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Operation strategy of residential centralized photovoltaic system in remote areas

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Abstract

Photovoltaic (PV) systems have found fairly wide application in remote isolated area. However, each individual PV system usually supplies energy only to one consumer. In such a case we have several consumers that each one of them uses a stand-alone PV system. This situation would expose such stand-alone systems to transient excessive loads larger than the power generated by the PVs, and then the battery is bound to discharge even during the day. For overcoming this problem, we suggest an autonomous centralized PV system, comprising one battery bank and plural subsystems connected to each other. From solar radiation data and load profiles, the performance of the PV centralized system is simulated by using a time step scheme. The advantages of this system are found to be the large charging rate of power, high efficiency, and low cost compared with conventional individual PV systems and hybrid systems. In addition, the economic study shows that the life cycle cost and the price of kilowatt hour generated in the centralized system is lower than that for the individual systems.

Keywords: Centralized system; Economic estimation; Individual system; Photovoltaic system subsystems

1. Introduction

In view of global environmental problems and resource draining, we must develop new energy resources that are abundant and provide substitutes for fossil fuels.

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Nomenclature

L_d	Daily consumed power for each subsystem (W h/day)
P_{Li}	Consumed power for i appliance (W)
N	Number of appliance
T_i	Duration use for appliance i
η	Efficiency of appliances (%)
NAD	Number of autonomous day
DOD	Depth of discharge (%)
SOC	State of charge
n_c	Number of autonomy days
E_L	Average daily load during the night over all subsystems (kW h/day)
η_{Bd}	Battery discharge efficiency (%)
η_W	DC wiring efficiency (%)
η_C	Charge/discharge controller efficiency (%)
B_{DC}	Battery capacity (kW h)
t_n	Time step (h)
P	Capacity of PV array (kW)
η_{PV}	PV array efficiency (W)
η_{out}	Controller efficiency×battery efficiency (W)
Q	Solar insolation received by PV on tilted plane (W h/day m^2)
$P_P(t)$	Instantaneous power generated for centralized PV system (W)
P_{Pi}	Power generated in the ith subsystem (W)
n	Total number of subsystems
L_{di}	Average daily load in subsystems (W h)
$\mathrm{P}_{Ei(t)}$	Excess power for one subsystem (W)
$P_{B(t)}$	Instantaneous energy stored in battery (W h)
ρ_{ch}	Efficiency of battery charge (%)
ρ_{dis}	Efficiency of battery discharge (%)
$P_{B\ min}$	Minimal storage capacity (W h)
$P_{B\ max}$	Nominal storage capacity (W h)
LCC	Life cycle cost (US$)
ALCC	Annualized life cycle cost (US$)
PW	Present worth (US$)
f	Annual inflation rate (%)
d	Market discount rate (%)
P_a	Cumulative present worth factor
P_r	Present worth factor
P_{a1}	Present worth factor for maintenance cost