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(54) **Method and device for charging a battery and battery charger.**

(57) The present invention relates to a method for charging a battery, comprising heating a battery if a battery temperature is below a low-threshold temperature; and charging the battery when the battery temperature is above the low-threshold temperature. In particular heating comprises generating dissipation energy in the battery by applying a current with at least an AC component to the battery. The current may be a PWM current. The invention further relates to a charger configured to perform the method.

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Method and device for charging a battery and battery charger

The present invention relates to a method and device for charging a battery. More in particular the method relates to a method for shortening the charging time of (li-ion) batteries with a low temperature prior to charging or at the beginning of a charging process, without damaging the battery or shortening its life.

Short charging times for batteries are desired in certain applications, for example when the batteries power an electric vehicle that needs to be used. However, short charging times require large currents, which have an impact on battery life. This negative effect even increases when the battery temperature is lower, resulting for example in damage to the battery caused by an effect known as lithium plating inside the battery.

It is a goal of the present invention to provide a method and device for charging a battery, in particular a lithium-ion battery that decreases the charging time at a low starting temperature, and that has a minimum impact on battery life.

It is a further goal of the present invention to provide a method that is useful to improve the battery life under a certain given charging pattern or usage scenario.

The invention thereto proposes a method for charging a battery, comprising heating a battery if a battery temperature is below a low-threshold temperature, and charging the battery when the battery temperature is above the low-threshold temperature.

The low-threshold temperature depends on the battery and may be varied in dependence of the battery type used. An average value may for example be at room temperature, i.e. about 20 degrees Celcius. By heating the battery, a larger charging current may be used, and the charging process can be performed quicker, without damaging the battery. The heating may be performed by a specific heating component such as an electric spiral or the like, or in hybrid cars with an combustion engine, the battery may be incorporated in the cooling system of the combustion engine, to receive heat deducted thereof.

As an alternative, heating may comprise generating dissipation energy in the battery by applying a current with at least an AC component to the battery. Dissipation then takes

place in the internal resistance of the battery. This has not only the advantage that the heat is generated exactly at the location where it is required, so that a high efficiency is obtained, but it also doesn't require any additional hardware or modifications, both in the battery, and in the charger.

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The connection between the charger and the battery is typically a conductor. This can be charging cable, for example with conductive connector or the DC bus of a vehicle (e.g. when using an on-board charger or motor controller for charging). Also an inductive coupling can be used. Such an inductive coupling already supplies AC current, that can be used to heat up the battery. For that the rectifier and or a low-pass filter may be switched on or off.

The battery may be a traction battery in particular a Li-ion battery and even more specific a Lithium Iron Phosphate (LiFePO_4) battery. The battery may have a BMS that may be altered or temporarily switched off or changed to a different mode to accept the PWM signal. This may be done by changing the software of the BMS. The battery may be a part of a grid storage buffer used for peak-shaving, in particular associated with a vehicle charging station.

The heating can also occur during, at the end and/or near the end of charging to heat up the battery for use in cold conditions, such as cold weather, cold-storage warehouse, high altitude, space, in polar regions, at night or near cooling machinery such as on an artificial ice track. Also a heated battery has less losses during use.

The temperature of the battery may be measured or estimated by measuring cooling water or gas of the battery, in particular the difference between entering and exiting coolant. The temperature may be estimated from other temperatures such as cabin temperature (air-conditioning sensor), ambient temperature (measured by the car) or the motor drive temperature. The latter can be an indication of motor usage and therefore battery usage. The temperature may alternatively be estimated from the date or time and geographic location or based on the temperature of batteries of other vehicles.

The battery temperature information can be communicated to the controller through any means. For example the information can be communicated from the vehicle or

battery to the charger through the charging cable. The information can be communicated through a computer network, such as a LAN or an internet connection. A vehicle can be equipped with a wireless communication device that communicates this information directly or indirectly (e.g. through an internet server) to the charger.

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Preferably, the average current towards the battery is positive, for charging the battery during heating. This leads to an even shorter overall charging time, and to more energy effectiveness.

10 A suitable waveform for this purpose is a one-directional DC current. The actual value of the current may be changed, as will be explained in the following, but the energy flow is only toward the battery, so that no discharge (costing extra time) takes place during heating.

15 To obtain a controllable one directional current, Pulse Width Modulation (PWM) may be applied. This waveform can usually be supplied by a standard battery charger, and it causes relatively high dissipation, thus contributing to a quick temperature rise, and as a result to a short charging time. The duty cycle of the PWM and thus the average current may then be controlled as a function of the battery temperature.

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It is advantageous when the edges of the PWM pulses are rounded to avoid or at least reduce electromagnetic interference due to harmonics. Rounding the pulses may be done by making use of (parasitic or internal) capacitances or inductances, but more sophisticated (digital) charging equipment may be programmable to generate any

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desired waveform.

Besides pulse PWM, also Pulse Density Modulation (PDM) can be applied, and it is even thinkable that sinusoidal pulses are used, in which again PWM (which then for example causes a phase cut signal) or PDM can be applied. The choice for a waveform
30 may be dependent on the charger used, and the sensitivity to specific harmonics of the environment of the battery to be charged.

The average current may be dependent on the temperature of the battery, which may be measured, or estimated based on a starting environment temperature and an estimated

cumulative dissipation. Both the desired (average) current, and a desired (maximum) temperature as an estimated cumulative dissipation may further be obtained from an external source, such as a vehicle or battery management system, or an external database with battery characteristics.

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The dependence of the average current on the temperature may be adapted for each specific battery, but preferably at least in a temperature interval, the average current is doubled for every 5-15, and in particular for about every 10 degrees of temperature increase.

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When the battery is above the threshold temperature, constant current charging or declining (continuous / non switched) current charging may be applied, the declining current charging for example obtained by constant voltage charging.

15 A constant-current charging at a level that is only limited by the battery of charger or grid specifications leads to the quickest energy transfer possible. Constant current charging may take place at the peak value of the PWM charging, but it is also possible that the peaks of the PWM charging are chosen above the constant current level. This is possible, since with a PWM signal, that comprises current-free intervals, components, in particular those of the charger, may be operated above their maximum values, which are usually determined for constant currents, voltages or power.

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According to the invention, current reduction may be applied when the battery temperature exceeds a high-threshold temperature or a predetermined voltage or a
25 predetermined state of charge, or a predetermined charging time. Current reduction usually leads to decreasing dissipation within the battery. Herewith, overtemperature is avoided during the charging process. Such a current reduction can be achieved by applying constant voltage (CV) charging or constant temperature charging.

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30 The invention further proposes a battery charging apparatus, configured to perform a method as described above. The charging apparatus may be a programmable or controllable charging apparatus.

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When applying PWM, the apparatus may be operated above its nominal level, since PWM comprises low-current timeslots, in which the components can cool down, enabling them to withstand higher peaks in the timeslots wherein current is conducted.

- 5 It is also possible to configure the battery charging apparatus to charge a plurality of batteries at a time, wherein a PWM signal for a second vehicle is set high when the PWM signal for a first vehicle is low. The output of the charger is then switched between the batteries to be charged. The actual current level that can be reached in this situation depends on the total duty cycle of the charger, when charging the plurality of
- 10 batteries. It is also possible to switch between a charging current of a battery, and a heating element for said battery. Herewith, an optimum charging time can be reached.

The invention will now be elucidated into more detail with reference to the following non limitative figures, wherein:

- 15 - Figures 1a and 1b show charging currents for a battery according to the present invention;
- Figures 2a and 2b show schematic overviews of a system for applying the present invention;
- 20 - Figures 3a-3f show embodiments of a PWM converter according to the present invention;
- Figures 4a-4f show process flows of a system making use of the present invention.

- Figure 1a shows a schematic charging curve of a current during battery charge
- 25 according to the present invention. The charging curve comprises the three following modes. A low temperature PWM mode A, wherein the battery is heated. Figure 1a schematically shows that during mode A, the current waveform does not necessarily need to be a square wave. A normal charging mode B wherein a steady charge current is used not to generate more losses than necessary. A high temperature mode C wherein
- 30 the battery current is reduced to prevent the battery from overheating. A steady (declining) charge current is used not to generate more losses than necessary.

The low temperature PWM mode A is typically at the beginning or at early stage of the charging process. It is intended to heat up the battery. The battery is also charged during

this phase. Arrhenius's law states that chemical processes in batteries are strongly dependent on temperature. A battery that can be charged in 30 minutes at room temperature cannot be charged that fast at lower temperatures. Attempting to do so can result in damage to the battery. Heating up the battery at the beginning of charge
 5 therefore enables faster charging. In particular an average charging current that is divided by roughly two for every 10°C drop in temperature gives good results. For example: at 20°C the battery is charged at 16A. At 10°C it is charged at 8A, at 0°C at 4A, at -10°C at 2A and at -20°C at 1A and so forth. The function may be approximated by using other functions, such as steps or polynomial, linear or goniometric functions.

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The benefit of using low temperature PWM with compared to using an AC current to heat up the battery is that this mode can be performed using components that are normally used in a charger. Therefore it requires minimal change to the system.

15 The benefit of using low temperature PWM with compared to using a large charging current to heat up the battery it that the damage to the battery will be lower when using a PWM charging.

When using a large current, the internal battery voltages will rise, damaging the battery.

20 Using the PWM charging will result in lower voltages because the average current is lower. This gives less strain on the battery when heating the battery at the same moment.

In an embodiment the pulses are rounded to reduce electro-magnetic interference. The
 25 pulses may be sinusoidal. The roundness of the pulses may be generated by controlling the charge current rather than relying on a low pass filter.

In another embodiment the height of the charging pulses can be made higher than the specifications of the components (e.g. power converter, cables, charging connector),
 30 because the components have a resting period to cool down due to the PWM. That way a 125A charger can be used at a 50% duty cycle at 175A, without wearing down the components more than necessary.

Because it can be expected that this situation will arise at low ambient temperatures, the charger can also be used at an (even higher) rating, because ambient air temperature is lower.

- 5 This charging mode can also be used to heat up the components of the charger or other components of the vehicle, such as the charging cable making it more flexible and easier to handle in cold weather.

- 10 It is further possible to use a charger device to switch charging current between the batteries. If the batteries each only have half the capacity of one big battery, the charging current is also half. Therefore the charging connector, cables and charger can be smaller.

- 15 The frequency of the duty cycle is usually in the range of 0.01Hz – 100kHz. For Lithium-ion batteries a low frequency is beneficial to prevent (parasitic) capacitance and use real Ohmic resistance as much as possible. A too low frequency will result in a too high voltage rise, damaging the battery.

- 20 The frequency of the duty cycle (the time of t_{on} and t_{off}) can also be chosen to match the response time of the charger. For instance of the ramp-up time of the charger is one second a frequency of 0.1 Hz can be used.

- 25 The low temperature PWM mode is usually followed by a mode B wherein the charge current is not limited by temperature. In a typical case a steady charge current is used not to generate more losses than necessary. In this mode the current may still rise with temperature, but the duty cycle is absent. This is particularly useful when the current is large enough to heat up the battery and a PWM in his case would result in too high temperature or a too high temperature for a later stage of the charging process.

- 30 In a third mode C the current is gradually reduced, to stop generating heat in the battery. With respect to using a PWM to reduce (average) charging current is that PWM introduces unnecessary losses in the battery, while the goal of reducing the current is to reduce losses. When temperature is the major limiting factor for the charging system, mode A can be followed by mode C directly.

A (part of a) charging output filter of a charger may be reconfigured when using mode A charging to enable better PWM performance. The reconfiguration can be done by bypassing parts of the filter. This can be done by using switches (e.g. relays, transistors) that shunt or disconnect inductors and/or capacitors.

Another embodiment has an isolation detection circuit. This circuit detects if galvanic isolation is maintained. The isolation circuit itself is not that important, because these are readily available components. What is important: The isolation detection in the vehicle or the charger is (temporarily) disabled during charge. This is because the isolation monitor may be confused by the pulsing currents.

Another embodiment uses the battery voltage, impedance or frequency response as a way to regulate the PWM. The impedance can be determined by applying an AC current or AC current component to the battery. In particular the PWM itself can be used as an impedance measurement.

For example at the PWM on-phase the voltage rise is monitored. When the voltage crosses a certain threshold the current is reduced or set to zero. The voltage will then fall. After a period of time or when the voltage drops below a threshold the current is switched back on again.

Figure 1b shows a situation, wherein the temperature drops during the charging (for example due to a low environmental temperature), and the charging switches back to PWM, as is indicated with D in curve 1'.

Figure 2a shows a first schematic overview 2 of a system according to the present invention. The simplest embodiment of this system comprises a charger 4 which is connected to a vehicle 3 and can communicate with said vehicle and more specifically the BMS of the battery by means of some channel such as a wireless communications system, through the charge cable 5 (either separate contacts or communication over the same pins as the charge current) or any other system for said communication. It can then obtain the battery temperatures from a BMS, and based on these temperatures modify the charge current. In this embodiment the charger has all details and algorithms

concerning this low-temperature stored locally, and can autonomously decide to apply these. For other tasks such as selecting the standard charge currents and prioritizing of vehicles it can still connect to a remote server.

- 5 It is also possible that the charger 4 has reduced local intelligence and data storage. The decision to use the low-temperature charging algorithm is made by a remote decision and storage facility 6 (shown in dashed lines), and also all parameters for this algorithm are calculated and decided by this facility. This has as advantages that the charger can be made much cheaper, as less logics and data storage is required. Besides, performance
10 of many chargers in the field can be upgraded in one go, as the code and parameters for the algorithm only have to be replaced in one place, and not all chargers have to be upgraded separately.

Furthermore, the charger may be coupled to a temperature sensing device 7, which may
15 be integrated in the battery, or form part of a battery management system. In another embodiment, the optional temperature sensing device lacks, and the charger is unable to obtain the actual temperature from the BMS of the vehicle. In this embodiment (which might work independently from the presence of a remote server) the temperature of the battery will have to be estimated or measured based on other methods. These methods
20 may be one or a combination of the following methods:

- Use the ambient temperature measured by the charger. Preferably here the estimation is backed up by statistical data which correlates environmental temperature with the batteries temperature for increased reliability. A precise model which models the battery temperature change caused by charging current is required to keep the
25 estimate accurate during the charge process;
- Use some infra-red sensing device to measure the heat radiated by the battery section of a car;
- If no local temperature measurement is available for whatever reason, weather measurements or forecast which could be available from a remote server can be used for
30 a temperature estimation. Also for this solution it would be preferable to have some sort of statistical relation between ambient temperature and battery temperature;
- A relation can be made between internal resistance of a battery and its temperature. As soon as the type of battery is known, its temperature can be estimated preferably when its age and SOH (State of Health) are known by applying a certain

predetermined current and measuring the instant voltage rise (or drop) to serve as a basis for temperature estimation;

- When the BMS of the car returns multiple temperature values, an average, a maximum or a minimum of these values may be used as input for the charging algorithm. When the difference between these multiple temperature values is known, the algorithm may be devised in such a way that it will not overheat the warmest parts of the battery, even when the low temperature of other parts is still limiting the average charge current;
- When more is known about the construction of the battery pack and the relative position of the different temperatures the average mentioned above can be a weighted average, where the weighting can be based on knowledge of the sensor positions, optimality knowledge of the charging algorithm or other prior knowledge. This battery data can also be combined with ambient temperature values, for instance for averaging one temperature value from the centre of the pack with the ambient temperature to obtain the average temperature in the pack.

The method to effectuate the low frequency PWM signal on the battery may be implemented in many ways, while leaving the essence of the invention intact. The following list contains possible embodiments of the PWM system:

- The output of a power converter with a DC output can be connected and disconnected from the battery by means of a relay.
- To save on wear said relay can be replaced by a solid-state relay, MOSFET, IGBT or other semiconductor technology.
- As said power converter may be susceptible to damage caused by abovementioned switching devices the PWM signal can be generated by applying a low-power PWM signal to the control input(s) of the power converter.
- When the used power converter is embodied by an on-board charger, the idea of the invention can still be applied by switching on and off the AC current fed to the on-board charger. Care has to be taken that the on-board charger does not apply some temperature correction itself as this might unnecessarily increase the charge time.

If none of the above methods for obtaining a temperature measurement are present, it is possible to derive the temperature indirectly, since the I-V characteristic of a battery changes with its temperature. This embodiment skips the measurement of the

temperature and just uses a high charge current. Due to higher internal resistance, a certain voltage threshold will be reached earlier. When the power converter is switched off at this threshold, and a certain time delay is implemented before it is switched on again, the idea of temperature dependent PWM pulse charging is still intact, but
 5 temperature sensing is eliminated. For determination of the current, determination of the time delay and actuation of the current ideas from aforementioned embodiments can be used without fundamentally altering the idea of the invention.

Figure 2b shows a second schematic view 8 of a system for performing the method
 10 according to the present invention, wherein a DC power supply (charger) 9 is coupled to a grid or DC-Bus 10. A BMS 12 of the battery 11 senses the temperature of the battery and passes this information on to the charger 9. This charger 9 is augmented with a temperature charging controller 13. The TCC 13 identifies the BMS 12 and sets the DC power supply current and voltage. The TCC 13 decides, based on the temperature and
 15 the battery type what the PWM duty cycle should be, and controls the DC power supply 9 to switch off and on accordingly. A PWM duty cycle is determined, based on an exponential decay of charge current with relation to battery temperature.

In an embodiment where multiple batteries are charged, two or more vehicles can be
 20 charged with a single power source if the power for one vehicle is “on” while for the other vehicles it is “off”.

Figure 3a shows yet another schematic view 14 of a system according to the present invention. A controller 15 can be a microcontroller a (web)server, a part of the power
 25 converter 16 (Such as a semi-conductor driver or electronics used to control the semi-conductor drivers). The controller 15 can be an analog or digital circuit, such as a multivibrator. The multivibrator can be controlled by changing the time constant and the amplitude by for instance changing the resistor(s) or capacitor(s) value(s) depending on (battery) temperature. In particular one or more of the resistors of the multivibrator can
 30 be an NTC, PTC or transistor (e.g. field effect transistor) or one or more of the capacitors can be a variable capacitor (varicap).

The PTC and NTC can be used to change the behaviour of the multivibrator dependent on (battery) temperature (for instance because the PTC or NTC is placed near or inside

the battery. The transistor and varicap are voltage dependent and can be used to change the behaviour of the multivibrator dependent on battery voltage, which can be an indication of the battery temperature. For that, the battery voltage may pass through an AM detection circuit. These components can be near or inside the battery 17, while the rest of the circuit is near the charger (that may be outside the vehicle). The battery 17 has a temperature 18 which is determined by a temperature sensor 19 that sends the measured value to the controller 15.

Figure 3b shows how the controller 15 can be a fuzzy logic circuit or a logic circuit with fuzzy logic programming. Depending on memberships of the parameters (e.g. Temperature, voltage, Set current) a different or combined control algorithm can be implemented, for example comprising the modes A, B and C from figures 1a and 1b.

The controller 15 may be trained using training data or real life situations. The controller 15 could therefore best comprise an adaptive system, such as a neural network. The controller can be a part of a cloud computing network. It can make its own decisions and/or leave solutions to partial decisions to other computers. The controller 15 can comprise or use a database that holds information about vehicles, batteries and environmental parameters.

Figure 3c shows an embodiment 20 with a hardware or software structure for a system that can have blocks for the different charging modes/phases. An event (e.g. change of temperature) can make the system switch to operate in one or more of the other modes.

Figure 3d shows another embodiment 21 with a current control that gets input from (optional) hardware or software that changes the current based on various factors. For instance a low-temperature module can change the duty cycle of the current. Under normal temperature the duty cycle is 100% (full current) but at lower temperatures the duty cycle becomes smaller. The high temperature control may lower the current value (amplitude) in case of high temperature. An high voltage control module may reduce the charging current in case of high voltage (constant voltage charging). A time target module may reduce the current if the vehicle has no urgency to leave soon. The modules for low and high temperature control may be a single module for temperature control.

The controller can be connected to the power converter using a network connection (e.g. TCP/IP). The connection between the controller and the power converter can be analog, such as a direct PWM control signal or parametric (0-10V for amplitude and 0-10V for duty cycle and/or frequency). The connection between the controller and the power
 5 converter can be digital control such as RS232, RS485, I2C, CAN or SPI. The connection between the controller and the power converter can be a PWM control that gives parametric signals (0-100% for amplitude and 0-100% for duty cycle). The controller can directly control a switch (e.g. relay or semiconductor) control signal that switches the input or output current of the power converter. This may be implemented
 10 in the vehicle while the rest of the power converter is inside or outside the vehicle. The connection between the controller and the power converter can be optical (e.g. using LDR or optocoupler). This is in particular interesting to maintain galvanic isolation. The controller may control a switch that switches the power converter between two vehicles. This way a single power converter can be used to charge multiple
 15 vehicles.

The power converter can be inside a vehicle or in a charging station or another type of charger. The power converter may be a regular power supply, such as a switch-mode power supply. The power supply may be a phase control dimmer.
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Figure 3e shows how using such a dimmer provides a basic way to change the frequency of the pulsed current (by skipping some of the phase pulses) and the amplitude.

25 An instable power supply such as aforementioned dimmer, a welding transformer or a low-cost power supply can be used to generate the PWM signal. Optionally a stabilisation stage that can be switched on or off can be added to stabilise the power when no PWM is required. The system can include a stable power supply for stable current and a signal generator of any sort to create the PWM signal. The PWM can be
 30 generated by the motor controller, that may function as or as a part of the charging circuit.

Figure 3f shows an embodiment 22 wherein the PWM can be coupled in from the net through a capacitor or an alternative 23 with a transformer that can be switched on or off.

5 Figures 4a-4f show process flows of a system making use of the present invention.

Figure 4a shows an embodiment wherein the system can optimize the charge speed through application of a data processing methods which make trade offs between battery life, charge speed and battery temperature. A data processing device in this
 10 specific embodiment decides that a battery should be heated first and then fast charged because this will deliver a faster charge than without preheating

In figure 4a the following text belongs to the corresponding boxes:

1. A vehicle connects to the energy exchange station.
- 15 2. The energy exchange station communicates with the vehicle and receives battery data such as state-of-charge and temperature of the battery which is very low.
3. The user of the vehicle indicates via a data entry interface that he wants to receive the fastest possible charge.
4. A battery knowledge base contains relationships between the temperature of the
 20 battery, the fastest possible charge rate and the battery life and other battery related parameters.

The battery knowledge base can be a large internet based storage system, but it can also be a small software program or register in the BMS or computer of the vehicle, or a small software program somewhere in the charger.

- 25 5. The data processing device calculates the best charging method for this situation: it requests the relationships between battery life, charge speed and temperature from a battery knowledge base. Based on this information it decides that the battery should be heated first before commencing fast charging. It tells the energy exchange station that it should preheat the battery by applying a pulsed current for a defined period of time and
 30 afterwards applying a fast charge at a defined level for several minutes.
6. The energy exchange station applies a pulsed current for several minutes followed by a fast charge at a defined level for several minutes

Figure 4b shows an embodiment wherein the system can optimize the battery life through application of a data processing methods which make trade offs between battery life, charge speed and battery temperature. A data processing device in this specific embodiment decides that a battery should be preheated first and then fast charged because this will enable a longer battery life than without preheating

In figure 4b the following belongs to the corresponding boxes:

1. A vehicle connects to the energy exchange station.
- 10 2. The energy exchange station communicates with vehicle 1 and receives battery data such as state-of-charge and temperature of the battery which is very low.
3. Via a software application or database or other input method the system receives information which indicates that the battery should be treated such that it will reach a battery life of at least 3000 charge cycles.
- 15 4. A battery knowledge base contains relationships between the temperature of the battery, the fastest possible charge rate and the battery life and other battery related parameters.
5. The data processing device calculates the best charging method for this situation: it requests the relationships between battery life, charge speed and temperature from a
- 20 battery knowledge base. Based on this information it decides that the battery should be heated first before commencing fast charging because it will enable a longer battery life. It tells the energy exchange station that it should preheat the battery by applying a pulsed current for a defined period of time and afterwards applying a fast charge at a defined level for several minutes.
- 25 6. The energy exchange station applies a pulsed current for several minutes followed by a fast charge at a defined level for several minutes.

Figure 4c shows an embodiment wherein the system can optimize the charge speed through application of a data processing methods which make trade offs between

30 battery life, charge speed and battery temperature. A data processing device in this specific embodiment initially decides that a slow charge is enough but when input from a service provider is received it decides to speed up charging by initially applying a short battery pre-heat and then an accelerated fast charge

In figure 4c the following belongs to the corresponding boxes:

1. A vehicle connects to the energy exchange station.
2. The energy exchange station communicates with the vehicle and receives battery data
- 5 such as state-of-charge and temperature of the battery which is low.
3. Via a customer input the system receives information that the user does not need a really fast charge: one hour charge time is requested.
4. A battery knowledge base contains relationships between the temperature of the battery, the fastest possible charge rate and the battery life and other battery related
- 10 parameters.
5. The data processing device calculates the best charging method for this situation: it requests the relationships between battery life, charge speed and temperature from a battery knowledge base. Based on this information it decides that the battery does not need pre-heating: the temperature of the battery is low but because 1 hour charging is
- 15 requested it can charge at a slow speed.
6. The energy exchange system applies a charge at relatively low rate.
7. New information enters the system through a service parameter input such as a fleet management system connection. This input tells the system that the battery must be charged as quickly as possible because another vehicle will arrive within a few minutes.
- 20 8. Based on the new information the data processing device decides that charging has to be changed: first the battery has to be heated by a pulsed current or by using an onboard heating device and then the highest possible charge rate has to be applied.
9. The energy exchange system changes the charging method according to 8, heats the battery and applies the highest possible charge rate.

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Figure 4d shows an embodiment wherein the system can optimize the charge speed through application of a data processing methods which make trade offs between battery life, charge speed and battery temperature. A data processing device in this specific embodiment initially decides that a slow charge is enough but when input from

30 a utility grid parameter is received it decides to speed up charging by initially applying a short battery pre-heat and then an accelerated fast charge

In figure 4d the following belongs to the corresponding boxes:

1. A vehicle connects to the energy exchange station.
2. The energy exchange station communicates with the vehicle and receives battery data such as state-of-charge and temperature of the battery which is low.
3. Via a customer input the system receives information that the user does not need a really fast charge: one hour charge time is requested. Also the customer input tells the system that the system should optimize according to the lowest price for electricity.
4. A battery knowledge base contains relationships between the temperature of the battery, the fastest possible charge rate and the battery life and other battery related parameters.
5. The data processing device calculates the best charging method for this situation: it requests the relationships between battery life, charge speed and temperature from a battery knowledge base. Based on this information it decides that the battery does not need pre-heating: the temperature of the battery is low but because 1 hour charging is requested it can charge at a slow speed.
6. The energy exchange system applies a charge at relatively low rate.
7. New information enters the system through a grid interface parameter. The utility grid tells the system that the price of electricity has changed to the lowest possible rate and therefore it is beneficial to use as much as possible of this low cost electricity.
8. Based on the new information the data processing device decides that charging has to be changed to the fastest possible rate: first the battery has to be heated by a pulsed current or by using an onboard heating device and then the highest possible charge rate has to be applied.
9. The energy exchange system changes the charging method according to 8, heats the battery and applies the highest possible charge rate.

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Figure 4e shows an embodiment wherein the system can optimize the charge speed through application of a data processing methods which make trade offs between battery life, charge speed and battery temperature. A data processing device in this specific embodiment initially decides that a slow charge is enough but when input from a utility grid parameter is received it decides to speed up charging by initially applying a short battery pre-heat and then an accelerated fast charge

30

In figure 4e the following belongs to the corresponding boxes:

1. A vehicle connects to the energy exchange station.
2. The energy exchange station communicates with the vehicle and receives battery data such as state-of-charge and temperature of the battery which is low.
3. Via a grid input it is indicated to the system that the grid can only deliver a certain
- 5 low amount of power at this point in time.
4. A battery knowledge base contains relationships between the temperature of the battery, the fastest possible charge rate and the battery life and other battery related parameters.
5. The data processing device calculates the best charging method for this situation: it
- 10 decides that the grid input overrules everything: the charging is done at a low speed.
6. The energy exchange system applies a charge at low rate.
7. New information enters the system through a grid interface parameter. The utility grid tells the system that the grid now can deliver a large amount of power.
8. Based on the new information the data processing device now calculates the best
- 15 charging method for this situation: it requests the relationships between battery life, charge speed and temperature from a battery knowledge base. Based on this information it decides that the battery has to be preheated in order to be able to absorb the maximum charge power.
9. The energy exchange system changes the charging method according to 8, heats the
- 20 battery and applies the highest possible charge rate.

Figure 4f shows an embodiment wherein the energy exchange station has more than one output and can optimize the charging on both outputs based on application of a data processing methods which make trade offs between battery life, charge speed and

25 battery temperature.

In figure 4f the following belongs to the corresponding boxes:

1. A vehicle 1 (containing battery 1) connects to the energy exchange station.
- 30 2. The energy exchange system communicates with vehicle 1 and receives battery data such as state-of-charge and temperature of the battery which is in this example 15 degrees C.
3. The user of the vehicle 1 indicates via a data entry interface that he wants to receive a fast charge in 30 minutes.

4. A battery knowledge base contains relationships between the temperature of the battery, the fastest possible charge rate and the battery life and other battery related parameters.
5. The data processing device calculates the best charging method for this situation: it requests the relationships between battery life, charge speed and temperature from a battery knowledge base. Based on this information it decides that the battery should be heated first before commencing fast charging because it will enable a 30 minute charge.
6. The energy exchange station applies a short preheating and then a fast charge.
7. A vehicle 2 (containing battery 2) connects to the energy exchange station.
- 10 8. The energy exchange system also receives the information from vehicle 2.
9. The user of the vehicle 2 indicates via a data entry interface that he wants to receive a fast charge in 15 minutes.
10. Based on the new information the system decides that battery 2 also needs quick preheating. Therefore it stops charging of vehicle 1 to make all power available to
- 15 create a powerful pulsed charge pattern for battery 2. After a short period of pulsation it restarts charging of battery 1 and also starts fast charging battery 2.
11. The energy exchange system performs all commands under 10.

All embodiments are to be interpreted as examples only. The scope of the present invention is defined in the following claims.

Conclusies

1. Werkwijze voor het opladen van een accu, omvattende:
 - verwarmen van een accu wanneer de accutemperatuur zich beneden een onderste
 - 5 temperatuurgrenswaarde bevindt;
 - opladen van de accu wanneer de accutemperatuur zich boven de onderste
 - temperatuurgrenswaarde bevindt.
2. Werkwijze volgens conclusie 1, waarbij het verwarmen het in de accu opwekken
- 10 van dissipatie-energie omvat door het op de accu aanleggen van een stroom met ten
- minste een wisselstroomcomponent.
3. Werkwijze volgens conclusie 2, waarbij gedurende het verwarmen de
- gemiddelde stroom richting de accu positief is, voor het opladen van de accu gedurende
- 15 het verwarmen.
4. Werkwijze volgens conclusie 1, waarbij gedurende het verwarmen de stroom
- een eenrichtingsgelijkstroom is.
- 20 5. Werkwijze volgens één der conclusies 2-4, waarbij de stroom een stroom is met
- pulsbreedtemodulatie.
6. Werkwijze volgens conclusie 5, waarbij de relatieve inschakelduur van de
- pulsbreedtemodulatie en dus van de gemiddelde stroom wordt geregeld als functie van
- 25 de accutemperatuur.
7. Werkwijze volgens één der conclusies 5 of 6, waarbij de pulsflanken van de
- pulsbreedtemodulatie worden afgerond ter voorkoming van elektromagnetische
- interferentie als gevolg van harmonischen.
- 30 8. Werkwijze volgens conclusie 7, waarbij de pulsen sinusoïdaal zijn.

9. Werkwijze volgens één der conclusies 5-8, waarbij in ten minste een temperatuurinterval, de gemiddelde stroom wordt verdubbeld voor iedere 5-15 graden, en in het bijzonder voor iedere 10 graden temperatuurstoename.
- 5 10. Werkwijze volgens één der voorgaande conclusies, waarbij het opladen van de accu, wanneer de temperatuur van de accu zich boven de temperatuur grenswaarde bevindt, ten minste omvat:
- opladen met constante laadstroom, of
 - opladen met afnemende laadstroom, bijvoorbeeld verkregen door opladen bij
- 10 constante spanning.
11. Werkwijze volgens conclusie 8, waarbij opladen bij constante laadstroom plaatsvindt op de piekwaarde van het opladen met pulsbreedtemodulatie.
- 15 12. Werkwijze volgens conclusie 10 of 11, waarbij het opladen met afnemende laadstroom, bijvoorbeeld verkregen door opladen met constante laadspanning, wordt toegepast wanneer de accutemperatuur een gegeven bovenste temperatuurgrenswaarde of een gegeven spanning of een gegeven laadtoestand of een gegeven laadtijd overschrijdt.
- 20 13. Werkwijze volgens één der voorgaande conclusies, waarbij de stroomwaarde wordt verhoogd gedurende het opladen.
14. Werkwijze volgens één der voorgaande conclusies, waarbij de accutemperatuur
- 25 wordt gemeten, of geschat, op basis van een omgevings- of voertuigtemperatuur.
15. Werkwijze volgens één der voorgaande conclusies, waarbij de accutemperatuur wordt gemeten, of geschat, op basis van het bewaken van een reactie van de accu op een laad- of ontlaadstroom, een stroomonderbreking of op een opeenvolging van
- 30 verschillende stromen.

16. Werkwijze volgens één der voorgaande conclusies, waarbij de accutemperatuur wordt verkregen via een datacommunicatiekanaal of een computernetwerk.
17. Werkwijze volgens één der voorgaande conclusies, waarbij een besluit tot het verwarmen van de accu en de verwarmingsduur van de accu bovendien zijn gebaseerd op een onderhoudsgerelateerde parameter, zoals de gewenste maximum tijd voor het verkrijgen van een bepaalde vooraf gedefinieerde laadtoestand van de accu.
18. Werkwijze volgens één der voorgaande conclusies, waarbij een besluit tot het verwarmen van de accu en de duur en andere parameters voor het verwarmen van de accu bovendien zijn gebaseerd op een aan het lichtnet gerelateerde parameter, zoals het op een bepaald tijdstip beschikbare vermogen of een aan de elektriciteitsprijs gerelateerde parameter.
19. Werkwijze volgens één der voorgaande conclusies, waarbij een besluit tot het verwarmen van de accu en de verwarmingsduur van de accu bovendien zijn gebaseerd op een aan de accu gerelateerde parameter, zoals een gewenste levensduur van de accu (of aspect van de levensduur van de accu, zoals een gewenst aantal laadcycli).
20. Werkwijze volgens één der voorgaande conclusies, waarbij een besluit tot het verwarmen van de accu en de verwarmingsduur van de accu bovendien zijn gebaseerd op een aan vermogensconversie gerelateerde parameter, zoals het maximale vermogen of het maximale pulsvermogen van een vermogensomvormer.
21. Acculader, ingericht voor het uitvoeren van een werkwijze volgens één der voorgaande conclusies.
22. Acculader volgens één der conclusies 5-20 en 21, waarbij de pulsen een hogere piekwaarde hebben dan gespecificeerd voor een toegepaste laadinrichting.
23. Acculader volgens conclusie 21 of 22, ingericht voor het gelijktijdig opladen van een aantal accu's, waarbij een signaal voor pulsbreedtemodulatie voor een tweede

voertuig hoog wordt, wanneer het signaal voor pulsbreedtemodulatie voor een eerste voertuig laag is.

24. Acculader volgens conclusie 23, ingericht voor het voeden van een
5 verwarmingselement of een accu wanneer het signaal voor pulsbreedtemodulatie voor de accu laag is.

25. Acculader volgens één der conclusies 21-24, ingericht voor het lezen van een
oplaadprofiel voor een accu van een externe inrichting, zoals een inrichting voor
10 voertuig- of accumanagement, of een database met oplaadprofielen.

26. Voertuig of inrichting voor energieoverdracht, omvattende een oplaadinrichting volgens één der conclusies 21-25.

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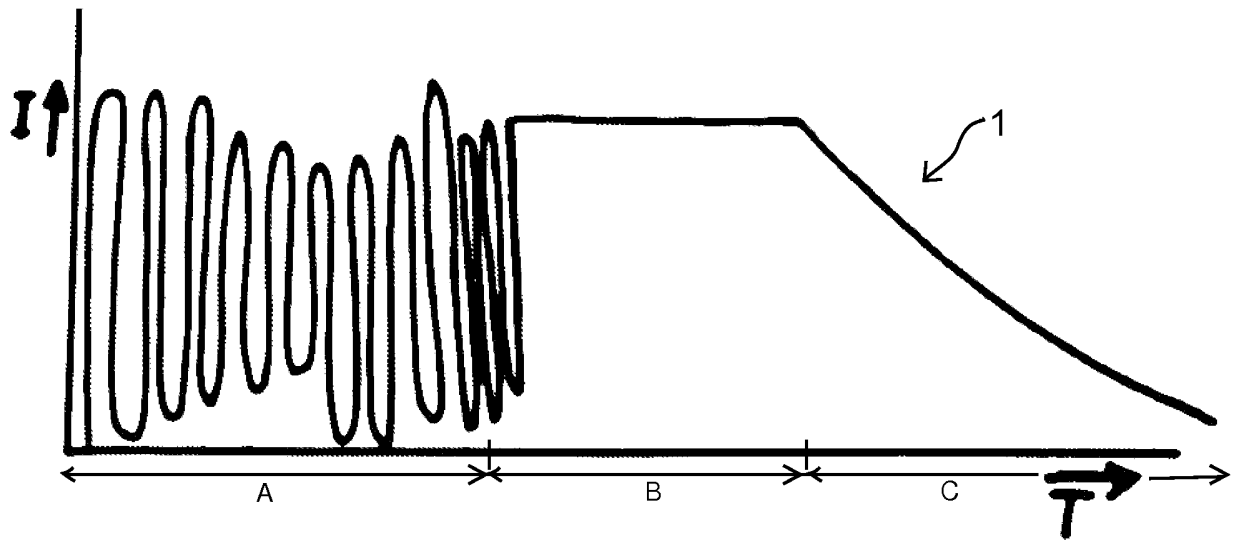


FIG. 1a

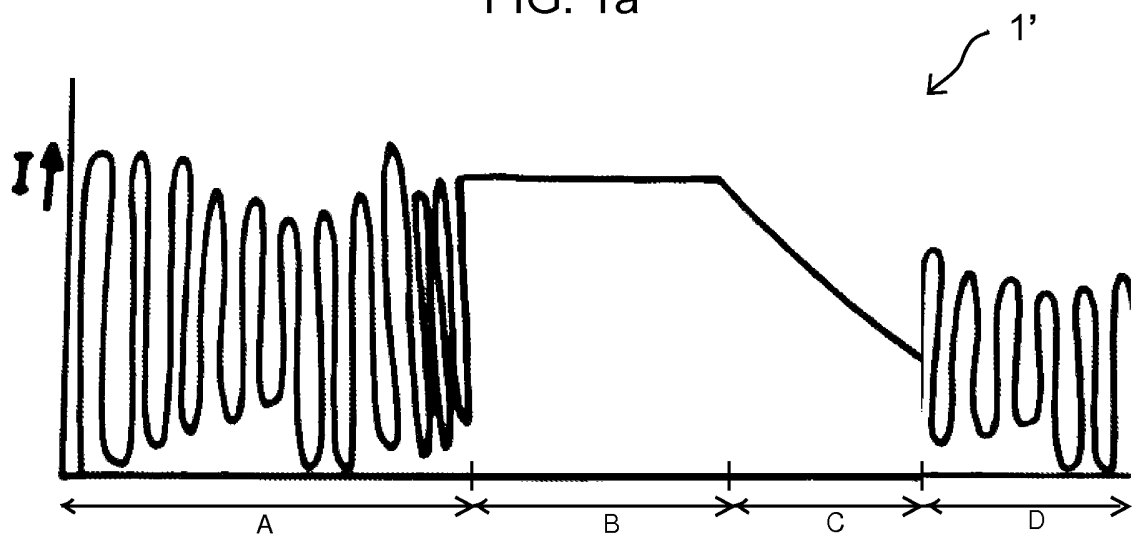


FIG. 1b

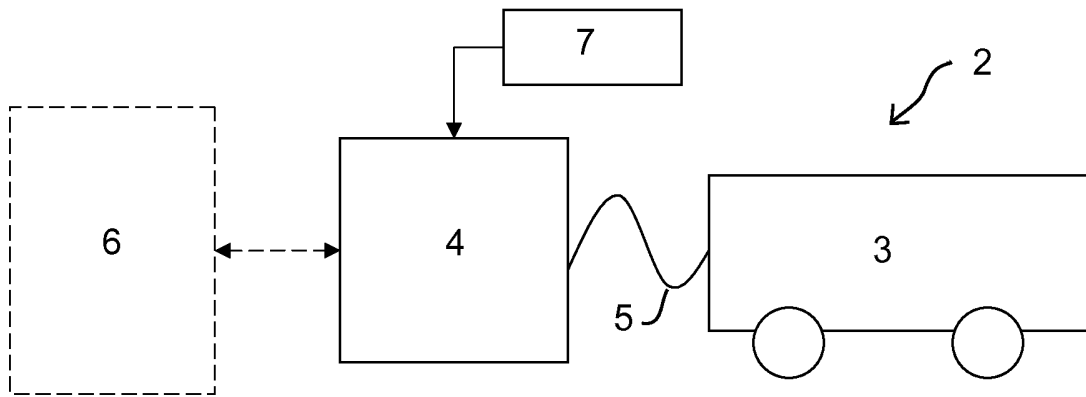


FIG. 2a

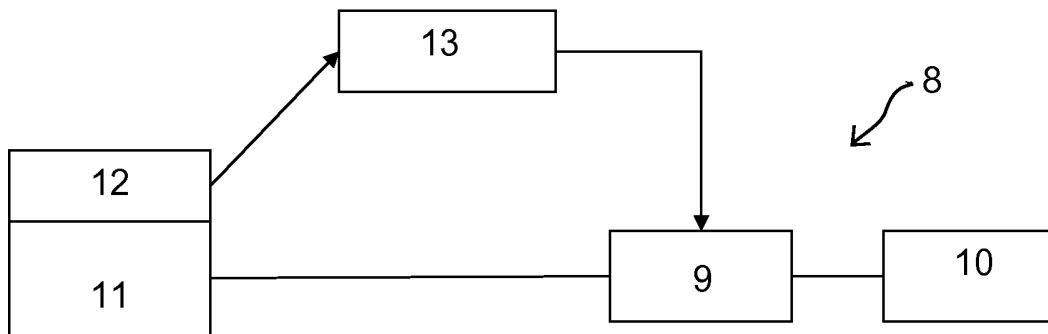


FIG. 2b

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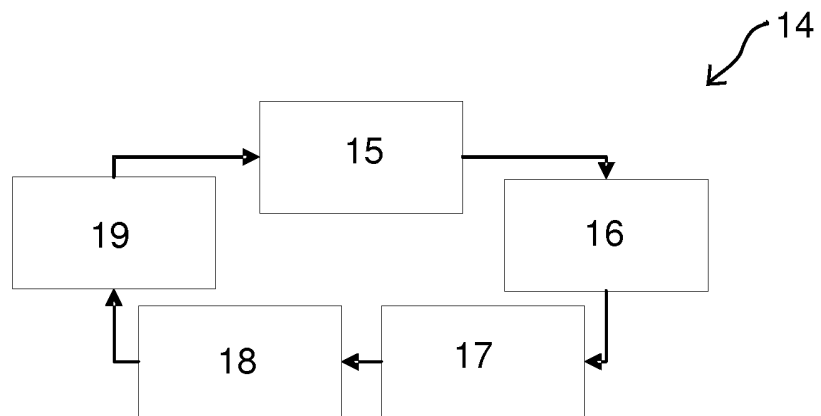


FIG. 3a

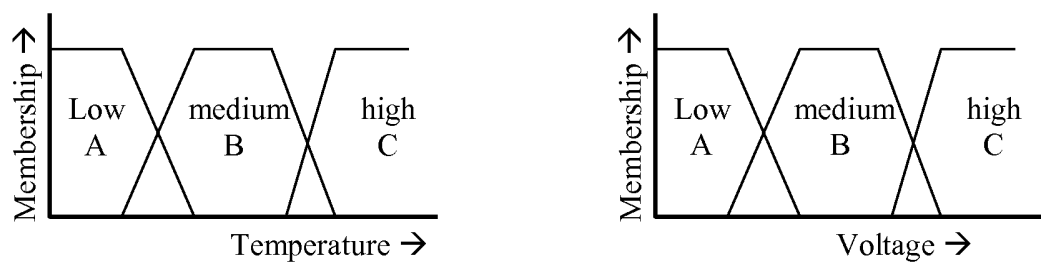


FIG. 3b

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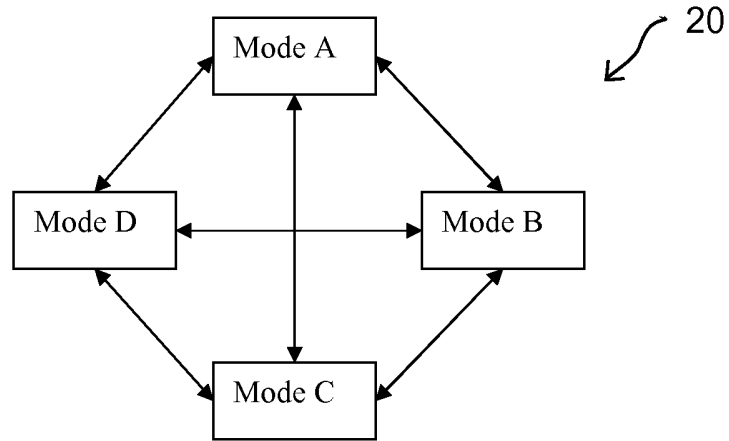


FIG. 3c

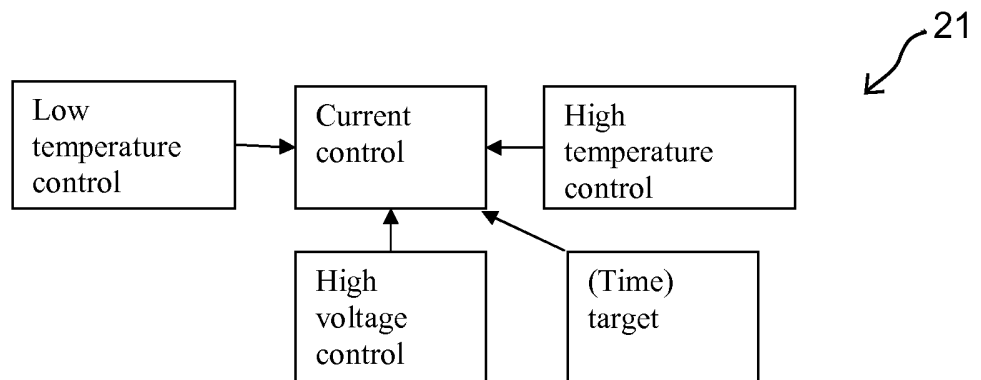


FIG. 3d

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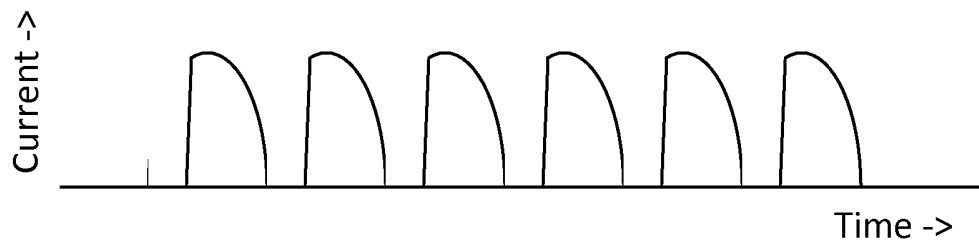
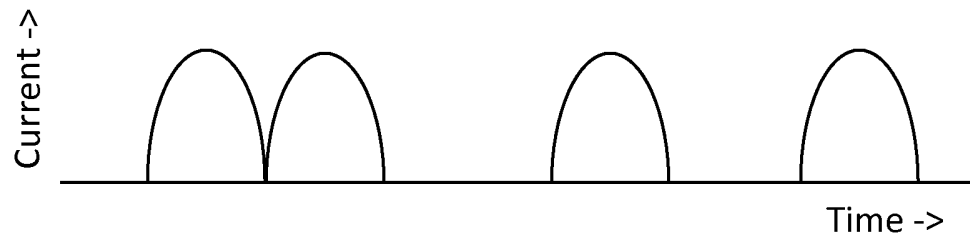


FIG. 3e

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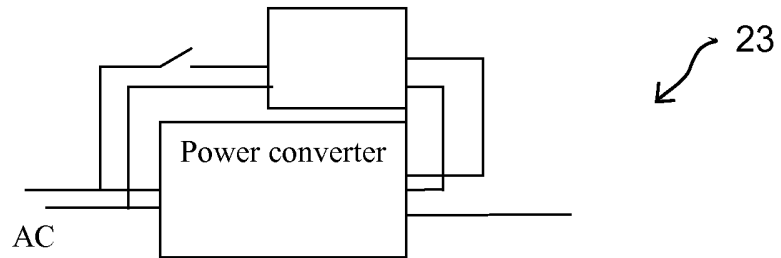
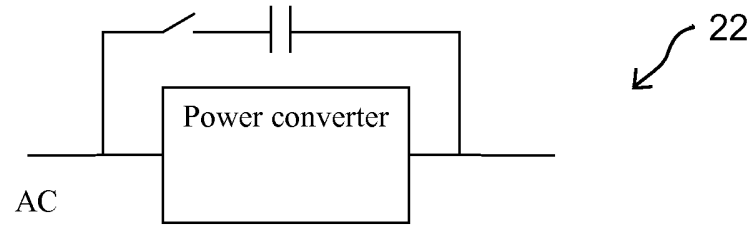


FIG. 3f

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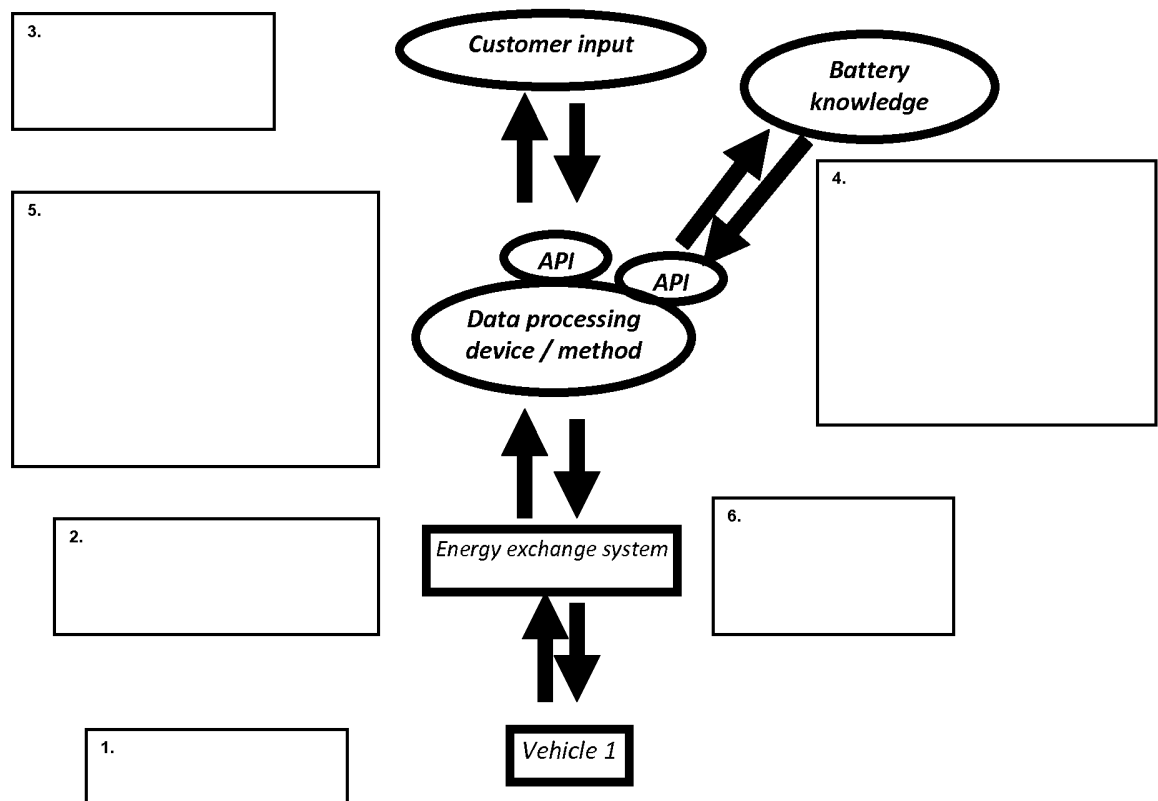


FIG 4a

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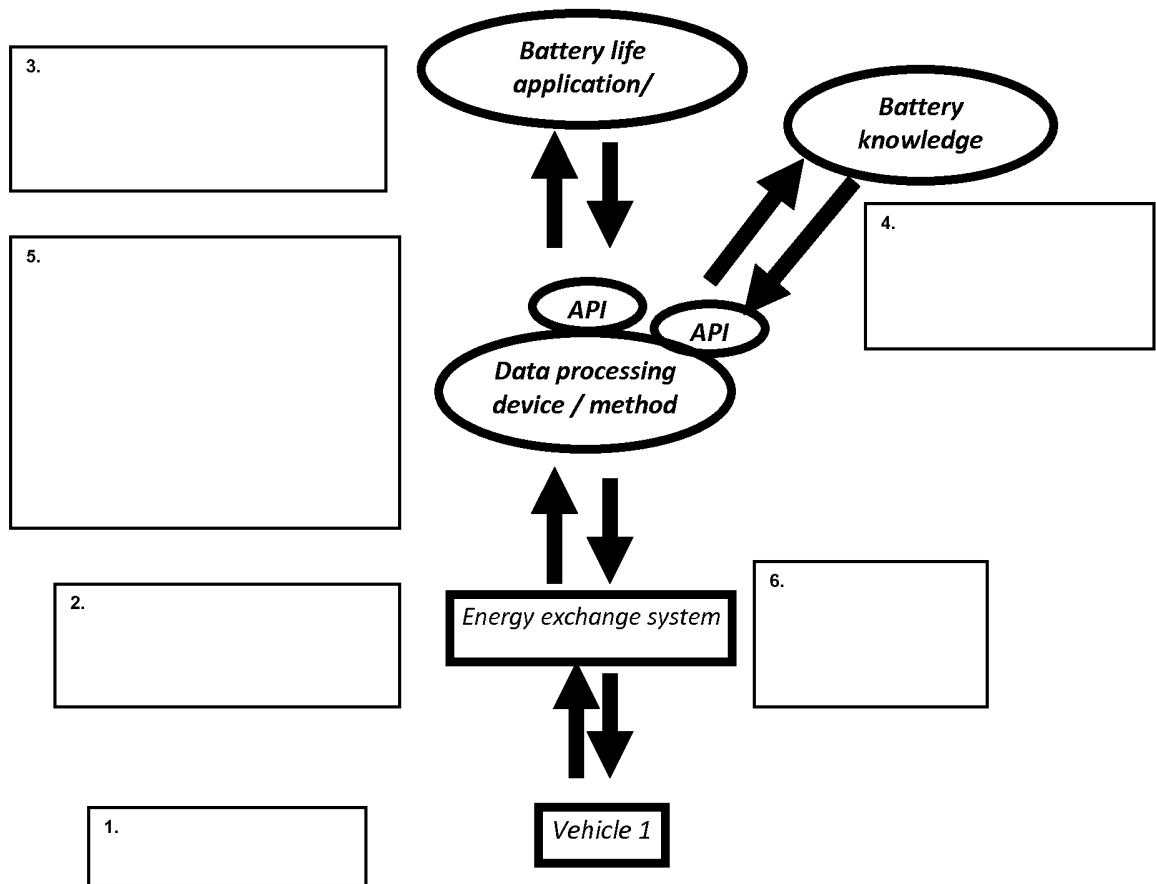


FIG 4b

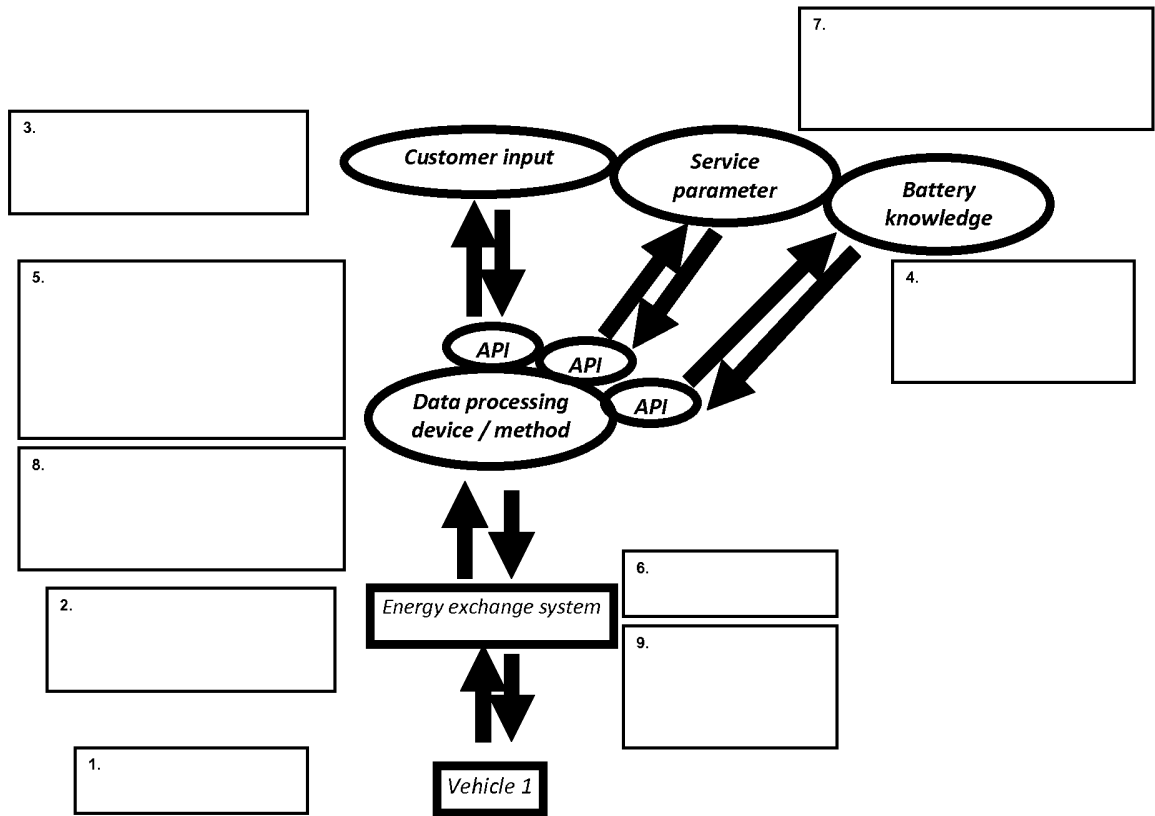


FIG 4c

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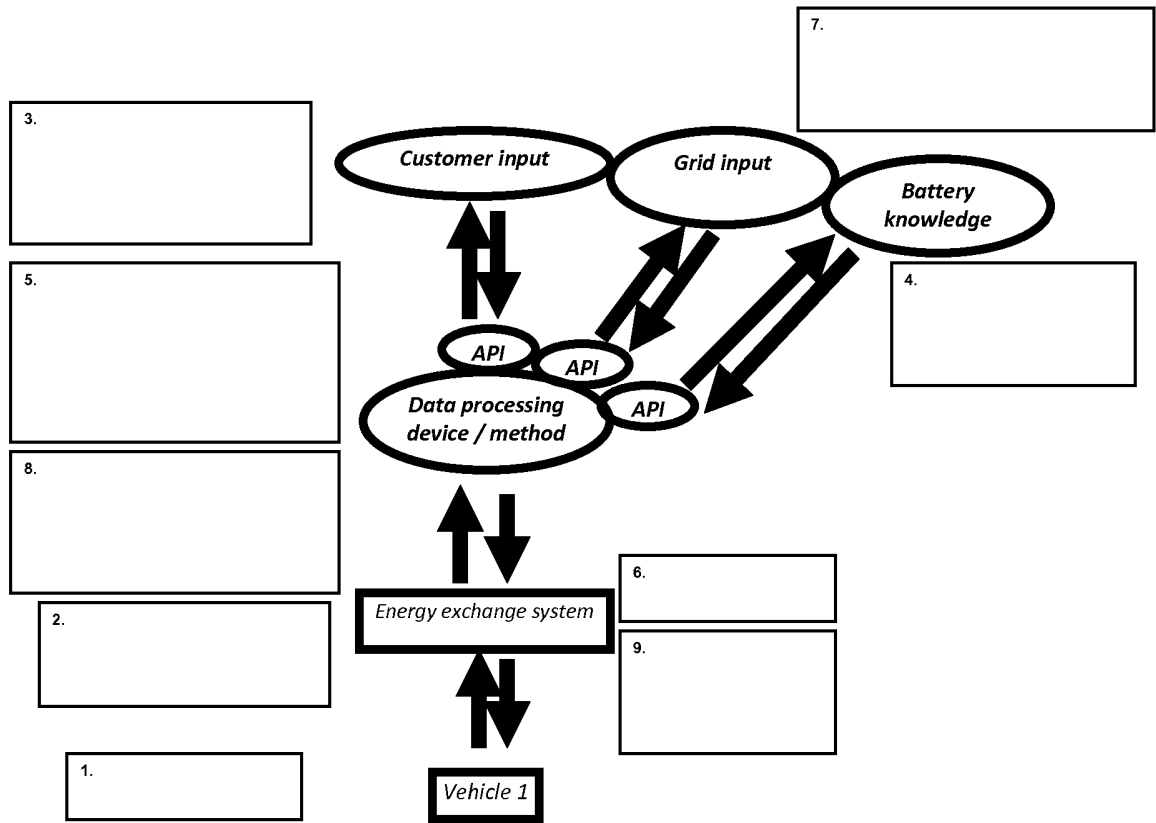


FIG 4d

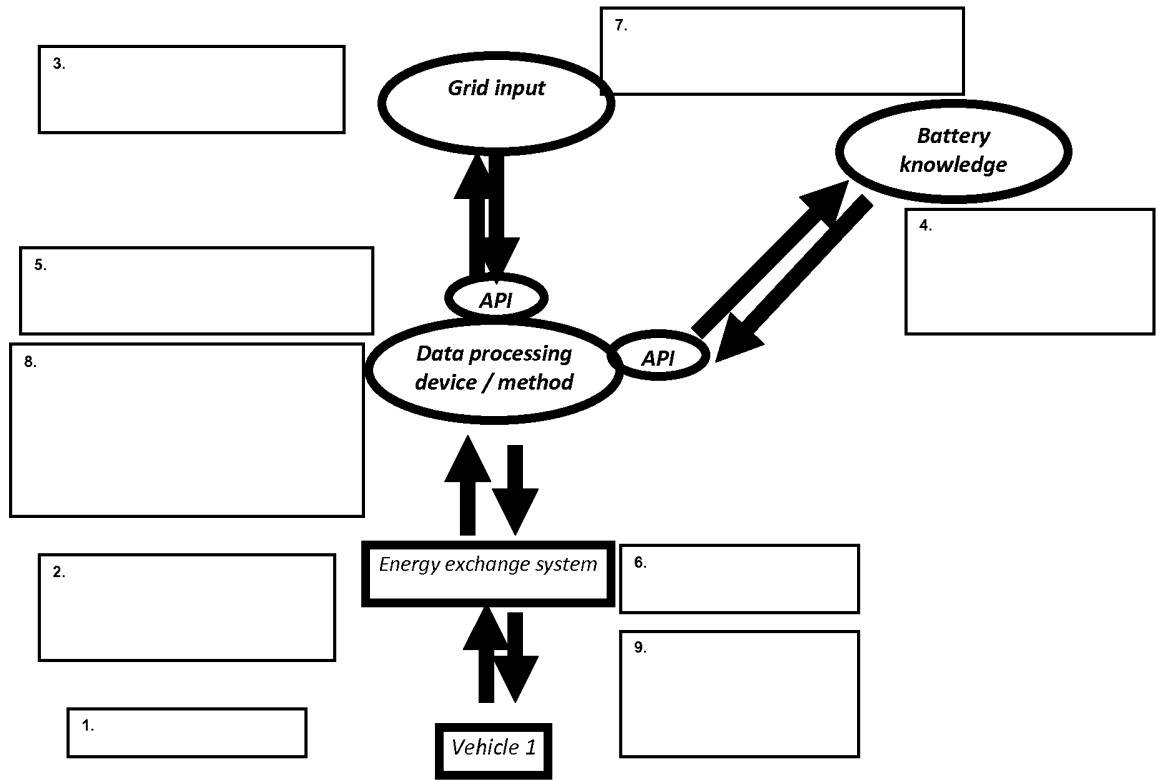


FIG 4e

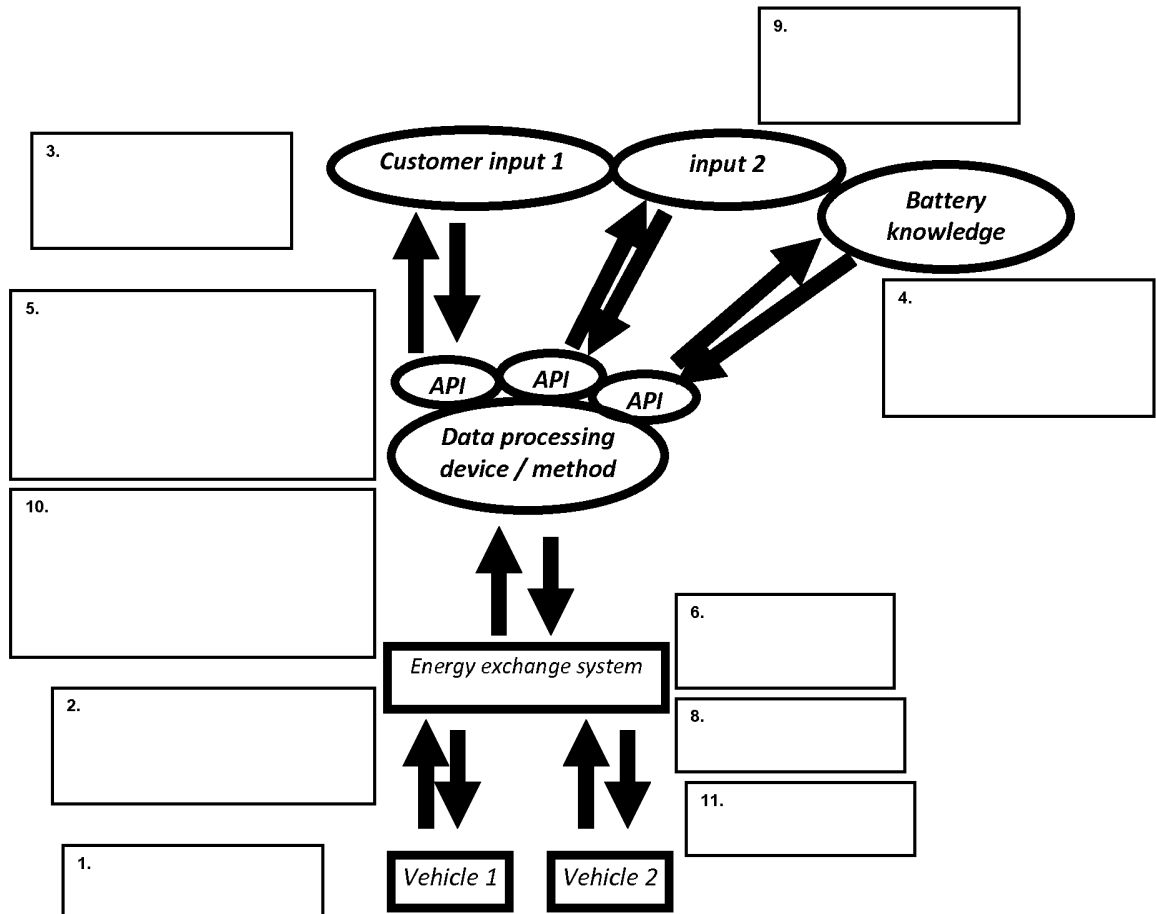


FIG 4f

SAMENWERKINGSVERDRAG (PCT)

RAPPORT BETREFFENDE NIEUWHEIDSONDERZOEK VAN INTERNATIONAAL TYPE

IDENTIFICATIE VAN DE NATIONALE AANVRAGE	KENMERK VAN DE AANVRAGER OF VAN DE GEMACHTIGDE
	1.599.007 NL
Nederlands aanvraag nr.	Indieningsdatum
2004503	02-04-2010
	Ingeroepen voorrangsdatum
Aanvrager (Naam)	
EPYON BV	
Datum van het verzoek voor een onderzoek van internationaal type	Door de Instantie voor Internationaal Onderzoek aan het verzoek voor een onderzoek van internationaal type toegekend nr.
31-07-2010	SN 54608
I. CLASSIFICATIE VAN HET ONDERWERP (bij toepassing van verschillende classificaties, alle classificatiesymbolen opgeven)	
Volgens de internationale classificatie (IPC)	
H02J7/00	B60L11/18
II. ONDERZOCHE GEBIEDEN VAN DE TECHNIEK	
Onderzochte minimumdocumentatie	
Classificatiesysteem	Classificatiesymbolen
IPC8	H02J B60L
Onderzochte andere documentatie dan de minimum documentatie, voor zover dergelijke documenten in de onderzochte gebieden zijn opgenomen	
III. ☐	GEEN ONDERZOEK MOGELIJK VOOR BEPAALDE CONCLUSIES (opmerkingen op aanvullingsblad)
IV. ☐	(opmerkingen op aanvullingsblad)

**ONDERZOEKSRAPPORT BETREFFENDE HET
RESULTAAT VAN HET ONDERZOEK NAAR DE STAND
VAN DE TECHNIEK VAN HET INTERNATIONALE TYPE**

Nummer van het verzoek om een onderzoek naar
de stand van de techniek
NL 2004503

A. CLASSIFICATIE VAN HET ONDERWERP
INV. H02J7/00 B60L11/18
ADD.

Volgens de Internationale Classificatie van octrooien (IPC) of zowel volgens de nationale classificatie als volgens de IPC.

B. ONDERZOCHE GEBIEDEN VAN DE TECHNIEK

Onderzochte minimum documentatie (classificatie gevolgd door classificatiesymbolen)
H02J B60L

Onderzochte andere documentatie dan de minimum documentatie, voor dergelijke documenten, voor zover dergelijke documenten in de onderzochte gebieden zijn opgenomen

Tijdens het onderzoek geraadpleegde elektronische gegevensbestanden (naam van de gegevensbestanden en, waar uitvoerbaar, gebruikte trefwoorden)
EPO-Internal

C. VAN BELANG GEACHTE DOCUMENTEN

Categorie °	Geciteerde documenten, eventueel met aanduiding van speciaal van belang zijnde passages	Van belang voor conclusie nr.
X	US 2002/070710 A1 (YAGI KAZUHIKO [JP] ET AL) 13 juni 2002 (2002-06-13) * alinea [0038]; figuren 1-7, 9 * * alinea's [0063] - [0072] *	1-26
X	US 5 710 507 A (ROSENBLUTH DAVID B [US] ET AL) 20 januari 1998 (1998-01-20) * figuren 1,2 * * kolommen 3-4 *	1,18,21, 26

☐ Verdere documenten worden vermeld in het vervolg van vak C.

☒ Leden van dezelfde octroofamilie zijn vermeld in een bijlage

° Speciale categorieën van aangehaalde documenten

A niet tot de categorie X of Y behorende literatuur die de stand van de techniek beschrijft

D in de octrooiaanvraag vermeld

E eerdere octrooi(aanvraag), gepubliceerd op of na de indieningsdatum, waarin dezelfde uitvinding wordt beschreven

L om andere redenen vermelde literatuur

O niet-schriftelijke stand van de techniek

P tussen de voorrangsdatum en de indieningsdatum gepubliceerde literatuur

T na de indieningsdatum of de voorrangsdatum gepubliceerde literatuur die niet bezwarend is voor de octrooiaanvraag, maar wordt vermeld ter verheldering van de theorie of het principe dat ten grondslag ligt aan de uitvinding

X de conclusie wordt als niet nieuw of niet inventief beschouwd ten opzichte van deze literatuur

Y de conclusie wordt als niet inventief beschouwd ten opzichte van de combinatie van deze literatuur met andere geciteerde literatuur van dezelfde categorie, waarbij de combinatie voor de vakman voor de hand liggend wordt geacht

& lid van dezelfde octroofamilie of overeenkomstige octrooipublicatie

Datum waarop het onderzoek naar de stand van de techniek van internationaal type werd voltooid

27 oktober 2010

Verzenddatum van het rapport van het onderzoek naar de stand van de techniek van internationaal type

Naam en adres van de instantie

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

De bevoegde ambtenaar

Marannino, M

**ONDERZOEKSRAPPORT BETREFFENDE HET
RESULTAAT VAN HET ONDERZOEK NAAR DE STAND
VAN DE TECHNIEK VAN HET INTERNATIONALE TYPE**

Informatie over leden van dezelfde octrooifamilie

Nummer van het verzoek om een onderzoek naar
de stand van de techniek

NL 2004503

In het rapport genoemd octrooigeschrift	Datum van publicatie	Overeenkomend(e) geschrift(en)	Datum van publicatie
US 2002070710	A1	13-06-2002 JP 2002125326 A	26-04-2002
US 5710507	A	20-01-1998 GEEN	



OCTROOICENTRUM NEDERLAND

WRITTEN OPINION

File No. SN54608	Filing date (day/month/year) 02.04.2010	Priority date (day/month/year)	Application No. NL2004503
International Patent Classification (IPC) INV. H02J7/00 B60L11/18			
Applicant Epyon B.V.			

This opinion contains indications relating to the following items:

- ☒ Box No. I Basis of the opinion
- ☐ Box No. II Priority
- ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☐ Box No. IV Lack of unity of invention
- ☒ Box No. V Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI Certain documents cited
- ☒ Box No. VII Certain defects in the application
- ☒ Box No. VIII Certain observations on the application

	Examiner Marannino, M
--	--------------------------

WRITTEN OPINION

Application number
NL2004503

Box No. I Basis of this opinion

1. This opinion has been established on the basis of the latest set of claims filed before the start of the search.
2. With regard to any **nucleotide and/or amino acid sequence** disclosed in the application and necessary to the claimed invention, this opinion has been established on the basis of:
 - a. type of material:
 - ☐ a sequence listing
 - ☐ table(s) related to the sequence listing
 - b. format of material:
 - ☐ on paper
 - ☐ in electronic form
 - c. time of filing/furnishing:
 - ☐ contained in the application as filed.
 - ☐ filed together with the application in electronic form.
 - ☐ furnished subsequently for the purposes of search.
3. ☐ In addition, in the case that more than one version or copy of a sequence listing and/or table relating thereto has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.
4. Additional comments:

Box No. V Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty	Yes: Claims	7-9, 11, 13-15, 17, 19, 20, 22-25
	No: Claims	1-6, 10, 12, 16, 18, 21, 26
Inventive step	Yes: Claims	
	No: Claims	1-26
Industrial applicability	Yes: Claims	1-26
	No: Claims	

2. Citations and explanations

see separate sheet

WRITTEN OPINION

Application number
NL2004503

Box No. VII Certain defects in the application

see separate sheet

Box No. VIII Certain observations on the application

see separate sheet

Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

Reference is made to the following document(s):

Prior art D1

1.1 The present application does not meet the criteria of patentability, because the subject-matter of claims 1, 21 is not new.

D1 discloses a method for charging a battery, comprising:

heating a battery if a battery temperature is below a low-threshold temperature ($T \leq 0$ see fig. 2 steps S2-S8, diagram fig. 3 and $0 < T \leq 10$, see fig. 2, steps S11-S17, diagram fig. 4; see also figs. 6-7); charging the battery when the battery temperature is above the low-threshold temperature ($T < 10$ see fig. 2 steps S21-S26, diagram fig. 5).

Therefore subject-matter of claim 1 is not new.

Prior art D2

1.2 The present application does not meet the criteria of patentability, because the subject-matter of claims 1, 21 is not new.

D2 (column 2, lines 24-35) discloses a method for charging a battery, comprising:

heating a battery if a battery temperature is below a low-threshold temperature ($T < 20$ see fig. 1 step S150); charging the battery when the battery temperature is above the low-threshold temperature ($T \geq 20$ see fig. 1 steps S170).

Therefore subject-matter of claim 1 is not new.

2 Dependent claims 2-19, 22-26 do not contain any features which, in combination with the features of any claim to which they refer, meet the requirements of novelty and/or inventive step.

In particular claims 2-6, 10, 12, 16, 18, 26 are not new.

- for claim 2-6: see D1: figs. 3, 4, 6 in particular in fig. 6 it is clear that the average current is positive; see also paragraph [0072];

- for claims 10, 12: see D1: step S24 of fig. 2; fig. 5 and current I of fig. 9, paragraphs [0063]-[0065];
- for claim 16: the temperature is measured (via sensor (6), fig. 1) and transmitted to control section via the data communication bus connecting the sensor and the control unit;
- for claim 18: see D2 see steps 140, 160 of fig. 1, column 4, lines 46-55;
- for claim 26: see D1 (paragraph [0004]) or D2 (column 4, lines 21-23).

Claims 7-9, 11, 13-15, 17, 22-25 are not inventive.

- for claims 7-9, 17, 19, 20: they relate to well known alternative ways of performing the battery heating phase in efficient for which the person skilled in the art will choose according to his needs;
- for claims 11, 13, 22 they relate to well known alternative ways of performing the battery charging phase for which the person skilled in the art will choose according to his needs;
- for claims 13-15 they relate to well known alternative ways for measuring battery temperature for which the person skilled in the art will choose according to his needs;
- for claim 23-25: they relate to normal , routine measures used by the person skilled in battery charger for vehicle system.

Re Item VII

Certain defects in the application

The relevant background art disclosed in D1, D2 is not mentioned in the description, nor are these documents identified therein.

Re Item VIII

Certain observations on the application

Claim 22 is not clear since it not possible that a battery charging apparatus is dependent on the method according to claims 5-20.

Similarly claims 23-26 when referring directly or indirectly to claim 22 are not clear.