Energy storage capacity optimization for autonomy microgrid considering CHP and EV scheduling

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HIGHLIGHTS

- A sizing strategy of power sources and ESS in an autonomy MG is proposed.
- A two-layer HESS with three storage types is constructed based on response speed.
- Power differences among different time intervals are supplied by HESS.
- DSM and EV scheduling can result in significant saving in sizing of power resources.

ABSTRACT

Microgrid is universally accepted as a new approach to solve the global energy problem. In a microgrid, the optimal sizing of energy storage is necessary to ensure reliability and improve economic efficiency. Its sizing results are impacted by uncertainty on natural resources, energy storage as well as load, and it is hard to coordinate these factors. Therefore, microgrid needs more improved strategies for optimal sizing. In this paper, we present a power source sizing strategy with integrated consideration of characteristics of distributed generations, energy storage and loads. Distributed generations consist of wind turbine, photovoltaic panels, combined heat and power generation (CHP) as well as electric vehicles. A two-layer hybrid energy storage system with three storage types (i.e. super capacitor, li-ion battery, lead-acid battery) is constructed based on their power density, energy density, response speed and lifetime, as well as load classification. Power load differences among different time intervals which are supplied by different types of storage leads to allocation of energy storage. An objective function is established based on life cycle cost (LCC) theory, which includes construction cost, operation maintenance cost, recycling profit, environment cost, and energy shortage compensation. Three scenarios, in which particle swarm optimization (PSO) is used for the optimal sizing, modeling and results calculating. From the simulations results analysis, it is found that the proposed model and strategy are feasible and practical.

1. Introduction

With the increasing demand on energy in modern society, more and more attention has been paid to the renewable energy and energy efficiency. However, installed capacity and penetration of renewable energy power generation system gradually increased, its inherent randomness and volatility bring lots of negative impact on the operation of power system. Therefore, in a microgrid based on distributed energy resource (DER) utilization, it is particularly important to provide optimal power source sizing which can guarantee both the reliability and economy [1,2]. The power sources in a MG covers a wide range including wind turbine (WT), photovoltaic panels (PV), combined heat and power generation (CHP), energy storage system (ESS), etc. Actually, ESS usually consists of many types of energy storage (ES) devices, forming a hybrid energy storage system (HESS) to achieve high performance and optimal economic efficiency.

At present, researchers have done lots of works on microgrid optimization from the aspects of power resources capacity and location [3–5], dispatch and operate strategy [6,7], energy management strategy [8,9] and so on. The ESS plays significant role in smoothing power output of renewable energy resource (RER), while unsuitable ESS sizing may lead to low economic efficiency...
Nomenclature

\begin{align*}
\text{Pr} & \text{(t)} \quad \text{WT output power at moment } t \\
\text{Pr} & \text{r-WT} \quad \text{WT rated power} \\
\text{\textit{t}} & \quad \text{rated wind speed of WT} \\
\text{\textit{t}} & \quad \text{cut-in wind speed of WT} \\
\text{\textit{t}} & \quad \text{cut-out wind speed of WT} \\
\text{Pr(t)} & \quad \text{PV output power} \\
\text{Pr(\text{PV})} & \quad \text{PV unit rated power in standard scenario} \\
\text{Rt(t)} & \quad \text{sunlight intensity at moment } t \\
\text{Rr} & \quad \text{rated sunlight intensity in standard scenario} \\
\text{Tg(t)} & \quad \text{temperature at moment } t \\
\text{T} & \quad \text{rated temperature in standard scenario} \\
\text{k} & \quad \text{total temperature coefficient} \\
\text{\textit{\eta}} & \quad \text{PV amount of PV units} \\
\text{Qe} & \quad \text{gas turbine exhaust heat at moment } i \\
\text{Pr(i)} & \quad \text{output power of the gas turbine at moment } i \\
\text{\eta P} & \quad \text{generation efficiency of the gas turbine} \\
\text{\eta 1} & \quad \text{heat loss coefficient of the gas turbine} \\
\text{Qe(\text{C})} & \quad \text{heating capacity of the gas generated by the gas turbine at moment } i \\
\text{Qe(\text{C})} & \quad \text{heating capability of the gas boiler} \\
\text{Qe} & \quad \text{total heat capacity} \\
\text{\textit{c\text{\textsubscript{g}}} (\text{g})} & \quad \text{heat exchanger coefficient} \\
\text{Cg} & \quad \text{total gas consumption} \\
\text{C} & \quad \text{gas consumption of the gas turbine} \\
\text{Q} & \quad \text{gas consumption of the gas boiler} \\
\Delta \text{t} & \quad \text{running time of the gas turbine} \\
\text{Mg} & \quad \text{low calorific value of gas} \\
\eta \text{Q} & \quad \text{heating efficiency of the gas boiler} \\
\text{E} & \quad \text{ES energy at moment } t \\
\text{\textit{s}} & \quad \text{self-discharge ratio} \\
\text{Pr(\text{ES})} & \quad \text{charge/discharge power in current time interval} \\
\Delta \text{t} & \quad \text{time interval duration} \\
\text{D\text{\textsubscript{N}}} & \quad \text{depth of discharge} \\
\text{N} & \quad \text{equivalent cycle times under } D\text{\textsubscript{N}} \\
\text{C_{ap,\text{\textsubscript{b}}}} & \quad \text{capital cost of one cycle} \\
\text{C_{\text{\textsubscript{b}}}} & \quad \text{operation cost of one charge/discharge cycle} \\
\text{S} & \quad \text{EV daily mileage} \\
\text{E} & \quad \text{charging capacity of } i\text{-th EV} \\
\text{\textit{t}} & \quad \text{starting time of charging of } i\text{-th EV} \\
\text{\textit{P}} & \quad \text{charging power of } i\text{-th EV} \\
\text{\textit{t}} & \quad \text{ending time of charging of } i\text{-th EV} \\
\text{\textit{d}} & \quad \text{electricity demand of power user} \\
\text{\textit{P}} & \quad \text{price of electricity users} \\
\text{\eta g} & \quad \text{incentive allowance} \\
\text{E} & \quad \text{cross-price elasticity} \\
\text{\textit{t}} & \quad \text{time limit of power interruption} \\
\Delta P & \quad \text{difference of generated power and load} \\
\Delta E & \quad \text{energy difference} \\
\text{t} & \quad \text{switching time of BESS} \\
\text{\textit{P}} & \quad \text{output power of renewable energy resource} \\
\text{\textit{t}} & \quad \text{certain time interval} \\
\text{\textit{C}} & \quad \text{capital cost} \\
\text{C\textit{\textsubscript{m}}} & \quad \text{operation and maintenance cost} \\
\text{\textit{\eta}} & \quad \text{recycling profit} \\
\text{\textit{\eta}} & \quad \text{environment compensation cost} \\
\text{\textit{\text{C}}\text{\textsubscript{g}}} & \quad \text{energy shortage compensation cost} \\
\text{\textit{N}} & \quad \text{amount of each DER or ES unit} \\
\text{\textit{\eta}} & \quad \text{unit price of device } i \\
\text{\textit{\eta}} & \quad \text{replacement times of device } i \\
\text{\textit{\eta}} & \quad \text{lifetime of device } i \\
\text{\textit{\eta}} & \quad \text{discount ratio} \\
\text{\textit{\text{c}_{\text{om},j}}} & \quad \text{annual operation and maintenance cost of device } i \\
\text{\textit{\text{J}}} & \quad \text{service lifetime of the MG} \\
\text{\textit{\text{c}_{r}}} & \quad \text{recycling profit of device } i \\
\text{\textit{\text{c}_{p}}} & \quad \text{environment compensation of each pollutant gas} \\
\text{\textit{\text{N}_{p}}} & \quad \text{annual emission amount of each pollutant gas} \\
\text{\textit{\text{c}_{p,j}}} & \quad \text{unit compensation of each gas pollutant} \\
\text{\textit{\text{E}_{i}}} & \quad \text{annual energy shortage of each type of load} \\
\text{\textit{\text{c}_{i,j}}} & \quad \text{unit punishment value of each type of load} 
\end{align*}
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