Dynamic Fuzzy-based Control Strategy for Optimal Power Allocation of EV-PV-HES DC microgrid

Du Yan, Wu Qibiao, Mao Meiqin, Yang Xiangzhen

Hefei University of Technology

***Abstract*—**A DC microgrid integrating photovoltaic (PV) systems, hybrid energy storage (HES), and electric vehicles (EVs) presents a promising and grid-friendly solution for EV charging. However , the State of Charge (SOC) of supercapacitors/batteries is prone to exceeding limits during operation. Traditional fixed-parameter filters and power frequency division control that only considers the SOC of supercapacitors struggle to achieve reasonable power allocation and protection based on the battery/capacitor SOC, leading to the attenuation of the service life of energy storage units. To address this, this paper proposes a dynamic fuzzy-based control strategy for optimal power allocation of HES in photovoltaic-storage charging stations. This strategy takes the DC bus reference current (Idcref), the SOC of energy storage batteries, and the SOC of supercapacitors as the input variables of the fuzzy controller, with the time constant T of the high-pass filter as the output variable. By formulating multi-dimensional fuzzy control rules and dynamically adjusting the time constant T, it realizes optimal power allocation and collaborative protection of the HES. Experimental results show that it can keep the SOC of HES within a reasonable range, prevent overcharging and over-discharging of HES, ensure the safe and stable operation of HES, and extend the service life of the equipment.

Research Objectives: Aiming at the problem that traditional fixed-parameter filters and power division control methods which only take the State of Charge (SOC) of supercapacitors into account are difficult to achieve reasonable power distribution and coordinated protection for the SOC of batteries and supercapacitors, this paper proposes a dynamic fuzzy-based optimal power distribution control strategy for hybrid energy storage systems in EV-PV-HES DC microgrids.

Research Conclusions: Through theoretical analysis and experimental verification, compared with traditional control methods, this strategy is better able to comprehensively consider the real-time State of Charge (SOC) of the system's energy storage components, optimize the power distribution among hybrid energy storage units, reduce the depth of discharge (DOD) of batteries, prevent overcharging and over-discharging of hybrid energy storage systems, and thus significantly extend the service life of batteries.

Research Results: Compared with traditional strategies, the strategy proposed in this paper can optimize the power distribution of hybrid energy storage systems under various operating states, reduce the depth of discharge (DOD) of batteries, and prevent overcharging and over-discharging of hybrid energy storage systems.

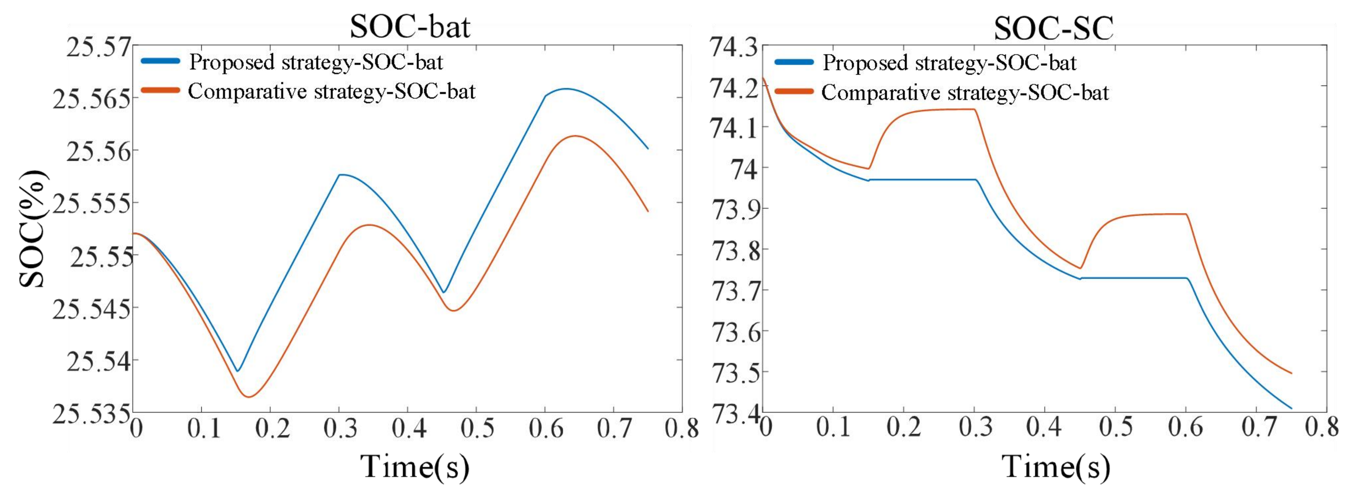

Fig.1 SOC Change Comparison Experiment in Working

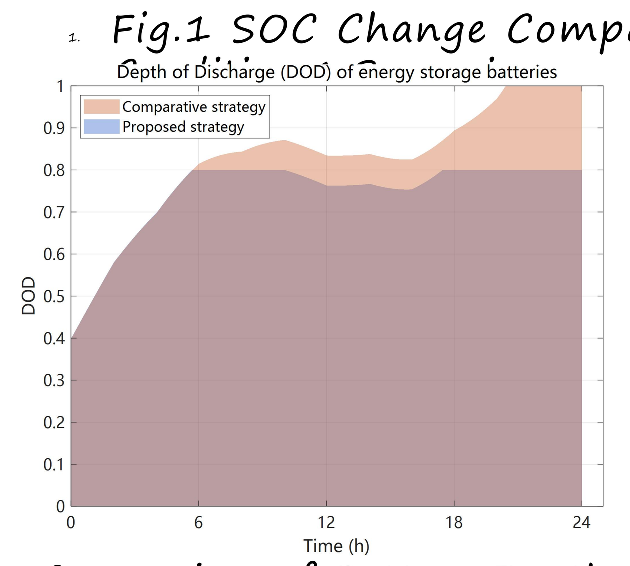

Fig2.Comparison of Battery Depth of Discharge

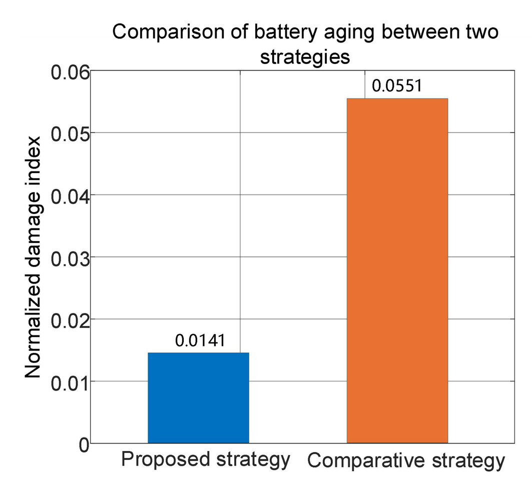

Fig2. Comparison of Battery Aging Index

Research Methods: Aiming at the issues that traditional hybrid energy storage control strategies fail to realize reasonable State of Charge (SOC)-based power distribution and coordinated protection for batteries/supercapacitors, and easily cause energy storage unit lifespan degradation, this paper proposes a dynamic fuzzy-based optimal power distribution strategy for hybrid energy storage in in EV-PV-HES DC microgrids. In this strategy, the DC bus reference current (I_{dcref}), battery SOC, and supercapacitor SOC are the inputs of the fuzzy controller, with the high-pass filter time constant T as the output. Based on the characteristic that a larger T enables the supercapacitor to smooth lower-frequency/more power, while a smaller T smooths higher-frequency/less power, fuzzy rules are formulated to dynamically adjust T for power distribution. In addition, a fuzzy rule (T=K) is designed to control the logic switch, forcing the battery's charge-discharge power to zero to prevent overcharging/over-discharging and extend equipment lifespan. The control strategy structure is shown in Figure 4.

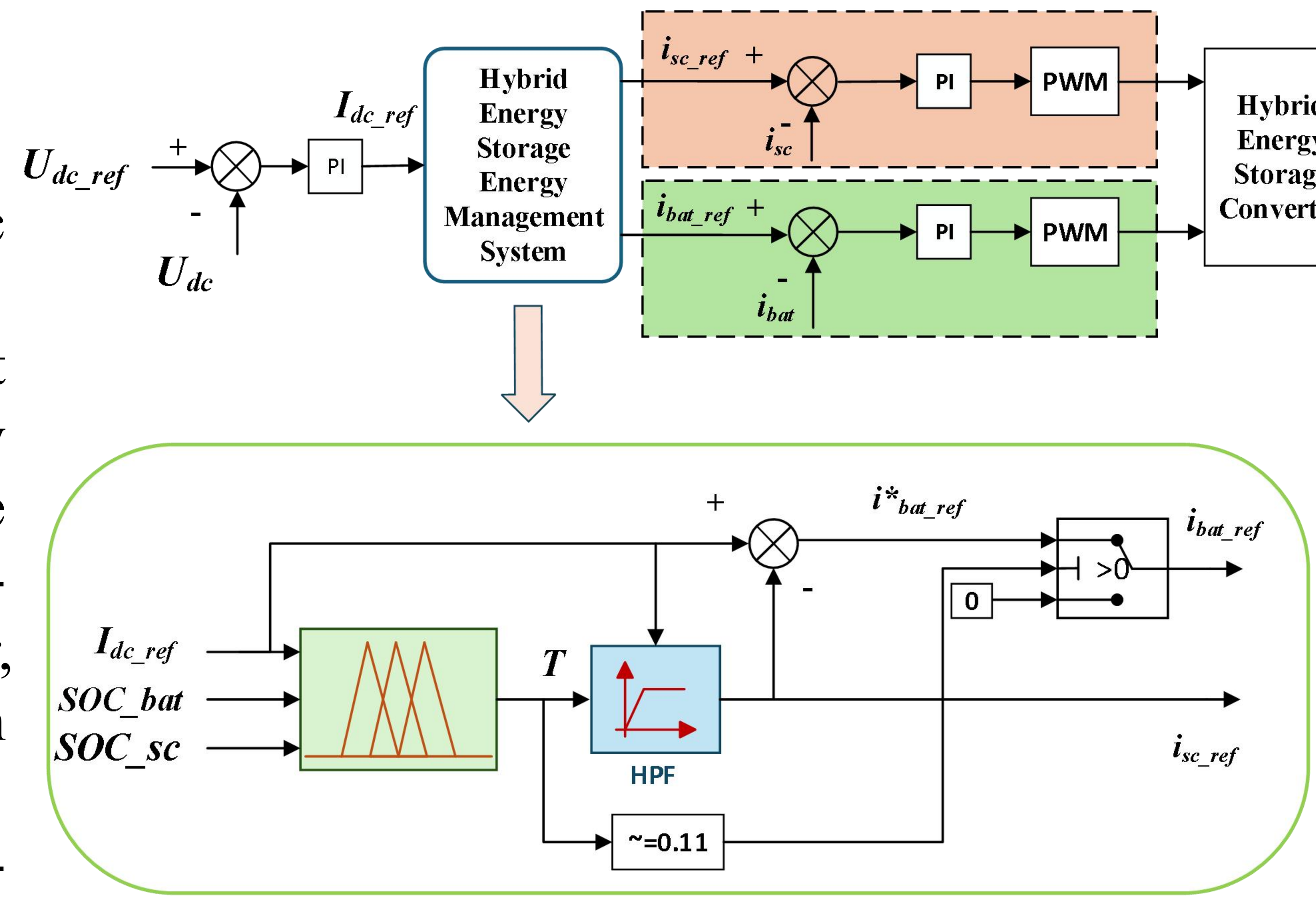

Fig4. Dynamic Fuzzy-based Control Block Diagram for Optimal Power Allocation of Hybrid Energy Storage in Photovoltaic-Storage Charging Stations

Tel: 13856051611
E-Mail: duyan@ hfut.edu.cn