# NEURAL NETWORK BASED OPTIMUM MODEL FOR LAXAPANA HYDRO POWER GENERATING SYSTEM

A dissertation submitted to the Department of Electrical Engineering, University of Moratuwa in partial fulfillment of the requirement for the Degree of Master of Science

by

### CGS GUNASEKARA

Supervised by : Dr. L Udawatta Mr. S. Witharana

## Department of Electrical Engineering University of Moratuwa, Sri Lanka



621.3 06

January 2006

85958

# Contents

| Declaration  | v    |
|--|------|
| Abstract   | vi   |
| Acknowledgements                                   | vii  |
| List of Figures                                    | viii |
| List of Tables                                     | ix   |
|  |      |
| Chapter 1 : Introduction                           | 01   |
| 1.1 .Background                                    | 01   |
| 1.2 Purpose and contribution of dissertation       | 03   |
| 1.3 Scope and organization of dissertation         | 03   |
| Chapter 2 : Overview of Modeling Strategy          | 05   |
| 2.1 Introduction                                   | 05   |
| 2.2 The problem                                    | 05   |
| 2.3 Goal and scope of the investigation            | 05   |
| 2.4 Reasons for selecting neural network approach  | 06   |
| 2.5 Data used for modeling                         | 06   |
| 2.5.1 Selection of data                            | 06   |
| 2.5.2 Acquisition of data                          | 06   |
| Chapter 3 : Artificial Neural Networks (ANN)       | 08   |
| 3.1 Introduction                                   | 08   |
| 3.2 The Basics of Artificial Neural Networks Model | 08   |
| 3.2.1 A formal Definition                          | 08   |
| 3.2.3 A General Framework for ANN models           | 09   |
| 3.2.4. Multi-layer neural networks                 | 12   |
| 3.3 Training the network                           | 13   |
| 3.3.1 Update of Weights and training               | 13   |
| 3.3.2. Generalization                              | 14   |
| 3.3.3 Termination of training                      | 15   |
| KA OF WA   |      |



| Chapter 4 : Developing the Model                    |                     |   |      |  |
|---|---------------------|---|------|--|
| 4.1 Introduction                                    |                     |   |      |  |
| 4.2 Tool used for implementation                    |                     |   |      |  |
| 4.3 Neural Network Architecture                     |                     |   | 16   |  |
|   | 4.3.1               | Number of input layer neurons             | 16   |  |
|   | 4.3.2               | Number of output layer neurons            | 17   |  |
|   | 4.3.3               | Creating and training the neural network  | 18   |  |
|   |                     | 4.3.3.1 Data used and Limitations         | 18   |  |
|   | 4.3.4               | Evaluating the training Performance       | 20   |  |
|   | 4.3.5.              | Effect on learning rate                   | 22   |  |
|   | 4.3.6.              | Modeling pond water level variation       | 24   |  |
| Chapter 5: Simulation Results and Performance       |                     |   |      |  |
| 5.1 Introduction                                    |                     |   | 26   |  |
| 5.2. Generator Load scheduling model                |                     |   | 26   |  |
| 5.2.1. Regression Analysis Results                  |                     |   | 28   |  |
| 5.3. Pond water level predicting model              |                     |   |      |  |
|   |                     |   |      |  |
| Chapter 6: App                                      | olication of Propos | ed Models for Maximizing Power Genera     | tion |  |
| 6.1 Introduction                                    |                     |   | 39   |  |
| 6.2.Methodology applied.                            |                     |   |      |  |
| 6.3.A case study                                    |                     |   |      |  |
|   | 6.3.1               | Effect to the pond water level            | 44   |  |
|   | 6.3.2               | Algorithm for simulating pond water level | 44   |  |
|   | 6.3.3               | Simulation results                        | 45   |  |
| Chapter 7 : Cor                                     | nclusion            |   | 56   |  |
| 7.  | 1 Conclusions. Re   | emarks and Discussion                     | 56   |  |
| 7.  | 2 Recommendation    | on for future Research                    | 57   |  |
| References  |                     |   | 59   |  |
| A   |                     |   | 60   |  |
| Appendices  |                     |   |      |  |
| Appendix A : Programming Codes for training model i |                     |   |      |  |

iii

| Appendix B : Programming Codes for testing model 1            |    |  |
|---|----|--|
| Appendix C : Programming Codes for Training model 2           | 66 |  |
| Appendix D : Programming Codes for testing model 2            | 68 |  |
| Appendix E : Programming Codes for dynamic simulation of pond | 70 |  |
| water levels  |    |  |
| Appendix F : Test data  | 80 |  |
| Appendix G : Description of Programming Code                  | 83 |  |

.



### DECLARATION

The work submitted in this dissertation is the result of my own investigation . except where otherwise stated.

It has not already been accepted for any other degree, and is also not being concurrently submitted for any other degree.

## **UOM Verified Signature**

C.G.S.Gunasekara

Date : 18 01 2006

We  $/\chi$  endorse the declaration by the candidate.

Dr. Lanka Udawatta

Mr. Sanjeewa Witharana

### Abstract

Laxapana hydro power generating system is a cascaded system which, consists of two main reservoirs Castlereigh and Moussakele. The power generating system comprises of five power stations at three levels. This system consists of thirteen generating units with different capacities and different characteristics (Pelton and Francies). The only function of this scheme is to generate electric power, making use of the hydro potential available at the upper-most two main reservoirs. The electric power generation of this system is characterized by several factors such as reservoir and pond levels, rainfalls to different reservoir areas, machine availabilities and turbine characteristics. At present, almost all hydro potentials available in the country has been used for electricity generation. There is a deficit between the electricity demand and generation. At present the balance is provided by thermal generation. Hence, getting the maximum share from hydro which reduces thermal power purchasing would be a great saving to the national economy.

The objective of this research is to model the system in order to get the maximum usage of the stored hydro potential to generate electricity. In this study, two models have been developed. First model to schedule the generator loads and the second model to, predict the water levels of three ponds for a short duration once the generator loads are fixed and other parameters are known.

In this research correlation between inputs and outputs are investigated to device a model, using a range of historical data available. As this is a multi dimensional system with large number of inputs as well as outputs, application of Artificial Neural Network (ANN) technology [1] to model this system is explored to discover a working mechanism of the system from the examples of past behavior. Then, by coupling the above two neural network models, developed for generator load scheduling and pond water level monitoring, system was dynamically simulated to explore the feasibility of maximum electrical power generation. Using this model water levels of ponds can be dynamically simulated , to evaluate whether the load share expected from Laxapana complex according to the system control center's daily load dispatch is feasible.



#### Acknowledgements

Thanks are due first to my supervisors. Dr Lanka Udawatta and Mr Sanjeewa Witharana . for their great insights guidance and sense of humor. My sincere thanks should go to the officers in Post Graduate Office. Faculty of Engineering. University of Moratuwa, Sri Lanka for helping in various ways to clarify the things related to my academic works in time with excellent cooperation and guidance. My sincere gratitude is also extended to the Head of the department Prof HYR Perera for the valuable guidance given and to the staff of the Electrical Engineering department.

Lastly, I should thank many individual friends and colleagues who have not been mentioned here personally in making this educational process a success. May be I could not have made it without your support.

#### **List of Figures**

- Figure 1.1 Schematic diagram of Laxapana hydro power complex
- Figure 3.2.3 General model of processing unit.
- Figure 3.2 b Architecture of neural network model
- Figure 3.2c Representation of the single hidden layer neural network in Matlab neural network tool box
- Figure 3.2 Matlab representation of a multilayer neural network
- Figure 3.3 Schematic diagram of process of training
- Figure 3.3.3. Variation of errors during the early stopping method
- Figure 4.3.3.1. Inputs and out puts of model for scheduling generator loads
- Figure 4.3.3a Correlation coefficient for different network architectures
- Figure 4.3.3.b Training, Validation and Testing errors for different architectures
- Figure 4.3.4.a Effect of the learning rate on the performance of network
- Figure 4.3.4.b Training parameters corresponds to  $\eta = 0.2$  for model 1
- Figure 4.3.5.a Inputs and output of the pond water level monitoring model
- Figure 4.3.5.b Performance of Neural Network Model of Canyon water level

Figure 5.2.1.0 Simulated and actual load curves for generators

Figure 5.2.1.a Canyon Machine 01 Load Simulation accuracy

- Figure 5.2.1.b Canyon Machine 02 Load Simulation accuracy
- Figure 5.2.1.c New Laxapana Machine 01 Load Simulation accuracy
- Figure 5.2.1.d New Laxapana Machine 02 Load Simulation accuracy
- Figure 5.2.1.e Old Laxapana total Load Simulation accuracy
- Figure 5.2.1.f Polpitiya Machine 01 Load Simulation accuracy
- Figure 5.2.1.g Polpitiya Machine 02 Load Simulation accuracy
- Figure 5.2.1.h Wimalasurendra Machine 01 Load Simulation accuracy
- Figure 5.2.1.i Wimalasurendra Machine 02 Load Simulation accuracy
- Figure 5.3a Simulated vs Actual water level variation of Canyon pond
- Figure 5. 3b Regression analysis results for Canyon water level Simulation
- Figure 5.3d Simulation vs Actual water level laxapanapond
- Figure 5.3e Regression analysis results of Laxapana pond water level simulation

- Figure 5.3.f Simulated vs Actual water level of Norton pond
- Figure 5.3g Regression analysis results of Norton pond water level
- Figure 5.3.1.b Model for predicting water level variation for 4 consecutive sampling periods
- Figure 5.3.c2 Variation of prediction accuracy (4 T = 240 minutes) Canyon pond
- Figure 6.3 a. Inflows and outflows to Canyon pond
- Figure 6.3 b. Percentage increase in generation vs generator load variation
- Figure 6.3.1.a Pond water level simulation model structure
- Figure 6.3.1.b Flow chart relevant to the algorithm
- Figure 6.3.3.a Actual and Simulated water levels of ponds (test data 3300-3350)
- Figure 6.3.3.b Actual and Simulated water levels of ponds (test data 3350-3400)
- Figure 6.3.3.c Water level variation due to 15% generation increase (test data set 1 & 2)
- Figure 6.3.3.d Water level variation due to increased generation by 15 % and for 16% for 24 hours test data records (3300-3350)
- Figure 6.3.4 Simulated and Actual water level variation for 120 hours for past loads
- Figure 6.3.5 Simulated and Actual water level variation for 120 hours increased loads
- Figure 6.3.6 Simulated and Actual water level variation for 15% and 16% increased generation for 120 hours
- Figure 6.3.3.a Total load variation due to increased maximum generation

#### List of Tables

- Table 4.3.3.a : Network Architecture vs Correlation Coefficient (R)
- Table 4.3.3.b Training, Validation and Testing errors (SSE)
- Table 4.3.4. Effect on Learning rate
- Table 4.5. Generator loads variation with percentage generation increase
- Table 6.3.3 Minimum operating levels of ponds
- Table 7.1 Typical thermal unit costs
- Table 7.2 Typical water values obtained from SCC(CEB)