A NEW APPROACH FOR MAXIMUM POWER POINT TRACKING

Edson de Paula Carvalho, edson-carvalho@oi.com.br
Pedro Paulo Leite do Prado, pplprado@iee.org
João Bosco Gonçalves, jbgoncal@unitau.br
Universidade de Taubaté – UNITAU – Rua Daniel Danelli, s/n, Jardim Morumbi, 12060-440, Taubaté, SP, Brasil

Abstract. *It is well known that photovoltaic generation is a renewable source of energy that offers many advantages, such as, absence of noise and pollution, relatively little maintenance and inexhaustibility. On the other hand, there are still some challenges to address: the size of the panels, the high cost of the system, the intermittent nature of the source, and mainly, the low stability and power-conversion efficiency. The research and development of new materials has been intense and has produced good results. Still, it remains very important to increase the conversion efficiency through the maximization of the input solar radiation and the optimization of the photovoltaic generator operating point. There are many methods for tracking the maximum power point (MPP) of different DC/DC converters: direct (sampling, modulation), non direct ways (curve fitting, lookup table, open circuit voltage, etc), fuzzy logic, etc. We present a new MPP seeking strategy, suitable for any DC/DC converter output configuration and capable to follow eventual rapid changing atmospheric conditions. Our MPP tracking approach measures only the photovoltaic generator current to control the duty cycle variation. A simple flag system guarantees the perfect tracking, under changing insolations and ambient temperatures. With few initial interactions the MPP is almost reached. Then, a fine tuning is carried out. The preliminary simulation tests carried out by Simulink/Matlab® proved good, confirming the advantages of this novel MPP tracking method.*

Keywords*: MPP, photovoltaic power, optimization*

1. INTRODUCTION

The greenhouse effect, the pollution caused by industries and vehicles, the growing demand of energy and other environment issues have boosted the research and development of sustainable energy supply technologies and systems.

The photovoltaic (PV) energy has been considered one of the most promising solutions for the worrying global environment conditions (Sen, 2008). Really, photovoltaic energy offers many advantages, such as, no fuel costs, lack of pollution, emissions and noise, ease maintenance, low operating costs, distributed allocation, ambient temperature operation, modularity, huge public acceptance, high module reliability, etc.

On the other hand, there some disadvantages to overcome: high installation costs, intermittent nature of the source, low-density energy of sunlight, poor storage reliability and mainly, the low stability and power-conversion efficiency.

So, at present one of the research branches is involved with the manufacturing, materials and technology of the photovoltaic cells: single-crystalline and polycrystalline silicon (c-Si); amorphous silicon (a-Si, thin-film technology); GaAs (Gallium Arsenide) and GaInP (Gallium Indium Phosphide), used mainly with sunlight concentrators; CdTe (Cadmium Telluride) and CIS (polycrystalline semiconductor compound of Copper, Indium and Selenium), both with thin-film technology, etc (Luque and Hegedus, 2003). The third-generation photovoltaic cells, divided into DSSC (Dye-Sensitized Solar Cell), organic, and polymer solar cells. The main research goals are to increase the conversion efficiency of the solar cells and produce low cost panels.

Besides, the solar energy varies yearly, with the geographic location and within the seasons of the year, during day and night and during a day, due to the weather conditions, clouds, radiation reflections, shadows, etc. The variations of atmospheric conditions (insolation and ambient temperature) can be sometimes fast. Consequently, there are two more major research topics to address: the control of the panel position in order to track the direction of maximum sunlight intensity (solar trackers) and the control of the maximum power point (MPP) of the photovoltaic system, in order to follow the rapid variations. The photovoltaic system is composed by a panel, an electronic inverter and a storage device. Our project aims at developing a new maximum power point tracking (MPT) approach.

1.1. Photovoltaic cell model

Figure 1 shows the equivalent electric circuit of the photovoltaic cell and Eq. (1) is its nodal variable analysis (Blas et. al., 2002). The shunt resistance r_p is neglected, since it is high enough to assure a very small leakage current to the ground. This way, the last term of equation can be deleted. So, for a panel composed by N cells, Eq. (2) is adopted .

$$i = i_{ph} - i_o \ [\exp(\frac{v + r_s\, i}{A V_t}) - 1] - \frac{v + r_s\, i}{r_p} \tag{1}$$

where i represents the output current of the PV, v is output voltage of the PV, i_o is the reverse saturation current, r_s and r_p are the series and shunt resistance of the cell, A is the cell area and Vt is the thermal voltage, Vt = (n K Tk) /q , where ; q is the electron charge ($1{,}6\ 10^{-9}$ C); n is a dimensionless factor (1,75 for amorphous silicon or 2 for crystalline silicon); K is the Boltzmann constant ($1{,}38\ 10^{-23}$ J/K), and Tk is the absolute cell temperature (K).

$$i = i_{ph} - i_o \ [\exp(\frac{v + N\, r_s\, i}{AN\, V_t}) - 1] \tag{2}$$

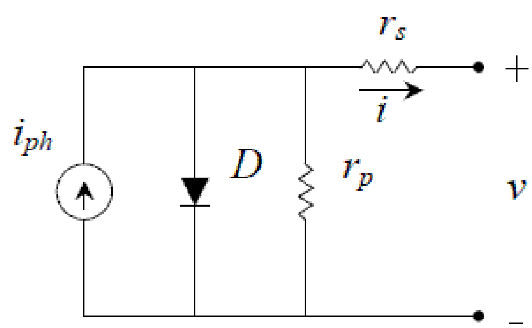
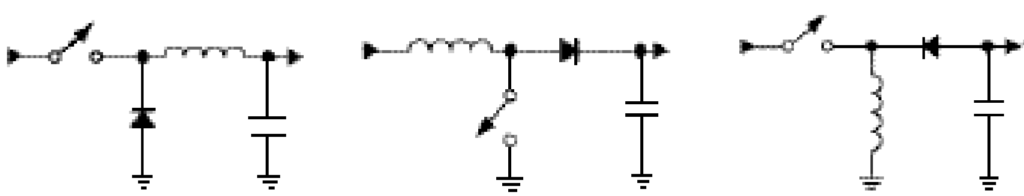


Figure 1. Equivalent electric circuit of the photovoltaic cell

1.2. DC/DC Converters

Our approach for MPP tracking is suitable for any switching regulator topology: buck (step-down), boost (step-up), inverter (flyback) and others. Figure 2 illustrates the main topologies (Maxim, 2001). The steady-state output is controlled by varying the converter duty cycle, commonly using PWM (Pulse-Width Modulation).



(a) Buck (b) Boost (c) Inverting

Figure 2. DC/DC converters topology

The equations for the three topologies are:

buck: Vo = D Vi (3)

boost: Vo = Vi /(1 - D) (4)

inverter: Vo = Vi D / (1-D) (5)

2. MAXIMUM POINT TRACKING (MPT)

There are many methods for tracking the maximum power point (MPP) of different DC/DC. The methods can be classified according to the number of control variables or the control strategy (Salas *et al*., 2006).

Table 1 summarizes their main characteristics for comparison purposes.

Table 1. MPP Methods

Classification	Methods	Disadvantages
Indirect Methods: based on database parameters and empirical data	**curve fitting**: off-line modeling of nonlinear characteristics of a photovoltaic generator	- resolution implies difficult control; - requires previous knowledge of physical parameters
	look-up table: storage of MPP values	- large memory; - fitted to a specific panel
	open-circuit voltage PV generator: linear proportionality between generator voltage and open-circuit voltage	- proportional constant is specific for each technology and meteorological conditions - the real power is not exact
	open-circuit voltage PV generator: linear proportionality between generator current and short-circuit current	- same as the open-circuit voltage PV generator
	open-circuit voltage photovoltaic test cell: generator's open-circuit voltage measurement.	- test supposes identical cells and can be incorrect
Sampling Methods (direct method): samples of PV´s generator current and/or voltage and comparing of successive output powers	**differentiation**: equation	- requires fast calculations and measurements
	feedback voltage or current: adjustment of the duty cycle of the DC/DC converter	- cannot adapt to sudden irradiance and temperature variations - system cannot use batteries.
	perturbation and observe (P & O): measurement and perturbation to find change direction	- cannot adapt to sudden irradiance and temperature variations
	incremental conductance: based on P & O method, uses I_{PV} /V_{PV} to determine the sign of [d (P_{PV}) / d (V_{PV})]	- complex control circuit
	parasitic capacitance: similar to the incremental conductance method, including the parasite capacitance	- complex control circuit
	current measurement: measurement only of the PV current	- simple only for buck converters
Modulation Methods	**forced oscillations**: a small voltage is added to the PV generator operation voltage	- complex implementation
Artificial Intelligent Methods	**fuzzy logic and neural networks**	- measurement of 2 variables: voltage and current - complex implementation

3. PROPOSED MPT APPROACH

We devised a novel MPP seeking strategy, suitable for any DC/DC converter topology and capable to follow eventual rapid changing atmospheric conditions.

Our MPP tracking is a one-variable control method. The approach measures only the photovoltaic generator current. Figure 3 is self explanatory. A simple flag system guarantees the perfect tracking, under changing insolations and ambient temperatures. With few initial interactions the MPP is almost reached. Then, a fine tuning is carried out.

The dashed lines and boxes (blue) in the flowchart refer to the flag action , while the dotted lines and boxes show the final tuning phase. Figure 4 illustrates the simulation of the adaptation to MPT to the sudden changes in the insolation level and temperature. The dashed arrows (red) shows the possible transitions from power curve 1 (continuous line, red) to the other curves (insolation or temperature sudden increase or decrease).

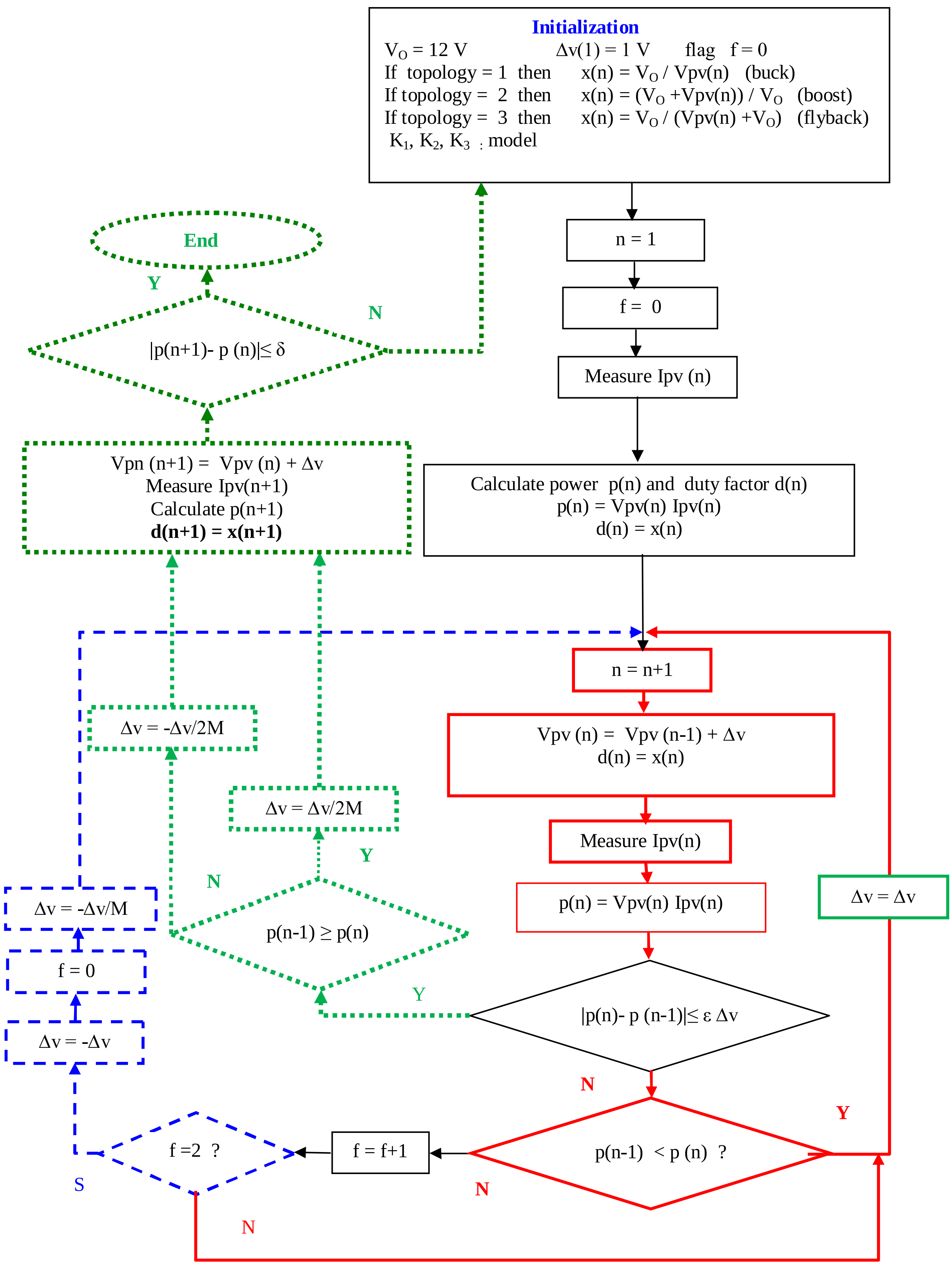


Figure 3. Proposed MPT

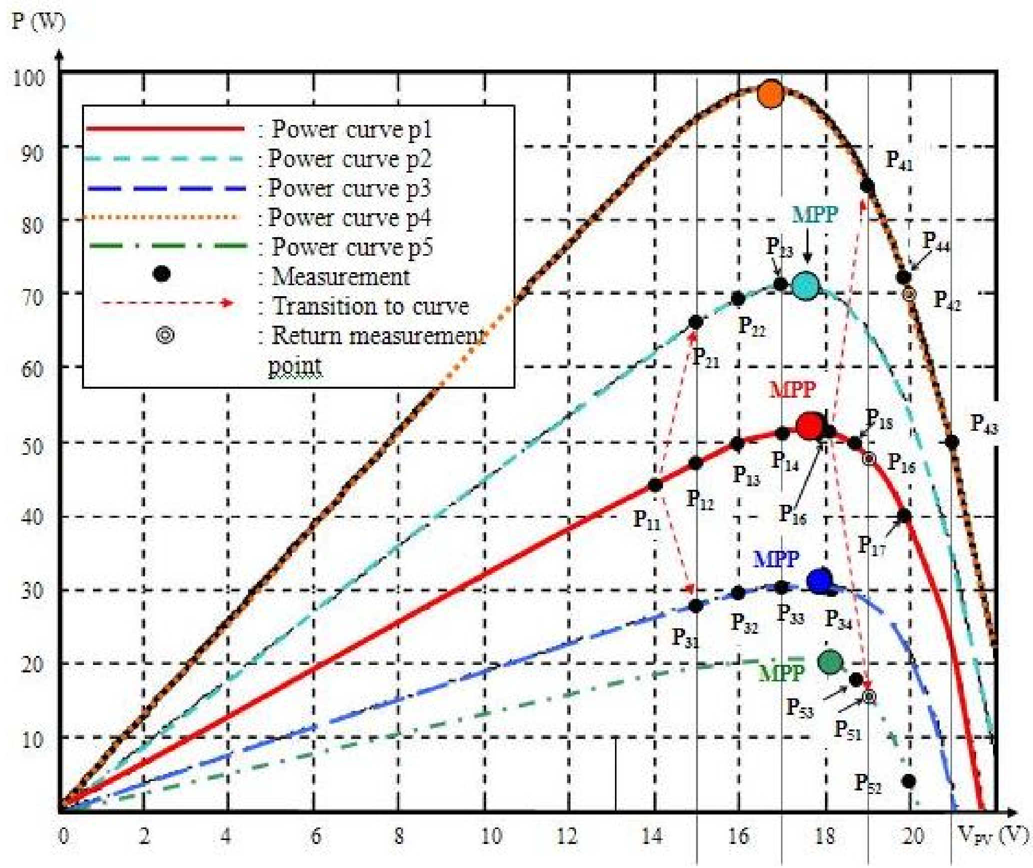


Figure 4. Illustration for the simulation of the adjustment to meteorological sudden changes

4. CONCLUSIONS

The preliminary simulation tests carried out by using Matlab® proved good, confirming the advantages of this novel MPP tracking method: simplicity, only one variable-control, possibility of even more simplification for buck converter, insensibility to fast changes in ambient temperature and irradiation density and fast convergence. The next step of our research will be the implementation, using electronic circuits and microcontrollers. Figure 5 shows the determination of the MPP in Matlab®.

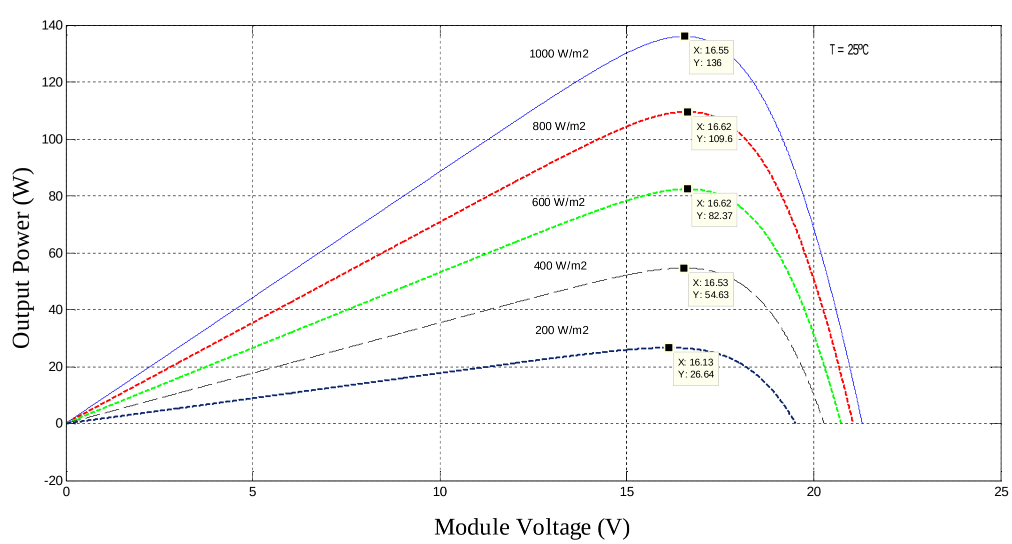


Figure 5. Determination of the maximum power point

5. REFERENCES

Blas *et al*, 2002, “Selecting a Suitable Model for Characterizing Photovoltaic Devices”, Renewable Energy Journal, Vol. 25, No. 3.

Luque, A. and Hegedus, S., 2003, Handbook of Photovoltaic Science and Engineering, Wiley,

Maxim App 2031, 2001, “ DC-DC Converter Tutorial”, 29 Nov 2010, < http: www.maxim-ic.com/app-notes/index.mvp/id/2031 29/11/2010>.

Salas *et al.*, 2006, “Review of the Maximum Power Point Tracking Algorithms for Stand-alone Photovoltaic Systems”, Solar Energy Materials & Solar Cells 90, Elsevier.

Sen, Z., 2008, “Solar Energy Fundamentals and Modeling Techniques – Atmosphere, Environment, Climate Change and Renewable Energy”, Springer-Verlag, London, UK.

6. RESPONSIBILITY NOTICE

The authors are the only responsible for the printed material included in this paper.