The Control of Buck Boost DC-DC Converters for DC Motor Drives on variable DC Voltage by Using Neural Network

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Abstract: In this paper, a neural network control scheme of a DC-DC Converter Buck Boost DC variable voltage to generate a DC motor drive has been applied, is proposed. In this technique, a neural network learning algorithm, a learning algorithm is back propagation. Controller design, the voltage output DC-DC Converter Buck Boost Converter pursues performance improves during the admittance process. Furthermore, to investigate the usefulness and effectiveness of the proposed controller, some operations such as starting and reference voltage variations are verified. Numerical results of simulation show that the proposed controller has better performance compared to PI controller is using.

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Keywords: Buck Boost Converter, Neural Network Controller, PWM.

1. Introduction

Recently DC power supplies are widely used in simple applications such as portable computers, and even more advanced applications such as electric vehicles or even air and space applications has been used. Thus, DC-DC converters are widely used by its conversion to a DC voltage, DC voltage levels required for providing power to the load can be removed. In addition, the DC-DC converter has an important application in electrical systems such as PV energy systems, energy systems, wind turbines and ... Is. For these reasons, more and more applications in the future will be DC-DC converters. Essentially a DC-DC converter includes high-power semiconductor devices that act as an electronic switch and DC-DC converters are classified in Switched-mode power supply (SMP). Performance switching equipment, makes it Converter DC-DC, have the inherent non-linear characteristics. Due to unintended non-linear characteristics, converters need a controller with high dynamic response. Recent research on switching control techniques to achieve high-quality system is focused. Pulse width modulation (PWM) is the most widely used method is the method for switching control [1]. In the past decade, the use of PWM to control the switching controller, the PID controller has been used before. This kind of control because of its simplicity, they often apply to control converters. However, this method of controlling non-linear systems such as power converters on the dynamic response of the converter output voltage regulation, good will change. In general, controller, PID, overshoot when the output voltage is reduced, it will produce a rise time. To improve the problem of the dynamic response of the DC-DC converter control several intelligent controller such as fuzzy logic, neural networks manage and control Hybrid - Nero Fuzzy Control Method for DC-DC converters are [3-8]. The purpose of using a fuzzy controller method in [5], the development is located. Implementation of fuzzy logic controller using microcontroller has been visited and investigated [6]. A natural, simple fuzzy controller with a performance of such systems is relatively simple when trouble linear control techniques can then be applied to any DC-DC converter topologies. Due to the lack of formal analysis and composition technique, the knowledge is there, but the most practical success has been achieved by a fuzzy logic controller. Thus, most research has been done to improve the control system [4]. Fuzzy – Neuro Sliding Mode (FNSM) control system, a pulse width modulation control methods for power electronic converters in power electronics systems have been developed [3]. FNSM control system including a compensation controller and a neural controller, where the controller is robust compensation are designed to recover the residual error of the neural controller is designed to approximate the ideal controller. Adaptive recurrent fuzzy neural network (ARFNN) is the system by which we can control and regulate achieved good performance [4]. Learning algorithms have been applied; ARFNN control scheme is suitable for controlling DC-DC converters. Neural Network Controller (NNC), another type of neural network controller that has the ability to be special. Each transfer function is a learning process. Therefore, this controller is suitable for non-linear systems. Neural network controller for DC-DC converter to the computer simulations, the test has been concluded successfully. Neural network control explains the difference between the output voltage and the reference voltage reaches its minimum [9]. In addition, the dynamic features of the DC-DC converter with improved forecast neural network can be realized excellent dynamic characteristics, compared with the conventional methods [10]. To improve the performance of NNC, NNC learn some researchers plan to expand and develop.

2. Buck Boost Converter

Buck Boost Converter, a converter, DC-DC, is decreasing and increasing. Output Buck Boost Converter Based on input constant frequency pulse width modulation cycle, has been set. When the duty cycle (d) is less than 0.5, the converter output voltage is less than the input voltage. When the duty cycle is greater than 0.5, the converter output voltage is greater than the input voltage. The buck boost converter circuit is shown in Figure 1. So that the input voltage source is V_s, V_o output voltage, S_w the key, d represents a diode, C represents the capacitance, L is the inductance and R represents the resistive load.

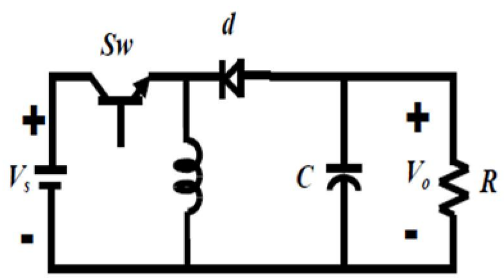

Figure 1: Buck Boost Converter circuit diagram

Buck Boost converter switching action of the equations in the following way:
When the switch is connected, the diode is on. Then we have:

$$v_l = v_s \quad (1)$$

$$v_l = L\frac{di_l}{dt} \quad (2)$$

From equations (1) and (2) we have:

$$v_s = L\frac{di_l}{dt} \quad (3)$$

$$\Delta i_{l(close)} = \frac{v_s}{L}DT \quad (4)$$

And when the switch is off and the diodes are:

$$v_l = v_o \quad (5)$$

$$v_L = L\frac{di_l}{dt} \quad (6)$$

Again, equations (5) and (6) we have:

$$L\frac{di_l}{dt} = v_o \quad (7)$$

$$\Delta i_{l(open)} = \frac{-v_0}{L}(1-D)T \quad (8)$$

So that D is the duty cycle. At steady state, the solution of the equations connecting the key cuts, the average value of output voltage is calculated as follows:

$$\Delta i_{l(open)} + \Delta i_{l(close)} = 0$$

$$\frac{v_s}{L}DT + \frac{v_o}{L}(1-D)T = 0$$

$$v_o = -v_s\frac{D}{1-D} \quad (9)$$

To develop a dynamic model of a buck-boost converter, we use state-space models. And
D '= 1-D where D is the duty cycle expresses consider. Then we have:

$$\dot{X} = AX + BU \quad (10)$$

$$Y = CX \quad (11)$$

So that

$$X = \begin{pmatrix} i_L \\ v_C \end{pmatrix}$$

$$U = v_1$$

$$Y = v_o$$

$$A = \begin{bmatrix} 0 & \frac{D'}{L} \\ \frac{-D'}{C} & \frac{-1}{RC} \end{bmatrix}$$

$$B = \begin{bmatrix} \frac{1}{L} \\ 0 \end{bmatrix}$$

$$C = [0 \quad 1]$$

As a result, the transfer function of the buck boost converter in continuous system is as follows:

$$G(s) = \frac{-D'R}{LRCs^2 + Ls + D'^2R} \quad (12)$$

3. Neural network architecture and learning plans

A) The Structure of the Neural Network Controller

Neural network controller design, some information about the project is required. Basically, the number of input and output neurons in each layer, respectively, equal to the number of input and output system. The structure of the proposed neural network controller for a buck boost converter is shown in Figure 2.

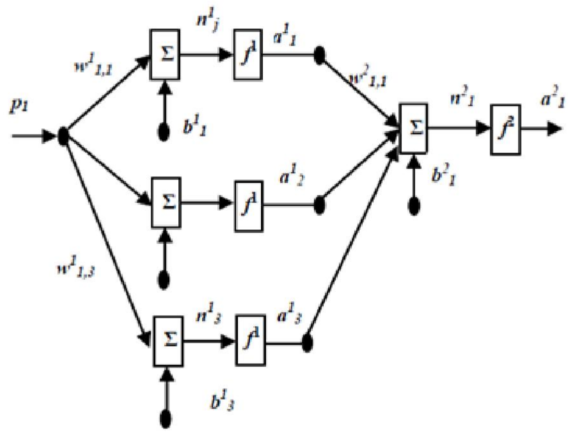

Fig.2. Architecture of the proposed neural network controller

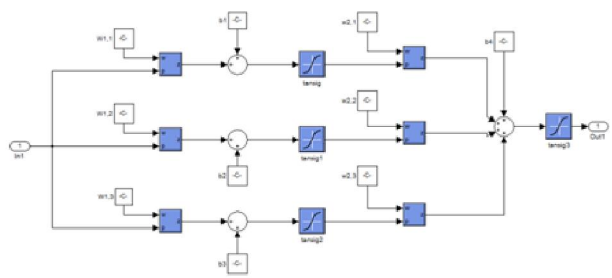

Fig.3. Architecture of the neural network controller is proposed and simulated in MATLAB

In this structure, the input layer consists of input neurons and the neurons of the input signal and the output signal of the error between the desired signals for us.

The bias for i_{th} neurons with b_i^m will display. Transfer function of the network i_{th} neurons and m_{th} layer is defined as follows:

$$n_i^m = \sum_{j=1}^{s^{m-1}} W_{ij}^m a_j^{m-1} + b_i^m \qquad (13)$$

Neuron in the output layer m_{th} is defined as follows:

$$a_i^m = f^m(n_i^m) \qquad (14)$$

So that f is the transfer function of neurons. In this design, the transfers function for the hidden layer and output layer is transfer function hyperbolic tangent. Hidden layer transfer function is given as follows:

$$f^m(n_i^m) = \frac{2}{1+e^{-2n_i^m}} - 1 \qquad (15)$$

And update weight and bias parameters is done with the following equation:

$$W_{ij}^m(k+1) = W_{ij}^m(k) - \alpha \frac{\partial F(k)}{\partial W_{ij}^m} \qquad (16)$$

$$b_i^m(k+1) = b_i^m(k) - \alpha \frac{\partial F(k)}{\partial b_i^m} \qquad (17)$$

In the above relation, k sampling time, α is the learning rate and network function F performance indicators.

B) The back propagation learning algorithm

After the structure of the neural network model came next stage of learning and updating the model parameters in the network. By learning abilities, the neural network can determine system parameters according to the environment. Output error of the network through a learning process optimization will be minimal. In general, the learning mode neural network controller sufficient information to map the input - output that is required. Based on the optimization method, parameters of the network are updated. Performance indicators, the total squared error are defined as follows:

$$F(k) = \frac{1}{2}\sum_i e_i^2(k) \qquad (18)$$

$$e_i(k) = t_i(k) - a_i(k) \qquad (19)$$

In relation (19), t_i target signal, a_i signal is output at the last layer. And the gradient of the performance index weighted connections is determined by the following equation:

$$\frac{\partial F}{\partial w_{ij}^m} = \frac{\partial F}{\partial n_i^m}\frac{\partial n_i^m}{\partial w_{ij}^m} \qquad (20)$$

Network sensitivity parameter is defined as follows:

$$s_i^m = \frac{\partial F}{\partial n_i^m} \qquad (21)$$

$$s_i^m = \frac{\partial F}{\partial a_i^m}\frac{\partial a_i^m}{\partial n_i^m} \qquad (22)$$

Weighted gradient transfer function parameter is as follows:

$$\frac{\partial n_i^m}{\partial w_{ij}^m} = a_i^{m-1} \qquad (23)$$

From equations (21), (23) and (16) we come to the following equation:

$$w_{ij}^{m-1}(k+1) = w_i^{m-i}(k) - \alpha s_i^m(k) a_i^{m-1}(k) \qquad (24)$$

And with the same technique and the bias parameter update equation we have:

$$b_i^{m-1}(k+1) = b_i^{m-i}(k) - \alpha s_i^m(k) \qquad (25)$$

4. The simulation results

Using computer simulation software in MATLAB Simulink, we can predict the effects of the proposed controller [10]. Block diagram of the proposed NNC Buck Boost converter is shown in Figure 4. A comparison of the PI controller and the proposed NNC simulation is shown in Figure 5.

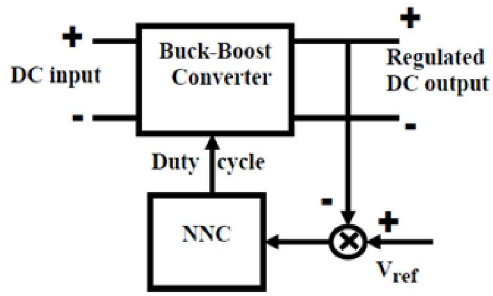

Fig.4. Block diagram of the proposed NNC Buck Boost Converter

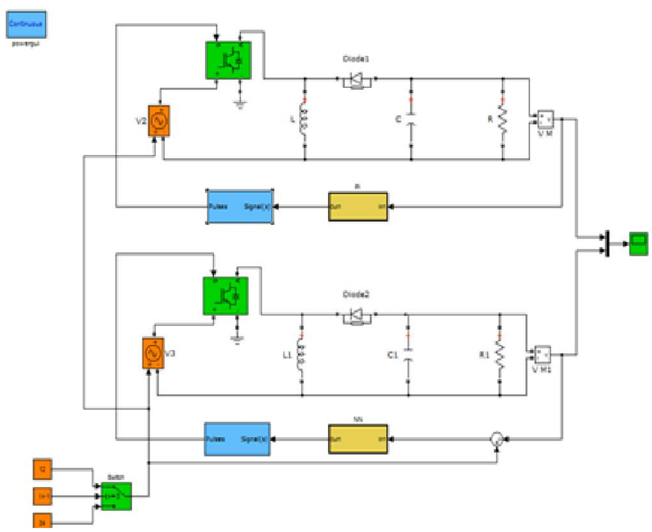

Fig.5. PI controller and NN simulations in MATLAB

Transient Response of Buck Boost converter output voltage is determined by the reference voltage of the boost converter when the input voltage source. Buck converter when the input voltage is less than the source. These cases are shown in figures 6 and 7.

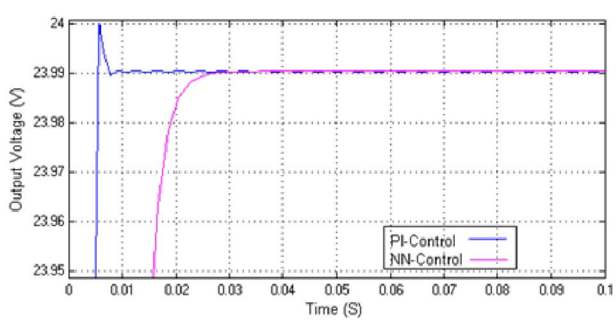

Figure.6. Transient Response at 24 V output voltage during startup

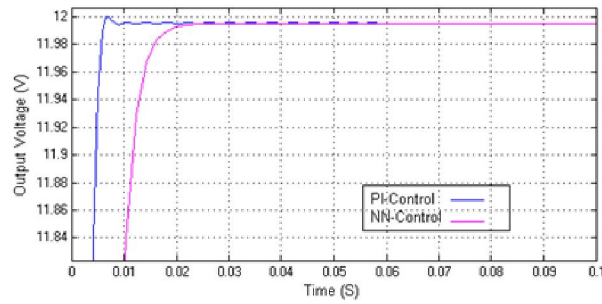

Fig.7. Transient Response at 12 V output voltage during startup

Neural Network Controller (NNC) is a better performance compared to PI controller to eliminate the oscillation and overshoot and NNC also meeting time is faster than PI controller. Figures 8 and 9 transient response of buck boost converter output voltage and the reference voltage changes represent them.

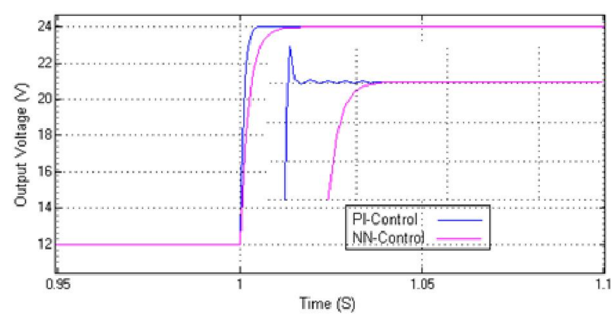

Figure.8. Transient response of the output voltage to the reference voltage from 12 volts to 24 volts

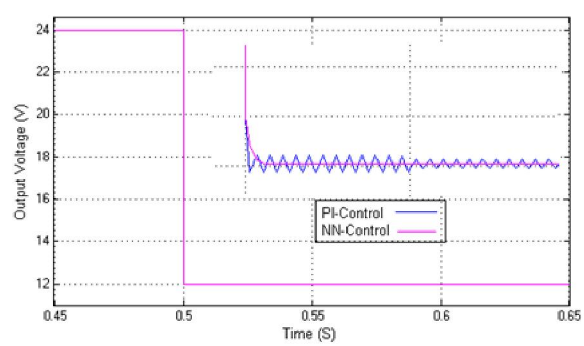

Figure.9. Transient response of the output voltage to the reference voltage from 24 volts to 12 volts

From Figures 8 and 9 it is apparent that the proposed NNC PI controller has better transient response under a step change in voltage reference.

5. Conclusions

In this paper, the neural network control for buck boost converter was discussed. To enhance the control performance of the neural network, back propagation algorithm was used. Synchronous learning technique based on simulation results for a buck converter, boost is feasible and doable. This is visible in the lower overshoot NNC session and a fast response time as well as fluctuations in the voltage output for the desired effect.

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