Technical University of Denmark

Electric vehicle battery charging controller

Pedersen, Anders Bro; Andersen, Peter Bach; Sørensen, Thomas Meier; Martinenas, Sergejus

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(71) **Applicant**: **DANMARKS TEKNISKE UNIVERSITET** [DK/DK]; Anker Engelunds Vej 101 A, 2800 Kgs. Lyngby (DK).

(72) **Inventors**: **PEDERSEN, Anders Bro**; Åbakkevej 22, 2. th., DK-2720 Vanløse (DK). **ANDERSEN, Peter Bach**; Lyongade 15, 4. th., DK-2300 Copenhagen S (DK). **SØRENSEN, Thomas Meier**; Laveskov Alle 408, DK-3050 Humlebæk (DK). **MARTINENAS, Sergejus**; Ordrupvej 67B, 1. th., DK-2920 Charlottenlund (DK).

(74) **Agent**: **GUARDIAN IP CONSULTING I/S**; Diplomvej, Building 381, DK-2800 Kgs. Lyngby (DK).

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(54) **Title**: ELECTRIC VEHICLE BATTERY CHARGING CONTROLLER

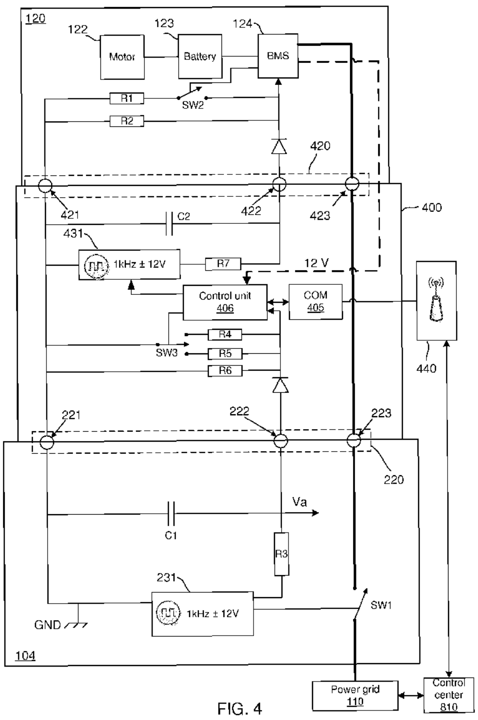

FIG. 4

(57) **Abstract**: The present invention provides an electric vehicle charging controller. The charging controller comprises a first interface connectable to an electric vehicle charge source for receiving a charging current, a second interface connectable to an electric vehicle for providing the charging current to a battery management system in the electric vehicle to charge a battery therein, a first communication unit for receiving a charging message via a communication network, and a control unit for controlling a charging current provided from the charge source to the electric vehicle, the controlling at least in part being performed in response to a first information associated with a charging message received by the first communication unit.

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ELECTRIC VEHICLE BATTERY CHARGING CONTROLLER

The present invention relates to electric vehicle charging controllers and charging systems for charging electric vehicles, such as cars, motorcycles and boats. The electric vehicle charging controllers and charging systems are capable of remotely controlling the charging process between an electric vehicle and a charging station.

BACKGROUND OF THE INVENTION

The world's energy use remains on an upward slope and new types of energy sources are employed to accommodate the need for energy. The two most important relatively new ways of producing energy are based on wind and sunlight. These are currently not particularly reliable because of the sources on which they depend. Winds for wind mills change on an hourly scale, being sometimes strong and highly favorable, other times even too strong and not allowing wind mills to operate safely; and yet other times, winds are insufficient for wind mills to produce any useful amount of energy. Solar energy can be harvested only during the between sunrise and sunset, which averages around 12 hours a day considered over a one-year period. Depending on latitude, the seasonal variation also influences the extent to which solar energy can be harvested. North of the Arctic Circle, the Sun never sets during summer, and during winter it never rises, making the seasonal variation particularly large.

As these energy sources make up an increasing part of the world's energy production, the energy production variations need to be accommodated. Residential, office and industry consumption each has its own individual daily and yearly cycles, which in turn depend on both latitude and longitude. Any measure that can shift energy or power consumption away from peak times is generally desirable for both consumers and utility or electricity providers.

As the ratio of electric vehicles against combustion-propelled vehicles increase, the demand for electricity increases. Electric vehicle usage is on a local scale also varies greatly over each day. During night time, the majority of vehicles, including electric vehicles, are idle, whereas during the day their usage peaks.

Accordingly, the timing of the charging of the electric vehicles has received substantial attention. A number of solutions have been provided to try to optimize the timing at which electric vehicles are being charged.

International patent publication WO 2013/124841 A1 discloses a charging management technique in which a charging spot, i.e. an apparatus to which an electric vehicle can be connected for charging, can control the charging scheme via data received from a data network.

SUMMARY OF THE INVENTION

A first aspect of the invention relates to an electric vehicle charging controller (400), the charging controller comprising:

- a first interface (220) connectable to an electric vehicle charge source (104) for receiving a charging current and receiving an input pilot signal via an input pilot signal pin (222), the input pilot signal being a pulse-width-modulated (PWM) voltage signal having a corresponding input duty cycle,
- a second interface (420) connectable to an electric vehicle (120) for providing the charging current to a battery management system (124) in the electric vehicle to charge a battery (123) therein and an output pilot signal pin (422) for providing a PWM output pilot signal having an output duty cycle,
- a first communication unit (405) for receiving a charging message via a communication network (440), and

a control unit (406) for controlling a charging current provided from the charge source (110) to the electric vehicle (120), the controlling at least in part being performed in response to a first information associated with the charging message received by the first communication unit (405).

The present charging controller may provide a transparent and remote control of a charging session between the electric vehicle charge source and the electric vehicle. This transparent and remote control is capable of modifying or changing the charging session compared to how the charging would have been able to proceed, had the charging controller not interfered. The charging session is now controllable not only by the electric vehicle charge source and the electric vehicle itself, but also by the charging controller. The remote controlling may be carried out based on the first information of the charging messages received by the charging controller.

The control unit is preferably configured to receive the input pilot signal from the electric vehicle charge source via the input pilot signal pin at the first interface, the input pilot signal comprising a pulse-width-modulated (PWM) voltage signal having a corresponding input duty cycle. The control unit (406) may be configured to generating a larger, smaller or identical output duty cycle of the PWM output pilot signal compared to the input duty cycle of the input pilot signal as discussed in further detail below with reference to the appended drawings. Accordingly, the control unit may be configured to provide a transparent mode or pass-through mode of operation of the charging controller wherein the output duty cycle of the PWM output pilot signal is substantially identical to the input duty cycle of the input pilot signal. This transparent mode of operation may for example be selected by default by the control unit in the absence of remote charging messages to alter or modify the duty cycle of the input pilot signal.

To reduce the charging current drawn by the electric vehicle, the control unit may therefore be configured to reducing the output duty cycle in accordance with the information of a received charging message. The charging controller may for instance be configured to providing an output duty cycle lower than or equal to 40 %, such as lower than 31 %, such as lower than 21 %, such lower than 10 % while the input duty cycle is equal to or higher than 50 %, such as higher than 60 %, such as higher than 84 %, such as higher than 86 %. In some embodiments, the control unit is capable of increasing the output duty cycle in response to receiving a charging message. Such a charging controller is able to reduce a charging suppression that it has previously imposed based on a previous charging message to that effect.

In some embodiments, wherein the control unit is responsive to a delay instruction associated with the charging message, the control unit delaying the controlling of the charging current for a pre-defined amount of time or for an amount of time represented by the delay instruction. This allows the charging message to be sent to the charging controller at a time earlier than the time at which the controlling is to take place, say, an hour (or 2 hours or 3 hours or 6 hours or 12 hours or 24 hours or other suitable time) in advance. In a planned reduction of the power consumed by electric vehicles charging at charging stations, this allows the charging control center sending the charging messages to send the charging messages ahead of the time at which they shall be effectuated. The sending of a charging message ahead of time reduces the likelihood that a communication network issue prevents the charging message to be delivered to the charging controller. Furthermore, it can help level the communication network load that charging messages are sent in a distributed fashion rather than in large numbers at a time.

In some embodiments, the charging controller is powered by a battery in the electric vehicle. This can allow the charging controller to be responsive to charging messages at all times. Alternatively, the charging controller may have a built-in battery. Alternatively, the charging controller may operate on power from the electric vehicle charge source (charging station). Alternatively, the charging controller is powered by a power pin in the charging controller after being connected to the electric vehicle charge source. In some cases, the charging controller can initialize using power from the pilot pin when initially connected to the electric vehicle charge source, before drawing power from the power pin. In the standard IEC 61851, this can allow the charging controller to cause the electric vehicle to switch from IEC 61851 standard State B to either IEC 61851 standard State C or IEC 61851 standard State D. This is advantageous if the charging controller is not powered by the electric vehicle battery.

In some embodiments, the charging controller is configured to receive the charging message by way of one or more wireless communication protocols, such as by way of at least one of: a GRPS mobile protocol, a CDMA mobile protocol, a 3G mobile protocol, a 4G mobile protocol, a HSDPA protocol, an LTE mobile protocol, a Wi-Fi protocol, a Bluetooth protocol, an NFC protocol, a ZigBee protocol, an ANT+ protocol, a GSM mobile protocol, a satellite communication protocol.

The charging controller might include just cell-based communication protocols, for instance GSM and/or CMDA and/or 3G or some other combination. In this case, the charging controller can receive instructions via cellular networks. In some cases, the charging controller may furthermore be able to receive message via another protocol, such as Wi-Fi or Bluetooth. This can allow communication of charging messages not just from a cellular network, but also from a mobile computing device, such as a mobile phone, tablet etc. The mobile computing device may itself have an application is configured to perform the sending of charging messages to the charging controller. This can allow the charging scheme to be changed via the mobile device. For instance, the application may allow the user to send a charging message to the charging controller that makes the charging controller increase the output duty cycle, i.e. reducing part of or any charge suppression previously imposed. The application might in connection therewith cause the user to be charged for the reducing of any charge suppression.

In some embodiments of the charging controller, the communication unit itself is capable of sending a response message to a remote charging control center, the response message triggering a further charging message from the charging control center, the further charging message comprising a second information different from the first information, whereby a charge scheme corresponding to the first information can be replaced by a charge scheme corresponding to the second information. This allows the electric vehicle user to request a change in charging scheme, if allowed by the charging control center. For instance, this can allow a user to receive charging current even though the charging control center prevented it with a previous charging message. Sending a response message may be considered an acceptance of a high charging current price. The further message from the charging control center instructs the charging controller to lift part of or any charge suppression previously applied.

To be easily implemented with existing electric vehicle conductive charging system standards, embodiments of the charging controller may be characterized in that:

- the first interface is a socket in accordance with the electric vehicle conductive charging system standard, and the second interface is a corresponding plug compatible with said socket, or
- the first interface is a plug in accordance with the electric vehicle conductive charging system standard, and the second interface is a corresponding socket compatible with said plug.

This means that the charging controller can be placed in-line between the electric vehicle charge source and the electric vehicle to intercept one or more electrical signals between the electric vehicle charge source and the electric vehicle provided for by the electric vehicle conductive charging system standard.

The control unit may in certain embodiments comprise a data communication bus or interface, such as a CAN bus, for receipt of electric vehicle battery data, such as charging status of the battery, generated and transmitted by the battery management system (124) of the electric vehicle. This data communication bus may comprise a wired or wireless data communication link. The functionality and merits of this optional data communication bus is discussed in further detail below with reference to FIG. 4A.

A second aspect of the invention relates to a charging controller system. Embodiments of the charging controller system comprise:

- a charging controller in accordance with the first aspect of the invention, and
- a second communication unit configured to send a charging request message to a charging control center via the communication network, wherein the second communication unit is associated with the charging controller, and wherein the charging request message causes the charging control center to send a further charging message to the associated charging controller, the charging request message causing the charging controller to increase the output duty cycle.

The charging controller system allows a user to send a message, for instance via a mobile electronic computing device, to the charging control center to change the charging scheme previously communicated to the charging controller. In some embodiments, the system comprises a user interface allowing a person to trigger the sending of the charging request message.

In some embodiments, the first and the second communication units are integrated into a single unit.

A third aspect of the invention provides an electric vehicle comprising an electric vehicle charging controller in accordance with the first aspect of the invention.

In some embodiments of the third aspect of the invention, the electric vehicle comprises a battery management system having the electric vehicle's charging connector operably connected to the second interface of the charging controller. This allows an electric vehicle charge source can be connected to the electric vehicle charging controller via the first interface of the charging controller to provide the charging current to the battery management system. Such an electric vehicle is compatible with existing charging stations, and readily connectable thereto, while at the same time having the charging controller functionality built in.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following, several embodiments of the present invention are described in more detail with reference to the appended drawings, wherein:

FIG. 1 illustrates a power source and load eco system,

FIG. 2 illustrates a charging station and an electric vehicle to be charged in accordance with prior art,

FIG. 3 illustrates a charging session when charging an electric vehicle at a charging station,

FIG. 4 illustrates a charging controller in accordance with a first embodiment of the present invention,

FIG. 4A illustrates a charging controller in accordance with a second embodiment of the present invention,

FIG. 5 illustrates a relationship between a duty cycle of a PWM pilot voltage signal and a current to be drawn,

FIG. 6 illustrates an example of a charging session in which an embodiment of the present invention is employed,

FIG. 7 illustrates another example of a charging session in which an embodiment of the present invention is employed,

FIG. 8 illustrates a charging controller in an operable position between a charging station and an electric vehicle; and

FIG. 9 illustrates a charging controller fitted into an electric vehicle, such as by retrofitting.

DETAILED DESCRIPTION OF EMBODIMENTS

FIG. 1 illustrates a power source and load eco system. A power grid 110 receives power from various sources 111, such as from fossil fuels, wind and the Sun. On the other hand, there are a number of loads, such as residential housing 101, industry 102 and electrified transportation 103. The figure also illustrates charging stations 104 (also known as electric vehicle supply equipment, EVSE) for charging electric vehicles 120 by for instance a wire or by induction (both represented by arrow 125)

For propulsion, electric vehicles 120 comprise an electric motor 122, a power source, in this case a battery 123, and along with a battery also a battery management system 124 for controlling the input and output of power to and from the battery.

FIG. 2 illustrates schematically a prior-art charging system. A charging station 104, which is equivalent to the EVSE 104 shown in Fig. 1, comprises a pilot signal generator 231 for providing a pilot signal to an electric vehicle 120. The electric vehicle and charging station are connected via an interface 220. The interface has a ground pin 221, a control pilot pin 222 and a power pin 223. The interface might for instance be a SAE J1772 interface or Mennekes electric vehicle charging interface. Mennekes includes Level1 (L1), Level2, Level3, N, GND, proximity and control pilot pins. SAE J1772 includes L1, L2, ground, proximity and control pilot pins.

The ground pin maintains a common ground between the charging station and the electric vehicle. The pilot pin is used to signal an upper charge current limit to the electric vehicle’s battery management system 124. The power pin 223 provides the actual charge current for charging the battery 123.

A charging session in accordance with certain prior art methods is illustrated in Fig. 3 in terms of signals on the pilot pin. Before connection of the charging station to the electric vehicle, marked by time *t1*, a voltage of 12 V is provided by the input pilot signal generator 231. When the electric vehicle is connected to the charging station at time t1, the voltage 12 V is provided over resisters R1 and R2 via the pilot pin 222 and ground pin 221 connections. These resisters are dimensioned to cause the voltage Va measured by the charging station to drop to 9 V. In response, the pilot signal generator 231 switches to a pulse-width modulation (PWM) mode. This is sensed by the battery management system 124, and depending on the battery management system and the properties of the battery, including its type, state of charge and other factors, the BMS may or may not request charging power from the charging station (104).

To request power at a time t2, the BMS causes closing of switch SW2, whereby resistor R3 in the electric vehicle is coupled into the circuit in parallel with resistor R2 in the electric vehicle. This results in a further voltage drop from Va=9 V to, for instance, Va=6 V. This indicates to the pilot signal generator 231 that the battery management system wants to draw a current for charging the battery. In response, the charging station provides a charge voltage (usually AC) on the power pin 223 of the interface 220 by switching the switch SW1 (contactor) to the on-state at time t3. The system is designed in such a way that the charging station provides a PWM signal having a duty cycle that represents a limit to the charging current the BMS may draw from the charging station. This communicates the capacity of the charging station to the electric vehicle. A relationship between PWM duty cycle and allowed charging current is illustrated in Fig. 5. At time t2, where the contactor SW1 is switched to on, the BMS can draw a current in accordance with (i.e. as limited by) the duty cycle and voltage amplitude on the pilot pin 222. The example in Fig. 3 shows that immediately after time t2, the duty cycle is approximately 60 %. Shortly after, from time t4, the BMS starts drawing a current ("AC current") within the limit set by this duty cycle. If the battery is already fully charged, the BMS will typically not draw much, if any, current even if the charging station allows it.

To limit the power drawn by the BMS in the electric vehicle, the charging station may reduce the duty cycle of the pilot signal. In the example in Fig. 3, this occurs at a time t5 in Fig. 3. The BMS responds by drawing a reduced current starting at a time t6 following the reduction in duty cycle at time t5. The charging may then proceed at a level limited by the new duty cycle, which is illustrated as being approximately 30 % in the figure. Depending on the state of charge of the battery, the BMS may charge the battery at the new limit or with a current lower than the limit.

The BMS can end the charging altogether by switching switch SW2 back to the off-state, as shown in Fig. 3 at a time t7. This takes resistor R3 out of the circuit, causing the voltage Va to go back from Va=6 V to Va=9 V. In response to the voltage change from 6 V to 9 V, the charging station shuts off the AC charge voltage by switching contactor SW1 to the off-state at time t8.

When the electric vehicle is ultimately unplugged at a time t9, the charging station switches back into its standby mode in which a steady 12 V rather than a PWM voltage is provided by the input pilot signal generator.

A first embodiment of an electric vehicle charging controller 400 in accordance with the present invention is illustrated in FIG. 4. The charging controller is shown inserted between a charging station 104 and an electric vehicle 120 via first and second interfaces 220 and 420, respectively. The charging controller interface 220 coupled to the charging station 104 is identical to that of the electric vehicle, and the charging controller can therefore readily be connected to the charging station’s connector. The second interface 420 of the charging controller 400 is identical to that of vehicle charging station, and, similarly, can therefore readily be connected to the electric vehicle’s charging connector.

In other words, the charging controller 400 comprises and the first or input interface 220 identical to that used in the prior art for connecting the charging station 104 to the electric vehicle 120. The input interface 220 allows the charging controller to be connected to the charging station as if it were an electric vehicle with such an interface. In FIG. 4, charge current is carried through the charging controller 400 from the input power pin 223 to an output power pin 423. Accordingly, the voltage at output power pin 423 may be substantially identical to the voltage at the input power pin 223 which in Fig. 4 is shown as operably coupled to the charging station to receive power from the power grid 110 (in case contactor/switch SW1 is in the on state).

Similarly to the power pins of the charging controller 400, ground is also carried through directly from input ground pin 221 to output ground pin 421 to ensure that the electric vehicle may be grounded in a similar manner as illustrated in the prior art conventional charging system of FIG. 2. The charging controller also operates using this ground, as shown.

The present charging controller 400 not only fits onto the charging station as if it were an electric vehicle. It also incorporates circuitry that mimics that of an electric vehicle. Resistor R6 plays the role of R2 in the electric vehicle. Accordingly, when the charging controller is connected to the charging station, the charging station registers a voltage drop and as a result switches to PWM mode, providing a 9 V PWM signal at input pilot pin 222. Resistor R4 corresponds to R1 which the electric vehicle 120 uses to signal to a conventional charging station that the electric vehicle 120 is ready to draw a charge current. The switching-on of resistor R1 in the prior art of FIG. 2 causes the voltage Va to drop from 9 V to 6 V. Resistor R4 in the charging controller is configured to provide the same effect. The skilled person will understand that resistor R5 in the charging controller allows the charging controller to be used with electric vehicles that use a different pilot voltage, such as 3 V. The different values of R4 and R5 allow the charging controller (400) to mimic or emulate an electric vehicle having either of these resistances.

The charging controller in this embodiment comprises an output pilot signal generator 431 which may be largely identical to the input pilot signal generator 231 in the charging station. Furthermore, resistor R7 is identical to R1 in the charging station. Capacitor C2 may or may not be identical to C1 in the charging station. These elements allow the charging controller to provide a PWM output pilot signal to the electric vehicle to control how much, if any, current the BMS in the electric vehicle draws on the power pin 423. In other words, vis-à-vis the electric vehicle, the charging controller 400 may appear as a conventional charging station.

In many practical applications, the charging controller may be retrofitted into existing electric vehicles. In order to be powered, the charging controller 400 is preferably connected to the battery 123 as illustrated by the dashed "12 V" line between the BMS 124 and the control unit 406 in FIG. 4. The dashed 12 V line does not pass through the interface 420, since the interface preferably (for the purpose of allowing retrofitting) is compatible with existing electric vehicles and charging stations. Therefore, the charging controller is powered by connecting it to the electric vehicle's battery via a separate connection or electrical wire. With some modification, the charging controller may draw power from the charging station either via the power pin or via the pilot pin signal.

The BMS operates based on the duty cycle of the PWM signal it receives via the pilot pin 422. The control unit 406 controls an output pilot signal generator 431 that provides a PWM signal to the electric vehicle via output pilot pin 422. Without the charging controller inserted, the electric vehicle 120 receives the PWM input pilot signal from input pilot signal generator 231 through resistor R1.

When the charging controller 400 is connected to the electric vehicle 120, the BMS therefore operates not based on the input pilot signal from the input pilot signal generator 231, but instead based on the output pilot signal on pilot interface pin 422 supplied by the output pilot signal generator 431. The control unit 406 controls the duty cycle of the output pilot signal from output pilot signal generator 431. Consequently, the present charging controller can provide an output duty cycle different from the input duty cycle which the charging station 104 provides on input pilot pin 222. Thereby, the control unit 406 is capable of causing the BMS in the electric vehicle 120 to draw a charging current not limited by the charging station, but by the charging controller 400.

In certain preferred embodiments of the invention, such as the first embodiment of FIG. 4, the charging controller 400 comprises electrical interface circuitry that allows the controller to act as an electric vehicle towards the charging station 104 and act as a charging station towards the electric vehicle 120. The electrical interface circuitry of the charging controller 400 may comprise two separate parts or interface circuits as shown in FIG. 4. The control unit 406 is configured to controlling when and if the input pilot signal on pin 222 of the charging station interface 220 is either duplicated to the output pilot signal at pin 422 of the second interface 420 towards the electric vehicle or the input pilot signal 222 is modified, e.g. by a change of duty cycle, by the control unit 406 before transmission to the electric vehicle via the output pilot pin 422 as the output pilot signal. Consequently, in the first situation, the control unit 406 is configured to provide a transparent mode of operation of the charging controller 400 wherein the output duty cycle, and possibly output amplitude, of the output pilot signal is substantially identical to the input duty cycle of the input pilot signal. This transparent mode of operation of the charging controller 400 may be set by a charging message delivered through a communication unit 405 of the charging controller 406 as discussed in further detail below.

The control unit 406 is connected to a communication unit 405 which is able to receive charging messages via a wireless network 440. The control unit 406 is preferably able to control the state of switch SW3 and adjust the duty cycle of the pilot signal from the output pilot signal generator based on charging information or charging content of such messages.

When the control unit 406 and communication unit 405 are powered by the battery of the electric vehicle 120, the communication unit 405 can receive charging messages from a wireless network 440. If the control unit 406 and communication unit 405 are unpowered, the communication unit can receive charging messages it has been powered and after having then connected to the wireless network 440. The wireless network is configured for receipt of charging messages, and possibly other types of messages, from a charging control center 810. The charging control center 810 may send charging messages on behalf of the utility provider (e.g. the operator of the power grid 110) with the purpose of leveling or balancing power load on the power grid 110.

An electric vehicle charging controller 500 in accordance with a second embodiment of the present invention is schematically illustrated on FIG. 4A. The circuits and first and second interfaces 420, 220 of the present charging controller embodiment 500 may be identical to the corresponding circuits and interfaces of the first embodiment of the electric vehicle charging controller 400 discussed above. Hence, similar circuits and features have been provided with identical reference numerals. However, the present embodiment 500 comprises an additional data bus or link 126, for example a standardized type of bi-directional data communication bus, interconnecting the control unit 406 and the BMS 124 of the electric vehicle 120. The bidirectional data bus or link 126 may comprise a CAN bus. The BMS 124 is on default configured to transmit electric vehicle data, such as a battery charging status or state of the battery 123 of the electric vehicle, to the control unit 406. The control unit 406 can subsequently transmit the electric vehicle data to the charging control center 810 via the previously discussed communication unit 405, possibly via the wireless network 440. This embodiment of the electric vehicle charging controller 500 possesses numerous advantages for the operation of the charging control center 810. The control center 810 may for example optimize the generation and distribution of electrical power within the power grid 110 over time based on knowledge of the respective battery charge states, e.g. expressed as a value between 0 and 100 %, of a plurality of electric vehicles coupled to the power grid 110 where the charging system associated with each of the plurality of vehicles comprises an electric vehicle charging controller 500 as schematically illustrated on FIG. 4A.

As described previously, FIG. 5 shows the relationship between PWM duty cycle and the allowed charging current. The electric vehicle BMS operates in accordance with the output duty cycle on the output pilot pin 422 of the charging controller (as opposed to the prior art where it operates in accordance with the duty cycle from the charging station). When the duty cycle increases of the output pilot signal, the BMS may draw a higher charging current through the output power pin 423. Therefore, by providing a smaller output duty cycle than input duty cycle, the control unit 406 is capable of reducing the charging current that the BMS may draw through the output power pin 423 compared to the charging current the charging station itself would actually allow. Providing an output duty cycle equal to the input duty cycle allows the electric vehicle to draw a charging current equal to that which the charging station itself would allow. For the purpose of fitting into existing standards, the charging controller 406 should preferably not provide an output duty cycle higher than the input duty cycle. So, for instance, if the input duty cycle corresponds to a charging current of 52 A, i.e. the duty cycle is 85 % (see FIG. 5), this should be considered the maximum current that the charging station, for one reason or another, is able to provide. If the charging controller overrules this duty cycle restriction, the BMS may start to draw a higher charging current, e.g. 60 A, which may cause the charging station to malfunction depending on the electrical characteristics of the charging station. Hence, in some embodiments of the invention, it may advantageous that the charging controller never provides an output duty cycle that exceeds the input duty cycle on the input pilot pin 222. However, in alternative embodiments of the invention the charging controller 406 may be configured to generate an output duty cycle that exceeds the input duty cycle.

The present embodiment of the charging controller 406 is capable of controlling a charging session of the electric vehicle 120 based on the charging messages received from a charging control center 810 via a wireless connection, as shown in FIG. 4. The charging controller 406 may intervene in the charging session in a way which is entirely transparent to both the charging station 104 and the electric vehicle 120 as discussed above. Neither the charging station nor the electric vehicle need to take any active part in the control of the charging session.

Examples of charging messages that convey charging session instructions to the charging controller 406 will be described in the following, along with the actions that may be taken by the charging controller to carry out or effectuate these charging instructions.

Charging messages and the controlling of charging current in response to receipt of charging messages by the charging controller can be realized in numerous ways. The operation of the charging controller 406 allows a change in the charging pattern of the electric vehicle beyond the constraints of the charging station itself.

To provide an output duty cycle of the PWM output pilot signal which is lower than the input duty cycle of the input pilot signal, the first information could comprise:

1) a charging message such as "decrease charge current" or "decrease charge current by 25 %". In such an embodiment, the control unit is configured to decode the changing message and lower the output duty cycle accordingly. FIG. 5 shows the relationship between duty cycle and allowed charging current.
2) "cut charge current". To effectuate this, the control unit 406 switches switch SW3 to off such that resistors R4 and R5 are removed from the circuit, in turn causing

voltage Va to increase to 9 V. In this state, the charging station switches off contactor SW1, and the BMS is no longer able to draw current.

3) "at time 7 am, decrease charge current". To implement this charging message , the control unit 406 may for example read the current time from the network. Alternatively, and simpler, the first information could correspond to "in 2 hours, decrease charge current", requiring only the relative time of 2 hours to be counted by a clock circuit of the control unit. A single charging message could comprise both a instruction to decrease and an instruction to increase the charging current for example: "reduce allowed charging current to 0 in 2 hours, increase allowed charging current to full [i.e. as set by the input duty cycle from the charging station] in 6 hours)".
4) The mere receipt of a charging message, whatever the content therein or lack thereof. The control unit might be configured switch off SW3 in response, meaning that the electric vehicle would stop charging. An advantage of this scheme is that the charging message needs not contain any information. It is therefore simpler, and the communication network load incurred by such messages is minimized. A following message with or without content could cause the control unit to cause the output pilot signal generator to provide an output duty cycle equal to the input duty cycle, allowing the BMS to draw a current limited only by the charging station.

The person skilled in the art will readily recognize other ways of designing the charging message. Information such as "cut charge current" could be represented by a coded or encoded string. In clear text, the information could for instance be encoded as "0". "Cut charge current in 3 hours" could be encoded as "0300.0" (i.e. time "0300", current to 0). A coded message could contribute to prevention of unauthorized controlling. Instead of "0300.0", the charging message could comprise the same instruction in an encrypted format. In a simple embodiment, a lookup table relates human-readable information to codes. "Cut charge in 4 hours" might be represented by the code "3e62e". The part "3e6" might represent "cut charge in" and 2e represent "4 hours".

Alternatively, the charging controller might operate in modes. In perhaps the simplest form, the charging controller can operate in two modes:

1) Mode 1: "cut charge", i.e. switch off SW3.
2) Mode 2: "allow full charging current", i.e. provide output duty cycle equal to the input duty cycle from the charging station.

The first information could then cause the change in charging current by addressing these modes. As an example, if the first information is the value "0", the charging controller enters Mode 1. If the first information is the value "1", the charging controller enters Mode 2. More complicated, but equivalent schemes can obviously be implemented.

It will be clear to a person skilled in the art that other ways to instruct changes to the maximum limit on charging current are available. In view of the present disclosure, it will be appreciated that times, percentages, number of hours, mode numbers, number of modes, code, encoding etc. described above are examples only, subject to numerous variation that can be implemented as required, depending or not depending on factors external to either the charging station 104 or to the electric vehicle 120 or to the charging controller 400. The change in charging current imposed by the charging controller may be effected in response to changes in the amount of power going in and out of the power grid 110. For instance, the amount of energy that can be harvested from energy sources such as the Sun varies greatly within a 24-hour period. During daytime, the power grid can rely more on solar energy and less on fossil fuels, and vice versa at nighttime. Electricity prices may change accordingly. On the other hand, the load also changes greatly within a 24-hour period. Electricity prices may also reflect also this mechanism.

As electric vehicles become more and more common, the load associated with their battery charging will increasingly contribute to the intraday consumption variation. During evenings, energy consumption increases locally as households prepare hot meals, use television sets, computers, game consoles, electric lights and so on. This is generally not an optimal time of the day for charging electric vehicles. For one, it would increase an already high load. Secondly, it is not a time at which most people will be using their electric vehicles, nor later in the evening. Only a few hours later, the load may have decreased substantially from the evening peak, and charging of for instance electric vehicles will fit in much better.

To achieve this by utilizing the present electric vehicle charging controllers 400, 500, the electricity provider may send messages to charging controllers in electric vehicles at, say, 5 pm instructing them reduce or even cut the charging current that the electric vehicle BMS's are allowed to draw. Then at 10 pm, when the household load is substantially lower, charging of electric vehicles can proceed. This could be effectuated by sending respective charging messages to all or at least a certain subset of available charging controllers as described above to reproduce the input duty cycle at the output interface 420.

In some periods, the need to control power consumption associated with charging of electric vehicles might be smaller, in other periods it might be larger. Charging messages, including their occurrence time and frequency, are adapted accordingly.

The charging controller of FIG. 4 may also be capable of transmitting or sending messages. If a consumer wants to charge his electric vehicle in a peak period, he or she may send a message to the charging control center, conveying that he is willing to pay a higher price for the energy at this time. Such a message can for instance either cause the charging control center to send a new charging message increasing the limit of current the electric vehicle may draw, or it can instruct the charging control center 810 to cancel a charging message that it would otherwise have sent.

In prior art, voltage Va shown in FIG. 2 is used by the charging station in determining which charging state to apply. This was described in relation to the prior-art charging session illustrated in FIG. 3. When the electric vehicle is connected, the potential Va drops from 12 V to 9 V, charging station to go into PWM mode, providing a 12 V PWM voltage signal having a duty cycle that represents the maximum current the electric vehicle may draw. To get the charging station to provide charging power, the electric vehicle closes switch SW2, causing the potential at Va to drop to 6 V.

When the charging controller is employed, this signaling between the electric vehicle and charging station is not direct. The charging controller can close switch SW3 and cause the delivery of charging current from the charging station coupled to an electric vehicle independent of the actual signaling by the electric vehicle.

FIG. 6 illustrates the voltage Va during a charging session in which the charging controller 400, 500 is temporarily instructed via a charging message to interrupt or cancel charging. In association with receiving the charging message and associated first information, say to switch off charging of the electric vehicle, the charging controller control unit 406 switches contactor SW3 to the off state. This causes the voltage Va to go from 6 V to 9 V. The charging station reacts by switching contactor SW1 to the off state, entirely disabling charging. The control unit 406 receives the input pilot signal from the charging station as before, shown in Fig. 4. However, by switching off switch SW3, resulting in the increase of Va to 9V, the charging controller acts as or mimics a BMS not requesting charging power. This is illustrated by the pseudo signal "Current suppression" in FIG. 6. Referring to FIG. 6, time t10 indicates the time at which the charging message or instruction transmitted from the charging control center to switch off charging is carried out. The input duty cycle from the charging station is still 60 % as illustrated on FIG. 3, but the electric vehicle cannot draw a current because the voltage Va of 9 V causes the switching-off of the contactor. The signal "AC voltage" illustrates this switch to off. Accordingly, the "AC current" signal, representing the current drawn by the BMS, is also 0 starting at time t10. In the example illustrated on FIG. 3, the BMS was operating within the 60% duty cycle provided by the charging station, which the electric vehicle BMS received in full. This is one way in which the charging controller 400, 500 can overrule the limit set by the charging station in order to further reduce the load on the power grid 110.

Time instant t5 in FIG. 6 indicates, similarly to FIG. 3, the time at which the charging station (not the charging controller) reduces the duty cycle from 60 % to 30 %. Time t6 was the time at which the current drawn by the electric vehicle was reduced accordingly. However, the duty cycle change at t5, previously implemented by the BMS at time t6 (by reducing the current drawn in accordance with the new duty cycle) and in fact still received at the charging controller input pilot pin 222, does not reach the electric vehicle. The electric vehicle experiences the pilot signal provided by the output pilot signal generator 431, not the input pilot signal generator 231. More important in this case, the duty cycle received at the BMS is of little importance, since at this time the charging controller has caused the charging station to switch off the contactor, making it impossible for the BMS to draw any charging current at all. Therefore, t6 is shown is parenthesis. It may be advantageous that the charging controller, despite the fact that the charging station has switched off the contactor, reproduces the input duty cycle at input pilot pin 222 at the output pilot pin 422.

At time t11, the charging controller switches on switch SW3, causing the voltage Va to drop to 6 V, in turn causing the charging station to switch on contactor SW1, thereby enabling the BMS to draw a charging current. This switching-on of SW3 by the charging controller (done by the control unit 406) could be in response to receiving a new charging message which includes an instruction to allow charging, or it could be contained in the message to suppress the charging for a limited amount of time, say 3 hours, to reduce the peak demand during that period. Accordingly, after having counted those three hours, the control unit in the charging controller will switch SW3 on to include resistor R4, causing the voltage Va to go to 6 V. Furthermore, the input pilot signal at input pilot pin 222 is reproduced by the charging controller at the output pilot pin 422. In this example, the output duty cycle is approximately 30 % and identical to the input duty cycle at this time as shown in Fig. 3. The residual portion of the session proceeds as in FIG. 3 since no interference by the charging controller takes place after time t11 in this example.

Until the charging controller receives instructions to the contrary, it may continue to suppress charging. Alternatively, the control unit could be programmed to automatically revert to either full input duty cycle or to increase the output duty cycle by some amount after some time, as described in the example above.

FIG. 7 shows another example of the charging controller 400, 500 changing the maximum charging current that the electric vehicle BMS must comply with. Rather than causing the charging station to switch off AC power by switching switch SW3 to off, the charging controller 400, 500 reduces the output duty cycle. This is schematically illustrated by the lower value of the pseudo-signal "Charging suppression" signal compared to the value in Fig. 6 in the suppression period t10 to t11. The session proceeds similarly to the sessions in Fig. 3 and Fig. 6, but rather than cutting the charging current entirely as in Fig. 6 or not at all as in Fig. 3, the control unit produces an output duty cycle of 50 % starting at time t10 In this example, the charging message first information causes the control unit to reduce the output duty cycle somewhat. In Fig. 7, the output duty cycle starting from t10 is approximately 50 %. The input duty cycle provided by the pilot signal generator is still 60 %, similarly to the example in Fig. 6. The electric vehicle BMS, however, receives the pilot signal from the charging controller, not from the charging station, and thus the BMS draws current within the limitation imposed by the 50 % duty cycle of the charging controller, not the 60 % duty cycle provided by the charging station. This current is, as Fig. 5 illustrates, lower than that corresponding to a duty cycle of 60 %.

Identically to the sessions illustrated in FIG. 3 and FIG. 6, the charging station reduces its duty cycle to 30 % at time t5, effectuated at time t6. The limitation is reproduced by the charging controller at the output pilot pin, causing a reduction in the charging current reflecting the relationship in FIG. 5. At time t11, as in FIG. 6, the control unit, via the communication unit 405, receives a message to no longer limit the duty cycle. The current drawn by the electric vehicle BMS corresponds to the full duty cycle from the pilot signal generator, i.e. 30 % (thus not changing the allowed charging current, since the charging current dictated by the charging station continues to be 30 %, less than the 50 % limit imposed via the charging message).

Had the control unit received a first information instructing it to limit the duty cycle to 20 % instead of 50 % as in FIG. 7, everything else being the same, the current drawn during the time between t10 and t11 would be 20 % as imposed by the charging controller (since it is less than the 30 % imposed by the charging station), increasing to 30 % after time t11, since at this time the limit is imposed by the charging station, not by the charging controller.

This illustrates how the charging controller 400, 500 can control the delivery of the charging current while still 1) appearing to be an electric vehicle towards the charging station, and 2) appearing to be a charging station towards the electric vehicle, and 3) obeying the limit in charging current dictated by the charging station.

FIG. 8 illustrates the charging controller 400, 500 in operable position inserted between an electric vehicle charge source 104 and an electric vehicle 120. The charging controller is connected to the vehicles existing vehicle charging connector via the second interface 420 and to the charging station 104 via the first interface 220. As the description above reflects, the charging controller 400, 500 can operate in a transparent manner to the electric vehicle charge source 104 and the electric vehicle 120. Neither the charging station 104 nor the electric vehicle 120 needs any adaption or modification since the respective interfaces of the charging controller mimics those of existing charging stations and existing electric vehicles. This feature is optional, but provides an advantageous compatibility with existing electric vehicle charging systems.

The charging stations 104 are connected to the power grid 110 for receipt of electrical power or energy. The power grid 110 has a charging control center 810 associated with it. One task of the charging control center 810 is to level the power consumption from the power grid. This is performed in part by communicating, via network 440, charging messages to the charging controllers 400, 500 as exemplified above. If the power grid 110 is loaded above average, the control center 810 may instruct selected charging controllers 400, 500 to reduce their respective charging currents drawn from the power grid 110 via the charging stations 104.

FIG. 8 also shows a charging controller system where a charging controller 400 is associated with a second communication unit 820. The second communication unit could be a mobile phone or it could be integrated with the first communication unit 405 in the charging controller (either as separate units or as a single, integrated unit). The second communication unit 820 can be used to send a charging request message. In some cases, the control center 810 might impose a certain charging limit via the charging controller in order to level out power consumption. By sending a charging request message, however, this charging limit may be changed, for instance removed for a particular charging controller 400, 500. A charge request message may for instance include acceptance by the electric vehicle owner to receive power at an elevated price. After acceptance, the charging control center will send a new charging message to the charging controller in question allowing the charging controller to maintain as high an output duty cycle as possible, or at least a higher output duty cycle than previously provided for by a previous charging message. As described previously, in preferred embodiments the charging controller does not provide an output duty cycle that exceeds the input duty cycle received from the charging station 104, thereby operating within the limit imposed by the charging station.

FIG. 9 shows a charging controller system with similarities to that of FIG. 8. The main difference is that the electric vehicle 120 has the charging controller 120 built in and operably connected to its battery management system BMS. Present electric vehicles have a connector that directly connects to electric vehicle charging stations such as EVSE 104. Normally, the electric vehicle user will simply connect a cable from the charging station to the connector in the electric vehicle. Charging controllers in accordance with the invention have two interfaces, one that mimics or matches the electric vehicle's connector, and one that matches or mimics the interface of the charging stations. One way of effectively employing the present charging controllers 400, 500 is to retrofit the charging controller onto existing electric vehicle connectors. Different vehicle makes use different charging systems, and accordingly the charging controller is adapted to fit the charging system that the particular electric vehicle uses. A retrofitted charging controller is readily connectable to a charging station since the relevant interface matches the charging station's connector. Instead of attaching the charge cable to the electric vehicle's original charging connector, the cable is attached to the charging controller. If receiving instructions to do so from the charging control center, the charging controller can cause the electric vehicle to modify the charge current that the battery management system draws from the power grid. The power or utility provider may reward a vehicle user having a mounted a charging controller in accordance with the present invention by a lower electricity price for allowing the utility provider to remotely adjust the vehicle charging process via charging messages.

The embodiments described herein are examples of how to carry out the invention and may not be construed as limiting the scope of the claims to those embodiments only. The direction of arrows or lack of arrows between elements in the drawings shall not be construed as limiting the scope of the protection conferred by the claims.

Also, the illustration of a lag for instance between times t2 and t3 and between t3 and t4 and between t7 and t8 in the figures and in text that includes these times shall not be construed as being a requirement for an embodiment to fall within the scope of the claims. Neither shall an apparent absence of such a lag be construed as a requirement. The transitions are shown only for illustrative purpose, and they also reflect the fact that in many cases, there is a transition time before a cause for change is fully expressed in a corresponding effect. Besides, these transitions are illustrated in the specification of IEC 61851, to which certain examples relate.

CLAIMS

1. An electric vehicle charging controller (400), the charging controller comprising:
   - a first interface (220) connectable to an electric vehicle charge source (104) for receiving a charging current and receiving an input pilot signal via input pilot signal pin (222), the input pilot signal being a pulse-width-modulated (PWM) voltage signal having a corresponding input duty cycle,
   - a second interface (420) connectable to an electric vehicle (120) for providing the charging current to a battery management system (124) in the electric vehicle to charge a battery (123) therein and an output pilot signal pin (422) for providing a PWM output pilot signal having an output duty cycle,
   - a first communication unit (405) for receiving a charging message via a communication network (440), and
   - a control unit (406) for controlling a charging current provided from the charge source (110) to the electric vehicle (120), the controlling at least in part being performed in response to a first information associated with the charging message received by the first communication unit (405).

2. A charging controller in accordance with claim 1, wherein the control unit (406) is configured to generating a smaller output duty cycle of the PWM output pilot signal than the input duty cycle of the input pilot signal.

3. A charging controller in accordance with claim 1 or 2, wherein the control unit (406) is configured to reducing the output duty cycle of the PWM output pilot signal in response to receiving the charging message.

4. A charging controller in accordance with claim 2 or 3, wherein the control unit (406) is configured to increasing the output duty cycle of the PWM output pilot signal in response to receiving the charging message.

5. A charging controller in accordance with any of claims 2-4, wherein the charging controller (406) is configured to providing an output duty cycle of the PWM output pilot signal lower than or equal to 40 % while the input duty cycle of the pulse-width-modulated (PWM) voltage signal is equal to or higher than 50 %.

6. A charging controller in accordance with any of the preceding claims, wherein the control unit is responsive to a delay instruction associated with the charging message, the control unit delaying the controlling of the charging current for a pre-defined time period or for a time period represented by information in the delay instruction.

7. A charging controller in accordance with any of the preceding claims, wherein the charging controller is powered by a battery of the electric vehicle via a separate connection or electrical wire.

8. A charging controller in accordance with any of the preceding claims, wherein the first communication unit is configured to receive the charging message by way of one or more wireless communication protocols, such as by way of at least one of: a GRPS mobile protocol, a CDMA mobile protocol, a 3G mobile protocol, a 4G mobile protocol, an LTE mobile protocol, a Wi-Fi protocol, a Bluetooth protocol, an NFC protocol, a ZigBee protocol, an ANT+ protocol, a GSM mobile protocol, a satellite communication protocol.

9. A charging controller in accordance with claim 8, wherein the first communication unit is configured to receive the charging message from a charging control center (810) via a cellular network (440) and to receive charging messages from a mobile computing device (820) via a Wi-Fi protocol or a Bluetooth protocol or an ANT+ protocol (110).

10. A charging controller in accordance with any of the preceding claims, wherein either:
    - the first interface comprises a socket in accordance with an electric vehicle conductive charging system standard, and the second interface comprises a corresponding plug compatible with said socket, or
    - the first interface comprises a plug in accordance with an electric vehicle conductive charging system standard, and the second interface is a corresponding socket compatible with said plug,

    whereby the electric vehicle charging controller can be placed in-line between the electric vehicle charge source and the electric vehicle to intercept one or more electrical signals between the electric vehicle charge source and the electric vehicle provided for by the electric vehicle conductive charging system standard.

11. A charging controller in accordance with any of the preceding claims, wherein the communication unit is configured to sending a response message to a remote charging control center (810), the response message triggering a further charging message from

the charging control center, the further charging message comprising a second information different from the first information, whereby a charge scheme corresponding to the first information can be replaced by a charge scheme corresponding to the second information.

12. A charging controller in accordance with any of the preceding claims, wherein the control unit comprises a data communication bus, such as a CAN bus, for receipt of electric vehicle battery data, such as charging status of the battery, generated and transmitted by the battery management system (124) of the electric vehicle.

13. A charging controller in accordance with any of the preceding claims, wherein the control unit is configured to provide a transparent mode or pass-through mode of operation wherein the output duty cycle of the PWM output pilot signal is substantially identical to the input duty cycle of the input pilot signal.

14. A charging controller system comprising:
   - a charging controller (400) in accordance with any of claims 1-13, and
   - a second communication unit (820) configured to send a charging request message to a charging control center (810) via the communication network, wherein the second communication unit (820) is associated with the charging controller, and wherein the charging request message causes the charging control center to send a further charging message to the associated charging controller, the charging request message causing the charging controller to increase the output duty cycle of the PWM output pilot signal.

15. An electric vehicle (120) comprising an electric vehicle charging controller (400) in accordance with any of claims 1-13, the electric vehicle comprising a battery management system (124) having an electric vehicle charging connector operably connected to the second interface (420) of the charging controller.

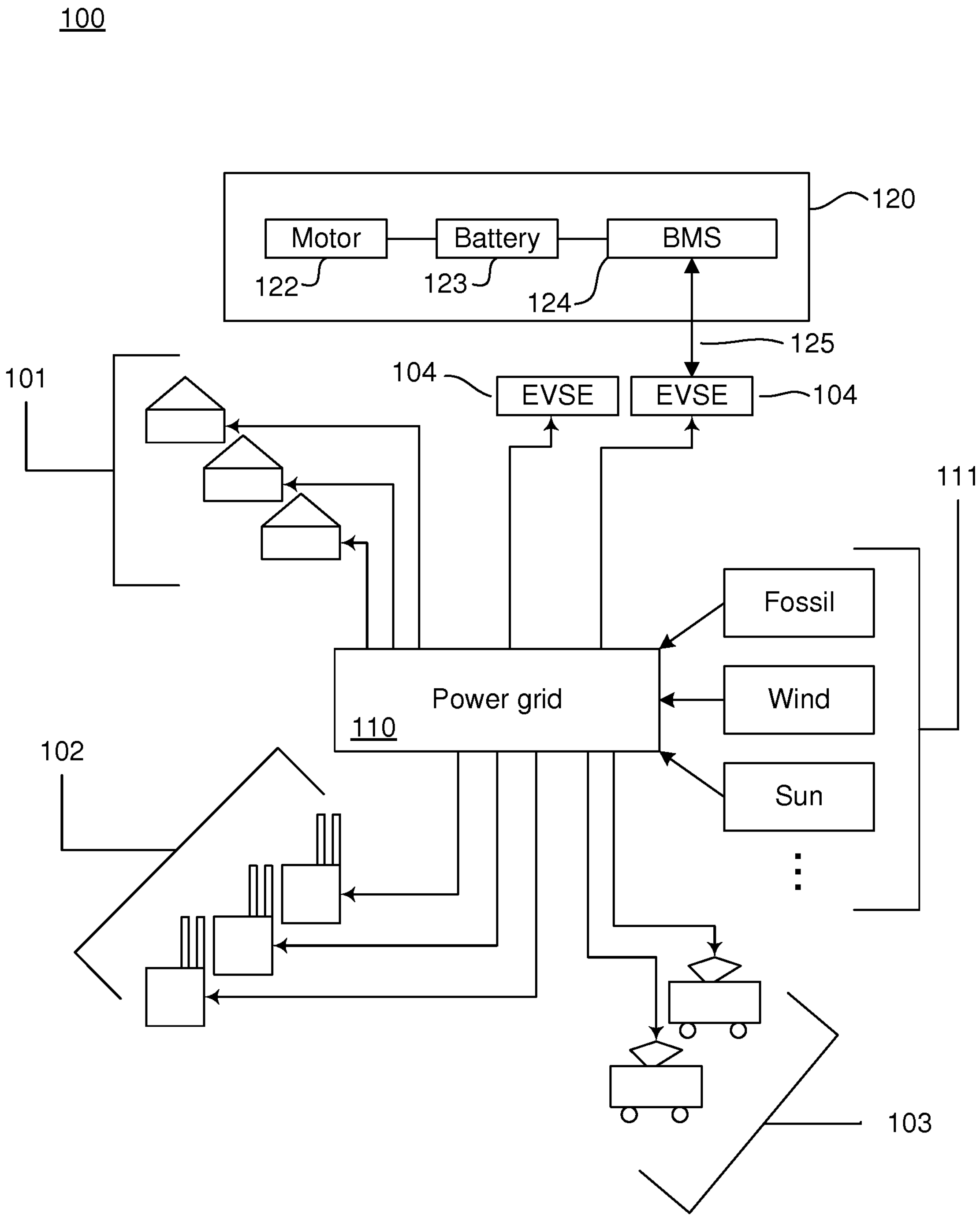

100
120
Motor
Battery
BMS
122
123
124
125
101
104
EVSE
EVSE
104
111
Fossil
Power grid
110
Wind
102
Sun
103

FIG. 1

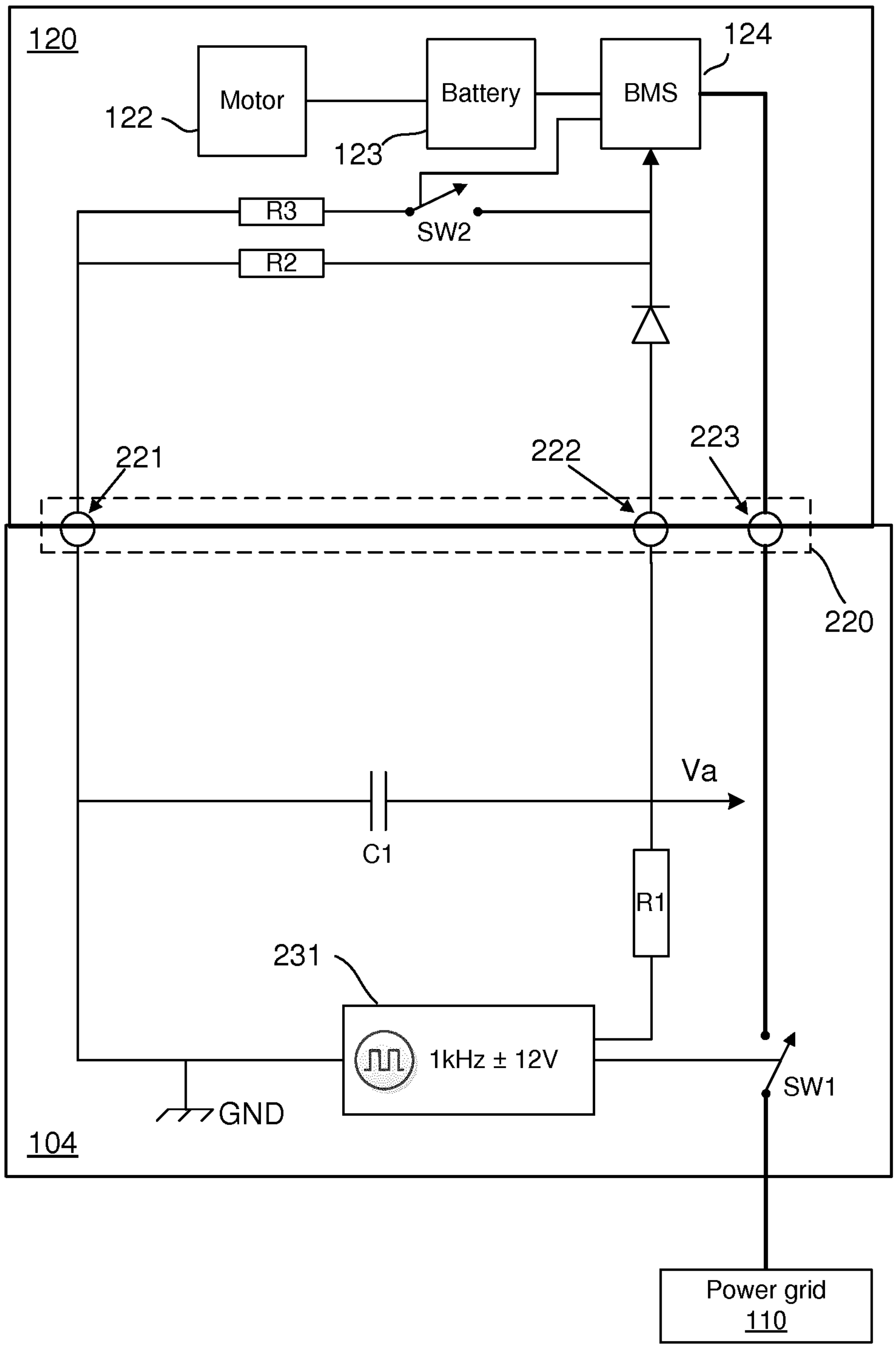

120
Motor
Battery
BMS
124
122
123
R3
SW2
R2
221
222
223
220
Va
C1
R1
231
1kHz ± 12V
SW1
GND
104
Power grid
110

FIG. 2

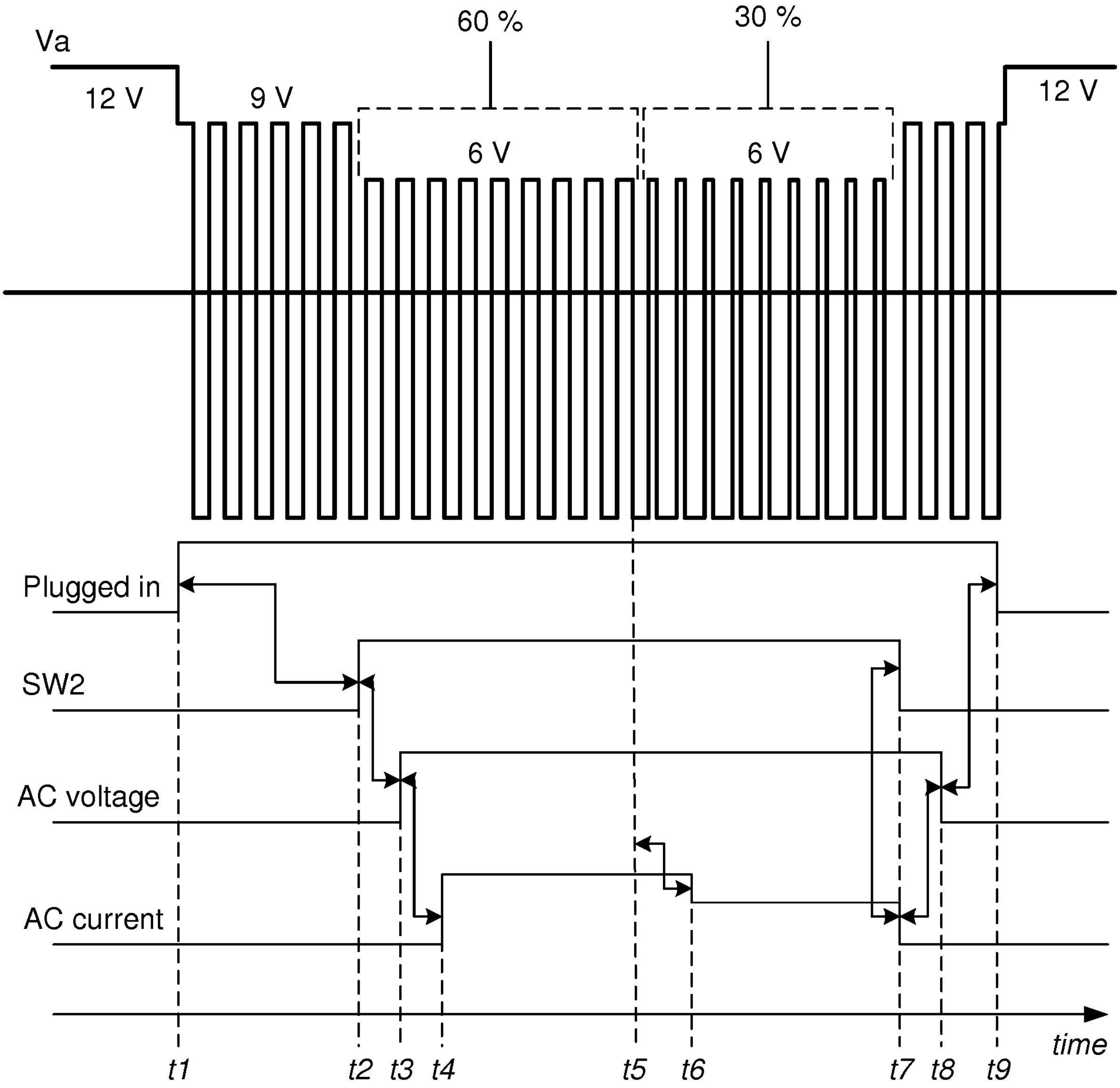

Va
12 V
9 V
60 %
6 V
30 %
6 V
12 V
Plugged in
SW2
AC voltage
AC current
time
t1
t2
t3
t4
t5
t6
t7
t8
t9

FIG. 3

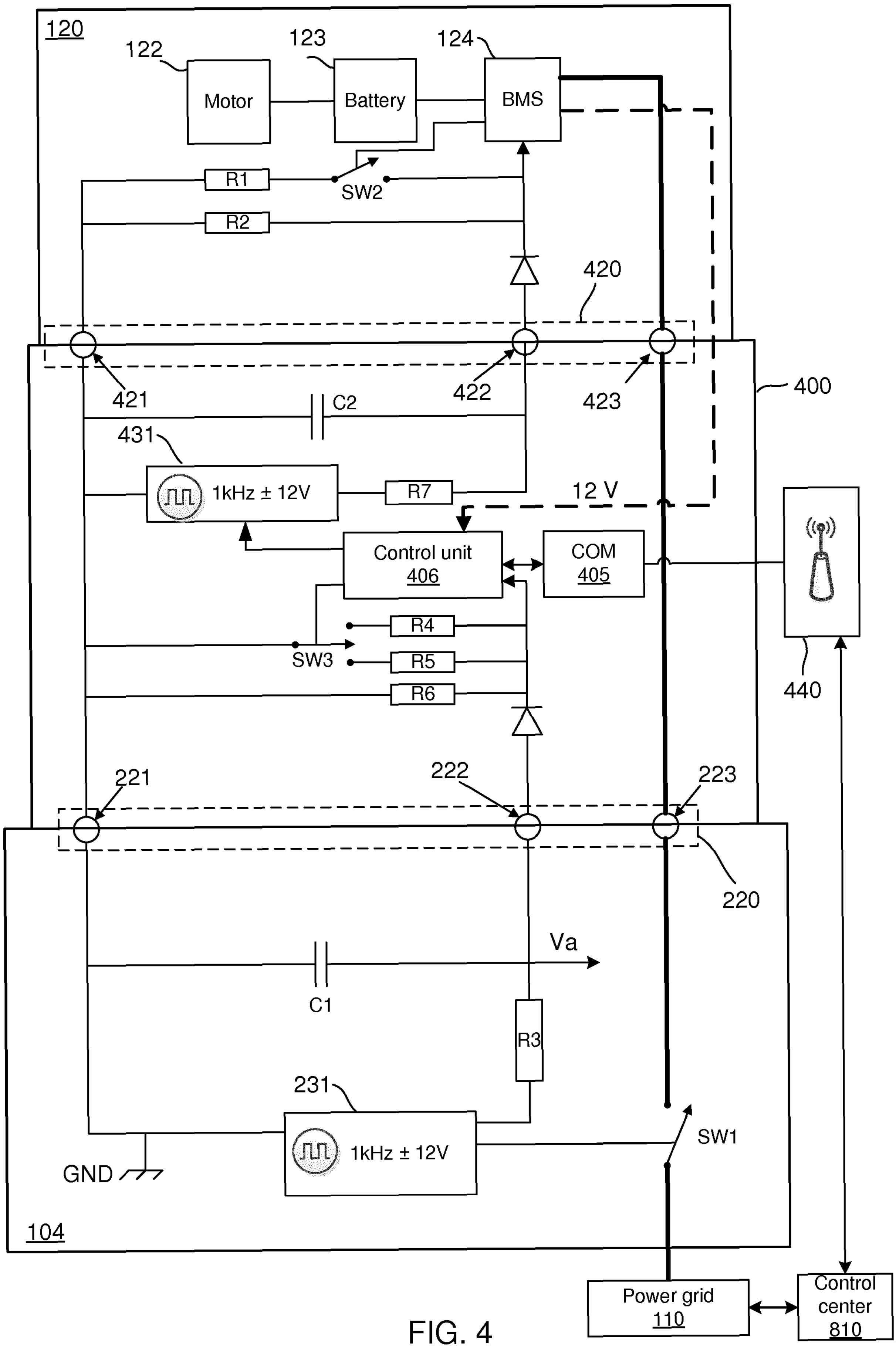
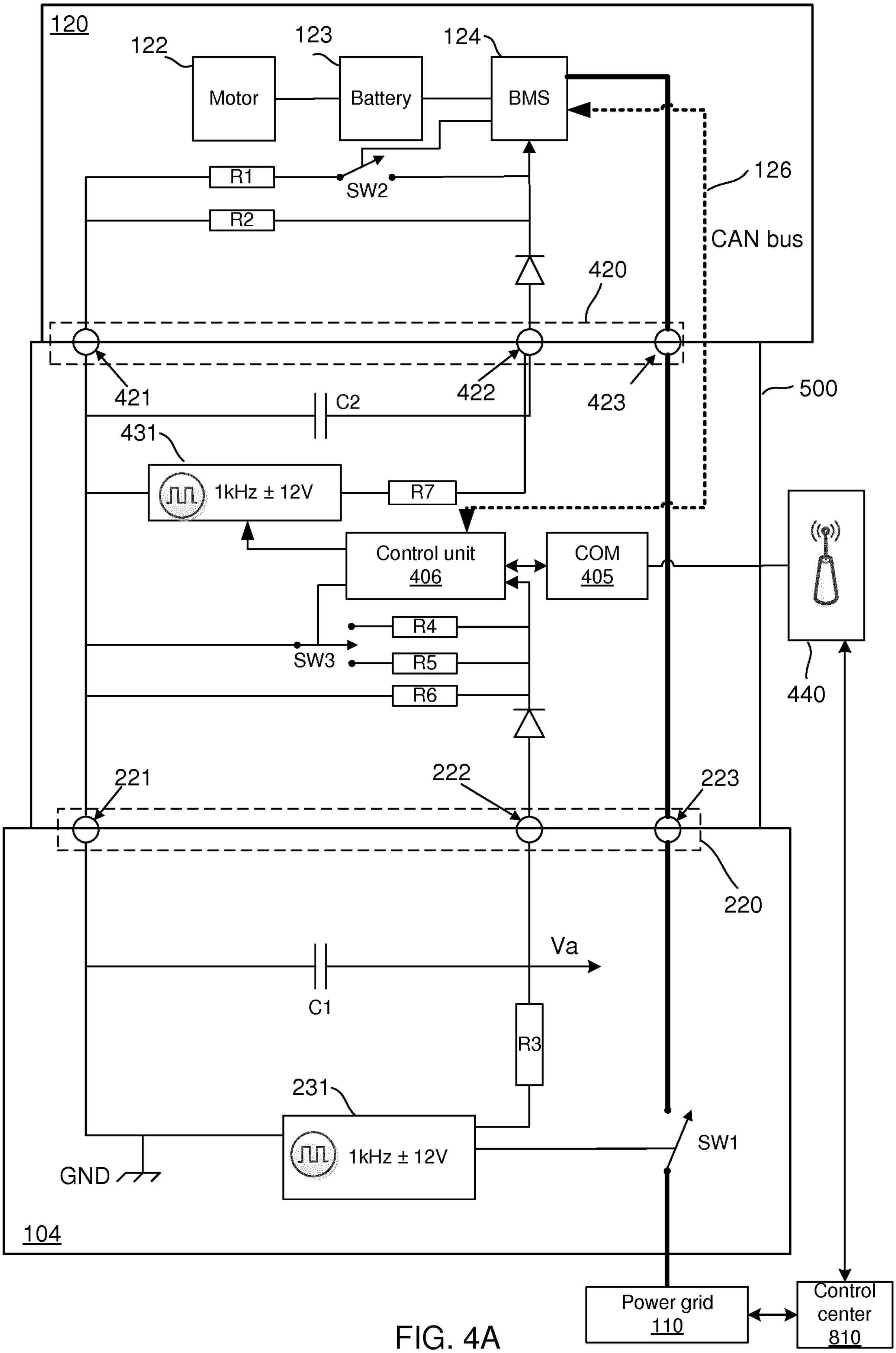

120
122
123
124
Motor
Battery
BMS
R1
SW2
R2
420
421
422
423
400
C2
431
1kHz ± 12V
R7
12 V
Control unit
406
COM
405
R4
SW3
R5
R6
440
221
222
223
220
Va
C1
R3
231
1kHz ± 12V
SW1
GND
104
Power grid
110
Control center
810

FIG. 4



120
122
123
124
Motor
Battery
BMS
R1
SW2
R2
126
CAN bus
420
421
422
423
500
C2
431
1kHz ± 12V
R7
Control unit
406
COM
405
R4
SW3
R5
R6
440
221
222
223
220
Va
C1
R3
231
1kHz ± 12V
SW1
GND
104
Power grid
110
Control
center
810

FIG. 4A

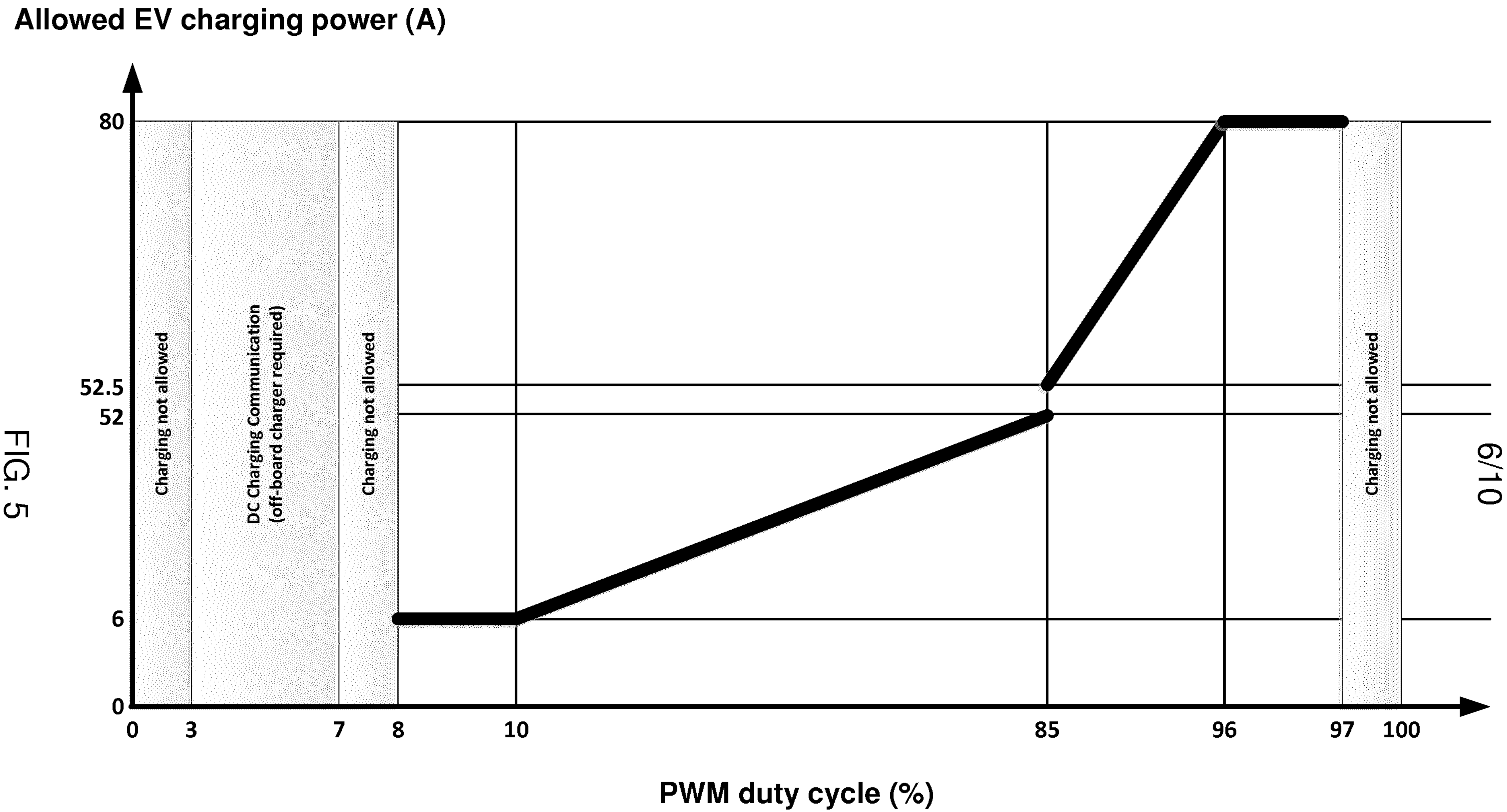

Allowed EV charging power (A)
80
52.5
52
6
0
0
3
7
8
10
85
96
97
100
PWM duty cycle (%)
Charging not allowed
DC Charging Communication
(off-board charger required)
Charging not allowed
Charging not allowed

FIG. 5

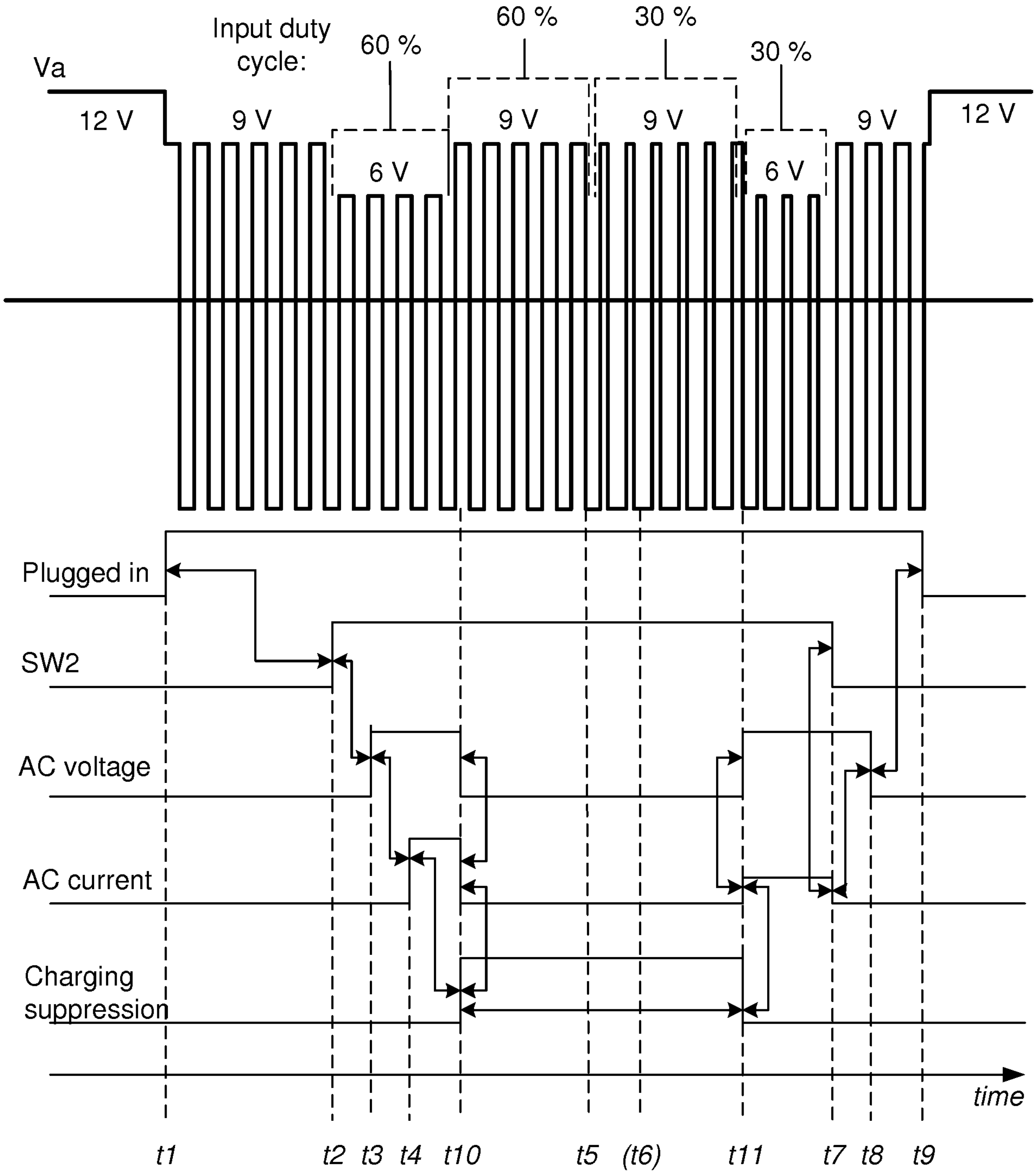

Input duty cycle:
60 %
60 %
30 %
30 %
Va
12 V
9 V
6 V
9 V
9 V
6 V
9 V
12 V
Plugged in
SW2
AC voltage
AC current
Charging suppression
time
t1
t2
t3
t4
t10
t5
(t6)
t11
t7
t8
t9

FIG. 6

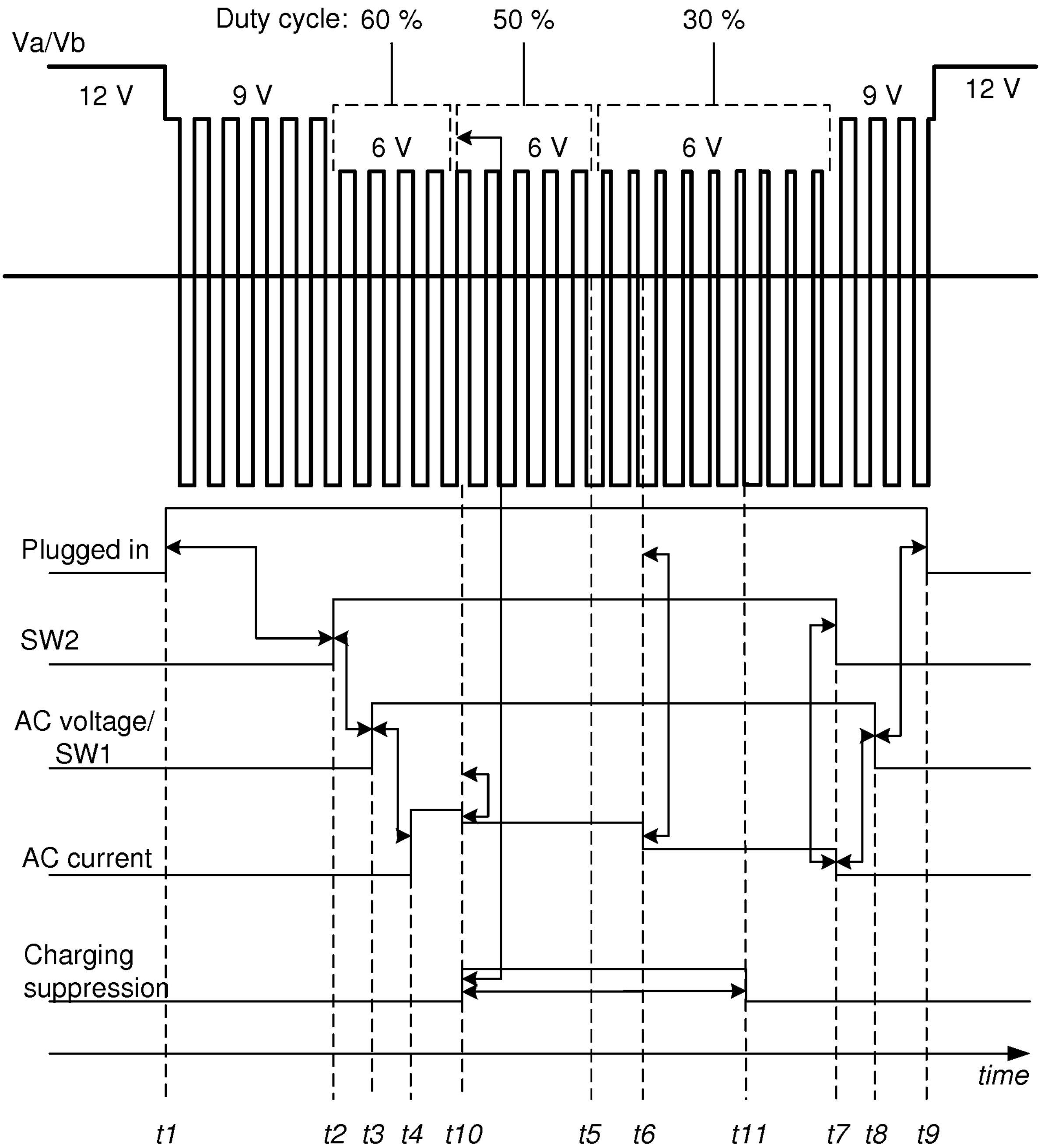

Duty cycle: 60 %
50 %
30 %
Va/Vb
12 V
9 V
6 V
6 V
6 V
9 V
12 V
Plugged in
SW2
AC voltage/ SW1
AC current
Charging suppression
time
t1
t2
t3
t4
t10
t5
t6
t11
t7
t8
t9

FIG. 7

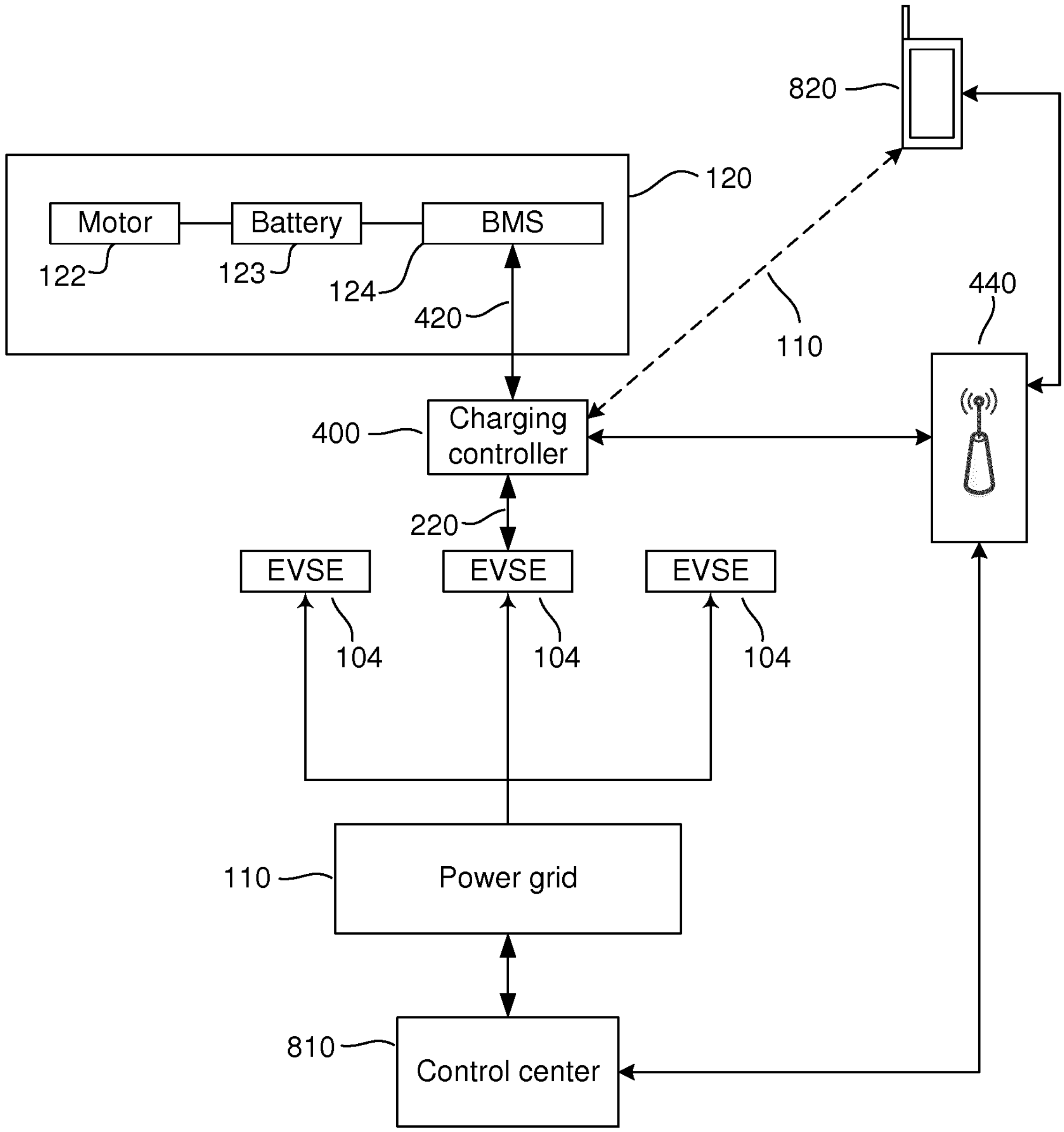

820
120
Motor
Battery
BMS
122
123
124
420
110
440
400
Charging controller
220
EVSE
EVSE
EVSE
104
104
104
110
Power grid
810
Control center

FIG. 8

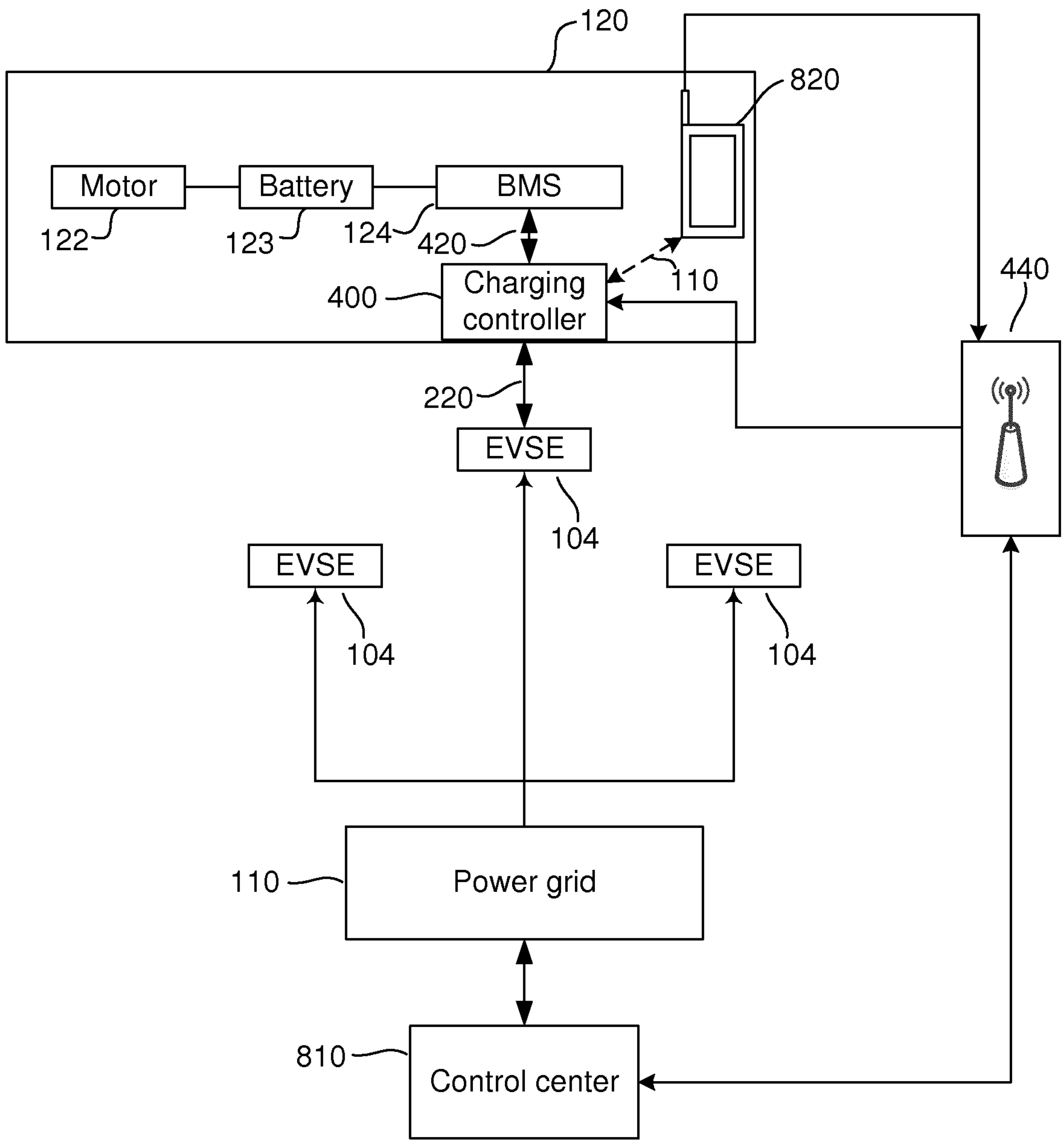

120
820
Motor
Battery
BMS
122
123
124
420
110
440
400
Charging controller
220
EVSE
104
EVSE
EVSE
104
104
110
Power grid
810
Control center

FIG. 9

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2015/075546

A. CLASSIFICATION OF SUBJECT MATTER
INV. B60L11/18
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B60L

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 10 2010 014417 A1 (MORICH ROLF [DE] HEPPNER HENNING [DE]) 13 October 2011 (2011-10-13) abstract figures 1-3 paragraphs [0004], [0009] - [0021] claims 1-5	1-15
X	DE 10 2009 025302 A1 (RWE AG [DE]) 16 December 2010 (2010-12-16) abstract page 1; figures 1, 2, 4 paragraphs [0005] - [0007], [0010] - [0017], [0020] - [0036], [0039] - [0042], [0048] - [0074] claims 1-20	1-10,13, 15

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
6 January 2016	26/01/2016

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Schmitt, Gilles

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