

CO₂ and Cost Impact Analysis of a Microgrid with Electric Vehicle Charging Infrastructure: a Case Study in Southern California

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Introduction

Methodology

Results

Conclusions and Future Work



- ▶ This paper examines the effectiveness of transportation-based microgrid configurations in reducing CO₂ emissions and electricity costs within an Intelligent Transportation System (ITS)
- ▶ A case study at the University of California, Riverside (UCR) using CAISO CO₂ emission data shows that a load-following microgrid strategy can reduce CO₂ emissions by 67%–84% and save approximately \$24,000 annually, even with daily EV charging
- ▶ Battery sizing is crucial, as doubling capacity may lead to diminishing returns in cost and emission reductions, highlighting the need for optimal battery capacity
- ▶ The study finds Level 2 chargers have minimal impact on building demand, while a single Level 3 DC fast charger significantly increases demand, requiring more solar and battery storage for cost reduction

Purpose and Contributions

- ▶ This research is crucial for advancing intelligent transportation systems by addressing the economic needs of EV charging infrastructure owners and optimizing configurations to benefit both EV owners and the environment.
- ▶ The paper investigates the impacts of Level 2 and Level 3 charging infrastructure on microgrid behavior, electricity costs, and CO₂ emissions in Southern California.
- ▶ Simulations are conducted using OpenModelica, a dynamic modeling and simulation environment.
- ▶ The study uses a higher time resolution, capturing CO₂ emissions data every 15 minutes.
- ▶ This approach distinguishes the research from previous studies by providing more detailed insights into emissions and cost impacts.

Microgrid Setup in OpenModelica

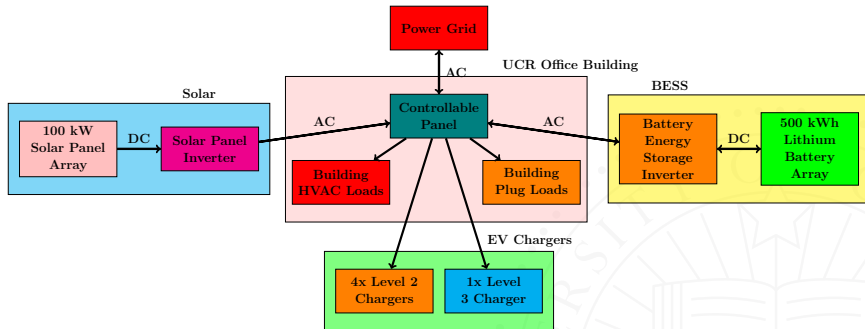


Figure 1: Microgrid Architecture of our Case Study Example BESS: Battery Energy Storage System

EV Charger Loads

Our model incorporates transportation loads through EV charging infrastructure, including both real-world Level 2 chargers (as depicted in Figs. 2 and 3) and simulated Level 3 chargers modeled using a Poisson distribution.

Level 2 Chargers Number of Sessions in One Year

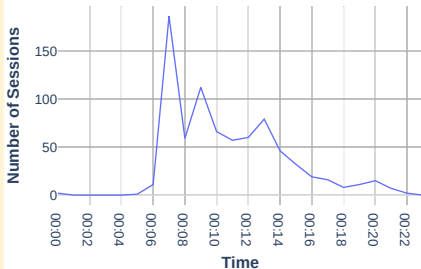


Figure 2: Level 2 EV Charger Probability Density Function Created by Using Actual Charging Data Obtained from a SCADA System



Figure 3: Level 2 Charging Setup

- ▶ The charging setup is modified in OpenModelica for different layouts and scenarios
- ▶ The scenarios are described in Table 1

Table 1: Simulated Scenarios of the example UCR Microgrid under Different Battery Sizes and EV Charging Demands

Scenario	
1	Standard Building with no EV Chargers
2	Standard Building with Level 2 Charging
3	Standard Building with Level 2 and Level 3 Charging
4	Microgrid Building with 100 kW Solar, 500 kWh BESS, and No EV Charging
5	Microgrid Building with 100 kW Solar, 500 kWh BESS, and Level 2 Charging
6	Microgrid Building with 100 kW Solar, 500 kWh BESS, Level 2, and Level 3 Charging
7	Microgrid Building with 100 kW Solar, 1 MWh BESS, and Level 2 Charging
8	Microgrid Building with 100 kW Solar, 1 MWh BESS, Level 2, and Level 3 Charging

Table 2: Microgrid Utility Prices and CO₂ Emissions Output under Different Battery Sizes and EV Charging Demands

Scenario	Demand Charges (\$)	Energy Charges (\$)	Total Cost (\$)	CO ₂ Emissions (mTons)
1	6616	22736	29352	34
2	8196	24607	32803	37
3	14235	29693	43928	43
4	3887	2387	6274	5
5	5133	3853	8986	7
6	11329	8238	19567	14
7	5022	3814	8836	7
8	11400	8133	19533	14

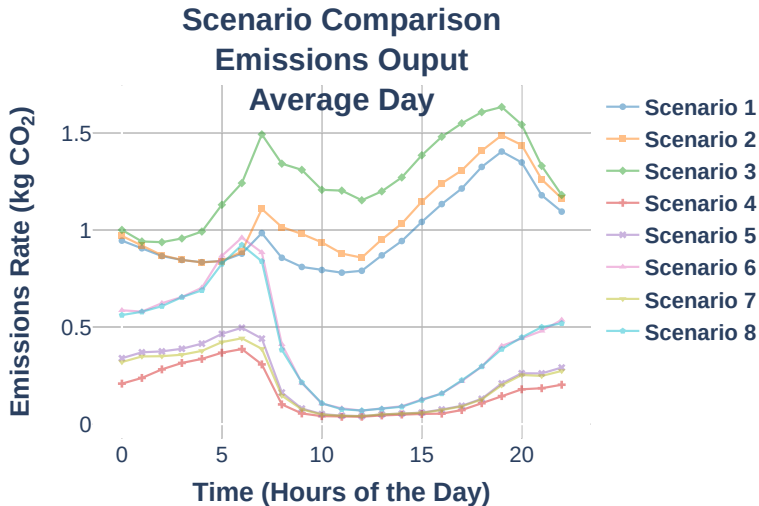


Figure 4: CO₂ Emissions Outputs Averages During Times of Day, using a microgrid setup

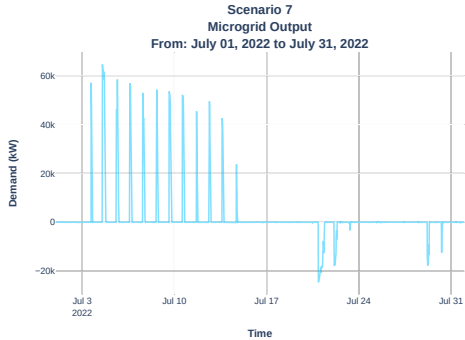


Figure 5: Load Following Failures after Battery Depletion (Level 2 Charging, 1 MWh BESS)

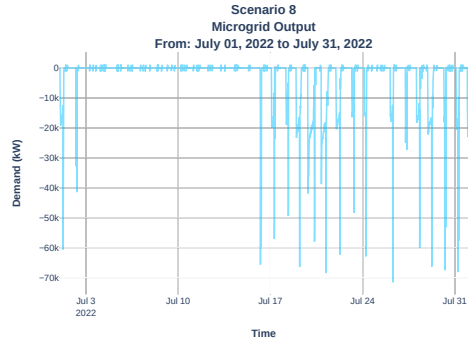


Figure 6: Load Following Failures after Battery Depletion (Level 2 and Level 3 Charging, 1 MWh BESS)

Conclusions

- ▶ Transportation-microgrids offer significant economic and environmental benefits
 - ▶ Annual savings for load-following transportation microgrids are approximately \$23,000 to \$24,000, despite the additional demand from EV chargers.
 - ▶ Cost of demand and energy savings trends are similar, with savings of \$3,000 and \$21,000 respectively.
 - ▶ Load-following microgrids can reduce CO₂ emissions by 67% to 85%, equating to about 30 tons of CO₂ reduction.
- ▶ Increased battery capacity does not guarantee improved performance
 - ▶ Increased capacity improves performance but not proportionally to the cost
 - ▶ Large capacity needed for challenging situations may not be cost-effective
- ▶ Key considerations for effective microgrid implementation and clean energy integration
 - ▶ Incentives exist to integrate additional clean energy sources (solar and wind), particularly when incorporating Level 3 fast chargers
 - ▶ Level 2 chargers have a minimal impact on office building energy demands
 - ▶ Effective microgrid planning requires a balance of clean energy generation, energy storage, and load management

- ▶ Explore advanced control strategies to optimize electric costs and CO₂ emissions for microgrids energy management
- ▶ Investigate electric vehicle load allocation during high peak times
- ▶ Minimize power drawn from the grid during periods of high CO₂ emissions.
- ▶ Assess the effects of the new net energy metering policy in California on the value of the Battery Energy Storage System (BESS).
- ▶ Analyze the impact of different time-of-use (TOU) rates in California on electric costs and CO₂ emissions.

Questions?



Thank You

