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Space Craft Power System Implementation using Neural Network

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ABSTRACT: *The usage of renewable source of energy is increasing in recent days. This is widely used in the spacecrafts for the power system built there. The power system of a spacecraft can be simulated using artificial intelligence. Designing and implementing intelligent systems has become a crucial factor for the innovation and development of better products of space technologies. The artificial neural network is used in implementing non-linear problems. The weights for the neural networks are calculated using MATLAB-SIMULINK and the architecture of the design can be programmed in VHDL. The multilayer perceptron model is used for implementing the generator, controller and the battery. Back propagation algorithm is used in modeling this network since the error can be reduced significantly.*

Keywords: *Spacecraft, Artificial Neural Network, VHDL.*

I. Introduction

A spacecraft is a vehicle, vessel or machine which is designed to fly in outer space. Spacecraft are used for a variety of purposes. Some applications in which spacecraft are used are communications, earth observation, meteorology, navigation, planetary exploration and transportation of humans and cargo. Spacecraft need an electrical power generation and distribution subsystem for powering the various spacecraft subsystems. The source for power available in the world nowadays are becoming very less. There are different technologies employed in power production. Photovoltaic are best known as a method for generating electric power by using solar cells to convert energy from the sun into a flow of electrons.

The Number of electronic applications using artificial neural network based solutions has increased considerably in the last few years. The main advantages of using ANN algorithms are simplifying the complicated algorithms, reducing heavy computation demands and improving fault tolerance.

The main objective is developing the photovoltaic simulator for the generating the power in the spacecraft. Several components are used in this simulation. An MLP(Multi-Layer Perceptron) is modeled for simulating each component of the system. After modeling an MLP the architecture of each component can be programmed using VHDL. The modeling of the MLP can be done with MATLAB-SIMULINK. The algorithm used in this modeling back-propagation which reduces the error significantly.

The paper is organized as follows: Section two gives the clear architecture of the system. Artificial Neural Network structure and the model is described briefly. Section four shows the implementation of the system. And section five gives the simulation results.

II. Architecture of the Power System

The block given in fig. 1 shows the complete architecture of the system. The components used in modeling this system are PV generator, Controller and a Battery. The PV generator is used to generate the current from the solar panel. This can be modeled with neural networks and the architecture of this generator can be programmed in VHDL. The battery is also modeled using MLP. The battery consists of accumulators. Each accumulator can deliver 2V.

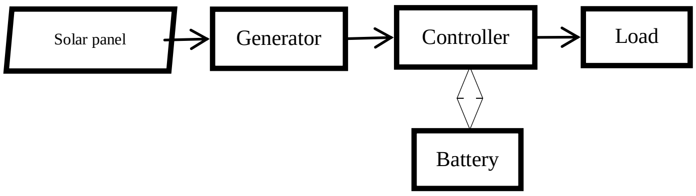

Figure 1 Block diagram of the power system

The controller modeling is also done with MLP. The controller is used to monitor the current generated by the generator module. The design of the controller[2] is shown in the fig. 2.

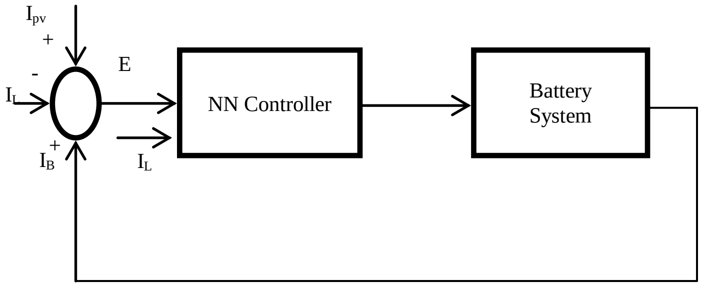

Figure 2 Block Diagram of the Controller

This controller is used in the power system of [1] instead of a regulator. Since the number of hidden layers and neurons in the controller is minimum the number of calculations can be reduced and the speed of the system will be improved.

III. Artificial Neural Networks

Artificial neural networks are information-processing systems that have the performance characteristics common to biological neurons. The neural network represents a network with a finite number of layers consisting of solitary elements that are similar to neurons with different types of connections between layers. The number of neurons in the layers is selected to be sufficient for the provision of the required problem solving quality. The number of layers is desired to be minimal in order to decrease the problem solving time. The structure of the neural network is shown in the fig. 3.

The weight updating is the major calculation in the neural networks. The neural network can be mathematically represented as given in the equation below.

$$y = f\left(y_j\right) \quad (1)$$

$$y_j = \sum_{i=1}^{n} x_i\, w_i + b \quad (2)$$

Xi is the input of the network. Wi is the weight co-efficient. B is the bias. y is the output of the neuron which is given by the f(x). f(x) is called the activation function. This activation function is a non-linear function that is widely used in feed-forward calculations of the algorithm.

$$f\left(y_j\right) = \frac{2}{(1+e^{-2y_j})-1} \quad (3)$$

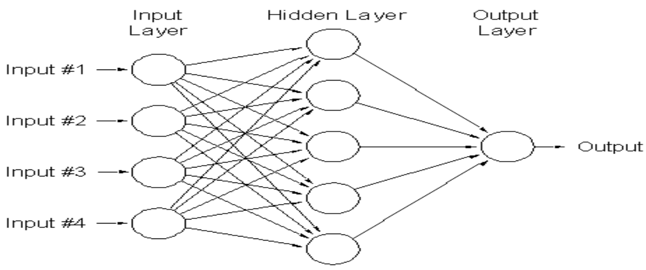

Figure 3 Neural Network Model

The main use of this neural network in the electronic applications is to reduce the error of the system. There are many algorithms designed for the implementation of the neural networks. The main algorithm that is widely used is the back-propagation algorithm which reduces the error significantly.

IV. Implementing the System

Generator: The PV generator can be designed with the artificial neural networks. The photovoltaic source from the solar panel is given to the generator. The input to the generator is solar radiation(H) and ambient temperature(Ta). The output of this will be voltage (Vpv) and current(Ipv).

Voltage and the current is the function of Temperature and radiation. It can be given by

$$V_{pv}, I_{pv} = f(T_a, H) \quad (4)$$

The neural network model for this contains an input layer, an output layer and two hidden layers. First hidden layer has seven neurons and second has nine neurons. The neural network model of the generator is given below with the inputs and outputs.

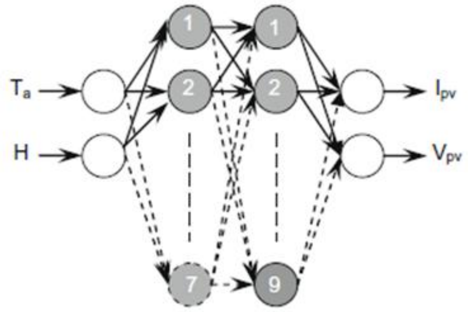

Figure 4 MLP Generator Model

Controller: the controller (Fig. 5 designing is the major part in the power system. Because it decides how the current generated from the solar panel should be utilized. The working of the controller will be disused briefly, before that the inputs for the controller is the error (E) and the load current (IL). The load current is the current value that is required by the system usage. That can be fixed manually.

The neural network model of controller is given below. This has a input layer, a output layer and a hidden layer with three neurons.

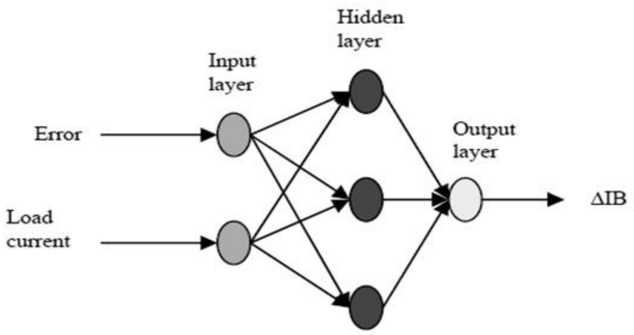

Figure 5 MLP Controller Model

The working of the controller is given in the fig. 6 as a flow chart.

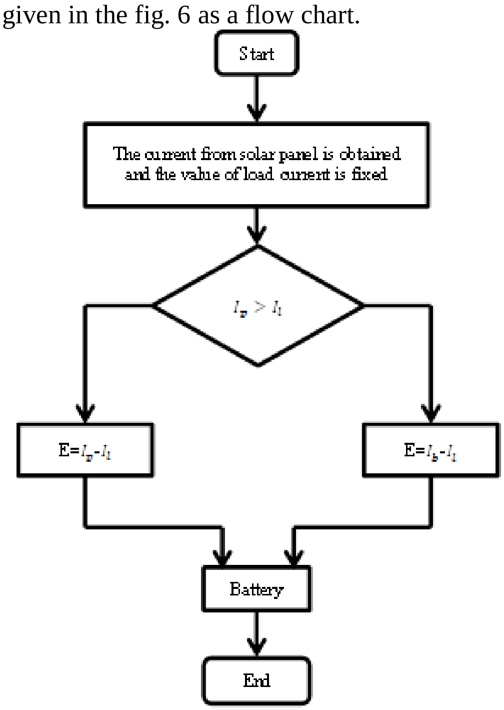

Figure 6 Flow chart of the working of controller

Battery: The battery is also designed with a multilayer neural network. The battery is used to store the excess current from the generator. The stored current can be further used in the eclipse time. The input data for the battery sub-system are the ambient temperature (Ta) the current coming from the regulator to battery(Ir). The output data is the battery voltage (Vb). The architecture of the battery consists of series of accumulators that can deliver 2V current.

The neural network design of the battery is given below in fig. 7.

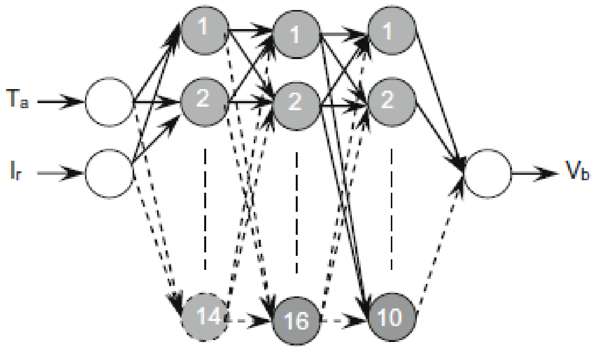

Fig. 7 MLP model of Battery

The design consists of an input layer, an output layer and three hidden layers. There are fourteen neurons in the first hidden layer, sixteen neurons in second hidden layer and ten neurons in second hidden layer.

I. RESULT

The ANN of each component is first modeled in the MATLAB-SIMULINK and the error of is calculated. The calculation of error is shown in the figure given below. This is the MATLAB command window with the calculations of error.

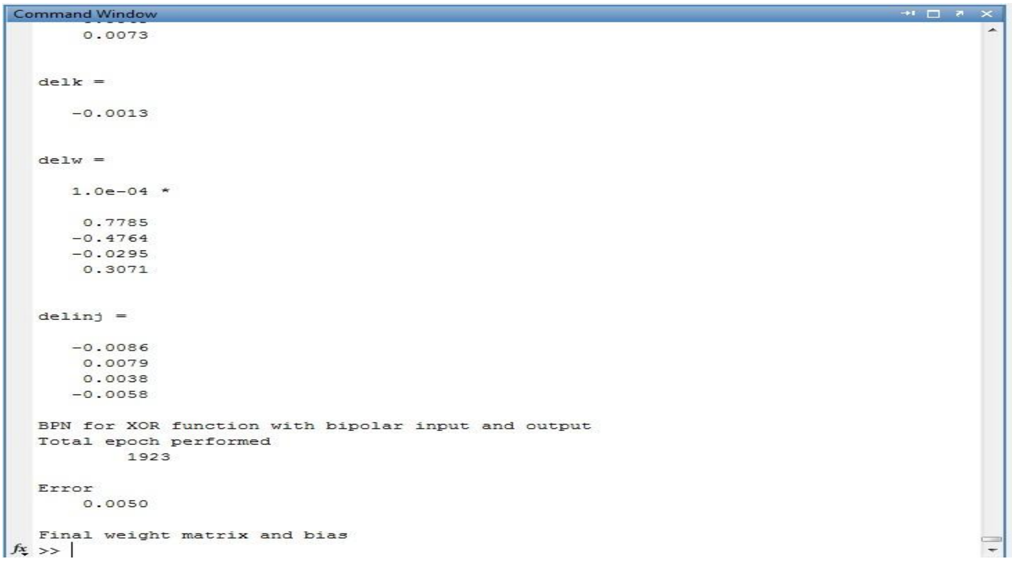

Figure 8 Error and the weights calculated in MATLAB for ANN

So finally the weight matrix and the error can be calculated. Instead of calculating this each time the results can be saved in the .mat file which is the matrix file. That can be used further while programming the architecture of each component.

The architecture of each component is developed in MODELSIM. The simulation results are given below.

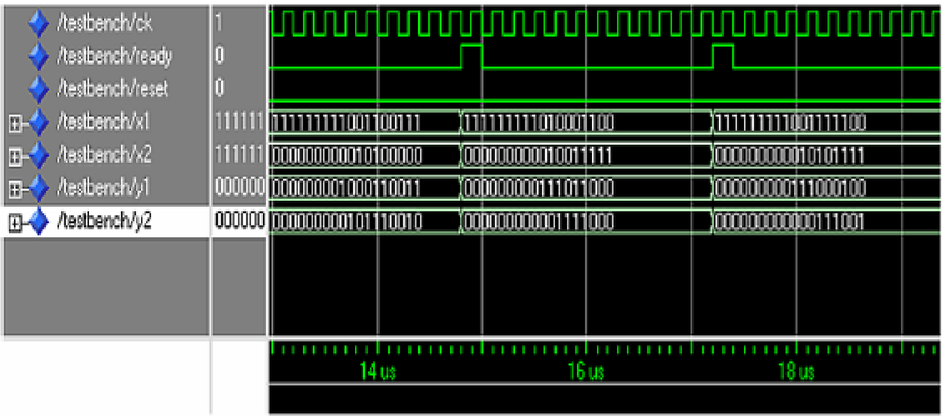

Figure 9 Simularion of MLP PV Generator in MODELSIM

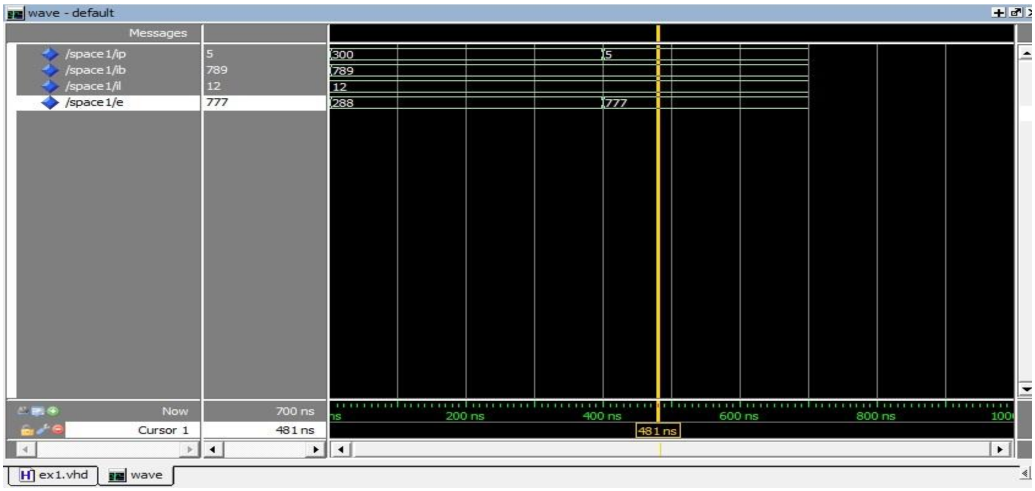

Fig. 10 Simulation of MLP Controller

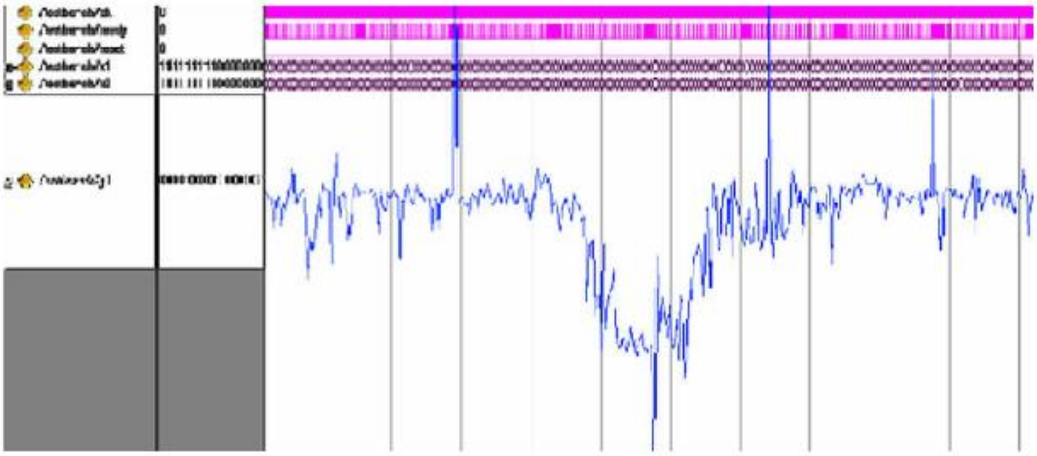

Fig. 11 Simulation of MLP PV Battery in MODELSIM

V. Conclusion

The simulation for a power system in spacecraft using neural networks is done. The advantage of using neural networks for this implementation is to improve the speed of the process and to solve the non-linear problems. A controller is first designed which decides how to utilize the current from the solar panel. The simulation of this architecture is done using ModelSim. The ANN's are simulated in MATLAB. The algorithm used for modeling the ANN is back propagation so the error can be minimum. The MATLAB is used for mathematical calculations and ModelSim for architecture development. The performance of this process can be improved by reducing the number of hidden layers. Since the number of hidden layers increases the calculation increases which consumes more time. The utilization of solar power efficiently is the major part in this design. When the calculation speed increases the process of obtaining the current can also be improved. The suns movement varies in space often, so the power system speed must be improved.

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