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Dynamic Performance Improvement of Non-isolated High – Gain Boost Converter using ANN Controller

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ABSTRACT

High gain transformer less dc-dc converters are gaining more attention in recent days due their inherent advantages like nominal voltage stress across the switches, minimal components, reduced additional circuitry components. The principal advantage of these converters is that they offer high conversion gain at reasonably good duty ratios this makes these circuits suitable for high conversion gain applications like switched modes power suppies, Photovoltaic cells and Fuel cell based ones. This paper mainly emphasizes on development of a closed loop control scheme based on Artificial Neural Networks (ANN). A Current mode control scheme is implemented with the help of ANN based Adaptive Linear Elements (ADALINE model).The ADALINE is used for the production of modulating signal for the pulse width modulator (PWM). The designed control scheme is applied to the circuit given in [1]. Simulation studies are performed for conversions gains 10, 12, 14, 16, 18 and 20 for a load rating of 250W.

KEYWORDS: *Current Mode Control, Transformer less DC – DC converter, ANN based controller, Pulse Width Modulator, Modulating Signal, High Conversion Gain.*

I. INTRODUCTION

Switched mode power supplies (SMPS) are the core of modern domestic power applications as these are widely used in household appliances, communication systems, railway, aviation and many other fields. The converter topology used in an SMPS applications form the basis for its attraction and had a great deal for its usage. The conventional buck, boost and buck-boost converters have limited applications due to their limited gain but are superior to any other available converter topologies due to their simple structure and high efficiency. This make their utility limited to very low or high output voltages.

Topologies proposed by Luo provide high voltage gains by employing voltage lift, but has difficulties like complex structure, higher in cost, increased losses. Interleaved converters offer high conversion gains with low voltage stress but the converter structure and control strategies are more complicated. Quadratic converters which are cascaded ones of conventional buck or boost converters can achieve good voltage gains with few switches, but operate with low efficiency. Additional switched networks are used to obtain high step-up or step-down voltage gain this is achieved at the cost of complicated construction and increased cost.

Compared to above mentioned topologies, which step-up, step-down voltage, the popular conventional bucking and boosting converters can regulate output voltage effectively under wide range of input voltage or output power ranges. So these converters are popular in the applications such as portable electronic devices, car electronic devices etc. The conventional buck – boost converter has simple structure and operates at high efficiency.

Shan Miao et. al. proposed a configuration that combines a switched network with conventional buck – boost converter. The principal merit of this converter is that the voltage gain of this converter is quadratic of the buck-boost converter as a result the converter can operate over a wide range of output voltage. So that the converter can achieve high or low voltage gains without extreme duty cycle.

The main objective of this paper is to design a neural network based closed loop current mode controller for the non-isolated transformer less high gain boost converter proposed by Shan Miao et.al.

The rest of the paper is organized as follows. In section II the structure and the model of the buck-boost converter for its boost operation in Continuous Conduction Mode is Presented. Implementation of Current mode control using ANN is presented in Section III. MATLAB based simulations are presented in Section IV.

II. Operation of High Gain Boost Converter

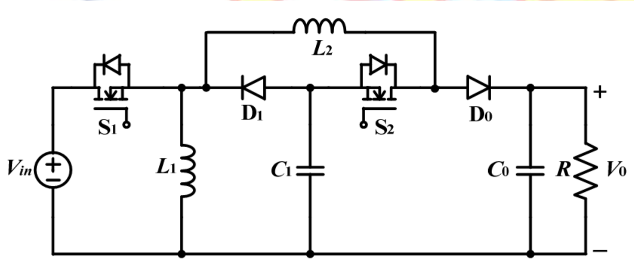

Figure 2.1: Transformer less high gain buck – boost converter proposed by Shan Miao et.al

Figure 2.1 shows the circuit configuration of transformer less non-isolated high gain buck-boost converter proposed by Shan Miao et.al. The converter consists of two power Switches S_1 and S_2, two diodes D_1 and D_2, two inductors L_1 and L_2, two capacitors C_1 and C_0. Power switches S_1 and S_2 are controlled synchronously. The converter taken for analysis operates in two modes, during mode 1 the switches S_1 and S_2 are turned on. And the Diodes D_1 and D_2 are reversed biased. The inductors L_1 and L_2 are magnetized from the source. The load is supplied from the capacitor C_0. Therefore

$$V_{L1} = V_{in} \quad (1)$$

$$V_{L2} = V_{in} + V_{C1} \quad (2)$$

During mode 2the switches S_1 and S_2 are turned off. And the Diodes D_1 and D_2 are forward biased. The energy stored in the inductor L_1 is released to the charge pump Capacitor C_1 via diode D_1. At the same time the energy stored in the inductor L_2 is released to the charge pump capacitor C_1, the output capacitor C_0 and the load is via diodes D_1 and D_0.

$$V_{L1} = -V_{C1} \quad (3)$$

$$V_{L2} = (V_0 + V_{C1}) \quad (4)$$

The voltage across the charge pump capacitor C_1 is given by

$$V_{C1} = \frac{D}{(1-D)} V_{in} \quad (5)$$

The Voltage gain of the converter is given by

$$M = \frac{D^2}{(1-D)^2} \quad (6)$$

From equation (6) it was evident that the converter operates in buck mode for duty ratio D values less than 0.5 and in boost mode for duty ratio D values higher than 0.5.

Voltage across different components of the circuit is given by

$$V_{C1} = \frac{D}{(1-D)} V_{in} \quad (7)$$

$$V_{S1} = \frac{1}{(1-D)} V_{in} \quad (8)$$

$$V_{S2} = \frac{D}{(1-D)^2} V_{in} \quad (9)$$

$$V_{D1} = \frac{1}{(1-D)} V_{in} \quad (8)$$

$$V_{D0} = \frac{D}{(1-D)^2} V_{in} \quad (9)$$

$$V_0 = \frac{D^2}{(1-D)^2} V_{in} \quad (10)$$

$$I_{L1} = \frac{D^2(2D-1)}{(1-D)^4 R} V_{in} \quad (11)$$

$$I_{L2} = \frac{D^2}{(1-D)^3 R} V_{in} \quad (12)$$

The total inductor current is given by

$$I_L = I_{L1} + I_{L2}$$

$$I_L = \left[\frac{D^3}{(1-D)^4 R} \right] V_{in} \quad (13)$$

III. ANN BASED CLOSED LOOP CURRENT MODE CONTROLLER

The load and line regulations of the switching converter largely depend upon their control schemes used for control. By varying the on time of the switches S_1 and S_2 of boost converter the output voltage is maintained constant during load variations and supply voltage variations.

Pulse width modulation (PWM) is the most commonly used control scheme for buck, boost and buck-boost converters.

There are two operating modes of PWM Control depending upon the control signal. They areVoltage – Mode PWM and Current – Mode PWM. In Voltage – Mode PWM drives its control signal from the output voltage and in Current – Mode or Current – Injected PWM the control signals are driven from both the output voltage and the inductor currents. In the proposed control scheme the inductor currents given in equations (11), (12) and (13) are taken for estimation of the reference values for implementation of Current Mode PWM control. Block diagram of the proposed ANN based Current mode PWM control is shown in Figure 3.1.

In the proposed control scheme the error generated while comparing the instantaneous total inductor current of equation (13) with the reference i.e error and change in error. The ANN controller is trained with a setof known inputs and known target outputs. The trained network is validated with different sets of known inputs. The output ofANN controllergives required modulating signal forgeneration of hysteresis based PWM signals.

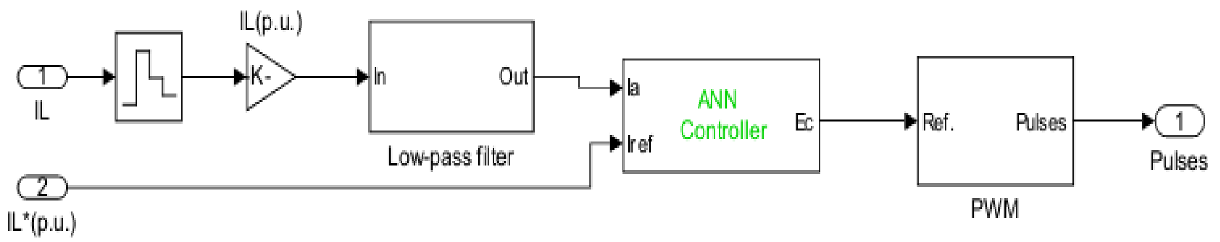

Figure 3.1: Block Diagram representation of Current Mode PWM

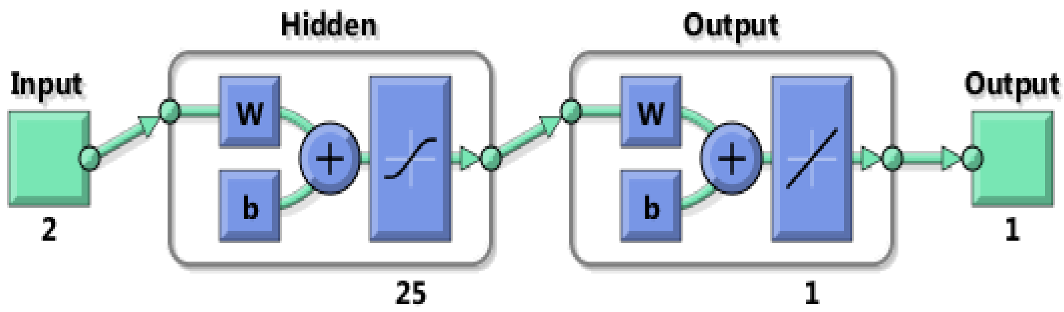

Figure 3.2: Architecture of ANN used for Training.

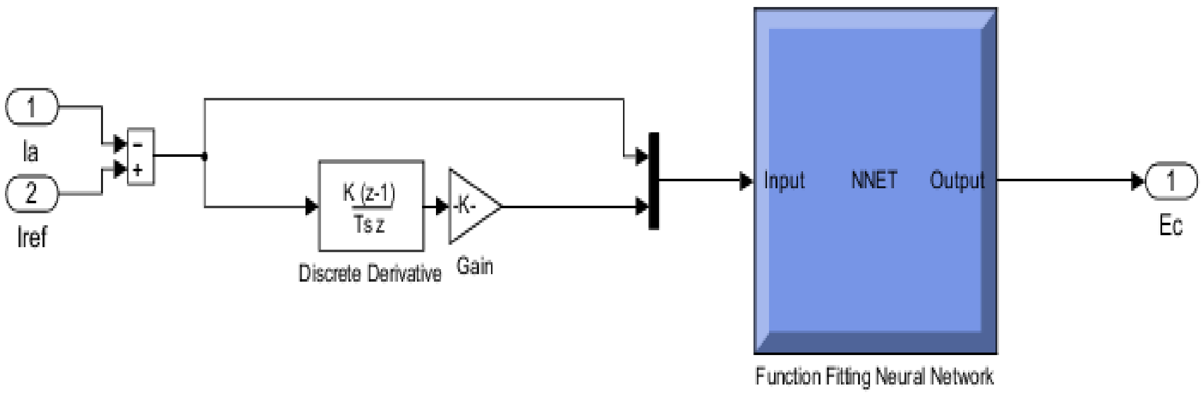

Figure 3.3: ANN based Current Mode Controller

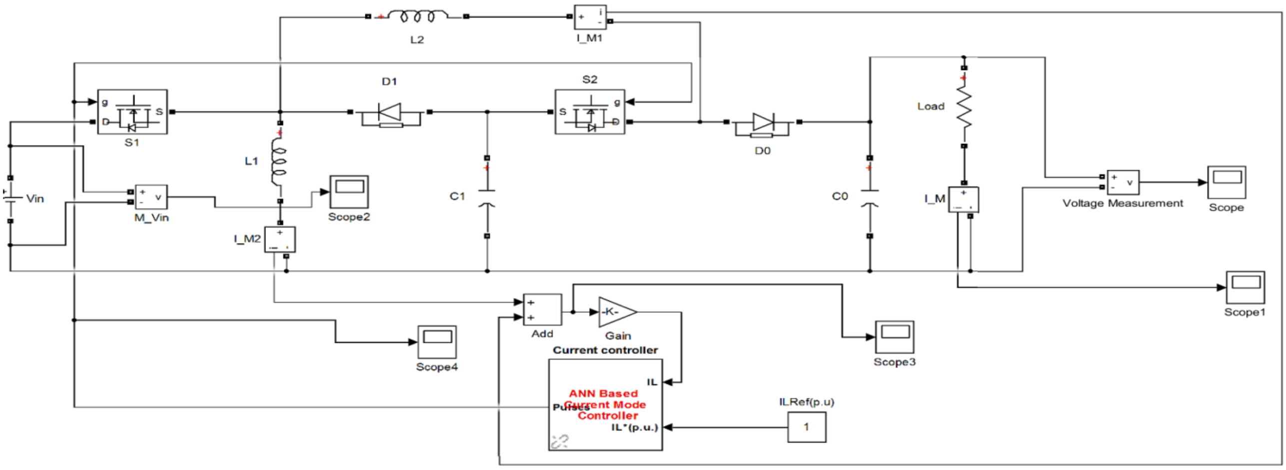

Figure 4.1: MATLAB Schematic of Transformerless Boost converter with ANN based Current mode Controller for closed loop Operation

The architecture of ANN used for training is shown in Figure 3.2. Training of the proposed ANN is performed with the help of nftool (Function Fitting Neural Network Tool) of MATLAB. In nftool the training is initiated with by keeping 70% training, 15% validation and 10% testing with 25 hidden neurons. The network is trained with the help of Levenberg-Marquardt back propagation algorithm. The ANN used Adaptive Linear Model for fitting the test data values. Complete control circuit with ANN controller is shown in Figure 3.3.

IV. Simulation And Results

Circuit shown in Figure 2.1 operated in open and is controlled with the help of ANN based closed loop current mode controller. MATLAB based schematic of circuit under simulation using current mode control is shown in Figure 4.1. The S_1 and S_2 are triggered at a frequency of 30 kHz with an input voltage equal to 18V. The load considered is pure resistance in nature and power rating is taken as 250W. Simulation studies are performed by varying D for obtaining conversion gains 10, 12, 14, 16, 18 and 20 by keeping load power constant at 250W. The circuit parameters used for study are presented in Table – 1.

Table – 1: Parameters used for Simulation study

Parameter	**Value**
Power	250 W
Switching Frequency	30kHz
Input Voltage	18V
L1	1mH
L2	3mH
C1	20µF
C0	40µF
Output Voltage	320V

Voltage across load, current through L_1, L_2 and load, Voltage across Pumping Capacitors C_1, Trigger pulses applied to S_1 and S_2 and modulating signal are shown in Figures 4.2 – 4.7 respectively when the converter is operated in boost mode with voltage gain equal to 10.

As voltage conversion gain varies the load voltage is maintained at the desired value and the duty cycle is adjusted accordingly for a constant input voltage. The ripple in the output voltage is also maintained with in the standards. The boost converter achieves a good regulation over a wide range of variation in D and maintains stability.

The results thus obtained are compared with those are obtained when the system is operated in open loop. It is found that the ANN based control scheme offers better damping to the system damping and makes the system critically damped and increases the settling time.

Table – 2: Time taken for response to attain its steady state.

Name of Control	***Settling Time in Seconds***	***Steady State value of V_0 in Volts***
Open loop Control	*0.1*	*288*

ANN Based current mode control	*0.02*	*300*

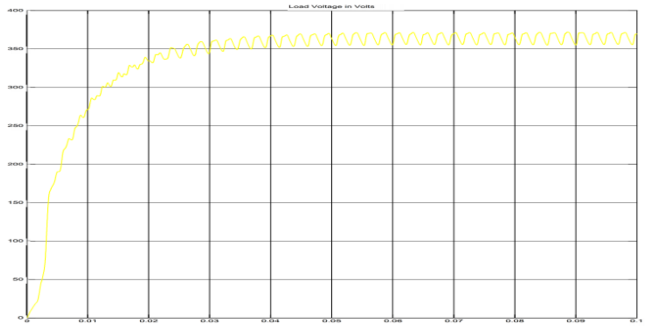

Figure 4.2: Voltage Across Load for M = 18 when supplying load power P = 250W

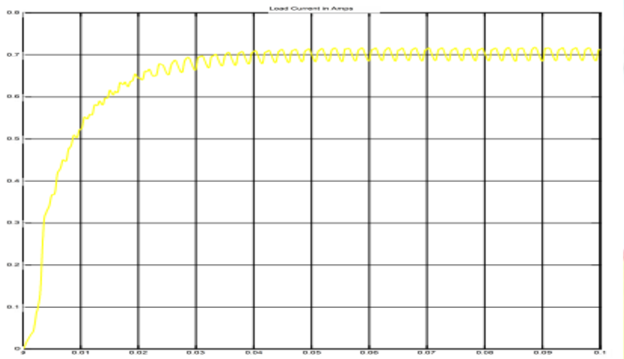

Figure 4.3: Load Current in Amperes for M = 18When supplying a load power P = 250W

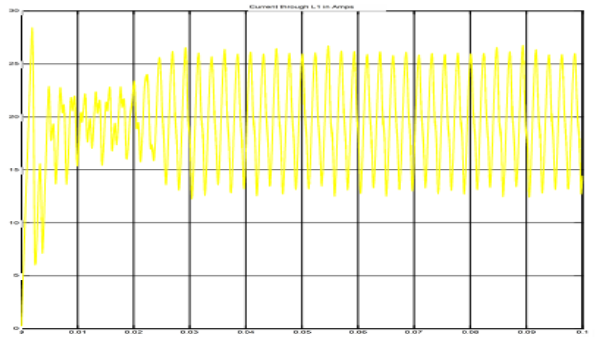

Figure 4.4: Current through L_1 in A for M = 18 for P = 250W

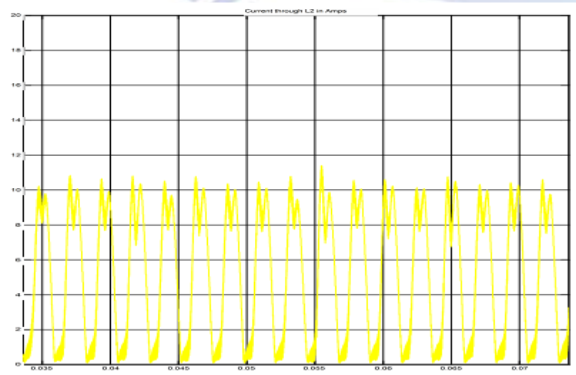

Figure 4.5: Current through L_2 in A for M = 18 for P = 250W

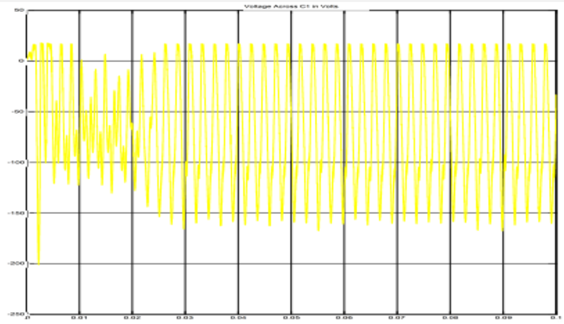

Figure 4.6: Voltage Across C_1 for M = 18 for P = 250W

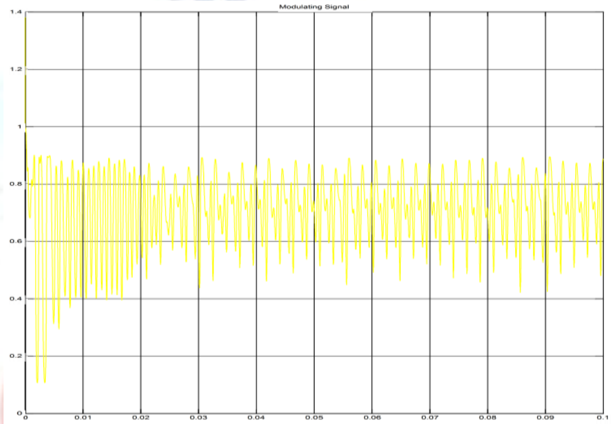

Figure 4.7: Modulating Signal Generated by ANN for M = 18 When supplying P = 250W

V. Conclusion

A new ANN based current mode PWM control is designed for Transformer-less high gain buck-boost converter to operate the converter in boost mode. The ANN controller maintains the load voltage within the specified limits over a wide range of duty ratios and the converter achieves high conversion gains at reasonably good duty ratios, for the maximum duty ratio that considered in the analysis is 0.8 for which the conversion gain is equal to 20. Similarly for achieving a conversion gain of 10 the duty ratio is adjusted to 0.756. The ANN control scheme has the ability of providing a tight control to maintain load regulation within the limits. From the simulation studies this converter configuration is suitable for the industrial applications requiring high conversion gains especially for boost operation.

References

[1]. Shan Miao, Faqiang Wang. "*A New Transformerless Buck-Boost Converter with Positive Output Voltage*". IEEE Transactions on Industrial Electronics, vol. 63, no. 5, pp. 2965-2975, 2016.

[2]. W. H. Li, and X. N. He, "*Review of non-isolated high step-up DC/DC converters in photovoltaic*

grid-connected applications," IEEE Trans. Ind. Electron. , vol. 58, no. 4, pp. 1239–1250, Apr. 2011.

[3]. C. T. Pan, and C. M. Lai, "*A high-efficiency high step-up converter with low switch voltage stress for fuel-cell system applications*," IEEE Trans. Ind. Electron., vol. 57, no. 6, pp. 1998–2006, Jun. 2010.

[4]. T. F. Wu, and Y. K. Chen, "*Modeling PWM DC-DC converters out of basic converter units*," IEEE Trans. Power Electron. , vol. 13, no. 5, pp. 870-881, Sep. 1998.

[5]. F. L. Luo, "*Six self-lift DC-DC converters, voltage lift technique*," IEEE Trans. Ind. Electron. , vol. 48, no. 6, pp. 1268-1272, Dec. 2001.

[6]. F. L. Luo, and H. Ye, "*Positive output cascade boost converters*," IEE Proc.-Electr. Power Appl., vol. 151, no. 5, pp. 590-606, Sep. 2004.

[7]. Y. He, and F.L. Luo, "*Analysis of Luo converters with voltage-lift circuit*," IEE Proc.-Electr. Power Appl., vol. 152, no. 5, pp. 1239-1252, Sep. 2005.

[8]. Y. T. Chen, W. C. Lin, and R. H. Liang, "*An interleaved high step-upDC-DC converter with double boost paths*" Int. J. Circ. Theor. Appl. ,DOI: 10.1002/cta.1986, 2014.

[9]. L. W. Zhou, B. X. Zhu, Q. M. Luo, and S. Chen, "*Interleaved non-isolated high step-up DC/DC converter based on the diode–capacitor multiplier*," IET Power Electron. , vol. 7, no. 2, pp. 390-397,Feb. 2014.

[10].C. T. Pan, C. F. Chuang, and C. C. Chu, "*A novel transformerless interleaved high step-down conversion ratio DC–DC converter with low switch voltage stress*," IEEE Trans. Ind. Electron. , vol. 61, no. 10, pp. 5290-5299, Oct. 2014.

[11].C. T. Pan, C. F. Chuang, and C. C. Chu, "*A novel transformerless adaptable voltage quadrupler DC converter with low switch voltage stress*," IEEE Trans. Power Electron., vol. 29, no. 9, pp. 4787-4796, Sep. 2014.

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