Cost-Effective Integration of Second-Life EV Batteries with Solar PV Systems

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Abstract: As a low cost and mature clean energy source, solar PV generation currently has a high penetration rate especially in sunshine-rich states like California. Battery energy storage systems (BESSs) are frequently incorporated with PV systems as a standard approach to buffer the volatile nature of the PV output. Household small PV and storage systems are popular products in the market. For commercial buildings, similar technology is also available, but normally featuring large centralized battery stacks and consequently high cost.

Electric vehicles (EVs) started to enjoy a booming market share since the last decade. The number of EVs on roads is enormous and keeps growing rapidly, and so is the quantity of EV batteries. It is estimated that the first huge wave of EV battery retirement in California will hit in 2025, and retired batteries will keep coming thereafter. EV batteries today, almost exclusively lithium-ion based, cost heavily in both production and recycling. Economically dealing with retired EV batteries is an important topic.

Retired EV batteries, though no longer roadworthy, still have considerable capacity for stationary applications where the requirement for energy and power density is not as stringent. As an abundant byproduct from the road, these second-life EV batteries cost much less than new products. Meanwhile, the high cost of (new) batteries in storage systems could be a major discouragement for potential clients, especially small/medium owners. Thus, developing proper technologies to bridge the supply and demand has great significance.

The aim of this research is to validate that using second-life EV batteries in BESS for PV and storage system for small/medium sized commercial buildings will reduce the overall cost over serviceable life compared to using new batteries. To achieve this, we are conducting thorough multi-scale analysis and modeling of the second-life EV battery aging process and building degradation models, accordingly developing optimized energy management strategy considering PV and load profiles, and building customized electrical and control systems for site pilot testing.

Downscaled lab test bench for electrical and control system and battery cycling lab test system are established in San Diego State University (SDSU), and tests are being conducted. Two pilot testing sites, both with existing solar PV systems but different penetration rate, have been selected and the respective BESSs designing processes are ongoing. Through pilot testing, we aim to achieve overall cost reduction and no less than 35% reduction in initial installation cost, and also to establish the supply chain for similar projects in the future.

Bio: Dr. Mi is the distinguished Professor of Electrical and Computer Engineering at San Diego State University. He is a Fellow of IEEE (Institute of Electrical and Electronics Engineers) and SAE (Society of Automotive Engineers). He is also the Director of the US Department of Energy-funded Graduate Automotive Technology Education (GATE) Center for Electric Drive Transportation at SDSU. He was

previously a faculty member at the University of Michigan-Dearborn from 2001 to 2015, and an Electrical Engineer with General Electric from 2000 to 2001. He also served as the CTO of 1Power Solutions from 2008 to 2011. Dr. Mi received his Ph. D from the University of Toronto, Canada, in 2001.

Dr. Mi has published five books, 204 journal papers, 126 conference papers, and 25 issued and pending patents. He served as Editor-in-Chief, Area Editor, Guest Editor, and Associate Editor of multiple IEEE Transactions and international journals, as well as the General Chair of over ten IEEE international conferences. Dr. Mi has won numerous awards, including the "Distinguished Teaching Award" and "Distinguished Research Award" from the University of Michigan-Dearborn, IEEE Region 4 "Outstanding Engineer Award," IEEE Southeastern Michigan Section "Outstanding Professional Award," and SAE "Environmental Excellence in Transportation (E2T) Award." He is the recipient of three Best Paper Awards from IEEE Transactions on Power Electronics and the 2017 ECCE Student Demonstration Award. In 2019, he received the Inaugural IEEE Power Electronics Emerging Technology Award. In 2022, he received the Albert W. Johnson Research Lectureship and named the Distinguished Professor, the highest honor given to a SDSU faculty member and only one award is given each year.

Dr. Mi was the Chair (2008-2009) and Vice-Chair (2006-2007) of the IEEE Southeastern Michigan Section. Dr. Mi was the General Chair of the 5th IEEE Vehicle Power and Propulsion Conference, Area Editor of IEEE Transactions on Vehicular Technology, associate editor of IEEE Transactions on Power Electronics, Associate Editor of IEEE Transactions on Industry Applications. He is the topic chair for the 2011 IEEE International Future Energy Challenge and the General Chair for the 2013 IEEE International Future Energy Challenge. Dr. Chris Mi is a Distinguished Lecturer (DL) of the IEEE Vehicular Technology Society.

He is Guest Editor-in-Chief of IEEE Journal of Emerging and Selected Topics in Power Electronics - Special Issue on WPT, Guest Co-Editor-in-Chief of IEEE Transactions on Power Electronics Special Issue on WPT, Guest Editor of IEEE Transactions on Industrial Electronics - Special Issue on dynamic wireless power transfer, and steering committee member of the IEEE Transportation Electrification Conference (ITEC-Asian). He is Program Chair or General Chair of a number of international conferences, including Workshop on Wireless Power Transfer (WoW), IEEE International Electric Vehicle Conference (IEVC), and IEEE International Transportation Electrification Conference – Asia-Pacific. He is the Guest Editor of a Special Issue of the Proceedings of the IEEE - Electric and Hybrid Vehicles.