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(54) **INTEGRATED ISOLATION SWITCH OPERATION FOR AC AND DC CHARGING**

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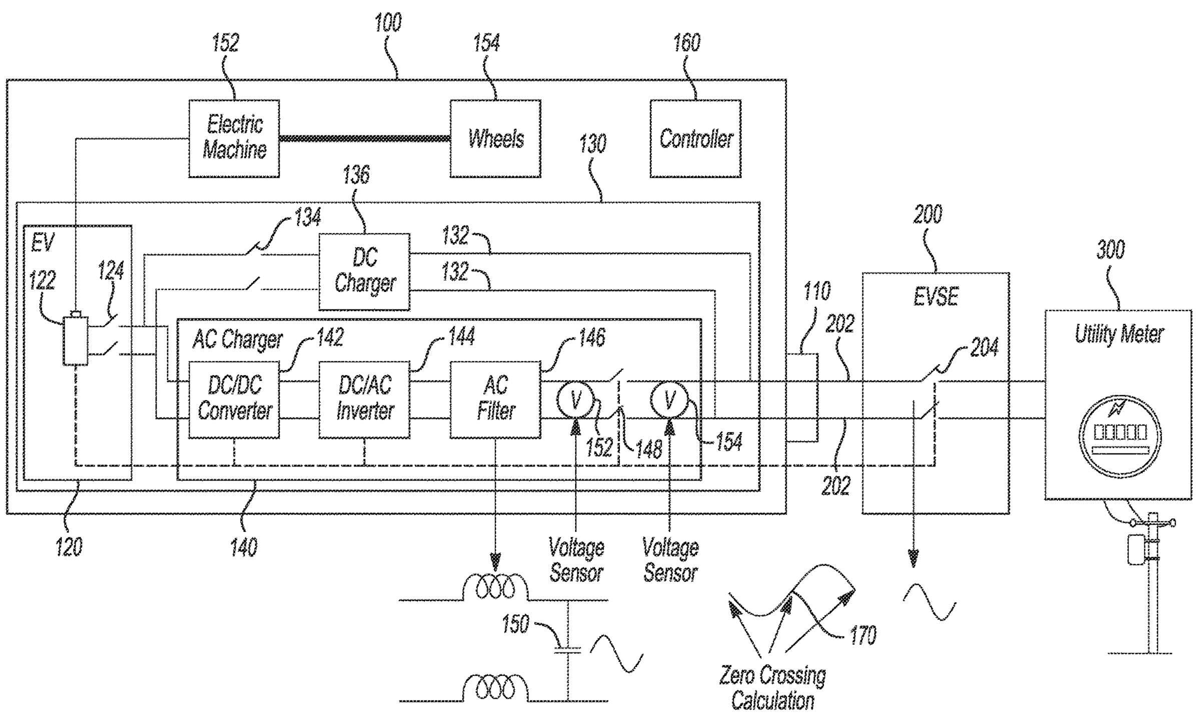
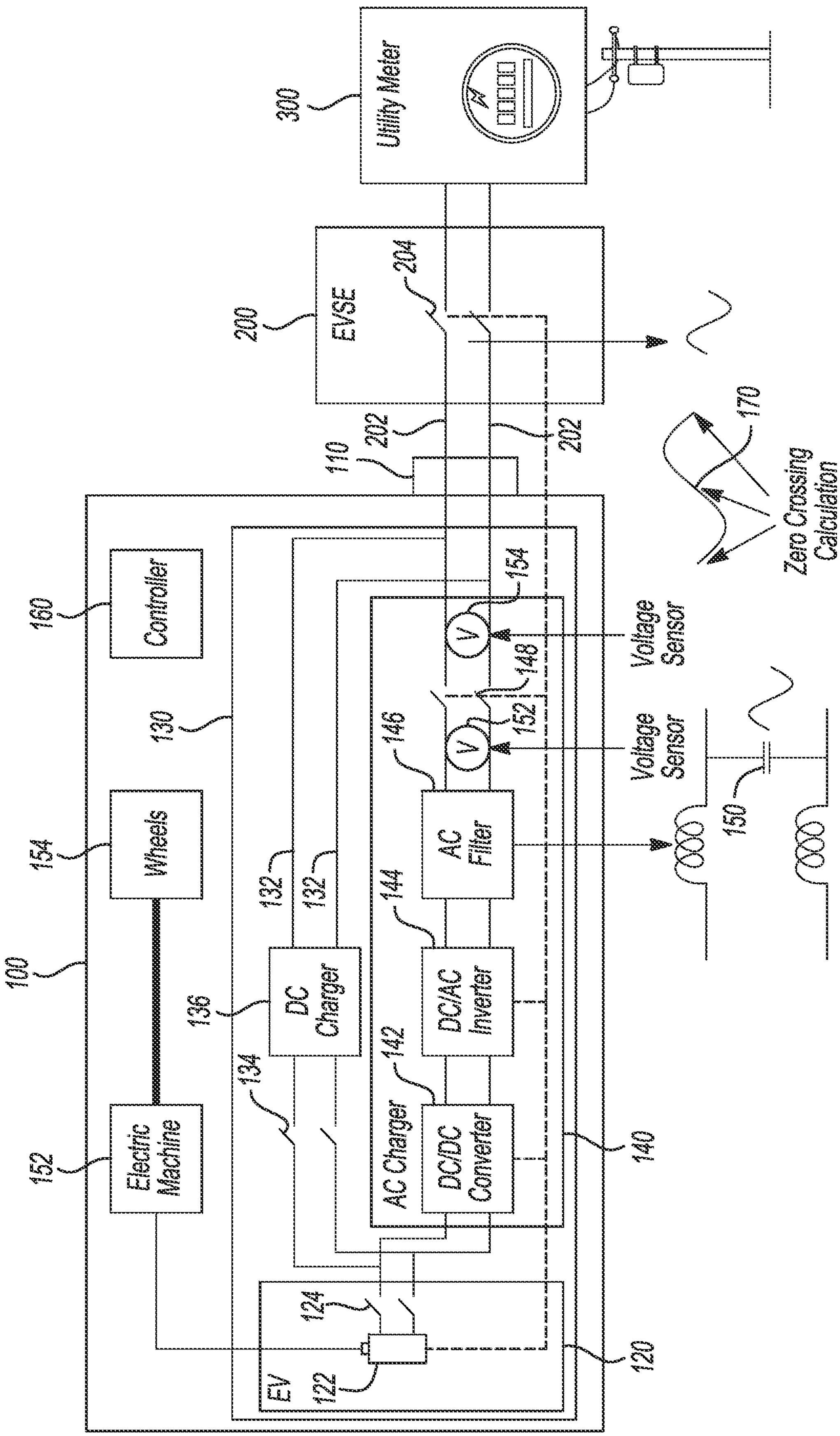
(57) **ABSTRACT**

A switch may be added to an AC charge path of an EV charge system. A controller may operate the switch and other switches. The controller may direct a traction battery to pre-charge a capacitor of an AC filter in the AC charge path before connecting the AC charge path between the traction battery and a power source. In embodiments including voltage sensing, the controller may track the power source voltage and command a voltage of the AC charge path to follow the power source voltage before connecting the AC charge path between the traction battery and the power source. After pre-charging, the controller may track the power source voltage and command the AC charge path connect between the traction battery and the power source at a zero-crossing of the voltage of power source.





300
Utility Meter
200
EVSE
204
202
202
110
170
Zero Crossing Calculation
100
160
Controller
154
Wheels
152
Electric Machine
130
132
132
136
DC Charger
134
142
AC Charger
DC/DC Converter
144
DC/AC Inverter
146
AC Filter
V
V
154
148
152
Voltage Sensor
Voltage Sensor
150
140
120
124
122
EV


Fig-1

# INTEGRATED ISOLATION SWITCH OPERATION FOR AC AND DC CHARGING

## TECHNICAL FIELD

**[0001]** This disclosure relates to automotive battery charging systems.

## BACKGROUND

**[0002]** The North American Charging Standard ("NACS") is being standardized as SAE J3400. To implement this standard within certain current vehicles, an on-board charger may need to be capable of withstanding 1000V DC potential when DC charging from an external power source.

## SUMMARY

**[0003]** A vehicle may include a charge port, a traction battery system including a traction battery and an isolating switch, a charging system including a DC charge path, connected between the charge port and isolating switch, including a DC enabling switch and a DC/DC charger and an AC charge path, connected between the charge port and isolating switch, including a DC/DC converter, a DC/AC inverter, an AC filter including a capacitor, and an AC enabling switch connected between the charge port and AC filter, and a controller programmed to, after the charge port is physically connected with a charge cord that is associated with a power source and before an electrical connection between the traction battery and power source is established, control at least some of the isolating, DC enabling, and AC enabling switches to permit pre-charging of the capacitor.

**[0004]** A method may include, responsive to data from at least one voltage sensor associated with an AC enabling switch of an AC charge path between a traction battery and charge port indicating a voltage across the AC enabling switch has remained unchanged after commanding the AC enabling switch to open while an isolating switch between the traction battery and AC charge path and a switch of a charge cord connected with the charge port remain closed, preclude DC charging of the traction battery with power supplied via the charge cord, and, responsive to the data indicating the voltage has reduced after the commanding, permit DC charging of the traction battery via a DC charge path that does not include the AC enabling switch.

**[0005]** An automotive charge system may include a DC charge path, connected between a charge port and an isolating switch of a traction battery system, including a DC enabling switch and a DC/DC charger, an AC charge path, connected between the charge port and isolating switch, including a DC/DC converter, a DC/AC inverter, an AC filter, an AC enabling switch connected between the AC filter and charge port, and a pair of voltage sensors connected such that the AC enabling switch is between the voltage sensors, and a controller programmed to command a closing of the AC enabling switch based on data from the voltage sensors such that the closing coincides with a zero crossing of voltage from a power source connected with the charge port.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0006]** FIG. **1** shows a schematic diagram of a vehicle charging arrangement.

## DETAILED DESCRIPTION

**[0007]** Embodiments are described herein. It is to be understood, however, that the disclosed embodiments are merely examples and other embodiments may take various and alternative forms. The figures are not necessarily to scale. Some features could be exaggerated or minimized to show details of particular components. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a representative basis for teaching one skilled in the art.

**[0008]** Various features illustrated and described with reference to any one of the figures may be combined with features illustrated in one or more other figures to produce embodiments that are not explicitly illustrated or described. The combinations of features illustrated provide representative embodiments for typical applications. Various combinations and modifications of the features consistent with the teachings of this disclosure, however, could be desired for particular applications or implementations.

**[0009]** Rather than redesigning components of an AC charge path of a present EV charging system to withstand high voltages of NACS operation, adding a switch that isolates the AC charge path from a separate charge path used when charging from an external power source may allow quicker adoption of NACS into present EV designs. Including the switch in present EV designs may present challenges. For example, components in the AC charge path may require pre-charging. For another example, a weld check of the switch may be required. Further, an improper weld may disable the specific EV's ability to accept a DC charge from an external power source. For yet another example, a power from the specific EV may require synchronization to power of a power source when connecting the specific EV to the power source to create an electrical connection between the traction battery and the power source. The electrical connection may allow the specific EV to supply power to the power source.

**[0010]** FIG. **1** shows a schematic diagram of an embodiment of a vehicle charge arrangement. A vehicle **100** may include a charge port **110**. The vehicle **100** may also include a traction battery system **120**. The traction battery system **120** may include a traction battery **122** and an isolating switch **124**. Between the traction battery system **120** and the charging port **110**, the vehicle **100** may include a charging system **130**. The charging system **130** may include multiple charging paths from the charging port **110** to the traction battery system **120**. One of the multiple charging paths of the charging system **130** may include a DC charge path **132**. Another of the multiple charging paths of the charging system **130** may include an AC charge path **140**. The DC charge path may include a DC/DC charger **136**, and a DC enabling switch **134**. The AC charge path **140** may include a DC/DC converter **142**, a DC/AC inverter **144**, an AC filter **146**, and an AC enabling switch **148**. The AC filter **146** may include a capacitor **150**. At least one of the vehicle **100** or the charging system **130** may also include a controller **160**.

**[0011]** The vehicle **100** may interface with an electric vehicle supply equipment **200**. The electric vehicle supply equipment **200** may connect to the vehicle **100** at the charge port **110** with a charge cord **202**. The electric vehicle supply equipment **200** may include a switch of the charge cord **204**. The switch of the charge cord **204** may be located within the electric vehicle supply equipment **200**, at a plug that interfaces with the charge port **110** of the vehicle **100**, or anywhere between the plug and the electric vehicle supply equipment **200** such as on the charge cord **202**. The electric vehicle supply equipment **200** may receive a power from a power source **300**. The power source **300** may provide a power to the electric vehicle supply equipment **200**, and the electric vehicle supply equipment **200** may charge the vehicle **100** using the power from the power source **300** when at least the switch **204** of the charge cord **202** is closed. Alternatively, the traction battery **122** may supply power to the power source **300** through the electric vehicle supply equipment **200** when at least the switch **204** of the charge cord **202** is closed. By these connections, the power source **300** may be considered associated with the electric vehicle supply equipment **200**, the charge cord **202**, and the switch of the charge cord **204**. The power source **300** may include a grid or other energy resource.

**[0012]** The controller **160** of the vehicle **100** may be programmed to selectively operate any subset of the isolating switch **124**, the DC enabling switch **134**, the AC enabling switch **148**, and the switch **204** of the charge cord **202** (together, "the switches **124**, **134**, **148**, **204**"). For many reasons, the controller **160** may be programmed to make the switches **124**, **134**, **148**, **204** assume a certain configuration responsive to a physical connection from the electric vehicle supply equipment **200** to the charge port **110** of the vehicle **100** before a power from the electric vehicle supply equipment **200** is provided to the vehicle **100** through the charge cord **202** or before a power from the vehicle **100** is provided to the power source **300** through the electric vehicle supply equipment **200**.

**[0013]** For example, the controller **160**, after sensing that the charge cord **202** has been physically connected to the charge port **110**, may close the isolating switch **124** and the DC enabling switch **134** and open the AC enabling switch **148** before requesting the electric vehicle supply equipment **200** close the switch **204** of the charge cord **202** to provide power to the vehicle **100**. By the controller **160** making the switches **124**, **134**, **148**, **204** assume the configuration described, the AC charge path **140** may be protected from a high-voltage power from the electric vehicle supply equipment **200** without inhibiting the DC charge path **132** from directing the high-voltage power to the traction battery system **120** to charge the traction battery **122**. Because of this configuration, components of the AC charge path **140** may not need to be rated to withstand the high-voltage power that will pass to the traction battery **122** through the DC charge path **132**.

**[0014]** For another example, the controller **160**, after sensing that the charge cord **202** has been physically connected to the charge port **110**, may close the isolating switch **124** and open the DC enabling switch **134** and the AC enabling switch **148**. This configuration may be present momentarily before closing the DC enabling switch **134** to assume the configuration previously described or before closing the AC enabling switch **148** to electrically connect the traction battery **122** and the charge port **110** over the AC charge path **140**. By leaving both the DC enabling switch **134** and AC enabling switch **148** momentarily open, power from the traction battery **122** may charge the capacitor **150** of the AC filter **146** of the AC charge path **140**. The pre-charging power may come from another energy source in the vehicle **100**, such as an auxiliary battery, etc. Because the capacitor **150** will have been pre-charged before the DC enabling switch **134** and the switch **204** of the charge cord **202** close to provide power to the vehicle **100**, the capacitor **150** of the AC filter **148** may experience less inrush current, which may be beneficial to the capacitor **150** or reduce the likelihood of arcing at one of the switches **124**, **134**, **148**, **204**. This pre-charging process may occur after the charge port **110** is physically connected with the charge cord **202** but before an electrical connection between the traction battery **122** and the power source **300** is established by the controller **160** controlling at least one of the switches **124**, **134**, **148**, **204**.

**[0015]** The previous example may be considered a method step including after the charge port **110** is physically connected with the charge cord **202** and before an electrical connection between the traction battery **122** and a power source **300** associated with the charge cord **202** is established, pre-charging a capacitor **150** of an AC filter **146** of the AC charge path **140**.

**[0016]** In some embodiments, a voltage sensor **152** may be located on the AC charge path **140** between the AC filter **146** and the AC enabling switch **148**. In some embodiments, another voltage sensor **154** may be located between the AC enabling switch **148** and the charge port **110**. That is, some embodiments may include only a single sensor, while other embodiments may include multiple sensors. The controller **160** may receive a signal from the voltage sensor **152** or the another voltage sensor **154** and may be programmed to respond in some way to that signal.

**[0017]** For example, at a certain time when the vehicle **100** is connected to the electric vehicle supply equipment **200**, the controller **160** may receive a first signal corresponding to a voltage from the voltage sensor **152** while the isolating switch **124**, the switch **204** of the charge cord **202**, and the AC enabling switch **148** are closed. At a subsequent time, the controller **160** may open the AC enabling switch **148** then receive a second signal from the voltage sensor **152**. The controller **160** may compare the first signal and the second signal. If the second signal shows a voltage drop caused by opening the AC enabling switch **148** occurred after the first signal, then the AC enabling switch **148** is working appropriately. If the second signal corresponds to about the same voltage as the first signal, then the AC enabling switch **148** may have malfunctioned or may include an improper weld. In the condition suggesting an appropriately working vehicle **100**, the controller **160** may permit or command at least one of the vehicle **100** or the electric vehicle supply equipment **200** to initiate a DC charge mode using the DC charge path **132**. Permitting or commanding may be directed to one or more of the switches **124**, **134**, **148**, **204**. In the condition suggesting a malfunction or improper weld of the AC enabling switch **148**, the controller **160** may restrict or preclude at least one of the vehicle **100** or the electric vehicle supply equipment **200** from initiating a DC charge mode. Restricting or precluding may be directed to of one or more of the switches **124**, **134**, **148**, **204**. Restricting or precluding may include the controller **160** transmitting or storing record of the restriction or signaling an error condition to the user. This example may be implemented with only the voltage sensor **152**.

**[0018]** The previous example may be considered a method that includes responsive to data from at least one the voltage sensors **152**, **154** associated with the AC enabling switch **148** of the AC charge path **140** between the traction battery **122** and charge port **110** indicating a voltage across the AC enabling switch **148** has remained unchanged after commanding the AC enabling switch **148** to open while the isolating switch **124** between the traction battery **122** and AC charge path **140** and the switch **204** of the charge cord **202** connected with the charge port **110** remains closed, preclude DC charging of the traction battery **122** with power supplied via the charge cord **202**; and responsive to the data indicating the voltage has reduced after the commanding, permit DC charging of the traction battery **122** via a DC charge path **132** that does not include the AC enabling switch **148**.

**[0019]** For another example, at a certain time when the vehicle **100** is physically connected to the electric vehicle supply equipment **200**, the controller **160** may receive a first signal corresponding to a voltage of the electric vehicle supply equipment **200** by the another voltage sensor **154**. The controller **160** may pre-charge the capacitor **150** as previously described. The controller **160** may then direct the DC/AC inverter **144** of the AC charge path **140** to follow the voltage corresponding to the first signal using known techniques. The first signal may include an amplitude and phase angle information. After the controller **160** directs the DC/AC inverter **144** to follow the voltage corresponding to the first signal, the difference between a battery-side voltage (between the AC enabling switch **148** and the traction battery system **120**) and a charger-side voltage (between the AC enabling switch **148** and the charge port **110**) may be reduced below a threshold value. The controller **160** may then close the AC enabling switch **148**. In some embodiments, the controller **160** may continue to receive signals from the voltage sensor **152** and the another voltage sensor **154** before closing the AC enabling switch **148** responsive to confirming from the signals that the battery-side and charger-side voltages are approximately equal.

**[0020]** The previous example may be considered a method step including commanding the DC/AC inverter **144** of the AC charge path **140** to follow a voltage from the power source **300** based on data from the at least one voltage sensor **152**, **154**.

**[0021]** For another example, at a certain time when the vehicle **100** is physically connected to the electric vehicle supply equipment **200**, the controller **160** may receive a signal corresponding to a voltage of the electric vehicle supply equipment **200** by the another voltage sensor **154**. The controller **160** may close the AC enabling switch **148** at a time coinciding with a zero crossing **170** of voltage from the electric vehicle supply equipment **200**. Considering an AC signal, the zero crossing **170** occurs when a voltage with respect to a ground changes from positive to negative or negative to positive.

**[0022]** The previous example may be considered a method step including commanding a closing of the AC enabling switch **148** based on data from the at least one voltage sensor **152**, **154** such that the closing coincides with the zero crossing **170** of voltage from the power source **300** associated with the charge cord **202**.

**[0023]** The algorithms, methods, or processes disclosed herein can be deliverable to or implemented by a computer, controller, or processing device, which can include any dedicated electronic control unit or programmable electronic control unit. Similarly, the algorithms, methods, or processes can be stored as data and instructions executable by a computer or controller in many forms including, but not limited to, information permanently stored on non-writable storage media such as read only memory devices and information alterably stored on writeable storage media such as compact discs, random access memory devices, or other magnetic and optical media. The algorithms, methods, or processes can also be implemented in software executable objects. Alternatively, the algorithms, methods, or processes can be embodied in whole or in part using suitable hardware components, such as application specific integrated circuits, field-programmable gate arrays, state machines, or other hardware components or devices, or a combination of firmware, hardware, and software components.

**[0024]** While exemplary embodiments are described above, it is not intended that these embodiments describe all possible forms encompassed by the claims. Other topologies and variations are, of course, contemplated.

**[0025]** The words used in the specification are words of description rather than limitation, and it is understood that various changes may be made without departing from the spirit and scope of these disclosed materials. The terms "controller" and "controllers," for example, can be used interchangeably herein as the functionality of a controller can be distributed across several controllers/modules, which may all communicate via standard techniques.

**[0026]** As previously described, the features of various embodiments may be combined to form further embodiments of the invention that may not be explicitly described or illustrated. While various embodiments could have been described as providing advantages or being preferred over other embodiments or prior art implementations with respect to one or more desired characteristics, those of ordinary skill in the art recognize that one or more features or characteristics may be compromised to achieve desired overall system attributes, which depend on the specific application and implementation. These attributes may include, but are not limited to strength, durability, marketability, appearance, packaging, size, serviceability, weight, manufacturability, ease of assembly, etc. As such, embodiments described as less desirable than other embodiments or prior art implementations with respect to one or more characteristics are not outside the scope of the disclosure and may be desirable for particular applications.

What is claimed is:

**1**. A vehicle comprising:

a charge port;

a traction battery system including a traction battery and an isolating switch;

a charging system including (i) a DC charge path, connected between the charge port and isolating switch, including a DC enabling switch and a DC/DC charger and (ii) an AC charge path, connected between the charge port and isolating switch, including a DC/DC converter, a DC/AC inverter, an AC filter including a capacitor, and an AC enabling switch connected between the charge port and AC filter; and

a controller programmed to, after the charge port is physically connected with a charge cord that is associated with a power source and before an electrical connection between the traction battery and power source is established, control at least some of the isolating, DC enabling, and AC enabling switches to permit pre-charging of the capacitor.

**2**. The vehicle of claim **1**, wherein energy for the pre-charging is from the traction battery.

**3**. The vehicle of claim **1** further comprising a voltage sensor connected between the AC filter and AC enabling switch.

**4**. The vehicle of claim **3**, wherein the controller is further programmed to, responsive to a voltage detected by the voltage sensor remaining same after commanding the AC enabling switch to open while the isolating switch and a switch of the charge cord are closed, preclude DC charging of the traction battery via the DC charge path.

**5**. The vehicle of claim **3** further comprising another voltage sensor connected between the charge port and AC enabling switch.

**6**. The vehicle of claim **5**, wherein the controller is further programmed to command the DC/AC inverter to follow a voltage from the power source based on data from the another voltage sensor.

**7**. The vehicle of claim **5**, wherein the controller is further programmed command a closing of the AC enabling switch based on data from the voltage sensors such that the closing coincides with a zero crossing of voltage from the power source.

**8**. The vehicle of claim **1**, wherein the controller is further programmed to, after the pre-charging, control at least some of the isolating, DC enabling, and AC enabling switches to establish an electrical connection between the traction battery and power source.

**9**. A method comprising:

responsive to data from at least one voltage sensor associated with an AC enabling switch of an AC charge path between a traction battery and charge port indicating a voltage across the AC enabling switch has remained unchanged after commanding the AC enabling switch to open while an isolating switch between the traction battery and AC charge path and a switch of a charge cord connected with the charge port remain closed, preclude DC charging of the traction battery with power supplied via the charge cord; and

responsive to the data indicating the voltage has reduced after the commanding, permit DC charging of the traction battery via a DC charge path that does not include the AC enabling switch.

**10**. The method of claim **9** further comprising, after the charge port is physically connected with the charge cord and before an electrical connection between the traction battery and a power source associated with the charge cord is established, pre-charging a capacitor of an AC filter of the AC charge path.

**11**. The method of claim **10** further comprising commanding a DC/AC inverter of the AC charge path to follow a voltage from the power source based on the data.

**12**. The method of claim **9** further comprising commanding a closing of the AC enabling switch based on the data such that the closing coincides with a zero crossing of voltage from a power source associated with the charge cord.

**13**. An automotive charge system comprising:

a DC charge path, connected between a charge port and an isolating switch of a traction battery system, including a DC enabling switch and a DC/DC charger;

an AC charge path, connected between the charge port and isolating switch, including a DC/DC converter, a DC/AC inverter, an AC filter, an AC enabling switch connected between the AC filter and charge port, and a pair of voltage sensors connected such that the AC enabling switch is between the voltage sensors; and

a controller programmed to command a closing of the AC enabling switch based on data from the voltage sensors such that the closing coincides with a zero crossing of voltage from a power source connected with the charge port.

**14**. The automotive charge system of claim **13**, wherein the controller is further programmed to, after the charge port is physically connected with a charge cord that is associated with the power source and before an electrical connection between a traction battery of the traction battery system and power source is established, control at least some of the isolating, DC enabling, and AC enabling switches to permit pre-charging of a capacitor of the AC filter.

**15**. The automotive charge system of claim **14**, wherein energy for the pre-charging is from the traction battery.

**16**. The automotive charge system of claim **13**, wherein the controller is further programmed to, responsive to the data indicating a voltage across the AC enabling switch remains same after commanding the AC enabling switch to open while the isolating switch and a switch of a charge cord connected with the charge port are closed, preclude DC charging of the traction battery via the DC charge path.

**17**. The automotive charge system of claim **13**, wherein the controller is further programmed to command the DC/AC inverter to follow a voltage from the power source based on the data.

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