Optimization of Load Forecasting in Smartgrid using Artificial Neural Network based NFTOOL and NNTOOL

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Abstract. The motivation behind the research is the requirement of error-free load prediction for the power industries in India to assist the planners for making important decisions on unit commitments, energy trading, system security & reliability and optimal reserve capacity. The objective is to produce a desktop version of personal computer based complete expert system which can be used to forecast the future load of a smart grid. Using MATLAB, we can provide adequate user interfaces in graphical user interfaces. This paper devotes study of load forecasting in smart grid, detailed study of architecture and configuration of Artificial Neural Network(ANN), Mathematical modeling and implementation of ANN using MATLAB and Detailed study of load forecasting using back propagation algorithm.

1. Introduction
The two variables on which the economic prosperity of developing countries like India is constantly dependent are the reliability and quality of electric power supply. Load forecast is a technique of predicting future loads for a power system. [1] Power companies use this methodology to forecast the amount of power required to balance supply and demand. Demand forecasting is used to determine generating, transmission, and distribution capacity. [2] The type of generation proficiency required is determined by the energy prediction. In the design and operation of power systems, accuracy in electrical load forecasting is critical. [3] It can assist market participants in lowering operating costs and building a more reliable energy supply system. Long-term load forecasting is utilized in expansion planning, intertie tariff fixing, and long-term capital investment planning that spans one to ten years. In order to schedule fuel supply for a few weeks, the medium term load forecast is used. [4] For unit commitment, maintenance & economic dispatch difficulties, a short-term load forecast is used.
2. Load Forecasting In Smart Grid
Prediction of electricity necessary to satisfy the short or medium-term & long-term load demand is known as “load forecasting”. The forecasting methodology is used by utility companies to aid in the operations and management of their customers' supplies. [5][14] Electricity load forecasting is an important procedure that helps electricity generating and distributing businesses improve their efficiency and income. It can be used to manage their capacity and operations so that they can reliably supply all of their customers with the energy they need. [6][15] The smart grid is a combination of electrical and digital technology, as well as information and communication technology that allows for the integration of business operations and the system to produce actual, measurable value across the power distribution chain. [7][18] Through a communication system, an intelligent future electrical system connects all supply grids and demand elements. The Smart grid uses two-way digital technology to transmit electricity to consumers, allowing for effective consumer management and grid use to notice and correct supply-demand imbalances. [8][17] Load forecasting has an impact on fuel resource planning and strategic decisions to balance power supply and demand. [16] When the energy market underwent a revolution, load forecasting became increasingly important, spreading across other business areas such as energy trading, financial planning, and so on. [9][19] Exact load projections serve as the foundation for the system's spot price initiation in order to obtain the lowest possible power purchasing cost in the market. It is also advantageous for electricity customers to comprehend the relationship between demand and price, as well as to adjust their electricity usage patterns in response to the price. In the Smart Grid scenario, grid components are responsible for variations in the consumer's electricity demand at different intervals of time at the utility level. [20]

3. Expert System
It is a computer program shown in figure 1, which is used to simulate the abilities of a human expert to make decisions. It’s a computer program that helps people solve problems by simulating human decision-making. Typically, it accomplishes this by extracting knowledge from its knowledge base and applying reasoning and inference rules to the questions raised by the user. The first commercial system to utilize knowledge-based architecture was the Expert System. The knowledge base and the inference engine are two subsystems that make up a knowledge-based system. The facts about the world are represented by the knowledge base. [9][10]

![Figure 1. Block diagram of Expert System](image)

An inference engine is a computerized reasoning system which is used to evaluate the condition of the knowledge base at the moment. After that in most cases, it applies appropriate rules before asserting new knowledge into the knowledge base. [8][11][22] An inference engine can be used to provide the ability for explanation, allowing it to describe the chain of reasoning to a user that led towards a certain conclusion by tracing back the rules that were fired as a result of the assertion. [21] Because the system has no memory constraints, it can be utilized to store as much data as needed and remember it during its applications. Because of the high efficiency feature, a highly efficient output is obtained if the knowledge base is updated with appropriate knowledge, which may not be possible with a human.
4. Artificial Neural Networks
An ANN-artificial neural network is a data processing system composed of a large number of high qualities interconnected processing components called artificial neurons which are inspired by the cerebral cortex’s structure. [7][12] It is known as the foundation of Artificial Intelligence (AI) which usually used to solve the problem that would prove to be impossible by human or statistical standards. [13] ANN is having self learning capability that can enable them to produce a better result. It is a mathematical model inspired from the working principle of human brain. ANNs are made up of three layers given as input layer, hidden layer, and output layer. The hidden layer is made up of nodes that aim to functionally link model inputs to model outputs during optimization. A specific activation function is used after each neuron to limit its output in a specific required range. With different activation functions and different synaptic weight adjustments, it is possible to solve numerous amounts of problems in artificial neural networks. The network usually gets information from the input & output data, using training techniques and transfer functions. [11][27] Back propagation is one of the supervised learning programs that utilize the universal function approximate to make use of a quadratic error function's gradient descent. The gradient descent methodology is used during the learning phase to reduce total error of the network's results and output generated. The weighted connections multiply the activation functions of the input nodes. The simple architecture diagram of ANN is given below figure no. 2.

![Figure 2. Simple architecture diagram of ANN](image)

Three layers make up a neural network given as input layer, hidden layer and output layer. Temperature, wind speed, rainfall, humidity, previous load data, and actual load data are among the six inputs employed in this study results optimized ANN design. [6][25] It is used in training with Levenberg-Marquardt back propagation algorithm. A four-layered feed forward network with sigmoid activation function in the hidden layer and a linear output neuron make up the neural network.

5. Mathematical Modeling of ANN
Biological neural network existing in human brain works swiftly as the network is massively parallel in nature. The biological network consists of biological neurons which are connected to other neurons forming a network which helps the brain to solve problems. [23] The connections in human neural networks are called as synapses. The strength of these connections is an important parameter as it will determine the overall output from the network. The connections transfer activation potentials from one neuron to the other with the help of neurotransmitters. In ANN-Artificial Neural Network, same strategy is used and the connections that represent synapses in biological networks are replaced by synaptic weights. A synaptic weight of a connection in artificial neural network determines the overall output of the networks. [5][26][28]
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Figure 3. Modeling of ANN

A specific activation functions are used after each neuron to limit its output in a specific required range. With different activation functions and different synaptic weight adjustments it is possible to solve numerous amounts of problems in Artificial Neural Networks. [4][24]

6. Results Comparison Between NFTOOL & NNTOOL
They should only be used for brief remarks that do not fit within the text if they are necessary. When at all possible, avoid using footnotes.

6.1 Results using NFTOOL
NFTOOL guides you through a data fitting challenge and solves it using a two-layer feed forward network with Levenberg Marquardt training.

Figure 4. Regression plot-1 using nftool

Figure 5. Regression plot-2 using nftool
Figure 6. Error histogram plot-1 using nftool

Figure 7. Error histogram plot-2 using nftool

6.2 Results using NNTOOL

NNTOOL launches the network/data management window, which allows us to import, create, utilize, and export neural networks and data.

Figure 8. Regression plot-1 using nntool
Figure 9. Regression plot-2 using nntool

Figure 10. Training parameters-1 using nntool

Figure 11. Training parameters-2 using nntool
7. Result Analysis Using Neural Network Toolbox
The predicted value of load using the neural network toolbox in MATLAB can be represented as given below.

![Figure 12. Performance plot-1 using nntool](image1)

![Figure 13. Performance plot-2 using nntool](image2)

![Figure 14. Target value ~ predicted value](image3)

Table 1. Output data from the neural network toolbox
| Month | Target value | Predicted value | Network output value | Error value |
|-------|--------------|----------------|---------------------|------------|
| JAN   | 1325         | 1325.0007      | 1325.0007           | -0.0007    |
| FEB   | 1367         | 1366.9998      | 1366.9998           | 0.0001     |
| MAR   | 1450         | 1449.9997      | 1449.9998           | 0.0002     |
| APR   | 1469         | 1432.4791      | 1432.4791           | 36.5208    |
| MAY   | 1435         | 1434.9999      | 1434.9999           | 7.0058     |
| JUN   | 1444         | 1443.9999      | 1443.9999           | 3.1258     |
| JUL   | 1441         | 1440.9999      | 1440.9999           | 1.7182     |
| AUG   | 1489         | 1488.9998      | 1488.9998           | 0.0001     |
| SEP   | 1469         | 1439.2015      | 1439.2015           | 29.7984    |
| OCT   | 1507         | 1506.9986      | 1506.9985           | 0.0014     |
| NOV   | 1451         | 1506.1408      | 1506.1408           | 55.1408    |
| DEC   | 1463         | 1463.6278      | 1463.6278           | -0.6278    |

**Figure 15.** Output predicted using neural network toolbox in MATLAB

8. Implementation Results Using MATLAB Code Result

**Figure 16.** Error histogram output using MATLAB simulink
Figure 17. Training parameters using MATLAB simulink

Figure 18. Regression plot formed using MATLAB simulink

Performance = 577.8535
Train performance = 591.3847
Val performance = 30.0030
Test performance = 1.0716e+03

Figure 19. Performance plot formed by MATLAB simulink

9. Conclusion
This is research work to present a desktop version of personal computer based expert system, which is used in smart grid for load forecasting. It studied the potential of various ANN training algorithms, transfer functions, learning rate, and momentum in order to find a suitable ANN model for developing an accurate and reliable load forecasting system in the smart grid, which could help to economically
optimize power system operations. Using MATLAB SIMULINK an adequate user interface could be provided in graphical user interfaces. The working and functionality of the overall process has also been described. Different learning algorithms have been studied along with the different types of neural networks. The mathematical modeling of ANN-Artificial Neural Network has been studied. The input and output vector composition, as well as the network design, are typically significant variables in a neural network's performance. Because normalization methods impact Back Propagation's prediction performance, normalization of input and output vectors is required.

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