

4 Charging interface

This section intends to give an overview and presentation of the various charging interface and the current North American standards development status on high power and high voltage, for transit buses and heavy vehicle. It does not intend to cover passenger cars standards. Most transit and heavy duty application have a higher battery voltage than passenger cars or light-duty application, at around 700V; this needs to be taken in consideration when selecting a standard as most passengers' cars have battery DC level below 500V, although recent standard drafts are targeting 1000V. Finally, V2G (vehicle to grid) bi-directional charging types won't be covered by this paper.

Table 6 – Various standardization committees

	Outside electric vehicle	Electric vehicle
International	IEC	ISO
European	CENELEC	CEN
American	SAE	

Within Europe, CENELEC (European Committee for Electrotechnical Standardisation) and CEN (European Committee for Standardisation) operate as the pendants of IEC and ISO [1].

4.1 Plug-type corded connection

4.1.1 SAE J1772

SAE J1772 is widely used in the passenger car North American market, mainly with the single phase AC connector. A version 6 is due for release and final publish in March 2017. This version will include enhancement and better harmonization with the IEC standard, but mainly improvements on the CCS – combo - DC charging with a voltage up to 1000 VDC from the previous 500 VDC, and current capability at 350A instead of 200A. As many buses OEM use higher voltage above this 500 VDC, the new standard could be used for the CCS portion. However, due to the high power level and energy throughput, the single phase connection AC connection is not suggested for heavy duty vehicle in commercial applications.

Figure 4 – SAE J1772 with CCS



Table 7 – J1772 has been harmonized with IEC standards

	IEC	SAE
Electrical (EVSE) requirements	IEC 61851-1 Annex A	J1772
Coupler requirements	IEC 62196 type 1	
Coupler requirements	IEC 62196-3	with CCS

4.1.2 SAE J3068

SAE J3068 is a North American initiative for plug-type AC three-phase charging system with higher power rating. The passenger car standard J1772 already covers single-phase AC and is widely use. J3068 standard is based on the IEC 61851-1 Annex D in Europe for three-phase AC, as well as DC charging through commutable AC/DC pins (see pictures). One of the purposes of creating the J3068 standard is that the IEC standard does not cover North American grid voltage configurations; the target of this standard is more toward commercial and industrial applications charging at 7-150kW. J3068 could also evolve in a higher power rating, to support even further power for heavy duty application. At the moment of writing, SAE J3068 is still in draft and no EVSE supplier has UL or CSA certified systems for North American use. European EVSEs are technically compatible with the use of a transformer for US or Canadian 3-phase voltage set-up, but needs localized certification and adaptation until the standard is issued and adopted by an EVSE manufacturer. Additionally, the SAE standard will look in the possibility to include the combo DC plug (CCS), similar to the J1772 combo coupler, with two large 8 mm pins, as reviewed in the previous section. Use of digital communication control instead of PWM control is another difference with J1772.

- o Power levels and voltage (Main new thing - different than European 400/230Y VAC 3-phase)
 - USA 208/120Y & 480/277Y VAC
 - Canada 208/120Y & 600/347Y VAC

Table 8 – J3068 targets harmonization with European standards while J1772 has already been harmonized

	IEC	SAE
Electrical (EVSE) requirements	IEC 61851-1 Annex D	J3068
Coupler requirements	IEC 62196 type 2	
Coupler requirements	IEC 62196-3	with CCS

Figure 5 - The plug type is based on IEC 62196 type 2 connector



Figure 6 – Summary of various coupler types [2].

	Type 1/North America	Type 2/Europe	GB/T standard/China
Conventional charging (AC)	 SAE J1772/IEC 62196-2	 IEC 62196-2	 GB Part 2
Fast charging (DC)	 SAE J1772/IEC 62196-3	 IEC 62196-3	 GB/T Part 3/IEC 62196-3

4.2 Conductive overhead charging

In Europe, various efforts are on-going to standardize the overhead charging systems, at National, European, North American and international levels. In North America, although some various initiatives exist, all are synchronized through SAE J3105.

4.2.1 ISO/IEC – CEN/CENELEC and other European initiatives

At the European level, CEN-CENELEC received a standardization request from the European Commission to on the deployment of alternative fuels infrastructure, with a specific section concerning electric recharging points for motor vehicles. This EU-Mandate M 553 is responsible for the European standard containing technical specifications with a single solution for electric bus supply connectors and socket outlet. For now it includes only the coupler-type charging (CSS combo), but the overhead opportunity charging will be added. European standards are expected to come in place 2019 and international standards in 2020.

As such, as this timeframe for a legal standard is years away, an initiative between most bus manufacturers at the European level, called eBus CS, sponsored by the German federal Minister of Industry, is comprised of Daimler/EvoBus, MAN, Volvo, Siemens, ABB, HHA and TH-Dortm. This work is also linked to the agreement between European bus manufacturers Irizar, Solaris, VDL and Volvo to ensure the interoperability of electric buses with charging infrastructure provided by ABB, Heliox and Siemens, as stated in a press release in March 2016[3]. This solution is compliant to ISO 15118-1:8 and IEC 61851-23 standards.

At the National level, there is the German standardization Group from VDA, VDV and DKE working on the same topic. Finally, UITP has formed a committee named ZeEUS, the Zero Emission Urban Bus System, with the mandate of evaluating technologies for electric bus in general by supporting 10 pilot projects, and providing recommendations on charging systems.

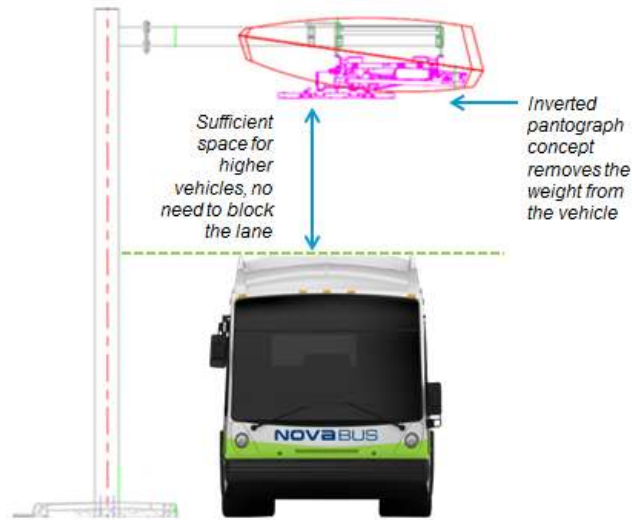
Figure 7 – Volvo and Siemens overhead charging system in Hamburg Germany



4.2.2 SAE J3105

In North America, all major bus OEMs have joined with the major charging system providers and with some members of transit association to define the SAE J3105 standard. The scope of this standard is a conductive power transfer system primarily for transit buses using an overhead coupler capable of, but not limited to, transferring DC power. At time of writing, various OEMs have presented their own systems, some of them being proprietary. Most of the systems are not compatible with each other. The work has been divided in three sections. The first section, the mechanical connection, targets to define the bus to charger interface, as well as the position of the system on the bus. Additionally, it considers the infrastructure interaction with other vehicles and with road clearance regulations. The second section is targeted towards electrical specification and requirements, the number of contacts points, power and voltage targets. The third section considers the communication between the charger and the vehicle, protocol, positioning and vehicle identification consideration. The SAE J3105 scope currently does not include charger to grid connection and requirements, being more concentrated in the vehicle to charger interface.

Figure 8 – Nova Bus / Siemens overhead charging system has an inverted pantograph to limit the complexity on the bus side



Issue of this standard is crucial to enable large deployment of opportunity charging electric buses. No date has been set at the time of writing, but a large effort is put by all participants to achieve an issued standard shortly as the industry is currently waiting on a standardized interface, not wanting to invest massively in a proprietary solution that not only limits the charger provider, but also the vehicle provider.

5 Non-technical considerations

The charging systems are basically a fuelling system. However, the purchase and installation of high power charging systems, either for multiple vehicles in a depot or elsewhere, brings other considerations than solely technical aspects and electricity management. The transit now faces interactions with the city officials, civil engineering considerations, road and constructions, law and standards, politicians and the community, and utility (electricity) providers, as the vehicle purchase becomes also an infrastructure project and investment.

6 Conclusion

Will one charging type prevails on the other is left to be proven. Currently, multiple parameters must be taken into account when selecting a charging scheme and location. No “one-size fits all” type of solution is possible at the moment as technology (batteries, charging standards, etc.) is still evolving, but most of all, operation and energy needs vary heavily depending on the industry, and even within the same industry. Petrol-based vehicles achieved a high flexibility; charging/fuelling them is now quite easy. This did not happen overnight however and if we now find it straightforward to have diesel fuel readily available in our depot, this system relies on an infrastructure developed during decades. Having oil sourced from deep sea or deep in the earth, carrying it in boats or pipeline to refinery, transport it by truck or pipeline to every street corner, storing it underground in fuel service centres and distributing via standardized fuel pumps has not been done without planning, investment and iteration; it did not happen by clicking fingers and is more a result of long process.

Most analysts compare electric vehicle to hybrids. Although the propulsion system and vehicles are relatively similar with batteries and high power electrical motors, they are fundamentally different in their refuelling process. A hybrid bus is basically a diesel bus, with a more energy efficient powertrain. An electric bus differs as it does require a completely different “fuelling” system, based on chargers instead of fuel pumps. Not only the plug or the charger must be considered, but also its location and the infrastructure needed to bring this electrical power at the desired location.

To achieve the level of integration, flexibility and “easiness” of the diesel distribution, the high power charging system will take years in the making, mainly due to the distribution infrastructure. Hence, even if charging system for electrical vehicles seems to all have compromises and investment needed in infrastructure, these steps are required to achieve parity with diesel. Gladly, the electrical infrastructure, the grid, is already quite developed compared to other novel fuel such as the hydrogen alternative, so the step required to achieve its potential is less risky and requires a more contain investment.

Finally, if comparing personal cars and heavy duty often occurs, this easy shortcut should not be taken, as showed in the first section. Due to the very high demand duty cycle, and thus important energy consumption combined with a relatively short time to charge, a heavy duty application is at another level in terms of infrastructure needs. Although both transportation systems requires new charging infrastructure, the applicable standards, the operation and the deployment level can’t be directly compared. What is valid for a car might not be for a transit bus. For example, power level of fast charging systems for cars (40 kW) are considered low power for buses, where a bus fast charger hovers around 300kW to 500 kW. Additionally, cars being what can be described as consumer or fashionable items, their purchase are often based on emotional criteria, rather than a rational and economical decision process. In the heavy-duty business, purchases are often based on total cost of ownership and funding opportunities. Finally, what is true in a small scale project might not be in a large deployment, as installing a single charger at depot is quite simpler than deploying 200 chargers that are used at the same time have a different grid impact.

We are the start of a new era for electric heavy duty applications; although focus is mainly on vehicles and their components, namely the battery, the charging infrastructure operation and deployment is the true paradigm shift.

Acknowledgments

Thanks to Volvo colleagues James McLaughlin and Andrei Wygowski for support on the background information for this paper.