HYBRID NEURO FUZZY-BASED RESERVOIR RE-OPERATION MODEL: CASE STUDY OF BHUMIBOL DAM IN THAILAND

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- INTRODUCTION

- METHODOLOGY

- RESULT AND DISCUSSION

- CONCLUSIONS

INTRODUCTION

- Dam and reservoir systems have long been introduced to support the water resources planning and management through a variety of the single and multi-purpose water resources development projects.

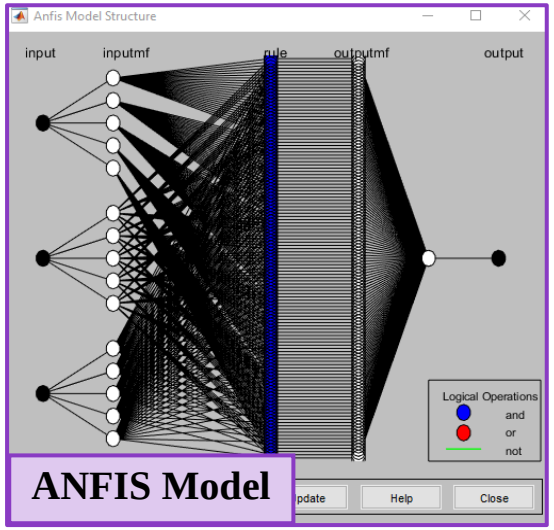
- Dam and reservoir operations in the era of climate change have become a challenging task to reduce the disaster risk such as flood and drought.

- Thailand is vulnerable to extreme weather events which were faced the major flood in 2011 and have also been experienced with worst drought in 40 years record.

INTRODUCTION (CONT;)

Reservoir Re-operation

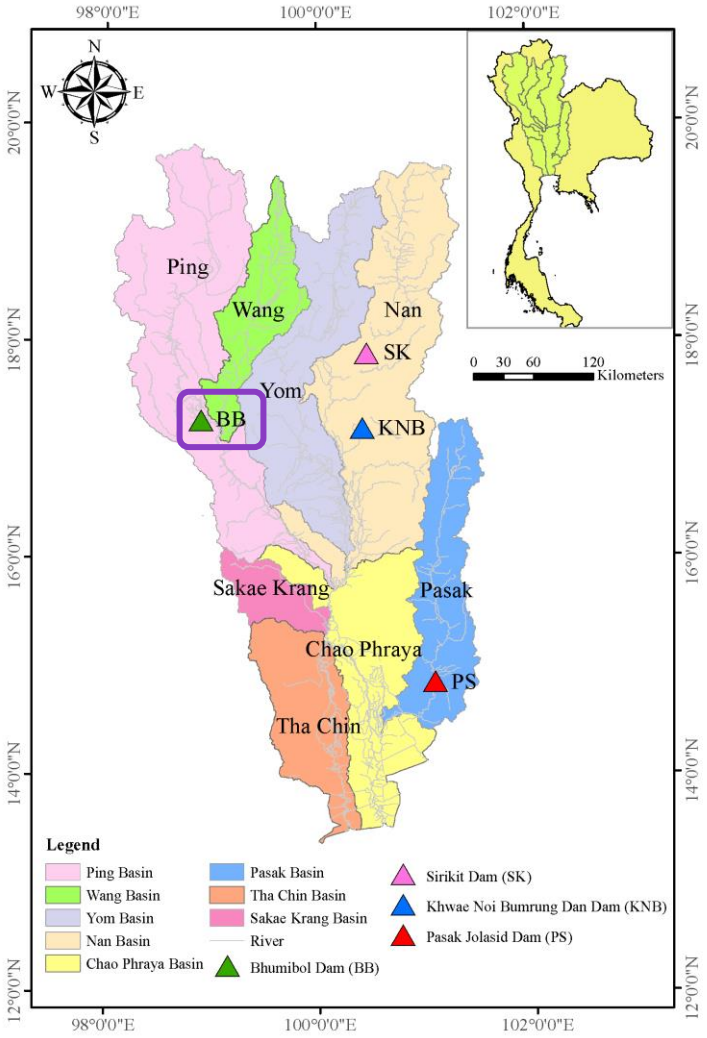
- The reservoir re-operation is considered as one of the best ways to achieve the water resource management activities particularly in views of the water allocation sustainability and the natural disaster risk management.



ANFIS Model

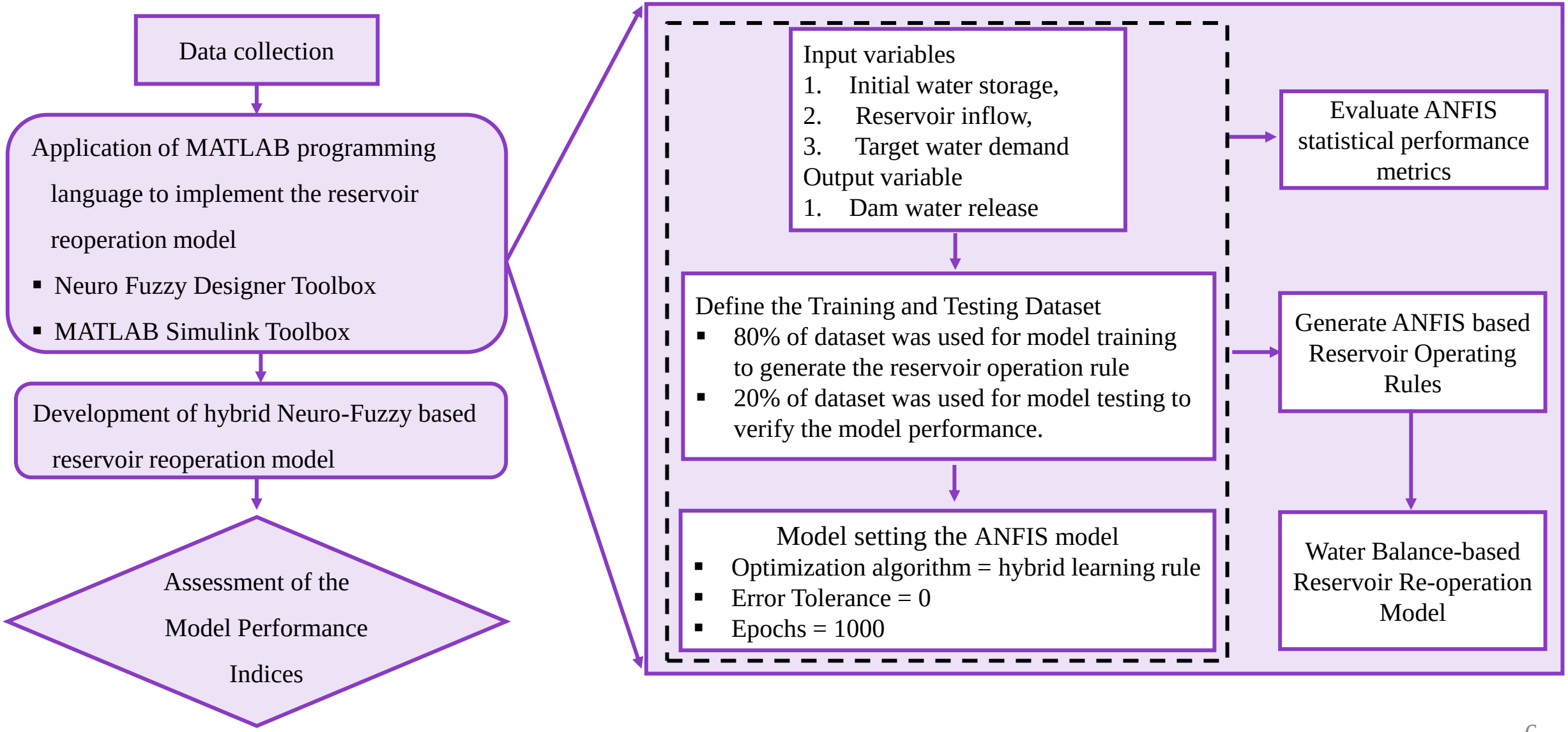
- This study aims to investigate the adaptation strategy through re-operating the reservoir using Artificial Intelligence Tool. To accomplish this research goals, the reservoir reoperation model was developed by applying Adaptive Neuro Fuzzy Inference System (ANFIS) aiming to assist the current operation system of Bhumibol Dam in Thailand.

INTRODUCTION (CONT;)



- Bhumibol (BB) dam is the principal source of water supply in the Greater Chao Phraya River Basin.
- BB Dam is the first multi-purposed concrete arch gravity-dam in Thailand constructed across the Ping River, which is the major tributary of the Chao Phraya River.
- The main objectives of BB dam are to provide hydropower generation, flood control, and water supply for multi-purpose.

METHODOLOGY



METHODOLOGY (CONT;)

Data collection

The reservoir data of BB Dam was collected starting from 2000 to 2020.

Data Type	**Data Source**
Reservoir Data	EGAT, RID
• Initial water storage • Reservoir inflow • Target water demand • Dam water release	
Reservoir Constrained	EGAT
• Maximum storage capacity • Minimum storage capacity • Maximum water release • minimum water release	= 13462 MCM = 3800 MCM = 69.76 MCM = 5 MCM

Note: EGAT = Electricity Generating Authority of Thailand
RID = Royal Irrigation Department
MCM = Million Cubic Meter

METHODOLOGY (CONT;)

Data collection

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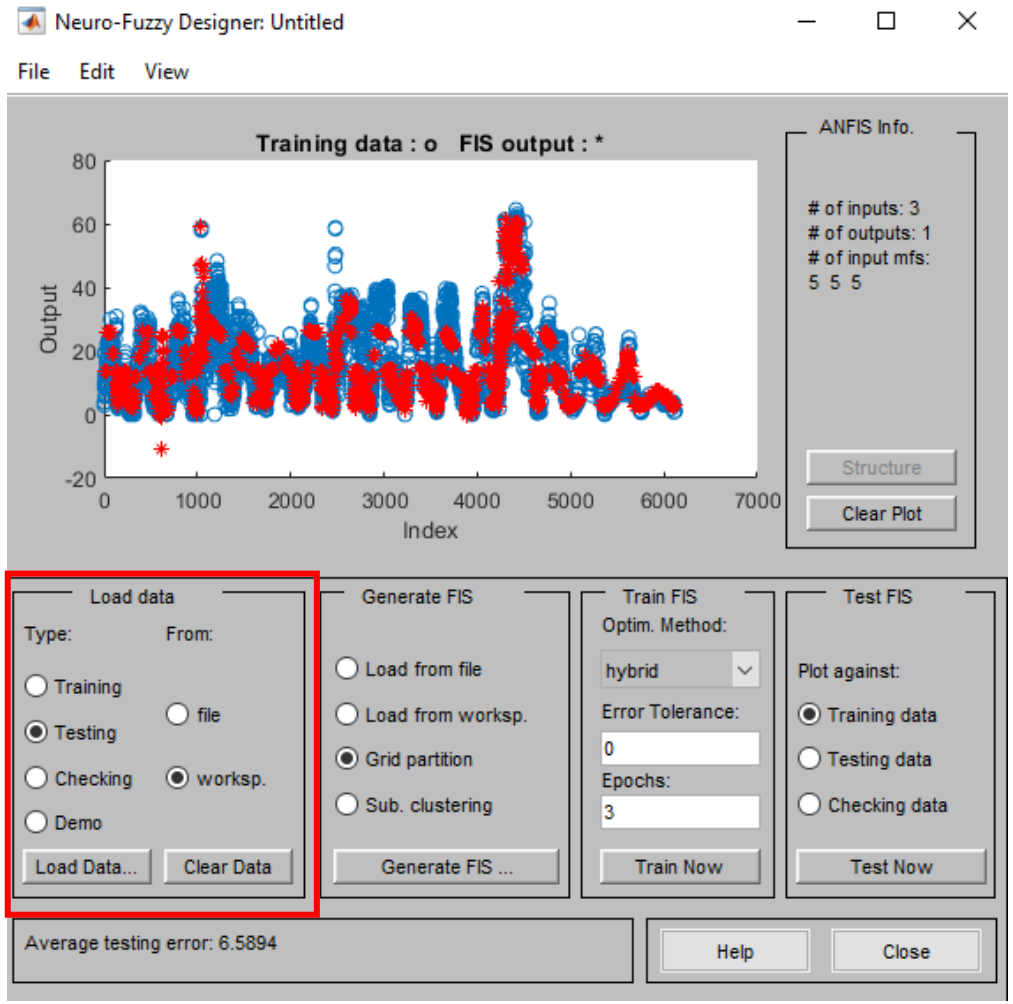
Reservoir re-operation model



- The 80% of dataset are used for model training to generate the reoperating rules between the input and output variables and 20% of dataset was used for model testing to verify the model performance.
- To evaluate ANFIS statistical performance metrics namely, Root Mean Square Error (RMSE) and R-squared (R^2) were evaluated to assess the ANFIS-based reservoir re-operation performances for both training and testing datasets.

METHODOLOGY (CONT;)

Data collection

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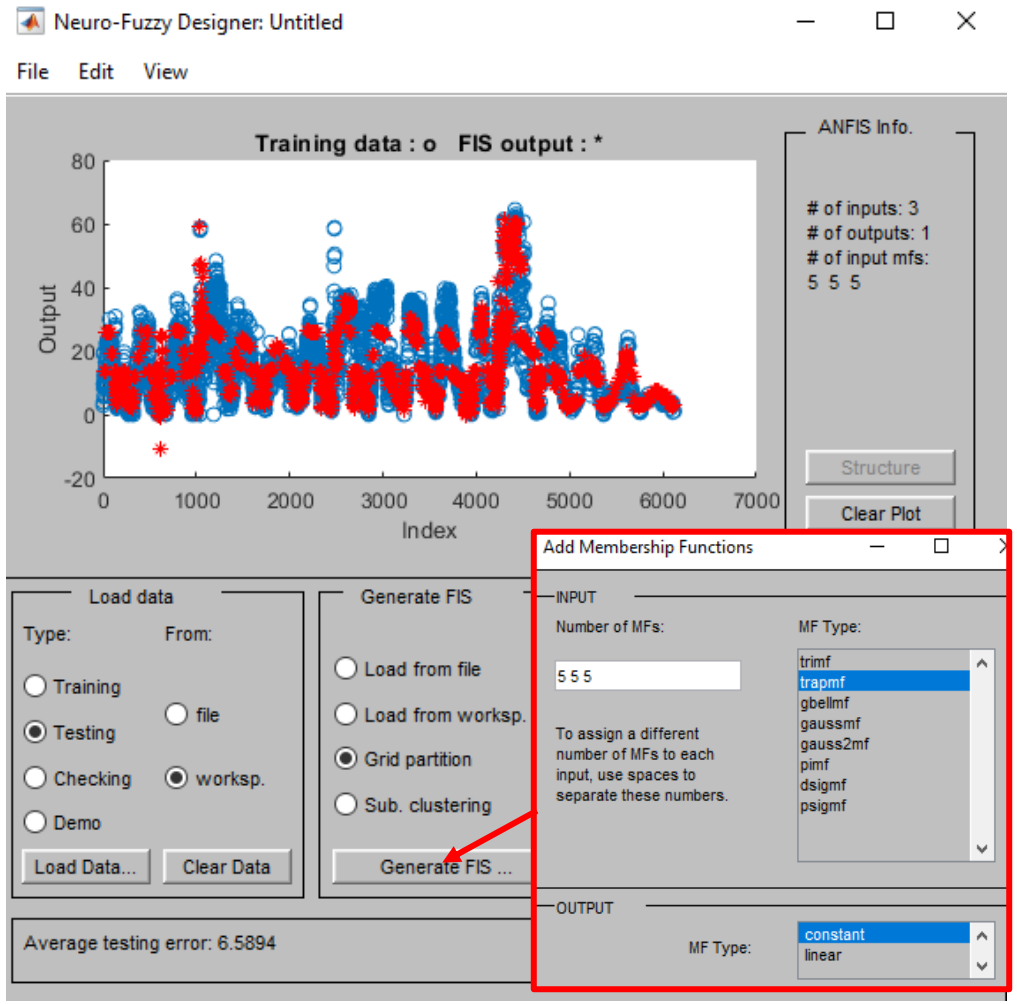
Reservoir re-operation model



- The membership functions of variables are assigned as trapezium types with five numbers in ANFIS model aiming to perform the better Root Mean Square Error (RMSE) and R-squared (R^2).

METHODOLOGY (CONT;)

Data collection

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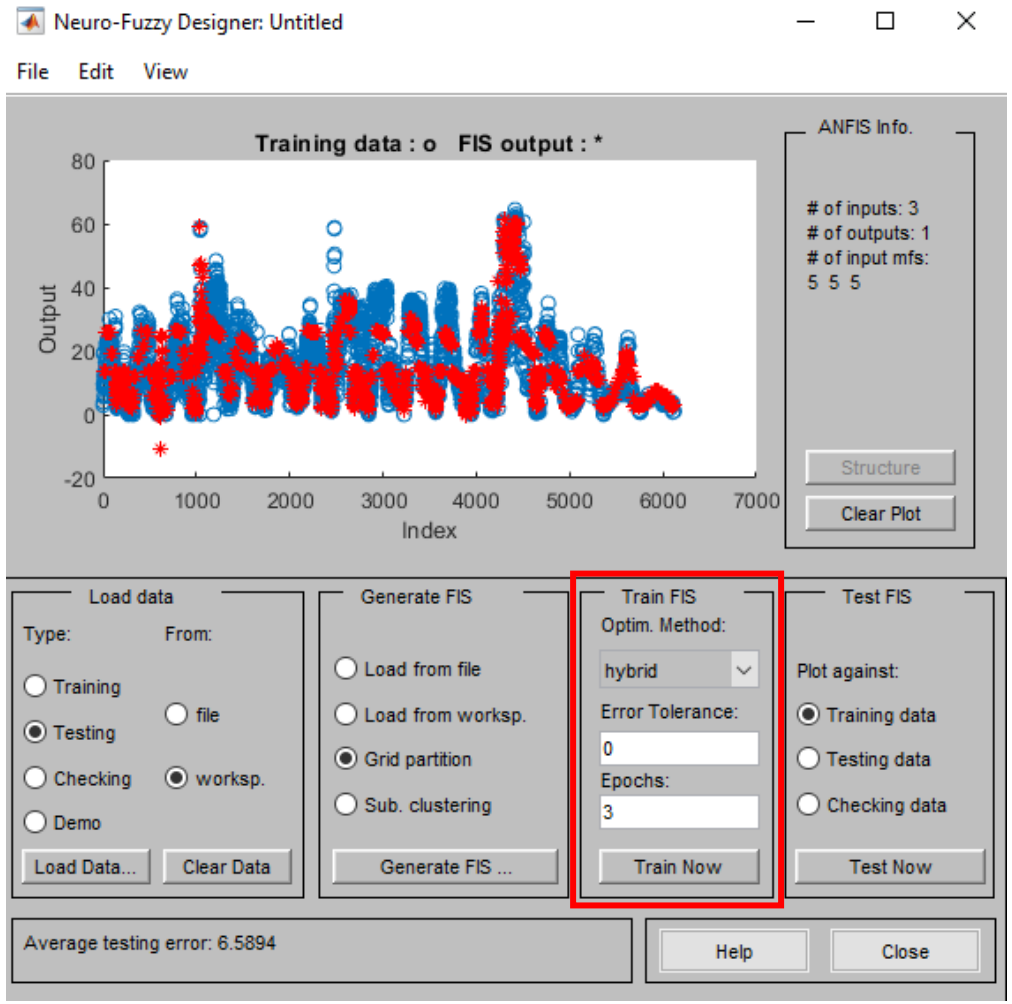
Reservoir re-operation model



- To train the fuzzy IF–THEN rules in ANFIS model, a hybrid learning rule which combines the back-propagation gradient descent, and a least squares method are used. The training model will stop when either desired Error Tolerance or Epochs are reached.

METHODOLOGY (CONT;)

Data collection

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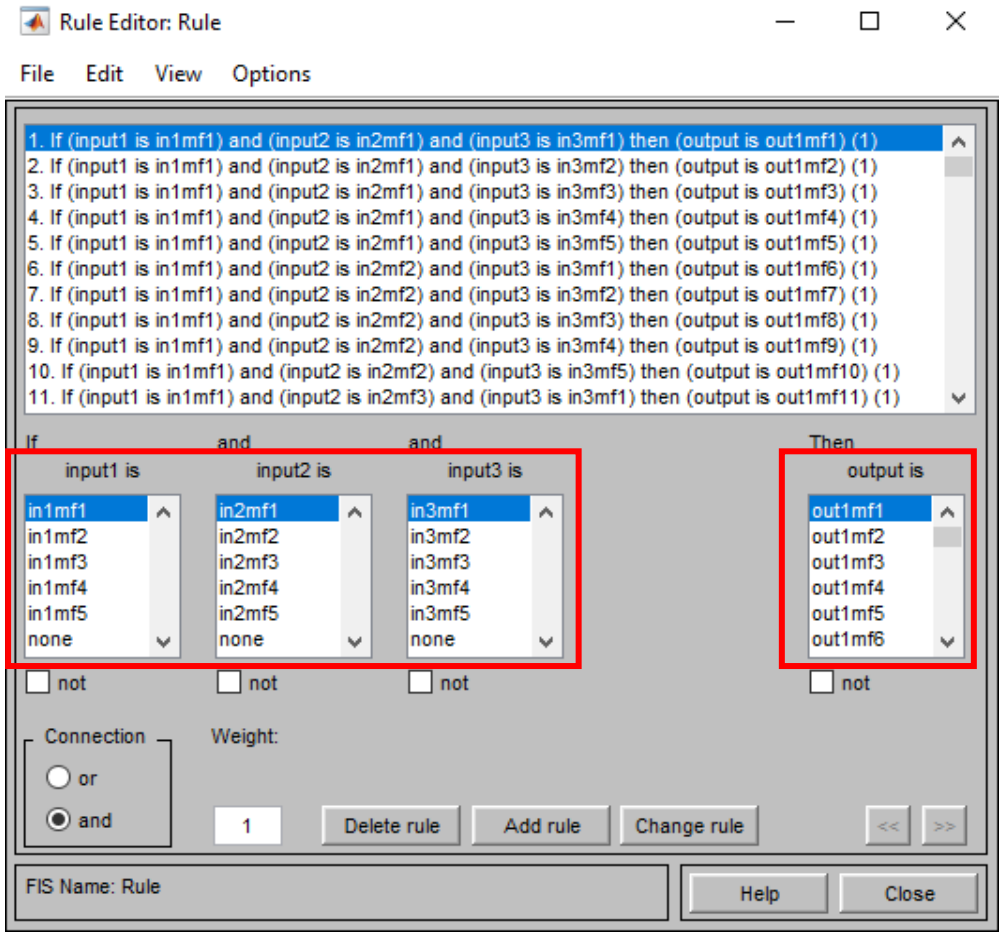
Reservoir re-operation model



- ANFIS can generate a set of fuzzy IF–THEN rules with desired membership functions identifying the input and output reservoir variables through a hybrid learning approach in Neuro Fuzzy Designer Toolbox.

METHODOLOGY (CONT;)

Data collection

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Reservoir re-operation model

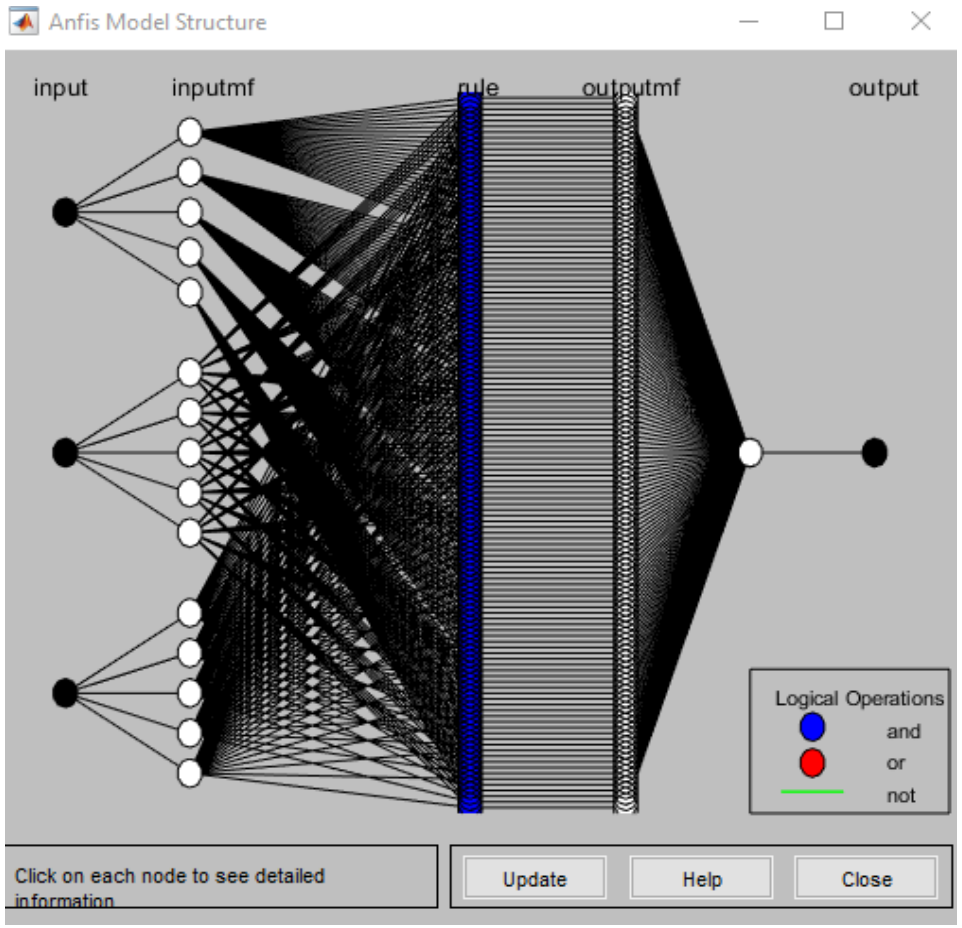


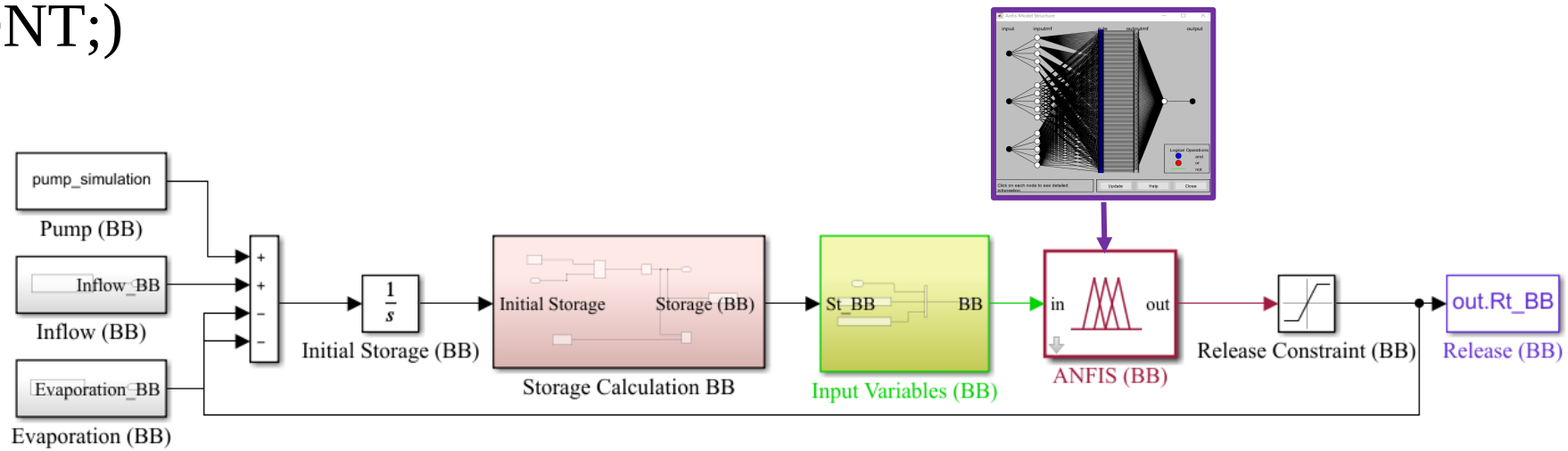
Figure: Accomplishment of ANFIS architecture for reservoir operating rules

- ANFIS can generate a set of fuzzy IF–THEN rules with desired membership functions identifying the input and output reservoir variables through a hybrid learning approach in Neuro Fuzzy Designer Toolbox.

METHODOLOGY (CONT;)

Data collection

Reservoir re-operation model



The ANFIS rule-based model were then applied in the water balance-based reservoir operation model developed by MATLAB Simulink Toolbox to re-operate the long-term reservoir operation of BB dam.

Water Balance Model

$S(t+1) = S(t) + I(t) - E(t) - R(t) + P(t)$

$S(t+1)$ represents the water storage of the reservoir at time step t+1,

$S(t)$ is the initial storage of the reservoir at time step t,

$I(t)$ is the reservoir inflow volume at time step t,

$E(t)$ is the evaporation loss from the reservoir at time step t,

$R(t)$ is the water release volume or the reservoir outflow discharging into the hydropower turbines.

METHODOLOGY (CONT;)

Data collection

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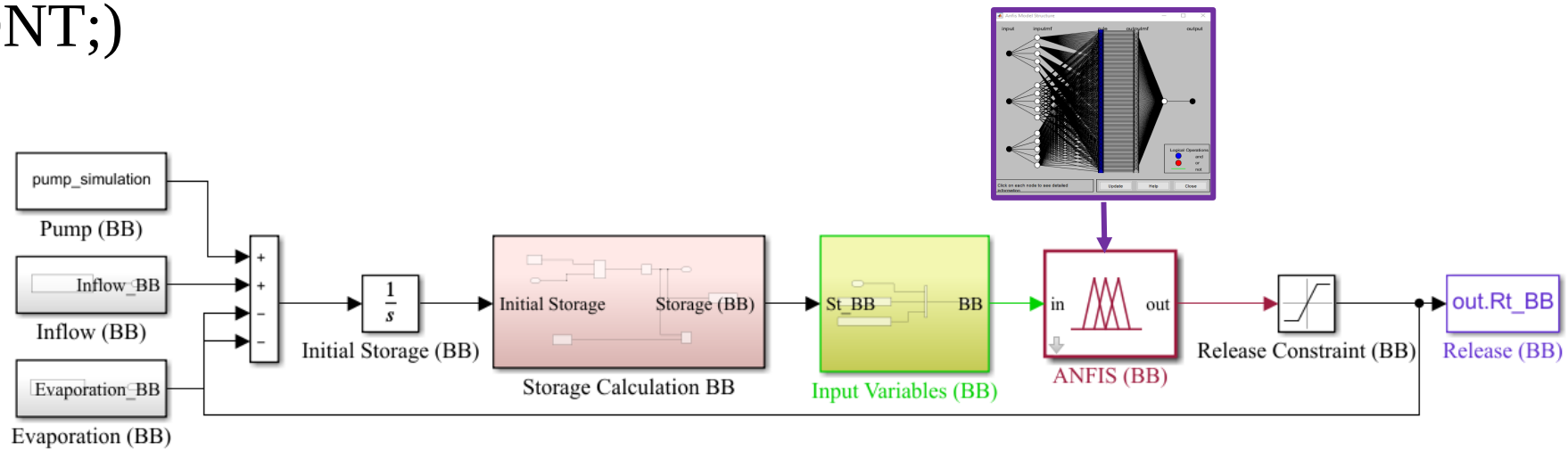
Reservoir re-operation model



In addition, the maximum and minimum constrained of reservoir water storage and water releases for the BB dam in the Lower Ping River Basin were also assigned in the model.

Finally, the daily reservoir re-operation for BB Dam can be simulated using hybrid Neuro Fuzzy model .

Reservoir Constrained

$$\begin{bmatrix} 9{,}505 \\ 5 \end{bmatrix} \leq \begin{bmatrix} St \\ Rt \end{bmatrix} \leq \begin{bmatrix} 13{,}462 \\ 69.76 \end{bmatrix}$$

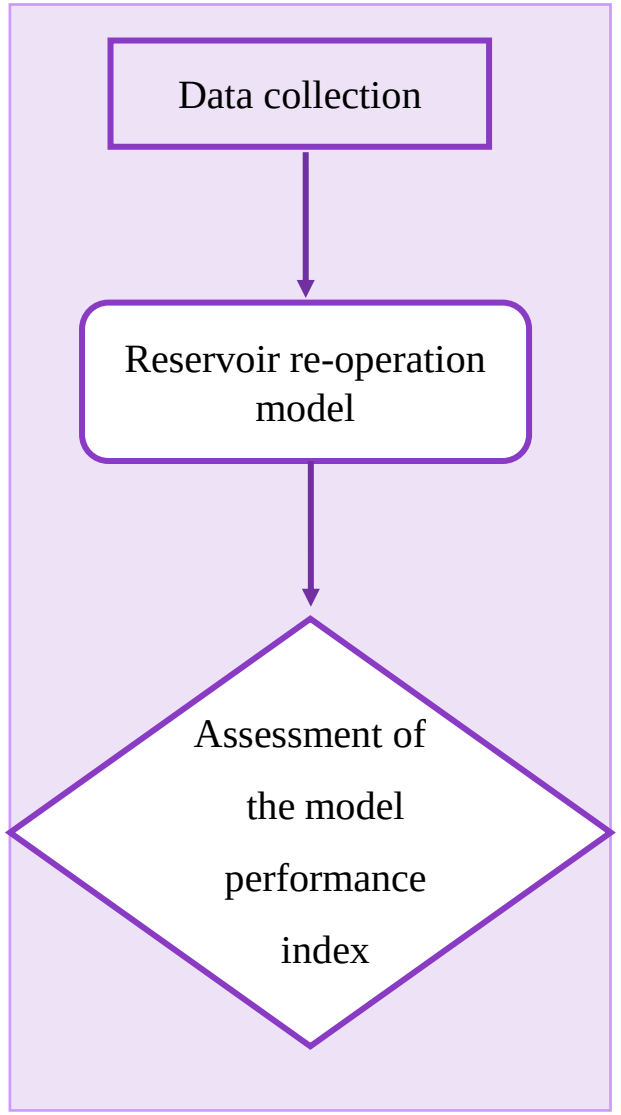
S(t) is the initial storage of the reservoir at time step t,

R(t) is the water release volume or the reservoir outflow.

[S(0)] = [9,505]

S(0) is the initial storage of BB Dam.

METHODOLOGY (CONT;)



Reservoir Performance Indices (RPI)

- A large number of reservoir performance indices (RPI) have been introduced and applied to assess the performances of the reservoir operation system for more than a decade.
- In this study, reliability index was used to assess the performance of the reservoir reoperation model.
- The reliability index measures how much the system is accessible or the system performs unsatisfactorily within the simulation time periods. It can be mathematically computed using the equation:

$$\text{Reliability (\%)} = \frac{\text{events that water demand are satisfied}}{\text{total events}} \text{x}100$$

(Hashimoto et al., 1982, McMahon et al., 2006)

RESULT AND DISCUSSION

Model Setting	Model Inputs
Training dataset	80% of dataset
Testing dataset	80% of dataset
Input variables	1. Initial water storage, 2. Reservoir inflow, 3. Target water demand
Output variable	1. Dam water release
Optimization algorithm	Hybrid learning rule which combines the back-propagation gradient descent and a least squares method
Error Tolerance	"0"
Epochs	1,000

Dataset	RMSE	R^2
Training dataset	6.52	0.70
Testing dataset	5.43	0.57

- The ANFIS-based reservoir operation rules were derived after the number of training epochs of 1,000 was reached and zero error tolerance was set in the model.
- To evaluate the ANFIS model performance, the statistical methods; Root Mean Squared Error (RMSE), and Coefficient of Determination (R^2) were used to indicate the perfect match between the observation values (O_i) and simulated values (S_i).
- The results show that the RMSE and R^2 between current release and simulated release accomplished by ANFIS are 6.52 and 0.70, respectively for the training dataset and 5.43 and 0.57, respectively for the testing dataset.

RESULT AND DISCUSSION (CONT;)

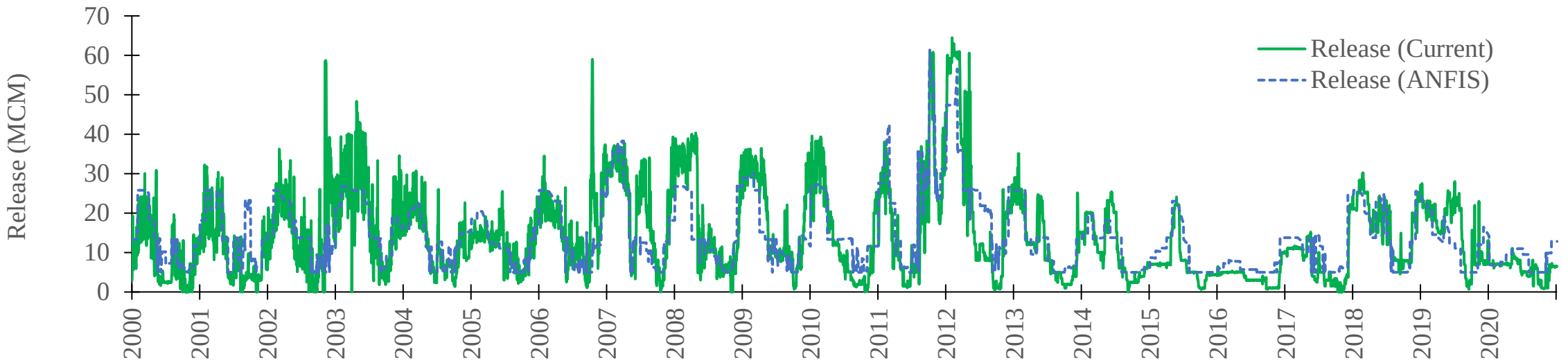


Table: Average seasonal and yearly reservoir storages re-operated with ANFIS-based reservoir operation rules during 2000-2020 and reservoir reliability

Reservoir Operation	Reservoir Storage (MCM)			Reliability Index (%)
	Dry Season	Wet Season	Yearly	
Current operation	8,353	7,073	7,713	52
Re-operating with ANFIS rule	8,390	7,162	7,776	77
Δ% Increase	+0.45	+1.26	+0.82	+25

Figure shows the comparison of daily reservoir releases between current operation and simulated release by ANFIS-based reservoir operation rules. It can be seen that the daily release by ANFIS-based reservoir operation rules is lower than the current operation. This leads to the increases in the reservoir storage significantly.

CONCLUSIONS

- Hybrid neuro fuzzy-based reservoir re-operation modelling is a state-of-the-art technology and self-learning approach between the input and output linguistic variables that resembles the current operation in controlling complex reservoir operating systems.
- Adaptive Neuro Fuzzy Inference System (ANFIS) which is a novel hybrid approach of artificial neural network (ANN) and fuzzy logic system (FLS), was used to conduct the daily reservoir operating rules of the Bhumibol Dam, Thailand.
- Research findings revealed that it can be effectively implemented in increasing reservoir storage and achieving better reservoir performance compared to the current operation.

THANK YOU FOR YOUR KIND ATTENTION…