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Reactive power compensation control for three phase grid-connected photovoltaic generator

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ABSTRACT

The high development of renewable energies research field has noticeably led to growing interest to connect such as devices of the electric distribution network. In this work an effectiveness power control strategy adapted on photovoltaic generation system is employed, whereas the performances of the global system are analyzed using MatLab/Simulink environment software. The employed strategy is the decoupling power technique based on the d-q currents components control using the proportional integral controllers. Moreover, a dc/dc boost converter adopted by MPPT control is proposed for the PV generated power enhancement. The main objective of the proposed structure is the improvement of the grid parameters under the power injection of photovoltaic generators. The simulation results confirm the global system ability for dc power control inside the PV generation system, transfer of the generated power to the distribution network and separately control of active and reactive powers. Inside grid, the proposed control enables to compensate the reactive power.

Introduction

The simplicity, effectiveness and low prices of the photovoltaic systems (PV) and also their devices added to the growth of power consumption and the exhaustion of fossil fuel reserves are the key factors that led to the increasing use of this type of green energy [1,2]. Nowadays the grid connection of the renewable energy sources applications especially the PV ones are became more important and competitive compared to stand alone systems [3]. However the output voltage of the PVS side is not significant and often influenced by the climatic changes effects such as temperature and irradiation, the adaptation of dc/dc boosting system adopted by maximum power point tracking (MPPT) control strategy becomes an inevitable requisite part [4]. In the other hand, since the PV generated power is continuous and contrary to the grid alternative power, under this variety the involvement of the dc/ac conversion plays a significant role in the integration of an effective photovoltaic power in the distribution network [5]. In order to ensure the performance power transfer, a separated active and reactive power control is introduced.

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Furthermore, kept synchronization of the inverter voltage and its counterpart of the grid and achievement of high power factor quality on the other hand require a specified detection of both phase and frequency in the grid side, hence the use of phase locked loop (PLL) becomes necessity [6].

This paper focuses the analysis performances of an electric utility network connected to photovoltaic generation system. In the literature, we can find several techniques which have been widely discussed the three phase grid-connection PVs, the used topology in the Ref. [7] is based on the power conditioning system using three-level control scheme with a separately active and reactive power exchange, however in Ref. [8] the study elaborated the problematic of current distortion inside the grid using hybrid active power filters, furthermore, the authors have realized a grid connected PV system using Power Balance theory presented in Ref. [9].

Otherwise, in this paper an expanded model of the control strategy based on PI regulators is depicted, where an adequate separated powers control technique premised on the control of the grid current is investigated. Besides the power control inside the distribution network, the photovoltaic generated power is reinforced by a dc/dc boost converter which adopted by MPPT control strategy based on Perturb and Observe (P&O) algorithm is proposed in favor of obtain a satisfactory voltage at the input of the dc/ac conversion system.

This paper will be presented as following: section Proposed system description contains the general structure of the studied system, also the mathematical basic models of the PV production system and the different conversions will be introduced in this section. The section Control strategy implementation presents the conception of an independent active and reactive powers control strategy with an aggregate demonstration of the used formulations in the control part. Thereafter, section Digital simulation results and discussion shows the global structure validation and obtained simulation results which show the efficiency and suitability of the proposed control system. Ultimately, in the last section some notes, advantages and also recommendations enriched the conclusion of this paper.

Proposed system description

The system configuration is composed of three principle structures. The photovoltaic power generation system as a secondary electric source, dc/dc and dc/ac conversion systems. The detailed model of each part is indicated as following:

Photovoltaic power generation system and characteristics

The photovoltaic generation system employed is consisted of several connected modules forming array. Generally, the PV generation is based on the direct transformation of the sunlight energy into electric energy named photovoltaic effect; this conversion is mostly performed by the basic element known by photovoltaic solar cell [10]. The simplified electric circuit of the photovoltaic solar panel is illustrated by Fig. 1.

As shown on Fig. 1, the photovoltaic solar panel is characterized by photoelectric current given by the dc current source, a diode presenting the PN junction, and serial and parallel resistances denoting the existence of internal resistance of the current flow and material resistance, respectively [11]. Mathematically, using the Kirchhoff fundamental lows on the given circuit the PV panel output current can be determined according to the following expression [12]:

$$I_{pv} = N_p I_{ph} - N_p I_{rs}\left[\exp\left(\frac{q}{K_B \cdot T_o \cdot A}\right)\left(\frac{V_{pv}}{N_s}\right) - 1\right] \tag{1}$$

where:

- I_{pv}: output photovoltaic current;
- V_{pv}: output photovoltaic voltage;
- I_{ph}: photo-electric current;
- I_{rs}: diode reverse saturation current;
- K_B: Boltzmann constant (1, 38.10^{-23} j/K^{-1});
- q: elementary charge (1602.10^{-19}C);
- A: diode ideality factor;
- T_o: cell's operating temperature;
- T_s: cell's temperature under standard conditions (298 K);
- N_p: number of parallel connected cells;
- N_s: number of serial connected cells.

The photoelectric current is strongly related to the operating meteorological conditions of the PV panel as it's mentioned by the below expression [13,14]:

$$I_{ph} = [I_{csc} + \beta(T_o - T_s)]\frac{S_o}{S_s} \tag{2}$$

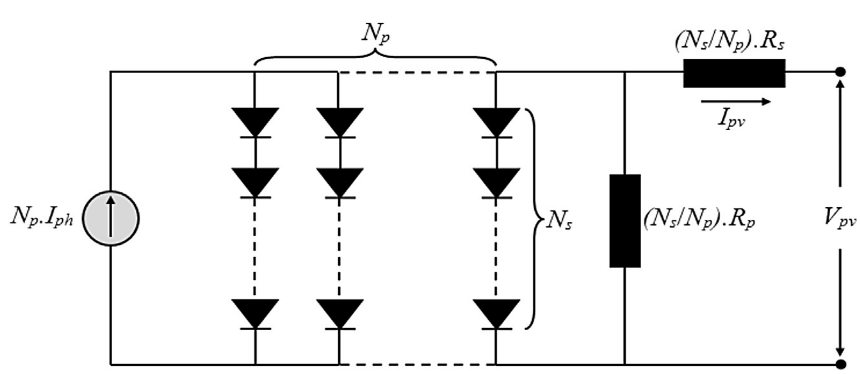

Fig. 1 – Equivalent circuit of the photovoltaic panel.