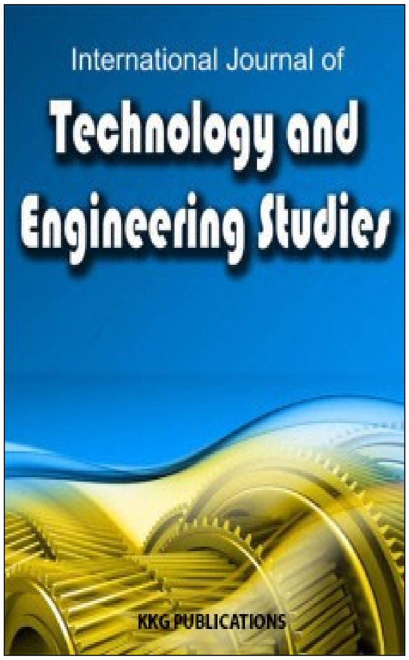

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FORECAST RAINFALL FOR POWER PRODUCTION MANAGEMENT OF NAMKHAN 2 AND 3 HYDROPOWER PLANTS

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Electricity Production
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Abstract. This research aims to study rainfall and forecast reservoir management for optimal electricity production for Namkhan 2 and 3 hydropower plants. The statistical data used is 50 years' data from 1960 to 2009, which is used to predict the rainfall in the future year of 2016. Forecasting algorithms are (1) Forecasts Function in Microsoft Excel (FFME), (2) Minitab software (MNT), (3) Statistical Package for Social Sciences (SPSS), and (4) Fast Fourier Transform (FFT). The SPSS method provides the most accurate results as compared to the others, which is 2.9% different from the actual data. The forecast results are next used as input data for a simulation model for optimizing reservoir management of both hydropower plants. Simulation software is HEC-ResSim3.1, which is used for operations testing for electricity production and water regulation. The input data are the technical data of both HPP and the monthly forecasted rainfall. This study shows the possibility to use the recorded data to predict near future data, which is used as input in the optimization software. The simulation benefits a hydropower plant operator to plan the optimal electricity production.

INTRODUCTION

Lao People's Democratic Republic is located in South East Asia at the center of the Indochina peninsula between latitude 13-23 degree north and longitude 100-108 degree east. Lao PDR has a population of 6.4 million people in year 2016 and a total area of 236,800 square kilometers. Laos has a boundary with the five nations Vietnam, Thailand, Cambodia, Myanmar, and China. The topography of Lao PDR has many rivers that appropriate for hydropower plant construction. Many hydropower resources will allow for up to 18,125 MW in 2025. Presently, power development corporation in Laos consists of Electricite Du Laos (EDL), Independent Power Producer domestic (IPPd), and Independent Power Producer exported (IPPe). Laos has the installed capacity of 6,538 MW, which is divided into 9.08% of EDL, 14.09% of IPPd, and 76.83% of IPPe. Energy resource consists of 66.79% of hydropower, 33.14% of thermal power, and 0.07% other power. The Namkhan river is the river branch of the Mekong river, which is located at latitude 20^{o}19'-19^{o}21' N, Longitude 103^{o}43'-101^{o}57'E, in the Luangprabang, northern Laos. The Namkhan River has drainage area of 7620 square kilometers (km^2), which is shown in Figure 1 as below. The previous operation of both HPPs for electricity production cannot produce the enough energy as demand, which is not on objectives. Oppositely, in rainy season, dams must release water through spillway for many million cubic meters from the reservoirs. So, this is a reason of this study for forecast rainfall and water regulation to manage the operation planning of two hydropower plants [1].

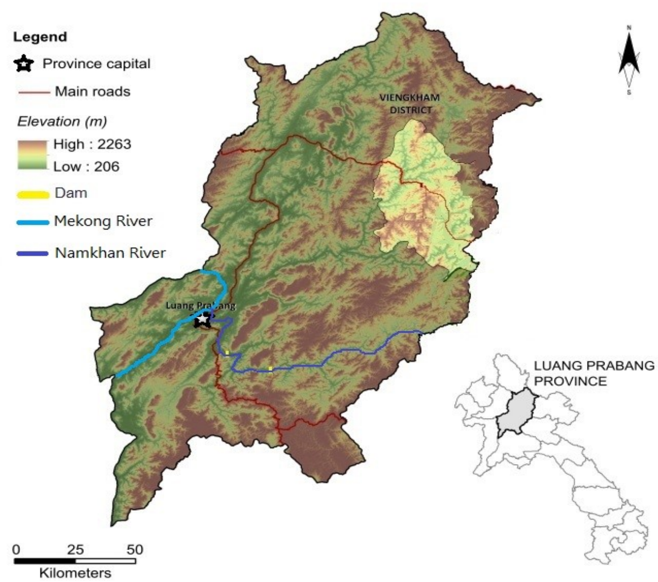

Fig. 1. Namkhan River located in the northern Laos

Namkhan 2 and Namkhan 3 hydropower plants have been constructed in the Namkhan River, which is owned by EDL. Both HPPs are operated and managed by Electricite Du Lao-Generation public company, which is an adopted child of EDL. The Namkhan 2 and 3 HPPs have started the power generation in September 2015 and April 2016, respectively. Both hydropower plants have the installed capacity of 190 MW and

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annual mean generating capacity of 794 GWh. They are connected to the grid at the Laungprabang 2nd substation in the Xiengnguen district northern Laos. The various technical data of Namkhan 2 and Namkhan 3 hydropower plants are shown in Table 1 for the principal features as follows:

TABLE 1
THE PRINCIPAL FEATURES OF NAMKHAN 2 AND 3 HPPS

Description	NK2HPP	NK3HPP	Units
Dam			
Type of the dam	CFRD	RCC	
Height of the dam body	136	61	m
Crest Length	365	156	m
Dam crest elevation	481	353	masl
Data of reservoir storage			
Reservoir capacity	686.2	224	MCM
Reservoir area	30.57	7.07	km^2
Full supply level	477.86	349.06	masl
Dead storage level	465	343	masl
Regulation storage capacity	229.1	48	MCM
Index of engineering benefit			
Annual energy generation	558	240	GWh/y
Installed capacity (2 Units)	130	60	MW
Water discharge turbine	135	176	m^3/s
Annual utilization hours	4,294	4,000	hour
Spillway gate discharge (Radial Gate)			
Amount of spillway gate	4	3	gate
Maximum discharge	9,974	5,710	m^3/s
Dimension of spillway (WxH)	13.5 x 21	13.5 x 21	m
Rate head			
Maximum net head	119.18	41.50	m
Minimum net head	104.58	36.50	m
Tailrace flood level	355.58	304.22	masl
Tailrace check flood level	357.30	306.09	masl
Hydrological data			
Catchment area of dam site	5,167	7,049	km^2
Annual average inflow	67	92.1	m^3/s
Design peak flow (0.1%)	8,640	9,410	m^3/s

LITERATURE REVIEW

Many researchers have suggested the principles concerned and adopted for this research, which are summarized as follows. [2] have presented the improved Thomas-Fiering (FT) and Wavelet Neural Network (WNN) models for cumulative errors reduction in the reservoir inflow forecast. The objective is to obtain enhanced accuracy in forecasting reservoir inflow to find the suitable parameters for the data series in the forecasting error's reduction. Furthermore, the WNN model was utilized to represent a learning approach for the model parameter training according to the errors, so as to reduce overall forecast errors as much as possible. [3] have presented the watershed rainfall forecasting using neuro-fuzzy networks with the assimilation of multi-sensor information.

The purposes are to analyze for finding rainfall sources that are complex of rainfall coupled with physiographic context for great challenge in the development of accurate rainfall forecasts. The forecast rainfall was carried out by using the Adaptive Network-Based Fuzzy Inference System (ANFIS). The results demonstrated that the ANFIS fed with the assimilated precipitation provided reliable results. These are valuable information for the flood warning during typhoon periods. [4] have presented the hydropower generation for multi-purposes of reservoir design. The purpose is the electricity production for economic benefits. Algorithms used are three algorithms: Progressive Optimization Algorithm (POA), Particle Swarm Optimization Algorithm, (PSO) and Genetic Algorithm (GA). The paper demonstrates the usefulness of procedures optimization to improve the operation of a real-life reservoir system for hydropower generation in Xiushui watershed, Jiangxi province, China. [5] have presented the reservoir operation for the benefits of river ecosystem. The objective of this study was concern for irrigation, cruise navigation, and water supply aspects. This paper has shown the methods for development of the optimization model to explore a problem solution between social-economic interests and nature flow maintenance base, which is fundamental to conserve the ecosystem of the river. [6] have presented an optimal simulation model, which is to solve the operational problems of multi-reservoir system between water demand and water transfer-supply in Liaoning, China. The objective of this research is the water transfer to alleviate water shortages in the region. The heuristic algorithm used is improved particle swarm optimization. In conclusion, this research built a new model for joint optimal operation for water diversion, period, and hedging rule of reservoir to determine the total released from the reservoir. [1]. have presented the multi-reservoir operational management for optimal electricity production of Namkhan 2 and 3 hydropower plants. Objective of this study is to study the operational methods for managing the reservoir system, which has a target to optimize the electricity production and water regulation. Theory used is Streamflow Synthesis and Reservoir Regulation (SSARR) and Improved Particle Swarm Optimization (IPSO). The results of this study can be helpful for planning the reservoir operation that has efficiency and sustainability. [7] have presented a Game Theory-Reinforcement Learning (GT-RL) method to develop optimal operation policies for multi-operator reservoir system, which has objective to maximize the total benefit of operation systems. The theory used is GT-RL method for determining the optimal operation policies in multi-operator multi-reservoir with respect to fairness and efficiency criteria. This research can be used to address this challenge and determ ine the gains of the beneficiaries for different levels of cooperation. [8] have presented the contrastive analysis of three parallel modes in multi-dimensional dynamic programming and its application in cascade reservoir operation, which proposes to combine dynamic programming with the parallel processing technology to improve the performance. By combining parallel technology with Multi-Dimensional Dynamic Programming (MDP) algorithm, we can effectively reduce the computational time-consuming and improve the efficiency of the algorithm, thus, effectively improve the application effect of MDP in solving Cascade Reservoirs Operation Optimization (CROO) problem. [9] have presented the fuzzy rule-based model for hydropower reservoirs operation, which has proposed fuzzy rule-based model that presents a set of suitable operation rules for releasing from reservoir based on ideal or target storage level. The required knowledge base for the formulation of the fuzzy rule is obtained from a Stochastic Dynamic Programming (SDP) model with a steady state policy. The results indicate the ability of the method to solve hydropower reservoir operation problem. [10] has presented the solution ranking for reservoir management optimization at Bathtiari reservoir in southwestern Iran, which used Electric-TRI method and NON-dominated Sorting Genetic Algorithm II model (NSGA-II). The objective of this research is to manage between water resource and water demand for balancing, and to build the new model for controlling flood and deficits of the agricultural area. In conclusion, the solution method by Electric-TRI is the optimal model for short- and long-term operation of Bakhtiari reservoir. [11] have presented an optimal management of the flood risk of floodplain development, which has proposed to develop a model of the floodplain problem in the United Kingdom. The model is used both to estimate the expected impact of floodplain development and to explore the impact of alternative policy instruments. The results show that the use of price-based instruments that signal the expected flood damage cost of the floodplain development that has the potential to lead to outcome close to the social optimum. The model error depends on the relation between precipitation and flood risk, and measurement error about the benefits of the developed floodplain. [12] have presented the synergistic gains from the multi-objective optimal operation of cascade reservoir in the Upper Yellow River basin, which proposes to inspire the incentive of joint operation. The contribution of the reservoir to joint operation needs to be quantified. This study investigates the synergistic gains from the optimal joint operation of two pivotal reservoirs along the upper yellow river. The research is analyzed based on three scenarios: neither reservoir participates in flow regulation, one reservoir participates in flow regulation, and both reservoirs participate in flow regulation. The method used is the progressive optimally algorithm-dynamic programming successive approximation to develop a multi-objective optimal operation. The results can be suitably quantified under the three scenarios, attained optimal methodology for an effective way and an important reference guideline for sustainable allocation of a water resource.

THEORY AND METHODOLOGY OPERATION

Rainfall Forecast Methodology

Rainfall Forecast by Forecast Function in Microsoft Excel (FFME)

The Forecast Function in Microsoft Excel is one of the methods for forecast of rainfall. Input data used are the historical data (fifty years of water flow) of Namkhan River. The forecast methodology studied the behavior of rainfall in each year to predict in the future. The algorithm used is shown as below for forecast model. The forecast result of rainfall in year 2016 is the normal year, which forecasted annual average inflow of 65.83 m^3/s, 90.39 m^3/s of Namkhan 2, and 3 hydropower plants, respectively [8].

$$F_t = F_{t-1} + \alpha(A_{t-1} - F_{t-1})/\alpha = 0 - 1 \quad (1)$$

where: F_t- New forecast,
$F_{t-1}-$ Previous period forecast,
$A_{t-1}-$ Previous period actual demand, and
$\alpha-$ Smoothing (weighing) constant,

Rainfall Forecast by MNT Software

Minitab software is a statistical analysis program, which is used in the forecast rainfall of Namkhan 2 and 3 hydropower plants. The forecast rainfall has been divided into two methods. First method is result forecast from the rainfall's statistic data to predict the rainfall in the future. Second method is result forecast from several variables that relate the rainfall such as: temperature, wind, humidity, and others. The method used is first method for rainfall forecast results. The function used is decomposition module of Time Series function in Minitab software. Forecast results in 2016 are for annual average inflow year, which show 65.1 m^3/s and 89.4 m^3/s of Namkhan 2 and 3 HPP, respectively. Accuracy measure of Minitab software consists of mean absolute percentage error and mean absolute deviation, which have values of 22.6 and 177.2, respectively.

Rainfall Forecast by SPSS Program

SPSS program was abbreviated from statistical package for the social sciences, which will be used in the statistical analysis for rainfall forecast results in the future. The result forecast has been divided into two methods. First forecast method is rainfall analysis from the rainfall's statistical data only. Second forecast method is rainfall predication from several variables that relate the rainfall such as: temperature, wind, and humidity of each year. The forecast results in 2016 are for annual average inflow year, which show 64.25 m^3/s and 88.19 m^3/s of Namkhan 2 and 3 hydropower plants, respectively. The function used is the Forecasting module of the Time Series function in the SPSS software. Accuracy measure of SPSS software consists of mean absolute percentage error (MAPE=19.03), mean absolute error (MAE=13.55), and R-squared deviation (R^2=0.808).

Behavioral Study of Rainfall by FFT Software

The FFT (online calculation) is one formulation to find the time loop of the repeat possibilities in the future. FFT software cannot be directly forecasted but it will help to find out the possibility for the repeat of rainfall loops. Namkhan 2 HPP has determined the water criterion as follows: The wet year is annual average inflow more than 99 m3/s. The average wet year is annual average inflow during 80-99 m^3/s. The average normal year is annual average inflow during 60-79 m^3/s. The average dry year is annual average inflow during 40-59 m^3/s. The dry year is annual average inflow less than 40 m^3/s. The result from FFT software shows the repeat possibilities that wet year will happen in every 30 years. Average wet year will happen in every 10 years. Average dry year will happen in every 10 years, and dry year will happen in every 30 years.

The forecast methodologies in this paper used four methods for predicting the rainfall. After receiving results, the results will be analyzed again to study the trend of forecast results that has near values. The near values will be used into the simulation model for the next step. However, the results selection should be considered from error value of each method. The rainfall forecast is the difficult prediction because the rainfall of each year has a difference. So, the selection of each method should be known and understood about the behavior of rainfall in each year before the decision.

Reservoir Operational Management

Multi-reservoir management has an important role to the electricity production and water requirement. It affects all sections of social and economic development. Presently, EDL is facing the operational problem of multi-reservoir management for optimizing electricity production. Namkhan 2 and 3 hydropower plants is a case study that is a challenge for the operator's decision for operational management. Therefore, optimal reservoir management can be helped to plan for power generation and benefit for water released requirement, and flood control in the downstream river. The reservoir management was defined with the schematic representation as in Figure 2.

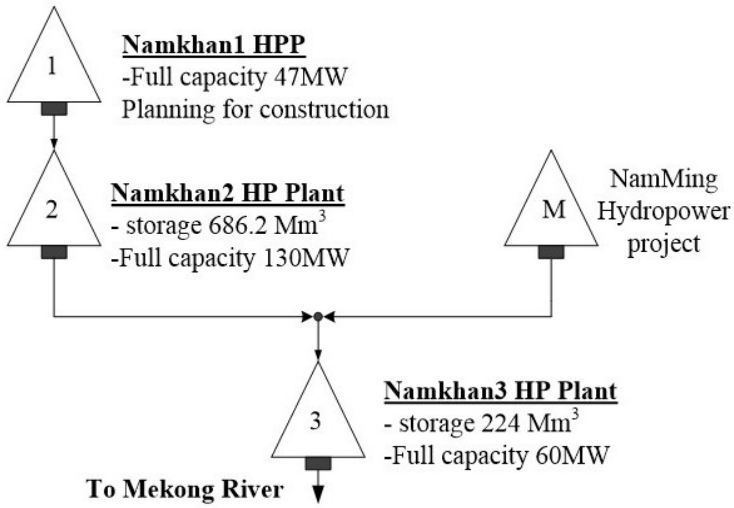

Fig. 2. Schematic representations of Namkhan 2 and 3 HPPs

According to the mentioned schematic, equations can be written as the following [8]:

Water balance equation can be written as below:

$$St_s = St_f + Qin_j - (Qtb_j + Sp_j + Bt_j) - Ev_j \quad (2)$$

where: St_s Water storage at the second time of the period *j*,
St_f- Water storage at the first time of the period *j*,
Qin_j -Water inflow during period *j*,
Qtb_j - Water discharge turbine during period *j*,
Sp_j -Water released through spillway during period *j*,
Bt_j -Water released through bottom tunnel during period *j*,
Ev_j -Evaporation loss during period *j*,

In that

$$Q_out = Qtb_j + Sp_j + Bt_j + Ev_j \quad (3)$$

If $Qin_j = Q_out$
$St_s = St_f$; $Rl_s = Rl_f$
If $Qin_j > Q_out$
$St_s > St_f$; $Rl_s > Rl_f$
And if $Qin_j < Q_out$
$St_s < St_f$; $Rl_s < Rl_f$

where: Q_{out} -Total water flow out during period *j*,
Rl_s -Reservoir level at the second time of period *j*, and
Rl_f -Reservoir level at the first time of the period *j*,

From considering the reservoir storage of both reservoirs, Namkhan 3 reservoir's equations can be written as below:

$$St_{3.j}(useful) = St_{3.j}(usage) + St_{2.j}(usage) \quad (4)$$

where: $St_{3.j}$ (useful) - Total water useful for storage of Namkhan 3 reservoir during period j,
$St_{3.j}$ (usage) - Water usage in the operation of Namkhan 3 HPP only during period j, and
$St_{2.j}$ (usage) - Water usage in the operation of Namkhan 2 HPP during period j,

Operational Management for Electricity Production

Total Energy Generated by Multi-Hydropower Plant

Total energy generation of many hydropower plants is dependent on power production capacity of each HPP. Maximum energy equation of Annual energy generation used is written for energy output calculation of the hydroelectric [8].
$E = [(P_1\Delta_{t1} + P_1\Delta_{t2} + .. + P_1\Delta_{tn}) + (P_2\Delta_{t1} + P_2\Delta_{t2} + .. + P_2\Delta_{tn}) + .. + (P_N\Delta_{t1} + P_N\Delta_{t2} + .. + P_N\Delta_{tn})]$

Maximum energy equation can be written below:

$$E = max \sum_{j=1}^{n} \sum_{j=1}^{N} \quad ; \quad n = T/\Delta_t \quad (5)$$

where: E - Total energy generation (kWh),
Δ_t -Time step of electricity production,
N - Number of time for operational period,
T - Length of the operational period,
N - Number of hydropower plants, and
$P_{i,j}$ - Power output of the (*i*) hydropower plant during the (*j*) time step,

Hydropower installation capacity

Hydraulic turbine is an important piece of the equipment which transforms the energy from the water into the mechanical energy. Then rotates the hydroelectric generator that becomes electric power. Power installed capacity is dependent on height and volume of water, which can be written as the following equation [13]:

$$P_G = \eta \rho g Q H \quad (6)$$

where: PG - Hydropower installed capacity (W),
η - Power plant efficiency
ρ - Water density (kg/m^3),
g - Gravitational acceleration (m/s^2),
Q - Water discharge turbine rate (m^3/s), and
H - Head rate (m),

Multi-Reservoir Management Optimization Method

Multi-reservoir management has many constraints related to the reservoir operation. The method used is optimization for multi-reservoir management. The operational method is shown in Figure 3 for the simulation process of electricity production and reservoir regulation as follows:

Fig. 3. Simulation process of operational methodology

The input data used consist of technical data and rainfall forecast results, which will be used in the simulation model. The software simulation used is HEC-ResSim3.1 for reservoir operational simulation. The optimizer methods of producing are the configuration for parameters that relate to the operation system. The parameter configuration has been divided into two configurations as: power generation by elevation of reservoir and periods-operation of electricity production. The simulation results will be revised to find the optimal results for rule curve of reservoir operation.

HISTORICAL DATA FOR SIMULATION MODEL

Water Inflow Data

Historical data of runoff (since 1960-2009) were collected from the Ban Mout and the Pakbak hydrological stations, which are used to calculate water inflow at the dam site of Namkhan 2 and Namkhan 3 HPPs. The actual annual average inflow of Namkhan 2 HPP is 62.4 m^3/s in 2016. Table 2 shows annual and monthly average flow reservoir's discharge data [14].

TABLE 2
ANNUAL AVERAGE INFLOW FOR BOTH HPPS (UNIT: m^3/s)

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Namkhan 2 HPP average inflow	23.09	18.06	13.85	15.59	26.12	64.92	120.86	193.07	167.52	79.05	42.05	28.82	66.08
Namkhan 3 HPP average inflow	31.69	24.78	19.07	21.41	35.86	89.78	165.08	264.92	229.77	108.41	57.63	39.49	90.65
Percentage (%)	2.91	2.28	1.75	1.97	3.30	8.25	15.17	24.35	21.12	9.97	5.30	3.63	100.00

Evaporation Data

Monthly average evaporation is one of the data sets that are used in software simulation for reservoir management and forecast information in the future. The Table 3 shows the reservoir evaporation net [14].

TABLE 3
THE RESERVOIR EVAPORATION NET (UNIT: mm)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
58.5	83.6	108.4	103.2	85.7	71.5	55.3	46.5	51.8	56	53	52.6	826.1

Technical Data of Hydropower Plants

Water used in plant station and hydraulic loss data will be used in simulation model for operational testing of hydroelectric plants. Table 4 shows the technical data of both hydropower plants [14].

TABLE 4
THE TECHNICAL DATA OF BOTH HYDROPOWER PLANTS

No.	Station Usage	Hydraulic Loss	Efficiency
Namkhan 2 HPP	2 m^3/s	1.15 m	97 %
Namkhan 3 HPP	2 m^3/s	0.40 m	97 %

Actual Data of Water Inflow

According to the yearly report of Namkhan 2 and 3 hydropower plants on 2016, actual data of water inflow are shown in Table 5 for both hydropower plants. Water inflow data are monthly and unit of water inflow is cubic meter per second (Monthly water inflow average) [15].

TABLE 5
WATER INFLOW OF NAMKHAN 2 AND 3 HPPS IN 2016 (m^3/s)

Description	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Monthly water inflow of Namkhan 2 HPP	23.26	20.74	17.41	16.74	15.30	26.62	52.33	258.4	175.2	74.01	40.36	28.03	62.41
Monthly water inflow of Namkhan 3 HPP	31.73	28.29	23.75	22.83	21.60	36.31	71.39	352.5	239.0	100.9	55.06	38.19	85.14

SIMULATION RESULTS

Rainfall Results of Forecasting Model

The data usage in rainfall forecast is water inflow data from 1960 to 2009 from the basic design data of Namkhan 2 and 3 HPP to predict the rainfall results in future. The forecast results from all methods have indicated that 2016 has average normal water per year. The results of all methods show different values, which show 5.3% average difference from actual data in 2016. Monthly average inflow reservoir's discharge data are shown in Table 6 and Table 7 for three method results, except FFT method. The FFT software cannot directly forecast but it will help to analyze and consider the time loops of repeat possibilities in future [16]. The rainfall forecast is difficult prediction because the rainfall in each year is of different volume. Therefore, this rainfall forecast is to find the rainfall trend that will be taken in the future and to find the maximum accuracy value of rainfall prediction.

TABLE 6
FORECAST RESULT OF NAMKHAN 2 HPP (AVERAGE m^3/s)

Monthly Generated	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Forecast results of FFME method	23.1	20.3	17.7	16.3	15.7	64.7	120.4	192.4	170.1	78.7	41.9	28.7	65.8
Forecast results of MNT method	22.7	20.1	17.5	16.1	15.5	63.9	119.1	190.3	168.2	77.9	41.4	28.4	65.1
Forecast results of SPSS method	22.4	19.8	17.3	15.9	15.3	63.1	117.5	187.8	166.1	76.8	40.9	28.1	64.2

However, forecasting of some methods can predict the yearly data but in this research, data used are daily. So, yearly data will be changed to the daily data according to the pattern of historical data that have annual rainfall equally.

Reservoir Operation Result from Simulation Model

This research has considered the three cases from rainfall-forecast result, which includes FFME, MNT, and SPSS. The simulation results consist of power generation, water storage, reservoir level, water inflow, and outflow of both hydropower plants. Figure 4 and Figure 5 show the relation between reservoir elevation, water inflow, and outflow for simulating the reservoir operation of Namkhan 2 and 3 hydropower plants. The graphic presented is the simulation result that used forecasted result of case MNT to explain the reservoir operational relationship [17], [18], [19].

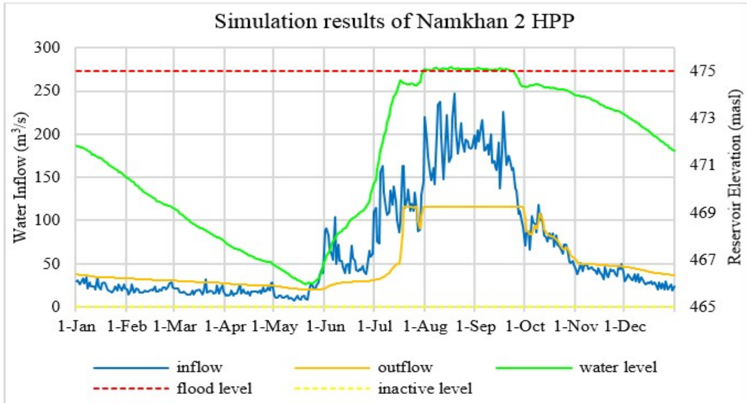

Fig. 4. The reservoir operational result of Namkhan 2 HPP

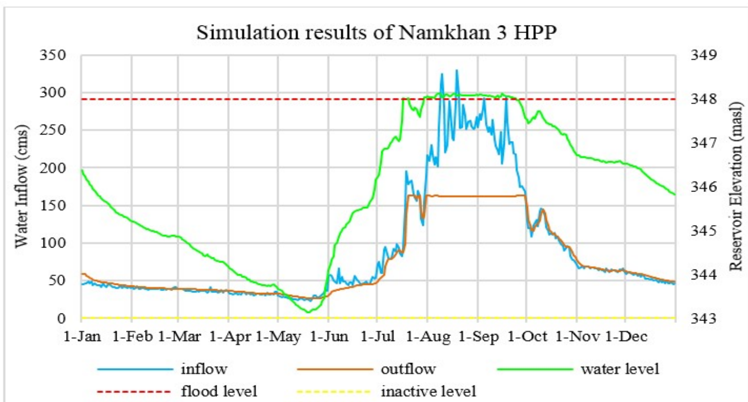

Fig. 5. The reservoir operational result of Namkhan 3 HPP

Annual and Monthly Energy Generated from Simulation

Annual energy generation from simulation results is shown in Table 8 of Namkhan 2 and 3 hydropower plants.

TABLE 8
THE ANNUAL ENERGY GENERATION FROM SIMULATION RESULTS

Case Study of Forecast	Energy Generation (GWh/year) in Year 2016		
	FFME	MNT	SPSS
Namkhan 2 HPP	529.634	526.363	525.770
Namkhan 3 HPP	242.362	240.524	239.197

The results of monthly energy generated from simulation are shown in Table 9 and Table 10 of Namkhan 2 and 3 hydropower plants, respectively.

TABLE 9
MONTHLY ENERGY GENERATED OF NAMKHAN 2 HPP (GWh)

Monthly Generated	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Energy generated from FFME results	28.84	23.85	22.94	19.20	16.33	22.18	64.29	96.72	93.60	68.24	39.42	34.08	529.63
Energy generated from MNT results	28.75	24.05	23.30	19.80	17.00	21.74	59.58	96.72	93.60	68.11	39.54	34.18	526.36
Energy generated from SPSS results	28.56	24.10	23.48	20.25	17.90	22.50	60.65	96.72	93.60	64.89	39.07	34.02	525.77

TABLE 10
MONTHLY ENERGY GENERATED OF NAMKHAN 3 HPP (GWh)

Monthly Generated	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Energy generated from FFME results	13.42	10.14	10.04	8.48	7.20	10.30	31.12	44.64	43.20	31.25	17.52	15.24	242.36
Energy generated from MNT results	13.10	10.03	9.96	8.47	7.31	10.59	29.70	44.64	43.20	31.12	17.52	15.02	240.52
Energy generated from SPSS results	12.84	9.96	9.83	8.38	7.42	11.08	30.24	44.64	43.20	30.32	17.04	14.63	239.19

Water Discharged Spillway of Simulation Results

Water released through spillway in year 2016 from simulation results must release water during mid-August to tail-September, which shows the water volume in Table 11 of both hydropower plants. Released water volume through spillway is 920 million cubic meters of Namkhan 2 hydropower plant in rainy season 2016, which is more than simulation results.

TABLE 11
THE WATER RELEASED FROM THE SIMULATION RESULT

Case Study of Forecast	Water Released Through Spillway (MCM)		
	FFME	MNT	SPSS
Namkhan 2 HPP	241.34	228.76	202.73
Namkhan 3 HPP	346.99	334.91	309.89

Water release is on Namkhan 3 HPP, which is a downstream plant. That water released in the dry months (Jan to Jun) is 80 to 100 million cubic meter, which is enough for water requirement on downstream Namkhan River.

DISCUSSION

The selecting of the forecasted results is to use in the simulation model for simulating the reservoir operation. So, the results selection from among methodology of rainfall prediction is the values selection that is nearly the volume with actual data according to the detail as follows:

- The forecasted results will be used as results of all methods.
- Comparison between the forecasted results and actual data of the period year.
- The selecting is considered from the rainfall trend according to the historical data.
- The result selected is result or method that has nearly the volume with actual data and has trend same as the historical data.

After consideration, the result of the SPSS method has nearly maximum value with actual data. Also, the Minitab method has the rainfall trend that is same as the historical data. In conclusion, all forecasted results among methodology show a little difference, which will be used in the simulation model for simulating the reservoir operation of the power production and water regulation for both hydropower plants. Furthermore, forecast uses all four methods to find the trend and to help the decision for selecting the forecasted results that will be used for planning in the future.

However, the forecast methodologies in this paper used all methods for predicting the rainfall in each year. The rainfall forecast will be predicted from year to year by using past data. The forecasted results will be considered again to analyze the trend and rainfall from predicted results that have near values with actual data. Any methodology that has maximum near values with actual data will be used for analyzing the rainfall and forecasted result will be used in the simulation model for testing in the next step.

CONCLUSION AND RECOMMENDATIONS

This work studies the forecast methodology to find the rainfall results of Namkhan 2 and 3 hydropower plants. The historical data were used to show for the 50 years' rainfall data between 1960 and 2009. The predicted year is 2016. The comparison of rainfall results between actual data and the forecasting model is 5.3% average difference of all methods. The rainfall forecast results show that the SPSS method has 2.9% different values better than other three methods. The forecasted rainfall is used as the input data for HEC-ResSim3.1. The simulation results for three forecasted rainfall show that the annual energy generation is more than actual production, which is counted for 139% of power production. Water released through spillway for Namkhan 2 reservoir fell 241 million cubic meters, which is less than actual released amount which is 920 million cubic meters in rainy season of 2016. These results can be described to be the problems for previous operations of Namkhan 2 and 3 hydropower plants, so it caused the flood at downstream Namkhan River in the rainy season and the power generation is not on target. This work can be based for planning and managing the electricity production and the reservoir operation for appropriate sustainability.

Declaration of Conflicting Interests

No financial as well as non-financial conflicts of interests are present in this work.

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— This article does not have any appendix. —