

Active Compensation in an Elevator System

The invention relates to an active compensation unit for a counterweight system in an elevator system. The invention also relates to a method of providing active
5 compensation in a counterweight system in an elevator system using an active compensation unit.

In general, an elevator system, such as a traction elevator, consists of the following main system components:

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- The elevator, including the elevator cage, used for transportation of passengers and/or other loads. The elevator will invariably have a design rated load which is not to be exceeded.
- The traction machine to provide the traction for moving the elevator.
- 15 • The counterweight (or counterweight system) to counterbalance the mass of the elevator as it moves up and down. The counterweight system is provided to reduce the duty load on the traction machine.
- A compensating element such as a rope and/or a chain, sometimes considered an optional element.

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A conventional elevator system 100 is illustrated in Figure 1. System 100 comprises, principally, of an elevator (cage etc) 102 installed in an elevator riser 104 (which may be considered an elevator shaft inside a building or, say, an elevator riser for an elevator such as those used for lifts on, for example, an external façade of a building,
25 or in an open atrium internal to a building as commonly seen in large hotels and the like). A traction machine 106 located in a machine room 108 provides the drive power for the raising and lowering of the elevator 102 within elevator riser 104. A roping system 110 connects the components of the elevator system 100 including the counterweight system 112 which, in the conventional elevator system 100 of

Figure 1, comprises a counterweight 114 and the compensating element (rope or chain) 116.

The counterweight is typically sized so that the traction machine consumes a maximum of 50% of the electrical power required for operation of the system with the elevator at rated load and designed to carry the combined mass of an elevator (including the cabinet, platform and any associated components) plus an additional 50% of the elevator's rated load.

10 So, if:

E = the mass of the elevator and components (a fixed mass);

L = the mass of passengers and/or load of the elevator (a variable load from 0% to 100% of the rated load of the elevator); and

W = the mass of the counterweight system; then

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$$W = [E + (50\% \times L)]$$

During operation, the traction machine 106 of Figure 1 will typically exhibit machine currents of the type characterised in Figure 2 which illustrates current-load curves showing variations in elevator traction machine current with elevator loading profile. (For the sake of simplicity, Figure 2 illustrates only machine current magnitude and does not consider whether the machine is acting as a motor or as a generator/regenerator.) Thus, the "X" axis 202 of Figure 2 illustrates the loading of the elevator as a percentage of the rated load. The "Y" axis 204 of Figure 2 illustrates the magnitude of the machine current. Curve 206 illustrates the variation in machine current as the elevator moves up in the elevator riser as the percentage loading in the elevator varies. Curve 208 illustrates the variation in machine current as the elevator moves down in the elevator riser as the percentage loading in the elevator varies.

It is to be noted that in the current minima for each of curves 206, 208 occurs at or near 50% of the elevator rated loading, with variations from 50% loading being accounted for by the nature and size of the inherent system losses.

- 5 Assuming negligible system losses, and the situation where the counterweight 114 is set to 50% of the elevator rated load, during the up direction of travel of the elevator cage, the traction machine 106 functions as a generator between 0% and 49% of the elevator rated load. When the elevator is loaded at between 51% and 100% of the elevator rated load, traction machine 106 operates as a motor when the elevator
10 102 is being raised in the elevator riser 104.

- For the down direction of travel of the elevator cage 102, the reverse situation occurs. That is, when the elevator is loaded at between 0% and 49% of the elevator rated load, traction machine 106 operates as a motor, and when the elevator is
15 loaded at between 51% and 100%, traction machine 106 operates as a generator.

No – or negligible – electrical power is either generated or consumed by traction machine 106 when the loading on elevator 102 is 50% of the rated load.

- 20 Hence, significant power is absorbed or generated by electrical machine 106 when the loading on elevator 102 departs significantly from 50% of the rated load. This is undesirable whether electrical power is being absorbed or generated. Obviously, when electrical power is being absorbed this is costly. When electrical power is being generated/regenerated by traction machine 106, steps have to be taken to handle
25 that. Either complex power electronics must be provided at significant capital cost to regulate the power supply back to the electrical grid (and this has a further undesirable side-effect of generating electrical harmonics in the system) or, say, one or more braking resistors must be provided to allow the electrical power generated to be dissipated as heat (but this also requires both a costly capital investment in the
30 provision of the braking resistor, additional space for the installation of the braking

resistor, and the heat generated therefrom must also be managed, such as by providing a large amount of space for locating the braking resistor or by adding cooling of the area in which it is installed).

- 5 Table 1 below shows the various loading conditions for both the motoring and generating phase of operation of traction machine 106 illustrating the desirability of the operating conditions from a user's perspective.

Loading	Up direction	Down direction	Elevator Mass	Counterweight Mass (Fixed Mass)
0%	Acceptable	Poor	E	$W = E + (50\% \times L)$
25%	Acceptable	Poor	$E + (25\% \times L)$	$W = E + (50\% \times L)$
50%	Good	Good	$E + (50\% \times L)$	$W = E + (50\% \times L)$
75%	Poor	Acceptable	$E + (75\% \times L)$	$W = E + (50\% \times L)$
100%	Poor	Acceptable	$E + (100\% \times L)$	$W = E + (50\% \times L)$

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TABLE 1

The invention is defined in the independent claims. Some optional features of the invention are defined in the dependent claims.

- 15 Implementation of the techniques disclosed herein may provide significant technical benefits. For instance, by varying an amount of weight of a variable weight unit coupled in an elevator counterweight system in dependence of an operating condition of the elevator system (for example, loading on the elevator), the effective weight in the counterweight system is varied to avoid the requirement for excessive
- 20 power consumption or significant power (re)generation. Thus, by actively compensating the counterweight system in accordance with an elevator operating condition (such as elevator travel direction, and/or loading condition) operation of the elevator's traction machine can be tuned to operate at its optimum level.

Additionally, the traction machine can be tuned to operate as a generator across a greater range of loading conditions as long as the active compensation unit is set for the total counterweight loading to be greater than the loading on the elevator during the up direction of travel and lower than the loading of the elevator in the down direction of travel, thereby reaping the substantial benefit of being able to generate electricity for use elsewhere. Just two examples of where the additional power may be used are in the power supply for the lift controller and/or for control of the active compensation unit described below. In such circumstances, the traction machine may be operated at beyond synchronous speed as a generator. Additionally or alternatively, operating the traction machine and the elevator system at or close to optimum conditions may obviate the requirement for installation of any devices required to manage any current which is being re-generated.

Implementation of the techniques disclosed herein may lead to a significant saving in electrical energy. It is estimated that the additional capital cost of an active compensation unit in accordance with the techniques disclosed herein might be recovered from the energy cost savings within a relatively short space of time from the date of installation.

Additionally, it may be possible for the conventional moving counterweight (counterweight 114 in Figure 1) and/or the compensating element (compensating element 116 in Figure 1) to be dispensed when implementing the techniques disclosed herein. At the very least, it may be possible for the amount of weight in the conventional counterweight to be reduced. When, for example, an active compensation unit as disclosed herein is retrofitted to an existing elevator system, the weights no longer necessary in the conventional moving counterweight can be redeployed at a different installation.

The invention will now be described, by way of example only, and with reference to the accompanying drawings in which:

Figure 1 is a schematic block diagram illustrating a conventional elevator system;

Figure 2 is a current-load curve illustrating variations in current of the elevator traction machine of Figure 1 with elevator loading profile;

Figure 3 is an arrangement diagram illustrating an active compensation unit for a counterweight system in an elevator system;

Figure 4 is a schematic block diagram illustrating the active compensation unit of Figure 3 in operation in a first configuration;

Figure 5 is a schematic block diagram illustrating the active compensation unit of Figure 3 in operation in a second configuration; and

Figure 6 is a current-load curve illustrating elevator traction machine current with elevator loading profile when using the active compensation unit of Figure 3.

Figure 3 is an arrangement diagram illustrating an active compensation unit 300 for a counterweight system in an elevator system. The arrangement of Figure 3 may be considered conceptual only, and exemplary scenarios for actual installations in elevator systems are discussed in more detail below with reference to Figure 4 and Figure 5.

Active compensation unit 300 will typically be installed in an elevator pit, omitted from the figure for the sake of clarity. In the example of Figure 3, active compensation unit 300 is mechanically coupled to a counterweight element 302, generally equivalent to the counterweight element 114 of Figure 1, subject to an optional modification as described in detail below.

Active compensation unit 300 is mechanically coupled with counterweight element 302 through mechanical linkage 304 which may be, for example, a rope such as those used in the hoisting ropes 110 of Figure 1 through pulley 306. In the example of Figure 3, pulley 306 is mounted through pulley mount 308 mounted on active compensation unit 300. Active compensation unit 300 is mounted on mounting rails 310 through guide shoes 312 which, in the example of Figure 3 are free to move

within the mounting rails 310. It is omitted for the sake of clarity from Figure 3, but active compensation unit is suspended above it floor (also omitted for the sake of clarity) level within the mounting rails 310, so that its weight is borne in the counterweight system through mechanical linkage 304 through pulley 306. The manner in which this is controlled and the manner in which a distance between an underside of the active compensation unit 300 and the floor of the elevator pit is described in greater detail with reference to Figures 4 and 5.

Active compensation unit 300 can be considered to comprise of two principal component parts: an interfacing unit 314, and a compensating unit 316. In the example of Figure 3, interfacing unit 314 comprises a control system (not shown) and controls the variation of weights in variable weight unit 317 of compensating unit 316. Variable weight unit 317 comprises principally of weight mounting structure 318, pickup device(s) 320 and one or more weight 322. It is also not shown in Figure 3, but each of the weights 322, prior to being "picked up" as is described below, are disposed on the floor of, or another surface in, the elevator pit. Thus, in at least one arrangement, active compensation unit 300 comprises a housing with an opening in an underside thereof for the weights 322 to move freely from the floor of the elevator pit to be picked up by and suspended in active compensation unit 300. It will also be appreciated that other arrangements are possible, such as a completely open frame. However some sort of housing, or at least shelter may be advantageous in order to prevent any falling debris within the elevator shaft fouling the working of active compensation unit 300.

Interfacing unit 314 controls the variation of weights in variable weight unit 317 in dependence of an input signal at input 324 which provides an indication of an operating condition of the elevator system, discussed in detail below.

Counterweight 302 is mounted on guide rails 326 and comprises a frame 328 movably mounted on guide rails 326 through guide shoes 330. The counterweight

302 is free to move up and down in directions 331 to counterbalance the moving of an elevator cage, not shown in Figure 3. The weight of counterweight 302 is made up of individual weight blocks 332 disposed within frame 328. In the Example of Figure 3, an optional modification from a conventional counterweight is provided in that counterweight 302 is a reduced-weight counterweight as a number of individual weight blocks 332 have been removed from frame 328 as depicted by empty space 334. The reasons for this implementation will be described below. Alternatively, and as mentioned above, a reduced-size frame may be provided instead.

It is to be noted, optionally, that the conventional-type counterweight 302 may be removed entirely from the elevator system, and the counterbalancing of the elevator cage may be catered for completely with active compensation unit 300. In which case, the counterweight system of the elevator system comprises solely of active compensation unit 300 (or, the variable weight unit 317 of active compensation unit 300) coupled directly through hoisting ropes with a traction machine, also omitted from Figure 3. In such a scenario, the traction elevator may be operated more like a hoist.

In operation, a signal indicating an operating condition of the elevator system is received at input 324 of interfacing unit 314 of active compensation unit 300. The input signal may be representative of a number of operating conditions of the elevator system. For instance, the input signal may give an indication of the loading on the elevator. As is known, elevator cages are provided with loading sensors (overload sensors and/or capacity load sensors) which measure the loading on the elevator cage. Thus, the techniques disclosed herein may provide for a new use of the signal from the loading sensor in order to vary the weight connected or coupled in the counterweight system by varying a weight of the variable weight unit 317 of active compensation unit 300. Additionally or alternatively, the input signal may be representative of, say, traction machine current which, in turn, may provide an indication of an operating condition of the elevator system, such as the speed and/or

direction of travel of the elevator cage, the loading on the elevator cage, and so on. Additionally or alternatively, the position of the elevator within the elevator riser may be derived from, say, an encoder installed on the traction machine. Thus, this is also a new use of an existing system parameter. In one implementation, the input
5 signal is derived from a current transformer positioned at or near the traction machine which may be used to detect machine current magnitude and direction (i.e., whether the machine is operating as a motor or as a generator, which can be used in deriving an indication as to the direction of travel).

10 The or another encoder may also be used to derive the elevator speed and/or be used in a determination of the direction of travel of the elevator as well as the position within the elevator riser.

The operating condition of the elevator system that the signal (or signals) received
15 on input (or inputs) 324 may be indicative of one or more of: elevator load; speed of elevator travel; direction of elevator travel; elevator position within an elevator riser; and elevator traction machine electrical current.

Not illustrated in Figure 3, active compensation unit 300 comprises a controller for
20 the processing of the signal received on input 324 and for a determination of whether and/or how the amount of weight of the variable weight unit 317 coupled in the counterweight system is to be varied. The controller may be implemented in a number of ways such as in electrical circuitry, in a programmable logic controller (PLC) and/or software running under control of a microprocessor. In at least one
25 implementation, the controller is installed in the interfacing unit 314.

If the signal received on input 324 indicates that the elevator is rated at a particular percentage of its rated load, say 75%, and if the elevator is to be moved in an upward direction within the elevator riser, the controller determines how much

weight is to be mechanically coupled in the counterweight system. This may also depend on the presence (or otherwise) and weight of counterweight 302.

As noted above, variable weight unit 317 comprises, in the example of Figure 3,
5 frame 318, one or more pickup device 320 and one or more weights 322. Frame 318 comprises a weight mounting structure for mounting of one or more weights 322 thereto. Additionally or alternatively, the weight mounting structure may be any structure capable of having weights mounted to or on, such as a plate with a flat surface for weights to be placed thereon. Weight mounting structure 318 is
10 mechanically coupled in the counterweight system through mechanical linkage 304 as described above. The active compensation unit 300 is suspended through mechanical linkage 304 for any weight in or on active compensation unit 300 – or, more specifically, weight mounting structure 318 – to be mechanically coupled in the counterweight system. In the example of Figure 3, both interfacing unit 314 and
15 compensating unit 316 are mechanically connected as a single unit, and the total weight of active compensating unit 300 is the combined weight of the two units. As described below with reference to Figure 4 and Figure 5, interfacing unit 314 may have different configurations to interface with various elevator system. Hence, mechanical linkage 304 and the controller may be housed here. Compensating Unit
20 300 with pick-up devices 320 are used to pick up the weight(s) 322.

Thus, the variable weight unit 317 comprises a weight 322 (or a plurality of weights 322) and a weight mounting structure 318, the weight mounting structure 318 being arranged to be mechanically coupled in the counterweight system and for mounting
25 of the weight 322. As indicated, the variable weight unit 317 may comprise of a plurality of weights 322 and wherein the weight mounting structure 318 is arranged for mounting for each of the plurality of weights 322.

Active compensation unit 300 varies an amount of weight of the variable weight unit
30 coupled in the counterweight system by mechanically coupling the or each weight

322 on the weight mounting structure/frame 318 under control of the controller. In one or more implementations, this is effected by control of pickup device 320 mechanically coupled to frame 318. One or more pickup devices 320 is arranged to "pickup" a corresponding one or more weights 322 from the elevator pit floor (not
5 illustrated), thereby to mount the or each weight 322 on weight mounting structure/frame 318. In this manner, the or each weight 322 is then mechanically coupled in the counterweight system, varying the weight coupled therein.

In one implementation, pickup devices 320 comprise a series of electromagnets
10 arranged to pick up any or all of the corresponding series of weights 322. The electromagnets may be located in close proximity to the corresponding weights and, when activated, arranged to pick up the weights from the floor (or other surface) thereby loading the weight mounting structure/frame 318 with its weight which is then mechanically coupled in the counterweight system, varying the weight of the
15 counterweight system. Thus, active compensation unit 300 may be arranged to mount the one or more weights 322 of the plurality of weights to the weight mounting structure 318 using a corresponding one or more electromagnets. Electromagnets provide an advantage in requiring minimal maintenance, but once in position require constant powering to maintain mounting of the or each weight 322
20 to weight mounting structure 318.

In another implementation, pickup devices 320 comprise a series of micro motors (e.g. servomotors) mechanically coupled to weight mounting structure/frame 318 and arranged to activate a lead screw or bolt to pick up a weight 322. The weight 322
25 has, in this implementation, an internal threaded bore for engagement with the lead screw or bolt. Thus, the active compensation unit 300 may be arranged to mount the one or more weights 322 of the plurality of weights to the weight mounting structure 318 using a corresponding one or more micro motors, each of which is arranged to engage a weight of 322 using a threaded screw. Micro motors with lead
30 screw design provide for a relatively simple arrangement, offering precise and

smooth operation with the capability of carrying large individual weights. Once in position, no further powering is required to hold the weights mounted on the weight mounting structure.

- 5 Of course it will be appreciated the alternative mechanisms may be provided for the mounting of weights to or on the weight mounting structure 318, depending on the precise characteristics of the weight mounting structure 318.

Thus it will be appreciated that Figure 3 illustrates an active compensation unit 300
10 for a counterweight system in an elevator system, the active compensation unit 300 having a variable weight unit 317, the active compensation unit being arranged to vary an amount of weight of the variable weight unit 317 coupled in the counterweight system in dependence of an operating condition of the elevator system. And it will also be appreciated that this describes a method of providing
15 active compensation for a counterweight system in an elevator system using an active compensation unit 300 having a variable weight unit 317 mechanically coupled in the counterweight system, the method comprising varying an amount of weight of the variable weight unit 317 in dependence of an operating condition of the elevator system.

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In the example of Figure 3, compensating unit 316 comprises a plurality of weights. It will be understood that these weights may be of different values when compared with one another. For example, a set of weights may comprise individual weights 322 which are, respectively, 5%, 10%, 20%, 30% and 40% of the desired design rated
25 load of the elevator system. By selective mounting of these weights on weight mounting structure/frame 318, the amount of weight mechanically coupled in the counterweight system may be varied from 0% to 100% of the elevator rated load in 5% increments.

Of course, other arrangements are possible in order to address specific design considerations.

In another alternative configuration, a set of weights may comprise individual weights 322 which are, respectively, 5%, 10%, 20%, 40% and 80% of the desired maximum weight of the weight 322 of active compensation unit 300. Thus, the amount of weight connected can exceed 100% of the elevator rated load. In another alternative configuration, each of the weights 322 has an identical weight to each other. Thus, and for example, the set of weights may comprise of 10 or 20 identical weights. It may be that electromagnets are particularly suitable as the pickup devices in such a configuration.

Therefore, active compensation unit 300 may comprise a plurality of weights 322 comprising individual weights having different weight values from one another, and the active compensation unit 300 is configured to select which of the individual weights 322 is to be mounted to the weight mounting structure 318 in dependence of the operating condition of the elevator system. The individual weights 322 of the plurality of weights may be selected to be a percentage of a rated capacity of the elevator system.

Table 2 indicates two different configurations for the selection of the individual weights 322. This also indicates how the selection of the individual weights may be selected according to a "binary" system. For instance, in the first and second columns "Multiple Weights Configuration 1", this indicates how a set of weights 322 may be selectively used to vary the weight of the active compensation unit 300 mechanically coupled in the counterweight system from 0% to 115% of the elevator rated load. (Although, of course, other maximum percentage values may be used depending on the combination of weights mounted to the weight mounting structure. Further, different configurations may be employed to vary the weight coupled in the counterweight system to values greater than 115%.) In this example,

the individual weights are, respectively, 80%, 40%, 20%, 10% and 5% of the elevator rated load. By selectively mounting these weights 322 to the weight mounting structure 318 as described above, the weight can be varied in increments of 5% through the range mentioned above, where a "0" indicates that the weight is not mounted to weight mounting structure 318 and the "1" indicates that a weight is mounted to weight mounting structure 318. Thus, for a configuration of "01001" (and reading the binary digits from right to left in order of increasing magnitude in this example), this indicates that the first and fourth weights of the plurality of weights – the 5% weight and the 40% weight – are mounted to the weight mounting structure 318, thereby mechanically coupling 45% of the rated elevator load in the counterweight system.

Multiple Weights Configuration 1: 80% / 40% / 20% / 10% / 5%		Multiple Weights Configuration 2: 40% / 30% / 20% / 10% / 5%	
00000	0%	00000	0%
00001	5%	00001	5%
00010	10%	00010	10%
00011	15%	00011	15%
00100	20%	00100	20%
00101	25%	00101	25%
00110	30%	01000	30%
00111	35%	01001	35%
01000	40%	01010	40%
01001	45%	01011	45%
01010	50%	01100	50%
01011	55%	01101	55%
01100	60%	01110	60%
01101	65%	01111	65%
01110	70%	11000	70%
01111	75%	11001	75%
10000	80%	11010	80%
10001	85%	11011	85%
10010	90%	11100	90%
10011	95%	11101	95%
10100	100%	11110	100%
10101	105%	11111	105%
10110	110%		
10111	115%		

TABLE 2

In the third and fourth columns "Multiple Weights Configuration 2", this indicates how a set of weights 322 may be selectively used to vary the weight of the active compensation unit 300 mechanically coupled in the counterweight system from 0% to 105% of the elevator rated load. In this example, the individual weights are,
5 respectively, 40%, 30%, 20%, 10% and 5% of the elevator rated load. By selectively mounting these weights 322 to the weight mounting structure 318 as described above, the weight can be varied in increments of 5% through the range mentioned above. Thus, for a configuration of "01001" in this arrangement, this also indicates that the first and fourth weights of the plurality of weights – the 5% weight and the
10 30% weight – are mounted to the weight mounting structure 318, thereby mechanically coupling 35% of the rated elevator load in the counterweight system.

It is thought that based on a typical passenger elevator with a rated load of 1000 kg, a weight 322 of 5% of the rated load will represent, say, 50 kg which will be sufficient
15 to provide fine control to compensate for an average passenger but it will be appreciated that different considerations may also be employed.

For elevators with higher rated loads, or requiring more refinement on the percentage of load compensation, more weights may be added. In the "binary"
20 system described above, this may require the addition of one or more binary digits in the control system.

Implementation of the techniques disclosed herein may also allow for the weight of the variable weight unit to be varied while the elevator is in transition from one level
25 to another in the elevator riser. This may be done by monitoring the current of the traction machine. This may allow for compensation of any current spiking arising from having to overcome the effects of inertia when the elevator begins to move.

Active compensation unit 300 may be used in multiple configurations, such as in a 1:1 roping or 2:1 roping system. Furthermore, the active compensation unit may be implemented in new elevator systems or retrofitted to existing elevator systems.

5 Figure 4 illustrates a first exemplary configuration. Thus, the new elevator system 400 of Figure 4 comprises an elevator (cage etc.) 402 installed in an elevator riser 404 (as defined above). A traction machine 406 located in a machine room 408 provides the drive power for the raising and lowering of the elevator 402 within elevator riser 404. A roping system 410 connects the components of the elevator
10 system 400 including the counterweight 412 and the active compensation unit 300, operating generally as described above for the active compensation unit 300 of Figure 3.

Counterweight 412 may be a reduced-weight counterweight as described above
15 because of the inclusion of the active compensation unit 300. Of course, and as also mentioned above, it may be desirable that the counterweight 412 (and any other elements in the counterweight system) is removed entirely, thereby meaning the counterweight system comprises solely of the active compensation unit 300.

20 In the example of Figure 4, active compensation unit 300 also comprises a pulley 414 around which the rope 410 runs to reeling mechanism 418 around which the rope 410 is wound. The reeling mechanism 418 may comprise of a shaft, hub or the like around which the rope 410 is wound, and which may be rotated by, say, an electrical motor to pay out and reel in rope 410.

25 As elevator 402 moves up and down within elevator riser 404, counterweight 412 will move in the opposite direction to counterbalance the load on elevator cage 402. As described above, active compensation unit 300 will typically be installed in a position in the elevator pit where it is suspended at a (substantially) fixed
30 level/height above pit floor level (not shown) and, therefore, the distance between

counterweight 412 and active compensation unit 300 will vary accordingly. Reeling mechanism 414 allows for rope to be paid out and the reeled back in as necessary so that the length of the rope 410 connecting counterweight 412 and active compensating unit 300 may vary, but at the same time maintaining active compensating unit 300 suspended above floor level. The control unit (also not illustrated in Figure 4) receives data relating to the lift operation – any or all of the parameters relating to elevator position, elevator travel speed, elevator direction and the like – and controls the pay out and reel in of rope 410 through reeling mechanism so that this is synchronised with the speed of travel of the elevator to maintain active compensation unit 300 in suspension and mechanically coupled in the counterweight system. Thus, reeling mechanism 414 is mechanically coupled with the weight mounting structure (not shown in Figure 4) so that the weight mounting structure is arranged for suspension in the counterweight system through reeling mechanism 414. (Actually, the entire active compensation unit 300 may be arranged for suspension in the counterweight system, as is the case in this example.) The reeling mechanism may operate in synchronised speed with the elevator's travelling speed, and this may be implemented by this motor-hoisting action in the example of Figure 4.

In a variant, reeling mechanism 418 is a separate passive reeling mechanism attached in the lift system. And pilot rope/element 416 is connected from counterweight 412 around pulley 414 and around a second pulley 420 to elevator cage 402. Thus, as elevator cage 402 moves up and down within the elevator riser, pilot rope/element 416 moves through the pulleys 414, 420 and passive reeling mechanism 418 to maintain active compensating unit 300 in suspension above pit floor level.

This configuration is effective for installation in (retrofitting) any existing elevator installation with minimal changes to the elevator system layout.

In this 1:1 roping configuration, the counterweight 412 may be reduced in mass by as much as 100% of the elevator rated load, and it may also be possible to lower the deadweight from the counterweight system so as to achieve $W = E - (50\% \times L)$ for a slight regeneration when the elevator is moving in the down direction. It also allows
5 for the elimination of any passive compensating element, such as compensating element 116 of the conventional arrangement illustrated in Figure 1.

A second exemplary configuration is illustrated in Figure 5. Thus the new elevator system 500 of Figure 5 comprises an elevator (cage etc) 502 installed in an elevator
10 riser 504. A traction machine 506 located in a machine room 508 provides the drive power for the raising and forwarding of the elevator 502 within elevator riser 504. Roping system 510 connects the components of the elevator 500 from a fixed mounting or anchor point 512 in machine room 508 through elevator pulley 514, traction machine 506, the counterweight 516 with its own pulley 518 pulley(s) 520
15 installed at or near machine room 508 and pulley 522 in interfacing unit 314 of active compensating unit 300 which operates generally as described above for the active compensation unit 300 of Figure 3. Counterweight 516 may be a reduced-weight counterweight as described above because of the inclusion of the active compensation unit 300.

20 As elevator 502 moves up and down within elevator riser 514, counterweight 516 will move in the opposite direction with the rope 510 being fed through counterweight pulley 518 to counterbalance the load on elevator cage 502. As with the arrangement of Figure 5, the distance (along rope 510) between active
25 compensating unit 300 and counterweight 516 will vary with the ropes 510 being fed through the pulley system 518, 520, 522. In the example of Figure 5, the weight mounting structure (not actually shown in Figure 3) is arranged for suspension in the counterweight system with hoisting ropes of the elevator system. In this example, the entire active compensating unit is in suspension, along with the elevator and
30 counterweight. Active compensating unit 300 may be arranged to be heavier than

the counterweight system, so that it can be held substantially stationary in suspension above pit floor level without moving up or down significantly.

Of course, machine roomless designs have become commonplace and it will be appreciated that the active compensation unit illustrated in Figures 3 to 6 and the techniques disclosed herein may also be implemented in such situations.

Figure 6 is a current-load curve 600 illustrating elevator traction machine current with elevator loading profile when using the active compensation unit of Figure 3. This is also indicative of the results which may be achieved in configurations such as those illustrated in Figure 4 and Figure 5. Again, and for the sake of simplicity, Figure 6 illustrates only machine current magnitude and does not consider whether the machine is acting as a motor or as a generator. Thus, the "X" axis 602 of Figure 6 illustrates the loading in the elevator as a percentage of the rated load. The "Y" axis 604 of Figure 6 illustrates the magnitude of the machine current. Line 606 illustrates the fact that the machine current may be kept constant as the elevator moves in the elevator riser as the percentage loading in the elevator varies. Note that the amount of weight connected in the counterweight system may be fine-tuned so that the magnitude of current – whether absorbed or generated – is set to a desired level. Indeed, the amount of weight connected in the counterweight system may be set so that the magnitude of the current is zero, close to zero and therefore of negligible concern.

This fine tuning to optimum operating conditions may allow a higher level of efficiency to be achieved across the entire operating spectrum as illustrated in Table 3.

Loading	Up direction	Down direction	Elevator Mass	Counterweight Mass (Variable Mass)
0%	Good efficiency		E	$W = E$
25%			$E + (25\% \times L)$	$W = E + (25\% \times L)$
50%			$E + (50\% \times L)$	$W = E + (50\% \times L)$
75%			$E + (75\% \times L)$	$W = E + (75\% \times L)$
100%			$E + (100\% \times L)$	$W = E + (100\% \times L)$

TABLE 3

It will be appreciated that a technique for real-time active compensation in a counterweight system of an elevator system may be used to compensate for the ever-changing elevator mass as well as any system losses, by monitoring the real-time variation within the elevator system such as the monitoring of the loading on the elevator cage and/or the traction machine current.

Therefore, it will be appreciated that the number of significant technical benefits may be realised with implementation of the techniques disclosed herein. These include, but are not necessarily limit to, the following:

- A reduction, perhaps a significant reduction, in traction machine absorbed power.
- A reduction in the mass of the conventional counterweight element, therefore with the potential to reduce the counterweight frame size, the guide rail size and so forth. Indeed, as set out above, it may be possible to remove the conventional counterweight element altogether.
- It may be possible to remove the compensating elements, such as compensating element 116 of Figure 1 (compensating chains, ropes or cables).

- Regenerator devices usually required to handle any regenerated current may be at least downsized so as to harvest enough energy to at least run the lift control circuitry and the Active Compensation Unit circuitry, or it may be eliminated in its entirety.

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It will be appreciated that the invention has been described by way of example only. Various modifications may be made to the techniques described herein without departing from the spirit and scope of the appended claims. The disclosed techniques comprise techniques which may be provided in a stand-alone manner, or
10 in combination with one another. Therefore, features described with respect to one technique may also be presented in combination with another technique.

Claims

1. An active compensation unit for a counterweight system in an elevator system, the active compensation unit having a variable weight unit, the active
5 compensation unit being arranged to vary an amount of weight of the variable weight unit coupled in the counterweight system in dependence of an operating condition of the elevator system.
2. The active compensation unit of claim 1, wherein the variable weight unit
10 comprises a weight and a weight mounting structure, the weight mounting structure being arranged to be mechanically coupled in the counterweight system and for mounting of the weight.
3. The active compensation unit of claim 1 or claim 2, wherein the weight
15 mounting structure is arranged for suspension in the counterweight system through a reeling mechanism.
4. The active compensation unit of claim 3, further comprising a control unit, the control unit being configured to control operation of the reeling mechanism in
20 dependence of the operating condition of the elevator system to maintain the weight mounting structure in suspension in the counterweight system.
5. The active compensation unit of claim 1 or claim 2, wherein the weight
25 mounting structure is arranged for suspension in the counterweight system with hoisting ropes of the elevator system.
6. The active compensation unit of claim 2 or claim 3, wherein the variable weight unit comprises a plurality of weights, and wherein the weight mounting structure is arranged for mounting of each of the plurality of weights.

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7. The active compensation unit of claim 6, arranged to mount the one or more weights of the plurality of weights to the weight mounting structure using a corresponding one or more electromagnets.
- 5 8. The active compensation unit of claim 6, arranged to mount the one or more weights of the plurality of weights to the weight mounting structure using a corresponding one or more micro motors, each of which is arranged to engage a weight using a threaded screw.
- 10 9. The active compensation unit of claim 6 or claim 7, wherein the plurality of weights comprises individual weights having different weight values from one another, and the active compensation unit is configured to select which of the individual weights is to be mounted to the weight mounting structure in dependence of the operating condition of the elevator system.
- 15 10. The active compensation unit of claim 9, wherein individual weights of the plurality of weights are selected to be a percentage of a rated capacity of the elevator system.
- 20 11. The active compensation unit of claim or 1 claim 2, wherein the operating condition of the elevator system is one or more of: elevator load; speed of elevator travel; direction of elevator travel; elevator position within an elevator riser; and elevator traction machine electrical current.
- 25 12. A method of providing active compensation in a counterweight system in an elevator system using an active compensation unit having a variable weight unit mechanically coupled in the counterweight system, the method comprising varying an amount of weight of the variable weight unit in dependence of an operating condition of the elevator system.

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