CO_2 and Cost Impact Analysis of a Microgrid with Electric Vehicle Charging Infrastructure: a Case Study in Southern California

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Outline

Abstract

- This paper examines the effectiveness of transportation-based microgrid configurations in reducing CO_2 emissions and electricity costs within an Intelligent Transportation System (ITS)
- A case study at the University of California, Riverside (UCR) using CAISO CO_2 emission data shows that a load-following microgrid strategy can reduce CO_2 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 CO_2 emissions in Southern California
- Simulations are conducted using OpenModelica, a dynamic modeling and simulation environment
- The study uses a higher time resolution, capturing CO_2 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

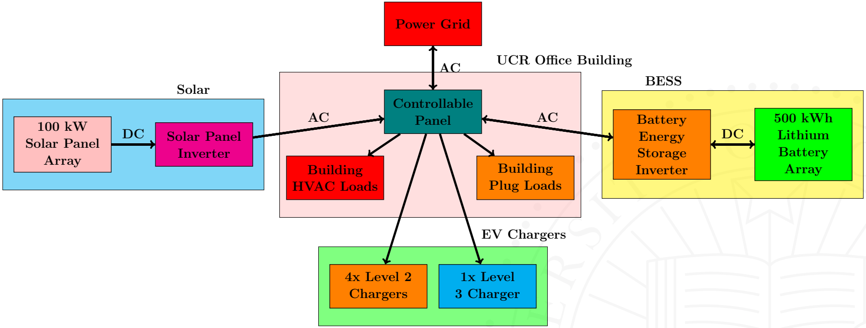


Figure 1: Microgrid Architecture of our Case Study Example BESS: Battery Energy Storage System

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

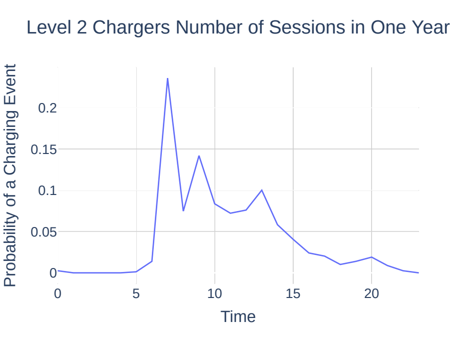


Figure 2: Level 2 EV Charger Probability Density Function Created by Using Actual Charging Data Obtained from a SCADA System

Figure 3: Level 2 Charging Setup

Results

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

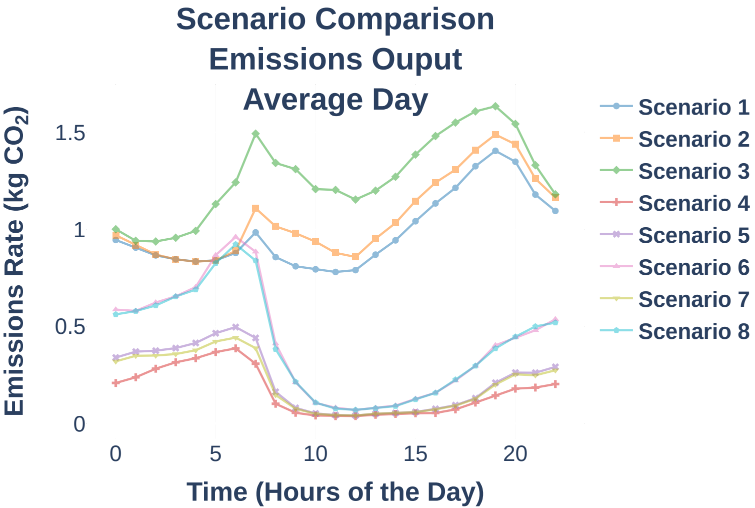
Table 1: Simulated Scenarios of the example UCR Microgrid under Different Battery Sizes and EV Charging Demands

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 CO_2 Emissions Output under Different Battery Sizes and EV Charging Demands

Scenario	Demand Charges ($)	Energy Charges ($)	Total Cost ($)	CO_2 Emissions ($_m$Tons)
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

Results


Scenario Comparison
Emissions Ouput
Average Day
Emissions Rate (kg CO_2)
1.5
1
0.5
0
0
5
10
15
20
Time (Hours of the Day)
Scenario 1
Scenario 2
Scenario 3
Scenario 4
Scenario 5
Scenario 6
Scenario 7
Scenario 8

Results

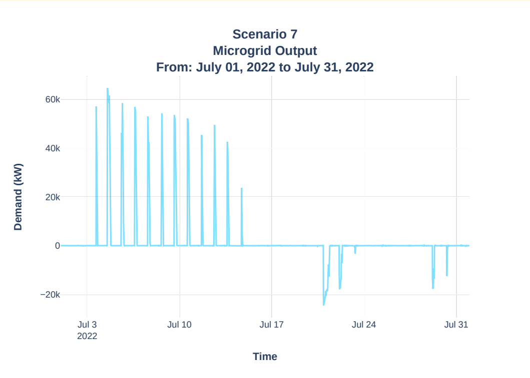


Figure 5: Load Following Failures after Battery Depletion (Level 2 Charging, 1 MWh BESS)

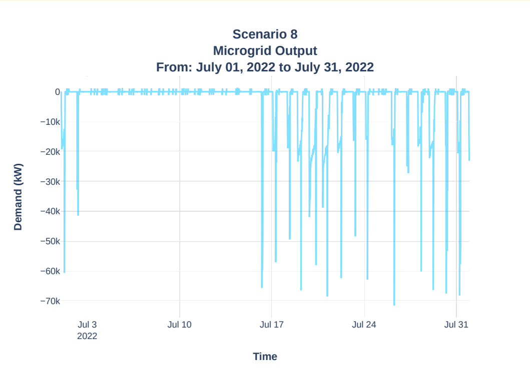


Figure 6: Load Following Failures after Battery Depletion (Level 2 and Level 3 Charging, 1 MWh BESS)

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 CO_2 emissions by 67% to 85%, equating to about 30 tons of CO_2 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

Future Work

- Explore advanced control strategies to optimize electric costs and CO_2 emissions for microgrids energy management
- Investigate electric vehicle load allocation during high peak times
- Minimize power drawn from the grid during periods of high CO_2 emissions
- Assess the effects of the new net energy metering policy in California on the value of the Battery Energy Storage System (BESS).
- Optimize the microgrid for EV truck charging

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Questions?

Thank You