

WIRELESS CHARGING SYSTEM BASED ON STRONGLY COUPLED MAGNETIC RESONANCE

TECHNICAL FIELD

[0001] The present disclosure relates to the technical field of wireless charging, in particular to a wireless charging system based on strongly coupled magnetic resonance.

BACKGROUND

[0002] With the development of the charging technology for portable electronic products, the traditional wired charging way gradually transforms into wireless power transfer (WPT) way. According to the power transfer mechanism employed and the effective transfer distance, the wireless transfer methods can be mainly classified into three categories: radiative transfer, inductive transfer, and resonant transfer ways. Among them, the strongly coupled magnetic resonance (SCMR) WPT way becomes a research-and-development hot point in recent years due to its many advantages such as high power, long-range distance, no radiation, etc.

[0003] At present, the existing SCMR WPT coil system is generally applied as single-input and single-output (SISO) elements in the transmitter (Tx) and receiver (Rx) sides respectively. The transfer efficiency and transfer power of the system both can reach high level in a certain distance. At the same time, there is also an example of applying the coils stacked vertically or horizontally to the Tx and Rx sides to improve the transfer efficiency and transfer power of the system.

[0004] However, this type of SCMR WPT coil system has following disadvantages: the system cannot achieve high enough transfer efficiency and rapid enough transfer speed over both mid-range and long-range distances, normally it has poor robustness of transfer separation distance, and additionally, a relatively large coil structure size is required to match up with the power needed in the whole system.

SUMMARY

[0005] A purpose of the present disclosure is to provide a wireless charging system based on strongly coupled magnetic resonance, which can obtain higher transfer efficiency and high transfer power over both mid-range and long-range distances, and has good robustness for variance of a spacing distance between a transmitter coil and a receiver coil.

[0006] The embodiments of the present disclosure are implemented as follows.

[0007] An embodiment of the present disclosure provides a wireless charging system based on strongly coupled magnetic resonance, which includes a transmitter coil and a receiver coil arranged oppositely; the transmitter coil includes at least one layer of a coil array and the receiver coil includes at least one layer of the coil array; each layer of the coil array includes at least two coil units and the coil units are arranged in a matrix; each coil unit includes a spiral coil and an annular feed coil sleeved with the spiral coil; a middle part of one side of the feed coil is disconnected to form an input port and an output port, and a middle part of another side of the feed coil is connected with an adjustable capacitor; the spiral coils of two adjacent coil units in the coil array have opposite spiral directions; each row of the coil unit in each layer of the coil array is arranged along a curved surface, each row of the coil unit is parallel to each other, and the input port and the output port of the feed coil included by the each row of the coil unit are connected in parallel.

[0008] In some embodiments, each layer of the coil array includes nine coil units arranged in the matrix of three rows and three columns.

[0009] In some embodiments, the transmitter coil includes three layers of the coil arrays arranged with intervals and the receiver coil includes three layers of the coil array arranged with intervals.

[0010] In some embodiments, a spacing between adjacent layers of the coil arrays is 0.5-1.5 cm.

[0011] In some embodiments, a dimension of the feed coil in the coil unit is 15.4 cm × 15.4 cm (length×width); a coil pitch of the spiral coil is 0.3-0.6 cm, and a quantity of coil turns of the spiral coil is 14.25; both a diameter of the spiral coil and a diameter of the feed coil are 0.3-0.5 cm.

[0012] In some embodiments, a spacing distance between a center of the coil arrays of the transmitter coil and a center of the coil arrays of the receiver coil is 40-60 cm.

[0013] In some embodiments, each row of the coil unit in the coil array is arranged along a curved surface with a curvature radius of 40-60 cm.

[0014] Beneficial effects of the present disclosure: a wireless charging system based on strongly coupled magnetic resonance provided by the present disclosure, includes a transmitter coil and a receiver coil arranged oppositely; the transmitter coil includes at least one layer of a coil array and the receiver coil includes at least one layer of the coil array; each layer of the coil array includes at least two coil units and the coil units are arranged in a matrix; each coil unit includes a spiral coil and an annular feed coil sleeved with the spiral coil; a middle part of one side of the feed coil is disconnected to form an input port and an output port, and a middle part of another side of the feed coil is connected with an adjustable capacitor; the spiral coils of two adjacent coil units in the coil array have opposite spiral directions; each row of the coil unit in each layer of the coil array is arranged along a curved surface, each row of the coil unit is parallel to each other, and the input port and the output port of the feed coil included by the each row of the coil unit are connected in parallel. The wireless charging system based on strongly coupled magnetic resonance, provided by the present disclosure, can obtain higher transfer efficiency and higher transfer power over both mid-range and long-range distances, and has good robustness for variance of the spacing distance (transfer separation distance) between the transmitter coil and the receiver coil.

BRIEF DESCRIPTION OF DRAWINGS

[0015] In order to more clearly illustrate the technical solutions of the embodiments of the present disclosure, the drawings required to be used in the embodiments are

briefly introduced below. It should be understood that the following drawings only show some embodiments of the present disclosure instead of limit the present protection scope. For those ordinary skilled in the art, other relevant drawings can be obtained based on the present drawings without any creative work.

[0016] FIG. 1 is a schematic diagram of a structure of a wireless charging system based on strongly coupled magnetic resonance provided by the embodiments of the present disclosure;

[0017] FIG. 2 is a schematic diagram of a structure of a coil array in a wireless charging system based on strongly coupled magnetic resonance provided by the embodiments of the present disclosure;

[0018] FIG. 3 is a schematic diagram of a structure of a coil unit in a wireless charging system based on strongly coupled magnetic resonance provided by the embodiments of the present disclosure;

[0019] FIG. 4 is a schematic diagram of a structure of an input port of a feed coil connecting with an AC-DC converter, an output port of the feed coil connecting with an AC-DC converter, and the feed coil connecting with a power source in parallel in a wireless charging system based on strongly coupled magnetic resonance provided by the embodiments of the present disclosure, among them, the feed coil is included by each row of coil units, and the each row of the coil units is arranged in parallel.

[0020] FIG. 5 is a schematic diagram of a partial structure of a wireless charging system based on strongly coupled magnetic resonance provided by the embodiments of the present disclosure;

[0021] FIG. 6 is a schematic diagram of a result of a simulation test of power transfer efficiency and frequency when a transmitter coil adopts one single coil unit and a receiver coil adopts one single coil unit in a wireless charging system based on strongly coupled magnetic resonance provided by the embodiments of the present disclosure;

[0022] FIG. 7 is a schematic diagram of a result of a simulation test of power transfer efficiency and frequency when a transmitter coil adopts three layers of coil arrays and a receiver coil adopts three layers of coil arrays in a wireless charging system based on

strongly coupled magnetic resonance provided by the embodiments of the present disclosure;

[0023] FIG. 8 is a curve graph of maximum power transfer efficiency varying with a transfer separation distance when a transmitter coil adopts one single coil unit and a receiver coil adopts one single coil unit in a wireless charging system based on strongly coupled magnetic resonance provided by the embodiments of the present disclosure; and,

[0024] FIG. 9 is a curve graph of maximum power transfer efficiency varying with a transfer separation distance when a transmitter coil adopts three layers of coil arrays and a receiver coil adopts three layers of coil arrays in a wireless charging system based on strongly coupled magnetic resonance provided by the embodiments of the present disclosure.

[0025] In the figures: 100, transmitter coil; 110, receiver coil; 120, coil array; 130, coil unit; 140, spiral coil; 150, feed coil; 160, input port; 170, output port; 180, adjustable capacitor.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0026] In order to make the purposes, technical solutions and advantages of the embodiments of the present disclosure clearer, the technical solutions in the embodiments of the present disclosure are clearly and completely described below in conjunction with the drawings in the embodiments of the present disclosure. Obviously, the described embodiments are part of the embodiments of the present disclosure, but not all of them. The components of the embodiments of the present disclosure generally described and illustrated in the drawings herein may be arranged and designed in a variety of different configurations.

[0027] Accordingly, the following detailed description of the embodiments of the present disclosure provided in the appended drawings is not intended to limit the protection scope of the present disclosure, but rather to represent selected embodiments of the present disclosure. Based on the embodiments in the present disclosure, all other

embodiments obtained by those ordinary skilled in the art without creative work fall within the protection scope of the present disclosure.

[0028] It should be noted that similar reference numerals and letters represent similar items in the following drawings. Therefore, once one item is defined in one drawing, it does not need further definition and explanation in subsequent drawings.

[0029] In the description of the present disclosure, it should be noted that the indicated orientation or positional relationship of the terms "center", "upper", "lower", "left", "right", "vertical", "horizontal", "inner", "outer", etc. is based on the orientation or positional relationship shown in the drawings, or the orientation or positional relationship where the product of the present application is commonly placed when used. It is only for the convenience of describing the present disclosure and simplifying the description, and is not intended to indicate or imply that the devices or elements referred to must have a specific orientation and be constructed and operate in a specific orientation, and therefore should not be construed as limiting the present disclosure. In addition, the terms "first", "second", "third", etc. are only used to distinguish descriptions and should not be understood as indicating or implying relative importance.

[0030] Furthermore, the terms "horizontal", "vertical", "overhanging" etc. do not imply a requirement that a component be absolutely horizontal or overhanging, but may be slightly tilted. For example, "horizontal" only means that its direction is more horizontal than "vertical", and the "horizontal" does not mean that a structure must be completely horizontal, but can be slightly tilted.

[0031] In the description of the present disclosure, it should also be noted that, unless otherwise clearly stated and limited, the terms "set", "arrange", "install", "mount", "connect", and "connection" should be understood in a broad sense. For example, it may be a fixed connection, also a detachable connection or an integral connection; it may be a mechanical connection or an electrical connection; it may be a direct connection, or an indirect connection through an intermediate medium, or an internal connection between two components. For those ordinary skilled in the art, the specific meanings of the above terms in the present disclosure can be understood on a case-by-case basis.

[0032] In the present disclosure, unless otherwise explicitly stated and limited, a first feature being "above/over" or "under/below" a second feature may include that the first feature directly contacts with the second feature, or the first feature indirectly contacts with the second feature by an additional feature between the first and second features. Furthermore, the first feature being "above", "over" or "upper" the second feature may include that the first feature is above or over the second feature, or the first feature is horizontally higher than the second feature. The first feature being "under", "below" or "lower" the second feature may include that the first feature is under or below the second feature, or the first feature is horizontally lower than the second feature.

[0033] The characteristics and performance of a wireless charging system based on strongly coupled magnetic resonance of the present disclosure are described in further detail below in conjunction with the embodiments.

[0034] As shown in FIGs. 1, 2, 3, 4, and 5, an embodiment of the present disclosure provides a wireless charging system based on strongly coupled magnetic resonance, which includes a transmitter coil 100 and a receiver coil 110 arranged oppositely. The transmitter coil 100 and the receiver coil 110 both include three layers of coil arrays 120. A spacing between adjacent layers of the coil arrays 120 is 1 cm. Each layer of the coil array 120 includes nine coil units 130 arranged in a matrix. Each coil unit 130 includes a spiral coil 140, and further includes an annular feed coil 150 sleeved with the spiral coil 140. A middle part of one side of the feed coil 150 is disconnected to form an input port 160 and an output port 170. A middle part of another side of the feed coil 150 is connected with an adjustable capacitor 180 as a resonant port. The spiral coils 140 of two adjacent coil units 130 in the coil array 120 have opposite spiral directions. Each row of the coil units 130 in each layer of the coil array 120 is arranged along a curved surface with a curvature radius of 50 cm, the each row of the coil units 130 is arranged in parallel to each other. The input port 160 of the feed coil 150 connects with an AC-DC converter, and the output port 170 of the feed coil 150 connects with an AC-DC converter, so that the feed coil 150 connects with a power source in parallel, among them, the feed coil 150 is included by the each row of the coil units 130. A dimension of the feed coil 150 in the coil unit 130 is 15.4 cm×15.4 cm (length×width);

both a diameter of the spiral coil 140 and a diameter of the feed coil 150 are 0.4 cm, both a coil pitch between the spiral coil 140 and the feed coil 150 and a coil pitch of the spiral coil 140 are 0.5 cm, the number of coil turns of the spiral coil 140 is 14.25; and a spacing distance between a center of the coil arrays 120 of the transmitter coil 100 and a center of the coil arrays 120 of the receiver coil 110 is 50 cm.

[0035] In the wireless charging system based on strongly coupled magnetic resonance provided by the embodiment of the present disclosure, a coil array 120 is formed by arranging nine coil units 130 in a matrix; three layers of the coil arrays 120 are formed to form a transmitter coil 100 and three layers of the coil arrays 120 are formed to form a receiver coil 110, and the transmitter coil 100 and the receiver coil 110 are arranged oppositely; each coil unit 130 includes a spiral coil 140 and further includes an annular feed coil 150 sleeved with the spiral coil 140; a middle part of one side of the feed coil 150 is disconnected to form an input port 160 and an output port 170, and a middle part of another side of the feed coil 150 is connected with an adjustable capacitor 180; the spiral coils 140 of two adjacent coil units 130 in the coil array 120 have opposite spiral directions; each row of the coil units 130 in each layer of the coil array 120 is arranged along a curved surface with a curvature radius of 50 cm; the each row of the coil units 130 is arranged in parallel to each other. The input port 160 and the output port 170 of the feed coil 150 included by the each row of the coil units 130 are connected in parallel. Therefore, the compact coil arrays 120 are used to make the magnetic-field distribution more concentrated to form an efficient SCMR WPT coil system. When circuit parameters are adjustable, a full-wave numerical method-method of moments (MoM) with its thin-wire approximation algorithm is used to comprehensively analyze the whole system and optimize the circuit parameters such as resonant capacitance, load resistance, etc.

[0036] As shown in FIG. 6, in the wireless charging system based on strongly coupled magnetic resonance provided by the present embodiment, when the transmitter coil 100 adopts one single coil unit 130 and the receiver coil 110 adopts one single coil unit 130, the resonant port is located near a frequency band of 19.22 GHz; within the frequency band, a wireless charging power transfer efficiency is about 54.6%. As shown

in FIG. 7, in the wireless charging system based on strongly coupled magnetic resonance, when the transmitter coil 100 adopts three layers of coil arrays 120 and the receiver coil 110 adopts three layers of coil arrays 120, a total power transfer efficiency is about 83.5%. As shown in FIGs. 8 and 9, a curve of maximum power transfer efficiency varying with a transfer separation distance when the transmitter coil 100 adopts one single coil unit 130 and the receiver coil 110 adopts one single coil unit 130 is shown in FIG. 8, a curve of maximum power transfer efficiency varying with a transfer separation distance when the transmitter coil 100 adopts three layers of coil arrays 120 and the receiver coil 110 adopts three layers of coil arrays 120 is shown in FIG. 9. It can be seen that the wireless charging system based on strongly coupled magnetic resonance provided by the present embodiment improves the robustness of the system efficiency varying with the transfer separation distance between the transmitter coil and the receiver coil.

[0037] The above-described embodiments are partial embodiments of the present disclosure, not all of the embodiments. The detailed description of the embodiments of the present disclosure is not intended to limit the protection scope of the present disclosure as claimed, but rather to represent selected embodiments of the present disclosure. Based on the embodiments in the present disclosure, all other embodiments obtained by those ordinary skilled in the art without creative work fall within the protection scope of the present disclosure.

What is claimed is:

1. A wireless charging system based on strongly coupled magnetic resonance, comprising a transmitter coil and a receiver coil both arranged oppositely; wherein the transmitter coil comprises at least one layer of a coil array and the receiver coil comprises at least one layer of the coil array; each layer of the coil array comprises at least two coil units and the coil units are arranged in a matrix; each coil unit comprises a spiral coil and an annular feed coil sleeved with the spiral coil; a middle part of one side of the feed coil is disconnected to form an input port and an output port, and a middle part of another side of the feed coil is connected with an adjustable capacitor; the spiral coils of two adjacent coil units in the coil array have opposite spiral directions; each row of the coil unit in each layer of the coil array is arranged along a curved surface, each row of the coil unit is parallel to each other, and the input port and the output port of the feed coil included by the each row of the coil unit are connected in parallel.

2. The wireless charging system based on strongly coupled magnetic resonance according to claim 1, wherein each layer of the coil array comprises nine coil units arranged in the matrix of three rows and three columns.

3. The wireless charging system based on strongly coupled magnetic resonance according to claim 1, wherein the transmitter coil comprises three layers of the coil arrays arranged with intervals and the receiver coil comprises three layers of the coil array arranged with intervals.

4. The wireless charging system based on strongly coupled magnetic resonance according to claim 3, wherein a spacing between adjacent layers of the coil arrays is 0.5-1.5 cm.

5. The wireless charging system based on strongly coupled magnetic resonance according to claim 1, wherein a dimension of the feed coil in the coil unit is 15.4 cm×15.4 cm (length×width); a coil pitch of the spiral coil is 0.3-0.6 cm, and a quantity of coil turns of the spiral coil is 14.25; both a diameter of the spiral coil and a diameter of the feed coil are 0.3-0.5 cm.

6. The wireless charging system based on strongly coupled magnetic resonance according to claim 1, wherein a spacing distance between a center of the coil arrays of the transmitter coil and a center of the coil arrays of the receiver coil is 40-60 cm.

7. The wireless charging system based on strongly coupled magnetic resonance according to claim 1, wherein each row of the coil unit in the coil array is arranged along a curved surface with a curvature radius of 40-60 cm.