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Rid-Connected Photovoltaic Systems of Fuzzy Logic Controlled Interleaved Boost Converter for Maximum Power Point Tracking

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ABSTRACT: A grid-connected photovoltaic (PV) power system with high voltage gain is proposed, and the steady-state model analysis and the control strategy of the system are presented. For a typical PV array, the output voltage is relatively low, and a high voltage gain is obligatory to realize the grid-connected function. The proposed PV system employs a ZVT-interleaved boost converter with winding-coupled inductors and active-clamp circuits as the first power-processing stage, which can boost a low voltage of the PV array up to a high dc-bus voltage. Accordingly, an accurate steady-state model is obtained and verified by the simulation and experimental results, and a full-bridge inverter with bidirectional power flow is used as the second power-processing stage, which can stabilize the dc-bus voltage and shape the output current. Two compensation units are added to perform in the system control loops to achieve the low total harmonic distortion and fast dynamic response of the output current. The solar energy has several advantages for instance clean, unlimited, and its potential to provide sustainable electricity in area not served by the conventional power grid. The stand-alone system is used in off-grid application with battery storage. Its control algorithm must have an ability of bidirectional operation, which is battery charging and inverting. There are three main types of switched power converters respectively called Boost, Buck and Buck Boost. The proposed method is mathematically modeled and the results are analyzed. A similar prototype model is designed and the results are compared with the theoretical values.

KEYWORDS: Boost converter, grid-connected, current ripples, fuzzy logic controller (FLC), maximum power point tracking, and solar photovoltaic.

I. INTRODUCTION

Photovoltaic (PV) power systems are becoming more and more popular, with the increase of energy demand and the concern of environmental pollution around the world. Four different system configurations are widely developed in grid-connected PV power applications: the centralized inverter system, the string inverter system, the multistring inverter system and the module-integrated inverter system [1]–[4]. Generally three types of inverter systems except the centralized inverter system can be employed as small-scale distributed generation (DG) systems, such as residential power applications. The most important design constraint of the PV DG system is to obtain a high voltage gain. For a typical PV module, the open-circuit voltage is about 21 V and the maximum power point (MPP) voltage is about 16 V. And the utility grid voltage is 220 or 110 Vac. Therefore, the high voltage amplification is obligatory to realize the grid-connected function and achieve the low total harmonic distortion (THD). The conventional system requires large numbers of PV modules in series, and the normal PV array voltage is between 150 and 450 V, and the system power is more than 500 W. This system is not applicable to the module-integrated inverters, because the typical power rating of the module-integrated inverter system is below 500 W [3] [4], and the modules with power ratings between 100 and 200 W are also quite common [5]. The other method is to use a line frequency step-up transformer, and the normal PV array voltage is between 30 and 150 V [3] [4]. But the line frequency transformer has the disadvantages of larger size and weight.

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II. BACKGROUND WORK

- **MPPT System Modeling**

The multi-string inverter depicted in Figure1 is the further development of the string inverter, where several strings are interfaced with their own dc–dc converter to a common dc–ac inverter. This is beneficial, compared with the centralized system, since every string can be controlled individually. Thus, the operator may start his/her own PV power plant with a few modules. Further enlargements are easily achieved since a new string with dc–dc converter can be plugged into the existing platform. A flexible design with high efficiency is hereby achieved

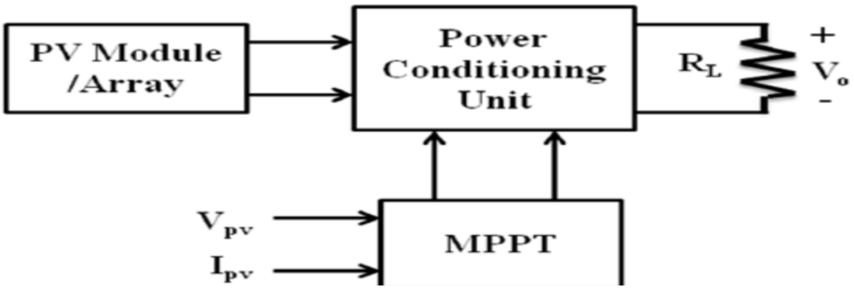

Fig: 1 MPPT system diagram

There are different techniques for MPPT such as Perturb and Observe (hill climbing method), Incremental conductance, Fractional Short Circuit Current, Fractional Open Circuit Voltage, Neural Network Control etc.

- **MPPT** or **Maximum Power Point Tracking**

MPPT **or** Maximum Power Point Tracking **is** algorithm that included in charge controllers used for extracting maximum available power from PV module under certain conditions. The voltage at which PV module can produce maximum power is called ‘maximum power point’ (or peak power voltage). Maximum power varies with solar radiation, ambient temperature and **solar cell** temperature.

- **Fuzzy Control**

Among all the methods Perturb and observe (P&O) and Incremental conductance are most commonly used because of their simple implementation, lesser time to track the MPP and several other economic reasons. Under abruptly changing weather conditions (irradiance level) as MPP changes continuously, P&O takes it as a change in MPP due to perturbation rather than that of irradiance and sometimes ends up in calculating wrong MPP. However this problem gets avoided in Incremental Conductance method as the algorithm takes two samples of voltage and current to calculate MPP. However, instead of higher efficiency the complexity of the algorithm is very high compared to the previous one and hence the cost of implementation increases. So we have to mitigate with a tradeoff between complexity and efficiency.

III. GRID-CONNECTED PHOTOVOLTAIC

3.1Boost model

The dynamic model of the solar generation system presented in figure 3 can be expressed by an instantaneous switched model as follows

$$c1.u\rfloor pv1 = ipv1 - iL1 \qquad (1)$$
$$L.iL1 = u\,pv1 - (1 - u1).uc\,2$$

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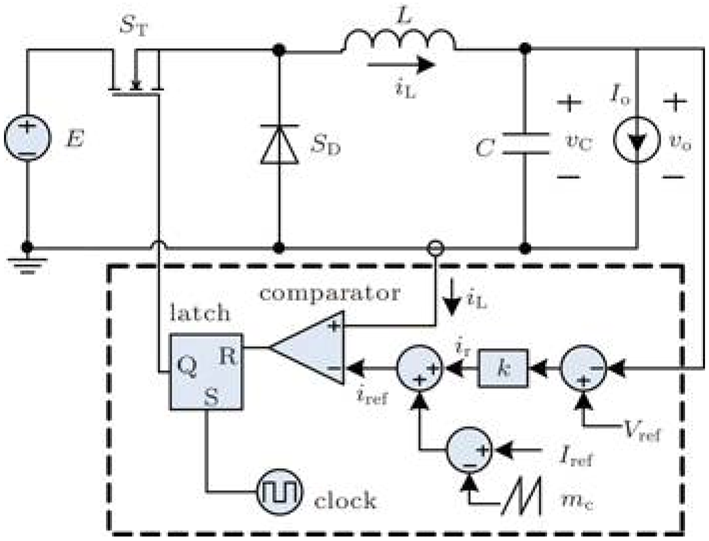


Fig; 2 boost model diagram

where $L_1$and i_{L1} represents the first dc-dc converter storage inductance and the current across it, u_{c2} is the DC bus voltage and u_1 is the switched control signal that can only take the discrete values 0 (switch open) and 1 (switch closed).

Using the state averaging method, the switched model can be redefined by the average PWM model as follows:

$$c1.\dot{u}pv1 = ipv1 - iL1 \qquad (2)$$

$$L.i_{L1} = u_{pv1} - \alpha.u_{c2} \qquad (3)$$

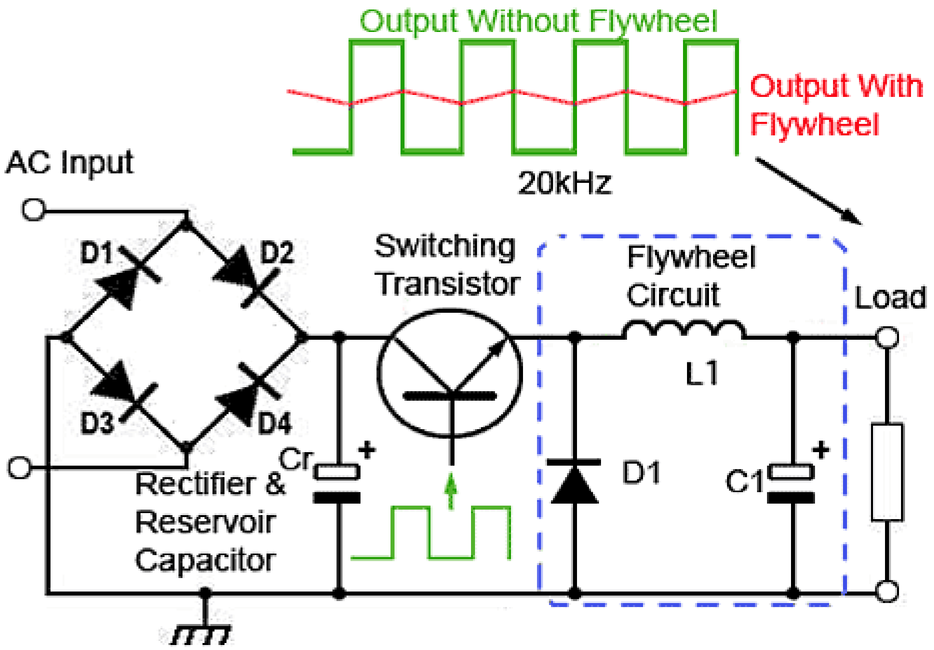


Fig: 3 Buck converter to grid line

Where α is averaging value of (1-u_1), u_{pv1} and i_{pv1} are the average states of the output voltage and current of the solar cell, i_{L1} is the average state of the inductor current.

3.2Inverter model

The active power transfer from the PV panels is accomplished by power factor correction (line current in phase with grid voltage). The inverter operates as a current-control inverter (CCI). Noticing that $u_2$stand for the control signal of buck inverter, the system can be represented by equations.

1. Simulation result

The PV model, interleaved boost converter, buck inverter model, back stepping controller and P&O MPPT algorithm are implemented in Matlab/Simulink as illustrated in Figure 5. In the study, RSM-60 PV module has been selected as PV power source, and the parameter of the components are chosen to deliver maximum 3kW of power generated by connecting 16 module of RSM-60 in parallel (1kw for each converter). Each boost converter operates at a maximum power point separately to other converters. The specification of the system and PV module are respectively summarized in the following tables.

TABLE I
MAIN CHARACTERISTICS OF THE PV GENERATION SYSTEM

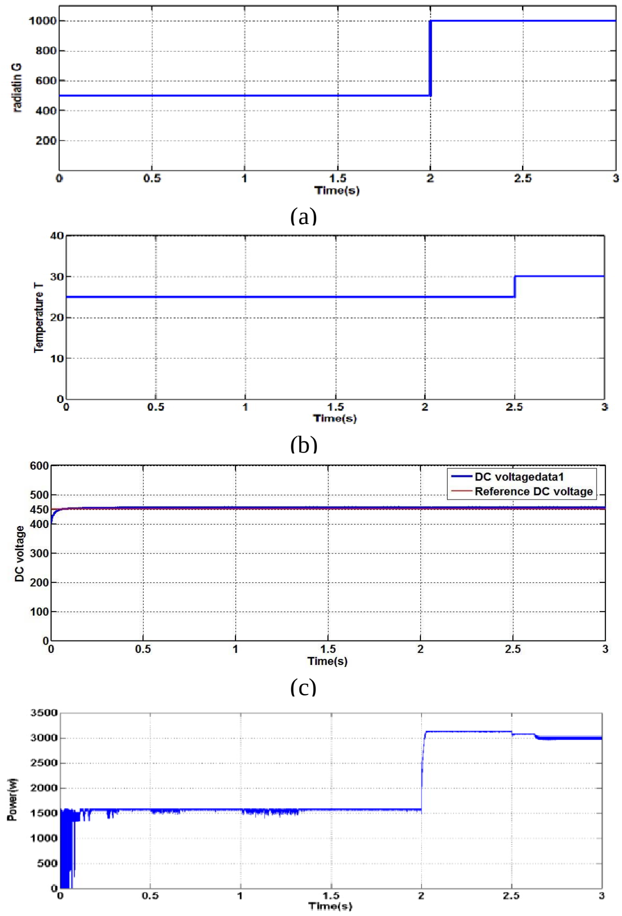
Maximum power	Output voltage at P_{max}	Open-circuit voltage	Short current circuit
60w	16v	21.5v	3.8A

The proposed controller is evaluated from two aspects: robustness to irradiance and temperature. In each figures, two different values of irradiance and temperature are introduced in order to show the robustness. Figure 7 shows the simulation results of the designed interleaved boost converter and buck inverter when the solar radiation changes from 500W/m^2 to 1000W/m^2 and then the temperature change from 25°c to 30°c at t=2s and t=2.5s respectively. Figure 7.c shows that the DC-link capacitor voltage reaches the commanded value of 450V which is greater than AC grid voltage. Figure 7.d shows the influence of temperature on the power transmitted to the grid. This power degrades slightly with increasing temperature.

IV. CONCLUSIONS

A back stepping control strategy has been developed for a solar generating system to inject

(a) Radiation, (b) Temperature,(c) DC voltage, (d) PV power



(a)

(b)

(c)

(d)

Fig.4. Simulation results of the designed interleaved boost

The power extracted from a photovoltaic array and obtain unitary power factor in varying weather conditions. A desired array voltage is designed online using an MPPT searching algorithm to seek the unknown optimal array voltage. To track the designed trajectory, a tow back stepping controller are developed to modulate the duty cycle of the interleaved boost converters and buck inverter. The proposed controller is proven to yield global asymptotic stability with respect to the

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