Enhanced Electric Vehicle Adoption Scenarios For Abu Dhabi Road Transportation

Deema Fathi Allan
Engineering Systems and Management
Masdar Institute
of Science and Technology
Abu Dhabi, United Arab Emirates
Email: dfallan@masdar.ac.ae
deema.allan@gmail.com

Toufic Mezher
Engineering Systems and Management
Masdar Institute
of Science and Technology
Abu Dhabi, United Arab Emirates
Email: tmezher@masdar.ac.ae

Amro M. Farid
Associate Professor of Engineering
Thayer School of Engineering
Dartmouth, Hanover, USA
MIT Mechanical Engineering
Research Affiliate
MA, USA
Email: Amro.M.Farid@dartmouth.edu
amfarid@mit.edu

***Abstract*—Electric Vehicles(EV) has emerged as a trend to support energy efficiency and CO_2 emissions reduction targets. They aim to reduce the use of non-renewable vehicle's fuel resources (Petrol, Diesel, etc.) and depend on renewable energy. However, EVs interact with three interconnected systems: the transportation system, the electric power grid, and their supporting information systems often called Intelligent Transportation Energy Systems (ITES). Therefore, the true success of electric vehicles depends on their successful integration with the infrastructure systems that support them. Consequently, the impact of these infrastructures is assessed in such a way that make EVs operation environment potentially applicable. This research aims to assess how can EV integration be systematically evaluated while preserving the quality of service and ensuring the reliability and security of the power grid within an enhanced ITES within Abu Dhabi context? A new methodological assessment based on hybrid dynamic model is proposed to evaluate the technical feasibility of EVs adoption within Abu Dhabi island.**

I. Introduction

Transportation Electrification (TE) has emerged as a trend to support energy efficiency and CO_2 emissions reduction targets. Electric vehicles (EVs) are one of the main modes of transportation electrification. The aim is to reduce the use of non-renewable vehicle's fuel resources (Petrol, Diesel, etc.) and depend on renewable energy. One challenge of EVs, however, is that they interact with three interconnected systems, namely: transportation system, the electric power grid, and their supporting information systems often called intelligent transportation systems (ITS) [1]–[3]. For that reason, the true success of electric vehicles depends on their successful integration with the infrastructure systems that support them. Furthermore, EVs generally behave differently than Internal Combustion Vehicles (ICVs) in two aspects. First, EVs typically have a travel range of approximately 150km [2]. Second, while ICVs can refuel in a matter of minutes, a typical EV may require 4-6 hours in order to recharge [4]. These two aspects of EVs can significantly impact user driving patterns and lead to different traffic behaviors [2]. Moreover, the challenge of electrified transportation is particularly important in the UAE. The transportation sector is responsible for 25.8% of CO_2 emissions [1]. In 2014, the average annual percent change in the population, in the UAE was recorded 2.71% [5]. The metropolis of Abu Dhabi anticipates population growth is to be around 3 million in 2030 [2]. Consequently, the demand for various transportation modes will increase. For that, the Department of Transport(DoT) is developing a surface transport master plan for EV integration scenarios in order to achieve a world class transportation system [6]. Several works have treated the integration of EVs within an intelligent transportation energy systems [1], [3], [7], [8]. The literature review shows many works in the power systems field [7], [8]. Of these only work has specifically addressed the Abu Dhabi transportation system [1], [2]. This previous study made a significant contribution to the role of EVs in Abu Dhabi using a preliminary set of case study scenarios [1]. The works found in [3] and [1] in this regard serve as the primary studies upon which much of this paper is based. Nevertheless, these works are not without their limitations. For example, in [3], the capacity of charging stations was neglected in the work. In [1], the simulation software did not accommodate changes to the decision-making functionality to the intelligent decision-making.

The key goal of this paper is to build upon previous work to be able overcome these limitation to develop a holistic assessment methodology for transportation electrification to be able to adopt EVs while overcoming the associated existing infrastructures challenges in Abu Dhabi city.

The remainder of the paper proceeds as follows. Section II briefly explains the assessment methodology with the associated results. Section III then shows the assessment conclusion.

II. METHOD OF ASSESSMENT

This section gives a general illustration for the proposed method of assessment of EVs adoption. Due to the total number of pages limitation, a small sample of the results for Abu Dhabi city is shown. However, the overall summary of the assessment methodology is explained.

Simulating AD traffic behavior using MATSim: Abu Dhabi traffic behavior is simulated using MATSim simulator based on mesoscopic traffic modeling. Previous work has already acquired the necessary Abu Dhabi data. **Simulate power grid behavior using MATLAB:** The process of charging EV is analyzed based on EV traffic behavior to assess the reliability and the security of the power grid. Since main purpose is to determine if EVs penetration will cause power fluctuation by exceeding power flow constraints in the existing electric distribution system. The reliability of power grid behavior id modeled using Matlab toolbox to produce power flow analysis. **Simulate energy consumption and CO_2 emissions reductions for the EV penetration scenarios:** Mitigating CO_2 emissions is the main purpose of using electric vehicles. For that, analyzing how CO_2 emissions could vary from scenario to another is also conducted.

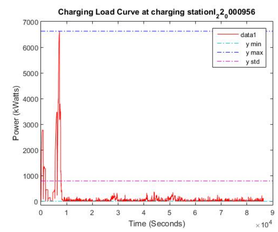
A. Abu Dhabi Case Study

This sections will identify the safety lines and regular average power demand for Abu Dhabi city then presents the results of the case study. Table I provides a list of facts in regard to Abu Dhabi city.

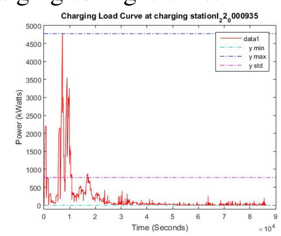
TABLE I: Abu Dhabi Power Distribution Network Transformer Limits.

Node Type	Architecture	Rating of Single Transformer
132/22 kV Substation	4 Parallel Transformers	80 MVA
132/11kV Substation	4 Parallel Transformers	40 MVA
33/11 kV Substation	2,3,or 4 Parallel Transformers	20 MVA
11/0.4kV Substation	4,6 or 12 parallel transformers	4 Transformers @ 1.5 mVA, 6 Transformers @ 1 MVA, 12 Transformers @ 0.5 MVA

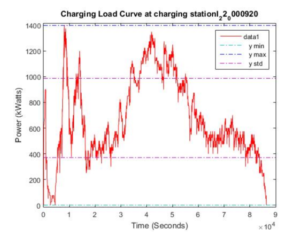
The case study was conducted on 3 zones within Abu Dhabi city which are Abu Dhabi Island, Khalifa city and Mussafah area for a taxi operation system. Figure 1 shows the charging curves for these three areas. As can be seen, Khalifa city maximum power consumption is the highest 6.6MW, then Mussafah at a value of 4.7 MW and Abu Dhabi is the smallest at a value of 1.4MW. This means, Khalifa and Mussafah exceed the transformers limits explained in table I when substation 11kW/0.4kw is used for 4,6,12 parallel transformers. However, Abu Dhabi island is within the limits and have not exceeded even at such a high penetration rate. Such an expected behavior due to the proposed charging station design, where, the total number of charging stations is limited to 3 in each of Khalifa and Mussafah areas, however almost 30 stations are distributed within the island. Therefore, the load imposed on a single charging station within Khalifa or Mussafah is much higher than in Abu Dhabi island. Another critical aspect that can be derived from the figure that the corresponding variability have a quiet different trend. Since the three zones have relatively high variability, this could degrade the feeder's performance. More interestingly, Abu Dhabi island has a variable load demand throughout the day opposite to Khalifa and Mussafah as can be seen in figure 1. These expected statistics reflects the real life behavior caused by the higher concentrated population in the center of Abu Dhabi. In other words, people have more activities to conduct within the island than the other two zones such as shopping, entertainment, etc. Noticeably, the peak charging hours for the three areas are between 1 pm to 4 pm which is a result of the regular Abu Dhabi end of business hours. However, not only that the power grid has to supply this extra electricity demand is the problem but the fact that the excessive load associated with EV charging during day time is imposed during the normal peak hours. This will force the utilities to supply more energy. Thus, without any charging management, these trends represent worst scenarios. Therefore, it is very much recommended to restrict the charging to night time.



(a) Charging Curves for Khalifa City



(b) Charging Curves for Mussafah City



(c) Charging Curves for Abu Dhabi Islan

Fig. 1: Charging Curves for Abu Dhabi City at 20% EV penetration rate

III. Conclusion

Since most of the taxi operation charging is during regular peak hours, huge disruptive influence on the grid will occur. Thus, with the given circumstances of charging patterns, higher penetration rate of EV imposes significant load increase on the grid. Consequently, one proposed solution is that the power system operation utilities should reduce the electricity tariff within off peaks hours to encourage consumers to change their charging behaviors.

References

[1] R. Al Junaibi and A. Farid, "A method for the technical feasibility assessment of electrical vehicle penetration," in *Systems Conference (SysCon), 2013 IEEE International*, 2013, pp. 606–611.

[2] R. Al Junaibi, A. Viswanath, and A. Farid, *Technical Feasibility Assessment of Electric Vehicles: An Abu Dhabi Example*. 2013 International Conference on Connected Vehicles and Expo, 2013.

[3] M. D. Galus, R. Waraich, F. Noembrini, K. Steurs, G. Georges, K. Boulouchos, K. Axhausen, and G. Andersson, "Integrating power systems, transport systems and vehicle technology for electric mobility impact assessment and efficient control," *IEEE Transactions on Smart Grid*, vol. 3, no. 2, pp. 934–949, 2012.

[4] J. Pointon, "The multi-unit dwelling vehicle charging challenge," *Electric Vehicles Virtual Summit*, vol. 69, 2012.

[5] C. I. A. (CIA), "Uae population growth rate," June 2014.

[6] *Abu Dhabi Surface Transport Master Plan 2050*. Department of Transport, 2007.

[7] A. M. Farid and A. Muzhikyan, *The Need for Holistic Assessment Methods for the Future Electricity Grid*. GSS CIGRE Power Conference, 2013.

[8] A. M. Farid, "Electrified transportation system performance conventional vs. online electric vehicles," in *Electrified Transportation System Performance Conventional vs. Online Electric Vehicles*, 2015.

[9] M. Balmer, K. Meister, M. Rieser, K. Nagel, K. W. Axhausen, K. W. Axhausen, and K. W. Axhausen, *Agent-based simulation of travel demand: Structure and computational performance of MATSim-T*, A. V. und Raumplanung, Ed. 2nd TRB Conference on Innovations in Travel Modeling, Portland, 2008.