

LIFT MONITORING APPARATUS AND SYSTEM

TECHNICAL FIELD

5 The present invention relates to lift monitoring apparatus and system.

BACKGROUND

10 Lift monitoring apparatus and system are used to detect the operation status of lifts. Known apparatus and system are dependent on the brand, model and type of each lift, and typically require modification to the lift system in order to perform monitoring functions. Many lift monitoring apparatus and systems are inherently built and developed by the lift manufacturer and the accessibility to these sensors are normally restricted. Due to constraints in lift system modifications and the accessibility to its sensors, lift status
15 monitoring according to known solutions is limited to a relatively low level.

SUMMARY

20 In one aspect, embodiments of the present invention provide a lift monitoring apparatus which comprises a housing mountable to a lift carriage, a controller disposed in the housing, and a detector coupled to the housing and the controller for obtaining a signal associated with the lift and transmitting the signal to the controller. The controller is configured to determine a lift status based on the signal.

25 In another aspect, embodiments of the present invention provides a lift monitoring system which comprises a controller, a backend in communication connection with the controller, and a detector coupled to a lift and the controller for obtaining a signal associated with the lift and transmitting the signal to the controller. The controller is configured to determine a present status of the lift based on the signal and to transmit the signal to the
30 backend.

Other aspects and advantages of the present disclosure will become apparent from the following detailed description, illustrating by way of example the inventive concept and technical solutions of the present invention.

5 BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the present invention are disclosed hereinafter with reference to the drawings, in which:

10 FIG. 1 is a block diagram showing a lift monitoring apparatus according to one embodiment;

FIG. 2A is a schematic diagram of a lift monitoring apparatus having a distance sensor and mounted to a lift carriage for detection of floor level;

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FIG. 2B is a schematic diagram of a lift monitoring apparatus of Fig. 2A used in a lift system;

FIG. 2C is a schematic diagram of a lift monitoring apparatus of Fig. 2A used in a lift system according to an alternative embodiment;

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FIG. 2D is a chart showing measurement data obtained by the distance sensor of the lift monitoring apparatus of Fig. 2A used in a lift system;

25 FIG. 3A is a schematic diagram of a lift monitoring apparatus having a pressure sensor and mounted to a lift carriage for detection of floor level;

FIG. 3B is a chart showing measurement data obtained by the pressure sensor of the lift monitoring apparatus of Fig. 3A;

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FIG. 3C is a schematic diagram of a lift monitoring apparatus having a distance sensor and a pressure sensor and mounted to a lift carriage for monitoring;

FIG. 4A is a schematic diagram of a lift monitoring apparatus having a current sensor and mounted to a lift carriage for detection of lift door status;

5 FIG. 4B is a chart showing data obtained by the current sensor of the lift monitoring apparatus of Fig. 4A corresponding to a lift door open status;

FIG. 4C is a chart showing data obtained by the current sensor of the lift monitoring apparatus of Fig. 4A corresponding to a lift door close status;

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FIG. 5A is a schematic diagram of a lift monitoring apparatus having a noise sensor and mounted to a lift carriage for detection of noise in a lift system;

FIG. 5B is a chart showing data obtained by the noise sensor of the lift monitoring
15 apparatus of Fig. 5A indicating an abnormal sound detected;

FIG. 6A is a schematic diagram of a lift monitoring apparatus having an accelerometer sensor and mounted to a lift carriage for detection of speed, acceleration and vibration of a lift system;

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FIG. 6B is a chart showing data obtained by the accelerometer sensor of the lift monitoring apparatus of Fig. 6A indicating a jerk occurred in a lift carriage;

FIG. 6C is a chart showing data obtained by the accelerometer sensor of the lift
25 monitoring apparatus of Fig. 6A indicating an excessive vibration occurred in a lift carriage;

FIG. 7A is a schematic diagram of a lift monitoring apparatus having a presence sensor and mounted to a lift carriage for detection of a presence in a lift carriage;

30 FIG. 7B is a chart showing data obtained by the presence sensor of the lift monitoring apparatus of Fig. 7A indicating less usage of a lift;

FIG. 7C is a chart showing data obtained by the presence sensor of the lift monitoring apparatus of Fig. 7A indicating a crowd usage of a lift;

FIG. 7D is a schematic diagram of a lift monitoring apparatus having a noise sensor
5 and a presence sensor mounted to a lift carriage for detection of a presence in a lift carriage.

Fig. 8 is a schematic diagram showing a lift monitoring system according to one embodiment;

10 Fig. 9 is a block diagram showing functional modules of the lift monitoring system of Fig. 8.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

15 As shown in the figures, according to technical solutions provided by the present invention, a lift monitoring apparatus 100 includes a housing 102, a controller 110 disposed in the housing 102, and a detector 120 including one or more sensors coupled to the controller 110. Housing 102 provides necessary structural support to the controller 110, the one or more sensors, parts and components affixed thereto, and is configured to be capable
20 of being mounted to a lift carriage, for detection / measurement of one or more predetermined status of the lift.

In one embodiment as shown in Fig. 1, the detector 120 includes a distance sensor 121, a pressure sensor 122, a current sensor 123, a noise sensor 124, a presence sensor 125,
25 an accelerometer sensor 126, a thermal sensor 127 and an ultrasonic sensor 128. Each sensor is coupled to controller 110. Apparatus 100 further includes a power supply 130, a data storage device 140 and a communication device 150 coupled to controller 110. Controller 110 is configured to receive electrical signals from each sensor, corresponding to a detection signal and/or measurement data generated by each sensor. Such signal / data are processed
30 by controller 110, and stored in the data storage device 140. Further, the data may be transmitted by the communication device 150 to a backend for further processing and analysis, via a wired or wireless network or a communication channel 160.

In the lift monitoring apparatus 100 shown in Fig. 1, each sensor performs a specific detection / measurement function independent from other sensors or, two or more sensors may work corporatively for detection / measurement of a certain physical / mechanical property of the lift. Accordingly, a lift monitoring apparatus may have one or some or all of the above-illustrated sensors, based on actual monitoring requirements. Controller 110 has sufficient number of interfaces each for connecting to one specific sensor, and may also include one or more extra interfaces or ports, e.g. spare interface 118 reserved for connection of one or more further sensors not listed above, e.g. a light sensor, a camera head, etc. Alternatively, a lift monitoring apparatus may have two or more sensors of the same type, for example two or more distance sensors, two or more pressure sensors, two or more current sensors, two or more noise sensors, two or more presence sensors, two or more accelerometer sensors, two or more thermal sensors, and / or two or more ultrasonic sensors. Each type of two or more sensors is operable independently, or capable of coordinating with each other, to perform the respective detection / measurement in a manner similar to that illustrated above.

Fig. 2A illustrates a lift monitoring apparatus 100a having a distance sensor 121, for detecting a lift status which, in the present embodiment, is the floor level at which a lift carriage 20 stops. Fig. 2B illustrates a lift monitoring apparatus shown in Fig. 2A used in a lift system.

As shown in Figs. 2A and 2B, apparatus 100a may be mounted to a top portion of the lift carriage 20 installed in a lift well 2 of a building 1, with the distance sensor 121 aiming upward to face the ceiling 19 of lift well 2. When lift carriage 20 stops at one floor level of building 1, for example floor level 12, a laser beam 121a with laser pulses emitted from the distance sensor 121 is targeted at the ceiling 19. The laser beam 121a reflected from the ceiling 19 is then received and detected at any time by the distance sensor 121 to obtain a measurement result of distance D1 between the ceiling 19 and the distance sensor 121. The actual floor level of the lift carriage 20 can be obtained based on the distance D1. The measurement may be carried out in a similar manner when the lift carriage 20 is stopped

at other floor levels, for example floor levels 11, 13, etc., to determine the corresponding floor level at which the lift carriage 20 is stopped.

5 In an alternative embodiment, as shown in Fig. 2C, apparatus 100a is mounted at the bottom portion of lift carriage 20, such that the laser beam 121a from distance sensor 121 is aiming downward to face the bottom surface 10 of lift well 2. When lift carriage 20 stops at one floor level of building 1, for example floor level 12, a laser beam 121a with laser pulses emitted from the distance sensor 121 is targeted at the bottom surface 10. The laser beam 121a reflected from the bottom surface 10 is then received and detected at any time by the
10 distance sensor 121 to obtain a measurement result of distance D2 between the ground floor 10 and the distance sensor 121. Distance D2 corresponds to the actual floor level of the lift carriage.

Fig. 2D shows distance measured from the lift carriage to the lift well ceiling using
15 distance sensor, as the lift carriage travels from the first floor to the top floor of a building. As shown in Fig. 2D, the measurement result data can distinctly and accurately detect the various floors as well as the duration that the lift carriage stops at each floor. Data is also accurate enough to tell if the lift carriage is flush with each floor level, and thus can be used to detect lift abnormality if lift carriage is not flush with a floor level when compared to
20 historical data or predetermined value. This data can also be used to measure the distance travelled by the lift over time.

According to an alternative embodiment, detection of floor level at which a lift carriage 20 stops may be performed by a lift monitoring apparatus 100b having a pressure
25 sensor 122 mounted to lift carriage 20, as illustrated in Fig. 3A. As illustrated in a chart showing the measurement result in Fig. 3B, the pressure sensor 122 measures the ambient air pressure at each floor level. The measurement results provide air pressure information corresponding to the respective floor level height up to certain accuracy, which can be used for data analysis depending on measurement tolerance requirement of a user.

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In one embodiment, a lift monitoring apparatus 100c may have both a distance sensor 121 and a pressure sensor 122, to perform floor level detection, as illustrated in Fig.

3C. Distance sensor 121 and pressure sensor 122 are connected to controller 110 in parallel to perform floor level detection independently. Detection results from the distance sensor 121 and the pressure sensor 122 can be compared to verify the reliability of each sensor.

5 Fig. 4A illustrates a lift monitoring apparatus 100d having a current sensor 123, for measurement of the electrical current of a lift door motor. As shown in Fig. 4A, lift monitoring apparatus 100d is mounted to lift carriage 20. Current sensor 123 has a clamp 123a gripping around the power cable 24 of a door motor 22 mounted to lift carriage 20. The clamp 123a may be coupled to the power cable 24 of the door motor 22 in a non-contact
10 manner. The current sensor 123 captures the electrical current of door motor 22 by the coupling of the clamp 123a and power cable 24, to determine door opening and closing status based on the electrical current measured. The current sensor 123 is not intrusive and is used without modification to a lift door motor and its wiring that is originally wired to the door motor. Alternatively, current sensor 123 may be wire-connected to door motor for
15 measurement of the electrical current of the door motor 22.

 Figs. 4B and 4C are charts showing the lift door motor current measured by the current sensor 123. Based on these charts, the lift monitoring apparatus 100d can be configured to cause alerts be triggered for maintenance, in the event that the current is
20 excessive or the time taken for the door to open or close exceeds a predetermined threshold. Alerts can be sent to the maintenance team via a wired network (e.g. Ethernet, LAN, WAN, optical network, cable network), a wireless network (e.g. Wi Fi), or a cellular network (e.g. 2G, 3G, 4G network).

25 Fig. 5A illustrates a lift monitoring apparatus 100e having a noise sensor 124, for detection of audio signals, for example the lift movement, door operating noise as well as other sound from the lift carriage. Noise sensor 124 may be mounted to any appropriate location in a lift system, for example inside the housing of lift monitoring apparatus 100e, or outside of housing of the lift monitoring apparatus 100e (such noise sensor 124' is shown
30 in dashed lines), or adjacent to the lift motor etc. In a sound measurement result chart illustrated in Fig. 5B, the sound captured is normal except for a spike 502 in the middle of the curve, which corresponds to an abnormal situation where a person shouting in the lift

carriage. The data corresponding to an abnormal situation can be used to trigger alerts of a stranded passenger in a lift carriage who presses the alarm bell. Noise from other parts of the lift, e.g. the lift motor, may be captured by the noise sensor 124 to alert possible faulty of the relevant part or components.

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Fig. 6A illustrates a lift monitoring apparatus 100f having an accelerometer sensor 126 mounted inside the housing 102, or accelerometer 126' mounted outside of housing 102, for detection of a dynamic operation status of the lift, for example the speed, acceleration and/or vibration of lift carriage 20. Accelerometer sensors arranged on the respective x, y and z axis directions may be used to detect speed, acceleration as well as abnormal jerks and vibrations at each direction as the lift carriage travels up and down.

Fig. 6B is a chart showing abnormal jerks across all axes directions, corresponding to spikes 602, detected at various parts of the journey as the lift carriage is travelling. This could be used to trigger alerts for maintenance when the spikes consistently exceed threshold at a certain floor.

Fig. 6C is a chart showing excessive vibration across all axes. A passenger jumping in the lift carriage is mapped to the spike 604. The accelerometer sensor data can be used to identify scenarios whereby passengers are stuck in the lift and are seeking help.

Fig. 7A illustrates a lift monitoring apparatus 100g having a presence sensor 125, for example a thermal sensor 127, or an ultrasonic sensor 128, to determine whether there is / are passenger(s) in the lift carriage. Presence sensor 125 is coupled to controller 110, and mounted inside a lift carriage 20, with direct access to the internal space of the lift carriage. When a passenger walks in or out of the lift carriage 20, the thermal radiation / ultrasonic reflection in the detection area of the lift carriage 20 is detected and captured by the thermal sensor 127 / ultrasonic sensor 128. From the detection result charts shown in Figs. 7B and 7C, the passenger presence status can be detected with reasonable accuracy. In the charts, Fig. 7B shows low readings from the presence sensor 125, indicating that few passengers have used the lift during the period charted. Fig. 7C shows higher readings from the presence sensor 125, indicating that more people have used the lift during the period

charted. This data can be used together with the other sensor data to trigger relevant alerts and responses.

5 A lift monitoring apparatus 100h may have both a noise sensor 124 and a presence sensor 125, to determine passenger presence, as illustrated in Fig. 7D. Noise sensor 124 and presence sensor 125 are connected to controller 110 in parallel to determine passenger presence independently. Detection results from the noise sensor 124 and the presence sensor 125 can be compared to verify the reliability of each sensor.

10 Each type of sensor can work individually as described in the preceding or used together in a lift monitoring apparatus to perform comprehensive detection, measurement and monitoring of a lift. As shown in Fig. 8, according to one embodiment, a lift monitoring system 200 includes a lift monitoring apparatus 201 and a back end 280 in communication connection with the lift monitoring apparatus 201.

15 The lift monitoring apparatus 201 includes a housing 202 mountable to a lift carriage 20. A controller 210 is mounted in the housing 202. A distance sensor 221 is mounted at top side of housing 202 for measurement of floor level by laser beam 221a aiming upward to a lift well ceiling. Mounted in housing 202 and coupled to controller 210 are also a
20 pressure sensor 222 for complementary measurement of the floor level, a current sensor 223 gripping around the power cable 24 of lift door motor 22 by a clamp 223a, for detection of lift door opening and closing status, a noise sensor 224 and an accelerometer sensor 226. A presence sensor 225, such as a thermal sensor or an ultrasonic sensor, is mounted in the lift carriage 20, for detection of passenger presence in the lift carriage. Lift monitoring
25 apparatus 201 is constructed as a standalone device capable of mounting to a lift carriage, by screw, nut, rivet and/or welding, etc., and irrespective of the type, model and brand of the lift.

30 Measurement result from each sensor, collected by controller 210, may be transmitted via communication device 250, to backend 280 for further processing and analysis. The sensors data will be read at predetermined frequencies, for example some at 1Hz while others at 10Hz interval. These readings will be sent to the cloud backend 280,

where machine learning and big data analytics will be carried out to predict the failure of the lifts.

5 In details, a machine learning algorithm can be utilized to analyse data collected from different sensors to learn what causes lift failure or abnormality and the trends that may occur in that data. The machine learning process includes normalization of data either collected from the historical records or real-time records of the backend 280 to remove missing information as well as incorrect data. The machine learning process also includes establishment of a model to classify lift with same or similar parameters as either working
10 normally or likely to fail. The normalized data can be fed to the machine learning algorithms to predict any feature breakdown of the lift. Before machine learning data become available, it is possible to use historical lift breakdown data to drive the prediction. The historical lift breakdown data is collected from lifts with same or similar parameters with respect to the current lift and hence is comparable to data collected from these lifts are comparable and of
15 practical value to the current lift. In addition to the historical lift breakdown data, information on whether the lift has been heavily utilized (and hence information on whether it needs more maintenance) can also be derived through the data collected by the sensors.

In one embodiment, the following routines will detect the status of the lifts in real-
20 time based on data from sensors in the lift monitoring apparatus:

- Maintenance routine – set maintenance bit if it is under maintenance and clear otherwise;
- 25 • Power failure routine – set power failure bit if sensor is on battery and clear otherwise;
- ARD (Automatic Rescue Device) failure – set ARD failure bit if power failure and door doesn't open after 10 min;
- 30 • Levelling routine – set levelling out if levelling > 10mm clear otherwise;

- Lift breakdown routine - Lift stops and door doesn't open, Door cannot close, Door cannot open, Lift doesn't move after 6 hours;
- Passenger trapped – Lift stops and door doesn't open and there are passengers inside carriage.

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These real-time statuses will be sent to the backend where they will be routed to various parties, such as lift manufacturer, property manager and/or lift maintenance contractor, to take necessary action.

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Fig. 9 is a block diagram showing functional modules in a lift monitoring system, which include an Over-The-Air (OTA) module 910, a monitor module 920, a collector module 930 and a predictive module 940, coupled to a communication module or agent 950. The collector module 930 is to collect data form the sensors. The OTA module 910 will update the Predictive Module 940 with new rules, parameters and programs to fine-tune its predictive capabilities. In addition to the predictive module 940, the OTA module 910 will also update the monitor module 920 / collector module 930, the communication module or agent 950 and the OTA module 910 itself. Data storage module 960 is coupled between the collector module 930 and the predictive module 940 for predictive fault detection. The communication module or agent 950 transmits the data to the backend 980.

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It should be appreciated that the present invention is not to be limited in scope by the specific embodiments described here in. Various modifications of the invention in addition to those described herein will become apparent to those skilled in the art from the foregoing description and accompanying drawings. Such modifications are intended to fall within the scope of the claims appended therein.

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CLAIMS

1. A lift monitoring apparatus comprising:
 - a housing mountable to a lift carriage;
 - 5 a controller disposed in the housing;
 - a detector coupled to the housing and the controller for obtaining a signal associated with the lift and transmitting the signal to the controller;
 - wherein the controller is configured to determine a lift status based on the signal.
- 10 2. The lift monitoring apparatus of claim 1, wherein the lift status includes a floor level at which the lift carriage stops, the detector includes a distance sensor, the signal includes a laser pulse emitted from the distance sensor to a reference target, reflected from the reference target and received by the distance sensor, wherein the controller is configured to determine the floor level based on the laser pulse.
- 15 3. The lift monitoring apparatus of claim 2, wherein the lift carriage is installed in a lift well, the reference target is a ceiling of the lift well, the housing being configured to be mountable to a top portion of the lift carriage, the laser pulse being emitted upwardly aiming the ceiling and reflected back to the distance sensor from the ceiling.
- 20 4. The lift monitoring apparatus of claim 2, wherein the lift carriage is installed in a lift well, the reference target is a bottom surface of the lift well, the housing being configured to be mountable to a bottom portion of the lift carriage, the laser pulse being emitted downwardly aiming the bottom surface and reflected back to the distance sensor from the bottom surface.
- 25 5. The lift monitoring apparatus of claim 1, wherein the lift status includes a floor level at which the lift carriage stops, the detector includes a pressure sensor, the signal includes an ambient air pressure obtained by the pressure sensor, wherein the controller is configured to determine the floor level based on the ambient air pressure.
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6. The lift monitoring apparatus of claim 1, wherein the lift status includes a lift door opening and closing status, the detector includes a current sensor configured to couple to a power cable of a door motor of the lift, the signal includes an operation electrical current of the door motor and obtained by the current sensor, wherein the controller is configured to determine the lift door opening and closing status based on the operation electrical current.
7. The lift monitoring apparatus of claim 1, wherein the lift status includes a lift parts operation status, the detector includes a noise sensor coupled to the lift, the signal includes an audio signal obtained by the noise sensor and associated with the lift parts, wherein the controller is configured to determine the lift parts operation status based on the audio signal.
8. The lift monitoring apparatus of claim 7, wherein the lift status includes a passenger usage status, the signal includes an audio signal obtained by the noise sensor and associated with passengers of the lift, wherein the controller is configured to determine the passenger usage status based on the audio signal.
9. The lift monitoring apparatus of claim 1, wherein the lift status includes a dynamic status of the lift, wherein the detector includes an accelerometer sensor coupled to the lift, the signal includes an acceleration of the lift obtained by the accelerometer sensor, wherein the controller is configured to determine the dynamic status based on the acceleration.
10. The lift monitoring apparatus of claim 1, wherein the lift status includes a passenger usage status, the detector includes a thermal sensor coupled to the lift, the signal includes a temperature in the lift carriage obtained by the thermal sensor, wherein the controller is configured to determine the passenger usage status based on the temperature.
11. The lift monitoring apparatus of claim 1, wherein the lift status includes a passenger usage status, wherein the detector includes a noise sensor coupled to the lift, the

signal includes an audio signal of the lift obtained by the noise sensor and associated with passengers of the lift, wherein the controller is configured to determine the passenger usage status based on the audio signal.

- 5 12. The lift monitoring apparatus of claim 1, wherein the lift status includes a passenger usage status, wherein the detector includes an ultrasonic sensor coupled to the lift, the signal includes an ultrasonic wave in the lift carriage and obtained by the ultrasonic sensor, wherein the controller is configured to determine the passenger usage status based on the ultrasonic wave.

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13. A lift monitoring system comprising:
 a controller;
 a backend in communication connection with the controller;
 a detector coupled to a lift and the controller for obtaining a signal associated
15 with the lift and transmitting the signal to the controller;
 wherein the controller is configured to determine a present status of the lift based on the signal and to transmit the signal to the backend.

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14. The lift monitoring system of claim 13, wherein the backend is configured to predict future status of the lift based on the signal.

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15. The lift monitoring system of claim 14, wherein the backend is configured to predict future status of the lift with an algorithm comprising normalization of the signal to generate normalized data.

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16. The lift monitoring system of claim 15, wherein the algorithm further comprising establishing a model to classify the lift as one of a normal-working lift and a due-for-maintenance lift.
17. The lift monitoring system of claim 16, wherein the algorithm further comprising feeding the normalized data to the model to predict future breakdown of the lift.