Controller based on Neural Networks for Power Electronics Circuits

Sunita Gupta[1], Kartik Tyagi[2], Sonal Chauhan[3]
Students[1, 2], Professor[3]
Department of ECE
Zakir Husain College of Engineering and Technology
Email:- *sg0002@gmail.com[1]*

Abstract

Artificial intelligence (AI) approaches, particularly neural networks, have had a considerable influence on power electronics in recent years. The concept of neural network applications in intelligent control for power electronics circuits is explored in this research. The Neural Network Controller (NNC) is a power electronics circuit controller that tracks output voltage and improves performance. MATLAB-SIMULINK is used to develop and simulate the controller.

Keywords: *Neural Networks, Control systems, MATLAB-SIMULINK, Power Electronics, Artificial intelligence (AI)*

INTRODUCTION

Control systems have long been a major concern in power electronics because they have such a large impact on total system performance. A controller in a feedback loop is required to accomplish the required regulation. The tiny signal model of the converter circuit is used in traditional approaches for designing controllers for power electronics converter circuits. The validity of the tiny signal model is limited, and it varies as the operating point changes. Models are also insufficient to depict systems with significant nonlinearity. Furthermore, the performance of the developed controllers is influenced by the operating point, parasitic system parts, and load and line conditions. Switched power electronics circuits, in particular, are very nonlinear. The switching actions and parameter fluctuations generated by external disturbances are the major causes of non-linearity's [1]. Proportional (P), Proportional-Integral (PI), PD (Proportional-Derivative), or Proportional-Integral-Derivative (PID) digital controllers are often used in industry since they are simple to construct and tune on a real process. These controllers, on the other hand, have very low performance and are designed to be non-optimal. These controllers have a number of drawbacks, including a high initial overshoot, sensitivity to controller gains, and a slow reaction to unexpected disturbances. As a result, designing a new controller is a difficult engineering task.

Since the early 1990s, AI-based control systems have become highly popular. In most cases, no model is required for these procedures. However, they were only employed in a few industrial applications. Artificial neural networks have recently seen increased usage in the field of power electronics and drives, owing to their remarkable learning, optimization, and adaption capabilities.

Neural networks are crucial in the development of controllers in this setting. A unique neural network controller for non linear power electronics circuits is proposed in this research. It is intended to deal specifically with switching power electronics circuits, which mostly consist of AC to DC power converters and DC to DC power converters of various topologies. The most essential aspects of the proposed Neural Network Controller are its simple and straightforward construction and superior performance over previous controllers.

Neural Network Controller

Neural Networks are a very advanced modeling tool capable of simulating incredibly complicated tasks. The Artificial Neural Network (ANN) is a strong tool for determining nonlinear correlations between input and output. To cope with nonlinearities and uncertainties in power electronics circuits, a Neural Network Controller (NNC) employs artificial neural networks as a design tool. Control and power electronics are interested in many essential properties of ANNs: (1) modeling: Because they may be taught using data records specific to the system of interest. (2) Nonlinear networks: Nonlinear networks may learn nonlinear connections. (3) Multivariable systems: Because ANNs have multiple inputs and outputs by definition, they may readily be used to multivariable systems. (4) Parallel structure: This indicates high parallel processing speeds, fault tolerance, and resilience. The design of a neural network makes it clear that it is essentially a parallel input-parallel output multidimensional computing system with distributed computation, as opposed to sequential computation in a traditional computer with a centralized CPU and store memory. It is unquestionably closer to analogue computing. As a result, ANN control is more sensitive to the system's unknown dynamics. Because an industrial control system also contains uncertainty and time-varying effects [4, 5], it makes it more appropriate for industrial control applications.

The protocol for training a neural network is shown in Figure 1:

The following is a summary of the general process for creating a neural network:

1. If feasible, choose a feed forward network.
2. Select as many input nodes as there are input signals and as many output nodes as there are output signals.
3. For normalization of input signals, choose acceptable input scale factors, and for de-normalization of output signals, choose appropriate output scale factors.

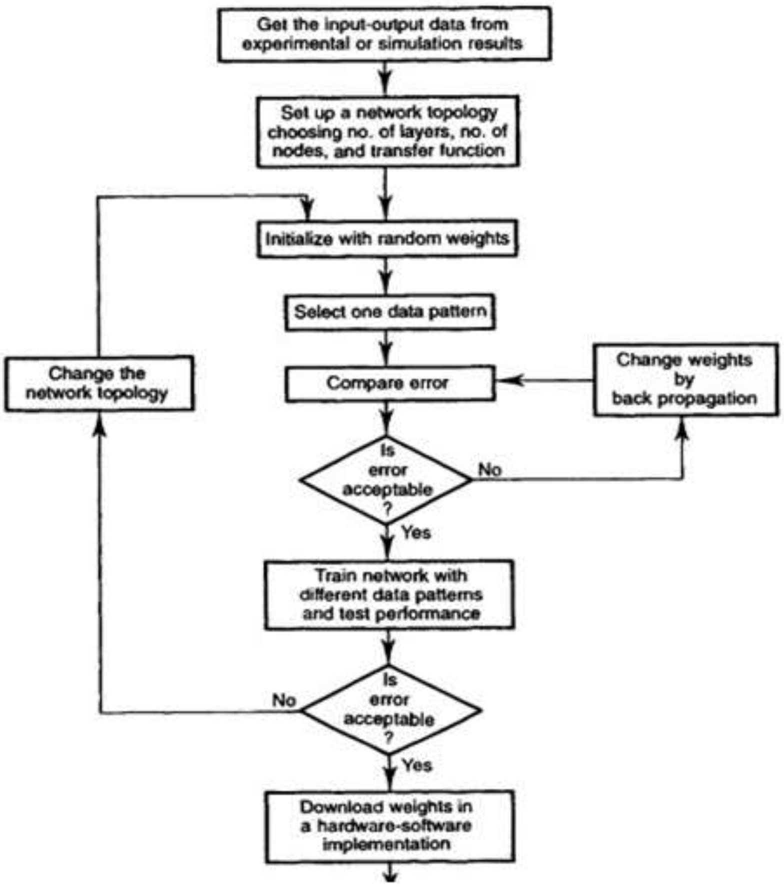

Figure 1. Flowchart for Training a Neural Network

1. Make an input-output data table for training. Data from an experimental plant should be captured. If a model is available, run a simulation and use the results to produce data.

2. Pick a development platform.

3. In the development system, create a network topology. Assume the network has three layers. The average of the input and output layer nodes is used to choose hidden layer nodes. Choose a transfer mode. In the development system, the training approach is largely automated. The procedures are outlined below.

4. Choose a reasonable network training mistake. E. Fill the network with positive and negative weights at random.

5. From the training data file, choose an input-output data pattern. The back propagation training principle is used to change the network's weights.

6. Select another pattern and repeat the operation once the acceptable error has been obtained. All of the patterns require complete training.

7. If a network fails to converge to an acceptable error, increase the hidden layer neurons or the number of hidden layers as needed (most issues may be handled with three layers). The training period will be longer if there are too many hidden layer neurons or layers, and the network will have a memory property.

8. After the network has been successfully trained, test its performance with some intermediate data input. The weights are now available for download.

9. Choose the right hardware or software for the job. Get the weights here.

DESIGN OF PROPOSED NNC

The Neural Network appears to have the greatest influence in the field of power electronics, as evidenced by articles in the literature. In comparison to other controllers, NNC is easier to build, simpler to use, and provides greater performance. Weighted linkages connect the neurons, which are strongly linked. The signal is carried via the weighted connections. A unique threshold value exists for each neuron. The activation signal of the neuron is obtained by forming a weighted sum of the input and subtracting it from the threshold value.

The output signal is created by passing the activation signal through an activation function.

This programmed was created with the Mat lab toolbox, and the NN structure was created using the gensim (net) command in the mfile, and the system design and simulation were made simple with Simulink.

The network has three layers:

1. Input layer
2. Hidden layer
3. Output layer.

The input and output layers are linked by the hidden layer. The number of neurons in the input and output layers (also known as buffers) is equal to the amount of signals. Although the input layer neurons lack a transfer function, each input signal is normalized by a scale factor. As indicated, the input layer sends the calculated signals to the hidden layer, which then sends them to the output layer. The output layer receives computed weights from the hidden layer. When the actual output differs from the required level, the error is transmitted to the input layer via back propagation (feedback). As a result, the weights are changed to reduce the error through neural network training and learning. The method is repeated until the output is satisfactory or the learning time is met. The back propagation network is currently the most common. In a neural network system, there are several strategies for determining parameters (weight and bias). The LM method, which is the quickest for NN training, is employed among these algorithms. It is more than four times quicker than the competition. This network uses supervised learning, which involves presenting a data set to train the network before running a simulation to obtain output results. Figures 2 and 3 are examples.

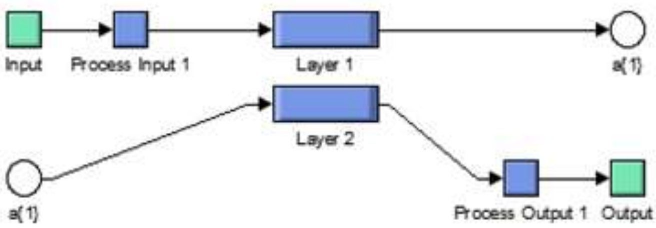

Figure 2 Neural Network Architecture

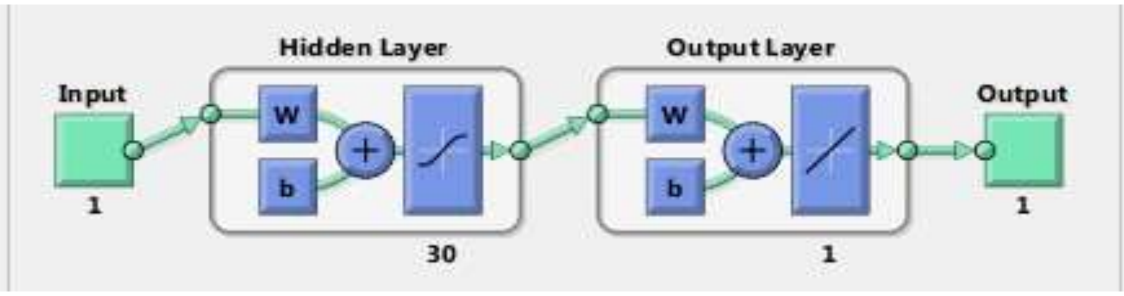

Figure 3 Custom Neural Network (Proposed Neural Network)

Network input and output signals may be logical (0, 1), discrete bidirectional (± 1) or continuous variables. The transfer function is sigmoid function which possesses continuous and nonlinear properties.

It is represented by the following equation:

$$f(x) = \frac{1}{1+e^{-ax}}$$

To convert to logical variables, clamp the sigmoid functions at output. As Artificial Neural Networks are trained by data sets in supervised learning, ANN control learns from experience. The analysis is conducted using the Mean Square Error (MSE), which represents the difference between the desired and actual output levels. The MSE approaches zero under ideal conditions.

As illustrated in Figures 4 and 5, the proposed NNC is simulated and its performance is assessed by employing it as a controller in DC-DC (buck/boost) and AC-DC converter circuits. A good model of the system is required to achieve high performance control of the system. The conversion should be done with minimal losses in the converter. Resistors are avoided in power electronics converter circuits to achieve minimal losses. Instead, capacitors and inductors are utilized because they have no losses. The electrical components can be mixed and linked in a variety of ways, resulting in various converter (DC-DC, AC-DC) topologies, each with its own set of attributes. The output voltage is regulated by adjusting the duty cycle of the switch using pulse-width modulation (PWM) control. The duty cycle is the ratio of the time a power semiconductor is turned on to the cycle time.

The switching device in the proposed converter circuit is an IGBT. IGBTs make it possible to construct converters that are both cheaper and better. They provide three appealing benefits: increased switching frequency, simplified gate control, and no requirement for snubbed circuits. During turn on and turn off, IGBTs may be controlled constantly. This simplifies over current protection and permits dV/dt regulation to lessen dV/dt stresses. Figure 6 illustrates this.

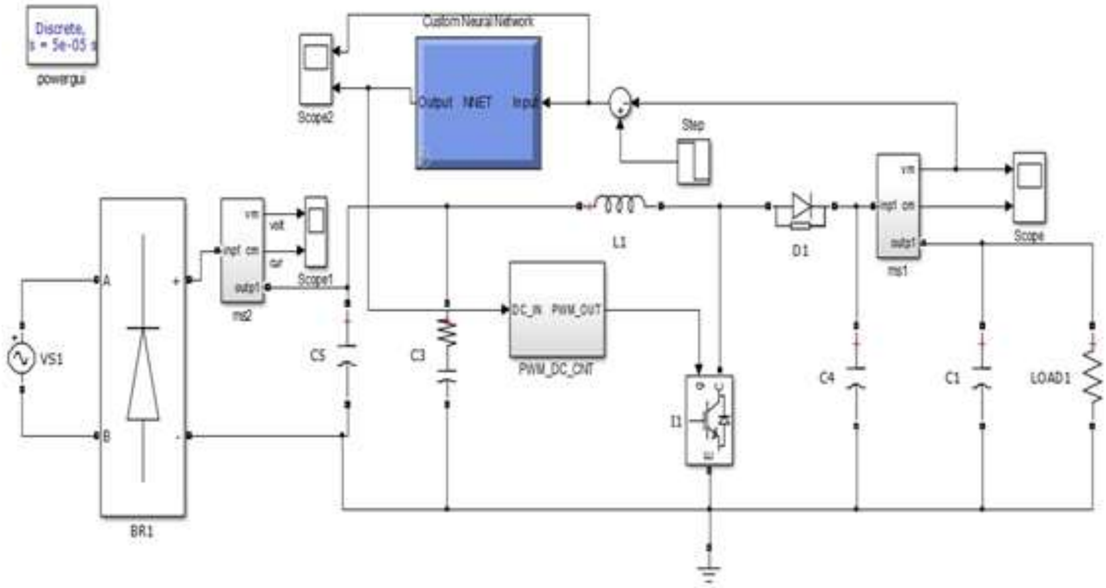

Figure 4. Neural Network Controller for DC-DC (Buck) Power Converter Circuit

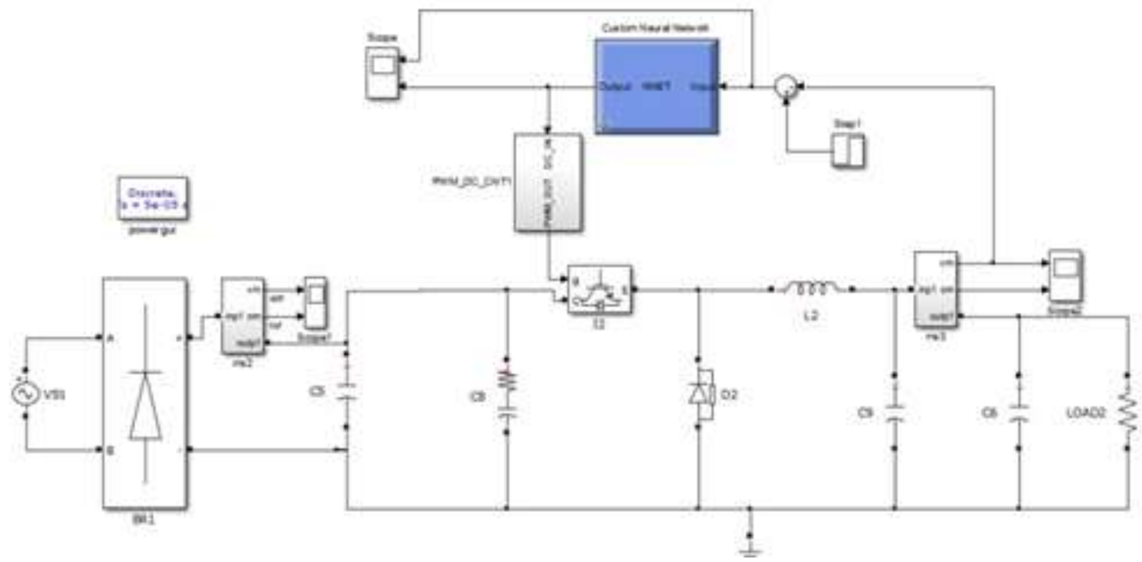

Figure 5. Neural Network Controller for DC-DC (Boost) Power Converter Circuit

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SIMULATION RESULTS

The suggested Neural Network Controller is constructed and simulated using the MATLAB SIMULINK toolbox [11], and the system's performance is assessed. The NNC's output creates the requisite PWM signal, which controls the semiconductor switch IGBT's switching activity to produce the appropriate output voltage. The simulation results are shown in Figures 7 and 8.

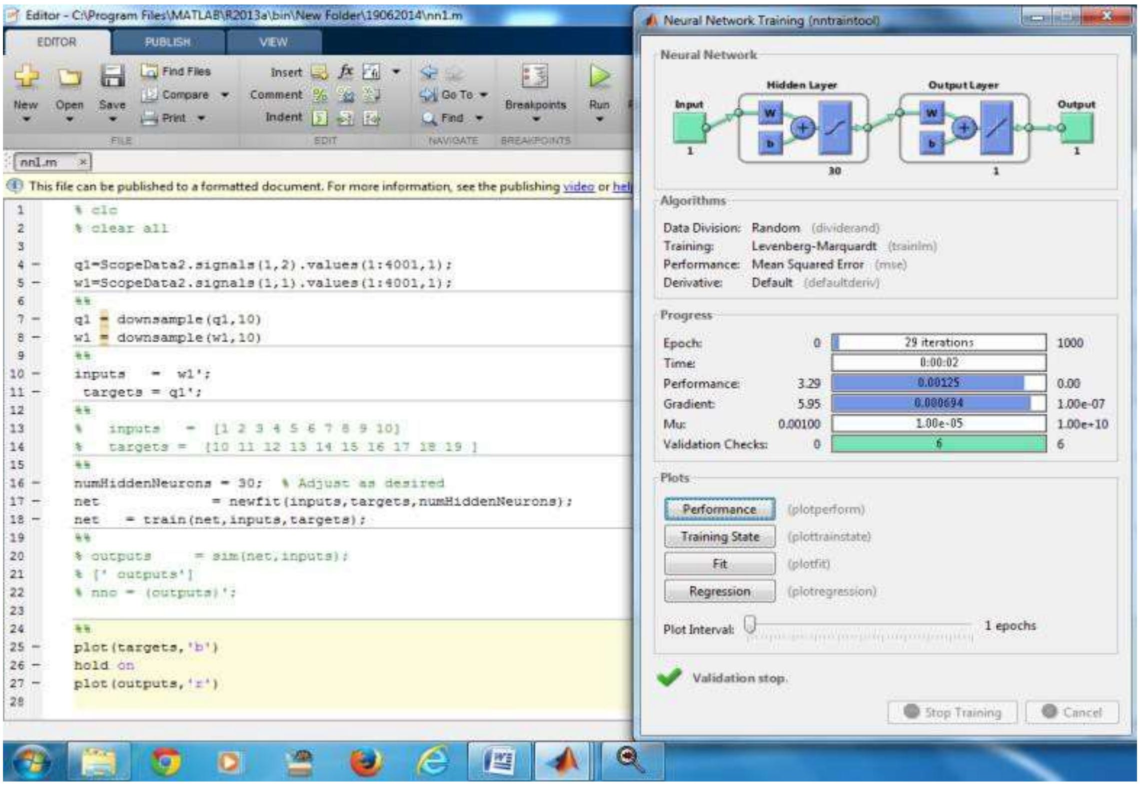

Figure 7 Training of Proposed NNC

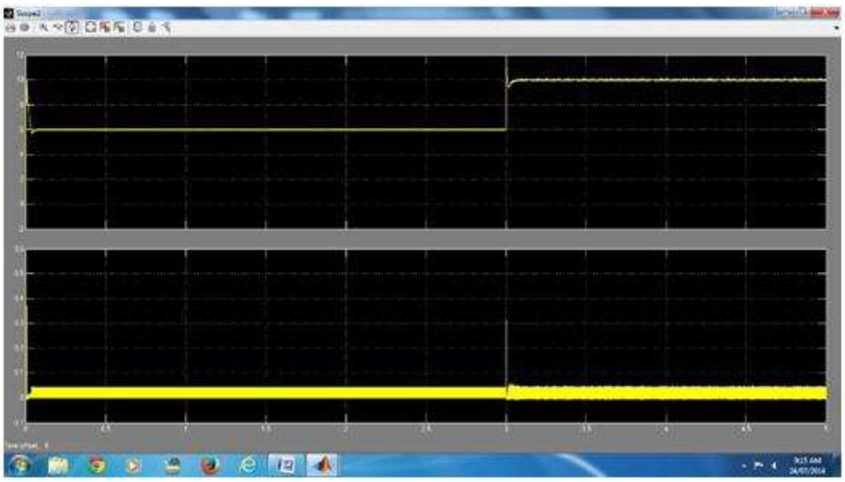

Figure 8 Output of DC-DC (buck) Converter using Proposed NNC

CONCLUSION

The simulation results demonstrate that the suggested Neural Network Controller outperforms the traditional PID controller. Any switching power electronics circuit, such as DC-DC (Buck/Boost) or AC-DC circuits can use the proposed controller.

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