

A Hoisting System With Energy Recovering Mechanism

Technical Field

5 The present disclosure relates to a hoisting system. More particularly, the disclosed hoisting system is incorporated with an energy recovery mechanism to harness gravitational potential energy when the system moves any load of predetermined weight to a position of relatively lower gravitational potential energy than a previous position of higher gravitational potential energy. The disclosed system also stores the harnessed energy to further power subsequent
10 operation of load lifting.

Background

Hoisting machine coupling to a carriage or receptacle has long been implemented for transporting goods or human passengers along a substantial vertical plane, in which the goods
15 or passengers are temporarily loaded and kept to be brought to the desired height for dropping off. Most of these transportation systems or equipment have hoisting machine operated on electricity acquired from a supplied power grid and/or a genset (engine-generator) fueled by diesel. In the operation where the load is lifted to a higher level, the motor in the hoisting machine consumes the supplied power that part of the consumed power is
20 transformed into the kinetic energy of the ascending load. In addition, a portion of the consumed energy is in fact converted to gravitational potential energy and stored in the transportation system pursuant to the elevated height of the carriage. The transportation system generally possesses no proper mechanisms or equipment to recover and make good use out of the accumulated gravitational potential energy. Rather, these conventional systems
25 drain energy from the prime mover to negate or counteract the potential energy discharged from the descending loaded carriage. Particularly, a descending loaded carriage tends to move downward in a constant acceleration owing to the pulling gravitational force, the gravitational force leads to ever increasing speed of the descending carriage when the downward movement is not carefully regulated. To negate the gravitational force and lower
30 the loaded carriage at an unvarying speed, the hoisting machine draws power from the prime mover for acting against the gravitational pulling force. More specifically, the hoisting machine uses the supplied electricity from the prime mover to slow down the electric motor

driving the descending loaded carriage. The higher level the loaded carriage descends from, the greater period the loaded carriage is subjected to the constant pulling force of the gravity with greater consumption on the counteracting power acquired from the prime mover. Considering the way the gravitational potential energy being wasted and unnecessary power incurred on the prime mover, the abovementioned conventional hoisting machines or systems are far from energy efficient.

In view of the aforesaid shortcomings, great effort has been devoted to develop hoisting systems or machines to attain better efficiency in the aspect of energy consumption. For example, European registered patent no. 0645338B1 describes an elevator system with an energy storage device that the described system continuously charges the energy storage device with direct current, through a charging device, which is permanently supplied from a power supply. When peak power is required, the stored energy is fed to the drive system in addition to a limited component of energy taken directly from the power supply. This European patent application claims to obtain a value of power supply lower than the power required for having the elevator travelled at constant speed by limiting the power drawn directly from the power supply, but rather distributing the consumed energy over the time which the elevator is at rest through charging the energy storage device. United States patent application no. 6742630 further improves the like elevator system by utilizing super-capacitor as the power storage device as the supplementary power to drive the system at the peak of the power usage. Nonetheless, the implementation of the super-capacitor in the elevator system as the supplementary power source may not be ideal considering potential current leakage, relatively large size and limited service life of super-capacitor. Aulanko et al. offers another elevator system for harnessing the gravitational potential energy in United States registered patent no. 7681694 that the system pairs at least one elevator car to a means for storing mechanical energy and discharging an energy storage, which is a weighted elevator connected to the at least one elevator via a common direct-current intermediate circuit. Another United States registered patent no. 8622177 describes an elevator system being configured to move the elevator car or carriage to the highest floor poising to recharge an energy storage device, preferably in the form of flywheel, once the energy level retained in the storage device reaches a level lower than a predetermined value. The flywheel progressively loses the stored energy when the elevator is put into idle for long period.

Despite the aforesaid systems are capable of achieving the basic objects setting out to impart the hoisting or elevator system with improved energy efficiency, these systems are not lack of shortcomings considering that the overall system of each abovementioned disclosure can be further enhanced on the basis of power management, especially in identifying the correct situations to harvest the gravitational energy and/or discharge the harvested energy to drive the elevator car.

Summary

The present disclosure aims to provide a hoisting system adapted to move a load in a receptacle along a substantially predefined vertical path that the receptacle and/or the load acquires greater gravitational potential energy when they are driven to a position or location relatively higher than the position before.

Another object of the present disclosure is to offer a hoisting system incorporated with a mechanism or function for recovering gravitational potential energy from the descending load driven by the system. More specifically, the disclosed system possesses an energy converting unit and an energy storing/discharging member for respectively recovering the potential energy and storing the recovered energy in the form of hydraulic energy.

Further object of the disclosed system is to cater a hoisting system being fashioned to recover gravitational potential energy based upon one or more predetermined logic sequences; such configuration in the disclosed system ensures the energy recovered is solely obtained from the potential energy. Without the mentioned configuration, energy from a primary power source may be drawn to descend the carriage or the load at a speed that the energy converting unit may harvest the energy supplied from the primary power source instead of charging the power or energy storing/discharging member using the recovered potential energy, especially when the load or the potential energy stored therein is insufficient to be harvested. Under the like circumstances, more energy from the primary power source is squandered and the disclosed system features to address said deficiencies by intelligently managing the available power or energy.

Still another object of the present disclosure is to realize a hoisting system imparted with preset configurations to only discharge the recovered energy of hydraulic form when the load is greater than a minimal threshold. Discharging the recovered energy uncontrollably or even the load is well under the predetermined threshold, may result in overcharging the hoist assembly or machine. Notwithstanding the potential energy is effectively recovered, the obtained energy is not productively use in these situations.

At least one of the preceding objects is met, in whole or in part, by the present invention, in which one of the embodiments of the present invention is a hoisting system. The hoisting system preferably comprises a receptacle of a defined load and movable between a first position and a second position, which is a position having greater gravitational potential energy than the first position; a hoist assembly comprising an winch motor, a drum wound with a cable having one end secured to the receptacle and another end affixed to the drum, and a gear mechanism interfacing the winch motor to the cable drum for driving the receptacle to move toward to or away from the second position by respectively winding the cable onto the drum or unwinding the cable from the drum; a primary power source for supplying an electrical current to the winch motor to drive the drum and move the receptacle; an energy converting unit detachably engaged to the hoist assembly to recover gravitational potential energy from the receptacle upon moving the receptacle from the second position to the first position; a power storage member connecting the energy converting unit to store the recovered potential energy and being fashioned to discharge the stored energy to at least partially power the hoist assembly to move the receptacle from the first position to the second position, through the energy converting unit, in addition to the primary power source; a frequency conversion unit configured to vary the magnitude and/or frequency of the electrical current supplied to the winch motor thereby regulating power output of the winch motor in moving the receptacle, the power output is positively correlated to the defined load; and a microcontroller in communication with the hoist assembly and the power storage member to initiate the recovery or discharge of the energy. Preferably, the microcontroller prohibits the stored energy from being discharged to power the winch motor to drive the receptacle to the second position by detaching the energy converting unit from engaging the hoist assembly when the defined load is below a predetermined discharging threshold. Preferably, the disclosed system is free from using any counter-weight.

In several embodiments, the recovered potential energy of the disclosed system is stored to or discharged from the power storage member in the form of fluid power. More preferably, the power storage member is a fluid accumulator and the energy converting unit is a hydraulic pump/motor unit that the fluid accumulator and the hydraulic pump/motor unit are interconnected through a hydraulic circuit containing pressurized hydraulic fluid. Preferably, the hydraulic pump/motor unit can be functionally connected to different components of the hoist assembly. This pump/motor unit serves as a pump when the hoist assembly is to lower the load at a pre-determined speed.

In one or more embodiments, the power storage member releases the stored pressurized hydraulic fluid, preferably hydraulic oil, to the pump/motor unit, which functions as a hydraulic motor to assist the electric motor to lift the defined load up in the operation to move the load upward. By this set up, the present disclosure recovers and recycles the wasted potential energy to become useful energy to at least partially assist lifting of the heavy load.

In a number of embodiments, a hydraulic system or circuit is established to work with the hoist assembly to recover and store the unwanted energy when the load is being lowered. This energy will then be released by the hydraulic system to assist the AC motor when the hoist assembly is to lift the load in the next cycle.

In few embodiments, the recovered energy is stored at the fluid accumulator as hydraulic fluid pressurized to at least 20bar and the stored energy is discharged by channeling the pressurized hydraulic fluid to the hydraulic circuit.

In a number of embodiments, the disclosed system may additionally comprise a fluid reservoir connected to the hydraulic circuit for collecting the hydraulic fluid channeled out from the fluid accumulator.

The disclosed system, in several embodiments, comprises a sensor in communication with the hoist assembly for substantially defining the load based upon the power output of the winch motor

One or more embodiments of the disclosed system further comprise a sensor, preferably a load cell sensor, in communication with the microcontroller for substantially defining load of the receptacle or loaded receptacle. In more embodiments, the disclosed system further
5 comprises a sensor in constant communication with the frequency unit for substantially defining the load based upon the magnitude and/or frequency of the electrical current supplied from the frequency conversion unit to the electrical motor.

A number of the preferred embodiment has the microcontroller configured to activate the
10 energy converting unit to recover the gravitational potential energy from the defined load moving towards the first position from the second position when the defined load is equal to and/or above a predetermined charging threshold. In more embodiments, the microcontroller samples or read frequency and/or magnitude varied current value supplied to the electric motor from the frequency conversion unit, preferably through a current sensor, for defining
15 the load and the microcontroller activates the energy converting unit to recover the gravitational potential energy from the receptacle enclosing the load moving towards the first position from the second position when the defined load is equal to and/or above a predetermined charging threshold. More preferably, the current sensor is in signal communication with the motor and/or the VFD inverter to monitor or read the supplied
20 current in real time.

A plurality of embodiments of the disclosed system may have the hydraulic circuit further comprised a first operation valve disposed in the hydraulic circuit between the fluid accumulator and the pump/ motor unit; and a second operation valve, located in the hydraulic
25 circuit between the pump/ motor unit and the fluid reservoir, with a filtering means and a cooler positioned downstream in relation to the second operation valve. The first operation valve directs the pressurized hydraulic fluid from the fluid accumulator to the pump/motor unit to at least partially power the hoist assembly to move the receptacle from the first position to the second position, and the second operation valve channels the discharged
30 pressurized hydraulic fluid from the pump/motor unit to pass through the filtering means and the cooler prior to collecting the discharged hydraulic fluid in the fluid reservoir.

According to several embodiments, the hydraulic circuit in the disclosed invention further comprises a first operation valve disposed in the hydraulic circuit between the fluid accumulator and the pump/ motor unit; and a third operation valve, located in the hydraulic circuit between the pump/ motor unit and the fluid reservoir. Preferably, the third operation valve channels the hydraulic fluid collected at the fluid reservoir to the pump/motor unit to be pressurized for storing the recovered potential energy, and the first operation valve directs the pressurized hydraulic fluid into the fluid accumulator for storing the pressurized hydraulic fluid.

10 In more preferred embodiments, the hydraulic pump/motor unit is connected to and capable of driving the winch motor, drum and/or gear mechanism of the hoist assembly to at least partially power the hoist assembly to move the receptacle from the first position to the second position.

15 In some embodiment, the system is installed with a fluid pressure sensor connected to the fluid circuit to monitor and/or sample reading on fluid pressure in the fluid accumulator and/or in the fluid circuit. Accordingly, the hydraulic circuit may include a pressure relief valve being regulated by the microcontroller and fashioned to discharge the pressurized hydraulic fluid from the fluid accumulator under instruction of the microcontroller.

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In another aspect of the present disclosure, a hydraulic circuit capable of being fitted into a hoisting system, which comprises a receptacle of a defined load and a hoisting assembly powered by a primary power source through a frequency conversion unit to move the defined load between a first position and a second position of greater gravitational potential energy than the first position, for recovering gravitational potential energy and discharging the recovered energy back to the hoisting system for moving the defined load towards the second position is disclosed herein. Preferably, the hydraulic circuit comprises an energy converting unit detachably engaged to the hoist assembly to recover gravitational potential energy from the defined load upon moving the defined load from the second position to the first position;

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30 a power storage member connecting the energy converting unit to store the recovered potential energy and being fashioned to discharge the stored energy, in the form of fluid power, to at least partially power the hoist assembly to move the defined load from the first

position to the second position, through the energy converting unit, in addition to the primary power source; and a microcontroller in communication with the power storage member to initiate the recovery or discharge of the energy, wherein the microcontroller activates the energy converting unit to recover the gravitational potential energy from the defined load moving towards the first position from the second position when the defined load is equal to and/or above a predetermined charging threshold.

Furthermore, in a number of embodiments, the microcontroller prohibits the stored energy from being discharged to power the hoist assembly to drive the defined load to the second position by detaching the energy converting unit from engaging the hoist assembly when the defined load is below a predetermined discharging threshold.

Several preferred embodiments of the disclosed hydraulic circuit have the power storage member established in the form of a fluid accumulator and the energy converting unit as a hydraulic pump/motor unit. The fluid accumulator and the hydraulic pump/motor unit are interconnected through pressurized hydraulic fluid flowing through the hydraulic circuit. A fluid reservoir can be connected to the disclosed hydraulic circuit for collecting the hydraulic fluid channeled out from the fluid accumulator in other embodiments.

In some embodiments of the hydraulic circuit, one or more sensors are installed in communication with the hoist assembly for substantially defining the load based upon the tension applied to or output of the hoist assembly and relaying the load defined in the form of digital signal to the microcontroller. Likewise, one or more sensor can be integrated in communication with the frequency conversion unit for substantially defining load based upon the magnitude and/or frequency of the electrical current supplied to the frequency conversion unit and relaying the load defined in the form of digital signal to the microcontroller.

In several embodiments, the hydraulic circuit comprises a first operation valve disposed in the hydraulic circuit between the fluid accumulator and the pump/ motor unit; and a second operation valve, located in the hydraulic circuit between the pump/ motor unit and the fluid reservoir, with a filtering means and a cooler positioned downstream in relation to the second operation valve, wherein the first operation valve directs the pressurized hydraulic fluid from the fluid accumulator to the pump/motor unit to at least partially power the hoist assembly to

move the defined load from the first position to the second position, and the second operation valve channels the discharged pressurized hydraulic fluid from the pump/motor unit to pass through the filtering means and the cooler prior to collecting the discharged hydraulic fluid in the fluid reservoir.

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For a plurality of embodiment, the hydraulic circuit may include a first operation valve disposed in the hydraulic circuit between the fluid accumulator and the pump/ motor unit; and a third operation valve, located in the hydraulic circuit between the pump/ motor unit and the fluid reservoir, wherein the third operation valve channels the hydraulic fluid collected at the fluid reservoir to the pump/motor unit to be pressurized for storing the recovered potential energy, and the first operation valve directs the pressurized hydraulic fluid into the fluid accumulator for storing the pressurized hydraulic fluid.

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Brief Description of the Drawings

15 FIG. 1 illustrates typical set up of a hoisting machine or assembly using AC electric motor as the driver to move the receptacle and/or load;

FIG.2 is a schematic diagram showing connections between various components of the conventional hoisting machine or assembly using AC electric motor as the driver to move the receptacle and/or load;

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FIG.3 illustrates one embodiment of the present disclosure employing AC electric motor as the driver to move the receptacle and/or load that the hydraulic pump/motor unit can be mounted to one or more different locations in the hoist assembly for energy recovery;

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FIG.4 illustrates typical set up of a hoisting machine or assembly using hydraulic motor as the driver to move the receptacle and/or load;

30 FIG.5 illustrates one embodiment of the present disclosure employing hydraulic motor as the driver to move the receptacle and/or load that the hydraulic pump/motor unit can be mounted to one or more different locations in the

hoist assembly to harvest the potential energy or channel the harvested energy back to the hoist assembly;

FIG.6 shows hydraulic circuit of one embodiment of the present disclosure;

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FIG.7 shows operation of different valves in the hydraulic circuit, as illustrated in FIG.6, to flow and keep the pressurized hydraulic fluid in the fluid accumulator;

10 FIG.8 shows operation of different valves in the hydraulic circuit, as illustrated in FIG.6, to power the hydraulic pump/motor unit for load lifting and drain the less pressurized hydraulic fluid to the fluid reservoir; and

15 FIG.9 shows one embodiment of the process flow implemented by the microcontroller or the computing processor to monitor and control operation of the disclosed system.

Detailed Description

20 The presently preferred embodiments of the present invention will be best understood by reference to the drawings, wherein like parts are designated by numerals throughout. It will be readily understood that the components of the present invention, as generally described and illustrated in the figures herein, could be arranged and designed in a wide variety different configurations. Thus, the following more detailed description of the embodiments of the hoisting system of the present invention, as represented in FIG.1 through 9, is not
25 intended to limit the scope of the invention as claimed, but is merely representative of presently preferred embodiments of the present invention.

The term “motor”, “winch motor”, “electric motor” or “AC motor” are used throughout the specification interchangeably referring to a motor means in the hoist assembly unless
30 mentioned otherwise. The motor means can run on electrical energy or kinetic energy.

The “receptacle” used throughout this specification by itself can be referred as a defined load or part of the defined load, owing to the weight of the receptacle, to take part in charging or discharging the power storage member in the lifting cycle besides being employed as a means to house and transport goods or passengers in the disclosed hoisting system.

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FIG.1 and 2 collectively show arrangement of typical winch or hoist assembly 180 employed in vertical load transportation of a hoisting system 100 to move the load 133 from one location of a first height position to another location of a second height position. In more specific, the conventional hoist assembly 180 includes a cable 186 having one end affixed to
10 a carriage or a receptacle 133, a drum or winch 184 on which the cable 186 has another end anchored to such that turning the drum 184 in one direction shall wind the cable 186 onto the outer surface of the drum 184 and vice versa, and a motor 183 to drive the drum 184 and cable through a gear mechanism 188. Preferably, the rotational speed and/or output power of the motor 183 is controlled by a frequency conversion unit 165 channeling the required
15 power from a supply network or genset 170. The frequency conversion unit 165 modulates the frequency and/or magnitude of the current channeled to the motor 183 corresponding to the speed and/or power output required to carry out an action to lift or lower a specific or predefined amount of load 133. The frequency conversion unit 165 is preferably a variable frequency drive (VFD) inverter 150. FIG.2 further illustrates another design of the typical
20 hoist assembly 180 having a variable frequency drive inverter 150 to drain the waste current generated from the motor 183 to the braking resistor 153. In addition, it is possible to drive the gear 188 and drum 184 using hydraulic motor 189, besides the electric motor 183, as shown in FIG.4. Pressurized hydraulic fluid is pumped through the hydraulic motor 189 to convert the hydraulic energy into rotational and angular displacements of the gear resided
25 within the hydraulic motor 189, which actuates the externally connected gear mechanism 188 to move and drive the drum 184 as well as the receptacle 133 secured to the drum 184 through the cable 186. The aforementioned typical vertical lifting system or hoisting system 100, in fact, can be modified or improved to arrive at the embodiments described hereinafter to be imparted with the ability to recover, reuse or recycle gravitational potential energy
30 accumulated along the ascending and/or descending movement of the load 133.

Some embodiments of the present disclosure are described hereinafter with reference to FIG.3 and FIG.5. Particularly, the disclosed hoisting system 400 has a receptacle 433 capable of enclosing a defined load and movable between a first position and a second position that the second position preferably has greater gravitational potential energy than the first position.

5 The receptacle 433 described in the present disclosure can refer to any car or carriage known in the field such as construction car or cage, passenger lift, suspended working platform, gondola or any other known platform in the field operable by the hoist assembly. In few embodiments, the receptacle 433 may even refer to wrapped package having the load retained within to be transported using the disclosed hoisting system 400 without resorting any
10 mechanically rigid platform. To move the receptacle 433, the disclosed hoisting system 400 essentially includes a hoist assembly 480. Preferably, the hoisting assembly 480 comprises a winch or electric motor 483, a drum 484 and a gear mechanism 488 connecting the motor 483 to the drum 484 in such way that operation of the motor 483 drives the drum 484 into a rotational movement or angular displacement. The motor 483 implemented in the present
15 disclosure can be a hydraulic motor or an electric motor of AC or DC type though electric motor is employed in the more preferred embodiments. The drum 484 is preferably wound with a cable 486 having one end secured to the receptacle 433 and another end affixed to the drum 484. The gear mechanism 488 interfacing the winch motor 483 to the cable drum 484 turns the kinetic energy produced from the motor 483 into a force to drive the receptacle 433
20 to move toward to or away from the second position by respectively winding the cable 486 onto the drum 484 or unwinding the cable 486 from the drum 484 at a controlled speed. Further, the disclosed system 400 activates or powers operation of the motor 483 via a primary power source 496 for supplying an electrical current to the winch motor 483 to drive the drum 484 and move the receptacle 433. The primary power source 496 can be any one or
25 combination of electrical power grid and genset fueled by diesel. In some embodiments, the disclosed system utilizes both power grid and genset as the primary power source 496 that the power from the genset is used to drive the motor 483 in the occurrence of electricity outage to ascertain uninterrupted operation of the disclosed system 400. The total power output and/or movement speed of the drum 484, together with the connecting receptacle and/or load 433,
30 corresponds to the frequency, phase and/or magnitude of the electric current supplied from the frequency conversion unit or VFD inverter 495 to the motor 483. The power output is positively correlated to the defined load 433 and the controlled speed. More specifically, the

power required for the operation of the motor 483 is positively correlated to the speed and/or total load in the receptacle 433. The faster the speed and/or the heavier the load 433, the greater power the motor 483 has to generate to lift the load 433.

5 In order to regulate the power output of the motor 483 and/or the rotational speed of the drum 484, the disclosed system 400 possesses a frequency conversion unit 495 configured, as briefly explained above, to vary the frequency and/or magnitude of the electrical current supplied to the winch motor 483 thereby regulating power output of the winch motor 483 in moving the receptacle 433. Preferably, one or more weight sensors (not shown) are
10 incorporated in several embodiments of the disclosed hoisting system 400 to continuously monitor or define the load then further relay the defined load to a microcontroller 510 to determine the power to be generated at the motor 483 to lift or lower the receptacle 433 accommodating the load at the controlled speed. The microcontroller 510 in the present disclosure can be in the form of logic circuit or low power computing apparatus capable of
15 performing simple calculation and running a set of prefixed logic sequences based upon the outcome of the calculation to manage current modulation at the frequency conversion unit 495, prior to directing the modulated current to the motor 483 for generating the required power to move the defined load at the controlled speed. More specifically, the microcontroller 510 is designed and programmed to work on the logic sequences for
20 managing various hydraulic components of the disclosed hoisting system 400. The microcontroller 510 is preferably in constant communication with the hoist assembly and the power storage member 540 to initiate the recovery or discharge of the energy. The microcontroller 510 also takes input from various sensing means or sensors arranged in the hoisting system 400 in accordance with the applied logic sequences, and performing a
25 corresponding action dependent on the computed results using the input. These inputs, feedbacks or information can be tapped via switches, joysticks movement and even CANBUS network relying upon the embodiments of the hoisting system 400. The microcontroller 510 also serves as a fault manger, taking input from the pressure sensors 545 and temperature sensor (not shown) found in several embodiments of the disclosed system
30 400 to ensure the system 400 is always working within the safe pressure and temperature limits. Furthermore, the microcontroller 510 may be arranged in constant communication with the controller 700 of other lifting equipment.

To meet at least one of the objects setting forth above, the disclosed hoisting system 400 comprises an energy converting unit 490 and a power storage member 540 to harness the potential energy when the load is lowered to the first position. Without the potential energy recovering features integrated, not only the potential energy is wasted but waste energy has to be counteracted using power derived from a primary power source. This further takes heavy toll towards the total energy consumed by the hoisting system, as found in those conventional hoisting systems 100. To address such deficiencies in the conventional system 100, a number of the disclosed embodiments comprise a power storage member 540, which is preferably a fluid accumulator 540, and an energy converting unit 490, preferably implemented as a hydraulic pump/motor unit 490. The disclosed hoisting system 400 preferably has the energy converting unit 490 detachably engaged to the hoist assembly 480 to recover gravitational potential energy from the receptacle 433 upon moving the receptacle 433 from the second position to the first position. As shown in FIG.3, the energy converting unit 490 can detachably mate with one or more elements in the hoist assembly 480 to materialize the potential energy recovery. The energy converting unit 490 can be detachably engaged to the interface between the gear mechanism 488 and the drum 484, interface between the gear mechanism 488 and the motor 483, the motor 483 directly and/or to the cable drum 484 through a clutch box 499 respectively corresponding to the location 1-4 depicted in FIG.3. In other embodiments using hydraulic motor instead of the electric motor, the hydraulic pump/motor unit 490 is connected to and actuated by the winch motor 483, drum 484 and/or gear mechanism 488 of the hoist assembly 480 directly or indirectly to recover the potential energy respectively corresponding to the location 1-3 illustrated in FIG.5. Accordingly, the power storage member 540 connects, preferably in fluid communication, to the energy converting unit 490 for storing the recovered potential energy and it is fashioned to discharge the stored energy to at least partially power the hoist assembly 480 to move the receptacle 433 from the first position to the second position, through the energy converting unit 490, in addition to the major power supplied by the primary power source 496. To deliver the recovered energy from the power storage member 540 to the hoist assembly 480 for load lifting, the hydraulic pump/motor unit 490 of the present disclosure is connected to and capable of driving the winch motor 483, drum 484 and/or gear mechanism 488 of the hoist

assembly 480 to at least partially power the hoist assembly 480 to move the receptacle 433 from the first position to the second position as aforementioned.

Pursuant to the preferred embodiments, the recovered potential energy is stored to or
 5 discharged from the power storage member 540 in the form of fluid power that the fluid accumulator 540 and the hydraulic pump/motor unit 490 are interconnected through a hydraulic circuit 500 containing pressurized hydraulic fluid. Hydraulic circuit 500 is known for its adaptability in arranging various components to form a functional circuit 500. The components such as hose and pipes, reservoir 550, accumulator 540 and the associating
 10 valves can flexibly located immediate to or remotely away from the hoisting assembly 480 depending upon the space available for the installation of the involved components. One embodiment of the hydraulic circuits 500 established in the disclosed system 400 is illustrated in FIG.6 to 8. Preferably, the hydraulic circuit 500 of several embodiments of the disclosed system 400 comprises the pump/motor unit 490, a fluid accumulator 540, a fluid
 15 reservoir 550, a pressure relief valve 544, a first operation valve or launch/charge valve 513, a second operation valve or cooling valve 516, a third valve or isolation valve 519 and hoses forming the fluid path joining all mentioned parts together.

According to the preferred embodiments, the pump/motor unit 490 of the disclosed hoisting
 20 system 400 is a variable displacement pump/motor unit 490. By adjusting the displacement of the pump/motor unit 490 to zero, the present disclosure can figuratively disengage the pump/motor unit 490 from the hoist assembly 480 when energy recovery or discharge is impractical. Employment of the variable displacement pump/motor unit 490 also facilitates regulation of the microcontroller 510 over the whole system 400 especially with respect to
 25 the extent of the energy stored to and released from the power storage member 540. While for those embodiments which a fixed load is consistently attached to the disclosed system 400, a pump/motor unit 490 with no adjustable displacement may be used to reduce the installation cost of the disclosed system 400. For example, hoist assembly 480 of some embodiments may carry a receptacle 433, which is about 20 to 30 % of the maximum load operable by the
 30 motor 483, that a fixed displacement pump/motor unit 490 is thus applicable to recover 80% to 90% of the potential energy accumulated in the lifting cycle, preferably due to the weight of the receptacle, despite the receptacle is not loaded at all. The logic sequences to be run on

the fixed displacement pump/motor unit 490 via the microcontroller 510 become much simple compared to other embodiments having the variable displacement counterpart incorporated.

5 In some embodiments, the fluid accumulator 540, serving as the power storage member 540, and the fluid reservoir 550 connected to the hydraulic circuit 500 are responsible for respectively collecting pressurized hydraulic fluid charged from the pump/motor unit 490 and depressurized hydraulic fluid released from the fluid accumulator 540. It is important to note that the depressurized hydraulic fluid kept at the reservoir 550 is still pressurized under a
 10 positive pressure (higher than atmospheric pressure) despite the fluid pressure maintain is much lower in comparison to the pressurized fluid stored in the accumulator 540. Inventors of the present invention designed the reservoir 550 to keep a preferred fluid pressure in the stored hydraulic fluid to ensure that positive pressure is maintained throughout the hydraulic circuit 500. As illustrated in FIG.6 to 8, the fluid path is composed of a first route and a
 15 second route. The first route preferably guides the pressurized fluid discharged from the fluid accumulator 540 through the first operation valve 513, the pump/motor unit 490, the second operation valve 516 and finally being retained in the fluid reservoir 550 as depressurized fluid; the second route directs the depressurized fluid from the fluid reservoir 550 to the pump/motor unit 490 to be compressed and stored in the fluid accumulator 540 as pressurized
 20 fluid through the third 519, second 516 and first operation valves 513. More specifically, the first operation valve 513 is installed in the hydraulic circuit 500 or fluid path at a location between the fluid accumulator 540 and the pump/motor unit 490; and the second operation valve 516 is located in the hydraulic circuit 500 between the pump/motor unit 490 and the fluid reservoir 550. Optionally, the disclosed hoisting system 400 incorporates a filtering
 25 means 525 and/or a cooler 524 at a location downstream in relation to the second operation valve 516 that the discharged pressurized hydraulic fluid is treated before being stored in the fluid reservoir 550. Furthermore, the third operation valve 519 is preferably located in the hydraulic circuit 500 between the pump/motor unit 490 and the fluid reservoir 550 that the disclosed hoisting system 400 routes the depressurized hydraulic fluid from the reservoir 550
 30 to the pump/motor unit 490 passing through the third 519 and second operation valves 516. Preferably, the operation valves are three ways dual positions valve switchable between the

on and off position to guide the hydraulic fluid to travel through different established fluid path.

As setting forth in the foregoing description, the disclosed hoisting system 400 is configured to recover potential energy and further charge the accumulator 540 with the recovered power when the hoisting assembly 480 moves the load towards the first position. The gravitational potential energy is firstly converted to kinetic energy at the motor 483 of the hoist assembly 480, which successively actuates the pump/motor unit 490 to draw the hydraulic fluid from the reservoir 550 to the accumulator 540 pressurizing the hydraulic fluid along the process to convert and store the kinetic energy into hydraulic power. More particularly, the disclosed system 400, under command of the microcontroller 510, activates pump function of the pump/motor unit 490 while have both third 519 and second operation valve 516 switched to allow flowing of the hydraulic fluid from the hydraulic reservoir 550 to the pump/motor unit 490 as shown n FIG.7. The hydraulic pump/motor unit 490 subsequently pressurizes the flowing hydraulic fluid and charges the pressurized fluid into the fluid accumulator 540 or power storage member 540 to store the recovered energy in the form of hydraulic power. Preferably, the recovered energy is stored at the fluid accumulator 540 as pressurized hydraulic fluid and the stored energy is discharged by channeling the pressurized hydraulic fluid to the hydraulic circuit 500 to transfer the recovered energy to the pump/motor unit 490. In short, the third operation valve 519 channels the hydraulic fluid collected at the fluid reservoir 550 to the pump/motor unit 490 to be pressurized for storing the recovered potential energy, and the first operation valve 513 directs the pressurized hydraulic fluid into the fluid accumulator 540 for storing the pressurized hydraulic fluid. The disclosed hoisting system 400 directs the depressurized fluid through the second route bypassing the filtering means 525 and cooler 524 in the process.

In several embodiments, the disclosed hoisting system 400 stop charging the fluid accumulator 540 once the microcontroller 510 detects or senses the hydraulic pressure in the accumulator 540 reached a pressure threshold. Preferably, the disclosed hoisting system 400 has one or more fluid pressure sensor 545 connected to the fluid circuit 500 to monitor and/or sample reading on fluid pressure in the fluid accumulator 540 and/or in the fluid circuit 500. The fluid pressure sensor 545 further feeds the sampled reading to the microcontroller 510.

Based upon the calculation and computing outcome using the fed readings, the microcontroller 510 decides whether the charging of the pressurized fluid should be continued or not. More specifically, the microcontroller 510 ends the charging process by having the pump/motor unit 490 disengaged or declutched from the hoist assembly 480. The

5 disengagement can be realized by adjusting the pump/motor unit 490's displacement to zero so that the pump/motor unit 490 does not produce high pressure oil at all but merely rotates freely by the motor 483. Alternatively, the disclosed system 400 can functionally install an electro-magnetic clutch 499 joining the hoist assembly 480 and the hydraulic pump/motor unit 490, the microcontroller 510 dissociates the pump/motor unit 490 from the hoisting

10 assembly through declutching the electro-magnetic clutch 499. In addition to that, the hydraulic circuit 500 may further comprise a pressure relief valve 544, in some embodiments, being regulated by the microcontroller 510 and fashioned to discharge the pressurized hydraulic fluid from the fluid accumulator 540 under instruction of the microcontroller 510. Presence of the pressure relief valve 544 provides an alternative exit for the pressurized fluid

15 in case the hydraulic pump/motor fails to response towards stop command of the microcontroller 510 to discontinue the charging action. The pressure relief valve 544 may not be regulated by the microcontroller 510 but being arranged to automatically drain off the pressurized fluid once the pressure reading surpasses a given value. The pressure relief valve 544 is catered to ensure pressurized fluid is capped within a safe operating pressure limit. The

20 disclosed system 400 may emit warning signal if the hydraulic pressure goes beyond the safe operating limit.

In the situation of load lifting requiring extra energy from the power storage member 540, the microcontroller 510 instructs the fluid accumulator 540 or power storage member 540 to

25 release the pressurized fluid to the hydraulic pump/motor unit 490 as illustrated in FIG.8. For discharging or launching of the stored energy, the first operation valve 513 directs the pressurized hydraulic fluid from the fluid accumulator 540 to the pump/motor unit 490 to at least partially power the hoist assembly 480 to move the receptacle 433 from the first position to the second position, and the second operation valve 516 channels the discharged

30 pressurized hydraulic fluid from the pump/motor unit 490 to pass through the filtering means 525 and the cooler 524 prior to collecting the discharged hydraulic fluid in the fluid reservoir 550. As shown in the FIG.8, the disclosed system 400 has the positions of the first, second

and third valves switched allowing pressurized fluid from the fluid accumulator 540 to drive the hydraulic pump/motor unit 490. At this instant, the pump/motor unit 490 acts as a motor propelled by the passing pressurized hydraulic fluid to drive the hoist assembly 480 to move or pull the load upward in addition to the power drained from the primary power source 496.

5 The initial ascending movement of the load consumes highest amount of power or energy that extra power has to be supplied to accelerate the moving speed of the load. With the aid of the recycled or recovered energy, the disclosed hoisting system 400 significantly reduces initial power levied against the primary power source 496. The disclosed hoisting system combines the recovered energy and the supplied energy from the primary power source 496 to meet the
10 power consumption peak at the beginning stage of the lifting action. Following release of the recovered energy to the hydraulic pump/motor unit 490, the hydraulic fluid exits thereof as depressurized hydraulic fluid then being channeled through the second operation valve 516 and the downstream positioned cooler 524 and filtering means 525 to be eventually kept in the fluid reservoir 550. Preferably, a check valve is placed at the outlet port of the filter. The
15 check valve prevents backflow of the hydraulic fluid from the reservoir 550. The charge/launch cycle of the present disclosure repeats throughout the operation of the hoisting system 400 to lower the power consumption through reduced torque and save fuel in the long run.

20 As described in the setting forth, the disclosed hoisting system 400, more specifically the hydraulic circuit 500, also features an idle state at which no energy is exchanged between the hoist assembly 480 and the hydraulic circuit 500 even the receptacle 433 and/or load is moved from the first position to the second position or vice versa. In the idle state, the disclosed system 400 literally detaches the fluid accumulator 540 from the hydraulic circuit
25 500. The first, second and third valves are in the position to circulate the hydraulic fluid from the fluid reservoir 550 back to the reservoir 550 through the pump/motor unit 490 and the second fluid path, as shown in FIG.6. The unique idle state of the present disclosure enable the described hoisting system 400 to attain better and improved energy efficiency as further explain in the follow.

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The gravitational potential energy of the disclosed system 400 can be varied from time to time upon placing additional load to or removing at least portion of the load off the receptacle

433 setting aside the relative location of the receptacle and/or load 433 in the hoistway or the travel path. Such inconsistency may predispose the disclosed system 400 to substantial energy wastage and diminish efficiency of the total energy recovered. For instance, it is important for the disclosed hoisting system 400 to sense or be informed the weight of the load
5 to be lowered in order to determine whether energy recovery, by charging the hydraulic accumulator 540, is feasible or not. Specifically, when the receptacle 433 is moving downward by the disclosed hoisting system 400 with no load or negligible load, there is no sufficient energy to be recovered or saved. Activating the hydraulic pump/motor unit 490 in such situations for charging the accumulator 540 actually subjects the pump/motor unit 490
10 to be driven by the electric motor 483 of the hoist assembly 480 rather the falling load. It is the energy of the primary power source 496 being used to charge the accumulator 540 through the hydraulic pump/motor unit 490; no potential energy is substantially recovered in such action. Instead, energy becomes wasted along the process when the energy is converted from one form to another. Apart from that, untimely discharge of the recovered potential
15 energy to the hoist assembly 480 for load lifting can give rise to energy wastage and inefficient energy consumption too. For example, when discharging the recovered energy to the hoist assembly 480 to lift an empty receptacle or a load 433 carried below a predetermined discharging threshold, the pump/motor unit 490 takes part in producing torque higher than the torque required by the electric motor 483 to lift the load. The excessive torque
20 generated further drives and stresses the electric motor 483 to literally turn the electric motor 483 into a generator.

In view of that, the hoisting system 400 as described in the present disclosure is preferably integrated with one or more special arrangements to intelligently harvest and/or discharge the
25 recovered energy to at least partly resolve the energy wastage arisen from aforesaid situations relating to lifting and lowering of empty receptacle 433 throughout the lifting cycle of the disclosed hoisting system 400.

In a plurality of embodiments 820 for load lowering operation 821, the microcontroller 510
30 samples the magnitude and/or frequency varied electrical current supplied to the electric motor 483 from the frequency conversion unit 495 for defining the load 822 that the microcontroller 510 activates 823 the energy converting unit 490 together with the involved

first 513 and second operation valves 516 to recover the gravitational potential energy from the receptacle 433 enclosing the load moving towards the first position from the second position when the defined load is equal to and/or above a predetermined charging threshold, preferably 5%-25% or more preferably 15% or above of the load capacity of the electric or winch motor 483. Referring to one embodiment of the logic sequence run in the disclosed hoisting system 400 to operate the hydraulic circuit 500 and shown in FIG.9, the hoisting system 400 needs to determine or define the load in the receptacle 433 to decide whether there is sufficient energy to be recovered from the operation. To determine the weight of the lowering load, a load sensor (not shown), preferably a load cell, is set to constantly measure the load in the receptacle 433 for substantially defining the load. The load cell is in signal communication with the microcontroller 510 to relay the reading of the measurement to the microcontroller 510. Apart from using load cell, the microcontroller 510 can also be configured to sample or read the value of the frequency and/or magnitude varied current value supplied to the electric motor from the VFD inverter, through a current sensor, for defining the load. Similarly, the current sensor can be in signal communication with the motor and/or the VFD inverter. With heavier lowering load placed to the receptacle 433, the AC or electric motor 483 is subjected to higher torque from the gravitational force thus draining current of greater magnitude from the power grid or genset. The microcontroller 510 can accurately correlate the current value to the load to be defined. Relying on the acquired input, the microcontroller 510 decides on whether the hydraulic circuit 500 should be activated or not to recover the potential energy. For example, the microcontroller 510 may decide to activate the pump/motor unit 490 when the load cell indicates that the load being lowered is 15% or more of the maximum load capacity of the motor 483 or hoist assembly 480. On the contrary, the pump/motor unit 490 will be disengaged from the hoist assembly 480 by either declutching the interfacing electro-magnetic clutch 499 or setting the displacement of the pump/motor unit 490 to zero, where the dissociated pump/motor unit 490 becomes free-wheeled and is not driven by the hoist assembly 480 at all that no hydraulic fluid is pressurized to the fluid accumulator 540. In connection to the decision to harness the potential energy when the load is around 5% to 25%, more preferably 15% and above, of the maximum load capacity of the electric motor 483, the microcontroller 510 switches the first 513, second 516 and third operation valves 519 to the positions to flow the depressurized fluid from the reservoir 550 to the pump/motor unit 490 for compression then further storing

the pressurized fluid at the fluid accumulator 540. Throughout the process of compressing or pressurizing the hydraulic fluid, the microcontroller 510 preferably monitors fluid pressure 824 in the accumulator 540 and may have to terminate or end the charging once the pressure exceeds a safety limit. Discontinuation or complete 825 of the recovery process put the hydraulic circuit 500 into the idle state followed by position switching or deactivation 826 of involved operation valves. The charging of the accumulator 540 can be ended before complete of the lowering operation 827. For embodiment utilizing a variable displacement pump/motor unit 490, logic sequence or algorithm can be written in such way that the pump/motor unit 490 carries out greater displacement volume corresponding to heavier load hooked to the disclosed hoisting system 400 so that more energy can be stored at the fluid accumulator 540. In response to lighter falling load, the displacement of the pump/motor unit 490 will be correspondingly reduced to a smaller value. Nonetheless, as stated above, the microcontroller 510 only activates the pump/motor unit 490, or the energy converting unit 490, to recover the gravitational potential energy from the receptacle 433 enclosing the load moving towards the first position from the second position when the defined load is equal to and/or above a predetermined charging threshold.

Referring again to the FIG.9, the disclosed hoisting system 400 also possesses another set of logic sequences 810 to effectively and intelligently to use the recovered potential energy for load lifting operation 811. At the beginning of a lifting operation, the microcontroller 510 has to recognize the need of using the recovered energy. It determines 812 the weight of the load to be lifted by acquiring the reading measured from the load cell or the value of the current supplied from the VFD inverter 495 to the electric motor 483 in the absence of load cell. The weight of the lifting load can be measured indirectly from the current supplied by the VFD inverter 495 supplied to the electric motor 483 because larger current has to be directed to the motor 483 to drive load of greater weight. The value of the supplied current is substantially proportional to the load being lifted. Particularly, a current sensor (not shown) is in communication with the frequency conversion unit 495 to substantially define the load based upon the frequency and/or magnitude of the electrical current supplied from the frequency conversion unit 495. The hoisting system also has the current sensor programmed to feed the defined load in the form of electrical signal to the microcontroller 510 to compute an outcome, which is further employed by the microcontroller to decide the next course of

action. Once the microcontroller 510 finds that the load is not lower than the predetermined discharging threshold of 5% to 25%, more preferably 15% or above, of the maximum load capacity of the electric motor 483, the disclosed hoisting system 400 permits discharge of the pressurized hydraulic fluid from the fluid accumulator 540. Meanwhile, the hoisting system 400 also changes position or activates 813 of the first 513 and second operation valves 516 to guide the discharged pressurized hydraulic fluid to route through the pump/motor unit 490, which functions as the motor 483 as this instant, launching the stored energy 814 and then to the cooler 524 as well as filtering means 525 to finally being stored in the fluid reservoir 550. The microcontroller may decide not to launch or terminate launching of the recovered energy earlier corresponds to the low fluid pressure detected in the accumulator 824. The disclosed hoisting system 400 may preferably halt the fluid discharge from the accumulator 540 before complete of the lifting action. Prior to complete of the lifting operation 818, the first 513 and second operation valves 516 are deactivated by way of switching to the off position 817 under the command of the microcontroller 510. More preferably, the disclosed system 400 only uses the recovered energy as the supplementary power to assist speed acceleration of the lifting load. Provision of the recovered energy, in addition of the primary power source 496, to the hoist assembly 480 is withdrawn when the moving load has reached controlled speed.

To manage the power consumption effectively, the disclosed hoisting system 400 preferably has the microcontroller 510 prohibited the stored energy from being discharged to power the winch or electric motor 483 for driving the receptacle 433 to the higher level or the second position, more preferably by way of detaching the pump/motor unit 490 from engaging with the hoist assembly 480, when the defined load is below a predetermined discharging threshold of 5%-25% of the maximum load capacity of the motor 483. The load cell and/or current sensor, as described in the foregoing embodiments communicating with the microcontroller 510 in assisting the microcontroller 510 to recognize the need 822 of harnessing the potential energy, are employed in the like process to determine the need to supply the system 400 using the recovered energy or not. Specifically, when the load cell signal or the value of the current supplied from the VFD inverter 495 indicates zero or negligible lifting load, the pump/motor unit 490 is declutched from the hoist assembly 480 by decoupling an electro-magnetic clutch 499, which is used to operationally interfacing the pump/motor unit 490 to the hoisting assembly 480 in some of the preferred embodiments.

Optionally, the displacement of the pump/motor unit 490 is adjusted to zero adaptably turning the pump/motor unit 490 into a free-wheeled mode in accordance with other embodiments incorporated with the variable displacement pump/motor unit 490. Through the variable displacement pump/motor unit 490, the present disclosure is able to control the amount of energy to be recovered and released positively correlating and corresponding to the weight of the load carried. Furthermore, the variable displacement pump/motor unit 490 also confers the system 400 the flexibility to charge the accumulator 540 or to release the pressurized oil from the accumulator 540 at a progressive manner or rate. The pump/motor unit 490 can be programmed to increase the displacement from zero to a higher displacement corresponding to the weight of the load gradually placed into the receptacle 433 from floor to floor. Likewise, when the disclosed hoisting system 400 is to stop the charging of accumulator 540 during load lowering or to stop the release of the recovered energy from the accumulator 540 during load lifting, the displacement of the hydraulic pump/motor unit 490 can be gradually decreased from its maximum value to zero before it is completely cut off from the hoisting system 400. The progressive transition of the displacement is done through the implemented algorithm or logic sequences followed by the microcontroller 510. Having gradual changes in the displacement rate or volume, instead of an abrupt one, ascertains switching of the disclosed hoisting system 400 from energy recovery or energy discharge to termination in a seamless fashion freeing the system 400 from any jerking effect or sudden jolt to the hoist assembly 480 or the receptacle 433 attached thereto. The seamless transition warrants better user experience.

In accordance with the more preferred embodiments, the microcontroller 510 also governs safety of the hydraulic circuit 500 by running through a set of safety checks 830 before proceeding with any load lifting or lowering operation as shown in the flowchart of FIG.9. The microcontroller 510 firstly verifies that the pressure in the hydraulic circuit 500 is within the permissible operational range. In the condition where the hydraulic pressure is higher than the acceptable ceiling, the microcontroller 510 will at least halt the operation of the hydraulic circuit 500 for energy recovery or discharge with a warning emitted to the system administrator 832 but leave the operation of the hoisting equipment uninterrupted to lift or lower the receptacle or the load 433. Similar action will be implemented when the microcontroller 510 detects hydraulic pressure below the limit 833; it sends out a warning

signal 834 and at least bans operation of the hydraulic circuit 500 for energy recovery or discharge while the lifting or lowering operation remains normal 837. Preferably, the microcontroller also checks the temperature of the hydraulic fluid 835 that issuance of warning signal 836 and prohibition on the operation of the hydraulic circuit 500 will be correspondingly carried out.

According to another aspect, the present disclosure also includes a hydraulic circuit 500 capable of being operably joined to a hoisting system 400, which comprises a receptacle 433 of a defined load and a hoisting assembly 480 having an electric motor powered by a primary power source 496 through a frequency conversion unit 495 to move the defined load between a first position and a second position of greater gravitational potential energy than the first position, for recovering gravitational potential energy and discharging the recovered energy back to the hoisting system 400 for moving the defined load towards the second position. The hydraulic circuit 500 essentially comprises, as depicted in the FIG.6-8, an energy converting unit 490 detachably engaged to the hoist assembly 480 to recover gravitational potential energy from the defined load upon moving the defined load from the second position to the first position; a power storage member 540 connecting the energy converting unit 490 to store the recovered potential energy and being fashioned to discharge the stored energy, in the form of fluid power, to at least partially power the hoist assembly 480 to move the defined load from the first position to the second position, through the energy converting unit 490, in addition to the primary power source 496; and a microcontroller 510 in communication with the power storage member 540 to initiate the recovery or discharge of the energy. Preferably, the microcontroller 510 activates the energy converting unit 490 to recover the gravitational potential energy from the defined load moving towards the first position from the second position when the defined load is equal to and/or above a predetermined charging threshold. Furthermore, the microcontroller 510 may be arranged in constant communication with the controller 700 of other lifting equipment.

Accordingly, the hoisting assembly 480 operable with the disclosed hydraulic circuit 500 may comprise a winch or electric motor 483, a drum 484 and a gear mechanism 488 connecting the motor 483 to the drum 484 in such way that operation of the motor 483 drives the drum 484 into a rotational movement or angular displacement. The drum 484 is

preferably wound with a cable 486 having one end secured to the receptacle 433 and another end affixed to the drum 484. The gear mechanism 488 interfacing the winch motor 483 to the cable drum 484 turns the kinetic energy produced from the motor 483 into a force to drive the receptacle 433 to move toward to or away from the second position by respectively winding the cable 486 onto the drum 484 or unwinding the cable 486 from the drum 484 at a controlled speed. Further, the operable hoisting assembly 480 activates or powers operation of the motor 483 via a primary power source 496. The primary power source 496 can be any one or combination of electrical power grid and genset fueled by diesel. The total power output of the operable hoist assembly 480, rotational speed of the drum 484 and/or the movement speed of the connecting receptacle 433 corresponds to the frequency, phase and/or magnitude of the electric current supplied from the VFD inverter 495 to the motor 483. The power output is positively correlated to the defined load and the controlled speed.

The disclosed hydraulic circuit 500 preferably has the energy converting unit 490 detachably engaged to the hoist assembly 480 to recover gravitational potential energy from the receptacle 433 upon moving the receptacle 433 from the second position to the first position. The energy converting unit 490 of the disclosed hydraulic circuit 500 can detachably mate with one or more elements in the hoist assembly 480 to materialize the potential energy recovery. The energy converting unit 490 of the disclosed hydraulic circuit 500 can be detachably engaged to the interface between the gear mechanism 488 and the drum 484, interface between the gear mechanism 488 and the motor 483, the motor 483 directly and/or to the cable drum 484 through a clutch box 499. For operably linked hoisting system with the electric motor replaced by a hydraulic motor, the hydraulic pump/motor unit 490 can be connected to and actuated by the winch motor 483, drum 484 and/or gear mechanism 488 of the hoist assembly 480 directly or indirectly to recover the potential energy. Accordingly, the power storage member 540 connects, preferably in fluid communication, to the energy converting unit 490 for storing the recovered potential energy and it is fashioned to discharge the stored energy to at least partially power the hoist assembly 480 to move the defined load from the first position to the second position, through the energy converting unit 490, in addition to the major power supplied by the primary power source 496. To deliver the recovered energy from the power storage member 540 to the hoist assembly 480 for load lifting, the hydraulic pump/motor unit 490 of the disclosed hydraulic circuit 500 is connected

to and capable of driving the winch motor 483, drum 484 and/or gear mechanism 488 of the hoist assembly 480 to at least partially power the hoist assembly 480 to move the receptacle 433 from the first position to the second position as aforementioned.

5 Pursuant to the preferred embodiments, the recovered potential energy is stored to or discharged from the power storage member 540 in the form of fluid power that the fluid accumulator 540 and the hydraulic pump/motor unit 490 are interconnected through the disclosed hydraulic circuit 500 containing pressurized hydraulic fluid. One embodiment of the disclosed hydraulic circuit 500s is illustrated in FIG.6 to 8. Preferably, the hydraulic
 10 circuit 500 of several embodiments of the disclosed system 400 comprises the pump/motor unit 490, a fluid accumulator 540, a fluid reservoir 550, a pressure relief valve 544, a first operation valve or launch/charge valve 513, a second operation valve or cooling valve 516, a third valve or isolation valve 519 and hoses forming the fluid path joining all mentioned parts together. More preferably, the pump/motor unit 490 of the disclosed hydraulic circuit 500 is a
 15 variable displacement pump/motor unit 490. By adjusting the displacement of the pump/motor unit 490 to zero, the hydraulic circuit 500 can figuratively disengage the pump/motor unit 490 from the hoist assembly 480 when energy recovery or discharge is impractical. Employment of the variable displacement pump/motor unit 490 also facilitates management of the microcontroller 510 over the disclosed hydraulic circuit 500 especially
 20 regarding the extent of the energy stored to and released from the power storage member 540.

Preferably, the recovered potential energy is stored to or discharged from the power storage member 540 in the form of fluid power that the fluid accumulator 540 and the hydraulic pump/motor unit 490 are interconnected through the disclosed hydraulic circuit 500
 25 containing pressurized hydraulic fluid. More specifically, in some embodiments, the hydraulic circuit 500 has a first operation valve 513 disposed in the hydraulic circuit 500 between the fluid accumulator 540 and the pump/motor unit 490; and a second operation valve 516, located in the hydraulic circuit 500 between the pump/motor unit 490 and the fluid reservoir 550, with a filtering means 525 and a cooler 524 positioned downstream in relation
 30 to the second operation valve 516. More preferably, the first operation valve 513 directs the pressurized hydraulic fluid from the fluid accumulator 540 to the pump/motor unit 490 to at least partially power the hoist assembly 480 to move the defined load from the first position

to the second position, and the second operation valve 516 channels the discharged pressurized hydraulic fluid from the pump/motor unit 490 to pass through the filtering means 525 and the cooler 524 prior to collecting the discharged hydraulic fluid in the fluid reservoir 550.

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In one or more further embodiments, the hydraulic has a first operation valve 513 disposed in the hydraulic circuit 500 between the fluid accumulator 540 and the pump/motor unit 490; and a third operation valve 519, located in the hydraulic circuit 500 between the pump/motor unit 490 and the fluid reservoir 550. The third operation valve 519 channels the hydraulic
 10 fluid collected at the fluid reservoir 550 to the pump/motor unit 490 to be pressurized for storing the recovered potential energy, and the first operation valve 513 directs the pressurized hydraulic fluid into the fluid accumulator 540 for storing the pressurized hydraulic fluid.

15 With further reference to FIG.6 to 8, the fluid path is composed of a first route and a second route. The first route preferably guides the pressurized fluid discharged from the fluid accumulator 540 through the first operation valve 513, the pump/motor unit 490, the second operation valve 516 and finally has the depressurized fluid retained in the fluid reservoir 550 as depressurized fluid; the second route directs the depressurized fluid from the fluid
 20 reservoir 550 to the pump/motor unit 490 to be compressed and stored in the fluid accumulator 540 as pressurized fluid through the third 519, second 516 and first operation valves 513. More specifically, the first operation valve 513 is installed in the hydraulic circuit 500 or fluid path at a location between the fluid accumulator 540 and the pump/ motor unit 490; and the second operation valve 516 is located in the hydraulic circuit 500 between the
 25 pump/motor unit 490 and the fluid reservoir 550. Optionally, the disclosed hydraulic circuit 500 incorporates a filtering means 525 and/or a cooler 524 at a location downstream in relation to the second operation valve 516 that the discharged pressurized hydraulic fluid is treated before being stored in the fluid reservoir 550. Furthermore, the third operation valve 519 is preferably located in the hydraulic circuit 500 between the pump/motor unit 490 and
 30 the fluid reservoir 550 that the disclosed hydraulic circuit 500 routes the depressurized hydraulic fluid from the reservoir 550 to the pump/motor unit 490 passing through the third 519 and second operation valves 516.

The disclosed hydraulic circuit 500 of several embodiments is configured to recover potential energy and further charge the accumulator 540 with the recovered power when the hoisting assembly 480 moves the load towards the first position. The gravitational potential energy is firstly converted to kinetic energy at the motor 483 of the hoist assembly 480, which successively actuates the pump/motor unit 490 to draw the hydraulic fluid from the reservoir 550 to the accumulator 540 pressurizing the hydraulic fluid along the process to convert and store the kinetic energy into hydraulic power. More particularly, the disclosed circuit 500, under command of the microcontroller 510, activates pump function of the pump/motor unit 490 while have both third 519 and second operation valves 516 switched to allow flowing of the hydraulic fluid from the hydraulic reservoir 550 to the pump/motor unit 490. The hydraulic pump/motor unit 490 subsequently pressurized the flowing hydraulic fluid and charges the pressurized fluid into the fluid accumulator 540 or power storage member 540 to store the recovered energy in the form of hydraulic power. Preferably, the recovered energy is stored at the fluid accumulator 540 as pressurized hydraulic fluid and the stored energy is discharged by channeling the pressurized hydraulic fluid to the hydraulic circuit 500 to transfer the recovered energy to the pump/motor unit 490.

In several embodiments, the disclosed hydraulic circuit 500 stop harvesting the gravitational potential energy once the microcontroller 510 detects or senses that the hydraulic pressure in the accumulator 540 has reached a pressure threshold. Preferably, the disclosed hydraulic circuit 500 has one or more fluid pressure sensor 545 connected to the fluid circuit 500 to monitor and/or sample reading about the fluid pressure in the fluid accumulator 540 and/or the fluid circuit 500. More specifically, the microcontroller 510 ends the charging process in the hydraulic circuit 500 by having the pump/motor unit 490 disengaged or declutched from the hoist assembly 480. The disengagement can be realized by adjusting the pump/motor unit's displacement to zero so that the pump/motor unit 490 does not produce high pressure oil at all but merely rotates freely by the motor 483. Alternatively, the hoisting system 400 incorporated with the disclosed circuit 500 can functionally install an electro-magnetic clutch 499 joining the hoist assembly 480 and the hydraulic pump/motor unit 490, the microcontroller 510 dissociates the pump/motor unit 490 from the hoist assembly by way of through declutching the electro-magnetic clutch 499. In addition to that, the disclosed

hydraulic circuit 500 may further comprise a pressure relief valve 544, in some embodiments, being regulated by the microcontroller 510 and fashioned to discharge the pressurized hydraulic fluid from the fluid accumulator 540 under instruction of the microcontroller 510. The pressure relief valve 544 may be arranged to automatically drain off the pressurized fluid
5 once the pressure reading surpasses a given limit. The pressure relief valve 544 is catered to ensure pressurized fluid is capped within a safe operating pressure limit.

For discharging or launching of the stored energy as in FIG.8, the disclosed hydraulic circuit 500 has the first operation valve 513 directed the pressurized hydraulic fluid from the fluid
10 accumulator 540 to the pump/motor unit 490 to at least partially power the hoist assembly 480 to move the receptacle 433 from the first position to the second position, and the second operation valve 516 channels the discharged pressurized hydraulic fluid from the pump/motor unit 490 to pass through the filtering means 525 and the cooler 524 prior to collecting the discharged hydraulic fluid in the fluid reservoir 550. Further referring to FIG.8, the disclosed
15 hydraulic circuit 500 has the positions of the first, second and third valves switched to allow the pressurized fluid, from the fluid accumulator 540, to drive the hydraulic pump/motor unit 490. The pump/motor unit 490 acts as a motor propelled by the passing pressurized hydraulic fluid to drive the hoist assembly 480 to move or pull the load upward in addition to the power drained from the primary power source 496. With the aid of the recycled or recovered energy,
20 the disclosed hydraulic circuit 500 significantly reduces initial power levied against the primary power source 496 in the operable hoisting system 400. The disclosed hydraulic circuit 500 allows the operably linked hoisting system 400 to combine the recovered energy and the supplied energy of the primary power source 496 in meeting the power consumption peak at the beginning stage of the lifting action. Following release of the recovered energy to
25 the hydraulic pump/motor unit 490, the hydraulic fluid exits thereof as depressurized hydraulic fluid then being channeled through the second operation valve 516 and the downstream positioned cooler 524 and filtering means 525 to be eventually kept in the fluid reservoir 550. In other embodiments, the microcontroller 510 prohibits the stored energy from being discharged to power the hoist assembly 480 to drive the defined load to the
30 second position by detaching the energy converting unit 490 from engaging the hoist assembly 480 when the defined load is below a predetermined discharging threshold.

Preferably, in few embodiments, the disclosed hydraulic circuit 500 comprises a sensor (not shown), more preferably a load cell sensor, in communication with the hoist assembly 480 for substantially defining the load based upon the tension applied onto the hoist assembly 480 by the weight of the load and relaying the load defined in the form of digital signal to the microcontroller 510. To achieve similar object to define the load, the disclosed hydraulic of further embodiments can possess a current sensor (not shown) in communication with the frequency conversion unit 495 and/or the electric motor 483 for substantially defining load based upon the frequency and/or magnitude of the electrical current supplied to electrical motor 483 from the frequency conversion unit 495 and relaying the load defined in the form of digital signal to the microcontroller 510.

It is important to note that the predetermined charging threshold and the predetermined discharging threshold can be of two different values implemented in the present disclosure for the microcontroller 510 to compute and decide the corresponding actions of recovering the potential energy from or discharging the recovered energy to the hoisting system 400. In some embodiments, there may be several values to be referred by the microcontroller 510 as the predetermined charging or discharging threshold factoring in the condition of the overall system 400. In some embodiments, the hydraulic circuit 500 or hoisting system 400 may further exploit the selectable and applicable thresholds as a leverage to regulate charging or discharging of the fluid accumulator 540. For instance, the microcontroller 510 may adaptably switch the predetermined discharging threshold from a lower or normal value to an extremely or impractically high value when the recovered energy stored in the fluid accumulator 540 is very low and it holds no usable energy at all to assist in powering the load lifting. By referring the predetermined discharging threshold to an impractically high value, the microcontroller 510 will not trigger the energy discharging process that it can virtually suppress an unfavorable charging or discharging action without resorting to physically declutching or disengaging the pump/motor unit 490 from the hoist assembly 480.

It is to be understood that the present invention may be embodied in other specific forms and is not limited to the sole embodiment described above. However modification and equivalents of the disclosed concepts such as those which readily occur to one skilled in the art are intended to be included within the scope of the claims which are appended thereto.

Claims

1. A hoisting system comprising
 - a receptacle of a defined load and movable between a first position and a second position,
 5 which is a position having greater gravitational potential energy than the first position;
 - a hoist assembly comprising an winch motor, a drum wound with a cable having one end
 secured to the receptacle and another end affixed to the drum, and a gear mechanism
 interfacing the winch motor to the cable drum for driving the receptacle to move toward
 to or away from the second position by respectively winding the cable onto the drum or
 10 unwinding the cable from the drum at a controlled speed;
 - a primary power source for supplying an electrical current to the winch motor to drive
 the drum and move the receptacle of the defined load;
 - an energy converting unit detachably engaged to the hoist assembly to recover
 gravitational potential energy from the defined load upon moving the defined load from
 15 the second position to the first position;
 - a power storage member connecting the energy converting unit to store the recovered
 potential energy and being fashioned to discharge the stored energy to at least partially
 power the hoist assembly to move the defined load from the first position to the second
 position, through the energy converting unit, in addition to the primary power source;
 - 20 a frequency conversion unit configured to vary the frequency and/or magnitude of the
 electrical current supplied to the winch motor thereby regulating power output of the
 winch motor in moving the defined load, the power output is positively correlated to the
 defined load and the controlled speed; and
 - a microcontroller in communication with the hoist assembly and the power storage
 25 member to initiate the recovery or discharge of the energy, wherein the microcontroller
 activates the energy converting unit to recover the gravitational potential energy from the
 defined load moving towards the first position from the second position when the defined
 load is equal to and/or above a predetermined charging threshold.
- 30 2. The system of claim 1, wherein the recovered potential energy is stored to or discharged
 from the power storage member in the form of fluid power.

3. The system of claim 2, wherein the power storage member is a fluid accumulator and the energy converting unit is a hydraulic pump/motor unit that the fluid accumulator and the hydraulic pump/motor unit are interconnected through a hydraulic circuit containing pressurized hydraulic fluid.

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4. The system of claim 3, wherein the recovered energy is stored at the fluid accumulator as a pressurized hydraulic fluid and the stored energy is discharged to the hoisting assembly by channeling the pressurized hydraulic fluid to the hydraulic pump/motor unit through the hydraulic circuit to drive the hoisting assembly.

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5. The system of claim 4, further comprising a fluid reservoir connected to the hydraulic circuit for collecting the hydraulic fluid channeled out from the fluid accumulator.

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6. The system of claim 1, further comprising a sensor in communication with the hoist assembly for substantially defining the load based upon the power output of the hoist assembly and to relay the load defined in the form of digital signal to the microcontroller.

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7. The system of claim 1, further comprising a sensor in communication with the frequency conversion unit and/or the winch motor for substantially defining load based upon the frequency and/or magnitude of the electrical current supplied to the winch motor from the frequency conversion unit and to relay the load defined in the form of digital signal to the microcontroller.

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8. The system of claim 1, wherein the microcontroller prohibits the stored energy from being discharged to power the winch motor to drive the defined load to the second position by detaching the energy converting unit from engaging the hoist assembly when the defined load is below the predetermined discharging threshold.

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9. The system of claim 1, wherein the microcontroller samples the electrical current supplied to the winch motor from the frequency conversion unit for defining the load and the microcontroller activates the energy converting unit to recover the gravitational potential energy from the defined load moving towards the first position from the second

position when the defined load is equal to and/or above the predetermined charging threshold.

10. The system of claim 5, wherein the hydraulic circuit further comprises:

- 5 a first operation valve disposed in the hydraulic circuit between the fluid accumulator and the pump/ motor unit; and
- a second operation valve, located in the hydraulic circuit between the pump/ motor unit and the fluid reservoir, with a filtering means and a cooler positioned downstream in relation to the second operation valve, wherein the first operation valve directs the
- 10 pressurized hydraulic fluid from the fluid accumulator to the pump/motor unit to at least partially power the hoist assembly to move the defined load from the first position to the second position, and the second operation valve channels the discharged pressurized hydraulic fluid from the pump/motor unit to pass through the filtering means and the cooler prior to collecting the discharged hydraulic fluid in the fluid reservoir.

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11. The system of claim 5, wherein the hydraulic circuit further comprises:

- a first operation valve disposed in the hydraulic circuit between the fluid accumulator and the pump/ motor unit; and
- a third operation valve, located in the hydraulic circuit between the pump/ motor unit and
- 20 the fluid reservoir, wherein the third operation valve channels the hydraulic fluid collected at the fluid reservoir to the pump/motor unit to be pressurized for storing the recovered potential energy, and the first operation valve directs the pressurized hydraulic fluid into the fluid accumulator for storing the pressurized hydraulic fluid.

- 25 12. The system of claim 3, wherein the hydraulic pump/motor unit is connected to and actuated by the winch motor, drum and/or gear mechanism of the hoist assembly to recover the potential energy.

13. The system of claim 3, wherein the hydraulic pump/motor unit is connected to and
- 30 capable of driving the winch motor, drum and/or gear mechanism of the hoist assembly to at least partially power the hoist assembly to move the defined load from the first position to the second position.

14. The system of claim 3, further comprising a fluid pressure sensor connected to the hydraulic circuit to monitor and/or sample reading on fluid pressure in the fluid accumulator and/or in the fluid circuit.

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15. The system of claim 14, wherein the hydraulic circuit further comprises a pressure relief valve being regulated by the microcontroller and fashioned to discharge the pressurized hydraulic fluid from the fluid accumulator under instruction of the microcontroller.

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16. A hydraulic circuit capable of being operably joined to a hoisting system, which comprises a receptacle of a defined load and a hoisting assembly having an electric motor powered by a primary power source through a frequency conversion unit to move the defined load between a first position and a second position of greater gravitational potential energy than the first position, for recovering gravitational potential energy and discharging the recovered energy back to the hoisting system for moving the defined load towards the second position, the hydraulic circuit comprising an energy converting unit detachably engaged to the hoist assembly to recover gravitational potential energy from the defined load upon moving the defined load from the second position to the first position;

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a power storage member connecting the energy converting unit to store the recovered potential energy and being fashioned to discharge the stored energy, in the form of fluid power, to at least partially power the hoist assembly to move the defined load from the first position to the second position, through the energy converting unit, in addition to the primary power source; and

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a microcontroller in communication with the power storage member to initiate the recovery or discharge of the energy, wherein the microcontroller activates the energy converting unit to recover the gravitational potential energy from the defined load moving towards the first position from the second position when the defined load is equal to and/or above a predetermined charging threshold.

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17. The hydraulic circuit of claim 16, wherein the power storage member is a fluid accumulator and the energy converting unit is a hydraulic pump/motor unit that the fluid

accumulator and the hydraulic pump/motor unit are interconnected through pressurized hydraulic fluid flowing through the hydraulic circuit.

- 5 18. The hydraulic circuit of claim 17, further comprising a fluid reservoir connected to the hydraulic circuit for collecting the hydraulic fluid channeled out from the fluid accumulator.
- 10 19. The hydraulic circuit of claim 16, further comprising a sensor in communication with the hoist assembly for substantially defining the load based upon the power output of the hoist assembly and relaying the load defined in the form of digital signal to the microcontroller.
- 15 20. The hydraulic circuit of claim 16, further comprising a sensor in communication with the frequency conversion unit for substantially defining load based upon the magnitude of the electrical current supplied to the electric motor from the frequency conversion unit and relaying the load defined in the form of digital signal to the microcontroller.
- 20 21. The hydraulic circuit of claim 18, further comprising
a first operation valve disposed in the hydraulic circuit between the fluid accumulator and the pump/ motor unit; and
a second operation valve, located in the hydraulic circuit between the pump/ motor unit and the fluid reservoir, with a filtering means and a cooler positioned downstream in relation to the second operation valve, wherein the first operation valve directs the pressurized hydraulic fluid from the fluid accumulator to the pump/motor unit to at least
25 partially power the hoist assembly to move the defined load from the first position to the second position, and the second operation valve channels the discharged pressurized hydraulic fluid from the pump/motor unit to pass through the filtering means and the cooler prior to collecting the discharged hydraulic fluid in the fluid reservoir.
- 30 22. The hydraulic circuit of claim 18, further comprising
a first operation valve disposed in the hydraulic circuit between the fluid accumulator and the pump/ motor unit; and

a third operation valve, located in the hydraulic circuit between the pump/ motor unit and the fluid reservoir, wherein the third operation valve channels the hydraulic fluid collected at the fluid reservoir to the pump/motor unit to be pressurized for storing the recovered potential energy, and the first operation valve directs the pressurized hydraulic fluid into the fluid accumulator for storing the pressurized hydraulic fluid.

23. The hydraulic circuit of claim 18, wherein the microcontroller prohibits the stored energy from being discharged to power the hoist assembly to drive the defined load to the second position by detaching the energy converting unit from engaging the hoist assembly when the defined load is below a predetermined discharging threshold.