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Upgrading Tests Using PSIM Tool of MPPT-PV Feedback-Current Controller

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Abstract

This paper presents improvement tests based in a feedback-current controller designed to Tracking Maximum Power Point in photovoltaic system (MPPT-PV). Previously, a version was developed exhibiting results satisfactory in simulation and through of a low cost prototype. Now, using a sophisticated physical model of solar cell available in PSIM program is shown other cases, considering variations both irradiation and temperature to evaluate successfully the controller. The results show that its system is suitable under dynamical changing atmospheric conditions operating with effectiveness acceptable.

Keywords

1. Introduction

A MPPT (Maximum Power Point Tracking) controller is most effective solution used to maximize the power extracted from PV modules under atmospheric conditions [1]-[5]. Although some MPPT methods are applicable for rural applications, they are implemented using powerful ICs, microprocessors or DSP (digital signal processor) [6]-[9]. Consequently, topologies mentioned are not the best for applications in underdeveloped countries, where the cost is a fundamental issue and where a highly trained installation and maintenance personnel is not easily available. As solution, a special feedback-current controller designed to operate as a MPPT system is developed [10], which is a circuit highly efficient, simple, rugged, low cost design, and ideal for applications in isolated locations in the less developed countries. This paper presents improvement tests using PSIM [11], a simulation program which allows additional verifications, specially focused to evaluate of the MPPT behavior

under some perturbations not considered previously [10]: insolation changes, temperature variations and dynamical response of the controller. New simulation tests prove that the proposed controller can achieve effective, precise and fast response, being a part of the essential characteristics of a MPPT unit, specifically when is oriented to be used in an isolated place.

2. System Description

Figure 1 shows the MPPT circuit using PSIM models. The main blocks used are: a sophisticated PV model available in PSIM, a simple power stage represented by an average model DC/DC converter (step-down topology), the MPPT controller constituted for a generic regulator, filtering stages and finally, simplest representation of a battery bank.

DC/DC converter is modeled using controlled sources of voltage *VCVSV*1 and current *IVCCSV*1. Both configurations depend on the duty cycle signal provided by the MPPT regulator. Its unit only requires measurement of the current I_{sal} which is proportioned for solar cells array. The controller structure is based on the model equations explained in a next section.

Connecting adequate sources on *S* and *T* terminals available of solar cell module is feasible simulate changing conditions of irradiation and temperature respectively. Either *S* or *T* can be configured independently using different profiles: fixed, staircase-ramp type, piecewise linear and with triangular variations.

Acquiring and comparing P_{max} and P_{out} signalsis possible evaluate the tracking method proposed under different operational conditions.

2.1. Solar Module Physical Model (PSIM)

Although physical and functional models are available in PSIM, the first option can simulate the behavior of the solar module more accurately, and can take into account the light intensity and temperature variation. Some parameters required are: number of cells, maximum power, voltage and current in maximum power, open-circuit voltage, short-circuit current, standard light intensity, reference temperature, internal resistances, bang energy, ideality factor, temperature and light coefficients.

Both light intensity and ambient temperature are incoming externally. Default parameters used in simulations test are listed in **Table 1** [12].

The node *S* refers to the light intensity input (W/m^2), and the node *T* is the ambient temperature input (˚C). The node on the top is theoretical maximum power given the operating conditions. While the positive (+) and negative (−) terminal nodes are power circuit nodes.
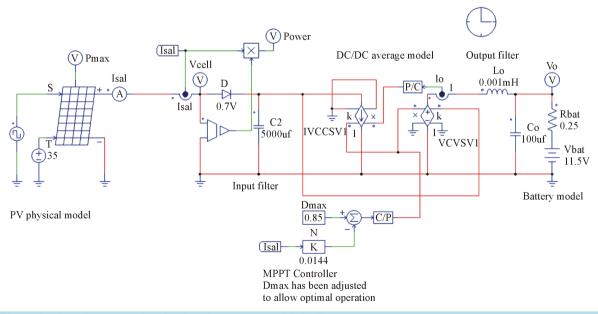

Figure 1. PSIM diagram used to simulate the MPPT-PV with feedback-current.

Table 1. Solar module (physical model)[a].

Manufacturer Datasheet	Parameter	Specified Valued	Unit
	Number of Cells Ns	36	
	Maximum Power Pmax	60	W
	Voltage at Pmax:	17.1	V
	Current at Pmax:	3.5	A
	Open-Circuit Voltage Voc:	21.1	V
	Short-Circuit Current Isc:	3.8	A
	Temperature Coeff. of Voc:	−0.38	%/°C
	Temperature Coeff. of Isc:	0.065	%/°C
Model Parameters (Defined)	Parameter	Specified Valued	Unit
	Band Energy Eg:	1.12	eV
	Ideality Factor A:	1.2	
	Shunt Resistance Rsh:	1000	Ω
	Coefficient Ks:	0	
Model Parameters (Calculated)	Parameter	Specified Valued	Unit
	Series Resistance Rs:	0.008	Ω
	Short Circuit Current Isc0:	3.8	A
	Saturation Current Is0:	2.16e−8	A
	Temperature Coefficient Ct:	0.00247	A/K

[a]PSIM tutorial. How to use solar module physical model.

The equations that describe a solar cell are:

$$i = I_{sc0}\left(\frac{S}{S_0}\right) + C_t \cdot \left(T - T_{ref}\right) - I_0\left(e^{\frac{qv_d}{AkT}} - 1\right) - \frac{v_d}{R_{sh}} \tag{1}$$

where

$$I_0 = I_{sc0}\left(\frac{T}{T_{ref}}\right)^3 \cdot e^{\frac{qE_g}{Ak}\left(\frac{1}{T_{ref}} - \frac{1}{T}\right)} \tag{2}$$

$$v_d = \frac{v}{N_s} + i \cdot R_s \tag{3}$$

and

$$T = T_a + k_s \cdot S \tag{4}$$

Defining q: electron charge ($q = 1.6 \times 10^{-19}$ C); N_s: corresponding to solar cells connected in series; C_t: temperature coefficient (°C); k: Boltzmann constant ($k = 1.3806505 \times 10^{-23}$); R_s: series resistance of each solar cell (Ω); A: ideality factor; R_{sh}(Ω): shunt resistance of each solar cell; S_0: light intensity under standard test conditions; E_g: band energy of each solar cell (eV); T_{ref}: temperature under standard test conditions (°C); v_d is the vol-

tage that appears on R_{sh}; $v(V)/N_s$ is the across the entire solar module; and $i(A)$ is the current flowing out of the positive terminal of solar module [11].

2.2. Feedback-Current Controller

MPPT strategy works as follows. The proposed MPPT based on output current measurements taking into account the theoretical straight line connecting the maximum power points in the PV panel characteristics. Specifically considering a couple points of power and voltage given by p_1: 11.12W, v_1: 15.31V and p_2: 69.38W, v_2: 16.32 V, is possible establish the load power as:

$$p(v) = 57.68v_d - 872 \tag{5}$$

According MPPT strategy previously presented [10], then $D_{control}$ or duty cycle expression is determined by:

$$D_{control} = D_{max} - N_s I_{sal} = 0.832 - 0.0144 I_{sal} \tag{6}$$

where D_{max} is a constant; and I_{sal} is the current generated according to Equation (1).

3. Simulation Tests

A first test is focused to evaluate MPPT behavior under temperature variations. When T_a is adjusted, tracker function is kept close such to PV power available as is illustrated in **Figure 2**. Temperature ranges adopted specifically between 25˚C - 40˚C, correspond to environmental conditions in isolated locations at south of Venezuela, regularly registered in some regions at Bolivar State. Under such circumstances the efficiency corresponds to 98.88%.

A second evaluation is realized to verify the possible impact when solar irradiance changes linearly, simulated through triangular waveform with amplitude range between 100 to 1100 W/m^2, applied as input signal to "S" terminal of solar cell model. **Figure 3** illustrate an acceptable tracking capability of designed controller. The theoretical maximum available power is 63.6357W, the extracted power is 63.3713W, and the MPPT efficiency is 99.58%.

Regarding to dynamic test, the MPPT controller respond quickly under step change of solar irradiance as is showed in **Figure 4**.

Finally, is considered a staircase function as irradiation over solar cell but adjusting simultaneously a temperature range between 25˚C to 45˚C.When upper temperature is reached, the theoretical maximum available power is 60.648W, the extracted power is 58.292W, and therefore the MPPT efficiency is 96.11%, such as showed in **Figure 5**. Although the extracted power value has been reduced, the tracker system continues operating satisfactorily.

Because significant modifications are not required, the control system can be implemented with conventional PWM regulators [10].
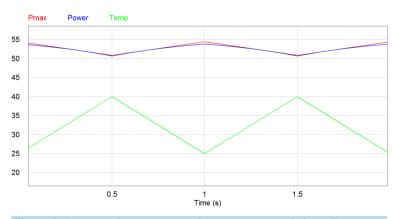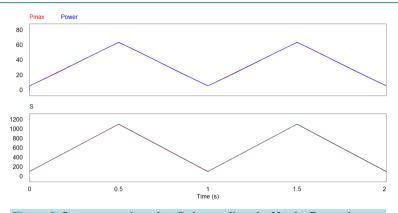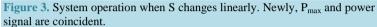

Figure 2. Power tracker response under temperature variations. Top traces: superimposed signals P$_{max}$ and extracted Power. Bottom trace: temperature profile applied.
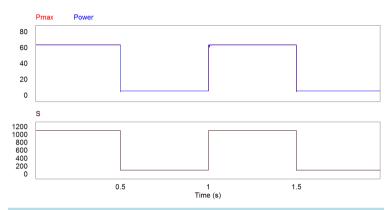
Figure 3. System operation when S changes linearly. Newly, P_{max} and power signal are coincident.

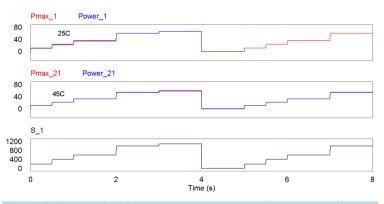**Figure 4.** Step change solar irradiance evaluation.

Figure 5. Staircase function as incoming signal over S terminal available in solar cell model. Simultaneously, a parameter sweep analysis is used in order to produce temperature variations considering a range between 25˚C to 45˚C.

4. Conclusions

MPPT controller reveals that it operates satisfactorily during each test realized. The controller is efficient but also optimizes energy production of PV array. However, just like any off-line techniques, it requires manufacturer data sheet of solar cell connected.

Under conditions considered, it is feasible to install the MPPT controller in isolated locations although atmospheric perturbations persist.

Although the design does not require a compensation stage, nevertheless, a simple network could be added to adapt the circuit to temperature changes.

Acknowledgements

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