

NEURO-FUZZY BASED MPPT IN TRANSFORMER LESS GRID USING CUK CONVERTER IN STEP-UP MODE

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Abstract --This paper is aimed at the implementation of a Neuro-Fuzzy Based MPPT in Transformer less grid using CUK Converter in Step-Up Mode. A single diode model is preferred for photovoltaic array and simulation study is done by using MATLAB SIMULINK. Voltage and current are the inputs of ANFIS logic controller and the effective value of maximum power is the output. Thus in addition to supplying voltage by the inverter without Transformer for compensate the reactive power not exceeding its power rating. This results in utilization of PV system at night and at periods of low irradiation. Rules relating the input and output of ANFIS Logic Controller are written and simulation is performed. A DC –DC CUK is used for maintaining constant DC input to the inverter at various conditions of irradiation and temperature. Gating pulses to the inverter are generated by PI (Proportional integral) controller. Simulation model of a 1000W solar panel is developed and results are obtained with ANFIS logic controller for different irradiation and temperature conditions.

Keywords—PV system, Maximum Power Point Tracking (MPPT), Irradiation, Transformer less Grid connected, Adaptive Neuro-Fuzzy Inference System(ANFIS) Controller, PI Controller, CUK

I. INTRODUCTION

Photovoltaic is the power of converting sunlight directly into electricity using solar cells .Today it is rapidly growing and increasingly important renewable alternative to conventional fossil electricity generation. Since Voltage and Current of a PV system are interdependent, for a given value of irradiation and temperature, there is only one value of load at which maximum power is extracted from the PV system. Various Maximum power point tracking (MPPT) methods are used to extract the maximum possible power from the PV array. Hill climbing and incremental conductance algorithm has some disadvantages .So neuro-fuzzy based MPPT algorithm has been chosen. There are literatures on MPPT using Soft Computing Techniques like Fuzzy Logic and Neural Network. In this paper, ANFIS controller based MPPT is used because of its advantages such need for approximate data with cost effective sensors. The Neuro-Fuzzy algorithms are quite understandable, robust, in the sense that they are not very sensitive to changing environments and erroneous or forgotten rules. Recent literatures show that in addition to Real Power (P) injection, inverter of PV system are controlled to inject Reactive Power (Q) thereby increasing the utility of the PV system at periods of low irradiation.

II. BLOCK DIAGRAM DESCRIPTION

The block diagram of a Neuro-Fuzzy Logic Based Transformer less Grid tied PV System is given in figure. Fig.1. Output of PV voltage and PV current are the input variables of the ANFIS controller. The CUK used for maintaining a constant DC output voltage and dc-dc converters operate by turning on and off a MOSFET switch. The ANFIS controller feedback loop should be able to increase the duty cycle to raise the output when the output is too low and decrease it when the output is too high. To do this, the output will need to be compared to a reference voltage which remains constant even if the input changes. The error between the output and the reference voltage is then amplified and added to a set bias voltage. The resulting voltage is then used as the control voltage for PWM. When the output is too low, the amplified error increases which causes the control voltage to increase. The increase in control voltage increases the duty cycle until the output is correct. The duty cycle (D) is used to drive the CUK converter so that input voltage to the inverter is maintained constant.

The measurement block is used to measure active and reactive power from the grid. The Output is given to the PI controller. Here Function of PI controller is reduce the error corresponding to the carrier signal for generating the pulse to the inverter.

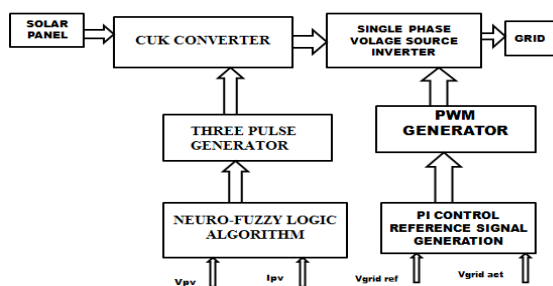


Fig.1 Block diagram of CUK Converter based Transformer less grid tied PV system using ANFIS Based MPPT.

III. OPERATION AND CONTROL

Modelling of solar array

Solar panel is simulated using one diode model. From the equivalent circuit of one diode model, it is evident that the current produced by the solar cell is equal to that produced by the current source, minus that which flows through the diode, minus that which flows through the shunt resistor:

$$I = I_{ph} - I_D - I_{sh}$$

Where

I = output current (ampere), I_{ph} = photovoltaic current (ampere), I_D = diode current (ampere), I_{sh} = shunt current (ampere).

The photovoltaic current is generated by the following equation:

$$I_{ph} = \frac{G}{G_{ref}} (I_{sc,ref} + \mu_{sc} \Delta T)$$

where, G = irradiation (Watt/m²), G_{ref} = irradiation at STC (Watt/m²) = 1000 W/m², $I_{sc,ref}$ = reference short circuit current (ampere), μ_{sc} = temperature coefficient (A/k), $\Delta T = T - T_{ref}$, T = Temperature (kelvin), T_{ref} = Temperature at STC (kelvin) = 25 + 273 = 298 K. By the Shockley diode equation, the current through the diode (I_D) is:

$$I_D = I_0 \left(\exp \left(\frac{V + I K_s}{\alpha} \right) \right)$$

Here,

$$I_0 = I_{sc,ref} \left(\frac{T}{T_{ref}} \right)^3 \exp \left[\left(\frac{q E_g}{A K} \right) \left(\frac{1}{T_{c,ref}} - \frac{1}{T_c} \right) \right]$$

where, I_0 = reverse saturation current of the diode (ampere), q = Charge of electron = 1.6021 * 10⁻¹⁹ coulombs, E_g = Band gap Energy = 1.12 eV for silicon, A = ideality factor = 1.3, K = Boltzmann's constant = 1.3806 * 10⁻²³ J/K, V_{oc} = Open circuit voltage = 22.5 V

where, 'a' is the "modified ideality factor" and is considered as a parameter to determine, and 'A' is the diode ideality factor. Substituting these into the first equation produces the characteristic equation of a solar cell, which is given by

$$I = I_{ph} - I_0 \left[\exp \left(\frac{V + I R_s}{\alpha} \right) \right] - I_{sh}$$

The values of R_s and R_p (series and parallel resistance) can be calculated from eqn (9) using Newton-Raphson method. The iterative method to compute the pair (R_s , R_p) gave $R_s=0.45\Omega$, $R_p=310.0248\Omega$. I-V and P-V characteristics of solar array are obtained by varying the load resistance from zero to infinity. The characteristics are plotted for different irradiation and temperature conditions as shown in Fig.2 and Fig.3

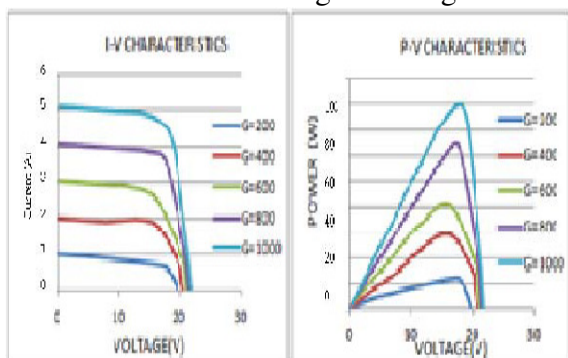


Fig.2 Solar array Characteristics with Varying Irradiation and Fixed Temperature $T=298\text{ K}$

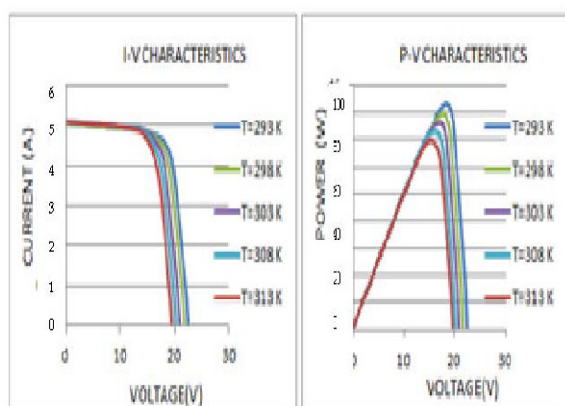


Fig. 3 Solar array Characteristics with Varying Temperature and Irradiation $G=1000\text{ W/m}^2$

From the Fig.2 and 3, it is inferred that increase in irradiation, increases the maximum power whereas the voltage at which maximum power is obtained remains constant. When temperature is increased, the maximum power decreases and the voltage corresponding maximum power also decreases.

DC-DC CUK Converter

The dc-dc converter is used to convert unregulated dc voltage to a constant voltage. The single ended primary converter is a type of DC to DC converter allowing the electrical potential (voltage) at its output to be greater than, less than, or equal to that at its input. A CUK is a traditional buck boost converter, but has advantages of having non inverted output (output has the same voltage polarity as the input), using series capacitor to couple energy from the input to the output and being capable of true shutdown. The voltage drop and switching time of diode D_1 is critical to a CUK reliability and efficiency. The diode's switching time needs to be extremely fast in order to not generate high voltage spikes across the inductors, which could cause damage to components.

$$V_o = \frac{V_s \cdot D}{1 - D}$$

The output voltage is always greater than the input voltage and is related directly to duty cycle. The reference voltage and the measured chopper voltage are compared and the error is given to the ANFIS logic controller.

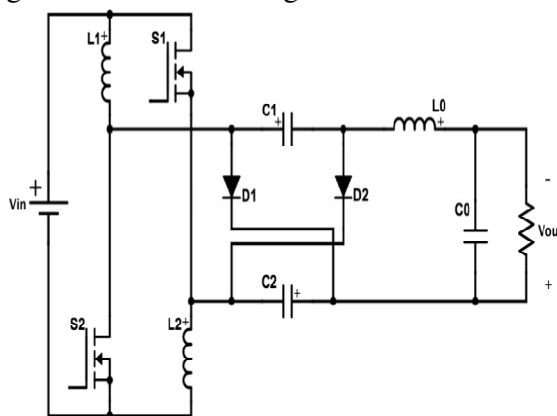


Fig.4 CUK Converter

The output of ANFIS controller is modulated with a triangular carrier of frequency 10 kHz and is given as gate pulse to the chopper

Maximum Power Point Tracking (MPPT)

This paper describes the method to track power maximum power point by using ANFIS logic control. ANFIS Logic Controller is simulated using Fuzzy Toolbox in MATLAB. The inputs to the ANFIS Logic Controller are voltage and current and the output is gate pulse of converter. Triangular Membership functions with uniform widths, Mamdani inference system and Centroid method of Defuzzification are used.

Inverter

The main function of inverter in this system is to produce an ac output current equal to the reference current and in phase with it. The PV grid connected system provides a power conversion. In addition to supplying real Power, Reactive Power is also supplied by the inverter. Based on the output of Hysteresis Current Controller the switches T1 and T4 are controlled for positive half cycle, and T2 and T3 are controlled for negative half cycle.

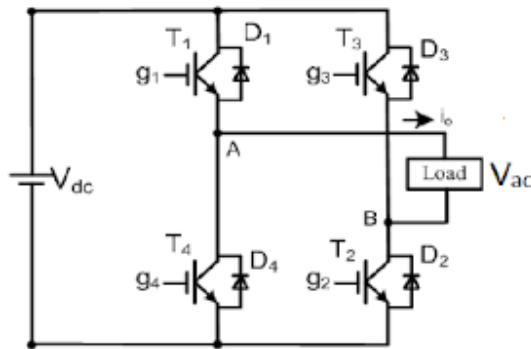


Fig 5. Inverter

IV. SIMULATION RESULTS

To verify the feasibility of the proposed strategy, simulations are carried out.

The figure 6 shows the Mat lab Simulink diagram including solar sources with CUK converter and inverter. Solar panel output voltage and current are the input to the CUK converter. The CUK converter allows arrange of dc voltage to be adjusted to maintain a constant voltage output. The ANFIS logic controller feedback loop should be able to increase the duty cycle to raise the output.

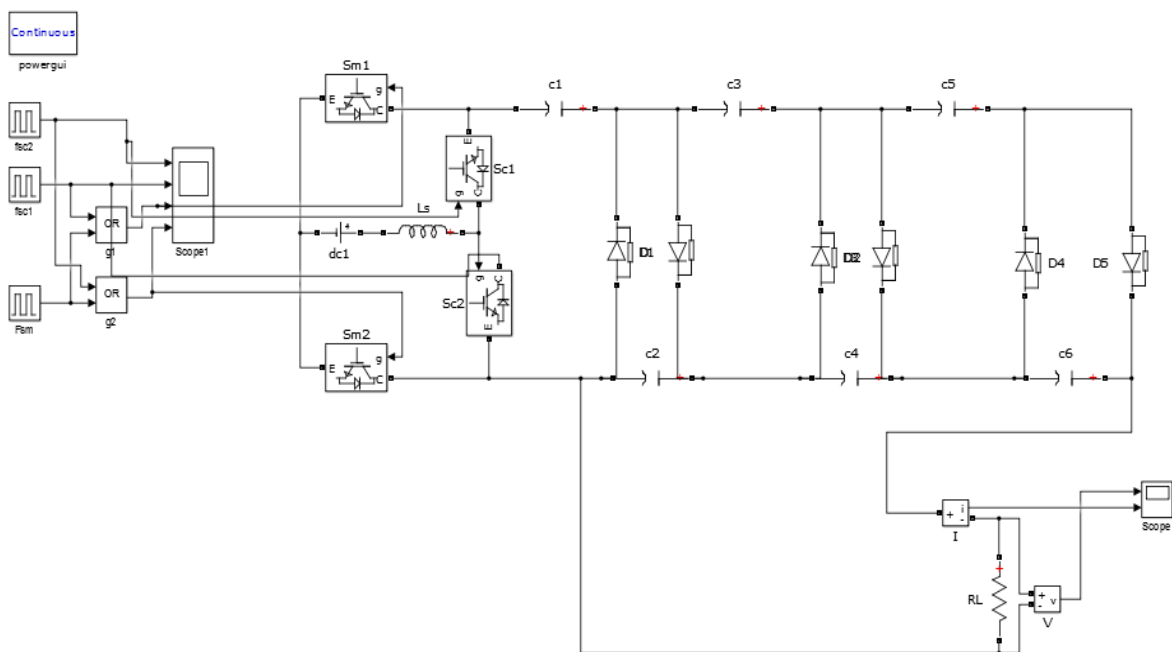


Fig.6. Proposed system Simulink diagram

The output voltage of a CUK converter is given to input of the inverter. Output voltage of an inverter can be higher or lower than the input voltage of the inverter is depending on the modulation index when Three pulse generation technique is used. The PI controller feedback loop should be able to increase the duty cycle to raise the output. The increase in control voltage increases the duty cycle until the output is correct.

The inverter output is directly connected to the grid line without transformer for reactive power compensation. Grid active and reactive power is measured by a measurement block. Measurement block output is given to the PI controller. Here Function of PI controller is reduce the error corresponding to the carrier signal for generating the pulse to the inverter. From solar cells the input voltage is 75V, it is given to the DC to DC converter. It is inferred that increase in irradiation, increases the maximum power whereas the voltage at which maximum power is obtained remains constant. When temperature is increased, the maximum power decreases and the voltage corresponding to maximum power also decreases.

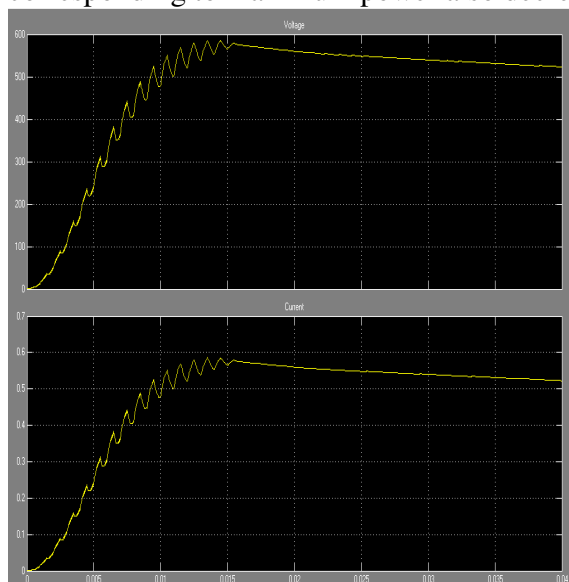


Fig .7. Inverter output voltage

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V. CONCLUSIONS

In this paper, renewable system based on solar cell energy system with CUK converter fed single phase three level inverter has been implemented. The generated voltages are filtered and boosted by Single Ended Primary Inductor converter. The CUK converter provides constant DC voltage to the single phase three level inverter. The ANFIS based MPPT algorithm has been used to extract the maximum power from the hybrid energy system. The PI controller makes the inverter output voltage equal to grid voltage. The corresponding simulated results shows that the voltage and current of inverter to Grid are in phase and there by the real power in the system is maintained constant. Hence the reactive power is compensated in the system by maintaining the real power as constant.

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