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Actuator failure detection and scissor lift loadsensing systems and methods

Abstract

A fully-electric lift device includes a base; a retractable lift mechanism, a work platform, an electric linear actuator configured to selectively move the retractable lift mechanism between an extended position and a retracted position, and a controller. The linear actuator includes an electric motor. The controller is in communication with the electric motor and configured to receive a lift command, monitor a required torque for the electric motor based on the lift command, and selectively inhibit the lift command based on the required torque.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS (1) This application is a continuation of U.S. patent application Ser. No. 17/328,885, filed on May 24, 2021, which is (i) a continuation-in-part of U.S. patent application Ser. No. 16/811,659, filed on Mar. 6, 2020, which claims the benefit of U.S. Provisional Application No. 62/829,853, filed Apr. 5, 2019, and (ii) a continuation-in-part of U.S. patent application Ser. No. 16/811,196, filed on Mar. 6, 2020, which claims the benefit of

BACKGROUND

(1) Lift devices commonly include a vertically movable platform that is supported by a foldable series of linked supports. The linked supports are arranged in an "X" pattern, crisscrossing with one another. A hydraulic cylinder generally controls vertical movement of the platform by engaging and rotating (i.e., unfolding) the lowermost set of linked supports, which in turn unfold the other linked supports within the system. The platform raises and lowers based upon the degree of actuation by the hydraulic cylinder. A hydraulic cylinder may also control various other vehicle actions, such as, for example, steering or platform tilt functions. Lift devices using one or more hydraulic cylinders require an on-board reservoir tank to store hydraulic fluid for the lifting process.

SUMMARY

(2) One exemplary embodiment relates to a fully-electric lift device. The fully-electric lift device includes a base having a plurality of wheels, a retractable lift mechanism having a first end coupled to the base and being moveable between an extended position and a retracted position, a work platform configured to support a load, an electric linear actuator configured to selectively move the retractable lift mechanism between the extended position and the retracted position, and a controller. The work platform is coupled to and supported by a second end of the retractable lift mechanism. The linear actuator includes an electric motor. The controller is in communication with the electric motor and configured to receive a lift command, monitor a required torque for the electric motor based on the lift command, and selectively inhibit the lift command based on the required torque.

(3) Another exemplary embodiment relates to a fully-electric lift device. The fully-electric lift device includes a base having a plurality of wheels, a retractable lift mechanism having a first end coupled to the base and being moveable between an extended position and a retracted position, a work platform configured to support a load, an electric linear actuator configured to selectively move the retractable lift mechanism between the extended position and the retracted position, and a controller. The work platform is coupled to and supported by a second end of the retractable lift mechanism. The controller is in communication with the electric linear actuator and configured to receive a lift command, monitor a drive power efficiency associated with the electric linear actuator, determine an allowable range for the drive power efficiency, and selectively inhibit, based on the drive power efficiency being outside of the allowable range, the lift command.

(4) Another exemplary embodiment relates to a method for operating a fully-electric lift device. The method includes receiving a lift command to ascend a work platform or descend the work platform, monitor, based on the lift command, a required torque for an electric linear actuator associated with ascending or descending the work platform, determining if the required torque is greater than an allowed torque, upon determining that the required torque is greater than an allowed torque, inhibiting the lift command, and upon determining that the required torque is less than the allowed torque, allowing the lift command.

(5) The invention is capable of other embodiments and of being carried out in various ways. Alternative exemplary embodiments relate to other features and combinations of features as may be recited herein.

Description

BRIEF DESCRIPTION OF THE FIGURES

(1) The disclosure will become more fully understood from the following detailed description, taken in conjunction with the accompanying figures, wherein like reference numerals refer to like elements, in which:

(2) FIG. **1**A is a side perspective view of a lift device in the form of a scissor lift, according to an exemplary embodiment;

(3) FIG. **1**B is another side perspective view of the lift device of FIG. **1**A;

(4) FIG. **2**A is a side view of the lift device of FIG. **1**A, shown in a retracted or stowed position;

(5) FIG. **2**B is a side perspective view of the lift device of FIG. **1**A, shown in an extended or work position;

(6) FIG. **3** is a side view of the lift device of FIG. **1**A, depicting various vehicle controllers;

(7) FIG. **4** is a side view of a linear actuator of the lift device of FIG. **1**A;

(8) FIG. **5** is a bottom view of the linear actuator of FIG. **4**;

(9) FIG. **6** is a side view of a push tube and a nut assembly of the linear actuator of FIG. **4**;

(10) FIG. **7** is a cross-sectional view of the nut assembly of FIG. **6**;

(11) FIG. **8**A is a detail cross-sectional view of a primary nut mechanism of the nut assembly of FIG. **7**;

(12) FIG. **8**B is a detail view of the primary nut mechanism of FIG. **8**A;

(13) FIG. **9** is a cross-sectional view of a secondary nut mechanism of the nut assembly of FIG. **6**;

(14) FIG. **10** is a flowchart detailing an exemplary lift process of the lift device of FIG. **1**A; and

(15) FIG. **11** is a side perspective view of another lift device in the form of a boom lift, according to another exemplary embodiment.

(16) FIG. **12**A is a side perspective view of a lift device in the form of a scissor lift, according to an exemplary embodiment;

(17) FIG. **12**B is another side perspective view of the lift device of FIG. **1**A;

(18) FIG. **13**A is a side view of the lift device of FIG. **1**A, shown in a retracted or stowed position;

(19) FIG. **13**B is a side perspective view of the lift device of FIG. **1**A, shown in an extended or work position;

(20) FIG. **14** is a side view of the lift device of FIG. **1**A, depicting various vehicle controllers;

(21) FIG. **15** is a side view of a linear actuator of the lift device of FIG. **1**A;

(22) FIG. **16** is a bottom view of the linear actuator of FIG. **4**;

(23) FIG. **17** is a side view of a push tube and a nut assembly of the linear actuator of FIG. **4**;

(24) FIG. **18** is a flow chart of an exemplary method of determining a load supported by a work platform of the lift device of FIG. **3**; and

(25) FIG. **19** is a side perspective view of another lift device in the form of a boom lift, according to another exemplary embodiment.

DETAILED DESCRIPTION

(26) Before turning to the figures, which illustrate the exemplary embodiments in detail, it should be understood that the present application is not limited to the details or methodology set forth in the description or illustrated in the figures. It should also be understood that the terminology is for the purpose of description only and should not be regarded as limiting.

(27) Referring to the figures generally, the various exemplary embodiments disclosed herein relate to systems, apparatuses, and methods for detecting actuator failure on a lift device. The lift device includes a linear actuator having central screw rod, a primary nut mechanism, and a secondary nut mechanism. The secondary nut mechanism provides a failsafe or a backup nut mechanism in the event that the primary nut mechanism fails. A lift controller is additionally provided, which monitors various lift characteristics to determine both whether a maximum allowable motor torque has been exceeded and whether actuator failure has been detected. The lift controller is configured to alert an operator in the case of an actuator failure, and to inhibit unsafe operating conditions. The various exemplary embodiments disclosed herein further relate to systems, apparatuses, and methods for sensing a load supported by a work platform. In some embodiments, an electromagnetic brake of a lift actuator motor may be disengaged and the lift actuator motor may be used to maintain a work platform height. A lift controller may then be configured to determine the load supported by the work platform using various actuator/motor characteristics and a measured

height of the work platform.

(28) According to the exemplary embodiment depicted in FIGS. **1**A and **1**B, a vehicle, shown as vehicle **10**, is illustrated. In some embodiments, the vehicle **10** may be a scissor lift, for example, which can be used to perform a variety of different tasks at various elevations. The vehicle **10** includes a base **12** supported by wheels **14**A, **14**B positioned about the base **12**. The vehicle **10** further includes a battery **16** positioned on board the base **12** of the vehicle **10** to supply electrical power to various operating systems present on the vehicle **10**.

(29) The battery **16** can be a rechargeable lithium-ion battery, for example, which is capable of supplying a direct current (DC) or alternating current (AC) to vehicle **10** controls, motors, actuators, and the like. The battery **16** can include at least one input **18** capable of receiving electrical current to recharge the battery **16**. In some embodiments, the input **18** is a port capable of receiving a plug in electrical communication with an external power source, like a wall outlet. The battery **16** can be configured to receive and store electrical current from one of a traditional 120 V outlet, a 240 V outlet, a 480 V outlet, an electrical power generator, or another suitable electrical power source.

(30) The vehicle **10** further includes a retractable lift mechanism, shown as a scissor lift mechanism **20**, coupled to the base **12**. The scissor lift mechanism **20** supports a work platform **22** (shown in FIG. **3**). As depicted, a first end **23** of the scissor lift mechanism **20** is anchored to the base **12**, while a second end **24** of the scissor lift mechanism **20** supports the work platform **22**. As illustrated, the scissor lift mechanism **20** is formed of a series of linked, foldable support members **25**. The scissor lift mechanism **20** is selectively movable between a retracted or stowed position (shown in FIG. **2**A) and a deployed or work position (shown in FIG. **2**B) using an actuator, shown as linear actuator **26**. The linear actuator **26** is an electric actuator. The linear actuator **26** controls the orientation of the scissor lift mechanism **20** by selectively applying force to the scissor lift mechanism **20**. When a sufficient force is applied to the scissor lift mechanism by the linear actuator **26**, the scissor lift mechanism **20** unfolds or otherwise deploys from the stowed or retracted position into the work position. Because the work platform **22** is coupled to the scissor lift mechanism **20**, the work platform **22** is also raised away from the base **12** in response to the deployment of the scissor lift mechanism **20**.

(31) As shown in FIG. **3**, the vehicle **10** further includes a vehicle controller **27** and a lift controller **28**. The vehicle controller **27** is in communication with the lift controller **28** and is configured to control various driving systems on the vehicle **10**. The lift controller **28** is in communication with the linear actuator **26** to control the movement of the scissor lift mechanism **20**. Communication between the lift controller **28** and the linear actuator **26** and/or between the vehicle controller **27** and the lift controller **28** can be provided through a hardwired connection, or through a wireless connection (e.g., Bluetooth, Internet, cloud-based communication system, etc.). It should be understood that each of the vehicle controller **27** and the lift controller **28** includes various processing and memory components configured to perform the various activities and methods described herein. For example, in some instances, each of the vehicle controller **27** and the lift controller **28** includes a processing circuit having a processor and a memory. The memory is configured to store various instructions configured to, when executed by the processor, cause the vehicle **10** to perform the various activities and methods described herein.

(32) In some embodiments, the vehicle controller **27** may be configured to limit the drive speed of the vehicle **10** depending on a height of the work platform **22**. That is, the lift controller **28** may be in communication with a scissor angle sensor **29** configured to monitor a lift angle of the bottom-most support member **25** with respect to the base **12**. Based on the lift angle, the lift controller **28** may determine the current height of the work platform **22**. Using this height, the vehicle controller **27** may be configured to limit or proportionally reduce the drive speed of the vehicle **10** as the work platform **22** is raised.

(33) As illustrated in the exemplary embodiment provided in FIGS. **4-6**, the linear actuator **26**

includes a push tube assembly **30**, a gear box **32**, and an electric lift motor **34**. The push tube assembly **30** includes a protective outer tube **36** (shown in FIGS. **4** and **5**), a push tube **38**, and a nut assembly **40** (shown in FIG. **6**). The protective outer tube **36** has a trunnion connection portion **42** disposed at a proximal end **44** thereof. The trunnion connection portion **42** is rigidly coupled to the gear box **32**, thereby rigidly coupling the protective outer tube **36** to the gear box **32**. The trunnion connection portion **42** further includes a trunnion mount **45** that is configured to rotatably couple the protective outer tube **36** to one of the support members **25** (as shown in FIG. **2B**).

(34) The protective outer tube **36** further includes an opening at a distal end **46** thereof. The opening of the protective outer tube **36** is configured to slidably receive the push tube **38**. The push tube **38** includes a connection end, shown as trunnion mount **48**, configured to rotatably couple the push tube **38** to another one of the support members **25** (as shown in FIG. **2B**). As will be discussed below, the push tube **38** is slidably movable and selectively actuatable between an extended position (shown in FIG. **2B**) and a retracted position (shown in FIG. **4**).

(35) Referring now to FIG. **6**, the push tube **38** is rigidly coupled to the nut assembly **40**, such that motion of the nut assembly **40** results in motion of the push tube **38**. The push tube **38** and the nut assembly **40** envelop a central screw rod **50** (shown in FIG. **7**). The central screw rod **50** is rotatably engaged with the gear box **32** and is configured to rotate within the push tube **38** and the nut assembly **40**, about a central axis of the push tube assembly **30**. The nut assembly is configured to engage the central screw rod **50** and translate the rotational motion of the central screw rod **50** into translational motion of the push tube **38** and the nut assembly **40**, with respect to the central screw rod **50**, along the central axis of the push tube assembly **30**.

(36) Referring again to FIG. **4**, the lift motor **34** is configured to selectively provide rotational actuation to the gear box **32**. The rotational actuation from the lift motor **34** is then translated through the gear box **32** to selectively rotate the central screw rod **50** of the push tube assembly **30**. Accordingly, the lift motor **34** is configured to provide rotational actuation to the central screw rod **50** via the gear box **32**. The rotation of the central screw rod **50** is then translated by the nut assembly **40** to selectively translate the push tube **38** and the nut assembly **40** along the central axis of the push tube assembly **30**. Accordingly, the lift motor **34** is configured to selectively actuate the push tube **38** between the extended position and the retracted position. Thus, with the trunnion mount **45** of the protective outer tube **36** and the trunnion mount **48** of the push tube **38** each rotatably coupled to their respective support members **25**, the lift motor **34** is configured to selectively move the scissor lift mechanism **20** to various heights between and including the retracted or stowed position and the deployed or work position.

(37) The lift motor **34** may be an AC motor (e.g., synchronous, asynchronous, etc.) or a DC motor (shunt, permanent magnet, series, etc.). In some instances, the lift motor **34** is in communication with and powered by the battery **16**. In some other instances, the lift motor **34** may receive electrical power from another electricity source on board the vehicle **10**.

(38) Referring now to FIGS. **7-9**, the nut assembly **40** includes an outer sleeve **52**, a primary nut mechanism, shown as ball screw nut **54**, and a secondary nut mechanism, shown as a backup jam nut **56**. The outer sleeve **52** envelops and is rigidly coupled to both the ball screw nut **54** and the backup jam nut **56**. As such, the outer sleeve **52**, the ball screw nut **54**, and the backup jam nut **56** are configured to move as a unit along the axis of the central screw rod **50**.

(39) The ball screw nut **54** is configured to engage the central screw rod **50** and translate the rotational motion of the central screw rod **50** into translational motion of the push tube **38** and the nut assembly **40**, with respect to the central screw rod **50**, along the central axis of the push tube assembly **30**. As best illustrated in FIGS. **8A** and **8B**, the ball screw nut **54** includes a helical thread **58** and a ball return passageway **60**. As depicted in FIG. **8B**, a plurality of balls **62** (e.g., ball bearings) are disposed between the helical thread **58** of the ball screw nut **54** and a helical thread **64** of the central screw rod **50**. As the central screw rod **50** is rotated, the plurality of balls **62** are configured to roll within the channel formed between the helical threads **58**, **64** to gradually move

the nut assembly **40** axially with respect to the central screw rod **50**, in response to rotation of the central screw rod **50**. The ball return passageway **60** allows for the plurality of balls **62** to be continuously recirculated from one axial location on the ball screw nut **54** to another axial location, such that the plurality of balls **62** provide a continuous engagement between the helical threads **58**, **64**, while minimizing frictional losses between the helical threads **58**, **64**.

(40) As depicted in FIG. **9**, the backup jam nut **56** includes a helical thread **66**. In some embodiments, the backup jam nut **56** is an Acme nut. The helical thread **66** is configured to normally be disengaged from the helical thread **64** of the central screw rod **50**. Specifically, the fit between the plurality of balls **62** and the helical threads **58**, **64** creates a gap between the helical thread **66** of the backup jam nut **56** and the helical thread **64** of the central screw rod **50**. As such, under normal operating conditions, the backup jam nut **56** does not contact or otherwise engage the central screw rod **50**, and the ball screw nut **54** is the primary nut mechanism.

(41) However, in the event that the ball screw nut **54** fails (e.g., the plurality of balls **62** escape from the channel between the helical threads **58**, **64** or the ball screw nut **54** is otherwise damaged), the helical thread **66** of the backup jam nut **56** engages the helical thread **64** of the central screw rod **50**, providing a failsafe, backup, or secondary nut mechanism. That is, in the event of a primary nut mechanism failure (e.g., the ball screw nut **54** failing) the secondary nut mechanism (e.g., the backup jam nut **56**) is configured to engage the central screw rod **50**.

(42) The lift controller **28** is configured to detect a drive power efficiency difference experienced by the lift motor **34** when the ball screw nut **54** is engaged versus when the backup jam nut **56** is engaged. For example, when the ball screw nut **54** is engaged, the lowered frictional losses of the ball screw nut **54** provide a high drive power efficiency of between approximately 80% and approximately 90%. Conversely, when the backup jam nut **56** is engaged, the increased frictional losses of the backup jam nut **56** provide a much lower drive power efficiency of between approximately 20% and approximately 30%. As such, the ball screw nut **54** requires a significantly lower amount of power to run than the backup jam nut **56**.

(43) Accordingly, in some instances, the lift controller **28** is configured to monitor drive power efficiency of the linear actuator **26**. The lift controller **28** is then configured to compare the monitored drive power efficiency to an expected drive power efficiency to determine whether the ball screw nut **54** is engaged or whether the backup jam nut **56** is engaged. If the lift controller **28** determines that the backup jam nut **56** is engaged, the lift controller **28** may then determine that there has been an actuator failure.

(44) In some embodiments, when the ball screw nut **54** is engaged, if the lift motor **34** is powered down or discharged, the ball screw nut **54** tends to allow the retractable lift mechanism **20** to retract due to gravity. As such, the lift motor **34** includes an electromagnetic brake **70** configured to maintain the position of the work platform **22** when the lift motor **34** is powered down or discharged. Conversely, when the backup jam nut **56** is engaged, the increased frictional forces may maintain the position of the work platform **22** without the electromagnetic brake **70**. That is, the work platform **22** having a rated payload may not descend due to gravity. Accordingly, the lift motor **34** may have to actively descend the work platform **22**.

(45) In some embodiments, the linear actuator **26** includes various built-in lift characteristic sensors configured to monitor various actuator/motor or lift characteristics. For example, the linear actuator **26** may include a motor speed sensor, a motor torque sensor, various temperature sensors, various vibration sensors, etc. The lift controller **28** may then be in communication with each of these sensors, and may use real-time information received/measured by the sensors to determine whether the primary nut mechanism (e.g., the ball screw nut **54**) or the secondary nut mechanism (e.g., the backup jam nut **56**) are engaged with the central screw rod **50** (i.e., whether the linear actuator **26** has failed).

(46) For example, in some instances, the lift controller **28** may sense the scissor arm angle using the scissor angle sensor **29** and use the scissor arm angle to determine a height of the work platform

22. The lift controller 28 may then process the height of the work platform 22 through a lookup table to determine a maximum allowable motor torque. The lift controller 28 may then compare the maximum allowable motor torque to a required motor torque to move (e.g., raise or lower) the work platform 22. In some instances, this maximum allowable motor torque and the required torque necessary to move the work platform 22 may be deduced using a maximum allowable current threshold to be applied to the motor and a monitored current being applied to the lift motor 34. If the required motor torque exceeds the maximum allowable motor torque (or the monitored current exceeds the maximum allowable current threshold), the lift controller 28 may indicate that the linear actuator 26 has failed (e.g., that the primary nut mechanism has failed and that the secondary nut mechanism is engaged). The lift controller 28 is then configured to allow for the work platform 22 to be lowered to the stowed or transport position to allow the worker or operator to safely exit the vehicle 10. Once the work platform 22 has been lowered, the lift controller 28 is configured to prevent continued use of the linear actuator 26 until the actuator failure has been repaired (e.g., the nut assembly 40 has been repaired or replaced).

(47) Unlike with traditional hydraulics-based systems, the linear actuator 26 is double-acting. That is, the linear actuator 26 can exert the same magnitude force required to raise the work platform 22 when lowering the work platform 22. Accordingly, if the retractable lift mechanism 20 encounters an obstruction while being lowered, it will exert a force approximately equal to the weight of the work platform 22 plus a rated load. As such, the lift controller 28 may further be configured to monitor the platform height, direction of movement, and actuator torque (current) to avoid structural damage.

(48) Referring now to FIG. 10, an exemplary flow chart is provided, showing an exemplary method of use for the retractable lift mechanism 20. The process starts at step 200. An operator then issues a lift command at step 202. The machine controller or lift controller 28 then determines the max allowable motor torque, at step 204. As alluded to above, this max allowable motor torque may be determined based on the height of the work platform 22. For example, the lift controller 28 may include a pre-stored torque-height chart or table to be used for the max allowable motor torque determination. The lift controller 28 then decides, at step 206, whether the required torque for the lift motor 34 to lift or lower the work platform 22 is below the maximum allowable torque.

(49) If the lift controller 28 decides, at step 206, that the required torque is below the maximum allowable torque, the lift controller 28 allows the linear actuator 26 to operate normally, at step 208. Once the commanded operation of the linear actuator 26 has concluded, the linear actuator 26 comes to a stop, at step 210.

(50) If the lift controller 28 decides, at step 206, that the required torque is above the maximum allowable torque, the lift controller 28 then decides whether the work platform 22 is being commanded to ascend or descend, at step 212.

(51) If the lift controller 28 decides, at step 212, that the work platform 22 is being commanded to ascend, the lift controller 28 then inhibits further ascension and alerts the operator regarding the overloading condition, at step 214. The linear actuator 26 then comes to a stop, at step 210.

(52) If the lift controller 28 decides, at step 212, that the work platform 22 is being commanded to descend, the lift controller 28 then alerts the operator regarding the excessive motor torque, at step 216. The operator then checks the surroundings of the vehicle 10 and remove any obstructions, at step 218. The operator then reissues the lift down command, at step 220. The lift controller 28 then again determines the maximum allowable motor torque, at step 222. The lift controller 28 then decides, at step 224, whether the required torque for the lift motor 34 to lower the work platform 22 is below the maximum allowable torque.

(53) If the lift controller 28 decides, at step 224, that the required torque is less than the maximum allowable torque, the lift controller 28 grants the linear actuator 26 normal operation, at step 208. Once the commanded operation of the linear actuator 26 has concluded, the linear actuator 26 comes to a stop, at step 210.

(54) If the lift controller **28** decides, at step **224**, that the required torque is more than the maximum allowable torque, the lift controller **28** inhibits any further lift commands and alerts operator to the actuator failure, at step **226**. That is, once the operator has made sure there are no obstructions, if the required torque is still higher than the maximum allowable torque, the lift controller **28** may reasonably deduce that there has been an actuator failure. The linear actuator **26** then comes to a stop, at step **210**.

(55) The preceding process flow chart is provided as one exemplary embodiment, and is in no way meant to be limiting. The particular order of the process steps may be changed or added to without departing from the scope of this disclosure. For example, in some embodiments, the lift controller **28** may decide whether the work platform **22** is being commanded to ascend or descend prior to determining the maximum allowable torque. Additionally, in some instances, the exemplary flow chart may be cyclical in nature, such that the flow chart returns to the start of the process, at step **200**, after the linear actuator **26** is stopped, at step **210** (as indicated by the dashed line).

(56) In some embodiments, the lift controller **28** may additionally monitor or determine the require force or torque needed to lift or lower the work platform **22**, and subsequently decide whether the required force is too low or too high to determine actuator failure.

(57) Accordingly, the lift controller **28** is configured to determine if the required torque needed by the lift motor **34** to lift or lower the work platform exceeds a maximum allowed torque, to inhibit further functionality if the maximum allowed torque is exceeded to prevent damage to the vehicle **10** or the surroundings of the vehicle **10**, and to alert the operator if the lift actuator is damaged and needs to be replaced. The lift controller **28** may further monitor various lift characteristics to determine if the linear actuator **26** is in an unsafe state (e.g., an actuator failure state or an excessive torque state).

(58) Referring again to FIGS. **1**A and **1**B, the battery **16** can also supply electrical power to a drive motor **72** to propel the vehicle **10**. The drive motor **72** may similarly be an AC motor (e.g., synchronous, asynchronous, etc.) or a DC motor (shunt, permanent magnet, series, etc.) for example, which receives electrical power from the battery **16** or another electricity source on board the vehicle **10** and converts the electrical power into rotational energy in a drive shaft. The drive shaft can be used to drive the wheels **14**A, **14**B of the vehicle **10** using a transmission. The transmission can receive torque from the drive shaft and subsequently transmit the received torque to a rear axle **74** of the vehicle **10**. Rotating the rear axle **74** also rotates the rear wheels **14**A on the vehicle **10**, which propels the vehicle **10**.

(59) The rear wheels **14**A of the vehicle **10** can be used to drive the vehicle, while the front wheels **14**B can be used to steer the vehicle **10**. In some embodiments, the rear wheels **14**A are rigidly coupled to the rear axle **74**, and are held in a constant orientation relative to the base **12** of the vehicle **10** (e.g., approximately aligned with an outer perimeter **76** of the vehicle **10**). In contrast, the front wheels **14**B are pivotally coupled to the base **12** of the vehicle **10**. The wheels **14**B can be rotated relative to the base **12** to adjust a direction of travel for the vehicle **10**. Specifically, the front wheels **14**B can be oriented using an electrical steering system **78**. In some embodiments, the steering system **78** may be completely electrical in nature, and may not include any form of hydraulics.

(60) It should be appreciated that, while the retractable lift mechanism included on vehicle **10** is a scissor lift mechanism, in some instances, a vehicle may be provided that alternatively includes a retractable lift mechanism in the form of a boom lift mechanism. For example, in the exemplary embodiment depicted in FIG. **11**, a vehicle, shown as vehicle **310**, is illustrated. The vehicle **310** includes a retractable lift mechanism, shown as boom lift mechanism **320**. The boom lift mechanism **320** is similarly formed of a series of linked, foldable support members **325**. The boom lift mechanism **320** is selectively movable between a retracted or stowed position and a deployed or work position using a plurality of actuators **326**. Each of the plurality of actuators **326** is a linear actuator similar to the linear actuator **26**.

(61) It should be further appreciated that the linear actuators used in the lift mechanism **20**, **320**, as well as in the steering system **78**, may be incorporated into nearly any type of electric vehicle. For example, the electric systems described herein can be incorporated into, for example, a scissor lift, an articulated boom, a telescopic boom, or any other type of aerial work platform.

(62) Additionally, although the depicted nut assembly **40** utilizes a primary nut mechanism in the form of the ball screw nut **54**, in some embodiments, the primary nut mechanism may alternatively be a roller screw nut. In some other embodiments, the primary nut mechanism may be any other suitable nut for translating rotational motion of the central screw rod **50** into translational motion of the push tube **38** and the nut assembly **40**.

(63) Advantageously, vehicles **10**, **310** may be fully-electric lift devices. All of the electric actuators and electric motors of vehicles **10**, **310** can be configured to perform their respective operations without requiring any hydraulic systems, hydraulic reservoir tanks, hydraulic fluids, engine systems, etc. That is, both vehicles **10**, **310** may be completely devoid of any hydraulic systems and/or hydraulic fluids generally. Said differently, both vehicles **10**, **310** may be devoid of any moving fluids. Traditional lift device vehicles do not use a fully-electric system and require regular maintenance to ensure that the various hydraulic systems are operating properly. As such, the vehicles **10**, **310** may use electric motors and electric actuators, which allows for the absence of combustible fuels (e.g., gasoline, diesel) and/or hydraulic fluids. As such, the vehicles **10**, **310** may be powered by batteries, such as battery **16**, that can be re-charged when necessary.

(64) According to the exemplary embodiment depicted in FIGS. **12**A and **12**B, a vehicle, shown as vehicle **1010**, is illustrated. The vehicle **1010** may be a scissor lift, for example, which can be used to perform a variety of different tasks at various elevations. The vehicle **1010** includes a base **1012** supported by wheels **1014**A, **1014**B positioned about the base **1012**. The vehicle **1010** further includes a battery **1016** positioned on board the base **1012** of the vehicle **1010** to supply electrical power to various operating systems present on the vehicle **1010**.

(65) The battery **1016** can be a rechargeable lithium-ion battery, for example, which is capable of supplying a direct current (DC) or alternating current (AC) to vehicle **1010** controls, motors, actuators, and the like. The battery **1016** can include at least one input **1018** capable of receiving electrical current to recharge the battery **1016**. In some embodiments, the input **1018** is a port capable of receiving a plug in electrical communication with an external power source, like a wall outlet. The battery **1016** can be configured to receive and store electrical current from one of a traditional 120 V outlet, a 240 V outlet, a 480 V outlet, an electrical power generator, or another suitable electrical power source.

(66) The vehicle **1010** further includes a retractable lift mechanism, shown as a scissor lift mechanism **1020**, coupled to the base **1012**. The scissor lift mechanism **1020** supports a work platform **1022** (shown in FIG. **14**). As depicted, a first end **1023** of the scissor lift mechanism **1020** is anchored to the base **1012**, while a second end **1024** of the scissor lift mechanism **1020** supports the work platform **1022**. As illustrated, the scissor lift mechanism **1020** is formed of a foldable series of linked support members **1025**. The scissor lift mechanism **1020** is selectively movable between a retracted or stowed position (shown in FIG. **13**A) and a deployed or work position (shown in FIG. **13**B) using an actuator, shown as linear actuator **1026**. The linear actuator **1026** is an electric actuator. The linear actuator **1026** controls the orientation of the scissor lift mechanism **1020** by selectively applying force to the scissor lift mechanism **1020**. When a sufficient force is applied to the scissor lift mechanism **1020** by the linear actuator **1026**, the scissor lift mechanism **1020** unfolds or otherwise deploys from the stowed or retracted position into the work position. Because the work platform **1022** is coupled to the scissor lift mechanism **1020**, the work platform **1022** is also raised away from the base **1012** in response to the deployment of the scissor lift mechanism **1020**.

(67) As shown in FIG. **14**, the vehicle **1010** further includes a vehicle controller **1027** and a lift controller **1028**. The vehicle controller **1027** is in communication with the lift controller **1028**. The

lift controller **1028** is in communication with the linear actuator **1026** to control the movement of the scissor lift mechanism **1020**. Communication between the lift controller **1028** and the linear actuator **1026** and/or between the vehicle controller **1027** and the lift controller **1028** can be provided through a hardwired connection, or through a wireless connection (e.g., Bluetooth, Internet, cloud-based communication system, etc.). It should be understood that each of the vehicle controller **1027** and the lift controller **1028** includes various processing and memory components configured to perform the various activities and methods described herein. For example, in some instances, each of the vehicle controller **1027** and the lift controller **1028** includes a processing circuit having a processor and a memory. The memory is configured to store various instructions configured to, when executed by the processor, cause the vehicle **1010** to perform the various activities and methods described herein.

(68) In some embodiments, the vehicle controller **1027** may be configured to limit the drive speed of the vehicle **1010** depending on a height of the work platform **1022**. That is, the lift controller **1028** may be in communication with a scissor angle sensor **1029** configured to monitor a lift angle of the bottom-most support member **1025** with respect to the base **1012**. Based on the lift angle, the lift controller **1028** may determine the current height of the work platform **1022**. Using this height, the vehicle controller **1027** may be configured to limit or proportionally reduce the drive speed of the vehicle **1010** as the work platform **1022** is raised.

(69) As illustrated in the exemplary embodiment provided in FIGS. **15-17**, the linear actuator **1026** includes a push tube assembly **1030**, a gear box **1032**, and an electric lift motor **1034**. The push tube assembly **1030** includes a protective outer tube **1036** (shown in FIGS. **4** and **5**), an inner push tube **1038**, and a nut assembly **1040** (shown in FIG. **17**). The protective outer tube **1036** has a trunnion connection portion **1042** disposed at a proximal end **1044** thereof. The trunnion connection portion **1042** is rigidly coupled to the gear box **1032**, thereby rigidly coupling the protective outer tube **1036** to the gear box **1032**. The trunnion connection portion **1042** further includes a trunnion mount **1045** that is configured to rotatably couple the protective outer tube **1036** to one of the support members **1025** (as shown in FIG. **13**B).

(70) The protective outer tube **1036** further includes an opening at a distal end **1046** thereof. The opening of the protective outer tube **1036** is configured to slidably receive the inner push tube **1038**. The inner push tube **1038** includes a connection end, shown as trunnion mount **1048**, configured to rotatably couple the inner push tube **1038** to another one of the support members **1025** (as shown in FIG. **13**B). As will be discussed below, the inner push tube **1038** is slidably movable and selectively actuatable between an extended position (shown in FIG. **13**B) and a retracted position (shown in FIG. **15**).

(71) Referring now to FIG. **6**, the inner push tube **1038** is rigidly coupled to the nut assembly **1040**, such that motion of the nut assembly **1040** results in motion of the inner push tube **1038**. The inner push tube **1038** and the nut assembly **1040** envelop a central screw rod. The central screw rod is rotatably engaged with the gear box **1032** and is configured to rotate within the inner push tube **1038** and the nut assembly **1040**, about a central axis of the push tube assembly **1030**. The nut assembly **1040** is configured to engage the central screw rod and translate the rotational motion of the central screw rod into translational motion of the inner push tube **1038** and the nut assembly **1040**, with respect to the central screw rod, along the central axis of the push tube assembly **1030**.

(72) Referring again to FIG. **15**, the lift motor **1034** is configured to selectively provide rotational actuation to the gear box **1032**. The rotational actuation from the lift motor **1034** is then translated through the gear box **1032** to selectively rotate the central screw rod of the push tube assembly **1030**. The rotation of the central screw rod is then translated by the nut assembly **1040** to selectively translate the inner push tube **1038** and the nut assembly **1040** along the central axis of the push tube assembly **1030**. Accordingly, the lift motor **1034** is configured to selectively actuate the inner push tube **1038** between the extended position and the retracted position. Thus, with the trunnion mount **1045** of the protective outer tube **1036** and the trunnion mount **1048** of the inner

push tube **1038** each rotatably coupled to their respective support members **1025**, the lift motor **1034** is configured to selectively move the scissor lift mechanism **1020** to various heights between and including the retracted or stowed position and the deployed or work position.

(73) In some embodiments, the nut assembly **1040** may be a ball screw nut assembly. In some other embodiments, the nut assembly **1040** may be a roller screw nut assembly. In some yet some other embodiments, the nut assembly **1040** may be any other suitable nut assembly configured to translate the rotational motion of the central screw rod into axial movement of the inner push tube **1038** and the nut assembly **1040**.

(74) When the lift motor **1034** is powered down or discharged, the nut assembly **1040** allows the scissor lift mechanism **1020** to gradually retract due to gravity. As such, the lift motor **1034** includes an electromagnetic brake **1050** configured to maintain the position of the work platform **1022** when the lift motor **1034** is powered down or discharged. In some instances, the electromagnetic brake **1050** is further configured to aid the lift motor **1034** in maintaining the position of the work platform **1022** during normal operation.

(75) The lift motor **1034** may be an AC motor (e.g., synchronous, asynchronous, etc.) or a DC motor (shunt, permanent magnet, series, etc.). In some instances, the lift motor **1034** is in communication with and powered by the battery **1016**. In some other instances, the lift motor **1034** may receive electrical power from another electricity source on board the vehicle **1010**.

(76) In some embodiments, the linear actuator **1026** includes various built-in sensors configured to monitor various actuator/motor characteristics. For example, the linear actuator **1026** may include a motor speed sensor, a motor torque sensor (e.g., a motor current sensor), various temperature sensors, various vibration sensors, etc. The lift controller **1028** may then be in communication with each of these sensors, and may use real-time information received/measured by the sensors to determine a load held by the work platform **1022**.

(77) In some embodiments, to determine the load held by the work platform **1022**, the lift controller **1028** may temporarily disengage the electromagnetic brake **1050** and maintain the height of the work platform **1022** using the lift motor **1034**. As alluded to above, in some instances, the electromagnetic brake **1050** is configured to aid the lift motor in maintaining the position of the work platform **1022** during normal operation. By disengaging the electromagnetic brake **1050**, the full load on the work platform **1022** must be supported using the lift motor **1034**. With the full load on the work platform **1022** being supported by the lift motor **1034**, the lift controller **1028** may then determine, based on the various actuator/motor characteristics, the load on the work platform **1022**. In some instances, the electromagnetic brake **1050** may be disengaged for less than five seconds. In some instances, the electromagnetic brake **1050** may be disengaged for less than one second.

(78) For example, referring now to FIG. **18**, a flow chart is provided, showing an exemplary method of determining the load on the work platform **1022**. As depicted, the lift controller **1028** may first disengage the electromagnetic brake **1050**, at step **1200**. The lift controller **1028** may then maintain the height of the work platform **1022** using the lift motor **1034**, at step **1202**.

(79) With the electromagnetic brake **1050** disengaged and the lift motor **1034** maintaining the height of the work platform **1022**, the lift controller **1028** may determine the applied motor torque output by the lift motor **1034**, at step **1204**, using a combination of the measured motor current of the lift motor **1034**, the measured motor slip of the lift motor **1034**, and various other motor characteristics associated with the lift motor **1034** (e.g., motor type, winding density of a coil of the lift motor **1034**, winding material of the coil of the lift motor **1034**, etc.). The lift controller **1028** may then use the applied motor torque and a model of the mechanics of the linear actuator **1026** to determine an actuator force applied by the linear actuator **1026** on the scissor lift mechanism **1020**, at step **1206**.

(80) Before, during, or after determining the actuator force applied by the linear actuator **1026**, the lift controller **1028** may determine a height of the work platform **1022**, at step **1208**, using the lift angle sensed by the scissor angle sensor **1029** and a model of the mechanics of the scissor lift

mechanism **1020**. The lift controller **1028** may then determine the load supported by the work platform **1022**, at step **1210**, using the applied actuator force, the platform height, and a height-force curve for the scissor lift mechanism **1020**.

(81) In some exemplary embodiments, a strain gauge **1052** (shown in FIG. **17**) may be coupled to the inner push tube **1038** to monitor a compression of the inner push tube **1038** during operation (e.g., along the axial length of the inner push tube). The lift controller **1028** may be in communication with the strain gauge **1052**. Accordingly, the lift controller **1028** may additionally or alternatively use the monitored compression of the inner push tube **1038**, various dimensional characteristics of the inner push tube **1038** (e.g., length, diameter, thickness, etc.), and the material properties of the inner push tube **1038** (e.g., Young's modulus) to determine the load supported by the inner push tube **1038**, and thereby the load supported by the work platform **1022**.

(82) In some embodiments, the lift controller **1028** may be configured to limit or scale the lifting functions of the scissor lift mechanism **1020** based on the determined load supported by the work platform **1022**. For example, in some instances, the lift controller **1028** may limit or scale the lifting functions when the load supported by the work platform is between 100% and 120% of a rated capacity of the vehicle **1010**. For example, between 100% and 120% of the rated capacity, the lift speed (raising or lowering) of the linear actuator **1026** may be reduced (e.g., 20%, 50%, 75% of normal operation speed).

(83) Referring again to FIGS. **12**A and **12**B, the battery **1016** can also supply electrical power to a drive motor **1054** to propel the vehicle **1010**. The drive motor **1054** may similarly be an AC motor (e.g., synchronous, asynchronous, etc.) or a DC motor (shunt, permanent magnet, series, etc.) for example, which receives electrical power from the battery **1016** or another electricity source on board the vehicle **1010** and converts the electrical power into rotational energy in a drive shaft. The drive shaft can be used to drive the wheels **1014**A, **1014**B of the vehicle **1010** using a transmission. The transmission can receive torque from the drive shaft and subsequently transmit the received torque to a rear axle **1056** of the vehicle **1010**. Rotating the rear axle **1056** also rotates the rear wheels **1014**A on the vehicle **1010**, which propels the vehicle **1010**.

(84) The rear wheels **1014**A of the vehicle **1010** can be used to drive the vehicle, while the front wheels **1014**B can be used to steer the vehicle **1010**. In some embodiments, the rear wheels **1014**A are rigidly coupled to the rear axle **1056**, and are held in a constant orientation relative to the base **1012** of the vehicle **1010** (e.g., approximately aligned with an outer perimeter **1058** of the vehicle **1010**). In contrast, the front wheels **1014**B are pivotally coupled to the base **1012** of the vehicle **1010**. The wheels **1014**B can be rotated relative to the base **1012** to adjust a direction of travel for the vehicle **1010**. Specifically, the front wheels **1014**B can be oriented using an electrical steering system **1060**. In some embodiments, the steering system **1060** may be completely electrical in nature, and may not include any form of hydraulics.

(85) It should be appreciated that, while the retractable lift mechanism included on vehicle **1010** is a scissor lift mechanism, in some instances, a vehicle may be provided that alternatively includes a retractable lift mechanism in the form of a boom lift mechanism. For example, in the exemplary embodiment depicted in FIG. **19**, a vehicle, shown as vehicle **1310**, is illustrated. The vehicle **1310** includes a retractable lift mechanism, shown as boom lift mechanism **1320**. The boom lift mechanism **1320** is similarly formed of a foldable series of linked support members **1325**. The boom lift mechanism **1320** is selectively movable between a retracted or stowed position and a deployed or work position using a plurality of actuators **1326**. Each of the plurality of actuators **1326** is a linear actuator similar to the linear actuator **1026**.

(86) It should be further appreciated that the linear actuators **1026**, **1326** used in the lift mechanisms **1020**, **1320**, as well as in the steering system **1060**, may be incorporated into nearly any type of electric vehicle. For example, the electric systems described herein can be incorporated into, for example, a scissor lift, an articulated boom, a telescopic boom, or any other type of aerial work platform.

(87) Advantageously, vehicles **1010**, **1310** may be fully-electric lift devices. All of the electric actuators and electric motors of vehicles **1010**, **1310** can be configured to perform their respective operations without requiring any hydraulic systems, hydraulic reservoir tanks, hydraulic fluids, engine systems, etc. That is, both vehicles **1010**, **1310** may be completely devoid of any hydraulic systems and/or hydraulic fluids generally. Said differently, both vehicles **1010**, **1310** may be devoid of any moving fluids. Traditional lift device vehicles do not use a fully-electric system and require regular maintenance to ensure that the various hydraulic systems are operating properly. As such, the vehicles **1010**, **1310** may use electric motors and electric actuators, which allows for the absence of combustible fuels (e.g., gasoline, diesel) and/or hydraulic fluids. As such, the vehicles **1010**, **1310** may be powered by batteries, such as battery **1016**, that can be re-charged when necessary.

(88) Although this description may discuss a specific order of method steps, the order of the steps may differ from what is outlined. Also two or more steps may be performed concurrently or with partial concurrence. Such variation will depend on the software and hardware systems chosen and on designer choice. All such variations are within the scope of the disclosure. Likewise, software implementations could be accomplished with standard programming techniques with rule-based logic and other logic to accomplish the various connection steps, processing steps, comparison steps, and decision steps.

(89) As utilized herein, the terms "approximately", "about", "substantially", and similar terms are intended to have a broad meaning in harmony with the common and accepted usage by those of ordinary skill in the art to which the subject matter of this disclosure pertains. It should be understood by those of skill in the art who review this disclosure that these terms are intended to allow a description of certain features described and claimed without restricting the scope of these features to the precise numerical ranges provided. Accordingly, these terms should be interpreted as indicating that insubstantial or inconsequential modifications or alterations of the subject matter described and claimed are considered to be within the scope of the invention as recited in the appended claims.

(90) It should be noted that the term "exemplary" as used herein to describe various embodiments is intended to indicate that such embodiments are possible examples, representations, and/or illustrations of possible embodiments (and such term is not intended to connote that such embodiments are necessarily extraordinary or superlative examples).

(91) The terms "coupled," "connected," and the like, as used herein, mean the joining of two members directly or indirectly to one another. Such joining may be stationary (e.g., permanent, etc.) or moveable (e.g., removable, releasable, etc.). Such joining may be achieved with the two members or the two members and any additional intermediate members being integrally formed as a single unitary body with one another or with the two members or the two members and any additional intermediate members being attached to one another.

(92) References herein to the positions of elements (e.g., "top," "bottom," "above," "below," "between," etc.) are merely used to describe the orientation of various elements in the figures. It should be noted that the orientation of various elements may differ according to other exemplary embodiments, and that such variations are intended to be encompassed by the present disclosure.

(93) The hardware and data processing components used to implement the various processes, operations, illustrative logics, logical blocks, modules and circuits described in connection with the embodiments disclosed herein may be implemented or performed with a general purpose single- or multi-chip processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA), or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general purpose processor may be a microprocessor, or, any conventional processor, or state machine. A processor also may be implemented as a combination of computing devices, such as a combination of a DSP and a microprocessor, a

plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration. The memory (e.g., memory, memory unit, storage device) may include one or more devices (e.g., RAM, ROM, Flash memory, hard disk storage) for storing data and/or computer code for completing or facilitating the various processes, layers and modules described in the present disclosure. The memory may be or include volatile memory or non-volatile memory, and may include database components, object code components, script components, or any other type of information structure for supporting the various activities and information structures described in the present disclosure. According to an exemplary embodiment, the memory is coupled to the processor to form a processing circuit and includes computer code for executing (e.g., by the processor) the one or more processes described herein.

(94) It is important to note that the construction and arrangement of the electromechanical variable transmission as shown in the exemplary embodiments is illustrative only. Although only a few embodiments of the present disclosure have been described in detail, those skilled in the art who review this disclosure will readily appreciate that many modifications are possible (e.g., variations in sizes, dimensions, structures, shapes and proportions of the various elements, values of parameters, mounting arrangements, use of materials, colors, orientations, etc.) without materially departing from the novel teachings and advantages of the subject matter recited. For example, elements shown as integrally formed may be constructed of multiple parts or elements. It should be noted that the elements and/or assemblies of the components described herein may be constructed from any of a wide variety of materials that provide sufficient strength or durability, in any of a wide variety of colors, textures, and combinations. Accordingly, all such modifications are intended to be included within the scope of the present inventions. Other substitutions, modifications, changes, and omissions may be made in the design, operating conditions, and arrangement of the preferred and other exemplary embodiments without departing from scope of the present disclosure or from the spirit of the appended claims.

Claims

1. A fully-electric lift device, comprising: a base having a plurality of wheels; a retractable lift mechanism having a first end coupled to the base and being moveable between an extended position and a retracted position; a work platform configured to support a load, the work platform coupled to and supported by a second end of the retractable lift mechanism; an electric linear actuator configured to selectively move the retractable lift mechanism between the extended position and the retracted position, the electric linear actuator including an electric motor; and a controller in communication with the electric motor and configured to: receive a lift command; monitor a required torque for the electric motor based on the lift command; monitor a required drive power efficiency associated with the electric linear actuator; and selectively inhibit the lift command based on the at least one of the required torque or the required drive power efficiency.

2. The fully-electric lift device of claim 1, wherein the electric linear actuator includes a screw rod coupled to the electric motor and a nut assembly coupled to the screw rod.

3. The fully-electric lift device of claim 2, wherein the nut assembly includes a ball screw nut.

4. The fully-electric lift device of claim 3, wherein the nut assembly further includes a backup jam nut.

5. The fully-electric lift device of claim 3, wherein the controller is further configured to inhibit the lift command upon determining that the ball screw nut is not engaged.

6. The fully-electric lift device of claim 1, wherein the lift command is a descend command, and wherein, upon determining that the required torque is greater than an allowed torque, the controller is configured to provide an alert.

7. The fully-electric lift device of claim 1, wherein the lift command is an ascend command, and wherein, upon determining that the required torque is greater than an allowed torque, the controller

is configured to inhibit the lift command.

8. The fully-electric lift device of claim 7, wherein, upon determining that the required torque is less than the allowed torque, the controller is configured to allow the lift command.

9. A fully-electric lift device, comprising: a base having a plurality of wheels; a retractable lift mechanism having a first end coupled to the base and being moveable between an extended position and a retracted position; a work platform configured to support a load, the work platform coupled to and supported by a second end of the retractable lift mechanism; an electric linear actuator configured to selectively move the retractable lift mechanism between the extended position and the retracted position; and a controller in communication with the electric linear actuator and configured to: receive a lift command; monitor a drive power efficiency associated with the electric linear actuator; determine an allowable range for the drive power efficiency; and selectively inhibit, based on the drive power efficiency being outside of the allowable range, the lift command.

10. The fully-electric lift device of claim 9, wherein the electric linear actuator includes a screw rod coupled to an electric motor and a nut assembly coupled to the screw rod.

11. The fully-electric lift device of claim 10, wherein the nut assembly includes a ball screw nut.

12. The fully-electric lift device of claim 11, wherein the nut assembly further includes a backup jam nut.

13. The fully-electric lift device of claim 11, wherein the controller is further configured to inhibit the lift command upon determining that the ball screw nut is not engaged.

14. The fully-electric lift device of claim 9, wherein the lift command is a descend command, and wherein, upon determining that the drive power efficiency is outside of the allowable range, the controller is configured to provide an alert.

15. The fully-electric lift device of claim 9, wherein the lift command is an ascend command, and wherein, upon determining that the drive power efficiency is outside of the allowable range, the controller is configured to inhibit the lift command.

16. The fully-electric lift device of claim 15, wherein, upon determining that the drive power efficiency is within the allowable range, the controller is configured to allow the lift command.

17. A method for controlling a fully-electric lift device, the method comprising: receiving a lift command to ascend a work platform or descend the work platform; monitor, based on the lift command, a required torque for an electric linear actuator associated with ascending or descending the work platform; monitoring a drive power efficiency associated with the electric linear actuator; determining if the required torque is greater than an allowed torque; upon determining that the required torque is greater than an allowed torque, inhibiting the lift command; and upon determining that the required torque is less than the allowed torque, allowing the lift command.

18. The method of claim 17, further comprising: determining an allowable range for the drive power efficiency.

19. The method of claim 18, further comprising: inhibiting, based on the drive power efficiency being outside of the allowable range, the lift command.