Development of an ANN Model to Simulate the Auxiliary Power Generation from an Irrigation Barrage

Koshy P.S., Prince Arulraj G., Brema J.

Abstract:-The aim of this paper is to correlate the auxiliary power generation from an irrigation reservoir with the power generation of its upstream hydro power project in a cascade reservoir system. System considered for the study is the Pamba Basin- Kakkad Hydro Power Project and Maniyar Reservoir of Pamba Irrigation Project of Kerala State. In a water year from the 1st June to 31st May, irrigation period spans for seven months from November to May in the Irrigation Project. As the water release of the upstream Hydro Electric Plant exceeds the irrigation demand, even during the peak irrigating months of January and February, there is surplus inflow for power generation. A water year is divided to two seasons namely, Irrigation and Non-Irrigation. An Artificial Neural Network (ANN) based model is developed to optimize the power generation using the surplus water and the outputs are compared with the real time data. In the ANN model, the inputs considered are the Generation in units of the upstream Kakkad Hydro Electric Project (Kakkad-HEP), the Rainfall in the catchment and the Irrigation Supply. Spillage from the barrage and the Power Generation in the adjoining Carborandum Universal Madras India Ltd. company's Small Hydro Electric Project (CUMI-SHEP) is considered as the output. The results obtained shows that the power generation from the ANN model closely matches with the real time data. Analysis is done with the aid of MATLAB ANN tool box.

Key words: Artificial Neural Networks (ANN), Small Hydro Electric Project (SHEP), Reservoir Operation, Feed Forward Back Propagation, MATLAB.

I. INTRODUCTION

Optimal operation of existing reservoirs is of crucial importance as 'the water saved is the water stored for auxiliary purposes or increasing demands'. Conflicting and complementary demands of reservoir storage have to be scientifically addressed for an efficient and effective water resources management. With the growing pressure on available resources, the problem of conservation and allocation has assumed importance in recent days. Multipurpose reservoir operation involves interactions and trade-offs between purposes, which are sometimes complementary but often competitive or conflicting. Due to

The temporal variation of inflows and multipurpose demands, the task of allocation of available water resources becomes more complex. The evaluation of current management procedures of existing reservoirs is very important to meet the changing demands according to the public needs and objectives.

In the analysis and design of hydrological structures, statistical data analysis plays an important role especially, for determining the behavior of an existing system. Conventional methods of analysis and design are trial-and -error procedures. Artificial Neural Networks (ANN) also learns the behavior of a system from the data available and predicts outputs with very high accuracy. This paper presents the application of ANN to forecast the secondary yield from an Irrigation Reservoir.

[1]Ankita Sharma and Geeta Nijhawan (2015) concludes that the back propagation gives best results out of the three networks namely, back propagation, cascaded back propagation and layer recurrent network they tried. Also it is affirmed that performance of the network increases with the increase in data and NNTOOL is best for training the data using other algorithms and functions. [2]Kumar Abhishek et.al. (2012) revealed that as the number of neurons increases in an ANN, the Mean Square Error decreases. [3]Shilpi Rani, Dr. Falguni Parekh2 (2014) done a reservoir water level forecasting using ten daily data of inflow, water level and release. For developing this ANN models, three alternative networks i.e. were evaluated and investigates the best model to forecast water level. The developed models are trained and validated on the collected data of Sukhi Reservoir project, located in Gujarat State, India. Based on these results, it is concluded that amongst the three methods namely, Cascade, Elman and Feedforward back propagation used for this study, ANN using Feed Forward Backpropagation is an appropriate predictor for real-time Water Level forecasting of Sukhi Reservoir Project.[4]Sonali B Maind and PrinyankaWankar (2014)explains that ANN, like people, learn by example and can be applied to problems where the relationship may be quite dynamic or non-linear. [5]Taofeeq Sholagberu Abdulkadiret. al. (2015) obtained the correlation coefficient between the forecast and observed reservoir storage in ANN for three reservoirs and suggested that the model fairly fit the variables and can subsequently be used for prediction of reservoir storage for operational performance.

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Neural networks with their remarkable ability to depict meaning from complicated or imprecise data, can be used to extract patterns and detect trends that are too complex to be noticed by either humans or other computer techniques.

II. ARTIFICIAL NEURAL NETWORK (ANN) AND ITS WORKING

Artificial Neural Network (ANN) is an information processing paradigm that is inspired by the way neural system of brain process information. This is modelled after the brain and does not utilize conventional programming but involves the creation of massively parallel networks and the training of those networks to solve specific problems. Each unit or node is a simplified model of real neuron which sends off a new signal or fires if it receives a sufficiently strong input signal from the other nodes to which it is connected. ANN is made up of interconnecting artificial neurons which are programmed like to 'mimic' the properties of biological neurons and work in unison to solve a specific problem. Generally an ANN consists of three layers called input, hidden and output. The layer of input neurons receive the data either from input files or directly from electronic sensors in real-time applications. The output layer sends information directly to the outside world. Between these two layers, there can be many layers called hidden layers. The architecture of a typical layered forward neural network is shown in Fig.1.

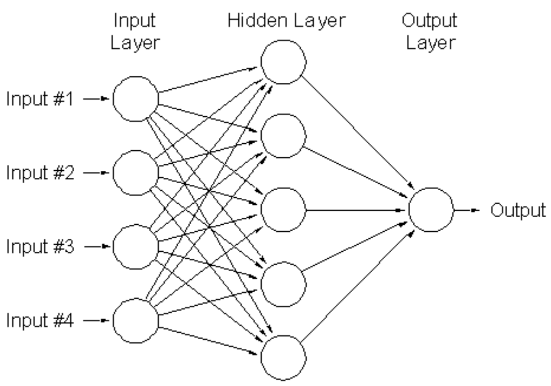

Fig. 1: Diagram of a typical Artificial Neural Network.

Once the network is structured for a specific problem, then the network has to be trained. Like human, here the network learn from examples. Training can be *supervised* with known inputs and outputs or may be *unsupervised* with the known inputs only. Training is accompanied by Validation and then the model is ready for Testing. In this reservoir operation modelling with ANN, the above three sequential steps are followed with the aid of MATLAB package.

2.1. The Feed Forward Back Propagation (FFBP)

The most common learning rule for multilayer perceptions is the back-propagation algorithm (BPA). BPA showed great consistency and accuracy with the target data. Back propagation involves two phases: a feed forward phase in which the external input information at the input nodes is propagated forward to compute the output information signal at the output unit, and a backward phase in which modifications to the connectionstrengths are made based on the differences between the computed and observed information signals at the output units. The neural network structure in this study possessed a three-layer learning network consisting of an input layer, a hidden layer and an output layer.

III. SYSTEM DESCRIPTION

The Pamba basin system of Kerala State, India has been selected for the study. The reservoir of Pamba Irrigation Project is impounded by Maniyar Barrage constructed across the river Kakkad, a tributary to the Holy river Pamba, Kerala State. The reservoir caters to the irrigation needs of 21135ha of command area in Pathanamthitta and Alappuzha districts. The project was commissioned in the year 1979 and the reservoir gets a perennial inflow from the tail race of Ullumkal-shep, which in turn gets inflow from the upstream Kakkad powerhouse of Kerala State Electricity Board. Sabarigiri, the top most power house of KSEB, draws water from Pamba Basin consisting of a number of reservoirs and after power generation its tail race water gets collected and is conveyed to the Kakkad powerhouse through penstocks. The reservoir has a catchment area of 280 km^2, which is partially impounded by barrages. The details of the cascade system are given in Table 1 below.

Table 1:Details of the cascade system

Sl. no.	Name of project	Installed capacity (MW)	Average water Use / unit generation (m^3)
1	KSEB- Kakkkad, Seethatode-HEP	50	3.25
2	Pamba Irrigation Project-Maniyar	Irrigation purpose.	-
3	CUMI- Maniyar- SHEP	12	30.00

The schematic diagram of the Pamba Irrigation Project is shown in Fig.2

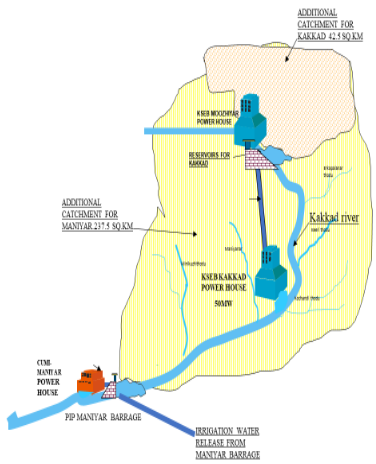

Fig. 2: Diagram showing the Source of Water to Pamba Irrigation Project, Maniyar Reservoir, Kerala State.

IV. APPLICATION OF ANN TO THE SYSTEM IN FORECASTING

Maniyar Barrage built across the river Kakkad for irrigation purpose forms the Pamba Irrigation Project reservoir and diverts water to the canal system. The storage of the barrage is very limited ie, 0.8Mcm and it is only an interim storage and hence it is not taken into account in this ANN modelling. The tailrace inflow to the reservoir varies as it depends on the State's power demand, but it is perennial. Runoff from the catchment to the reservoir is intermittent as it depends on seasonal rains. In the present study, a water year from June to May is divided to two seasons namely ***Irrigation Season -S1,*** from November to May, and ***Non-irrigation Season- S2,*** from June to October, and two sets of inputs are taken into account. Each month is divided to 3, 10 day periods and this results in 36 periods in a water year. Thus number of 10 day periods per water year in seasons S1and S2 are respectively 21 and 15.The excess or shortage of days if any, is adjusted with the 3rd period of the month. Data for the five consecutive water years from 2009-2010 to 2013-14 are taken and the total sets in S1 is 105 and in S2 is 75.

Season No.- 1- Irrigation (dry) season:- The irrigation demand starts in the month of November and ends by May. But during this period the inflow is less as there is little rainfall and it is contributed mainly by the upstream tailrace. The priority is to be given to irrigation supply and the surplus if any, may be used for power generation during this period. Out of the two demands namely, irrigation demand and power generation, irrigation demand is to be satisfied to its maximum degree during **Season-1**and power generation is to be planned to avoid spill/wastage of water during the same period.

The Inputs given to the model are:

Kakkad-HEP generation

b) Rainfall in the catchment

c) Irrigation supply

The Outputs to be obtained from the model are:

i) Power generation at CUMI-SHEP

ii) spillage from the reservoir

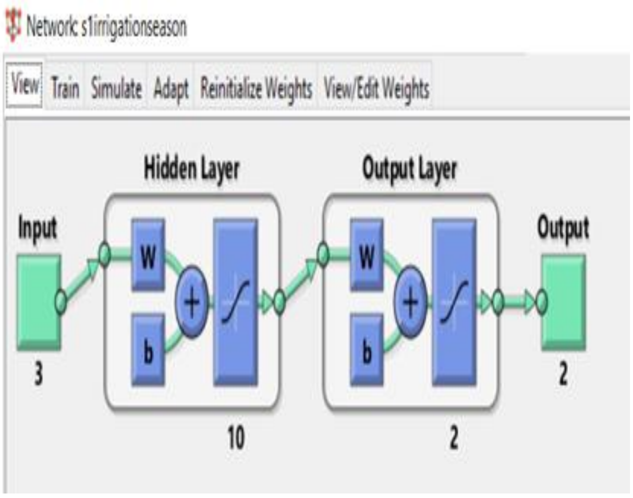

Fig.3 ANN Architecture for season S1

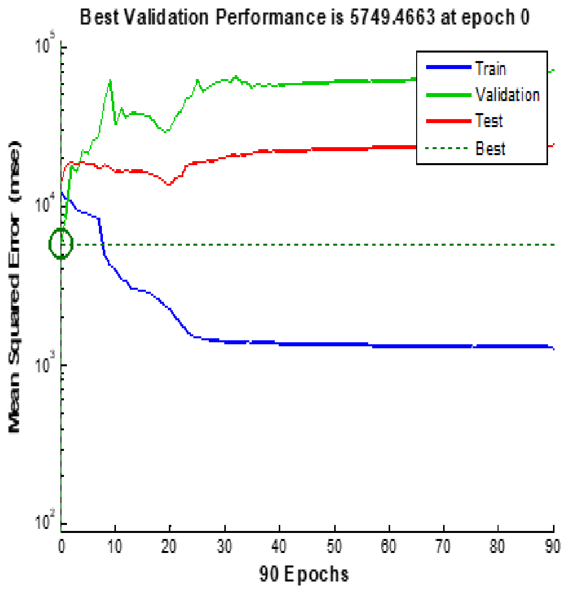

Fig. 4: Performance plot during training for season S1.

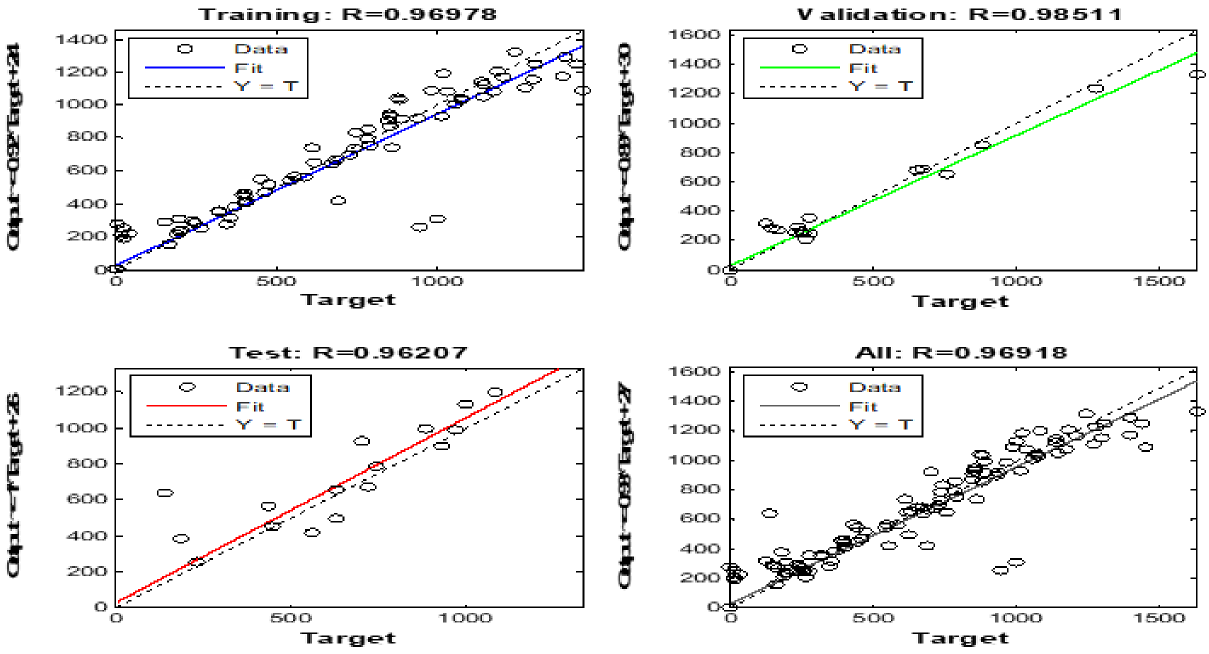

Fig. 5: Regression plot using NNTOOL for season S1.

Season no. 2 - Non-irrigation (rainy) period:-The inflow to the reservoir is contributed by both the Rainfall in the catchment and the tailrace and there is no irrigation requirement during this period. Thus the whole inflow can be used for power generation and there is occasional spill of water due to excessive rains. During **Season-2** , maximum power is to be generated in order to mitigate spill/wastage as far as possible.

The Inputs to the model are:

1) Kakkad-HEP generation
2) Rainfall in the catchment

The Outputs obtained from the model are:

i) Power generation at CUMI-SHEP
ii) spillage from the reservoir

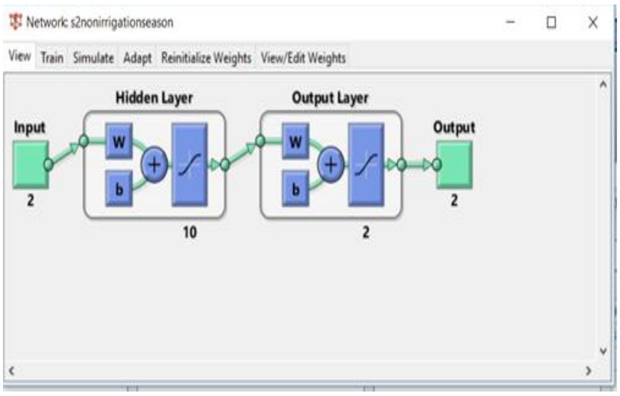

Fig.6 ANN Architecture for season S2

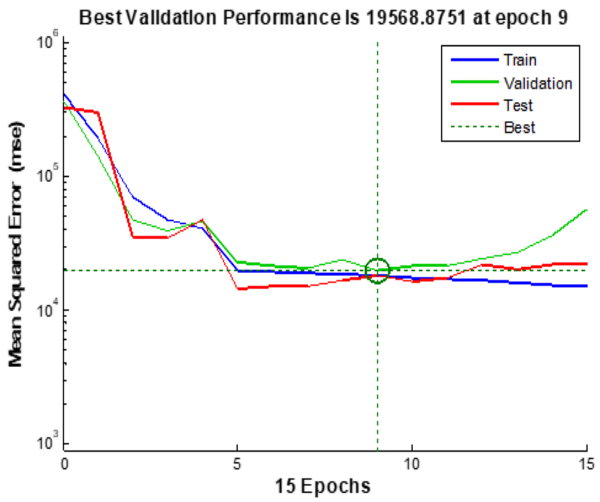

Fig. 7: Performance plot during training for season S2.

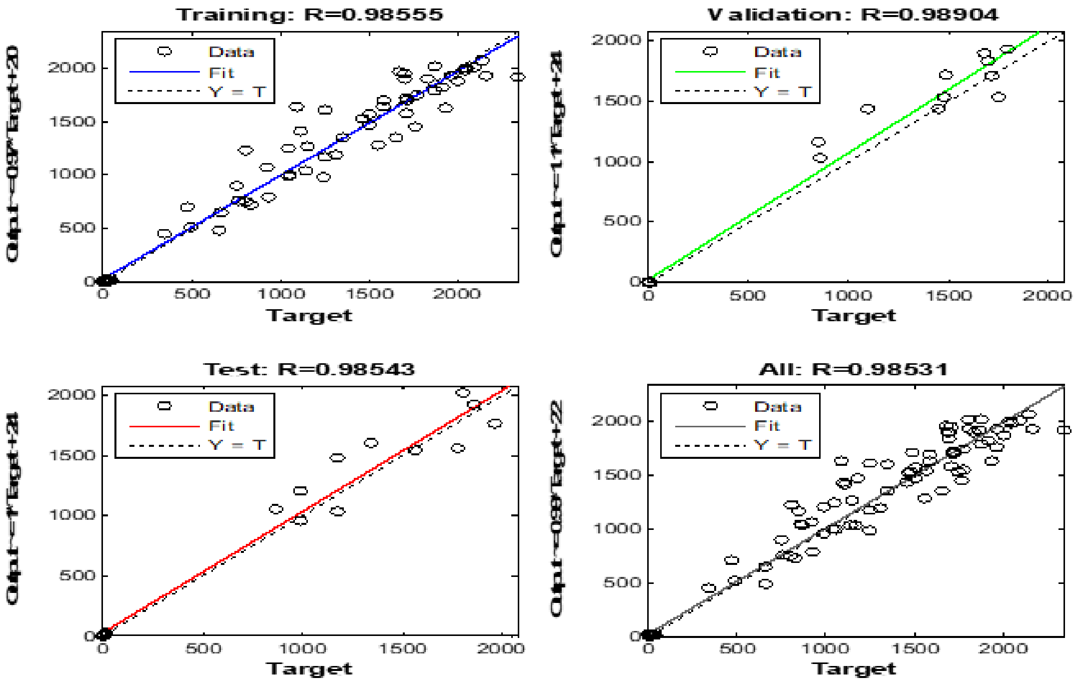

Fig. 8: Regression plot using NNTOOL for season S2.

V. RESULTS AND DISCUSSION

A water year is divided to 36, 10 day periods for the study with 03 periods per month as explained earlier. As the Season S1extends for seven months from November to May, subsequently there are 21 periods occur in this Season. The rainy season S2, which spans for five months from June to October, consists of15, 10 day periods. Data for five successive water years from 2009-10 to 2013-14 are taken for the present study and thus there are 21x5=105, 10 day periods of S1 and 15x5=75, 10 day periods of S2 for comparison. The Real and ANN Forecasted values of Secondary Generation at CUMI-SHEP are plotted against the 105 periods of S1and 75 periods of S2in two plots for the five water years and shown in Fig.6 & Fig.7 respectively. From the Fig. 6 & 7, it is observed that the trend highly matches with the real values.

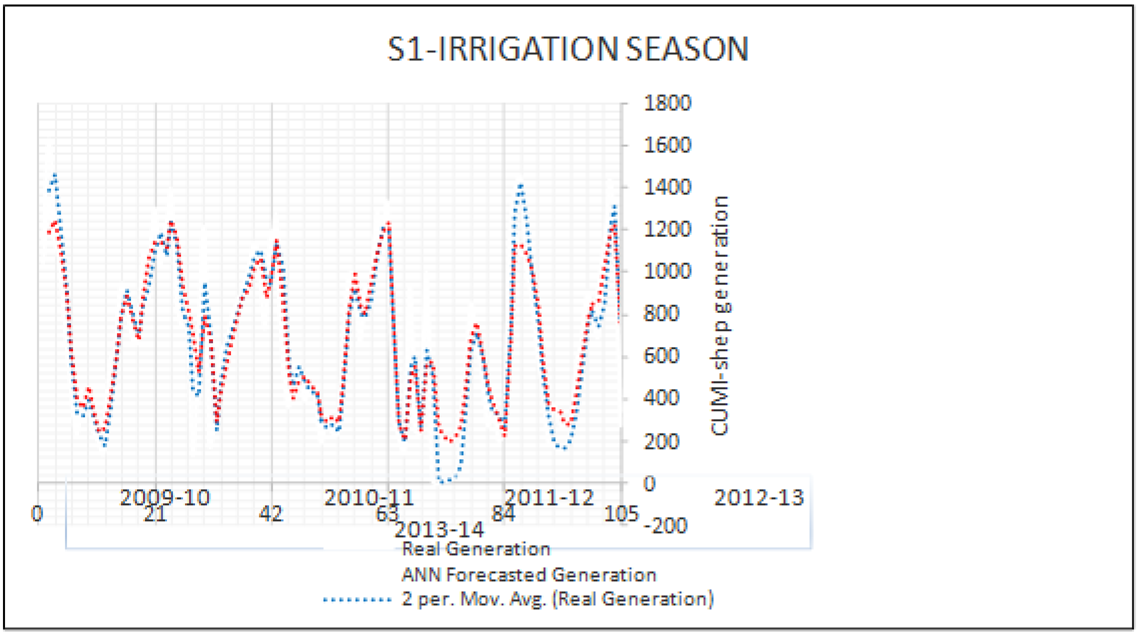

Fig.9: Comparison of Secondary Generation - Real and ANN Forecasted - during S1

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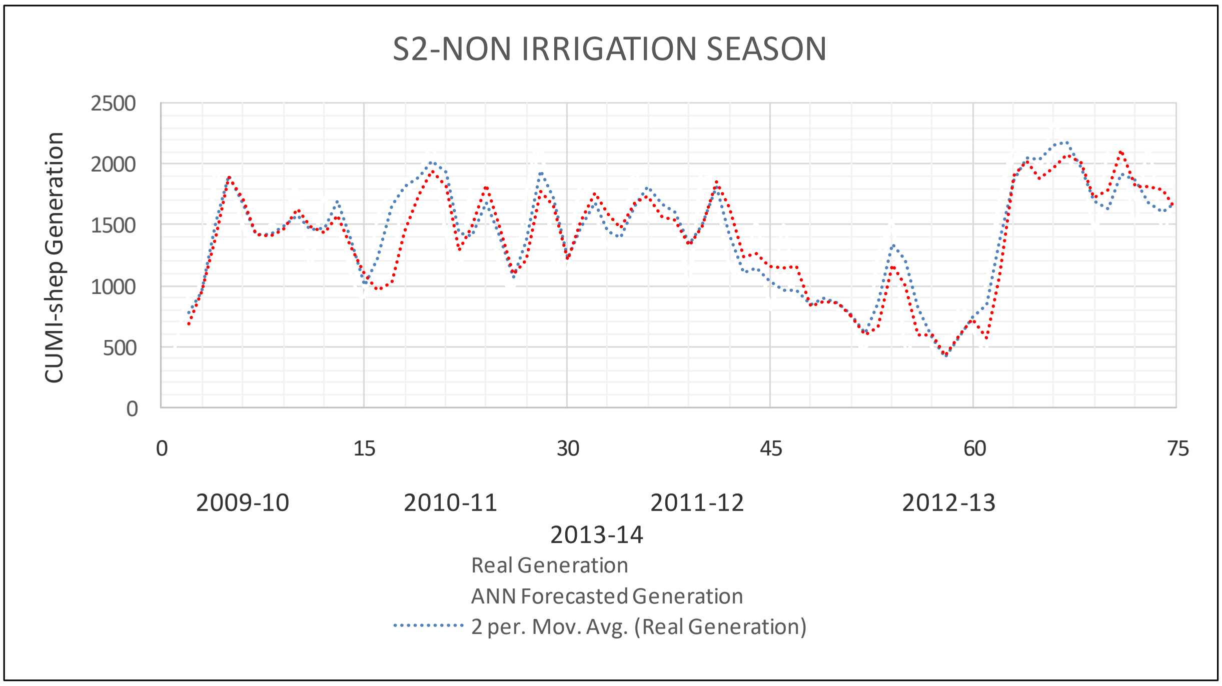

Fig.10: Comparison of Secondary Generation - Real and ANN Forecasted - during S2

In the present study, ANN model for forecasting secondary power generation is developed and demonstrated over an existing Irrigation reservoir impounded by Maniyar Barrage of Pamba Irrigation Project, Kerala State. The Neural Network tool available with the MATLAB software was used for developing the model. The inputs to the ANN system are 'Power Generation in units at the upstream HEP-Kakkad', 'Rainfall' and 'Irrigation release' on a 10 day period basis. The output is the 'Power Generation at the downstream CUMI-SHEP' and the 'Spillage at the Barrage'. The Feed Forward Back Propagation (FFBP) learning rule for multilayer perceptions is the back-propagation algorithm (BPA). Back propagation involves two phases: a feed forward phase in which The results obtained shows that the values of secondary power generation at CUMI-SHEP, from the FRB model are satisfying the real time data. As the storage of a reservoir impounded by the Barrage is very limited and highly fluctuating, that is not considered in the study.

VI. CONCLUSIONS AND RECOMMENDATIONS

The aim of the paper is to apply ANN to Simulate the Auxiliary Power Generation from an Irrigation Barrage. Three layered model has been used in this study and back propagation algorithm was used to train the ANN model. ANN learns from the data during training and gives output having better agreement with results without much effort and hence it avoids complex optimization procedures. The performance of the ANN model is found highly satisfactory on verification with the real time data. As the data strength in Training increase in an ANN, the Mean Square Error decreases. The ANN are good in learning the underlying pattern in a data set. It is concluded that from the above observations that the ANN models can be successfully used as a simple tool to decide the secondary yield from an existing reservoir.

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