DESIGN AND HARDWARE IMPLEMENTATION OF CLOSED LOOP CUK CONVERTER USING ARITIFICAL NEURAL NETWORK CONTROLLER

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***Abstract* –This paper presents a control scheme of a neural network for a DC-DC Cuk converter. The proposed neural network control strategy is designed to produce regulated DC output voltage. The mathematical model of Cuk converter and artificial neural network algorithm is derived. The nonlinearity characteristic of the Cuk converter due to the switching technique is difficult to be handled by conventional controller such as proportional-integral-derivative controller. To overcome this problem, a neural network controller with back propagation algorithm is developed. to track the converter voltage output and improve the dynamic performance regardless of load disturbances and supply variations. The proposed controller effectiveness during dynamic transient response is analyzed and verified using MATLAB-Simulink. Simulation results confirm the performance of the proposed neural network exhibits better dynamic response compared to the classical proportional-integral-derivative controller.**

Keywords – DC-DC converter, Aritifical neural network controller, Cuk converter, PV array, pulse width modulation.

I.INTRODUCTION

The research and developments in the area of Solar Photo Voltaic technology is at par with growing commercial applications. At present, the solar PV market is growing rapidly with worldwide around 55 GW in 2015 and which makes photovoltaic as one of the fastest industry [1]. The improvement of overall efficiency of SPV system depends upon various factors including materials of solar cells, Maximum Power Tracking, DC power conditioning, factor affecting the performance of PV module.

Switched mode DC-DC converters may be thought of as non-linear and time varying dynamical systems. They contain switches that cause the topological structure of the converter to vary with time, energy storage components and diodes with non-linear voltage, current characteristics. CUK converters capable of operating in either step-up or stepdown mode are mainly applied to DC power supplies[2]. The classic CUK converter circuit topology has often been modified for better performance. The research on the CUK converter is concentrated on lowering switching or conduction loss, reducing component size, improve system efficiency, mitigating voltage or current stress, speeding up transient response, etc,

Neural networks can be implemented in both ways: analog and digital. As it is well known that digital systems have more advantageous then analog in following aspects: higher accuracy, better repeatability, lower noise sensitivity, better testability, higher flexibility, and compatibility with other types of pre processors[3].

Power converters can be classified as, ac-ac converters, ac- dc converters, dc-dc converter, dc-ac converters, This paper is used to design DC-model with three sets of rules: Multiplication, summation, and activation. At the entrance of artificial neuron, the inputs are weighted,. This design of Cuk converter with Aritifical neural network controller is presented in this paper.

II. MODELLING OF CUK CONVERTER

It consists of an input voltage source Vs, a MOSFET switch S, an anti-parallel diode D, a capacitor C1 for transferring energy, a capacitor C2 for storing energy, two inductors L1 and L2, and a load resistor R. Let V1 and V2 be the voltages across the capacitors C1 and C2, respectively. Let I1 and I2 be the currents through the inductors L1 and L2, respectively.

When Switch S is ON, the circuit is in charging mode. When Switch S is OPEN, the circuit is in discharging mode. The equations of the CUK converter are as follows:

The average output voltage is

$$Vo = -(D/(1-D))*E \text{ Volts} \quad (1)$$

Where,

E = supply voltage D = duty ratio

The average load current is

$$Io = Vo/R \text{ Ampere} \quad (2)$$

Where, R = load resistance

Energy stored in inductor

$$E = \tfrac{1}{2} LI2 \text{ Joules} \quad (3)$$

The minimum values of inductor for continuous conduction mode is,

$$L1min = (1-D)2*R/2Df \text{ H} \quad (4)$$

L2min = (1-D)*R/2f H (5)

The minimum values of capacitor for continuous conduction mode is,

C1min = D/2fR F (6)

C2min = 1/8fR F (7)

The peak-to-peak ripple currents

ΔI1 = (V/L1)*DTs Ampere (8)

ΔI2 = (V/L2)*DTs Amperes (9)

The peak-to-peak ripple voltages

ΔV1 = (I2/C1)*DTs Volts (10)

ΔV2 = Ts2 (V1+V2) D/8L2C2 (11)

The dynamic response of this converter has been analyzed by applying Kirchhoff's voltage law on the loop containing the inductor and Kirchhoff's current law on the node with the capacitor branch connected to it [3].

There are two modes of operation: mode 1 and mode 2. They are discussed as follows:-

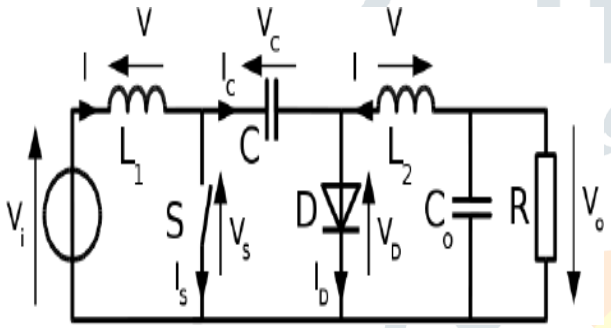

Figure 1. Circuit Diagram of Cuk Converter.

A . MODE1: WHEN SWITCH IS OPEN

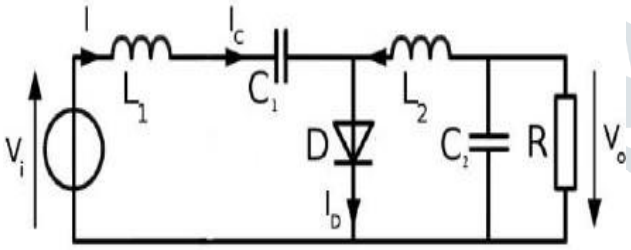

Figure 2. Converter in MODE 1

When the switch S is open, the inductor currents IL1 and IL2 flow through the diode. Capacitor C1 is charged through the diode by energy from both the input and L1. Currents IL1 decreases, because VC1 is lesser than Vd. Energy stored in L2 feeds the output. Therefore , IL2 also decreases [4].

B. MODE2: WHEN SWITCH IS CLOSED

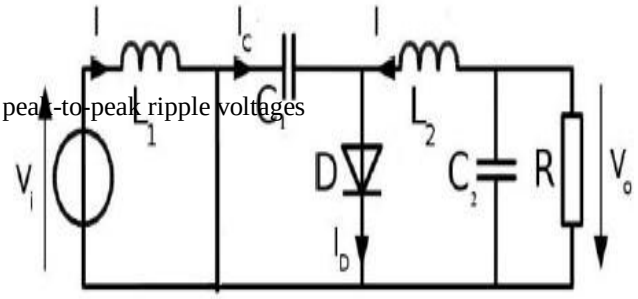

Figure 3. Converter in MODE 2

When switch S is closed, VC1 reverse biases the diode. The inductor currents IL1 and IL2 flow through the switch. Since VC1 > VO, C1 discharges through the switch and transferring energy to the output and L2. Therefore, IL2 increases. The input feeds energy to L1 causing IL1 to increase.

III.METHODOLOGY

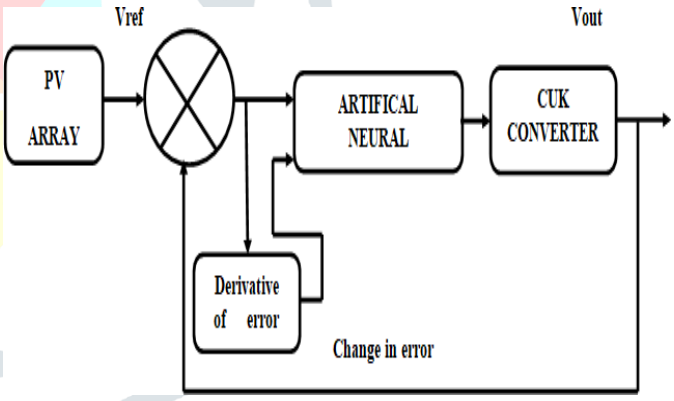

Figure 4. Block diagram for Cuk converter Using ANN Controller.

The goal of this system is to keep output voltage constant if there are variations in the load and power supply. Here difference in the output voltage and desired voltage (V_{ref}) is considered. This difference values is called error (e) and then change in error (ee) that is derivative of error will be applied to ANN through multiplexer. This output is applied to the power switch of cuk converter through PWM generator. Thus a desired output voltage will be obtained. Figure 2 shows the flowchart for algorithm. Using the

research and observation (literature survey) as the guide for mathematical model of Cuck converter, a mathematical model is designed in order is achieved using MATLAB Simulink. Initially the performance of the system for membership functions is evaluated in simulation.

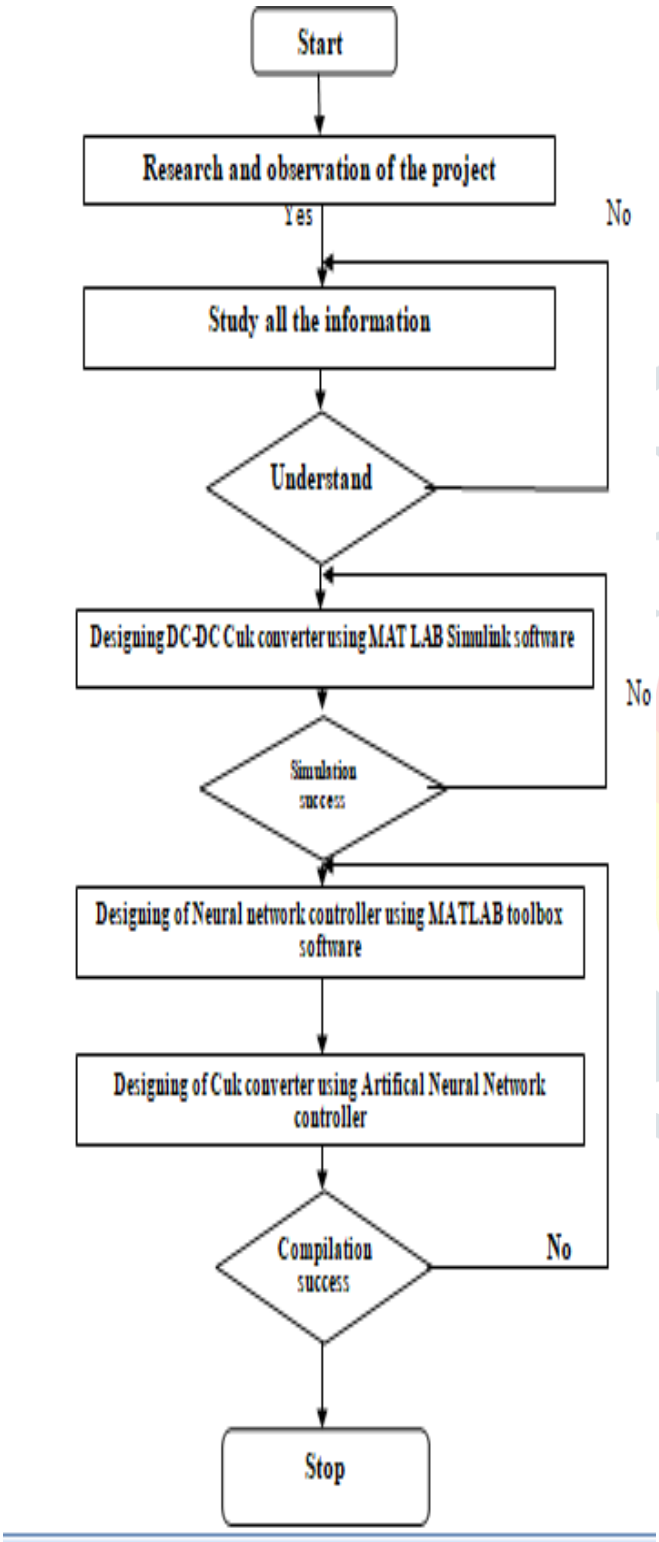

Figure 5. Flow chart of the project.

IV. ARITIFICAL NEURAL NETWORK CONTROLLER

In information technology (IT), a neural network is a system of hardware and/or software patterned after the operation of neurons in the human brain. Neural networks -- also called artificial neural networks are a variety of deep learning technology, which also falls under the umbrella of artificial intelligence, or AI. Each processing node has its own small sphere of knowledge, including what it has seen and any rules it was originally programmed with or developed for itself. The tiers are highly interconnected, that node in tier *n* will be connected to many nodes in tier *n-1* its inputs and in tier *n+1*, which provides input for those nodes. There may be one or multiple nodes in the output layer, from which the answer it produces can be read.

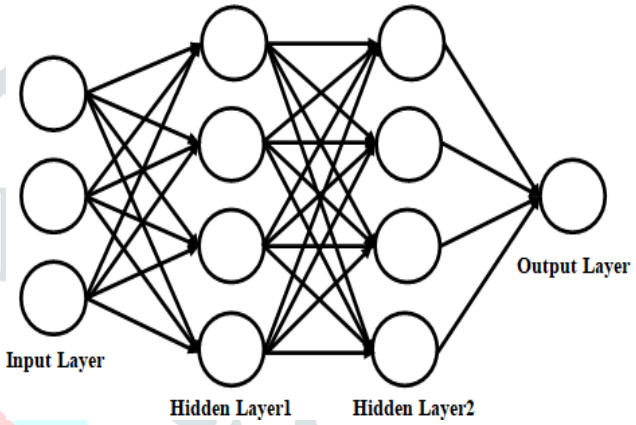

Figure 6. Block diagram Aritifical neural network controller.

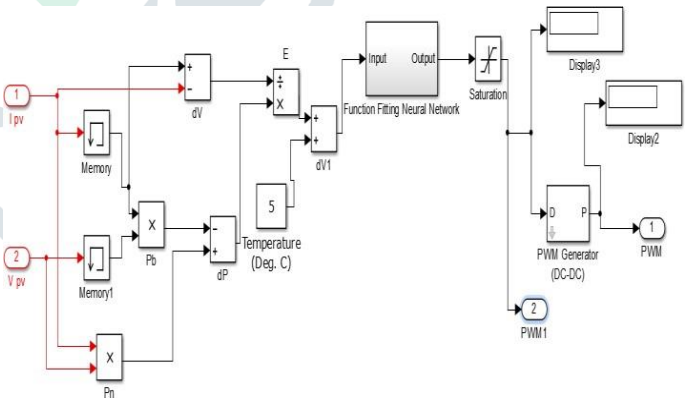

Figure 7. Fis file 1 of MATLAB.

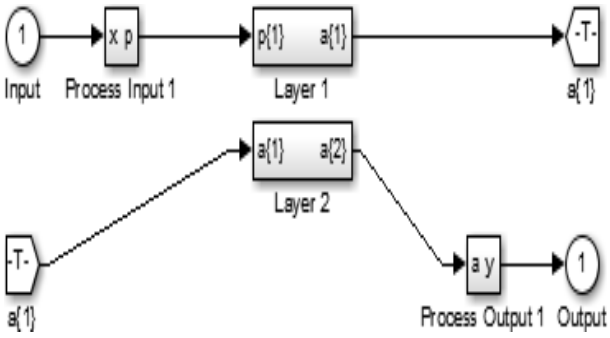

Figure 8. Fis file2 of MATLAB.

The simplest variant is the feed-forward neural network. This type of artificial neural network algorithm passes information straight through from input to processing nodes to outputs. It may or may not have hidden node layers, making their functioning more interpretable.

Implementation of proposed strategy is done in MATLAB environment. The parameters for simulation were varied and corresponding changes were observed. The tables below show the results.

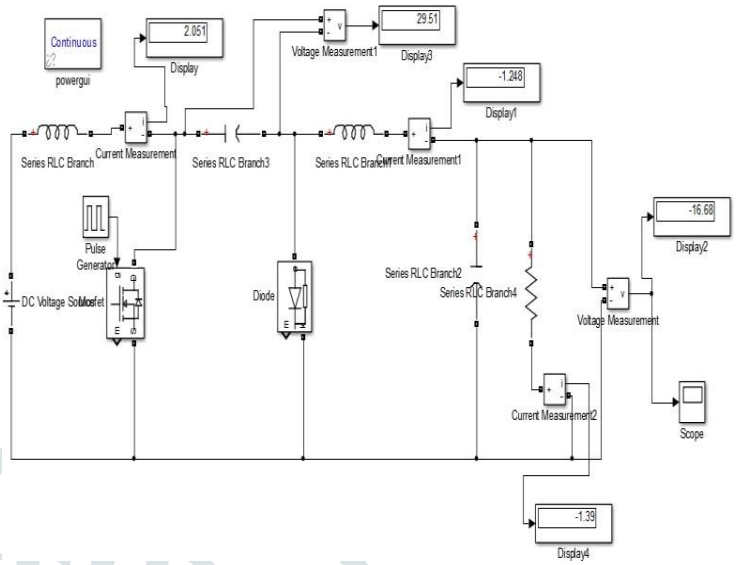

Figure 9. Simulation circuit diagram for Cuk converter.

V. SIMULATIONS RESULTS

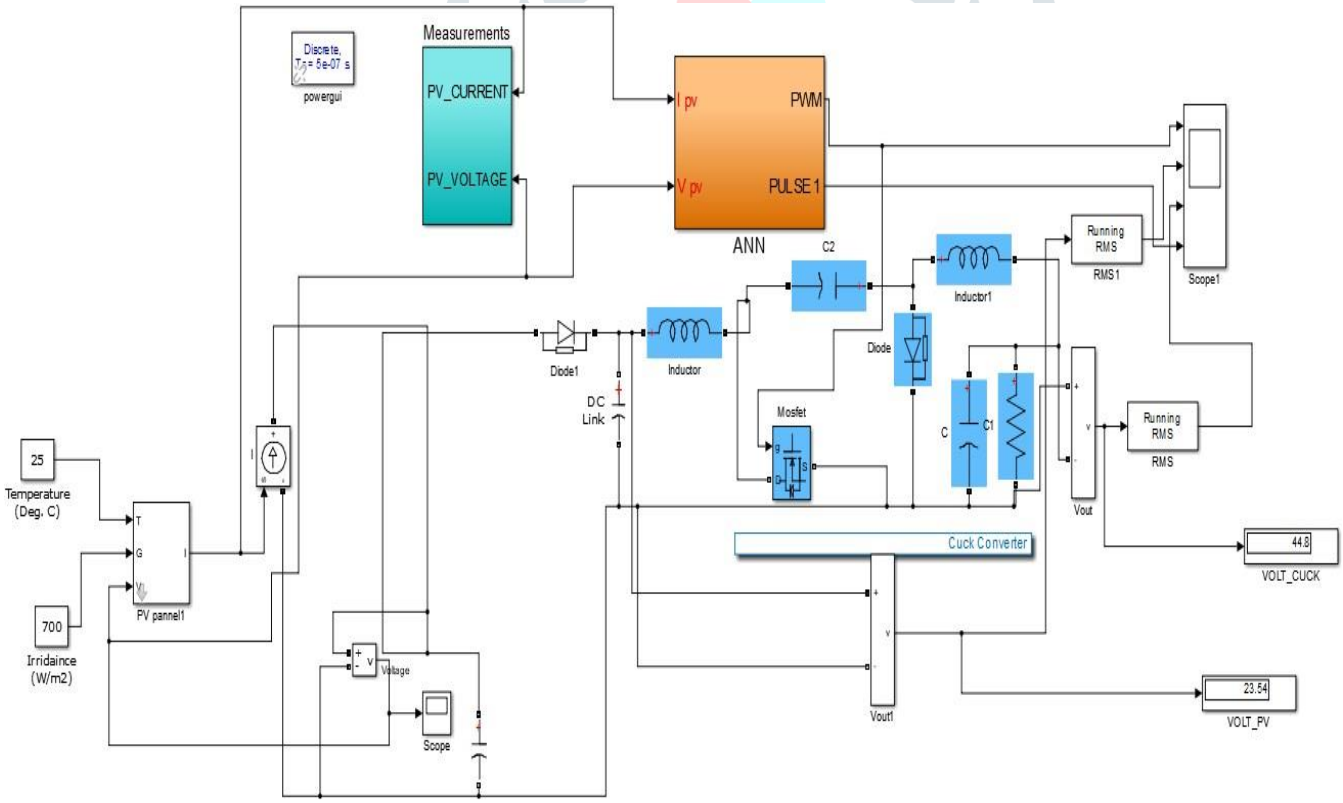

Figure 10. Simulation circuit diagram for Cuk converter using Artificial neural network controller.

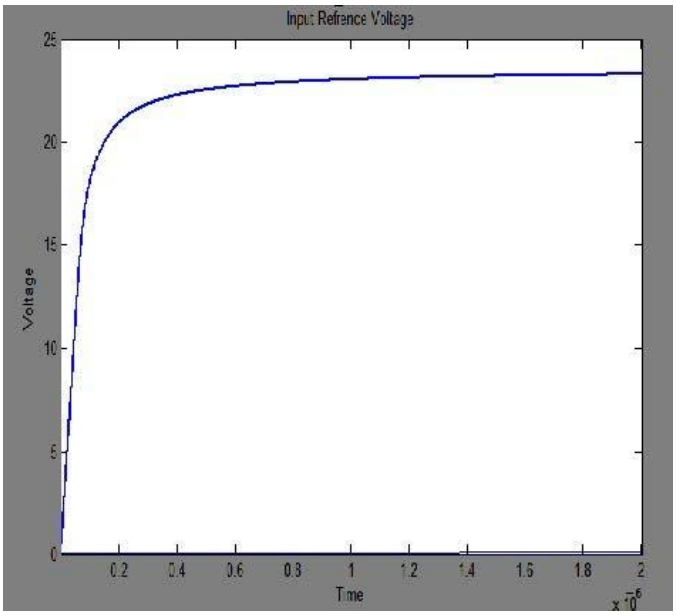

Figure 11. Simulation for 23 V reference input voltage.

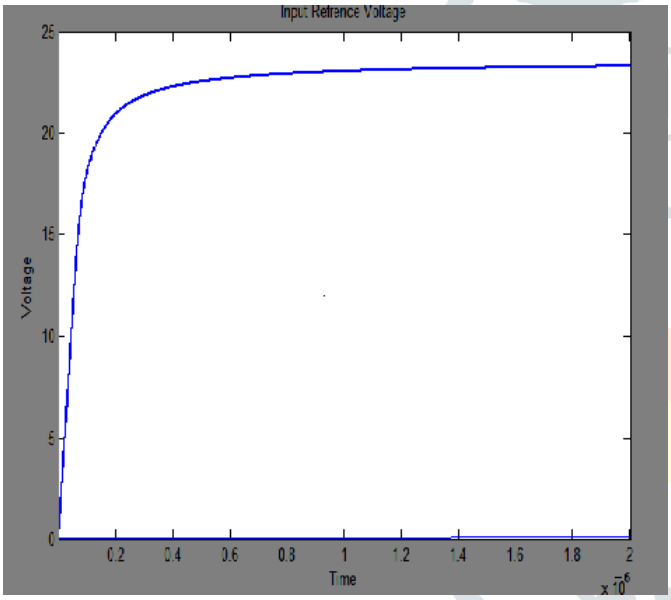

Figure 12. Simulation output for Cuk converter using ANN Controller for 44V.

Figure 13: Hardware implementation of Cuk converter using Arduino.

PARAMETERS	VALUES
Inductor L1,L2	$200\mu H, 100\mu H$
Capacitor C1,C2	$2\mu F, 2\mu F$
PWM Frequency	$250kHz$
Input voltage	$12V$
Output voltage	$-17V$

Table I: Cuk Converter Parameters.

VI. HARDWARE IMPLEMENTATION

The fig 13 depicts the hardware implementation setup of Cuk converter using Arduino. A PWM signal is generated using an Arduino for triggering the MOSFET. The frequency of PWM signal is same as that of simulation value. The controller takes voltage as feedback and calculates error and change of error. T he ANN logic is coded in embedded controller such that it follows the rule base designed in the simulation.

VII. CONCLUSION

In this paper the simulation of artifical neural network controller for Cuk converter is developed. The PV array is used as an input source for the converter. The results justify that to get a constant voltage at the output of Cuk converter for change in load and change in supply voltage by using Aritifical neural network controller Method. The Cuk converter performance is increased, as the efficiency of the converter is increased.

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