RS&H Jacobs LOUISVILLE MUHAMMAD ALI INTERNATIONAL AIRPORT

Modified Microgrids: Integrating Electric Vehicles to Support the Airport Energy Evolution

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1 Introduction

Airports experience many operational challenges every day and are consistently striving to find and implement innovative solutions. Three main energy related issues that many airports are facing today are:

- High energy costs and growing energy demand
- More extreme natural threats and man-made hazards to the electrical grid
- The electrification movement and accommodating evolving technology such as electric vehicles (EVs)

Airports are identifying solutions that address each of these key challenges, but often their solutions are not integrated, causing long term operations and maintenance issues, poor financial outcomes, and impacts to airport patron experience. Our solution seeks to empower airports by addressing all three of these key challenges in the creation of one system: an advanced microgrid concept that incorporates EV charging infrastructure as flexible battery storage centers.

This innovation requires a review of the key challenges faced by airports, which our technology seeks to address. We will utilize case studies, peer reviewed literature, and personal accounts to demonstrate the need for an energy-saving solution in the aviation industry and potential benefits of this proposed solution. Subsequent sections will address the main considerations for implementing this technology including feasibility in the industry, cost impacts, and expected challenges. This proposal will close with an explanation of how this idea will benefit the aviation industry and the significance on airports, airport patrons, and local communities.

2 The Need for a Solution

2.1 Peak Demand and High Energy Cost

Airport operations often rely on equipment which uses significant levels of energy, and some can even require a 24/7 power supply. Understanding that airports have high energy consumption, researchers performed a study at Seve Ballesteros-Santander Airport in Santander, Spain to understand energy demand patterns (Alba and Manana, 2017). In mapping the daily, monthly, and yearly electric load profiles, the results demonstrate that there is a curve-type pattern with peaks and falls based on various factors (Figure 1).

Figure 1: Example average power demand at an airport. Source: Alba and Manana. (2017).

The researchers found that the energy demand was correlated with terminal building use; heating, ventilation, and air conditioning (HVAC); lighting; and outside temperature and daylighting. The researchers also discovered that the airport operated in cycles with high and low points in energy use throughout the day corresponding with peak travel periods. On the monthly and yearly scale, cycles were also driven by weather conditions and daylight hours.

Since the airport's busiest periods tend to correspond with peak demand times, strain is added to the utility grid. To address this issue, utility providers use a variable rate structure for usage that charges higher fees (i.e., demand charges) during these peak times, which often leaves airports paying extra (Figure 2). Airports are continually searching for ways to avoid energy use during peak hours.

CURRENT ELECTRIC CHARGES	
Contract: 159909	**Rate:** Time-of-Day Primary Service
Basic Service Charge ($10.84 x 30 Days)	325.20
Energy Charge ($0.02662 x 1,749,600 kWh)	46,574.35
Peak Demand Charge ($9.78 x 3,374.1 kVA)	32,998.70
Intermediate Demand ($7.49 x 3,374.1 kVA)	25,272.01
Base Demand ($2.45 x 3,500.9 kVA)	8,577.21
Electric DSM ($0.00035 x 1,749,600 kWh)	612.36
Electric Fuel Adjustment ($0.00335 x 1,749,600 kWh)	5,861.16
Economic Relief Surcredit ($-0.00343 x 968,400 kWh)	-3,321.61
Economic Relief Surcredit ($0.00 x 781,200 kWh)	0.00
Environmental Surcharge (2.71% x ($111,038.22 - $41,080.61))	1,895.85
Total Charges Contract 159909	**$118,795.23**

Figure 2: Louisville Muhammad Ali International Airport Peak Demand Charges. Source: Louisville Regional Airport Authority.

2.2 Increasing Climate and Man-Made Risks

Acknowledging that disruptions to the power supply are becoming more prevalent, airports are starting to integrate resilience strategies into their operations (Masrur, Hasan, et al., 2021). Risks to the grid from increasing demand, cyber and local attacks, and climate change-induced threats increase the vulnerability of the airport to lost revenue, airline schedule changes, and impacted public perception. Traditionally, airports have incorporated redundancy into their operations to ensure that backup power through fossil fuels (e.g., diesel powered generators) is available in case of an emergency. However, these systems may be unreliable if they are sitting unused for long periods of time, they have lower efficiency over time, and they may have aged technology. Further, since climate change induces more severe storms with longer lasting outages, small generators may not have the capacity to respond to high impact disasters. Because of these evolving risks, many airports are already turning towards microgrids as a transformative solution, offering increased resilience to low and high impact outages, using new efficient technology, and when paired with renewable energy generation, reducing the reliance on the grid and fossil fuels (Rana, Atef, et al. 2022). One function of microgrids is to manage energy consumption more efficiently through intentional charging of battery systems during periods of low demand and use of the battery during periods of peak demand (Figure 3).

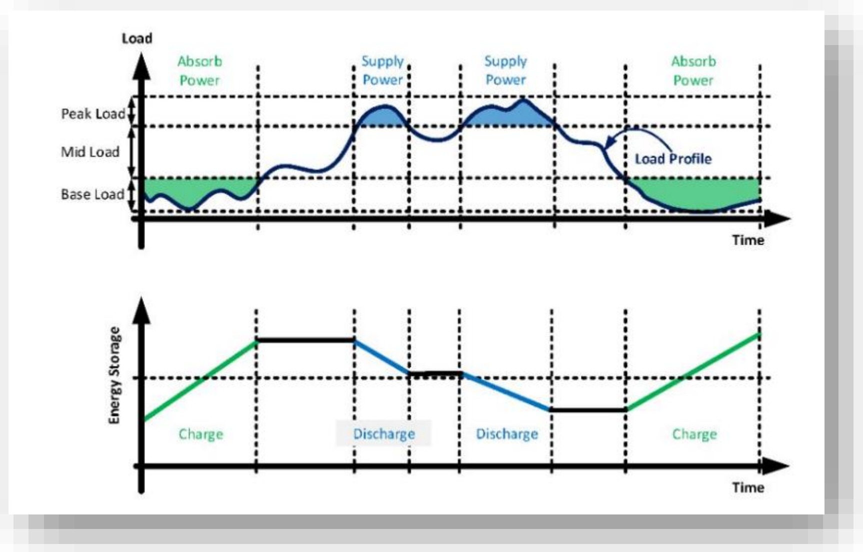

Figure 3: Illustration of storage-based peak-shaving, which could be accomplished through a microgrid system. Source: Rana et. Al (2022).

2.3 Uncertain Transitions to Electric Vehicles and Equipment

Electrification and the adoption of EVs, as a response to climate change and increasing resilience, have become more common. Airports are additionally challenged to accommodate these customer needs as a result of a new type of demand on existing infrastructure systems that do not have the ability to adapt in meaningful periods of time. In a study of airport representatives, researchers found that one of the primary concerns for implementing EV charging includes evolving technology and regional demand (Richard, 2014). The most commonly available public EV chargers can typically charge a vehicle fully in an hour. This quick charging capability creates an issue unique to long-term parking. With cars parked for several days, EV chargers remain largely unused, leading to various economic, efficiency and practicality constraints. Namely, customers may have access to chargers, but even with a level 1 charger, the slowest commercially available charger, a vehicle could remain in a charging spot for days after being fully charged. This scenario is known as idle time, where EVs are connected to chargers but have full batteries (Grøtan et al. 2022). Since most parking spots with chargers will be unavailable, there may be customer service issues if customers expect charging to be available when it is not. Some airports have considered using valet or mobile charging approaches to address these concerns, but these solutions add other operations and maintenance costs that often are extensive.

Another issue for airport representatives was the return on investment and the revenue potential associated with this new service (Richard, 2014). With vehicles occupying spaces for times longer than is needed for charging, is unclear how customers can be fairly charged for their parking product and their power usage. Due to these concerns, some airports have chosen to offer electric vehicle charging as an included service within a paid premium lot, while others have opted against implementing EV specific parking entirely. However, both pathways are fraught with challenges.

3 The Solution

Our proposed solution seeks to address a combination of the growing issues faced by airports: reduce utility costs while increasing resilience and to also effectively provide EV-related amenities to airport patrons.

3.1 Advanced Microgrid Concept

An advanced microgrid concept could allow for the EVs to be used in an energy sharing program that benefits both the EV owner and the airport. Specifically, this proposal investigates the viability of EVs connecting to a bidirectional charging point that allows the airport to use stored power in the EVs during peak energy rate periods and recharging the EV during timed off-peak times to ensure the EV is fully charged upon the owner's return. In this scenario, bidirectional charging infrastructure could simultaneously monitor energy usage and store user data pertaining to travel return times. Ideally, vehicles that are stored for several days will be "cycled" through multiple times, being charged during periods of low energy cost and having that energy used during peak rate periods. This cycle would end at the time the customer returns with their car fully charged. This solution seeks to solve many of the EV challenges faced at airports, including long storage periods, inefficiencies of chargers, and fair fee rate systems while also addressing concerns to improve resiliency in economically viable ways. While microgrids that utilize various forms of renewable energy and battery storage are already being implemented to create the same "peak shaving" effect, this solution offers another supplemental tool to further encourage the implementation of a microgrid, while also addressing the separate airport specific issue of EV charging. If renewable sources and outside battery systems are combined with this approach, the airport could further purchase more "cheap" energy to offset the peak demand periods.

3.2 Feasibility

When discussing advanced microgrids there is not a one size fits all solution. Therefore, it is important that a feasibility study is conducted to determine whether these energy solutions are a viable option for each location. A feasibility study will determine what configuration and components are needed to meet the specific needs of the location. Specific to the advanced microgrid solution, it is important to determine whether EVs have saturated the market sufficiently to support an advanced microgrid in that geological location. The Louisville Muhamad Ali International Airport (Louisville Airport) designed a microgrid that not only generates enough power to back up the entire terminal facility, but their microgrid also contains a battery energy storage system that is supplemented by solar energy. Louisville Airport, like most other airports, has high peak demand periods and is a perfect example of how microgrids are beneficial to airports. If Louisville Airport had the EV charging demand to support an advanced microgrid and the technology was in place, they would be a great use case for this type of innovation. For example, it may have allowed for the downscaling of the battery system, further reducing an often-costly piece of the microgrid concept.

3.2.1 Vehicle to Grid (V2G) Systems

With increasing electrification, the idea of vehicle to grid (V2G) integration has been proposed, which occurs when power is sent from the EV back to the grid (Wang, 2016; Ecomento.de. 2016). The benefits of this system include peak load shaving and providing redundancy for power outages. By increasing the diversity of the distribution network, energy systems are more resilient which can lead to more reliability and lower cost. This technology is a recent innovation but anticipated to become more common place, allowing the "bidirectional" charging needed for this solution.

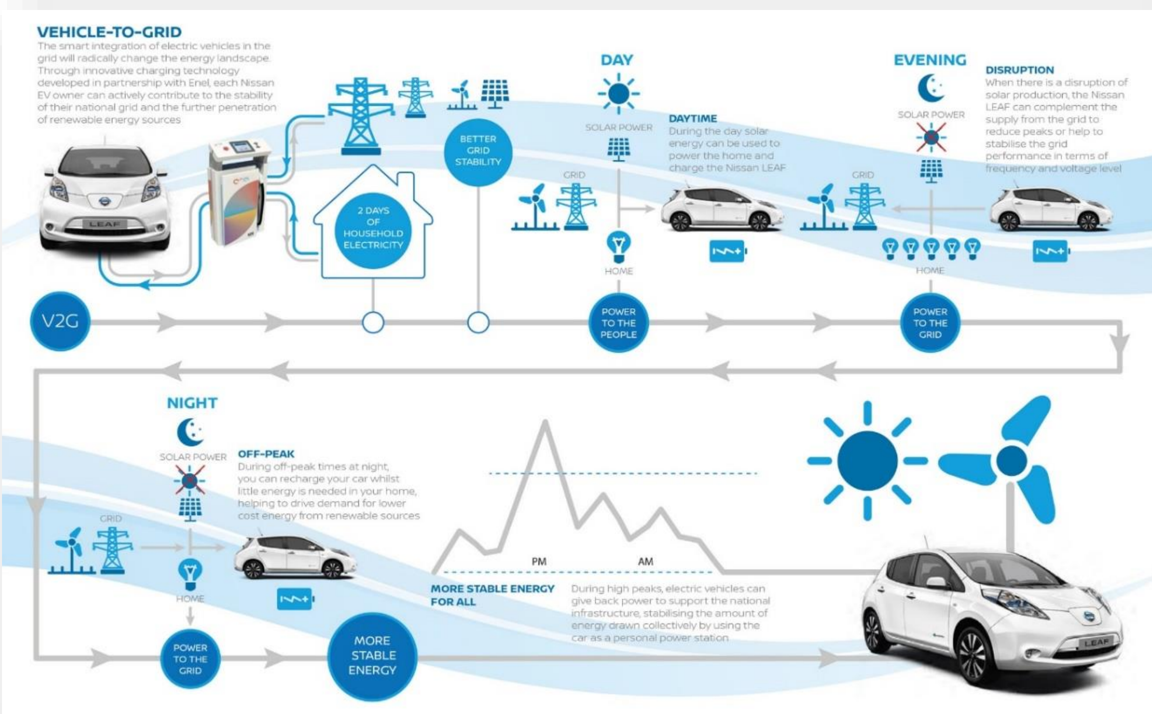

Figure 4: Diagram explaining the Vehicle to Grid system that would be integrated into our microgrid technology. Source: Ecomento.de.

3.2.2 Scheduled Charging

In a study of electric vehicle charging at Oslo Airport Gardermoen (OSL) in Norway, researchers leveraged car's idle time to implement scheduled charging in their lots (Grøtan et al. 2022). Through smart technology, the airport was able to schedule charging during non-peak times to reduce energy demand, in a process known as load shifting. Through this action, airports can save money. Combining this with the V2G bidirectional charging, a smart system could be created for the advanced microgrid to efficiently determine when to charge or consume the energy from EVs.

3.2.3 EV Battery Cycling

The implementation of smart microgrid infrastructure enables EVs to undergo strategic charging cycles via V2G. Under this proposal, the car would be discharged and recharged continuously as a part of the microgrid system if the car is parked and plugged in at the airport. One concern from EV vehicle owners may be battery degradation; however, if EVs are only used in a V2G microgrid model occasionally, the increases in battery degradation will be minimal (Wang et al. 2016). Specifically, researchers found that "The 10-year average capacity losses are 0.38%, 0.21% and 1.18% more than that in the base case, if EVs provide peak load shaving (V2G), frequency regulation (V2G) and net load shaping (V2G) for 20 times per year." Considering most airport patrons are more likely to only travel 5-10 times per year, it is highly unlikely that significant battery degradation would occur through this technology. It is also reasonable to expect continued advancements in battery technologies that would further reduce this concern.

3.3 Costs and Savings

Inherently, establishing a microgrid with integrated EV charging will have high upfront costs. Some of the system's upfront costs can be paid back through cost savings from reduced demand charges. For example, Louisville Airport was able to calculate a payback period of 10 years for their microgrid with battery storage. However, that system did not include EV charging. Therefore, with a system that includes EV infrastructure, additional cost recovery would be expected from EV energy management and parking rates. This approach provides another "tool" for airports to reduce the return on investment of emerging technologies.

The bidirectional capability of our design transforms EVs into mobile energy storage units, offering a dynamic solution for demand response and grid balancing. Financial gains arise from participating in grid services, where the EV fleet can be leveraged to provide ancillary services during peak demand periods. By selling excess stored energy back to the grid at favorable rates, organizations can generate additional revenue streams. Furthermore, the optimized use of energy contributes to cost savings by avoiding peak electricity rates. In essence, the financial advantages of bi-directional EV chargers lie in their ability to turn EVs into flexible energy assets, providing both cost savings and revenue-generation opportunities for airports operating within microgrid ecosystems.

A unique and location-specific analysis of the expected energy cost savings and return period would need to be performed to best determine the rate structure for a given airport's parking products. It may be possible that an airport is able to provide free or, as a minimum, discounted parking to attract EV users to the facility. Also, airports could consider setting a minimum "per day" fee for the parking facility (e.g., the first day is $15 and then each subsequent day is $5). This solution would help reduce the use of EV chargers by short term vehicles that are not contributing to the microgrid system while directly benefiting the customer financially.

In addition, airports are constantly subject to new regulatory requirements and a changing energy landscape. To avoid potentially lofty retrofitting costs in the future or requirements to make immediate upgrades to EV infrastructure to promote its continued adoption, airports can be strategic on how to efficiently integrate this technology into their operations or current microgrid systems. This strategic move would anticipate potential regulatory changes and grant opportunities favoring eco-friendly initiatives, helping airports develop in the most cost-effective way.

3.4 Challenges and Solutions

3.4.1 Education and Gaining Consent

One prominent obstacle involves ensuring that passengers are not only cognizant but also willingly accept the ramifications of their vehicles undergoing multiple battery cycles. This awareness is crucial for establishing a transparent and informed relationship between the users and the technology, as well as fostering a sense of trust and understanding. Education of the consumer on the system and gaining consent would be a crucial part for this system. One way to create awareness for users would be to create an online booking system. This booking system could integrate terms and conditions that must be agreed to by the EV owner before making the reservation. In the system, customers would need to acknowledge that they read and understood the guidelines of the microgrid system and the impacts of these operations on their vehicle. A major component of the agreement would state that their car battery would only go through one cycle per day (simulating a normal day in which the vehicle would be driven a long distance), and their battery would be kept between 20%-80% charged. Studies have concluded that degradation over time of the EV's battery will be increased if the charge of the vehicle falls outside of the 20%-80% charge level.

3.4.2 Travel Schedule Changes

Another significant challenge revolves around adapting to changes in travel schedules for individuals utilizing the facility. Given the dynamic nature of travel plans, the system must be flexible enough to accommodate alterations in user itineraries seamlessly. This requires the implementation of a responsive and user-friendly interface that allows for easy adjustments, ensuring a smooth and efficient experience for passengers. Changes in travel schedules for individuals are not new and should always be expected for a certain percentage of the passengers using the lot. To mitigate these challenges, technology will be used that requires passengers to enter travel data into the system. This would be through the previously mentioned online booking system prior to arriving at the airport. Should there be changes to the travel schedule, the user would ultimately be responsible for updating their return time in the online system. To ensure the vehicle would be ready for use upon arrival, there would be a required minimum notification time. In rarer circumstances where enough notification cannot be given, a few stationary or mobile rapid chargers would be made available in the lot to accommodate any users who had to leave before their vehicle was fully charged.

4 Conclusion

As fleet vehicles, rental cars, ground service equipment, aircraft, and other vehicles are increasingly electrified, airports have an increasing need to manage their energy load more effectively and reduce their peak demand to ensure long term financial sustainability. In addition, airports must consider the needs of their customers and the surrounding community. Offering services such as electric vehicle parking increases customer amenities while traveling. Increasing resilience ensures that the airport can continue serving the public even during major impact events. While research about this technology is still early and there are no known pilots, the feasibility of this proposal can be understood through its major components of V2G systems, scheduled charging, and EV battery cycling. Successfully proposed solutions would employ increased public education, consistent customer service, and unique pricing models to maximize the efficiency of the system based on location. In the end, introducing EV infrastructure into microgrids at airports offers many potential benefits to the airport, consumers, the community, and greater industry. Airports can expand their microgrid system “toolbox,” enabling greater resilience and reducing the risk of major financial impacts from grid outages. Consumers can benefit from integrated electric vehicle charging and smart system technology to charge their car at ideal times. Finally, the community benefits from less strain on the grid during peak times and lower GHG emissions from energy production.

While our proposal was focused on leveraging customer electric vehicles parked within long term economy lots, future studies and pilot programs could investigate how this technology could be applied to fleet vehicles and large machinery that remain stationary during non-use periods, and rental car fleet vehicles. Depending on the airport size, the region, grid energy composition, and other factors, this technology can be amended to meet a particular need. Inherently, successful microgrid advancement will reverberate throughout the aviation industry and empower more airports to adopt these evolving technologies to better serve their stakeholders, customers, and communities.

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