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SYSTEM AND A METHOD FOR HARVESTING ENERGY FROM A CONTAINER HANDLING VEHICLE

Abstract

A container-handling vehicle for handling storage containers in a three-dimensional grid of an underlying storage system, comprising: at least one lifting device for lifting storage containers from and lowering storage containers to the underlying storage system, said lifting device comprises a lifting frame for gripping a storage container, a winch system for lifting and lowering the lifting frame, a motor to drive the winch system and a driver circuit with a controller controlling the motor; and at least first and second rechargeable power sources for providing power to the motor, wherein the driver circuit further comprises a regenerative energy circuit configured to harvest energy from the motor when the lifting frame is lowered 10 into the storage system and where the driver circuit is configured to direct harvested energy to the rechargeable power sources according to levels of charge in the rechargeable power sources.

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Background/Summary

BENEFIT CLAIM [0001] This application claims the benefit under 35 U.S.C. § 120 as a continuation of application Ser. No. 17/432,045, filed Aug. 18, 2021, which claims the benefit of PCT international application PCT/EP2020/053909, filed Feb. 14, 2020, which claims the benefit of Norway application 20190219 filed Feb. 18, 2019, the entire contents of which are hereby incorporated by reference for all purposes as if fully set forth herein.

TECHNICAL FIELD
[0002] The present invention regards a system and a method for harvesting energy from a container handling vehicle powered by a rechargeable battery and handling storage containers in a three-dimensional grid of an underlying storage system. More specifically a system and a method for harvesting energy from a container handling vehicle, powered by rechargeable power sources and handling storage containers in a three-dimensional grid of an underlying storage system where charging levels of the power sources are monitored and controlled.
BACKGROUND AND PRIOR ART
[0003] FIG. **1** discloses a typical prior art automated storage and retrieval system **1** with a framework structure **100** and FIGS. **2** and **3** discloses two different prior art container handling vehicles **201**, **301** suitable for operating on such a system **1**.
[0004] The framework structure **100** comprises several upright members **102** and several horizontal members **103** which are supported by the upright members **102**. The members **102**, **103** may typically be made of metal, e.g. extruded aluminum profiles.
[0005] The framework structure **100** defines a storage grid **104** comprising storage columns **105** arranged in rows, in which storage columns **105** storage containers **106**, also known as bins, are stacked one on top of another to form stacks **107**. The storage grid **104** guards against horizontal movement of the stacks **107** of storage containers **106**, and guides vertical movement of the containers **106**, but does normally not otherwise support the storage containers **106** when stacked.
[0006] The automated storage and retrieval system **1** comprises a rail system **108** arranged in a grid pattern across the top of the storage grid **104**, on which rail system **108** a plurality of container handling vehicles **201**, **301** are operated to raise storage containers **106** from, and lower storage containers **106** into, the storage columns **105**, and to transport the storage containers **106** above the storage columns **105**. The rail system **108** comprises a first set of parallel rails **110** arranged to guide movement of the container handling vehicles **201**, **301** in a first direction X across the top of the frame structure **100**, and a second set of parallel rails **111** arranged perpendicular to the first set of rails **110** to guide movement of the container handling vehicles **201**, **301** in a second direction Y which is perpendicular to the first direction X. In this way, the rail system **108** defines grid columns **112** above which the container handling vehicles **201**, **301** can move laterally above the storage columns **105**, i.e. in a plane which is parallel to the horizontal X-Y plane.

[0007] Each prior art container handling vehicle **201**, **301** comprises a vehicle body **201***a*, **301***a*, and first and second sets of wheels **201***b*, **301***b*, **201***c*, **301***c* which enable the lateral movement of the container handling vehicles **201**, **301** in the X direction and in the Y direction, respectively. In FIGS. **2** and **3** two wheels in each set are fully visible. The first set of wheels **201***b*, **301***b* is arranged to engage with two adjacent rails of the first set **110** of rails, and the second set of wheels **201***c*, **301***c* is arranged to engage with two adjacent rails of the second set **111** of rails. Each set of wheels **201***b*, **301***b*, **201***c*, **301***c* can be lifted and lowered, so that the first set of wheels **201***b*, **301***b* and/or the second set of wheels **201***c*, **301***c* can be engaged with the respective set of rails **110**, **111** at any one time.
[0008] Each prior art container handling vehicle **201**, **301** also comprises a lifting device **302** for vertical transportation of storage containers **106**, e.g. raising a storage container **106** from, and lowering a storage container **106** into, a storage column **105**. The lifting device comprises one or more gripping/engaging devices (not shown) which are adapted to engage a storage container **106**, and which gripping/engaging devices can be lowered from the vehicle **201**, **301** so that the position of the gripping/engaging devices with respect to the vehicle **201**, **301** can be adjusted in a third direction Z which is orthogonal the first direction X and the second direction Y.
[0009] Each prior art container handling vehicle **201**, **301** comprises a storage compartment or space for receiving and stowing a storage container **106** when transporting the storage container **106** across the rail system **108**. The storage space may comprise a cavity arranged centrally within the vehicle body **201***a* as shown in FIG. **2** and as described in e.g. WO2015/193278A1, the contents of which are incorporated herein by reference.
[0010] FIG. **3** shows an alternative configuration of a container handling vehicles **301** with a cantilever construction. Such a vehicle is described in detail in e.g. NO317366, the contents of which are also incorporated herein by reference.
[0011] The central cavity container handling vehicles **201** shown in FIG. **2** may have a footprint that covers an area with dimensions in the X and Y directions which is generally equal to the lateral extent of a grid column **112**, i.e. the extent of a grid column **112** in the X and Y directions, e.g. as is described in WO2015/193278A1, the contents of which are incorporated herein by reference. The term ‘lateral’ used herein may mean ‘horizontal’.
[0012] Alternatively, the central cavity container handling vehicles **201** may have a footprint which is larger than the lateral area defined by a grid column **112**, e.g. as is disclosed in WO2014/090684A1.
[0013] In the X and Y directions, neighboring grid cells are arranged in contact with each other such that there is no space there-between.
[0014] In a storage grid **104**, most of the grid columns **112** are storage columns **105**, i.e. grid columns **105** where storage containers **106** are stored in stacks **107**. However, a grid **104** normally has at least one grid column **112** which is used not for storing storage containers **106**, but which comprises a location where the container handling vehicles **201**, **301** can drop off and/or pick up storage containers **106** so that they can be transported to an access station (not shown) where the storage containers **106** can be accessed from outside of the grid **104** or transferred out of or into the grid **104**. Within the art, such a location is normally referred to as a ‘port’ and the grid column **112** in which the port is located may be referred to as a ‘port column’ **119**, **120**. The transportation to the access station may be in any direction, that is horizontal, tilted and/or vertical. For example, the storage containers **106** may be placed in a random or dedicated grid column **112** within the storage grid **104**, then picked up by any container handling vehicle and transported to a port **119**, **120** for further transportation to an access station. Note that the term ‘tilted’ means transportation of storage containers **106** having a general transportation orientation somewhere between horizontal and vertical.
[0015] When a storage container **106** stored in the grid **104** disclosed in FIG. **1** is to be accessed, one of the container handling vehicles **201**, **301** is instructed to retrieve the target storage container

106 from its position in the grid **104** and transport it to the drop-off port **119**. This operation involves moving the container handling vehicle **201**, **301** to a grid location above the storage column **105** in which the target storage container **106** is positioned, retrieving the storage container **106** from the storage column **105** using the container handling vehicle's **201**, **301** lifting devices (not shown), and transporting the storage container **106** to the drop-off port **119**. If the target storage container **106** is located deep within a stack **107**, i.e. with one or a plurality of other storage containers **106** positioned above the target storage container **106**, the operation also involves temporarily moving the above-positioned storage containers prior to lifting the target storage container **106** from the storage column **105**. This step, which is sometimes referred to as “digging” within the art, may be performed with the same container handling vehicle that is subsequently used for transporting the target storage container to the drop-off port **119**, or with one or a plurality of other cooperating container handling vehicles. Alternatively, or in addition, the automated storage and retrieval system **1** may have container handling vehicles specifically dedicated to the task of temporarily removing storage containers from a storage column **105**. Once the target storage container **106** has been removed from the storage column **105**, the temporarily removed storage containers can be repositioned into the original storage column **105**. However, the removed storage containers may alternatively be relocated to other storage columns.

[0016] When a storage container **106** is to be stored in the grid **104**, one of the container handling vehicles **201**, **301** is instructed to pick up the storage container **106** from the pick-up port **120** and transport it to a grid location above the storage column **105** where it is to be stored. After any storage containers positioned at or above the target position within the storage column stack **107** have been removed, the container handling vehicle **201**, **301** positions the storage container **106** at the desired position. The removed storage containers may then be lowered back into the storage column **105** or relocated to other storage columns.

[0017] For monitoring and controlling the automated storage and retrieval system **1**, e.g. monitoring and controlling the location of respective storage containers **106** within the grid **104**, the content of each storage container **106**; and the movement of the container handling vehicles **201**, **301** so that a desired storage container **106** can be delivered to the desired location at the desired time without the container handling vehicles **201**, **301** colliding with each other, the automated storage and retrieval system **1** comprises a control system which typically is computerized and which typically comprises a database for keeping track of the storage containers **106**.

[0018] It is a known concept to harvest energy from electromotors while they are working in reverse. This is called regenerative braking and is an energy recovery mechanism which slows an object (e.g. like a car) down by converting its kinetic energy into electric energy. The harvested electric energy can be stored in a rechargeable power source like a battery or a capacitor. By using regenerative braking and storing the generated electric energy in a rechargeable power source the operational time of the rechargeable power source is prolonged before it must be recharged.

[0019] A preferred rechargeable power source used to power vehicles is lithium-ion batteries. They are preferred due to their high energy density and low self-discharge. Further they can be recharged multiple times with little loss of charge capability.

[0020] However, a problem with using Li-ion batteries is that they must be charged correctly. Li-ion batteries can be a safety hazard since they contain a flammable electrolyte. A battery cell charged too quickly could cause a short circuit, leading to explosions and fires. Further, if a Li-ion battery is overcharged, lithium ions can build up on the anode as metallic lithium. This is called lithium plating. Lithium plating degrades the battery's life and durability. It can also lead to a short circuit which again might lead to a fire. Overcharging of Li-ion batteries is a known problem when using regenerative braking in vehicles.

[0021] An alternative rechargeable power source is capacitors, and preferably supercapacitors. They have the benefit of being able to take a large amount of charge quickly without the risk of overcharging. However, a problem with capacitors is that they have low energy density and that they have a high level of internal leakage current. The result is that they must be charged often in order to keep their charge level and that it requires many capacitors to be able to give the required amount of power to manoeuvre the container handling vehicle. This also requires a lot of space and unnecessary weight.

[0022] From prior art, one should refer to US 2016/297307 A1 which discloses a vehicle includes an electric drive motor for driving the vehicle, an electrochemical accumulator for storing and providing electric energy for the drive motor. The accumulator is configured to only take up a charging power which is smaller than a predetermined maximal power value, an electric auxiliary storage for storing and providing electric energy for the drive motor. The auxiliary storage is configured to take up a charging power during charging which is greater than the maximal power value. The auxiliary storage may have at least one of a capacitor a flywheel energy storage, and a magnetic storage for storing the energy received via the charging device. The vehicle further comprises a charging device for receiving energy from a vehicle-external charging station as a power pulse which has an amplitude greater that the maximal power value and to store the received energy in the auxiliary storage; and a coupling circuit coupling the auxiliary storage with the accumulator and configured to transmit the energy from the auxiliary storage into the accumulator with a charging power which is smaller than the maximal power value.

[0023] It would be desirable to use regenerative braking in the system described in FIGS. **1-3** to regenerate energy when e.g. the container handling vehicles lowers the lifting frames into the underlying storage grid. It is an object of the present invention to overcome the problems mentioned above with damaging the battery and to ensure that the regenerative braking does not overcharge the battery.

SUMMARY OF THE INVENTION

[0024] The present invention is set forth and characterized in the independent claims, while the dependent claims describe other characteristics of the invention.

[0025] The invention is defined by a container-handling vehicle for handling storage containers in a three-dimensional grid of an underlying storage system, comprising at least one lifting device for lifting storage containers from and lowering storage containers to the underlying storage system, said lifting device comprises a lifting frame for gripping a storage container, a winch system for lifting and lowering the lifting frame, a motor to drive the winch system and a driver circuit with a controller controlling the motor; and at least first and second rechargeable power sources for providing power to the motor, wherein the driver circuit further comprises a regenerative energy circuit configured to harvest energy from the motor when the lifting frame is lowered into the storage system and where the driver circuit is configured to control and direct harvested energy to the rechargeable power sources according to preset levels of charge in the rechargeable power sources.

[0026] The harvested energy is directed to either the first rechargeable power source or the second rechargeable power source. In a preferred embodiment of the present invention the first rechargeable power source is a rechargeable battery and the second rechargeable power source is a capacitor. The capacitor may be a supercapacitor.

[0027] Supercapacitors are divided into two different categories, one called double layer capacitors which uses electrostatically charge storage and the other called pseudocapacitors which uses electrochemical charge storage. A further sub category is hybrid capacitors which uses both electrostatically and electrochemically storage capacity.

[0028] To keep track of the charge level of the two rechargeable power sources of the present invention the driver circuit is in communication with a charge sensor connected to the first and/or second rechargeable power sources. The charge sensor keeps track of the charging capacity of the rechargeable power sources and communicates its reading to the driver circuit which in turn decides where the harvested energy is directed. The energy is directed to either of the two

rechargeable power sources according to their levels of charge.
[0029] If the rechargeable battery is a Li-ion battery it keeps its charge capacity best if the battery is kept within 25%-75% of its charging capacity. So, in order to maintain the battery's life best, the charge of the battery has to be kept below 75% and above 25% of its charging capacity.
[0030] Hence if the battery has a charge level below 75%, the harvested energy is directed to the Li-ion battery. If the charge of the battery is above 75% the harvested energy is directed to the capacitor.
[0031] Alternatively, in order to avoid the buildup of lithium plating, a safety measure is built into the system. If the battery is in danger of being overcharged the driver circuit directs the harvested energy to the capacitor.
[0032] In an embodiment of the present invention the container handling vehicle exchanges its battery when the battery is discharged to below a prescribed level. This reduces the down time for a container handling vehicle to almost nothing. However, the empty battery and the fully charged battery may not necessarily be located at the same charging station. So, in order to move the container handling vehicle from a drop off charging station to a pick-up charging station, the container handling vehicle uses power from the capacitor. It is therefore necessary to ensure that the capacitor has enough stored energy to maneuver the vehicle between the two charging stations. Consequently, if the charge level of the capacitor is determined to be dropping below a set threshold level the harvested energy may be directed to the capacitor.
[0033] The invention is further defined by a method for harvesting energy when a container-handling vehicle is handling a storage container in a three-dimensional grid of an underlying storage system, wherein said vehicle comprises a vehicle body with at least a first set of wheels for moving the container-handling vehicle in a first direction, at least one rechargeable battery, and at least one capacitor, a control system for controlling the charging level of the rechargeable battery and the capacitor, at least one lifting device for lifting storage containers from and lowering storage containers to the underlying storage system, wherein said lifting device comprises a lifting frame for gripping a storage container, a winch system for lifting and lowering the lifting frame, a motor to drive the winch system and a driver circuit with a controller controlling the motor; the method comprises the following steps: [0034] connecting motor and regenerative charging circuit for harvesting the energy to the lifting device; [0035] lowering the lifting device into the underlaying storage system, [0036] directing harvested energy to the rechargeable battery and/or the capacitor by means of the control system.
[0037] In a further alternative embodiment of the present invention energy is also harvested from the deceleration of the container handling vehicle itself.
[0038] An advantage of the invention is that it provides optimal maintenance of the rechargeable power sources while at the same time ensuring optimal storage of energy harvested while the container handling vehicle is in operation.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0039] The following drawings are appended to facilitate the understanding of the invention. The drawings show embodiments of the invention, which will now be described by way of example only, where:
[0040] FIG. **1** is a perspective view of a grid of a prior art automated storage and retrieval system.
[0041] FIG. **2** is a perspective view of a prior art container handling vehicle having a centrally arranged cavity for containing storage containers therein.
[0042] FIG. **3** is a perspective view of a prior art container handling vehicle having a cantilever for containing storage containers underneath.

[0043] FIG. **4** is a box drawing of how the different parts of the system are connected according to a preferred embodiment of the present invention.

[0044] FIG. **5** is a flow chart of a process, according to an embodiment of the present invention, wherein the generated energy is directed to either of the rechargeable power sources depending on preset capacity levels.

[0045] FIG. **6** is a flow chart of a process, according to an embodiment of the present invention, wherein the generated energy is directed to the capacitor if the rechargeable battery is at 100% of its current charging level.

DETAILED DESCRIPTION

[0046] In the following, the invention will be discussed in more detail with reference to the appended drawings. It should be understood, however, that the drawings are not intended to limit the invention to the subject-matter depicted.

[0047] A typical prior art automated storage and retrieval system with a framework structure **100** was described in the background section above.

[0048] The container handling vehicle rail system **108** allows the container handling vehicles **201** to move horizontally between different grid locations, where each grid location is associated with a grid cell.

[0049] In FIG. **1**, the storage grid **104** is shown with a height of eight grid cells. It is understood, however, that the storage grid **104** can in principle be of any size. The storage grid **104** can be considerably wider and/or longer than disclosed in FIG. **1**. For example, the grid **104** may have a horizontal extent of more than 700×700 storage columns **105**. Also, the grid **104** can be considerably deeper than disclosed in FIG. **1**. For example, the storage grid **104** may be more than twelve grid cells deep, i.e. in the Z direction indicated in FIG. **1**.

[0050] The container vehicles **201** can be of any type known in the art, e.g. any one of the automated container handling vehicles disclosed in WO2014/090684 A1, in NO317366 or in WO2015/193278A1. The method and control system for controlling said prior art system is well known.

[0051] FIG. **2** is a perspective view of a prior art container handling vehicle having a centrally arranged cavity for containing storage containers therein.

[0052] FIG. **3** is a perspective view of a prior art container handling vehicle having a cantilever for containing storage containers underneath.

[0053] FIG. **4** is a box drawing of how the different parts of the system are connected according to a preferred embodiment of the present invention. The motor **407** and regenerative charging circuit for harvesting the energy harvests energy due to regenerative braking. In the present invention, regenerative braking can occur when the lifting frame is lowered down. Due to the weight of the lifting frame, both with or without a container attached, gravity will pull the lifting frame down without the motor **407** doing any work. Hence kinetic energy is generated from the change in potential energy. The kinetic energy from the lifting frame being lowered into the underlying storage system forces the rotor of the electric motor **407** to rotate. This rotation allows the electric motor **407** to work as a generator. The motor **407** can now harvest energy by converting the kinetic energy of the rotor into electrical energy. This electrical energy can again be stored in the rechargeable power sources.

[0054] A driver circuit **404** with a controller attached controls the motor **407**. This driver circuit **404** further comprises a regenerative energy circuit **403**. This regenerative energy circuit **403** is configured to harvest the electric energy generated by the motor **407**. Further the driver circuit **404** directs the harvested energy to either the first or the second rechargeable power sources according to the levels of charge in the rechargeable power sources. To keep track of the charge levels of the rechargeable power sources a charge sensor **401**, **402** is attached to the first and the second rechargeable power source **405**, **406**. The charge sensor **401**, **402** communicates the charge level of the first and the second rechargeable power source **406** to the driver circuit **404**.

[0055] In a preferred embodiment of the present invention the first rechargeable power source **405** can be a rechargeable battery **405**. The rechargeable battery **405** can be a Li-ion battery. The second rechargeable power source **406** can be a capacitor **406**. The capacitor **406** can be a supercapacitor.
[0056] Any other type of rechargeable battery and capacitor can be used.
[0057] FIG. **5** is a flow chart of a process, according to an embodiment of the present invention, wherein the harvested energy is directed to either of the rechargeable power sources depending on algorithms determining when to charge the Li-ion battery and when to charge the capacitor.
[0058] The driver circuit **404** comprises a regenerative energy circuit **403**. The regenerative energy circuit **403** harvests energy from the motor during regenerative braking.
[0059] A charge sensor **401**, **402** is connected to either of the rechargeable power sources **405**, **406**. The charge sensor **401**, **402** reads of the charge level of the power sources **405**, **406**. This information is communicated to the driver circuit **404**.
[0060] In an embodiment of the present invention a drop-off charging station is a charging station where the container handling vehicle places discharged batteries. A pick-up charging station is a charging station where the container handling vehicle picks up charged batteries.
[0061] Based on the information transmitted to the driver circuit **404** from the charge sensors **401**, **402** and information on how far it is to the closest drop-off charging station and the closest pick-up charging station and the next operational task, the harvested energy is transmitted to either the first or the second rechargeable power source to ensure that the container handling vehicle has sufficient power to either perform the next operational task or drive to a charging station. Alternatively, harvested energy can be split between the two rechargeable power sources.
[0062] An algorithm determining if the harvested energy is to be sent to either the first or the second rechargeable power source is in one embodiment based on preset charging levels of the first and second rechargeable power sources.
[0063] In an embodiment of the present invention the decision to direct the harvested energy to either the battery or the capacitor or both is based on information received by the driver circuit. The information is gathered from the charge sensors attached to either of the rechargeable power sources. The charge sensors deliver information of what charge level the two power sources are at. The main object of the system is to ensure that the Li-ion battery is not overcharged or damaged through charging it too much too fast, risking fire or explosions. However, there is a further object which is to ensure that the battery has enough power to get the container handling vehicle to the drop-off charging station and that the capacitor has enough energy to ensure that the container handling vehicle can get from the drop-off charging station to the pick-up charging station.
[0064] In order to make these decisions, the container handling vehicle always needs to know the charge level of the two rechargeable power sources, the distance to the closest drop-off charging station, and the distance to the closest pick-up charging station and the next task of operation. Other information used in the algorithm may include how far it is to the next pick-up point of a container and how far it is between the pick-up point and the drop-off point of the container, as well as how deep the container handling vehicle needs to dig and the weight of the container that needs to be lifted and transported.
[0065] The information regarding the charging level of the rechargeable batteries is provided by the charge sensors connected to both the Li-ion battery and the capacitor. The information regarding the closest drop-off charging station and the closest pick-up charging station is provided to the container handling vehicle by a central computer system through e.g. Wi-Fi communication. The information regarding the next task of operation is also provided by the central computer system.
[0066] The central computer system transmits information regarding the next task of operation and the container handling vehicles calculates, based on the given information and the information gathered by the charge sensors, if it can take on the next task. If a container handling vehicle can take on the next task it communicates to the central computer system that it takes the next task of operation. If, however it cannot take on the next task of operation it communicates to the central

computer system that it needs to change battery.
[0067] If a container handling vehicle has too low charge level on the battery to handle the next task of operation, but has high charge level on the capacitor, the container handling vehicle makes the decision to change the battery.
[0068] Alternatively, the container handling vehicle can use the capacitor to charge the battery if that ensures that the battery has enough power to complete the task, and the harvested energy from the lowering of the lifting frame can be used to charge the capacitor.
[0069] If the container handling vehicle has low charge level on the capacitor but high charge level on the battery the container handling vehicle can direct the energy harvested from the lowering of the lifting frame to the capacitor. Alternatively, the battery can be used to top up the capacitor.
[0070] If the container handling vehicle has high charge level on the battery and high charge level of the capacitor the harvested energy can be divided between the two rechargeable power sources. The division of how much is to be sent to the battery and how much is to be sent to the capacitor is made on current charge levels of the individual power sources. In an embodiment of the present invention the charge level of the battery should be kept within the range of 25%-75% of full charging level.
[0071] If the charge level of the battery is below 25% of the full charging capacity, the battery can be changed, or the harvested energy can be directed to the battery in order to make sure that the battery stays within its best working range. If the charge level of the battery is within 25%-75% of the full charging capacity the harvested energy can be directed to the battery in order to keep it within its best working range. If the charge level of the battery is above 75% of the full charging level the harvested energy can be sent to the capacitor.
[0072] Alternatively, if the charge levels of the two rechargeable power sources are at their full current charging level the container handling vehicle can decide to not harvest the energy generated from the lowering of the lifting frame.
[0073] If the container handling vehicle has low charge on battery and low charge on capacitor, the container handling vehicle will ensure that the capacitor has enough energy to maneuver from one charge point to another. Alternatively, the battery can be used to fully charge the capacitor if the battery has enough power left to ensure that it can manoeuvre the container handling vehicle to the closest drop-off charging station.
[0074] The purpose is to ensure that the combined power of the two rechargeable power sources always has enough power to transport the container handling vehicle to the closest drop-off charging station and from the closest drop-off charging station to the closest pick-up charging station.
[0075] The rules for when to charge the rechargeable battery and when to charge the capacitor stated above is not meant to be exclusive, but an example of a set of rules. Other rules can be used and are within the scope of the invention.
[0076] FIG. **6** is a flow chart of a process, according to an embodiment of the present invention, wherein the harvested energy is directed to the capacitor **406** if the rechargeable battery **405** is at 100% of its current charging level.
[0077] As stated earlier if a Li-ion battery is overcharged, lithium ions can build up on the anode as metallic lithium, this is called lithium plating. Lithium plating degrades the battery's lifetime and durability. It can also lead to a short circuit which again might lead to a fire.
[0078] Hence in order to avoid the buildup of lithium plating, a safety measure is built into the system. If the battery is in danger of being overcharged the driver circuit **404** directs the harvested energy to the capacitor **406**.
[0079] The battery is fully charged when it is at 100% of its current charging level. To overcharge it would be to try and charge the battery when it is at 100% of its current charge level. A battery's charging level may drop during its life time. However, 100% of its current charging level is to be considered as the maximum level of charge it can hold on any given time.

[0080] In an embodiment of the present invention the battery can be used to charge the capacitor **406** if the charge level of the capacitor **406** is lower than the set level for transporting the container handling vehicle between one charging station to the other.

LIST OF REFERENCE NUMBERS

Prior Art (FIGS. **1-4**)

[0081] **1** Prior art automated storage and retrieval system [0082] **100** Framework structure [0083] **102** Upright members of framework structure [0084] **103** Horizontal members of framework structure [0085] **104** Storage grid [0086] **105** Storage column [0087] **106** Storage container [0088] **106**′ Particular position of storage container [0089] **107** Stack [0090] **108** Rail system [0091] **110** Parallel rails in first direction (X) [0092] **110***a* First rail in first direction (X) [0093] **110***b* Second rail in first direction (X) [0094] **111** Parallel rail in second direction (Y) [0095] **111***a* First rail of second direction (Y) [0096] **111***b* Second rail of second direction (Y) [0097] **112** Access opening [0098] **119** First port column [0099] **120** Second port column [0100] **201** Prior art storage container vehicle [0101] **201***a* Vehicle body of the storage container vehicle **201** [0102] **201***b* Drive means/wheel arrangement, first direction (X) [0103] **201***c* Drive means/wheel arrangement, second direction (Y) [0104] **301** Prior art cantilever storage container vehicle [0105] **301***a* Vehicle body of the storage container vehicle **301** [0106] **301***b* Drive means in first direction (X) [0107] **301***c* Drive means in second direction (Y) [0108] **304** Gripping device [0109] **500** Control system [0110] **401** Charge sensor [0111] **402** Charge sensor [0112] **403** Regenerative energy circuit [0113] **404** Driver circuit [0114] **405** Rechargeable power source [0115] **406** Rechargeable power source [0116] **407** Motor [0117] X First direction [0118] Y Second direction [0119] Z Third direction

Claims

1. A container-handling vehicle for handling containers in a three-dimensional grid of an underlying storage system, the container-handling vehicle comprising: at least one lifting device for lifting storage containers from and lowering storage containers to the underlying storage system, said lifting device comprising a lifting frame for gripping a storage container, a winch system for lifting and lowering the lifting frame, a motor to drive the winch system and a driver circuit with a controller controlling the motor; and at least a first rechargeable power source and a second rechargeable power source for providing power to the motor, wherein the driver circuit further comprises a regenerative energy circuit configured to harvest energy from the motor when the lifting frame is lowered into the storage system, the driver circuit is configured to control and direct harvested energy to the first rechargeable power source and/or the second rechargeable power source according to preset levels of charge in the first rechargeable power source and the second rechargeable power source, and wherein the driver circuit is further connected to charge sensors connected to the first rechargeable power source and/or the second rechargeable power source.

2. The container-handling vehicle according to claim 1, wherein the first rechargeable power source is a Li-ion battery, and the second rechargeable power source is a capacitor.

3. The container-handling vehicle according to claim 2, wherein said driver circuit is configured to direct the energy harvested by the regenerative energy circuit to the capacitor if the Li-ion battery is greater than 75% of a full charge level.

4. The container-handling vehicle according to claim 2, wherein said driver circuit is configured to direct the energy harvested by the regenerative energy circuit to the Li-ion battery if the Li-ion battery is below 75% of a full charge level.

5. The container-handling vehicle according to claim 2, wherein said driver circuit is configured to direct the energy harvested by the regenerative energy circuit to the Li-ion battery and to the capacitor if both rechargeable power sources are below 50% of a full charge level.

6. The container-handling vehicle according to claim 2, wherein the capacitor is a capacitor using electrochemical and/or electrostatic charge storage.

7. The container-handling vehicle according to claim 1, where the regenerative energy circuit further is configured to harvest energy from motors driving wheels of the container-handling vehicle for generating energy when the container-handling vehicle decelerates.
8. The container-handling vehicle according to claim 1, wherein the underlying storage system comprises a drop-off charging station and a pick-up charging station, and wherein the charge sensors communicate a charge level of the first rechargeable power source and/or the second rechargeable power source to the driver circuit such that the first rechargeable power source has power to ensure that the container-handling vehicle can get to the drop-off charging station and that the second rechargeable power source has energy to ensure that the container-handling vehicle can get from the drop-off charging station to the pick-up charging station.
9. A method for harvesting energy when a container-handling vehicle is handling a storage container in a three-dimensional grid of an underlying storage system, wherein the container-handling vehicle comprises a vehicle body with at least a first set of wheels for moving the container-handling vehicle in a first direction, at least a first rechargeable power source and a second rechargeable power source, a driver circuit for controlling a charging level of the first rechargeable power source and the second rechargeable power source, at least one lifting device for lifting storage containers from and lowering storage containers to the underlying storage system, wherein said lifting device comprises a lifting frame for gripping a storage container, a winch system for lifting and lowering the lifting frame, a motor to drive the winch system, and a driver circuit with a controller controlling the motor, wherein the driver circuit is further connected to charge sensors connected to the first rechargeable power source and/or the second rechargeable power source; the method comprises: connecting the motor and a regenerative energy circuit to the lifting device; lowering the lifting device into the underlying storage system, and directing generated energy to the first rechargeable power source and/or the second rechargeable power source using the driver circuit.
10. The method according to claim 9, wherein the second rechargeable power source is a capacitor, and where the method further comprises directing energy harvested by the regenerative energy circuit to the capacitor if the first rechargeable power source is at a full current charging level.
11. The method according to claim 9, further comprising directing energy harvested by the regenerative energy circuit to the first rechargeable power source if the first rechargeable power source is below 75% of a full charge level.
12. The method according to claim 9 wherein the underlying storage system comprises a drop-off charging station and a pick-up charging station, and wherein the method further comprises: monitoring the power for the first rechargeable power source to ensure there is sufficient energy to get the container-handling vehicle to the drop-off charging station, and monitoring the power of the second rechargeable power source to ensure there is sufficient energy to get the container-handling vehicle from the drop-off charging station to the pick-up charging station.