selected the location for installation of small hydropower plants at HOUAY CHAMPI river basin was a case study suitable for the optimization power network system in Lao P.D.R

มหาวิทยาลัยเทคโนโลยีสุรนารี

School of Electrical Engineering　　　　Student Signature ________________

Academic Year 2017　　　　Advisor's Signature ________________

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Douangtavanh khamkeo

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CHAPTER I

INTRODUCTION

1.1 Current energy problem in Lao PDR

There are many natural water resources in the world which can be used to benefit human beings, whether those water resources are small or big. These natural water resources can be used to generate electricity. This kind of power generation is pollution free and environmental friendly. These days power demand expanded altogether in numerous parts of the world. Large water resources for electricity generation are not enough to meet this increasing demand, therefore there is a need to consider energy from small water resources.

Laos PDR is a country high potential of small and large water resources, with the government's policy to make the source of this hydropower becomes a battery in the ASEAN locale in 2020. Furthermore, with characteristic of the terrain of the country, Laos PDR is also a lot of small river basin, suitable for installation of small hydropower plants.

For research to study the network water flow rate for and use the results water distribution system data planning of the development of sustainable small hydro power plants. The most important factors to be considered are unit head and flow rate per size of small hydro power plant. Currently, the optimal for the method of calculating the size of water distribution system data for install small hydro power plant, which was determined by the characteristics of river basins. To improve the performance of network water flow rate which are different in length and sizes river basin. In the study and analysis of the performance of small power plant will be new calculate method to the development for define data of water distribution system of small hydro power plant.

More inquire about to consider the potential of small hydropower plants. The foremost imperative components to be considered are unit cost generation and venture per measure of the small hydropower plant. Thus, the optimal for the method of calculating the size of small hydro power plant, which was determined by the characteristics of turbines. In each type it will be optimal with different flow rates, but it had electrical power production together to corresponding. To improve the performance of turbines which are different in types and size. In the study and analysis of the performance of small power plant will be new calculate method to the development. Data in the calculation to define the capacity and the performance of the investment were shown. At the first step, to find the optimal network flow rate in XEDON River Basin. In the next step, the development will be to increase the efficiency of the process, with to find the optimal minimum cost function for co-production between power and water of network flow rate for install small hydro power plants in XEDON River Basin. From the study it was found that, three types of turbines for small hydro power plants used more energy efficiency production to compared result with economic investment.

1.2 Background

Most of the vitality we utilize nowadays comes from fossil powers. Coal, oil and normal gas are all fossils fill made a few million a long time sometime recently by the rot of plants and creatures. These powers lie buried between layers of soil and shake. Whereas fossil fills are still being made nowadays by underground warm and weight, they are being expended 3 more quickly than they are created. For that reason, fossil fills are considered as non- renewable; that's, they are not supplanted as before long we utilize them. Moreover burning fossil fuels leads to pollution and many environmental impacts (S.K. Singal, 2009).

However, world is entering a new chapter in energy generation. Lessening CO2 emanations, expanding energy security and improving supportability is within the prime center. Therefore we need to use sources of energy that will last forever. These sources are called renewable, as they can be used repeatedly. Renewable energy frameworks utilize assets that are continually supplanted and are less contaminating. That is renewable energy sources have been from hydropower origins in activities of the sun (Anuradha, et al., 2011).

In this way, hydropower is nowadays the foremost vital kind of renewable and feasible energy. Depending on the geographic situation small hydropower is also interesting for Laos PDR, because small hydroelectric power plants may be an efficient local solution for the energy supply in developing countries (Joachim, et al., 210). Since, SHP schemes are mainly run-of-river with little or no reservoir impoundment for types of hydropower turbines (David, et al., 2013).

Hence, considering that hydro power potential is strongly correlated to the changes in water discharge, it is necessary to estimate the impact that global climate change could have on it (Sachin, et al., 2013). SHP projects can be installed in rivers, small streams, dams and canals with negligible apparent environmental effects. In this way, in arrange to maximize water preservation, unmistakable quality has been given to the advancement and integration of SHP ventures into river systems amid final few a long time. Since little hydropower plant could be a key component for feasible improvement (Himanshu, et al., 2011).

Thus, Hydropower is nowadays the foremost critical kind of renewable and 4 feasible energy and most of the critical water power plants have been created (Havva, 2007). In addition, SHP technical aspects expressed by quantitative estimates are briefly discussed here, namely: SHP potential; plants in operation and contribution to the net and renewable power generation blend; fabricating industry and support mechanism; SHP improvement natural issues; estimate of SHP introduced capacity and power generation. And SHP legal, regulatory frame work, economic and main barriers to the SHP promotion, which are crucial for sector development, are also briefly considered in (Petras, et al., 2007).

In any case, a water turbine developed on the water turbulence or whirlpool guideline is able of utilizing exceptionally little sources indeed for undiscovered water, and it is profoundly appropriate for the closed circuit generation of electrical energy (V. Beran, et al., 2013). A turbine changes over the energy from falling water into turning shaft power. Which is the determination of the finest turbine for any specific hydro location depends upon the location characteristics, the prevailing ones being the head and stream available.

Moreover, the determination moreover depends on the required running speed of the generator or other gadget stacking the turbine. And all turbines have a power-speed characteristic and an efficiency-speed characteristic. In this manner, they will tend to run most productively at a specific speed, head, and stream (Oliver, 2002). Short-term estimating of power generation, for each kind of renewable power plant, could be a key matter for the Power System since such short-term estimating is a fundamental apparatus for guaranteeing power supply, arranging of save plants, or inter-power-systems electric energy exchanges or making a difference to fathom power arrange clog problems. For the renewable control maker, short-term estimating is pivotal for playing within the 5 power advertise or planning upkeep assignments (Claudio, et al., 2013).

Hence, the development of SHPs may be coordinates with territorial improvement plans, particularly for disconnected frameworks. It is conceivable to calculate the streams of vitality, request, and future dissemination with common energy-economic models. Of these future properties of energy systems, consistent estimates of indicators based on energy can be derived (Geraldo, et al., 2012).

In Laos, 97.5% of the power generation comes from hydropower and the nation is right now expanding its capacity, generally driven by electrical trades to Thailand and China. The total untapped planned capacity for 2006–2011 is 4013 MW and 2226MW from 2011 to 2020 (Mariano, 2010).

Therefore, corresponding to the small Hydropower (SHP) is defined as installed hydropower capacity of up to 10-15 MW. The taking after divisions inside SHP appears vital potential for development: Modern low-head SHP plans; Mini- and micro-hydro power; Repowering and updating of existing destinations; Improvement of pumped-storage facilities. The most important were SHP benefits: Clean, sustainable and emissions-free source of renewable energy; Highly efficient (from 70% to 90%); Proven and solid innovation; Unsurprising and simple to oversee; Long life expectancy of up to 100 a long time; Alluring vitality pay-back proportion; Makes strides framework soundness; Is an innate asset; Moves forward the differences of vitality supply; Innovation appropriate for provincial zap eminently in creating nations (Gema, 2008). A small hydro power plant can be upgraded with Power former generators yielding an increase in active power by 1 MW (Karin, et al., 2005).

1.3 Types of small hydro turbines

Turbines utilized in hydroelectric frameworks have runners of distinctive shapes and sizes. There are two main categories of hydro the theories of three types of small hydro turbines are presented.

1.3.1 Francis Turbine

Usually the foremost common sort of hydropower turbine in utilizing. Francis turbines are response turbines, with settled runner blades and movable direct vanes, utilized for medium heads. In this turbine, the affirmation is continuously outspread but the outlet is axial. Their regular field of application is from 25 to 350 m head.

This turbine, for the most part, has a spiral or blended spiral/ axial flow runner which is most commonly mounted in a winding casing with inside flexible guide vanes. Water streams radially inwards into the runner and rises pivotally, causing it to turn. In expansion to the runner, the other major components incorporate the wicket gates and draft tube.

The runners with a little distance across are made of aluminum bronze casting, whereas the bigger runners are manufactured from bent stainless steel plates that are welded to cast steel center. Francis turbines are connected in hydroelectric frameworks with a medium head estimate and their productivity can be above 90%, but tend to be less productive when there's less water accessible than their planned stream. For littler heads and control, the turbine is set in an open flume. However, the turbine can also be attached to a penstock and steel spiral is casings to use in cases of relatively higher heads.

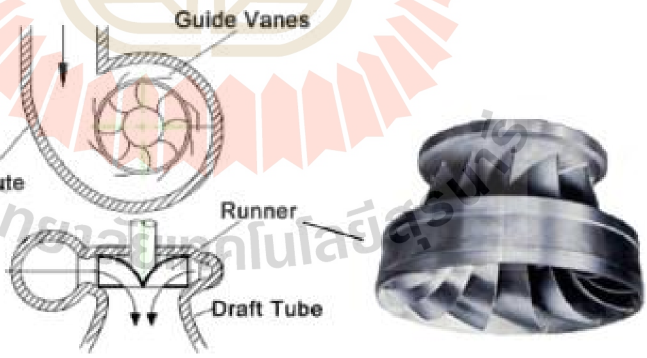

Figure 1.1 Typical Francis turbine (David, et al., 2013)

1.3.2 PELTON Turbine

PELTON turbines are impulse turbines where one or more jets encroach on a wheel carrying on its outskirts a huge number of buckets. Each jet issues water through a spout with a needle valve to control the stream. "The jets are issued through nozzles, each with a pivot within the plane of the runner and a needle (or spear) valve to control the stream". The jet is part in half and each half is turned and avoided back nearly through 180. They are as it was utilized for tall heads from 60 m to more than 1 000 m. The axes of the nozzles are in the plan of the runner.

In case of an emergency stop of the turbine (e.g. in case of load rejection), the jet may be occupied by a diverter so that it does not encroach on the buckets and the runner cannot reach runaway speed. In this way, the needle valve can be closed exceptionally gradually, so that overpressure surge within the pipeline is kept to a worthy level (max 1. static pressure). As any active energy taking off the runner is misplaced, the buckets are planned to keep exit speeds to a least.

This turbine does not require draft tubes since the runner are situated over the greatest tail water to allow operation at climatic pressure. PELTON turbines are usually applied in systems with large water heads. One or two jet PELTON turbines can have horizontal or vertical axis. Three or more nozzles turbines 8 have a vertical hub. The greatest number of nozzles is 6 not normal in little hydro. The turbine runner is as a rule straightforwardly coupled to the generator shaft and should be over the downstream level. The turbine producer can as it allowed the clearance. The efficiency of a PELTON is good from 30% to 100% of the maximum discharge for a one-jet turbine and from 10% to 100% for a multi-jet one.

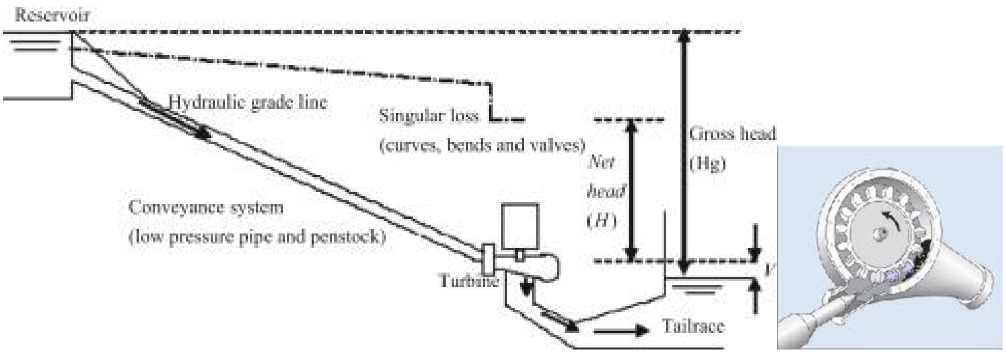

Figure1.2 Typical PELTON turbines (David, et al., 2013)

1.3.3 Kaplan and Propeller Turbines

Turbines Kaplan and propeller turbines are axial-flow response turbines; by and large utilized for low heads. For higher productivity, the water ought to be given a few whirls some time recently entering the turbine runner. The Kaplan turbine has flexible runner blades and may or may not have a movable guide- vanes movable blade pitch and it can accomplish tall proficiency beneath shifting control yield blades and guide-vanes are flexible it is portrayed as "double-regulated". In the event that the guide-vanes are settled, it is "single-regulated". Settled runner blade Kaplan turbines are called propeller turbines.

They are utilized when both stream and head stay essentially consistent, which could be a characteristic that creates them unordinary in little hydropower plans. The twofold direction permits, at any time, for the adjustment of the runner 9 and guide vanes coupling to any head or discharge variety.

It is the foremost adaptable Kaplan turbine that can work between 15% and 100% of the most extreme plan discharge. The methods used for adding inlets wirl include fixed guide vanes mounted upstream of the runner and a “snail shell” housing for the runner, in which the water enters tangentially and is forced to winding into the runner. Single directed Kaplan permits a great adjustment to changing accessible stream but is less adaptable within the case of vital head variety. They can work between 30% and 100% of the maximum design discharge.

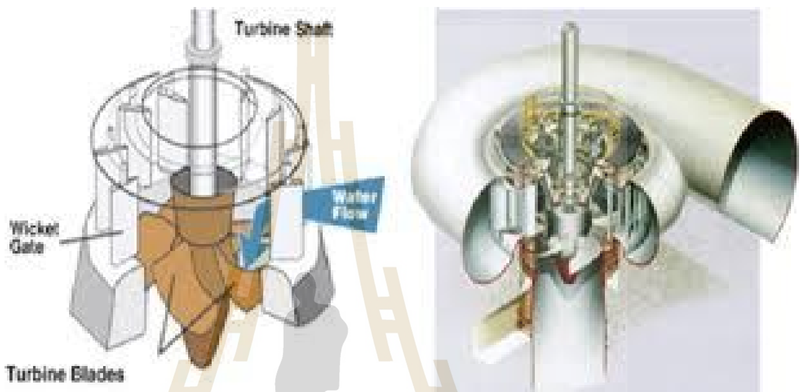

Figure1.3 Typical Kaplan and propeller turbines (David, et al., 2013)

1.4 Statement of the Problem

Optimal network flow rate for install small hydropower plant events affect the reliability of power quality. In the event that not well overseen, it may be jeopardized for system network and their results may get to be extreme and cruel to the framework operations. Therefore, the entire system may be driven into losses of the investment.

The optimal network flow rate analysis depends mainly on the selection suitable variables, i.e. the head and the inflow of the network water flow in river basin at a time. Essentially, the power cost of contributing in assessing the unwavering quality of the particular power system. Therefore an approach should be able to minimize cost by using the water demand and the power demand are parameter begin.

The approach considered in this research is based on minimize cost. Flow rate are assigned to perform tasks in each river basins and then coordinated so that the optimal flow rate of the entire system network is analyzed at a real time, hence the computational of cost is reduced.

Challenges intended to be addressed in this research include: computation time in both the water and power analysis and appropriate installation during network power system analysis. The function of minimize cost is a key factor of accuracy in optimal power flow for network analysis, therefore, it is considered together to accomplish the objective related to the computing time and its accuracy. The achievement of the goals mentioned, at a certain level, the risk related to the system network will be managed and the power losses of the power system will be improved. The planning ensures that system water network and system power network are corresponding for troubleshooting power flows through the transmission system.

1.5 Motivation of the Thesis

Lao PDR have been known that the landlocked country which also known the battery of Southeast Asia, according to the development strategy plan of LAO P.D.R government to expand the small hydroelectric power plants. There are many river basin of big river in Southern part of Lao PDR. The XEDON River Basin is rich in natural resources when measured in proportion to the population, with high potential for future economic growth and much potential for development in the river basin. It is favourable for agriculture especially tea, coffee plantation, animal husbandry and forestry with many valuable species. The XEDON tributaries are convenient for farming rice and other types of agriculture. Attributed to the XEDON River Basin is rich in natural such a vastly waterfall. Thus, the XEDON River Basin is vital to the Energy Development of hydropower in Lao P.D.R.

1.6 Research Objectives

This research has been Research Objectives, as below:

Network flow rate analysis and to find the location for installation small hydroelectric power plants in XEDON river basin

To find the optimal cost of small hydro power plants to improve power and water networks in XEDON river basin.

To find the optimal flow rate by using objective function is the total generation cost function CG,

The power production facility for the power generated at the i^{th} power plant for demand supply to customer.

The water production facility for the water produced at the j^{th} water plant for demand supply to customer.

The co-generation facility for the power generated and the water produced at the k^{th} of co-production plant for demand supply to customer.

1.7 Scope and Limitations of the Study

Analysis water flow balance in water network that suitable for flow rate in XEDON river basin.

Analysis water flow balance in pipe network that suitable for the location is selecting of the appropriate small hydropower plants with the XEDON river basin.

And the selection pressure suitable for in pipe network or in each node of the pipe network.

It also, to find optimal cost of the small hydropower plant to improve the quality of power and water networks in Laos P.D.R. And co-optimization for the economic dispatch with particle swarm optimization and optimal network flow in XEDON river basin. Therefore, optimal network flow for the potential of developing energy sources in Laos P.D.R and selection a XEDON river basin is data of research.

1.8 Methodology

This research is guided by several literature surveys of methods. Each the method is interpreted according to the effect on the power and water operations. In this segment, these elucidations are displayed.

1.8.1 Analysis water rainfall data of stations in XEDONE RIVER to find location for installation small hydro power plants using technique interpolation methods.

1.8.2 Literature survey of power distribution network systems.

1.8.3 Literature survey of water distribution network systems.

1.8.4 Literature survey of small hydro power plants.

1.8.5 Find of current research on the flow rate depicted before to study new designs

1.8.6 Find of current research on optimal flow rate depicted before to study new designs.

1.8.7 Find of current research on optimal small hydro power plants

1.8.8 Using personal computer (PC) and MATLAB programs to simulate the various systems.

1.8.9 The operations with method in the engineering simulation. Analysis of the model to find the optimal cost for installation small hydro power plants using technique optimal power and water.

1.9 Expected Benefit

This research has been expected benefit, as below:

1.9.1 Able to determine the location of installed small hydropower properly.

1.9.2 Able to determine the capacity of installed small hydropower properly.

1.9.3 Able to determine the optimal flow rate suitable to types of small hydro turbine

1.9.4 Able to determine the optimal flow rate for applied network water flow rate system.

1.10 Organization of the Thesis

The thesis is divided into eight chapters.

I. In chapter I Current energy problem in Lao PDR, background, types of small hydro turbines, statement of the problem, motivation, objectives, scope and Limitations of the Study, methodology are presented. Chapter II gives the information of the literature review, optimal water flow, optimal power flow and optimal cogeneration power and water networks. Chapter III gives the information of the XEDON River Basin. In the chapter, IV gives the analysis flow rate in XEDON river basin for defining the potential point of small hydropower plants. Chapter V gives the

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analysis method for optimal network flow rate for installation small hydro power plant. Hence, Chapter VI gives co-optimization for optimal network flow rate for installation small hydro power plant. Chapter VII gives the analysis simulation methodology and results for optimal network flow rate for installation small hydro power plant. Finally, Chapter VIII presents the conclusion and related remarks.

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CHAPTER II

LITERATURE REVIEW

2.1 Introduction

The fundamental objective of this work is to explore the essential vitality and save generator production optimization (co- optimization) in the setting of a pool-based showcase. Specific intrigued is in the modeling of misplaced opportunity taken a toll presented by saving allocation. Therefore, they have received the marginal costs of energy and reserves under a variety of market designs. In the expansion, they also analyzed presence, calculation, and variety of ideal solutions. The results of this study were used to support the reserve market design and implementation in ISO New England control area1 (Gan, Deqiang, et al., 2002).

An inventive approach of co-optimizing the vitality and auxiliary administrations markets in the Australian National Power Advertise is discussed. Horizon Scan is a heuristic based strategy to look for the ideal arrangement in a non-linear arrangement space. In the expansion, this article moreover incorporates a few case considers delineating streamlined advertise models. Direct and non-linear limitation conditions are moreover included in the demonstrate to take into account elements of the control framework (Chand, et al., 2005). A co- optimization approach for ex-post estimating requires characterized complex estimating rules and executing heuristics to guarantee steady official imperatives with the ex-ante expedite. This approach streamlines the execution of ex-post estimating rules in the ISO-NE showcase (Zheng, et al., 2006). Security obliged financial expedite (SCED) is connected to issue detailing speaking to physical and utilitarian necessities in the multi-interconnected control areas. The straight optimization show is a streamlined advertising plan and execution while not compromising any fundamental properties of electric power system (Siriariyaporn, et al., 2008).

The different strategies for utilizing incline capability in the Midwest ISO co-optimized real-time vitality and auxiliary benefit showcase plan. A basic component of the effective showcase plan is moved forward showcase financial effectiveness as well as lattice reliability. This paper also compared the study on various proposed ramp models (Chen, et al., 2009).

The security- constrained commitment and dispatch algorithms and their implementation for ISdy -ahead co-optimized energy and ancillary service markets. The MIP strategy is utilized to unravel the DA advertise and the RA commitment issues and the LP strategy tackles the DA advertise clearing issue. Request reaction assets qualified for the arrangement of vitality and subordinate administrations (Ma, et al., 2009).

Therefore, co-optimization of Midwest ISO's real-time market designs with energy and ancillary service. The key components of Midwest ISO's real-time market had described including intra-day reliability commitment, transmission security management, real-time dispatch, and pricing. Moreover, it had also presented for the RT SCED formulation at the core of the real-time dispatch and pricing market (M, et al., 2009).

Co - optimization detailing of the generation unit commitment and transmission exchanging issue while guaranteeing N-1 unwavering quality appeared that the ideal the network topology may vary from each hour. They too appeared that optimizing the topology can alter the ideal unit commitment plan and too displayed deterioration and computational approaches to solving this problem (Hedman, et al., 2010).

A demonstrate for vital offering and short-term generation planning in save co-optimized markets like the Philippine Discount Power Spot Market. Several bidding strategies, derived from the model had then presented and discussed (Francisco, et al., 2010). Hence, the formulation to accommodate the two-part regulation compensation under co-optimized energy and ancillary service market (Chen, et al., 2013).

Which, the strategy addresses two key challenges in power advertise plan: coordination wind control more productively and moving forward shortage estimating. From that, they compared the proposed probabilistic approach to conventional working save rules. At long last, they utilized the Illinois control framework to demonstrate the productivity of the proposed save advertise modeling approach when it had combined with probabilistic wind control determining (Zhou, et al., 2014).

And it was considered the co-optimization of repairs, load pickups, and power production to deliver a sequencing of the repairs that minimizes the measure of the blackout over time. Hence, to address this computational obstruction, the paper analyzes two approximations of the control stream conditions: The DC demonstrate and the as of late proposed LPAC model (Coffrin, et al., 2015).

The paper proposes to consider certain factors such as equipment failure, prediction errors of loads, wind power, a novel risk reserve constrained generation and working save ideal dispatching model. The proposed method could strike the balance between reliability and economy of the wind power system by setting the value of confidence level and give optimal scheme for the assignment of thermal power yields and save among the generator delivered (Wang, et al., 2015).

An unused showcase plan proposed utilizes a joint day-ahead (DAM) exchanging stage for vitality and security saves. Its primary reason has been to address the developing challenges in the acquirement of European subordinate administrations. The concept of co-optimization is portrayed, taken after by a proposition of a co-optimized control trade (PX) complying with the European consecutive vitality and control reserve procurement (Divényi, et al., 2016).

They have proposed a fuzzy based energy and reserve co-optimization model with consideration of high penetration renewable energy. Moreover, it was proposed for clearing vitality and saves in the, to begin with organizing and checking the achievability and strength of re-dispatches in the moment organize. The arrangements got by changing the fuzzy numerical programming definition into conventional blended straight linear programming issues. It demonstrated that the fuzzy model provided a trade-off solution between the system operating risks and total scheduling cost (Liu, et al., 2017).

2.2 The Production in Power and Water Network

2.2.1 Introduction of Power and Water Networks

This brief description of the link in the high level of mainstreaming from the perspective of developing countries and through case studies, get to some promising directions for connecting Nexus. It also features a modeling framework that identifies the Nexus, and can be used to inform national policies more effectively and regulations (Bazilian et al., 2011).

A meta-architecture of the power-water nexus in power supply, plumbing engineering, and wastewater management systems have been developed using Systems Modeling Language (SysML).

Then it was applied to quantization concepts from the terrain of Egypt (Farid, et al., 2013). This meta-architecture serves to describe the Nexus for qualitative discussions. When such architecture can be used as a framework for quantitative planning and control methods can be used (Lubega, et al., 2013).

The policy is to focus on restructuring agricultural land use and reduce imports of fossil fuels. Results from an assessment of the energy system with no modeled inter- linkages to land-use, energy, and water systems were first presented. After all, it gets compared to those from integrated climates, energy, Water and Land Use Systems (CLEWS) (Duić, Neven, et al., 2013).

Some studies have examined the relationship between energy use and water use and analysis of China's water-power linkages using input-output tables. They use a coefficient that identifies the relationship between energy and water consumption to describe the relationship between the supply and supply of water supply to the primary energy sector. This study demonstrates that participation in the relationship between water and energy conservation efforts should be an important factor in creating policies that stimulate both resource savings simultaneously (Gu, Alun, et al., 2014).

The models of this model include the use of water for electricity supply and the use of electricity for water supply in a single network describe the various interactions that may be influenced by policy and management decisions to achieve the desired objectives. Engineering models that capture these interactions depend on the basic form of basic physics of junctions and points that have been developed in previous work. Jacobian's system of equation results has been defined for a particular example case. This Jacobian helps in analyzing the sensitivity of the input and output of this system to the changes in water and electricity demand (Lubega, et al., 2014).

There has been a clear development of the space-based model of Arizona's water power and the assessment of the potential for a mutually beneficial conservation program. Mutual benefits of investing in eight conservation strategies have been assessed in the context of renewable energy portfolio legislation and energy efficiency standards (Bartos, et al.,(2014).

The energy- water Nexus has been largely educated through a discussion of policy options supported by data exploration and technology considerations. There is small wrangle about on the association of the energy-water nexus from the viewpoint of framework designing. It was developed using a language modeling system (SysML). Hence, the models have been developed that characterize the various transmissions of matter and energy in and between the electricity and water systems (Lubega, et al., 2014).

The analysis shows that reliance on water, energy, and land is very important and cannot be managed effectively without a mix of sectors. Research indicates that the diversification of power generation technologies with the expansion of solar and wind power can help reduce the need for additional land and water for future control supplies (Senger, et al., 2015).

It has focused on the extent to which the water-energy nexus (as applied to the use of energy in urban water systems) is treated in Norway, a country blessed with an abundance of both clean energy and freshwater. Urban water utilities have realized the importance and the possibility of improving the energy efficiency of their operations; and also have started looking at urban water utilities as essentially energy-producers. The driving factors are economic issues, environmental goals, self-image, public demands etc., (Govindarajan, et al., 2015).

They have created a modern energy-water nexus examination system for wind power generation system, which incorporates both component and pathway nexus examinations. It utilized vitality for water extraction, wastewater treatment and water expended for power generation were examined. The common intuitive and control circumstances inside the wind control era framework were moreover inspected in pathway nexus examination based on Arrange Environ Examination (NEA) (Yang, et al., 2016).

The investigation of the energy-water nexus epitomized in universal vitality exchange through a combination of input-output investigation (IOA) and environmental arrange examination (ENA). The energy-water component Nexus was portrayed based on a mixed- unit IOA to explore the parallel relationship between energy and water. ENA was utilized to reveal energy-water pathways interlaced in worldwide energy exchange and distinguish the pair-wise relationship between nations concurring to the power-water pathway nexus. At long last, approach and financial proposals were put forward to ease the potential impacts of worldwide energy exchange on water shortage in China (Duan, et al., 2016).

There are writing to survey of the current status investigate crevices, reliance variables, and conceivable change measures to diminish energy utilization in the water segment. The comes about appear that water supply and wastewater administrations were energy seriously universally owing to ancient frameworks and innovations (Wakeel, et al., 2016).

They displayed a synchronous strategy for the ideal plan of coordinates water and energy systems. The show was a non-convex MINLP (mixed-integer non-linear program) demonstrate, in which the objective is to play down the add up to yearly costs. The ideal speed and warm exchange coefficients for the streams in the warm exchangers were decided, and the answer was in great understanding with the writing. In this way, the demonstrate reflects the genuine circumstance in mechanical systems where warm, electrical energy and water necessities connected exceptionally closely (Torkfar, et al., 2016).

It is to distinguish and propel a few openings for upgraded coordinates operations administration and arranging in the energy-water nexus in multi-utilities in the MENA. It continues in four parts. To begin with, an article of the energy-water nexus particularly as it applies to the MENA is given. The moment, the paper shifts to openings in coordinates operations administration highlighted by an energy-water nexus supply-side financial expedite outline. Thirdly, the talk shifts to arranging openings for the energy-water nexus for the economic improvement of water and energy assets (Farid, et al., 2016). The created demonstrate spoken to a methodological commitment to the challenge of consecutive choice making in energy-water nexus through the arrangement of a coordinates modeling framework/tool. An intuitively fluffy optimization strategy is presented to look for a palatable arrangement to meet the in general fulfillment of the two-level choice creators. The tradeoffs between the two-level choice creators in energy-water nexus administration are viably tended to and measured. Application of the proposed demonstrate to an engineered illustration issue has illustrated its appropriateness in commonsense energy-water nexus administration. Ideal arrangements for power era, fuel supply, water supply counting groundwater, surface water and reused water, capacity development of the control plants, and GHG emanation control are created (Zhang, et al., 2016).

The benefits to be picked up from and the disadvantages of disregarding different water-energy interlinks for approach creators and organizers in destinations to meet long-term stability. There is too requires to harmonize the energy and water frameworks from both a specialized and approach viewpoint (Khan, et al., 2017).

2.2.2 Energy Production in Water Network

A mid the past few a long time, issues concerning the economical administration of water dissemination frameworks have pulled in intrigued through a coordinates arrangement pointed at decreasing spillage through a weight administration procedure. In this paper, PRVs and PATs were utizinsia in Naples conveyance appeared potential and an appealing capital payback period (Fontana, et al., 2011).

Pump working as turbine (PAT) has been to be a compelling source of diminishing the hardware fetched in little hydropower plants. A planning method has proposed that couples a parallel pressure drove circuit with the by and large plant effectiveness criteria for the showcase pump determination inside a WDN. The proposed plan strategy permits distinguishing the execution bends of the PAT that maximizes the delivered vitality for a relegated stream and weight head dispersion design. Computational liquid flow (CFD) had appeared to be an appropriate elective for execution bend appraisal covering the restricted number of test information (Carravetta, et al., 2012).

It displayed the potential conceivable outcomes of vitality recuperation amid lessening of weight in the warming systems. The fundamental point was to substitute the existing mechanical weight lessening valve. Preparatory ponders appeared conceivable outcomes of accomplishing a fulfilling proficiency of vitality transformation and point the way for the future investigated and advancement exercises (Dariusz, et al., 2015).

It has displayed the application of four administration apparatuses: 1) An vitality review to assess the potential hydro vitality in the water pressurized frameworks of Alcoy, 2) Multi- criteria decision- making strategies for the determination of the favored vitality proficient operation of a framework with a pump-storage supply and hydro-turbines in the Algarve, 3) A numerical energetic apparatus for ideal turbine operation in the water dissemination of Langhirano, 4) An urban water spearheading instrument to appraise the hydropower potential of the outside reservoir conduit arrange in Athens. These strategies appeared that through coordinates approach the water supply frameworks could be optimized for both pressures driven execution and hydro vitality generation (Frijns, Jos, et al., 2015).

The financial advantage of Taps application in water dissemination systems was explored in a little area of Palermo arrange (Italy). For the investigation of vitality recuperation, carried out by implies of a numerical demonstrate based on the strategy of characteristics, appears that Taps can lead to an exceptionally appealing financial advantage in terms of vitality generation (De Marchis, et al., 2015).

It displayed the energetic reenactment of an urban water supply framework based on a phenomenological show of conveyed parameters competent of foreseeing the water-powered behavior and the vitality utilization. This case think about includes a section of the supply and conveyance water framework in the city of Salvador (Brazil), the investigation centers on the pumping station, water mainline, and conveyance tanks. The utilized of energetic modeling for the case think about was imperative for the reenactment comes about to be steady. The answer appeared the potential pick up in vitality (Diniz, et al., 2015).

A coordinates unused specialized arrangement with financial and framework adaptability benefits was displayed which replaces weight lessening stations (PRSs) with pumps utilized as turbines (Taps). Ideal PAT execution is gotten by a Variable Working Technique (VOS), as of late created for the plan of little hydropower plants on the premise of valve time operation, and net return decided by both vitality generation and investment funds through minimizing spillage. The think about appears that the hydropower establishment produces curiously financial benefits, indeed in the nearness of little accessible control, and that could energize the spillage diminishment indeed on the off chance that water reserve funds are not financially significant, with resulting natural benefits (Fecarotta, et al., 2015).

The potential exists for micro-hydro control that utilizes the weight abundance in the systems to create power. An optimization calculation has proposed to supply a determination of ideal areas for the establishment of a given number of turbines in a dispersion organize. This work centered on the definition of the neighborhood of the mimicked tempering handle and the investigation of meeting towards the ideal arrangement for distinctive limitations and numbers of introduced turbines (Samora, et al., 2016).

In water supply frameworks has been to the potential for hydropower generation at a few scales, from little hydro to small scale. The vitality recuperation inside the urban water supply systems was a sort of micro-hydro that may be valuable for the control of over the top weights. A conspire uncommonly conceived for water supply systems making utilize of a micro- turbine was proposed. Preparatory comes about gotten for a organize case consider appear that the usage of the proposed vitality recuperation arrangement was attainable (Samora, et al., 2016).

Existing applications for vitality recuperation from gravity water supply frameworks and water dispersion systems were displayed. Also, a pilot application of a pump as turbine (PAT) in Antalya water dissemination arrange was portrayed for vitality recuperation from abundance weight. By utilizing of a water-powered show, ideal operational weight at each DMA of a organize could be characterized and abundance weight regions could be decided (Karadirek, et al., 2016).

It displayed an appraisal of the effect of the stream and head varieties on turbine productivity and control yield over a twenty year period. This planning procedure opens up the opportunity to conduct vitality recuperation from locales which may already have been considered unacceptable for MHP. Where stream and head rates showed significant vacillation, the integration of a two PAT arrangement could progress working proficiency and maximize control yield. Comes about shown that Taps speak to a practical low-cost alternative over the long-term, at locales with littler control yield potential (Brady, et al., 2016).

Micro-hydropower is a way of moving forward the enthusiastic effectiveness of existent water frameworks. In the specific case of drinking water frameworks, a few think about have appeared that weight decreasing valves can be by-passed with turbines in arranging to recuperate the disseminated pressure driven vitality to deliver power (Samora, et al., 2016).

2.2.3 Water Production in Water Network

A strategy called linear programming gradient (LPG) was displayed, by which the ideal plan of a water conveyance framework could be gotten. The objective work to be minimized reflects the generally fetched capital additionally displayed the esteem of working costs. The arrangement was gotten through a progressive deterioration of the optimization issue. This strategy was actualized in a computer program (Alperovits, et al., 1977).

The show is consolidated into a common reason distribution-system water-quality reenactment program called EPANET. This paper examines how EPANET was utilized to calibrate the show to field perceptions taken from a parcel of the South Central Connecticut Regional Water Authority (SCCRWA) and reports on its capacity to coordinate measured changes in chlorine levels all through the framework over time (Rossma, et al., 1994).

The advancement of a computer show, known as GANET, that includes the application of a generally modern optimization method to the issue of the least-cost plan of water dissemination systems. The Genetic Algorithm (GA) has presented in its unique shape taken after by distinctive conceivable enhancements fundamental for its successful usage in the optimization of water scattering frameworks (Savic, et al., 1997).

The quality of drinking water was closely related to human wellbeing and given secure drinking water was a major open wellbeing need. Be that as it may, there are different strategies for moving forward the quality of drinking water, and open wellbeing authorities frequently must choose which strategies are suitable for most cases. They conducted a randomized intercession trial in Nukus, Uzbekistan to supply epidemiologic information to help such an approach choice (Semenza, et al., 1998).

It displayed a survey of the methods to plan and retrofit water systems. The strategies were utilized truly for any handle plants. One issue was the freshwater, wastewater reuse allotment and the other was the wastewater treatment issue. A few arrangement approaches were briefly laid out emphasizing the primary slant inclining towards the utilized of scientific programming (Bagajewicz, et al., 2000).

They have proposed a degree of economies of scope to survey the advantage related with the joint generation of water for last clients and water misfortunes, and a few measures of returns to assess potential pick up in misusing the mechanical adaptabilities of water systems. We gauge the fetched structure of water utilities utilizing a GMM method with a Translog fetched work and board information. Estimation comes about uncover a positive degree of economies of scope, and short- run returns to generation thickness and returns to client thickness that is not essentially distinct from 1. Noteworthy economies of scale demonstrate that neighborhood communities may advantage from consolidating into water areas (Garcia, et al., 2001).

Quickly developing populaces and relocation to urban regions in creating nations have brought about in an imperative requirement for the foundation of centralized water frameworks to spread consumable water to inhabitants. Secured source water and present day, well-maintained drinking water treatment plants can give water satisfactory for human utilization. Through progressed investigate, observing and observation, expanded understanding of dissemination framework lacks may center constrained assets on key zones in an exertion to progress open wellbeing and diminish worldwide illness burden (Lee, et al., 2005).

The reason for this consider was to anticipate future water utilization sums from forerunner values. TS fluffy show was utilized for modeling month to month water utilization time arrangement from Istanbul city. The paper was organized in a taking way. Firstly, the essential concepts of the fluffy rationale hypothesis and the Takagi-Sugeno fluffy framework were presented. Furthermore, the conceivable drift was expelled from water utilize time arrangement. In conclusion, the de-trended information set was consolidated into TS fluffy framework to get most effective demonstrate setup (Altunkaynak, et al., 2005).

A half-breed strategy, based upon an moved forward GA, is utilized to fathom the optimization issue of finding the least water supply concomitantly with the water organize topology guaranteeing the most extreme water reuse. The half-breed character of the calculation is given by the neighborhood reshape of the chromosome, at the quality level, to manage with the mass adjust confinements, while the change of the GA is given by the contracting neighborhood cloning procedure, which favors the people encompassing the best-so-far arrangement (Lavric, et al., 2005).

They have displayed a mixed-integer programming (MIP) detailing for sensor situation optimization in metropolitan water dissemination framework that incorporates the transient characteristics of defilement occasions and their impacts. The MIP detailing is scientifically comparable to the well-known p-median office area (Berry, et al., 2006).

The information envelopment investigation (The data envelopment analysis) strategies were utilized to get gauges of the multi-input, multi-output generation innovation. The potential clients of these execution measures in price-cap direction were talked about. The impact of variable determination and information quality upon observational comes about was emphasized (Coelli, et al., 2006).

The surveys water-saving agrarian frameworks and approaches to move forward rural water utilize proficiency in the parched and semiarid ranges of China. It has been covering organic components of water-saving horticulture and water-saving water system advances, counting low-pressure water system, wrinkle water system, plastic mulches, dribble water system beneath the plastic, precipitation gathering and terracing. In the expansion, it had tended to the compensatory impact of the constrained water system and fertilizer supplementation on water utilize effectiveness and highlights the require to breed unused assortments for tall water utilize effectiveness (Deng, et al., 2006).

An unused approach for defilement source distinguishing proof in water dissemination frameworks through a coupled demonstrate trees straight programming calculation. Show trees were an expansion of tree- based models utilized to fathom forecast issues in which the reaction variable is a numerical esteem in the sense that they relate takes off with multivariate straight models. The proposed strategy gives an estimation of the time, area, and concentration of the defilement infusion sources. The show was illustrated utilizing two case applications. It utilized to show trees speak to forward modelling (Preis, et al., 2006).

The joins pressure driven models for water stream through dispersion frameworks to models for evaluating wellbeing impacts in arrange to anticipate the spread of infection over time in a populace utilizing sullied water. The center is on organic operators, such as microscopic organisms and infections, but a few of the strategies would too be fitting for chemical operators. The proposed system gives data approximately the spatial and worldly dissemination of wellbeing dangers in dissemination frameworks and is valuable for understanding the powerlessness of drinking water frameworks to defilement occasions, as well as for plan open wellbeing and water utility procedures to decrease dangers (Murray, et al., 2006).

The modernization and optimization of water system frameworks can contribute to the increment of water efficiency in a setting of worldwide water shortage. Consideration will be paid to the part of flooded farming in the fulfillment of the developing nourishment request (Playán, et al., 2006).

It was planning to serve as a presentation to the POWADIMA investigate venture, whose objective was to decide the possibility and adequacy of presenting real-time, near-optimal control for water- distribution systems. The approach received was laid out, together with the reasons for the choice. The potential benefits emerging from actualizing the control framework created were briefly surveyed, as were the conceivable outcomes of utilizing the same approach for other application zones (Jamieson, et al., 2007).

The apparent reason for having one case think about bigger than the other was to evaluate the effect of scale on the degree of trouble experienced in applying the control framework created. It would too serve to supply a comparison of the computing time required to calculate the near- optimal control procedure at each upgrade, which is a basic issue in deciding whether the real-time control is a down to earth suggestion. The comes about show a potential operational-cost sparing of 17.6% over a total (reenacted) year relative to current hone, which effectively legitimizes the fetched of executing the control framework created (Martinez, et al., 2007).

A multiobjective demonstrate for water dispersion framework ideal sensor arrangement utilizing the nondominated sorting hereditary calculation II was created and illustrated utilizing two water dissemination frameworks of expanding complexity. Tradeoffs between three goals were investigated: (1) Sensor discovery probability, (2) Sensor location repetition, (3) Sensor anticipated discovery time (Preis, et al., 2008).

The objective is abused in arrange to plan effective arrangement calculations with provable execution ensures. The strategy displayed here could be expanded to multicriteria optimization, selecting the situations vigorous to sensor disappointments and optimizing minimax criteria. In this paper on two benchmark dissemination systems, and a genuine drinking water dissemination framework of more noteworthy than 21,000 nodes, was displayed (Krause, et al., 2008).

It has displayed almost treated water quality confirmation and portrayal of dispersion systems by multivariate chemometrics. The classification and relapse tree (C&RT) calculation appeared that the fundamental parameters utilized in the separation of the WTP tests were EC and Al. The answer with respect to the

WTPs were subjected to a principal component analysis (PCA) with 75% of the add up to change was clarified (Smeti, et al., 2009).

Rigid prerequisites on cost-effectiveness and natural compatibility produce an expanded request for model-based choice back apparatuses for planning and working metropolitan water supply frameworks. It bargains with the least taken a toll operation of drinking water systems. They have proposed a nonlinear programming approach that yields essentially palatable working plans in satisfactory computing time indeed for expansive systems. Comes about for chosen application scenarios at Berliner Wasserbetriebe illustrate the victory of the approach (Burgschweiger, et al., 2009).

They give valuable climate data to urban water asset directors for regular water utilization determining at numerous worldly scales. Comes about of the think about will give a premise for future comparison of how the climate-modulated utilization shifts (or is comparable) over distinctive climatic administrations, in terms of whether water utilize is more touchy to temperature or precipitation or other factors (Burgschweiger, et al., 2009).

The levelheaded utilize of water assets and lessening of water misfortunes, based on the presumption that it is distant more temperate to create and make strides existing frameworks or maybe than constructing unused frameworks in parallel to the existing one. They had created a program to prioritize options, at the same time taking into account subjective, objective criteria, in this manner giving choice producers a clear, comprehensive diagram of options, and demonstrating the most appropriate elective based on the inclinations of bunch individuals from distinctive regions (Trojan, et al., 2012).

The plan of water dissemination systems (The design of water distribution networks) was an optimization issue with minimization of channels and their related establishment costs as the objective work. It has created a probabilistic show based on the Monte Carlo recreation (the Monte Carlo simulation) strategy to survey impacts of those instabilities at the same time in the long-term execution of the arrange by considering different scenarios for varieties of nodal requests and pipe unpleasantness utilizing diverse values of the coefficient of variety (CV) as the vulnerability degree (Seifollahi-Aghmiuni, et al., 2013).

The administration of the urban water cycle (UWC) was a subject of expanding intrigued since of its social, financial and natural effect. The most vital issues incorporate the maintainable utilize of restricted assets and the unwavering quality of benefit to customers with satisfactory quality and weight levels, as well as the urban seepage administration to avoid flooding and contaminating releases to the environment. A UWC was primarily comprised of the taking after frameworks: (i) Supply/production: water supply from shallow or underground sources and treatment to accomplish essential quality levels, (ii) Transport systems which utilize characteristic or counterfeit open-flow channels and/or pressurized conduits to provide water from the treatment plants to the buyer zones, (iii) Water dissemination to shoppers, including pressurized pipeline systems, capacity tanks, booster pumps and pressure/flow control valves, (iv) Urban waste and sewer frameworks carrying squander- and rain water together to wastewater treatment plants (WWTP), some times recently returning for the environment (Ocampo-Martinez, et al., 2013).

In the proposed modeling plot, sensor areas are coordinates not as it were for accomplishing water security objectives but too for finishing other water utility goals, such as satisfying authoritative checking prerequisites. Hence, the ponder extraordinary to display two scientific models for the ideal area of sensors as static double used benefit model (SDUBM) and dynamic double used benefit model (DDUBM) to supply tradeoffs between greatest request scope and least utilization of sullied water in inactive and energetic dreams. The think about illustrates the proficiency and execution of the proposed multi-objective subterranean insect colony optimization calculation for understanding the issue (Afshar, et al., 2015).

2.3 Co-optimization for the Economic Dispatch of Power and Water Network

The purpose of economic dispatch can be considered the most basic algorithm to deliver power in an economic fashion (Allen J, et al., 1996). It minimizes the total power generation cost subject to the capacity limits of the power plants and the balance of power generation and demand (Allen J, et al., 1996) . Formally:

This basic mathematical formulation can be extended to include additional phenomena such as power losses, transmission constraints (Allen J, et al., 1996) as in the case of optimal power flow, and startups, shutdowns, and ramping constraints as in the case of unit commitment (Hobbs, et al., 2001). Other literature has enhanced the basic economic dispatch formulation to minimize carbon dioxide (Ming, et al., 2007) or improve reliability (Han, et al., 1993).

2.3.1 Purposes of Economic Dispatch Problem (EDP)

2.3.1.1 Economic Dispatch of Power

Economic dispatch of power Economic dispatch (Kirchmayer et al., 1958) is the process of allocating the generation of power in a manner so as to minimize the cost of production of the needed power by encouraging the use of cheap fuels and/or most efficient plants. This is a region which has been created broadly both scholastically and mechanically (Wood AJ, et al., 1996), (Gómez Expósito A, et al., 2008).

One of the most critical preferences of the financial expedite issue is that it permits for all sorts of producing plants to be treated similarly in spite of their personal physical characteristics and imperatives. It does so by focusing on creating a generalized algorithm with a uniform cost function and constraints in order to effectively handle different types of plants. Typically, the cost function is taken to be of the quadratic form, however, different approaches also consider the cost to be linear, piecewise linear, and in certain cases of higher polynomials as needed (Wood AJ, et al., 1996), (Ongsakul W, et al., 2011).

Speaking of the energy delivery industry, the economy is often managed at a higher frequency stage than in a single-pass optimization. The first step is called day-to-day energy market and uses a class of optimization program called the unit of commitment. It serves to define resources and set estimated levels and prices for the next 24 hours based on preferred bids, Production proposals and bilateral transactions as scheduled (Sheble GB, et al., 1994), (Sen S, et al., 1998), (Hobbs BF, et al., 2001), (Padhy NP, et al., 2003), (Padhy NP, et al., 2004), (Das D, et al., 2005), (Philpott AB, et al., 2006), (Asir Rajan CC, et al., 2011), (Xie L, et al., 2011), (Bhardwaj A, et al., 2012), (Aghaei J, et al., 2013). The next step in economic delivery is real-time marketing (Saravanan B, et al., 2013), (Chowdhury BH, et al., 1990), (Yamin HY, et al., 2004), (Mahor A, et al., 2009), (Boqiang R, et al., 2009), (Xia X, et al., 2010).

In the real-time economic dispatch, electricity production and prices are calculated periodically from 5 minutes to 1 hour according to the conditions of the actual grid system. This article may be seen as a real-time economic development for both energy and water. The two steps are shared so that delivery can correct errors in anticipation of demand while being able to start and run up of model facilities (Kopsakangas Savolainen M, et al., 2012), (Boogert A, et al., 2005).

At last, the optimal power flow issue considers the power transmission limitations inside the network (Arciniegas Rueda IE, et al., 2005), (Huneault M, et al., 1991), (Momoh JA, et al., 1999), (Momoh JA, et al., 1999), (da Costa G, et al., 2000), (Abdel-Moamen, et al., 2003), (Pandya KS, et al., 2005), (Qiu Z, et al., 2009).

The usage of economic dispatch to shifts broadly depending upon the administrative structure. They are broadly classified as directed and unregulated. In the previous, in spite of the fact that the utility may buy from a neighboring utility, it is vertically coordinates and hence basically capable for its possess generation, transmission and conveyance of control to the clients in its zone. In the deregulated supply framework, generation and dissemination are uncoupled and clients are no longer bound to one utility but are free to buy from any providers on the lattice. Acquiring of control is done through the power showcase components and transmission planning is conducted by the free framework administrator (Frank S, et al., 2012), (Hogan WW, et al., 2012), (Hogan W, et al., 2002).

Comprehensive medications of deregulated power markets can be found in (Hogan WW, et al., 2010), (Chao H-P, et al., 1998), (Sheblé GB, et al., 1999), (Ilic MD, et al., 1998), (Kirschen DS, et al., 2004), (Shahidehpour M, et al.,

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2005), while the writing too gives specialized medicines in deregulated cost estimating, dispatching and offering recreation (Ragupathi R, et al., 2004), (Shrestha GB, et al., 2004), (Careri F, et al., 2010).

It is, for the most part, concurred that deregulated power systems give more noteworthy showcase motivations for generation capacity speculations and as a result permit for a smoother move into more current advances and more prominent adaptability (Perez-Arriaga IJ, et al., 2011).

Economic Dispatch: Problem Formulation of Power

The formulation of the power optimization is as follows. Minimize the production cost objective function C_{pG} with respect to the quantity of power generated by the power plant x_{pi} in the type of plants. The following notation is introduced:

$$X_{pi} = \left[x_{pi}, 0 \right]^T, \ \mathrm{D} = \left[D_p \right]^T \tag{1}$$

$$C_{pi} = X_{pi}^T A_{pi} X_{pi} + B_{pi} X_{pi} + K_{pi} \tag{2}$$

$$C_{pi} = a_{1i} x_{pi}^2 + b_{1i} x_{pi} + c_{1i} \tag{3}$$

$$C_{pG}\left(x_{pi}\right) = \sum_{i=1}^{n_{pp}} C_{pi}\left(x_{pi}\right) \tag{4}$$

Subject to the capacity (5), demand (6).

$$MinGenPP_i \le X_{pi} \le MaxGenPP_i \quad , \qquad \forall \ \mathrm{i=1,....,n}_{pp} \tag{5}$$

$$\sum_{i=1}^{n_{pp}} X_{pi} = D_p \tag{6}$$

Where

A_{pi} is the quadratic production cost function coefficient of the i^{th} power plant. B_{pi} is the linear production cost function coefficient of the i^{th} power plant. C_{pG} is the production cost function. K_{pi} is the constant production cost function coefficient of i^{th} power plant. C_{pi} is the scalar cost functions for the i^{th} power production facility. Additionally, n_{pi}, is the numbers of power. D_p represents the power product demand vector. Finally, MinGenPPi, MaxGenPPi are the least and greatest water capacity limits for power production facilities. The cost functions C_{pi} is assumed to exhibit a quadratic structure in their respective production variables.

The cost function coefficients are appropriately sized positive constant matrices based upon the heat rate characteristics of their respective production units. Figure 2.1 gives a graphical representation of the conceptual demonstrate control generation that serves as the premise for the improvement of the optimization program. It comprises of a coordinates control utility that was interested in at the same time serving an electrical control request. The particular lattices were modeled as single hubs. The utility dispatches control offices that may be free or vertically coordinates. The dispatchable control plant requires a fuel source. The particular lattices by ideals of the generation taken a toll capacities and the handle limitations. The electrical vitality was expected to draw and infuse only from their individual lattice. The control request was measured net of any control necessity to the greasy chosen to the butter client.

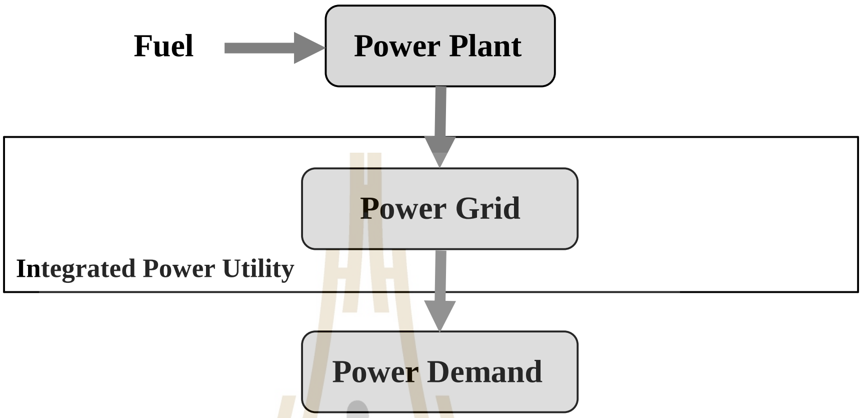

Figure 2.1 Model for the dispatch of power supply

2.3.1.2 Economic Dispatch of Water

In differentiate to the created controlled and deregulated markets inside the electrical foundation, the financial expedite of water has accomplished not one or the other a comparable mental agreement nor far-reaching mechanical appropriation. In their later audit, Chong and Sunding diagram the wide classes of complaints to water markets and exchanging (Harou JJ, et al., 2009).

That said, the Dublin Standards emerging from the 1992 Worldwide Conference on Water and Environment state (Anonymous-United-Nations, et al., 1992).

Overseeing water as a financial great is a critical way of accomplishing effective and impartial utilize, and of empowering preservation and assurance of water assets. A number of diverse financial approaches to water administration have developed counting common balance models, cost- benefit examinations, agent-based models, and economic and energy models (Harou JJ, et al., 2009).

The broader course of hydro-economic models is of most prominent pertinence here in that they can be considered to consolidate the real-time financial expedite of water. Hydro- economic models ordinarily utilize optimization over discrete time-steps to mimic the water asset administration of a locale. As the title recommends, they combine a financial demonstrate in the shape of a monetization work of the water's esteem with arithmetical limitations that depict the building material science of the water streams in the locale (Harou JJ, et al., 2009).

When connected to metropolitan water, the monetization regularly reflects the utility's variable costs for water treatment and pumping. The fundamental designing demonstrate depends on the expecting application but regularly incorporates state-space conditions of the hydrodynamics, a network framework to speak to the water-powered organize, and capacity limits on the supply sizes and discharges (Labadie JW, et al., 2004).

The worldly determination can run from hours to a long time and the spatial determination can extend from a family to bunches of nations (Harou JJ, et al., 2009), (Anonymous-United-Nations, et al., 1992), (Labadie JW, et al., 2004).

Interests, the scholastic writing concerning the ideal pumping control issue for multi-reservoir frameworks has drawn broadly from strategies as changed as direct and nonlinear programming, stochastic optimization, energetic programming and discrete-time ideal control (Labadie JW, et al., 2004), (Ormsbee LE, et al., 1994), (Singh A, et al., 2012), (Hossain MS, et al., 2013), (Buras N, et al., 1972), (Hall WA, et al., 1970), (Loucks DP, et al., 1981), (Maass A, et al., 1962), (Mays LW, et al., 2002), (ReVelle C, et al., 1999), (Wurbs RA, et al., 1996).

As in control frameworks, multi-stage optimizations in which medium-term operations are cascaded into hourly optimizations have moreover been detailed (Becker L, et al., 1974), (Divi R, et al., 1988).

These may be assist cascaded into real-time supply control frameworks (Labadie JW, et al., 1981), (Mishalani NR, et al., 1988), (Georgakakos AP, et al., 1989).

In all, there exists a wealthy scholarly writing to address the different sorts of financial expedite of metropolitan water. By the by, these scholastic commitments have not essentially interpreted to mechanical execution (Harou JJ, et al., 2009), (Labadie JW, et al., 2004), (Ormsbee LE, et al., 1994).

Noteworthy recounted prove has been detailed in the writing over a few decades proposing a need of mechanical certainty in the pertinence of the optimization models, combined with ineffectively outlined motivations to move forward operational proficiency (Harou JJ, et al., 2009), (Labadie JW, et al., 2004), (Ormsbee LE, et al., 1994), (Shepherd A, et al., 1996).

That said, the dozen or so effective real-time ideal pumping control executions have depended on choice back frameworks and SCADA as empowering innovations. The proceeded advancement of these advances in combination with expanding water shortage weights is likely to impact the more prominent selection of real-time financial alacrity of civil water (Labadie JW, et al., 2004), (Ormsbee LE, et al., 1994).

Economic Dispatch: Problem Formulation of Water

The formulation of the water optimization is as follows. Minimize the production cost objective function C_{wG} with respect to the quantity of water produced by the water x_{wj} in the type of plants. The following notation is introduced:

$$X_{wj} = \left[0, x_{wj}\right]^T, \ \mathrm{D}=\left[D_w\right]^T \tag{7}$$

$$C_{wj} = X_{wj}^T A_{wj} X_{wj} + B_{wj} X_{wj} + K_{wj} \tag{8}$$

$$C_{wj} = a_{2j} x_{wj}^2 + b_{2j} x_{wj} + c_{2j} \tag{9}$$

$$C_{wG}\left(x_{wj}\right) = \sum_{j=1}^{n_{wp}} C_{wj}\left(x_{wj}\right) \tag{10}$$

Subject to the capacity (11), demand (12).

$$MinGenWP_j \le X_{wj} \le MaxGenWP_j \quad , \qquad \forall \ \mathrm{i}=1,....,\mathrm{n}_{wp} \tag{11}$$

$$\sum_{j=1}^{n_{wp}} X_{wj} = D_w \tag{12}$$

Where

A_{wj} is the quadratic production cost function coefficient of the j[th] water plant.

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B_{wj} is the linear production cost function coefficient of the j^{th} water plant. C_{wG} is the water production cost function. C_{wj} is the cost function for j^{th} water production plant. K_{wj} is the constant production cost function coefficient of the j^{th} water plant. C_{wj} is the scalar cost functions for the j^{th} water production facility. Additionally, n_{wp} is the numbers of water facilities. D_w represents the power and water product demand vector. At last, MinGenWP, MaxGenWP are the least and greatest water capacity limits for water generation facilities. The cost functions C_{wj} is assumed to exhibit a quadratic structure in their respective production variables.

The cost function coefficients are appropriately sized positive constant matrices based upon the heat rate characteristics of their respective production units. Figure 2.2 gives a graphical representation of the conceptual show water generation that serves as the premise for the improvement of the optimization program. It consists of an integrated water utility that was interested in simultaneously serving water demand. The respective grid was modeled as a single node. The utility dispatches water facility that may be autonomous or vertically coordinates. The dispatchable water plant requires a water source.

The particular lattices by ideals of the generation taken a toll work and the handle imperatives. The water plant may be a ground or surface pumping station or a reverse osmosis desalination plant. Each water facility was assumed to draw from its own independent water source. The water sources are assumed to be able to support the maximum water flow capacities of the water production facilities that they serve. The water request was measured net of any water prerequisite to the dispatched office and was eventually conveyed to the utility’s water client.

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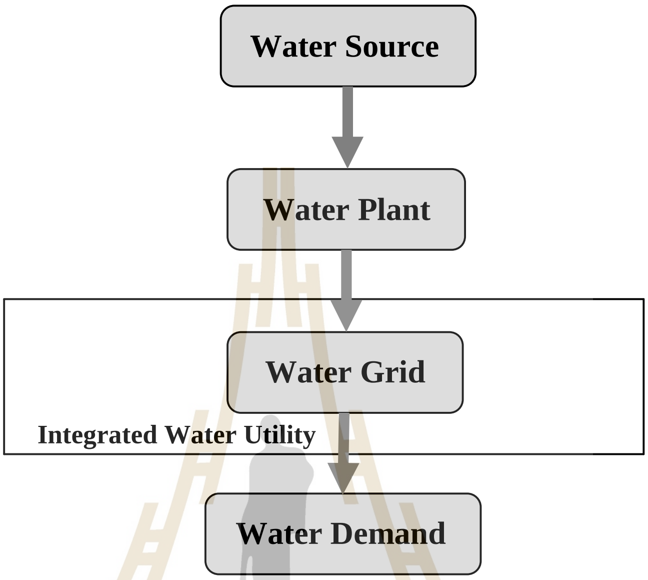

Figure 2.2 Model for the dispatch of water supply

2.3.2 Solution of Co-optimization for the Economic Dispatch

2.3.2.1 Co-dispatch of Power and Heat

The corresponding application of economic dispatch of power over the decades has given the market signals to not only reduce costs but moreover contribute to more vitality effective innovations. In this respect, combined-cycle control plants have been methodically favored over single cycle offices. Moreover, facilities that cogenerated control and warm could illustrate indeed higher efficiencies by utilizing warm as an esteemed item for adjacent mechanical divisions such as food processing, chemical production, and district heating (Kiameh P, et al., 2012), (Tsai W-T, et al., 2007).

The profits also bring about cost savings, reducing air pollution and greenhouse gas emissions, increased reliability and quality of power, reduce grid congestion and avoid loss of distribution (Ziebik A, et al., 2012). Many policymakers, especially in Northern Europe, additionally supported for dual products through regulatory development (Rosen MA, et al., 2009).

However, the technical and economic rationalization of a cogeneration solving often depended on the challenging conditions of having a consistently available, dedicated and co- located heat consumer (EIPPCB-TWG, et al., 2006) often in the form of a contentiously negotiated (Chertow MR, et al., 2005), (Romagnoli PL, et al., 1995) long-term contract (Ibrahim HD, et al., 2005). Naturally, some have argued to ease these restrictions on heat and power as dual products with a more dynamic treatment (Humphrey RL, et al., 1982).

To that effect, a power-heat economic dispatch approach has been to apply to the literature. Regularly, it makes a single objective work for coproduction plants that is subordinate to the sum of control and warms created. Imperatives were at that point included to set up limits for both control and warm capacities. These limits usually define a feasible region in which the cogeneration plant is able to operate respect to power and heat produced (Greenwald SF, et al., 2010), (Algie C, et al., 2004), (Piperagkas GS, et al., 2011), (Tao G, et al., 1996), (Linkevics O, et al., 2005), (Rifaat RM, et al., 1998).

Economic Dispatch: Problem Formulation of Power and Water

The formulation of the power-water co-optimization is as follows. Minimize the production cost objective function C_G with respect to the quantity of power generated by the power plant x_{pi} , water produced by the water x_{wj} , the power generated by the cogenerator plant x_{ckp} and water produced by the cogeneration plant x_{ckw} in the three types of plants: i ,j ,k power, water, and generation respectively. The following notations are introduced:

$$\mathrm{X}_{ck} = \left[x_{ckp}, x_{ckw} \right]^T, \ \mathrm{D} = \left[D_{ck} \right]^T \tag{13}$$

$$C_{ck} = X_{ck}^T A_{ck} X_{ck} + B_{ck} X_{ck} + K_{ck} \tag{14}$$

$$C_{ck} = a_{1k} x_{ckp}^2 + a_{2k} x_{ckw}^2 + a_{1k} a_{2k} x_{ckp} x_{ckw} + b_{1k} x_{ckp} + b_{2k} x_{ckw} + c_{0k} \tag{15}$$

$$C_{cG}\left(x_{ck}\right) = \sum_{k=1}^{n_{cp}} C_{ck}\left(x_{ckp}, x_{ckw}\right) \tag{16}$$

Subject to the capacity (17), demand (18).

$$MinGenCP_k \le X_{ck} \le MaxGenCP_k \quad , \qquad \forall \ \text{i=1,....,n}_{cp} \tag{17}$$

$$\sum_{k=1}^{n_{cp}} X_{ck} = D_{ck} \tag{18}$$

Where

A_{ck} is the quadratic production cost function coefficient of k^{th} coproduction plant. B_{ck} is the linear production cost function coefficient of k^{th} coproduction plant. C_{cG} is the production cost function. C_{ck} is the cost function for k^{th} coproduction plant. K_{ck} is the constant production cost function coefficient of k^{th} coproduction plant. C_{ck} is the scalar cost functions for the k^{th} co-production facility. Additionally, n_{cp} is the numbers of power, water and co-production facilities respectively. D represents the

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power and water item request vector. At last, MinGenCP, MaxGenCP are the least and greatest power and water capacity limits for co- production facilities. The cost functions C_{ck} is assumed to exhibit a quadratic structure in their respective production variables.

The cost function coefficients are appropriately sized positive constant matrices based upon the heat rate characteristics of their respective production units. Figure 2.3 gives a graphical representation of the conceptual show co-production that serves as the premise for the advancement of the optimization program. It consists of an integrated power & water utility that is interested in simultaneously serving an electrical power demand as well as a potable water demand.

The particular networks are modeled as single hubs. The utility dispatches co-production facilities that may be free or vertically coordinates. The dispatchable co-production plant requires a fuel source and a water source. The co-production facility may be either hydroelectric or warm desalination; requiring fuel in the last mentioned case. They couple the particular frameworks by ideals of their generation cost capacities and their handle imperatives. The power and water demands are measured net of any power and water requirements to the dispatched facilities and are ultimately delete unit power and to customers.

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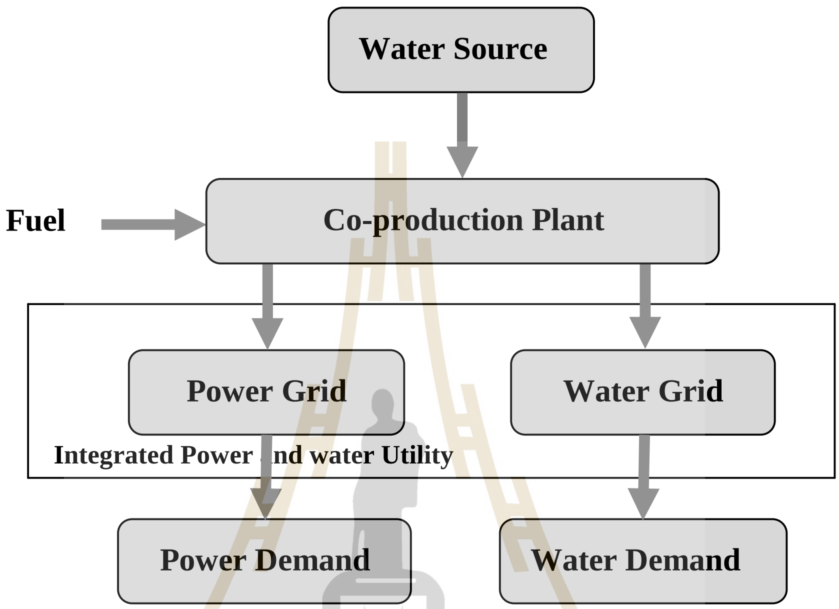

Figure 2.3 Model for the co-dispatch of power and water supply.

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2.3.2.2 Co-optimization of Power-Water

Most of the research in this area has been conducted on dual energy and heat products because heat is a useful gemstone product in Northern Europe. They are considered to be profoundly successful (Rosen, et al., 2009), Co-generation captures warm misplaced amid the generation of power and changes over it into valuable warm vitality in the shape of steam. This steam can be used for heating purposes such as district heating or industrial processes (Tsai, et al., 2007).

The coming about proficiency picks up moreover bring approximately cost reserve funds, decreased discuss contamination and nursery gas outflows, expanded power unwavering quality and quality, diminished lattice clog and dodges conveyance misfortunes (Rosen, et al., 2009). Double item co-optimization writing has regularly tended to the cogeneration of power and warm from a single fuel source by making a single objective work for co-generation plants that is subordinate on the sum of control and warmly delivered. Limitations are at that point included to set up limits for both control and warm capacities. These limits as a rule characterize a doable locale in which the cogeneration plant can work with regard to control and water created (Algie, et al., 2004), (Piperagkas, et al., 2011), (Tao, et al., 1996), (Linkevics, et al., 2005), (Rifaat, et al., 1998).

One creator straightforwardly addresses the financial alacrity of a single MSF desalination office composed of a number of sub-units but not one or the other generalizes the definition nor applies it to all the water and generation units in the water and control networks (El-nashar, et al., 1991). Still, others discover strategies taken a toll assignment (Ali M, et al., 1999). These works ordinarily characterize a single objective work for cogeneration plants that is a work of the control and warm created subject to request and capacity limitations (J. L. Silveira et al., 2003). Dual-product multi-plant optimization programs have also been developed. The first encounter was that of northern European nations where the financial alacrity approach has been connected to control and warm. A single objective function for cogeneration plants based on power and heat is formed and then optimized subject to power and heat production capacity (C. Algie, et al., 2004).

Optimization research has been conducted on cogeneration water and power facilities. Generally speaking, this research has focused on the optimization and proper operation of one specific plant and hence do not provide an extensible and general optimization the definition of different plant optimization. More dual- product multi-plant optimization programs have been conducted in

northern European countries where co-produced steam is seen as a potential valuable by product of power production (A. Abusoglu, et al., 2009).

Heat, form of steam, can be used for heating purposes in industrial as well as district applications leading to numerous quantifiable benefits including gains in energy efficiency, power reliability and quality and reductions in costs, air pollution, greenhouse emissions, and grid congestion (M. A. Rosen, et al., 2009). Optimization investigate has been brought to bear on cogeneration water and control offices. For the most part talking, this inquire about has centered on the optimization of one specific plant and consequently, do not give an extensible and common optimization detailing. For case, (Cardona, E, et al., 2004), (Ali M, et al., 2008), (Shakib, et al., 2012) center for optimized arranging and plan or maybe than operations.

The manufactured safe framework had based on the clonal choice guideline which actualizes versatile cloning, hypermutation, maturing administrator and competition choice. The proposed calculation had outlined for a test framework and the test comes about compared with those getting from molecule swarm optimization and developmental programming (Basu, et al., 2012).

An optimization program given that minimizes add up to costs as a work of control and water era subject to request, capacity and handling limitations. The optimization had illustrated on a theoretical framework composed of four control plants, three co-generators, and one unadulterated water plant. The program given a precise strategy of accomplishing ideal comes about and can serve as the premise for set-points upon which person plants can actualize their ideal control. Comparably, and most as of late, one work co-optimizes the add up to working costs of control plants, immaculate water plants and cogeneration plants subject to request, capacity and handle imperatives (A. Santhosh, et al., 2012).

This thinks about inspected the combined warm and control dispatching needs of co-generation plants and examines the execution of a developmental computing approach which was based on both hereditary calculation (GA) and agreement look (HS). The test comes about were conducted for a broad compared with GA and HS to affirm the predominant execution of this half-breed approach in taking a toll minimization and computation times. The yield comes about demonstrate that the proposed calculation was competent of overseeing the CHPED issue and yields high-quality arrangements (Huang, et al., 2013).

It was made up of optimizations gotten from past work to create two optimization programs with and without capacity offices and comparative comes about. Capacity offices were appeared to diminish add up to working costs and lead to more leveled day by day generation recommending that they have an imperative part to ideal for the optimization of the energy-water nexus (Santhosh, et al., 2013).

A scientific optimization program for the co- expedite of the two commodities for three sorts of plants: control era plants, co-production offices, and water generation plants. In hone, the program can be utilized straightforwardly in middle-eastern nations where water and control dissemination were ordinarily beneath the obligation of a single utility. Besides, the program moreover given a precise strategy of accomplishing ideal comes about and able to serve as a premise for set-points upon which person plants can execute their ideal control (Santhosh, et al., 2013).

It was displayed an adaptable calculation to unravel the combined warm and control financial expedite issue. The calculation has been tried numerically on three benchmarks of combined warm and control financial celerity issue with a non-convex doable locale. Comes about have demonstrated that the calculation is dependable and could be effortlessly executed indeed on a much complex and non-convex issues (Sashirekha, et al., 2013).

The effect of electric control and water capacity was an innovation that can offer assistance moderate the authoritative imperatives, made to deliver more level, and lower the fetched level. The capacity offices have appeared a lessening in add up to working costs by up to 38% and lead to less everyday generation changes (Santhosh, et al., 2014).

The generation costs were minimized subject to capacity, request and prepare imperatives. The program given a precise strategy of accomplishing ideal comes about and able to serve as a premise for set-points upon which person plants can execute their ideal control (Santhosh, et al., 2014). As it were as of late, a financial celerity approach for control and water has been created that considers the request, prepare, and capacity imperatives (Lubega, et al., 2014).

They have utilized the concurrent co-optimization strategy for the financial alacrity of systems that incorporate water, control and coproduction offices in such as coordinates advertise. It examined the effect of electrical vitality and water capacity as an innovation that could offer assistance reduce authoritative imperatives, lead to compliment generation and decreased taken a toll levels for the unit commitment issue (Basu, et al., 2015).

Opposition-based bunch look optimization has been utilized here to make strides the adequacy and quality of the arrangement. The comes about of the proposed approach compared with those getting by other formative procedures. It had found that the proposed opposition-based gather look optimization based approach was able to supply a way better arrangement (Nguyen, et al., 2016).

The main objective had to minimize the total fuel cost for produced electricity and heat supplied to a load demand. Therefore, it had presented a cuckoo search algorithm (CSA) for solving for the combined heat and power economic dispatch (CHPED) problem. The methods for the test systems had revealed that the CSA method could obtain a higher quality solution with faster computational time than many other methods (Ghorbani, et al., 2016).

It utilized trade advertise calculation for connected combined warm and control financial alacrity. Trade advertise calculation is an effective and strong calculation. Trade advertise calculation was able to extricate ideal point in the optimization issue. To test systems valve-point effect was considered, system power loss and system constraints are optimized. The results have proved the high capability of exchange market algorithm in extracting optimum points. The results also show that this algorithm could utilize as an efficient and reliable tool in solving combined heat and power economic dispatch problem (Basu, et al., 2016).

They have displayed bunch look optimization to unravel the complex non-smooth non- raised combined heat and power economic dispatch

(CHPED) issue. The adequacy of the proposed strategy has been confirmed on four test frameworks. The results of the proposed approach had compared with those getting by other developmental strategies. It had found that the proposed group search optimization based approach was able to provide a better solution (Jayakumar, et al., 2016).

They have displayed a Dim Wolf Optimization (GWO) calculation for CHPD issues. The viability of the proposed strategy approved by carrying out broad tests on three diverse CHPD issues such as inactive financial expedite, environmental-economic celerity, and energetic financial celebrity. The recreation tests uncovered that Develop performs way better in terms of arrangement quality and consistency, 2011.

Co-optimization of Power and Water: Problem Formulation

The formulation of the power-water co-optimization is as follows. Minimize the production cost objective function C_G with respect to the quantity of power generated by the power plant x_{pi} , water produced by the water x_{wj} , the power generated by the cogenerator plant x_{ckp} and water produced by the cogeneration plant x_{ckw} in the three types of plants: i ,j ,k power, water, and generation respectively. The following notations are introduced:

$$X_{pi}=\left[x_{pi},0\right]^T,\ \mathrm{X}_{wj}=\left[0,x_{wj}\right]^T,\ \mathrm{X}_{ck}=\left[x_{ckp},x_{ckw}\right]^T,\ \mathrm{D}=\left[D_p,D_w\right]^T \qquad (19)$$

$$\begin{aligned} C_{pi} &= X_{pi}^T A_{pi} X_{pi} + B_{pi} X_{pi} + K_{pi} \\ C_{wj} &= X_{wj}^T A_{wj} X_{wj} + B_{wj} X_{wj} + K_{wj} \\ C_{ck} &= X_{ck}^T A_{ck} X_{ck} + B_{ck} X_{ck} + K_{ck} \end{aligned} \qquad (20)$$

$$C_{pi} = a_{1i}x_{pi}^2 + b_{1i}x_{pi} + c_{1i}$$
$$C_{wj} = a_{2j}x_{wj}^2 + b_{2j}x_{wj} + c_{2j} \qquad (21)$$
$$C_{ck} = a_{1k}x_{ckp}^2 + a_{2k}x_{ckw}^2 + a_{1k}a_{2k}x_{ckp}x_{ckw} + b_{1k}x_{ckp} + b_{2k}x_{ckw} + c_{0k}$$

$$C_G\left(x_{pi}, x_{wj}, x_{ck}\right) = \sum_{i=1}^{n_{pp}} C_{pi}\left(x_{pi}\right) + \sum_{j=1}^{n_{wp}} C_{wj}\left(x_{wj}\right) + \sum_{k=1}^{n_{cp}} C_{ck}\left(x_{ckp}, x_{ckw}\right) \qquad (22)$$

Subject to the capacity (23), demand (24), and process constraints (25).

$$MinGenPP_i \le X_{pi} \le MaxGenPP_i \quad , \quad \forall \ \text{i=1,....,n}_{pp}$$
$$MinGenWP_j \le X_{wj} \le MaxGenWP_j \quad , \quad \forall \ \text{i=1,....,n}_{wp} \qquad (23)$$
$$MinGenCP_k \le X_{ck} \le MaxGenCP_k \quad , \quad \forall \ \text{i=1,....,n}_{cp}$$

$$\sum_{i=1}^{n_{pp}} X_{pi} + \sum_{j=1}^{n_{wp}} X_{wj} + \sum_{k=1}^{n_{cp}} X_{ck} = D \qquad (24)$$

$$r_k^{lower} \le \frac{x_{ckp}}{x_{ckw}} \le r_k^{upper} \quad , \quad \forall \text{k=1,....,n}_{cp} \qquad (25)$$

Where

A_{ck} is the quadratic production cost function coefficient of k^{th} coproduction plant. A_{pi} is the quadratic production cost function coefficient of the i^{th} power plant. A_{wj} is the quadratic production cost function coefficient of the j^{th} water plant. B_{ck} is the linear production cost function coefficient of k^{th} coproduction plant. B_{pi} is the linear production cost function coefficient of the i^{th} power plant. B_{wj} is the linear production cost function coefficient of the jth water plant. C_G is the production cost function. C_{ck} **is** the cost function for k^{th} coproduction plant. C_{pi} is the cost function for i^{th} power generation plant. C_{wj} is the cost function for j^{th} water production plant. K_{ck} is the constant production cost function coefficient of k^{th} coproduction plant. K_{pi} is the constant production cost function coefficient of the ith power plant. K_{wj} is the constant production cost function coefficient of the jth water plant. Additionally, n_{pp}, n_{wp}, n_{cp} are the numbers of power, water and co-production facilities respectively.

rupper and rlower are upper and lower bounds on the power-water production ratio for the cogeneration plants. D represents the power and water product demand vector. At last, MinGenPP, MinGenWP, MinGenCP, MaxGenPP, MaxGenWP, and MaxGenCP are the least and greatest power and water capacity limits for power, water, and co- production facilities respectively. The cost functions C_{pi}, C_{wj}, C_{ck} are assumed to exhibit a quadratic structure in their respective production variables.

The cost function coefficients are appropriately sized positive constant matrices based upon the heat rate characteristics of their respective production units. Figure 2.4 gives a graphical representation of the conceptual demonstrates that serves as the premise for the improvement of the optimization program. It consists of an integrated power & water utility that is interested in simultaneously serving an electrical power demand as well as a potable water demand. The individual frameworks are modeled as single hubs. The utility dispatches control, electrical vitality capacity, water, water capacity, and co-production offices that may be autonomous or vertically coordinates.

The celerity control plant requires a fuel source. The co-production office may be either hydroelectric or warm desalination; requiring fuel in the last mentioned case. They couple the particular lattices by ethicalness of their generation cost functions and their handle limitations. The water plant may be a ground or surface pumping station or a reverse osmosis desalination plant. Each water and co- production facility is assumed to draw from its own independent water source.

Moreover, the show applies to a single total water source; as in the viable case of the Persian Inlet serving all desalination offices in the U.A.E. Hydro-logically speaking, the water sources are assumed to be able to support the maximum water flow capacities of the water production facilities that they serve. The electrical vitality and water capacity are expected to draw and infuse only from their particular grids. The power and water requests are measured net of any power and water necessities to the dispatched offices and are eventually conveyed to the utility's power and water clients.

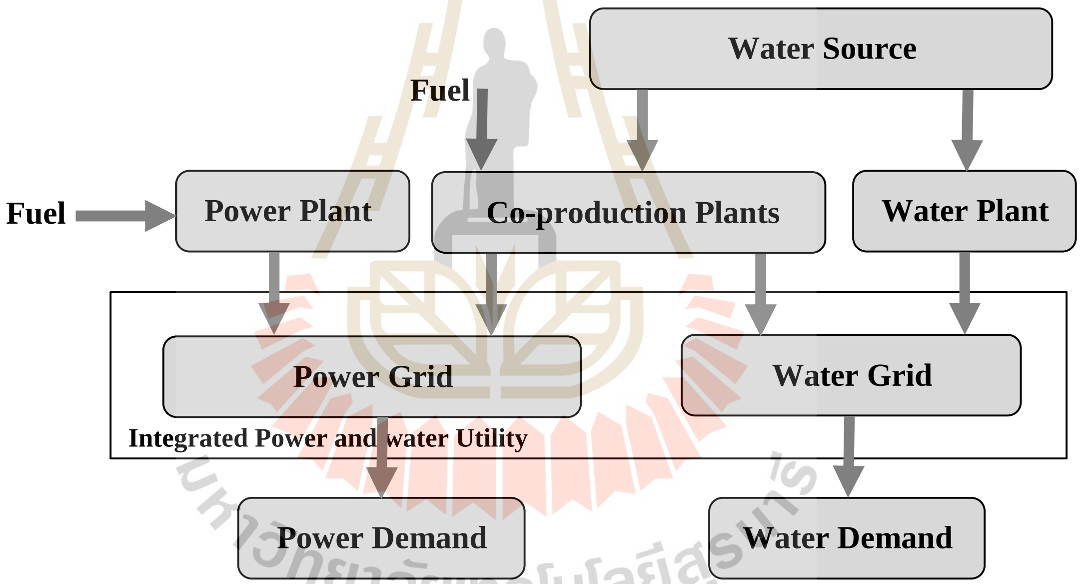

Figure 2.4 the total system of model for the co-dispatch of power and water supply

2.3.3 Conclusion of Co-optimization for the Economic Dispatch

Figures 2.5 and 2.6 show the generation levels of power and water respectively. At last, Figure 2.7 appears the total costs caused over the 24 hour period. In figure 5 and figure 6, the total of power and water generated in each hour matches the power demand and water demand profiles exactly. This shows that the effect of the optimization is feasible. This feasibility has been to maintain despite exaggerated peaks and troughs for both power and water. It is also noted that the power and water demand profiles were not necessarily trending together leading to the important variation in power to water ratio over the course of the day. These request profiles have been chosen in a way so as to reflect the common power and water request profiles observed in the real-life dispatch. Regularly, the top of control request has utilized electricity in the afternoon, when greatest control has been utilized by mechanical ranges, workplaces etc. And the lowest levels of power required are early in the morning and later on in the evening. Water request has an early crest for the water system and residential utilize and another top around early afternoon for mechanical utilize.

Figure 2.5 Power generation & demand profile over 24 hour period

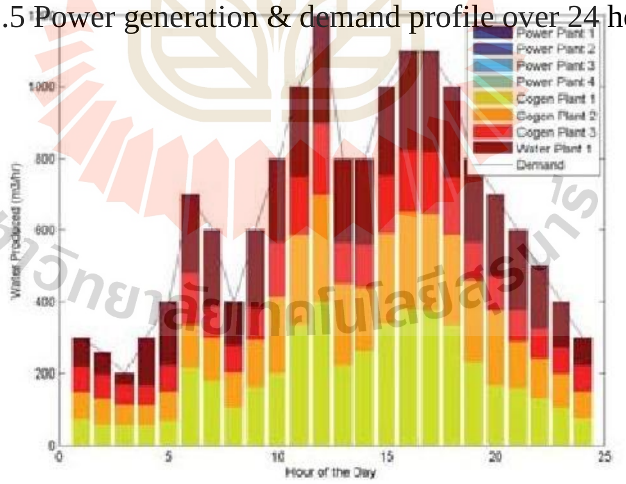

Figure 2.6 Water production & demand profile over 24 hour period

In Figure2.7 the total costs of generation are shown. At first glance, the results seem to be easy-to- use counterparts with higher total cost over periods of low production. The co- generator heat rates were higher than single product plants in absolute terms for all production levels and also exhibit a much sharper downward trend for all generation levels. The costs have ruled with the cogeneration offices which were as it was dispatched due to their handle imperatives. The high cost of low demand arises from the fact that any incremental decreases in load are more than compensated with increases in the corresponding heat rate.

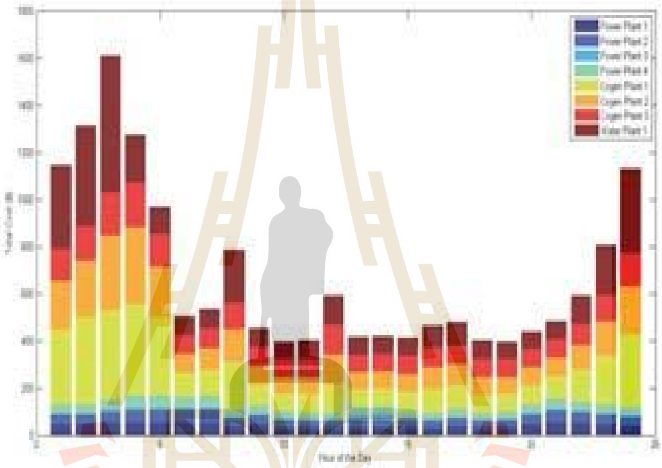

Figure 2.7 Cost incurred by different units over the period of 24 hours

2.4 Impact of Economic Dispatch of Power and Water

2.4.1 Storage Facilities for Power and Water

Increased attention has been devoted to storage facilities within dispatch algorithms of power grids. Fundamentally speaking, energy storage facilities couple the normally independent optimization time blocks as the storage state of a subsequent time block depends in the earlier statements by the sum of control charged or released. As such, dispatch formulations with storage lend themselves to a unit commitment formulation (T. Senjyu, et al., 2007), (M. Ashari, et al., 1999).

It used “centralized look-ahead” economic dispatch which closely resembles the real- time market operations of North American independent system operators. These formulations have been customized for battery (M. Ding, et al., 2011), (C. Crampes, et al., 2010) and pumped hydro (T. Kennedy, et al., 1965), (L. Ramirez-Elizondo, et al., 201) storage.

These are particularly so interesting in the context of the energy-water nexus as it presents a new technology by which the two resources have been coupled. Finally, these works differ in their treatment of the objective function with some formulations especially those addressing pumped hydro storage include a specific operating cost to charge and discharge while others (Klein, et al., 1998) add no additional terms.

2.5. Conclusions

This chapter has discussed the mainstream methods implemented to make use of co- optimization for the economic dispatch of power and water networks. First, power and water production in water distribution networks, the potential benefits of the optimal power flow and optimal water flow have been discussed. Second, the economic dispatch of power and the economic dispatch of water were introduced to induce of the network to energy and water supply patterns, and the co-optimization of power and water production in the network were demonstrated in detail. Third, the impact of the economic distribution of energy and water has been discussed by using storage facilities for co-optimization in energy and water networks. Fourth, the paper established new dimensions of objectives and solutions co-optimization for the economic dispatch of power and water networks. Finally, the potential coordination of the co-optimization of power and water networks for small scale and large scale system operation has been discussed. Research in this field and the co- optimization of power and water network is still preliminary. There are many applications of co-optimization of power and water network that have yet to be discovered. Taking full advantage of co-optimization of power and water requires highly advanced complementation methods for both the electricity production and the water production. In this respect, some efforts can be made in the future, for example, the development of co- optimization of power and water with large network.

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CHAPTER III

THE XEDON RIVER BASIN

3.1 Significance of the XEDON basin

The XEDON river basin is very important because it's covered an area of PAKSONG District or Lao people called "Golden Land", with the characteristic of topography of a river basin that is different from other river basins. The area of the river basin mainly in the zone BOLAVEN plateau which is region of the crater thus making river basin has rich in minerals. In the soil that are suitable for the growth of plants which makes the area is richness of both the forest floor and major agricultural plants such as the coffee, which has famous and can be grown in an area. There are also other agricultural plants that are valuable to the economy as well. Attributed to XEDON River Basin has many the natural attractions such as traveling waterfall which has vastly, sightseeing plants, travelling winter. Hence, thus making the area of river basin is important to the economic development of the Lao PDR.

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3.2 General Description

The XEDON River Basin is situated between the latitudes 15^{o}00’ - 16^{o}00’ N and longitudes 105^{o}35’ - 106^{o}40’ E (Figure 3.1). XEDON mainstream has a total length of 1,574 km. XESET is the main tributary, flowing from the BOLAVEN Plateau. Perhaps the country’s most important resource is its water resources.

The XEDON basin has the total area of 7,229 km^2 which spans across the provinces of SARAVAN, (5,160 km2 or 72% of basin area), SEKONG (698 km2 or 9.7% of basin area) and CHAMPASAK (1,355 km2 or 18% of basin area) provinces and a bit part in SAVANNAKHET Province (16 km2 or 0.3% of basin area) in southern Lao PDR. The river has a length of 1,574 km, a basin area of 7,229 km2 and originates on the northeast side of the BOLAVEN Plateau (Figure 4). The XEDON River comprises of five main tributaries namely HOUAY NAMSAY, XESET, HOUAY KAPEU, HOUAY PALAY and HOUAY CHAMPI. Its main tributary is the XESET which also flows from the BOLAVEN Plateau. The main sub-basin of XESET covers an area of some 323 km2.

The XEDON basin is rich in natural resources when measured in proportion to the population, with high potential for future economic growth and much potential for development in the river basin. It is favourable for agriculture especially tea, coffee plantation, animal husbandry and forestry with many valuable species. XEDON tributaries are convenient for farming rice and other types of agriculture. Basin land use is over 55% forest cover and 35% agriculture. Maps of soil classes and land use

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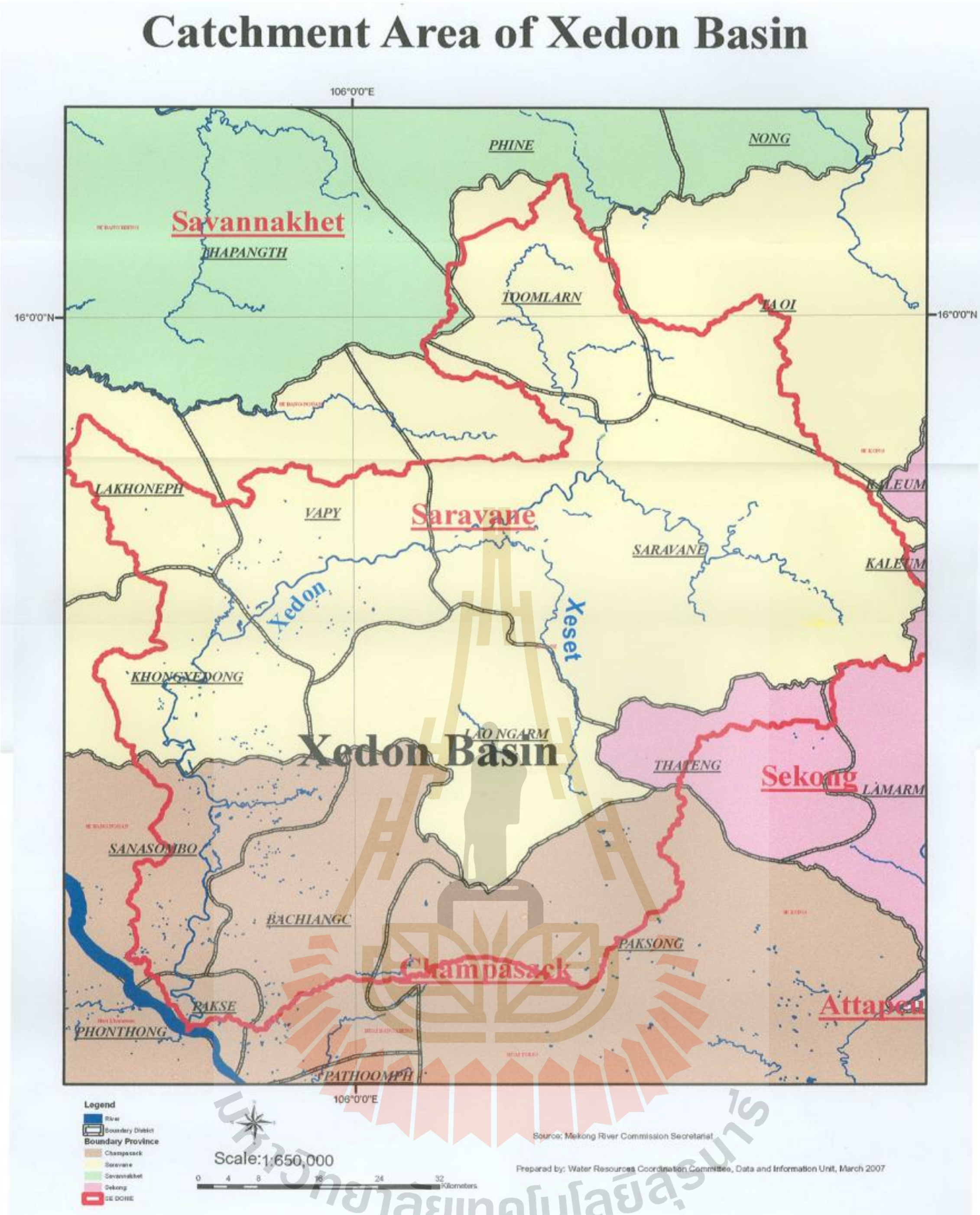

Figure 3.1 Location map of XEDON River Basin

Source: Mekong River Commission Secretariat
Prepared by: Water Resources Coordination Committee. Data and Information Unit. March 2007

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3.3 Population and the Settlement Pattern

In 2005, the population within the basin was about 591,436 and increased to 620,790 in 2007 distributed in Table 3.1. At the provincial level, CHAMPASAK is the most populated. This is followed by SARAVAN at 336,017 (2007) and SEKONG has the least number of inhabitants. There are 13 districts in XEDON River Basin with 4 districts in CHAMPASAK (PAKSE, BACHIANG, SANASOMBOON and PAKSONG), 7 of SARAVAN (SARAVAN, TAOI, LAONGARM, KHONG SEDONE, TOOMLARN, VAPY and LAKHONPHENG) and 2 from SEKONG.

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Table 3.1: population within XEDON River Basin in 2005 and 2007

Province	**Provincial Population**	**Districts cover by SRB**	**Population cover by SRB**	**villages**	**Village population (Number of villages)**
CHAMPASAK Population:	607,370 (2005) 612,843 (2007)	PAKSE	77,097 (2005) 81,889 (2007)	42 (954 total villages whole province)	Ban KAE Ban SONG Ban KENGLAI Ban MOUANGKAI
		BACHIANG	48,205 (2005) 51,373 (2007)	45	Ban OUDOMSOUK
		SANASOMBOON	62,282 (2005) 66,076 (2007)	63	
		PAKSONG	64,008 (2005) 68,240 (2007)	45	
SARAVAN Population:	324,470 (2005) 336,017 (2007)	SARAVAN	86,108 (2005) 88,723 (2007)	153 (644 total villages whole province,2008)	PHONBOK Village: 438 people VATKANG Village: 953 people NABAK Village: 480 people Ban PHAO Village: 675 people (9 November 2007)
		TAOI	22,526 (2005) 23,460 (2007)	57	
		TOOMLARN	21,787 (2005) 22,339 (2007)	55	
		LAKHONPHENG	37,667 (2005) 40,833 (2007)	84	
		VAPY	31,542 (2005) 34,405 (2007)	60	
		KHONGSEDONE	54,269 (2005) 58,146 (2007)	96	
		LAONGARM	58,745 (2005) 58,106 (2007)		
SEKONG	85,316 (2005)	THATAENG	27,200 (2005)	717 whole province	KONGTAYUN Village : 1467 people LIK Village: 522 people THATAENG NUA Village: 1582 people KAPEU Village: 958 people
		LAMARM	Forest Area		

Sources:

- Population and Housing Census Year 2005, Steering Committee of Population Census Secretariat Office, National Statistic Center, September 2005
- Local Administration Census, FY 2006-7, Cabinet of SARAVAN Provincial Authority, September 2007
- SARAVAN Cabinet, SARAVAN Province, Report for the RRA Training, 5–14 November 2007 at CHAMPASAK Province.

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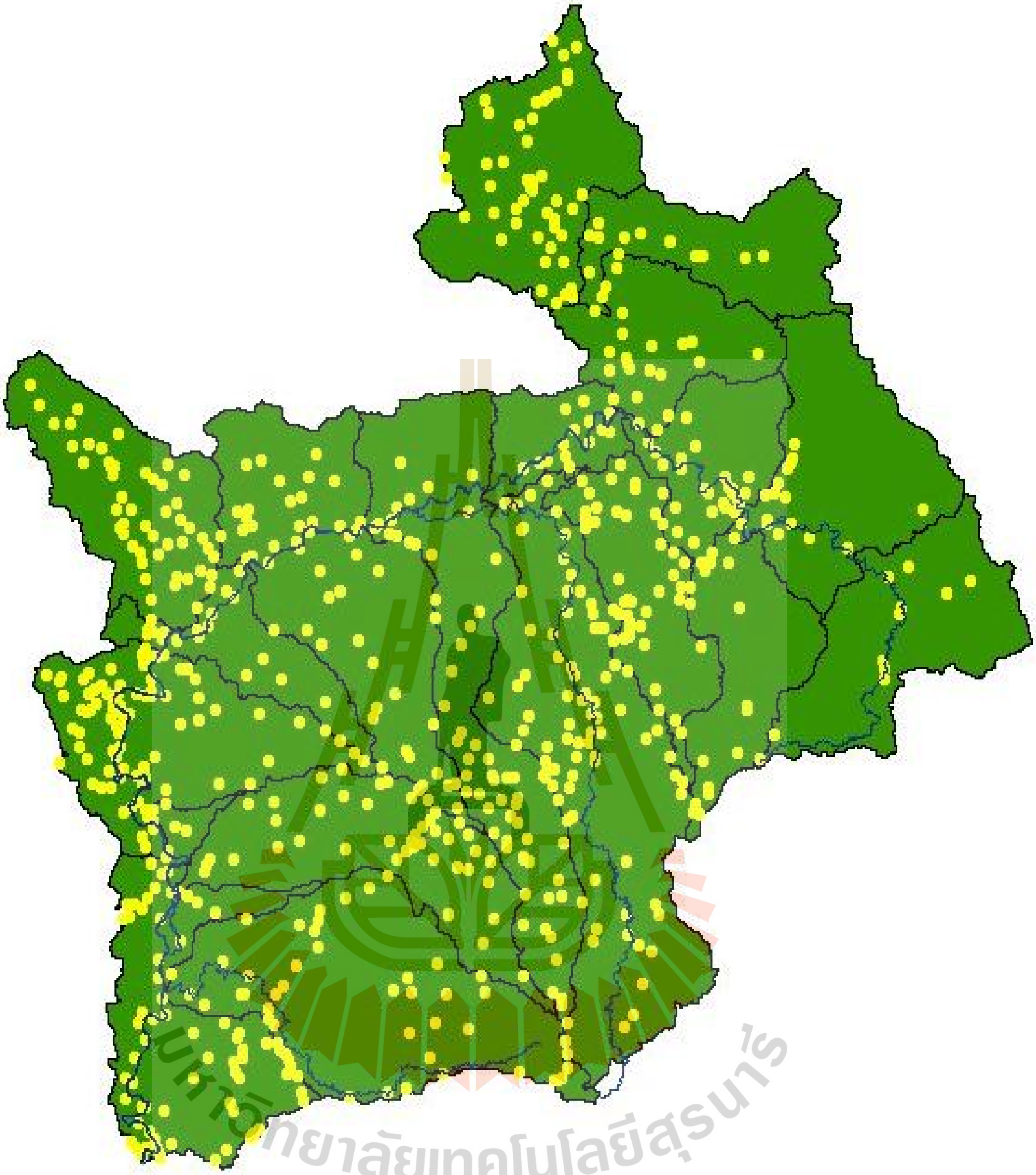

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Figure 3.2 Map of population density in XEDON Basin

Table 3.2 Population classification by age group each Districts in XEDON River Basin 2005

Province	Districts	Age Classification (People)				
		Age 0-4	Age 5-9	Age 10-14	Age 15-60	More than 61
CHAMPASAK	PAKSE	7,073	8,088	9,614	44,361	4,902
	BACHIENG	11,829	8,856	7,757	31,867	4,330
	SANASOMBOON	6,134	9,418	10,596	35,272	2,217
	PAKSONG	4,733	6,723	8,856	22,573	2,854
SARAVAN	Note: District population not provided.	46.658	49.089	46.649	163.295	18.636
SEKONG	THATAENG	5,246	3,876	3,854	13,853	1,484

3.4 Policy, Strategies and Plans

3.4.1 Location River Basin Profile and Environmental Risk Assessment

While there has been no separate profile compiled for the XEDON River basin consisting of SARAVAN, SEKONG and CHAMPASAK provinces, some information on the basin are included in this profile. To date, this report presents a compilation of the socio-economic, biophysical and ecological profile of the three provinces of the XEDON River Basin. This report integrates the current socio-economic and environmental status including priority issues in the Basin.

Table 3.3: planning Area of XEDON River Basin in 2007

Province	Districts	Zone (L, M, U)	Area (km^2)	Village	Area (Ha)
CHAMPASAK (Area: 14,973.4 Km^2)	PAKSE	L	108	KAE	NA
				SONG	80,794
	BACHIENG	25% L 75% U	907	OUDOMSOUK	1,876
				KENGLAI	NA
				MOUANGKAI	NA
				NONGKOK	NA
	SANASOMBOON	L	1,026		
	PAKSONG	U	4,038		
SARAVAN (Area 10,691 Km^2)	SARAVAN	L	222	PHONBOK	141.8
				VATKANG	83,439
				NABAK	16,000
				Ban PHAO	11,968
	TAOI	M	306		
	SAMOUI	M	57		
	TOOMLARN	L	83		
	LAKHONPHENG	L	139		
	VAPY	L	87		
	KHONGSEDONE	L	80		
	LAONGARM	U	97		
SEKONG (Area: 8,106.6 Km^2)	THATAENG	U	70,500 ha	LIK	800
				KAPEU	2,880
				THATAENG	
				KONGTAYUN	4,217
	LAMARM	40%L, 60%M			

Category: L – lowland (<200 meters above sea level); U – upland (200 - < 1000 MASL); M – mountainous (> 1000 MASL)

NA – means not applicable

Table 3.4: Area of XEDON River Basin

Province	Total Area (Km^2)	Area in XEDON river basin	Percent of river basin
CHAMPASAK	14,973.4 Km^2	1,355 Km^2	18 %
SARAVAN	10,691 Km^2	5,160 Km^2	72 %
SEKONG	8,106.6 Km^2	698 Km^2	9.7 %
SAVANAKHET	21,774 Km^2	16 Km^2	0.3 %
Total area of SRB		7,229 Km^2	100 %

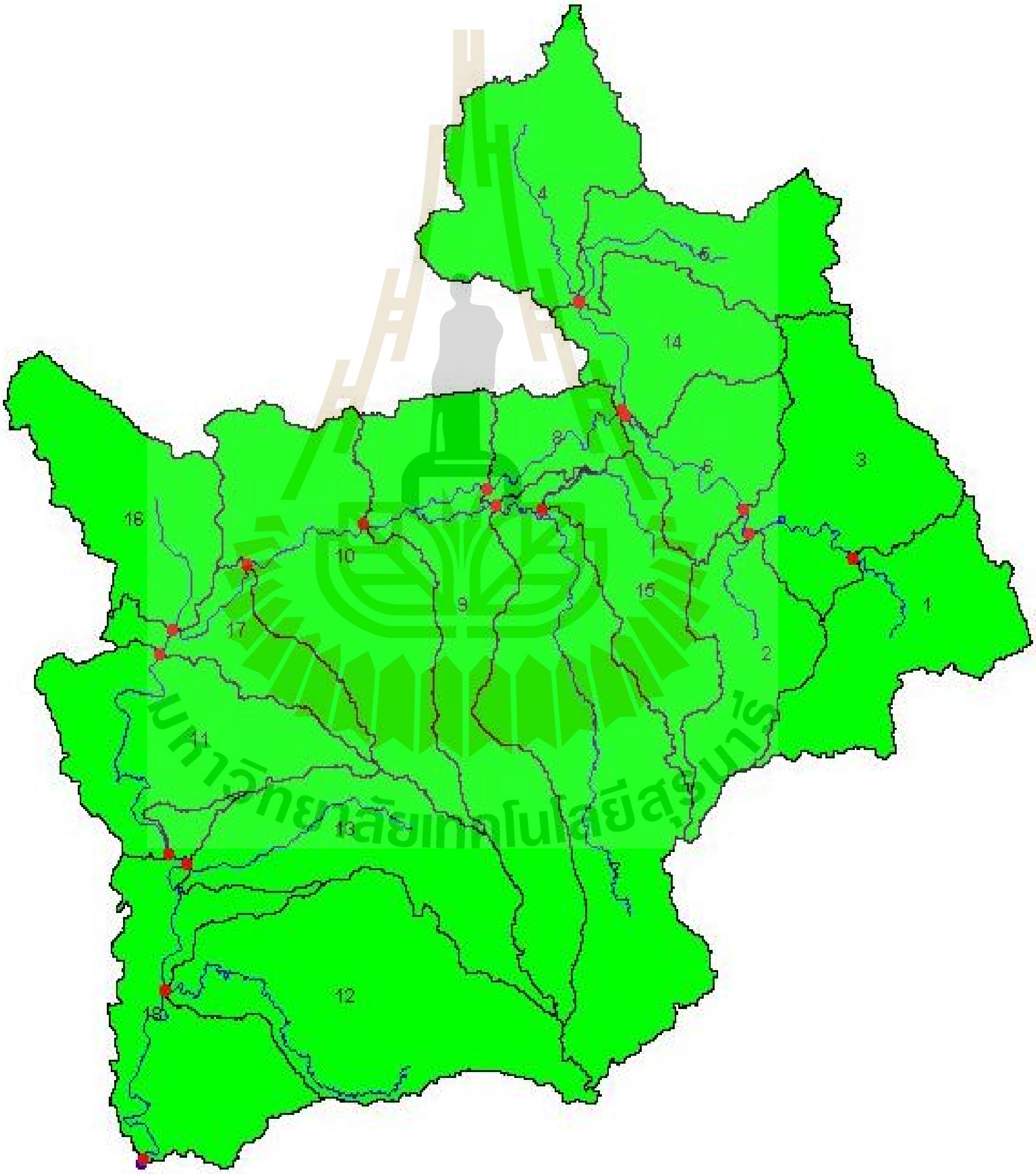

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Figure 3.3 Delineation into 18 sub-basins

Table 3.5 detail of XEDON Sub-basins (Numbers & Areas)

SUBBASIN	**AREA (Km^2)**
1	387
2	259
3	416
4	429
5	269
6	213
7	766
8	134
9	571
10	581
11	433
12	635
13	408
14	264
15	269
16	358
17	183
18	457
Total	**7,032**

3.4.2 Geophysical and Biophysical Environments

The basin is mainly composed of hard marl (PELITE). Such materials are completely dry during the dry season, except on the volcanic BOLAVEN Plateau. The highest point, located at PHOUKATE NOA is 1,588 meters above sea level (ASL), while the lowest point is 100 m ASL and is located at SOUVANNAKHILLI. There are several secondary tertiary rivers that drain into the XEDON River (Table 3.6).

Table 3.6: secondary and tertiary rivers that drain into the XEDON River

MAIN SEDONE RIVER	LENGTH (Km)
Flows through CHAMPASAK Province	55
Flows through SARAVAN Province	159.3
Flow through SEKONG Province (THATAENG District)	13
SECONDARY RIVERS	
XESET (in SARAVAN)	68.6
HOUAY KAPEU (in CHAMPASAK)	25
XEKONE (in SARAVAN)	55
SELAMANA (in SARAVAN)	27
HOUAY NAM SAY (in THATAENG)	23
HOUAY NAM KALEUMBAN (in THATAENG)	6,5
HOUAY NAM NONG (in THATAENG)	7
HOUAY NAM DAKANG (in THATAENG)	16
HOUAY NAM NONGKOK (in THATAENG)	5,5
HOUAY NAM SAVANG (in THATAENG)	22
HOUAY NAM LO (in THATAENG)	14
HOUAY NAM TID (in THATAENG)	8
HOUAY CHAMPI	37

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3.4.3 Climate

Climate of the studied area is influenced by tropical monsoons (south-west and north-east monsoons), tropical cyclones and depressions. The seasons consist mainly of a rainy season (from May to October) and dry season (from November to April) as well as minimum temperature of 15 – 18 degrees in January 2003 (except on the BOLAVEN plateau) and maximum temperature approximately 35-40 degrees in April-May 2003.

3.4.4 Land Use

Data of land use is data of year 2008 by the Ministry of Agriculture and Forestry of Lao PDR (Figure 3.4). The most 70% of the total river basin is forest areas and the agricultural area of around 30%. By the land-use to consist of dipterocarp forest are area of about 2679 square kilometers (km2), 37% evergreen forest about 2267 square kilometers (km2), 31% of rice paddy about 1248 square kilometers (km2), 17% of agricultural plantation about 911 square kilometers (km2), the only about 13% and other areas such as barren land, grassland, urban or built-up area, water bodies, combination with approximately 2%. The information must be combined with soil data to provide of simulate determine the hydrologic response units (HRUs), which given the nature of the land use code of SWAT model to simulate rainfall – stream flow of the XEDON river basin.

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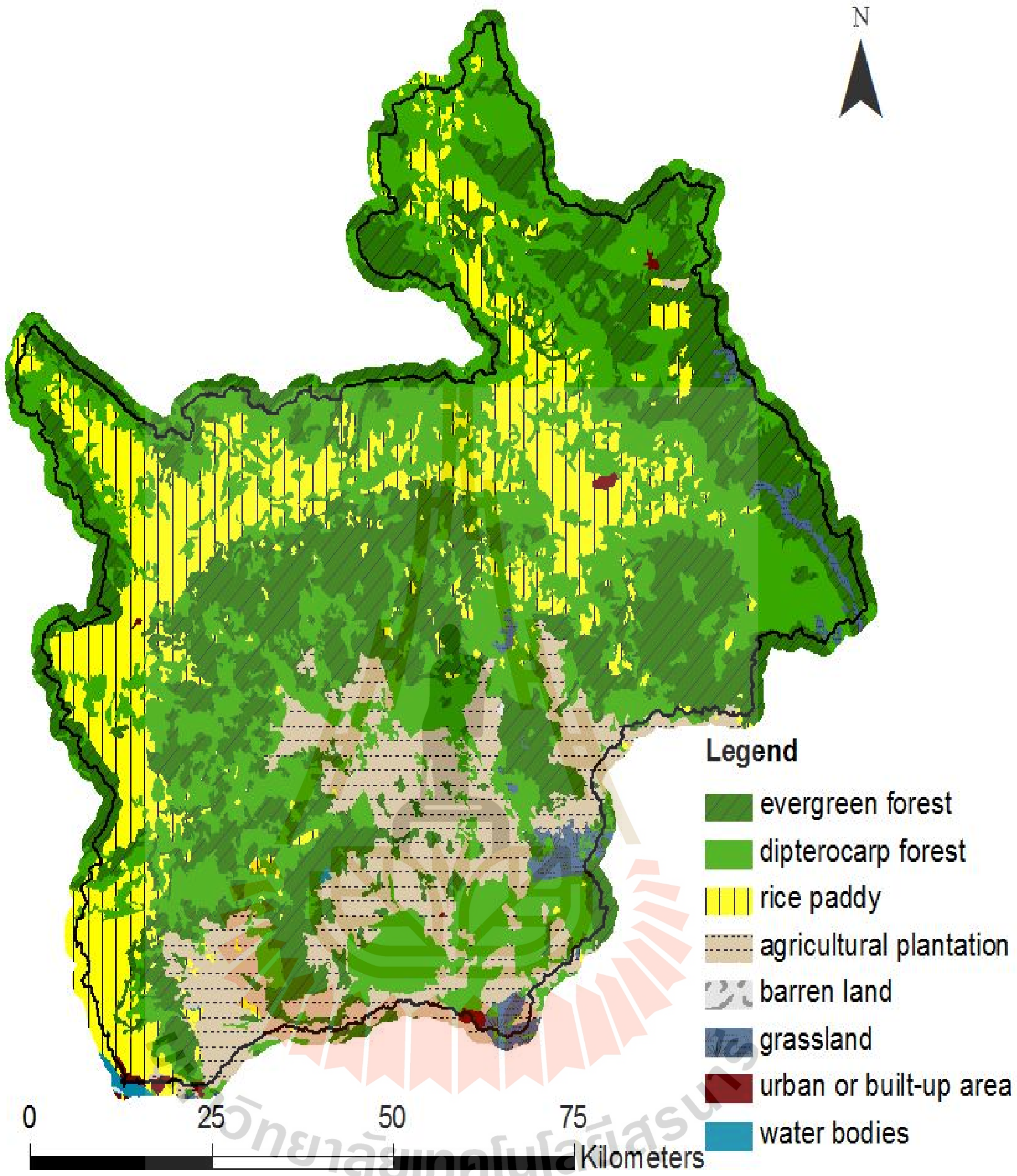

Figure 3.4 Land use map of the XEDON river basin

3.4.5 Soil

This information obtained from the Ministry of Agriculture and Forestry of Lao PDR (Figure 3.5) to consist of clay loam with 2995 square kilometers (km2) area, about 41% sandy loam with an area of 2447 square kilometers (km2), about 40% loam with an area of 872 square kilometers (km2), about 12% loamy sand with an area of 577 square kilometers (km2), about 8% and clay with an area of 324 square kilometers (km2), Approximately 4% and the Food and Agriculture Organization of the United Nations (FAO, 1997) and Major Soils of the world (FAO, 2002), which detailed the physical properties of soil are soil texture, soil dept, saturated hydraulic conductivity(K sat), soil bulk density(BD), The AWC (available water capacity), (Table 3.7) as a basis for calculating the properties of the hydrological model SWAT.

Table 3.7: the physical properties of soil

No.	**Soil name**	**layer**	**Depth (mm)**	**Texture (%)**			**Soil physical properties**		
				Sand	**Silt**	**Clay**	**AWC (mm/mm)**	**BD (g/cm3)**	**Ksat (mm/h)**
1	loam	1	200	40.5	34.3	25.2	0.12	1.8	65.4
		2	415	35.3	33.2	31.4	0.11	0.8	60.7
		3	825	32.5	38.2	30.3	0.13	0.5	55.3
		4	1525	34.2	36.3	29.5	0.12	0.3	45.8
2	clay loam	1	178	4.3	45.5	50.2	0.13	1.4	8.5
		2	432	6.2	35.3	58.5	0.20	0.8	5.8
		3	534	10.4	30.2	60.4	0.22	0.5	4.1
		4	1650	5.3	39.5	55.2	0.25	0.3	3.2
3	Loamy sand	1	200	58.2	27.3	10.5	0.12	1.5	68.5
		2	460	60.4	26.2	13.4	0.12	0.5	64.8
		3	760	59.2	31.2	9.6	0.10	0.3	69.2
		4	1830	61.2	25.5	13.2	0.10	0.1	65.9
4	sandy loam	1	100	50.4	26.2	23.4	0.13	2.1	60.1
		2	155	45.2	27.2	29.6	0.12	1.4	55.3
		3	660	42.2	30.5	27.3	0.10	1.1	53.3
		4	1780	50.1	29.6	19.3	0.12	0.2	58.7
5	clay	1	180	11.3	26.2	62.5	0.20	1.5	5.8
		2	915	7.4	27.4	65.2	0.2 2	0.6	4.7
		3	1170	8.5	18.3	75.2	0.18	0.2	3.5
		4	1570	10.2	19.6	70.2	0.13	1.32	4.1

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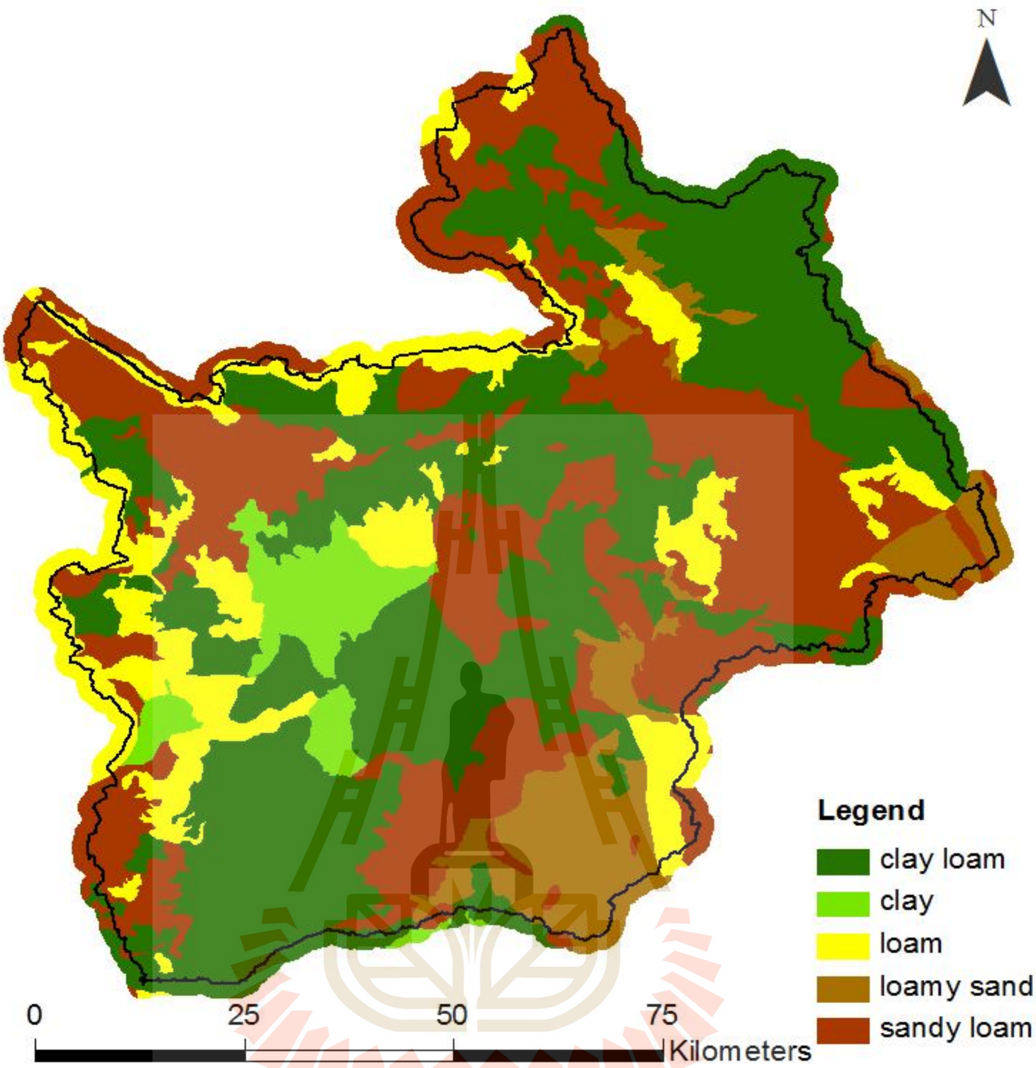

Figure 3.5 Soil map of the XEDON River Basin

3.4.6 Other Population Characteristics

The majority of the population is dependent upon the use of natural resources. Economically, many of them are engaged in the agricultural sector, with a few engaged in industry and services.

In 2008, the national GDP per capita were US$ 841, while the GPD each provinces cover in XEDON River Basin as follows: CHAMPASAK (PAKSE

US$ 792, PAKSONG US$ 638, BACHIENG US$ 300 and SANASOMBOON district US$ 770), (District governor office 2008) ; SARAVAN US$ 667(2009) ; US$ 653 (2008), US$ 510 (2007), US$ 482 (2006), US$ 433 (2005). There was no available information on GDP for SEKONG. Figures for the three provinces were higher compared with the north provinces this shows the rapid development in the southern provinces, which means to some extent, potential opportunities for poverty eradication. However, the figures were lower compared with the central provinces.

3.5 Infrastructure and Utility Profiles

3.5.1 Road and Bridge Networks

The road network within the basin consists of approximately 350 km. this is the main road which links the three provinces (CHAMPASAK-SAARAVAN-SEKONG) together. This does not include the road link between the districts and access roads to the local villages of each province. About 60% of the 350 km is paved. CHAMPASAK province has the most stretches of paved roads

There are 5 bridges (that can hold motor vehicles) that cross the basin's several tributaries. There is 1 main airport, which is located in PAKSE City that serves both domestic and international flights. There are airports in the provinces of SARAVAN and SEKONG where only helicopters can land. There are no railways in this river basin or anywhere in the southern region of Lao PDR.

Figure 3.6 Road and Bridge Networks of the XEDON River Basin

3.5.2 Communication utilities

About a decade ago, the government mainly relied on radio-telephone network to communicate with remote and rural areas. These days, cellular phones are the most common way to communicate. The Government of Laos together with private enterprise is expanding the cellular phone network nationwide, including in the XEDON River Basin. There are telecom branches in the three southern provinces; the companies have set their cellular phone stations in districts, some villages and along main roads to provide a wide-range and convenient communication for trade and other benefits. The two main communicational companies are ETL (Enterprise of Telecommunication of Laos) and LTC (Lao Telecommunication Company).

3.6 Analysis system water resources of the river basin

Analysis system of the river basin is study the components of the XEDON river basin. The objective is to understand the system of the river basin which is studying the physical boundaries of the river basin, a terrain, weather, water resources. Including processes occurred in the river basin both occurring naturally and by humans the overall to get the conclusions status of the river basin. In order to bring the information to test the models for optimal network flow rate in XEDON river basins to install small hydroelectric power plant with program MATLAP.

3.6.1 Physical geography nature

The SEDON river basin located south of the Lao PDR has a catchment area of approximately 7217 km^2, the river basin covers an area of 13 districts , there are seven districts of SARAVAN province (SARAVAN, TAOI, LAONGAM, KHONGSEDONE, TOOMLARN, VAPY and LAKHONPHENG) an area of about 5,168 km2 and 72 percent of the watershed. There are 4 districts of CHAMPASAK province (PAKSE, BACHIANG, SANASOMBOON and PAKSONG) with an area of 1356 square kilometers, accounting for 18 percent and 2 districts of SEKONG province (Pumpkins and at the port) is Covering an area of about 693 square kilometers, accounting for 10 percent of the watershed is shown in Table 3.9.

The topography of the XEDON river basin the most areas are high mountain range covered with forest intricate with perfection and there are lowlands along the waterfront XEDON, which was the community the slope of the drainage basin (Figure 3.7) and Table 3.10 the river basin had an average height of about 700m from average sea level, which has highest peak at 2,000m from average sea level (Near the PAKSONG District, CHAMPASAK Province) and a minimum at 100m from average sea level (located in PAKSE District, CHAMPASAK Province) by the characteristics of the area of the river basin can be divided into 2 types.

The area has an altitude ranging from 500-2000 m from sea level. Such area s mostly covered by natural forest meadow, there are county grow field crops and industrial crops such as coffee and tea.

The lowland 100-500m from average sea level it is the location of district and residential of population the area suitable for agriculture production most of area use grow rice fields waterlogging there are XEDON river flows through which is the water source for Consume of population.

The river basin of characteristics is percent of slope at the more different. By the area is about 45 percent, with a slope of less than between (0-2%). Approximately 29 percent, there are of slope at relatively low between (2-8%). Approximately 8 percent, the slope is moderate between (8-16%). Approximately 8 percent, it is the slope quite a lot between (16-30%). And has an area of about 9 percent, the slope more than 30 (> 30%) as shown in Figure 3.8 and Table 10.

Table 3.8 the area of each province in XEDON river basin.

No.	**province**	**area (km^2)**	**Percent(%)**
1	Champasak	5,168.00	71.60
2	Saravan	1,356.00	18.80
3	Sekong	693.00	9.60
	Total	**7,217.00**	**100.00**

Table 3.9 the physical characteristics of the area of XEDON river basin

No.	Physical characteristics	Unit	Value
1	Watershed area	km^2	7,217.00
2	Perimeter	km	752.30
3	Max. elevation	m	2,000.00
4	Min. elevation	m	100.00
5	Mean elevation	m	700.00
6	Aspect	-	West
7	Shape	-	trapezoid

Table 3.10 the slope levels of an area of the XEDON river basin.

No.	slope levels	Area (km^2)	Percent (%)
1	Little (0-2%)	3,261.45	45.19
2	Quite a few (2-8%)	2,097.42	29.06
3	Moderate (8-16%)	586.70	8.13
4	Quite a lot (16-30%)	607.40	8.42
5	Very steep (>30%)	664.13	9.20
	Total	**7,217.00**	**100.00**

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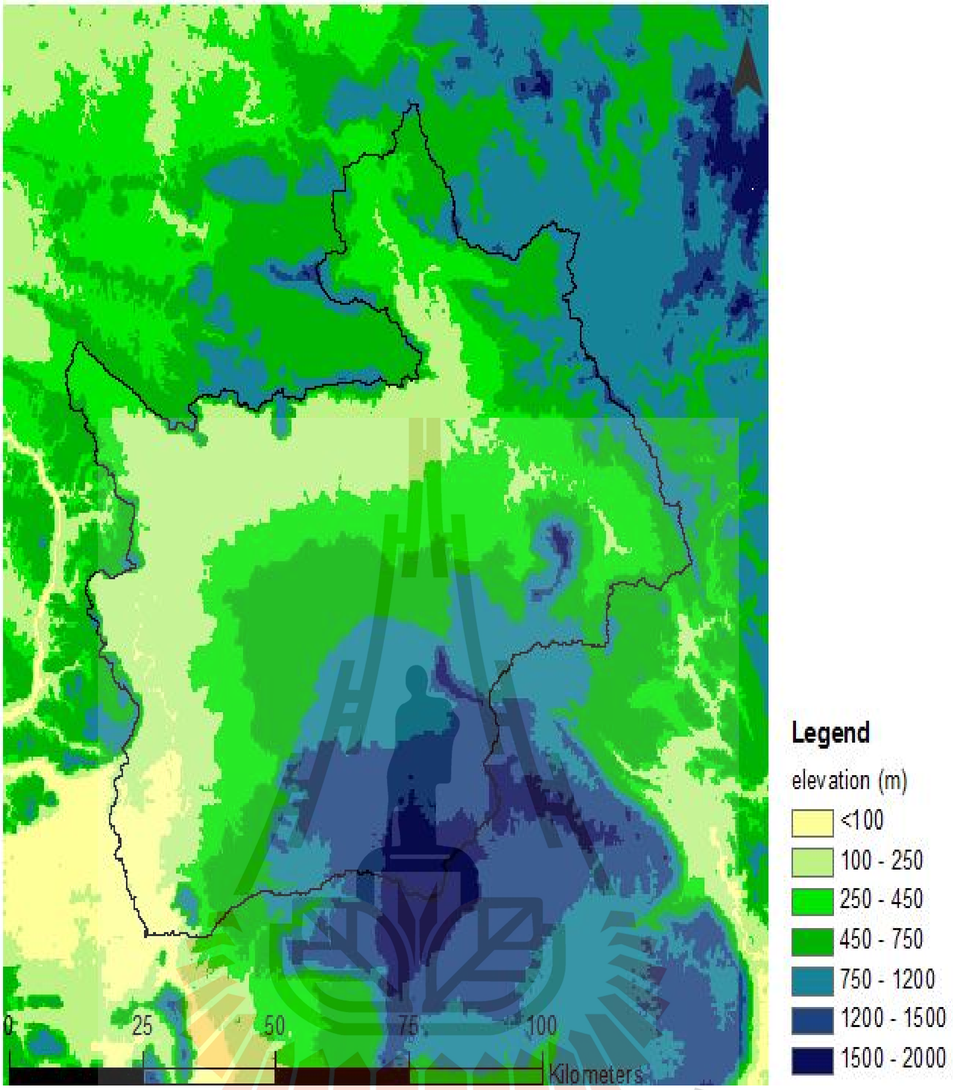
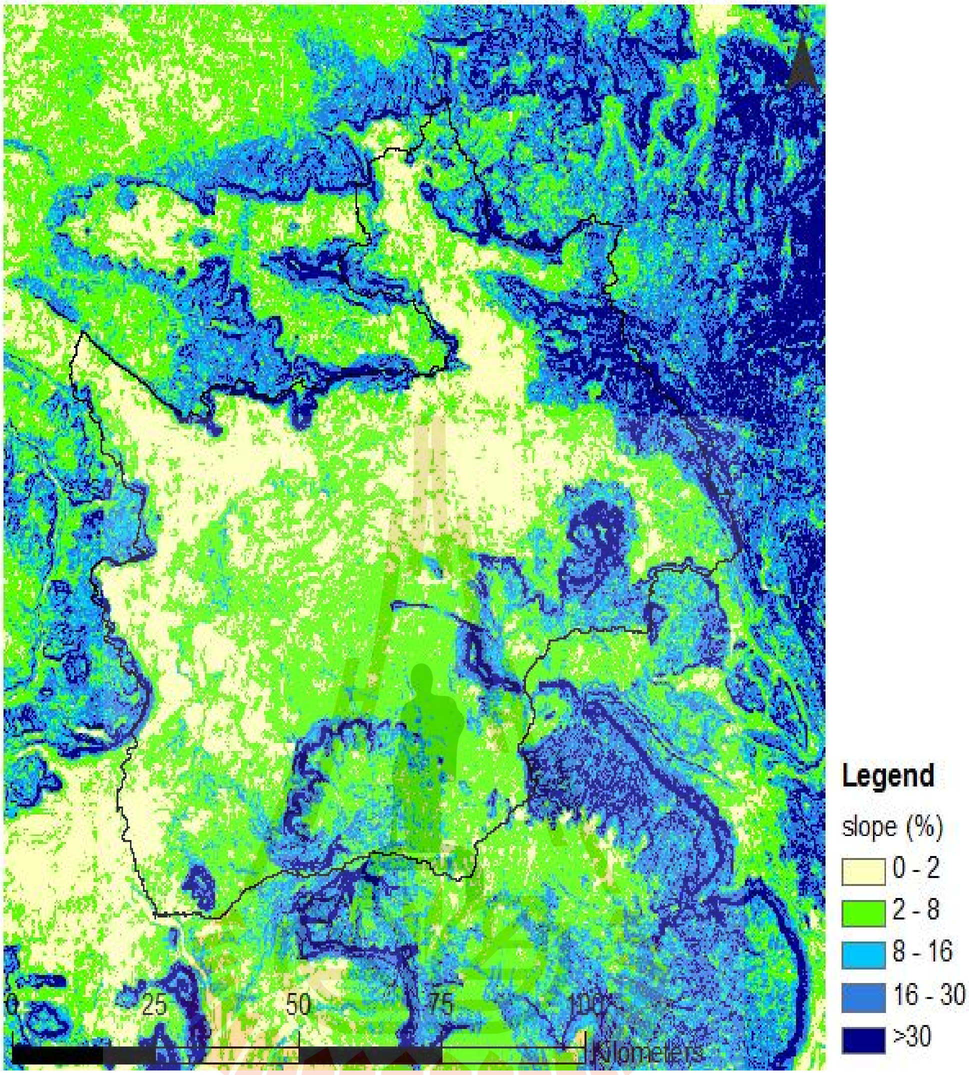


Pictures 3.7 the characteristics terrain of the XEDON river basin



Pictures 3.8 the slope levels of the XEDON river basin

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3.6.2 The Climate Characteristics

The climate of the river basin is generally in tropical zone, the most of rainy season have been the influence of the tropical cyclone. Moreover, it is influenced by depression which is from the South China Sea causing the rain in the months of May to October. It is causing two seasons clearly such as the rainy season is also a time of about six months. Start from April to October of year and the dry season begin from November to March of year. In this phase there is little rainfall average maximum temperature in during the month of April and January with average minimum temperature.

The XEDON river basin is the area of climate monitoring stations at no more. Attributed to data collection of some stations is not ongoing, so it is the area with extremely limited. For climate data from studies and already gathered the river basin with only four monitoring stations. The climate data are continuously collected data time series as shown in Figure 3.9 and Table 3.11. The climate monitoring stations consisting of PAKSE, the station of Pak Chong (CHAMPASAK Province), the climate monitoring stations SARAVAN district and the station of KHONGSEDONE District (SARAVAN Province) which data is collected continuously on a daily basis. By the data is From 1 January 1996 to 31 December 2010 the total period of 15 years.

3.6.2.1 Rainfall

Analysis rainfall of river basin are summary an annually from data of the four stations. The results from the analysis rainfall of all basins, was found (Table 3.12). The river basin has rainfall quite a lot. By the rainfall of PAKSONG stations which has the maximum average rainfall per year is different from the other stations. By the minimum rainfall average annual at 2,130 mm, of the year 1998 and the maximum rainfall average annual at 4,270 mm of the year 2000. By sections of annual rainfall of the stations PAKSE, SARAVAN district, and KHONGSEDONE District which has quantity similar to approximately 2000 mm per year.

Considering the average monthly rainfall data during 1996 to 2010 as shown in Figure 3.10 Figure 3.11 Figure 3.12 Figure 3.13 and Figure 3.14 is found there is a lot of rain in the rainy season, which in the August has highest rainfall more than 400 mm and during small rain in January has the minimum of rainfall at 2 mm of the station of PAKSE District, the station of SARAVAN District and the station of KHONGSEDONE District. For the stations of PAKSONG District in August, the average monthly rainfall of more than 800mm the small rainfall include January has the minimum of rainfall 18 mm.

3.6.2.2 Temperature

The XEDON river basin has very different of levels terrain. That is the minimum level at 100 m to a maximum of 2,000 m. The considering data the average monthly (Table 3.13) shows that, the temperature in the wetlands of the river basin is the average annual temperature at 27○C, which has the station of PAKSE District, the station of SARAVAN District and the station of KHONGSEDONE District. By the month of January is the month with the lowest temperature average monthly at 25○C and April are the months with the highest temperatures that average monthly temperature at 30○C. In the areas with altitudes ranging 1000-2000m, which PAKSONG station has a mean annual temperature is 19○C. By the month of January is the month with the lowest temperature average monthly at 17○C and April are the months with the highest temperatures that average monthly temperature at 20○C.

Table 3.11 measurement stations climate in XEDON river basin.

No.	Code Station	Station Name	Coordinates	
			Latitude	Longitude
1	17040000	The station of PAKSE	15° 17′ 00″	105° 47′ 00″
2	17052002	The station of PAKSONG	15° 11′ 00″	106° 14′ 00″
3	15060000	The station of SARAVAN	15° 43′ 00″	106° 27′ 00″
4	15072001	The station of KHONGSEDONE	15° 34′ 00″	105° 38′ 00″

Table 3.12 the average monthly rainfall of measurement stations on XEDON river basin in 1996 to 2010.

Station Name	Average monthly rainfall (mm.)												Annually (mm)
	Jen	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
PAKSE	2	14	38	78	260	302	425	504	326	115	25	4	2,096
PAKSONG	18	51	103	235	320	432	812	854	452	210	75	29	3,589
SARAVAN	2	15	32	70	221	254	414	485	319	113	20	3	1,950
KHONG SEDONE	2	13	31	68	215	239	402	465	316	104	15	2	1,880

Table 3.13 the average monthly temperature of measurement stations on XEDON river basin in 1996 to 2010.

Station Name	Average monthly temperature (°C)												Annually (°C)
	Jen	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
PAKSE	24.8	27.6	29.7	30.6	29.3	28.5	27.9	27.6	27.5	27.4	26.5	25.4	27.1
PAKSONG	16.1	17.4	20.0	20.9	21.0	20.5	19.9	19.8	19.7	19.5	18.3	17.3	19.1
SARAVAN	25.3	27.3	29.9	30.7	29.4	28.7	27.4	27.5	27.7	26.8	26.6	24.8	27.3
KHONG SEDONE	25.5	27.5	29.7	30.8	29.1	28.8	27.9	27.6	27.5	27.4	26.2	24.5	27.6

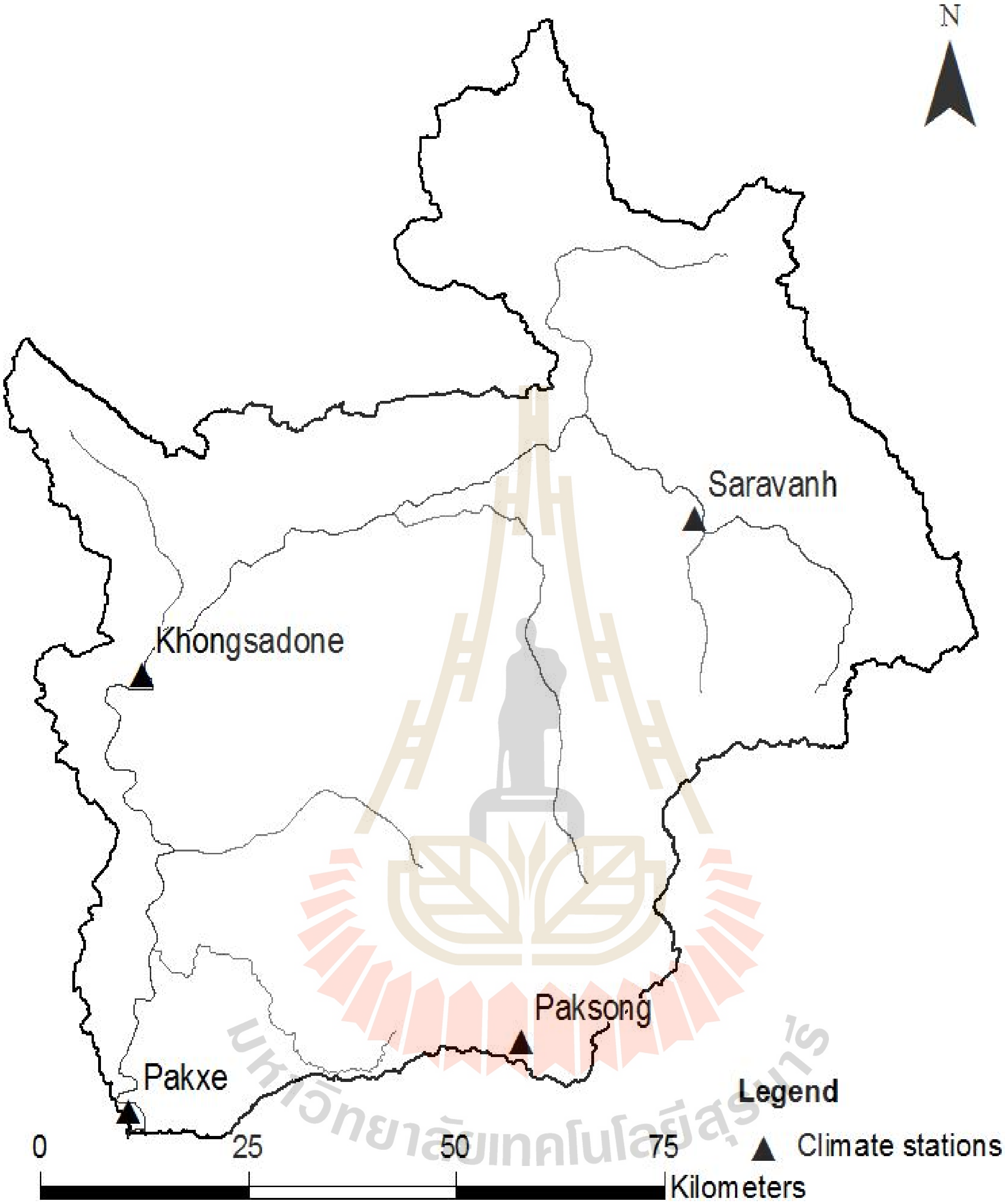

Figure 3.9 Placement of measurement stations climate in XEDON river basin

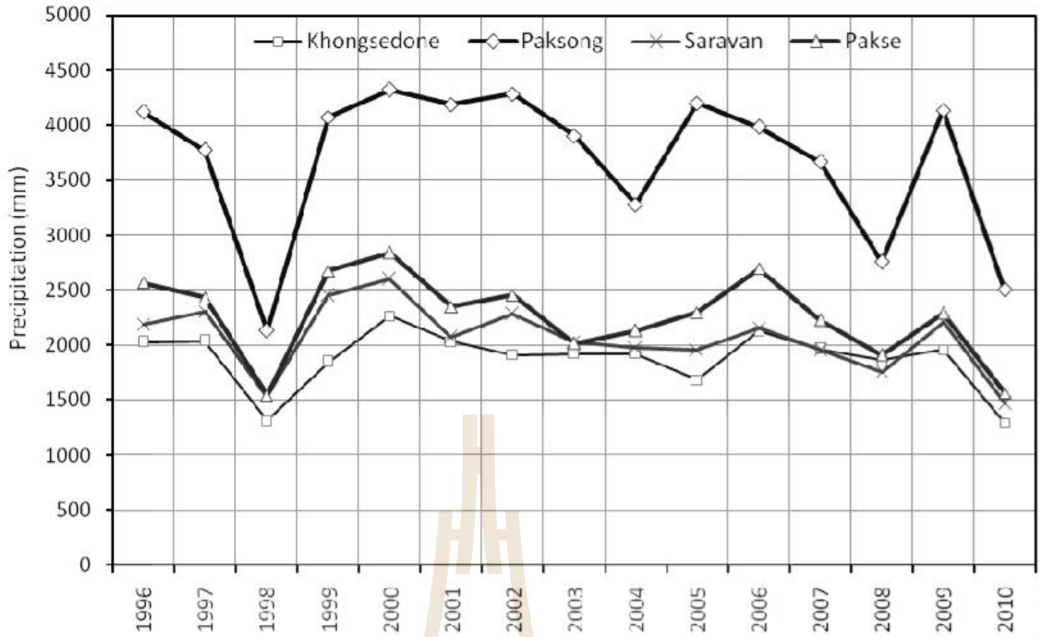

Figure 3.10 Average annual rainfall of four measurement stations climate during 1996 to 2010

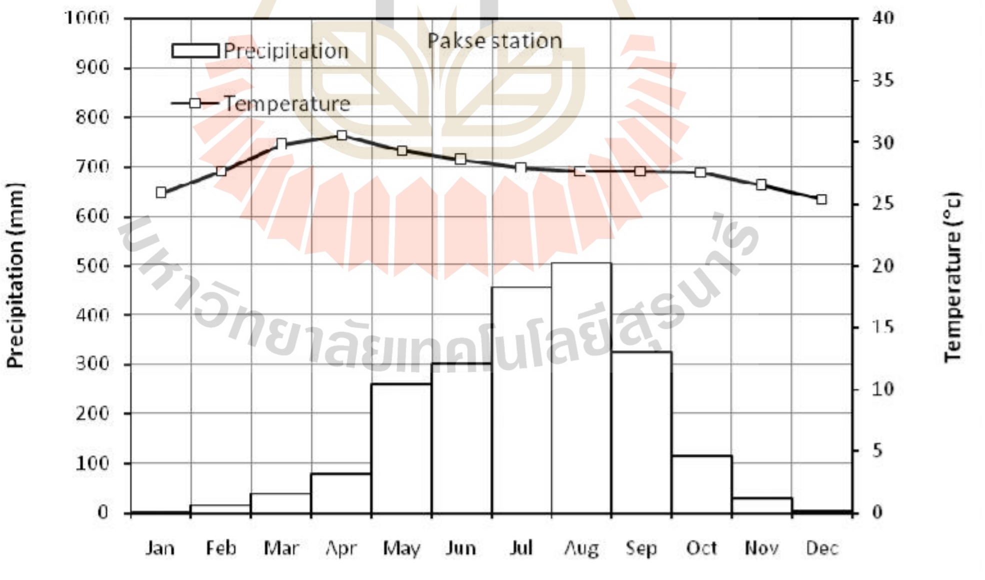

Figure 3.11 Average monthly rainfall and temperature of PAKSE stations in period 1996 to 2010

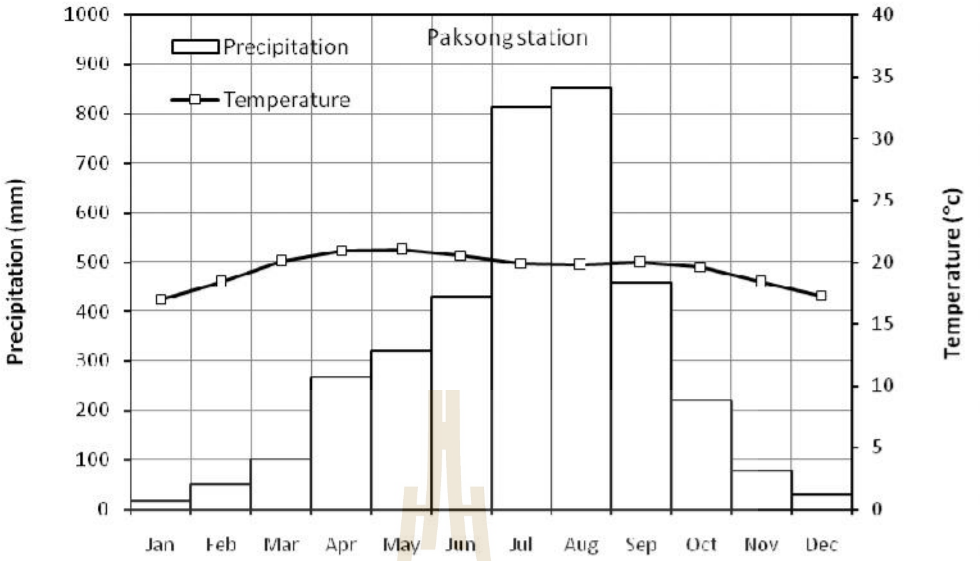

Figure 3.12 Average monthly rainfall and temperature of PAKSONG stations in period 1996 to 2010

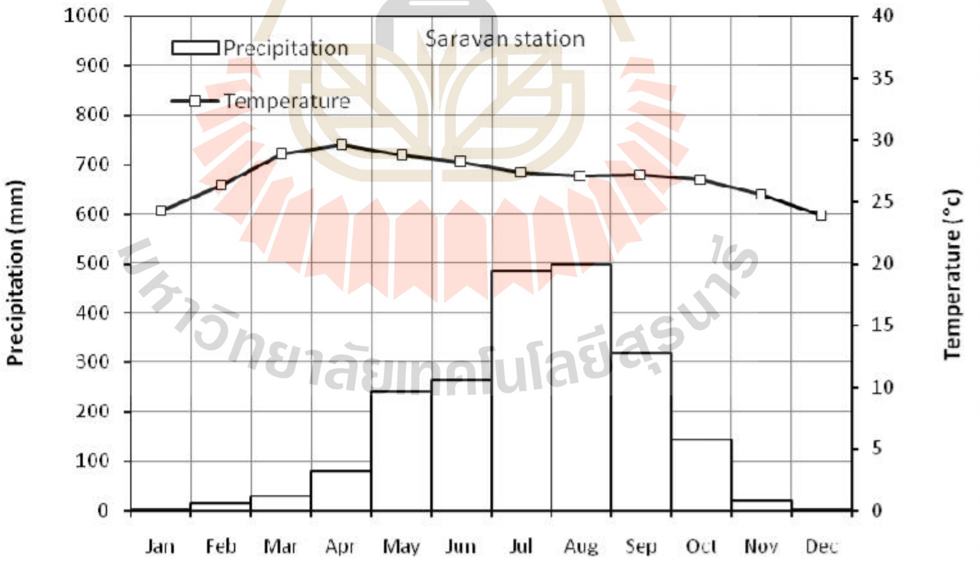

Figure 3.13 Average monthly rainfall and temperature of SARAVAN stations in period 1996 to 2010

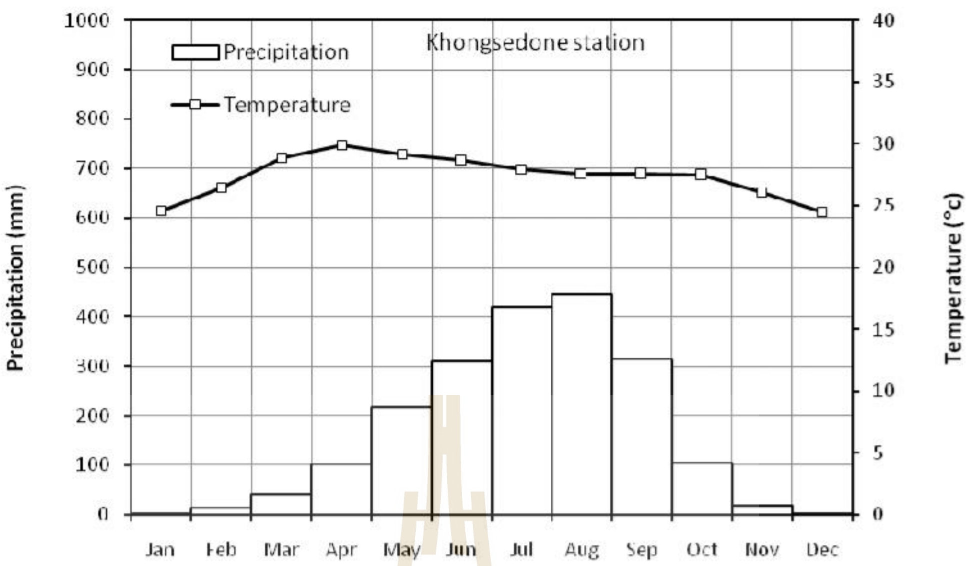

Figure 3.14 Average monthly rainfall and temperature of KHONGSEDONE stations in period 1996 to 2010

3.6.2.3 Characteristics of the water resources of XEDON river basin

The XEDON river basin is a large catchment area. By the rainfall is the source of water resources that into the system, there are making water resources costs of the management in the area of river basin. In overall of the river basin is in status not a lack of the water, due to XEDON river of flowing through the river basin and a network of river branches is distributed all areas of river basin. There are irrigation systems that use water during the dry season and for water to consumption has been system placing for water supply to use in SARAVAN Province and CHAMPASAK Province.

3.6.2.3.1 XEDON River Basin and River Branches are Important

The XEDON river basin is the river main line of river basins with a total length of about 228 km, which has watershed in a specific area of THATAENG District of SEKONG province in located BOLAVEN plateau. The XEDON River is the important river of the population in river basin used for consumption - consumers, agriculture animal farming and is used to the boat of transportation in the river basin. By the river flows through the town that are important such as SARAVAN district, VAPY district, KHONGSEDONE district, SARAVAN province and SANASOMEBOON District then inflows with MEKHONG River at PAKSE District, CHAMPASAK Province. The XEDON River has the river branches which are important, as shown in Figure 3.15 contains.

- XEXET has the area of headwaters in the southeast that is a specific area BOLAVEN plateau PAKSONG District, CHAMPASAK Province, the river is particularly important, with the length of the river about 68 km which in the river has a small hydroelectric power plant.

- HUOAY PAPU has the area of headwaters in north-east of urban specific area of TA OI District, SARAVAN province which has a long of the river, about 35 km.

- HUOAY CHAMPI has the area of headwaters in the southeast of BOLAVEN plateau specific area of PAKSONG District, CHAMPASAK province which has a long of the river, about 37 km.

- HUOAY PALAY has the area of headwaters in the southeast of BOLAVEN plateau specific area of PAKSONG District, CHAMPASAK province which has a long of the river, about 45 km.

- HUOAY NAMSAY has the area of headwaters in the southeast of BOLAVEN plateau specific area of THATAENG District, SEKONG province which has a long of the river, about 23 km.

- HUOAY SELAMANA has the area of headwaters in the northwest of urban specific area of NAKHONPENG District, SARAVAN province which has a long of the river, about 39 km.

3.6.2.3.2 The Water Content

Analysis the water content of the river basin was concluded an annually by using data of SUVANAKILLI stations. By data from 1 January 1996 to 31 December 2010 are total period of 15 years, the analysis results of the rainfall all of river basin, as show in Figure 3.16, which found that, the water content of XEDON river basin has been from the XEDON River, with an average of about 8,900 million m^3 and in 1998 as a drought year, the minimum of annual water content at about 3500 million m^3 and in 2000 year the maximum of annual water content at about 3500 million m^3.

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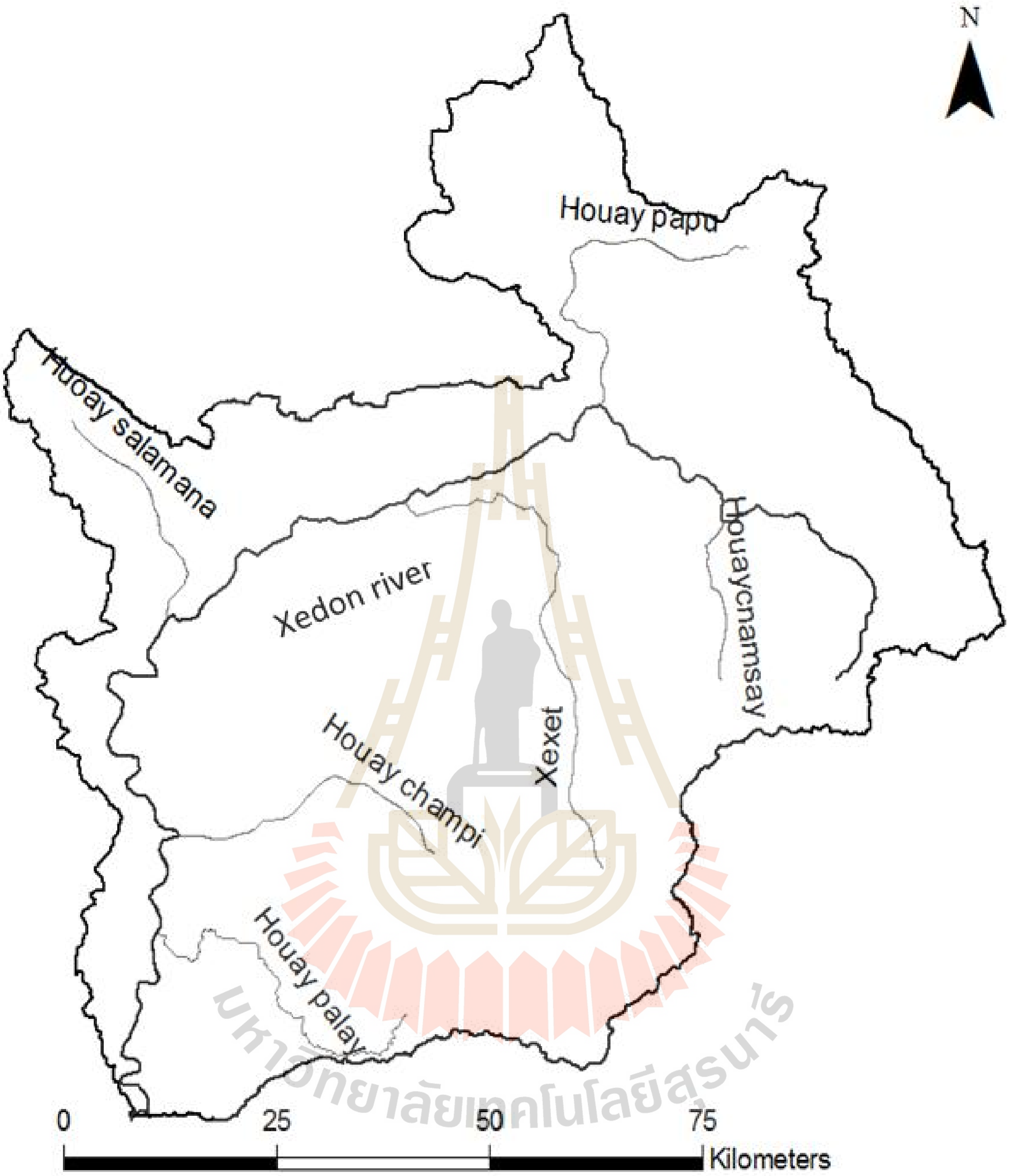

Figure 3.15 the main rivers and river branches in the XEDON river basin

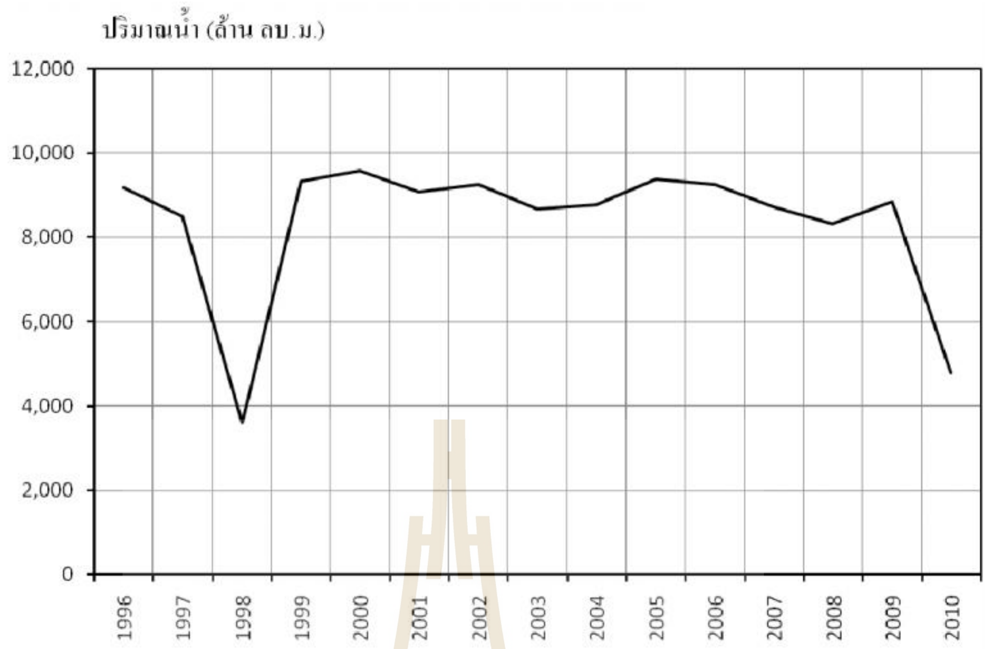

Figure 3.16 the annual water content of SUVANAKILLI station during 1996 to 2010

3.6.2.4 The Characteristics Water Use in the Area of River Basin

3.6.2.4.1 The Population in the Area of River Basin

XEDON is the river important in the area of river basin, the most population is located city along the river which the suitable for using water to supply - consumers. The characteristics of population in the river basin are Buddhists, Christ, Roman novel CATHOLIK and the animist minority. Also offers treatment the original traditional customs. From the data collected by the Department of Statistics of three provinces in 2010, it found that the SEDON river basin has a population of 625,090 people (Table 3.14). The population of consists of 13 District are SARAVAN, TAOI, LAONGARM, KHONGSEDONE, TOOMLARN, VAPY, LAKHONPHENG, PAKSE, BACHIENG, SANASOMBOON, PAKSONG, THATAENG and LAMARM. In the first, SARAVAN Province are the most numerous population, the second is CHAMPASAK province and SEKONG Province (Department of Statistics, 2010). For the water demand for consumption - consumers of the population in the District are using the rate of water 200 liters / person / day (FAO, 2007), which from analysis showed that the population in the watershed area is used water for consumption - consumers of 40 million m3/year. By the SARAVAN province have the highest water demand for consumption - consumers to 70 Percentage of the water demand for consumption - consumers there are due the area covers most in the river basin.

3.6.2.4.2 Tourism

The tourism is involved with in natural resources especially of Water Resources with the area conditions the abundance of watershed among the factors that attract tourists has resulted in a continued increase in tourism business. In addition, the tourism is also important source of income in the area of the XEDON river basin, especially in southern Laos. Which river basin has many ecotourism attractions by tourists who frequented by visit on the BOLAVEN Plateau that is located at the northeast of the CHAMPASAK province. Furthermore, the areas are also many beautiful landscaped, natural attractions, tourism activities, including waterfall, hikes, camping and the traditional homestay program. Moreover, there is a famous coffee such as Arabica. Because, the river basin is important attractions of provide opportunities for livelihood a significant of the population. By the number of tourist arrivals from the data collection of tourist Department of three provinces in 2008 found there were about 188,000 visitors per year. In CHAMPASAK province has the most number of tourists, about 165 000 people per year, SARAVAN province, about 11,000 people per year and SEKONG province, about 12,900 people per year (Department of Statistics, 2009). For the water demand for consumption - consumers of tourism, there are the rate of water consumption of 100 liters / person / day (FAO, 2007). Finally, the analysis found that is equal to 10 million m3 per year.

Table 3.14: the population of each provinces in the area of the XEDON river basin.

No.	District	Population (people)	Density (people / Km^2)
1	PAKSE	94,889	958
2	BACHIANG	51,373	57
3	SANASOMBOON	66,076	64
4	PAKSONG	68,240	17
5	SARAVAN	78,723	490
6	TA OI	23,460	283
7	TOOMLARN	22,339	73
8	LAKHONPHENG	50,833	292
9	VAPY	24,405	95
10	KHONGSEDONE	68,146	727
11	LAONGAM	48,106	299
12	THATAENG	28,500	286
	Total	**625,090**	**87**

3.6.2.4.3 The Water Use for Agriculture in the XEDON River Basin

The most of water irrigation use in the river basin for agriculture and there are the rice cultivation paddy waterlogging in the dry season of once a year. Therefore, the most of areas for using of irrigation water is in SARAVAN District, VAPY District, KHONGSEDONE District (SARAVAN province) and SANASOMBOON District, PAKSE District (CHAMPASAK province). By the data collection from the Department of Irrigation the XEDON river basin has an irrigation area of approximately 14,000 hectares (Table 3.15). Thus, the

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characteristic of the rice cultivation in the area of river basin is divided into two phases. In the first phases the, planting season of rice begin July through October and second rice by pulling water from XEDON river used in the irrigated area for the dry season, which starts from December to May. In addition, it's also the planting rice with seedlings - black lace (Department of Irrigation, 2012) and the locations shown in Figure 3.16. Hence, the central of the XEDON river basin has the highest of water demand 50 percent of total water demand. Because, there are a large area for high agricultural water demand.

Table 3.15: irrigable area in the XEDON river basin 2011

No.	**Province**	**District**	**irrigation projects**	**Area (ha)**
1	SARAVAN	SARAVAN	NONGDAENG	2,500
			NAKHOYSAO	650
			VIENGKHAM	470
			NAMSAY	530
			BOUNGKHAM	650
			KHONGKOY	450
		VAPY	VAPY NORTH	430
			VAPY SOUTH	250
			PHATKHA	450
			KAENGSUTI	450
			NONNONGBUA	520
		KHONGSEDONE	BIG KHONG	1,200
			SMALL KHONG	850
			BUARAPHA	440
			HEENXILL	570
			DONMUEANG	450
			NONGBUA	580

Table 3.15: irrigable area in the XEDON river basin 2011 (continued)

No.	Province	District	irrigation projects	Area (ha)
2	CHAMPASAK	SANASOMBOON	BIG SOLO	480
			SMALL SOLO	650
			PAK SONE	720
		PAKSE	PHOTAK	150
			PHONESYKHAI	400
			PHONE NGAM	210
TOTAL				**14,050**

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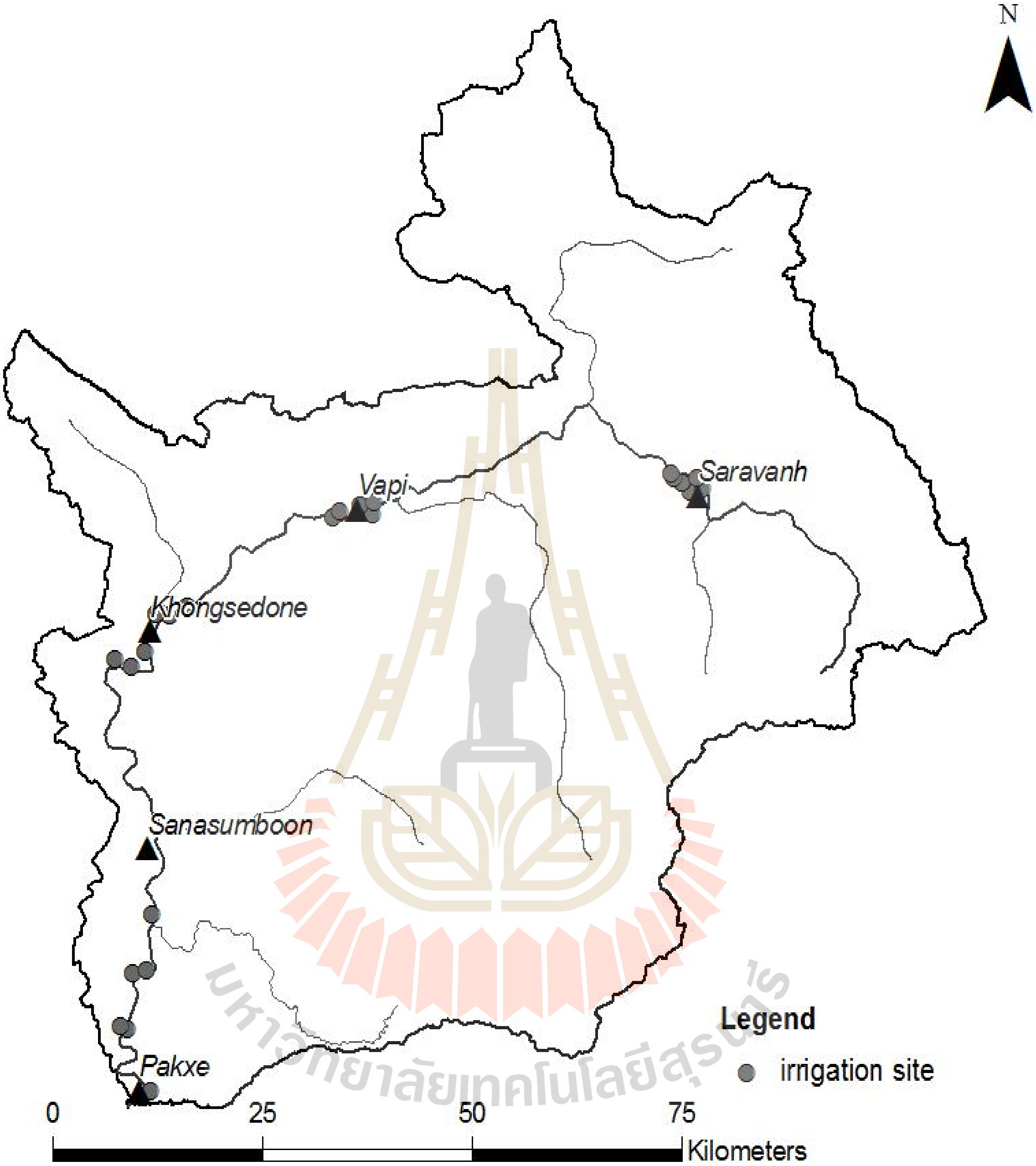

Figure 3.17 the irrigation in the XEDON river basin

3.6.2.4.4 The industrial plants

The industrial plants areas in the river basin have manufacturing industry consists of small industrial plants and medium sized such as sawmills, medicine factory, water drinking plant, and grain mills, etc. The productivity and resources in the river basin with all factories of 1934 the plant consists CHAMPASAK Province, with a total of 1802 factories, SARAVAN province has 93 factories and SEKONG province has 39 factories (Department of Industry, 2009) as shown in Table 3.16.

Table 3.16 the number of plants in each province is on the XEDON river basin.

No.	Province	Small	Medium	Amount
1	CHAMPASAK	1,792	10	1,802
2	SARAVAN	57	16	93
3	SEKONG	13	26	39
	Total	**1,862**	**52**	**1,934**

3.6.2.4.5 Hydroelectric Power Plants

In the XEDON river basin has three small hydroelectric power plants consists of XEXET1, XEXET 2 in the district of SARAVAN, which use water from the HOUAY XEXET is the source electricity. One part of electricity produced used in SARAVAN District and partly is sending out electricity to THAILAND and another dam is a XELABUM dam at the bottom of the river basin in the CHAMPASAK province. By making a weir and in some water to generate electricity used in the District of PAKSE (Department of Industry, 2009) are shown in Table 3.17

Table 3.17 hydroelectric power plants in XEDON river basin.

No.	Dam	Province	Capacity (MW)
1	XEXET 1	SARAVAN	45
2	XEXET 2	SARAVAN	76
3	XEXET 3	SARAVAN	23
4	XELABUM	CHAMPASAK	5

CHAPTER IV

EVALUATION OF POTENTIAL AND XEDON RIVER HYDROBASIN DEVELOPMENTAL PLAN

4.1 Data Used to Determine the Potential of Hydropower

Considering the potential of hydropower in XEDON River basin, this data must be used.

1. Laos topographic map scale 1: 50,000 covers the whole area of XEDON River Basin have shown elevation, river line, community area, industrial area, planting area, and a 1: 4,000-scale Laos terrain map covering the area, which is expected to have potential hydropower development.

2. The location of catchment area which has potential of hydropower and the use of water in various activities on the XEDON river and branches of river basins

3. Field monitoring at a significant point in the electrical activity and water use in the XEDON River and tributaries of the river basin are considered.

4. Hydrological data include flow rates and the water level of the XEDON River and the branch are considered. Especially, the location of the water gauge station of the various units located in the River basins and rainfall data for all stations measuring the rainfall of the XEDON River Basin. Table 4-1 details of the stations measure the amount of water applied.

5. Irrigation project data include the volume capacity reservoir, the water level, the hydraulic heights, the water discharge rate from the reservoir, the amount of

water flowing into the reservoir, physical characteristics of the canal, an irrigation project area, and the demand for water in all areas that the irrigation project must provide.

Table 4.1: Details of the gauging station

sequence	station code	Name substation	Catchment area(km2)	coordinates	
				latitude	latitude
1	17040000	PAKSE	650	15° $17'$ $00''$	105° $47'$ $00''$
2	17052002	PAKSONG	1,280	15° $11'$ $00''$	106° $14'$ $00''$
3	15060000	SALAVAN	3,260	15° $43'00''$	106° $27'$ $00''$
4	15072001	KHONGSED ONE	2,027	15° $34'00''$	105° $38'$ $00''$

4.2 The Consideration to Select Location the Potential of Hydropower Plants

4.2.1 Considering the Range of the XEDON River, tributaries and irrigation reservoirs with potential for hydropower. Use the following criteria:

1. For the river, a slope of the river or of the terrain around the river must be suitable. Can make the height of the water head was suitable for the production of electricity.

2. For the reservoir of the irrigation project must have a suitable head height for electricity generation.

3. The amount of water flow rate sufficient to produce hydroelectric power at least 1 MW.

4. There are areas where the demand for electricity or a transmission system of the EDL is located in the vicinity of the river.

5. There are areas where major production activities require electricity and water such as community area, an urban area, an industrial area, an agricultural area, an economic area, commerce and the area of tourism.

6. It isn't a sensitive area which there are limits to the development such as forest area, park area, world heritage sites and the areas of wildlife breeding, aquatic animal, fishery.

4.2.2 The Consideration to Select Location the Potential of Hydropower Plants

The consideration to select the location the potential of hydropower plants,use the following criteria.

1. To study of existing irrigation reservoirs, with the study that has a sufficient amount of water and the elevation of water head enough to be used in the production of electricity. Because, the water used for power production must not affect the purpose of the use of water.

2. To study the part of the river basin with sufficient slope to provide the height of the head to generate electricity properly. Include there must have enough water after diversion to produce electricity. In order to be able to have the water for the original water of the river section. To minimize the impact of water diversion from the river to used minimal electricity produce.

3. The location to be featured are: the location is near the village and the outside of the service area of Electricity Du Laos (EDL), and without electricity transmission system through, and the location with EDL transmission line through, the electric power produced will enhance the stability of the electrical system in the area, and reduce the use of fossil fuels imported from abroad.

4. Consider the locations two power plants.

The run of the river type is the water entering the power plant will flow directly from the river (when the river does not flow, it can produce electricity.), as shown in Figure 4.1. And the reservoir type as shown in Figure 4.2. However, the reservoir model considers the only reservoir that flooded the area is not much, and it has little impact on the people and less environment.

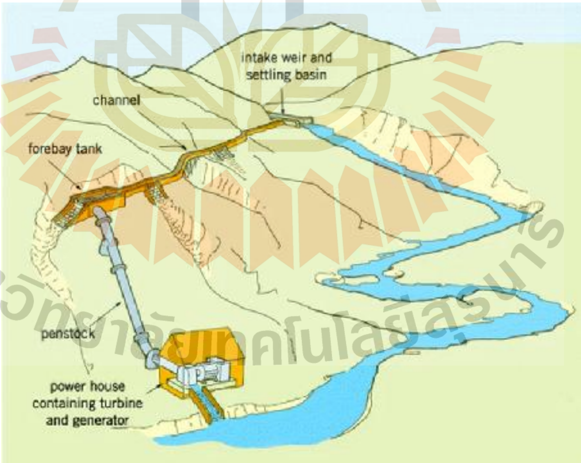

Figure 4.1 Run of the river type

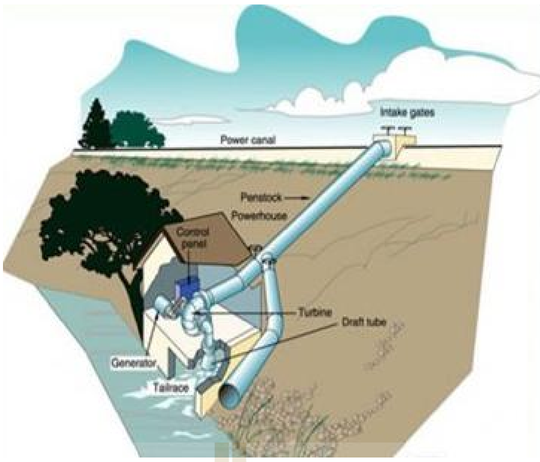

Figure 4.2 Reservoir type

4.2.3 Segmentation of potential location

The consideration to select the location of the potential hydropower plants in XEDON river basin, it will consider small hydropower plant with a capacity more than of 1 megawatts and do not consider the location to build a large reservoir this will cause flooding of large areas. The primary of potential location is:

1. Locations and organizations are already studied such as the Electricity Du Laos, Ministry of Energy and Mines, Ministry of Natural Resources and Environment.

2. The location is in the development plan of the organization or the relevant agency such as Ministry of Natural Resources and Environment.

3. The reservoir and weir irrigation of the existing Royal Irrigation Department, Ministry of Natural Resources and Environment.

4. Study new of location which is to consider both upstream in the maximum head of the water and a big river with a flow rate sufficient. These criteria,

it will help to maximize both benefits in the development of water resources and energy sources.

When considering such criteria. We can arrange the group of potential hydropower is classified into 6 groups, as follows.

Group 1 irrigation reservoir is available.

The existing irrigation reservoirs are the main objects for cultivation and consumption the study of water for use in power production which will try not to affect the main purpose of water use.

Group 2 located on the mainstream XEDON River Basin.

The locations in this group consider selecting the mainstream of the XEDON River Basin appropriate is the amount of water and the maximum of the head are enough to produce electricity.

Group 3 the location was studied by the Electricity Du Laos.

The location was studied by the agency concerned that there is potential for hydropower development. The study was conducted by analyzing new water content. By using data to present which hydropower development project of Electricity Generating Authority in Laos P.D.R for 9 projects in XEDON River Basin include XEXET1 hydropower plant, XEXET2 hydropower plant, XEXET3 hydropower plant, HOUAY PALAY hydropower plant, HOUAY CHAMPI hydropower plant, HOUAY NAMSAY hydropower plant, HOUAY KAPU hydropower plant, SELAMMANA hydropower plant. Show details of the project table 4.2

Table 4.2 Hydroelectric Power Plant at XEDON River Basin

Hydropower Project	Head (m)	Flow rate (m3 / s)	Capacity (MW)	Annual electricity (MW-hours)	Turbine type	Dam type
XEXET1	155	33,3	45	180x1000000	Francis	Concrete
XEXET2	271	33,3	76	320x1000000	Francis	Concrete
XEXET3	162	17,703	23	80x1000	Francis	Concrete

Group 4 the location was studied by the Electricity Du Lao, Ministry of Energy and Mines, Ministry of Natural Resources and Environment.

Group 5 water resources are in the plan of other agencies.

Group 6 selected locations for learning more

Locations in this group are considering to the selected the river with the suitable terrain, head of water and the flow rate is sufficient to produce electricity.

4.3 The Volume Synthesis of Water Flow Rate Data in Case it doesn't have Water Flow Rate Data

The most common problems encountered in water resources management are there is no data for measuring the reservoir inflow or flow rate in the study area which small hydropower developments need to know the daily flow to consider the potential of electricity generation. But how to find the daily flow is not also how to do precisely, because the daily flow is a fluctuating value very high compared to annual flow. The hydrological assessment is a technique used to provide hydrological data

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indirectly that there are several ways either in the model of the regression model and the mathematical model which simplified model to difficult model and complex.

The flow rate study is appropriate for short-term projects or projects that do not require much resolution of the data such as potential study and small hydropower development in basic for power generation in the XEDON River Basin area. How to use of calculating 2 cases to synthesize daily flow data at position expected potential for hydropower include 1) Catchment area ratio and 2) The relationship between annual average rainfall and rainfall area both methods have the same basic equation as $Q = kA^n$, which is a widely used method and suitable for use in the study of the early study (Desk study) and step detailed study (Feasibility) which each method is detailed as this.

4.3.1 Method the Proportion of Catchment Area

This method is used for cases at the dam site and gauging station is located in the same river basin or the same river as figure 4.3. It is based on the assumption of similarity in the physical characteristics of the area hydrology and meteorology include calculating the flow rate at the dam site by using the proportion of water area and the water area should be similar, as the equation (26).

$$Q_d = Q_g \times \frac{CA_d}{CA_g} \qquad (26)$$

Where

Q_d flood peak discharge at dam site (m^3/s)

Q_g flood peak discharge at gauging site (m^3/s)

CA_d catchment area at dam site (km^2)

CA_g catchment area at gauging station (km^2)

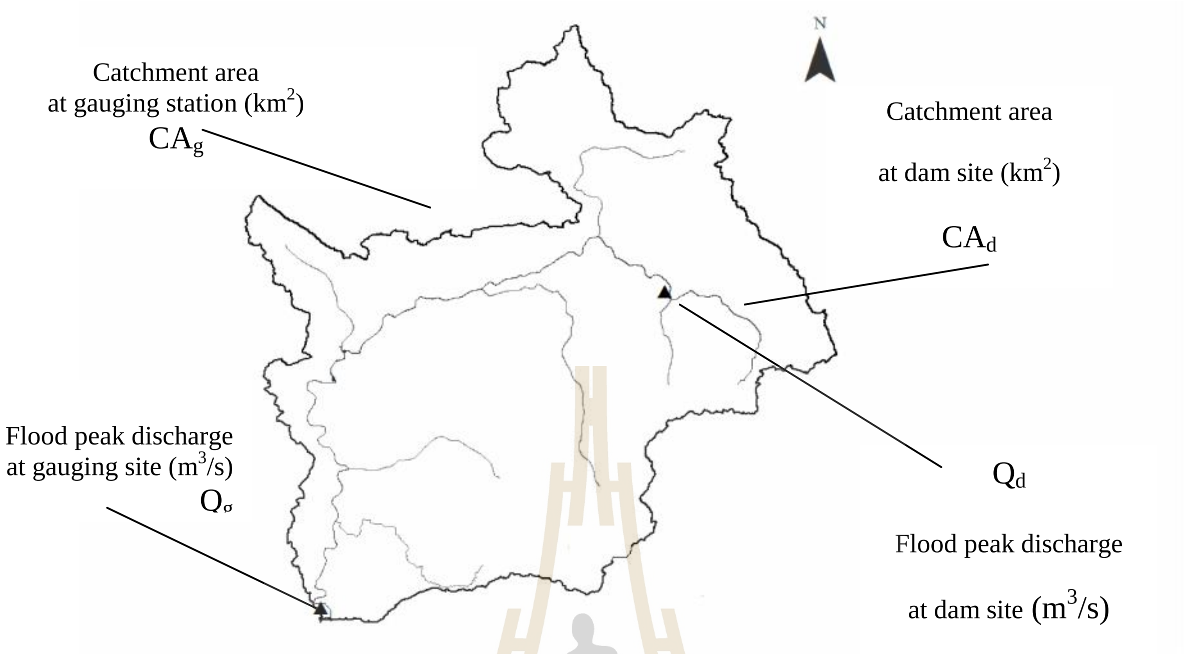

Figure 4.3 Catchment areas for flow rate by using method the proportion of catchment area

4.3.2 The Method Relationship between Annual Average Flow Rate and Rainfall Catchment Area.

It used the method to counterbalance of water quantity the flow distributions on river basin which characterizes the relationship in the regression equation as follow in equation 27 and is a method that can be used to find water quantity in areas where no gauging stations and it is suitable for the river basins which has characteristic hydrological similarities.

$$Q = k(CA)^n \tag{27}$$

Where

Q is the annual average flow of (m^3 / s)

k, n is the constant of the regression equation.

CA is the catchment area of rainfall (km^2).

The analysis of the relationship between annual average flow rate and catchment area of rainfall was R^2 this can be used to evaluate the annual average flow rate in areas where no gauging stations when you knowing the value of the catchment area of rainfall at that point. By calculating a factor for the change in flow rate (F), that is the value of the proportion catchment area to the power of n as follow in equation 27 if the value n is the value of 1, show that the annual average flow rate per unit an area is the same throughout the river basin but if the value n is less than 1, show that the annual average flow rate per unit an area of the small river basin it will more than of the large river basin. This method should have R^2 correlation values more than 0.6 and n values should be close to 1.

$$F = \frac{Q_d}{Q_g} \times \left[\frac{CA_d}{CA_g} \right]^n \qquad (28)$$

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Where

Q_d is flood peak discharge at dam site (m^3/s)

Q_g is flood peak discharge at gauging site (m^3/s)

CA_d is catchment area at dam site (km^2)

CA_g is catchment area at gauging station (km^2)

F is a factor for changing the flow rate

1. Steps to evaluate water volume by the relationship method between annual average flow rate and catchment area of rainfall.

- To find the annual average flow rate of each gauging station is located in the catchment area of the river basin or nearby the catchment area of the river basin.
- To find the catchment area of the gauging station site used to study.
- Establish a relationship between annual flow rate and catchment area.
- Select agent station and the representative year of that station to be the basic data for finding flow rate at the dam site, the station should be located near the point need to find flow rates, should have a difference of area size, not more than 50 percent and should be a station located in the terrain to similar such as condition geology, condition hydrology and should be stationed with complete data such as daily flow data and have many years.
- Then find the value of F in equation 28.
- Bring value F that is multiplied by the catchment area at the point of rainfall to find the annual average flow rate at that point. Then the annual flow rate can be adjusted as the daily flow rate by method proportional.

2. Calculation to find relationship value between the annual average flow rate and catchment area

From data of area expected to have the potential for production of hydroelectric power as figure 4.3 that see at the points 1, 2 and 3 are located on the river at the gauging station which has data of the flow rate at that station. It is possible to find flow rate at point expected to have all 6 potential by using proportional catchment area. But for in the case at potential points 1, 2, 3, 4, 5 and 6 are places where there is no water gauging station in the river, as figure 4.4. Therefore, to create a relationship between the annual average flow rate and catchment area by using the gauging station at the adjacent area and there are data flow rate of 4 stations are each station has data in table 4.3 to table 4.6 by each the station has a catchment area and the annual average flow rate is as follows.

- PAKSE station, the catchment area of 650 square kilometers, there are 15 years statistics data, the annual average flow rate of 2.12 cubic meters per second.
- PAKSONG station, the catchment area of 1280 square kilometers, there are 15 years statistics data, the annual average flow rate of 1.86 cubic meters per second.
- KHONGSEDONE station, the catchment area of 2027 square kilometers, there are 15 years statistics data, the annual average flow rate of 2.11 cubic meters per second.
- SALAVAN station, the catchment area of 3260 square kilometers, there are 15 years statistics data, the annual average flow rate of 3.63 cubic meters per second.

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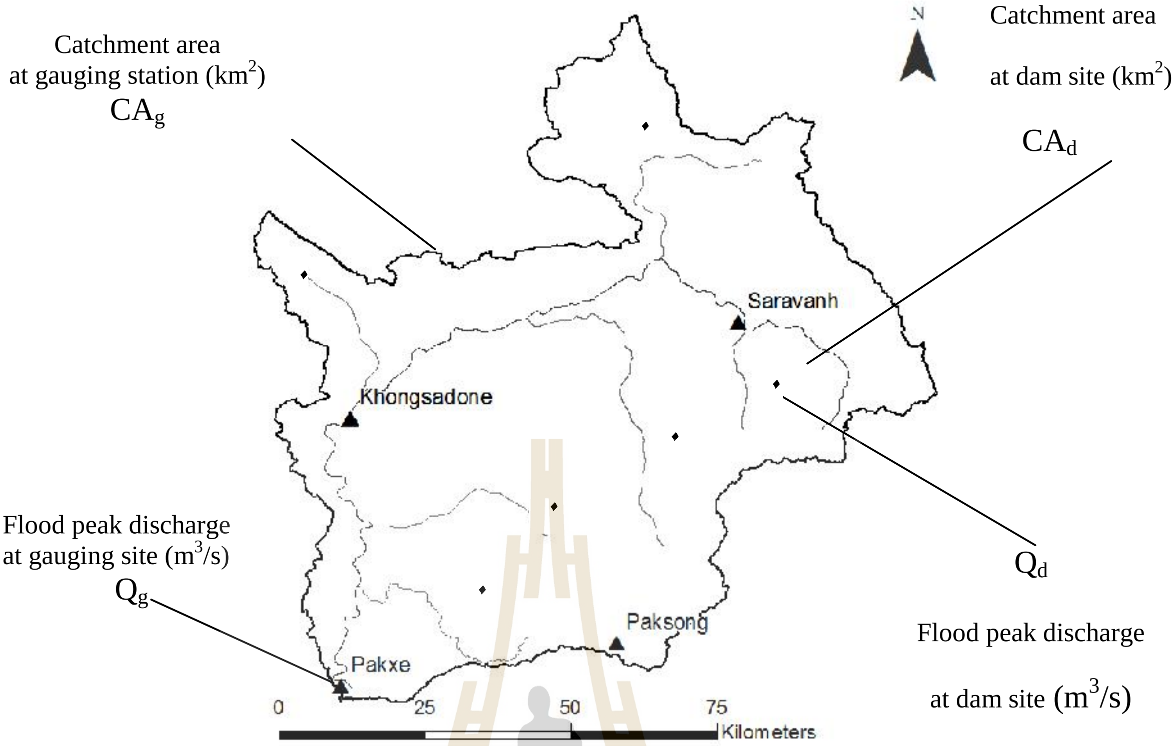

Figure 4.4 Potential points not in the same gauging station of river basin

Table 4.3 the data of monthly average flood peak discharge in each year at PAKSE station

Year	Q (m3/s)												Annual Average
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1996	0.00	0.00	0.27	2.50	4.12	2.49	3.87	3.63	6.87	0.82	1.18	0.00	2.14
1997	0.06	0.93	0.11	1.05	2.35	5.60	8.24	7.72	3.21	1.28	0.12	0.00	2.55
1998	0.00	1.03	0.00	0.44	3.27	1.77	2.13	5.50	4.82	0.60	0.73	0.09	1.70
1999	0.00	0.00	0.73	1.62	4.74	5.72	6.97	4.41	2.23	1.31	1.05	0.00	2.40
2000	0.00	0.08	0.14	1.43	6.28	3.38	8.54	5.98	2.74	1.95	0.06	0.01	2.55
2001	0.00	0.18	1.25	0.23	2.16	5.60	4.15	7.83	4.40	1.37	0.41	0.07	2.30
2002	0.00	0.00	0.41	0.27	1.48	7.12	7.34	7.64	2.77	2.08	0.02	0.03	2.43
2003	0.00	0.03	0.43	0.24	5.44	2.83	2.74	5.65	5.87	0.60	0.04	0.01	1.99
2004	0.00	0.02	0.94	0.26	2.21	5.22	4.69	6.87	2.89	0.00	0.18	0.00	1.94
2005	0.00	0.00	0.17	0.62	2.72	3.42	5.11	6.02	4.20	0.10	0.65	0.00	1.92
2006	0.00	0.00	0.08	1.83	2.73	2.42	9.96	8.70	2.83	3.03	0.13	0.00	2.64
2007	0.00	0.00	0.83	0.41	1.44	2.53	4.35	4.41	2.57	3.42	0.31	0.00	1.69
2008	0.00	0.00	0.62	0.69	2.27	2.77	2.03	8.14	4.31	1.06	0.56	0.00	1.87
2009	0.00	0.15	0.62	1.45	3.39	3.70	7.20	3.06	5.28	0.86	0.02	0.26	2.17
2010	0.19	0.16	0.11	0.81	1.37	1.99	3.11	4.97	2.63	1.85	0.04	0.00	1.44
Monthly Average	***0.02***	***0.17***	***0.45***	***0.92***	***3.06***	***3.77***	***5.36***	***6.04***	***3.84***	***1.35***	***0.37***	***0.03***	**2.12**

Table 4.4 the data of monthly average flood peak discharge in each year at PAKSONG station

Year	Q (m3/s)												Annual Average
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1996	0.04	0.88	1.06	1.94	4.32	3.70	9.52	7.92	13.58	1.92	2.00	0.00	3.91
1997	0.05	0.93	1.27	3.76	2.92	5.87	12.77	10.47	3.73	1.54	0.69	0.41	3.70
1998	0.00	0.84	1.97	1.96	4.08	2.19	2.70	4.45	3.04	2.43	0.69	0.70	2.09
1999	0.59	0.00	1.88	3.13	4.79	4.57	17.65	9.22	5.42	3.08	1.14	0.00	4.29
2000	0.18	1.72	0.90	3.41	3.45	3.70	13.92	11.58	5.03	3.06	0.23	0.14	3.94
2001	0.50	0.52	1.28	3.47	3.73	8.27	9.72	12.90	4.79	3.79	0.31	0.03	4.11
2002	0.00	0.02	0.99	3.23	3.68	6.40	10.47	13.18	6.67	3.22	1.05	1.51	4.20
2003	0.00	0.90	1.72	2.80	5.13	5.00	7.35	11.45	8.63	1.70	1.28	0.00	3.83
2004	0.64	0.02	1.22	2.97	4.12	9.84	6.44	9.29	3.70	0.05	0.31	0.00	3.22
2005	0.00	0.00	2.37	2.27	3.94	5.16	14.24	14.65	5.87	0.36	2.51	0.44	4.32
2006	0.02	0.99	0.61	3.84	2.42	6.18	14.49	12.47	4.24	5.54	1.41	0.05	4.35
2007	0.01	0.05	0.19	3.11	4.40	3.60	10.01	8.18	3.31	5.63	0.49	0.60	3.30
2008	0.00	0.33	1.63	3.43	4.03	4.45	3.31	6.23	4.78	3.08	0.73	0.44	2.70
2009	0.16	1.17	0.95	4.37	4.74	4.75	14.11	8.43	6.06	2.98	0.27	0.72	4.06
2010	0.95	0.57	0.07	3.50	4.32	2.48	3.98	6.77	3.85	2.23	0.64	0.06	2.45
Monthly Average	***0.21***	***0.60***	***1.21***	***3.14***	***4.00***	***5.08***	***10.05***	***9.81***	***5.51***	***2.71***	***0.92***	***0.34***	**3.63**

Table 4.5 the data of monthly average flood peak discharge in each year at KHONGSEDONE station

Year	Q (m3/s)												Annual Average
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1996	0.00	0.04	0.57	1.68	3.26	2.47	4.13	2.67	6.25	1.83	0.92	0.00	1.99
1997	0.02	0.23	0.67	2.61	2.88	3.56	4.77	6.14	2.35	0.73	0.00	0.00	2.00
1998	0.01	0.80	0.00	0.87	2.41	1.08	1.66	3.07	4.63	0.66	0.18	0.04	1.29
1999	0.01	0.00	0.88	2.13	4.67	3.31	3.96	2.10	2.85	1.25	0.55	0.01	1.81
2000	0.00	0.29	0.09	1.94	5.22	3.41	5.72	4.67	3.43	1.85	0.01	0.00	2.22
2001	0.00	0.14	1.29	0.20	2.32	4.37	4.83	7.62	3.63	1.81	0.02	0.03	2.19
2002	0.00	0.00	0.45	0.28	1.75	4.08	7.15	3.13	4.17	0.92	0.12	0.46	1.87
2003	0.00	0.14	0.81	1.08	3.74	2.11	1.94	4.77	7.58	0.46	0.00	0.00	1.88
2004	0.07	0.82	0.47	1.17	3.32	4.26	6.31	4.48	2.84	0.00	0.00	0.00	1.98
2005	0.00	0.00	0.12	1.19	2.03	2.17	3.84	5.12	3.75	1.26	0.28	0.01	1.65
2006	0.00	0.00	0.69	0.92	3.86	2.25	7.30	5.96	2.60	1.74	0.42	0.00	2.14
2007	0.00	0.00	0.56	1.76	3.42	3.78	2.93	4.76	2.68	2.98	0.19	0.00	1.92
2008	0.00	0.00	0.37	0.73	3.31	2.30	3.27	4.46	5.86	1.01	0.56	0.06	1.83
2009	0.00	0.66	0.65	1.33	3.73	3.01	4.72	3.95	4.27	0.70	0.01	0.00	1.92
2010	0.00	0.07	0.00	0.62	1.04	1.79	2.59	5.12	2.02	1.90	0.04	0.00	1.27
Monthly Average	***0.01***	***0.21***	***0.51***	***1.23***	***3.13***	***2.93***	***4.34***	***4.53***	***3.93***	***1.27***	***0.22***	***0.04***	**1.86**

Table 4.6 the data of monthly average flood peak discharge in each year at SALAVAN station

Year	Q (m3/s)												Annual Average
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1996	0.00	0.44	0.20	1.65	3.74	1.56	3.08	5.84	12.34	2.37	1.35	0.00	2.71
1997	0.14	0.58	0.26	1.65	3.06	3.64	4.92	6.04	1.99	0.49	0.00	0.00	1.90
1998	0.03	0.73	0.00	0.68	2.81	3.38	1.80	2.72	3.15	1.07	0.54	0.09	1.42
1999	0.01	0.30	0.56	0.95	3.61	4.26	10.68	5.40	2.91	2.09	0.71	0.01	2.62
2000	0.00	0.45	0.03	1.31	3.43	3.21	10.43	8.64	3.38	2.53	0.01	0.00	2.78
2001	0.00	0.60	1.04	0.61	3.41	3.44	3.63	5.88	3.80	1.87	0.02	0.03	2.03
2002	0.00	0.00	0.12	0.83	1.20	4.59	8.22	8.30	4.00	1.46	0.06	0.13	2.41
2003	0.00	0.37	1.20	0.65	3.95	3.01	2.76	6.05	4.67	1.01	0.02	0.00	1.97
2004	0.01	0.14	0.46	0.76	2.89	3.17	6.10	6.51	4.80	0.23	0.03	0.00	2.09
2005	0.00	0.00	0.15	1.45	2.34	3.37	5.19	9.49	4.44	0.34	0.16	0.08	2.25
2006	0.00	0.57	0.35	1.33	2.00	3.45	6.30	5.73	3.27	2.14	0.26	0.01	2.12
2007	0.00	0.02	0.26	0.95	1.97	3.27	6.92	4.12	3.08	5.24	0.37	0.00	2.18
2008	0.00	0.00	0.34	0.78	2.90	3.37	1.83	4.91	3.15	1.44	0.10	0.01	1.57
2009	0.00	0.20	0.30	1.50	3.31	1.37	9.86	3.47	5.28	1.38	0.00	0.07	2.23
2010	0.09	0.04	0.06	1.10	1.94	1.57	3.85	4.82	2.10	1.66	0.00	0.00	1.44
Monthly Average	***0.02***	***0.30***	***0.36***	***1.08***	***2.84***	***3.11***	***5.70***	***5.86***	***4.16***	***1.69***	***0.24***	***0.03***	**2.11**

From the above data bring to find a relationship between the annual average flow rate and catchment area by it can be divided into 5 cases study as follows.

- **Case 1** use 4 stations are PAKSE station, PASONG station, KHONGSEDON station, SALAVAN station. To find the relationship between annual average flow rate and catchment area. From the graph, it was found that n = 0.9065 and R^2 = 0.8216. It can be seen that, there is good enough.

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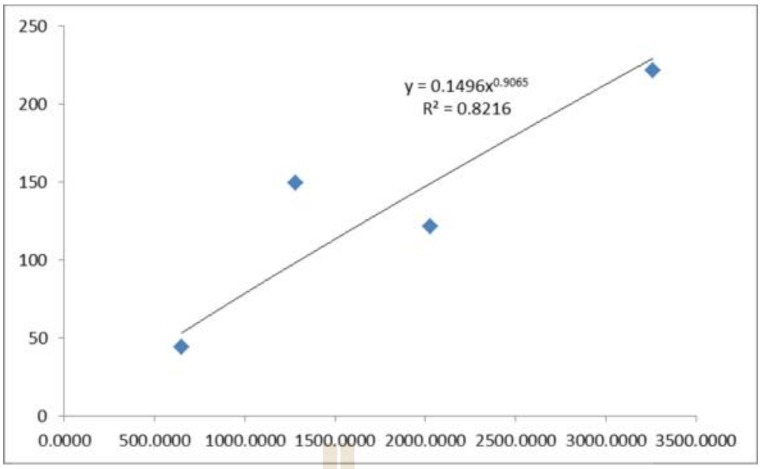
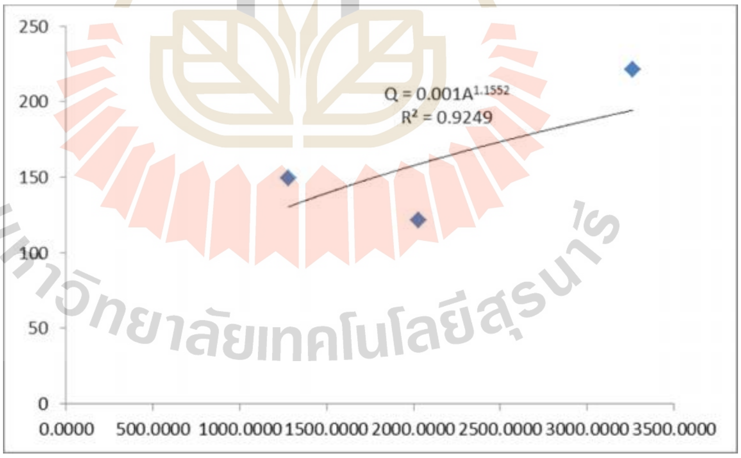
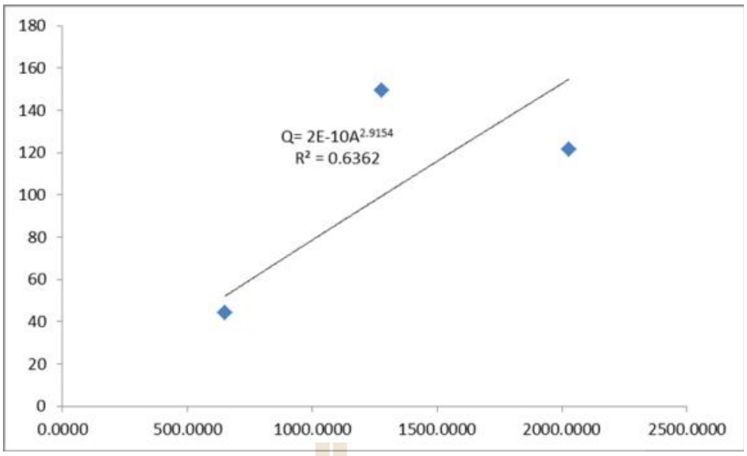


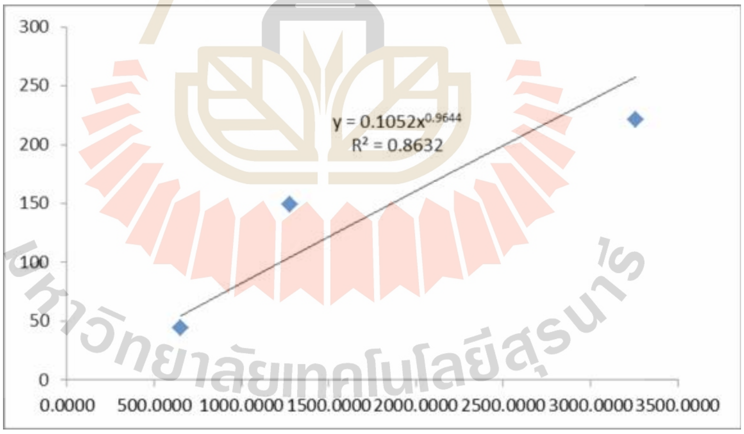
- **Case2** uses three stations are PASONG station, KHONGSEDON station, SALAVAN station. To find the relationship between annual average flow rate and catchment area. From the graph, it was found that n = 1.1552 and R^2 = 0.9249. It seems that there are few relationships.



- **Case3** uses three stations are PAKSE station, PASONG station, KHONGSEDON station. To find the relationship between annual average flow rate and catchment area. From the graph, it was found that n = 2.9154 and R^2 = 0.6362. It seems that there are very few relationships.



- **Case 4** uses three stations are PAKSE station, PASONG station, SALAVAN station. To find the relationship between annual average flow rate and catchment area. From the graph, it was found that n = 0.9644 and R^2 = 0.8632. It can be seen that the relationship is very good.



- **Case 5** uses three stations are PAKSE station, KHONGSEDON station, SALAVAN station. To find the relationship between annual average flow rate and catchment area. From the graph, it was found that n=0.9796 and R^2=0.9925. It is seen that the relationship it's best. Can be used as shown in Figure 4.5.

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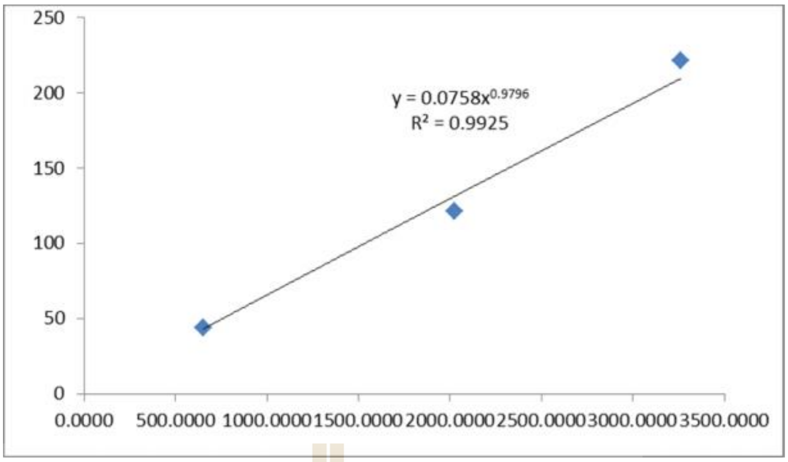

Figure 4.5 the relationship between annual average flow rate and catchment area in XEDON River Basin

Case 5 there is the relationship between annual average flow rate and catchment area it's best. Therefore, the select such case is the case of finding the flow rate at potential points 1, 2, 3, 4, 5 and 6 or other nearby points which the area that is close to the area's potential is PAKSE station. The annual average flow rate was 2.12 cubic meters per second and that is close to the 1996 data. Therefore, select 1996 the year the annual average flow rate was 2.14 cubic meters per second. Then can find the annual average flow rate at any potential point. As follows:

$$Q_{annual(potencial\ \text{point})} = Q_{annual(at\ \text{station})} \times \left[\frac{CA_{potencial\ \text{point}}}{CA_{at\ \text{station}}} \right]^n \qquad (29)$$

Or daily flow rate

$$Q_{daily(potencial\ \text{point})} = Q_{daily(at\ \text{station})} \times \frac{Q_{annual(potencial\ \text{point})}}{Q_{annual(at\ \text{station})}} \qquad (30)$$

Table 4.7 the flow rate at the potential point in XEDON river basin.

Name of river basin	Q (m3/s)												Annual Average
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Houay Namsay	0.000	0.001	0.108	1.015	1.672	1.010	1.570	1.475	2.787	0.333	0.478	0.000	0.871
Houay papu	0.000	0.001	0.113	1.053	1.735	1.048	1.629	1.531	2.893	0.346	0.496	0.000	0.904
Xexest	0.000	0.003	0.314	2.936	4.836	2.920	4.540	4.268	8.063	0.963	1.382	0.000	2.519
Houay Palay	0.000	0.002	0.261	2.443	4.024	2.430	3.778	3.552	6.710	0.802	1.150	0.000	2.096
Houay Champi	0.000	0.001	0.169	1.584	2.609	1.576	2.450	2.303	4.350	0.520	0.746	0.000	1.359
Salamana	0.000	0.001	0.149	1.393	2.296	1.386	2.155	2.026	3.827	0.457	0.656	0.000	1.196
Monthly Average	***0.000***	***0.002***	***0.186***	***1.737***	***2.862***	***1.728***	***2.687***	***2.526***	***4.772***	***0.570***	***0.818***	***0.000***	**1.491**

4.4. Calculating the potential of small reservoirs in the XEDON River basin

In general the data of the reservoir project needed for potential assessment are maximum water volume (A), minimum water volume (B), maximum water level (h), average annual flow rate: Q (m3/s). As shown in Figure 3-6 which the data is as follows can find power electrical derived from the following equation.

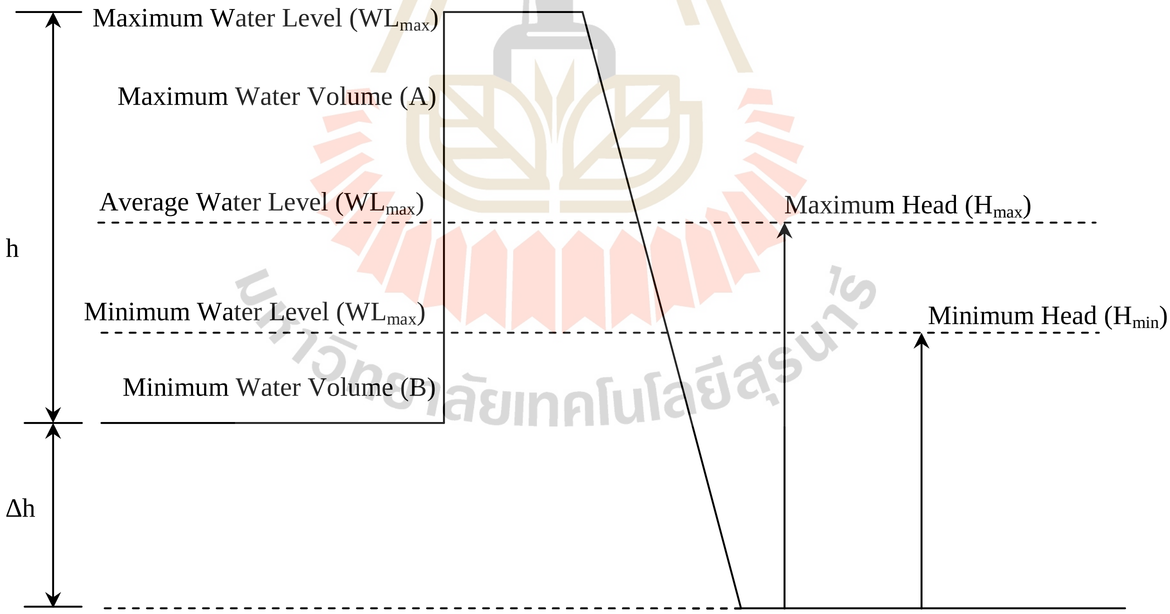

Figure 4.6 Diagram of small reservoir and calculation

$$P_E = ¦¥ Q_{ave} H \tag{31}$$

Where

¦ The total efficiency 50 %

¥ The specific weight of water ($9810 \approx 10^4$ kg per cubic meter per power second)

$$Q_{ave} = \frac{Annual\ \text{Discharge}\left(m^3\right)}{365 \times 24 \times 3600 / year} \qquad (32)$$

H Head (m)

Due to the data limitations of the reservoir and the reservoir data of each project is different. Therefore the evaluation annual average power production of the reservoir had specifically the reservoir with data various which classified as 6 cases as follows:

Case 1 data known value

- Maximum volume (A: cubic meter)
- The volume of water storage (B: cubic meter)
- Maximum Water Level (h: m)

Finding Variable Values

$H = \frac{1}{2}h$ The maximum head is half the maximum water level of a ridge of reservoir

$$Q_{ave} = \frac{A - B\left(m^3\right)}{365 \times 24 \times 3600s} \qquad (33)$$

Case 2 data known value

- Maximum volume (A: cubic meter)

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- The volume of water storage (B: cubic meter)

- Maximum Water Level (h: m)

Finding Variable Values

$H = \frac{1}{2}h$ The maximum head is half the maximum water level of a ridge of reservoir

$$Q_{AVE} = \frac{1}{2}\left(\frac{B\left(m^3\right)}{365 \times 24 \times 3600s}\right) \quad (34)$$

The volume of water used to power production is half the volume of storage.

Case 3 data known value

- Maximum Water Level (h: m)

- Annual average flow rate (F_{ave}: cubic meters per second)

Finding Variable Values

$H = \frac{1}{2}h$ The maximum head is half the maximum water level of a ridge of reservoir

Case 4 data known value

- Maximum volume (A: cubic meter)

- The volume of water storage (B: cubic meter)

Finding Variable Values

$H = 2\left(meter\right)$

Due to the small reservoir and is not know the maximum water level. Therefore, for a rough estimation, the water head is 2.0 meters for this assessment.

$$Q_{ave} = \frac{A - B\left(m^3\right)}{365 \times 24 \times 3600s} \tag{35}$$

<u>Case 5</u> data known value

- The volume of water storage (B: cubic meter)

Finding Variable Values

$H = 2\left(meter\right)$

$$Q_{ave} = \frac{B\left(m^3\right)}{365 \times 24 \times 3600s} \tag{36}$$

<u>Case 6</u> data known value

- Annual average flow rate (Q_{ave}: cubic meters per second)

Finding Variable Values

$H = 2\left(meter\right)$

Q_{ave}

4.4.1 Design of small hydropower plants with reservoirs

The micro hydroelectric power plant is defined by a maximum of 1MW. Set up to installed capacity suitable for a small reservoir at a spread over the XEDON river basin. From the survey area found that the most of the water storage retention above the dam compared to the level of the canal is less than 5 meters. It made the problem of designing a micro hydropower plant in the XEDON River Basin, because it is a minimum head. The power was produced not very highly suitable for distribution for the community or the distant area of countryside. Consider a form of modification of reservoir ridge to produce micro hydropower of minimum head as shown in figure 4.8.

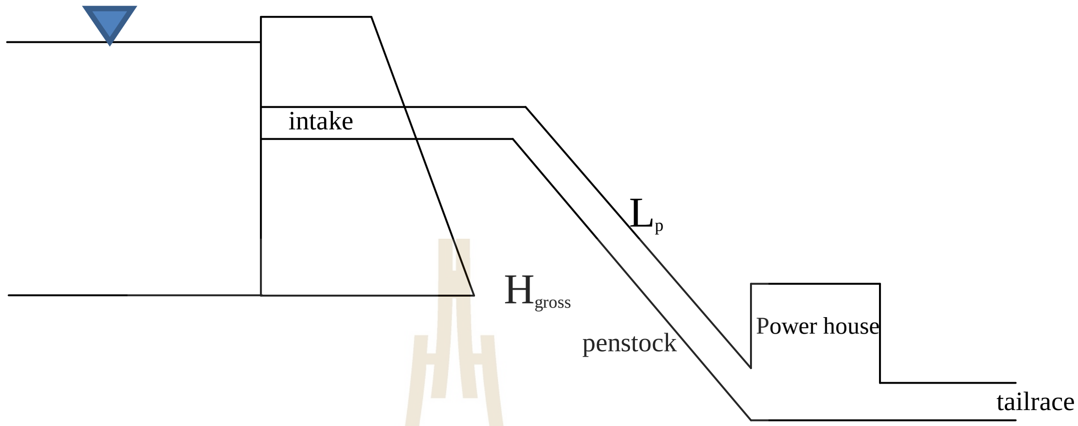

Figure 4.8 Diagram micro hydropower plant, minimum head and reservoir type

Where

L_p The length of the pipeline (meter) (penstock)

H_{gross} The gross head (meter)

H_{net} The net head (meter)

When calculating the losses due to the factors that will cause the net head values according to the following equation.By

$$H_{net} = H_{gross} - H_{loss} \tag{37}$$

$$H_{loss} = H_{major} + H_{minor} \tag{38}$$

Maximum head loss can be divided into 2 parts are major head losses caused by the friction of the flow in the pipe and minor head losses caused by the results of the turbulence of the flow from other elements such as valve or connection point various, as follows

$$H_{major} = \frac{f \times L_p \times Q^2}{d^5} \tag{39}$$

$$H_{\min or} = \P \frac{V^2}{2g} \tag{40}$$

Where

f Friction coefficient

Q Flow rate in the pipeline (cubic meters per second)

d The diameter of the pipe (meter)

V The speed of water in the pipe (Meters per second)

¶ Minor loss coefficient

Friction coefficient can be assessed from Moody diagram as shown in Figure 4.8 which the value is with Reynold number and Relative roughness while minor loss coefficient can be classified into subsystems such as Entrance, Bending, Contract and Valve as follow in equation 41

$$\P = \P_{Entrance} + \P_{Bending} + \P_{Contract} + \P_{Valve} \tag{41}$$

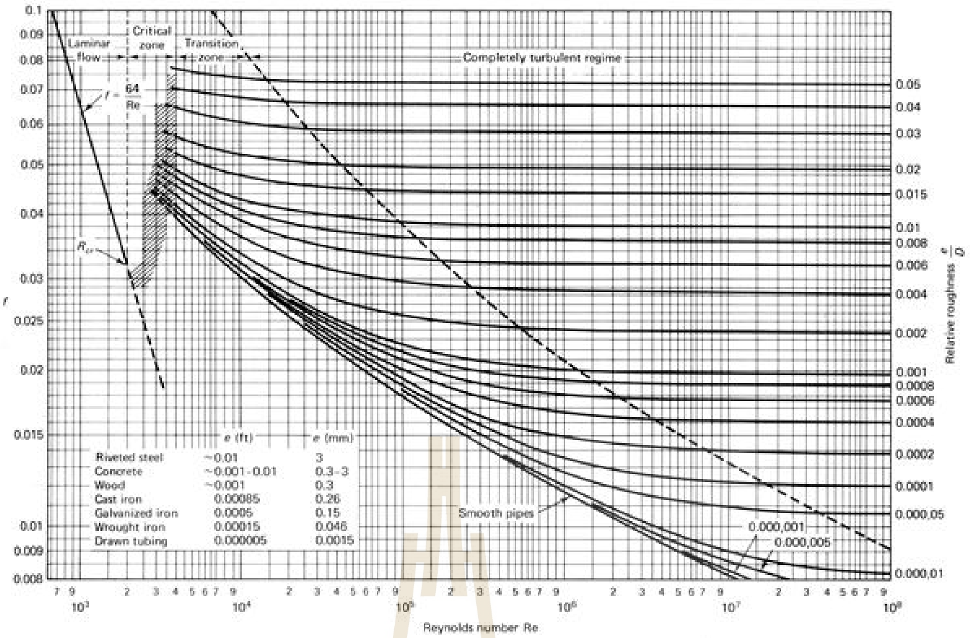

Figure 4.8 Moody Diagram

An experiment designed by medium diameter pipe, 0.3 0.5 0.6 and 1 meter respectively. Determined the flow rate is 0.38 cubic meters per second. The head loss was 2.72 meters, 0.21 meters, 0.085 meters and 0.0066 meters respectively. In case the low minimum head must be compensated by using a large pipe.

$$P_E = \eta \gamma Q H_{net} \qquad (42)$$

Where

P_E Power output (Watt)

η The total efficiency

γ The specific weight of water ($9810 \approx 10^4$ kg per cubic meter per power second)

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Q Flow rate in the pipeline (cubic meters per second)

Hydropower plant design in addition to the need to take into account to the head of water and head loss already another important factor is: Flow rates or the volume of water that can be used to generate electricity as equation 42 due to this production model use a reservoir type. Therefore, the water used to generate electricity is the amount of water that the dam drains into the canal and depend on the provision of time to release water from the reservoir had independent. It will know the amount of water to drain into the canal daily which reflects electricity produced. However, due to the limitation of water retention, it can't be drained daily. Consideration of production from date of water allocation to drain irrigation canal will be guidelines to apply the coordinate assessment of the hydropower plant.

CHAPTER V

ANALYSIS THEORIES

5.1 Investigation Water Distribution System

5.1.1 Introduction

As in numerous designing fields, the state of craftsmanship of water conveyance systems (WDNs) has been significantly moved forward after the rise of computers. Not as it were more efficient approaches proposed for analyzing of WDNs, but too the burden of the unavoidable emphasis parts of tackling nonlinear overseeing conditions was given to computer-aided programs. Subsequently, water powered modeling of WDNs is these days conducted with vigorous strategies utilizing either open-source or commercial computer program. Be that as it may, the commercial ones may not be fitting sufficient for teachers in gracious and mechanical designing courses, who endeavor to ended up commonplace with the basic foundations of WDN investigation. Furthermore, from an instructive point of see, these programs may moreover stifle imaginative thoughts of teachers and analysts. On the other hand, appraisal of composed codes displayed in relevant references (R. W. Jeppson, 1983), (B. E. Larock, et al., 2000), (A. M. G. Lopes, 2004), (E. M. Wahba, 2015), (H. Zhang, et al., 2016) or utilizing computer program, such as MATLAB and Exceed expectations spreadsheet, can play the part of computer application in this

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field of ponder for fulfillment of instructive purposes (D. H. Huddleston, et al., 2004), (G. Recktenwald, 2007), (D. Brkic, 2016), (M. Niazkar, et al., 2016).

In substance, the point of modeling a WND is basically to decide the flow field all through the organization. As this flow field may have transient and spatial varieties, the water-powered modeling of WDN is subordinate to the rate in which the state factors alter within the flow field. In case this variety can be assumed steady with regard to time, the steady-state condition administers the flow field. Extended-period recreation and temporal investigation are other conceivable conditions in which the state factors shift with time at distinctive time interims and quickly, individually. Beneath the steady-state condition, the state factors depend on either requests or pressure driven heads at nodal focuses. In case the fundamental pressure driven head values are met in all of the nodal focuses in a normal arrange, the demand-driven examination requires finding the state factors, i.e., flow rates in channels (Q) or pressure driven heads at nodal focuses (h). In this case, the vitality and progression conditions administer the flow field within the organization. These conditions can be cast in terms of Q or h factors and the iteration-based strategies for understanding the administering conditions may be called Q-based or h-based strategies, separately. In both strategies, the overseeing conditions give a framework of nonlinear arithmetical conditions. This framework of conditions is essentially illuminated utilizing an iteration-based strategy which commences the examination by expecting a set of starting surmises for the state variables.

In spite of the fact that all strategies for analyzing WDNs actually merge to the same arrangement, they define and unravel systems in an unexpected way. For instructive point of see, these contrasts may get to be much clearer when they are executed utilizing appropriate programs.

Agreeing to the state of craftsmanship of WDN examination, examination of computer-aided programs has been an indivisible portion of this field. Many instructive computer program and codes, which were for the most part composed in FORTRAN dialect, have been as of now displayed for water powered modeling of WDNs. For occurrence, Lopes (A. M. G. Lopes, 2004) displayed a computer program for executing Tough Cross strategy. Huddleston et al. (D. H. Huddleston, et al., 2004) suggested the solver of Exceed expectations to unravel a Q-based framework of conditions of a pipe arrange. Recktenwald (G. Recktenwald, 2007) displayed a few straightforward and individual MATLAB capacities solely for computing the full head and head awkwardness in vitality condition for a single pipe. More as of late, Brkic (D. Brkic, 2016) proposed spreadsheet-based calculations for instructing WDNs investigation and actualized the node-loop strategy (Q-based framework of conditions) and progressed Tough Cross strategy. In show disdain toward of all different computer application conducted in modeling WDNs, the application of MATLAB and Exceed expectations spreadsheet for understanding WDNs isn't enough tended to. As this program has been effectively utilized for tackling other designing issues, a comprehensive think about, which is more centering on the usage of diverse strategies, is required to misuse the offices of this valuable computer program for WDN investigation.

In this think about, the detailing of the common h-based approaches counting h-based Newton–Rapshon strategy is displayed for a test pipe organize. In arrange to more center on the instructive perspective of the usage, a basic organize is chosen for the test from the writing. At that point, MATLAB is utilized to independently execute the strategy. In this respect, the step-by-step method of appraisal of this strategy with the code is displayed. It ought to be famous that indeed in spite of the fact that the code is connected for fathoming the test arrange to utilize an h-based strategy, they can be basically made strides to handle much more complex water organize.

5.1.2 Analysis Water Distribution System

Investigation of the stream conditions in a circled pipe arrange is generally portrayed by a set of conditions communicating the relationship of essential determinants, that's, the release Q and breadth D of the branches, and the water-powered head h at each intersection (hub). Newton-Raphson (Shamir, 1968), (Larock, et al., 2000) the strategy is among the foremost prevalent strategy for analyzing circled pipe arrange. All this strategy is numerical iterative calculation pointed at understanding a set of direct and non-linear conditions. Depending on the obscure determinant, this strategy is characterized as h or Q strategy (Jeppson, 1976), (Swamee, et al., 2008). Of specific intrigued is the strategy of h-Newton-Raphson. In Europe, this strategy frequently employments the Darcy-Weisbach head misfortune condition rather than other observational conditions for accomplishing higher exactness. In any case, in each the emphasis the release changes in each department, and so the resistance to stream within the branch changes. Moreover, the Darcy-Weisbach grinding coefficient f is considered free of the overall pressure driven head at the starting and conclusion of the department amid the cycle. In spite of the fact that the f coefficient changes for each the emphasis, it is considered constant amid calculation of the subsidiaries. This presumption makes a complicated calculation method and comes about in moderate joining to the ultimate results.

The proposition presents a strategy for progressing the h-Newton-Raphson iterative strategy by specifically calculating the stream release of each department by utilizing the condition of (Swamee, et al., 1976). The proposed strategy leads to a more streamlined calculation and more precise assurance of the Jacobian network, which quickens the joining of the algorithm.

The calculation of the release at each branch of a water dissemination network can be calculated based on the hydraulic head losses within the branch (Walski, et al., 2003), (Spiliotis, et al., 2007). According to the conventional methodology, which is based on the Darcy-Weisbach equation, this can be achieved by establishing an iterative process (e.g., sub-Newton-Raphson algorithm or trial-error method) based on the following equations:

$$|h_i - h_n| = \frac{8 f_{in} L_{in}}{g \pi^2 D_{in}^5} Q_{in}^2 \tag{53}$$

$$\frac{1}{\sqrt{f_{in}}} = -2\log\left(\frac{\varepsilon}{3.7 D_{in}} + \frac{2.51}{R_{in}\sqrt{f_{in}}}\right) \tag{54}$$

Where v = kinematic viscosity of water; Q_{in} and Res_{in} = discharge (m^3/s) and the resistance ($Res_{in} = 8f_{in}L_{in}/g\pi^2D^5_{in}$) of the branch i-n[$m/(m^3/s)^2$], respectively. Also, ε = roughness coefficient (m); R_{in} = Reynolds number; f_{in} = friction factor. Finally, D_{in} = internal diameter (m); L_{in} = length of the branch (m); h_i and h_n = hydraulic head at the nodes i and n (m), respectively. Eq. (54) is the well-known equation of Colebrook-White valued for R_{in} >4,000

The method of h-Newton-Raphson based on the continuity equation at each node n may be written (Lansey, et al., 2000) as follows:

$$\sum_{i}^{I(n)} Q_{i\rightarrow n} = q_n, \qquad \forall n \in (N-1) \tag{55}$$

Where N = total number of nodes of the network; I(n) = set of all branches including the n node; and q_n = water demand concentrated at node n. All the hydraulic heads are assumed to be positive numbers. Thus, the problem is to solve a set of N-1 non-linear equations with respect to h_n. An effective way to realize typically the application of the Newton-Raphson strategy.

Having decided the hydraulic head at each node, the next step is to decide the comparing releases, friction coefficients, and resistance to flow.

5.1.3 Proposed Technique

Utilizing both the Darcy-Weisbach condition and the condition of Colebrook-White that holds for the turbulent stream, it is simple to demonstrate with straightforward logarithmic calculations that the taking (Swamee, et al., 1976): after unequivocal condition holds

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$$V_{in} = -2\sqrt{2gD_{in}\frac{|h_i - h_n|}{L_{in}}}\log\left(\frac{\pounds}{3.7D_{in}} + \frac{2.51\hbar}{D_{in}\sqrt{2gD_{in}\frac{|h_i - h_n|}{L_{in}}}}\right) \tag{56}$$

This expression of the speed, known as the Swamee and Jain condition, has the advantage that it could be a coordinate condition, counting the impact of the friction factor f_{in}.

To adjust Eq. (57) in the h-Newton-Raphson method, the following modification may be introduced:

$$Q_{i\to n} = -sign(h_i - h_n)\text{®} D_{in}^2/2\sqrt{2gD_{in}\frac{|h_i-h_n|}{L_{in}}}\times\log\left(\frac{\text{£}}{3.7D_{in}}+\frac{2.51\text{⊢}}{D_{in}\sqrt{2gD_{in}\frac{|h_i-h_n|}{L_{in}}}}\right) \quad (57)$$

According to this notation, if $h_i < h_n$, then the discharge at branch i-n diverges from node n ($Q_{i\to n} < 0$). Conversely, if $h_i > h_n$, the discharge at branch i-n converges to node n ($Q_{i\to n} > 0$).

Inserting the previous equations in Eq. (55), the nodal equations of continuity can be written as follows:

$$F_n = \sum_{i}^{I(n)}\left[-sign(h_i - h_n)\frac{\text{®} D_{in}^2}{2}\sqrt{2gD_{in}\frac{|h_i-h_n|}{L_{in}}}\times\log\left(\frac{\text{£}}{3.7D_{in}}+\frac{2.51\text{⊢}}{D_{in}\sqrt{2gD_{in}\frac{|h_i-h_n|}{L_{in}}}}\right)\right] = q_n,$$

$$\forall \in n(\text{N-1}) \quad (58)$$

The flow in each pipe is reduced by the flow direction. We can find it from.

$$\Delta P = \text{¥}\, h_f \quad (59)$$

Where ΔP is water pressure in the pipes (Pa), ¥ is specific weight (9803.6Pa), h_f is main energy loss or head loss (m).

The point of water use is not less than 137900 Pa. As seen in the direction and flow in the pipeline network in figure 6.4, shows that at node 3 is the low pressure point. Therefore, at the node 3 the pressure was 137900 Pa. Thus, the pressures in each node can find it from.

$$P_{node,A} = P_{node,B} + \Delta P_{pipe,AB} \quad (60)$$

5.2 Power Flow Solution

Power flow studies, commonly known as load flow, form an important part of power system analysis. They are necessary for planning, economic scheduling, and control of an existing system as well as planning its future expansion. The issue comprises of deciding the magnitudes and phase angle of the voltage at each bus and active and reactive power flow in each line.

In fathoming a power stream issue, the system is accepted to be working under balanced conditions and a single-phase model is utilized. Four quantities are related to each bus. These are voltage magnitude $|V|$, phase angle ¢, real power P, and reactive power Q. The system buses are generally classified into three sorts.

Slack bus: One bus, known as slack or swing bus, is taken as a reference where the magnitude and phase angle of the voltage is indicated. This bus makes up the difference between the planned loads and the common power that's caused by the losses within the network.

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Load buses: At these buses the active and receptive power are indicated. The magnitude and the phase angle of the voltages are obscure. These buses are called P-Q buses.

Regulated buses: These buses are the generator buses. They are moreover known as voltage controlled buses. At these buses, the real power and voltage magnitude are indicated. The phase angles of the voltages and the reactive power indicated. These buses are called P-V buses.

5.2.1 Power Flow Equation

Consider a typical bus of a power system network as shown in Figure 5.1 Transmission lines are spoken to by their identical ® models where impedances have been changed over to per unit admittances on a common MVA base.

Application of KCL to this bus comes about in

$$\begin{aligned} I_i &= y_{i0}V_i + y_{i1}(V_i - V_1) + y_{i2}(V_i - V_2) + \ldots + y_{in}(V_i - V_n) \\ &= (y_{i0} + y_{i1} + y_{i2} + \ldots + y_{in})V_i - y_{i1}V_1 - y_{i2}V_2 - \ldots - y_{in}V_n \end{aligned} \tag{61}$$

Or

$$I_i = V_i \sum_{j=0}^{n} y_{ij} - \sum_{j=1}^{n} y_{ij}V_j \qquad j \neq i \tag{62}$$

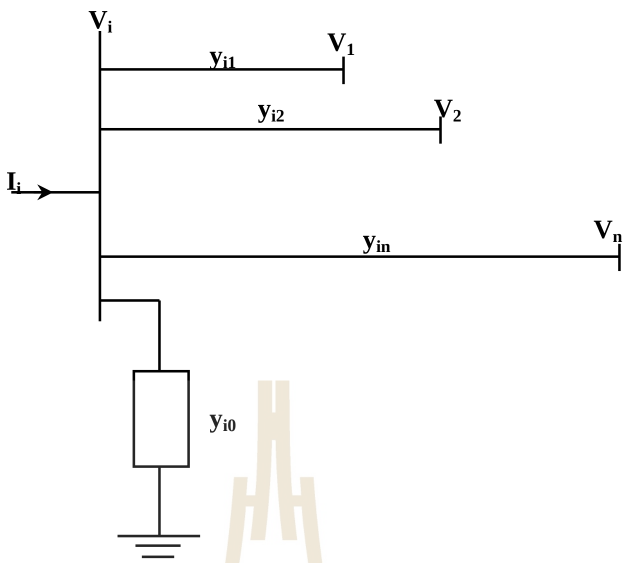

Figure 5.1 normal bus of the power system

The real and reactive power at bus i is

$$P_i + Q_i = V_i I_i^* \tag{63}$$

Or

$$I_i = \frac{P_i - jQ_i}{V_i^*} \tag{64}$$

Substituting for I_i in (75) yields

$$\frac{P_i - jQ_i}{V_i^*} = V_i \sum_{j=0}^{n} y_{ij} - \sum_{j=1}^{n} y_{ij} V_j \qquad j \neq i \tag{65}$$

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From the over the connection, the scientific definition of the power flow issue comes about in a system of algebraic nonlinear conditions which must be illuminated by iterative procedures.

5.2.2 Power Flow Program

Several computer programs have been developed for the power flow solution of practical systems. The method solution consists of four programs. But in this thesis we are using Newton-Raphson method to considerations. The program for the Newton-Raphson strategy is **lfnewton**, which is by **lfybus**, and is taken after by **busout** and **lineflow**. Programs **lfybus**, **busout**, and **lineflow** are designed to be used with two more power flow pograms. **lfybus** This program requires the line and transformer parameters and transformer tap settings specified in the input file named **linedata**. It changes over impedances to admittances and gets the bus admittance matrix. The program is planned to handle parallel lines.

lfnewton This program gets the power flow arrangement by Newton-Raphson strategy and requires the records named busdata and linedata. It is planned for the coordinate utilize of load generation in MW and Mvar, bus voltages in per unit, and angle in degrees. Loads and generation are changed over to per unit amounts on the base MVA chosen. A arrangement is made to preserve the generator reactive power of the voltage controlled buses inside indicated limits. The infringement of reactive power limit may happen on the off chance that the desired voltage is either as well high or too low. After a number of iterations (10th iteration within the Newton-Raphson strategy), the var calculated at the generator buses are inspected.

If a limit is reached, the voltage magnitude is adjusted in steps of 0.5 percent up to ± 5 percent to bring the var demand within the specified limits.

busout This program produces the bus yield result in a arranged frame. The bus yield result incorporates the voltage magnitude and angle, real and reactive power of generator and load, and the shunt capacitor/reactor Mvar. Total generation and total load are also included as outlined in the sample case.

lineflow This program prepares the line output data. It is outlined to show the active and reactive power stream entering the terminals and line losses as well as the net power at each bus. Also included are the total real and reactive losses in the system. The output of this portion is also shown in the sample case.

5.2.3 Data Preparation

In arrange to perform a power stream examination by the Newton-Raphson strategy within the MATLAB environment, the taking after factors must be characterized: power system base MVA, power bungle accuracy, and a greatest number of iterations. The title (in lowercase letters) saved for these factors are basemva, accuracy, and maxiter, separately. Normal values are as takes after:

basemva = 100; accuracy = 0.002; maxiter = 2;

The beginning step within the arrangement of input record is the numbering of each bus. Buses are numbered consecutively. In spite of the fact that the numbers are successively relegated, the buses require not be entered in the grouping. In addition, the following data files are required.

BUS DATA FILE – budata The format for the bus entry is chosen to facilitate the required data for each bus in a single row. The data required must be included in a lattice called busdata. Column 1 is the bus number. Column 2 contains the bus code. Column 3 and 4 are voltage magnitude in per unit and phase angle in degrees. Column 5 and 6 are stack MW and Mvar. Column 7 through 10 are MW, Mvar, least Mvar and Greatest Mvar of generation, In that arrange. The final column is the infused Mvar of shunt capacitors. The bus code entered in column 2 is utilized for distinguishing load, voltage-controlled, and slack buses as sketched out underneath:

1 This code is utilized for the slack bus. The as it were essential data for this bus is the voltage magnitude and its phase angle.

0 This code is utilized for stack buses. The loads are entered positive in megawatts and megavars. For this bus, beginning voltage estimate must be indicated. This is usually 1 and 0 for voltage magnitude and phase angle, respectively. In case voltage magnitude and phase angle for this sort of bus are indicated, they will be taken as the beginning starting voltage for that bus rather than a level begin of 1 and 0.

2 This code is utilized for the voltage-controlled buses for this bus, voltage magnitude, real power generation in megawatts, and the least and greatest limits of the megavar demand must be indicated.

LINE DATA FILE – linedata Lines are distinguished by the node - pair. The data required must be included in a matrix called **linedata**. Column 1 and 2 are theline bus number. Column 3 through 5 contain the line resistance, reactance, and one-half of the full line charging susceptance in per unit on the required MVA base. The final column is for the transformer tap setting; for lines, 1 must be entered in this column. The lines may be entered in any sequence or order with the as it were confinement being that on the off chance that the passage may be a transformer, the cleared out bus number is expected to be the tap side of the transformer.

5.3 Newton-Raphson for Power Flow Solution

Because of its quadratic convergence, Newton’s method is mathematically predominant to the Gauss-Seidel strategy and is less inclined to dissimilarity with ill-conditioned issues. For expansive power systems, the Newton-Raphson strategy id found to be more effective and viable. The number of iterations required to get an arrangement is autonomous of the system measure, but more useful assessments are required at each iteration. Since within the power flow issue real power and voltage magnitude are indicated for the voltage-controlled buses, the power flow condition is defined in the polar form. For the typical bus of the power system shown in Figure 30, the current entering bus i is given by (75). This condition can be modified in terms of the bus admittance matrix as

$$I_i = \sum_{j=1}^{n} Y_{ij} V_j \tag{66}$$

Within the over the condition, j incorporates bus i. Communicating this condition in polar form, we have

$$I_i = \sum_{j=1}^{n} |Y_{ij}||V_j| \angle \theta_{ij} + \delta_j \tag{67}$$

The complex power at bus i is

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$$P_i - jQ_i = V_i^* I_i \tag{68}$$

Substituting from (6.49) for in (6.50)

$$P_i - Q_i = |V_i| \angle -\delta_i \sum_{j=1}^{n} |Y_{ij}||V_j| \angle \theta_{ij} + \delta_j \tag{69}$$

Isolating the real and nonexistent part,

$$P_i = \sum_{j=1}^{n} |V_i||V_j||Y_{ij}| \cos\left(\theta_{ij} - \delta_i + \delta_j\right) \tag{70}$$

$$Q_i = \sum_{j=1}^{n} -|V_i||V_j||Y_{ij}| \sin\left(\theta_{ij} - \delta_i + \delta_j\right) \tag{71}$$

Condition (36) and (37) constitute a set of nonlinear algebraic conditions in terms of the autonomous factors, voltage magnitude in per unit, and phase angle in radians. We have two conditions for each load bus, given by (36) and (37), and one condition for each voltage-controlled bus, given by (36). Expanding (36) and (37) in Taylor's series about the initial estimate and neglecting all higher order terms results in the following set of linear equations.

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$$\begin{bmatrix} \Delta P_2^{(k)} \\ \vdots \\ \Delta P_n^{(k)} \\ \hline \Delta Q_2^{(k)} \\ \vdots \\ \Delta Q_n^{(k)} \end{bmatrix} = \left[\begin{array}{ccc|ccc} \frac{\Delta P_2^{(k)}}{\partial \delta_2} & \cdots & \frac{\Delta P_2^{(k)}}{\partial \delta_n} & \frac{\Delta P_2^{(k)}}{\partial |V_2|} & \cdots & \frac{\Delta P_2^{(k)}}{\partial |V_n|} \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ \frac{\Delta P_n^{(k)}}{\partial \delta_2} & \cdots & \frac{\Delta P_n^{(k)}}{\partial \delta_n} & \frac{\Delta P_n^{(k)}}{\partial |V_2|} & \cdots & \frac{\Delta P_n^{(k)}}{\partial |V_n|} \\ \hline \frac{\Delta Q_2^{(k)}}{\partial \delta_2} & \cdots & \frac{\Delta Q_2^{(k)}}{\partial \delta_n} & \frac{\Delta Q_2^{(k)}}{\partial |V_2|} & \cdots & \frac{\Delta Q_2^{(k)}}{\partial |V_n|} \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ \frac{\Delta Q_n^{(k)}}{\partial \delta_2} & \cdots & \frac{\Delta Q_n^{(k)}}{\partial \delta_n} & \frac{\Delta Q_n^{(k)}}{\partial |V_2|} & \cdots & \frac{\Delta Q_n^{(k)}}{\partial |V_n|} \end{array}\right] \begin{bmatrix} \Delta \delta_2^{(k)} \\ \vdots \\ \Delta \delta_n^{(k)} \\ \hline \Delta |V_2^{(k)}| \\ \vdots \\ \Delta |V_n^{(k)}| \end{bmatrix} \tag{72}$$

Within the over condition, bus 1 is accepted to be the slack bus. The Jacobian matrix gives the linearized relationship between little changes in voltage angle $\Delta \delta_i^{(k)}$ and voltage magnitude $\Delta |V_i^{(k)}|$ with the little changes in real and reactive power $\Delta P_i^{(k)}$ and $\Delta Q_i^{(k)}$. Elements of the Jacobian matrix are the partial derivatives of (36) and (37), evaluated at $\Delta \delta_i^{(k)}$ and $\Delta |V_i^{(k)}|$. In brief frame, it can be composed as

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J_1 & J_2 \\ J_3 & J_4 \end{bmatrix} \begin{bmatrix} \Delta \delta \\ \Delta |V| \end{bmatrix} \tag{73}$$

For voltage-controlled buses, the voltage magnitudes are known. Subsequently, on the off chance that m buses of the system are voltage-controlled, m condition including ΔQ and ΔV and the comparing columns of the Jacobian matrix are disposed of. Appropriately, there are $n-1$ real power constraints and $n-1-m$ reactive power constraints, and the Jacobian matrix is of order $(2n-2-m)\times(2m-2-m)$. J_1 is of the order $(n-1)\times(n-1)$, J_2 is of the order

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$(n-1)\times(n-1-m)$, J_3 is of the order $(n-1-m)\times(n-1)$, and J_4 is of the order $(n-1-m)\times(n-1-m)$.

The diagonal and off-diagonal components of J_1 are

$$\frac{\partial P_i}{\partial \delta_i} = \sum_{j\neq i} |V_i||V_j||Y_{ij}| \sin(\theta_{ij} - \delta_i + \delta_j) \tag{74}$$

$$\frac{\partial P_i}{\partial \delta_j} = -\sum |V_i||V_j||Y_{ij}| \sin(\theta_{ij} - \delta_i + \delta_j) \qquad j \neq i \tag{75}$$

The diagonal and off-diagonal components of J_2 are

$$\frac{\partial P_i}{\partial |V_i|} = 2|V_i||Y_{ii}|\cos\theta_{ii} + \sum_{j\neq i} |V_j||Y_{ij}| \cos(\theta_{ij} - \delta_i + \delta_j) \tag{76}$$

$$\frac{\partial P_i}{\partial |V_j|} = |V_i||Y_{ij}| \cos(\theta_{ij} - \delta_i + \delta_j) \qquad j \neq i \tag{77}$$

The diagonal and off-diagonal components of J_3 are

$$\frac{\partial Q_i}{\partial \delta_i} = \sum_{j\neq i} |V_i||V_j||Y_{ij}| \cos(\theta_{ij} - \delta_i + \delta_j) \tag{78}$$

$$\frac{\partial Q_i}{\partial \delta_j} = -\sum |V_i||V_j||Y_{ij}| \cos(\theta_{ij} - \delta_i + \delta_j) \qquad j \neq i \tag{79}$$

The diagonal and off-diagonal components of J_4 are

$$\frac{\partial P_i}{\partial |V_i|} = -2|V_i||Y_{ii}|\sin \bar{\ }_{ii} - \sum_{j \neq i} |V_j||Y_{ij}|\sin\left(\bar{\ }_{ij} - \text{¢}_i + \text{¢}_j\right) \tag{80}$$

$$\frac{\partial Q_i}{\partial |V_j|} = -|V_i||Y_{ij}|\sin\left(\bar{\ }_{ij} - \text{¢}_i + \text{¢}_j\right) \qquad j \neq i \tag{81}$$

The terms $\Delta P_i^{(k)}$ and $\Delta Q_i^{(k)}$ are the contrast between the planned and calculated values, known as the *power residuals*, given by

$$\Delta P_i^{(k)} = P_i^{sch} - P_i^{(k)} \tag{82}$$

$$\Delta Q_i^{(k)} = Q_i^{sch} - Q_i^{(k)} \tag{83}$$

The modern gauges for bus voltages are

$$\text{¢}_i^{(k+1)} = \text{¢}_i^{(k)} + \Delta \text{¢}_i^{(k)} \tag{84}$$

$$\left|V_i^{(k+1)}\right| = \left|V_i^{(k)}\right| + \Delta\left|V_i^{(k)}\right| \tag{85}$$

The strategy for power flow arrangement by the Newton-Raphson strategy is as takes after:

1. For load buses, where P_i^{sch} and Q_i^{sch} are specified, voltage magnitudes and phase angles are set equal to the slack bus values, or 1.0 and 0.0, i.e., $\left|V_i^{(0)}\right| = 1.0$ and $\text{¢}_i^{(0)} = 0.0$. For voltage-regulated buses, where $|V_i|$ and P_i^{sch} are specified, phase angles are set equal to the slack bus angle, or 0, i.e., $\text{¢}_i^{(0)} = 0$.

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2. For load buses, $P_i^{(k)}$ and $Q_i^{(k)}$ are calculated from (36) and (37) and $\Delta P_i^{(k)}$ and $\Delta Q_i^{(k)}$ are calculated from (48) and (49).

3. For voltage-controlled buses, $P_i^{(k)}$ and $\Delta P_i^{(k)}$ are calculated from (36) and (48), respectively.

4. The elements of the Jacobian matrix $\left(J_1,\ J_2,\ J_3\ and\ J_4\right)$ are calculated from (40) – (47).

5. The linear simultaneous equation (39) is solved directly by optimally ordered triangular factorization and Gaussian elimination.

6. The new voltage magnitudes and phase angles are computed from (50) and (51).

7. The process is continued until the residuals $\Delta P_i^{(k)}$ and $\Delta Q_i^{(k)}$ are less than the specified accuracy, i.e.,

5.4 Foundations by Using Particle Swarm Optimization Method

Particle swarm optimization (PSO) is a population-based on computational strategy motivated by the recreation of the social behavior of a run of winged creatures. PSO was initially outlined and created by Eberhart and Kennedy (J. Kennedy, et al., 2008). A more current form was presented in 1998 by joining inactivity weight. In the group of the particles, the optimization issue is the same answers and they have scattered arbitrarily in the search space. The position of these particles, which alludes to their swarms, is collected from one another. The particles positions are upgraded by utilizing their encounters and the encounters of neighboring particles. In any case, PSO tries to discover the optimal arrangement to the issue by moving the particles and assessing the wellness of the modern position. This upgrade is done by the particle speed vector (A. Mahor, et al., 2009).

The position vector and velocity vector of ith particle in a d-dimensional search space are expressed as follows (Q. Bai, et al., 2010), (J.B. Park, et al., 2005):

$$X_i = \left(x_{i1}, x_{i2}, \ldots, x_{id}\right) \tag{86}$$

$$V_i = \left(v_{i1}, v_{i2}, \ldots, v_{id}\right) \tag{87}$$

The finest previous position of a particle is recorded and shown based on the assessment function value as takes after:

$$pbest = \left(p_{i1}, p_{i2}, \ldots p_{id}\right) \tag{88}$$

On the off chance that g as the particle has the finest position in a swarm in comparison with other particles at that point the circumstance is appeared as underneath:

$$gbest = gbest_g = \left(p_{g1}, p_{g2}, \ldots, p_{gd}\right) \tag{89}$$

$$\left|gbest^k - gbrst^{k-1}\right| < £ \tag{90}$$

Each particle tries to progress this position from individual best position (pbest) by utilizing speed and separate to global best position (gbest). Speed and position of each particle in the current position will be connected to the particle position to fit in the next step, which is calculated by utilizing the taking after equations (Q. Bai, et al., 2010):

$$v_{id}^{k+1} = C\left[w \times v_{id}^{k} + c_1 \times rand_1\left(pbest_{id} - x_{id}\right) + c_2 \times rand_2\left(gbest_{gd} - x_{id}\right)\right] \quad (91)$$

$$x_{id}^{k+1} = x_{id} + v_{id}^{k+1} \quad (92)$$

$$c = \frac{Z}{\left|2 - ¤ - \sqrt{¤^2 - 4¤}\right|}, \quad ¤ = c_1 + c_2 \quad (93)$$

Where c is constriction factor, w is inertia weight parameter, c_1 is cognitive coefficient, c_2 is social coefficient and $rand_1$, $rand_2$ are the random number between 1, 0.

The PSO parameters impact in optimization huge sum of inactivity weight parameter (w) has contributed to worldwide look, while a little sum of it is the nearby personality. So, at the starting of the look, we select an expansive sum of inactivity weight parameter and slowly diminishes in the next emphasizes. So, idleness weight parameter is gotten by utilizing the taking condition: Where iter is the number of current iterations and itermax is the greatest number of iterations.

$$w = \left(w_{\max} - w_{\min}\right)\frac{\left(iter_{\max} - iter\right)}{iter_{\max}} + w_{\min} \quad (94)$$

Where iter is the number of current iterations and $iter_{max}$ is the maximum number of iterations. Normally, parameter w can be changed between 0.4 and 0.9. Although the PSO method leads to acceptable answer by using w time variant, it is weak for global optimization.

Study results demonstrate that the PSO strategy is optimal by setting parameters based on the nature and type of issue, a key factor in accomplishing an exact and effective arrangement. On the one hand, in case we select expansive values for cognitive coefficient (c_1) in comparison with a social coefficient (c_2), the particle direction is a huge search space. In the other words, a generally huge amount of social coefficient leads the position of the particle in the untimely neighborhood optimization.

The optimization methods based on PSO are:

• In the early stages of the search, the particles are transmitted by the whole search space, without being caught in nearby optimum focuses, and

• Next steps in the search, the particles are pushed towards the worldwide optimum point, appropriately, the optimal point to be accomplished proficiently. In arrange to optimize, we utilize c_1 and c_2 time-varying increasing speed.

The fundamental thought is in the early stages of updates across the nation search, and at that point in the last stages of the search, particles move in the heading of merging towards the worldwide optimal point.

In this methodology, with the advance of the search prepare, the cognitive coefficient (c_1) steadily declined, while the social coefficient (c_2) increments. With the expansive amount of force coefficient c_1 and a little amount of speeding up coefficient c_2 are permitted in search of the particles, Or maybe than going to the neighborhood optimal point in their travel over the search space. On the other hand, the increasing speed coefficient c_1 is little and c_2 is expansive that permits for the particles move to the worldwide optimum point.

c_1 and c_2 on the increasing speed coefficient can be communicated:

$$c_1 = \left(c_{1f} - c_{1i}\right)\frac{iter}{iter_{\max}} + c_{1i} \tag{95}$$

$$c_2 = \left(c_{2f} - c_{2i}\right)\frac{iter}{iter_{\max}} + c_{2i} \tag{96}$$

Where c_{1i} is initial cognitive coefficient: c_{1f} is final cognitive coefficient, c_{2i} is initial social coefficient and c_{2f} is final social.

The unique particle swarm optimization algorithm has experienced a number of changes since it was, to begin with, proposed. Most of these changes influence the way the speed of a particle is overhauled. In the taking after subsection, Discrete PSO briefly portrays a few of the most imperative advancements (M. Dorigo, et al., 2008).

Most particle swarm optimization algorithms are planned to search in persistent spaces. In any case, there are a number of variations that work in discrete spaces. The to begin with variation proposed for discrete spaces was the double particle swarm optimization algorithm (Kennedy and Eberhart, et al., 1997). In this algorithm, a particle's position is discrete but its speed is persistent. Speeds are overhauled as in the standard PSO algorithm, but positions are overhauled utilizing the taking run the show (M. Dorigo, et al., 2008).

$$x_{id}^{k+1} = \begin{cases} 1 & \text{if } \mathrm{R} < \mathrm{Sig}\left(\mathrm{v}_{\mathrm{id}}^{\mathrm{k+1}}\right) \\ 0 & \text{otherwise} \end{cases} \tag{97}$$

$$Sig(x) = \frac{1}{1+e^{-x}} \tag{98}$$

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CHAPTER VI

CO-OPTIMIZATION FOR OPTIMAL NETWORK FLOW

6.1 Introduction

Clean energy and water are two fundamental assets that any society must safely provide (A. R. Hoffman.,2012) in arrange to create reasonably; i.e. meet its economic, social and natural objectives. In the case of energy, the abuse of ordinary assets has driven to their quick exhaustion (S. M. N. Islam, et al., 2003). Besides, the related emanation of carbon, nitrogen, and sulfur oxides has caused natural issues such as worldwide climate alter, brown haze, and corrosive rain separately (J. Glasson, et al., 2005). Thus, investigate clean renewable energy assets and energy efficiency strategies have expanded. Additionally, consumable water is another imperative asset for survival and advancement. Expanded water utilize has developed significantly in later a long time; following emphatically with energy utilities and economic advancement and driving to drained water tables in numerous geographic regions (United Nations, 2012). Subsequently, there is an imperative require to optimize both energy and water assets. Hence, the co-optimization of water generation and power generation has picked up a newly discovered significance (A. M. El-Nashar, 2001) in light of rapidly draining worldwide energy assets (F. Akdeniz, et al., 2002), expanded concern around national security (J. J. Bogardi, et al., 2012), and the requirements for feasible financial development (S. M. N. Islam, et al., 2003).

Customarily water dissemination and power transmission systems are thought of as partitioned uncoupled foundation frameworks. In any case, in reality, they are exceptionally much coupled in what is commonly known as the energy-water nexus (G. Olssonn, 2012). As appeared in Table I, the energy and water frameworks may be seen as two interlinked value chains. The most prominent consideration has been given to the cross-interactions of energy supply to water request or bad habit versa. Numerous observational strategies have endeavored to quantitatively evaluate the water utilization necessities of thermal power generation facilities (J. Macknick et al., 2011). Additionally, inquire about is underway to move forward innovations that would decrease this affect (R. Pate, et al., 2007). Another cross-coupling is the electrical pumping energy required to deliver and alacrity consumable water (B. Griffiths-Sattenspiel, et al., 2009). As the subject of this paper, co-production facilities like hydroelectric and thermal desalination plants (A. M. El-Nashar, 2001) couple the individual supply sides of energy and water (A. Cipollina, et al., 2009). At long last, the private, commercial, and mechanical utilize of electric warming and cooling for water utilization presents a major coupling on the request side of both frameworks (G. M. Thirwell, et al., 2007).

Table 6.1 Supply and demand side couplings

Item	**Power Supply**	**Power Demand**
Water Supply	Co-generation	• Pumped Water
	• Thermal Desalination	• Water Distribution
	• Hydroelectric	• Wastewater Recycling
Water Demand	Thermal-Power Generation Facilities	Residential, Commercial, & Industrial Use of Electric Heating &Cooling of Water

In spite of the fact that the energy-water nexus has as of late caught the consideration of various arrangement and administrative offices (J. Macknick et al., 2011), once in a while is it comprehensively tended to in terms of a coordinates designing framework system for its administration, arranging, and direction as an intriguing concern. Later investigate into smart (power) lattice activities verifiably requires a rebalancing of the power generation innovation portfolio (G. Kassakian, et al., 2011). Furthermore, smart (water) grid activities certainly require a rebalancing of the water supply advances be they desalination, groundwater pumping or water reusing (T. M. Walski, et al., 2007). Paradigmatically, as well as mechanically, there is a extraordinary potential for the merging of these work streams. As of late, the energy-water nexus has been modeled as a coordinates designing framework (W. N. Lubega, et al., 2013) and starting work for all-encompassing quantified arranging is detailed (W. Lubega, et al., 2013). This work specifically addresses the supply side of this coordinates building framework system in acknowledgment of the coupling part that cogeneration facilities play. Mechanically, cogeneration gives numerous preferences; the first being the more efficient utilize of fuel, and the second being the generation of more than one valuable product. In northern European nations, co-production can be utilized to supply power and heat, while in Middle Eastern countries, co-production of power and water is the common sense of the deficiency of new water assets. Since both these assets require to be dispatched through a distribution network and co-production plants deliver both power and water, there are significant focal points to optimizing both at the same time (A. M. El-Nashar, 2001), (M. J. Safi, et al., 1999). In this manner, this paper takes as its subject optimal network flows for the supply side of the energy-water. Past work on the subject by the authors has explored the couplings inside the simultaneous dispatch of power and water (A. Santhosh, et al., 2012).

In this paper, the consideration centers on economic dispatch with comparing the Particle Swarm Optimization (PSO) strategy and Optimal Power Flow (OPF) strategy. Economic dispatch issue has ended up a significant assignment in the operation and arranging of the power system. Particle swarm optimization has been utilized to illuminate numerous optimization issues. In PSO, each particle moves in the look space with a speed concurring to its possess past best arrangement and its group's past best arrangement (A.P. Engelbrecht, 2005).

The unique PSO portrayed moo is fundamentally created for the persistent optimization issue. The objective of an Optimal Power Flow (OPF) strategy is to discover relentless state working point which minimizes generation cost, losses, etc. or maximizes social welfare, load capacity etc. Customarily, classical optimization strategies were utilized to successfully unravel OPF. In later a long time, Artificial Intelligence (AI) strategies have developed which can illuminate exceedingly complex OPF issues (H.W. Dommel, et al., 1986).

6.2 Background

This area highlights perspectives of the foundation writing for power-water co-optimization in four steps. To begin with, the writing on power and water co-optimization is reviewed. Next, optimal power flow is presented as a prerequisite single item optimization. Optimal water flow is at that point additionally depicted. And the optimal cost of small hydropower plant to improve quality of power and water networks.

6.2.1 Co-Optimization of Power and Water

The operations inquire about writing on cogeneration control and water offices have advanced over a long time from single plant optimization to full-scale multi-plant inquire about. For example, a few works has centered on the optimized arranging and plan or maybe than operation (E.-N. Ali M, 2008). Still, others find strategies of cost allocation (E.-N. Ali M, 1999). At long last, one creator specifically addresses the economic dispatch of a single specific office composed of a number of sub-units but not one or the other generalizes the detailing nor applies it to all the water and generation units in their individual grids (A. M. El-nashar, et al., 1991). These works do not give an extensible and common optimization pertinent to dual-product multi-plant markets. Dual-product multi-plant optimization programs have too been created. The first involvement was that of northern European nations where an economic dispatch approach has been connected to power and heat. A single objective work for cogeneration plants based on power and heat is shaped and at that point optimized subject to power and heat generation capacity (C. Algie, et al., 2004). As it were recently, an economic dispatch approach for power and water has been created that considers demand, prepare, and capacity imperatives (A. Santhosh, et al., 2012), (A. Santhosh, et al., 2013). An expansion of this work considered inclining rates and the presentation of power and water capacity facilities (A. Santhosh, et al., 2013), (A. Santhosh, et al., 2013). These works took as their focus require meeting the power and water demand. In so doing, they highlighted the interaction that develops as capacity, inclining, and storage constraints move power and water generation levels over the two grids.

6.2.2 Optimal Power Flow

A wide assortment of optimization procedures have been connected in understanding the OPF issues (Dommel H, et al., 1999) such as nonlinear programming (Dommel H, et al., 1989), quadratic programming (Burchett RC, et al., 1987), linear programming (Abou El-Ela AA, et al., 1992),(Stadlin W, et al., 1986), Newton-based methods (Sun DI, et al., 1984),(Santos A, et al., 1995), successive unconstrained minimization method (Rahli M, et al., 1999), and insides point strategies (Yan X, et al., 1999),(Momoh JA, et al., 1999). For the most part, nonlinear programming based methods have numerous downsides such as uncertain merging properties and algorithmic complexity. Quadratic programming based methods have a few drawbacks related to the piecewise quadratic cost estimation. Newton-based procedures have a disadvantage of the meeting characteristics that are delicate to the introductory conditions and they may indeed fall flat to merge due to the unseemly beginning conditions. Successive unconstrained minimization procedures are known to display numerical troubles when the punishment components ended up amazingly expansive. In spite of the fact that linear programming strategies are quick and solid, they have a few impediments related to the piecewise linear cost estimation. Insides point strategies have been detailed as computationally productive. In any case, on the off chance that the step measure is not chosen legitimately, the sub-linear issue may have an arrangement that is infeasible in the unique nonlinear space (Yan X, et al., 1999). In the expansion, insides point strategies, in common, endure from terrible introductory, end, and optimality criteria and, in most cases, are incapable to fathom nonlinear and quadratic objective capacities (Momoh JA, et al., 1999). For more dialogs on these methods, we coordinate the peruser to consult the comprehensive study displayed in Ref. (Momoh J, et al., 1999).

Heuristic calculations such as genetic algorithms (GA) (Lai LL, et al., 1997) and developmental programming (Yuryevich J, et al., 1999) have been as of late proposed for fathoming the OPF issue. The results detailed were promising and empowering in advance investigate in this course. For the purposes of this paper, the least difficult and most commonly displayed OPF details suffice. The AC OPF issue is portrayed as (F. Milano, 2010):

$$\min C_p\left(X_p\right) = \sum_{n=1}^{n_{pp}} C_{pi}\left(x_{pi}\right) \quad (99)$$

Subject to:

$$x_{pz} - D_{pz} = v_z \sum_{y=1}^{m_p} v_y \left[G_y \cos\left(\text{¯}_{yz}\right) + B_{yz} \sin\left(\text{¯}_{yz}\right)\right] \quad (100)$$

$$x_{qz} - D_{qz} = v_z \sum_{y=1}^{m_p} v_y \left[G_{yz} \sin\left(\text{¯}_{yz}\right) - B_{yz} \cos\left(\text{¯}_{yz}\right)\right] \quad (101)$$

$$P^{\min} \le X_p \le P^{\max} \quad (102)$$

$$Q^{\min} \le X_q \le Q^{\max} \quad (103)$$

$$V^{\min} \le V \le V^{\max} \quad (104)$$

$$\begin{aligned} p_{yz}^{\min} &\le v_y z_y \left(G_{yz} \cos\text{¯}_{yz} + B_{yz} \sin\text{¯}_{yz}\right) - G_{yz} v_y^2 \le p_{yz}^{\max} \\ q_{yz}^{\min} &\le v_y z_y \left(G_{yz} \sin\text{¯}_{yz} - B_{yz} \sin\text{¯}_{yz}\right) - B_{yz} v_y^2 \le q_{yz}^{\max} \end{aligned} \quad (105)$$

$$\text{¢}_1 = 0 \quad (106)$$

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Where Equation 99 is the cost function, Equation 100, 101 gives the power flow Equations, Equation 102, 103captures the generator active and reactive power limits, Equation 104 limits the bus voltages and Equation 105 describes the line flow limits. The power plant index i is taken to be same as the bus indices y and z for all power plants. G_{yz}, B_{yz} θ_{yz} are the conductance, the susceptance and the voltage angle difference between buses y and z. x_{pz} and D_{pz} are the active power injections of the generators and loads while x_{qz} and D_{qz} are the reactive power injections. V is the bus voltage vector. Equation 106 sets the slack bus to zero. The AC OPF formulation is not straightforwardly tractable and is often replaced by the linearized DC OPF problem. Three approximations are made to that effect (P. Schavemaker, et al., 2008):

1) v_y = 1pu ∀y. Node voltages are set to unity per unit.

2) G_{yz} = 0. Lines are assumed to be lossless.

3) $\sin(\theta_{yz})=\theta_{yz}$, $\cos(\theta_{yz})$ = 1. Trigonometric terms have small angles.

6.2.3 Optimal Water Flow

In spite of being comparable in numerous ways, water flow has not been investigated to the same degree. In any case, there are a few papers that bargain with optimization for both plan and optimization purposes (B. Coulbeck, 1979),(E. Ramirez-Llanos, et al., 2010),(E. Salomons, 2010). When considering water flow systems, one needs to guarantee progression: that add up to flow entering a hub is rise to the entirety of the request at that point and the outflow. Furthermore, the weight (head) misfortune between hubs needs to be included.

These constraints are formulated as shown below:

$$\sum_{t=1}^{m_w} Q_{tu} - D_{wt} - L_{wj} = 0 \tag{107}$$

$$H_t - H_u = R_{tu} Q_t \left| Q_u \right|^{n-1} \tag{108}$$

Where Q_{tu} is the water flow in between nodes t and u, m_w is the total number of pipes, D_{wt} is water demand at the t^{th} node, H_t is tth nodal head, R_{tu} is the resistance coefficient in the pipe connecting t and u and n is flow exponent in the head loss equation. The flow exponent depends on the selection of the head loss relationship. In the Darcy-Weisbach relationship, n=2, whereas in Hazen-Williams relationship n=1.852. The Darcy-Weisbach equation is generally speaking more accurate, but the Hazen-Williams equation can also provide useable values for head loss with much less intensive calculation needed (1984), (T. Haktanr, et al., 2004).

6.2.4 Optimal Small Hydro Power Plant

Displayed fetched decrease contemplations in little hydropower improvement (Minott D, et al., 1983). Moreover, displayed the examination of the taken a toll for the restoration of small hydropower plants (Ogayar B, et al., 2009). Additionally, utilized relapse investigation based on genuine amounts of different components of a dam toe SHP (Singal SK, et al., 2008). Therefore, displayed a genuine alternatives approach for making the ideal venture choice in little hydropower plants (Backman T, Fleten SK, Juliussen E, Langhammer Havard J, Revdal I.,(2008)). Parallel, examined that small hydropower innovation ought to be cost-effective and appropriate for neighborhood conditions for maintainable improvement (Jiandong T, et al., 2009). Hence, decided the ideal establishment capacity of the SHP plant and assessed its ideal yearly vitality esteem. A program was created to analyze and appraise the financial files of an SHP plant utilizing affectability investigation (Hosseini SMH, et al., 2005). And, displayed a demonstrate for assessment of SHP plant era framework unwavering quality and time arranging. The show considers the instabilities of stream flows and time units operation (Borges Carmen LT, et al., 2008). But, displayed an investigation of capital fetched per unit of appraised capacity and relative cost correlations of distinctive sub-systems of small-scale hydropower ventures were carried out (Nouni MR, et al., 2006). Finally, talked about the cost correlations relationships of diverse components of canal-based SHP plans were decided. The fetched relationships were created based on distinctive head and capacity (Singal SK, et al., 2008). The establishment cost of the small hydropower extend is primarily partitioned into two parts - Civil works and electromechanical gear. The cost of the gear implies a tall rate of the total budget of the plant. The show paper extraordinary to create a relationship to decide the fetched based on the impacting parameters such as power and head (Sachin Mishra, et al., 2012).

These constraints are formulated as shown below:

$$C_{(a,b,c)} = a \times P^{b} \times H^{c} \qquad (109)$$

Where

a, b and c are coefficients

C = Cost in rupees

P = Installed capacity in kilo Watt (kW)

H = Head in meter (m)

The AC OPF issue is portrayed as:

$$\min C_{s}\left(X_{s}\right) = \sum_{h=1}^{n_{ph}} C_{ph}\left(x_{ph}\right) \qquad (110)$$

Subject to:

$$P^{\min} \le X_s \le P^{\max} \tag{111}$$

Where Equation 110 is the cost function, Equation 100, 101 gives the power flow equations

6.3 Economic Dispatch with Particle Swarm Optimization

As specified prior, the PSO algorithm for tackling the complex issues of ED, fuel costs, capacity impediments and other limitations will be considered. The PSO is a property of supreme convergence.

6.3.1 The Power Economic Dispatch Model (J.B. Park, et al., 2005),(A. Mahor, et al., 2009),(M. Dorigo, et al., 2008),(H. Shayeghi, et al., 2012),(H.A. Shayanfar, et al., 2012).

1. Specification of the objective function

$$\min\cos t = \sum_{i}^{N_{gg}} F_i\left(P_i\right) \tag{112}$$

Where N_{gg} is the number of units (generator), and F_i (P_i) is cost function for i^{th} unit.

$$F_i\left(P_i\right) = a_i P_i^2 + b_i P_i + c_i \tag{113}$$

Where a_i, b_i , c_i are the coefficients of the cost of i^{th} generator.

2. Limitations (Constraints):

a) Limitations for the operation of the unit:

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$$P_i^{\min} \le P_i \le P_i^{\max} \tag{114}$$

The $P_i^{\min}$ and $P_i^{\max}$ are minimum and maximum generation, respectively.

b) Balance of power:

$$\sum_{i=I}^{N_g} P_i = P_L + P_D \tag{115}$$

Where P_L is the loss function and P_D is the load power losses can be obtained from matrix format (B matrix).

The P_L can be obtained with loss matrix.

$$P_L = P^T BP + P^T B_0 + B_{00} \tag{116}$$

Where B_0 and B_{00} are the coefficients of the loss matrix.

3) Constraint of power transition:

$$\left|Lf_i\right| \le Lf_i^{\max} \quad ,\text{i=1,2,.....,N}_L \tag{117}$$

Where $Lf_i^{\max}$ is the maximum allowable power from transmission line based on MW and NL is the transmission line.

4) Limitations on network stability

$$\left|¢_i - ¢_j\right| \le ¢_{ij}^{\max} \quad ,\text{i,j,.....N}_D \text{ , i} \ne \text{j} \tag{118}$$

Where ϕ_{ij} is the first voltage angle (load angle) at the bus of (*i*, *j*) and $\phi_{ij}^{\max}$ is the maximum voltage angle. The (*i*-*j*) are indicators of the line i-j and N_D is the number of bus that has limitation for network stability.

6.3.2 The Water Economic Dispatch Model (M. Spiliotis, et al., 2011),(MAJID NIAZKAR, et al., 2017)

1. Specification of the objective function

$$\min \cos t = \sum_{j}^{N_{wg}} q_j \left(W_j\right) \tag{119}$$

Where N_{wg} is the number of units (water generation), and q_j (W_j) is cost function for j^{th} unit.

$$q_j \left(W_j\right) = a_j W_j^2 + b_j W_j + c_j \tag{120}$$

Where a_j, b_j , c_j are the coefficients of the cost of j^{th} water generation.

2. Limitations (Constraints):

a) Limitations for the operation of the unit:

$$W_j^{\min} \le W_j \le W_j^{\max} \tag{121}$$

The $W_j^{\min}$ and $W_j^{\max}$ are minimum and maximum water generation, respectively.

b) Balance of water:

$$\sum_{j=I}^{N_{wg}} W_j = W_L + W_D \tag{122}$$

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Where W_L is the loss of water and W_D is the load water demand

The W_L can be obtained with loss matrix.

$$R_{in} = \frac{8 f_{in} L_{in}}{g® ^2 D_{in}^5} \tag{123}$$

$$W_L = R_{in} \times Q_{in}^2 \tag{124}$$

Where

Q_{in} and R_{in} = discharge (m3/s) and the resistance of the branch i-n [m/m3/s)^2], respectively. Also, f_{in} = friction factor. Finally, D_{in} = internal diameter (m); L_{in} = length of the branch (m); respectively.

6.3.3 Implementation

The quickened particle swarm optimization has been executed by utilizing MATLAB. In the event that we run the program, we will get the worldwide optimum after around 200 assessments of the objective work (for 20 particles and 10 iterations).

6.3.4 Limitations

For obliged optimization, there are numerous ways to execute the constraint equities and disparities. In any case, we will as it talked about two approaches: coordinate usage and change to unconstrained optimization. The modern arrangements are assessed by utilizing the standard PSO method. In this way, all of the modern areas ought to be in the doable locale, and all infeasible arrangements are not chosen. There are other varieties of particle swarm optimization, and PSO algorithms are regularly combined with other existing algorithms to create unused cross breed algorithms. In reality, it is still an active region of investigating with numerous modern considers are being distributed each year.

6.4 Problem Formulation

An optimal cost of the small hydropower plant to improve the quality of power and water networks in Laos P.D.R can be viewed as the combination of the four types of literature reviewed in Section II into a single optimization program. The problem formulation builds upon the previous work on simultaneous co-dispatch of power and water while introducing the constraints from optimal power flow and optimal water flow.

Prior to proceeding a summary of the utilized nomenclature is provided in Table 6.2

Table 6.2 Summary of nomenclature for the optimal flow of developing energy sources Laos P.D.R

	Power Domain	Water Domain
Power plant		
Index	I	
Number	n_{pp}	
Product	x_{pi}	
Minimum Capacity Limit	$P_i^{\min}$	
Maximum Capacity Limit	$P_i^{\max}$	
Incidence Matrix	I_{piy}	
Cost Function	$C_{pi}(x_{pi})$	
Water Plant		
Index		j
Number		n_{wp}
Product		x_{wj}
Minimum Capacity Limit		$W_j^{\max}$

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Table 6.2 Summary of nomenclature for the optimal flow of developing energy sources Laos P.D.R (Continued)

	Power Domain	Water Domain
Maximum Capacity Limit		$W_j^{\min}$
Incidence Matrix		I_{wjt}
Cost Function		$C_{wj}\left(x_{wj}\right)$
Cogeneration Plant		
Index	k	k
Number	n_{cp}	n_{cp}
Product	x_{cpk}	x_{cwk}
Minimum Capacity Limit	$CP_k^{\min}$	$CW_k^{\min}$
Maximum Capacity Limit	$CP_k^{\max}$	$CW_k^{\max}$
Incidence Matrix	I_{cky}	I_{ckt}
Cost Function	$C_{ck}\left(x_{cpk}, x_{cwk}\right)$	
Distribution Network		
Bus Node Indices	Y, z	T, u
Number	m_p	m_w
Demand	D_{py}	D_{wt}
Electric Admittance	B_{yz}	
Electric Conductance	G_{yz}	
Hydraulic Resistance		R_{tu}
Voltage	V_y	
Voltage Angle	¢$_y$	
Pressure		H_t
Flow		F_{tu}
Minimum Flow	$PFlow_{yz}^{\min}$	$PFlow_{yz}^{\max}$
Maximum Flow	$WFlow_{tu}^{\min}$	$WFlow_{tu}^{\max}$
Small Hydro Power Plant		
Index	h	
Number	n_{ps}	
Product	x_{ph}	
Minimum Capacity Limit	$P_h^{\min}$	

Table 6.2 Summary of nomenclature for the optimal flow of developing energy sources Laos P.D.R (Continued)

	Power Domain	Water Domain
Maximum Capacity Limit	$P_h^{\max}$	
Incidence Matrix	I_{pht}	
Cost Function	$C_{ph}\left(x_{ph}\right)$	
Head in meter (m)	H_{ph}	

The issue definition builds upon the past work on simultaneous co-dispatch of power and water while presenting the constraints from optimal power flow and optimal water flow.

The primal issue is at that point formally depicted as the constrained optimization of the total generation cost function C_G:

$$\min C_G\left(x_{pi}, x_{wj}, x_{ck}, x_{ph}\right) = \sum_{i=1}^{n_{pp}} C_{pi}\left(x_{pi}\right) + \sum_{j=1}^{n_{wp}} C_{wj}\left(x_{wj}\right) + \sum_{k=1}^{n_{cp}} C_{ck}\left(x_{cpk}, x_{cwk}\right) \quad (125)$$

Where $C_{pi}\left(x_{pi}\right)$, $C_{wj}\left(x_{wj}\right)$, $C_{ck}\left(x_{cpk}, x_{cwk}\right)$ are the cost functions for i^{th} power generation plant, the j^{th} water production facility, the k^{th} cogeneration and the h^{th} small hydro power plants facility respectively. The cost functions may take any one of a number of functional forms including linear, piecewise linear, quadratic and cubic. The latter three are most often applied to account for the economies of scale found in most industrial production facilities. As in prior work (A. Santhosh, et al., 2012), (A. Santhosh, et al., 2013), the costs functions here are taken as quadratic in their respective decision variables.

$$C_{pi}\left(x_{pi}\right)=a_{2i}x_{pi}^{2}+a_{1i}x_{pi}+a_{0i}$$
$$C_{wj}\left(x_{wj}\right)=a_{2j}x_{wj}^{2}+a_{1j}x_{wj}+a_{0j}$$
$$C_{ck}\left(x_{cpk},x_{cwk}\right)=a_{11k}x_{cpk}^{2}+a_{22k}x_{cwk}^{2}+a_{12k}x_{cpk}x_{cwk}+a_{1k}x_{cpk}+a_{2k}x_{cwk}+a_{0k} \qquad (126)$$

The objective function is subjected to active power flow constraint in Equation 110, 111 with the DC power flow approximations. It also specifically adds a term for the cogeneration facilities.

$$\forall y=\{1......m_{p}\}$$
$$\sum_{k=1}^{n_{cp}} I_{cky}x_{cpk}+\sum_{i=1}^{n_{pp}} I_{piy}x_{pi}-D_{py}-\sum_{y=1}^{m_{p}} B_{yz}\left(\text{¢}_{y}-\text{¢}_{z}\right)=0 \qquad (127)$$

Similarly, the water balance constraint in Equation 107, 108 adds another term for the cogeneration facilities.

$$\forall t=\{1.....m_{w}\}$$
$$\sum_{k=1}^{n_{cw}} I_{ckt}x_{cwk}+\sum_{j=1}^{n_{wp}} I_{wjt}x_{wj}-D_{wt}-\sum_{t=1}^{m_{w}} F_{tu}=0 \qquad (128)$$

The power and water generation limits are then gathered together for all three types of production facilities.

$$P_{i}^{\min}\le X_{p}\le P_{i}^{\max}$$
$$W_{j}^{\min}\le X_{w}\le W_{j}^{\max}$$
$$CP_{k}^{\min}\le X_{cpk}\le CP_{k}^{\max} \qquad (129)$$
$$CW_{k}^{\min}\le X_{cwk}\le CW_{k}^{\max}$$

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The power and water flow limits are then gathered

$$\forall y, z = \{1.....m_p\} : \text{ and } \forall \text{t,u} = \{1.....m_w\}$$

$$\begin{aligned} PFlow_{yz}^{\min} \le B_{yz}\left(\text{¢}_y - \text{¢}_z\right) \le PFlow_{yz}^{\max} \\ WFlow_{tu}^{\min} \le Q_{tu} \le WFlow_{tu}^{\max} \end{aligned} \qquad (130)$$

6.5 Simulation Methodology

The optimization program given over was carried out on a recently created hypothetical system. As this program is the to begin with of its kind, no standardized test cases could be found in the writing. Instep, a single system of the direct estimate was created from individual power and water topologies. The power network admittance data was taken from the standard IEEE 14 bus system, IEEE 30 bus system, and IEEE 118 bus system. The bus system of these was taken as a cogeneration facility.

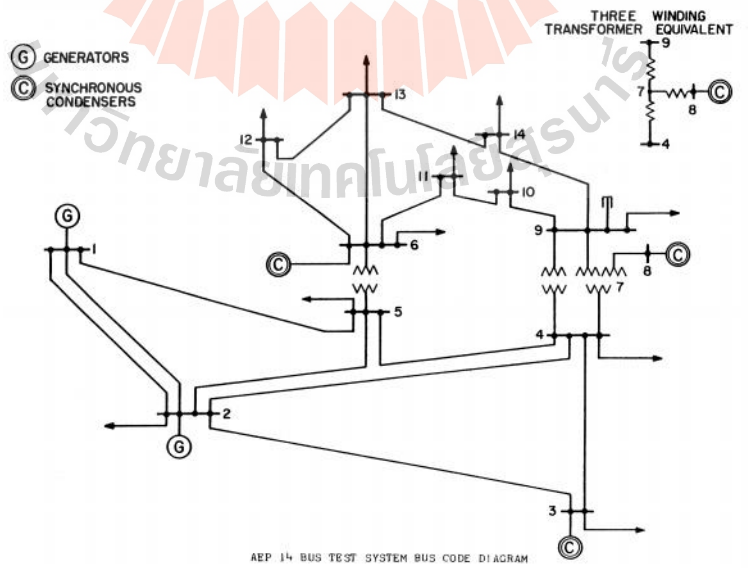

Figure 6.1 Power Network - IEEE 14 bus system

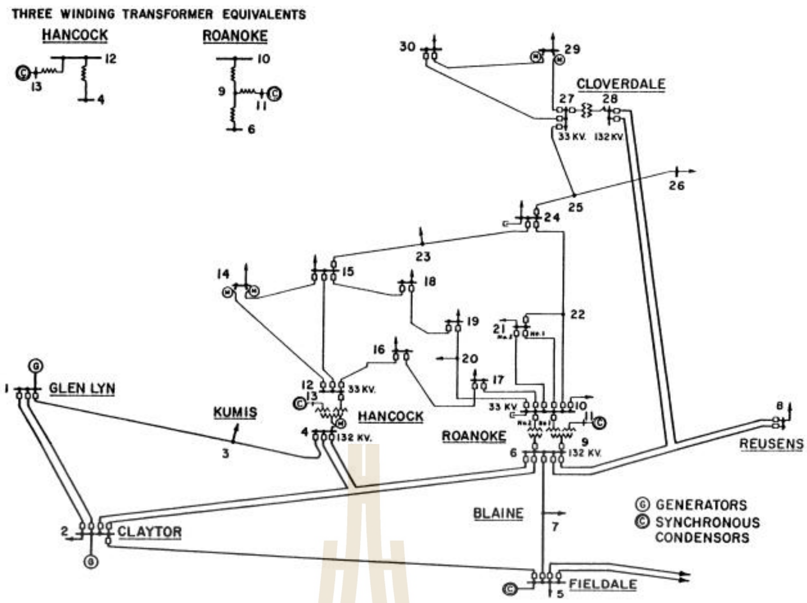

Figure 6.2 Power Network - IEEE 30 bus system

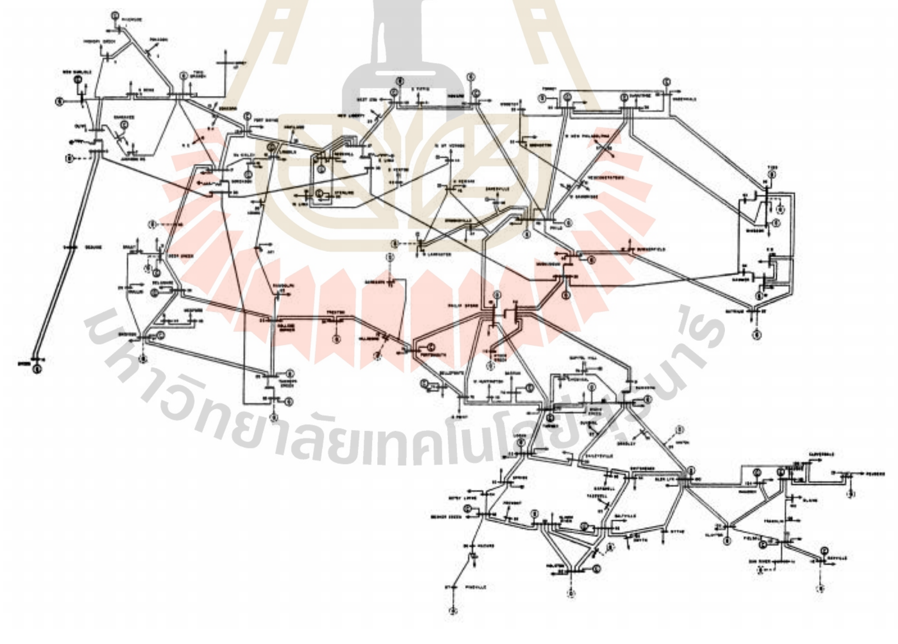

Figure 6.3 Power Network - IEEE 118 bus system

The water network system comprises of six nodes has appeared in (MAJID NIAZKAR, et al., 2017) and incorporates a water plant at node 6, small hydropower plants at node 1, 2 and a cogeneration office at node 3, 4, 5. The interested peruser alludes to the supporting (M. Spiliotis, et al., 2011) , (MAJID NIAZKAR, et al., 2017) for a total set of the input data.

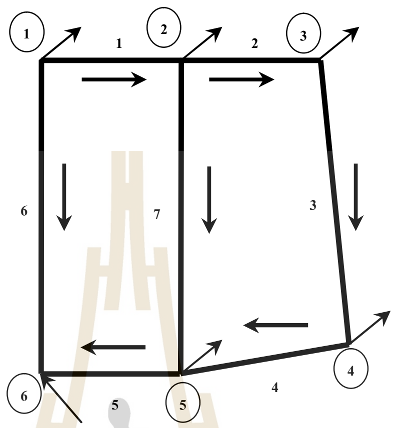

Figure 6.4 Water Network - 6 node systems

The optimization was conducted for 1 hourly power and water requests values with significantly distinctive greatest and least values and actualized in the MATLAB code program on a HP Laptop with an Intel Celeron CPU1.9 GHz processor.

6.5.1 Case Study in Laos P.D.R

The optimization program given over was carried out on a recently created hypothetical system. As this program is the to begin with of its kind, no standardized test cases could be found in the writing. Instep, a single system of the direct estimate was created from individual power and water topologies. The power network admittance data was taken from 16 bus system in southern Laos.

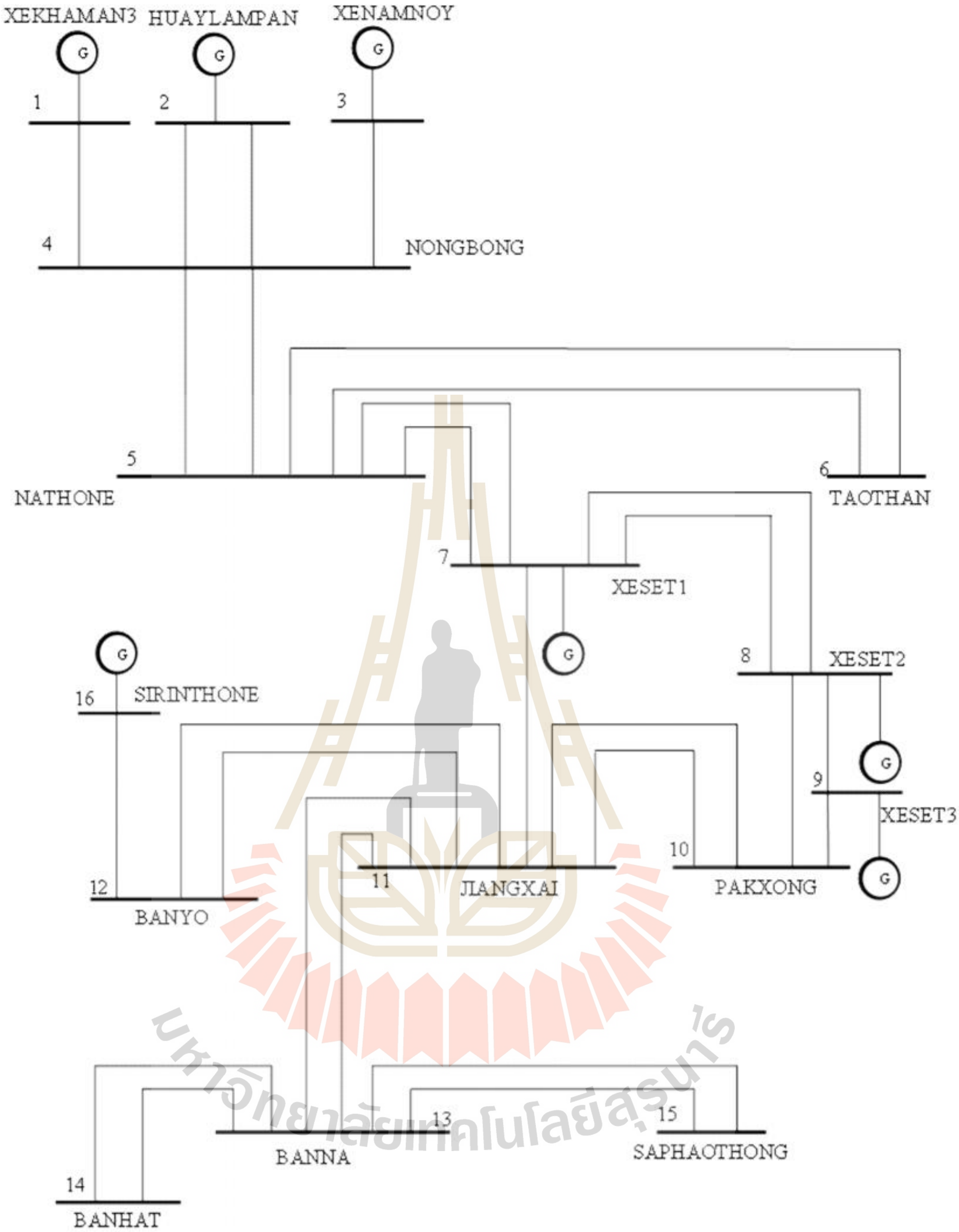

Figure 6.5 Power Network - 16 bus system in southern Laos

In this sector will be able to draw network diagrams corresponding to flow problems and an interpret networks in XEDON river basin. In addition, be able to find optimum flow rates in a network in XEDON river basin, subject to constraints.

Moreover, be able to use the algorithm to find the minimum flow rate in a network of XEDONE river basin. Finally, be able to interpret the analysis of a network for real life problems

Using two model dams in the simulation will be applied to the standard system. Which will be simulation to install dam at the location various in Xedon Basin then test a power supply into the standard system IEEE 14 bus, IEEE 30 bus, IEEE 118 bus and tested deemed adequate by water supply needs of the user.

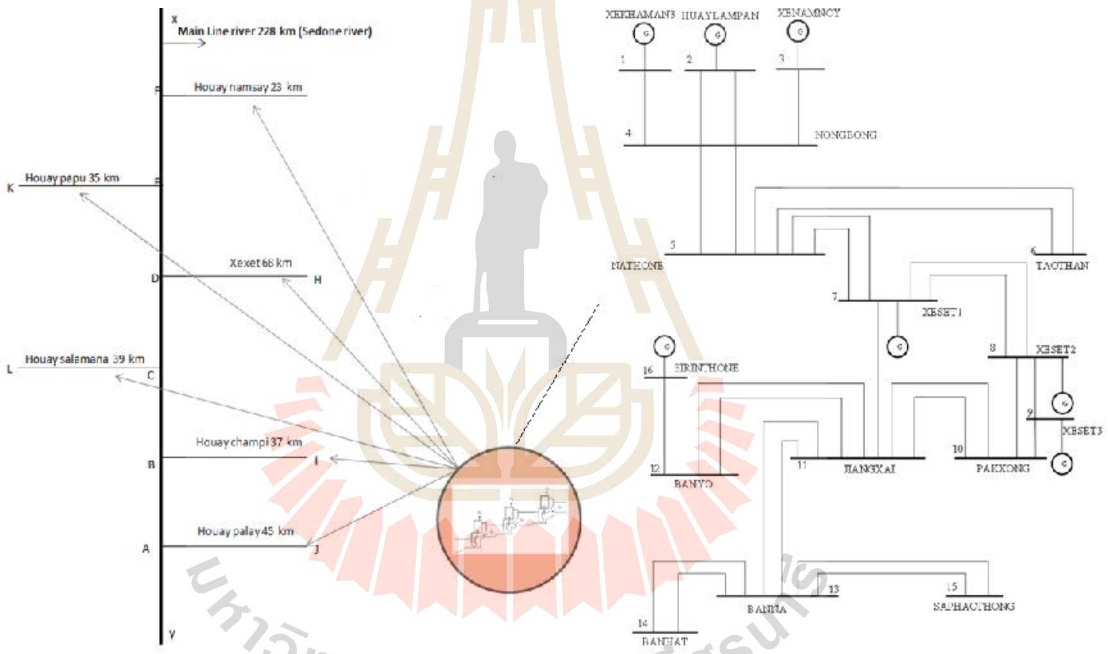

Figure 6.6 the model for test optimal power flow

The optimization was conducted for 1 hourly power and water requests values with significantly distinctive greatest and least values and actualized in the MATLAB code program on a HP Laptop with an Intel Celeron CPU1.9 GHz processor.

6.6 Conclusion

In this chapter are presented the background of the thesis. This area highlights perspectives of the foundation writing for power-water co-optimization in four steps. To begin with, the writing on power and water co-optimization is reviewed. Next, optimal power flow is presented as a prerequisite single item optimization. Optimal water flow is at that point additionally depicted

And the optimal cost of small hydropower plant to improve quality of power and water networks. The PSO algorithm for tackling the complex issues of ED, fuel costs, capacity impediments and other limitations will be considered. The PSO is a property of supreme convergence. The quickened particle swarm optimization has been executed by utilizing MATLAB. In the event that we run the program, we will get the worldwide optimum after around 200 assessments of the objective work (for 20 particles and 10 iterations). There are other varieties of particle swarm optimization, and PSO algorithms are regularly combined with other existing algorithms to create unused cross breed algorithms. In reality, it is still an active region of investigating with numerous modern considers are being distributed each year. The problem formulation builds upon the previous work on simultaneous co-dispatch of power and water while introducing the constraints from optimal power flow and optimal water flow. The optimization program given over was carried out on a recently created hypothetical system. As this program is the to begin with of its kind, no standardized test cases could be found in the writing. Instep, a single system of the direct estimate was created from individual power and water topologies. The power network admittance data was taken from the standard IEEE 14 bus system, IEEE 30 bus system, and IEEE 118 bus system. The bus system of these was taken as a cogeneration facility.

And case study using the power network admittance data was taken from 16 bus system in southern Laos. The water network system comprises of six nodes has appeared in (MAJID NIAZKAR, et al., 2017) and incorporates a water plant at node 6, small hydropower plants at node 1, 2 and a cogeneration office at node 3, 4, 5. The interested peruser alludes to the supporting (M. Spiliotis, et al., 2011) , (MAJID NIAZKAR, et al., 2017) and XEDON river basin for the total set of the input data.

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CHAPTER VII

RESULT OF THESIS

7.1 Test the Result for 16 bus in Southern Laos

In case1, consider has been to considering of the two unit small hydropower plant at HOUAY PAPU by the connection with a bus of XESET1 hydropower station of 16 bus system in southern Laos for optimal of power generation. Because the XESET1 hydropower station is near the location of the river basin at the potential point (HOUAY PAPU) for installation small hydropower plants in XEDON river basin. Which is, It changes the water flow rate to energy with two unit generations, unit 1 the power load demand of 4.22MW with PELTON turbine at head 56 m and unit 2 the power load demand of 1.884MW with FRANCIS turbine at head 25 m, with length 130km from HOUAY PAPU to XESET1 hydropower station. The system has the power load demand of 207.114MW of the arrangement of power generation and the minimum cost of system hydro power plants. It is too characterized optimal minimum losses for the considered system. Through the proposed algorithm the best of arrangement for fathoming this issue appear in Table 7.1 the gotten results fulfill the craved producing unit's imperatives. The convergence property of the algorithm is outlined in Figure 7.1.

Table 7.1 Results of the PSO optimal power flow for 16 bus system for case 1

Bus No	Voltage Mag.	Angle Degree	P_g(MW)	Q_g(MW)
1	0.986	0.000	52.317	0.000
2	1.009	21.073	27.272	1.387
3	1.054	9.089	33.511	0.270
4	1.051	27.389	0.000	0.000
5	1.040	14.956	0.000	0.000
6	1.068	11.853	0.000	0.000
7	1.034	-9.468	21.471	2.449
8	0.961	-4.697	14.187	0.813
9	0.996	-4.160	24.002	2.652
10	0.980	-13.637	0.000	0.000
11	0.991	23.145	0.000	0.000
12	1.064	16.372	0.000	0.000
13	1.035	5.674	0.000	0.000
14	1.078	-11.064	0.000	0.000
15	1.044	-6.439	0.000	0.000
16	0.983	5.196	28.356	2.344
17	1.058	-12.676	3.636	8.206
18	1.075	17.119	4.270	4.452

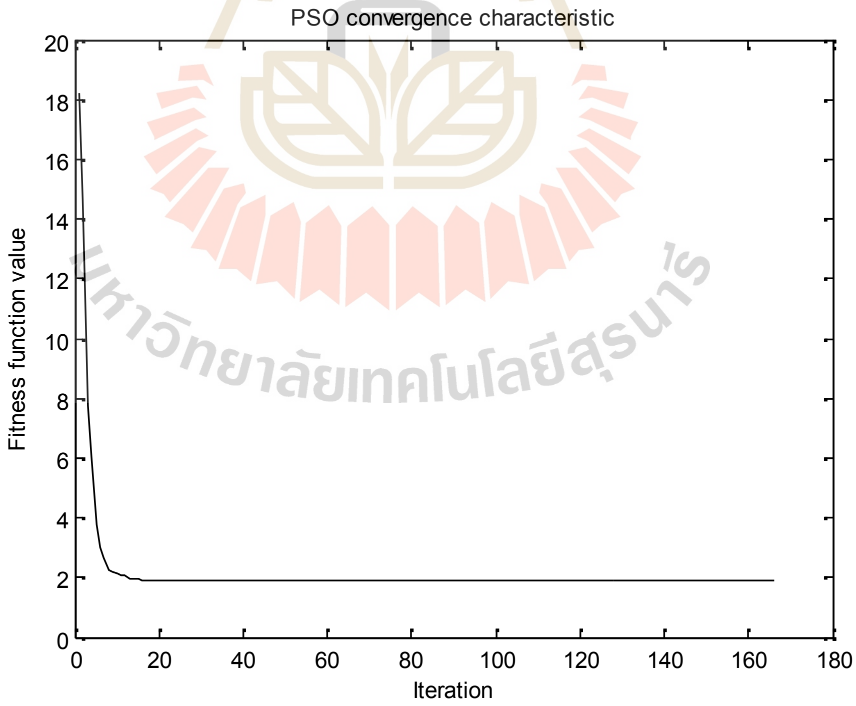

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Figure 7.1 the final curve obtained from the convergence of particles in the 16 bus system in southern Laos

In case2, consider has been to considering of the two unit small hydropower plant at HOUAY NAMSAY by the connection with a bus of XESET1 hydropower station of 16 bus system in southern Laos for optimal of power generation. Because the XESET1 hydropower station is near the location of the river basin at the potential point (HOUAY NAMSAY) for installation small hydropower plants in XEDON river basin. Which is, It changes the water flow rate to energy with two unit generations, unit 1 the power load demand of 4.066MW with PELTON turbine at head 56 m and unit 2 the power load demand of 1.815MW with FRANCIS turbine at head 25 m, with length 120km from HOUAY NAMSAY to XESET1 hydropower station. The system has the power load demand of 206.891MW of the arrangement of power generation and the minimum cost of system hydro power plants. It is too characterized optimal minimum losses for the considered system. Through the proposed algorithm the best of arrangement for fathoming this issue appear in Table 7.2 the gotten results fulfill the craved producing unit's imperatives. The convergence property of the algorithm is outlined in Figure 7.2.

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Table 7.2 Results of the PSO optimal power flow for 16 bus system for case 2

Bus No	Voltage Mag.	Angle Degree	P_g(MW)	Q_g(MW)
1	0.986	0.000	52.066	0.000
2	1.009	21.479	27.134	1.389
3	1.054	8.932	33.158	0.270
4	1.051	27.384	0.000	0.000
5	1.040	14.988	0.000	0.000
6	1.068	11.954	0.000	0.000
7	1.032	-9.316	21.432	2.447
8	0.960	-4.750	14.202	0.809
9	0.996	-4.015	23.941	2.659
10	0.980	-13.810	0.000	0.000
11	0.990	23.335	0.000	0.000
12	1.064	16.440	0.000	0.000
13	1.035	5.825	0.000	0.000
14	1.079	-11.055	0.000	0.000
15	1.044	-6.571	0.000	0.000
16	0.983	5.137	28.322	2.321
17	1.059	-13.063	3.653	8.233
18	1.075	17.118	4.209	4.429

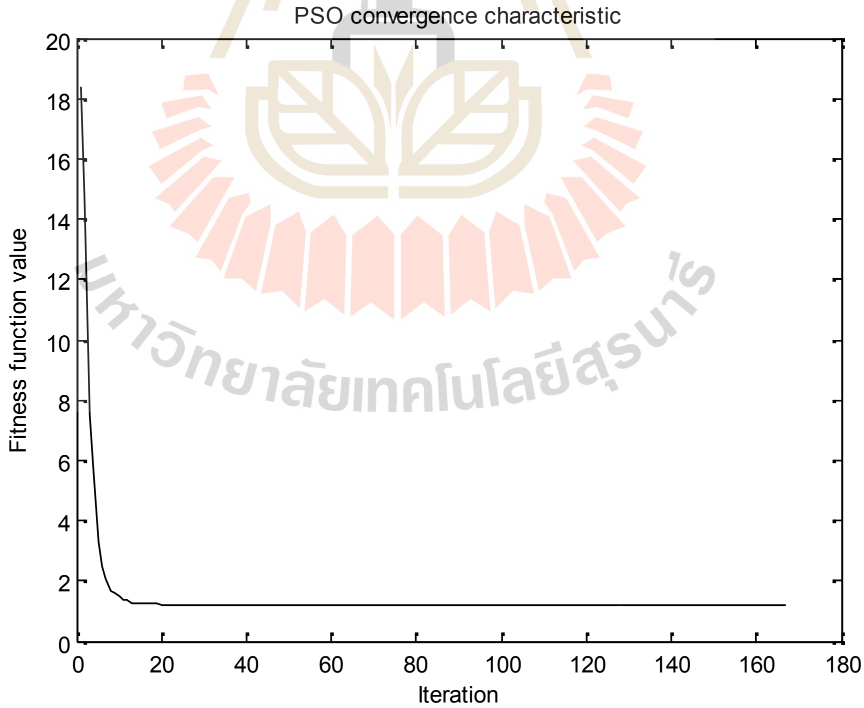

Figure 7.2 the final curve obtained from the convergence of particles in the 16 bus system in southern Laos

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In case3, consider has been to considering of the two unit small hydropower plant at HOUAY CHAMPI by the connection with a bus of XESET1 hydropower station of 16 bus system in southern Laos for optimal of power generation. Because the XESET1 hydropower station is near the location of the river basin at the potential point (HOUAY CHAMPI) for installation small hydropower plants in XEDON river basin. Which is, It changes the water flow rate to energy with two unit generations, unit 1 the power load demand of 9.788MW with PELTON turbine at head 56 m and unit 2 the power load demand of 4.370MW with FRANCIS turbine at head 25 m, with length 45km from HOUAY CHAMPI to XESET1 hydropower station. The system has the power load demand of 215.168MW of the arrangement of power generation and the minimum cost of system hydro power plants. It is too characterized optimal minimum losses for the considered system. Through the proposed algorithm the best of arrangement for fathoming this issue appear in Table 7.3 the gotten results fulfill the craved producing unit's imperatives. The convergence property of the algorithm is outlined in Figure 7.3.

Table 7.3 Results of the PSO optimal power flow for 16 bus system for case 3

Bus No	Voltage Mag.	Angle Degree	P_g(MW)	Q_g(MW)
1	0.986	0.000	54.919	0.000
2	1.011	13.655	27.156	1.376
3	1.052	9.339	34.637	0.277
4	1.043	22.421	0.000	0.000
5	1.037	13.799	0.000	0.000
6	1.070	11.603	0.000	0.000
7	1.046	-16.539	21.801	2.546
8	0.977	-1.746	14.147	0.816
9	0.992	-6.722	24.101	2.205
10	0.989	-13.005	0.000	0.000
11	0.997	19.701	0.000	0.000
12	1.067	14.766	0.000	0.000
13	1.033	3.050	0.000	0.000

Table 7.3 Results of the PSO optimal power flow for 16 bus system for case 3 (Continued)

Bus No	Voltage Mag.	Angle Degree	P_g(MW)	Q_g(MW)
14	1.076	-10.270	0.000	0.000
15	1.044	-7.264	0.000	0.000
16	0.981	3.757	29.508	2.704
17	1.052	-7.241	3.581	8.071
18	1.074	17.403	5.489	4.337

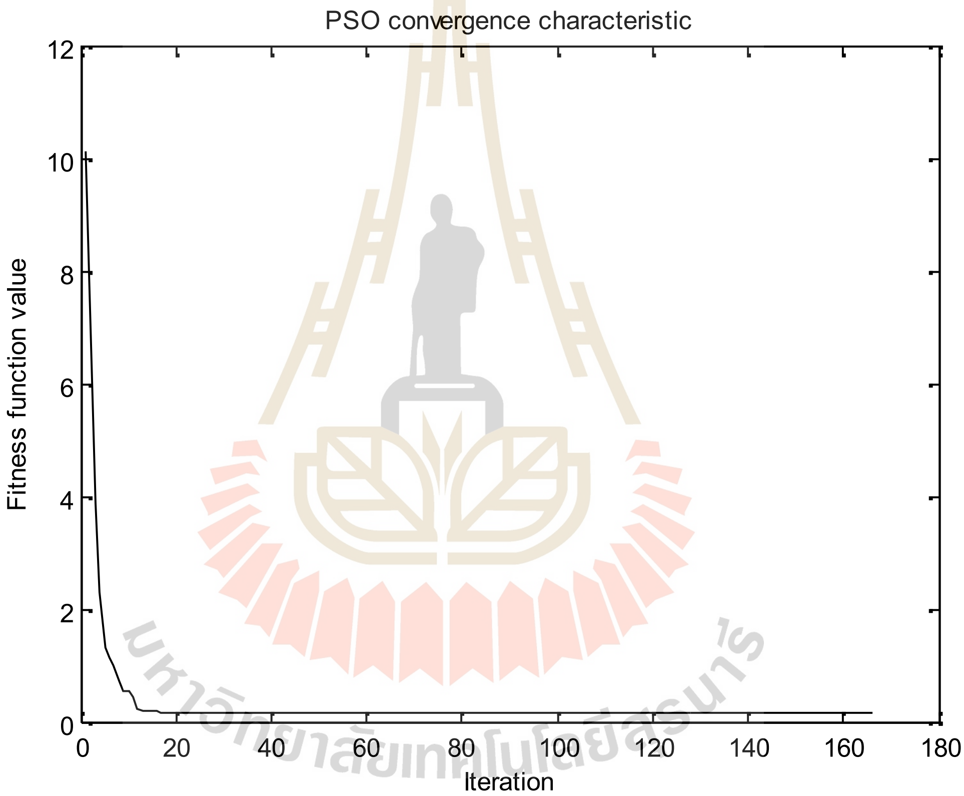

Figure 7.3 the final curve obtained from the convergence of particles in the 16 bus system in southern Laos

In case4, consider has been to considering of the two unit small hydropower plant at HOUAY PALAY by the connection with a bus of XESET1 hydropower station of 16 bus system in southern Laos for optimal of power generation. Because the XESET1 hydropower station is near the location of the river basin at the potential point (HOUAY PALAY) for installation small hydropower plants in XEDON river basin. Which is, It changes the water flow rate to energy with two unit generations, unit 1 the power load demand of 6.346MW with PELTON turbine at head 56 m and unit 2 the power load demand of 2.833MW with FRANCIS turbine at head 25 m, with length 60km from HOUAY PALAY to XESET1 hydropower station. The system has the power load demand of 210.198MW of the arrangement of power generation and the minimum cost of system hydro power plants. It is too characterized optimal minimum losses for the considered system. Through the proposed algorithm the best of arrangement for fathoming this issue appear in Table 7.4 the gotten results fulfill the craved producing unit's imperatives. The convergence property of the algorithm is outlined in Figure 7.4.

Table 7.4 Results of the PSO optimal power flow for 16 bus system for case 4

Bus No	Voltage Mag.	Angle Degree	P_g(MW)	Q_g(MW)
1	0.987	0.000	52.362	0.000
2	1.009	20.134	27.515	1.383
3	1.054	9.133	34.193	0.268
4	1.050	27.297	0.000	0.000
5	1.039	14.858	0.000	0.000
6	1.069	11.980	0.000	0.000
7	1.036	-9.555	21.522	2.440
8	0.962	-4.605	14.377	0.818
9	0.998	-4.260	24.042	2.632
10	0.981	-13.162	0.000	0.000
11	0.992	22.859	0.000	0.000
12	1.065	16.225	0.000	0.000
13	1.035	5.408	0.000	0.000
14	1.077	-11.091	0.000	0.000
15	1.043	-6.345	0.000	0.000
16	0.983	5.288	28.548	2.400
17	1.058	-12.626	3.652	8.151
18	1.075	17.105	4.307	4.500

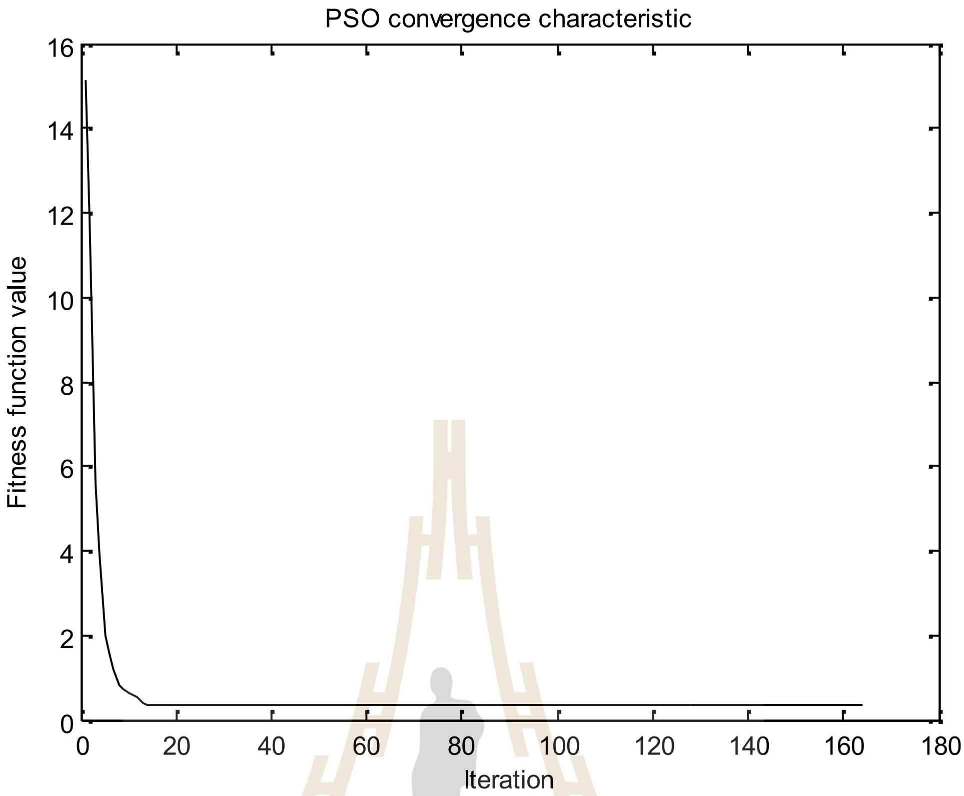

Figure 7.4 the final curve obtained from the convergence of particles in the 16 bus system in southern Laos

In case5, consider has been to considering of the two unit small hydropower plant at HOUAY SELAMANA by the connection with a bus of XESET1 hydropower station of 16 bus system in southern Laos for optimal of power generation. Because the XESET1 hydropower station is near the location of the river basin at the potential point (HOUAY SELAMANA) for installation small hydropower plants in XEDON river basin. Which is, It changes the water flow rate to energy with two unit generations, unit 1 the power load demand of 5.583MW with PELTON turbine at head 56 m and unit 2 the power load demand of 2.492MW with FRANCIS turbine at head 25 m, with length 110km from HOUAY SELAMANA to XESET1 hydropower station. The system has the power load demand of 209.085MW of the arrangement of power generation and the minimum cost of system hydro power plants. It is too characterized optimal minimum losses for the considered system. Through the proposed algorithm the best of arrangement for fathoming this issue appear in Table 7.5 the gotten results fulfill the craved producing unit's imperatives. The convergence property of the algorithm is outlined in Figure 7.5.

Table 7.5 Results of the PSO optimal power flow for 16 bus system for case 5

Bus No	Voltage Mag.	Angle Degree	P_g(MW)	Q_g(MW)
1	0.986	0.000	52.439	0.000
2	1.009	20.665	27.389	1.385
3	1.054	9.152	33.853	0.269
4	1.051	27.336	0.000	0.000
5	1.039	14.910	0.000	0.000
6	1.068	11.868	0.000	0.000
7	1.035	-9.526	21.506	2.446
8	0.962	-4.648	14.232	0.815
9	0.997	-4.256	24.035	2.643
10	0.980	-13.493	0.000	0.000
11	0.991	23.005	0.000	0.000
12	1.064	16.324	0.000	0.000
13	1.035	5.541	0.000	0.000
14	1.078	-11.074	0.000	0.000
15	1.043	-6.368	0.000	0.000
16	0.983	5.234	28.460	2.374
17	1.058	-12.581	3.641	8.177
18	1.075	17.116	4.296	4.477

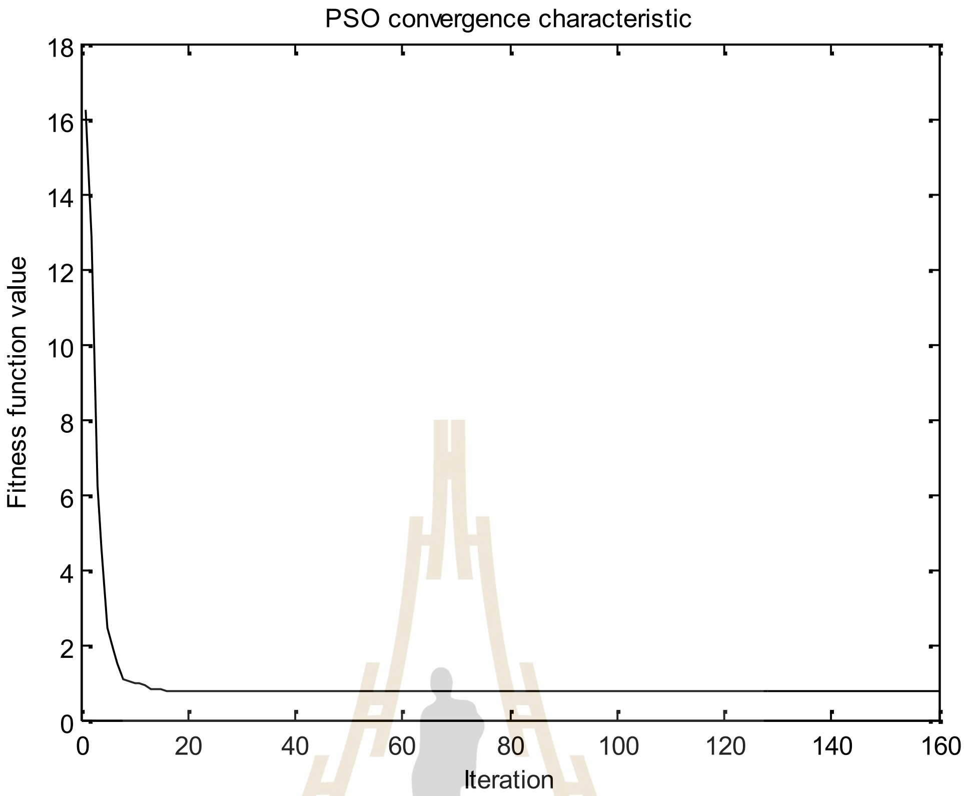

Figure 7.5 the final curve obtained from the convergence of particles in the 16 bus system in southern Laos

Through the proposed algorithm the best of arrangement for fathoming this issue appear the gotten results fulfill the craved producing unit's imperatives. After the test, we have obtained the minimum total cost of each case and the minimum total loss in Table 7.6. Finally, we selected the location for installation of small hydropower plants at HOUAY CHAMPI river basin was a case study suitable for the optimization power network system in Lao P.D.R

Table 7.6 Results of the PSO for total minimum power loss

Potential point	Name of the Location	Total Power Loss(MW/h)
1	Houay papu	1.9071
2	Houay Namsay	1.2266
3	Houay Champi	0.1710
4	Houay Palay	0.3282
5	Salamana	0.7650

7.2 Conclusion

This thesis purposes an application of population-based PSO algorithm and OPF to unravel the different ED issues. The particle swarm optimization is a modern heuristic optimization strategy based on swarm intelligence. The strategy is exceptionally basic, effortlessly completed and it needs fewer parameters, which made it completely created. To be that as it may of the inquire about on the PSO is still at the starting, a part of issues are to be settled. Particle swarm optimization has paid a parcel of consideration for the arrangement of such issues, as it will not endure from stuck into neighborhood optimal solution, constancy on starting factors, untimely and moderate meeting and reviles of dimensionality in comparison to routine optimization methods, PSO has given an made strides result inside less computational time.

OPF strategy has been utilized in classical strategies, which can lead to a nearby minimum and but not a worldwide minimum. For the most part, In OPF strategy destitute convergence may get stuck at neighborhood optimum, they can discover as it were a single optimized arrangement in a single simulation run, they ended up as well moderate on the off chance that a number of factors are expansive and they are computationally costly for the arrangement of a large system.

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Hence it can be seen that the economic dispatch of power can be extended by taking into thought the power flow systems. This does lead to a more complex optimization with more serious imperatives and subsequently finding the attainable locale and optimal arrangement is more troublesome in a few cases. Be that as it may, the optimization does run effectively for a complex hypothetical system that comprises of a 16 bus system in southern Laos. Besides, the results propose that the extension of the optimal dispatch of power network model is not fair successful in assembly supply-demand balance but too is successful in guaranteeing the security limitations forced by the line flow limits.

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CHAPTER VIII

CONCLUSION AND RECOMMENDATIONS

8.1 Conclusion

This research is built upon five main components; evaluation of potential and XEDON river hydro basin developmental plan, co-optimization for the economic dispatch with particle swarm optimization and optimal network flow, optimal network flow for the potential of developing energy sources, optimal cost of the small hydropower plant to improve the quality of power and water networks, to find minimum cost and minimum loss of systems.

Method expressed in chapter four expresses the details of the method suitable for the analysis of system water network to find potential point suitable for optimal water flow on location in the river basin for installation small hydropower plant. Moreover, the method expressed in chapter five expresses the details of the proposed algorithm suitable for the system analysis and condition forecast of the system power and water networks. In this chapter, the problem condition is used to explain the performance result of the method. The result of the problem in a system component, in this case, water flow rate balance in pipe network system, the pressure of the water in the piping system network to prevent the pipe to break, the water pressure at the node in the piping system network to prevent the pipe to break, minimum loss of water, power production, water production, the coproduction of power and water, minimum of total cost system network and the minimum of the total loss system network are presented. Simulation result of system condition is presented in chapter seven. The relationship between power and water in joint production seamlessly and effectively.

The system state forecast presents the expected situation upon the contingency event. The optimal system network flow presents co-optimization power and water to find the minimum total cost of the system and the minimum total loss of the system. Power and water networks are organized in a manner that, the co-production will be the optimization of the power and water and to solve compensate in case of the contingency event.

In this research, the computation time can be analysis water network to find the potential point of water flow rate when regression method is used because no iteration process takes place in this method, hence less time consumption. Additionally, it also can use the Newton–Raphson method to the analysis of water distribution networks using MATLAB code to consider.

The results are the best obtained for water flow rate balance in pipe water network, seven pipes, six nodes are the best obtained 0.0025441m3/h, 0.004497m3/h, 0.030503m3/h, 0.040503m3/h, 0.097456m3/h, 0.032544m3/h, 0.041953m3/h. Parallel, the water pressure at the nodes is the best obtained 152.97kPa, 146.99kPa, 138kPa, 157.91kPa, 169.79kPa, 178.14kPa. Moreover, the best obtained for water networks include minimum total head loss of systems was 10.513m.

Parallel, the Particle Swarm Optimization algorithm to optimal power flow and co-optimization power and water networks are using MATLAB code to consider. In this research, the particle swarm optimization is tested to three power networks is the IEEE 14 bus, IEEE 30bus, and IEEE 118bus, three co-production plants of power and water, and a water plant for the production of tap water to more customers.

The results are the best obtained for three power networks IEEE include minimum total cost production was 5950.3$/h, 8765.5$/h, 69898$/h, respectively and minimum total loss of systems was 24.574MW/h, 24.785MW/h, 2.8765MW/h, respectively.

Moreover, the case study in Laos PDR is presented the XEDON river basin to analysis potential point of water flow rate for installation small hydropower plant and a power network 16 bus system in southern Laos and the model piped water network, seven pipes, six node to optimal network flow for the potential of developing energy sources in Laos P.D.R and optimal loss of the small hydropower plant to Improve the quality of power and water networks in Laos P.D.R.

The results are obtained for the minimum loss in the system before connecting with the small hydropower plants is 31.1208 MW/h. In addition, it also to simulation the performance of the system by connection with of small hydropower plants at the potential point of water flow rate in XEDON river basin is the test case. Hence, the results are obtained for the minimum loss in the system after connecting with the small hydropower plants at the potential points in five cases tested as shown in below:

Case1 from HOUAY PAPU to XEXET1 with length 130 km and it got the minimum loss in the system 1.9071 MW/h.

Case 2 from HOUAY NAMSAY to XEXET1 with length 120 km and it got the minimum loss in the system 1.2266 MW/h.

Case 3 from HOUAY CHAMPI to XEXET1 with length 45 km and it got the minimum loss in the system 0.1710 MW/h.

Case 4 from HOUAY PALAY to XEXET1 with length 60 km and it got the minimum loss in the system 0.3282 MW/h.

Case 5 from HOUAY SALAMANA to XEXET1 with length 110 km and it got the minimum loss in the system 0.7650 MW/h.

It also able to the results utilizing the proposed approach was compared between to five cases after association with 16 bus system in southern Laos to select the location of the potential point for installation of small hydropower plants. Finally, we selected the location for installation of small hydropower plants at HOUAY CHAMPI river basin was a case study suitable for the optimization power network system in Lao P.D.R

8.2 Recommendation

Although most functions of power and water networks analysis are discussed in this thesis, only the production, minimum cost, and minimum loss are considered. Minimum of total cost and total loss of systems are to improve optimal of the power generation plants, co-production plants of power and water, and the water production plants for water supply. Among potential shrewdly look strategies, particle swarm optimization is well-known and widely-used in fathoming co-optimization for the economic dispatch. Therefore, the other side of corrective requires further the research, especially in data of the power network and water network must be complete.

One of the most important performances of the water network is output for water flow rate balance in the piped water network and the water pressure at the node in the piping system network to prevent the pipe to break. Moreover, this can be accompanied by the selection of the location to analysis the potential point of the water flow rate, which is the data for the planning of power production of small hydropower plants, it includes power production and loss in the system.

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APPENDIX A

SYSTEM DATA

Year	Catchment area : 650.000 km2												Annual Average
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1996	0.00	0.20	22.70	212.40	349.90	211.30	328.50	308.80	583.40	69.70	100.00	0.00	**2186.90**
1997	5.10	78.90	9.40	89.10	199.30	475.80	699.90	655.70	272.60	108.40	10.20	0.00	**2604.40**
1998	0.00	87.80	0.40	37.30	278.10	150.20	181.30	467.70	409.70	50.80	62.00	7.90	**1733.20**
1999	0.00	0.00	62.30	137.90	402.50	486.40	592.30	374.90	189.70	111.20	89.20	0.10	**2446.50**
2000	0.30	7.00	11.90	121.10	533.50	286.90	725.70	507.80	232.50	165.80	5.10	0.80	**2598.40**
2001	0.00	15.10	106.10	19.70	183.20	475.80	352.40	665.10	374.10	116.20	35.10	5.80	**2348.60**
2002	0.00	0.00	35.00	23.00	125.80	605.30	623.80	649.30	235.20	176.70	1.30	2.60	**2478.00**
2003	0.00	2.20	36.70	20.00	462.70	240.20	233.10	480.20	498.70	51.20	3.30	0.80	**2029.10**
2004	0.00	2.10	79.60	21.70	187.50	443.70	398.70	583.70	245.40	0.30	15.20	0.00	**1977.90**
2005	0.00	0.00	14.80	53.10	230.80	290.70	434.30	511.70	356.90	8.20	55.60	0.00	**1956.10**
2006	0.00	0.00	6.40	155.30	231.90	205.60	846.30	739.70	240.60	257.50	11.20	0.00	**2694.50**
2007	0.00	0.00	70.80	34.60	122.39	215.10	370.00	375.10	218.80	290.60	26.10	0.00	**1723.49**
2008	0.00	0.00	53.00	58.60	192.60	235.10	172.90	691.40	366.00	90.00	48.00	0.00	**1907.60**
2009	0.00	12.70	52.70	123.50	287.80	314.50	611.60	260.40	448.40	73.50	2.00	22.50	**2209.60**
2010	16.30	14.00	9.20	69.20	116.60	168.70	264.10	422.70	223.30	156.80	3.40	0.00	**1464.30**
Monthly Average	**1.45**	**14.67**	**38.07**	**78.43**	**260.31**	**320.35**	**455.66**	**512.95**	**326.35**	**115.13**	**31.18**	**2.70**	**2157.24**

Year	Catchment area : 2027.000 km2												Annual Average
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1996	0.00	3.60	48.10	142.60	277.00	210.00	350.60	226.90	531.50	155.90	78.40	0.00	**2024.60**
1997	2.10	19.70	56.70	221.80	244.40	302.80	405.50	522.00	199.80	62.00	0.20	0.00	**2037.00**
1998	1.10	68.10	0.00	74.00	204.80	91.50	141.00	261.00	393.60	56.50	15.30	3.80	**1310.70**
1999	0.50	0.00	74.70	181.30	396.90	281.40	336.60	178.60	242.00	106.50	47.10	1.00	**1846.60**
2000	0.00	25.00	7.90	164.60	443.20	289.70	485.70	396.50	291.40	157.20	1.20	0.00	**2262.40**
2001	0.00	11.70	109.40	16.80	197.00	371.60	410.40	647.40	308.80	154.20	2.00	2.50	**2231.80**
2002	0.00	0.00	37.90	23.40	148.60	346.80	607.20	265.90	354.60	77.90	9.80	39.10	**1911.20**
2003	0.00	11.60	68.50	91.50	317.70	179.00	164.60	405.10	643.90	39.20	0.00	0.00	**1921.10**
2004	6.20	69.60	39.60	99.20	282.10	362.20	536.40	380.60	241.40	0.00	0.30	0.00	**2017.60**
2005	0.00	0.00	10.40	100.70	172.70	184.40	326.30	434.80	318.90	106.80	23.60	1.20	**1679.80**
2006	0.00	0.00	58.40	78.10	327.60	191.00	620.10	506.40	221.20	147.50	35.80	0.00	**2186.10**
2007	0.00	0.40	48.00	149.60	290.60	321.00	248.80	404.70	227.60	253.50	16.30	0.00	**1960.50**
2008	0.00	0.00	31.30	62.30	281.60	195.70	277.90	378.60	497.60	85.80	47.20	5.00	**1863.00**
2009	0.00	55.90	55.30	113.40	317.00	256.00	401.50	335.40	363.20	59.90	1.20	0.00	**1958.80**
2010	0.24	5.90	0.10	53.00	88.10	152.50	220.40	435.20	171.90	161.30	3.50	0.00	**1292.14**
Monthly Average	**0.68**	**18.10**	**43.09**	**104.82**	**265.95**	**249.04**	**368.87**	**385.27**	**333.83**	**108.28**	**18.79**	**3.51**	**1900.22**

Year	Catchment area : 3260.000 km2												Annual Average
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	
1996	0.00	37.40	17.10	140.10	317.60	132.20	261.70	496.50	1048.60	201.50	114.90	0.00	**2767.60**
1997	11.50	49.00	22.20	139.80	260.10	309.10	418.00	513.50	168.90	41.30	0.00	0.00	**1933.40**
1998	2.60	61.90	0.00	57.40	238.60	287.10	153.00	230.80	268.00	91.30	46.30	7.30	**1444.30**
1999	1.10	25.20	47.70	80.60	306.70	362.20	907.70	458.50	247.10	177.20	60.60	0.50	**2675.10**
2000	0.40	38.40	2.60	111.40	291.70	272.50	886.00	733.90	287.40	214.90	0.70	0.00	**2839.90**
2001	0.00	51.10	88.10	51.60	289.70	292.60	308.50	499.80	322.90	158.80	1.70	2.70	**2067.50**
2002	0.00	0.00	10.10	70.30	101.60	389.70	698.80	705.30	339.80	123.90	4.90	11.00	**2455.40**
2003	0.00	31.80	102.30	54.90	335.70	255.91	234.30	514.40	396.50	86.20	1.50	0.00	**2013.51**
2004	1.10	12.30	39.30	64.30	245.90	269.00	518.00	552.90	407.80	19.50	2.30	0.00	**2132.40**
2005	0.00	0.00	13.00	123.30	198.70	286.00	440.90	806.40	377.30	28.50	13.60	6.60	**2294.30**
2006	0.00	48.10	29.90	112.80	169.80	293.30	535.00	487.10	277.90	181.80	22.10	0.80	**2158.60**
2007	0.00	2.10	22.50	80.70	167.50	277.70	588.10	349.90	262.10	445.40	31.60	0.00	**2227.60**
2008	0.00	0.00	29.10	66.60	246.30	286.80	155.30	417.60	267.30	122.60	8.10	1.00	**1600.70**
2009	0.00	16.60	25.70	127.10	281.50	116.60	837.80	295.00	448.30	117.10	0.00	6.20	**2271.90**
2010	7.50	3.40	5.50	93.10	164.80	133.00	327.00	409.30	178.70	141.20	0.00	0.00	**1463.50**
Monthly Average	**1.61**	**25.15**	**30.34**	**91.60**	**241.08**	**264.25**	**484.67**	**498.06**	**353.24**	**143.41**	**20.55**	**2.41**	**2156.38**

Year	Catchment area : 1280.000 km2												**Annual Average**
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	
1996	3.80	74.40	89.80	165.00	367.50	314.20	809.20	673.30	1153.60	163.20	170.10	0.00	**3984.10**
1997	4.20	79.20	108.10	319.80	248.00	499.10	1084.80	889.60	316.60	130.60	58.40	34.80	**3773.20**
1998	0.40	71.50	167.80	166.60	347.00	186.40	229.30	378.20	258.20	206.90	58.60	59.50	**2130.40**
1999	50.40	0.30	159.60	265.70	407.30	388.50	1499.90	783.30	461.00	262.00	97.10	0.00	**4375.10**
2000	15.10	145.90	76.60	289.70	293.10	314.70	1182.80	983.70	427.40	259.80	19.80	11.70	**4020.30**
2001	42.10	44.20	108.40	294.70	316.70	702.90	825.90	1095.80	407.30	321.80	26.20	2.30	**4188.30**
2002	0.30	2.00	84.10	274.50	312.60	543.80	889.80	1120.00	566.70	273.70	89.20	128.20	**4284.90**
2003	0.00	76.60	146.50	237.90	435.80	425.00	624.60	972.90	733.70	144.30	109.10	0.00	**3906.40**
2004	54.10	1.50	103.60	252.10	350.00	836.00	547.60	789.70	314.30	4.20	26.60	0.00	**3279.70**
2005	0.00	0.00	201.50	192.50	334.40	438.30	1209.90	1245.00	498.50	30.30	213.20	37.70	**4401.30**
2006	1.70	83.80	51.60	326.10	205.60	525.10	1231.10	1059.80	360.10	471.20	120.20	3.90	**4440.20**
2007	1.19	4.64	16.02	264.00	374.00	306.00	850.80	694.70	281.40	478.10	42.00	51.40	**3364.25**
2008	0.00	27.80	138.80	291.50	342.70	378.50	281.60	529.40	405.90	261.80	62.40	37.10	**2757.50**
2009	13.50	99.80	80.70	371.50	402.50	403.30	1199.30	716.40	514.70	253.20	22.70	61.10	**4138.70**
2010	81.00	48.10	5.90	297.20	367.10	211.00	338.40	575.70	327.30	189.10	54.40	4.70	**2499.90**
Monthly Average	**17.85**	**50.65**	**102.60**	**267.25**	**340.29**	**431.52**	**853.67**	**833.83**	**468.45**	**230.01**	**78.00**	**28.83**	**3702.95**

Table 5 Data of annual average rainfall at meteorological stations near hydropower station

Station	Catchment area(km^2)	Annual average rainfall (mm)
PAKSE	650	2157.24
KHONGSEDONE	2027	1900.22
SALAVAN	3260	2156.38
PAKSONG	1280	3702.95
XESET hydropower station	323.7	2406

Calculation formula is:

$$Q_2 = \frac{A_2}{A_1} \times \frac{P_2}{P_1} \times Q_1 \qquad \text{(b.1)}$$

In this formula,

Q_2 -- monthly flow at gauging station (m^3/s)

Q_1 -- monthly flow at dam site (m^3/s)

A_1 -- Catchment area at dam site (km^2)

A_2 -- Catchment area at gauging station (km2)

P_1 -- Annual average rainfall on area of A_1 (mm/year)

P_2 -- Annual average rainfall on area of A_2 (mm/year)

Station	Catchment area(km2)	Annual average rainfall (mm)	Annual average (m^3/s)
PAKSE	650	2157.24	25.386
KHONGSEDONE	2027	1900.22	22.361
SALAVAN	3260	2156.38	25.376
PAKSONG	1280	3702.95	43.575
XESET hydropower	323.7	2406	14.1

Year	Q (m3/s)												Annual Average
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1996	0.00	0.00	0.27	2.50	4.12	2.49	3.87	3.63	6.87	0.82	1.18	0.00	2.14
1997	0.06	0.93	0.11	1.05	2.35	5.60	8.24	7.72	3.21	1.28	0.12	0.00	2.55
1998	0.00	1.03	0.00	0.44	3.27	1.77	2.13	5.50	4.82	0.60	0.73	0.09	1.70
1999	0.00	0.00	0.73	1.62	4.74	5.72	6.97	4.41	2.23	1.31	1.05	0.00	2.40
2000	0.00	0.08	0.14	1.43	6.28	3.38	8.54	5.98	2.74	1.95	0.06	0.01	2.55
2001	0.00	0.18	1.25	0.23	2.16	5.60	4.15	7.83	4.40	1.37	0.41	0.07	2.30
2002	0.00	0.00	0.41	0.27	1.48	7.12	7.34	7.64	2.77	2.08	0.02	0.03	2.43
2003	0.00	0.03	0.43	0.24	5.44	2.83	2.74	5.65	5.87	0.60	0.04	0.01	1.99
2004	0.00	0.02	0.94	0.26	2.21	5.22	4.69	6.87	2.89	0.00	0.18	0.00	1.94
2005	0.00	0.00	0.17	0.62	2.72	3.42	5.11	6.02	4.20	0.10	0.65	0.00	1.92
2006	0.00	0.00	0.08	1.83	2.73	2.42	9.96	8.70	2.83	3.03	0.13	0.00	2.64
2007	0.00	0.00	0.83	0.41	1.44	2.53	4.35	4.41	2.57	3.42	0.31	0.00	1.69
2008	0.00	0.00	0.62	0.69	2.27	2.77	2.03	8.14	4.31	1.06	0.56	0.00	1.87
2009	0.00	0.15	0.62	1.45	3.39	3.70	7.20	3.06	5.28	0.86	0.02	0.26	2.17
2010	0.19	0.16	0.11	0.81	1.37	1.99	3.11	4.97	2.63	1.85	0.04	0.00	1.44
Monthly Average	***0.02***	***0.17***	***0.45***	***0.92***	***3.06***	***3.77***	***5.36***	***6.04***	***3.84***	***1.35***	***0.37***	***0.03***	**2.12**

Year	Q (m3/s)												Annual Average
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1996	0.00	0.04	0.57	1.68	3.26	2.47	4.13	2.67	6.25	1.83	0.92	0.00	1.99
1997	0.02	0.23	0.67	2.61	2.88	3.56	4.77	6.14	2.35	0.73	0.00	0.00	2.00
1998	0.01	0.80	0.00	0.87	2.41	1.08	1.66	3.07	4.63	0.66	0.18	0.04	1.29
1999	0.01	0.00	0.88	2.13	4.67	3.31	3.96	2.10	2.85	1.25	0.55	0.01	1.81
2000	0.00	0.29	0.09	1.94	5.22	3.41	5.72	4.67	3.43	1.85	0.01	0.00	2.22
2001	0.00	0.14	1.29	0.20	2.32	4.37	4.83	7.62	3.63	1.81	0.02	0.03	2.19
2002	0.00	0.00	0.45	0.28	1.75	4.08	7.15	3.13	4.17	0.92	0.12	0.46	1.87
2003	0.00	0.14	0.81	1.08	3.74	2.11	1.94	4.77	7.58	0.46	0.00	0.00	1.88
2004	0.07	0.82	0.47	1.17	3.32	4.26	6.31	4.48	2.84	0.00	0.00	0.00	1.98
2005	0.00	0.00	0.12	1.19	2.03	2.17	3.84	5.12	3.75	1.26	0.28	0.01	1.65
2006	0.00	0.00	0.69	0.92	3.86	2.25	7.30	5.96	2.60	1.74	0.42	0.00	2.14
2007	0.00	0.00	0.56	1.76	3.42	3.78	2.93	4.76	2.68	2.98	0.19	0.00	1.92
2008	0.00	0.00	0.37	0.73	3.31	2.30	3.27	4.46	5.86	1.01	0.56	0.06	1.83
2009	0.00	0.66	0.65	1.33	3.73	3.01	4.72	3.95	4.27	0.70	0.01	0.00	1.92
2010	0.00	0.07	0.00	0.62	1.04	1.79	2.59	5.12	2.02	1.90	0.04	0.00	1.27
Monthly Average	***0.01***	***0.21***	***0.51***	***1.23***	***3.13***	***2.93***	***4.34***	***4.53***	***3.93***	***1.27***	***0.22***	***0.04***	**1.86**

Year	Q (m3/s)												Annual Average
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1996	0.00	0.44	0.20	1.65	3.74	1.56	3.08	5.84	12.34	2.37	1.35	0.00	2.71
1997	0.14	0.58	0.26	1.65	3.06	3.64	4.92	6.04	1.99	0.49	0.00	0.00	1.90
1998	0.03	0.73	0.00	0.68	2.81	3.38	1.80	2.72	3.15	1.07	0.54	0.09	1.42
1999	0.01	0.30	0.56	0.95	3.61	4.26	10.68	5.40	2.91	2.09	0.71	0.01	2.62
2000	0.00	0.45	0.03	1.31	3.43	3.21	10.43	8.64	3.38	2.53	0.01	0.00	2.78
2001	0.00	0.60	1.04	0.61	3.41	3.44	3.63	5.88	3.80	1.87	0.02	0.03	2.03
2002	0.00	0.00	0.12	0.83	1.20	4.59	8.22	8.30	4.00	1.46	0.06	0.13	2.41
2003	0.00	0.37	1.20	0.65	3.95	3.01	2.76	6.05	4.67	1.01	0.02	0.00	1.97
2004	0.01	0.14	0.46	0.76	2.89	3.17	6.10	6.51	4.80	0.23	0.03	0.00	2.09
2005	0.00	0.00	0.15	1.45	2.34	3.37	5.19	9.49	4.44	0.34	0.16	0.08	2.25
2006	0.00	0.57	0.35	1.33	2.00	3.45	6.30	5.73	3.27	2.14	0.26	0.01	2.12
2007	0.00	0.02	0.26	0.95	1.97	3.27	6.92	4.12	3.08	5.24	0.37	0.00	2.18
2008	0.00	0.00	0.34	0.78	2.90	3.37	1.83	4.91	3.15	1.44	0.10	0.01	1.57
2009	0.00	0.20	0.30	1.50	3.31	1.37	9.86	3.47	5.28	1.38	0.00	0.07	2.23
2010	0.09	0.04	0.06	1.10	1.94	1.57	3.85	4.82	2.10	1.66	0.00	0.00	1.44
Monthly Average	***0.02***	***0.30***	***0.36***	***1.08***	***2.84***	***3.11***	***5.70***	***5.86***	***4.16***	***1.69***	***0.24***	***0.03***	**2.11**

Year	Q (m3/s)												Annual Average
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1996	0.04	0.88	1.06	1.94	4.32	3.70	9.52	7.92	13.58	1.92	2.00	0.00	3.91
1997	0.05	0.93	1.27	3.76	2.92	5.87	12.77	10.47	3.73	1.54	0.69	0.41	3.70
1998	0.00	0.84	1.97	1.96	4.08	2.19	2.70	4.45	3.04	2.43	0.69	0.70	2.09
1999	0.59	0.00	1.88	3.13	4.79	4.57	17.65	9.22	5.42	3.08	1.14	0.00	4.29
2000	0.18	1.72	0.90	3.41	3.45	3.70	13.92	11.58	5.03	3.06	0.23	0.14	3.94
2001	0.50	0.52	1.28	3.47	3.73	8.27	9.72	12.90	4.79	3.79	0.31	0.03	4.11
2002	0.00	0.02	0.99	3.23	3.68	6.40	10.47	13.18	6.67	3.22	1.05	1.51	4.20
2003	0.00	0.90	1.72	2.80	5.13	5.00	7.35	11.45	8.63	1.70	1.28	0.00	3.83
2004	0.64	0.02	1.22	2.97	4.12	9.84	6.44	9.29	3.70	0.05	0.31	0.00	3.22
2005	0.00	0.00	2.37	2.27	3.94	5.16	14.24	14.65	5.87	0.36	2.51	0.44	4.32
2006	0.02	0.99	0.61	3.84	2.42	6.18	14.49	12.47	4.24	5.54	1.41	0.05	4.35
2007	0.01	0.05	0.19	3.11	4.40	3.60	10.01	8.18	3.31	5.63	0.49	0.60	3.30
2008	0.00	0.33	1.63	3.43	4.03	4.45	3.31	6.23	4.78	3.08	0.73	0.44	2.70
2009	0.16	1.17	0.95	4.37	4.74	4.75	14.11	8.43	6.06	2.98	0.27	0.72	4.06
2010	0.95	0.57	0.07	3.50	4.32	2.48	3.98	6.77	3.85	2.23	0.64	0.06	2.45
Monthly Average	***0.21***	***0.60***	***1.21***	***3.14***	***4.00***	***5.08***	***10.05***	***9.81***	***5.51***	***2.71***	***0.92***	***0.34***	**3.63**

Bus number	a	b	c	Wmin	Wmax
6	4.286e-13	-0.04167	-4.423	0	250

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Bus Number	a	b	c	d	e	f	Pmin	Pmax	Wmin	Wmax
10	0.0004433	0.003546	0.007093	-1.106	-4.426	737.4	200	800	30	160
11	0.0007881	0.006305	0.01261	-1.475	-5.901	737.4	150	600	23	120
12	0.001773	0.01419	0.02837	-2.213	-8.851	737.4	100	400	15	80

Table 13 generator cost coefficients of small hydropower plants

Bus number	a	b	c	Pmin	Pmax
4	17.693	-0.3644725	-0.281735	1	10
5	25.698	-0.560135	-0.127243	1	10

Table 14 head of small hydropower plant

Type of turbine	Head of small hydropower plant(m)
Pelton	56
Francis	25

Table 15 generator cost coefficients of IEEE 14 bus

Bus number	a	b	c	P_{min}	P_{max}
1	0.0070	7	240	100	500
2	0.0095	10	200	50	200
3	0.0090	8.50	220	80	300
6	0.0090	11	200	50	150
8	0.0080	10.50	220	50	200

Table 16 Bus data IEEE 14 bus

Bus No	code	Voltage Mag.	Angle Degree	P_{Load}(MW)	Q_{Load}(Mvar)
1	1	1.06	0	0	0
2	2	1.045	-4.98	21.7	12.7
3	2	1.01	-12.72	94.2	19
4	0	1.019	-10.33	47.8	-3.9
5	0	1.02	-8.78	7.6	1.6
6	2	1.07	-14.22	11.2	7.5
7	0	1.062	-13.37	0	0
8	2	1.09	-13.36	0	0
9	0	1.056	-14.94	29.5	16.6
10	0	1.051	-15.1	9	5.8
11	0	1.057	-14.79	3.5	1.8
12	0	1.055	-15.07	6.1	1.6
13	0	1.05	-15.16	13.5	5.8
14	0	1.036	-16.04	14.9	5

Table 17 Line data IEEE 14 bus

nl	nr	R p.u	R p.u	B	a	Line flow limits MW
1	2	0.01938	0.05917	0.0528	1	500
1	5	0.05403	0.22304	0.0492	1	500
2	3	0.04699	0.19797	0.0438	1	500
2	4	0.05811	0.17632	0.034	1	500
2	5	0.05695	0.17388	0.0346	1	500
3	4	0.06701	0.17103	0.0128	1	500
4	5	0.01335	0.04211	0	1	500
4	7	0	0.20912	0	0.978	500
4	9	0	0.55618	0	0.969	500
5	6	0	0.25202	0	0.932	500
6	11	0.09498	0.1989	0	1	500
6	12	0.12291	0.25581	0	1	500
6	13	0.06615	0.13027	0	1	500
7	8	0	0.17615	0	1	500
7	9	0	0.11001	0	1	500
9	10	0.03181	0.0845	0	1	500
9	14	0.12711	0.27038	0	1	500
10	11	0.08205	0.19207	0	1	500
12	13	0.22092	0.19988	0	1	500
13	14	0.17093	0.34802	0	1	500

Table 18 generator cost coefficients of IEEE 30 bus

Bus number	a	b	c	P_{min}	P_{max}
1	0.00375	2	0	50	200
2	0.0175	1.75	0	20	80
5	0.0625	1	0	15	50
8	0.0083	3.25	0	10	35
11	0.025	3	0	10	30
13	0.025	3	0	12	40

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Table 19 Bus data IEEE 30 bus

Bus No	code	Voltage Mag.	Angle Degree	P_{Load}(MW)	Q_{Load}(Mvar)
1	1	1.06	0	0	0
2	2	1.043	-5.48	21.7	12.7
3	2	1.021	-7.96	2.4	1.2
4	2	1.012	-9.62	7.6	1.6
5	2	1.01	-14.37	94.2	19
6	0	1.01	-11.34	0	0
7	0	1.002	-13.12	22.8	10.9
8	2	1.01	-12.1	30	30
9	0	1.051	-14.38	0	0
10	0	1.045	-15.97	5.8	2
11	2	1.082	-14.39	0	0
12	0	1.057	-15.24	11.2	7.5
13	2	1.071	-15.24	0	0
14	0	1.042	-16.13	6.2	1.6
15	0	1.038	-16.22	8.2	2.5
16	0	1.045	-15.83	3.5	1.8
17	0	1.04	-16.14	9	5.8
18	0	1.028	-16.82	3.2	0.9
19	2	1.026	-17	9.5	3.4
20	2	1.03	-16.8	2.2	0.7
21	2	1.033	-16.42	17.5	11.2
22	0	1.033	-16.41	0	0
23	0	1.027	-16.61	3.2	1.6
24	0	1.021	-16.78	8.7	6.7
25	0	1.017	-16.35	0	0
26	0	1	-16.77	3.5	2.3
27	0	1.023	-15.82	0	0
28	0	1.007	-11.97	0	0
29	0	1.003	-17.06	2.4	0.9
30	0	0.992	-17.94	10.6	1.9

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Table 20 Line data IEEE 30 bus

nl	nr	R p.u	R p.u	B	a	Line flow limits MW
1	2	0.0192	0.0575	0.0264	1	130
1	3	0.0452	0.1852	0.0204	1	130
2	4	0.057	0.1737	0.0184	1	65
3	4	0.0132	0.0379	0.0042	1	130
2	5	0.0472	0.1983	0.0209	1	130
2	6	0.0581	0.1763	0.0187	1	65
4	6	0.0119	0.0414	0.0045	1	90
5	7	0.046	0.116	0.0102	1	70
6	7	0.0267	0.082	0.0085	1	130
6	8	0.012	0.042	0.0045	1	32
6	9	0	0.208	0	0.978	65
6	10	0	0.556	0	0.969	32
9	11	0	0.208	0	1	65
9	10	0	0.11	0	1	65
4	12	0	0.256	0	0.932	65
12	13	0	0.14	0	1	65
12	14	0.1231	0.2559	0	1	32
12	15	0.0662	0.1304	0	1	32
12	16	0.0945	0.1987	0	1	32
14	15	0.221	0.1997	0	1	16
16	17	0.0824	0.1923	0	1	16
15	18	0.1073	0.2185	0	1	16
18	19	0.0639	0.1292	0	1	16
19	20	0.034	0.068	0	1	32
10	20	0.0936	0.209	0	1	32
10	17	0.0324	0.0845	0	1	32
10	21	0.0348	0.0749	0	1	32
10	22	0.0727	0.1499	0	1	32
21	22	0.0116	0.0236	0	1	32
15	23	0.1	0.202	0	1	16
22	24	0.115	0.179	0	1	16
23	24	0.132	0.27	0	1	16
24	25	0.1885	0.3292	0	1	16
25	26	0.2544	0.38	0	1	16
25	27	0.1093	0.2087	0	1	16
28	27	0	0.396	0	0.968	65
27	29	0.2198	0.4153	0	1	16
27	30	0.3202	0.6027	0	1	16
29	30	0.2399	0.4533	0	1	16
8	28	0.0636	0.2	0.0214	1	32
6	28	0.0169	0.0599	0.065	1	32

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Table 21 generator cost coefficients of IEEE 118 bus

Bus number	a	b	c	P_{min}	P_{max}
1	0.010875	12.8875	6.78	50	200
4	0.069663	26.2438	31.67	5	30
6	0.069663	26.2438	31.67	5	30
8	0.069663	26.2438	31.67	5	30
10	0.010875	12.8875	6.78	150	300
12	0.010875	12.8875	6.78	100	300
15	0.069663	26.2438	31.67	10	30
18	0.0128	17.82	10.15	25	100
19	0.069663	26.2438	31.67	5	30
24	0.069663	26.2438	31.67	5	30
25	0.010875	12.8875	6.78	100	300
26	0.003	10.76	32.96	100	350
27	0.069663	26.2438	31.67	8	30
31	0.069663	26.2438	31.67	8	30
32	0.0128	17.82	10.15	25	100
34	0.069663	26.2438	31.67	8	30
36	0.0128	17.82	10.15	25	100
40	0.069663	26.2438	31.67	8	30
42	0.069663	26.2438	31.67	8	30
46	0.0128	17.82	10.15	25	100
49	0.002401	12.3299	28	50	250
54	0.002401	12.3299	28	50	250
55	0.0128	17.82	10.15	25	100
56	0.0128	17.82	10.15	25	100
59	0.0044	13.29	39	50	200
61	0.0044	13.29	39	50	200
62	0.0128	17.82	10.15	25	100
65	0.01059	8.3391	64.16	100	420
66	0.01059	8.3391	64.16	100	420
69	0.010875	12.8875	6.78	80	300
70	0.045923	15.4708	74.33	30	80
72	0.069663	26.2438	31.67	10	30
73	0.069663	26.2438	31.67	5	30
74	0.028302	37.6968	17.95	5	20
76	0.0128	17.82	10.15	25	100
77	0.0128	17.82	10.15	25	100
80	0.010875	12.8875	6.78	150	300
82	0.0128	17.82	10.15	25	100
85	0.069663	26.2438	31.67	10	30
87	0.003	10.76	32.96	100	300
89	0.010875	12.8875	6.78	50	200
90	0.028302	37.6968	17.95	8	20

Table 21 generator cost coefficients of IEEE 118 bus (Continued)

Bus number	a	b	c	P_{min}	P_{max}
91	0.009774	22.9423	58.81	20	50
92	0.010875	12.8875	6.78	100	300
99	0.010875	12.8875	6.78	100	300
100	0.010875	12.8875	6.78	100	300
103	0.028302	37.6968	17.95	8	20
104	0.0128	17.82	10.15	25	100
105	0.0128	17.82	10.15	25	100
107	0.028302	37.6968	17.95	8	20
110	0.009774	22.9423	58.81	25	50
111	0.0128	17.82	10.15	25	100
112	0.0128	17.82	10.15	25	100
113	0.0128	17.82	10.15	25	100
116	0.009774	22.9423	58.81	25	50

Table 22 Bus data IEEE 118 bus

Bus No	code	Voltage Mag.	Angle Degree	P_{Load}(MW)	Q_{Load}(Mvar)
1	2	0.955	10.67	51	27
2	0	0.971	11.22	20	9
3	0	0.968	11.56	39	10
4	2	0.998	15.28	30	12
5	0	1.002	15.73	0	0
6	2	0.99	13	52	22
7	0	0.989	12.56	19	2
8	2	1.015	20.77	0	0
9	0	1.043	28.02	0	0
10	2	1.05	35.61	0	0
11	0	0.985	12.72	70	23
12	2	0.99	12.2	47	10
13	0	0.968	11.35	34	16
14	0	0.984	11.5	14	1
15	2	0.97	11.23	90	30
16	0	0.984	11.91	25	10
17	0	0.995	13.74	11	3
18	2	0.973	11.53	60	34
19	2	0.963	11.05	45	25
20	0	0.958	11.93	18	3
21	0	0.959	13.52	14	8
22	0	0.97	16.08	10	5
23	0	1	21	7	3

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Table 22 Bus data IEEE 118 bus (Continued)

Bus No	code	Voltage Mag.	Angle Degree	P_{Load}(MW)	Q_{Load}(Mvar)
24	2	0.992	20.89	0	0
25	2	1.05	27.93	0	0
26	2	1.015	29.71	0	0
27	2	0.968	15.35	62	13
28	0	0.962	13.62	17	7
29	0	0.963	12.63	24	4
30	0	0.968	18.79	0	0
31	2	0.967	12.75	43	27
32	2	0.964	14.8	59	23
33	0	0.972	10.63	23	9
34	2	0.986	11.3	59	26
35	0	0.981	10.87	33	9
36	2	0.98	10.87	31	17
37	0	0.992	11.77	0	0
38	0	0.962	16.91	0	0
39	0	0.97	8.41	27	11
40	2	0.97	7.35	20	23
41	0	0.967	6.92	37	10
42	2	0.985	8.53	37	23
43	0	0.978	11.28	18	7
44	0	0.985	13.82	16	8
45	0	0.987	15.67	53	22
46	2	1.005	18.49	28	10
47	0	1.017	20.73	34	0
48	0	1.021	19.93	20	11
49	2	1.025	20.94	87	30
50	0	1.001	18.9	17	4
51	0	0.967	16.28	17	8
52	0	0.957	15.32	18	5
53	0	0.946	14.35	23	11
54	2	0.955	15.26	113	32
55	2	0.952	14.97	63	22
56	2	0.954	15.16	84	18
57	0	0.971	16.36	12	3
58	0	0.959	15.51	12	3
59	2	0.985	19.37	277	113
60	0	0.993	23.15	78	3
61	2	0.995	24.04	0	0
62	2	0.998	23.43	77	14
63	0	0.969	22.75	0	0
64	0	0.984	24.52	0	0
65	2	1.005	27.65	0	0

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Table 22 Bus data IEEE 118 bus (Continued)

Bus No	code	Voltage Mag.	Angle Degree	P_{Load}(MW)	Q_{Load}(Mvar)
66	2	1.05	27.48	39	18
67	0	1.02	24.84	28	7
68	0	1.003	27.55	0	0
69	1	1.035	30	0	0
70	2	0.984	22.58	66	20
71	0	0.987	22.15	0	0
72	2	0.98	20.98	0	0
73	2	0.991	21.94	0	0
74	2	0.958	21.64	68	27
75	0	0.967	22.91	47	11
76	2	0.943	21.77	68	36
77	2	1.006	26.72	61	28
78	0	1.003	26.42	71	26
79	0	1.009	26.72	39	32
80	2	1.04	28.96	130	26
81	0	0.997	28.1	0	0
82	0	0.989	27.24	54	27
83	0	0.985	28.42	20	10
84	0	0.98	30.95	11	7
85	2	0.985	32.51	24	15
86	0	0.987	31.14	21	10
87	2	1.015	31.4	0	0
88	0	0.987	35.64	48	10
89	2	1.005	39.69	0	0
90	2	0.985	33.29	78	42
91	2	0.98	33.31	0	0
92	2	0.993	33.8	65	10
93	0	0.987	30.79	12	7
94	0	0.991	28.64	30	16
95	0	0.981	27.67	42	31
96	0	0.993	27.51	38	15
97	0	1.011	27.88	15	9
98	0	1.024	27.4	34	8
99	2	1.01	27.04	0	0
100	2	1.017	28.03	37	18
101	0	0.993	29.61	22	15
102	0	0.991	32.3	5	3
103	2	1.001	24.44	23	16
104	2	0.971	21.69	38	25
105	2	0.965	20.57	31	26
106	0	0.962	20.32	43	16
107	2	0.952	17.53	28	12
108	0	0.967	19.38	2	1

Table 22 Bus data IEEE 118 bus (Continued)

Bus No	code	Voltage Mag.	Angle Degree	P_{Load}(MW)	Q_{Load}(Mvar)
109	0	0.967	18.93	8	3
110	2	0.973	18.09	39	30
111	2	0.98	19.74	0	0
112	2	0.975	14.99	25	13
113	2	0.993	13.74	0	0
114	0	0.96	14.46	8	3
115	0	0.96	14.46	22	7
116	2	1.005	27.12	0	0
117	0	0.974	10.67	20	8
118	0	0.949	21.92	33	15

Table 23 Line data IEEE 118 bus

nl	nr	R p.u	R p.u	B	a	Line flow limits MW
1	2	0.0303	0.0999	0.0254	1	15
1	3	0.0129	0.0424	0.01082	1	48
4	5	0.00176	0.00798	0.0021	1	129
3	5	0.0241	0.108	0.0284	1	85
5	6	0.0119	0.054	0.01426	1	111
6	7	0.00459	0.0208	0.0055	1	44
8	9	0.00244	0.0305	1.162	1	551
8	5	0	0.0267	0	0.985	423
9	10	0.00258	0.0322	1.23	1	557
4	11	0.0209	0.0688	0.01748	1	80
5	11	0.0203	0.0682	0.01738	1	97
11	12	0.00595	0.0196	0.00502	1	43
2	12	0.0187	0.0616	0.01572	1	41
3	12	0.0484	0.16	0.0406	1	12
7	12	0.00862	0.034	0.00874	1	21
11	13	0.02225	0.0731	0.01876	1	44
12	14	0.0215	0.0707	0.01816	1	23
13	15	0.0744	0.2444	0.06268	1	1
14	15	0.0595	0.195	0.0502	1	5
12	16	0.0212	0.0834	0.0214	1	9
15	17	0.0132	0.0437	0.0444	1	130
16	17	0.0454	0.1801	0.0466	1	22
17	18	0.0123	0.0505	0.01298	1	100
18	19	0.01119	0.0493	0.01142	1	24
19	20	0.0252	0.117	0.0298	1	13

Table 23 Line data IEEE 118 bus (Continued)

nl	nr	R p.u	R p.u	B	a	Line flow limits MW
15	19	0.012	0.0394	0.0101	1	14
20	21	0.0183	0.0849	0.0216	1	36
21	22	0.0209	0.097	0.0246	1	54
22	23	0.0342	0.159	0.0404	1	67
23	24	0.0135	0.0492	0.0498	1	10
23	25	0.0156	0.08	0.0864	1	203
26	25	0	0.0382	0	0.96	113
25	27	0.0318	0.163	0.1764	1	179
27	28	0.01913	0.0855	0.0216	1	41
28	29	0.0237	0.0943	0.0238	1	20
30	17	0	0.0388	0	0.96	289
8	30	0.00431	0.0504	0.514	1	93
26	30	0.00799	0.086	0.908	1	280
17	31	0.0474	0.1563	0.0399	1	18
29	31	0.0108	0.0331	0.0083	1	11
23	32	0.0317	0.1153	0.1173	1	116
31	32	0.0298	0.0985	0.0251	1	37
27	32	0.0229	0.0755	0.01926	1	16
15	33	0.038	0.1244	0.03194	1	9
19	34	0.0752	0.247	0.0632	1	4
35	36	0.00224	0.0102	0.00268	1	1
35	37	0.011	0.0497	0.01318	1	42
33	37	0.0415	0.142	0.0366	1	20
34	36	0.00871	0.0268	0.00568	1	38
34	37	0.00256	0.0094	0.00984	1	118
38	37	0	0.0375	0	0.935	304
37	39	0.0321	0.106	0.027	1	69
37	40	0.0593	0.168	0.042	1	55
30	38	0.00464	0.054	0.422	1	78
39	40	0.0184	0.0605	0.01552	1	34
40	41	0.0145	0.0487	0.01222	1	19
40	42	0.0555	0.183	0.0466	1	15
41	42	0.041	0.135	0.0344	1	27
43	44	0.0608	0.2454	0.06068	1	21
34	43	0.0413	0.1681	0.04226	1	2
44	45	0.0224	0.0901	0.0224	1	41
45	46	0.04	0.1356	0.0332	1	45
46	47	0.038	0.127	0.0316	1	39
46	48	0.0601	0.189	0.0472	1	18
47	49	0.0191	0.0625	0.01604	1	12
42	49	0.0715	0.323	0.086	1	81

Table 23 Line data IEEE 118 bus (Continued)

nl	nr	R p.u	R p.u	B	a	Line flow limits MW
42	49	0.0715	0.323	0.086	1	81
45	49	0.0684	0.186	0.0444	1	62
48	49	0.0179	0.0505	0.01258	1	44
49	50	0.0267	0.0752	0.01874	1	67
49	51	0.0486	0.137	0.0342	1	83
51	52	0.0203	0.0588	0.01396	1	36
52	53	0.0405	0.1635	0.04058	1	13
53	54	0.0263	0.122	0.031	1	16
49	54	0.073	0.289	0.0738	1	47
49	54	0.0869	0.291	0.073	1	47
54	55	0.0169	0.0707	0.0202	1	9
54	56	0.00275	0.00955	0.00732	1	23
55	56	0.00488	0.0151	0.00374	1	27
56	57	0.0343	0.0966	0.0242	1	29
50	57	0.0474	0.134	0.0332	1	45
56	58	0.0343	0.0966	0.0242	1	8
51	58	0.0255	0.0719	0.01788	1	23
54	59	0.0503	0.2293	0.0598	1	38
56	59	0.0825	0.251	0.0569	1	35
56	59	0.0803	0.239	0.0536	1	37
55	59	0.04739	0.2158	0.05646	1	43
59	60	0.0317	0.145	0.0376	1	54
59	61	0.0328	0.15	0.0388	1	65
60	61	0.00264	0.0135	0.01456	1	140
60	62	0.0123	0.0561	0.01468	1	12
61	62	0.00824	0.0376	0.0098	1	32
63	59	0	0.0386	0	0.96	190
63	64	0.00172	0.02	0.216	1	190
64	61	0	0.0268	0	0.985	38
38	65	0.00901	0.0986	1.046	1	227
64	65	0.00269	0.0302	0.38	1	228
49	66	0.018	0.0919	0.0248	1	165
49	66	0.018	0.0919	0.0248	1	165
62	66	0.0482	0.218	0.0578	1	46
62	67	0.0258	0.117	0.031	1	30
65	66	0	0.037	0	0.935	11
66	67	0.0224	0.1015	0.02682	1	66
65	68	0.00138	0.016	0.638	1	18
47	69	0.0844	0.2778	0.07092	1	70
49	69	0.0985	0.324	0.0828	1	58
68	69	0	0.037	0	0.935	157
69	70	0.03	0.127	0.122	1	135

Table 23 Line data IEEE 118 bus (Continued)

nl	nr	R p.u	R p.u	B	a	Line flow limits MW
24	70	0.00221	0.4115	0.10198	1	8
70	71	0.00882	0.0355	0.00878	1	21
24	72	0.0488	0.196	0.0488	1	2
71	72	0.0446	0.18	0.04444	1	13
71	73	0.00866	0.0454	0.01178	1	8
70	74	0.0401	0.1323	0.03368	1	20
70	75	0.0428	0.141	0.036	1	1
69	75	0.0405	0.122	0.124	1	138
74	75	0.0123	0.0406	0.01034	1	65
76	77	0.0444	0.148	0.0368	1	76
69	77	0.0309	0.101	0.1038	1	78
75	77	0.0601	0.1999	0.04978	1	43
77	78	0.00376	0.0124	0.01264	1	57
78	79	0.00546	0.0244	0.00648	1	32
77	80	0.017	0.0485	0.0472	1	121
77	80	0.0294	0.105	0.0228	1	55
79	80	0.0156	0.0704	0.0187	1	81
68	81	0.00175	0.0202	0.808	1	55
81	80	0	0.037	0	0.935	55
77	82	0.0298	0.0853	0.08174	1	4
82	83	0.0112	0.03665	0.03796	1	59
83	84	0.0625	0.132	0.0258	1	31
83	85	0.043	0.148	0.0348	1	53
84	85	0.0302	0.0641	0.01234	1	45
85	86	0.035	0.123	0.0276	1	21
86	87	0.02828	0.2074	0.0445	1	5
85	88	0.02	0.102	0.0276	1	63
85	89	0.0239	0.173	0.047	1	89
88	89	0.0139	0.0712	0.01934	1	124
89	90	0.0518	0.188	0.0528	1	73
89	90	0.0238	0.0997	0.106	1	139
90	91	0.0254	0.0836	0.0214	1	2
89	92	0.0099	0.0505	0.0548	1	252
89	92	0.0393	0.1581	0.0414	1	79
91	92	0.0387	0.1272	0.03268	1	11
92	93	0.0258	0.0848	0.0218	1	72
92	94	0.0481	0.158	0.0406	1	65
93	94	0.0223	0.0732	0.01876	1	56
94	95	0.0132	0.0434	0.0111	1	51
80	96	0.0356	0.182	0.0494	1	24
82	96	0.0162	0.053	0.0544	1	12
94	96	0.0269	0.0869	0.023	1	25

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Table 23 Line data IEEE 118 bus (Continued)

nl	nr	R p.u	R p.u	B	a	Line flow limits MW
80	97	0.0183	0.0934	0.0254	1	33
80	98	0.0238	0.108	0.0286	1	36
80	99	0.0454	0.206	0.0546	1	24
92	100	0.0648	0.295	0.0472	1	39
94	100	0.0178	0.058	0.0604	1	5
95	96	0.0171	0.0547	0.01474	1	2
96	97	0.0173	0.0885	0.024	1	14
98	100	0.0397	0.179	0.0476	1	7
99	100	0.018	0.0813	0.0216	1	28
100	101	0.0277	0.1262	0.0328	1	21
92	102	0.0123	0.0559	0.01464	1	56
101	102	0.0246	0.112	0.0294	1	49
100	103	0.016	0.0525	0.0536	1	152
100	104	0.0451	0.204	0.0541	1	70
103	104	0.0466	0.1584	0.0407	1	41
103	105	0.0535	0.1625	0.0408	1	54
100	106	0.0605	0.229	0.062	1	75
104	105	0.00994	0.0378	0.00986	1	61
105	106	0.014	0.0547	0.01434	1	11
105	107	0.053	0.183	0.0472	1	33
105	108	0.0261	0.0703	0.01844	1	30
106	107	0.053	0.183	0.0472	1	30
108	109	0.0105	0.0288	0.0076	1	27
103	110	0.03906	0.1813	0.0461	1	76
109	110	0.0278	0.0762	0.0202	1	17
110	111	0.022	0.0755	0.02	1	45
110	112	0.0247	0.064	0.062	1	87
17	113	0.00913	0.0301	0.00768	1	3
32	113	0.0615	0.203	0.0518	1	5
32	114	0.0135	0.0612	0.01628	1	12
27	115	0.0164	0.0741	0.01972	1	26
114	115	0.0023	0.0104	0.00276	1	2
68	116	0.00034	0.00405	0.164	1	230
12	117	0.0329	0.14	0.0358	1	25
75	118	0.0145	0.0481	0.01198	1	50
76	118	0.0164	0.0544	0.01356	1	9

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Table 24 generator cost coefficients

Bus number	a	b	c	P_{min}	P_{max}
1	0.00375	2	0	50	200
2	0.0175	1.75	0	20	80
3	0.0625	1	0	15	50
7	0.0083	3.25	0	10	35
8	0.025	3	0	10	30
9	0.025	3	0	12	40
16	0.0175	1.75	0	20	80

Table 25 Bus data 16 bus system in southern Laos

Bus No	code	Voltage Mag.	Angle Degree	P_{Load}(MW)	Q_{Load}(Mvar)
1	1	1	0	0	0
2	2	1	0	18	2
3	2	1	0	5.3	0.5
4	0	1	0	5	1.4
5	0	1	0	15.45	5.12
6	0	1	0	5.93	1.61
7	2	1	0	16.71	-0.7
8	2	1	0	28.47	0
9	2	1	0	0	0
10	0	1	0	7.77	2.62
11	0	1	0	9.67	-2.62
12	0	1	0	24	8.6
13	0	1	0	8.53	-2.37
14	0	1	0	15.51	-1.5
15	0	1	0	12.2	3.8
16	2	1	0	28.47	0

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Table 26 Line data 16 bus system in southern Laos

nl	nr	R p.u	R p.u	B	a	Line flow limits MW
1	4	10.14083	2.21219	0.21948	1	130
2	4	1.04946	0.22894	0.68227	1	130
2	4	1.04946	0.22894	0.68227	1	65
3	4	3.77333	0.82314	0.35981	1	130
4	5	6.48542	1.41477	0.27445	1	130
4	5	6.48542	1.41477	0.27445	1	65
5	6	8.09734	1.76641	0.24562	1	90
5	6	8.09734	1.76641	0.24562	1	70
5	7	3.06583	0.6688	0.39917	1	130
5	7	3.06583	0.6688	0.39917	1	32
7	8	0.36554	0.07974	1.15603	1	65
7	8	0.36554	0.07974	1.15603	1	32
7	11	8.96167	1.95496	0.23348	1	65
8	9	1.93383	4.21859	0.15894	1	65
8	10	4.99967	1.09066	0.31258	1	65
9	10	3.06583	0.6688	0.39917	1	65
10	11	5.094	11.11239	0.09793	1	32
10	11	5.094	11.11239	0.09793	1	16
11	12	1.08483	0.23665	0.67105	1	32
11	12	1.08483	0.23665	0.67105	1	32
11	13	7.02783	15.33099	0.08337	1	16
11	13	7.02783	15.33099	0.08337	1	16
13	14	7.33442	1.59998	0.25808	1	65
13	14	7.33442	1.59998	0.25808	1	16
13	15	13.26563	2.89385	0.1919	1	16
13	15	13.26563	2.89385	0.1919	1	32

B.3 Results of Analyzing the Water Network

The described codes for the three h-based methods were utilized to analyze the sample network depicted in Figure 6.4. All the methods converge successfully and the obtained results are shown in Table 27. According to Table 27 the results achieved by solving the sample network using three h-based methods are in a perfect agreement with one another. Moreover, it also shows that the stopping criterion fluctuates in the h-based Newton–Raphson method implying that this method is more sensitive to initial guess and also pipe flow rates used at the beginning of each the iteration. In order to more focus on the educational facets of computer application in WDN analysis, the presented MATLAB codes were utilized to solve a relatively simple network in this thesis. However, the codes can be simply modified to analyze more complicated networks. Finally, successful application of MATLAB for implementing h-based methods for solving WDNs demonstrates that not only these programs can facilitate teaching the backgrounds of available h-based methods but also they can be suitably utilized for enhancing educational and practical aspects of analyzing WDNs.

Table27 Results of the optimal flow rate in pipe, water loss in pipe and pressure at node in network water of Laos P.D.R

Pipe	Flow rate in pipe (m^3/h)	Water loss (m)	node	Pressure at the node (kPa)
1	0.0025441	0.6101	1	152.97
2	0.004497	0.91704	2	146.99
3	0.030503	2.0301	3	138
4	0.040503	1.2125	4	157.91
5	0.097456	0.85109	5	169.79
6	0.032544	2.5666	6	178.14
7	0.041953	2.3256		
Total	900	10.513	Total	943.8

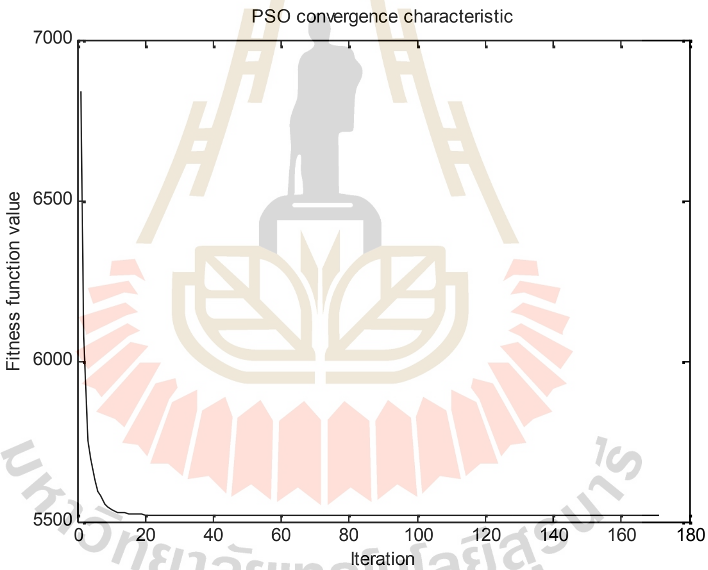
B.4 Results Optimal Power and Water Networks

Here, the results of this thesis considers have been brought to confirm the achievability of the proposed PSO algorithm. In these cases, the gotten results are compared to existing PSO based results. In each case, beneath the same function of operation and algorithm, we performed 10 trials to make beyond any doubt that the arrangement is not stammered at any nearby optimum point. Considering optimal the power generation, the water generation, co-generation, power generation for establishment small hydropower plant, minimum total system cost, power system losses and water system losses, the impediment of power stream and water flow imperatives has been utilized the processor, individual computer with 2.00GB RAM. PSO strategy appears to be touchy to the variety of weights and factors; consequently, in the display consider diverse factors and parameters can influence the swarm execution. In any case, the results displayed as it had a place to the best set of parameters which leads the swarm to the optimum place.

B.4.1 Test Result for IEEE 14 bus

In this case, consider has been to considering of the co-generation plant between power and water by utilizing thermal generator units in IEEE 14bus system containing two small hydropower plants, three co-generation plants, and a water plant. The system has the power load demand of 1509 MW and the water load demand of 468m3/h. The arrangement of power generation, the water generation, co-production of power and water and the minimum cost of system plants. It is too characterized optimal minimum losses for the considered system. Through the proposed algorithm the best arrangement for fathoming this issue appear in Table 28 the gotten results fulfill the craved producing unit's imperatives. The convergence property of the algorithm is outlined in Figure B.1.

Type of plant	unit	Power produced (MW/h)	Water produced (m^3/h)
Thermal plant	1	100.1701	
	2	52.3443	
	3	82.204	
	4	63.66482	
	5	75.64733	
Co-generation plant	1	557.1475	71.54101
	2	472.2008	115.7763
	3	279.676	24.00271
Water plant	1		126.9958



IEEE 30bus system containing two small hydropower plants, three co-generation plants, and a water plant. The system has the power load demand of 1533.4MW and the water load demand of 468m3/h. The arrangement of power generation, water generation, co-production of power and water and the minimum cost of system plants. It is too characterized optimal minimum losses for the considered system. Through the proposed algorithm the best arrangement for fathoming this issue appear in Table 29 the gotten results fulfill the craved producing unit's imperatives. The convergence property of the algorithm is outlined in Figure B.2.

Table 29 Results of the PSO optimal power flow for 30 bus system and water flow for 6 nodes

Type of plant	unit	Power produced (MW/h)	Water produced (m^3/h)
Thermal plant	1	52.26999	
	2	30.08932	
	3	16.91058	
	4	10.00194	
	5	17.47139	
	6	29.73693	
Co-generation plant	1	465.797	95.36191
	2	459.8176	68.35301
	3	145.1498	68.38637
Water plant	1		201.4172

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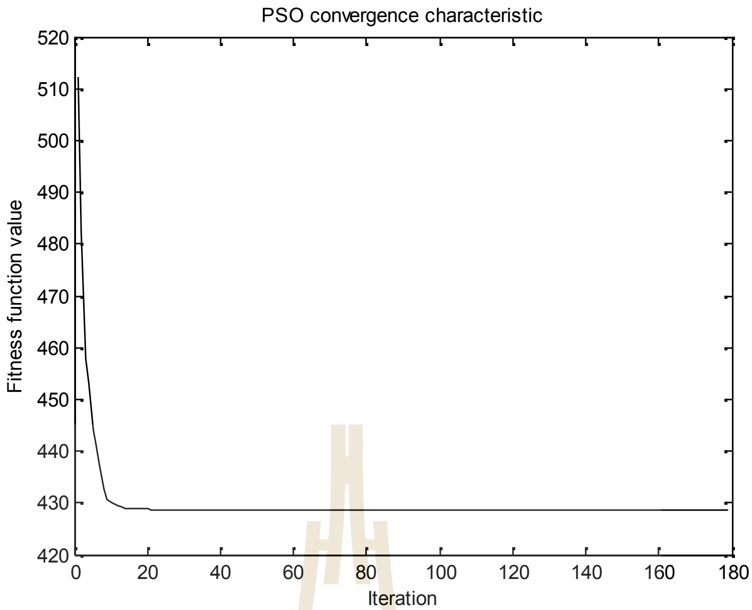

PSO convergence characteristic
Fitness function value
Iteration
520
510
500
490
480
470
460
450
440
430
420
0
20
40
60
80
100
120
140
160
180

Table 30 Results of the PSO optimal power flow for 118 bus system and water flow for 6 nodes

Type of plant	unit	Power produced (MW/h)	Water produced (m^3/h)
Thermal plant	1	134.5347	
	2	18.8040	
	3	24.7909	
	4	16.9075	
	5	181.8554	
	6	153.0910	
	7	16.0946	
	8	86.1811	
	9	20.6677	
	10	21.1713	
	11	150.3177	
	12	291.3223	
	13	19.6247	
	14	19.9547	
	15	61.5754	
	16	19.1136	
	17	42.6756	
	18	14.0095	
	19	17.4480	
	20	47.9802	
	21	91.3146	
	22	162.4735	
	23	32.9876	
	24	75.1737	
	25	137.8718	
	26	118.2979	
	27	46.3068	
	28	213.6489	
	29	249.5791	
	30	138.7884	
	31	51.3483	
	32	21.4360	
	33	15.7794	
	34	15.5460	
	35	60.4973	
	36	50.7942	
	37	202.8585	
	38	80.4218	
	39	24.8307	
	40	174.5245	
	41	122.5033	
	42	11.1173	
	43	31.5762	
	44	237.6650	
	45	137.7756	
	46	159.0390	
	47	11.5590	
	48	60.0662	
	49	52.8105	
	50	14.8768	
	51	35.0396	
	52	68.7866	
	53	51.4716	
	54	58.7282	
	55	34.2415	
Co-generation plant	1	602.4879	82.0016
	2	384.0166	77.9483
	3	180.2885	25.0140
Water plant	1		160.4157

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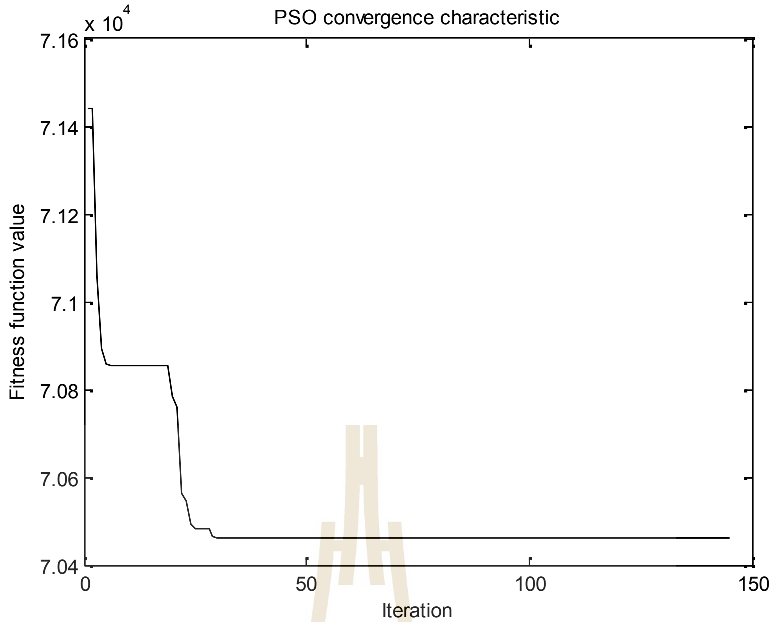

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Type of bus system	Type of plant	Power Loss (MW/h)	Total cost (unit of cost/hr)
14	Thermal plant	26.001	5521.3
	Co-generation plant		
	Water plant		
30	Thermal plant	70.49	428.75
	Co-generation plant		
	Water plant		
118	Thermal plant	31.709	71480
	Co-generation plant		
	Water plant		

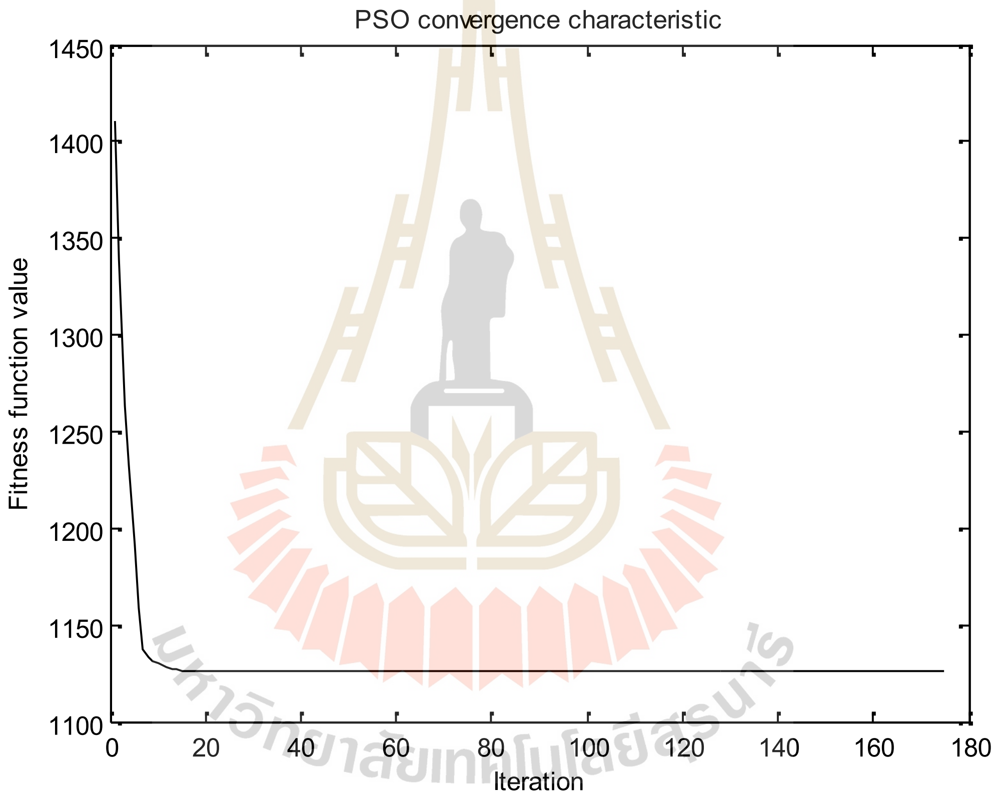
7.1.1 Test Result for 16 bus in Southern Laos

In this case, consider has been to considering of the co-generation plant between power and water by utilizing thermal generator units in 16 bus system in southern Laos containing two small hydropower plants, three co-generation plants, and a water plant. The system has the power load demand of 354.48MW and the water load demand of 468 m3/h of the arrangement of power generation, water generation, co-production of power and water and the minimum cost of system plants. It is too characterized optimal minimum losses for the considered system. Through the proposed algorithm the best of arrangement for fathoming this issue appear in Table 32, 33 the gotten results fulfill the craved producing unit's imperatives. The convergence property of the algorithm is outlined in Figure B.4.

Table 32 Results of the PSO optimal power flow for 16 bus system and water flow for 6 nodes

Type of plant	unit	Power produced (MW/h)	Water produced (m^3/h)
Hydro power plant	1	51.6379	
	2	25.5168	
	3	18.1362	
	4	22.4012	
	5	19.4406	
	6	18.0156	
	7	44.6553	
Co-generation plant	1	71.1298	159.9781
	2	24.3758	75.8469
	3	39.5025	79.8816
Water plant	1		83.2858

Type of bus system	Type of plant	Total Power Loss (MW/h)	Total Water Loss (m^3/h)	Total cost (unit of cost/hr)
16	Hydro power plant Co-generation plant Water plant	60.099	10.513	1125.9



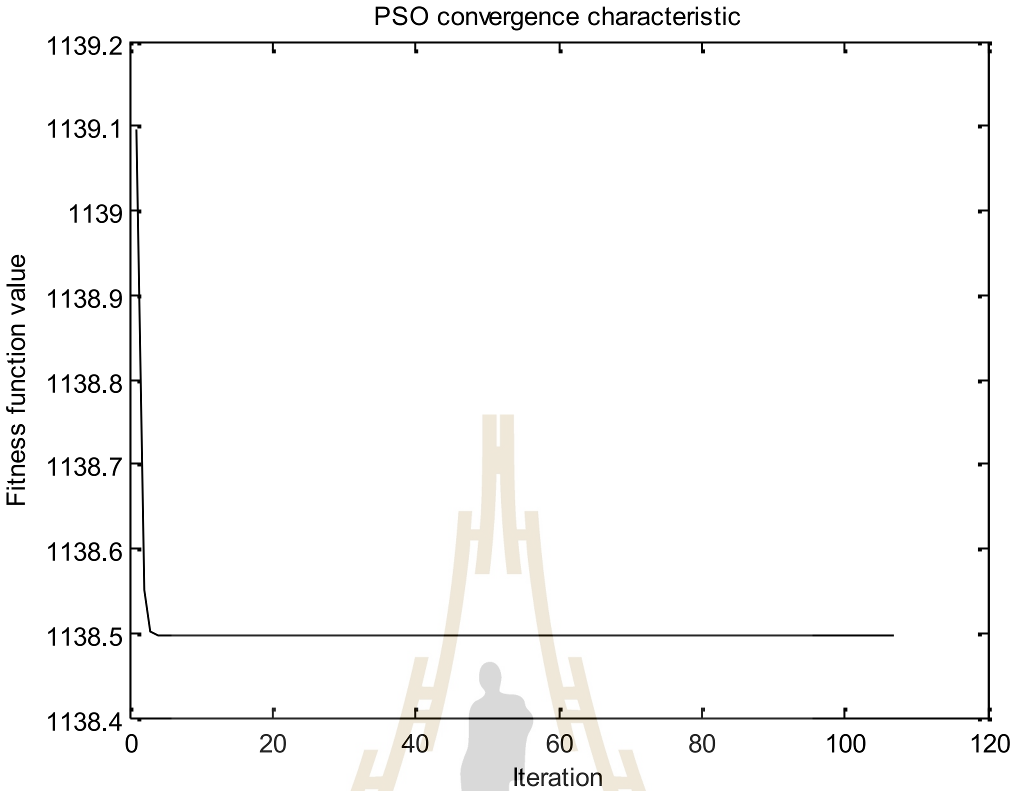
and a water plant. The system has the power load demand of 368.638MW and the water load demand of 468 m3/h of the arrangement of power generation, water generation, co-production of power and water and the minimum cost of system plants. It is too characterized optimal minimum losses for the considered system. Through the proposed algorithm the best of arrangement for fathoming this issue appear in Table 34, 35 the gotten results fulfill the craved producing unit's imperatives. The convergence property of the algorithm is outlined in Figure B.5.

Table 34 Results of the PSO optimal power flow for 16 bus system and water flow for 6 nodes

Type of plant	unit	Power produced (MW/h)	Water produced (m^3/h)
Hydro power plant	1	61.6032	
	2	26.2571	
	3	17.1681	
	4	19.1879	
	5	19.1879	
	6	25.2472	
	7	32.3165	
Co-generation plant	1	23.2275	155.5229
	2	31.3066	75.7417
	3	26.2571	73.7219
Water plant	1		40.3956
Small hydro power plant	1	4.0396	
	2	8.0791	

Table 35 Results of the PSO optimal power loss, water loss and minimum total system cost

Type of bus system	Type of plant	Total Power Loss (MW/h)	Total Water Loss (m^3/h)	Total cost (unit of cost/hr)
16	Hydro power plant	42.482	10.513	1138.5
	Co-generation plant			
	Water plant			
	Small hydropower			


PSO convergence characteristic
Fitness function value
Iteration
1139.2
1139.1
1139
1138.9
1138.8
1138.7
1138.6
1138.5
1138.4
0
20
40
60
80
100
120

their evaluation can give valuable facilities for upgrading instructing conjointly inquiring about on WDN examination.

Additionally, this thesis purposes an application of population-based PSO algorithm and OPF to unravel the different ED issues. The particle swarm optimization is a modern heuristic optimization strategy based on swarm intelligence. The strategy is exceptionally basic, effortlessly completed and it needs fewer parameters, which made it completely created. To be that as it may of the inquire about on the PSO is still at the starting, a part of issues are to be settled. Particle swarm optimization has paid a parcel of consideration for the arrangement of such issues, as it will not endure from stuck into neighborhood optimal solution, constancy on starting factors, untimely and moderate meeting and reviles of dimensionality in comparison to routine optimization methods, PSO has given an made strides result inside less computational time.

OPF strategy has been utilized in classical strategies, which can lead to a nearby minimum and but not a worldwide minimum. For the most part, In OPF strategy destitute convergence may get stuck at neighborhood optimum, they can discover as it were a single optimized arrangement in a single simulation run, they ended up as well moderate on the off chance that a number of factors are expansive and they are computationally costly for the arrangement of a large system.

Hence it can be seen that the economic dispatch of power and water can be extended by taking into thought the power and water systems flows. This does lead to a more complex optimization with more serious imperatives and subsequently finding the attainable locale and optimal arrangement is more troublesome in a few cases. Be that as it may, the optimization does run effectively for a complex hypothetical system that comprises of a 16 bus system in southern Laos and a practical water network. Besides, the results propose that the that the extension of the simultaneous co-dispatch of power and water from a single node model to a network model is not fair successful in assembly supply-demand balance but too is successful in guaranteeing the security limitations forced by the line flow limits.

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APPENDIX A

LIST OF PUBLICATIONS

List of Publication

Khamkeo, D., & Oonsivilai, A. (2014) Flow Rate Analysis Method for Small Hydro Power Plant. **In the IAFOR North American Conference on Sustainability**, Energy & the Environment NACSEE 2014. 11-14 September 2014, Providence, Rhode Island, USA

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BIOGRAPHY

Mr. Douangtavanh Khamkeo was born on March 4, 1977, in Champasak Province, Loa P.D.R. He received the Bachelor degree in Electrical Engineering from the National University of Laos, Master degree of in Electrical Engineering from Vietnam National University – Ho Chi Min City University of Technology, Vietnam in 1996 and 2005 respectively. After graduation, he has been worked for Champasak University, Lao P.D.R. He continued with his graduate studies in the School of Electrical Engineering, Institute of Engineering, Suranaree University of Technology.

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