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DESIGN AND IMPLEMENTATION OF ANN BASED CONTROL SCHEME FOR COUPLED INDUCTOR BASED HIGH GAIN DC – DC CONVERTER

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ABSTRACT

The basic Conventional DC – DC configurations like buck, boost and buck – boost are used in many of the industrial applications. The converters are fall under the category of non-isolated converters. These converters use reactive elements like inductors and capacitors for energy transfer purposes. Especially inductors used in these circuits will receive energy from source and stores it. Release the energy to the load. These conventional configurations suffer with drawback of low conversion gains. To overcome this drawback many of the derived configurations are proposed. Fly-back converters are one of such derived configurations. These converters suffer with issues like high switching losses, large stress across the switch and magnetic components. To avoid these issues coupled inductor based non isolated type converters [1] are used. These converters have the ability of achieving high conversion gains. This paper aims in development of closed loop control scheme for control of the load voltage with the help of Artificial Neural Network. Training of the ANN for the targeted values is done by using function fitting tool of ANN and simulation of the model is done using MATLAB / SIMULINK. The circuit thus modeled is simulated for different values of duty ratios and results are presented.

KEYWORDS: Boost, Buck, Coupled Inductors, Energy Recovering snubber, High Gain Dc–Dc Converter, ANN Based Controller, Pulse Width Modulation (PWM)

I. INTRODUCTION

Application like the front-end stage for clean-energy sources, the dc back-up energy system for associate uninterruptible power provide (UPS), high-intensity discharge lamps for automobile head-lamps, telecommunications trade [2]–[4] need DC-DC converters with steep voltage quantitative relation. The traditional boost converters cannot offer such a high dc voltage gain, even for associate extreme duty cycle. High gain dc–dc converters for higher than mentioned applications have the subsequent common options. 1) High increase voltage gain. Generally, a few denary increase gain is needed. 2) High potency. 3) No isolation is needed. High accelerate gain from constant power low voltage provides either massive input current with high output voltage or the big input current from low input voltage; It additionally end in serious reverse-recovery issues and increase the rating of all devices. Manipulated voltage clamped techniques are utilized in coming up with of converters to beat the severe reverse recovery downside of the switches in high-level voltage applications, there still exists large switch voltage stresses and also the voltage gain is restricted by the input time of the auxiliary switches [6], [7]. Once input power could be a low-tension supply like electric battery and also the needed output could be a high dc voltage, there's a necessity to develop a high power density boost dc–dc device that options less complexness, compact size, and low price. The most important downside in developing such a device is that the device suffers from high current stress and, thus, it's troublesome to boost the power potency. In such cases energy storage reactor is massive live in crucial the performance of those converters. No different element has such dramatic result on the distribution of element losses. As a result, the conversion potency is degraded and also the magnetic force interference (EMI) problem is severe beneath this case [5]. so as to extend the voltage gain, boost converter topologies are to be changed.

Switching mode power provides supported the fly back device were wide utilized in industrial merchandise for low-power applications. Within the fly back device, the electrical device is adopted to realize circuit isolation and energy storage.

Introducing a electrical device in fly back device helps attaining massive increase or change of magnitude voltage conversion quantitative relation. Transformers' flip quantitative relation ought to be chosen on offer the required voltage gain whereas keeping the duty cycle among an inexpensive very for higher potency. The electrical device, however, brings during a whole new set of issues related to the magnetizing and run inductances, that cause voltage spikes and ringing, exaggerated core and cooper losses moreover as exaggerated volume and price.

Compared with associate isolation device, a coupled inductance contains a simpler winding structure, lower natural phenomenon loss, and continuous natural phenomenon current at the primary winding, resulting in a smaller coil current ripple and lower input filtering capacitance. Thus, a coupled-inductor-based convertor is comparatively engaging as a result of the convertor presents low current stress and low part count. However, for applications with low input voltage however high output voltage, it desires a high flip quantitative relation, and its leak inductance still traps vital energy, which is able to not solely increase the voltage stress of the switch however conjointly induce vital loss.[8] Introduces giant voltage increase victimization cascaded boost converters that implement the output voltage increasing in progression. Voltage transfer quantitative relation of these converters effectively increased however the circuits of those converters square measure quite complicated. [9] and [10] proposes a broach inductance based mostly boost convertors these converter circuits attain high conversion quantitative relation with easy circuits. In [11] a brand new configuration is planned by connecting the boost convertor output terminal and fly-back convertor output terminals nonparallel to extend the output voltage gain with the assistance of coupled inductance. The boost convertor functions as a lively clamp circuit to recycle the snubber energy. This eliminates reverse recovery issues related to fly back converters. This makes attainable to realize higher voltage conversion ratios. In [1] a brand new wide-input–wide-output (WIWO)dc–dc convertor is planned. This convertor is associate integration of buck and boost converters via a broach inductance. By applying proper control to the 2 active switches, buck and boost actions square measure attainable. Configurations planned in [1] use changed pulse breadth modulation for management of switches.

This paper proposes new management theme supported ANN for the boost mode operation of a broach inductance based mostly buck derived converters with 3 switches S1, S2 and S3.Topology of the planned dc–dc convertor principles mentioned in section II in conjunction with the operational principle well providing the steady-state (dc) and dynamic (ac) models also. ANN based mostly switch theme is bestowed in section III. Section IV presents the results verified with the assistance of MATLAB simulation. Conclusions square measure given in Section V.

II .COUPLED INDUCTOR BASED DC-DC CONVERTERS

Coupled inductor type DC-DC converter circuits uses coupled inductors for energy transfer during conduction period. Most of the configurations use inductors for charging purposes. These inductors are charged by connecting in parallel during charging mode and discharged by connecting in series.

Literature available for high gain dc –dc converter applications proves that these configurations offer range of conversion ratios.

Haig gain bi-directional DC-DC converter topology given in [1] is considered for analysis purposes.

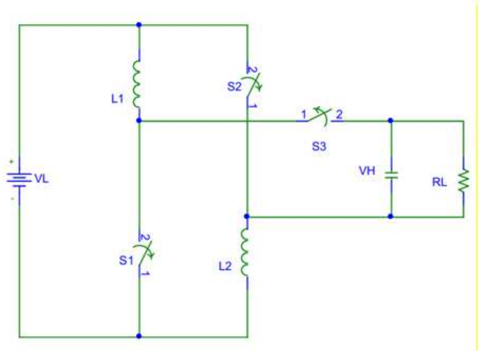

Figure 2.1: Model Proposed in [1]

Operation of the circuit is explained as follows:

Mode – I:

During this mode of operation the converter Inductors are charged and capacitor is discharged.

Amount energy stored by the inductor during charging period is

$$W = \int p(t).dt \tag{1}$$

Current flowing through the inductor is given by

$$\frac{di_{L1}(t)}{dt} = \frac{di_{L2}(t)}{dt} = \frac{V_s}{(1+k)L}$$

$$i_{L1} = \int_0^{t_1} \frac{V_s}{(1+k)L} dt$$

$$i_{L1} = \frac{V_s}{(1+k)L} t_1 \tag{2}$$

Where

$p(t)$ is Instantaneous power is

V_s is Applied Voltage

$L_1 = L_2 = L$ isInductance of the coils

k is Coefficient of coupling

W is Energy stored by inductor

Instantaneous power consumed by inductor is given by $p(t) = v_{L1} i_{L1}$

Substitute values of v_{L1} and i_{L1} in equation (2)

$$W = \int v_{L1} i_{L1} .dt$$

But from equation (3) substitute value of i_{L1}

$$W = \int v_{L1} \frac{V_s}{(1+k)L} t_1 .dt$$

Energy stored by inductor by the end of mode1 is

$$W = \int_0^{t_1} V_s \frac{V_s}{(1+k)L} t_1 .dt$$

$$= \frac{V_s^2 t_1^2}{2(1+k)L}$$

Total energy stored by the inductors is $W_L = \frac{V_s^2 t_1^2}{(1+k)L_1}$ J (3)

Mode II:

During this mode of operation load connected to the source as a result the inductors are connected in series and will get discharged, the energy thus stored by these inductors will be transferred to the capacitor, there by the capacitor starts charging.

During this mode

$i_{L1} = i_{L2} = i_L$ And

$$v_{L1} + v_{L2} = V_s - V_c$$

$$\frac{di_L}{dt} 2(1+M)L = V_s - V_c$$

$$\frac{di_L}{dt} = \frac{V_s}{2(1+M)L} - \frac{V_c}{2(1+M)L}$$

Voltage across capacitor is given by

$$v_c = \frac{1}{C}\int i_L dt = V_0$$

$$\frac{dv_c}{dt} = \frac{1}{C} i_L$$

PWM based control signals are generated with the help of ANN based Controller by taking x_1 and Δx_1 input variables to the ANN Controller. Training of the network and their weights are presented in Chapter III.

III. ARTIFICIAL NEURAL CONTROLLER APPLIED TO DC – DC CONVERTER

- **Introduction to ANN**

Work on synthetic neural network has been motivated from its inception by the consciousness that the human brain computes in a wholly specific method from the typical digital computer. The brain is an extremely difficult, nonlinear and parallel information processing system. It has the potential to prepare its structural elements, often called neurons, to be able to participate in specific computations regularly rapid than the quickest digital computer in existence in these days. The brain sometimes accomplishes perceptual recognition tasks, e.g. recognizing a well-recognized face embedded in an unfamiliar scene, in approximately 100-200ms, whereas tasks of a lot lesser complexity may take days on a regular computer. A neural community is a laptop that is designed to lay out the way in which where the brain performs a special assignment. The network is implemented through utilizing electronic components or is simulated in software on a digital computer. A neural community is a vastly parallel distributed processor made up of simple processing units, which has a common propensity for storing experimental abilities and making it to be had to be used. It resembles the mind in two respects: 1) Knowledge is attained by using the network from its atmosphere by a training process. 2) Interneuron connection strengths, often called synaptic weights, are used to store the attained knowledge.

Neural networks, with their amazing potential to derive that means from problematic or imprecise information, can be used to extract patterns and observe trends that are too difficult to be observe by either people or different computer strategies. Other benefits consist: 1) Adaptive learning: An ability to learn tips on how to do duties depend on the data given for training or preliminary experience. 2) Self-organization: An ANN can create its own organization or representation of the information it receives throughout learning time. 3) Real Time Operation: ANN computations can also be implemented in parallel, and certain hardware gadgets are being designed and manufactured which take benefit of this capability.

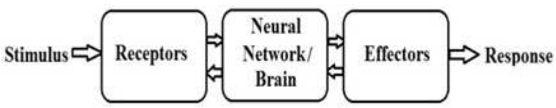

Figure 3.1: Block Diagram Representation of Human Nervous System

The human nervous system can be divided into three stages that can be defined as follows:

The receptors acquire information from the atmosphere. The effectors generate interactions with the environment e.g. activate muscles.

There are roughly 10 billion neurons in the human cortex. Each biological neuron is hooked up to several thousands of other neurons. The common operating pace of biological neurons is measured in milliseconds. Nearly all of neurons encode their activations or outputs as a series of brief electrical pulses. The neuron's nucleus include the incoming activations and converts them into output activations. The neurons nucleus includes the genetic material within the form of DNA. This exists in most types of cells. Dendrites are fibers which emanate from the cell body and furnish the receptive zones that acquire activation from other neurons. Axons are fibers appearing as transmission lines that ship activation to different neurons. The junctions that enable signal transmission between axons and dendrites are referred to as synapses.

- **Training of Artificial Neural Networks**

A neural network must be configured such that the application of a set of inputs produces (either 'direct' or through a relaxation system) the required set of outputs. Various ways are there to set the strengths of the connections exist. A technique is to set the weights explicitly, utilizing a priori potential. Yet another method is to train the neural network through feeding it instructing patterns and letting it exchange its weights according to a few training rule.

- **Implementation of ANN Based Control Scheme**

In the proposed circuit, the error generated while comparing instantaneous capacitor voltage with reference magnitude given as input to an artificial neural network based controller shown in Fig 3.2. The controller is trained with a set of inputs and target outputs. The trained network is validated with different sets of known inputs. The output of ANN controller gives required modulating signal for generation of PWM signals for triggering the switches of DC – DC Converter.

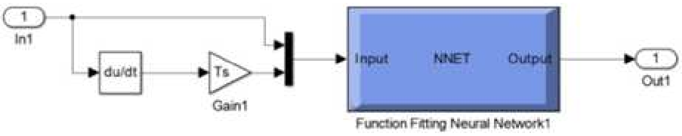

Figure 3.2: Schematic Diagram of ANN Block in Subsystem

The ANN block shown in Fig.3.2 is simulated from the NFTOOL from the MATLAB. In the nftool box training of the network is initiated, the training, validation and testing percentages so that the ANN iterations depending on the percentage values. Here we are giving 80% training, 10% validation and 10% testing with 10 hidden layers. The output of the ANN block generates the required modulating signals to trigger the switches. When the ANN based control scheme is used it is clearly observed that the converter gives better regulation over wide operating ranges of power and duty ratios.

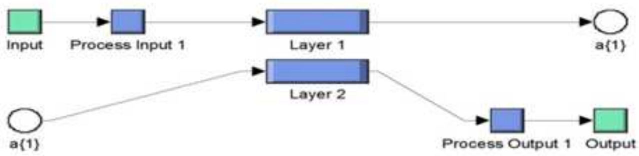

Figure 3.3: The ANN Block Scehemetic Diagram

IV. SIMULATION & RESULTS

ANN based closed loop control scheme is developed for the circuit shown in Fig. 2.1. The ANN control circuit that developed is modeled and applied to the converter circuit and the convert circuit is simulated for different duty ratios of the converter when supplying different loads. The load that was connected to the converter is varied from 50W to

1000W and regulation of the load voltage is evaluated for each case and the results are presented in table 4.1 for D = 0.8.

Voltage across the load, current through the load, Voltage across switches S1, S2, S3 and currents through them, trigger pulses applied to S1,S2 and S3, Currents through inductors, Trigger pulses applied to S1, S2 and S3 and Modulating Signal generated by ANN are presented in Fig. 4.1 – Fig.4.11 when the converter is supplying a load power = 250W and Duty Ratio D = 0.8.

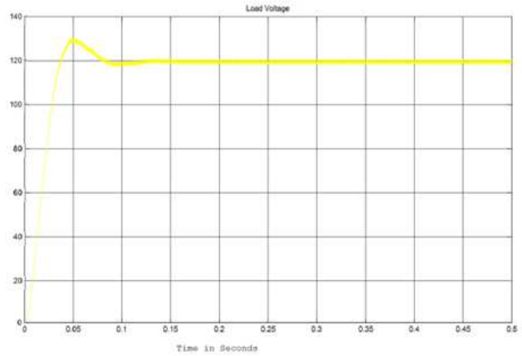

Figure 4.1: Voltage Across Load When Supplying A Load of 250W And D = 0.8

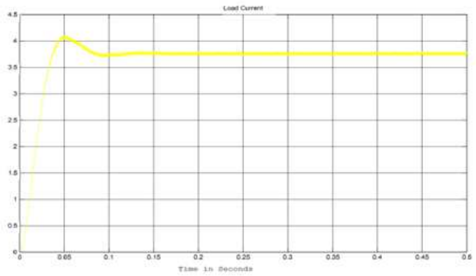

Figure 4.2: Current Through Load When Supplying a Load of 250W and D = 0.8

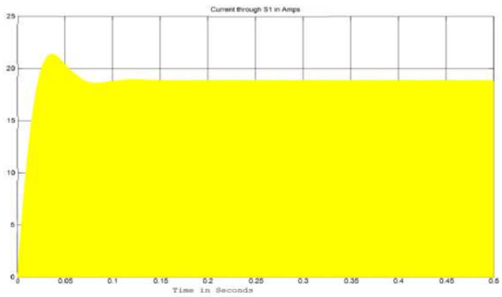

Figure 4.3: Current Through Switch S1 When Supplying a Load of 250W and D = 0.8

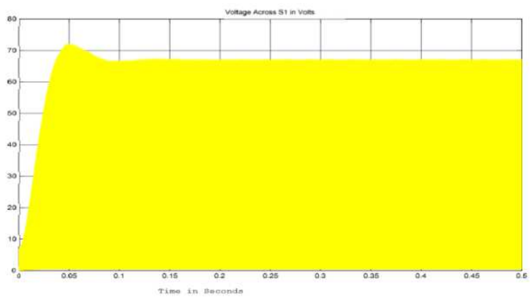

Figure 4.4: Voltage Across Switch S1 When Supplying a Load of 250W and D = 0.8

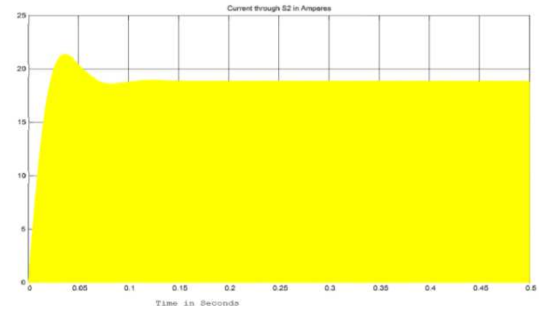

Figure 4.5: Current Through Switch S2 When Supplying a Load of 250W and D = 0.8

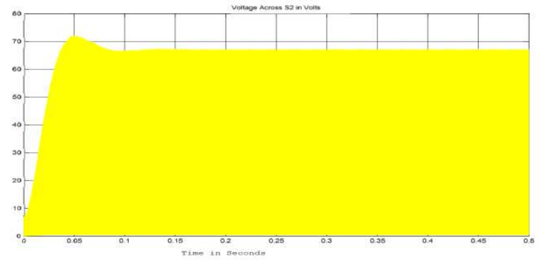

Figure 4.5: Voltage Across Switch S2 When Supplying a Load of 250W and D = 0.8

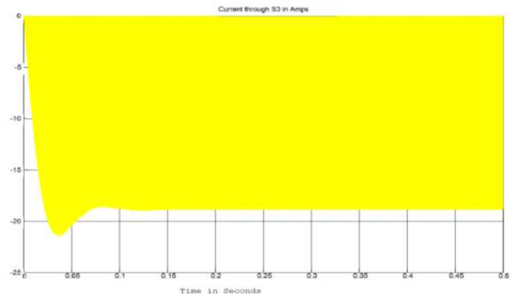

Figure 4.6: Current Through Switch S3 When Supplying a Load of 250W and D = 0.8

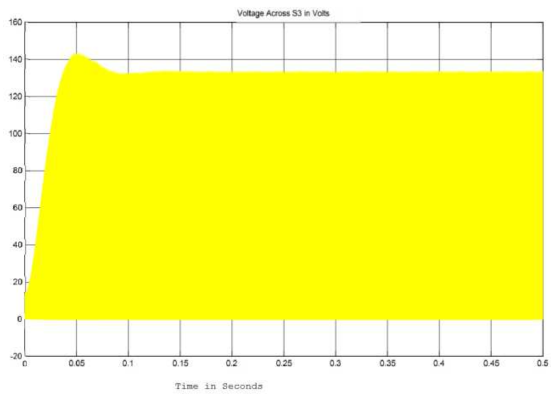

Figure 4.7: Voltage Across Switch S1 When Supplying a Load of 250W and D = 0.8

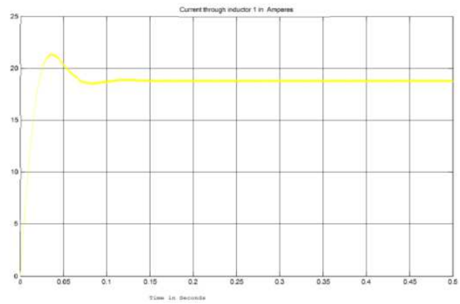

Figure 4.8: Current through Inductor L1 When Supplying a load of 250W and D = 0.8

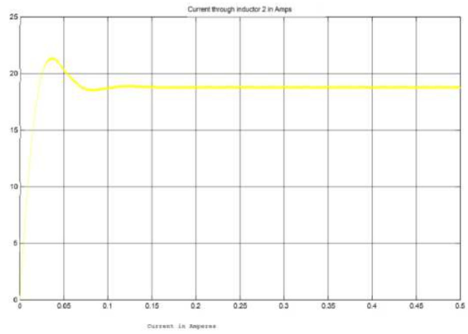

Figure 4.9: Current through Inductor L2 When Supplying a load of 250W and D = 0.8

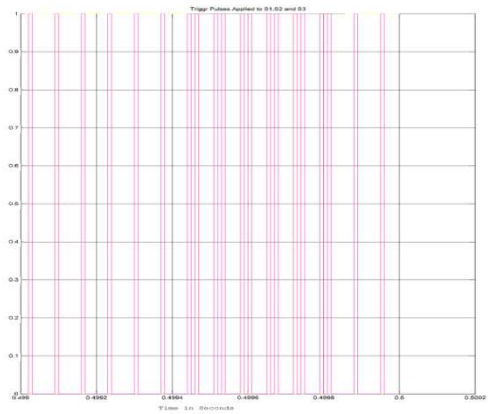

Figure 4.10: Trigger Pules Applied to S1, S2 and S3 When supplying a load of 250W and D = 0.8

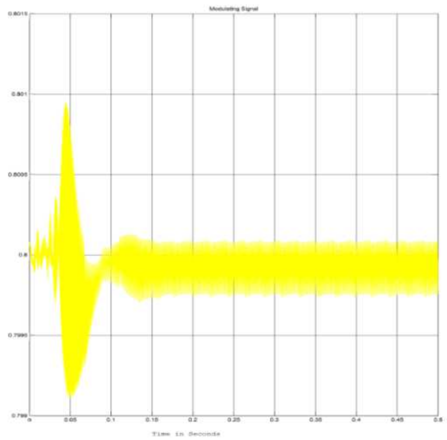

Figure 4.11: Modulating Signal Generated by ANN When Supplying a Load of 250W and D = 0.8

Table 4.1: Variation of Load Voltage of Converter When VREF = 126 V and Duty Ratio = 0.8 for Vin = 14V

S. No	P_0 (W)	I_0 (A)	V_0(V)	ΔV	% Regulation
1	50	0.4	124.6	1.4	1.11
2	100	0.8	124.5	1.5	1.19
3	150	1.2	124.3	1.7	1.35
4	200	1.55	124.1	1.9	1.51
5	250	1.95	124	2	1.59
6	300	2.3	122.5	3.5	2.78
7	350	2.69	122	4	3.17
8	400	3.05	121	5	3.97
9	450	3.42	120.5	5.5	4.37
10	500	3.7	119.5	6.5	5.16
11	750	5.5	116.5	9.5	7.54
12	1000	7.15	113	13	10.32

Table 4.2: Variation of Load Voltage of Converter When VREF = 79 V and Duty Ratio = 0.7 for VIN = 14V

S. No	P_0 (W)	I_0 (A)	V_0(V)	ΔV	% Regulation
1	50	0.63	79	0	0.00
2	100	1.24	78.4	0.6	1.07
3	150	1.86	77.7	1.3	2.32
4	200	2.46	77.4	1.6	2.86
5	250	3.06	77.1	1.9	3.39
6	300	3.66	76.8	2.2	3.93
7	350	4.25	76.6	2.4	4.29
8	400	4.84	76	3	5.36
9	450	5.43	75.7	3.3	5.89
10	500	5.97	75.4	3.6	6.43
11	750	8.7	73.5	5.5	9.82
12	1000	11.35	71.5	7.5	13.39

Table 4.3: Variation of Load Voltage of Converter When VREF = 79 V and Duty Ratio = 0.6 for Vin = 14V

S. No	P_0 (W)	I_0 (A)	V_0(V)	ΔV	% Regulation
1	50	0.87	55	1	1.79
2	100	1.75	54.9	1.1	1.96
3	150	2.6	54.5	1.5	2.68
4	200	3.46	54.2	1.8	3.21
5	250	4.33	54.1	1.9	3.39
6	300	6	53.9	2.1	3.75
7	350	6.1	53.8	2.2	3.93
8	400	6.8	53.5	2.5	4.46
9	450	7.6	53.2	2.8	5.00
10	500	8.4	52.5	3.5	6.25
11	750	12.2	51	5	8.93
12	1000	15.8	49.5	6.5	11.61

Table 4.4: Variation of Load Voltage of Converter When VREF = 56 V and Duty Ratio = 0.5 for VIN = 14V

S. No	P_0 (W)	I_0 (A)	V_0(V)	ΔV	% Regulation
1	50	0.87	55	1	1.79
2	100	1.75	54.9	1.1	1.96
3	150	2.6	54.5	1.5	2.68
4	200	3.46	54.2	1.8	3.21
5	250	4.33	54.1	1.9	3.39
6	300	6	53.9	2.1	3.75
7	350	6.1	53.8	2.2	3.93
8	400	6.8	53.5	2.5	4.46
9	450	7.6	53.2	2.8	5.00
10	500	8.4	52.5	3.5	6.25
11	750	12.2	51	5	8.93
12	1000	15.8	49.5	6.5	11.61

Table 4.5: Variation of Load Voltage of Converter When VREF = 266 V and Duty Ratio = 0.9 for VIN = 14V

S. No	P_0 (W)	I_0 (A)	V_0(V)	ΔV	% Regulation
1	100	0.39	276.5	-10.5	-3.95
2	200	0.78	273.8	-7.8	-2.93
3	300	1.14	270.5	-4.5	-1.69
4	400	1.5	267	-1	-0.38
5	500	1.87	265	1	0.38
6	600	2.23	262.5	3.5	1.32
7	700	2.56	260	6	2.26
8	800	2.89	256	10	3.76
9	900	3.23	254	12	4.51
10	1000	3.55	251	15	5.64

CONCLUSIONS

ANN based closed loop control scheme for a Fuzzy logic Control is designed for Coupled Inductor based high gain DC – DC Converter. This converter has the ability of achieving high conversion gains. With the help of ANN control the converter has got the ability of maintaining good regulation for large variations in loads that were connected to it are varied. It found that the voltage regulation of the converter circuit is maintained with in the specified limits even there was a large change in load that was applied to it.

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