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Maximum power extractions in a single stage PV sourced grid connected inverter during low irradiations and nonlinear loads

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ABSTRACT

Grid connected PV systems are becoming increasingly popular due to an exponential energy demand and also due to depletion of fossil fuels and environmental concerns. However, extraction of peak power for such system which reduce cost has always been an area of concern. Many Maximum power point tracking (MPPT) algorithms were proposed for a two stage and single stage grid connected system with some limitations in system performance. A simple strategy to extract peak power from the grid connected PV with nonlinear load at Point of common coupling (PCC) is attempted. To achieve the same task in a single stage Photovoltaic (PV) grid system, two PV emulated virtual DC voltage sources are connected in series with the PV array. The operation of this strategy is tested under low irradiation and Voltage swell at the PCC connected to the grid. A control strategy to achieve dual mode control for MPPT and to regulate DC link voltage is achieved simultaneously by the proposed control. Analysis of the control strategy is carried out using MATLAB and experimentally validated with a TMS320F28335 controller.

1. Introduction

In the present scenario, rapid modernization with advance technology has increased the demand for electric power. Installation of additional power sources pose challenges due to the depletion of conventional fossil fuels in addition to environmental pollution and global warming. This necessitated the exploitation of renewable sources of energy like solar and wind energy by judiciously accommodating their seasonal variations. Wide spread use of renewable energy sources in dispersed power generation and a high penetration level is anticipated in the near future. PV generators are individually becoming increasingly popular to supply remote loads (for rural, urban, metropolitan electrification and for agriculture pumping) and grid connected schemes. The introduction of dispersed generators with renewable energy sources offers advantages like relieving transmission and distribution congestion, voltage profile improvement, line loss reduction, environment contaminations and enhanced utility reliability. It also becomes imperative that grid integrated power converters applied in renewable energy based DG systems being stochastic need careful controller design to ensure good performance compared to the conventional power plants they replace. Grid connected PV systems were increasingly used to directly feed energy to ac grids due to advantages like clean technology, reduced emission, availability and reduced cost for battery storage [1]. However such integration leads to power quality challenges such as voltage regulation issues, flicker and frequency volatility which need to be addressed. PV power extraction is affected by unbalanced grids leading to pulsating current and voltage ripples [2,3] in the PV array. Single and two stage power conversions based grid connected PV power systems are discussed in Refs. [4,5]. In Ref. [6], the PV is directly connected to dc-dc power converter to achieve MPPT for variable irradiations for fixed grid impedance. MPPT with grid impedance variations is not taken up. The module integrated converter systems is used in Ref. [7] reduces small input current ripples and improves system efficiency. But the specified technique requires specially wound transformers and inductors and additional power electronic modules which may lead to system conduction losses lowering system reliability. DC output voltage with currents waveforms are not presented. Instantaneous power ripple with partial shading effect is included in Ref. [8] where the load current and voltage variations are not depicted. Conventional power converters create voltage and current ripples, which affect the operating point of MPPT and actual power drawn from the PV is less than the maximum power p^{m}_{pv} [9]. The maximum power operating point of the PV curve is shifted from p^{m}_{pv} to average p^{av} due to the

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Nomenclature

$p^m{}_{pv}$	Maximum power from PV array(W)
$p^m{}_{pv}$	Power from PV array(W)
p^{av}	Average power from PV array (W)
p^{er}	Error power (W)
v_{vpv}	Virtual PV DC voltage(V)
v_g	Grid voltage(V)
v_i	Inverter voltage(V)
V_{dc}	DC link voltage (V)
i_{dc}	DC link current (A)
$v^m{}_{pv}$	PV output voltage during maximum power point (V)
$i^m{}_{pv}$	PV current during maximum power point (A)
δ	Power angle (deg)
γ	Firing angle (deg)
ω	Angular frequency (rad/sec)
n	Non-fundamental component
1	Fundamental component
P_i	Inverter power injection(W)
P_r	Power ripple(W)
MPPT	Maximum power point tracking
PCC	Point of common coupling

presence of ripple content in the input, which produces significant power losses in the PV array. However the topology in Ref. [10], ensures that the steady state input current and output voltage are reached and simultaneously output current wave is not described as it may pulsate per logical observations. It is observed from recent techniques using boost converter control techniques for grid connected PV systems [11,12], that ripple current in the load is reduced. But it has increased control circuit complexity and pulsating output voltage. In Ref. [13], regulation of voltage and currents through variable switching frequency is attempted, but the output current and voltages have significant ripple content and higher THD values. Further, the overall conversion efficiency of the entire two stage grid integrated system with MPPT is addressed in Ref. [14], where the tracker (dc-dc conversions) reduces the efficiency caused by conduction and switching losses specifically at low irradiation. An attempt is made in Ref. [15] to overcome this achieving improved efficiency but it leads to operating difficulties with variable loads (inverter with nonlinear loads) caused by coupled inductor complications. Such two stage grid connected PV systems are used widely, despite suffering [16–18] from high frequency switching losses, complex control techniques, fabrication of designed inductor, large capacitor size, pulsating and ripple powers due to voltage and current. Further, in two stage PV sourced grid connected inverters the MPPT should regulate the DC link apart from extracting maximum power from the PV array for irradiation variation. In such controls, perturbing the duty ratio of the DC-DC converter alters array parameters as input impedance across the PV array is altered to track peak power. But this results in the DC link voltage deviating from the required value. There is a possibility of operating in peak power tracking mode or voltage regulation mode [19] in the reported MPPT for single stage grid connected PV systems [20,21]. In this work, an inductive grid is assumed, which means that the MPPT is only function of current amplitude with the tracking range being restricted. The automatic mechanical tracking system based on the sun's movement for power extraction from PV is followed in many places [22]. This mechanical tracking systems follows the sun's movement to get maximum irradiation strength, but it does not consider changes in irradiation due to weather and other atmospheric conditions for maximum power extraction. The electrical control systems can be designed to respond to such highly intermittent variations at the sources. Though it is possible to move the maximum power extraction point during grid side voltage variation or source power control in a two stage conversion method for grid connected PV inverter, the objective of this research paper is to integrate the PV source inverter with the grid into one stage. In the proposed method, a simple power and control circuit is tried to overcome the drawbacks cited above. This is done through adding PV emulated DC sources in series with the PV array. The detailed operation of the proposed method is analyzed under low irradiations at the source and voltage swell on the ac side. The controller is designed to attain steady state DC voltage with smoothed input dc currents despite disturbances. The proposed methodology is simulated using MATLAB/Simulink package and the scheme is validated through an experimental prototype model.

2. Functional block diagram description

A functional block diagram is shown in Fig. 1. A PV array is connected in series to two controlled rectifier DC sources which emulate the characteristic of the actual PV panel. This arrangement is connected to the grid connected inverter with capacitor.

The inverter is integrated with the grid through a LC filter. A nonlinear load is connected at the PCC. The control circuit comprises of a maximum power computation unit based on instantaneous irradiation input and a look-up table. The synchronizing circuit is used to synchronize inverter output voltage with respect grid voltage at PCC. The value of firing angle γ and the power angle δ decide the output voltage of PV emulated DC sources and the power injected from the inverter.

3. Operation of proposed method

A control strategy is proposed to achieve dual mode control of the MPPT and DC link voltage regulation simultaneously. To

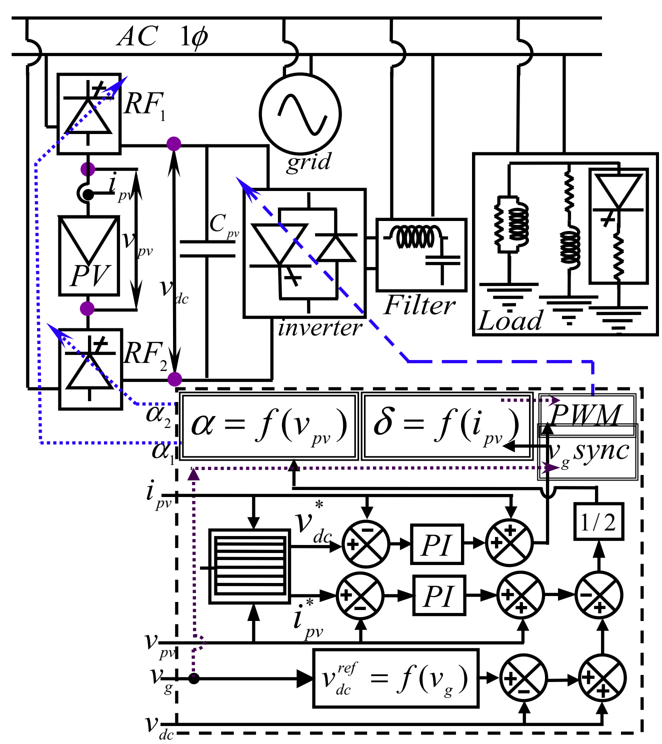

Fig. 1. Functional block schematic for proposed scheme.