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Elimination of Transient Overshoots in Multi-Level DC – DC Converter by Using Neural Network Controller

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Abstract—Multilevel DC – DC converter system is the recently developed system which can be used as a DC link where several controlled voltage levels are needed with self balancing and unidirectional current flow. Multi level concept can be implemented for both DC – DC buck converter as well as boost converter. The topology can easily be extended to give multiple outputs. This paper proposes the implementation of Neuro controller for the Multilevel DC – DC converters to reduce the ripples in output voltage and to suppress the transient overshoots so as to achieve the faster transient response. Furthermore most accurate output voltage is obtained. The losses in the conventional buck and boost converter can be eliminated by suing this multi level DC – DC converter. In this paper the simulation of Multi level DC – DC converter using Neural network controller is designed using MATLAB and the results of converter for Neuro controller is compared.
Keywords—Neuro controller; DC – DC converter; multi level converters; Overshoots; Output ripples

I. INTRODUCTION

In the recent years power electronics industries progressed widely. Particularly DC power supplies are largely used in many areas comprising of simple electronic devices such as notebook computers, till even more advance application such as electric vehicle and also the aerospace applications. Also increased development of communication devices and electric drives increases the necessity of DC – DC converters. DC – DC converters are widely used in both low and high power applications. To meet the need of many number of converters, the concept multi level DC – DC converters are introduced recently.

Usage of multi level DC – DC converters decreases the number of converter requirement as well as it can be used for many applications with a single input supply. Multi level DC – DC converters has more advantages such as reduced voltage stress on the output capacitor, low electromagnetic interference, low switching frequency and the efficiency is high. The main advantage of use of this multi level DC- DC converter is that it requires less number of magnetising components so the total volume of the system is minimized. There are several topologies are employing in multi level concept such topologies are: diode clamped, capacitor clamped and cascaded multi-cell.

This configuration can be set up by using several dc links. The diode clamped configuration requires many number of switches hence the switching losses are increased. In this paper capacitor clamped or fly wheel capacitor multi level converter configuration is presented. This configuration has reduced output voltage ripples and increased transient response. The main drawback of this configuration is balancing of capacitor is somewhat difficult.

In the past decade, the generation of PWM signal was accomplished by using the P, PI, PID controllers. These converters can be used for controllers due to its simplicity in design. However, implementation of these control methods to the nonlinear plants such as the power electronic converters will undergo from dynamic response of the converter output voltage regulation. In general, all these controllers produce long rise time when the overshoot in output voltage decreases.

In recent years, there has been increased interest in the development of efficient control strategies to improve the dynamic behaviour of converters, by using Neural networks. Implementation of Neural network controller aims to reduce the ripple upto zero and to suppress the peak overshoot voltage to zero. Also the neuro controller eliminates the problem of capacitor balancing. Multi level concept can be used for both buck converter as well as boost converter. The design of neuro controller for multilevel DC – DC converter using MATLAB simulink is presented in this paper.

Volume 3, Special Issue-I1, June 2015
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II. MULTILEVEL INVERTER

The proposed multi-level boost converter is operated based on one inductor, one switch, 2N-1 diodes, 2N-1 capacitors for N levels. This converter is operated based on the principle of normal multi level converter. Here DC link is used for various levels where self balancing and unidirectional current flow is needed.

This converter is able to extend upto N number of levels, maintaining the same voltage in each and every level.

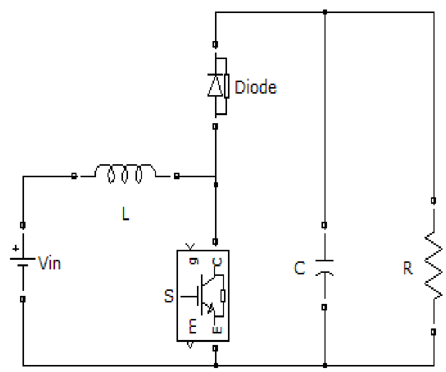

Fig. 1. Basic Boost converter

The fig 1 shows the basic configuration of Boost converter. From this configuration we can design a multi level boost converter by extending the dc liks upto N levels.

The steady state voltage across Inductor V_L is

$$V_L = D(V_{in}) - (1 - D)(V_{in} - V_c) = 0 \quad (1)$$

$$\frac{V_C}{V_{in}} = \frac{1}{(1-D)+\frac{R_L}{(1-D)R_O}} \quad (2)$$

If the inductor losses are ignored

$$\frac{V_c}{V_{in}} = \frac{1}{(1-D)} \quad (3)$$

The fig 2 shows the multi level converter upto N levels. Here if the level is increased the switch used will be the same but the capacitors and diodes will be increased. The voltage of each level is given by the product of number of level (N) and V_c. The difference between conventional boost converter and multilevel boost converter is that in multilevel boost converter the output is Vc times N, where N+1 is the number of levels.

Volume 3, Special Issue-I1, June 2015
ISSN: 2321-9653
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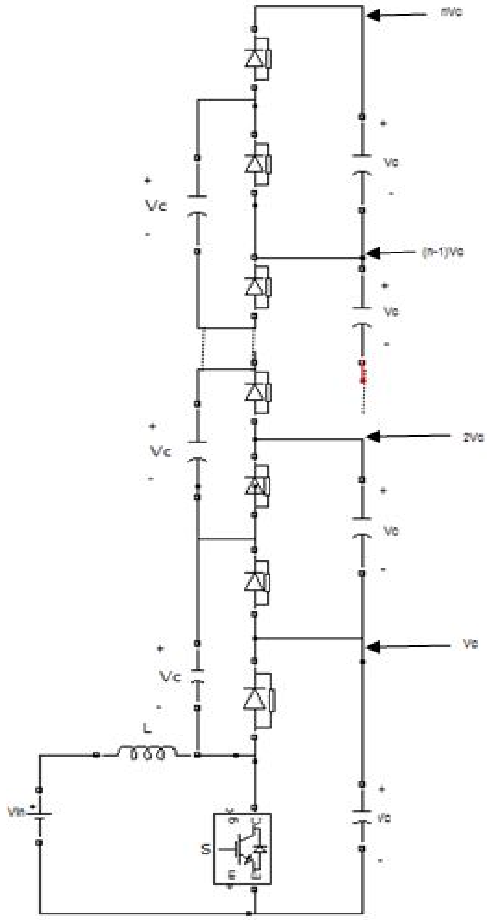

Fig. 2 Multilevel boost converter for N level

The output voltage of multilevel boost converter is given by

$$V_{out} = nV_c = \frac{nV_{in}}{(1-D)} \qquad (4)$$

If the losses are taken into account the boost ratio of multilevel boost converter topology is given by

$$\frac{V_{in}}{V_{out}} = \frac{1}{\frac{(1-D)}{N} + \frac{NR_L}{(1-D)R_O}} \qquad (5)$$

Where R_o is the resistance of the switch and R_L is the resistance of the inductor, D is the duty cycle of the switch, N is the number of levels.

III. OPERATION OF FIVE LEVEL BOOST CONVERTER

The detailed operation of 5 level boost converter can be explained with the help of fig 3. Let us assume that the duty cycle of the switch D is 0.5. During the switch S is ON, the inductor is connected to V_{in}. If C_6's voltage is smaller than C_7's voltage then C_7 clamps C_6's voltage through D_6 and switch (S). At the same time, if the voltage across C_4+C_6 is smaller than the voltage across C_5+C_7, then C_5 and C_7 clamp the voltage across C_4 and C_6 through D_4 and S. Similarly, voltage across C_2, C_4, and C_6 are clamped by

Volume 3, Special Issue-I1, June 2015
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International Journal for Research in Applied Science & Engineering Technology (IJRASET)

the voltage across C_3, C_5, and C_7. When the switch S is turned off, the inductor current closes diode D_7, and switches all diodes. When D_7 closes, C_6 and the voltage in V_{in} plus the inductor's voltage clamp the voltage across C_5 and C_7 through D_5. Similarly, the voltage across the inductor plus V_{in}, C_4, and C_6 clamp the voltage across C_3, C_5, and C_7 through D_3. Finally, the voltage across C_1, C_3, C_5, and C_7 is clamped by C_2, C_4, C_6, V_{in}, and the inductor's voltage.

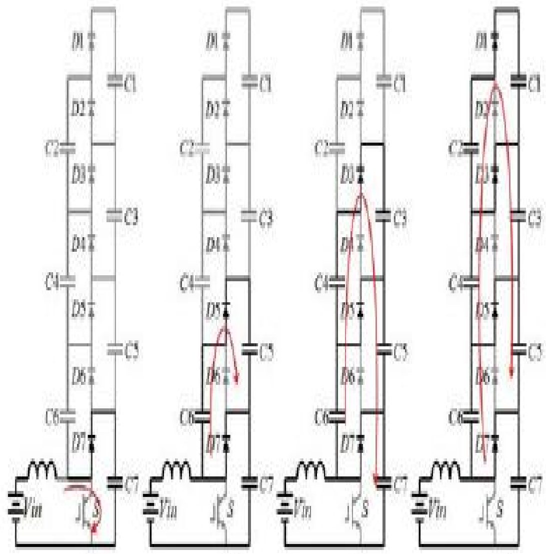

Fig 3. Operating modes of 5 level boost converter

IV. BLOCK DIAGRAM OF PROPOSED SYSTEM

The proposed neural network controller for the multilevel boost converter is illustrated in the fig.4. The main blocks of the system is multilevel boost converter, neuro controller, Pulse width modulation (PWM) generator and a comparator. The total output of the multilevel boost converter is compared with the help of comparator. After that comparator produces the error signal 'e'. Then the error signal is fed to the neuro controller for further processing. The output signal which is fed from the neuro controller is the duty cycle that is fed to the PWM generator which produces the gating pulse to the switch S.

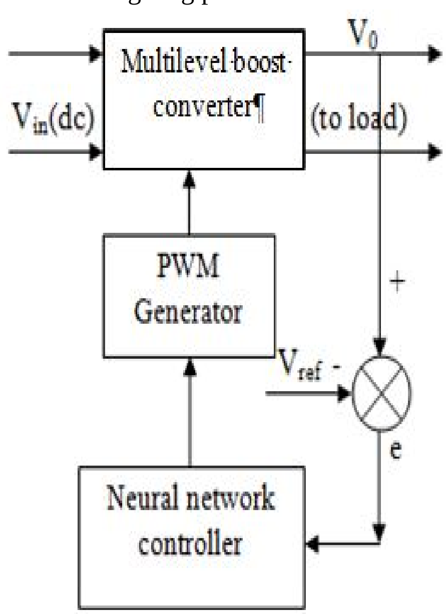

Fig. 4 Block diagram of proposed system

Volume 3, Special Issue-I1, June 2015
ISSN: 2321-9653
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V. MATLAB SIMULINK MODEL FOR THE PROPOSED SYSTEM

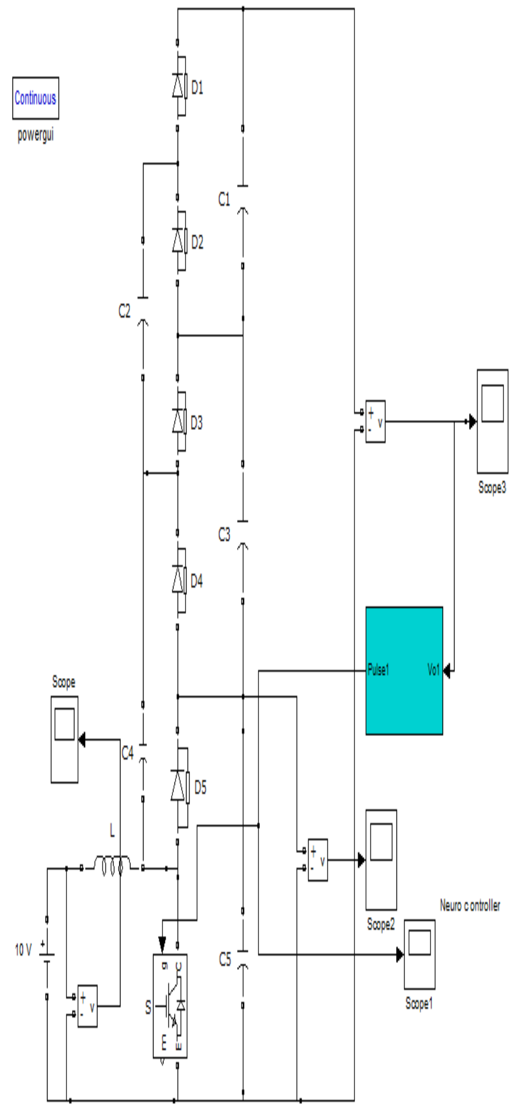

Fig 4 MATLAB Simulink model of the proposed system

Fig 4 shows the simulink model of the proposed system. Here IGBT is used as a switch for the proposed converter. In this system there are totally 3 levels taken into account for simulation. There are 5 diodes, each diode shares 2 levels and 5 capacitors which are connected across each two diodes. In this diagram scope 2 gives the output voltage of first level, scope 3 gives the total output voltage. The gating signal to the switch is given from neuro controller.

VI. NEURO CONTROLLER

Artificial neural network is a useful technique in analysing multi variant input conditions to optimize for specific output conditions. They can be therefore trained with the help of known examples to acquire knowledge about a problem. Once appropriately trained, the network can be put to effective use in solving unknown or untrained instances of the problem. The input data necessary for the off-line training of the neural network have been obtained in the present work using voltage transfer ratio of the proposed system. A typical multi layer perceptron model is shown in fig 5. This consists of three layers, those are input layer, hidden layer and output layer.

Volume 3, Special Issue-I1, June 2015
ISSN: 2321-9653

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

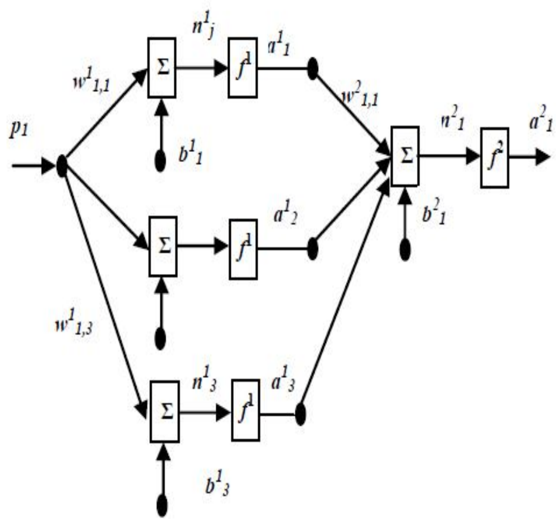

Fig. 5. Perceptron model of three layer neural network

This controller is represented as an output layer,

$$\Delta u(k) = g_{NN}(I(k);w) \qquad (6)$$

Where g_{NN} (I(k);w) is a function approximator, I(k) denotes the information which is available to the controller at the instant k, and w denotes a vector of approximator parameters.

Quasi-Newton back-propagation algorithm is employed to update weights in this work in view of the following reasons: Quasi-Newton method is a one-dimensional minimization related numerical interpolation method which has a powerful (fast) convergence property known as quadratic convergence and hence it exhibits super linear convergence near the target. This algorithm requires less memory space than other training algorithms. It is the most popular supervised learning rule for multi-layer feed forward networks. With this algorithm, the input data is repeatedly presented to the neural network. With each presentation, the output of the neural network is compared with the desired output and an error is computed. This error is then fed back (back-propagated) to the neural network and used to adjust the weights such that the error decreases with each iteration and the neural network output gets closer and closer to the desired output.

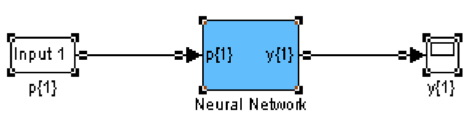

Fig. 6 Simulink model of Neuro controller

In fig 6 the neural network consists of three layers. One is input layer, second one is hidden layer and the last one is output layer. P{1} refers input layer, Y{1} refers output layer.

VII. SIMULATION RESULTS

To confirm the validation of the proposed multilevel boost converter the proposed neuro controller fed multilevel boost converter is simulated with MATLAB software.

A. Input voltage

Volume 3, Special Issue-I1, June 2015
ISSN: 2321-9653

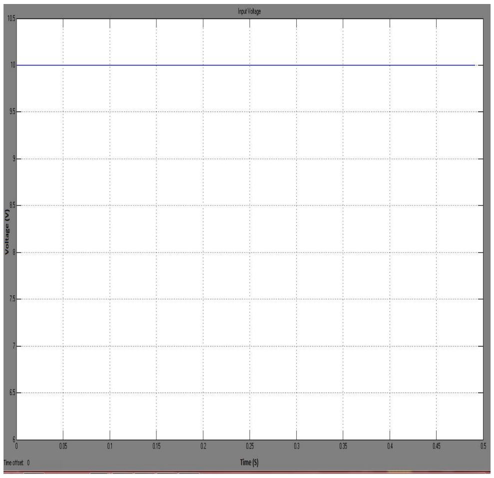

Fig 7. Input voltage

The fig .8 shows the input voltage applied to the multilevel boost converter. Here the voltage applied to the converter is 10 V.

B. Total Output voltage

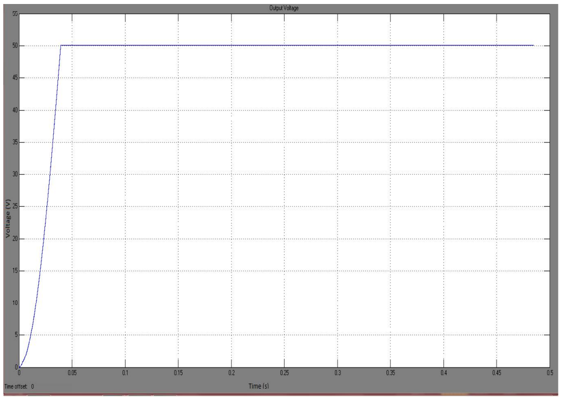

Fig. 8 Total output voltage

The fig 8 shows the total output voltage which is obtained from the proposed system. Here we are using 10 V as the input voltage and it yields the output voltage which is measured as 50 V. From this figure we can justify there is no transient overshoots. The output voltage ripples are quite reduced upto zero.

C. Output voltage of First level

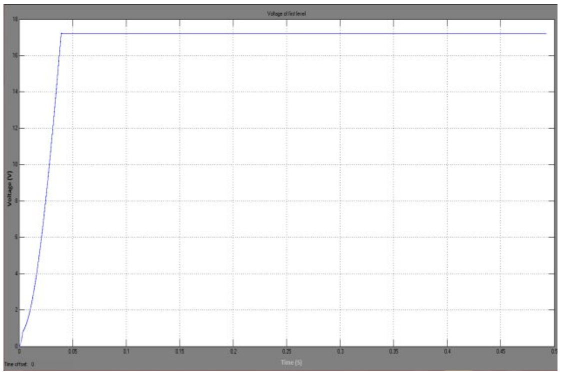

Fig. 9 Output voltage of first level

Volume 3, Special Issue-I1, June 2015
ISSN: 2321-9653

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Fig 9 shows the output voltage of first level. In the proposed system the level used is 3 level. Therefore the first level voltage is 16.6 V.

D. Gating signal

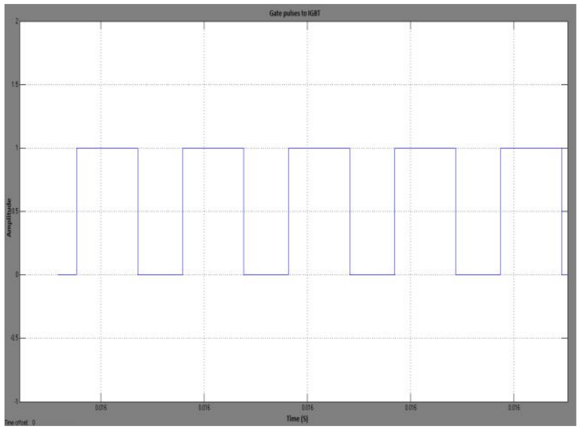

Fig 10 Gating pulse to the switch

Fig 10 shows the output of neuro controller which is fed to the gate of the switch S1.

TABLE 1. Converter Specifications

Specification	Ratings
Input voltage	10 V
Capacitors	120μF
Inductor	250mH
Reference Voltage	50 V
Output voltage	50 V
Output voltage of 1^{st} level	16.6 V

VIII. CONCLUSION

Thus the neural network controlled multilevel boost converter is designed. The output is obtained accurately with that of the reference voltage which is of about 50 V. There is no ripple in the output voltage. The output voltage of each and every level is same of about 16.6 V.There is no transient overshoots.

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Volume 3, Special Issue-I1, June 2015
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