FORM 2

The Patent Act 1970

(39 of 1970)

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The Patent Rules, 2005

(See Section 10 and Rule 13)

COMPLETE SPECIFICATION

TITLE OF THE INVENTION

A vehicle-to-vehicle charging controller and a method thereof

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The following specification particularly describes the invention and the manner in which it is to be performed: -

Technical field

[0001] The disclosed subject matter in general relates to peer to peer charging by electric vehicles. The subject matter in particular relates to charging a recipient electrical vehicle by a donor vehicle by setting a cut off limit for charging.

Background

[0002] As electric vehicles (EVs) become more popular, vehicle-to-vehicle (V2V) energy transfer has emerged as a potential solution to address range anxiety and emergency charging scenarios. In V2V charging, one vehicle (the donor or first vehicle) provides electric energy to another (the recipient or second vehicle), typically in emergency or low-battery situations.

[0003] However, an unresolved challenge in V2V energy transfer is ensuring that the first/donor vehicle does not deplete its battery to a point where it can no longer reach a charging station. This poses a risk to both vehicles and can negate the benefits of the energy transfer. Currently, no robust systems are in place to intelligently manage a safe cut-off limit for the first vehicle during such energy transfer sessions.

[0004] Conventional V2V systems suffer from several drawbacks, examples are given below:

[0005] Uncontrolled transfer: Donor vehicles may discharge excessively, risking immobility.

[0006] Lack of intelligence: No integrated mechanism exists to calculate safe discharge thresholds based on real time driving conditions, navigation data and energy requirements.

[0007] Some known arts disclose peer to peer charging by electrical vehicles.

[0008] One known art US20240140211A1 discloses methods and apparatuses that can facilitate charging of a battery cell of an electric vehicle in the process of electrical charge transfer between electric vehicles. In this known art, a first vehicle needing charging, locates a second vehicle which can charge the battery of the first vehicle. Once it is agreed between the vehicles, the charging is initiated by the second vehicle to the first vehicle.

[0009] However, in the above known art, it is not mentioned when the second vehicle stops the charging process. It may so happen that the charge level in the second vehicle may reach low level even to drive to a nearest charging station.

[0010] Another known art US 2020/0333151 A1 discloses a system for Peer to Peer Charge Sharing and Smart Electric Vehicle Charging Infrastructure Integration using Internet of Things (IoT). It utilizes an on demand EV charging model with a mobile app to locate nearest available charging for users through GPS, SMS text messaging notification to confirm booking in real time. However, in this known art also, it is not mentioned when the second vehicle stops the charging process. It may so happen that the charge level in the second vehicle may reach so low level that it may not be possible to drive to a nearest charging station.

[0011] Accordingly, there is a need for an intelligent system that allows controlled V2V charging while ensuring that the donor EV retains sufficient charge to reach at least one nearby charging station.

[0012] The disclosed subject matter addresses the above issues.

Summary

[0013] The subject matter is defined in the independent claims. Further details are defined in the dependent claims.

[0014] The present disclosure provides a method and system for vehicle-to-vehicle energy transfer in which the donor vehicle calculates and enforces a reserve state of charge (SoC) of the battery. This reserve SoC is dynamically determined based on the estimated energy required to reach the nearest charging station, accounting for real-time route data, traffic, elevation, weather conditions and vehicle consumption parameters.

[0015] During a charging session between the donor vehicle and the recipient vehicles, the donor vehicle continuously updates the reserve energy to be retained, monitors its own SoC and automatically terminates the energy transfer once the calculated reserve SoC is reached. This ensures the donor vehicle retains enough charge to reach a charging station safely.

[0016] Brief description of the drawings

[0017] The detailed description is described with reference to the accompanying figures. In the figures, similar reference numerals are used throughout the drawings to reference like features and components.

Figure 1 illustrates a donor vehicle according to an embodiment

Figure 2 illustrates a recipient vehicle according to an embodiment

Figure 3A, 3B illustrate power transfer units according to an embodiment

Figure 4 illustrates a charging controller according to an embodiment

Figure 5 illustrates a memory unit according to an embodiment

Figure 6 illustrates a method of transferring electric power form a donor vehicle to a recipient vehicle according to an embodiment

Detailed description

[0018] The subject matter now will be described with exemplary embodiments. However, the claimed subject matter may be embodied in many different forms and should not be construed as limited to the embodiments described herein. These embodiments are provided only as examples so that this disclosure is clear and concise.

[0019] Only the details/components required to describe the claimed subject matter in specific, are disclosed in this document. The details/components which are commonly known or understood by people skilled in the art may not be covered in this document.

[0020] In this document some terms may be used interchangeably. The term ‘vehicle’ may refer to the electrical vehicle, hybrid vehicle or any other vehicle which uses electrical power for driving. The terms ‘power transfer’ and ‘energy transfer’ may be used interchangeably. The terms ‘vehicle’ and ‘electrical vehicle’ may be used interchangeably.

[0021] The subject matter provides a method and system for vehicle-to-vehicle energy transfer in which the first vehicle calculates and enforces a reserve battery state of charge (SoC). This reserve SoC is dynamically determined based on the estimated energy required to reach a nearest charging station, accounting for real-time navigation data like, route details, traffic, terrain, weather conditions, historical driving data and vehicle consumption parameters.

[0022] During a charging session between the donor and recipient vehicles, the donor vehicle continuously updates the reserve SoC to be retained, monitors its own SoC and automatically terminates the energy transfer once the calculated reserve SoC is reached. This ensures the donor vehicle retains enough charge to reach a charging station safely.

[0023] Figure 1 illustrates a donor vehicle 100 which is in a position to transfer energy to a recipient vehicle 200 shown in figure 2. The donor vehicle 100 comprises a power transfer system 102, a communication unit 104, navigation unit 108 and a notification unit 106. The communication unit 104 may comprise one of a Bluetooth module or any other wired or wireless communication module which can establish communication with the recipient vehicle 200. The navigation unit 108 is responsible for route guidance for the donor vehicle100 and also provides information/data on points of interest destinations like a nearest charging station, distance, and other navigation data like traffic conditions, weather conditions, terrain conditions etc. The notification unit 106 comprises at least one of a display of the infotainment device, instrumentation cluster, a lamp, a buzzer, an audio output device etc. The notification unit 106 is output with notifications before starting of the power transfer, during power transfer and after termination of the power transfer. The power transfer system 102 is responsible for controlling and monitoring the power/energy transfer from the donor vehicle 100 to the recipient vehicle 200. The power transfer system 102 comprises a charging controller 112, a power transfer unit 110, a battery 114 and a Battery Management System, BMS 116. The power transfer unit 110 mainly comprises power related components.

[0024] Figure 2 illustrates a recipient vehicle 200. The recipient vehicle 200 comprises similar components as of donor vehicle 100. The recipient vehicle 200 comprises a power transfer system 202, a communication unit 204 and a notification unit 206. The communication unit 204 comprises one of a Bluetooth module, or any other wired or wireless communication module which can establish communication with the donor vehicle 100. The notification unit 206 comprises at least one of a display of the infotainment device, instrumentation cluster, a lamp, a buzzer, an audio output device etc. The notification unit 206 is output with notifications before starting of the power transfer, during power transfer and after termination of the power transfer. The power transfer system 202 is responsible for controlling and monitoring the power/energy transfer from the donor vehicle 100 to the recipient vehicle 200. The power transfer system 102 comprises a charging controller 212, a power transfer unit 210, a battery 214 and a Battery Management System, BMS 216. The power transfer unit 210 mainly comprises power related components.

[0025] Figure 3A and 3B illustrate the block diagrams of the power transfer units 110 and 210 of the donor and recipient vehicles 100, 200 respectively. Whatever is described for power transfer unit 110 with respect to figure 3A is also applicable to power transfer unit 210 with respect to figure 3B.

[0026] The power transfer unit 110 comprises a DC-DC converter 300, protection circuits 302, isolation circuits 304, a fail-safe relay 306 and output ports and connectors 308.

[0027] Whatever is described with the system 102, components of the donor vehicle 100 is also applicable for recipient vehicle 200.

[0028] The DC-DC Converter 300 is a Bidirectional DC-DC Converter capable of stepping up/down voltage/current from donor vehicle battery 114 to recipient vehicle battery voltage/current level. The DC-DC converter 300 comprises high-power MOSFETs/ Insulated Gate Bipolar Transistor IGBTs with gate drivers for regulating duty cycle; inductor & capacitors for energy storage for voltage smoothening and current regulation, current sense resistor/hall-effect sensor for real-time current measurement at output side.

[0029] The Pulse Width Modulation, PWM, duty cycle of MOSFETs in the DC-DC converter 300 is dynamically adjusted by the charging controller 112 to regulate current flow. Feedback loop ensures constant current (CC) or constant voltage (CV) mode as per recipient vehicle's power parameters. If overcurrent/over-temperature is detected, the charging controller 112 reduces PWM duty cycle or shuts down the DC-DC converter 300. In an embodiment the DC-DC converter 300 is a programmable DC-DC converter which can be programmed/controlled by the charging controller 112.

[0030] The protection circuits 302 comprise overcurrent protection components like fuses, relays, circuit breakers; overvoltage and under-voltage cutoff circuits, surge protection and reverse polarity protection. The protection circuits 302 are controlled and monitored by the charging controller 112 through input output interfaces 404.

[0031] The isolation circuits 304 enable the transfer of power while blocking high currents, ensuring that one circuit does not interfere with another. Typical example of isolation circuits are isolation transformers.

[0032] The fail-safe relay 306 is an electromechanical or solid-state relay. If a fault occurs, the fail-safe relay 306 is opened by the charging controller. In V2V charging, this prevents uncontrolled current flow leading to battery damage.

[0033] Output ports and connectors 308 comprise standardized charging interfaces/connectors such as Combined Charging System, CCS, connector, CHAdeMO (short for *"CHArge de MOve"*) connector or wireless inductive pads etc.

[0034] The connectors 308 are connected to the connector of the power transfer system 202 for charging the recipient vehicle 200.

[0035] The recipient vehicle 200 comprises similar components for power transfer and have similar functionalities as described for the donor vehicle 100.

[0036] Figure 4 illustrates a block diagrams of the charging controller 112 disposed in the donor vehicle 100. Similar charging controller is located in the recipient vehicle 200. Whatever is described for donor vehicle 100 is also applicable to recipient vehicle 200.

[0037] The charging controller 112 comprises a processor unit 400, a memory unit 402, input output interfaces 406, power electronics driver circuits 408, a navigation interface 410 and a BMS interface 412.

[0038] The processor unit 400 may comprise one or more of microcontrollers, central processing units (CPU), graphical processing units (GPU), digital signal processors (DSP), application specific integrated circuits (ASIC), a controller, field programmable gate arrays (FPGA), or any other hardware device, a firmware device, or any combination of these. The processor unit 400 is configured using its control registers, input output ports, firmware, input output interfaces 404 etc. to perform the operations described herein.

[0039] In an embodiment, the memory unit 402 comprises one or more volatile and non-volatile memory components which are capable of storing data and instructions to be executed.

[0040] The input output interfaces 404 may comprise input ports and output ports of the processor unit 400, connected to input output devices like displays, buzzer, audio output unit etc. The input output interfaces 404 are also connected to Power electronics driver circuits 406 to control and monitor the transfer of power between the donor and recipient vehicles 100, 200. The power electronics driver circuits 406 are interfaces between a low-power charging controller 112 (microcontroller, DSP, or FPGA) and a high-power switching device (MOSFET or IGBT) of the DC-DC converter 300.

[0041] The charging controller 112 outputs low-voltage logic signals through the input output interfaces 404. The power switches (MOSFETs/IGBTs) need higher drive voltages and fast current pulses to charge and discharge their capacitances. The power electronics driver circuits 406 amplify and isolates these signals so the switches can turn on/off efficiently and safely.

[0042] The navigation interface 410 may comprise a Controller Area Network bus (CAN Bus), or Media Oriented Systems Transport, MOST, bus. The CAN bus is used by the navigation unit 108 to send and receive data such as navigation data, vehicle speed, steering angle, and GPS coordinates. MOST bus is used to transmit multimedia data.

[0043] The BMS interface comprises CAN bus for exchange of data, commands with the BMS 116.

[0044] The recipient vehicle 200 comprises similar components for charging controller 212.

[0045] Figure 5 illustrates details of the memory unit 402. The memory 402 comprises various firmware modules. The firmware modules comprise communication module 502, navigation interface module 504, SoC computation module 506, notification generation module 508, power transfer control module 510 and fail-safe handling module 512.

[0046] The communication module 502 is responsible for exchanging messages between the donor vehicle 100 and recipient vehicle 200. The communication module 500 is implemented as combination of firmware and hardware. The hardware part may comprise input output ports, data bus, for configuring the communication component, for example, Bluetooth module or Universal Asynchronous Receiver/Transmitter, UART component, which may be available in the microcontroller, ex. the processor unit 400.

[0047] The navigation interface module 504 is implemented as combination of firmware and hardware. The hardware part may comprise configuring the CAN bus and exchanging the commands and navigation data on the CAN bus with the navigation unit 108.

[0048] The SoC computation module 506 interacts with the machine learning module/model 500 to compute the reserve SoC.

[0049] The notification generation module 508 generates notifications for the user. The notifications may be visual or audio outputs, buzzers, lamps etc. The notifications indicate the status of the charging. The notification generation module is implemented as combination of firmware and hardware. The hardware part comprises the output ports of the processor unit and sending signals through the input output interfaces 404 to the notification unit 108.

[0050] The power transfer control module 510 controls and monitors the power transfer unit 110. The power transfer control module 510 is implemented as combination of firmware and hardware. The hardware part comprises the output ports of the processor unit and sending signals through the input output interfaces 404 to the Power electronics driver circuits 406.

[0051] The fail-safe handling module 512 monitors for any fault conditions and immediately disconnects the battery 114 of the donor vehicle 100 from the battery 214 of the recipient vehicle 200 by opening the fail-safe relay 306. The fail-safe handling module 512 is implemented as combination of firmware and hardware. The hardware part comprises the output ports of the processor unit and sending signals through the input output interfaces 404 to the fail-safe relay 306.

[0052] The working of the power transfer system 102 is described below with reference to figures 1-5.

[0053] When the recipient vehicle 200 is running low on its battery, the communication unit 204 comprising a Bluetooth module scans the nearby vehicles for transfer of power. If a device for pairing is found in a nearby vehicle referred as donor vehicle 100, the communication unit 204 initiates pairing process with the communication unit 104 of the donor vehicle 100. Once pairing is done, messages are exchanged between the vehicles 100, 200 through the communication units 104, 204 by the communication module 502. As part of messages, a request message is sent by the recipient vehicle 200 through a wired communication or wireless communication, for example over a standard connection like a Controller Area Network, CAN bus or through Bluetooth module. The request message comprises vehicle identifier, message code and error detection codes. The error detection codes are used to determine integrity of the message. A notification is generated by the notification generation module 508, to the user of the donor vehicle 100 informing about the request from the recipient vehicle 200 for power transfer. The notification may be through a message on the dashboard, lighting of a lamp, an audio output etc. Once the user of the donor vehicle 100 accepts the request for potential transfer of power, a positive acknowledgement is sent to the recipient vehicle 200, otherwise a negative acknowledgement is sent. The acceptance by the user may be through pressing of a key on a dashboard. The positive acknowledgement also comprises request for power parameters from the recipient vehicle 200. The recipient vehicle 200 sends power parameters like charging voltage, charging current, connector type/details to the donor vehicle 100. All the message exchanges are handled by the communication module 502.

[0054] The charging controller 112 receives the power parameters from the recipient vehicle 200 through the communication module 502. The power transfer control module 510 checks whether the recipient vehicle's power parameters are compatible with the donor vehicle's power parameters. The checking may involve comparing with a database in the memory 402 where the power parameters of the donor vehicle 100 are stored.

[0055] Once the recipient vehicle's power parameters are compatible with the donor vehicle's power parameters, the power transfer control module 510 proceeds to check available state of charge, SoC, in the battery 114 of the donor vehicle 100.

[0056] The available SoC is obtained by power transfer control module 510, from the battery management system 116 over the CAN bus through the BMS interface 412. The battery management system 116 of the donor vehicle maintains the battery parameters like SoC, State of Health, SoH, voltage level, current level etc. and sends the data regularly on CAN bus.

[0057] If the available SoC is below a pre-defined threshold, a negative acknowledgement is sent to the recipient vehicle 200 and the communication is terminated.

[0058] If the available SoC is above or equal to the pre-defined threshold, the processor unit 400 requests the navigation unit 108 regarding information about the distance to a nearest charging station, and other navigation data like route conditions, traffic condition, terrain information, weather conditions etc. The request is sent over navigation interface 410 to the navigation unit 108.

[0059] The navigation unit 108 obtains the navigation data like, route conditions, traffic condition, terrain information, weather conditions etc. from a cloud server. Weather data is collected by the cloud provider (from meteorological services, satellites, government weather agencies, etc.). The Traffic data comes from multiple sources: GPS probes from vehicles, mobile devices, road sensors, cameras, and third-party traffic data providers. The cloud server processes, aggregates, and compresses this raw information into usable datasets for navigation (e.g., congestion levels, road closures, rainfall along a route). The navigation unit 108 connects to the cloud server through the vehicle's connectivity module or a paired device, Built-in modem (Telematics Control Unit – TCU), cellular network (3G, 4G, 5G, Long-Term-Evolution vehicle to anything, LTE-V2X), Smartphone tethering via Bluetooth, Wi-Fi, or USB, Head unit with Wi-Fi connects to hotspot or external network.

[0060] The navigation unit 108communicates with the cloud sever via standard internet protocols - HTTP/HTTPS, REpresentational State Transfer, REST, APIs for periodic updates; Message Queuing Telemetry Transport (MQTT), WebSockets for real-time updates. Data is typically encoded in JSON or XML format.

[0061] The navigation unit 108 requests weather and traffic layers from the cloud server based on Current location (from GNSS/GPS), Destination & route (map-matching). The cloud responds with relevant data. The navigation unit 108 merges this with map data and recalculates routes, distance to a destination etc.

[0062] The navigation unit 108 identifies a nearest charging station, computes the distance to the nearest charging station, acquires navigation data like the route conditions, traffic condition, weather conditions etc. from a cloud server and sends all the navigation data to the charging controller 112.

[0063] The SoC computation module 506, using the navigation data, computes a reserve SoC based on: (i) route energy estimate to nearest charging station determined from navigation data like, real-time traffic data, weather data, terrain data etc. (ii) an energy/km model trained on historical driving data; and (iii) a safety buffer.

[0064] The reserve SoC is the amount of charge added with a safety buffer, that needs to be retained to travel to a nearest charging station.

[0065] The safety buffer may be pre-defined or dynamically computed based on traffic conditions. Example, if the traffic is high or unpredictable, the safety buffer may be dynamically set as 30% of energy/km model to the charging station. If the traffic is low or predictable, the safety buffer may be dynamically set as 20% of energy/km model to the charging station. Similarly if the terrain gradient is high a certain factor for safety buffer is set. Based on the travel time to the charging station certain factor for safety buffer is set.

[0066] Once the reserve SoC is computed, the reserve SoC is used as cut-off limit for transfer of power. During the charging session, the reserve SoC is computed in real time using real time navigation data.

[0067] The power transfer control module 510 checks the present SoC. If the present SoC is higher than reserve SoC, a notification is generated indicating the power transfer system 102 is ready for power transfer. The power transfer system 102 of the donor vehicle 100 and the recipient vehicle 200 are connected using standard cables. A power transfer message is sent to the recipient vehicle 200 to prepare it for power transfer.

[0068] The power transfer control module 510 configures the DC-DC converter 300 to the required power parameters of the recipient vehicle 200. The DC-DC converter 300 may be configured to either step-up or step-down the voltage, current, to meet the power parameters of the recipient vehicle 200. The power transfer control module 510 uses input output interfaces 404 and power electronics driver circuits 404 for this.

[0069] The power transfer control module 510 activates the power transfer unit 110. This involves below steps:

[0070] Fail-safe relay 306 is closed to connect the donor battery 114 to recipient battery 214 through the DC-DC converter 300 and the connector. The DC-DC converter's input and output sense circuits are checked by the power transfer control module 510 to confirm healthy connections.

[0071] The power transfer control module 510 sends signals, through input output interfaces 404 to power electronics driver circuits 406 to switch them on. The power electronics driver circuits 406 are connected to the DC-DC converter 300. The MOSFETs/IGBTs in the DC-DC converter 300 start switching under PWM control. DC-DC converter 300 gradually increases duty cycle to ramp current smoothly. Output current is regulated according to recipient vehicle's charging current, reserve SoC and thermal limits of DC-DC converter 300.

[0072] The power transfer control module 510 continually monitors over-current, over-voltage, short circuit, SoC, reserve SoC, temperatures of DC-DC converter 300 and other components through reading the signals through the input output interfaces 404. The power transfer starts.

[0073] If any fault occurs fail-safe relay 306 is opened.

[0074] The reserve SoC is updated in real time based on real time navigation data by the SoC computation module 506.

[0075] The power transfer control module 510 continuously monitors the present SoC and the dynamically updated reserve SoC. Once the present SoC in the donor vehicle 100 is equal to or lesser than the reserve SoC, the power transfer is stopped.

If there is any malfunction, the power transfer is stopped. Stopping the power transfer is done by opening the fail-safe relay 306 by the power transfer control module 510 through the input output interfaces 404 and the power electronics driver circuits 406.

[0076] The charging controller 112 may incorporate machine learning models 500 trained on historical driving patterns, and navigation data like traffic data, terrain data, weather data and energy usage to improve prediction accuracy of reserve SoC. Over time, this enables more precise allocation of transferable energy.

[0077] In an embodiment, prior to charging and during a charging session, the power transfer control module 510 continuously computes the reserve SoC using machine learning models 500 and the real time navigation dat. In one embodiment, the reserve state-of-charge is dynamically computed by applying a machine learning (ML) model 500 that accounts for the donor vehicle’s historical driving patterns and real-time operating conditions and real time navigation data.

[0078] Machine Learning Model Architecture

[0079] The ML model 500 comprises at least one of a regression model, neural network, or gradient boosting algorithm trained to predict energy consumption per unit distance under varying conditions. Input features to the model 500 comprise Current vehicle weight/load, Road gradient (from GPS and map data), Real-time traffic congestion level, Ambient temperature and weather forecast, Battery temperature and state-of-health (SoH).

[0080] Regression Model: Learns linear/nonlinear mapping between route conditions and energy consumption per km.

[0081] Neural Network: Captures nonlinear dependencies (e.g., effect of slope + congestion + temperature).

[0082] Gradient Boosting Trees (e.g., eXtreme Gradient Boosting, XGBoost, Light Gradient Boosting Machine, LightGBM): Handles mixed feature inputs and outputs high accuracy in prediction.

[0083] This comprises the below steps.

[0084] Training Data Collection

[0085] The donor vehicle's charging controller 112 continuously collects historical driving data, comprising Average and peak energy consumption (Wh/km), Vehicle speed and acceleration patterns, Driving terrain (flat, hilly, mountainous), Ambient temperature and weather effects, Battery aging and degradation trends, Traffic conditions encountered (slow traffic, stop-and-go vs. highway). These data sets are periodically uploaded to a local or cloud-based ML training module. This step is handled by Driving history collection module 514. The ML model 500 uses this historical driving data to compute reserve SoC and safety buffer.

[0086] Real-Time Prediction

[0087] During the charging session, the power transfer control module 510 invokes the ML model 500 to predict the energy required for the donor vehicle 100 to travel from its current location to the nearest charging station.

[0088] The model 500 predicts and outputs an estimated energy consumption (kWh) value, which includes adjustments for real-time traffic, terrain, weather etc.

[0089] A safety buffer is added to the prediction to account for uncertainty.

[0090] Reserve SoC Computation

[0091] The predicted energy requirement plus the safety buffer is the reserve SoC to be maintained at the donor vehicle's battery 114.

[0092] Dynamic Updating

[0093] As traffic, route, or weather conditions change, the ML model 500 re-computes the energy requirement in real time. The reserve SoC is dynamically updated during charging session, ensuring that even if conditions worsen, the donor vehicle 100 always retains sufficient energy to reach a charging station.

[0094] Once the SoC of recipient vehicle 200 reaches above a pre-defined threshold, the recipient vehicle sends a message to stop the power transfer. The charging is terminated. The charging is also terminated by any vehicle, if any fault conditions are detected.

[0095] The firmware modules may be implemented using various languages like, C, Embedded C, C++, JAVA etc.

[0096] Given below are some examples how the modules for communicating through Bluetooth modules are developed for Android devices like Internet of Things (IoT) devices.

[0097] Tools and technologies used:

The tools used may comprise, Android Studio, Java or Kotlin programming language, Android Software Development Kit, Android Native Development Kit, Wi-Fi or Bluetooth module, Message Queuing Telemetry Transport, MQTT broker etc.

[0098] Android SDK: Software development kit for tools and libraries for developing Android apps.

[0099] Android NDK: a software development kit that provides tools and libraries for developing native code for Android apps.

[0100] MQTT, Message Queuing Telemetry Transport: A messaging protocol for IoT devices.

[0101] Different Application Programming Interface, APIs, like Nearby Connections API may be used to search, establish connection and transfer data between Android devices. Within the Nearby Connections API, the function startDiscovery () function may be used to discover other devices like system 100.

Once other devices are discovered, the function requestConnection () is used to request a connection. The connection request is accepted through acceptConnection () or rejected through rejectConnection () by devices. Once the connection is accepted, the two communication units 104 and 204, can exchange messages/data. Also the JAVA APIs like navigator.bluetooth.requestDevice may be used to discover, connect and transfer data between IoT devices.

[0102] Figure 6 illustrates a method 600 for transferring electric power form the donor vehicle 100 to the recipient vehicle 200. The method 600 is performed by the power transfer system 102 on the donor vehicle 100. The method starts with step 602.

[0103] Step 602 discloses receiving, from the recipient vehicle 200, a request for power transfer. The step 602 is performed by the communication module 502 using the communication unit 104.

[0104] Step 604 discloses obtaining real-time state-of-charge (SoC) data from a battery management system 116 of the donor vehicle 100. The step 602 is performed by the SoC computation module 506 through the BMS interface 412.

[0105] Step 606 discloses receiving, form a navigation unit 108, distance to a nearest charging station, including navigation data comprising at least one of terrain information, traffic conditions and weather conditions. Step 606 is performed by the Navigation interface module 504 using the navigation interface 410.

[0106] Step 608 discloses computing, a reserve SoC for the donor vehicle 100, based on an estimated power consumption, required to travel from a current location of the donor vehicle to the nearest charging station based on the navigation data and further including a safety buffer. The step 608 is performed by the SoC computation module 506.

[0107] Step 610 discloses starting a charging session by activating a DC-DC converter 300 of the power transfer unit 110 to transfer power from the donor vehicle 100 to the recipient vehicle 200, if the present SoC is greater than the reserve SoC. The step 610 is performed by the Power transfer control module 510 using Power electronics driver circuits 406.

[0108] Step 612 discloses continuously computing, during the charging session, the reserve SoC required for the donor vehicle 100 to reach the nearest charging station. The step 612 is performed by the SoC computation module 506.

[0109] Step 614 discloses terminating the charging session when, the SoC of donor vehicle 100 reaches the reserve SoC; or the recipient vehicle sends a stop message; or a fault condition including overvoltage, overcurrent, over-temperature, or communication failure is detected. The step 614 is performed by the Power transfer control module 510 using the Power electronics driver circuits 406.

[0110] The method 600 discloses receiving a request for power transfer comprising pairing between the two communication units 104, 204; exchanging messages comprising vehicle identification numbers; and exchanging pre-transfer messages like power parameters.

[0111] The method 600 discloses exchanging pre-transfer messages comprising receiving, from the recipient vehicle 200, power parameters, wherein the power parameters comprise voltage required for charging, current required for charging and connector type; sending a positive acknowledgement to the recipient vehicle 200 if the power parameters of the recipient vehicle 200 are compatible with the power parameters of the donor vehicle 100.

[0112] The method 600 discloses starting the charging session comprising generating a notification at the donor vehicle 100 to indicate that the power transfer has started.

[0113] The method 600 discloses starting the charging session comprising dynamically adjusting at least one of the charging current and charging voltage according to power parameters of the recipient vehicle 200.

[0114] The method 600 discloses activating the DC-DC converter comprising closing the failsafe relay 306; and activating the power electronics circuits 406 through the input output interfaces 404 by the power transfer control module 510.

[0115] The method 600 discloses computing the reserve SoC, comprising applying a machine learning model trained on historical driving data of the donor vehicle 100 to predict power consumption under current traffic, weather and terrain conditions, wherein the machine learning models 500 comprise at least one of a regression model, neural network, or gradient boosting algorithm trained to predict power consumption per unit distance under varying conditions.

[0116] The method 600 discloses terminating the charging session comprising actuating a fail-safe relay to electrically isolate the donor and recipient vehicles 100, 200.

[0117] The method 600 discloses where the safety buffer is dynamically adjusted based on at least one of: ambient temperature, battery health state, or historical variance in energy prediction accuracy.

[0118] The subject matter provides various technical advantages/technical effects. Some are mentioned below as examples.

[0119] The subject matter ensures that the donor vehicle 100 always retains sufficient energy for continued operation.

[0120] The subject matter improves reliability and trust in vehicle to vehicle charging scenarios.

[0121] The subject matter provides dynamic adaptability based on real-time driving conditions.

[0122] The subject matter reduces range anxiety by offering stranded vehicles emergency charging support.

[0123] The subject matter enhances EV ecosystem resilience in areas with limited charging infrastructure.

Reference numerals and their description:

100	Donor vehicle
102	Power transfer system
104	Communication unit
106	Notification unit
108	Navigation unit
110	Power transfer unit
112	Charging controller
114	Battery
116	Battery management system
200	Recipient vehicle
202	Power transfer system
204	Communication unit
206	Notification unit
210	Power transfer unit
212	Charging controller
214	Battery
216	Battery management system
300	DC-DC converter
302	Protection circuits
304	Isolation circuits
306	Fail-safe relay
308	Output port and connectors
400	Processor unit
402	Memory unit
404	Input output interfaces
406	Power electronics driver circuits
500	Machine learning models
502	Communication module
504	Navigation interface module

506 SoC computation module 506

508 Notification generation module 508

510 Power transfer control module

512 Fail-safe handling module 512

514 Driving history collection module

We claim:

1. A method (600) for transferring electric power form a donor vehicle (100) to a recipient vehicle (200), the method (600) performed by the donor vehicle (100), the method (600) comprising:

    receiving (602), from the recipient vehicle 200, a request for power transfer;

    obtaining (604) real-time state-of-charge, SoC, from a battery management system (116) of the donor vehicle (100);

    receiving (606), form a navigation unit (108), distance to a nearest charging station and navigation data comprising at least one of predicted travel time to the nearest charging station, traffic data, terrain data, weather data on the route to the nearest charging station, historical driving data;

    computing (608), a reserve SoC for the donor vehicle (100), based on an estimated power consumption, required to travel from a current location of the donor vehicle (100) to the nearest charging station based on the navigation data and further including a safety buffer;

    starting (610) a charging session by activating a power transfer unit (110) to transfer power from the donor vehicle (100) to the recipient vehicle (200), if the present SoC is greater than the reserve SoC;

    computing (612), continuously, during the charging session, the reserve SoC required for the donor vehicle (100) to reach the nearest charging station based on the real time navigation data; and

    terminating (614) the charging session when:
    - the SoC of donor vehicle (100) is equal to or less than the reserve SoC; or
    - the recipient vehicle (200) sends a stop charging message; or
    - a fault condition comprising overvoltage, overcurrent, over-temperature, or communication failure is detected.

2. The method (600) as claimed in claim 1 wherein receiving a request for power transfer comprises:
    pairing between the communication units (104, 204) of the donor vehicle (100) and the recipient vehicle (200); and

exchanging messages comprising vehicle identification numbers; and
exchanging pre-transfer messages.

3. The method (600) as claimed in claim 2 wherein exchanging pre-transfer messages comprises:
   receiving, from the recipient vehicle (200), power parameters, wherein the power parameters comprise charging voltage, charging current and connector type;
   sending a positive acknowledgement to the recipient vehicle (200) if:
      the power parameters of the recipient vehicle (200) are compatible with the power parameters of the donor vehicle (100).

4. The method (600) as claimed in claim 1 wherein starting the charging session further comprises:
   generating a notification at the donor vehicle (100) indicating start of power transfer.

5. The method (600) as claimed in claim 3, wherein starting the charging session further comprises dynamically adjusting at least one of the charging current and charging voltage according to power parameters of the recipient vehicle (200).

6. The method (600) as claimed in claim 1, wherein activating the power transfer unit (110) comprises:
   closing a fail-safe relay (306); and
   activating the power electronics circuits (406) through the input output interfaces (404) by the charging controller (112) to switch on the MOSFETs/IGBTs in the DC-DC converter (300).

7. The method (600) as claimed in claim 1, wherein computing the reserve SoC, further comprises applying a machine learning model (500) trained on historical driving data of the donor vehicle (100) to predict power consumption based on the navigation data, wherein the machine learning models comprise at least one of a regression model, neural network, or gradient boosting algorithm trained to predict power consumption per unit distance under varying conditions.

8. The method (600) as claimed claim 1, wherein terminating the charging session further comprises opening the fail-safe relay (306) to electrically isolate the batteries (114, 214) of the donor and recipient vehicles (100, 200).

9. The method (600) as claimed claim 1, wherein the safety buffer is dynamically adjusted based on at least one of: ambient temperature, battery health state, navigation data and historical driving data.

10. A vehicle-to-vehicle charging controller (112), the charging controller (112) comprising:

    a battery management system interface (412) to interact with a battery management system (116);

    a navigation interface (208) to receive, from a navigation unit (108) of the electric vehicle (100):
        a distance to a nearest charging station; and
        navigation data comprising at least one of a predicted travel time, traffic data, terrain data, weather data on the route to the charging station and historical driving data;

    a state-of-charge, SoC, computation module (506) to compute a reserve state of SoC to reach the nearest charging station, based on the navigation data, the computation including a safety buffer;

    a power transfer control module (510) to:
        monitor SoC of the battery (114) of the vehicle (100) during the charging;
        control a power transfer unit (110) to:
            transfer power to the recipient vehicle based on the reserve SoC and real time navigation data;
            terminate the charging session when:
                the SoC of donor vehicle (100) reaches the reserve SoC; or
                the recipient vehicle (200) sends a stop message; or
                a fault condition comprising overvoltage, overcurrent, over-temperature, or communication failure is detected.

11. The vehicle-to-vehicle charging controller (112) as claimed in claim 10, comprising at least one machine learning models (500) to apply machine learning, trained on donor vehicle’s historical driving data, to predict energy consumption under current conditions for computing the reserve SoC, wherein the machine learning models (500) comprise at least one of a regression model, neural network, or gradient boosting algorithm trained to predict power consumption per unit distance under varying conditions.

12. The vehicle-to-vehicle charging controller (112) as claimed in claim 10, wherein the power transfer unit (110) is configured to dynamically adjust

charging current according to power parameters of the recipient vehicle (200).

13. The vehicle-to-vehicle charging controller (112) as claimed in claim 10, wherein the charging controller (112) is configured to dynamically update the safety buffer based on at least one of ambient temperature, battery aging, navigation data, or historical driving data of energy prediction models.

14. The vehicle-to-vehicle charging controller (112) as claimed in claim 10, wherein the safety buffer is dynamically computed according to real time navigation data comprising at least one of terrain data, weather data and traffic data.

15. The vehicle-to-vehicle charging controller (112) as claimed in claim 10, comprising:

    a communication module (502) to exchange messages with the receiver vehicle (200);

    a Navigation interface module (504) to request and receive navigation data from the navigation unit (108);

    a SoC computation module (506) to compute reserve SoC;

    a Notification generation module (508) to generate and send at least one notification to the notification unit (106);

    a Power transfer control module (510) to control the power transfer unit (110);

    a Fail-safe handling module (512) to handle fail-safe condition; and

    a Driving history collection module (514).

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Date: 15th Oct, 2025

ABSTRACT

TITLE: A vehicle-to-vehicle charging controller and a method thereof

The present disclosure provides a method 600 and a charging controller 112 for vehicle-to-vehicle energy transfer in which the donor vehicle 100 calculates and enforces a reserve state of charge (SoC) of the battery 114. This reserve SoC is dynamically determined based on the estimated energy required to reach the nearest charging station, accounting for real-time route data, traffic, elevation, weather conditions and vehicle consumption parameters.

To be published with figure 1