

A Minimal-Order Observer Based Control Method for PV Generator to Reduce Frequency Deviations of Power System

Tomonobu Senjyu¹, Manoj Datta¹, Atsushi Yona¹, Toshihisa Funabashi², and Chul-Hwan Kim³

¹ Department of Electrical and Electronics Engineering
University of the Ryukyus, 1 senbaru Nishihara-cho Nakagami, Okinawa 903-0213, Japan
Phone: +81988958686, e-mail: b985542@tec.u-ryukyuu.ac.jp, k068472@eve.u-ryukyuu.ac.jp

² Meidensha Corporation, Riverside Bldg 36-2, Nihonba-shi
Hokozaki-cho, Chuo-ku, Tokyo 103-8515, Japan
Phone: +810356417509, e-mail: funabashi-t@mb.meidensha.co.jp

³ School of Electrical and Computer Engineering,
Sungkyunkwan University, Suwon City 440-746, Korea
E-mail: chkimskku@yahoo.com

Key words

Frequency deviation, Minimal-order observer, Maximum Power Point Tracking, load variation, PV base power.

1. Interest of the Work

The demand of renewable energy has been increased significantly because of the shortage of fossil fuel and the global green house effect. Among various renewable energy systems, PV systems are expected to play a promising role as a clean power electricity source in meeting future electricity demands. To date, it has not been necessary for small PV generators to provide frequency regulation services to the power system. In the future, with an increasing penetration of PV generation, their impact upon the overall control of the power system will become significant [1]. This will lead to a situation where the PV generators will be required to share some of the duties, such as load frequency control. However, no literatures have been found concerning this issue.

2. Objective

To design a control method for PV generators involving themselves in the operation of power system by contributing to frequency control. This control method will reduce the frequency deviations introduced to the power system by variation of load and will supply PV power near maximum PV power.

3. Methodology

This paper presents a minimal-order observer [2] based control method of PV generator to reduce the frequency deviations introduced to the power system by the variation of load. The proposed method supply power in conjunction with diesel generator. This method is usually used to supply power in isolated island. The proposed method is compared with the method where Maximum Power Point Tracking (MPPT) control [3] is used to produce the command PV power. From simulation results, it has been found that the proposed method is effective to reduce the frequency deviation of the utility and delivers PV power near maximum PV power to the utility. The small power system model [4]

used in this paper is shown in Fig. 1. It consists of diesel generator in detail, PV generator, and minimal-order observer for load and diesel power estimation where S_i is the insolation, P_{inv}^* is the command power generated by output power command system, P_A is the generated power by PV power generation system, P_d is generated power by diesel generators, R is the speed regulation, T_g is the governor time constant, T_d is the diesel generator time constant, ΔP_L is load, M is the inertia constant, D is the damping constant, u is the input to the governor, Δf is the frequency deviation of small power utility, \hat{P}_d is the estimated diesel power, \hat{P}_L is the estimated load power.

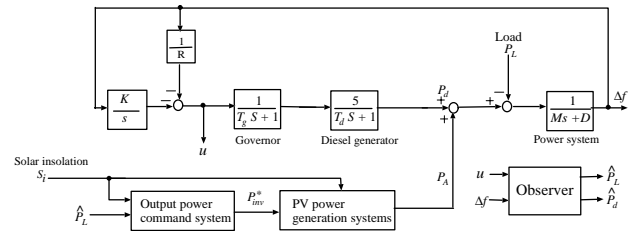


Fig. 1. Small power system model

Firstly, a minimal-order observer is designed using the power system parameters. The observer is shown in Fig. 2 and the model used to design the observer is shown in Fig. 3.

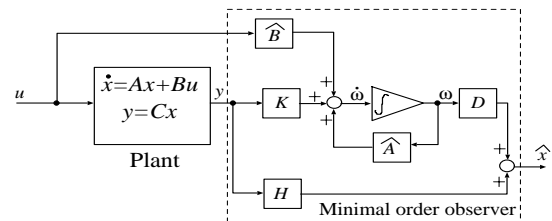


Fig. 2. Minimal-order observer

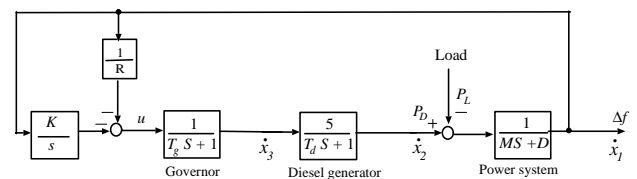


Fig. 3. Power system model for observer

From Fig. 2, a minimal-order observer can be written as

$$\dot{\omega}(t) = \hat{A}\omega(t) + Ky(t) + \hat{B}u(t) \quad (1)$$

$$\hat{x}(t) = D\omega(t) + Hy(t) \quad (2)$$

where $\hat{A} = A_{22} - LA_{12}$, $K = \hat{A}L + A_{21} - LA_{11}$, $\hat{B} = -LB_1 + B_2$, $D = S^{-1} \begin{bmatrix} 0 \\ I_{n-l} \end{bmatrix}$, and $H = S^{-1} \begin{bmatrix} I_l \\ L \end{bmatrix}$

The simulation parameters are given in Table I.

TABLE I. Simulation Parameters

Parameters of small power system	
Inertia constant, M	0.150 puMW.sec/Hz
Damping constant, D	0.008 puMW/Hz
Governor time constant, T_g	0.10 sec
Diesel Time constant, T_d	8.0 sec
Speed regulation, R	2.5 Hz/puMW
Parameters of PV array	
Rated output power	241 kW
Open circuit voltage	588.80 V
Short circuit current	520.37 A
Number of modules in series	16
Number of modules in parallel	65
Total number of cells	62,400

The estimated load power is shown in Fig. 4 by solid line.

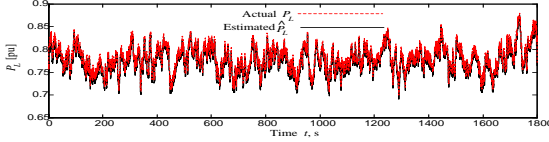


Fig. 4. Estimated load power

From Fig. 4, it can be said that the designed observer estimates the load power successfully. After estimating load power \hat{P}_L , load variation index can be found as

$$\Delta P_L = \hat{P}_L - \frac{1}{T} \int_{t-T}^t \hat{P}_L dt \quad (3)$$

Then, PV base power is obtained by

$$P_{base} = P_{max} \frac{0.78}{10s+1} \quad (4)$$

Finally, PV output power command is given by

$$P_{inv}^* = P_{base} + \Delta P_L \quad (5)$$

The output power command generation system is shown in Fig. 5

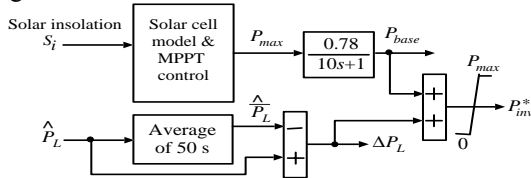


Fig. 5. PV output power command generation

4. Simulation Results

The comparative simulation results of the proposed control and MPPT control are shown in Fig. 5 by solid line and dotted line respectively. Insolation, load variation index, and PV base power are shown in Fig. 6 (a), (b), and (c) respectively. Fig 6(d) shows the PV power produced by MPPT control and proposed control. From, Fig. 6(d), the proposed method produced power near MPPT power and this power is controlled according

to the load variation index to minimize the frequency deviations. Fig. 6(e) shows diesel power where diesel power produced by proposed method fluctuates less than the diesel power produced by MPPT control. Fig. 6(e) shows the frequency deviations where frequency deviations produced by MPPT control are ± 0.3 Hz. On the other hand, frequency deviations produced by proposed method is almost zero. Therefore, it can be said that the proposed method is effective to reduce the frequency deviation of the utility and delivers PV power near maximum PV power.

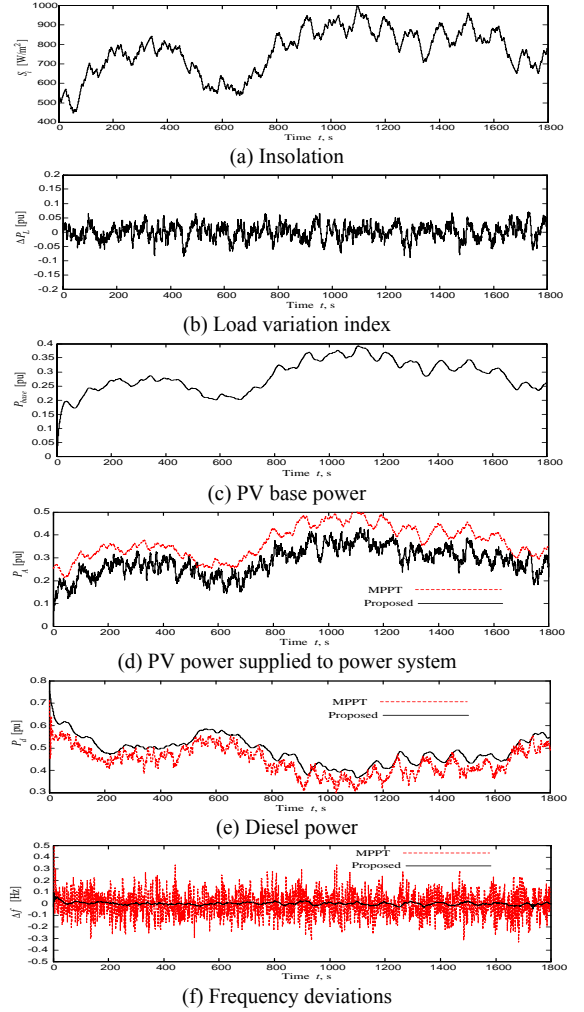


Fig. 6. Comparative simulation results of the proposed control and MPPT control

References

- [1] Y. T. Tan, D.S. Kirschen and N. Jenkins, "A Model of PV Generation Suitable for Stability Analysis," IEEE Trans. Energy Convers., vol. 19, no. 4, pp. 748-755, Dec. 2004.
- [2] S. Goto and M. Nakamura, "Multidimensional feedforward compensator for industrial systems through pole assignment regulator and observer," IEEE Trans. Industrial Electron., vol. 53, no. 3, pp. 886-894, June 2006.
- [3] A. N. Femia et. al., "Optimization of perturb and observe maximum power point tracking method," IEEE Trans. Power Electron., vol. 20, no. 4, pp. 963-973, July 2006.
- [4] T. Senjuy et. al., "A New Method for Smoothing Output Power Fluctuations of PV System Connected to Small Power Utility," presented at the 7th International Conference on Power Electronics, Daegu, Korea, 2007.