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Neural Network Based High-Performance Double Boost DC-DC Converter in Using Renewable Energy System

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***Abstract*— Difference types of DC-DC converter are used in various electronic devices and applications for so many years. But conventional converter cannot afford in high voltage and high current applications. Many researchers have been tried to full-fill the requirements. In this paper, dual stage double boost DC-DC converter is used for renewable energy system. To obtain a control method has the best performance under any condition is always demand. Voltage mode control technique is applied to achieve the constant high output voltage with the help of advanced controller. The main objective of this paper is the study of Neural Network Controller (NNC) under the response of different parameters of proposed converter using Matlab/Simulink Software.**

***Keywords* — Double boost DC-DC converter, Electronic device, Neural network controller (NNC), Renewable energy system, Voltage mode control.**

1) INTRODUCTION

DC-DC converters are used in many different applications like electric vehicles, distributed DC systems, electric traction, machine tools, fuel cell, special electrical machine drives and solar PV based applications. DC-DC converter can convert low input voltage to high output voltage (required voltage) [1]. But, the basic boost topology does not provide a high boost factor. This has led to many proposed topologies. If a very high voltage gain is required, it may be more beneficial to use of two or more series connected (cascaded) boost converters. This approach gives some advantages, but it creates new challenges in the same time. Main advantages include a high voltage gain, a good power decoupling between the output and input, better utilization of semiconductors, presence of an intermediate DC bus. Main drawbacks are more complex circuit, more complex controls and a potential stability problem [2]. DC-DC boost converter is specialized making control in this paper. Schematic diagram of DC-DC boost converter in solar energy application system is described in Fig. 1.

The classical control methods employed to design the controllers for double boost converter depends on the operating point so that it is very difficult to select control parameters because of the presence of parasitic elements, time varying loads and variable supply voltages [3].

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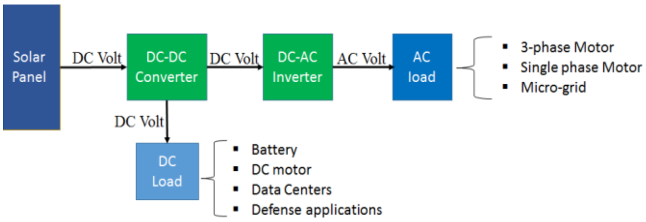

Figure 1. Schematic diagram of solar energy application system

Conventional controllers require a good knowledge of the system and accurate tuning in order to obtain the desired performances [5]. Neural Network Controller (NNC) are gaining popularity in modeling, identification and control of power electronic converters [6]. The linear controllers such as Proportional (P), Proportional-Integral (PI) and Proportional-Integral-Derivative (PID) control were widely used to control the active performance of the converter [4]. However, the linear control of converter is not sufficient to face the changes in line voltage or load current. Hence non-linear controlling techniques such as Fuzzy Logic Control (FLC), Neuro-Fuzzy Logic Control (NFLC), Adaptive Neural Network (ANN) and Genetic algorithm (GA) controlling techniques are implemented to increase the performance of the converter [7].

In this regard, the objectives of this study are to propose a simple and efficient method of advanced converter based on the properties of simple boost converter topology and to analyze the performance of proposed method for the voltage loop. The main objectives are to make the current in the inductor to track and to regulate the output dc voltage to desired reference voltage. The designed controllers have been tested using MATLAB/Simulink. The rest of the paper is organized as follows. Double boost DC-DC converter is presented in section 2. Neural network controller for proposed system is described in section 3. Simulation controlled results for proposed converter are presented and discussed in section 4 followed in by conclusion section 5.

2) DOUBLE BOOST DC-DC CONVERTER

The double boost DC-DC converter will operate in Continuous Conduction Mode (CCM). The voltage gain of the converter is the product of the voltage gain of each stage.

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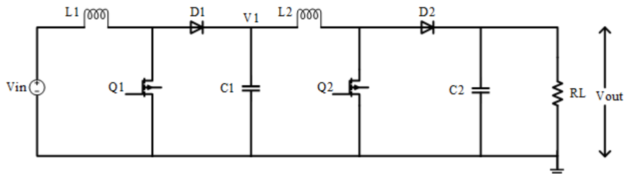

Figure 2. Double boost DC-DC converter [8]

The circuit diagram of double boost DC-DC converter is shown in Figure 2. The inductors L_1 & L_2 have the same values, the diodes D_1 & D_2 are the same type and the same assumption is for the transistors (Q_1 & Q_2). Each inductor has its own switch and thus is similar with the cascading of two single/classic converters. The transistor Q_1 and diode D_1 have to handle the intermediate voltage V_1, while the transistor Q_2 and diode D2 have to handle the output voltage V_{out}. For a large voltage gain cascading of two or more boost converters lead to significant reduction of the required transistors power rating, but in the same time it increases required diodes power rating by number of cascaded converter stages.

3) NEURAL NETWORK CONTROLLER FOR THE PROPOSED SYSTEM

Artificial neural networks have many characteristics similar to the human brain are capable of learning from experience, generalization, abstracting essential characteristics from inputs high tolerance to faults, real time operation, etc. Therefore, neural networks offer many advantages for the control of double boost converter. A neural network is characterized by (1) its pattern of connections between the neurons (called its architecture), (2) its method of determining the weights on the connections (called its training, or learning, algorithm), and (3) its activation function [6]. A neural net consists of a large number of simple processing elements called neurons, units, cells, or nodes. Each neuron is connected to other neurons by means of directed communication links, each with an associated weight. The weights represent information being used by the net to solve a problem. The actual output voltage is fed back and is compared with reference voltage. After comparison, error and the change in error are calculated and are given as input to the controller. The NNC attempts to reduce the error to zero by changing the duty cycle of switching signal. Fig. 3 shows the block diagram of NNC for double boost converter.

MATLAB/Simulink model of the double boost converter was developed and simulated with Fuzzy Logic Controller using Fuzzy Tool Box. From the simulation, error and duty cycle was acquired. These data were used to train the ANN controller. Then the closed loop operation was simulated with Neuro controller using Matlab NN Tool Box to achieve the desired performance. In this work Quasi-Newton back-propagation algorithm is employed to update weights Mean Square Error (MSE) is the performance criterion that evaluates the network according to the mean of square of error between the target and computed output

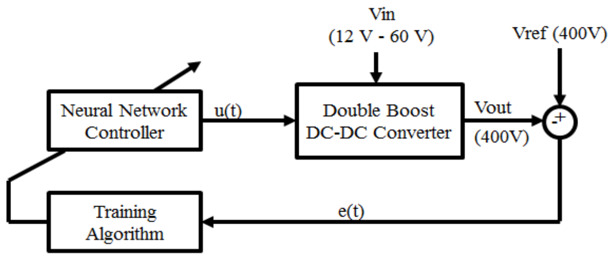

Figure 3. Block diagram of double boost DC-DC converter with neural network controller (NNC)

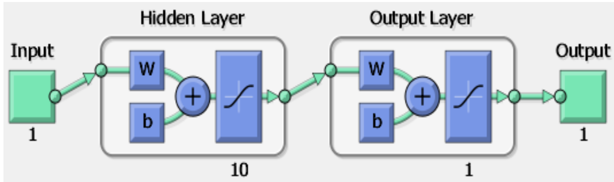

Figure 4. Neural network controller design for double boost converter

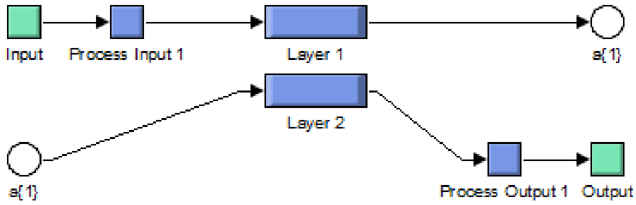

Figure 5. Simulink model of neural network chosen for double boost converter

The size of the network developed in this work showed itself satisfactory as far as the output voltage regulation is concerned. Trials have been carried out to obtain maximum accuracy with minimum number of neurons per layer. The feed forward neural network controller developed consists of three layers with one neuron in the input layer, 10 neurons in the hidden layer and one neuron in the output layer (Fig. 4 and 5). Feedforward networks have one-way connections from input to output layers. Supported feedforward networks include feedforward backpropagation, cascade-forward backpropagation, feedforward input-delay backpropagation, linear, and perceptron networks.

4) RESULT AND DISCUSSION

The power switching device that is used to develop the simulation of boost converter is MOSFET. This is because the characteristics of MOSFET are fast switching due to its operating frequency is very high. While designing the DC-to-DC boost converter, the parameters value of design requirement has been set. It is revealed that the transient response of the double boost converter is improved by adding NN controller. The simulation diagram of proposed system is shown in Fig. 6. Voltage range of converter is setup from 12V to 400V, switching frequency that is used is about 48 kHz and the load resistor is fixed at 3000Ω.

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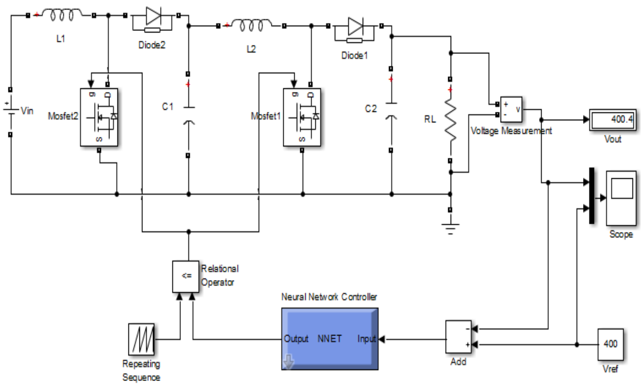

Figure.6. Simulation diagram of the proposed system

In this paper, the transient response and system stability is mainly analyzed in Continuous Current Mode (CCM) of the double boost converter for voltage mode control. According to Fig. 7, the characteristic of different simulation results with different input voltage can be seen clearly. The output voltage of the double boost converter with Vin = 32V show that the % overshoot is a little big and the settling time is 0.2 sec. In Vin=60 V, the system has big overshoot and the voltage deviation is a little increase. Nevertheless, the settling time of the output is very fast. The NN controller gives the proper output regulation minimum value for steady state error and peak overshoot. The more increase incoming voltage, the more increase overshoot occurs at the transient response of the system according to result. According to these results in Fig. 7, the numerical simulation results show that the AI controllers has a good performance.

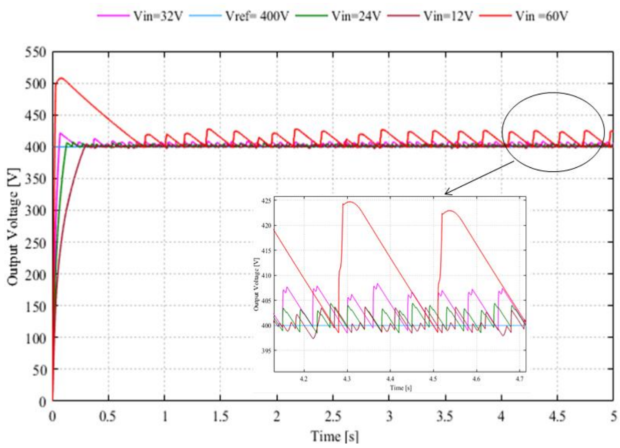

Figure 7. Simulation result of the proposed system

5) Conclusion

In conclusion of this paper is the double boost DC-DC converter with Neural Network controller through Matlab Simulink package. According to the simulation, the output voltage of the converter with NNC has minimum overshoot and produces high output voltage gain. In this paper, the only voltage error is used as the input of neural network. The system with neural network is still needed other considerations to be more adaptive. As the further work, the experiment of the system with adaptive neural network controller will be built to be more intelligent in invisible disturbances condition.

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