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Photovoltaic output power fluctuations smoothing methods for single and multiple PV generators

Manoj Datta [a,*], Tomonobu Senjyu [a], Atsushi Yona [a], Toshihisa Funabashi [b], Chul-Hwan Kim [c]

[a] Faculty of Engineering, University of the Ryukyus, Okinawa 903-0213, Japan
[b] Meidensha Corporation, Tokyo 103-8515, Japan
[c] School of Electrical and Computer Engineering, Sungkyunkwan University, Suwon City, Republic of Korea

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ABSTRACT

As a new measure for smoothing PV output power fluctuations and for reducing frequency deviations of isolated power utility, firstly, this paper discusses a control method based on fuzzy reasoning for single PV system. The fuzzy reasoning produces output power command for smoothing PV system's power fluctuations considering insolation and power utility conditions. Secondly, an energy storage based method is proposed. Here, PV output power fluctuations are leveled through battery charge/discharge action and the optimal size of the battery is calculated to minimize the system cost. Thirdly, a simple coordinated control method is proposed for multiple PV systems clustered in different locations. The coordinated method produces central leveling output power command by fuzzy reasoning. Local output power command is generated by multiplying individual maximum power command with tuning factor. All of the proposed methods are compared with the MPPT control and found effective in smoothing PV output power fluctuations.

1. Introduction

The maximum power point tracking (MPPT) control [1] used in most PV systems assures that insolation is converted to electricity to the maximum degree possible. However, the insolation as well as the power output of PV systems fluctuates depending on weather conditions. In the future, when a significant number of PV systems will be connected to the grids of power utilities, power output fluctuation may cause problems like voltage fluctuation and large frequency deviation in electric power system operation [2]. This paper investigates some approaches for smoothing PV output power fluctuations of single PV system or multiple PV system and compares their performances with conventional MPPT control.

Firstly, this paper presents a new control method based on fuzzy reasoning [3,4] for single PV system. The fuzzy reasoning used in this method produces necessary output power command for smoothing PV system's power fluctuations considering average insolation, variance of insolation and absolute average of frequency deviations.

Secondly, an energy storage based method for smoothing PV output power fluctuations is proposed. Here, PV output power fluctuations are levelled through battery charge/discharge action and the optimal size of the battery is calculated to minimize the capital cost. In the optimization problem of energy storage system (ESS), the control parameter for ESS is selected in all combinations and local search is performed to find the optimal size of the battery.

Thirdly, a simple coordinated control method is proposed for smoothing PV output power fluctuations of multiple PV systems clustered in different locations. The coordinated method produces central leveling output power command by fuzzy reasoning [3,4]. The fuzzy reasoning has three inputs: average of all instant insolations, variance of insolation, and absolute average of frequency deviation. Local output power command is generated by multiplying individual MPPT command with tuning factor. The tuning factor is produced by dividing the central power command by the sum of all MPPT commands. The individual MPPT command is generated by the method given in Ref. [1].

All of the proposed methods are compared with the system where the power extracted by MPPT control [1] is always fed to the utility without smoothing. Simulation results show that the proposed methods are effective in smoothing PV output power fluctuations and feasible to reduce the frequency deviations of the power utility.

2. Methodologies

The isolated power system model consisted of a diesel generator, a PV system and load is shown in Fig. 1.

* Corresponding author. Fax: +81 98 895 8686.
E-mail address: k088659@eve.u-ryukyu.ac.jp (M. Datta).

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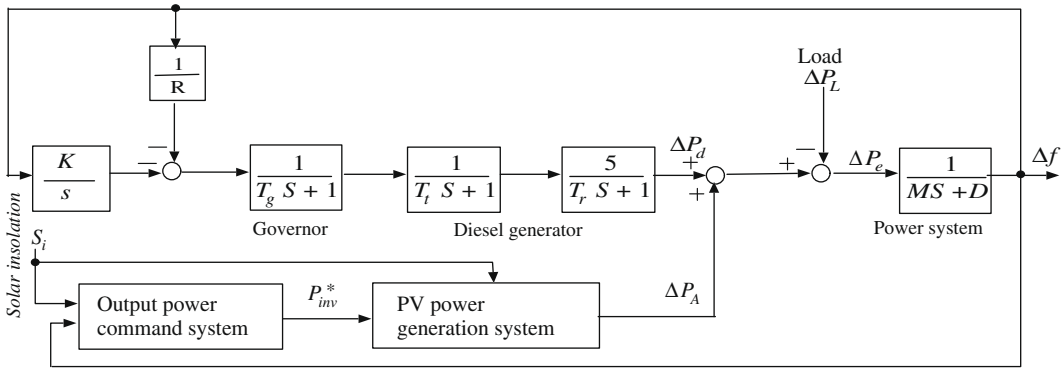

Fig. 1. Isolated power system model.

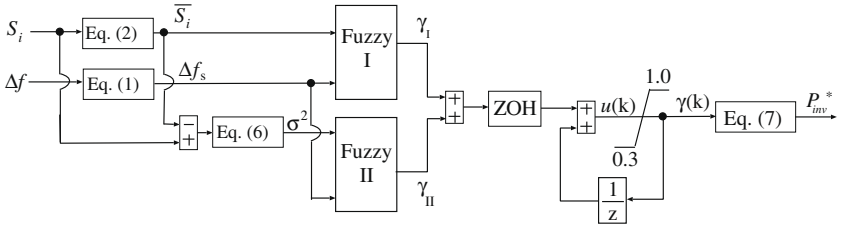

Fig. 2. Output power command system for method 1.

Table 1
Fuzzy rules for fuzzy reasoning I.

$\bar{S}_i$	Δf_s						
	NB	NM	NS	ZO	PS	PM	PB
NB	ZO	NS	NM	NB	NB	NB	NB
NM	PS	ZO	NS	NM	NB	NB	NB
NS	PM	PS	ZO	NS	NM	NB	NB
ZO	PB	PM	PS	ZO	NS	NM	NB
PS	PB	PB	PM	PS	ZO	NS	NB
PM	PB	PB	PB	PM	PS	ZO	NS
PB	PB	PB	PB	PB	PM	PS	ZO

2.1. Fuzzy based smoothing method for single PV system

Output power command P^*_{inv} is decided by the output power command system shown in Fig. 2. It consists mainly of two fuzzy reasoning and fuzzy reasoning I has two inputs. One is absolute average of frequency deviation Δf_s and is expressed by

$$\Delta f_s = \frac{1}{T}\int_{t-T}^{t} |\Delta f| dt \tag{1}$$

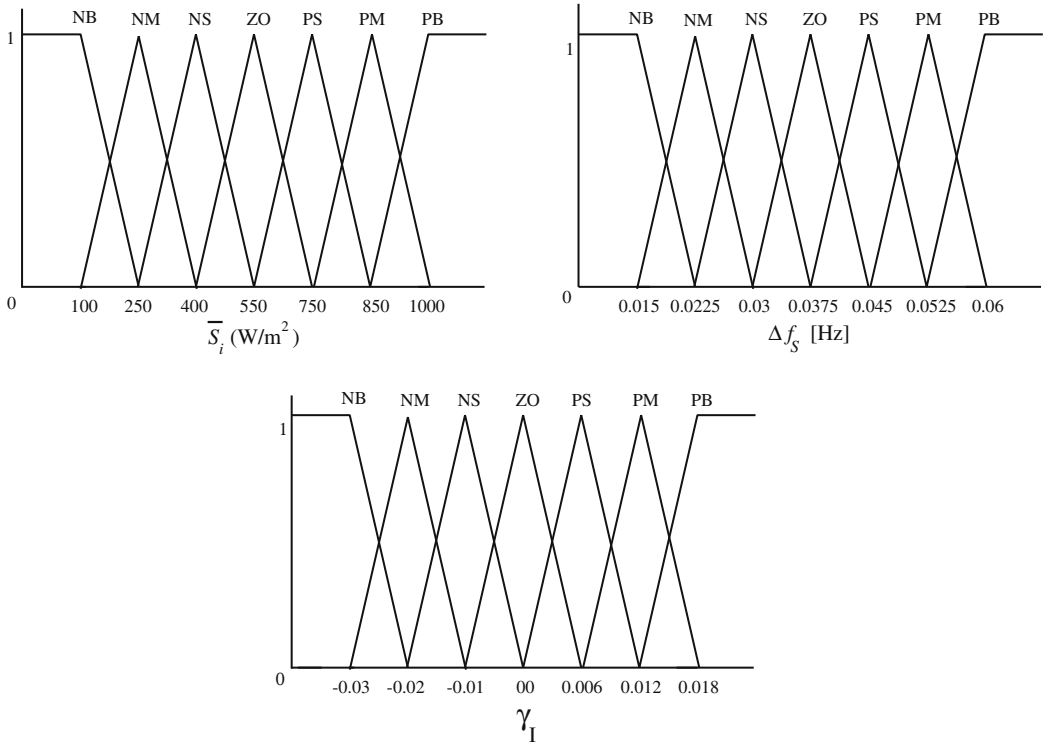

Fig. 3. Membership function of fuzzy reasoning I.