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Sliding mode controller for the single-phase grid-connected photovoltaic system

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Abstract

A sliding mode controller for the single-phase grid-connected photovoltaic system has been proposed in this paper. Contrary to the conventional controller, the proposed system consists of maximum power point tracker (MPPT) controller and sliding mode current controller only. The proposed MPPT controller generates current reference directly from the solar array power information and the current controller uses the sliding mode technique for the tight regulation of current. The new MPPT controller does not require the measurement of the voltage derivative which can be a cause of divide-by-zero singularity problems. The sliding mode controller has been constructed based on a time-varying sliding surface to control the sinusoidal inductor current and solar array power simultaneously. The proposed system can avoid the current overshoot and make optimal design for the system components. The structures of a proposed system are simple, but they show the robust tracking property against modeling uncertainties and parameter variations. The mathematical modeling is developed and the experimental results verify the validity of the proposed controller.

Keywords: Photovoltaic power systems; Sliding mode controller; Maximum power point tracker

1. Introduction

In recent years the need for renewable energy has become more pressing. Among them, the photovoltaic system (PV) such as solar cell is the most promising energy. The PV

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Nomenclature

A	deviation factor from the ideal p–n junction diode, dimensionless
C_n	nominal input dc link capacitor in μF
$e_s(t)$	grid voltage in V
f_s	inverter switching frequency in Hz
I	solar cell output current in A
i_L	inductor current in A
I_{ph}	light generated current in A
I_{pk}	peak value of the current in A
I_{ref}	current reference in A
i_{sa}	solar array current in A
i_{sa_avg}	average solar array current in V
I_{sat}	cell reverse saturation current in A
L_n	nominal output filter inductor in mH
N_p	number of parallel modules, dimensionless
N_s	number of series modules, dimensionless
P_E	power transferred to the grid in W
P_{E_avg}	average power of the grid in W
P_{ref}	power reference in W
P_{sa}	solar array power in W
P_{sa_avg}	average solar array power in W
q	electronic charge: 1.6022×10^{-19} C
R_L	output filter inductor resistance in Ω
R_s	series resistance in Ω
R_{sh}	shunt resistance in Ω.
S_1–S_4	full-bridge inverter switch
T	cell temperature in K
$u(t)$	control input, dimensionless
u_{eq}	equivalent input, dimensionless
u_n	nonlinear control input, dimensionless
V	solar cell output voltage in V
V_{EP}	peak grid voltage in V
V_{mp}	maximum power voltage in V
V_{sa}	solar array voltage in V
V_{sa_avg}	average solar array voltage in V
α	sliding mode controller gain, dimensionless
η_1,η_2	boundary values of the uncertainties, dimensionless
k	Boltzmann's constant: 1.3807×10^{-23} J/K
θ	grid voltage phase angle in °
σ	sliding surface, dimensionless
$\Delta f_1,\Delta f_2$	modeling uncertainties, dimensionless

energy is free, abundant and distributed through the earth. Among the PV energy applications, they can be divided into two categories: one is stand-alone system and the other is grid-connected system. Stand-alone system requires the battery bank to store the PV