Adaptive Hysteresis Current Control for PV Connected Inverter in Digital Grid Router

Triet Nguyen-Van, *Member, IEEE*, Eri Maeda, Rikiya Abe, Kenji Tanaka, *Member, IEEE*

***Abstract*-- This paper presents an adaptive hysteresis current control for the Photovoltaic (PV) connected inverter in the Digital Grid Router (DGR), which is composed of multi-functional inverters connected to a common DC bus. The PV connected to the DGR is controlled in both Maximum Power Point Tracking (MPPT) and Specified Power Point Tracking (SPPT) modes, depending on the electricity transactions that the DGR receives from the smart-contracts. The simulation results show that the PV under the proposed control algorithm generates the desired power almost exactly despite the varying irradiance.**

I. INTRODUCTION

Nowadays, distributed energy becomes a solution to most countries in energy security concerns, power quality issues, and emission standards. The energy grid has been developed with numerous distributed small sources, such as diesel, gas, fuel turbines, and renewable energy including photovoltaic (PV), wind turbine etc. However, these distributed generations cause problems such as voltage rise and protection problem in the utility grid. The interconnection between these sources may increase the risk of cascading failures because any imbalance on the grid may propagate over a wide area immediately. Furthermore, it is difficult to control the supply-demand balance with the current grid architecture due to fluctuations caused by the increase of renewable and variable energy generations [1], [2].

In order to maintain the reliability of the current grid while accepting more and more penetration of renewable energy, a new power system concept called digital grid has been proposed [3]. The digital grid enhances the current grid by dividing a large-scale synchronized power system into some smaller size power systems called by digital grid cell. The digital grid cells are connected together, to the current grid, and other distributed generations via a digital grid router (DGR), which is composed of multi-functional inverters connected to a common dc bus. In this work, we present an adaptive hysteresis current control for a PV connected inverter in the DGR.

II. DIGITAL GRID ROUTER

The main concept of the digital grid is dividing a large synchronous grid into smaller segmented grid cells, which are connected the current main grid, and connected to each other's asynchronously, via the DGRs. The DGR also plays a role of a shock absorber so that intermittent renewables in cells will not affect the main grid. The DGR is composed of multi-functional inverters connected to a common DC bus as shown by Fig. 1, and has the following features

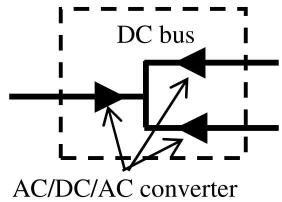

Fig. 1. PV connected inverter circuit.

1) The DGR connects the independent cells with mutually unsynchronized phases and frequencies together, to the current grid, and other distributed generations.

2) A digital grid controller (DGC) transfers information to control power equipment such as generators and energy storage devices in each synchronized system within a cell.

3) Each DGR and DGC has a CPU, memory, data storage, and network communication via power line using an IP protocol like on the Internet.

4) The energy transactions through the DGR can be recorded the certified service providers along with particular properties such as generation source, price, time, location, CO credits, etc. It enables consumers to specify the electrical power that they want to purchase, for example, power produced by PV farm in Fukushima area, Japan.

III. ADAPTIVE HYSTERESIS CURRENT CONTROL FOR PV CONNECTED INVERTER

A. *Adaptive hysteresis current control*

There are two main methods to control a switching inverter: linear sine-triangle PWM (Pulse Width Modulation), and hysteresis current control methods. While the popular linear sine-triangle PWM technique requires a PI (Proportional-Integral) regulator to modulate the current error, which may lead to an unavoidable delay, the hysteresis current control has fast and stable dynamic response and does not require any information about the system parameters, which enhances its robustness.

In the classical hysteresis controllers, the current band is fixed to a certain value, which makes the switching frequency varies to control the current ripple within the band. However, in our study, we use the adaptive hysteresis current control, whose current band is controlled adaptively to maintain the switching frequency at constant [4]. The hysteresis current band Δi_b is calculated using the DC voltage V_{dc}, the output voltage v_o and the desired constant switching frequency f_{sw}

as

$$\Delta i_b = \frac{V_{dc}{}^2 - v_o{}^2}{V_{dc}} \frac{1}{f_{sw} 4L} \qquad (1)$$

where L is the output inductor of the inverter.

B. Hysteresis current control for PV connected inverter

Consider the PV connected half-bridge inverter circuit shown in Fig. 2. The common DC bus as shown in Fig. 1 is supplied by two constant and balanced DC sources, each of value is V_{dc}. The inverter is controlled by the switching devices S_1 and S_2.

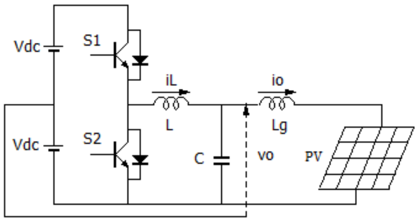

Fig. 2. PV connected inverter circuit.

In the conventional system, the PV is usually controlled in Maximum Power Point Tracking (MPPT) mode. However, in our study, in order to reduce the effect of the demand-supply balance problem to the grid, we propose an additional control mode for the PV called by Specified Power Point Tracking (SPPT) mode. The control mode of the PV is based on the electricity transactions that the DGR receives from the smart-contracts. The reference currents used in the adaptive hysteresis current control are regulated to track the maximum power point or a specified power point based on the characteristics of the PV array shown in Fig. 3.

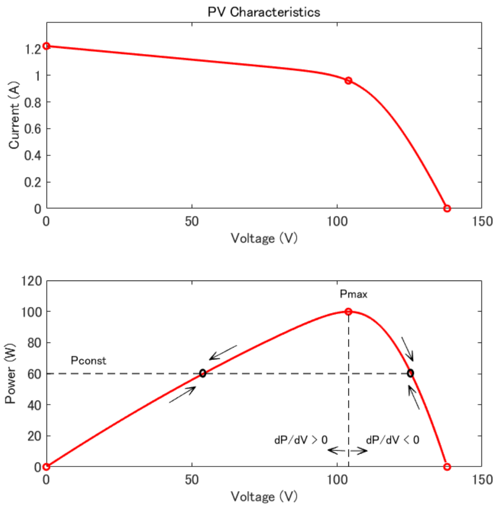

Fig. 3. Voltage-current and voltage-power characteristics of PV

IV. SIMULATION RESULTS

The simulations were carried out by using Matlab/Simulink for the inverter model shown in Fig. 2 with the circuit parameters given by $L = 2.2\,\text{mH}$, $C = 6.8\,\mu\text{F}$, $L_g = 1.1\,\text{mH}$, and $V_{dc} = 175$ V. The sampling frequency of analog/digital converter and the switching frequency are 4 Mhz and 20 khz respectively. Figure 4 shows the responses of the PV array, whose output power is controlled at SPPT mode with the specified power P_{const} of 50 W almost exactly under the varying irradiance.

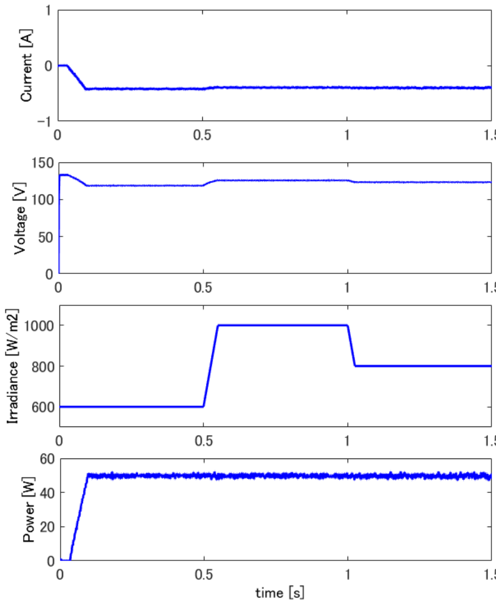

Fig. 4 Current, voltage responses, and output power of the PV with varying irradiance

V. CONCLUSIONS

An adaptive hysteresis current control has been proposed for the PV connected inverter in the DGR. The PV connected to the DGR is not only controlled in the conventional MPPT mode but also in the SPPT mode, depending on the electricity transactions that the DGR receives from the smart-contracts. This operation method is expected to contribute to the improvement of the demand-supply balance problem, which is inhibiting the vast employment of renewable energy. The simulation results show that the PV under the proposed control algorithm generates the desired power almost exactly despite the varying irradiance.

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