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United States Patent	12384261
Kind Code	B2
Date of Patent	August 12, 2025
Inventor(s)	Goble; Jos Christopher et al.

Vehicle charging systems and methods of positioning a charging cable to engage a charging adapter

Abstract

A vehicle charging adapter including a connector configured to engage with a charging port of a vehicle, and a receiver coupled to the connector. The receiver includes a receiver charging surface, an indicator provided on the receiver charging surface, an inner radial wall extending from the receiver charging surface and defining a receiver cavity extending along an insertion axis, and one or more receiver electrical contacts provided on the inner radial wall within the receiver cavity. The one or more receiver electrical contacts are electrically connected to the connector.

Inventors: **Goble; Jos Christopher (Milpitas, CA), Weldon; David Edwin (Gilroy, CA), Anderson; Connor James (Alameda, CA)**

Applicant: **Volley Automation, Inc.** (Denver, CO)

Family ID: **1000008748837**

Assignee: **VOLLEY AUTOMATION, INC. (Denver, CO)**

Appl. No.: **17/858251**

Filed: **July 06, 2022**

Prior Publication Data

Document Identifier	Publication Date
US 20240010082 A1	Jan. 11, 2024

Publication Classification

Int. Cl.: **B60L53/16** (20190101); **B60L53/18** (20190101); **B60L53/36** (20190101); **H01R13/66** (20060101); H01R103/00 (20060101)

U.S. Cl.:

CPC **B60L53/16** (20190201); **B60L53/18** (20190201); **B60L53/36** (20190201); **H01R13/665** (20130101); H01R2103/00 (20130101); H01R2201/26 (20130101)

Field of Classification Search

CPC: B60L (53/16); B60L (53/18); B60L (53/36); B60L (53/37); H01R (13/665); H01R (2103/00); H01R (2201/26); Y02T (10/70); Y02T (10/7072); Y02T (90/14)

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Primary Examiner: Chambers; Travis S

Attorney, Agent or Firm: Dinsmore & Shohl

Background/Summary

TECHNICAL FIELD

(1) The present specification generally relates to charging systems and, more specifically, charging systems for electric vehicles.

BACKGROUND

(2) Automated parking systems may be used to automatically park a vehicle in a parking structure. The automated parking systems may transport vehicles to various spots in the parking structure. Additionally, a user may desire to charge their vehicle while parked in the parking structure. However, various charging port locations on different vehicles make it difficult to automate vehicle charging when the vehicles are parked in the parking structure.

SUMMARY

(3) In one embodiment, a vehicle charging adapter includes a connector configured to engage with a charging port of a vehicle, and a receiver coupled to the connector. The receiver includes a receiver charging surface, an indicator provided on the receiver charging surface, an inner radial wall extending from the receiver charging surface and defining a receiver cavity extending along an insertion axis, and one or more receiver electrical contacts provided on the inner radial wall within the receiver cavity. The one or more receiver electrical contacts are electrically connected to the connector.

(4) In another embodiment, a vehicle charging system includes a vehicle charging adapter, a plunger, and a charging cable. The adapter includes a connector configured to engage with a charging port of a vehicle, and a receiver coupled to the connector. The receiver includes a receiver charging surface, an indicator provided on the receiver charging surface, an inner radial wall extending from the receiver charging surface and defining a receiver cavity extending along an insertion axis, and one or more receiver electrical contacts provided on the inner radial wall within the receiver cavity, the one or more receiver electrical contacts are electrically connected to the connector. The plunger includes an insertion member extending from a plunger charging plate along the insertion axis, the insertion member at least partially positionable into the receiver cavity of the receiver, and one or more plunger electrical contacts that mate with the one or more receiver electrical contacts when the insertion member is positioned within the receiver cavity. The charging cable transfers electrical current to the one or more plunger electrical contacts of the plunger.

(5) In yet another embodiment, a method includes detecting a location of an adapter extending from a charging port of a vehicle, positioning a plunger relative to the adapter such that the plunger is positioned above the receiver of the adapter along an insertion axis, and lowering the plunger along the insertion axis such that the insertion member is positioned within the receiver cavity of the receiver and the one or more plunger electrical contacts of the plunger engage the one or more receiver electrical contacts of the receiver. The adapter includes a receiver coupled to the connector, the receiver including a receiver charging surface, an indicator provided on the receiver charging surface, an inner radial wall extending from the receiver charging surface and defining a receiver cavity extending along an insertion axis, and one or more electrical contacts provided on the inner radial wall within the receiver cavity, the one or more electrical contacts electrically connected to the connector. The plunger includes an insertion member extending from the plunger charging plate along the insertion axis, the insertion member at least partially positionable into the receiver cavity of the receiver, one or more plunger electrical contacts that mate with the one or more receiver electrical contacts when the insertion member is positioned within the receiver cavity, and a charging cable transferring electrical current to the one or more plunger electrical contacts.

(6) These and additional features provided by the embodiments described herein will be more fully understood in view of the following detailed description, in conjunction with the drawings.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) The embodiments set forth in the drawings are illustrative and exemplary in nature and not intended to limit the subject matter defined by the claims. The following detailed description of the illustrative embodiments can be understood when read in conjunction with the following drawings, where like structure is indicated with like reference numerals and in which:

(2) FIG. **1** schematically depicts a partial environmental view of a vehicle charging system, according to one or more embodiments shown and described herein;

(3) FIG. **2** schematically depicts a side view of the vehicle charging system of FIG. **1** with the vehicle charging system in a disengaged position, according to one or more embodiments shown and described herein;

(4) FIG. **3** schematically depicts a side view of the vehicle charging system of FIG. **2** with the vehicle charging system in an engaged position, according to one or more embodiments shown and described herein;

(5) FIG. **4** schematically depicts a side view of the vehicle charging system of FIG. **1** including a gantry, according to one or more embodiments shown and described herein;

(6) FIG. **5** schematically depicts a control system for operating the vehicle charging system of FIG. **1**, according to one or more embodiments shown and described herein;

(7) FIG. **6** depicts a flowchart for a method of operating the vehicle charging system of FIG. **1**, according to one or more embodiments shown and described herein;

(8) FIG. **7** schematically depicts an upper perspective view of another vehicle charging system in a disengaged position, according to one or more embodiments shown and described herein;

(9) FIG. **8** schematically depicts a partial lower perspective view of a plunger of the vehicle charging system of FIG. **7**, according to one or more embodiments shown and described herein;

(10) FIG. **9** schematically depicts a cross-sectional side view of the vehicle charging system of FIG. **7** in an engaged position, according to one or more embodiments shown and described herein;

(11) FIG. **10** schematically depicts a cross-sectional side view of another vehicle charging system in a disengaged position, according to one or more embodiments shown and described herein; and

(12) FIG. **11** schematically depicts a cross-sectional side view of the vehicle charging system of FIG. **10** in an engaged position, according to one or more embodiments shown and described herein.

DETAILED DESCRIPTION

(13) FIG. **1** generally depicts one embodiment of a vehicle charging system for charging an electric vehicle. The vehicle charging system generally includes a plunger connected to an electric vehicle charging station, a vehicle charging adapter, a gantry for maneuvering the plunger, and a control system for controlling the vehicle charging system. The plunger is connected to a current source that provides electrical current to the plunger and is configured to engage the adapter to transfer current to the adapter. The adapter is configured to engage a charging port on the electric vehicle to transfer current from the plunger to a vehicle battery connected to the charging port. The control system is configured to locate the adapter and operate the gantry to move the plunger into the adapter.

(14) The vehicle charging system may be used in conjunction with an automated parking system for automatically parking vehicles within a parking structure. The automated parking system may use a lift that picks up and transports the vehicle to a parking space in the parking structure. A driver can insert the adapter into a charging port of the vehicle before the vehicle is transported to the parking structure. Once the vehicle is automatically parked in the parking structure by the automatic parking system, the gantry can automatically insert the plunger into the adapter to begin charging the vehicle. Various embodiments of the vehicle charging system and the operation of the vehicle charging system will be described in more detail herein.

(15) As used herein, the term “longitudinal direction” refers to the forward-rearward direction of

the vehicle (i.e., in the +/−Y-direction depicted in FIG. **1**). The term "lateral direction" refers to the cross-vehicle direction (i.e., in the +/−X-direction depicted in FIG. **1**), and is transverse to the longitudinal direction. The term "vertical direction" or "above" or "below" refer to the upward-downward direction of the vehicle (i.e., in the +/−Z-direction depicted in FIG. **1**).

(16) Referring now to FIG. **1**, a vehicle charging system **100** for an electric vehicle **10** is depicted. The electric vehicle **10** may include one or more wheels **12**, one or more motors **14** operatively coupled to the one or more wheels **12** to drive the wheels **12**, a battery **16** operatively coupled to the motors **14** to provide current to the motors **14**, and a charging port **18** operatively coupled to the battery **16** to transfer current to the battery **16**. While FIG. **1** depicts the electric vehicle **10** as a passenger vehicle, such as a car or SUV, it is contemplated and possible that the electric vehicle **10** is any vehicle having a battery **16** that supplies current to motors that assist in driving the wheels **12** of the vehicle **10**, such as, for example, a hybrid vehicle. The charging port **18** may be any traditional charging port for transferring current from an electric vehicle charger, or charging station **50** (FIG. **4**), to the battery **16** of the electric vehicle **10**. For example, the charging port **18** may be a type 1 or type 2 AC connector type charging port. Alternatively, the charging port **18** may be a DC type charging port.

(17) The vehicle charging system **100** may include a plunger **102**, an adapter **104**, a gantry **106** (FIG. **4**), and a control system **108** (FIG. **5**). Referring now to FIGS. **1-3**, the adapter **104** may include a connector **110** configured to engage with the charging port **18** of the electric vehicle **10**, a receiver **112** coupled to the connector **110**, and a neck **114** extending between the receiver **112** and the connector **110**. The neck **114** may include a first end **116** fixed to the connector **110** and an opposite second end **118** fixed to the receiver **112**. The neck **114** may include a first portion **120** extending from the first end **116** toward the second end **118**, and a second portion **122** extending from the first portion **120** to the second end **118**. The second portion **122** may extend obliquely to the first portion **120**. The distance that the neck **114** extends may be limited so that the adapter **104** does not extend from the charging port **18** a distance greater than a distance that a vehicle side mirror of the vehicle **10** extends in the vehicle lateral direction. In other words, the neck **114** may extend a predetermined distance such that the receiver **112** does not extend passed the vehicle side mirror in the vehicle lateral direction when the adapter **104** is attached to the charging port **18**. However, it is contemplated and possible that the adapter **104** extends further than the vehicle side mirror. In embodiments, the vehicle **10** may include cameras instead of vehicle side mirrors. In such embodiments, the neck **114** may be sized so that the adapter **104** does not extend from the charging port **18** a distance greater than a distance the vehicle camera extends in the vehicle lateral direction.

(18) The connector **110** may be a traditional charging connector for an electric vehicle **10**, such as, for example, an SAE J1772 connector. The connector **110** may include a charging portion **124** configured to engage the charging port **18** of the electric vehicle **10**, and a handle **126** extending from the charging portion **124**. The charging portion **124** may include a plurality of charging pins (not shown) configured to transfer current to the charging port **18** when the connector **110** engages the charging port **18**. The handle **126** may extend obliquely from the charging portion **124** at an angle that is equal to an angle that the second portion **122** extends from the first portion **120** of the neck **114**. In other words, the second portion **122** of the second portion **122** may extend colinear to the charging portion **124** of the connector **110**.

(19) The receiver **112** may include a receiver charging surface **130**, an opposite lower surface **132**, an outer radial surface **134** extending around the receiver charging surface **130**, an indicator **136** provided on the receiver charging surface **130**, an inner radial wall **138**, and one or more receiver electrical contacts **140**. The outer radial surface **134** may be fixed to the second end **118** of the neck **114**. The inner radial wall **138** may extend from the receiver charging surface **130** to the lower surface **132** to define a receiver cavity **142** extending along an insertion axis **144**. As depicted in FIGS. **2** and **3**, the receiver cavity **142** may extend through the entirety of the receiver **112**.

However, it is contemplated and possible that the receiver cavity **142** may extend only partially through the receiver **112**. The insertion axis **144** may extend perpendicularly through the receiver charging surface **130** so that the receiver charging surface **130** of the receiver **112** extends along a plane perpendicular to the insertion axis **144**, and the insertion axis **144** may be circumferentially surrounded by the inner radial wall **138**. In embodiments, the insertion axis **144** may extend parallel to the vertical direction (e.g., in the +/−Z direction). However, it is contemplated and possible that the insertion axis **144** may extend perpendicularly to the vertical direction, such as in the longitudinal direction (e.g., in the +/−Y direction) or the lateral direction (e.g., in the +/−X direction), or obliquely to the vertical direction to extend in a combination of the vertical direction, the lateral direction, and/or the longitudinal direction.

(20) As depicted in FIGS. **2** and **3**, the receiver cavity **142** may be shaped as a truncated cone having an upper end **146** at the receiver charging surface **130** and an opposite lower end **148** at the lower surface **132**, the lower end **148** having a lower width extending across the receiver cavity **142** less than an upper width of the upper end **146** extending across the receiver cavity **142**. However, it is contemplated and possible that the receiver cavity **142** has any shape capable of receiving the plunger **102**, such as a cylinder.

(21) The indicator **136** functions as a locator for locating the receiver cavity **142** relative to the indicator **136**. For example, the indicator **136** may be a fiducial marking. The indicator **136** may be provided radially outside of an opening **150**. The opening **150** extends through the receiver **112** that is sized and shaped to circumferentially surround the insertion axis **144**, and surround the receiver cavity **142** to allow the plunger **102** to extend through the opening **150** into the receiver cavity **142**. The indicator **136** may include a ferromagnetic material positioned at the receiver charging surface **130** of the receiver **112** that indicates a location of the receiver cavity **142** of the receiver **112**. In embodiments, the indicator **136** may cover the entire receiver charging surface **130**. The ferromagnetic material may engage with a magnet to retain the adapter **104** in contact with the plunger **102**, as will be described in further detail herein.

(22) The one or more receiver electrical contacts **140** may be provided on the inner radial wall **138** within the receiver cavity **142** and coupled thereto. Each of the receiver electrical contacts **140** may be arranged such that the receiver electrical contact **140** is ring-shaped and extends along the inner radial wall **138** to circumferentially surround the insertion axis **144**. In embodiments, the receiver electrical contacts **140** may be canted coils. However, it is contemplated and possible that the receiver electrical contacts **140** may be any other traditional electrical contact positionable within the receiver cavity **142** and capable of transferring current to the charging portion **124**.

(23) The one or more receiver electrical contacts **140** may be electrically connected to the charging pins of the connector **110** via an electrical conduit that transfers current from the receiver electrical contacts **140** to the charging pins. The one or more receiver electrical contacts **140** may include a first electrical contact **152** and a second electrical contact **154**. The first electrical contact **152** circumferentially surrounds the insertion axis **144** and is spaced apart from the receiver charging surface **130** by a first distance, and the second electrical contact **154** circumferentially surrounds the insertion axis **144** and is spaced apart from the receiver charging surface **130** by a second distance greater than the first distance.

(24) In embodiments where the receiver cavity **142** is shaped as a truncated cone, the first electrical contact **152** and the second electrical contact **154** may each have a radius extending across the receiver cavity **142**, the radius of the first electrical contact **152** being greater than the radius of the second electrical contact **154**. However, in other embodiments where the receiver cavity **142** is shaped as a cylinder, the one or more electrical contacts may include a plurality of electrical contacts, each of the electrical contacts having a radius, the radius of the first electrical contact **152** being equal to the radius of the second electrical contact **154**.

(25) The plunger **102** may include a charging cable **160**, an insertion member **162**, one or more plunger electrical contacts **164**, a locating member **166**, and a locking mechanism **168**. The

charging cable **160** may include a first end **170** operatively coupled to the charging station **50** and an opposite second end **172**. The charging cable **160** may further include an electrical conduit (not shown) extending from the first end **116** to the second end **118**, the first end **116** being electrically connected to the charging station **50** to receive current from the charging station **50**, and transfer the current to the second end **118**, specifically the plunger electrical contacts **164**.

(26) The insertion member **162** may be operatively coupled to the second end **118** of the charging cable **160** to receive electrical current from the charging station **50**. The insertion member **162** may include a plunger plate **174** and an insertion projection **176** extending from the plunger plate **174** away from the charging cable **160**. The plunger plate **174** may include a receiver-facing surface **178** that is oriented along a plane extending perpendicular to the insertion axis **144**, and a periphery **180** surrounding the receiver-facing surface **178**.

(27) The insertion projection **176** may include a first end **182** coupled to the receiver-facing surface **178** of the plunger plate **174**, an opposite second end **184** spaced apart from the receiver-facing surface **178**, and an outer radial surface **186** extending between the first end **116** and the second end **118**. The insertion projection **176** may extend from the receiver-facing surface **178** of the plunger plate **174** along the insertion axis **144** defined by the receiver **112**. The insertion projection **176** may be at least partially positionable into the receiver cavity **142** of the receiver **112**. The insertion projection **176** may be sized and shaped to be positionable in the receiver cavity **142**. As depicted in FIGS. **1-3**, the insertion projection **176** is shaped as a truncated cone. However, it is contemplated and possible that the insertion projection **176** has other shapes, such as a cylinder, a triangle, a square, or the like.

(28) The one or more plunger electrical contacts **164** may be provided on the insertion projection **176**, such as positioned along the outer radial surface **186**. The plunger electrical contacts **164** may be spaced apart from one another along the insertion projection **176** between the first end **182** and the second end **184**. The plunger electrical contacts **164** may mate with the one or more receiver electrical contacts **140** when the insertion member **162** is positioned within the receiver cavity **142** to transfer current to the receiver electrical contacts **140**. Each of the plunger electrical contacts **164** may be arranged such that the plunger electrical contact **164** is ring-shaped and extends along the outer radial surface **186** to circumferentially surround the insertion projection **176**. In embodiments, the plunger electrical contacts **164** may be canted coils. However, it is contemplated and possible that the plunger electrical contacts **164** may be any other traditional electrical contact that is positionable around the insertion projection **176** and capable of transferring current to the receiver electrical contacts **140**.

(29) The plunger electrical contacts **164** may be electrically connected to the electrical conduit of the charging cable **160** so that the current from the charging station **50** may be transferred to the plunger electrical contacts **164**. The plunger electrical contacts **164** may be formed of any material capable of transferring current between the charging station **50** and the receiver electrical contacts **140**.

(30) The locating member **166** may include one or more fingers **188** that extend obliquely from the periphery **180** of the plunger plate **174**. The fingers **188** may extend at an angle and a distance such that the fingers **188** extend around the outer radial surface **134** of the receiver **112** when the insertion member **162** is positioned within the receiver cavity **142** of the receiver **112**. The fingers **188** may act as a counterweight to orient the insertion projection **176** along the insertion axis **144** when the plunger **102** contacts the receiver **112**, allowing the insertion projection **176** to be inserted into the receiver cavity **142**. When the plunger **102** is engaged with the receiver **112**, the fingers **188** may be spaced apart from the outer radial surface **134**. The locating member **166** may have any operable number of fingers **188** for locating the insertion member **162** relative to the receiver **112**, such as, for example, one, two, three, four, or more than four. In embodiments, the locating member **166** may have a single finger that extends entirely around the plunger plate **174** to be shaped as a cone extending around at least part of the outer radial surface **134**. Accordingly, the

locating member **166** may operate to align the plunger **102**, and specifically the insertion projection **176**, with the receiver cavity **142** of the receiver **112** upon contact of the locating member **166** with the receiver **112** as the plunger **102** is being lowered toward the receiver **112**.

(31) The locking mechanism **168** may engage the receiver charging surface **130** of the receiver **112** to retain the plunger **102** in contact with the receiver charging surface **130** when in a locked position. The locking mechanism **168** may include an electromagnet **190** that may be actuated to magnetically attract the indicator **136** of the adapter **104** to thereby retain the plunger **102** in contact with the receiver **112**. However, it is contemplated and possible that the locking mechanism **168** includes a physical locking mechanism, such as a bayonet lock, for retaining the plunger **102** in contact with the receiver **112**. In embodiments, it should be appreciated that the locating member **166** may provide physical locking in lieu of or in addition to locking by the locking mechanism **168**.

(32) The locking mechanism **168** may be provided on the receiver-facing surface **178** of the plunger plate **174** to face the receiver charging surface **130** and the indicator **136** of the receiver **112**. The locking mechanism **168** may be operable between a locked position and an unlocked position, such that the locking mechanism **168** retains the insertion member **162** within the receiver cavity **142** when in the locked position and permit the insertion member **162** to be removed from the receiver cavity **142** when in the unlocked position. In the locked position, the locking mechanism **168** may be actuated to generate a magnetic force to attract the indicator **136** of the receiver **112** and attract the receiver **112** to the locking mechanism **168**.

(33) The plunger **102** may be movable between a disengaged position (FIG. **2**) and an engaged position (FIG. **3**). Referring to FIG. **2**, in the disengaged position, the insertion member **162** of the plunger **102** may be spaced apart from the receiver **112**. Referring to FIG. **3**, in the engaged position, the insertion member **162** is positioned within the receiver cavity **142** of the receiver **112** such that the plunger electrical contacts **164** engage the receiver electrical contacts **140**. In the engaged position, the charging station **50** may be activated to supply current to the receiver electrical contacts **140** through the plunger electrical contacts **164**. Current may then be transferred through the connector **110** to the charging port **18** of the vehicle **10**.

(34) Referring to FIGS. **2**-**4**, the gantry **106** may be operable to move the plunger **102** relative to the adapter **104** when the adapter **104** is positioned in the charging port **18** of the vehicle. The gantry **106** may span a plurality of parking spaces S in a parking structure to be operable to insert the plunger **102** into the adapter **104**. The gantry **106** may include a gripper **200**, a movement mechanism **202** coupled to the gripper **200**, and an imaging device **204** for identifying the location of the receiver **112** of the adapter **104**. The movement mechanism **202** may be operable for 3-axis movement to move the gripper **200** in any of the X-direction, the Y-direction, and the Z-direction. The gripper **200** may be fixedly coupled to the plunger **102** to move the plunger **102** with the gripper **200**.

(35) The depicted gantry **106** is a cable-driven parallel robot (CDPR), where the movement mechanism **202** includes a first motor **206**, a first cable **208** operatively coupled to the first motor **206** and the gripper **200**, a second motor **210**, a second cable **212** operatively coupled to the second motor **210** and the gripper **200**, a third motor **214**, and a third cable **216** operatively coupled to the third motor **214** and the gripper **200**. The motors **206**, **210**, **214** and cables **208**, **212**, **216** are oriented in different directions, with at least two of the motors **206**, **210**, **214** and respective cables **208**, **212**, **216** extending in both the X-direction and the Y-direction. In the depicted gantry **106**, the first motor **206** is oriented so the first cable **208** extends in the X-direction and the Y-direction, and the second motor **210** is oriented so the second cable **212** extends in the X-direction and the Y-direction. Each of the motors **206**, **210**, **214** may take up and pay out the respective cable **208**, **212**, **216** to move the gripper **200** in any of the X-direction, the Y-direction, and the Z-direction. The charging cable **160** may extend from the charging station **50** with slack so that the plunger **102** is maneuverable between multiple vehicles in the plurality of parking spaces S. While the depicted

gantry **106** is a CDPR, it is contemplated and possible that the gantry **106** may be any known robot or gantry **106** that can move in the X-direction, the Y-direction, and the Z-direction. For example, the gantry **106** may be a Delta robot, a SCARA robot, a cobot, an industrial robot, or the like.

(36) The imaging device **204** may identify the location of the indicator **136** on the adapter **104**. The gantry **106** may then move the gripper **200** via the movement mechanism **202** to the location of the indicator **136** when the gripper **200** is holding the plunger **102**. The imaging device **204** may be any device capable of identifying the indicator **136** (FIG. **2**), such as, for example, a camera. The imaging device **204** may be mounted on the gripper **200** so as to move with the gripper **200**.

(37) In some embodiments, the plunger **102** may be fixed to the gripper **200** so that the gantry **106** may charge a single vehicle at a time. However, it is contemplated and possible that there are a plurality of charging stations **50** and plungers **102** arranged about the plurality of parking spaces S, where the gripper **200** may selectively grip one of the plungers **102** and insert the plunger **102** into an adapter **104** of a respective vehicle. In further embodiments, a pair of charging stations **50** may be positioned on opposing sides of each parking space S to be able to charge vehicles that include a charging port **18** on either the driver side or the passenger side of the vehicle **10**. In such embodiments, the gantry **106** may grip the plunger **102** attached to the charging station **50** on the side of the vehicle **10** that the charging port **18** is on, and insert that plunger **102** into the adapter **104**.

(38) Referring now to FIG. **5**, the control system **108** may be operated in conjunction with the vehicle charging system **100**, as well as any of the vehicle charging systems discussed herein. However, for brevity, the control system **108** will only be described with reference to the vehicle charging system **100**. The control system **108** may include a controller **220** and a communication path **222** communicatively coupling the controller **220** to the first motor **206**, the second motor **210**, the third motor **214**, the locking mechanism **168**, the imaging device **204**, and the charging station **50**. The controller **220** includes a processor **224** and a non-transitory electronic memory **226** to which various components are communicatively coupled. In some embodiments, the processor **224** and the non-transitory electronic memory **226** and/or the other components are included within a single device. In other embodiments, the processor **224** and the non-transitory electronic memory **226** and/or the other components may be distributed among multiple devices that are communicatively coupled. The controller **220** includes non-transitory electronic memory **226** that stores a set of machine-readable instructions. The processor **224** executes the machine-readable instructions stored in the non-transitory electronic memory **226**. The non-transitory electronic memory **226** may include RAM, ROM, flash memories, hard drives, or any device capable of storing machine-readable instructions such that the machine-readable instructions can be accessed by the processor **224**. Accordingly, the control system **108** described herein may be implemented in any conventional computer programming language, as pre-programmed hardware elements, or as a combination of hardware and software components. The non-transitory electronic memory **226** may be implemented as one memory module or a plurality of memory modules.

(39) The processor **224** may be any device capable of executing machine-readable instructions. For example, the processor **224** may be an integrated circuit, a microchip, a computer, or any other computing device. The non-transitory electronic memory **226** and the processor **224** are coupled to the communication path **222** that provides signal interconnectivity between various components and/or modules of the actuation system. Accordingly, the communication path **222** may communicatively couple any number of processors with one another, and allow the modules coupled to the communication path **222** to operate in a distributed computing environment. Specifically, each of the modules may operate as a node that may send and/or receive data. As used herein, the term "communicatively coupled" means that coupled components are capable of exchanging data signals with one another such as, for example, electrical signals via conductive medium, electromagnetic signals via air, optical signals via optical waveguides, and the like.

(40) As schematically depicted in FIG. **5**, the communication path **222** communicatively couples

the processor **224** and the non-transitory electronic memory **226** of the controller **220** with a plurality of other components of the control system **108**. For example, the control system **108** depicted in FIG. **5** includes the processor **224** and the non-transitory electronic memory **226** communicatively coupled with the first motor **206**, the second motor **210**, the third motor **214**, the locking mechanism **168**, the imaging device **204**, and the charging station **50**. The controller **220** may be configured to actuate each of the first motor **206**, the second motor **210**, and the third motor **214** to move the gripper **200** in any of the X-direction, the Y-direction, and the Z-direction.

(41) The controller **220** may be configured to receive a signal from the imaging device **204** indicative of a location of the indicator **136** relative to the gripper **200**, and operate the motors **14** to move the gripper **200** into a position relative to the indicator **136**. The controller **220** may position the gripper **200** such that the insertion member **162** of the plunger **102** is positioned along the insertion axis **144**, and further operate the motors **206**, **210**, **214** to move the plunger **102** along the insertion axis **144** toward the receiver **112** until the insertion projection **176** is positioned in the receiver cavity **142**, i.e., in the engaged position. Once the insertion projection **176** is positioned in the receiver cavity **142**, the controller **220** may actuate the locking mechanism **168** to generate a magnetic force that attracts the indicator **136** on the receiver **112** to the electromagnet **190** on the plunger **102**, thereby positioning the locking mechanism **168** into the locked position and retaining the insertion projection **176** within the receiver cavity **142**. Once the locking mechanism **168** is actuated, the controller **220** may activate the charging station **50** to begin transferring current to the vehicle battery **16** through the plunger electrical contacts **164**, the receiver electrical contacts **140**, the charging pins on the connector **110**, and the charging port **18**.

(42) Referring now to FIG. **6**, a flowchart of a method **250** of operating the vehicle charging system **100** is depicted with respect to the components described herein and illustrated in FIGS. **1-5**. As discussed above, the vehicle **10** may be parked in a parking structure using an automated parking system that automatically parks the vehicle in a parking structure. The automated parking system may use a lift that picks up and transports the vehicle **10** to a parking space S in the parking structure. When the driver gets out of the vehicle **10** and before the automated parking system transports the vehicle **10** to the parking space, the driver may insert the adapter **104** into the charging port **18**. Once the vehicle **10** is transported to the parking space, the method **250** may include, at step **252**, detecting a location of the adapter **104** extending from the charging port **18** of the vehicle **10**. The location may be detected by identifying the indicator **136** on the receiver **112** to locate the position of the receiver cavity **142**, and moving the plunger **102** via the gantry **106** to align the insertion member **162** with the receiver cavity **142** in the receiver **112**. The location of the adapter **104** may be detected using the imaging device **204** of the gantry **106** that identifies the indicator **136** on the receiver **112** and thereby locates the receiver cavity **142** of the receiver **112**. The imaging device **204** may additionally be used to identify a side of the vehicle **10** that the adapter **104** is positioned on, such as the driver side or the passenger side of the vehicle **10**.

(43) At step **254**, the method **250** may include positioning the plunger **102** relative to the adapter **104** such that the plunger **102** is positioned above the receiver **112** of the adapter **104** along the insertion axis **144**. The plunger **102** may be positioned along the insertion axis **144** using the movement mechanism **202** of the gantry **106**. At step **256**, the method **250** may include lowering the plunger **102** along the insertion axis **144** such that the insertion projection **176** of the insertion member **162** is positioned within the receiver cavity **142** of the receiver **112** and the one or more plunger electrical contacts **164** of the plunger **102** engage the one or more receiver electrical contacts **140** of the receiver **112**, thereby allowing current to flow from the plunger **102**, through the adapter **104**, and to the vehicle battery **16**.

(44) At step **258**, the method **250** may include positioning the locking mechanism **168** into the locked position from the unlocked position to retain the insertion member **162** in contact with the receiver **112**. In the locked position, the electromagnet **190** positioned on the receiver-facing surface **178** electromagnetically engages the receiver charging surface **130** of the receiver **112** to

retain the insertion member **162** in contact with the receiver **112**. At step **260**, the method **250** may further include supplying an electrical current from the charging cable **160** through the plunger electrical contacts **164** to the receiver electrical contacts **140**. The current may pass from the charging station **50** through the charging cable **160** and to the adapter **104** through the contact between the plunger electrical contacts **164** and the receiver electrical contacts **140**. Once the electrical current is supplied to the adapter **104**, the current may pass to the charging port **18** through connection with the connector **110**, and charge the vehicle battery **16**.

(45) When either the vehicle battery **16** is fully charged, at a desired charge level, or the automated parking system begins a process of moving the vehicle **10**, the vehicle charging system **100** may perform the above steps in reverse order to unplug the plunger **102** from the adapter **104**. Particularly, the method **250** may include stopping the supply of electrical current, and operating the locking mechanism **168** from the locked position to the unlocked position. The method **250** may further include moving the plunger **102** along the insertion axis **144** away from the receiver **112** so that the insertion projection **176** is spaced apart from the receiver cavity **142**. Once the plunger **102** is removed from the receiver cavity **142**, the plunger **102** may be moved away from the adapter **104**, and the vehicle **10** may be moved by the automated parking system.

(46) Referring now to FIGS. **7-9**, an alternative vehicle charging system **300** is depicted. It should be understood that the alternative vehicle charging system **300** is similar to the vehicle charging system **100** with the exceptions of the features described herein. As such, like features will use the same reference numerals with a prefix “3” for the reference numbers. As such, for brevity reasons, these features will not be described again.

(47) The vehicle charging system **300** may include an alternative plunger **302** and an alternative adapter **304**. The alternative plunger **302** may include a charging cable **360**, a plunger plate **374**, and one or more biasing members **305** extending between the charging cable **360** and the plunger plate **374**. The plunger plate **374** may include a cable-facing surface **375**, a receiver-facing surface **378**, and an insertion member **362** extending from the receiver-facing surface **378**. The cable-facing surface **375** may face the charging cable **360**, and may be positioned opposite the receiver-facing surface **378**. The plunger plate **374** may be convex at the cable-facing surface **375** such that the cable-facing surface **375** is curved. The plunger plate **374** may define a pair of cavities **377** that extend into the plunger plate **374** from the cable-facing surface **375** toward the receiver-facing surface **378**.

(48) The insertion member **362** may include an extension **363** and an insertion end **365** spaced apart from the receiver-facing surface **378** by the extension **363** that is coupled between the insertion end **365** and the receiver-facing surface **378**. The insertion end **365** may be sized and shaped to be positioned in a receiver cavity **342** of the adapter **304**. As depicted in FIGS. **7-9**, the insertion end **365** may be a sphere. However, it is contemplated and possible that the insertion end **365** includes any shape capable of being positioned in the receiver cavity **342**, such as, for example, a cube.

(49) As shown in FIG. **8**, the plunger plate **374** may define a pair of channels **367** formed within the receiver-facing surface **378** and extending into the plunger plate **374** that may receive one or more plunger electrical contacts **364**. The pair of channels **367** may circumferentially surround the insertion member **362** and be sized and positioned such that one of the pair of channels **367** circumferentially surrounds the other of the pair of channels **367** with each of the pair of channels **367** being concentrically disposed. The one or more plunger electrical contacts **364** of the plunger **302** may positioned on the receiver-facing surface **378** within the pair of channels **367**.

(50) Referring again to FIGS. **7-9**, the charging cable **360** may include a pair of charging wires **361** that extend from a terminal end surface **359** of the charging cable **360**. The charging cable **360** may be concave at the terminal end surface **359** such that the terminal end surface **359** is curved to complement the shape of the cable-facing surface **375** of the plunger plate **374**. The charging wires **361** are electrically coupled to the plunger electrical contacts **364** to transfer electrical current to the

plunger electrical contacts **364**. The biasing members **305** may extend from the terminal end **359** of the charging cable **360** to the plunger plate **374** and be coupled to the plunger plate **374**. The biasing members **305** may at least partially extend into the pair of cavities **377** of the plunger plate **374**. The pair of charging wires **361** may extend through the biasing members **305** with the biasing members **305** positioned around the pair of charging wires **361** between the charging cable **360** and the plunger plate **374**. The pair of charging wires **361** may extend to be electrically coupled to the plunger electrical contacts **364**. In embodiments, the biasing members **305** may include a pair of biasing members **305** with one of the pair of charging wires **361** extending through one of the pair of biasing members **305**, and the other of the pair of charging wires **361** extending through the other of the pair of biasing members **305**. It is contemplated and possible that the biasing members **305** include any number of biasing members **305**, such as one, two, three, four, or more than four.
(51) As shown in FIG. **9**, when the plunger plate **374** contacts the alternative adapter **304**, the charging cable **360** may be further moved toward the adapter **304** to bring the terminal end surface **359** of the charging cable **360** into contact with the cable-facing surface **375**. The biasing members **305** may compress between the terminal end surface **359** and the cable-facing surface **375** so that the biasing members **305** are entirely positioned within the cavities **377** of the plunger plate **374**.
(52) Referring again to FIGS. **7-9**, the alternative adapter **304** may include a receiver **312** with a receiver charging surface **330**, a locking mechanism **368** (FIG. **9**), and one or more receiver electrical contacts **340**. The receiver **312** may define a pair of channels **331** formed within the receiver charging surface **330** and extending into the receiver **312** that may receive one or more receiver electrical contacts **340**. The pair of channels **331** may circumferentially surround the receiver cavity **342**. The one or more receiver electrical contacts **340** of the receiver **312** may be positioned on the receiver charging surface **330** within the pair of channels **331**.
(53) The one or more receiver electrical contacts **340** of the receiver **312** may be positioned on the receiver charging surface **330** of the receiver **312** such that the one or more plunger electrical contacts **364** and the one or more receiver electrical contacts **340** are positioned to contact one another when the insertion end **365** of the insertion member **362** is positioned within the receiver cavity **342** of the receiver **312**, i.e., in the engaged position.
(54) The locking mechanism **368** may be positioned in the receiver cavity **342**, and may be operable between a locked position and an unlocked position. The locking mechanism **368** may grip the insertion end **365** when positioned within the receiver cavity **342** and the locking mechanism **368** is in the locked position to prevent the insertion end **365** from being removed from the receiver **312**. The locking mechanism **368** may release the insertion end **365** to permit the insertion end **365** from being removed from the receiver **312** when the locking mechanism **368** is in the unlocked position. The locking mechanism **368** may include one or more actuators **369** operatively coupled to one or more locking members **371**. The locking members **371** may be disposed on opposing sides of the insertion end **365**. The actuators **369** may be actuated to move the locking members **371** into and out of contact with the insertion end **365** of the plunger **302** when the insertion end **365** is positioned in the receiver cavity **342**. In the unlocked position, the locking members **371** may be spaced apart from the insertion end **365**, and in the locked position (shown in phantom), the locking members **371** may contact the insertion end **365** to retain the insertion end **365** within the receiver cavity **342**.
(55) Referring now to FIGS. **10** and **11**, another alternative vehicle charging system **400** is depicted. It should be understood that the alternative vehicle charging system **400** is similar to the vehicle charging system **100** with the exceptions of the features described herein. As such, like features will use the same reference numerals with a prefix “4” for the reference numbers. As such, for brevity reasons, these features will not be described again.
(56) The vehicle charging system **400** may include an alternative plunger **402** and an alternative adapter **404**. The alternative plunger **402** may include a plunger plate **474** having an end surface **477**, a receiver-facing surface **478** opposite the end surface **477**, a flange **479**, and a movable

insertion member **462**. The plunger plate **474** of the plunger **402** may define an opening **481** that extends from the receiver-facing surface **478** to the end surface **477**. The flange **479** may extend radially inward and partially into the opening **481** to reduce a radius of the opening **481** at the end surface **477**.

(57) The insertion member **462** may include a charging portion **463** and a connection portion **465**. The connection portion **465** may be fixedly coupled to the charging cable **460**, and may be positioned between the charging cable **460** and the charging portion **463**. The connection portion **465** may have a thickness that is less than a thickness of the charging portion **463** such that the insertion member **462** defines a contact surface **476**. The thickness of the connection portion **465** may be less than the width of the opening **481** through the flange **479** such that the connection portion **465** may pass through the opening **481** at the flange **479**. The charging portion **463** may have a width that is greater than the width of the opening **481** through the flange **479** such that the contact surface **476** may contact the flange **479** to prevent the charging portion **463** from passing through the opening **481** at the flange **479**.

(58) The connection portion **465** may be connected to the charging cable **460** so that movement of the charging cable **460** moves the insertion member **462**, and contact between the contact surface **476** of the insertion member **462** and the plunger **402** moves the plunger plate **474** of the plunger **402** with the insertion member **462**. The insertion member **462** may be movably positioned in the opening **481** of the plunger plate **474** such that the insertion member **462** may move relative to the plunger plate **474**. The insertion member **462** may be extendable out of the opening **481** of the plunger **402** to extend into the receiver cavity **442** in the receiver **412** when the plunger **402** is positioned along the insertion axis **444**.

(59) The insertion member **462** may be movable between a disengaged position (FIG. **10**) and an engaged position (FIG. **11**). As shown in FIG. **10**, in the disengaged position, the insertion member **462** is positioned within the opening **481** in the plunger plate **474** of the plunger **402** to be spaced apart from the receiver cavity **442**. As shown in FIG. **11**, in the engaged position, the charging portion **463** of the insertion member **462** is extended out of the opening **481** of the plunger plate **474** of the plunger **402** to be positioned in the receiver cavity **442** with the plunger electrical contacts **464** in contact with the receiver electrical contacts **440**. The insertion member **462** may move relative to the plunger plate **474** of the plunger **402** when the plunger plate **474** contacts the receiver **412** and the charging cable **460** is further advanced toward the plunger plate **474** to move the insertion member **462** relative to the plunger plate **474**. The charging cable **460** may be advanced until the charging portion **463** of the insertion member **462** is positioned in the receiver cavity **442** with the plunger electrical contacts **464** in contact with the receiver electrical contacts **440**.

(60) In embodiments, a stopper **482** may be provided on the charging cable **460** to prevent overextension of the charging cable **460** and the insertion member **462** into the receiver **412**. The stopper **482** may circumferentially surround and extend from the charging cable **460** to have a width that is greater than a width of the receiver cavity **442** at the flange **479**. The stopper **482** may be positioned on the charging cable **460** a distance from the charging portion **463** of the insertion member **462** such that the stopper **482** contacts the end surface **477** when the plunger electrical contacts **464** are in contact with the receiver electrical contacts **440**.

(61) In embodiments, an actuator **484** may be provided for positioning the insertion member **462** between the engaged position and the disengaged position. The actuator **484** may be operatively coupled to the charging cable **460** and/or the insertion member **462** to move the charging cable **460** and/or the insertion member **462** relative to the receiver **412**.

(62) While particular embodiments have been illustrated and described herein, it should be understood that various other changes and modifications may be made without departing from the spirit and scope of the claimed subject matter. Moreover, although various aspects of the claimed subject matter have been described herein, such aspects need not be utilized in combination. It is

therefore intended that the appended claims cover all such changes and modifications that are within the scope of the claimed subject matter.

Claims

1. A vehicle charging system comprising: a vehicle charging adapter comprising: a connector configured to engage with a charging port of a vehicle; and a receiver coupled to the connector, the receiver comprising: a receiver charging surface; an indicator provided on the receiver charging surface; an inner radial wall extending from the receiver charging surface and defining a receiver cavity extending along an insertion axis; one or more receiver electrical contacts electrically connected to the connector; a plunger comprising: an insertion member extending from a plunger plate along the insertion axis, the insertion member at least partially positionable into the receiver cavity of the receiver; and one or more plunger electrical contacts that mate with the one or more receiver electrical contacts when the insertion member is positioned within the receiver cavity; and a charging cable transferring electrical current to the one or more plunger electrical contacts of the plunger; wherein the plunger further comprises a locating member, the locating member comprises one or more fingers that extend around the receiver when the insertion member is positioned within the receiver cavity of the receiver.
2. The vehicle charging system of claim 1, wherein the plunger further comprises a locking mechanism operable between a locked position and an unlocked position, the locking mechanism retains the insertion member within the receiver cavity when in the locked position and permit the insertion member to be removed from the receiver cavity when in the unlocked position.
3. The vehicle charging system of claim 2, wherein the plunger plate is oriented along a plane extending perpendicular to the insertion axis, and the plunger further comprises an insertion projection extending from the plunger plate, the one or more plunger electrical contacts are provided on the insertion projection, and the locking mechanism is provided on a receiver-facing surface of the plunger plate, the locking mechanism electromagnetically engages the receiver charging surface of the receiver to retain the plunger plate in contact with the receiver charging surface when in the locked position.
4. The vehicle charging system of claim 1, wherein: the plunger plate defines an opening, the insertion member is movable relative to the plunger plate between a disengaged position and an engaged position; in the disengaged position, the insertion member is positioned within the opening in the plunger plate; and in the engaged position, the insertion member is positioned within the receiver cavity.
5. The vehicle charging system of claim 4, wherein: the insertion member comprises a charging portion and a connection portion, the connection portion is coupled to a charging cable, the insertion member defines a contact surface; the plunger plate further comprises a flange extending partially into the opening; and in the disengaged position, the contact surface of the insertion member contacts the flange.
6. The vehicle charging system of claim 1, wherein the plunger comprises a plunger plate having a receiver-facing surface and the insertion member extends from the receiver-facing surface and includes an insertion end spaced apart from the receiver-facing surface, the one or more plunger electrical contacts are positioned on the receiver-facing surface, the one or more receiver electrical contacts are positioned on the receiver charging surface of the receiver, the one or more plunger electrical contacts and the one or more receiver electrical contacts are positioned to contact one another when the insertion end of the insertion member is positioned within the receiver cavity of the receiver.
7. The vehicle charging system of claim 6, wherein the insertion end is a sphere, and the receiver includes a locking mechanism operable between a locked position and an unlocked position, the locking mechanism grips the insertion end when positioned within the receiver cavity and the

locking mechanism is in the locked position to prevent the insertion end from being removed from the receiver, the locking mechanism releases the insertion end to permit the insertion end from being removed from the receiver when the locking mechanism is in the unlocked position.

8. The vehicle charging system of claim 7, wherein the plunger further comprises one or more biasing members extending between and coupled to a charging cable and the insertion member.

9. A method comprising: detecting a location of an adapter extending from a charging port of a vehicle, the adapter comprising: a connector configured to engage with the charging port of the vehicle; a receiver comprising: a receiver charging surface; an indicator provided on the receiver charging surface; an inner radial wall extending from the receiver charging surface and defining a receiver cavity extending along an insertion axis; and one or more receiver electrical contacts electrically connected to the connector; positioning a plunger relative to the adapter such that the plunger is positioned above the receiver of the adapter along the insertion axis, the plunger comprising: an insertion member extending from a plunger plate along the insertion axis, the insertion member at least partially positionable into the receiver cavity of the receiver; one or more plunger electrical contacts that mate with the one or more receiver electrical contacts when the insertion member is positioned within the receiver cavity; and a charging cable transferring electrical current to the one or more plunger electrical contacts of the plunger; wherein the plunger further comprises a locating member, the locating member comprising one or more fingers that extend around the receiver when the insertion member is positioned within the receiver cavity of the receiver; and lowering the plunger along the insertion axis such that the insertion member is positioned within the receiver cavity of the receiver and the one or more plunger electrical contacts of the plunger engage the one or more receiver electrical contacts of the receiver.

10. The method of claim 9, further comprising supplying an electrical current from the charging cable through the plunger electrical contacts to the receiver electrical contacts.

11. The method of claim 9, further comprising positioning a locking mechanism into a locked position from an unlocked position to retain the insertion member in contact with the receiver, the locking mechanism comprising an electromagnet positioned on a receiver-facing surface of the plunger plate that electromagnetically engages the receiver charging surface of the receiver to retain the insertion member in contact with the receiver.

12. The method of claim 9, wherein locating the plunger relative to the adapter comprises identifying the indicator on the receiver to locate a position of the receiver cavity relative to the indicator, and moving the plunger via a gantry to align the insertion member with the receiver cavity in the receiver.