

Developing a Common Charging Infrastructure for Electric Buses

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Short Abstract Summary

In the next few years the number of electric transit buses is expected to grow from 300 presently in 2016 to 775 in 2018 and 1,000 in 2019. This exponential growth may be in danger if standardized common charging infrastructure is not developed rapidly. This paper discusses the charging system available now and presents the requirements for a common interoperable charging infrastructure for electric buses and the pathway necessary for its deployment and roll-out.

Keywords: bus, infrastructure, standardization

1 Introduction

Electric transit buses offer an attractive clean transportation alternative to diesel buses – they operate quietly and produce no tailpipe emissions. The deployment of electric transit buses continues to grow in China, North America, and Europe. In the United States by the end of 2014 there were 125 electric transit buses deployed or on order at 42 transit properties and this is expected to double for each of the next two years [1]. In 2016 we are aware of 300 buses already on order.

Figure 1 below shows the projected path for zero-emission buses according to Federal Transit Administration's 2009 Electric Drive Strategic Plan of 12,000 zero-emission buses by 2030. According to this, by 2018 we expect 775 buses and by 2019, 1000 buses to be on the road in the United States.

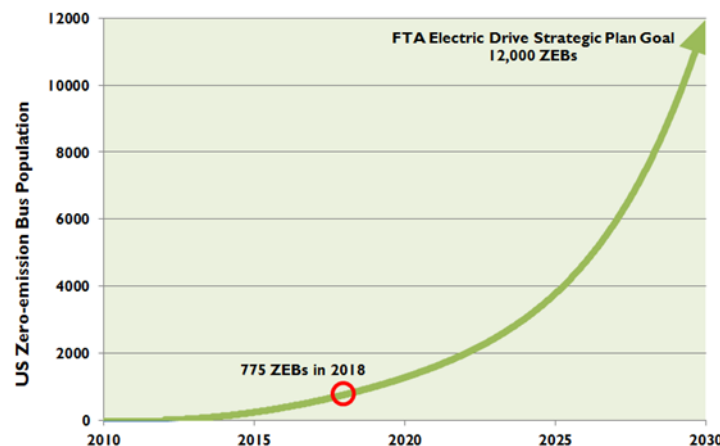


Figure 1: US Zero-emission bus population projections

While a growing number of transit properties are interesting in adopting electric buses, a clear barrier they are encountering is developing a plan for adequate charging infrastructure that would accommodate different models of electric buses. Today, each model uses a unique charging system. The lack of standardized charging systems and a common infrastructure presents a significant barrier to quicker adoption of electric buses and reaching the projected numbers.

The purpose of this paper is to provide an overview of electric bus charging and support standardization and development of a common interoperable charging infrastructure system that could be used with different types of electric buses. The first section briefly describes the types of charging for electric buses. The second section describes the current standardization efforts in North America for conductive charging. The third section addresses characteristics that are important for a common interoperable infrastructure. The fourth section presents the need to support the deployment and roll-out of common standardized charging systems.

2 Types of Charging

2.1 On-route opportunity charging

In this situation, the buses charge while in operation. These buses have smaller on-board battery packs and are rapidly charged at one or more stops along their route using overhead chargers at rates of 120kW, 200kW or 500kW. The design and specifications of overhead chargers varies with location and bus manufacturer. The duration of the charging can be on the order of 5 to 10 minutes to very rapid or flash charging, around 10 seconds [3]. Examples of commercially available transit buses with on-route charging include ABB TOSA, Hengton, New Flyer, PRIMOVE, Proterra, PVI, Siemens, Sinautec, VDL Bus Coach, Volvo) [4]. Figure 2 shows several examples of different overhead chargers deployed.



Figure 2: Examples of electric buses with on-route charging

In addition to overhead charging, some fleets have been adopting a wireless charging system. Systems that have been demonstrated to date are 50 kW but there are plans to develop wireless charging at higher levels, 200kW or more.

2.2 Depot or overnight charging

This system is used with buses that have larger battery packs, sufficient to meet the daily range. The bus charges at the end of the day for an extended period of time, 6h or 8h, at the bus depot location. The chargers may be conventional chargers which operate at lower charging rates, below 100kW for DC chargers. Examples of commercially available transit buses that rely on depot or overnight charging are BYD, CCW, EBusco, New Flyer, and Proterra.

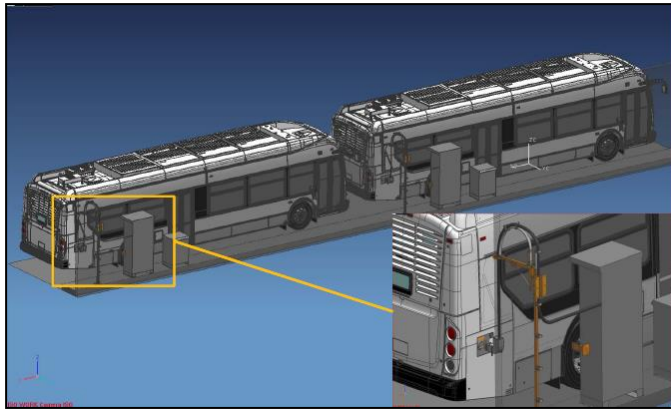


Figure 3: Electric bus with depot charging (Courtesy of New Flyer)

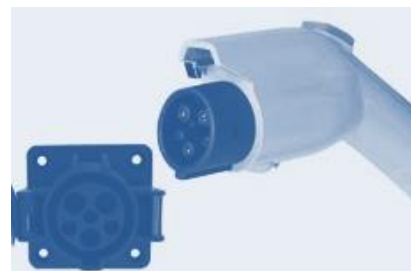
3 Current Standardization Efforts

The standardization efforts underway in North America are taking place under the SAE Medium- and Heavy-duty Conductive Power Task Force: SAE J3068 and J3105. Two documents are being developed within these two committees and will address standardization of the cable coupler, digital communication, and overhead charging interface for high power charging coupler.

SAE J3068 Committee – is developing the general physical, electrical, functional, testing, and performance requirements for conductive power transfer of three-phase AC power to an electric vehicle. The document would describe the cable coupler and digital communications for electrical power transfer that would become the US recommended practice for heavy-duty vehicles (trucks and buses). It will cover digital communications system and physical and functional requirements for the vehicle inlet, supply equipment outlet and mating and housing contacts. The current effort aims to standardize IEC Type 2 connector and inlet (shown in Figure 4a) up to 600 VAC (USA 480VAC and Canada 600VAC). This would provide a path for UL listing and regulatory approval of Type 2 connector in North America.



a)



b)

Figure 4: **a)** IEC Type 2 connector (Mennekes plug) limited to 44 kW at 400V/64A **b)** Type 1 connector (current US standard J1772) limited to 19 kW and 500V

SAE J3105 Committee – started in fall 2015 and will be focusing on a document describing conductive power transfer system transferring DC power primarily for transit buses using an overhead coupler. The committee will work on a document defining the standardization of curb side electrical contact interface, the vehicle connection interface, the electrical characteristics of the DC supply and the communication system.

The standardization for wireless charging is part of **SAE J2954 committee** in North America.

4 Characteristics of Common Interoperable Infrastructure

In addition to the technical standards development, there are sets of operational characteristics that are required in order to ensure easy and efficient charging protocols.

4.1 Operational characteristics

Depot charging operational characteristics may include – number of buses per station, bus-charger station detection, detection of appropriate V and A, monitoring (SOC, T, kWh), data logging and summary, selection of lower and higher charging power level, emergency stop and ground fault activation, safety requirements.

Overhead rapid charging operational characteristics may include – easy start-up from driver side, automated charging control, automatic shutdown when full, easy emergency procedures, driver allowed termination of charging, monitoring.

Universal Charging Systems – for the overhead rapid charging systems as well as depot charging systems the goal will be to assure the charges are universal in terms of full interoperability and full performance on any like charged electric bus product. While interoperability may be the minimum required, full charging performance without any limitations of V or A or charge profiles is the ultimate goal so that one set of infrastructure can provide full electric bus performance, no matter which bus is being charged.



Figure 5: Rapid charging system – a potential universal charger option and overhead interface connector (Courtesy of Siemens)

The European electric bus manufacturers (Irizar, Solaris, VDL and Volvo) have agreed to support interoperability of buses with charging infrastructure provided by ABB, Heliox and Siemens [5]. The standardization activities have started via the European body (CEN-CENELEC) and via the international organization for standardization (ISO/IEC). European standards are expected to come in place 2019.

In North America within the EPRI Bus and Truck Charging Working Group information is being collected on what parameters are important for proper operation of the charging infrastructure. The group is discussing parameters related to the design characteristics, installation, and safety and preparing survey questions for fleet customers. These activities in parallel to the technical standardization efforts, will assist in developing a charging infrastructure system compatible with the needs of transit fleets.

5 Deployment and Roll-out

The growing electric bus market will greatly benefit from the development of a common infrastructure that would allow the transit properties to plan adoption of electric buses from a number of suppliers, independent of the charging systems. The standardized coupler and communication with full interoperability will allow electric buses from different manufacturers to connect and recharge at needed voltage and current levels.

Once standardization is adopted, which may occur in the 2017 timeframe in North America, we anticipate development of best practices for installation and operation followed by proper testing and demonstration of the interoperability involving different charging equipment suppliers and different bus manufacturers.

The demonstrations would ensure that the charging equipment can work on multiple electric bus models and also that the operational characteristics are included.

The first goal will be to ensure that true interoperability and that charging can occur and different voltage and current levels as required by the bus. The second goal is to provide information on how the existing deployed chargers can be modified and retrofitted to the interoperable standardized connectors and common systems. This would ensure that the existing infrastructure is not wasted but can be made operational. Migration to the new standards can start occurring as early as 2018.

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Jasna Tomic is Research Director at CALSTART. Her work focuses on bringing hybrid and electric vehicles to the marketplace through programs that include field testing and evaluation of advanced vehicle technologies and public policy initiatives improving their business case. Her expertise includes research in vehicles-to-grid power (V2G) – innovative use of electric-drive vehicles for transportation and power generation. She holds a Ph.D. in Fuel Science from Pennsylvania State University.



Fred Silver is Vice President at CALSTART. Fred provides executive oversight on the Bus Program. He has worked with the Federal Transit Agency for more than twelve years focusing on the commercialization of new bus technologies including Zero Emission Fuel Cell and Battery Buses, Hybrid Vehicles and Advanced Bus Rapid Transit Vehicles. Fred has a background in power electronics including a Bachelor of Science Degree in Electrical Engineering from Fairleigh Dickinson University. He also holds a Master's Degree in Business Administration from Pepperdine University.



Kristian Jokinen is a Project Manager at CALSTART. He is responsible for overseeing advanced vehicle development and deployment projects with a focus on the transit bus and medium and heavy duty truck industries. Prior to CALSTART, Kristian worked with several startups active in the electric vehicle space. He also gained extensive experience in the clean technology sector during his tenure as the Environmental Specialist for the Finnish Consulate in Los Angeles. Kristian has a MS in Chemical Engineering and Industrial Economics from Abo Akademi University, Finland.