Design & Simulation of an ANFIS MPPT Controller for Solar Power Application in MATLAB

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ABSTRACT

In this paper we present an intelligent control technique for the MPP tracking of a photovoltaic (PV) system using adaptive neuro-fuzzy inference system (ANFIS) under variable solar irradiation conditions. For this a solar photovoltaic module and a DC/DC Boost converter is developed in MATLAB/SIMULINK environment. Initially, MPPT controllers were designed using Perturbation and Observation (P&O) methods. However, this conventional method cannot effectively track rapidly changing incident solar irradiation levels. Hence, an intelligent MPPT controller was designed using ANFIS toolbox which draws much energy and produces fast response under continuously changing operating conditions. The PV module with proposed MPPT controller was analyzed in stand-alone mode. The major disadvantage with PV system is its uncertain and intermittent power output which depends on weather conditions. PV module alone cannot supply reliable power to the isolated load effectively. To predict the power supplied to the load under different operating conditions sensitivity analysis has been carried out for the PV system with designed MPPT controller.

Keywords: Solar cell, Photovoltaic, P&O, ANN, ANFIS, MPP, MPPT, Fuzzy logic, Buck-boost converter

1 INTRODUCTION

The generation of solar-powered photovoltaic energy conversion, which can directly transform solar energy into DC electricity, aims to be a sustainable green energy source. In the past few decades, scientists have demonstrated a high level of interest in PV technologies. Progress in cell performance and device stability has provided broad acceptance both for interactive as well as stand-alone power production sectors through the PV power generation technology [1]. Viable growth in global PV-based electricity production often considerably reduces fossil fuel reliance and demand. A non-linear feature is the observed in output voltage vs. current curve of the solar cells[2]. From the non-linear relation it could be established that a particular point which, is the so-called maximal power point (MPP) of the PV-cell under certain intensity of light and temperature [3].

In addition, market demand is increasing considerably for photovoltaic (PV) generation of energy also in power systems as well as distributors. At just the end of 2014, the global photovoltaic capability was 178GW and by the end of 2021 it could grow by 10% and in the next four years it will reach a minimum of 450GW. In this sense, Algeria has initiated an aggressive renewable energies (REn) policy for the diversification of energy supplies and a balanced energy use [4]. In view of the hot, dry and sunny climate, which is suitable for solar power use, the 20% increase for renewable energy production is anticipated by 2021 [5][6].

Quite apart from the recent improvements in factors related to photovoltaics use, also including lowering costs, the PV-cell efficiencies and improving essential structural implementations, [7] the low-energy transformation produced by the PV systems continues to be a significant issue when it comes to the use of PV systems in power generation and is crucial to the precision of the MPPT. The strong reliance on environmental conditions is another problem for PV-based power generations, including ambient temperature and solar irradiance [8].

Even then, because of the high construction costs for PV arrays and the associated facilities, the awareness of PV systems remains a big challenge. In addition, due to directly depending on environmental factors, photovoltaic solar electricity generation lacks confidence [9]. The addition of a reliable maximum power point tracking (MPPT) controller is important also because cost of PV devices and their low performances (between 10 and 23 percent) [5][10]; in this context MPPT means getting a maximum power out of the PV power generation.

1.1 RESEARCH OBJECTIVES

- Creating a MPPT controller and loading point for full non-linear PV panel model having DC-DC converters.
- Design an MPPT controller utilizing Adaptive Neuro-Fuzzy Inference framework (ANFIS).
- To analyze the optimal performance in relation to the balanced efficacy of the entire structure under various conditions for temperature and solar irradiance.

2 MATERIALS AND METHOD

The current-voltage-power (I-V-P) feature of PV systems is non-linear, due to erratic patterns of solar irradiance, temperature and load impedance. There is generally the V-P curve, known as the Maximum Power Point (MPP) which operates with maximum efficiency and maximizes the output power of all PV systems[3]. The system also has its own P-V curve. Only when radiation is present is maximum energy generated from the solar PV system. Lack of irradiance makes supplying the necessary requirement for load challenging. Thus, the solar PV system that provides a single load is attached to the grid to address this disadvantage.

2.1 PHOTOVOLTAIC MODELING

2.1.1 Equivalent Electric Circuit of Photovoltaic Cell

The new voltage terminal features for PV cells have been mathematically defined. The single exponential equation, which models a PV cell and is widely agreed as representing the characteristic behavior of the cell, is derived from the mechanics of this connection. For polycrystalline silicon cells a double exponential equation can be used to represent the same:

$$I = I_{ph} - I_s\left(\frac{\exp(q.(V+IR_S))}{N.K.T} - I\right) - \frac{(V+IR_S)}{R_{sh}}$$

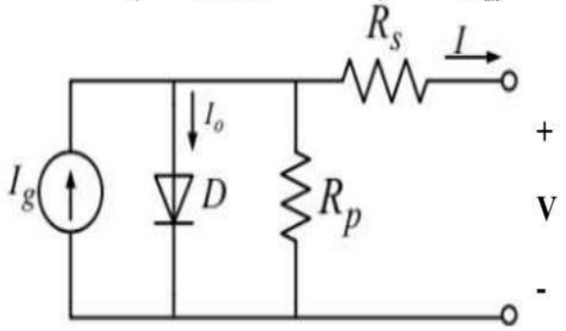

Fig 1: Ideal PV cell's equivalent circuit using single diode

$$I = I_g - I_o - I_p \tag{1}$$

$$I = I_g - I_o \ \{e^{a[V + \frac{IR_s}{kV_T}]}\} - \frac{V + IR_s}{R_p} \tag{2}$$

where, I is the current generated by solar cell, I_g is the incident light generated current (A); (which, is directly proportional to the solar irradiation), I_o represents the leakage current or reverse saturation of the diode, a represent the electron charge (1.6x10-19C), T denotes temperature of the cell (in Kelvin), V denotes solar cell's output voltage (V), R_s denotes the resistance in series (Ω), Rp denotes the shunt resistance connected in parallel (Ω) and k represents diode's ideality constant (Boltzmann constant).

Table 1: Key specifications of 70W PV module

Parameters	**Value**
Maximum power (Pm)	70W
Maximum Voltage (Vm)	20.1V
Total No.of cells in Series	Ns 36
Open circuit voltage (Voc)	21.06V
Current at max power (Im)	4.2A
Short circuit current (Isc)	3.83A

Total No.of cells in Parallel (Np)	1

3.1.1 Adaptive neuro fuzzy inference system

ANFIS is a learning technology for input data using Fuzzy Logic to translate inputs into an expected outcome, which can be weighed into a dynamically integrated neural network that maps inputs into output. ANFIS incorporates the advantages of the two methods of computer learning (Fuzzy Logic and neural networks). An ANFIS is used to set the parameters of a fuzzy inference system (FIS) by using techniques of learning by the Neural Network [20].

The ANFIS toolbox creates a Fuzzy Inference System (FIS) with a given input/output maped info, whose membership function criteria can be modified using back propagation algorithm or combining the least-square rule and back propagation algorithm. This learning process is called the method of hybrid learning. This enables fluid structures to benefit from the information they model.

3.1.2 Procedure for ANFIS MPPT

Input and output data sets[9] are essential to monitor the MPPT with ANFIS model. This data sets are derived from the operational restrictions of the system. Training data can be collected in two different ways. The first is to gather data on the real-time system; the second is to simulate a precise conceptual framework for the PV module[10]. Owing to the irregularity of the weather and the failure to monitor weather conditions, the collection of data from the real - time application was really challenging. Consequently, training data was gathered only after implementation of the dynamic PV module from simulations in this study [14].

In order to input and predict the maximum output power from the PV module, the proposed ANFIS dependent MPPT model takes the operational temperature and irradiation [13]. The real output power of the solar PV module is determined by sensing operating current and voltage at the same operating irradiation and temperature [20].

Comparison of the predicated energy and measured energy and errors of the functional signal generator is made to a ratio-integral (PI) controller[9]. The PWM generator receives the working signal from the PI controller. In comparison to the performing signal, the PWM signal is produced at higher frequencies of the carrier signals. The transmitter signal frequency used is 25kHz. The PWM signal produced adjusts the DC-DC converter processing period to change the PV module's operating MPP. Figure 2 represent the data flow-diagram for the ANFIS based MPPT controller

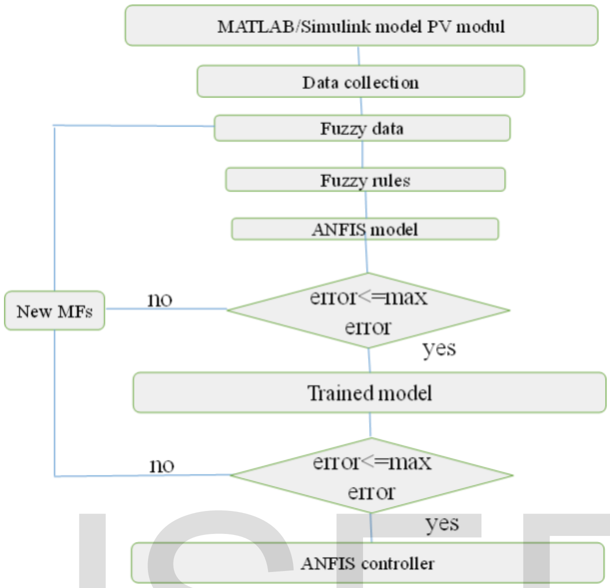

Figure 2: Data flow-diagram for the ANFIS based MPPT controller

3 RESULTS

The MPPT controller causes PV panel to operate to reach full power at a given point of operation. In the sky, both the temperature and the cloud allow the irradiation values and the performance of the PV to change rapidly. Therefore, the energy generated by the panel continually varies. ANFIS-MPPT controller can obey these sudden adjustments and obtain full power at every operating point in a stable fashion, as can be seen from the figures

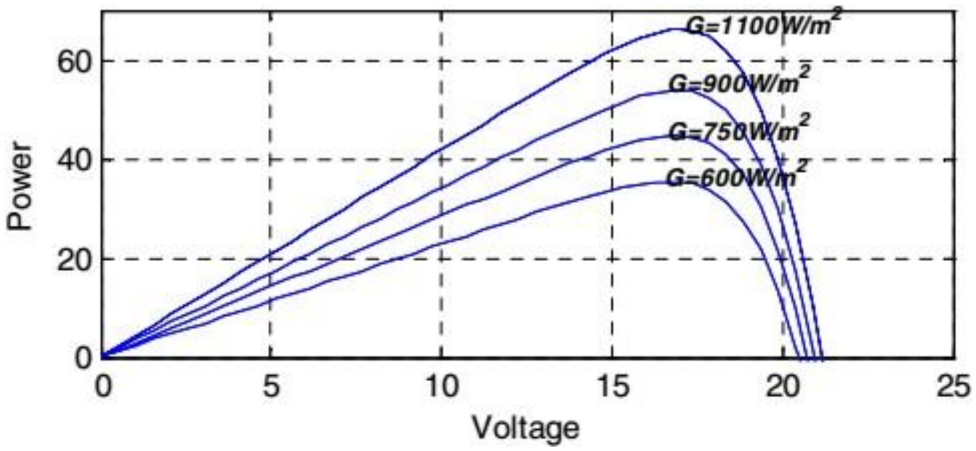

Figure 3: Power-voltage characteristics of PV system for various irradiance (G)

The results for a simulation for the reference voltage are given in Figure 3 and Figure 4. In Figure 4 in the fast-change irradiation condition the simulation outputs for the referenced voltage were provided by the ANFIS-based MPPT control unit which in turn was produced by a right pulse (Duty Cycle) to drive the transfer unit in the buck converter, PV array's current (I_{PV}) and voltage (V_{PV})respectively. Figure 4 represents PV curve for varying temperature (25℃/15℃)

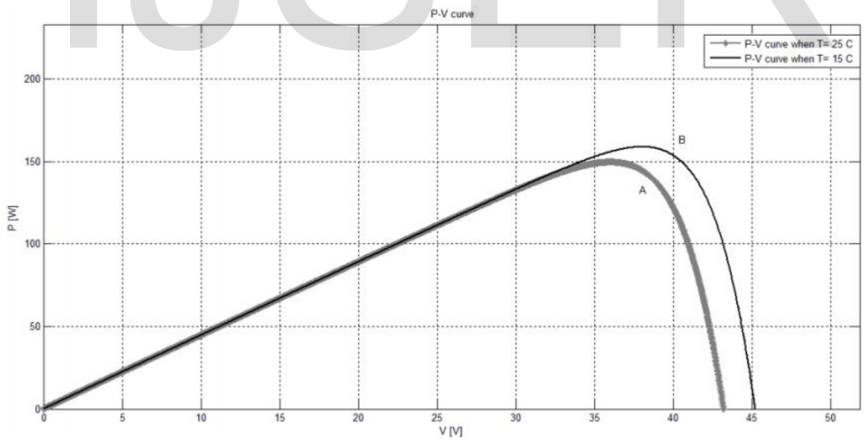

Figure 5: PV curve for varying temperature (25℃/15℃)

From the above estimates, when the proposed MPPT controller is implemented, the output of the PV system shall be constant. PV screen, buck boost converter and arming, is built into the ANFIS-based MPPT controller. MPPT controller monitors the irradiation and temperature level adjustments.

Therefore, the energy generated by the panel continually varies. ANFIS-based MPPT controller can carry out these sudden adjustments and obtain full power at every operating point in a stable fashion, as can be seen from the figures.

4 CONCLUSION

It has been observed that solar radiation affects specifically solar cell electricity and the open circuit Voltage after drawing of solar cell I-V and P-V courves by varying two major parameters. In the range of 600W/m2 radiation values were changed to 1100 W/m2, and power and voltage performance were reported. However, the photo-current has a marked effect. Secondly, temperature increases which, lower the cell's open circuit tension. The temperature varies between 25°C and 42°C. These curves can also be used to trace the maximum power point of the solar cell series. It has been concluded that this finding is useful to investigate the behaviour, update the model into the solar panel (36 or 72 solar cells), and apply various MPPT strategies to achieve optimum performance in the solar module.

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