2020 Facilities Engineering Awards:
Design and Construction of Smart eTruck Charging

Title of Project:

Port of Long Beach Smart eTruck Charging

Names of Applicants:

Port of Long Beach

International Transportation Service Long Beach

Cavotec USA

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Project Description

Cavotec, in partnership with the Port of Long Beach and International Transportation Service designed, built and delivered a hands free “smart” charging solution for battery electric class 8 terminal tractors. Under the California Energy Commission’s *FY 2017 Sustainable Freight Transportation Projects*, the Port of Long Beach was awarded funding to implement the *Zero-Emissions Terminal Equipment Transition Project*. One component of this overall Project is the demonstration of battery-electric class 8 terminal tractors and associated electric supply (i.e., recharging) equipment within the Port.

The SPS E-Truck charging unit is currently in operation and has met all required electrical standards.

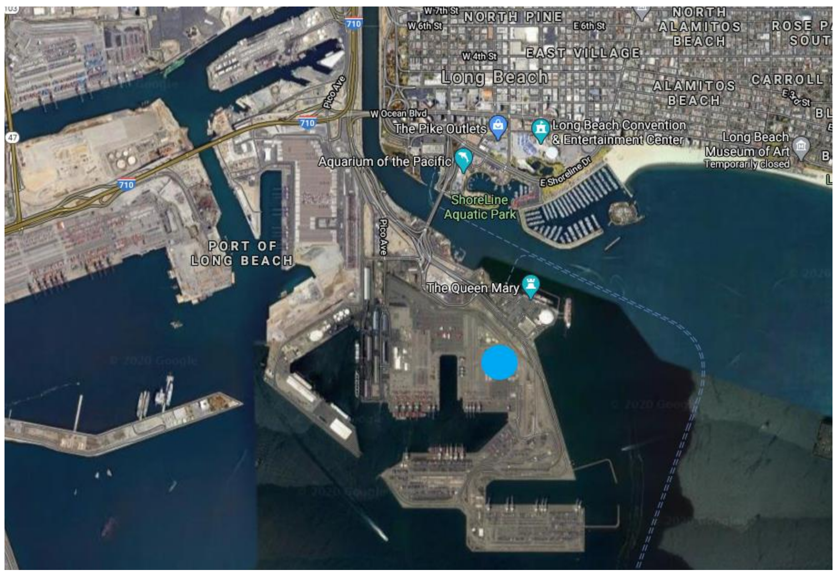

Figure 1: Project Location – Port of Long Beach, ITS

Introduction

At the Port of Long Beach, yard tractors are the most common cargo handling equipment (CHE) used in on-terminal container movement. According to the 2017 Air Emissions Inventory, yard tractors account for approximately 46% of total CHE at the Port of Long Beach. The total number of yard tractors operated within the Port exceeds 650 vehicles. Over 86% of these yard tractors are currently equipped with non-road diesel engines.

E-trucks can be electrically charged cost effectively, safely and efficiently using utilizing smart plug-in systems. The system includes two components; the fixed charging unit located in the charging bay (dedicated area on the yard) and the charging receptacle mounted on the truck itself. The fixed unit will extend and connect to the receptacle on the e-truck when positioned in the bay and charging is required.

The prime benefits of the equipment include:

1. Safe and "hands off" connection
2. Easy connection and maintenance
3. Fast charging
4. IoT ready for data collection

Goals and Objectives

As part of the California Air Resources Board's (CARB) initiative to reduce emissions from fossil fueled vehicles (including all modes of transit), there has been a need to implement electrification of these vehicles. By combining this with the megatrend of industrial vehicle automation, users are faced with the challenge of providing both high power charging levels (due to the operation and size of the vehicles) and doing this in a safe manner around automated vehicles. These are the core business needs that lead to the creation of the Smart Plug-In System (SPS). By removing the need for human interaction during the most critical phase, which is connecting the vehicle, you increase safety drastically while still allowing you to charge the vehicles at a higher power rate. This connection brings a level of efficiency to operating autonomous port vehicles that would not possible otherwise.

The principal goal of the overall POLB project is to conduct one of the nation's largest demonstration and deployment projects for medium- and heavy-duty (MHD), advanced, zero-emissions cargo-handling equipment at three major terminals at POLB

Discussion

Background

Cavotec has been utilizing unmanned connection systems in the past for other industries, specifically the electric ferry industry as well as electric rubber-tired gantry cranes (eRTG). The challenge was adapting these technologies to the smaller scale yet higher frequency use of the electric yard tractors utilized at Port of Long Beach operator terminals. This meant sizing all the connection points, materials used and vehicle side accessories to fit both on the infrastructure footage allowed as well as the smaller space available on the e-trucks. While doing this, the units also must maintain a significant outreach and tolerance capability to ensure there is flexibility in the vehicle positioning. These are the core challenges that needed to be addressed.

POLB has installed two 150-kW “smart chargers” that support the fast, large-scale charging system that is necessary to transition its fleet to zero-emissions. These innovative chargers possess charging “arms” that intelligently engage with a properly modified yard tractor and disengage when charging is complete.

Figure 2: Cavotec SPS Charging System – ITS/POLB

These high-power chargers will enable ITS and LBCT to overcome one of the key barriers to widespread market adoption of zero-emissions technologies: the ratio of charge time to operating time. With a lower-power charger, ITS and LBCT might be forced to limit use of the new yard trucks to a single shift per day—a condition that would be considered a failure right from the very start of the project. By deploying 150-kW chargers, ITS and LBCT anticipate being able to use the yard trucks for two shifts per day, meeting the real-world minimum requirements of a marine terminal.

Currently, the unit at ITS is in operation daily connection activities occurring as part of the demonstration initiative. The unit at LBCT is in the process of commissioning and the demonstration period will begin later this year (2020)

Objectives and Methodology

The core objectives of this project where to evaluate new solutions that will allow the move to zero emission technologies in container handling equipment. The detailed objectives included:

1. Demonstrate proposed vehicles/technologies for 12 months
2. Displace 271,401 DGEs over the demonstration period
3. Reduce 1,207 MTCO2e during the demonstration period
4. Reduce emissions of nitrogen oxides (NOx) by 26.84 tons during the demonstration
5. Reduce emissions of PM10 by 0.49 tons during the demonstration
6. Convene a Zero-Emission Port Workforce Development group to improve existing workforce development and training programs in support of the electrification of port equipment
7. Establish the proposed technologies as cost-competitive purchase options through development of estimates of future costs versus baseline technology costs.

One of the key requirements to enable this move to zero emission container handling is the capability to charge the vehicles within their operating envelope.

The yard tractors at ITS are used in two shifts. The tractors must be charged during shift changes and breaks. To meet these requirements, a high-powered charging solution was needed to provide the power required to charge within the allotted time. This brought some further challenges to the project related to performing the high power connections.

As the power rises in a charging application, the size of the connectors and cables to bring the power to the vehicle increase in size and weight as well. This makes manual connection of these devices cumbersome for personnel. The bulk of the weight is in the cables and these are driven directly by the amperage used and the shape of the charge cycle itself which drives the heat rise characteristics. There are various methods to combat this higher weight:

1. Liquid cooling of cable and connector to minimize cable core size.
    a. This adds significant complexity to a charging application and brings environmental risk in case of coolant leaks.
2. Automate the connection from charger to vehicle
    a. Less complex and no risk of environmental impact

With the growing autonomy environment in ports and the complexity of liquid cooled charging, the decision was made to use the automated connection. When sizing the connection solution, the key variables considered were:

1. AC or DC charging.
    a. This solution is an AC charging solution as the inverter is located on the tractor itself

2. Power required (150kW).
    a. It was calculated that 150kW would provide the charging power need to bring the tractor to required charge in the windows provided
3. Available footprint.
    a. The goal is to keep the unit as small as possible as there are significant constraints in the yard for tractor parking. Size is driven by number 4.
4. Repeatability of yard tractor parking orientation.
    a. Based on how repeatable the yard tractor can be parked in the bay, charging solution can reduce the operating range of motion need and thus reducing overall size.
5. Location of charging funnel on yard tractor.
    a. This dictates the height of the structure supporting the charging unit.

The final configuration had to accommodate all the above variables and produced a smart plug in solution with the following characteristics:

Outer Dimensions (Charging Side)	
Charging Side	1710x885x935mm (L x W x H)
Truck Side (Socket side)	347x500x549mm (L x W x H)
Connector	
Truck Side	PC5, 3 phase pins + N + E = 2P
Charging Station Side	PC5 Socket, max 250A, 1000V, 95mm2
Compensation tolerance	
Lateral compensation (X)	X = ± 70mm
Height compensation (Y)	Y = ± 70mm
Distance from charging station (Z)	0 – 1000mm
Angular slanting	X = 3°, Y= 3°
Rotation	± 5°

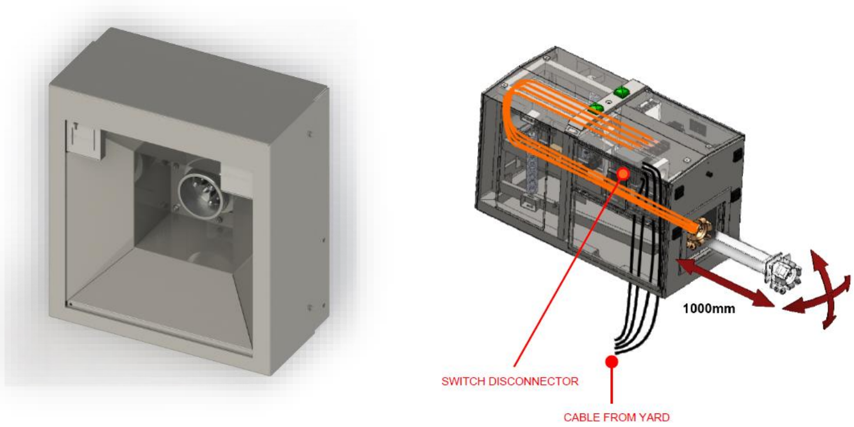

Figure 3: Cavotec Funnel and Charging System – ITS/POLB

Due to the number of connections the units would be making, there was a need to maintain connector serviceability. This is achieved through pins that are replaceable without the need to perform electrical terminations.

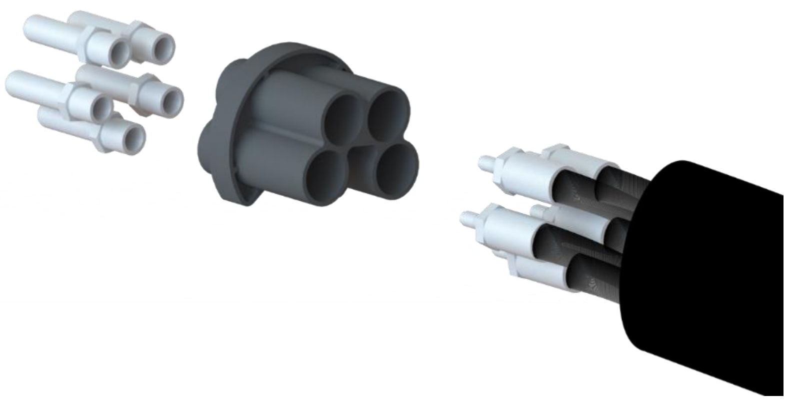

Figure 4: Field Replaceable Connector Pins

The end configuration provides a safe and future proofed smart connection to enable POLB and ITS to continue the move to zero emission solutions.

Hardware / Software Used

The central hardware for the SPS units is the mechanism allowing extension of the arm to connect with the yard tractor. This mechanism is operated by linear slide guides that are suspended to allow funnel variation and driven by stepper motors to allow accurate positioning.

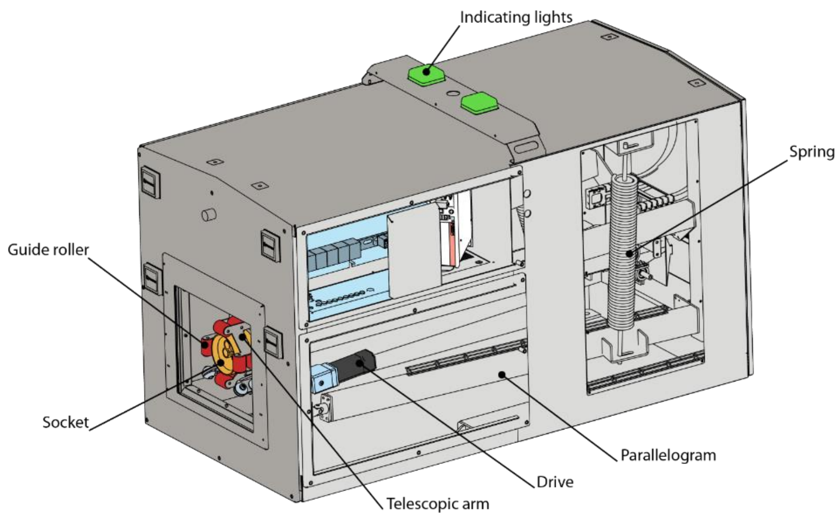

Figure 5: SPS E-Truck Unit – Internal Components

On the software side, a Beckhoff embedded programmable controller is used in conjunction with a Beckhoff servo motor controller. The Beckhoff package includes the control program itself as well as the data logging capabilities. Custom written software on the Beckhoff platform is used to control the unit.

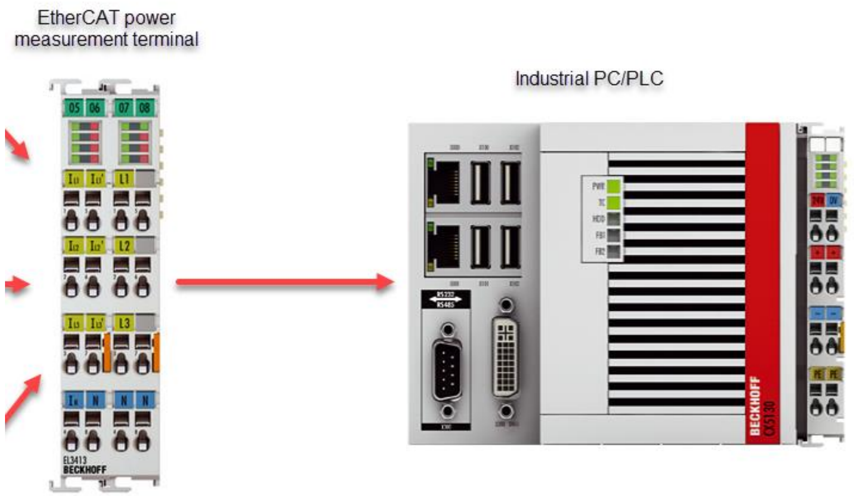

Figure 6: Beckhoff EPC and Input Module

Project Cost

In order to support operations of the proposed zero-emissions cargo handling vehicles and equipment, POLB will work closely with project partner SCE to complete approximately $3.45 million in infrastructure upgrades that will provide power to 24 charging points for the proposed 12 electric yard tractors, as well as the electrical infrastructure necessary to support the nine proposed e-RTGs.

Performance Measures

The performance measures for this project are broken into two; environmental impact and function of equipment.

For the environment side, the measurements to be taken are:

1. $MTCO_2$ values before and after project
2. NOx measurements and reduction
3. PM10 measurement and reduction

On the equipment side, the metrics to be recorded are:

1. Number of charging cycles over the demonstration period
2. Total time connect to trucks for charging
3. Total power used during demonstration period
4. Average power charging curve

How Project Fulfills Award Criteria

The SPS-Etruck project brings an innovative connection to the port industry that enables yard tractors to move to an all electric model and be able to bring this portion of yard handling equipment to zero emission while maintaining current operational capabilities. This is only possible through higher powered connections that can charge the battery as required within the time allotted.

By providing a unit that connects the tractor once it in position without operator input, the risks of high power charging to personnel are removed. The core function of these units are not only to charge trucks but also to ensure safety of personnel. When you combine these with the capabilities of remote data monitoring and future predictive maintenance services, these connections future proof the path to electrification of port industry yard handling equipment.

Conclusion

The Port of Long Beach is one of the nation's foremost seaports and a pinnacle of goods movement and environmental leadership. POLB has extensive experience overseeing major projects designed to incorporate advanced technology across the goods movement sector to reduce impacts on the environment and surrounding communities. POLB is also a global leader in the development and implementation of market-driving environmental policies, including the groundbreaking Green Port Policy and the San Pedro Bay Ports Clean Air Action Plan (CAAP). The Port also has extensive experience collaborating with off-road vehicle and equipment manufacturers, technology providers, and other key project stakeholders in the implementation of large-scale air quality and advanced technology incentive programs. The success of this project is yet another example of their future facing leadership.