Aspects of the invention include an electric vehicle charging system that comprises a battery module, a power input component, a power output component, and at least one AC/DC power converter configured to convert AC power to DC power. Aspects of the invention also include methods of using an electric vehicle charger to charge and/or power an electric vehicle.
ELECTRIC VEHICLE CHARGING SYSTEM AND METHODS OF USE

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority benefit of the filing date of US Provisional Patent Application Serial No. 62/389,037, filed on February 16, 2016, the disclosure of which application is herein incorporated by reference in its entirety, and claims priority benefit of the filing date of US Provisional Patent Application Serial No. 62/445,162, filed on January 11, 2017, the disclosure of which application is herein incorporated by reference in its entirety.

FIELD OF THE INVENTION

[0002] The present invention relates to electric vehicle charging systems and methods of use. In some aspects, the present invention relates to portable, hand-held charging systems and their methods of use to charge an on-board battery of an electric vehicle and/or to provide power to an electric vehicle.

BACKGROUND OF THE INVENTION

[0003] Aspects of the invention include a charging system for an electric vehicle, and methods of using an electric vehicle charging system to charge and/or power an electric vehicle. In some embodiments, a subject electric vehicle charging system includes a battery module, a power input component, a power output component, and at least one AC/DC power converter that is configured to convert AC power to DC power.

[0004] Electric vehicle usage is currently limited by several issues. These include, but are not limited to: 1) a general lack of workplace and public charging infrastructure that is sufficient to reliably re-charge an electric vehicle; 2) in-home charging systems are expensive, can require permitting for installation, or may be prohibited in certain residences (e.g., in rental housing); 3) charging stations suffer from frequent malfunctions and periods of unavailability (such as when other electric vehicles are actively charging), making them unreliable for vehicle re-charging on a consistent basis; and 4) the costs associated with most public charging infrastructure are equivalent to gas prices due to high premiums set by operators, or are prohibitively expensive to the average electric vehicle owner, thus discouraging everyday use by electric vehicle owners.

[0005] The current invention provides charging systems that eliminate reliance on public charging stations, which are frequently unavailable, and enable a user of an electric vehicle to
extend the range of the vehicle by providing greater flexibility for travel both inside and outside
the normal operating range of the vehicle without having to rely on the availability of public
charging station infrastructure. Rather than replacing electric vehicle charging infrastructure, the
current invention provides electric vehicle drivers with an alternative source of power that can
be used in situations where charging stations are difficult to find, or are unavailable (e.g., due to
malfunctioning equipment, or due to use of equipment by other electric vehicle owners).

[0006] The following published patent applications are herein incorporated by reference in their
entirety:
- WO 2015/135687
- WO 2013/030637

**SUMMARY**

[0007] Aspects of the invention include a charging system for an electric vehicle, the charging
system comprising a battery module; a power input component; a power output component; and
at least one AC/DC power converter configured to convert AC power to DC power. In some
embodiments, the charging system further comprises a DC to DC power converter. In some
embodiments, the DC to DC power converter comprises a step-up DC to DC power converter.
In some embodiments, the DC to DC power converter comprises a step-down DC to DC power
converter.

[0008] In some embodiments, the AC/DC power converter is a bi-directional AC/DC power
converter that is configured to convert AC power to DC power, and to convert DC power to AC
power. In some embodiments, the battery module comprises one or more individual batteries,
and is configured to operably connect each of the one or more individual batteries to the
charging system. In some embodiments, the battery module of the charging system has an
energy storage capacity that ranges from 10% to 50% of the energy storage capacity of an on-
board battery of the electric vehicle. In some embodiments, the charging system is a portable,
hand-held charging system.

[0009] In some embodiments, the charging system further comprises an alternative energy
power input component. In some embodiments, the alternative energy power input component
comprises a solar power generation component. In some embodiments, the solar power
generation system comprises one or more solar panels. In some embodiments, the alternative
energy power input component comprises a wind power generation component. In some
embodiments, the alternative energy power input component comprises a manual power
generation component. In some embodiments, the manual power generation component
comprises a hand crank. In some embodiments, the alternative energy power input component
comprises a fuel cell component.

[0010] In some embodiments, the charging system further comprises an internal temperature
sensor. In some embodiments, the charging system further comprises a tilt sensor. In some
embodiments, the charging system further comprises a motion sensor. In some embodiments,
the charging system further comprises a light sensor. In some embodiments, the charging system
further comprises an external temperature sensor.

[0011] In some embodiments, the charging system further comprises a charge controller. In
some embodiments, the charging system further comprises a power flow sensor. In some
embodiments, the charging system further comprises a power conversion circuit. In some
embodiments, the charging system further comprises a wireless communication component.

[0012] In some embodiments, the charging system is configured for remote operation. In some
embodiments, the charging system further comprises an external indicator component. In some
embodiments, the charging system further comprises a moisture sensor. In some embodiments,
the charging system is configured for load sharing.

[0013] In some embodiments, the charging system further comprises an input selector. In some
embodiments, the charging system further comprises an output selector. In some embodiments,
the charging system further comprises an AC power outlet (or AC connector). In some
embodiments, the charging system further comprises a DC power outlet (or DC connector). In
some embodiments, the charging system further comprises a housing. In some embodiments, the
charging system further comprises at least one electrical cord.

[0014] Aspects of the invention include a method for charging an on-board battery of an electric
vehicle, the method comprising: connecting an AC power source to an electric vehicle charging
system; wherein the electric vehicle charging system comprises: a battery module; a power input
component; a power output component; and at least one AC/DC power converter configured to
convert AC power to DC power; converting AC power from the AC power source into DC
power using the AC/DC converter; transferring the DC power to the battery module to charge
the battery module; connecting the battery module to the on-board battery of the electric
vehicle; and transferring DC power from the battery module of the electric vehicle charging
system to the on-board battery of the electric vehicle to charge the battery of the electric vehicle.
Aspects of the invention include a method for providing power to an electric vehicle, the method comprising: connecting an AC power source to an electric vehicle charging system, wherein the electric vehicle charging system comprises: a battery module; a power input component; a power output component; and at least one AC/DC power converter configured to convert AC power to DC power; converting AC power from the AC power source to DC power using the AC/DC converter; transferring the DC power to the battery module to charge the battery module; connecting the battery module to the electric vehicle; and transferring DC power from the battery module of the electric vehicle charging system to the electric vehicle to power the electric vehicle.

Aspects of the invention include a method for charging an on-board battery of an electric vehicle, the method comprising: connecting a DC power source to an electric vehicle charging system, wherein the electric vehicle charging system comprises: a battery module; a power input component; a power output component; and at least one AC/DC power converter configured to convert AC power to DC power; transferring the DC power to the battery module to charge the battery module; connecting the battery module to the on-board battery of the electric vehicle; and transferring DC power from the battery module of the electric vehicle charging system to the on-board battery of the electric vehicle.

Aspects of the invention include a method for providing power to one or more auxiliary electrical components of an electric vehicle, the method comprising: connecting a DC power output of a system according to claim 1 to one or more auxiliary electrical components of the electric vehicle; and transferring DC power from the battery module of the electric vehicle charging system to the auxiliary electrical component of the electric vehicle.

**BRIEF DESCRIPTION OF THE DRAWINGS**

FIG. 1 is an illustration of a subject charging system that is electrically connected to a plurality of solar panels, and is also electrically connected to an electric vehicle.

FIG. 2 is another illustration of a subject charging system that is electrically connected to a plurality of solar panels, and is also electrically connected to an electric vehicle. In the depicted embodiment, the solar panels are foldable solar panels that have been extended.

FIG. 3 is an illustration of a subject charging system and an electrical cord. The depicted charging system comprises a plurality of foldable solar panels that are folded for storage. The depicted charging system and electrical cord are stored in the rear area of an electric vehicle.
FIGS. 4-14 provide results from a survey of electric vehicle owners on a variety of topics. The survey was conducted nationally in the US with over 500 participants. Of the 500 participants, 18 were selected to answer questions relating to electric vehicle ownership issues and driving behaviors.

Before the present invention is further described, it is to be understood that this invention is not limited to particular embodiments described, as such may, of course, vary. It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to be limiting, since the scope of the present invention will be limited only by the appended claims.

Where a range of values is provided, it is understood that each intervening value, to the tenth of the unit of the lower limit unless the context clearly dictates otherwise, between the upper and lower limit of that range and any other stated or intervening value in that stated range, is encompassed within the invention. The upper and lower limits of these smaller ranges may independently be included in the smaller ranges, and are also encompassed within the invention, subject to any specifically excluded limit in the stated range. Where the stated range includes one or both of the limits, ranges excluding either or both of those included limits are also included in the invention.

Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. Although any methods and materials similar or equivalent to those described herein can also be used in the practice or testing of the present invention, the preferred methods and materials are now described. All publications mentioned herein are incorporated herein by reference to disclose and describe the methods and/or materials in connection with which the publications are cited.

It must be noted that as used herein and in the appended claims, the singular forms "a," "an," and "the" include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to "the battery module" includes reference to one or more battery modules, and so forth. It is further noted that the claims may be drafted to exclude any optional element. As such, this statement is intended to serve as antecedent basis for use of such exclusive terminology as "solely," "only" and the like in connection with the recitation of claim elements, or use of a "negative" limitation.
The publications discussed herein are provided solely for their disclosure prior to the filing date of the present application. Nothing herein is to be construed as an admission that the present invention is not entitled to antedate such publication by virtue of prior invention. Further, the dates of publication provided may be different from the actual publication dates which may need to be independently confirmed.

Definitions

The term "electric vehicle" as used herein refers to a vehicle that is capable of transporting one or more passengers and that is at least partially powered by electricity. As such, the term "electric vehicle" broadly includes vehicles that are solely powered by electricity, as well as hybrid electric vehicles that are partially powered by electricity and partially powered by, e.g., fossil fuel engines (e.g., gasoline engines), fuel cells, etc.

The term "on-board battery" as used herein refers to a battery component of an electric vehicle that is physically coupled to the electric vehicle and that is intended to remain electrically connected to the electric vehicle during its operation.

The term "alternative energy" as used herein refers to energy that is derived from a source other than a fossil fuel energy source. Non-limiting examples of alternative energy sources include solar, wind, and fuel cell energy sources.

The terms "charge controller," "charge regulator" and "battery regulator" as used interchangeably herein refer to a component that is configured to limit the rate at which electric current is added to or drawn from a battery. Charge controllers in accordance with embodiments of the invention can be stand-alone components, or can be integrated into control circuitry within a battery module.

The term "power flow sensor" as used herein refers to a sensor that is configured to detect one or more attributes related to the movement of electrical energy through a system. Non-limiting examples of power flow sensors include sensors that are configured to detect the direction and magnitude of DC power that is moving through a system (e.g., the direction and magnitude of DC power that is being transferred from a battery module of a subject charging system to an on-board battery of an electric vehicle).

The terms "power conversion circuit" and "power converter" as used interchangeably herein, refer to an electrical or electro-mechanical component that is configured to covert electrical energy from one form to another. Non-limiting examples of electrical energy
conversion include: converting between AC and DC, changing a voltage, or changing a
current. frequency of an AC current.

[0033] The terms "load sharing" and "load balancing," as used interchangeably herein, refer to
the ability of a subject charging system to simultaneously store energy in a battery module as
well as provide power to an electric vehicle for purposes of operating the vehicle and/or one or
more auxiliary electrical components. In some embodiments, "load sharing" refers to
simultaneously connecting a plurality of separate charging systems to the same electric vehicle
to store and/or transfer energy, thereby establishing a redundant power supply.

[0034] The term "auxiliary electrical component" as used herein refers to a component that
requires electricity to operate, but is not required to be operational in order to operate an electric
vehicle. Non-limiting examples of auxiliary electrical components include audio systems (e.g.,
radios, speakers); navigation systems; window defrosters (e.g., windshield, rear window
defrosters); head, tail and interior lights, and the like.

[0035] The term "portable" as used herein refers to an item that is easily carried or transported
by an average adult human.

[0036] The term "hand-held" as used herein refers to an item that is design to be held and/or
carried by a user's hand. In some embodiments, a hand-held item comprises a strap or handle
that can be easily grasped by a user in order to carry the item.

DETAILED DESCRIPTION

[0037] Aspects of the invention include a charging system for an electric vehicle, and methods
of using an electric vehicle charging system to charge and/or power an electric vehicle, or one or
more components thereof. In some embodiments, a subject electric vehicle charging system
includes a battery module, a power input component, a power output component, and at least
one AC/DC power converter that is configured to convert AC power to DC power. Each of
these components is described in further detail below.

[0038] In certain embodiments, a subject charging system is a portable, hand-held charging
system that can be easily carried by a user. In one preferred embodiment, a portable, hand-held
electric vehicle charging system has a weight that ranges from about 5 to about 50 pounds, and
can be lifted and transported by an average adult.
Battery Module:

[0039] Aspects of the invention include a charging system that comprises one or more battery modules. Battery modules for electric vehicles (EVs) generally incorporate a combination of mechanical and electrical components and systems that are configured to store electrical energy and transfer the electrical energy to the EV as needed. Charging systems in accordance with embodiments of the invention are configured to utilize any suitable number of battery modules while maintaining the portability of the charging system (i.e., the ability to be easily carried or transported by an average adult human). In some embodiments, a subject charging system comprises a number of battery modules that ranges from 1 to about 25, such as 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23 or 24 battery modules.

[0040] In some embodiments, a battery module of a subject charging system is configured to provide an energy storage capacity that is less than the storage capacity of the EV's on-board battery. For example, in some embodiments, a battery module of a subject charging system is configured to provide from about 10% to about 50% of the energy storage capacity of an EV's on-board battery. In certain embodiments, a battery module of a subject charging system is configured to provide about 15%, about 20%, about 25%, about 30%, about 35%, about 40%, or about 45% of the energy storage capacity of an EV's on-board battery.

[0041] Battery modules in accordance with embodiments of the invention can utilize any suitable chemistry, including but not limited to: lead-acid, nickel metal hydride, sodium, lithium-ion chemistry, or any combination thereof. Battery modules in accordance with embodiments of the invention can have any suitable physical shape and size.

[0042] In some embodiments, a battery module comprises a plurality of individual batteries, or cells, that are connected in series and/or parallel to achieve the total voltage and current requirements of the battery module. In certain embodiments, a battery module comprises a number of individual batteries that ranges from 1 to 25, such as 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23 or 24 individual batteries. In some embodiments, one or more of the individual batteries are rechargeable. In some embodiments, a battery module is configured to charge one or more individual batteries when the battery module is electrically connected to a power source (e.g., via an electrical cord). In some embodiments, a battery module is configured for wireless charging, wherein the battery module is positioned adjacent to (e.g., on top of) a charging stand, and power is wirelessly transferred from the charging stand to
the battery module to charge one or more individual batteries. In some embodiments, a wireless charging stand is connected to a standard electrical outlet.

[0043] In some embodiments, one or more battery modules are configured to be removably coupled to a subject charging system, such that a user can remove and replace the one or more battery modules (e.g., to repair or replace a battery module, to separately charge an individual battery module, etc.). In some embodiments, one or more individual batteries within a battery module are configured to be removably coupled to the battery module, such that a user can remove and replace the one or more individual batteries (e.g., to repair or replace an individual battery, to separately charge an individual battery, etc.).

[0044] In some embodiments, a battery module can include one or more cooling mechanisms, temperature monitors, and/or other controlling or monitoring components. In some embodiments, a battery module includes a battery management system (BMS) that is configured to monitor one or more electrical characteristics (e.g., voltage production) of each individual battery in the battery module.

[0045] In some embodiments, a battery module includes a main fuse that limits the current of the module under a short circuit condition. In some embodiments, a battery module can contain one or more relays, or contactors, which control the distribution of the battery module's electrical power to one or more output terminals. In some embodiments, a battery module includes two main relays that connect the battery module to the main positive and negative output terminals, which supply high current to the electrical drive motor of the EV. In some embodiments, a battery module includes alternate current paths for pre-charging the drive system through a pre-charge resistor, or for powering one or more auxiliary components (e.g., an auxiliary buss component) that can also have their own associated control relays.

[0046] In some embodiments, a battery module contains a variety of temperature, voltage, and/or current sensors. In some embodiments, collection of data from the battery module sensors, and/or activation of the battery module relays, can be accomplished using a BMS. In some embodiments, the BMS can be used to manage communication between the battery module and one or more additional components or systems.

[0047] In one preferred embodiment, a battery module comprises a plurality of individual, rechargeable lithium-ion batteries. In one preferred embodiment, a subject charging system comprises 5 battery modules, each containing 10 individual batteries. In one preferred embodiment, a subject charging system comprises 6 battery modules, each containing 10
individual batteries. In one preferred embodiment, a subject charging system comprises 7 battery modules, each containing 10 individual batteries. In one preferred embodiment, a subject charging system comprises 8 battery modules, each containing 10 individual batteries. In one preferred embodiment, a subject charging system comprises 5 battery modules, each containing 35 individual batteries. In one preferred embodiment, a subject charging system comprises 6 battery modules, each containing 35 individual batteries. In one preferred embodiment, a subject charging system comprises 7 battery modules, each containing 35 individual batteries. In one preferred embodiment, a subject charging system comprises 8 battery modules, each containing 35 individual batteries.

**Power Input and Output Components:**

[0048] Aspects of the invention include a charging system that comprises a power input component and a power output component. In some embodiments, a power input component is configured to connect to an AC power source and to transfer AC power between two components. In some embodiments, a power input component is configured to transfer AC power from an AC power source to an AC/DC converter, described further herein. In some embodiments, a power input component comprises a National Electrical Manufacturers Association (NEMA) AC input cable, which may optionally comprise one or more adaptors. In some embodiments, a NEMA AC input cable is rated for between 2 to 10 kW. In some embodiments, a NEMA AC input cable is rated for at least about 10 kW or more. In some embodiments, a power input component comprises an SAE J1722 (IEC Type 1) AC input component, which can be used with standard electric vehicle equipment.

[0049] In some embodiments, a power output component is configured to connect to a DC power source and to transfer DC power between two components. In some embodiments, a power output component is configured to transfer DC power from the battery module of the electric vehicle charging system to the battery of the electric vehicle to charge the battery of the electric vehicle. In some embodiments, a power output component is configured to transfer DC power from the battery module of the electric vehicle charging system to the electric drive motor of the electric vehicle. In some embodiments, a power output component comprises an SAE J1772 Type 1 DC output cable.
In certain embodiments, a subject electric vehicle charging system comprises an AC output component that is configured to provide AC power to an external component. In certain embodiments, an AC output component comprises a NEMA AC output cable.

In some embodiments, a power input or output component comprises a transformer that is configured to reduce or increase the voltage of an alternating current that is running through the input or output component.

AC/DC Converter

Aspects of the invention include a charging system that comprises an AC/DC converter. AC/DC converters in accordance with embodiments of the invention are configured to convert alternating current (AC) to direct current (DC). In some embodiments, an AC/DC converter is a bi-directional AC/DC converter that can convert AC to DC, and DC to AC, as desired.

DC to DC Power Converter

Aspects of the invention include a charging system that comprises a DC to DC power converter. In some embodiments, a DC to DC power converter is a step-up DC to DC power converter that steps up a voltage from an input (supply) to an output (load), while stepping down a current. In some embodiments, a DC to DC power converter is a step-down DC to DC power converter that steps down a voltage from an input (supply) to an output (load), while stepping up a current.

In some embodiments, a DC to DC power converter is a switched-mode power supply that contains at least two semiconductors (a diode and a transistor) and at least one energy storage element: a capacitor, an inductor, or a combination thereof. In some embodiments, a DC to DC power converter is configured to meet one or more power requirements on an EV, such as, e.g., auxiliary electric loads, such as head, tail and interior lights, heating and air conditioning fans, audio systems, navigation systems, and the like.

Alternative Power Inputs

Aspects of the invention include alternative power inputs that can be used in combination with or instead of electric energy inputs to charge a battery module of a subject system. Non-limiting examples of alternative power inputs include solar, wind, fuel cell and manual power inputs.
[0056] Solar power inputs generally include at least one solar panel that is configured to convert solar energy into electricity. In some embodiments, a solar panel is a portable solar panel. In some embodiments, a solar panel is flexible or foldable, and is configured to be stored in a collapsed or folded state when not in use.

[0057] Wind power inputs generally include at least one wind turbine that is configured to convert wind energy into electricity. In some embodiments, a wind turbine is a portable wind turbine. In some embodiments, a wind turbine is flexible or foldable, and is configured to be stored in a collapsed or folded state when not in use.

[0058] Fuel cell power inputs are configured to convert chemical energy from a chemical reaction into electricity. In some embodiments, a fuel cell is a hydrogen fuel cell.

[0059] Manual power inputs are configured to convert kinetic energy into electricity. In some embodiments, a manual power input is a hand crank that is powered by an operator.

Selectors

[0060] Aspects of the invention include selectors that can optionally be included in a subject charging system in order to select from two or more different operating modes, or to switch between two or more different operating modes. Non-limiting examples of selectors include input selectors, output selectors, and power mode selectors. For example, in one embodiment, a subject charging system can include an input selector that is configured to allow a user to select between an AC power input and a DC power input. In one embodiment, a subject charging system can include an output selector that is configured to allow a user to select between an AC power output and a DC power output.

[0061] In some embodiments, a selector is a digital selector. In some embodiments, a digital selector is configured to automatically detect which type of electrical charging cord has been connected to the system, and to select an electricity output setting that corresponds to the type of electrical charging cord (e.g., an optimal power output based on the make of the electric vehicle whose charging cord has been connected to the system).

Sensors

[0062] Aspects of the invention include sensors that can optionally be included in a subject system in order to collect and utilize information relating to the system and/or its environment. Non-limiting examples of sensors that can be used in conjunction with the subject charging
systems include: internal and external temperature sensors, tilt sensors, motion sensors, light sensors, power flow sensors, and moisture sensors.

Controllers

Aspects of the invention include a controller, processor and computer readable medium that are configured or adapted to control and/or operate one or more components of the subject systems. In some embodiments, a system includes a controller that is in communication with one or more components of the subject systems or sensors, as described herein, and is configured to control aspects of the systems and/or execute one or more operations or functions of the subject systems, e.g., to carry out one or more methods described herein. In some embodiments, a system includes a processor and a computer-readable medium, which may include memory media and/or storage media. Applications and/or operating systems embodied as computer-readable instructions (or "firmware", i.e., permanent software that is programmed into a read-only memory) on computer-readable memory can be executed by the processor to provide some or all of the functionalities described herein, including by not limited to, carrying out one or more of the method steps described herein, and/or acquiring and processing data obtained from the subject systems.

In some embodiments, a system includes a user interface, such as a graphical user interface (GUI), and/or one or more user input devices that are adapted or configured to receive input from a user, and to execute one or more of the methods as described herein. In some embodiments, a GUI is configured to display data and/or information to a user.

Communication Components

Aspects of the invention include communication components that are configured to remotely operate and/or control one or more features of the subject charging systems. For example, in some embodiments, a subject charging system can comprise a communication component that is configured to remotely operate subject charging system by turning the system on and initiating a charging procedure to charge the battery module of the charging system. In some embodiments, a subject charging system comprises a communication component that is configured for Internet-enabled operation of a subject charging system, wherein a user can remotely operate the charging system via the Internet by accessing a web page or smart phone application and entering one or more commands. The Internet-enabled communication
component then receives the one or more commands from the user carries out the one or more commands.

Aspects of the subject charging systems also include data exchange features, such as, e.g., USB ports, Ethernet ports, or other data ports that are configured to establish a connection that can be used to exchange/transmit data between two or more components of the system. Aspects of the subject systems also include wireless transmission components, such as, e.g., Bluetooth or WiFi/3G components, that are configured to wirelessly transmit data between two or more components of the system.

Housing

Aspects of the invention include charging systems that are formed into a single device that includes a housing formed from suitable materials, such as, e.g., plastic, metal, glass or ceramic materials, or any combinations thereof. For example, in some embodiments, a subject charging system comprises a plastic housing, and various components of the system are located within the housing. Housings in accordance with embodiments of the invention can have any suitable dimensions. In some embodiments, a housing can have a square, rectangular, round or oval cross sectional shape. In some embodiments, a housing can have a width, a depth, and a height dimension. In some embodiments, a width dimension of a housing can range from about 6 inches up to about 24 inches, such as 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23 inches. In some embodiments, a depth dimension of a housing can range from about 6 inches up to about 24 inches, such as 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, or 35 inches.

In some embodiments, a housing can include one or more electrical outlets. Non-limiting examples of electrical outlets include AC outlets and DC outlets. In some embodiments, a housing can include one or more data ports. Non-limiting examples of data ports include Ethernet ports and USB ports. In some embodiments, a housing can include one or more electrical cords and/or cables. In certain embodiments, one or more electrical cords or cables can be integrated with the housing, such that they are not configured to be separated from the housing by a user. In some embodiments, an electrical cord or cable is configured to be freely attached and/or detached from the housing by a user.
In some embodiments, a housing comprises one or more indicator components that are configured to communicate information about the subject charging system to a user. For example, in some embodiments, a housing can comprise one or more visual indicator components, such as, e.g., one or more LED indicators that show, e.g., a mode of operation (e.g., charging mode) or, e.g., a charge status of the battery module of the charging system.

In some embodiments, a housing comprises one or more user input or control devices that are configured to receive an input from a user. For example, in some embodiments, a housing can comprise, e.g., a power button that is configured to turn the charging system on and off; a charging mode button that is configured to place the charging system into one of a plurality of charging modes; a reset button that is configured to reset the charging system; or any combination thereof. One of ordinary skill in the art will readily appreciate that any of a variety of buttons, switches, or other suitable using input components can be incorporated into the housing a subject charging system.

In some embodiments, a subject charging system is configured to couple to a charging receptacle in or on an electric vehicle. Charging receptacles in accordance with embodiments of the invention can be located in any suitable location on an electric vehicle, such as, e.g., in the trunk of the electric vehicle, or in the interior of the electric vehicle (e.g., in the glove box of the electric vehicle, or on the floor of the electric vehicle in front of a passenger seat). In some embodiments, a subject charging system is configured to be electrically connected, or coupled, to the electrical system of the electric vehicle when the charging system is coupled to the charging receptacle. In some embodiments, a charging system is configured to wireless connect to the electrical system of the electric vehicle when the charging system is coupled to the charging receptacle, wherein an electrical cord is not required to connect the charging system to the electrical system of the electric vehicle. In such embodiments, the charging receptacle can comprise one or more electrical connectors that are configured to interface with one or more corresponding electrical connectors on the charging system to establish an electrical connection when the charging system is coupled to the charging receptacle. In some embodiments, a charging receptacle can comprise an electrical cord that is configured to electrically connect the charging system with the electrical system of the electric vehicle when the charging system is placed in the charging receptacle. In some embodiments, a charging receptacle is configured to at least partially contain, or restrain the movement of, a subject charging system, such that the charging system is held in place when the electric vehicle is operated. In some embodiments, a
charging receptacle can comprise a locking mechanism that is configured to lock the charging system in place within the charging receptacle.

**Methods of Use**

[0072] Aspects of the invention include a method for charging an on-board battery of an electric vehicle, the method comprising: connecting an AC power source to an electric vehicle charging system, wherein the electric vehicle charging system comprises: a battery module; a power input component; a power output component; and at least one AC/DC power converter configured to convert AC power to DC power; converting AC power from the AC power source into DC power using the AC/DC converter; transferring the DC power to the battery module to charge the battery module; connecting the battery module to the on-board battery of the electric vehicle; and transferring DC power from the battery module of the electric vehicle charging system to the on-board battery of the electric vehicle to charge the on-board battery of the electric vehicle.

[0073] Aspects of the invention include a method for providing power to an electric vehicle, the method comprising: connecting an AC power source to an electric vehicle charging system, wherein the electric vehicle charging system comprises: a battery module; a power input component; a power output component; and at least one AC/DC power converter configured to convert AC power to DC power; converting AC power from the AC power source to DC power using the AC/DC converter; transferring the DC power to the battery module to charge the battery module; connecting the battery module to the electric vehicle; and transferring DC power from the battery module of the electric vehicle charging system to the electric vehicle to power the electric vehicle.

[0074] Aspects of the invention include a method for charging an on-board battery of an electric vehicle, the method comprising: connecting a DC power source to an electric vehicle charging system, wherein the electric vehicle charging system comprises: a battery module; a power input component; a power output component; and at least one AC/DC power converter configured to convert AC power to DC power; transferring DC power from the DC power source to the battery module to charge the battery module; connecting the battery module to the on-board battery of the electric vehicle; and transferring DC power from the battery module of the electric vehicle charging system to the on-board battery of the electric vehicle to charge the on-board battery of the electric vehicle.
Aspects of the invention include a method for providing power to one or more auxiliary electrical components of an electric vehicle, the method comprising: connecting a DC power output of a subject charging system to an auxiliary electrical component of an electric vehicle, wherein the charging system comprises: a battery module; a power input component; a power output component; and at least one AC/DC power converter configured to convert AC power to DC power; transferring DC power from the battery module of the charging system to the one or more auxiliary components of the electric vehicle to power the one or more auxiliary electrical components of the electric vehicle without depleting the on-board battery of the electric vehicle.

Utility

One aspect of electric vehicle use is a phenomenon known as range anxiety. Range anxiety is a fear that an electric vehicle will have insufficient range, or charge capacity in its on-board battery, to reach the next destination at which charging equipment is available, thereby stranding the vehicle and its occupants in an undesired location. This phenomenon is considered to be one of the major barriers to large-scale adoption of all-electric vehicles by consumers. In addition to range anxiety, there is also a fear among electric vehicle owners that public charging equipment will not be sufficiently available (either because it is not functioning or because it is already in use) when it is needed to recharge an electric vehicle. In fact, in a recent exchange between Tesla CEO Elon Musk and a frustrated EV owner, the issue of occupied charging stations was highlighted, resulting in Tesla Motors implementing a new policy wherein EV owners would be charged for leaving their vehicles parked at a charging station after the charging process had been completed. See, e.g., https://medium.com/@loic/elon-musk-turns-a-tweet-into-reality-in-6-days-6189cf795a41#46d65918b (last visited Feb. 14, 2017). Shortly thereafter, Tesla implemented a new feature in their EVs that allows owners to see how many spaces are available at a given charging station. This is further evidence that availability of public charging equipment for EVs is an ongoing concern. See, e.g., http://www.theverge.com/2017/2/8/14554948/tesla-supercharger-free-spots-parking (last visited Feb. 14, 2017).

A survey of electric vehicle owners was conducted by the inventor, and the results are provided in FIGS. 4-14. Among other things, the results demonstrate that range anxiety remains a significant unmet need for electric vehicle owners. See FIGS. 8-12. Furthermore, the results of the survey indicate that a majority of electric vehicle owners are concerned that publicly
available charging stations would be unavailable for use upon their arrival. See FIGS. 8-10. As such, there is an unmet need in the electric vehicle space for charging systems that can alleviate range anxiety and alleviate the concern that public charging facilities will not be available when they are needed by EV drivers. The present invention addresses these and other needs by providing a charging system that can be used at home or at work by plugging it into a standard 110-120V AC outlet. Furthermore, the present invention optionally includes alternative power inputs that can be used if and when standard electric power sources are unavailable or are insufficient to achieve a desired charge level.

[0078] Charging equipment for EVs is available in three different levels. Level 1 charging refers to a U.S. standard 110-120V AC charging outlet. Level 1 charging is slow, typically requiring about 1 hour of charging time to replenish about 4.5 miles of vehicle range. Level 2 charging refers to a 240V power supply that can charge an EV slightly faster than a level 1 charging station. Level 2 charging typically requires about 1 hour of charging time to replenish about 70 miles of vehicle range. Finally, level 3 (or "DC fast charging") can replenish about 40 miles of vehicle range in about 10 minutes.

[0079] Publicly available charging stations provide either level 2 or level 3 charging equipment because of the desire to quickly replenish the entire energy storage capacity of an EV's on-board battery, or to "top off" the storage capacity of an EV's on-board battery and bring it back to full charge. At present, there are no EV charging solutions that combine a stand-alone battery module (one that is separate from the EV's on-board battery module) and an AC power input that provides slower charging capability. This is because of the desire by EV manufacturers to quickly recharge an EV's on-board battery using DC fast charging to minimize the amount of time required. Furthermore, there are no EV charging solutions that include a battery module (one that is separate from the EV's on-board battery module) that only provides a partial range for an electric vehicle (e.g., 10% to 50% of the range of the EV's on-board battery module). To the contrary, prevailing wisdom in the EV space is that DC fast charging is most desirable, and a battery module having a capacity of 10% to 50% of the EV's on-board battery range would not be useful or desired by consumers.

[0080] However, as provided in FIG. 13, the results of the survey conducted by the inventor are contrary to this thinking, and indicate that there is consumer demand for a system with a battery module that can provide a range of 10% to 50% of the vehicle's on-board battery range while traveling inside the EV's mileage range. The present invention addresses this and other needs by
providing charging systems with a battery module that is capable of being charged by level 1 charging equipment, thereby providing the EV owner with a battery module that can be used in situations where public charging equipment is unavailable.

[0081] Additionally, battery recharging suffers from a scientific drawback, which is the fact that the final 20% of a rechargeable battery's capacity is slower to charge than the first 80%. Due to this phenomenon, EV infrastructure providers advertise that they can recharge 80% of an EV's on-board battery capacity in about half an hour at a level 3 charging station, but omit information relating to the amount of time required to charge the final 20% of the on-board battery's capacity. See, e.g., http://www.latimes.com/business/autos/la-fi-hy-agenda-ev-charging-20160920-snap-story.html (last visited Feb. 14, 2017). As such, EV owners need well over half an hour at a level 3 charging station to fully recharge, or else are left with only an 80% charge in the EV's on-board battery.

[0082] The present invention addresses this issue by supplying additional energy storage capacity that can be utilized as needed, for example, in situations where a full 100% recharge of an EV's on-board battery is not available. When an EV owner is only able to secure an 80% recharge of the EV's on-board battery, the present charging system can be utilized to supply some or all of the missing 20%. Furthermore, the subject charging system can be used to supply power to one or more auxiliary electrical components of the EV, thereby reducing the rate at which power from the EV's on-board battery is consumed, and enabling further vehicle range from the on-board battery due to reduced power consumption.

[0083] While the present invention has been described with reference to the specific embodiments thereof, it should be understood by those skilled in the art that various changes may be made and equivalents may be substituted without departing from the true spirit and scope of the invention. In addition, many modifications may be made to adapt to a particular situation, material, composition of matter, process, process step or steps, to the objective, spirit and scope of the present invention. All such modifications are intended to be within the scope of the claims appended hereto.
What is claimed is:

1. A charging system for an electric vehicle, the charging system comprising:
   a battery module;
   a power input component;
   a power output component; and
   at least one AC/DC power converter configured to convert AC power to DC power.

2. The charging system according to claim 1, further comprising a DC to DC power converter.

3. The charging system according to claim 2, wherein the DC to DC power converter comprises a step-up DC to DC power converter.

4. The charging system according to claim 2, wherein the DC to DC power converter comprises a step-down DC to DC power converter.

5. The charging system according to claim 1, wherein the AC/DC power converter is a bi-directional AC/DC power converter that is configured to convert AC power to DC power, and to convert DC power to AC power.

6. The charging system according to claim 1, wherein the battery module comprises one or more individual batteries, and is configured to operably connect each of the one or more individual batteries to the charging system.

7. The charging system according to claim 1, wherein the battery module has an energy storage capacity that ranges from 10% to 50% of the energy storage capacity of an on-board battery of the electric vehicle.

8. The charging system according to claim 1, wherein the charging system is a portable, hand-held charging system.
9. The charging system according to claim 1, further comprising an alternative energy power input component.

10. The charging system according to claim 9, wherein the alternative energy power input component comprises a solar power generation component.

11. The charging system according to claim 10, wherein the solar power generation system comprises one or more solar panels.

12. The charging system according to claim 9, wherein the alternative energy power input component comprises a wind power generation component.

13. The charging system according to claim 9, wherein the alternative energy power input component comprises a manual power generation component.

14. The charging system according to claim 13, wherein the manual power generation component comprises a hand crank.

15. The charging system according to claim 9, wherein the alternative energy power input component comprises a fuel cell component.

16. The charging system according to claim 1, further comprising an internal temperature sensor.

17. The charging system according to claim 1, further comprising a tilt sensor.

18. The charging system according to claim 1, further comprising a motion sensor.

19. The charging system according to claim 1, further comprising a light sensor.

20. The charging system according to claim 1, further comprising an external temperature sensor.
21. The charging system according to claim 1, further comprising a charge controller.

22. The charging system according to claim 1, further comprising a power flow sensor.

23. The charging system according to claim 1, further comprising a power conversion circuit.

24. The charging system according to claim 1, further comprising a wireless communication component.

25. The charging system according to claim 24, wherein the charging system is configured for remote operation.

26. The charging system according to claim 1, further comprising an external indicator component.

27. The charging system according to claim 1, further comprising a moisture sensor.

28. The charging system according to claim 1, wherein the charging system is configured for load sharing.

29. The charging system according to claim 1, further comprising an input selector.

30. The charging system according to claim 1, further comprising an output selector.

31. The charging system according to claim 1, further comprising an AC power outlet.

32. The charging system according to claim 1, further comprising a housing.

33. The charging system according to claim 1, further comprising at least one electrical cord.
34. A method for charging an on-board battery of an electric vehicle, the method comprising:
   connecting an AC power source to an electric vehicle charging system, wherein the electric vehicle charging system comprises:
   a battery module;
   a power input component;
   a power output component; and
   at least one AC/DC power converter configured to convert AC power to DC power;
   converting AC power from the AC power source into DC power using the AC/DC converter;
   transferring the DC power to the battery module to charge the battery module;
   connecting the battery module to the on-board battery of the electric vehicle; and
   transferring DC power from the battery module of the electric vehicle charging system to the on-board battery of the electric vehicle to charge the on-board battery of the electric vehicle.

35. A method for providing power to an electric vehicle, the method comprising:
   connecting an AC power source to an electric vehicle charging system, wherein the electric vehicle charging system comprises:
   a battery module;
   a power input component;
   a power output component; and
   at least one AC/DC power converter configured to convert AC power to DC power;
   converting AC power from the AC power source into DC power using the AC/DC converter;
   transferring the DC power to the battery module to charge the battery module;
   connecting the battery module to the electric vehicle; and
   transferring DC power from the battery module of the electric vehicle charging system to the electric vehicle to power the electric vehicle.
36. A method for charging an on-board battery of an electric vehicle, the method comprising:

   connecting a DC power source to an electric vehicle charging system, wherein the electric vehicle charging system comprises:
   
   a battery module;
   
   a power input component;
   
   a power output component; and
   
   at least one AC/DC power converter configured to convert AC power to DC power;

   transferring the DC power to the battery module to charge the battery module;

   connecting the battery module to the on-board battery of the electric vehicle; and

   transferring DC power from the battery module of the electric vehicle charging system to the on-board battery of the electric vehicle to charge the on-board battery of the electric vehicle.

37. A method for providing power to one or more auxiliary electrical components of an electric vehicle, the method comprising:

   connecting a DC power output of a system according to claim 1 to one or more auxiliary electrical components of the electric vehicle; and

   transferring DC power from the battery module of the electric vehicle charging system to the auxiliary electrical component of the electric vehicle.
On average how many miles do you drive on your electric vehicle daily?

- 51 or more miles
- 21 to 50 miles
- 11 to 20 miles
- 0 to 10 miles
Do you charge your electric vehicle at public charging stations? (i.e. at a local grocery store or shopping area. NOT including charging at work)
In an average month, how many times do you arrive at a public charging station and have to wait more than 30 minutes until the station is available for use? (NOT including charging at work)
How long do you typically charge your vehicle at a public charging station?

- 30 minutes or less
- 1 hour or less
- 2 hours or less
- 2 hours or more
FIG. 8

If you were to locate a public charging station that you were not familiar with, on a scale of 0 to 10, how concerned would you be that the public charging station would be unavailable for use upon your arrival?

Average = 7
When traveling outside your vehicle's mileage range, how concerned are you about locating a public charging station that would be available for use?

Average = 8
When traveling within your vehicle's mileage range, how concerned are you about locating public charging stations that are available for use?

Average = 5
When traveling outside my vehicle’s mileage range, I am primarily concerned with:

- Being able to locate and use a charging station where I can restore 100% of the mileage range of the vehicle (bring the vehicle up to full charge).

- Being able to locate and use a charging station where I can restore 10-50% of the mileage range of the vehicle (partially recharge the vehicle).
When traveling inside my vehicle's mileage range, I am primarily concerned with:

- Being able to locate and use a charging station where I can restore 100% of the mileage range of the vehicle (bring the vehicle up to full charge).
- Being able to locate and use a charging station where I can restore 10-50% of the mileage range of the vehicle (partially recharge the vehicle).
Imagine there was a portable charging device. You could carry it with you, wherever you go. You could store energy in it via a standard household 110v outlet. It would store a partial charge of 10 to 50% of your electric vehicle’s range. On a scale of 0 to 10, how likely is it that you would purchase this item to charge your electric vehicle?

Average = 7
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) ... Box 1450, Alexandria, Virginia 22313-1450
Facsimile No. 571-273-8300
Form PCT/ISA/210 (second sheet) (January 2015)

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
See Search History Document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
See Search History Document

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
See Search History Document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
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Further documents are listed in the continuation of Box C.

* Special categories of cited documents:
  "A" document defining the general state of the art which is not considered to be of particular relevance
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  "O" document referring to an oral disclosure, use, exhibition or other means
  "P" document published prior to the international filing date but later than the priority date claimed

Date of the actual completion of the international search
11 April 2017

Date of mailing of the international search report
05 MAY 2017

Name and mailing address of the ISA/US
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