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A Perturb and Observe Based Solar MPPT System for Stand-alone Applications

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Abstract— **Solar energy can be projected to be beneficial only when used to its full potential. The power obtained from the solar panel can be maximized by operating it under Maximum Power Point (MPP). Of various MPP tracker algorithms, Perturb and Observe (P&O) is the standard. Though easier in implementation, P&O drifts from MPP in fast changing atmospheric conditions. This paper proposes a P & O based MPPT algorithm which has improves the dynamic performance of P&O algorithm. The output power of the solar panel is used for tracking MPP thus reducing the complexity of the algorithm. This paper presents a battery charger system using buck converter. Here a microcontroller dsPIC30F4011 is used as MPPT controller to efficiently charge the lead acid battery from solar panel. The proposed charger system is economical and is appropriate for domestic applications. Analytical results shows significant increase in power harnessed from solar panel using the proposed algorithm.**

Keywords— Perturb and Observe algorithm, MPPT system, Stand-alone, Battery.

I. Introduction

Solar energy is a clean, a maintenance-free, and an abundant source of energy. However, there are some shortcomings: the installation costs of solar panels are high and conversion efficiency is low. Therefore, to make it feasible, it becomes important to maximize the utilization of the arrays. The utilization of solar photovoltaic (PV) cells is fettered by the fact that the power versus voltage (P–V) curve in solar cells has unique maximum point at a particular operating voltage. Moreover, the peak available power varies with solar insolation and ambient temperature. Maximum power point trackers (MPPTs) are, therefore, engaged to track this peak power and transfer it to the load at all times. An MPPT is basically a dc–dc converter whose duty cycle is adjusted for drawing the correct amount of current so that the system functions at the MPP. The operating voltage and current are detected and fed to the control unit for the computation of duty cycle corresponding to the optimal instantaneous operating point. Of the several algorithms proposed in the literature for an optimal adjustment of the duty cycle, the most popular technique is the real-time realization of the gradient following method termed perturb and observe (P&O) algorithm and used widely for the MPPT.

The P&O algorithm has the advantage of software and hardware realization. In this implementation, the reference voltage (V_{ref}) is perturbed in an arbitrary direction and the power levels of two consecutive samples are compared. Depending upon the sign of the power change, the direction for further perturbation is decided. A feedback control loop ensures that the output voltage tracks its reference.

The drawback of this algorithm in which instantaneous power level is evaluated to decide search direction is drift. During changing atmospheric conditions, these algorithms allow the operating point to drift away from the MPP. This problem is addressed by the incremental conductance method. Incremental conductance algorithm locates the MPP by searching for an operating point. Claimed to be a more advanced algorithm, its hardware and software implementation is reasonably complex. Though Incremental conductance is considered superior to all others, it has been shown that the efficacy of the P&O algorithm is approximately equal to the more complex Incremental conductance algorithm. The sampling time is manipulated according to the dynamics of the converter system. Although more accurate, this requires the calculation and knowledge of the intrinsic transient oscillation time of the system. In the actual implementation, design time tunable parameters have to be introduced and dynamics versus steady-state tradeoff has to be satisfactorily addressed. Moreover, a variable sampling frequency makes scheduling of MPPT algorithms in processors difficult in a multitasking system.

Steady state oscillations at MPP can be eliminated by evaluating power at multiple operating points. Amendments to P&O algorithm have been proposed to evaluate the previous history of operating points or perturbation and evaluation of multiple operating points to identify oscillations. These techniques, although simple, do not address the issue of tradeoff directly. To handle diverse requirements at startup and steady state, hybrid algorithms have also been proposed to improve startup dynamics. These techniques require somewhat complex computation to bring the system to a region near the MPP and then, allow conventional algorithms to take over and gradually bring the operating point to the MPP.

In this paper, novel techniques are proposed to eliminate drift condition and dynamics versus tracking tradeoff. Strategies are also proposed to automate tuning parameters such as scaling factor (M) which simplifies the design of the MPPT. The proposed algorithms are implemented using a hardware system that extends to the present environment to allow the performance evaluation of proposed algorithms as part of a larger power processing system.

II. Literature survey

Esram et al. [1] had discussed various MPPT algorithms in the literature. A detailed comparison has been on major characteristics of MPPT algorithms and a note on suitable application for each MPPT had been proposed. From [1], the most preferred MPPT algorithm for battery charging applications is Perturb and Observe (P&O) and Incremental conductance method.

The operation of MPPT controller is based on the DC-DC converter used. The DC/DC converters are widely used in photovoltaic generating systems as an interface between the photovoltaic panel and the load, allowing the follow-up of the maximum power point (MPP).To extract the maximum power, the load must be adjusted to match the current and voltage of the solar panel. The converter must be designed to be connected directly to the photovoltaic panel and perform operation to search the maximum power point (MPPT). Kothak et al. [2] had introduced a DC/DC converters together with maximum power point tracking systems (MPPT) to avoid these losses. Manju et al. [3] had presented the PV charger system using Buck-Boost converter with control design and modeling. The battery charging loop and maximum power point tracking PV module control loop are used to determine the voltage command. The output power of the PV panel is utilized efficiently and the battery is charged in three charging stages. This is done by a controller which is designed such that the power flow is balanced from PV module to the battery. This paper had evaluated the performance of photovoltaic modules in non-ideal conditions and had proposed topologies to minimize the degradation of performance caused by these conditions. A new MPPT system consisting of a Buck-type dc/dc converter, which is controlled by a microcontroller-based unit, is developed by Koutroulis et al. [4]. The resulting system had high efficiency, lower cost and is easily modified to handle more energy sources.

The MPPT controller designed can either be analog or digital. Jiang et al. had designed an analogue Maximum Power Point Tracking (MPPT) controller for a Photovoltaic (PV) solar system that utilizes the load current to achieve maximum output power from the solar panel [5]. Comparing to the existing MPPT controller circuitry which requires multiplication of the sensed PV panel voltage and current to yield panel power, the cost and size of the system can be reduced. Koutroulis et al. [4] had developed a microcontroller based MPPT controller. The microcontroller based MPPT controller has significant advantages over analog controller in terms of computational speed and efficiency.

The P&O algorithm though simple in implementations has severe drawbacks such as inefficienct tracking under fast changing atmospheric conditions and partial shaded conditions. Xiao et al. [6] had found that the peak power point of a module is significantly decreased due to only the slightest shading of the module, and that this effect is proliferated through other non shaded modules connected in series with the shaded one. Murtaza et al. [7] had addressed the problematic behavior of P&O technique and hence had presented a novel MPPT hybrid technique that had combined both P&O and Fractional Open Circuit Voltage (FOCV) technique in order to overcome the inherited deficiencies found in P&O technique. The proposed MPPT technique was much more robust in tracking the MPP even under the frequent changing irradiance conditions and was less oscillatory around the MPP as compared to P&O.

Modifications had been made in P&O algorithm to rectify the above mentioned problems by Pandey et al. [8]. He had proposed the Perturb and Observe algorithm with variable step size. His algorithm had worked efficiently under rapidly changing surrounding conditions. It had eliminated dynamics and trade off by examining the entire situation in panel power versus panel voltage curve. The FulCurve algorithm had handled drift situation effectively because it entirely evaluates the curve at an isolation level. Such variable step sized algorithms have better performance when compared to conventional P&O algorithm.

III. Proposed Approach

An overall block diagram of the proposed system is shown in Fig. 1. The proposed system comprises of a dc-dc buck converter interfaced with the solar PV panel and a battery. The duty ratio of power converter is tuned by the microcontroller to achieve the maximum power point of the solar panel. The maximum power which is extracted by the converter is fed to the battery for charging. A DC load is connected to the battery. The implementation of the hardware model has been discussed later.

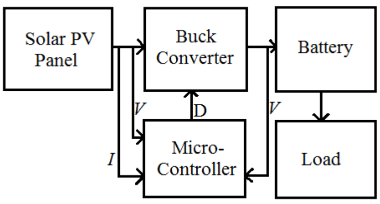

Fig. 1. Overall block diagram of the proposed system

IV. Implementation

A prototype of an MPPT system is built to project the results of improved Perturb an Observe solar MPPT. The various hardware components used in the MPPT system are described in this section.

A. *System Design*

For duration of 10 hours a load of 50W is connected to the PV panel. Total energy required for the load is, 500Wh. Ministry of New and Renewable Energy (MNRE) gives the peak sun hours in the tested station as 5 hours. Hence 500W of power is to be generated per hour. According to nominal operating conditions a panel gives an output maximum of 50W. Therefore, to get a power of 100W in an hour, the number of solar PV panels required is 2. So the panels are connected in series combination.

B. *Panel Specifications*

From the data sheet of the solar PV panel at the Normal Operating Cell Temperature (NOCT), (irradiance 800W/m^2, Air mass 1.5 units, wind speed 1m/s)

Maximum Power,	P_{max}=53W
Voltage at maximum power,	V_{mpp}=15.4V
Current at maximum power,	I_{mpp}=3.42A
The open circuit voltage,	V_{OC}=21.1V
The short circuit current,	I_{SC}=4.1A

By referring to the datasheet of the PV panel an amorphous type solar PV panel is suitable for the proposed application. Hence an amorphous type solar PV panel is used.

C. *Battery Specifications*

A 150Ah lead acid battery is used to supply the load. Since the converter gives an output voltage of 12V and energy of 500Wh, the current through the battery is 41.67A. Hence a 150Ah battery can withstand a 41.67Ah energy and so it is opted.

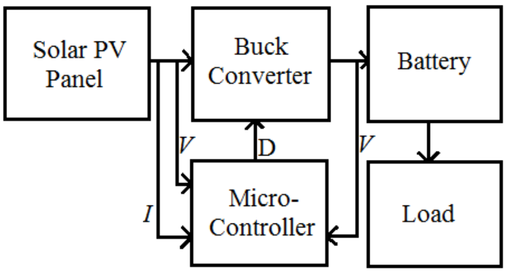

Fig. 2 Block diagram of the proposed model

D. *DC-DC Buck Converter*

The buck converter is a DC to DC converter. It comprises of the following components as shown below in Fig. 3

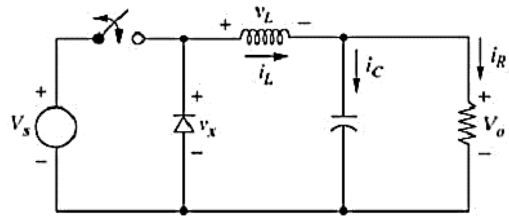

Fig. 3 Circuit diagram of Buck Converter

The specified datas for designing the buck converter is as follows,

Switching frequency,	f_S=20 kHz
Source voltage,	V_S=42.2V
Output voltage,	V_o=12V
Average current,	I=4.1A
Ripple current,	ΔI=0.902A
Ripple Voltage,	ΔV=100mV

From the above specified values by taking the Duty ratio D, into account as zero,

$$L = \left(\frac{V_0(1-D)}{\Delta I \times f_S} \right) \quad (1)$$

The value of inductor is calculated from the equation (1) and the value is,

$$L = 665.18 \mu H$$

$$C = \left(\frac{V_0(1-D)}{8L\Delta V f_S^2} \right) \quad (2)$$

From the inductor value the corresponding capacitor value which has been calculated from equation (2) is,

$$C = 56.37 \mu F$$

To implement the calculated value of the inductor, the following things should be known such as core material, material type, size, window area, winding area and the number of turns. EE type core of ferrite material has been chosen and the other parameter has been calculated.

Energy stored in an inductor,

$$E = \frac{1}{2} L i^2 \quad (3)$$

E = 0.0326 joules

Area product is

$$A_P = \frac{2 \times E}{K_W K_C J B_M} \quad (4)$$

Since the ferrite core is selected for the design of inductor their corresponding values of K_W , K_C , J and B_M are

$$K_W = 0.6$$

$$J = 3\times10^6 A/m^2$$

$$B_M = 0.25T$$

$$K_C = 1.1612$$

$$P = \frac{\mu_0 \mu_r A_C}{l_m + \mu_r l_g} \quad (5)$$

By substituting the above values in the area product equation the value of area product have been found to be, $A_P = 90027.006mm^4$. From the area product, the value of the core has been found from the table, E65/32/13 and the corresponding core and window areas have been found to be $266\times10^{-3} m$ and $537\times10^{-3} m$ respectively. The permeance can be calculated from the equation (5), where, $l_m = 146.3\times10^{-3} m$ air gap length $l_g = 0.5\times10^{-3} m$, relative permeability for ferrite core $\mu_r = 1500$ and $\mu_0 = 1.2566\times10^{-6}$. By introducing these values into the permeance equation, the value of permeance is found to be $P = 5.594\times10^{-7}$ wb /AT.

$$N = \sqrt{\frac{L}{P}} \quad (6)$$

The number of turns can be calculated from the permeance and the inductance values by using the equation (6). Hence the number of turns for the inductor has been found as 35 turns.

E. ***Implementation of MPPT Algorithm***

This section covers about MPPT algorithm formulated by Pandey et al. [1].

1) **Choice of the Microcontroller**

dsPIC30F4011 microcontroller from Microchip has been chosen for implementations. It has a 10 bit ADC with 4 Sample and Hold circuits and allows simultaneous sampling. The MAC unit in the above mentioned controller aids computation with single instruction cycle multiplication. The enhanced flash memory and 30 MIPS operation of dsPIC30F4011 enables efficient tracking of MPP.

2) **MPPT algorithm:**

Pandey et al. [1] had prposed a variable step sized P&O algorithm. It samples the panel voltage and panel current at three different time period. Let Va , Ia and Pa be panel voltage, panel current and panel power respectively at an instance. The panel voltage, panel current and panel power at the next consecutive instances is representd by the sub script b and c respectively. Let D be the duty ratio of PWM signal generated to control the buck converter. Let Dmax be the maximum possible duty cycle and M be the factor which decided the step size of duty ratio. The variable step sized algorithm is shown in Fig. 5.

3) **Pseudocode**

The algorithm for tracking MPPT is given below.

Input: Panel voltage V_p and I_p

Output: Duty cycle of PWM signals for buck converter

1: Initialize V_a =0, V_b =0, V_c =0, I_a =0, I_b =0, I_c =0, P_a =0, P_b=0, P_c=0, D=.05, M=0.4, D_{max}=0.4

2: assign V_a =V_p and I_a=I_p

3: Increment duty cycle by 0.05

4: assign V_b =V_p& I_b=I_p

5: Increment duty cycle by 0.05

6: A: Read V_c & I_c

7: Compute P_a=V_a*I_a, P_b=V_b*I_b, P_c=V_c*I_c

8: Compute $M = \left(\frac{(V_c - V_b) D_{max}}{P_c - P_b} \right)$

9: **If** P_a<P_b and P_b<P_c,

10: Compute $D = D + \left(\frac{M(P_b - P_a)}{V_b - V_a} \right)$

11: **Else If** P_a>P_b and P_b>P_c

12: $D = D - \left(\frac{M(P_b - P_a)}{V_b - V_a} \right)$

13: assign V_a=V_b

14: assign V_b=V_c

15: assign I_a=I_b

16: assign I_b=I_c

17: **Goto** A

4) Flow Chart

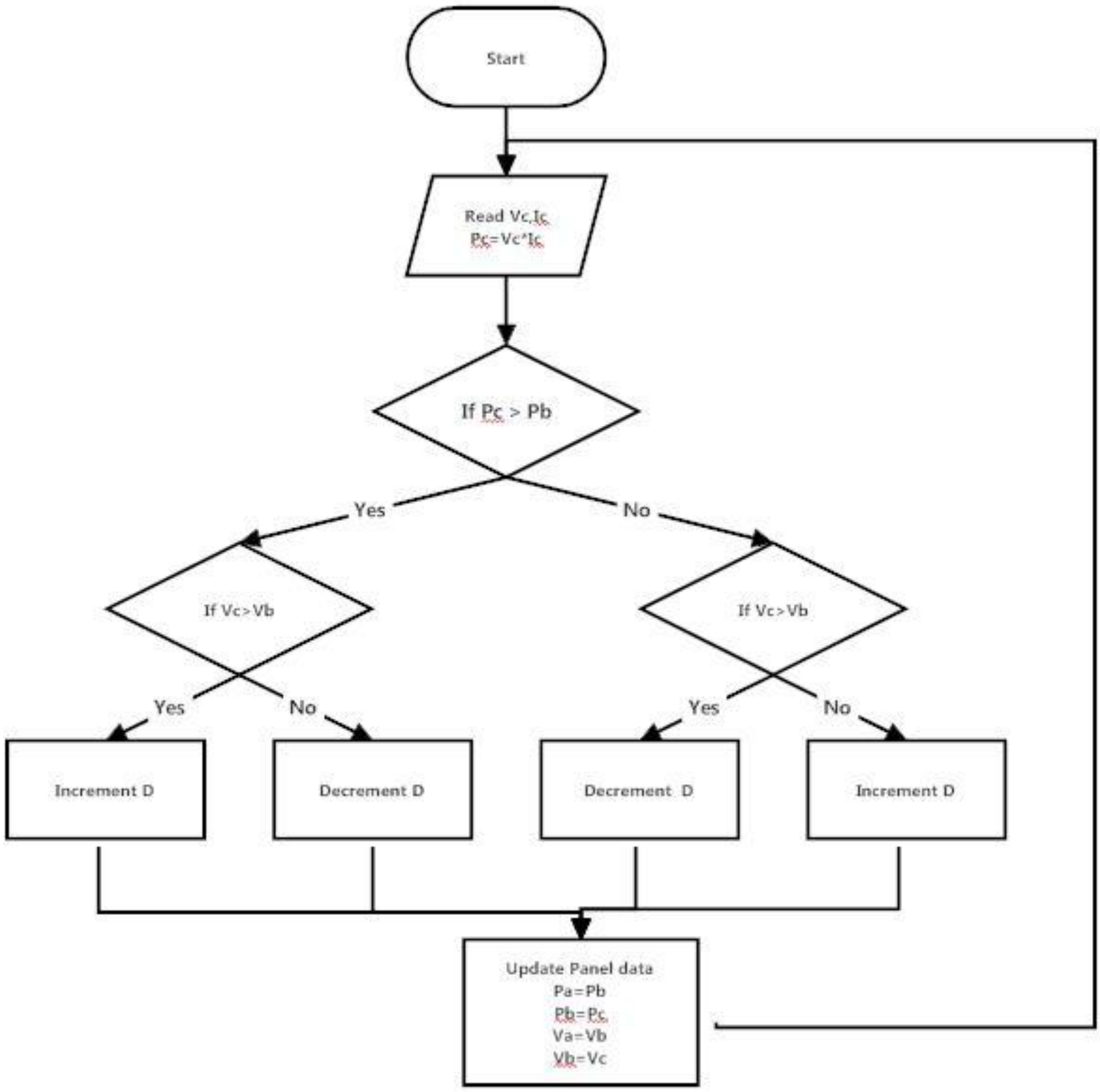

Fig 4. Flow Chart of variable step sized MPPT algorithm.

Arduino board has been used to test the implemented perturb and observe algorithm. The maximum power point of the solar panel under operated atmospheric conditions is found by operating the system in open loop configuration. In open loop configuration arduino board is used to generate PWM signals for buck converter. . The arduino board is programmed to vary the duty ratio of PWM and record the panel voltage and panel current at corresponding duty ratios. The measured readings are used to plot the P-V curve of the solar panel under tested atmospheric conditions. Figure 5 shows the P-V characteristics of solar panel. The maximum power from figure 5 is found to be 95.08W.

Under the same atmospheric condition, the power delivered by the solar panel in the implemented MPPT system is 91.52 W. The efficiency of the MPPT algorithm is the ratio of total power drawn to the maximum power available from the panel. The efficiency of the implemented MPPT algorithm is 96.27%.

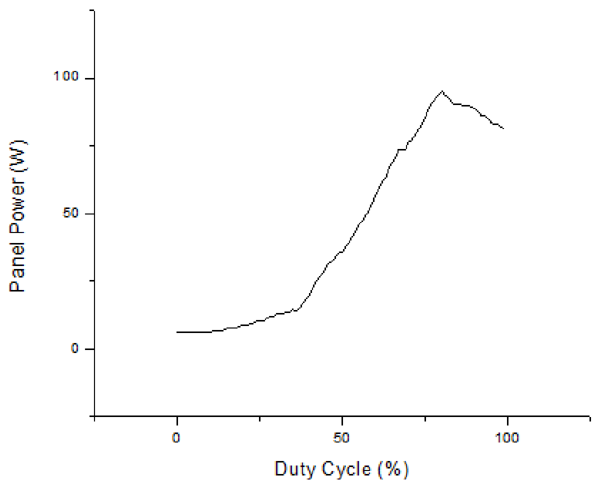

Fig.5 P-V characteristics of solar panel under tested atmospheric conditions.

V. Conclusion

A simplified perturb and observe based Solar MPPT charge controller is implemented and tested in this paper. The performance of the implemented perturb and observe based MPPT algorithm eliminates important draw backs of MPPT algorithm such as drifting under varying atmospheric conditions. The risk of huge oscillations at maximum power point is reduced by the dynamic update of step size in perturb and observe algorithm. . The improved performance with the ease in implementation makes the proposed MPPT system inexpensive and profitable

This paper deals with battery charging application which is preferred for stand-alone applications. The same algorithm can be extended to grid interconnected MPPT systems. Though variable step sized P&O algorithm has improved tracking speed, hybrid algorithms such as variable step size P&O with fractional open circuit voltage or fractional short circuit method can be introduced. These hybrid algorithms can improve the converging speed under partial shaded conditions and fast varying atmospheric conditions.

References

[1] Trishan Esram and Patrick L.Chapman, "Comparison of Photovoltaic Array Maximum Power Point Tracking Techniques," *IEEE Transactions on Energy Conversion*, Vol. 22, No. 2, June 2007.

[2] V.C. Kothak and Preti Tyagi, "DC To DC Converter in Maximum Power Point Tracker," *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, Vol. 2, Issue 12, December 2013.

[3] B. Sree Manju, R.Ramaprabha and Dr.B.L.Mathur, "Modelling and Control of Standalone Solar Photovoltaic Charging System," *Proceedings of ICETECT*, Nagercoil, 2011.

[4] Eftichios Koutroulis, Kostas Kalaitzakis and Nicholas C. Voulgaris, "Development of a Microcontroller-Based, Photovoltaic Maximum Power Point Tracking Control System," *IEEE Transactions on Power Electronics*, Vol. 16, No. 1, Jan. 2001.

[5] Yuncong Jiang, Ahmed Hassan, Emad Abdelkarem and Mohamed Orabi, "Load Current Based Analog MPPT Controller for PV Solar Systems," *Applied Power Electronics Conference and Exposition (APEC)*, 2012.

[6] Weidong Xiao, Nathan Ozog and William G. Dunford, "Topology Study of Photovoltaic Interface for Maximum Power Point Tracking," *IEEE Transactions on Industrial Electronics*, Vol. 54, No. 3, June 2007.

[7] Ali F Murtaza, Hadeed Ahmed Sher, et al., "A Novel Hybrid MPPT Technique for Solar PV Applications Using Perturb & Observe and Fractional Open Circuit Voltage Techniques," 2012..

[8] Ashish Pandey, Nivedita Dasgupta and Ashok Kumar Mukerjee, "High-Performance Algorithms for Drift Avoidance and Fast Tracking in Solar MPPT System," *IEEE Transactions on Energy Conversion*, Vol. 23, No. 2, June 2008.

[9] Arash Shafiei, Ahmadreza Momeni and Sheldon S. Williamson, "A Novel Photovoltaic Maximum Power Point Tracker for Battery Charging Applications," *25th Canadian conference on Electrical and computer Engineering*, Montreal, 2012.

[10] Chihchiang Hua, Jongrong Lin, Chihming Shen, "Implemenation of a DSP-Controlled Photovoltaic System with Peak Power Tracking," *IEEE Transactions On Industrial Electronics*, Vol. 45, No. 1, February 1998.

[11] Eftichios Koutroulis, Kostas Kalaitzakis and Nicholas C. Voulgaris, "Development of a Microcontroller-Based, Photovoltaic Maximum Power Point Tracking Control System," *IEEE Transactions on Power Electronics*, Vol. 16, No. 1, Jan. 2001.

[12] Roger Gules, Juliano De Pellegrin Pacheco and Hélio Leães Hey, "A Maximum Power Point Tracking System with Parallel Connection for PV Stand-Alone Applications," *IEEE Transactions on Industrial Electronics*, Vol. 55, No. 7, July 2008.