Electrifying Food Trucks: A Sustainable Approach

7.5 Grid and charging system infrastructure

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Abstract

In the dynamic landscape of mobile gastronomy, food trucks have transformed into lively culinary hubs. Despite their success, conventional food truck vehicle models have raised concerns due to their environmental impact. Currently, food trucks rely on onsite diesel generators, contributing to increased local air pollution and noise levels. First, in this study, we assess the air pollution and noise levels generated by these food trucks. To address these environmental issues, we evaluate connecting the food trucks to the grid and therefore phasing out the diesel generators. Second, by integrating food trucks into the distribution network, we examine the thermal and voltage performance in the grid. Our findings demonstrate that electrifying food trucks by integrating them into the grid presents a viable solution to move away from fossil fuels. This approach provides valuable insights into mitigating carbon emissions, reducing noise levels, and cutting operational costs typically associated with traditional food truck operations.

Index Terms

food truck, electrification, air emissions, grid-connected, GridLAB-D

I. Introduction

In recent years, the food truck industry has experienced a remarkable surge in popularity, emerging as a dynamic and innovative force within the broader culinary landscape [1]. These mobile kitchens, once associated primarily with street food culture, have evolved into sophisticated culinary ventures. Despite their rising popularity, the environmental impact of traditional food trucks cannot be overlooked. The conventional reliance on fossil fuels for powering these mobile establishments contributes significantly to air pollution due to the use of onsite diesel generators to power the culinary operations [2], [3]. By adopting electric power, food trucks can transition towards a more sustainable and environmentally conscious model, aligning with the broader societal shift toward cleaner and greener technologies.

Studies show that the carbon footprint of conventional food trucks extends beyond mere fuel consumption, encompassing factors such as noise pollution, waste generation, and inefficient energy utilization. Carbon footprint, narrowly speaking, denotes the quantity of greenhouse gases (GHGs) generated by human activities for a product, encompassing carbon monoxide, methane, nitrous oxide, ozone, and chlorofluorocarbons [4]. However, quantifying carbon emissions generated by food preparations in food trucks differs from traditional carbon footprint assessments, as it necessitates consideration of the amount and categories of food involved [5]. Additionally, research studies have shown the impact of exposure to particulate matter on the health of food truck workers and the community environment [6], [7].

Previous attempts to address the environmental impact of food trucks have largely centered around the electrification of their operations [8]. While limited in number, notable studies, and pilot projects have demonstrated the feasibility of transitioning mobile food services to electric power. These initiatives showcase the potential for reducing carbon emissions, noise levels, and operational costs associated with traditional food trucks. However, challenges such as the development of suitable electric infrastructure, the integration of efficient kitchen appliances, and the financial considerations of transitioning to electric models remain topics of exploration. Connecting the food trucks directly to the grid, as opposed to relying on diesel generators, would impose a substantial burden on the grid. There is some prior work on analyzing the impacts of heavy-duty EV integration into the grid that highlights the impacts on the thermal violation and losses caused due to the grid integration of EV [9].

The main contributions of the paper are summarized below:

1) We quantify the air pollution emissions from diesel generators used in food trucks.
2) We highlight the challenges and demonstrate the need for feeder upgrades to enable connecting the electrified food trucks to the grid.

II. Food trucks as a grid load

Distribution power systems serve as the backbone for supplying electricity to various end loads, including food trucks [10]. As these mobile kitchens increasingly go online with electrified setups, unforeseen loads and curve variations can pose significant challenges and potential risks to distribution networks. These unexpected events can lead to several adverse effects on the distribution system, potentially causing damage or disruptions.

1) Overloading and Voltage Instability: Unforeseen loads, especially those exceeding the network's capacity, can result in overloading. This excess demand can lead to voltage instability and fluctuations, potentially damaging equipment and causing interruptions in the power supply.
2) Voltage Fluctuations and Power Quality Issues: Rapid and unexpected load changes can cause voltage fluctuations and power quality issues within the distribution network. These fluctuations may negatively impact sensitive electronic equipment, leading to malfunctions or even permanent damage.

GridLAB-D is an open-source simulation platform designed for analyzing the dynamic behavior of distribution systems in smart grids [11], developed by Pacific Northwest National Laboratory (PNNL). 24 prototypical feeder models, created under the Modern Grid Initiative by PNNL with input from 17 utilities, are categorized according to voltage, approximate feeder loading, and climate region [12]. Some work using similar prototypical feeder-based analysis is presented in [13], [14]. These attributes play a crucial role in shaping the design of the feeder system. A 12.47 kV, 640-node, R5-12.47-2 feeder from a hot climate zone is chosen for this analysis. It represents a heavily populated urban center with 138 residential transformers and 46 commercial transformers. This feeder model is selected to evaluate the feeder readiness for electric food truck integration with the distribution system.

Figure 1 shows the section of the feeder that is augmented with food truck loads at different locations in the feeder model. Four commercial load locations are identified to evaluate the grid integrated electric food trucks. The commercial loads at these locations have distribution system transformers. The base case feeder model (no electric food trucks integrated in the feeder) has no thermal or voltage violations.

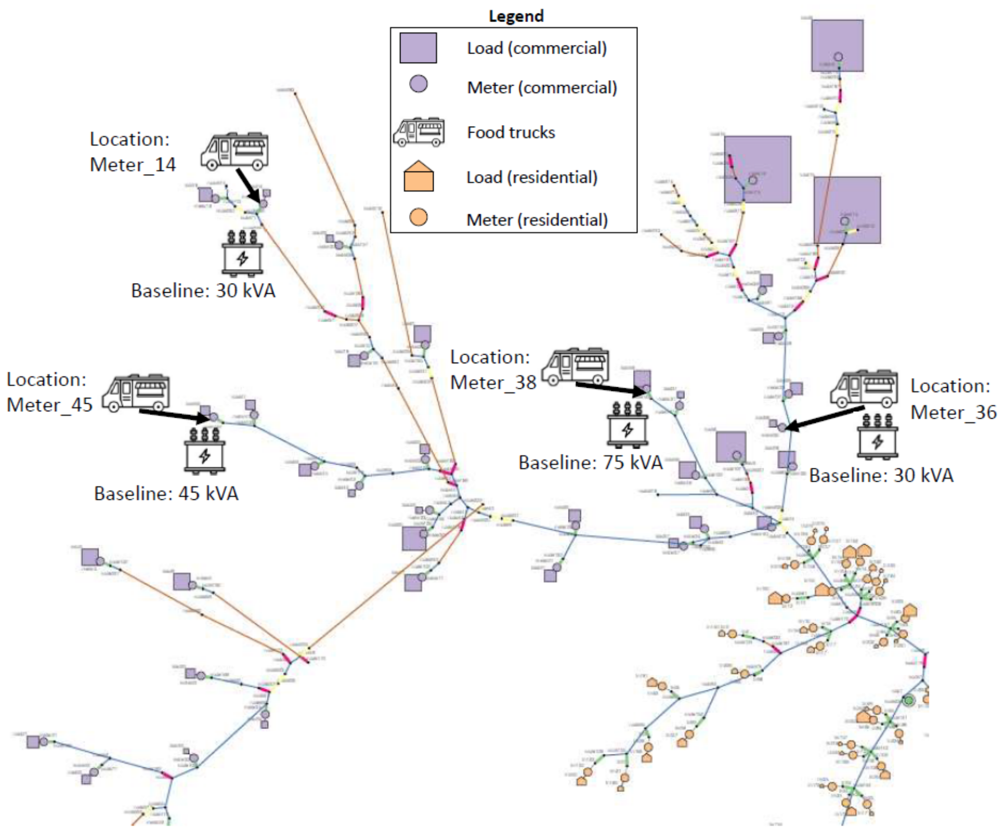

Fig. 1. Prototype feeder section showing location fo Food Trucks.

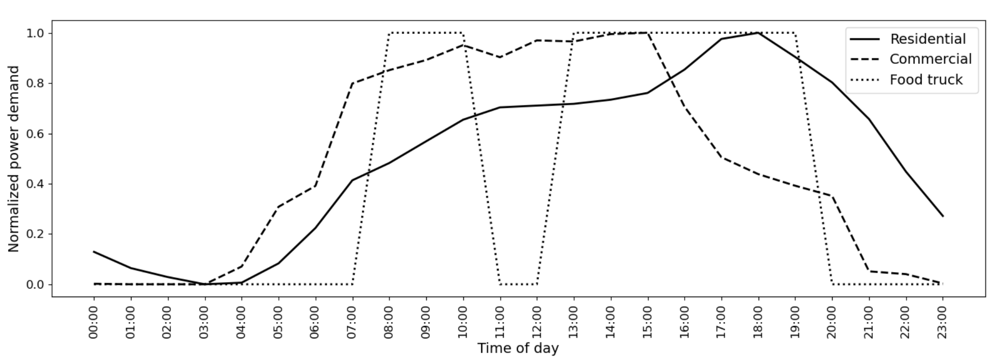

Fig. 2. Load profiles for residential and commercial buildings as well as for food trucks during summer in the prototype feeder.

A 24-hour simulation is done for a summer day. Figure 2 shows the daily load profiles for residential, commercial buildings, and food truck loads. The assumed duration of the food truck load is 10 hours, with 3 hours allocated for food preparation and 7 hours dedicated to service. For the simulations, we have considered the load of each food truck will be 6.5 kW [15].

TABLE I
FOOD TRUCK PENETRATION WITHOUT SYSTEM VIOLATIONS

Location	Transformer rating (kVA)	Food truck penetration
Meter 36	30	0
Meter 38	75	2
Meter 45	45	2
Meter 14	30	0

The simulation results for different numbers of electric food trucks being connected to the grid at the indicated locations are performed to assess the allowable penetration of the food trucks without any system violations. Table I provides the details of the simulation results. The results show that the base case (as-is) grid is not ready to integrate a significant number of food trucks. There are some locations on the feeder with slightly larger transformers where a couple of food trucks could be integrated, however, it would be difficult to host the typical number of food trucks at a food truck park (about 15-20 food trucks).

Next, we consider upgrading the transformers at the locations “Meter 36” and “Meter 38” to understand how much food truck penetration is feasible with the transformer upgrades. Table II indicates that the levels of transformer upgrades for a small load growth is insufficient to electrify a food truck park that is indicated by location “Meter 36.” The upgrade at location “Meter 38” is significant and aims to host a larger number of food trucks and could now host up to 18 food trucks on the feeder.

TABLE II
FOOD TRUCK PENETRATION WITH TRANSFORMER UPGRADES

Location	Transformer rating (kVA)	# Food trucks (BEFORE upgrades)	# Food trucks (AFTER upgrades)
Meter 36	30 upgraded to 90	0	2
Meter 38	75 upgraded to 375	0	18

A. Impact of Food Truck Electrification on Emissions

The emissions analysis for the present use case is shown in Table III. A small diesel generator emits: NO_X: 1.5 lbs/MWh; Particulate Matter: 0.07 lbs/MWh; CO: 2 lbs/MWh [16]. The annual emissions in Table III assume the operation of 48 weeks, with each week consisting of 6 operational days. The impact of the emissions can be devastating with such quantities of pollutants being released in a concentrated location. Furthermore, from available online data, the cost of a 3-phase 75 kVA, 1.47 KV/480V is approximately $26,000 and the cost of a similar 375 kVA transformer is approximately $93,000. This infrastructure upgrade cost for a utility could be easily recovered, but the impact on pollution and human health in the absence of these grid upgrades is significantly higher.

TABLE III
AIR POLLUTION EMISSIONS

Use Case	NO_X **(lbs)**	**Particulate Matter (lbs)**	CO **(lbs)**
1 food truck (1 day)	0.0975	0.004455	0.13
1 food truck (annual)	28.08	1.3104	37.44
18 food trucks (annual)	505.44	23.5872	673.92

III. CONCLUSIONS

The food trucks are usually powered by diesel generators, which can lead to large amounts of pollutant emissions. Food truck electrification and integration to the grid will need significant infrastructure upgrades. The paper uses a prototypical urban feeder model for the feasibility analysis of energizing food trucks through grid integration. The analysis shows that the base case (as-is) grid may not be ready to host a significant number food trucks, and may need upgrades to add these loads to the distribution system. The case study also shows that the cost of upgrades to the grid may be significant to allow for grid-integrated food trucks, however, this will eliminate the air pollution caused by diesel generator-operated food trucks significantly.

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