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Cuk Converter to charge a battery employing ANN Controller based MPPT

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Abstract: Solar energy has become an emerging topic for the renewable energy world. The effective utilization of the solar panel and the constant power for small system to big energy system is required. Therefore, it becomes imperative that maximum power should be derived from solar PV panels via Maximum Power Point Tracking (MPPT) which in turn increases its efficiency. In this paper, a PV model has been used to simulate actual PV arrays behavior, and then a Maximum Power Point tracking method using Artificial Neural Network (ANN) is proposed in order to control the on goings of the Cuk Converter. Simulation results show that MPPT method has been carried out which has shown the effectiveness of artificial neural networks controller to draw much energy and fast response against change in working conditions.

Keywords: PV, Buck-Boost converters, MPPT, Tracking efficiency, Simulink modeling of PV

I Introduction

One of the major concerns in the power sector is the day-to-day increasing power demand but the unavailability of enough resources to meet the power demand using the conventional energy sources. Demand has increased for renewable sources of energy to be utilized along with conventional systems to meet the energy demand. It is also required that constant voltage be supplied to the load irrespective of the variation in solar irradiance and temperature. So it is necessary to couple the PV array with a buck boost converter. This converter that has an output voltage magnitude that is either greater than or less than the input voltage magnitude. The system can be used to supply constant stepped up/stepped down voltage to dc loads.

Photovoltaic (PV) systems require interfacing power converters between the Photovoltaic arrays and the grid. The power converters are used for two major tasks. It is first is to inject a sinusoidal current in to the grid. In second is to reduce the harmonics content in the grid inject voltage and current [1].

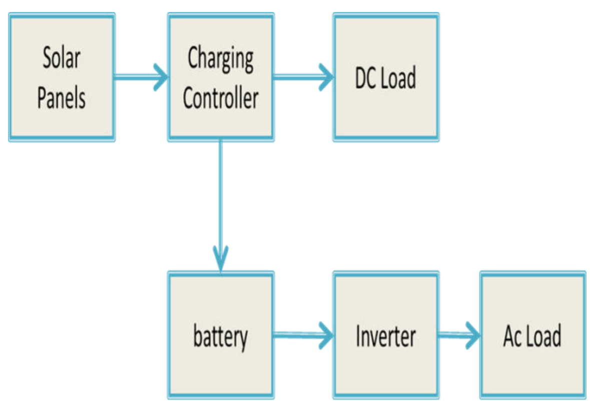

Fig 1: General Block of Solar System

The solar panels are only a part of a complete photovoltaic solar scheme. Solar modules are the heart of the system and are usually called the power generator. The one must have also mounting structures to which Photovoltaic modules are fixed and directed towards the sun. Photovoltaic (PV) system that have to operate at night or during the period of bad withstand the storage of energy are required, the batteries for electricity storage are needed. In the output of a Photovoltaic module depends on sunlight intensity and cell temperature; therefore components that condition the DC output and deliver it to batteries, grid, and/or load are required for a smooth operation of the Photovoltaic technique shown in fig 1. These components are referred to as charge regulators process [2]. For applications requiring AC, the DC/AC inverters are implemented in photovoltaic (PV) cell. These additional components form that part of a Photovoltaic system that is called balance of system.

In this paper, we have used Artificial Neural Network (ANN) to track Maximum Power Point in a PV system. Training of the Neural Network is done by Feed Forward Back propagation technique. Precision in tracking maximum power point and speed of convergence make ANN apt and suitable for such systems. Under this methodology the reference voltage and current for MPPT is computed under diverse atmospheric circumstances. Through the appropriate governance of the Cuk converter, MPPT becomes effective [4]. For the verification of the theory and methodology, the, simulation outcome is acquired through MATLAB/SIMULINK.

II PV Module Modeling

A p-n junction manufactured in a thin wafer of semiconductor material constitutes a solar cell. The electricity through a PV panel can be produced by converting electromagnetic rays of sun into electrical via PV effect. The incident photons from sunlight with energy larger than the energy of the semiconductor band-gap, induces the electron hole pairs comparative to the incident radiation and this phenomena constitutes photocurrent. The equivalent circuit is shown in Fig 2.

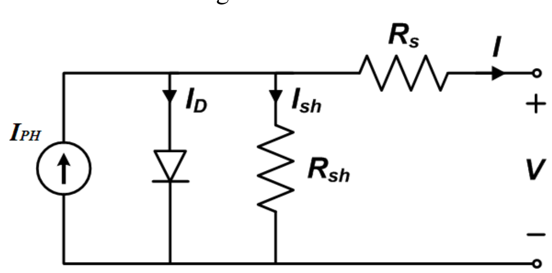

Fig 2: Equivalent Circuit of Solar Cell

PV module equations – The phase current of PV module (I_{ph}) is computed as a function of short circuit (SC) current:

$$I_{ph} = [I_{scr} + K_i(T - 298]\,\lambda/1000$$

$$I_{rs} = I_{scr}/[\exp\left(\frac{qV_{oc}}{N_s KAT}\right) - 1]$$

The variation of the module saturation current with respect to panel's temperature is computed as:

$$I_o = I_{sr} T_r^3 \exp\left(\frac{qE_{go}}{AK}\right)\left[\frac{1}{T_r} - \frac{1}{T}\right]$$

The I_{pv} representing the PV current output is computed as:

$$I_{pv} = N_p I_{ph} - N_p I_o[\exp\left\{\frac{q(V_{pv} + I_{pv}R_s)}{N_s AKT}\right\} - 1]$$

Rated Power	21.07 V
Voltage at Maximum power	21.32 V
Current at Maximum power	0.9886 A
Open circuit voltage	21.4 V
Short circuit current (I_{SCr})	7.45 A
Total number of cells in series (N_s)	36
Total number of cells in parallel (N_p)	1

Table 1: Electrical Characteristic Data of a PV Module

The testing platform was chosen to be with the isolation of 1 kW/m^2, spectrum of 1.5 air mass and cell temperature of 25°C. The variables for the above mathematical module of the PV panel are defined as follows –

V_{pv}: PV module output voltage in volts,
I_{pv}: PV module output current in Amperes,
T_{rk}: reference temperature (298.5 K),
T_{ak} : operating temperature of panel expressed in Kelvin,
I_{ph}: Photocurrent current of PV module in Amperes
I_0: saturation current of a PV module in Amperes,
B: an ideality factor (1.6),

K: Boltzmann constant (1.3805 x 10-23 11K),
q: charge on an electron = 1.6 x 10-19 C
R_s: series resistance of a PV module (0.0263),
I_{SCr}: PV module short-circuit current at 25°C and $1000W/m^2 = 7.45A$,
K_i: short-circuit current temperature co-efficient at $I_{SCr} = 0.0017A$,
I_e: PV module illumination (W/m^2) = $1000W/m^2$,
E_{go}: band gap for silicon = l.l2 eV,
N_s: number of cells connected in series,
N_p: no. of parallel connected solar cells

III MPPT System

The efficiency of a solar cell is very low and also when solar cells are connected together to form a panel then its efficiency is still not increased. In order to increase the efficiency (η) of solar cell or solar panel we have to use maximum power transfer theorem. The maximum power transfer theorem says that the maximum power is transfer when the output resistance of source matches with the load resistance i.e. solar cell or solar panel impedance. So all MPPT technique's principles are based on maximum power transfer theorem that always trying to matching the impedance of load to source.

The effectiveness of MPPT is given by following equation.

$$\eta_{MPPT} = \frac{\int_0^t P_{measured}(t)\,dt}{\int_0^t P_{actual}(t)\,dt}$$

The MPPT is now habitual in grid connected PV power generation system and it is becoming more popular in isolated or stand-alone power generation systems as well because of the I-V characteristics in PV power generation systems is nonlinear, So it is difficult to supply a constant power to a certain load. There is confusion with MPPT that many people think that it is a mechanical device that tracking the sun, it rotates the solar panel or solar cells as well as tilts it in the direction of sun where the solar irradiance is more. But the MPPT is an electronic device that extracts maximum possible power from solar panel. It varies the electrical operating point of the panel by changing the DC/DC converter duty cycle to matching the load impedance with PV cells impedance. Mechanical tracking system can be used with MPPT, but these two systems are completely different from each other.

IV Artificial Neural Network Architecture

Neural network architecture is specified in finding the appropriate solution for the non-linear and complex systems or the random variable ones. Among its types, there is the back propagation (or feed-forward) network which is more widespread, important and useful. The function and results of ANN are determined by its architecture that has different kinds, and the simpler architecture contains three layers as shown in Fig 3. The input layer receives the extern data, the second layer (hidden layer) contains several hidden neurons which receive data from the input layer and send them to the third layer (output layer). This later responds to the system.

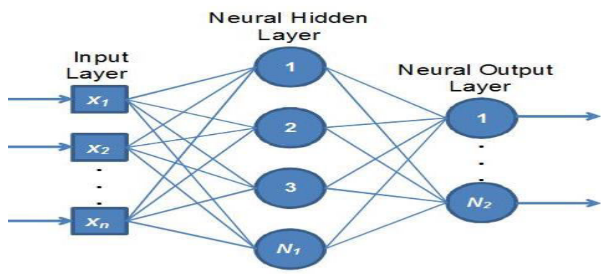

Fig 3: Architecture of Back Propagation Neural Network

We can conclude unlimited neural network architecture, more several hidden layer and neuron in each layer are added; the more complex they become. The realization of the back propagation network is based on two main points: learning and knowledge. This use of sigmoid function is as an activation function in order to calculate the hidden layer output and a linear function to calculate the output. The output for the sigmoid function varies continuously but not linearly as the input changes. Sigmoid units bear a greater resemblance to real neurons than do linear or threshold units, but all three must be considered rough approximations.

V Simulation Results

A general overview of simulation model is shown in Figure 4. It consists of Photovoltaic panel, ANN technique, DC/DC Cuk converter and Battery.

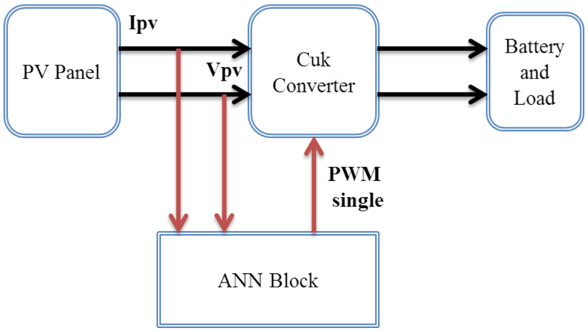

Fig 4: Simulation Model

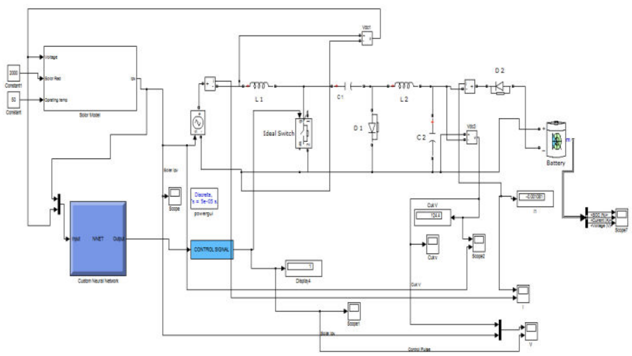

Fig. 5: PV based Cuk Converter with Battery

The Simulink model of the Photovoltaic system using Cuk converter and ANN module are shown separately in Fig. 5. To verify the proper tracking of ANN, sudden changes in irradiance and temperature of PV system is introduced and the performance is verified.

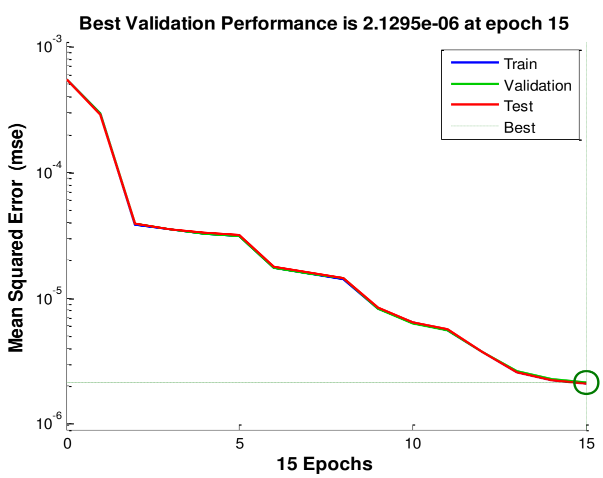

Fig 6: Neural Network Performance

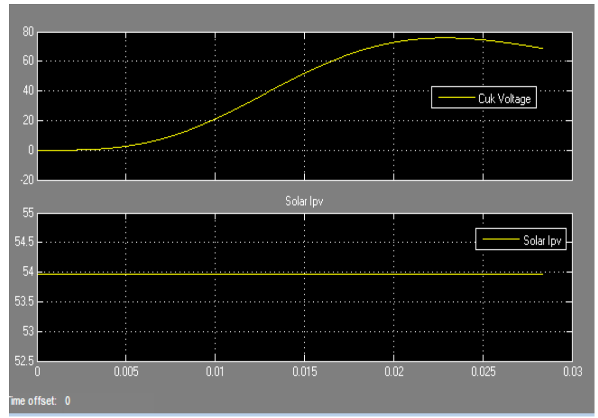

Fig 7: PV and Cuk Output Voltage

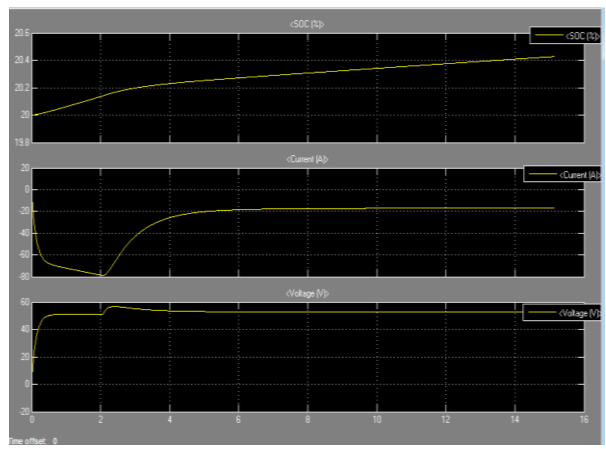

Fig 8: Battery Performance

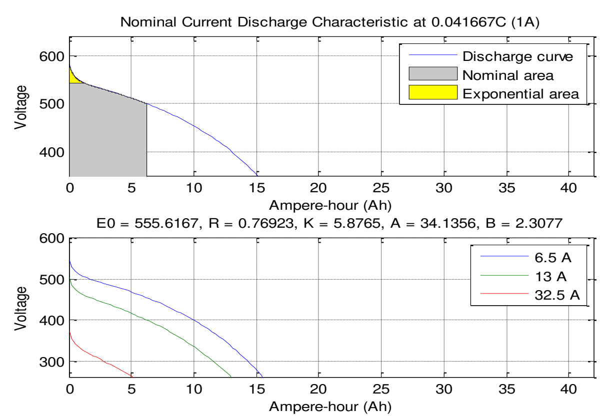

Fig 9: Battery Discharging Characteristics

VI Conclusion

The simple and effective artificial neural network (ANN) based Photovoltaic (PV) system is modeled and analyzed using Cuk converters. The paper describes a MPPT being implemented via

Artificial Neural Network (ANN) trained under real time circumstances of solar insulation. The algorithms used for training and for adaptive learning used has proved to be efficient than the ones found in earlier literature and also the number of hidden neurons chosen has produced the desired outputs. It means that the Artificial Neural Network topology is well trained to produce the required outputs.

References

[1] Taraksalmi, “MATLAB/SIMULINK Based Modeling of Solar Photovoltaic Cell”, International journal of renewable energy research, TarakSalmi et al., Vol.2, No.2, 2012.

[2] Moacyr Aureliano Gomes de Brito, “Evaluation of the Main MPPT Techniques for Photovoltaic Applications”, IEEE transactions on industrial electronics, vol. 60, no. 3, march 2013.

[3] Om Prakash Mahela & Sheesh Ram Ola, “Modeling and Control of Grid Connected Photovoltaic System: A Review”, vol. 3, issue 1, Mar 2013.

[4] Nidhi Agarwal, “Design and SIMULINK of Intelligent Solar Energy Improvement with PV Module”, International Journal of Information & Computation Technology, Volume 4, Number 6 (2014).

[5] M.B. Eteiba, “A Photovoltaic (Cell, Module, Array) Simulation and Monitoring Model using MATLAB®/GUI Interface”, International Journal of Computer Applications (0975 – 8887) Volume 69– No.6, May 2013.

[6] Amarnath Kurella, “Simulation of incremental conductance MPPT with direct control method using cuk converter”, International Journal of Research in Engineering and Technology, Volume: 02 Issue: 09, Sep-2013.

[7] Srushti R.Chafle, “Design of Cuk converter with MPPT technique”, International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering, Vol. 1, Issue 4, July 2013.

[8] N. Chettibi et. Al., “Adaptive Neural Network-Based Control of a Hybrid AC/DC Microgrid”, IEEE Transactions on Smart Grid, 1–13.

[9] Lina M. Elobaid et. Al., “Artificial Neural Network-based photovoltaic Maximum Power Point Tracking Techniques: a survey”, IET Renew. Power Gener., 2015, Vol. 9, Iss. 8, pp. 1043–1063.

[10] S.A. Rizzo & G. Scelba, “ANN based MPPT method for rapidly variable shading conditions”, Applied Energy, vol. 145, pp. 124-132, ISSN: 0306-2619, May 2015.

[11] K. Jyotheeswara Reddy & N. Sudhakar, “High Voltage Gain Interleaved Boost Converter With Neural Network Based MPPT Controller for Fuel Cell Based Electric Vehicle Applications”, Digital Object Identifier, IEEE ACCESS, 2017.

[12] Mostefa Kermadi & El Madjid Berkouk, “Artificial intelligence-based maximum power point tracking controllers for Photovoltaic systems: Comparative study”, Renewable and Sustainable Energy Reviews · March 2017.