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Modeling of solar PV module and maximum power point tracking using ANFIS

Ravinder Kumar Kharb [a,*], S.L. Shimi [b], S. Chatterji [b], Md. Fahim Ansari [c]

[a] Department of Electronics Engineering, Government Polytechnic, Jhajjar 124103, Haryana, India
[b] Department of Electrical Engineering, National Institute of Technical Teachers' Training and Research, Chandigarh 160019, India
[c] Department of Electrical & Electronics Engineering, BRCM College of Engineering & Technology, Bahal 127028, Haryana, India.

A R T I C L E I N F O

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A B S T R A C T

Solar energy, at the present time is considered as an important source in electricity generation. Electricity from the solar energy can be generated using solar photovoltaic (PV) modules. The maximization of solar power extracted from a PV module is of special concern as its efficiency is very low. The output power of a PV module is highly dependent on the geographical location and weather conditions such as solar irradiation, shading and temperature. To obtain maximum power from PV module, photovoltaic power system usually requires maximum power point tracking (MPPT) controller. In this paper, an adaptive neuro-fuzzy inference system (ANFIS) based maximum power point tracker for PV module has been presented. To extract maximum power, a DC–DC boost converter is connected between the PV module and the load. The duty cycle of DC–DC boost converter is modified with the help of the ANFIS reference model, so that maximum power is transferred to load. Due to the complexity of the tracker mechanism and non-linear nature of photovoltaic system, the artificial intelligence based technique, especially the ANFIS method, is used in this paper. In order to observe the maximum available power of PV module, the ANFIS reference model directly takes in operating temperature and irradiance level as input. The response of proposed ANFIS based control system shows accuracy and fast response. The simulation result reveals that the maximum power point is tracked satisfactorily for varying irradiance and temperature of PV module. Simulation results are provided to validate the concept.

Contents

1. Introduction

The fossil fuel reserves are depleting at a rapid rate and their use for electric power generation is degrading our environment at even

* Corresponding author. Tel.: +91 9416312461.
E-mail addresses: kharb_ravinder@yahoo.co.in (R.K. Kharb), shimi.reji@gmail.com (S.L. Shimi), chatterjis@yahoo.com (S. Chatterji).

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faster rate. It is the need of the hour to develop commercially feasible and environment friendly alternative sources of electric power generation. Sunlight is an excellent source of energy which can be utilized for electric power generation. Solar energy is renewable which is the best option for electricity generation because it is never-ending, non-polluting and free to harness. Moreover the solar energy is available everywhere in huge amount. Various benefits of solar power have been identified for different sectors and are tabulated in [1]. With the advancements in solar technology [58,59], the uses of solar power have diversified, expanded and become commercialized.

Solar power might replace fossil fuel dependent energy sources very soon; however solar power cost per kilowatt-hour has to be competitive with fossil fuel energy sources [4,5]. At present, solar modules are not very efficient with their ability to convert sunlight to electrical power [3,56]. The efficiency can drop further due to other factors such as solar module temperature, available sunshine and load conditions. Solar module characteristics are dynamic in nature and their power generation capabilities keep on changing with the geographical location and weather conditions [2]. The temperature dependence of solar electrical efficiency of PV modules and analysis of variation of the junction temperature with the radiation intensity and ambient temperature is briefly discussed in [49,53]. A simple model is proposed in [55] to predict the dependence of PV module performance upon solar-irradiance intensity and temperature. In the literature, many methods have been proposed to extract maximum power from PV module [6–21]. The proposed methods can be broadly classified as the perturb & observation (P&O) method, the incremental conductance (INC) method and artificial intelligence (AI) based methods. Although the P&O method [9,10,13] is commonly used in the MPPT applications due to its simplicity and easy implementation, it has number of problems. Its accuracy in steady-state sunshine condition is low because the perturbation process would make the operating point of the PV module oscillate around the MPP, which consequently waste the energy. By minimizing the perturbation step size, oscillation can be reduced, but a smaller perturbation size slows down the speed of MPPT. Further, the P&O method probably fails to track the maximum power point due to the sudden changes in sunshine. The INC method [6,7,19,54] has been proposed to improve the tracking accuracy and dynamic performance under rapidly varying environmental conditions. The advantages of the INC method over the P&O method have been analyzed in [60]. The INC method is based on the fact that the slope of the PV module power curve is zero at the MPP, positive on the left side and negative on the right side of the MPP. It uses the derivative algorithm to find the MPP. This method requires more computation in the controller because the differentiation process involves a relatively complex decision making process. Therefore the INC method needs more complex calculation capacity and memory [16,20,22,46], which may increase the cost of system. Moreover, the results of the INC method are unsatisfactory at low level of irradiance as the differentiation process becomes difficult.

The performance of different maximum power point tracking techniques is compared in [11,17,46]. As per [48], most of the presented methods in literature suffer from the drawback of poor stability and can produce oscillations in power output due to the highly non-linear characteristics of the PV module. In addition to that, it is impossible for the conventional methods to quickly acquire the maximum power points for the power generated by PV modules and

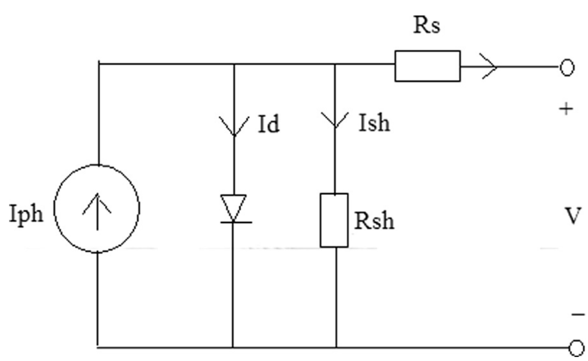

Fig. 1. Equivalent circuit of solar cell.

Table 1
Key specification of MXS 60 PV module.

Parameter	Variable	Value
Maximum power	Pm	60 W
Maximum voltage	Vm	17.1 V
Current at max power	Im	3.5 A
Open circuit voltage	Voc	21.06 V
Short circuit current	Isc	3.74 A
Total no. of cells in series	Ns	36
Total no. of cells in parallel	Np	1

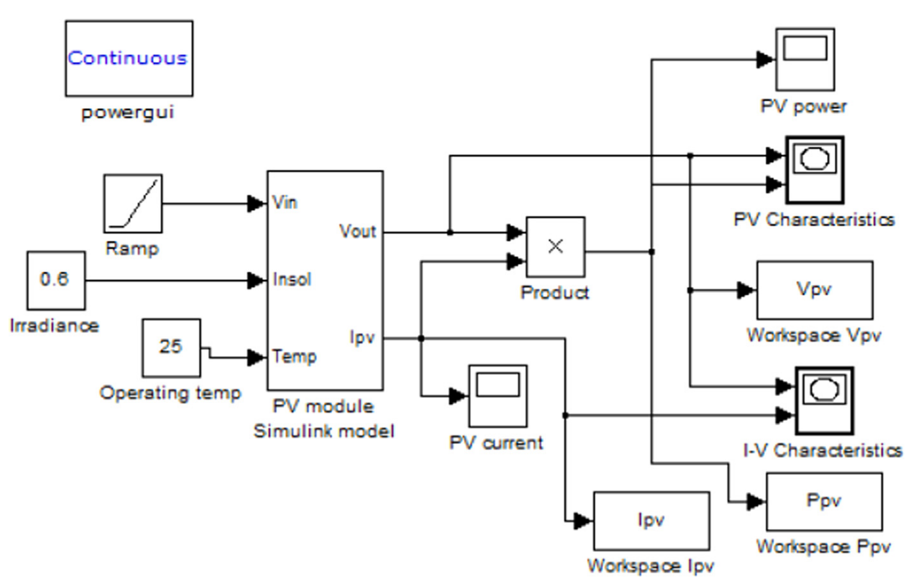

Fig. 2. Matlab/Simulink model of PV module.