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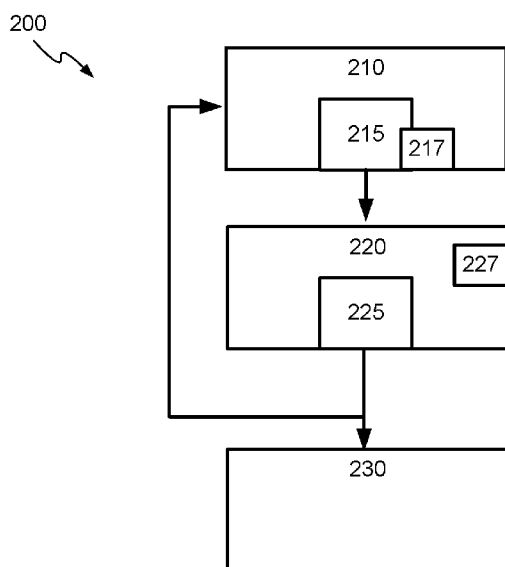


Fig 6

(57) Abstract: A method (200) of heating a battery is disclosed. The battery is arranged in an entrance system for providing power to one or more electric motors of the entrance system. The method (200) comprises monitoring (210) of a current temperature of the battery and a current state of charge of the battery. If the current temperature of the battery is below a first temperature threshold and the current state of charge of the battery is below a first charge threshold, the battery is discharged (220) by means of a load impedance until the current temperature of the battery is above a second temperature threshold. An entrance system is also disclosed.



Heating of battery in entrance system

TECHNICAL FIELD

The present invention relates to a control method of an entrance system and
5 more precisely to a control method of heating a battery comprised in an entrance system.

BACKGROUND

Entrance systems having automatic door operators are frequently used for
10 providing automatic opening and closing of one or more movable door members. These entrance systems may comprise sectional door operator systems for providing automatic opening and closing of doors to facilitate entrance and exit to buildings, cargo bays, rooms and other areas. The door operator systems typically comprise a number of drive units responsible for driving the sectional door between closed and open positions.

15 The sectional door operator systems are typically used in both private and public areas during long time periods and under various conditions in terms of time of day, time of week, time of year, passage frequencies, etc. Therefore, the systems need to remain long-term operational without malfunctions even during heavy traffic by persons or objects passing through the doors. At the same time, safety is crucial in order to
20 ensure that the entrance system is operational also in case of emergencies like fire etc.

Many entrance systems utilize electric motors in order to transition the doors from a closed state to an open state and/or vice versa. Many of the doors, e.g. sectional doors for cargo bays, are very heavy and the electric motors driving the doors have to be heavy duty equipment in order to exert the required torque to open and/or close the
25 door. The electric motors require significant amounts of current when putting the door into motion, currents of 30 to 40 A are not unusual. In order not to have to source this current directly from a mains supply, the entrance system may be provided with a rechargeable battery that is used to drive the high currents for the electric motors. The battery may be used as the sole source of power in case of e.g. a power outage and in
30 many cases it is crucial that the entrance system is operational also in cases of power outage.

The temperature of the rechargeable battery is very important since, for instance a lithium based battery can be severely damaged if charged at too low temperature. In addition to this, as the temperature drops, the internal resistance of the battery increases and the ability of the battery to provide high currents decreases. Also,
5 the usable energy stored in the battery decreases with temperature. In other words, there is a risk that a door will not open at all, or will only open to a certain degree if the temperature of the battery driving the electric motor of the entrance system is too low.

Prior art entrance systems are in some cases provided with heating elements arranged to ensure that the batteries are maintained at a desired temperature. These
10 heating elements are typically powered by the same power source that is used to charge the batteries. Apart from not working in cases of a power shortage, these heating elements are very costly and could significantly add to the cost of the bill of material of an entrance system.

From the above it is understood that there is room for improvements.

SUMMARY

An object of the present invention is to provide a new type of method of heating batteries of entrance systems which is improved over prior art and which eliminates or at least mitigates the drawbacks discussed above. More specifically, an
20 object of the invention is to provide a method of heating batteries and an entrance system with heated batteries wherein the heating functionality has little or no impact on the cost of the bill of material of an entrance system. These objects are achieved by the technique set forth in the appended independent claims with preferred embodiments defined in the dependent claims related thereto.

25 In a first aspect of the invention, a method of heating a battery is presented. The battery is arranged in an entrance system for providing power to one or more electric motors of the entrance system. The method comprises monitoring a current temperature of the battery and a current state of charge of the battery. If the current temperature of the battery is below a first temperature threshold and the current state of
30 charge of the battery is below a first charge threshold, the battery is discharged by

means of a load impedance until the current temperature of the battery is above a second temperature threshold.

In one embodiment of the method, the load impedance is further configurable to be arranged to dissipate power generated by said one or more electric motors. This
5 means that the load impedance can have two functions which reduces the need for additional components of the entrance system when performing the method of the invention. In other words, the cost of the entrance system can be reduced.

In one embodiment of the method, the step of discharging comprises
controlling one or more switches to electrically connect the load impedance to the
10 battery and electrically disconnect said one or more electric motors from the battery. Having switches such as relays, transistors or other switching means is beneficial since it allows for automatic control of the state of the switches, further to this, by selectively isolating the electrical motor from the battery reduces the risk that the motor is unintentionally operated during discharging of the battery, thereby reducing the risk of
15 violating any standard requirement, e.g. EN, FCC requirements etc.

In one embodiment of the method, the load impedance is one or more of said one or more electric motors of the entrance system and the step of discharging further comprises controlling a discharge current flowing through said one or more electric motors such that said one or more electric motors are not operated. Having the electric
20 motors also configurable to act as the load impedance reduces the need for additional components and the cost of the entrance system can be reduced. Controlling the current such that the electrical motor is not activated reduces the risk that the motor is unintentionally operated during discharging of the battery, thereby reducing the risk of violating any standard requirement, e.g. EN, FCC requirements etc.

25 In one embodiment of the method, the step of discharging further comprises controlling the discharge current flowing through the load impedance, preferably by means of PWM control of one or more switches arranged to connect and disconnect the load impedance from the battery. Controlling the discharge current is beneficial as it enables more advanced control of the heating of the battery. The rate of the temperature
30 rise of the battery can be decreased as the current temperature of the battery closes in on the second temperature threshold. The control of the current temperature of the battery

be implemented with an integral part and/or a derivative part as a PI-, PD or PID controller.

In one embodiment of the method, the step of monitoring further comprises monitoring a current temperature time derivative of the current temperature of the battery and if the current temperature time derivative is below a temperature derivative
5 threshold, performing the step of discharging the battery. This enables a predictive algorithm for controlling the current temperature of the battery.

In one embodiment of the method, the step of monitoring further comprises monitoring an exterior temperature. The exterior temperature is external to the battery,
10 and if the exterior temperature is below an exterior temperature threshold, performing the step of discharging the battery. The exterior temperature may be an outside temperature and by monitoring also exterior temperature, sudden drops can be detected and a smarter, more energy efficient heating of the battery can be implemented.

In one embodiment of the method, it further comprises, if the current
15 temperature is above the second temperature threshold, and the current state of charge is below a second charge threshold, charging the battery until the current state of charge of the battery is above a third charge threshold. Recharging the battery only when its temperature is above a threshold reduces the risk of damaging the battery during charging and only charging the battery when its current state of charge is below a
20 threshold reduces the number of charging cycles of the battery. Combined, the life of the battery is extended with all savings on cost and the environment as this entails.

In one embodiment of the method, the third charge threshold is lower than a maximum state of charge of the battery, preferably lower than 95 % of the maximum state of charge of the battery. Having the threshold where the charging is stopped at a
25 level below the maximum state of charge of the battery is beneficial as this will increase the number of charging cycles the battery can withstand without deteriorating, thereby the life of the battery is extended with all savings on cost and the environment as this entails.

In a second aspect of the invention, an entrance system is presented. The
30 entrance system comprises one or more electric motors, a load impedance, a controller module and a battery connectable to provide power to said one or more electric motors.

The control module is configured to monitor a current temperature of the battery and a current state of charge of the battery. If the current temperature of the battery is below a first temperature threshold and the current state of charge of the battery is below a first charge threshold, then the control module is configured to discharge the battery by
5 means of the load impedance until the current temperature of the battery is above a second temperature threshold.

In one embodiment of the entrance system, it further comprises one or more switches to electrically connect the load impedance to the battery and electrically disconnect said one or more electric motors from the battery. Having switches such as
10 relays, transistors or other switching means is beneficial since it allows for automatic control of the state of the switches, further to this, by selectively isolating the electrical motor from the battery reduces the risk that the motor is unintentionally operated during discharging of the battery, thereby reducing the risk of violating any standard requirement, e.g. EN, FCC requirements etc.

15 In one embodiment of the entrance system, the load impedance is further connectable to dissipate power generated by said one or more electric motors. This means that the load impedance can have two functions which reduces the need for additional components of the entrance system. In other words, the cost of the entrance system can be reduced.

20 In one embodiment of the entrance system, the load impedance is one or more of said one or more electric motors, and the control module is further configured to control, when discharging the battery by means said one or more electric motors, a discharge current flowing through said one or more electric motors such that said one or more electric motors are not operated. Having the electric motors also configurable to
25 act as the load impedance reduces the need for additional components and the cost of the entrance system can be reduced. Controlling the current such that the electrical motor is not activated, reduces the risk that the motor is unintentionally operated during discharging of the battery, thereby reducing the risk of violating any standard requirement, e.g. EN, FCC requirements etc.

In one embodiment of the entrance system, it further comprises a charging module. The control module is further configured to, if the current temperature is above the second temperature threshold, and the current state of charge is below a second charge threshold, charge the battery until the current state of charge of the battery is
5 above a third charge threshold. The charging module is very beneficial since it enables the recharging of the battery, and in the entrance system according to the invention, recharging the battery only when its temperature is above a threshold reduces the risk of damaging the battery during charging and only charging the battery when its current state of charge is below a threshold reduces the number of charging cycles of the
10 battery. Combined, the life of the battery is extended with all savings on cost and the environment as this entails.

In one embodiment of the entrance system, the third charge threshold is lower than a maximum state of charge of the battery, preferably lower than 95 % of the maximum state of charge of the battery. Having the threshold where the charging is
15 stopped at a level below the maximum state of charge of the battery is beneficial as this will increase the number of charging cycles the battery can withstand without deteriorating, thereby the life of the battery is extended with all savings on cost and the environment as this entails.

20 **BRIEF DESCRIPTION OF THE DRAWINGS**

Embodiments of the invention will be described in the following; references being made to the appended diagrammatical drawings which illustrate non-limiting examples of how the inventive concept can be reduced into practice.

25 Figures 1a-d are schematic sectional views of entrance systems workable with embodiments of the invention.

Figure 2 is a block diagram of an automatic door operator according to embodiments of the invention.

Figure 3 is a time series plot of temperature and state of charge of an entrance
30 system according to embodiments of the invention.

Figure 4 is a time series plot of temperature and state of charge of an entrance system according to embodiments of the invention.

Figures 5a-c are simplified electric schematics of part of an entrance system according to embodiments of the invention.

5 Figure 6 is a schematic view of a method of heating a battery according to embodiments of the invention.

DETAILED DESCRIPTION OF EMBODIMENTS

Hereinafter, certain embodiments will be described more fully with reference
10 to the accompanying drawings. The invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided by way of example so that this disclosure will be thorough and complete, and will fully convey the scope of the invention, such as it is defined in the appended claims, to those skilled in the art.

15 The terms "substantially," "approximately," and "about" are defined as largely, but not necessarily wholly what is specified, as understood by a person of ordinary skill in the art. The terms "comprise" (and any form of comprise, such as "comprises" and "comprising"), "have" (and any form of have, such as "has" and "having"), "include" (and any form of include, such as "includes" and "including") and "contain" (and any
20 form of contain, such as "contains" and "containing") are open-ended linking verbs. As a result, a method that "comprises," "has," "includes" or "contains" one or more steps possesses those one or more steps, but is not limited to possessing only those one or more steps.

With reference to Figures 1a to 1d, different types of entrance systems 100 in
25 which the present invention can be implemented will be described. Starting with Figure 1a, a first embodiment of an entrance system 10 in the form of a sliding door system 10 is shown in a schematic top view. The sliding door system 10 comprises first and second sliding doors or wings D1 and D2, being supported for sliding movements M1 and M2 in parallel with first and second wall portions 20 and 25. The first and second
30 wall portions 20 and 25 are spaced apart; in between them there is formed an opening which the sliding doors D1 and D2 either blocks (when the sliding doors are in closed

positions), or makes accessible for passage (when the sliding doors are in open positions). An automatic door operator 100, not seen in Figure 1a but will be explained below, causes the movements M1 and M2 of the sliding doors D1 and D2.

In Figure 1b, another embodiment of an entrance system 10 in the form of a revolving door system 10 is shown in a schematic top view. The revolving door system 10 comprises a plurality of revolving doors or wings D1-D4 being located in a cross configuration in an essentially cylindrical space between first and second curved wall portions 27 and 28 which, in turn, are spaced apart and located between first and second wall portions 20 and 25. The revolving doors D1-D4 are supported for rotational movement M1 in the cylindrical space between the first and second curved wall portions 27 and 28. During the rotation of the revolving doors D1-D4, they will alternately prevent and allow passage through the cylindrical space. An automatic door operator 100, not seen in Figure 1b but will be explained below, causes the rotational movement M1 of the revolving doors D1-D4.

A further embodiment of an entrance system 10 in the form of a swing door system 10 is shown in a schematic top view in Figure 1c. The swing door system 10 comprises a single swing door D1 being located between a lateral edge of a first wall 20 and an inner surface of a second wall 25 which in this embodiment is perpendicular to the first wall 20. The swing door D1 is supported for pivotal movement M1 about pivot points on or near the inner surface of the second wall 25. The first and second walls 20 and 25 are spaced apart; in between them an opening is formed which the swing door D1 either blocks (when the swing door is in closed position), or makes accessible for passage (when the swing door is in open position). An automatic door operator 100, not seen in Figure 1c but will be explained below, causes the movement M1 of the swing door D1.

Turning to Figure 1d, an embodiment of an entrance system 10 in the form of a sectional door system 10 is shown in a schematic front view. The sectional door system 10 comprises a sectional door D1 which in turn comprises a plurality of horizontal and interconnected sections D1a-e forming the sectional door D1. The sectional door D1 is located between a first wall 20 and a second wall 25. The first and second walls 20 and 25 are spaced apart; in between them an opening is formed in which the sectional door

D1 is sandwiched between tracks 23 attached to the first and second walls 20 and 25.

The sectional door D1 is supported for vertical movement M1 along the tracks 23. The tracks 23 may be arranged to change directions to a substantially horizontal direction at an upper section of the sectional door D1. The sectional door D1 is arranged to either

5 block the opening, when the sectional door D1 is in a lower closed position, or make the opening accessible for passage, when the sectional door D1 is in an upper open position. An automatic door operator 100, causes the movement M1 of the sectional door D1.

With continued reference to Figure 1d, the automatic door operator 100 typically comprises one or more electric motors 110 operatively connected to move the
10 door or swing according to its intended movement M1, M2. In the embodiment of Figure 1d, the electrical door operator 100 is connected to the rails 23 by means of a transmission 105 and the automatic door operator 100 is arranged on one of the sections D1e of the sectional door D1. As the sectional door D1 is opened, i.e. raised, the section D1e carrying the automatic door operator 100 is raised, and the automatic door operator
15 100 is moved along the rails 23. Since the electric motors 110 consume large currents when operated, having a flexible cabling being able to source high currents would be very expensive and cumbersome. Therefore, the automatic door operator is typically provided with a battery 120 arranged to source the high currents directly to the one or more electric motors 110, reducing the need of heavy duty cables between a power
20 source, e.g. mains power, and the electric motor 110. Albeit only the embodiment of Figure 1d, sectional door system 10, is illustrated with the automatic door operator 100, other entrance systems 10 are also usable with an automatic door operator 100 comprising a battery 120 and the present invention is relevant for any entrance system 10 comprising a battery 120 for driving one or more electric motors 110 of the entrance
25 system 10. The battery 120 may be any suitable battery but is preferably a battery using lithium based chemistry such as a Lithium-Ion, Li-Ion, or Lithium Polymer, LiPo, type batteries 120.

In Figure 2, a schematic view of the electrical door operator 100 according to one embodiment is shown. The electrical door operator 100 comprises a control module
30 130 operatively connected to at least one electric motor 110. The electric motor 110 may be comprised in the electrical door operator 100, or operatively connected to the

electrical door operator 100. The control module 130 is operatively connected to one or more batteries 120 and preferably to an external power source 150. The control module 130 is configured to drive the electric motor 110. The electrical door operator 100 is typically provided with a suitable wired or wireless external interface, not shown, for
5 sending and/or receiving operational data and/or control data associated with e.g. operation of the entrance system 10.

As explained above, the temperature of the battery 120 is very important, and in order to measure a current temperature T_c of the battery 120, the battery 120 may be provided with one or more temperature sensors 125. The battery 120 is typically formed
10 as a battery pack 120 comprising a plurality of battery cells connected in series and/or parallel in order to provide the required voltage and capacity for the electrical door operator 100. The temperature sensor 125 is typically embedded in the battery pack 120 and may be any suitable temperature sensor 125 such as a simple resistive element having a positive temperature curve, PTC, or a resistive element having a negative
15 temperature curve, NTC. The temperature sensors 125 of the battery 120 are arranged to measure a current temperature T_c equal to, or related to a cell temperature of the battery 120.

The current temperature T_c of the battery is provided to the control module 130 for monitoring. The control module 130 is further configured to monitor a current state
20 of charge SOC_c of the battery 120. The state of charge is the ratio of a currently available capacity Q_c and the maximum possible charge that can be stored in a battery 120, i.e., the nominal capacity Q_n of the battery 120. The current state of charge SOC_c of the battery and/or the currently available capacity Q_c may be determined in any suitable means known from the art such as, but not limited to, voltage based methods,
25 current integration method, coulomb counting or combinations thereof.

The control module 130 may further be provided with a charging module 135 for charging the battery 120. There may be entrance systems 10 that are configured to be portable or for other reasons are provided without a charging module 130. The present invention is applicable also for these types of entrance systems 10.

30 An internal resistance R_i is inherent to all batteries 120, and albeit lithium based batteries 120 have a comparably low internal resistance R_i , typically in the range

of 50 mΩ to 500 mΩ, it is still high enough to generate heat when dissipating power in the internal resistance R_I . In addition, as mentioned earlier, the internal resistance R_I is high enough to limit a maximum current possible to be sourced from the battery 120 as the voltage drop across the internal resistance R_I is based on the sourced current

5 according to Ohms law. As mentioned, the internal resistance R_I increases as the current temperature T_c decreases. One key aspect of the control module 130 is that it, based on the current state of charge SOC_c and the current temperature T_c , selectively heats the battery 120 by utilizing the internal resistance R_I of the battery 120. This is accomplished by loading, i.e. discharging, the battery by means of a load impedance Z_L .

10 The load impedance Z_L may, as is explained in other sections of this disclosure, be comprised in the control module 130 and/or in the electric motor 110. Using the internal resistance R_I to heat the battery 120 is very beneficial as the battery cells will be heated from the inside, thus providing a much more efficient heating of the battery 120. The battery 120 can be heated to a desired temperature without having a surface temperature

15 of the battery 120 increase more than necessary, as would have been the case if an external heating element was used. Consequently, using the internal resistance R_I to heat the battery 120 is also more energy efficient and thereby environmentally friendly compared to using external heating elements.

A discharge current I_d , the current that will flow through the load impedance Z_L during discharge, will depend on an impedance of the load impedance Z_L . The increase of the current temperature T_c of the battery 120 will depend on the discharge current I_d , the internal resistance R_I of the battery 120 and a specific heat capacity C_p of the battery 120. The specific heat capacity of the battery 120 is inherent to the design and chemistry of the battery 120, and measure the amount of energy required to heat 1 kg of a

25 compound 1 Kelvin, a typical heat capacity of a Lithium based battery is in the region of 1,0 to 2,5 J/g°C. The specific heat capacity of a battery having a mass m and can be calculated according to Equation 1a below, where $E_{\Delta T}$ is the energy required to raise the temperature of the battery ΔT degrees. The energy E dissipated in the battery 120 when discharging is calculated according to Equation 1b below, where t is the discharge time.

30
$$C_p = \frac{E_{\Delta T}}{\Delta T \cdot m} \quad \text{Eqn. 1a}$$

$$E = I_d^2 \cdot R_I \cdot t \quad \text{Eqn. 1b}$$

The equations above can be combined and the end result can be used to optimize the heating based on discharge time or a discharge current I_d in order to arrive at a desired current temperature T_c of the battery 120 within a desired time.

5 With reference to Figure 3, showing a time series plot of the current temperature T_c and the current state of charge SOC_c , the conceptual idea of the present invention will be explained. In the plot of Figure 3, the current state of charge SOC_c and the current temperature T_c drops over time t . The drop in current state of charge SOC_c may be e.g. due to the drop in current temperature T_c and/or self-discharge of the battery
 10 120. As the current temperature T_c of the battery 120 drops below a predefined or configurable first temperature threshold T_{T1} , the battery 120 is discharged via the load impedance Z_L . As the battery 120 is discharged, the current temperature T_c of the battery 120 increases, and the discharging preferably continues until the current temperature T_c of the battery 120 is a predefined or configurable second temperature
 15 threshold T_{T2} . In Figure 3, this can be seen as the solid line showing the current temperature T_c , tilting upwards, i.e. increase, after having fallen below the first temperature threshold T_{T1} and then, after crossing the second temperature threshold T_{T2} , start to tilt downwards, i.e. decrease, again as the discharging has seized. The first temperature threshold T_{T1} is at a lower temperature than the second temperature
 20 threshold T_{T2} .

In Figure 3, a dotted line illustrates the current state of charge SOC_c , and as the current temperature T_c start to increase, the drop in current state of charge SOC_c seize and the current state of charge SOC_c effectively increases until the discharging is stopped, after which the current state of charge SOC_c drops once more.

25 Note that the plot in Figure 3 is for illustrative purposes only and the slope of the current state of charge SOC_c will depend greatly on the amount of energy consumed when discharging the battery 120 in order to increase the temperature of the battery 120, and the temperature dependency of the currently available capacity Q_c of the battery 120. Low temperatures of the battery 120 effect the currently available capacity Q_c of
 30 the battery 120 and the possibility to charge the battery 120 without damaging it, it is beneficial to only heat the battery 120 by discharging of the battery 120 by means of the

load impedance Z_L only when the current state of charge SOC_c is below a first charge threshold T_{SOC1} . This is done in order not to cycle the battery 120 more than necessary, as batteries have a limited amount of charge/discharge cycles. The actions and monitoring described above with reference to Figure 3, are preferably performed by the control module 130 of the electrical door operator 100.

The second temperature threshold T_{T2} is greater than or equal to the first temperature threshold T_{T1} . The second temperature threshold T_{T2} is preferably set at a level at which the battery 120 have a current temperature T_c at which the battery 120 can be charged without being damaged. The second temperature threshold T_{T2} is preferably in the range of 5 to 40 °C, more preferably in the range of 5 to 20 °C and most preferably in the range of 10 to 15 °C.

In Figure 4, charging capabilities are available, e.g. embodiments wherein the control module 130 comprises the charging module 135. As the current temperature T_c of the battery 120 drops below the first temperature threshold T_{T1} and the current state of charge SOC_c drops below the first charge threshold T_{SOC1} , the discharging by means of the load impedance Z_L is started. The current temperature T_c of the battery 120 increases, and as the current temperature T_c of the battery 120 is above the second temperature threshold T_{T2} , discharging by means of the load impedance Z_L is stopped and charging of the battery 120 is started. The current state of charge SOC_c of the battery 120 is below a second charge threshold T_{SOC2} and the battery 120 is charged, effectively increasing the current state of charge SOC_c of the battery 120. The current state of charge SOC_c is monitored such that the charging can be stopped when the current state of charge SOC_c reaches a third charge threshold T_{SOC3} . As the battery 120 is charged, the current temperature T_c of the battery 120 typically increase. The actions and monitoring described above with reference to Figure 4, are preferably performed by the control module 130 of the electrical door operator 100.

Although not illustrated in the Figures 3 or 4, other temperature and/or charge thresholds may be implemented. If, due to unforeseen actions or extreme utilization of the entrance system 10, the state of charge SOC_c of the battery 120 should be at a level where it is too low to increase the current temperature T_c of the battery 120 and/or operate the entrance system 10, an error message could be generated by the control

module 130. Alternatively or additionally, scheduling features may be added such that the controlled discharging of the battery 120 by means of the load impedance Z_L is scheduled at times where utilization of the entrance system 10 is low.

Batteries in general, and Lithium based batteries in particular have a limited
5 number of charge/discharge cycles before their nominal capacity Q_n start to drop and the battery deteriorates. At least in the case of Lithium based batteries, the number of charge/discharge cycles of a battery 120 is reduced if the battery 120 is fully charged or fully discharged. In order to increase the life time of the battery, the third charging threshold T_{SOC3} , the threshold at which charging is stopped, is preferably lower than a
10 maximum state of charge SOC_{MAX} , i.e. when the currently available capacity Q_c of the battery 120 is substantially equal to the nominal capacity Q_n of the battery 120. Even more preferably, lower than 95 % of the maximum state of charge SOC_{MAX} of the battery 120, and most preferably, lower than 90 % of the maximum state of charge SOC_{MAX} . Similarly, the second charging threshold T_{SOC2} , the threshold at which
15 charging is started of the current temperature of the battery T_c is above the second temperature threshold T_{T2} , is typically above a minimum state of charge SOC_{MIN} , i.e. when the currently available capacity Q_c of the battery 120 is substantially zero. Even more preferably, more than 5 % of the minimum state of charge SOC_{MIN} of the battery 120, and most preferably, more than 10 % of the minimum state of charge SOC_{MIN} . It
20 should be understood that the first charging threshold T_{SOC1} is larger than, or equal to the second charging threshold T_{SOC2} , and the third charging threshold T_{SOC3} is equal to or larger than the first charging threshold T_{SOC1} but the third charging threshold T_{SOC3} is always greater than the second charging threshold T_{SOC2} .

The drop in the current temperature T_c of the battery 120 as described above
25 and illustrated in Figures 3 and 4, is due to the ambient temperature of the electrical door operator 100. Often, the electrical door operator 100 is used to control doors that separate a heated indoor environment from an outside and the electrical door operator 100 is mounted at a location with comparably good heat conduction to the outside. This is the case with for instance warehouse sectional door systems 10, where the doors D1
30 are located at docking bays. In order to increase the predictability of the current temperature T_c of the battery 120, some embodiments of the invention monitor also an

exterior temperature that is external to the battery 120. If the exterior temperature is below an exterior temperature threshold, the control module 130 is configured to discharge the battery 120 to increase the current temperature T_c of the battery 120. The exterior temperature may be provided by any suitable temperature sensing means
5 operative connector to, e.g. the control module 130 of the electrical door operator 100. The connection to the control module 130 may be any wired or wireless connection and it may be that the exterior temperature is provided to the control module 130 based on weather data available through a cloud service.

As mentioned, the monitoring of the current temperature T_c of the battery 120
10 and, where applicable, the exterior temperature, is preferably done by the control module 130. The control module 130 may further be configured to determine trends of the current temperature T_c of the battery 120 and/or the exterior temperature. The control module 130 can be configured to monitor a current time derivative of the current temperature T_c , a current temperature time derivative. Discharging of the battery 120 in
15 order to increase the current temperature T_c of the battery 120 may be performed if the current temperature time derivative is below a predetermined or configurable temperature derivative threshold. Additionally, or alternatively, the control module 130 may be configured to monitor a current time derivative of the exterior temperature, an exterior temperature time derivative. Discharging of the battery 120 in order to increase
20 the current temperature T_c of the battery 120 may be performed if the exterior temperature time derivative is below a predetermined or configurable exterior temperature derivative threshold.

All electric motors 110 are inductive and if they are forced to rotate by external forces, they will induce an electric potential across windings of the electric motor 110.
25 In an entrance system 10, this will happen when a door is returned to an idle position, such as when the sectional door system 10 of Figure 1d is returned to its lower closed position. If nothing is done to handle the induced potential, it can build up to several thousands of volts causing voltage transients that can severely damage the electrical motor 110 and/or the automatic door operator 100. In order to avoid this, the energy
30 generated when the entrance system 10 is returned to its idle position is returned to the battery 120 and/or dissipated in a load, preferably the load impedance Z_L .

With reference to Figures 5a-c, simplified electric schematics of part of the entrance system 10 according to embodiments of the invention, optional configurations of the load impedance Z_L will be explained. In all Figures 5a-c, the load impedance Z_L is arranged to be connected in parallel with the battery 120 or the electric motor 110. In

5 Figure 5a, the connection of the load impedance Z_L is determined by a first switch S_1 arranged to either disconnect the load impedance from both the battery 120 and the electrical motor 110, connect the load impedance Z_L to only the electrical motor 110 or connect the load impedance Z_L only to the battery 120. This type of switch S_1 is commonly referred to a single pole three throw, SP3T. In embodiments where SP3T

10 switches are undesirable, the embodiment of Figure 5b offers an alternative by utilizing two switches S_1 , S_2 . The first switch S_1 is connected to control the general activation of the load impedance Z_L , and a second switch S_2 , a single pole dual throw switch, SPDT, is used to connect either the battery 120 or the electric motor 110 to the load impedance Z_L . Alternatively, as illustrated in Figure 5c, several switches S_1 - S_3 can be utilized to

15 control the connection of the load impedance Z_L . In the embodiment of Figure 5c, simple on-off switches such as simple relays or single transistors can be used. The first switch S_1 is connected to control the general activation of the load impedance Z_L , the second switch S_2 connects the electric motor 110 to the first switch S_1 and a third switch S_3 connects the battery 120 to the first switch S_1 .

20 The embodiments exemplified with reference to Figures 5a-c are exemplary only and the skilled person understands, after reading this disclosure, that many further configurations are possible, e.g. incorporating motor control switches etc. The control of switches S_{1-3} is preferably provided by the control module 130, and none, some or all of the switches S_{1-3} may be comprised in the control module 130 and the remaining

25 switches S_{1-3} may be external to the control module 130. The load impedance Z_L may be any suitable load impedance Z_L , preferably the load impedance Z_L is a resistive load impedance Z_L , more preferably in the form of a power resistor Z_L .

The load impedance Z_L may optionally be provided by the electrical motor 110 itself. By controlling the electrical motor 110 such that it is not operated, the electrical

30 motor 110 will act as a load impedance Z_L for the battery 120. The use of the electrical motor 110 as load impedance Z_L may be accomplished in different ways depending on

the type of electric motor 110. If the electric motor 110 is a permanent magnet synchronous motor 110, which are commonly used in entrance systems 10, a current can be applied to the different windings of the permanent magnet synchronous motor 110 such that a rotor of the permanent magnet synchronous motor 110 is not rotated, i.e.
5 the applied currents may be configured to drive the rotor in opposite directions.

The different embodiments of the load impedance Z_L , i.e. the external load impedance Z_L or the use of the electric motor 110 as load impedance Z_L are possible to combine and are not mutually exclusive.

The discharge current I_d can be controlled, preferably by the control module
10 130, in order to keep the current temperature T_c of the battery 120 substantially constant or raise the current temperature T_c of the battery 120 to e.g. the second temperature threshold T_{T2} . The discharge current I_d can be controlled either by changing the load impedance Z_L by having the load impedance Z_L configured to be a variable impedance. Such variable impedances are known and readily available on the market. Alternatively,
15 and preferably, the discharge current I_d is controlled by pulse width modulation, PWM, of the control signal(s) controlling the connection of the load impedance Z_L to the battery 120. In practice, this may be achieved by applying PWM control to the switches S_{1-3} of Figures 5a-c, or PWM control of switches controlling the electric motor 110 if the electric motor 110 is the load impedance Z_L .

20 With reference to Figure 6, a method 200 of heating a battery 120 will be explained. The battery 120 is arranged in an entrance system 10 for providing power to one or more electric motors 110 of the entrance system 10. As previously explained, the battery 120 may be the sole source of power for the entrance system 10, used as a backup source of power, or provided to source high currents for the electrical motor(s)
25 110. The method 200 may be executed by the control module 130 of the entrance system 10. The method 200 may be configured to control, perform and/or monitor any features listed throughout this disclosure.

The method 200 is based on monitoring 210 the current temperature T_c of the battery 120 and the state of charge SOC_c of the battery 120. Periodically or continuously
30 during the monitoring 210, the current temperature T_c is compared 215 to the first temperature threshold T_{T1} and the current state of charge SOC_c is compared 215 to the

first charge threshold T_{SOC1} . If the current temperature T_c of the battery 120 is below the first temperature threshold T_{T1} and the current state of charge SOC_c is below the first charge threshold T_{T1} , the method 200 executes the step of discharging 220 the battery 120 by means of the load impedance Z_L . During the discharging 220, the current
5 temperature T_c is compared 225 to the second temperature threshold T_{T2} , and if the current temperature T_c is above or equal to the second temperature threshold T_{T2} , the discharging is stopped.

The discharging 220 may be performed by controlling e.g. the switches S_{1-3} of Figures 5a-c in order to electrically connect the load impedance Z_L to the battery 120
10 and electrically disconnect the electric motor 110 from the battery 120.

In one embodiment of the method 200, after the step of discharging 220, the method 200 is restarted by resuming, if it was stopped, the monitoring 210 the current temperature T_c of the battery 120 and the state of charge SOC_c of the battery 120.

In one embodiment of the method 200, the load impedance Z_L is the same
15 impedance that is used to dissipate power generated by the electric motor 110 when the electrical motor returns to its idle state. That is to say, the load impedance Z_L is further configurable to be arranged to dissipate power generated by said one or more electric motors 110.

The discharging may further comprise controlling 227 the discharge current I_d
20 flowing through the load impedance Z_L . This controlling 227 is preferably done, as previously explained, by means of PWN control of the signals controlling the discharging 220. If the electrical motor 110 is used as the load impedance Z_L , the discharge current I_d is preferably controlled 227 such that the electrical motor 110 is not operated.

25 In one embodiment of the method 200, the load impedance Z_L is the electrical motor 110 as previously explained. This means that there will be no requirement for external load impedances and the method may be implemented in a control module 130 without having to make any hardware modifications to the entrance system 10.

The step of monitoring 210 and/or comparing 215 may further comprise
30 monitoring the time derivative of current temperature T_c . If the time derivative of current temperature T_c is below the temperature derivative threshold, i.e. if the current

temperature T_c of the battery 120 drops at a rate that is below the temperature derivative threshold, the method 200 may be configured to perform the step of discharging 220 the battery 120. Further to this, the step of monitoring 210 may further comprises monitoring the exterior temperature as previously explained. If the exterior temperature
5 is below the exterior temperature threshold, the method 200 may be configured to perform the step of discharging 220. The step of discharging 220 may in this case be configured such that the discharge current I_d is controlled such that the current temperature T_c of the battery 120 is kept substantially constant.

In a preferred embodiment of the method 200, the method 200 further
10 comprises the step of charging 230 of the battery 120. The step of charging 230 is executed if the current temperature T_c of the battery 120 is above the second temperature threshold T_{T2} , and the current state of charge SOC_c is below the second charge threshold T_{SOC2} . The charging 230 is preferably performed until the current state of charge SOC_c of the battery 120 is above the third charge threshold T_{T3} .

15 Albeit many embodiments and features of the invention have been described such that the current state of charge SOC_c of the battery 120 is to be increased by increasing the current temperature T_c of the battery 120, it should be understood that the step of charging 230 in the method 200 and the charging module 135 of the control module, are preferred embodiments.

CLAIMS

1. A method (200) of heating a battery (120), wherein the battery (120) is arranged in an entrance system (10) for providing power to one or more electric motors (110) of the entrance system (10), the method comprising:
- 5 monitoring (210) a current temperature (T_c) of the battery (120) and a current state of charge (SOC_c) of the battery (120), and
- if the current temperature (T_c) of the battery (120) is below a first temperature threshold (T_{T1}) and the current state of charge (SOC_c) of the battery (120) is below a
- 10 first charge threshold (T_{SOC1}),
- discharging (220) the battery (120) by means of a load impedance (Z_L) until the current temperature (T_c) of the battery (120) is above a second temperature threshold (T_{T2}).
- 15 2. The method (200) of claim 1, wherein the load impedance (Z_L) is further configurable to be arranged to dissipate power generated by said one or more electric motors (110).
3. The method (200) of any of the preceding claims, wherein the step of
- 20 discharging (220) comprises controlling (227) one or more switches (S_1 , S_2 , S_3) to electrically connect the load impedance (Z_L) to the battery (120) and electrically disconnect said one or more electric motors (110) from the battery (120).
4. The method (200) of claim 1, wherein the load impedance (Z_L) is one or
- 25 more of said one or more electric motors (110) of the entrance system (10) and the step of discharging (220) further comprises controlling (227) a discharge current (I_d) flowing through said one or more electric motors (110) such that said one or more electric motors (110) are not operated.
- 30 5. The method (200) of any of the preceding claims, wherein the step of discharging (220) further comprises controlling (227) the discharge current (I_d) flowing

through the load impedance (Z_L), preferably by means of PWM control of one or more switches (S_1 , S_2 , S_3) arranged to connect and disconnect the load impedance (Z_L) from the battery (120).

5 6. The method (200) of any of the preceding claims, wherein the step of monitoring (210) further comprises monitoring (217) a current temperature time derivative of the current temperature (T_c) of the battery (120) and if the current temperature time derivative is below a temperature derivative threshold, performing the step of discharging (220) the battery (120).

10

 7. The method (200) of any of the preceding claims, wherein the step of monitoring (210) further comprises monitoring an exterior temperature, wherein the exterior temperature is external to the battery (120), and if the exterior temperature is below an exterior temperature threshold, performing the step of discharging (220) the
15 battery (120).

 8. The method (200) of any of the preceding claims, further comprising, if the current temperature (T_c) is above the second temperature threshold (T_{T2}), and the current state of charge (SOC_c) is below a second charge threshold (T_{SOC2}):
20 charging (230) the battery (120) until the current state of charge (SOC_c) of the battery (120) is above a third charge threshold (T_{SOC3}).

 9. The method (200) of claim 8, wherein the third charge threshold (T_{SOC3}) is lower than a maximum state of charge (SOC_{MAX}) of the battery (120), preferably lower
25 than 95 % of the maximum state of charge (SOC_{MAX}) of the battery (120).

 10. An entrance system (10) comprising one or more electric motors (110), a load impedance (Z_L), a controller module (130) and a battery (120) connectable to provide power to said one or more electric motors (110), wherein the control module
30 (130) is configured to:

monitor a current temperature (T_c) of the battery (120) and a current state of charge (SOC_c) of the battery (120), and

if the current temperature (T_c) of the battery (120) is below a first temperature threshold (T_{T1}) and the current state of charge (SOC_c) of the battery (120) is below a
5 first charge threshold (T_{SOC1}),

discharge the battery (120) by means of the load impedance (Z_L) until the current temperature (T_c) of the battery (120) is above a second temperature threshold (T_{T2}).

10 11. The entrance system (10) of claim 10, further comprising one or more switches (S_1 , S_2 , S_3) to electrically connect the load impedance (Z_L) to the battery (120) and electrically disconnect said one or more electric motors (110) from the battery (120).

15 12. The entrance system (10) of claim 10 or 11, wherein the load impedance (Z_L) is further connectable to dissipate power generated by said one or more electric motors (110).

20 13. The entrance system (10) of claim 10, wherein the load impedance (Z_L) is one or more of said one or more electric motors (110), and the control module (130) is further configured to control, when discharging the battery (120) by means said one or more electric motors (110), a discharge current (I_d) flowing through said one or more electric motors (110) such that said one or more electric motors (110) are not operated.

25 14. The entrance system (10) of any one of claims 10 to 13, further comprising a charging module (135) and the control module (130) is further configured to, if the current temperature (T_c) is above the second temperature threshold (T_{T2}), and the current state of charge (SOC_c) is below a second charge threshold (T_{SOC2}):

30 charge the battery (120) until the current state of charge (SOC_c) of the battery (120) is above a third charge threshold (T_{SOC3}).

15. The entrance system (10) of claim 14, wherein the third charge threshold (T_{SOC3}) is lower than a maximum state of charge (SOC_{MAX}) of the battery (120), preferably lower than 95 % of the maximum state of charge (SOC_{MAX}) of the battery (120).

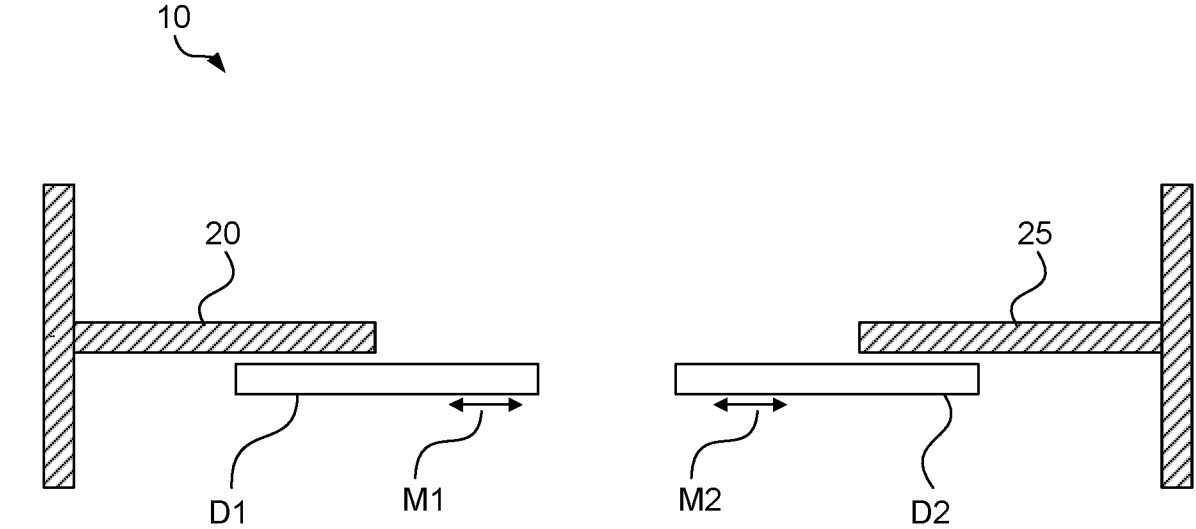


Fig 1a

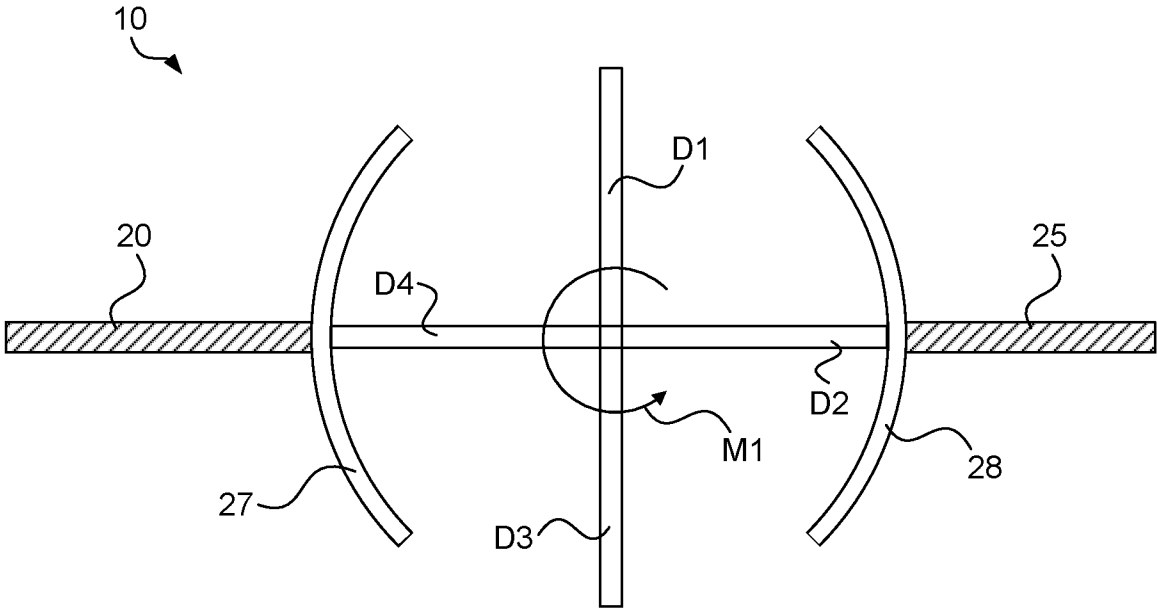
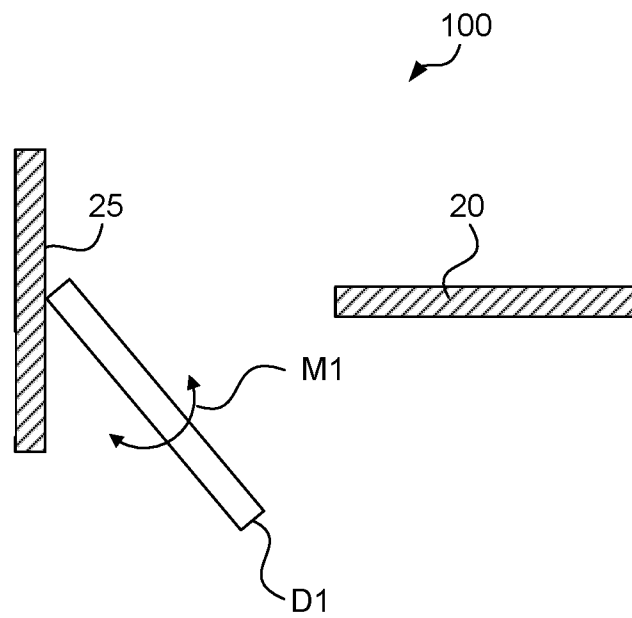
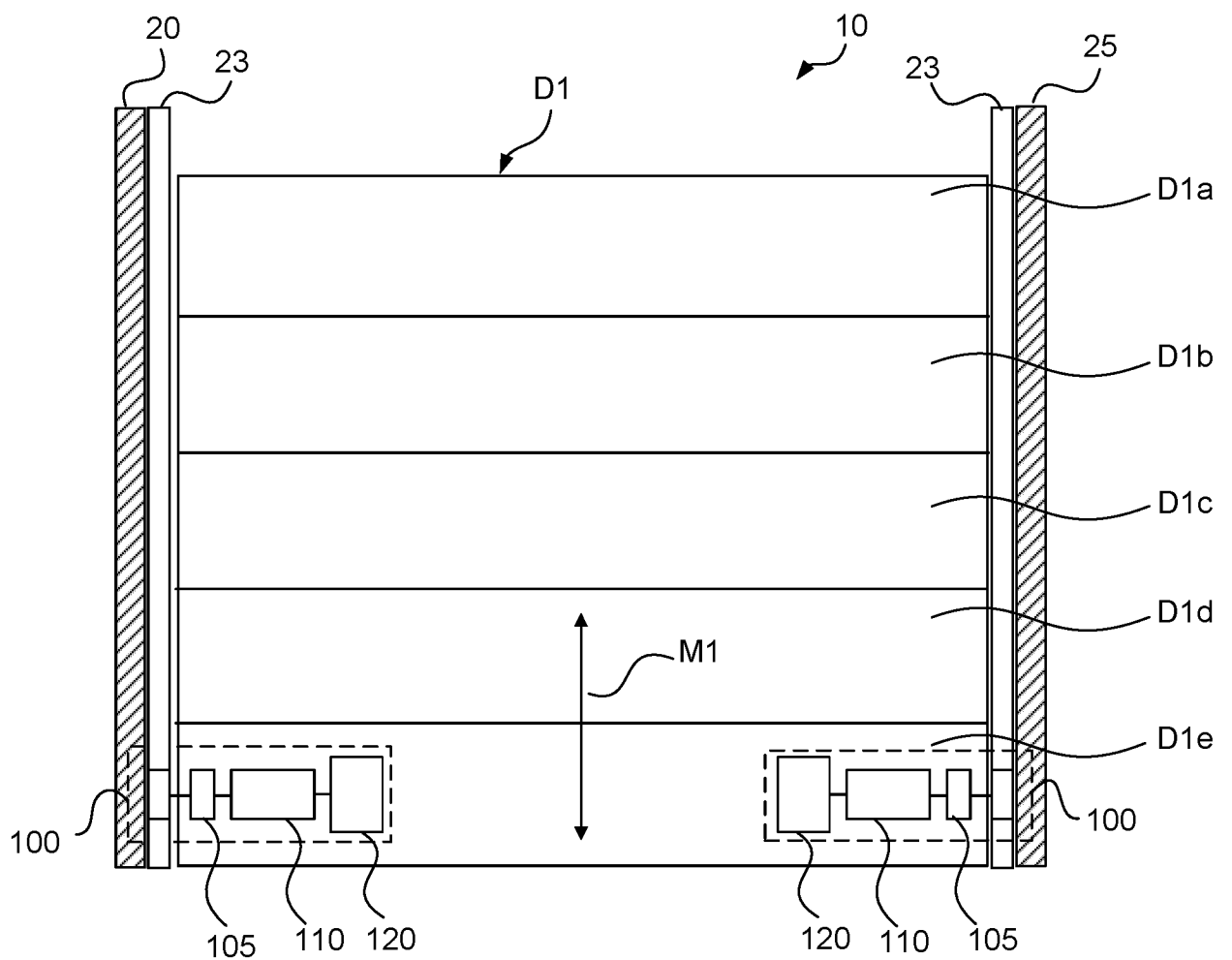


Fig 1b

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*Fig 1c**Fig 1d*

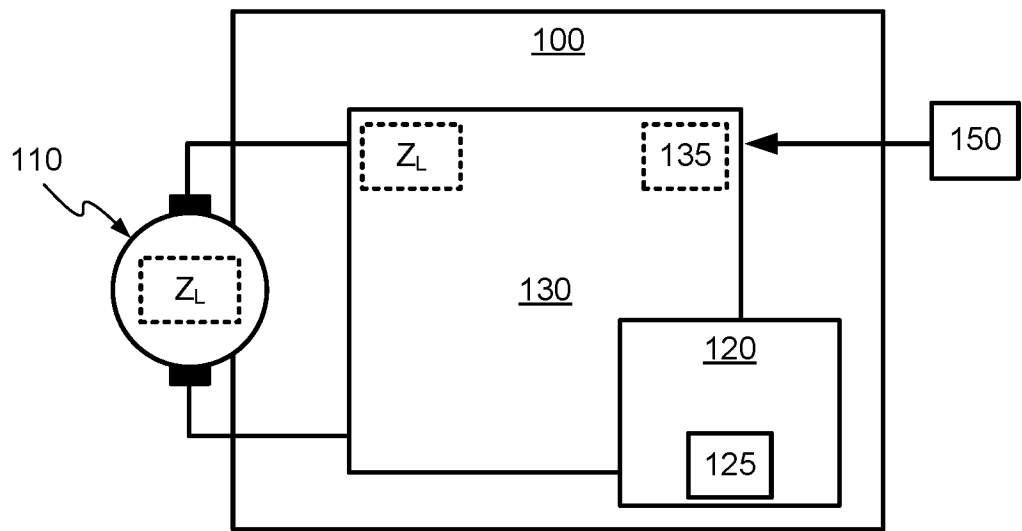


Fig 2

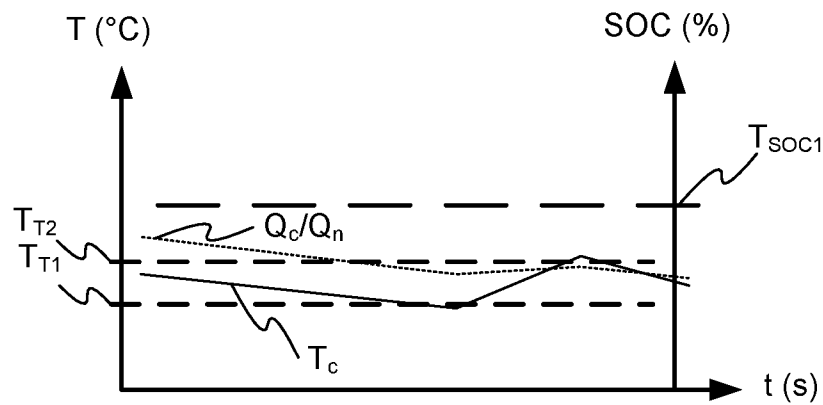


Fig 3

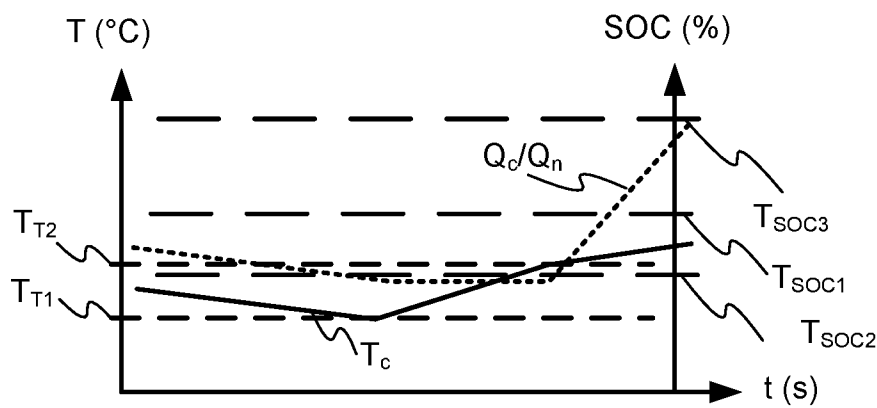


Fig 4

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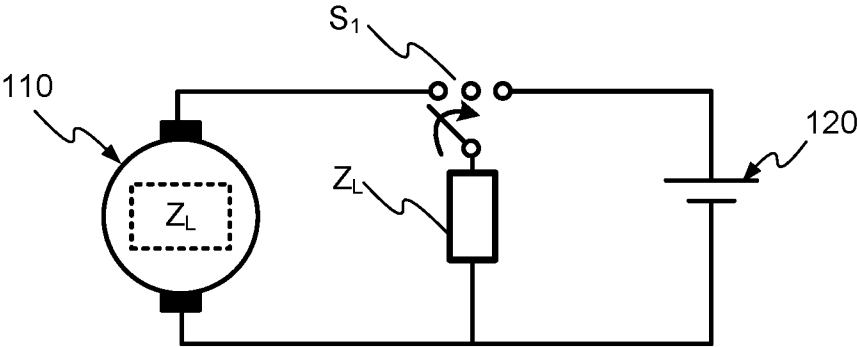


Fig 5a

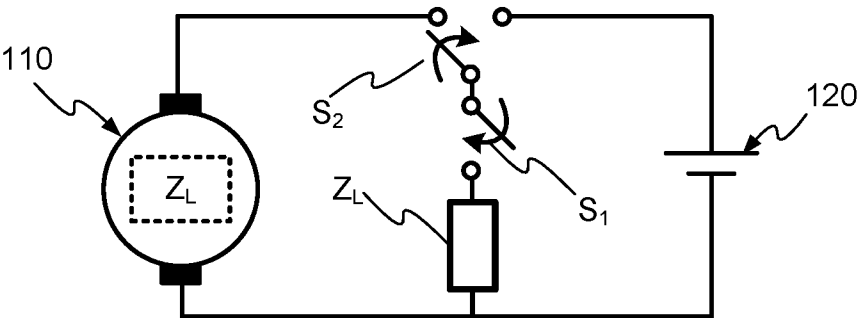


Fig 5b

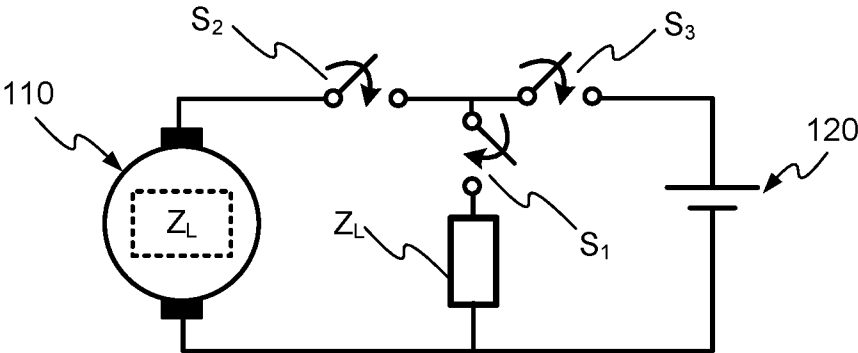


Fig 5c

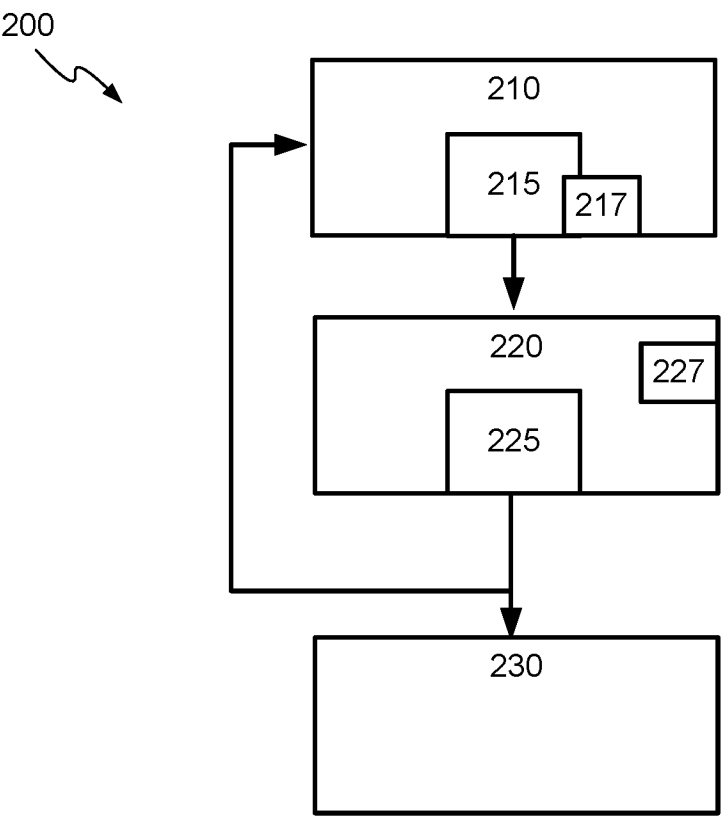


Fig 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2022/059170

A. CLASSIFICATION OF SUBJECT MATTER INV. H01M10/637 H01M10/44 H01M10/48 H01M10/615 H01M10/635 ADD. H01M10/052		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols) H01M		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2019/372179 A1 (SINGER NOAH [US] ET AL) 5 December 2019 (2019-12-05) paragraphs [0003] - [0005], [0029], [0031], [0033], [0048] - [0050] -----	1, 2, 5-10, 12, 14, 15
X	DE 10 2011 010048 A1 (DAIMLER AG [DE]) 3 November 2011 (2011-11-03) paragraphs [0006] - [0024] -----	1, 8, 9
X	CN 108 501 746 B (GEELY AUTOMOBILE RES INSTITUTE NINGBO CO LTD ET AL.) 7 July 2020 (2020-07-07)	1, 8, 9
A	paragraphs [0004] - [0041] abstract ----- -/--	2-7, 10-15
☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 14 July 2022		Date of mailing of the international search report 22/07/2022
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Mercedes González

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2022/059170

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 111 762 066 A (SHENZHEN VMAX NEW ENERGY CO LTD) 13 October 2020 (2020-10-13) paragraphs [0043] - [0082] abstract -----	1, 8, 9

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2022/059170

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2019372179 A1	05-12-2019	NONE	

DE 102011010048 A1	03-11-2011	NONE	

CN 108501746 B	07-07-2020	NONE	

CN 111762066 A	13-10-2020	NONE	
