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New current control based MPPT technique for single stage grid connected PV systems

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Abstract

This paper presents a new maximum power point tracking algorithm based on current control for a single stage grid connected photovoltaic system. The main advantage of this algorithm comes from its ability to predict the approximate amplitude of the reference current waveform or power that can be derived from the PV array with the help of an intermediate variable β. A variable step size for the change in reference amplitude during initial tracking helps in fast tracking. It is observed that if the reference current amplitude is greater than the array capacity, the system gets unstable (i.e. moves into the positive slope region of the p–v characteristics of the array). The proposed algorithm prevents the PV system from entering the positive slope region of the p–v characteristics. It is also capable of restoring stability if the system goes unstable due to a sudden environmental change. The proposed algorithm has been tested on a new single stage grid connected PV configuration recently developed by the authors to feed sinusoidal current into the grid. The system is operated in a continuous conduction mode to realize advantages such as low device current stress, high efficiency and low EMI. A fast MPPT tracker with single stage inverter topology operating in CCM makes the overall system highly efficient. Specific cases of the system, operating in just discontinuous current mode and discontinuous current mode and their relative merits and demerits are also discussed.

Keywords: Buck-boost inverter; Continuous conduction mode; Just discontinuous current mode; Maximum power point tracking; Photovoltaic; Grid connected

1. Introduction

The sun radiates an enormous amount of power, out of which approximately 1.8×10^{11} MW is intercepted by Earth. This is several thousand times the present energy consumption of the entire world. The abundance of solar energy has prompted several researchers to look for ways of making the most of solar energy to meet the ever increasing demand for energy in the world. There are two methods of utilizing solar energy, as depicted in Fig. 1:

(1) Through solar collectors, like flat plate collectors, parabolic concentrators, etc. in the form of thermal energy [1].
(2) Through photovoltaic cells in the form of electrical energy [2].

Solar thermal energy is obtained by intercepting solar radiation by a blackened body either with or without concentration with a collecting device. The black body acts as a good absorber of heat. Coolants like air, water, etc are circulated inside the black body to take away the absorbed heat. Photovoltaic (PV) cells, on the other hand, facilitate the conversion of solar energy directly into electric (DC) power by the photoelectric principle [2]. This DC power, upon appropriate conditioning, can be used to drive electrical loads. Alternatively, this energy can be stored in batteries or fed directly into a power grid. This paper, however, is only concerned with photovoltaics, and therefore, no further reference will be made to solar thermal energy.

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Nomenclature

λ	Insolation level
I_{pv}	average PV array output current
V_{pv}	average PV array output voltage
I_{ph}	photo generated current
I_o	reverse saturation current
D_X	diode ($X = 1$, 2, pr)
D	duty cycle
SW_{xx}	bi-directional switch
c	constant
q	electronic charge
k	Boltzmann's constant
η	diode ideality factor
T	ambient temperature (K or C)
R_s	cell series resistance (Ω)
AI_{ref}	reference current amplitude
β	approximate MPP tracking variable
V_p	amplitude of grid voltage V_{ac}
I_p	amplitude of grid current i_g
I_{ref}	reference current wave form
ω	angular frequency of fundamental grid voltage (radians)
β_g	reference β value for MPP tracking
$AI_{ref(new)}$	new value of AI_{ref}
$AI_{ref(old)}$	old value of AI_{ref}
L	buck-boost inductor
T_s	high frequency switching time period
v_{out}	average voltage across (grid) capacitor (C_f) when device is OFF
ΔI	current tolerance denoting hysteresis band
t_k	turn ON switching instants during kth interval
t'_k	turn OFF switching instants during kth interval
f_c	lower cut off switching frequency in hysteresis band
C_f	filter capacitor across grid
L_f	filter inductor
e_k	energy transferred during kth switching interval
x	state parameter
v_{ac}	grid voltage as function of time

Subscripts

C	capacitor
L	inductor

Superscript

$'$	d/dt

Abbreviations

CCM	continuous conduction mode
JDCM	just discontinuous current mode
DCM	discontinuous current mode
PV	photovoltaic
OP	operating point
MPP	maximum power point
MPPT	maximum power point tracking
KCL	Kirchoff's current law
KVL	Kirchoff's voltage law
i–v	current–voltage
p–v	power–voltage
SSSP	single stage single phase
FFT	fast Fourier transform
SPWM	sine triangle pulse width modulation

A group of PV cells connected in series to provide a significant voltage (typically ⩾ 20 V) is called a PV module. Series or parallel combinations of PV modules form a solar panel, and again, a group of PV panels results in a PV array. This is depicted in Fig. 1(b). PV systems are popular due to the many advantages they offer. Not only are they pollution free, but also, they do not incur any maintenance and running cost. The major deterrent factor in their use is the high initial investment required [3]. However, with gradual reduction in the cost of PV modules, the conversion of solar energy into electrical energy is becoming more and more affordable.

Because of the high initial investment and limited life span of a PV array, it is important to utilize it effectively

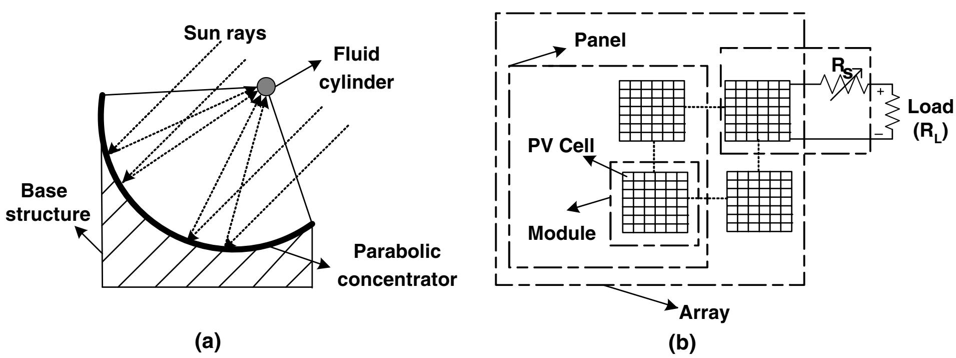

Fig. 1. PV energy utilization in the form of (a) thermal energy and (b) in the form of electrical energy through photovoltaic cells.