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(54) Title of the Invention: **Apparatus and method for wirelessly charging batteries**
Abstract Title: **Vehicle charging apparatus having a deployable wireless charging pad**

(57) A vehicle (e.g. EV, BEV, PEV, PHEV) charging apparatus 300 has a wireless charge receiving pad (charging pad 110) with an electrically conductive coil 301. The charging pad is attached to a first arm 117A, which is pivotally attached to a supporting structure 107 of the vehicle about a first axis. When the batteries of the vehicle are to be charged, the first arm pivots about the first axis and the charging pad is swung through an arc between a stowed position and a deployed position. A positioning means 305 (e.g. electric motor 306) causes the first arm to pivot about the first axis to move the charging pad between the deployed and stowed positions. The charging pad is pivotally mounted on the first arm and a mechanical linkage (e.g. second arm 117B) maintains the charging pad in a horizontal orientation, parallel to a transmission coil: in the stowed position; in the deployed position; and when the charging pad is moved through a range of different deployed positions. A control means may measure an electric signal induced in the charging pad for each one of a plurality of different deployed positions, or positions of the first arm. The charging pad is moved to the position corresponding to the largest measured electric signal.

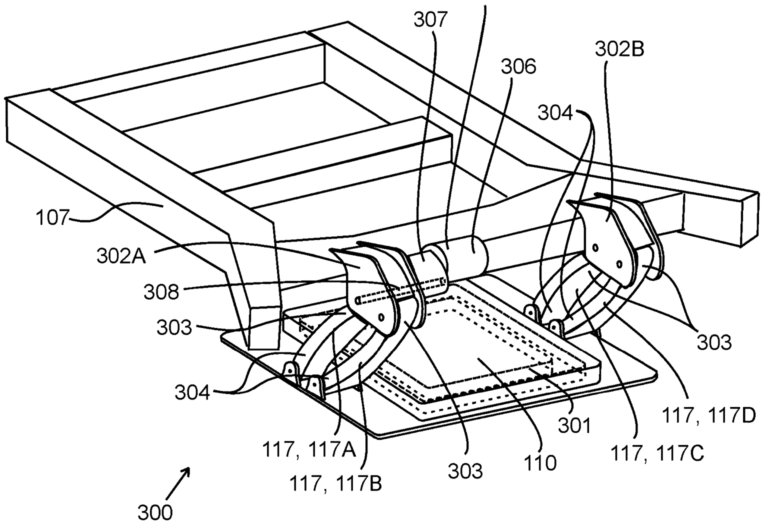

Fig. 3

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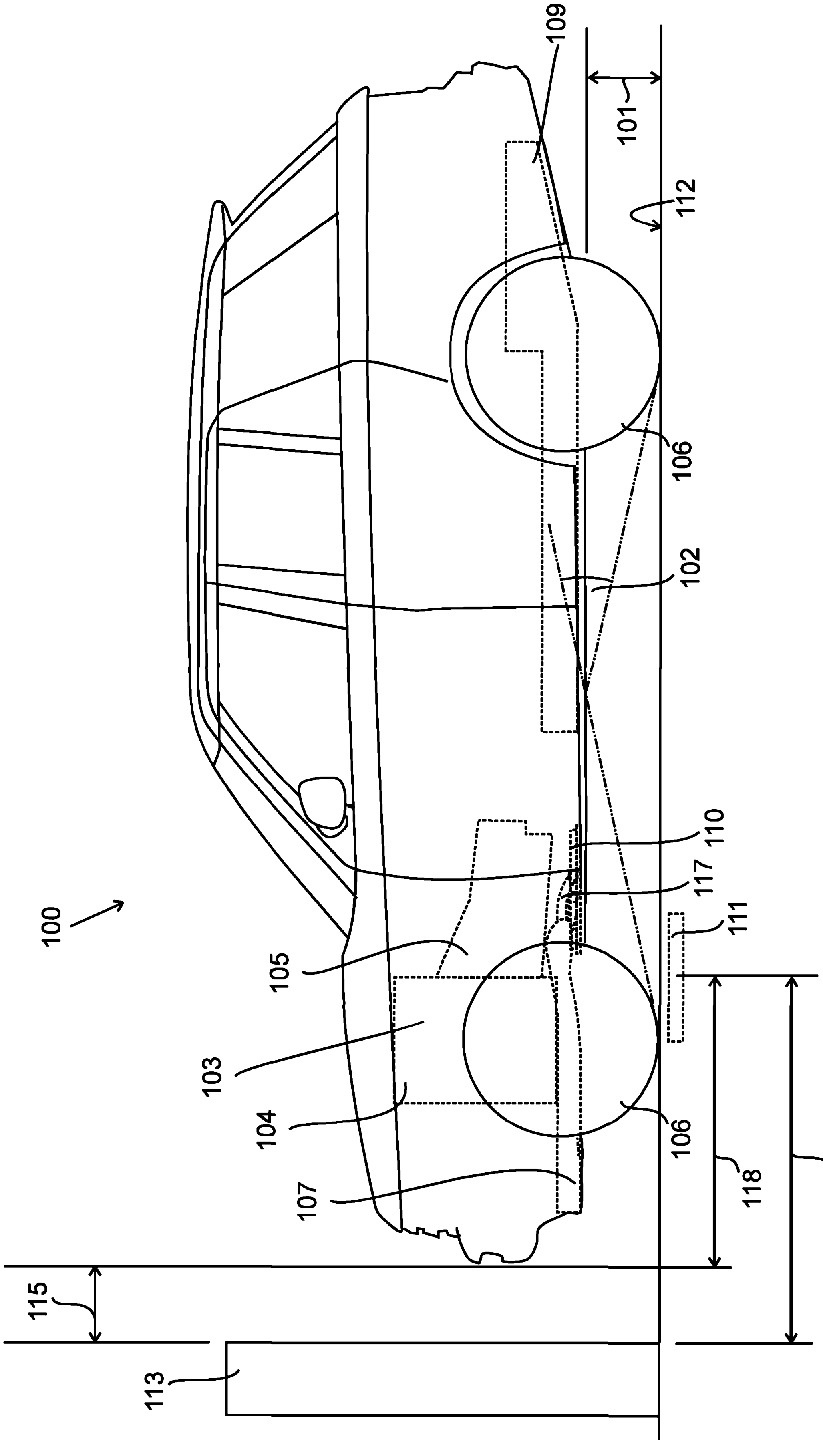
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Fig. 1

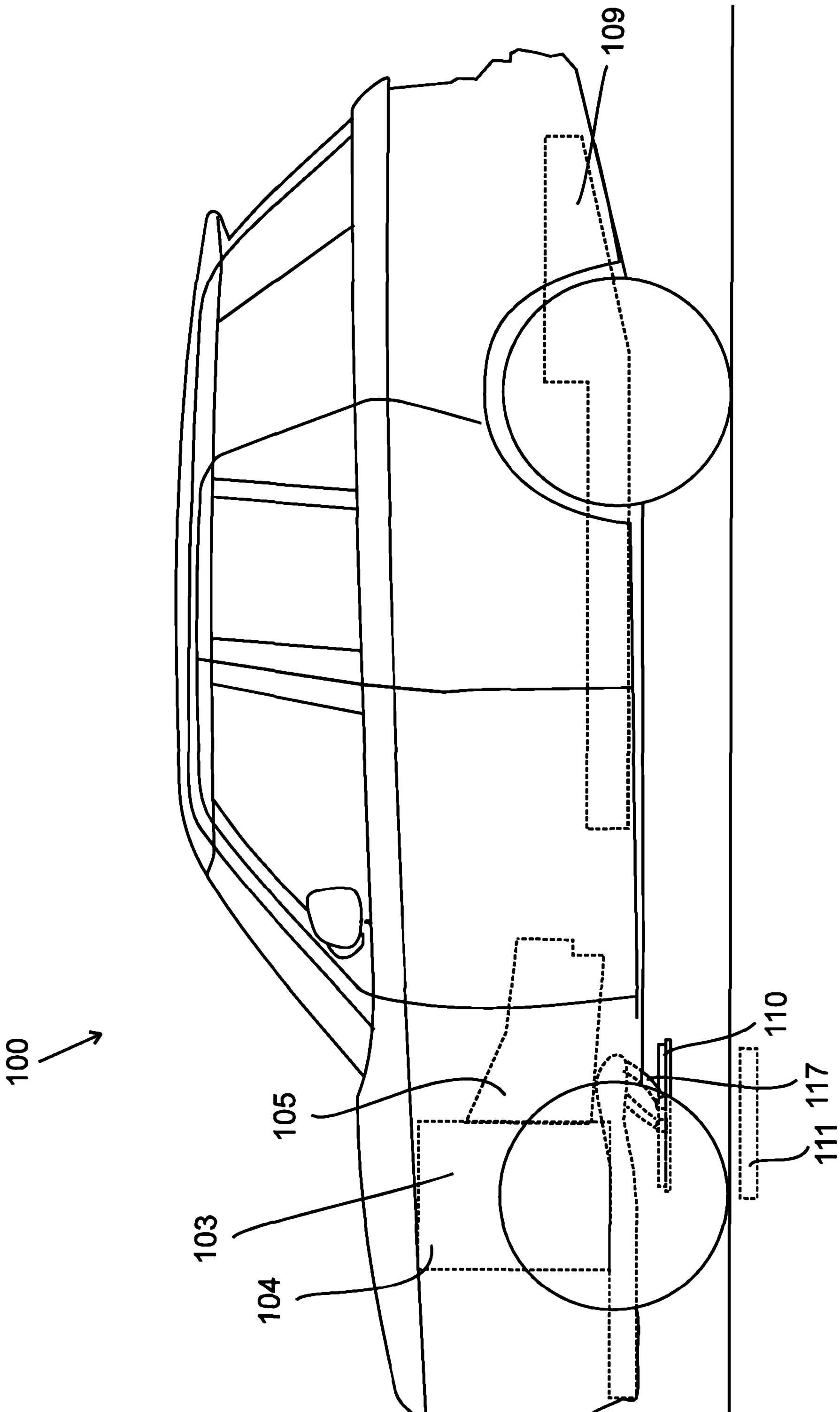


Fig. 2

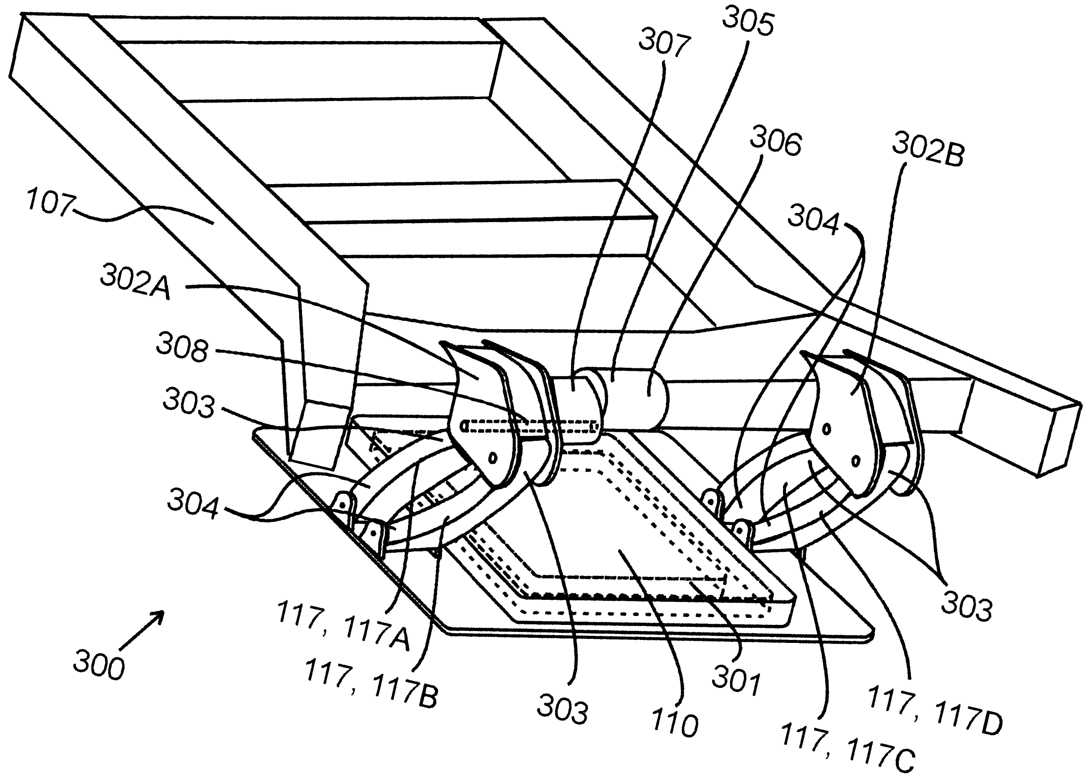

305
307
306
302B
107
304
302A
308
303
304
303
300
117, 117A
117, 117B
303
110
301
117, 117C
117, 117D

Fig. 3

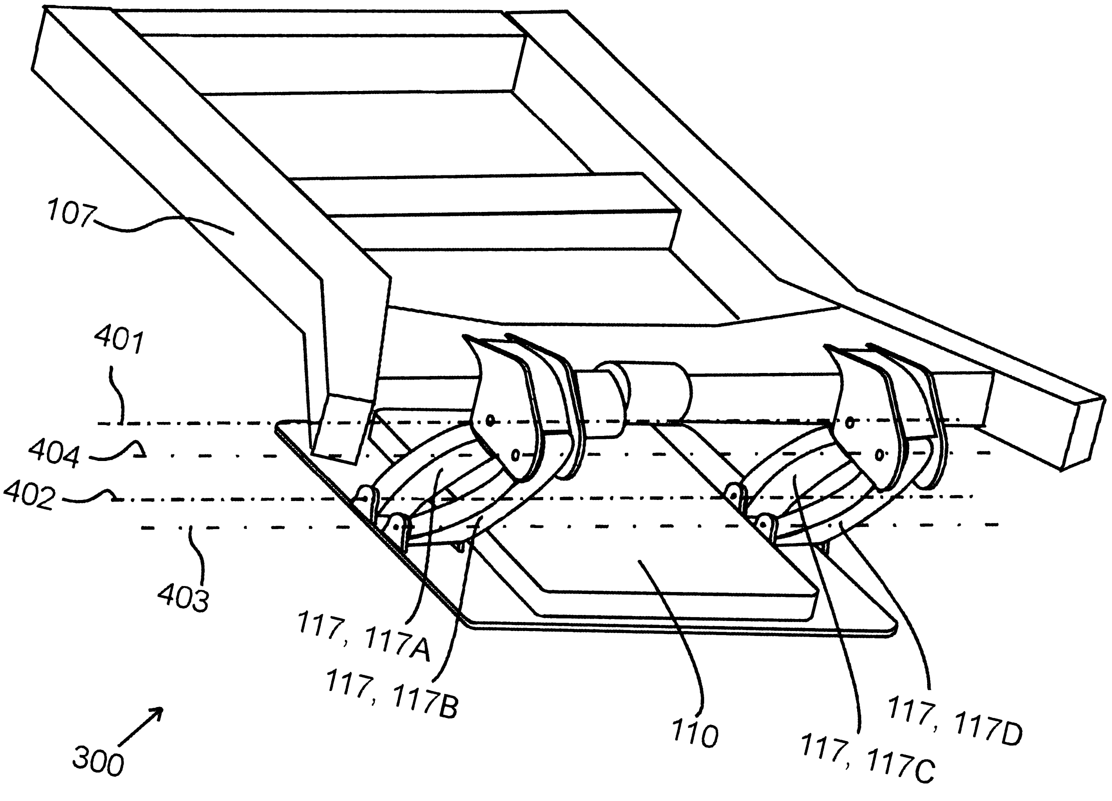


Fig. 4

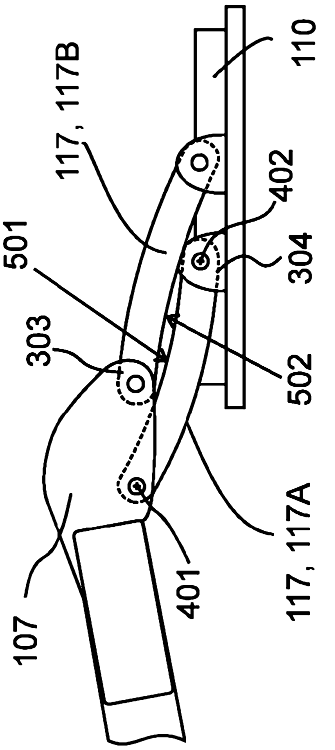


Fig. 5

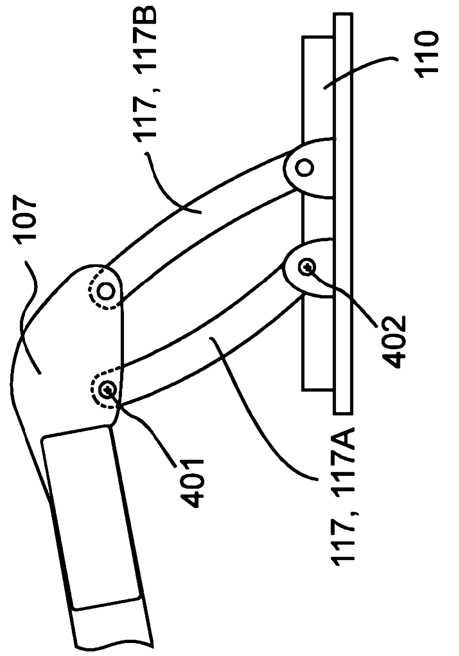


Fig. 6

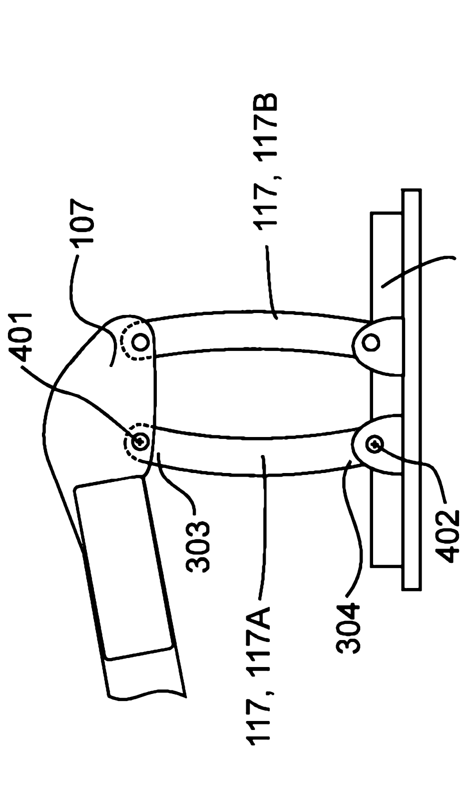


Fig. 7

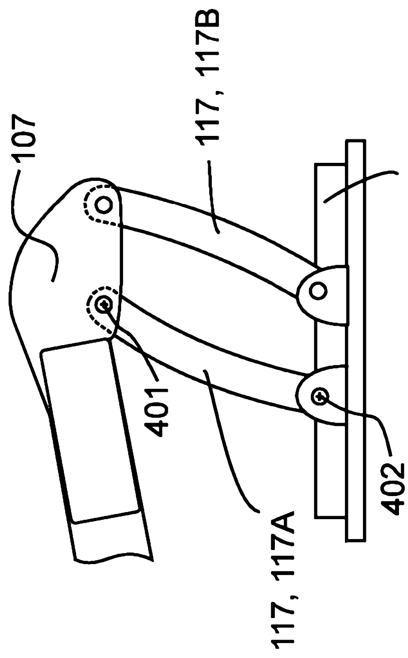
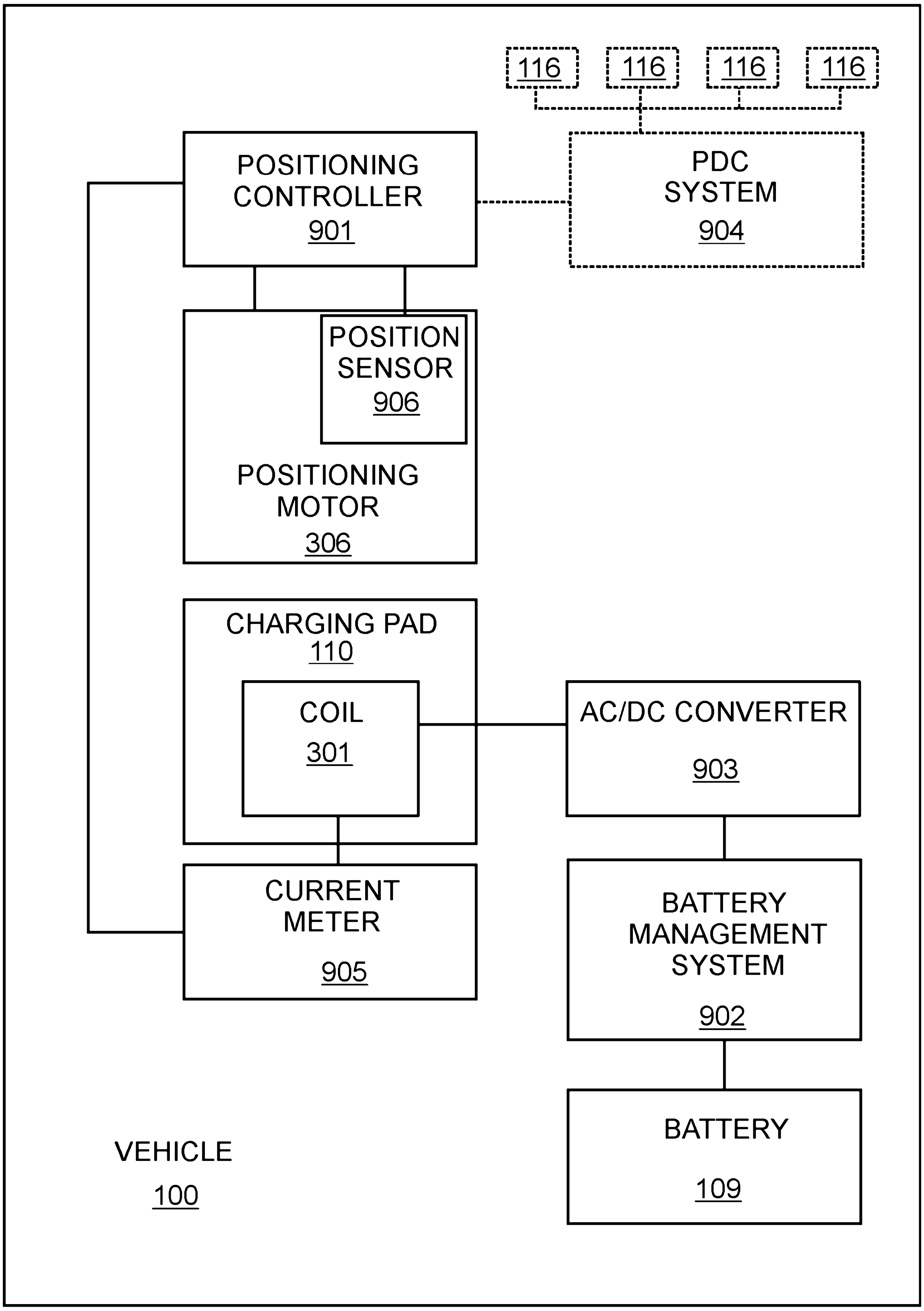


Fig. 8


116
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POSITIONING CONTROLLER 901
PDC SYSTEM 904
POSITION SENSOR 906
POSITIONING MOTOR 306
CHARGING PAD 110
COIL 301
AC/DC CONVERTER 903
CURRENT METER 905
BATTERY MANAGEMENT SYSTEM 902
BATTERY 109
VEHICLE 100

Fig. 9

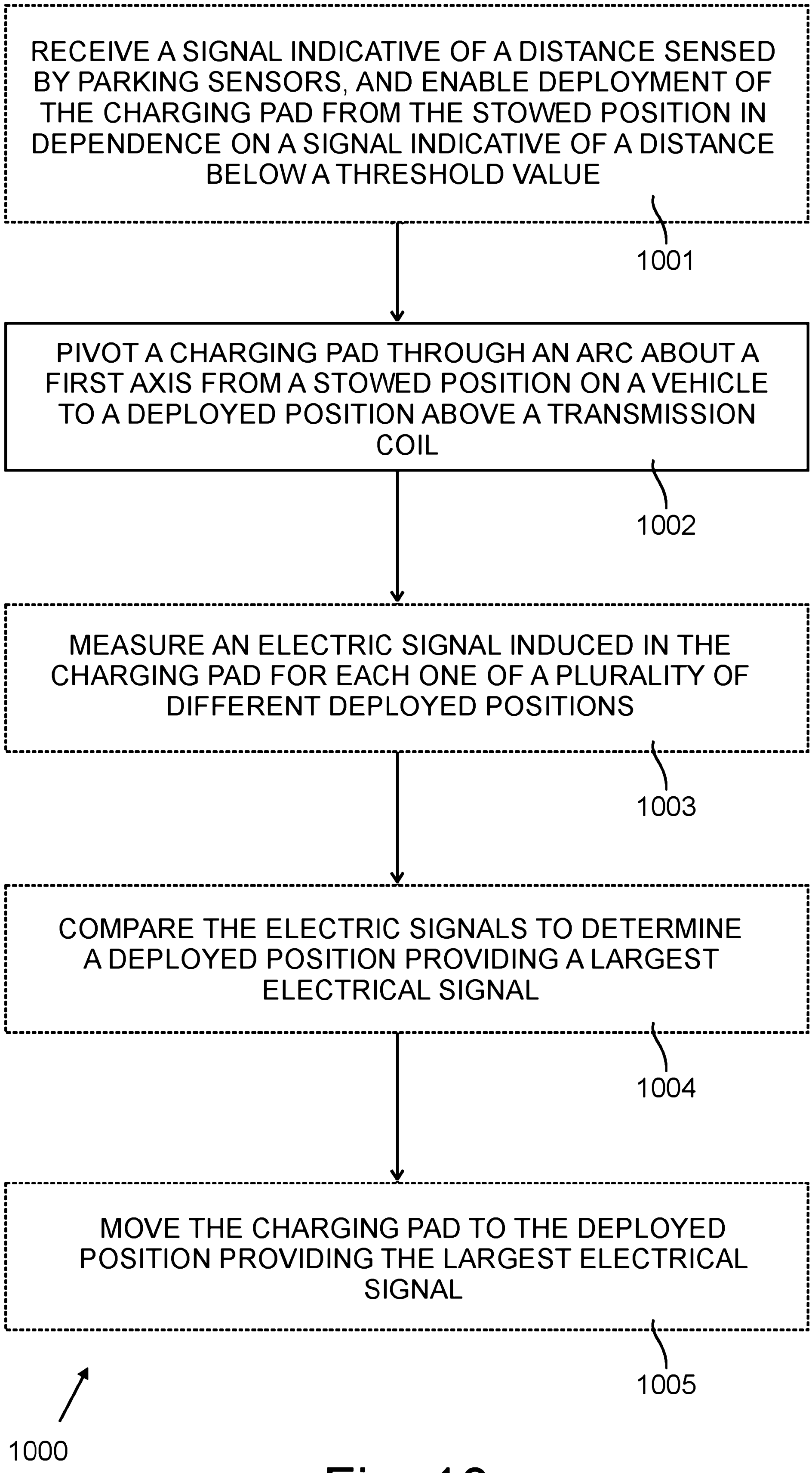
RECEIVE A SIGNAL INDICATIVE OF A DISTANCE SENSED BY PARKING SENSORS, AND ENABLE DEPLOYMENT OF THE CHARGING PAD FROM THE STOWED POSITION IN DEPENDENCE ON A SIGNAL INDICATIVE OF A DISTANCE BELOW A THRESHOLD VALUE
1001
PIVOT A CHARGING PAD THROUGH AN ARC ABOUT A FIRST AXIS FROM A STOWED POSITION ON A VEHICLE TO A DEPLOYED POSITION ABOVE A TRANSMISSION COIL
1002
MEASURE AN ELECTRIC SIGNAL INDUCED IN THE CHARGING PAD FOR EACH ONE OF A PLURALITY OF DIFFERENT DEPLOYED POSITIONS
1003
COMPARE THE ELECTRIC SIGNALS TO DETERMINE A DEPLOYED POSITION PROVIDING A LARGEST ELECTRICAL SIGNAL
1004
MOVE THE CHARGING PAD TO THE DEPLOYED POSITION PROVIDING THE LARGEST ELECTRICAL SIGNAL
1005
1000

Fig. 10

APPARATUS AND METHOD FOR WIRELESSLY CHARGING BATTERIES

TECHNICAL FIELD

The present disclosure relates to an apparatus for wirelessly charging batteries, a vehicle and a method. In particular, but not exclusively it relates to apparatus for wirelessly charging batteries of a vehicle such as a road vehicle.

Aspects of the invention relate to an apparatus, a vehicle and a method.

BACKGROUND

Inductive wireless charging of batteries in electric vehicles has been proposed in which a transmitting coil is positioned on or below ground level and a receiving coil is positioned on the underside of a vehicle. The efficiency and rate of charging of batteries depends upon the proximity of the receiving coil to the transmitting coil and the alignment of the two coils. The optimum position of a parked vehicle over a transmitting coil at a fixed position cannot always be achieved by a driver of a vehicle. It is known to have a positioning mechanism for positioning the receiving coil longitudinally and transversely along the underside of a vehicle. One problem with such a positioning mechanism is its complexity. Another problem is that the receiving coil must be positioned at a relatively low height, in order to provide the desired proximity to the transmitting coil, and therefore it may reduce the ground clearance of the vehicle to which it is fitted.

It is an aim of the present invention to address the disadvantages of the prior art.

SUMMARY OF THE INVENTION

Aspects and embodiments of the invention provide an apparatus, a vehicle and a method as claimed in the appended claims.

According to an aspect of the invention there is provided an apparatus for wirelessly charging batteries of a vehicle, the apparatus comprising: a charging pad comprising an electrically conductive coil; a supporting structure of the vehicle; and a first arm attached to the charging pad and pivotally attached to the supporting structure to enable the first arm to pivot about a first axis with respect to the supporting structure to move the charging pad along an arc between a stowed position and a deployed position for charging the batteries.

This provides the advantage that the height of the charging pad may be lowered from the stowed position to a deployed position and the position of the charging pad along the vehicle may be adjusted to improve alignment of the coil of the charging pad with a transmission coil using the same pivot mechanism.

In some embodiments the apparatus comprises a positioning means configured to cause the first arm to pivot about the first axis to move the charging pad between the deployed position and the stowed position.

In some embodiments the positioning means comprises an electric motor.

In some embodiments the charging pad is pivotally mounted on the first arm to enable the charging pad to pivot about a second axis relative to the first arm, and the second axis is parallel to the first axis. This provides the advantage that it enables the orientation of the charging pad to be adjusted as required when being deployed and/or when being stowed.

In some embodiments the apparatus comprises orientation means configured to orient the charging pad about the second axis.

In some embodiments the orientation means is configured to orient the charging pad in a first orientation with respect to horizontal in the stowed position and orient the charging pad in the first orientation with respect to horizontal in the deployed position. This provides the advantage that the charging pad may be, for example, stowed in a horizontal orientation when stowed and when deployed.

In some embodiments the orientation means is configured to orient the charging pad in the first orientation with respect to horizontal in a range of different deployed positions. This provides the advantage that the charging pad may be moved through a range of deployed positions to optimize alignment with a transmission coil, while maintaining the charging pad in an orientation that is parallel to the transmission coil.

In some embodiments the orientation means comprises a mechanical linkage between the support structure and the charging pad for maintaining the charging pad in the first orientation.

In some embodiments the apparatus comprises a second arm; the charging pad is pivotally mounted on the second arm to enable the charging pad to pivot about a third axis relative to the second arm; and the second arm is pivotally attached to the support structure to pivot about a fourth axis. This provides the advantage of a simple mechanical linkage between the support structure and the charging pad for maintaining the charging pad in the first orientation.

In some embodiments the apparatus comprises a third arm pivotally connected to the charging pad on the second axis and pivotally connected to the support structure on the first axis. This provides the advantage of improved stability of the orientation of the charging pad.

In some embodiments the apparatus comprises a fourth arm pivotally connected to the charging pad on the third axis and pivotally connected to the support structure on the fourth axis. This provides the advantage of improved stability of the orientation of the charging pad.

In some embodiments the positioning means is configured to pivot the first arm to position the charging pad in a range of different deployed positions. This provides the advantage of enabling the position of charging pad to be adjusted to optimize its alignment to a transmission coil.

In some embodiments the apparatus comprises a control means configured to: measure an electric signal induced in the charging pad for each one of a plurality of different deployed positions; compare the electric signals to determine a deployed position providing a largest electrical signal; and cause the positioning means to move the charging pad to the deployed position providing the largest electrical signal. This provides the advantage that the rate of charging of the batteries may be increased to reduce the time required to charge them.

In some embodiments the apparatus comprises a control means configured to: measure an electric signal induced in the charging pad for each one of a plurality of different positions of the first arm; compare the electric signals to determine one of the different positions of the first arm providing a largest electrical signal; and cause the positioning means to move the first arm to the one of the different positions providing the largest electrical signal. This provides the advantage that the rate of charging of the batteries may be increased to reduce the time required to charge them.

In some embodiments the control means is configured to: receive a signal indicative of a distance sensed by parking sensors, and enable deployment of the charging pad from the stowed position in dependence on a signal indicative of a distance below a threshold value. This provides the advantage that the control means does not waste time trying to position the charging pad for charging the batteries when the vehicle is in a position where sufficient alignment of the charging pad and a transmission coil is not possible.

According to another aspect of the invention there is provided a vehicle comprising a powertrain and apparatus according to any one of the previous claims. The powertrain comprises vehicle components, which may include a source of motive power, such as an electric motor and/or internal combustion engine, associated transmission and drive shafts, but excludes vehicle wheels.

The apparatus provides the advantage that the height of the charging pad may be lowered from the stowed position on the vehicle to a deployed position and the position of the charging pad along the vehicle may be adjusted to improve alignment of the coil of the charging pad with a transmission coil using the same pivot mechanism.

In some embodiments the powertrain has a lowest point at a first height, the charging pad in the stowed position has a lowest point at a second height, and the second height is greater than or equal to the first height. This provides the advantage that the charging pad does not reduce the ground clearance of the vehicle.

In some embodiments the deployed position is forward of the stowed position and below the powertrain. This provides the advantage that the charging pad may be aligned with a transmission coil that is in a position directly beneath the powertrain.

According to another aspect of the invention there is provided a method of positioning a charging pad for wirelessly charging batteries of a vehicle, the method comprising pivoting a charging pad through an arc about a first axis from a stowed position on the vehicle to a deployed position above a transmission coil. This provides the advantage that the charging pad is moved from a stowed position to a deployed position by a single simple movement, requiring only a simple pivot mechanism.

In some embodiments the charging pad is mounted on a first arm; and the method comprises pivoting the first arm about the first axis to move the charging pad from the stowed position to the deployed position and pivoting the charging pad about a second axis relative to the first arm to orient the charging pad relative to horizontal. This provides the advantage that required orientation of the charging pad may be obtained while it is moved from a stowed position to a deployed position

In some embodiments the method comprises pivoting the first arm to position the charging pad in a range of different deployed positions. This provides the advantage that a position for the charging pad may be found to optimize mutual inductance between a coil of the charging pad and a transmission coil, and therefore optimize the rate of charging of the batteries.

In some embodiments the method comprises: measuring an electric signal induced in the charging pad for each one of a plurality of different deployed positions; comparing the electric signals to determine a deployed position providing a largest electrical signal; and causing a movement of the charging pad to the deployed position providing the largest electrical signal. This provides the advantage that the rate of charging of the batteries is optimized.

In some embodiments the method comprises pivoting the charging pad from the stowed position at the rear of a powertrain of the vehicle to the deployed position, which is forward of the stowed position and below the powertrain. This provides the advantage that batteries of the vehicle may be charged using a transmission coil that has a position directly underneath the powertrain, without requiring the charging pad to be positioned below the powertrain at other times, such as when the vehicle is being used. The stowed position may in some embodiments be rear of the source of motive power. In other embodiments the stowed position may be rear of the source of motive power and associated transmission.

Within the scope of this application it is expressly intended that the various aspects, embodiments, examples and alternatives set out in the preceding paragraphs, in the claims and/or in the following description and drawings, and in particular the individual features thereof, may be taken independently or in any combination. That is, all embodiments and/or features of any embodiment can be combined in any way and/or combination, unless such features are incompatible. The applicant reserves the right to change any originally filed claim or file any new claim accordingly, including the right to amend any originally filed claim to depend from and/or incorporate any feature of any other claim although not originally claimed in that manner.

BRIEF DESCRIPTION OF THE DRAWINGS

One or more embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Fig. 1 shows a vehicle embodying the present invention with a charging pad in a stowed position;

Fig. 2 shows the vehicle of Fig. 1 with the charging pad in a deployed position;

Figs. 3 and 4 show perspective views of an apparatus comprising the charging pad attached to a support structure of the vehicle by four arms;

Fig. 5 shows a side view of a portion of the support structure and the charging pad in a stowed position;

Figs. 6, 7 and 8 provide a similar view to Fig. 5 but with the charging pad in three different deployed positions;

Fig. 9 shows a schematic diagram illustrating electrical and electronic components of the vehicle relating to the operation of the apparatus of Fig. 3; and

Fig. 10 shows a flowchart of a method of positioning a charging pad for wirelessly charging batteries of a vehicle.

DETAILED DESCRIPTION

A vehicle 100 embodying the present invention is shown in Fig. 1. The vehicle 100 is a road vehicle and, in the present embodiment, the vehicle 100 is a car suitable for off-road driving, which has a relatively large ground clearance 101 and a relatively large break-over angle 102.

The vehicle 100 comprises a powertrain 103 including an electric motor 104 and a transmission 105 configured to provide torque to road wheels 106. The electric motor 104 is mounted above a supporting structure 107 which, in the present embodiment, is in the form of a sub-frame 107. The supporting structure 107 has a lower surface 108 that is at, or just above, a height defining the ground clearance 101 of the vehicle 100.

Electrical energy, for supply to the motor 104, is stored in one or more energy storage means, which may be batteries 109, which are discharged during use of the vehicle 100. The vehicle 100 includes a charging pad 110 comprising an electrically conductive coil 301 (shown in Fig. 3), which may be used for recharging the batteries 109 in a wireless charging process. During the charging process the coil of the charging pad 110 is inductively coupled to a transmission coil 111 to which an alternating current is supplied. Such a transmission coil 111 may be positioned at approximately ground level, or just below ground level, as illustrated in Fig. 1.

To maintain the ground clearance 101 of the vehicle 100, the charging pad 110 is positioned in a stowed position as shown in Fig. 1, to the rear of the supporting structure 107 and above the height of the ground clearance 101. Also, in the stowed position, the lowest part of the charging pad 110 may be arranged to be at a height that is at least as high as the lowest part of the powertrain 103.

To provide rapid and efficient charging of the batteries 109, there is a requirement for the coil 301 (shown in Fig. 3) of the charging pad 110 and the transmission coil 111 to be sufficiently aligned to each other and sufficiently close together.

The vehicle 100 is shown in Fig. 1 parked in a parking bay that has transmission coil 111 positioned just below ground level 112. The middle of the transmission coil 111 is a fixed distance (indicated by arrow 114) from a wall 113 positioned at the front of the parking bay. For example, the fixed distance may be a standardized distance, for example 1.5 metres that may be used for all parking bays.

The front of the vehicle 100 is positioned a short distance 115 from the front of the parking bay. For example, the vehicle 100 may have been positioned using a parking distance control (PDC) system comprising sensors 116 positioned along the front of the vehicle 100, or may have been positioned by a driver of the vehicle 100 using his or her own judgement of distance. Typically, the short distance 115 between the front of the vehicle 100 and the front of the parking bay is about 200mm and therefore the distance (indicated by arrow 118) from the front of the vehicle 100 to the middle of the transmission coil 111 is typically about 1.3 metres. As illustrated in Fig. 1, this results in the transmission coil 111 being positioned forward of the charging pad 110.

However, the charging pad 110 is mounted from the supporting structure 107 such that it is moveable into one or more deployed positions that enable rapid and efficient charging of the batteries 109. Specifically, the charging pad 110 is attached to one or more arms 117 that are pivotally attached to the supporting structure 107 to enable the one or more arms 117 to pivot about an axis with respect to the supporting structure 107 to move the charging pad 110 along an arc between the stowed position, as illustrated in Fig. 1, and a deployed position for charging the batteries 109, as illustrated in Fig. 2.

As illustrated in Fig. 2, the one or more arms 117 may be pivoted about the support structure 107 to move the charging pad 110 to a deployed position forward of the stowed position, lower than the stowed position, and below the powertrain 103. Thus, the alignment between the coil (301, shown in Fig. 3) of the charging pad 110 and the transmission coil 111 is improved and the vertical distance between the coil of the charging pad 110 and the transmission coil 111 is reduced when compared to the stowed position of Fig. 1.

Furthermore, by adjusting the position of the one or more arms 117, the longitudinal position of the charging pad 110 (i.e. the position of the charging pad 110 from the front of the vehicle 100) may be adjusted. Consequently, the longitudinal position of the charging pad 110 may be adjusted to compensate for variations in the parked position of the vehicle 100 relative to the transmission coil 111, in order to obtain an optimum coupling between the transmission coil 111 and the coil of the charging pad 110. i.e. if the vehicle 100 is parked too far back from the front of the parking bay, the charging pad 110 may be deployed to a more forward position relative to the support structure 107, whereas if the vehicle 100 is parked too close to the front of the parking bay, the charging pad 110 may be deployed to a more rearward position relative to the support structure 107.

Apparatus 300 comprising the charging pad 110 attached to the support structure 107 by four arms 117 is shown in the perspective views of Figs. 3 and 4. In the present embodiment, the coil 301 (shown in Fig. 3) of the charging pad 110 is located between a first set of arms comprising the arms 117A and 117B and a second set of the arms comprising the arms 117C and 117D.

A first end 303 of each of the first and second arms 117A and 117B is pivotally attached to a first mounting bracket 302A forming a part of the support structure 107 and a second end 304 of those arms 117A and 117B is pivotally attached to the charging pad 109. Similarly, a first end 303 of each of the third and fourth arms 117C and 117D is pivotally attached to a second mounting bracket 302B forming a part of the support structure 107 and a second end 304 of those arms 117C and 117D is pivotally attached to the charging pad 109.

As illustrated in Fig. 4, the first arm 117A and the third arm 117C are both arranged to pivot about a first axis 401 with respect to the support structure 107. The first axis 401 is substantially perpendicular to the lengths of the first arm 117A and the third arm 117C. The charging pad 110 is arranged to pivot about a second axis 402 with respect to the first arm 117A and the third arm 117C. Similarly, the charging pad 110 is arranged to pivot about a third axis 403 with respect to the second arm 117B and the fourth arm 117D, and the second arm 117B and the fourth arm 117D are both arranged to pivot about a fourth axis 404 with respect to the support structure 107. The four axes 401, 402, 403 and 404 are parallel to each other and, in the present embodiment, they extend laterally across the width of the vehicle 100.

In the present embodiment, the distance between the first axis and the second axis is equal to the distance between the third axis and the fourth axis, and the distance between the first axis and the fourth axis is equal to the distance between the third axis and the second axis. Consequently, the four axes 401, 402, 403 and 404 are positioned at the four corners of a parallelogram regardless of the position of the arms 117. As a result, the orientation of the charging pad 110 relative to horizontal is maintained when the arms 117 and the charging pad 110 are pivoted with respect to the support structure 107. Thus, the orientation of the charging pad 110 may be in a first orientation with respect to horizontal in the stowed position and in the same first orientation with respect to horizontal in the deployed position.

The apparatus 300 also comprises a positioning means 305 configured to cause the first arm 117A to pivot about the first axis 401 to move the charging pad 110 between deployed positions and the stowed position. In the present embodiment, the positioning means comprises an electric motor 306 configured to drive a driveshaft 308 via a gear mechanism 307. The first arm 117A is fixed to the driveshaft 308 so that the first arm 117A rotates with the driveshaft 308 when it is driven by the electric motor 306.

It should be understood that in alternative embodiments, the apparatus 300 may comprise just a single arm, like the first arm 117A of Figs. 3 and 4, that is supported by the support structure 107 and which supports the charging pad 110. For example, the single arm may be positioned at an edge of the charging pad 110, or along a centre-line of the charging pad 110. As in the embodiment of Figs. 3 and 4, the position of the single arm about the first axis 401 determines the position the charging pad 109. In the embodiment of Figs. 3 and 4, the second arm 117B provides a mechanical linkage between the support structure 107 and the charging pad 110, which provides an orientation means for orienting the charging pad 110 about the second axis 402. However, in an embodiment with just a single arm, alternative orientation means to the second arm 117B may provide required orientation(s) of the charging pad 110. For example, to maintain the orientation of the charging pad 109, a respective one of two parallel tethers of equal length, such as two chains, may be connected between the charging pad 110 and the support structure 107, behind and in front of the single arm. In a further alternative embodiment, a second motor is located at the lower end of the single arm and the second motor is arranged to adjust the orientation of the charging pad 110 with respect to the single arm. Thus, as the single arm is pivoted by the motor 306 about the first axis 401 with respect to the support structure 107, the second motor pivots the charging pad 110 to required orientations with respect to the single arm.

It should also be understood that in alternative embodiments the apparatus 300 may comprise just two arms, similar to the first and second arms 117A and 117B of the embodiment of Figs. 3 and 4. The two arms may be positioned at an edge of the charging pad 110, or on a centre-line of the charging pad 110. In the embodiment of Figs. 3 and 4, the second set of arms comprising arms 117C and 117D provide the charging pad 110 with increased stability of orientation about an axis extending along the length of the vehicle 110. However, in embodiments with just two arms, one or both of the two arms may be provided with increased width when compared to the arms 117 illustrated in Figs. 3 and 4, in order to provide such stability.

Stowage and deployment of the charging pad 110 is illustrated in Figs. 5, 6, 7 and 8. Fig. 5 shows a side view of a portion of the support structure 107 and the charging pad 110 in a stowed position and Figs. 6, 7 and 8 provide a similar view but with the charging pad 110 in three different deployed positions.

As illustrated in Fig. 5, the first arm 117A has a concave curved face 501 that faces the second arm 117B, and the second arm 117B has a concave curved face 502 that faces the first arm 117A. Consequently, when the charging pad 110 is in its stowed position, and the first and second arms 117A and 117B are brought close together, the curved face 501 of the first arm 117A curves away from the first end 303 of the second arm 117B and similarly the curved face 502 of the second arm 117B curves away from the second end 304 of the first arm 117A. This enables the first arm 117A and the second arm 117B, and therefore the charging pad 110, to be raised higher than they otherwise could be.

From the stowed position of Fig. 5, the first arm 117A may be pivoted downwards through a first deployment position shown in Fig. 6 to a second deployment position shown in Fig. 7 and through to a third deployment position shown in Fig. 8. The deployment position of Fig. 7 is such that the second axis 402 (which extends out of the page in Figs. 5 to 8) at the second end 304 of the first arm 117A is directly below the first axis 401 at the first end 303 of the first arm 117A. Consequently the charging pad 110 is at its lowest possible position relative to the support structure 107 when it is in the deployment position of Fig. 7.

In the example of Fig. 6, the first arm 117A is approximately 25 degrees from the orientation of Fig. 7 towards the rear of the vehicle 100 and in the example of Fig. 8 the first arm 117A is approximately 25 degrees from the orientation of Fig. 7 towards the front of the vehicle 100. Thus the longitudinal distance from the first deployment position to the third deployment position is more than 0.8 (i.e. 2 x sin 25º) times the distance between the first axis 401 and the second axis 402 of the first arm 117A. However, the maximum change in height of the charging pad 110, as it pivots from the first deployment position to the third deployment position, is less than 0.1 (i.e. 1 – cos 25º) of the distance between the first axis 401 and the second axis 402. It will therefore be appreciated that the longitudinal position of the charging pad 110 may be adjusted over a substantial distance without unduly affecting its height.

As illustrated in Figs. 5 to 8, the second arm 117B acts on the charging pad 110 to maintain its orientation with respect to horizontal in a range of different deployed positions as well as the stowed position.

A schematic diagram illustrating electrical and electronic components of the vehicle 100 relating to the operation of the apparatus 300 is shown in Fig. 9. As discussed above, the coil 301 of the charging pad 110 are moved between the stowed position (shown in Fig. 5) and deployed positions (such as those of Figs. 6 to 8) by the operation of the electric motor 306. The electric motor 306 operates under the control of a control means comprising a positioning controller 901. The positioning controller 901 may comprise an electronic control unit dedicated to the deployment and stowage of the charging pad 110. Alternatively, the positioning controller 901 may comprise a software module of an electronic control unit that has another function, such as a battery management system 902. The battery management system 902, amongst other things, may be arranged to control current supplied to the battery 109 from AC to DC conversion circuitry 903, which itself is arranged to receive electric current from the coil 301 of the charging pad 110.

In the present embodiment the positioning controller 901 is configured to receive signals from a position sensor 906, associated with the electric motor 306, which indicates the position of the charging pad 110. In the present embodiment the position sensor 906 comprises a Hall sensor.

The positioning controller 901 may be arranged to receive a signal from a parking distance control (PDC) system 904, which comprises parking sensors 116. The PDC system 904 may be configured to provide a signal indicating the distance of the vehicle 100 from a front of a parking bay or a signal indicating that said distance is below a threshold value. The positioning controller 901 may also be arranged to receive a signal from a current meter 905 that is configured to measure a current generated in the coil 301 and provide a signal indicative of the measured current to the positioning controller 901. The current meter 905 may be included within the battery management system 902. The purpose of the signals provided by the PDC system 904 and the current meter 905 to the positioning controller 901 will be explained below with reference to Fig. 10.

Fig. 10 is a flowchart of a method 1000 of positioning a charging pad 110 for wirelessly charging batteries 109 of a vehicle 100. The method 1000 comprises, at block 1002, pivoting a charging pad 110 through an arc about a first axis 401 from a stowed position on the vehicle 100 to a deployed position above a transmission coil 111. The process at block 1002 may be performed in response to a user input received at a user interface of the vehicle 100, or alternatively the positioning controller 901 may be configured to cause the charging pad 110 to be deployed in response to a signal from a sensing device indicating that the vehicle 100 is positioned in a parking bay that provides inductive charging. For example, the vehicle 100 may be provided with a satellite navigation system, such as a GPS (Global Positioning System), that includes co-ordinates for such parking bays. Alternatively, the parking bay may be provided with a wireless system for detecting the presence of a vehicle within the parking bay, for example by triangulation or trilateration, and providing a signal to the vehicle requesting the deployment of the charging pad. For example, the parking bay may include wireless LAN (local area network) based positioning technology (i.e. a Wi-Fi positioning system) configured to detect the position of a transceiver on the vehicle and request deployment of the charging pad when it is determined that the vehicle is within the parking bay. Alternatively, the presence of the vehicle within the parking bay may be determined by an RFID (radio frequency identification) real time locating system. For example, such a system may comprise ultra-wideband active RFID modules to provide accurate verification of the presence of the vehicle in the parking bay. The charging pad may then be automatically deployed in dependence on such verification.

Before the deployment of the charging pad 110 at block 1002, the method 1000 may comprise, at block 1001, enabling deployment in dependence on receiving a signal at the control means 901 indicating that a distance sensed by the parking sensors 116 is below a threshold value. Thus, if such a signal is received, the method 1000 proceeds to block 1002, and the charging pad 110 is deployed. Alternatively, if a driver fails to position the vehicle 100 far enough forward in a parking bay, resulting in such a signal not being received, then the deployment of the charging pad 110 is not enabled.

As discussed above with respect to Figs. 6 to 8, the charging pad 110 may be positioned within a range of deployment positions corresponding to different angles of the arm 117A. At block 1002, the charging pad 110 may be positioned at a preset position based on an assumption that the vehicle 100 will be in a particular position relative to the transmission coil 111. For example, the preset position may be based on the optimum position for the coil 301 of the charging pad 110 when the parking sensors at the front of the vehicle 100 are a particular distance, such as 200mm, from the front of the parking bay.

However, as shown in Fig. 10, the method 1000 may comprise blocks 1003, 1004 and 1005 to determine where to position the charging pad 110 in order to optimize the rate at which the battery 109 may be charged. At block 1003 an electrical signal induced in the coil 301 of the charging pad 110 is measured for each one of a plurality of different deployed positions of the charging pad 110. At block 1004, the electrical signals that were measured at block 1003 are compared, to determine a deployed position providing the largest electrical signal. Then at block 1005, the charging pad 110 is moved to the deployed position providing the largest electrical signal. The charging pad 110 is then held in this deployed position while charging of the battery 109 takes place.

In an example of the processes at blocks 1003 and 1004, the transmission coil 111 is initially arranged to transmit a relatively small signal for detection by the coil 301 of the charging pad 110. The positioning controller 901 is arranged to move the charging pad 110 in a first direction (i.e. forwards or backwards) through a series of different deployed positions, and obtain a signal from the current meter 905 indicative of the current measured in the coil 301 for each of the different deployed positions. During this process, the positioning controller 901 may compare each current measurement with the next current measurement, and when the next current measurement is less than the current measurement preceding it, the process at block 1004 ends. At block 1005, the charging pad 110 is then returned to the position that provided the largest current measurement.

For purposes of this disclosure, it is to be understood that the controller(s) described herein can each comprise a control unit or computational device having one or more electronic processors. A vehicle and/or a system thereof may comprise a single control unit or electronic controller or alternatively different functions of the controller(s) may be embodied in, or hosted in, different control units or controllers. A set of instructions could be provided which, when executed, cause said controller(s) or control unit(s) to implement the control techniques described herein (including the described method(s)). The set of instructions may be embedded in one or more electronic processors, or alternatively, the set of instructions could be provided as software to be executed by one or more electronic processor(s). For example, a first controller may be implemented in software run on one or more electronic processors, and one or more other controllers may also be implemented in software run on or more electronic processors, optionally the same one or more processors as the first controller. It will be appreciated, however, that other arrangements are also useful, and therefore, the present disclosure is not intended to be limited to any particular arrangement. In any event, the set of instructions described above may be embedded in a computer-readable storage medium (e.g., a non-transitory computer-readable storage medium) that may comprise any mechanism for storing information in a form readable by a machine or electronic processors/computational device, including, without limitation: a magnetic storage medium (e.g., floppy diskette); optical storage medium (e.g., CD-ROM); magneto optical storage medium; read only memory (ROM); random access memory (RAM); erasable programmable memory (e.g., EPROM ad EEPROM); flash memory; or electrical or other types of medium for storing such information/instructions.

The blocks illustrated in Fig. 10 may represent steps in a method and/or sections of code in the computer program. The illustration of a particular order to the blocks does not necessarily imply that there is a required or preferred order for the blocks and the order and arrangement of the block may be varied. Furthermore, it may be possible for some steps to be omitted.

Although embodiments of the present invention have been described in the preceding paragraphs with reference to various examples, it should be appreciated that modifications to the examples given can be made without departing from the scope of the invention as claimed.

Features described in the preceding description may be used in combinations other than the combinations explicitly described.

Although functions have been described with reference to certain features, those functions may be performable by other features whether described or not.

Although features have been described with reference to certain embodiments, those features may also be present in other embodiments whether described or not.

Whilst endeavoring in the foregoing specification to draw attention to those features of the invention believed to be of particular importance it should be understood that the Applicant claims protection in respect of any patentable feature or combination of features hereinbefore referred to and/or shown in the drawings whether or not particular emphasis has been placed thereon.

CLAIMS

1. Apparatus for wirelessly charging batteries of a vehicle, the apparatus comprising:

a charging pad comprising an electrically conductive coil;

a supporting structure of the vehicle; and

a first arm attached to the charging pad and pivotally attached to the supporting structure to enable the first arm to pivot about a first axis with respect to the supporting structure to move the charging pad along an arc between a stowed position and a deployed position for charging the batteries.

2. An apparatus according to claim 1, wherein the apparatus comprises a positioning means configured to cause the first arm to pivot about the first axis to move the charging pad between the deployed position and the stowed position.

3. An apparatus according to claim 2, wherein the positioning means comprises an electric motor.

4. An apparatus according to any one of claims 1 to 3, wherein the charging pad is pivotally mounted on the first arm to enable the charging pad to pivot about a second axis relative to the first arm, and the second axis is parallel to the first axis.

5. An apparatus according to any one of claims 1 to 4, wherein the apparatus comprises orientation means configured to orient the charging pad about the second axis.

6. An apparatus according to claim 5, wherein the orientation means is configured to orient the charging pad in a first orientation with respect to horizontal in the stowed position and orient the charging pad in the first orientation with respect to horizontal in the deployed position.

7. An apparatus according to claim 6, wherein the orientation means is configured to orient the charging pad in the first orientation with respect to horizontal in a range of different deployed positions.

8. An apparatus according to any one of claims 5 to 7, wherein the orientation means comprises a mechanical linkage between the support structure and the charging pad for maintaining the charging pad in the first orientation.

9. An apparatus according to any one of claims 5 to 8, wherein the apparatus comprises a second arm; the charging pad is pivotally mounted on the second arm to enable the charging pad to pivot about a third axis relative to the second arm; and the second arm is pivotally attached to the support structure to pivot about a fourth axis.

10. An apparatus according to claim 9, wherein the apparatus comprises a third arm pivotally connected to the charging pad on the second axis and pivotally connected to the support structure on the first axis.

11. An apparatus according to claim 10, wherein the apparatus comprises a fourth arm pivotally connected to the charging pad on the third axis and pivotally connected to the support structure on the fourth axis.

12. An apparatus according to any one of claims 1 to 11, wherein the positioning means is configured to pivot the first arm to position the charging pad in a range of different deployed positions.

13. An apparatus according to claim 12, wherein the apparatus comprises a control means configured to: measure an electric signal induced in the charging pad for each one of a plurality of different deployed positions; compare the electric signals to determine a deployed position providing a largest electrical signal; and cause the positioning means to move the charging pad to the deployed position providing the largest electrical signal.

14. An apparatus according to claim 12, wherein the apparatus comprises a control means configured to: measure an electric signal induced in the charging pad for each one of a plurality of different positions of the first arm; compare the electric signals to determine one of the different positions of the first arm providing a largest electrical signal; and cause the positioning means to move the first arm to the one of the different positions providing the largest electrical signal.

15. An apparatus according to claim 13 or claim 14, wherein the control means is configured to: receive a signal indicative of a distance sensed by parking sensors, and enable deployment of the charging pad from the stowed position in dependence on a signal indicative of a distance below a threshold value.

16. A vehicle comprising a powertrain and apparatus according to any one of the previous claims.

17. A vehicle according to claim 16, wherein the powertrain has a lowest point at a first height, the charging pad in the stowed position has a lowest point at a second height, and the second height is greater than or equal to the first height.

18. A vehicle according to claim 16 or claim 17, wherein the deployed position is forward of the stowed position and below the powertrain.

19. A method of positioning a charging pad for wirelessly charging batteries of a vehicle, the method comprising pivoting a charging pad through an arc about a first axis from a stowed position on the vehicle to a deployed position above a transmission coil.

20. The method according to claim 19, wherein: the charging pad is mounted on a first arm; and the method comprises pivoting the first arm about the first axis to move the charging pad from the stowed position to the deployed position and pivoting the charging pad about a second axis relative to the first arm to orient the charging pad relative to horizontal.

21. The method according to claim 19 or claim 20, wherein the method comprises pivoting the first arm to position the charging pad in a range of different deployed positions.

22. The method according to any one of claims 19 to 21, wherein the method comprises:

measuring an electric signal induced in the charging pad for each one of a plurality of different deployed positions;

comparing the electric signals to determine a deployed position providing a largest electrical signal; and causing a movement of the charging pad to the deployed position providing the largest electrical signal.

23. The method according to any one of claims 19 to 22, wherein the method comprises pivoting the charging pad from the stowed position at the rear of a powertrain of the vehicle to the deployed position, which is forward of the stowed position and below the powertrain.

24. An apparatus, a vehicle or a method as disclosed herein with reference to the accompanying figures.

Intellectual Property Office

Application No:	GB1719664.3	**Examiner:**	Mr Gareth John
Claims searched:	1-23	**Date of search:**	29 May 2018

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1-12, 16-21 & 23	US 2016/0114687 A1 (ICHIKAWA et al) Paragraphs [0090]-[0094], [0130]-[0133], [0176]-[0184], [0199]-[0209], [0230], [0231]; figures 1-3, 9-14 & 41-43.
X	1-7, 12, 16-21 & 23	WO 2010/122598 A1 (TAKENAKA CORP.) Paragraph [0109]; figure 34.
X	1-7, 12, 16-21 & 23	US 2016/0303980 A1 (CYR et al) Whole document relevant - especially figures 2A-3.
X	1-12, 16-21 & 23	JP 2011193617 A (HINO MOTORS LTD.) Whole document relevant - especially figures 1 & 2.
X	1-12, 16-21 & 23	US 5821728 A (SCHWIND) Whole document relevant - especially figures 4-6.

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X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
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Field of Search:

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B60L; H02J

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International Classification:

Subclass	Subgroup	Valid From
B60L	0011/18	01/01/2006
H02J	0050/10	01/01/2016