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Electric boom

Abstract

A fully electric lift device includes a base assembly, a lift assembly, a platform assembly, tractive elements, an energy storage device, and a control system. The lift assembly is coupled with the base assembly and is driven by an electric linear actuator for a lifting function. The platform assembly is positioned at a top of the lift assembly and can be raised or lowered as the lift assembly performs the lifting function. The tractive elements are rotatably coupled with the base assembly and can be driven by an electric wheel motor to perform a driving function. The control system includes a controller that operates the electric wheel motor and the electric linear actuator to perform the driving function and the lifting function using power drawn from the energy storage device. The lift assembly and the tractive elements use only electrical energy to perform the lifting and driving functions.

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Background/Summary

CROSS-REFERENCE TO RELATED PATENT APPLICATIONS (1) This application is a continuation of U.S. application Ser. No. 17/881,322, filed Aug. 4, 2022, which is a continuation of U.S. application Ser. No. 16/811,180, filed Mar. 6, 2020, now U.S. Pat. No. 11,492,239 which claims the benefit of and priority to U.S. Provisional Patent Application No. 62/829,919, filed Apr. 5, 2019, U.S. Provisional Patent Application No. 62/829,972, filed Apr. 5, 2019, U.S. Provisional Patent Application No. 62/829,960, filed Apr. 5, 2019, U.S. Provisional Patent Application No. 62/830,128, filed Apr. 5, 2019, and U.S. Provisional Patent Application No. 62/829,976, filed Apr. 5, 2019, the entire disclosures of which are incorporated by reference herein.

BACKGROUND
(1) The present disclosure relates to boom lifting devices. More particularly, the present disclosure relates to electrical systems used in boom lifting devices.
SUMMARY
(2) One implementation of the present disclosure is a fully electric boom lift, according to an exemplary embodiment. The fully electric boom lift includes a base assembly, a lift assembly, a platform assembly, multiple tractive elements, and a control system. The base assembly includes a base and a fully electric turntable configured to be driven to rotate relative to the base by an electric turntable motor. The lift assembly is coupled with the turntable. The lift assembly includes multiple articulated arms configured to be driven to increase and decrease in height by multiple electric linear actuators. The platform assembly is disposed at a top of the lift assembly and is configured to be raised and lowered as the lift assembly increases or decreases in height. The multiple tractive elements are rotatably coupled with the base assembly and configured to be driven by an electric wheel motor. The control system includes a controller and an energy storage device, wherein the controller is configured to operate the electric turntable motor, the plurality of electric linear actuators, and the electric wheel motor, the electric turntable motor, the plurality of electric linear actuators, and the electric wheel motor configured to consume electrical power from the energy storage device.
(3) The fully electric boom lift can further include a steering system. The steering system is configured to drive the multiple tractive elements to pivot to indicate a turn of the fully electric boom.
(4) The steering system may include a linear electric steering actuator, and a steering knuckle. The linear electric steering actuator is pivotally coupled to the base at a first end, and fixedly coupled with an arcuate steering member at a second end. The steering knuckle is rotatably coupled with one of the multiple tractive elements and pivotally coupled with the base. The arcuate steering member is pivotally coupled with the steering knuckle and is configured to drive the steering

knuckle to pivot as the linear electric steering actuator extends and retracts. The arcuate steering member is shaped to provide clearance for a portion of the base as the linear electric steering actuator extends and retracts.

(5) The controller can be configured to operate the electric wheel motors and the linear electric steering actuator to drive and steer the fully electric boom lift for transportation of the fully electric boom lift.

(6) The fully electric turntable may include a ring gear, a reduction gear box, and an electric brake. The ring gear is rotatably coupled with the base through a slewing bearing. The ring gear is fixedly coupled with the lift assembly. The reduction gear box is configured to receive output rotational kinetic energy from the electric turntable motor and output rotational kinetic energy at an output torque to the ring gear to rotate the ring gear and the lift assembly relative to the base. The output torque is greater than the motor torque. The electric brake is configured to limit rotation of the ring gear when activated in response to receiving a control signal from the controller.

(7) The fully electric boom lift may also include a platform rotator configured to pivot the platform assembly relative to the lift assembly. The platform rotator includes a barrel, a structural support member, an electric platform rotator motor, and an electric brake. The barrel is fixedly coupled with the platform assembly. The structural support member is fixedly coupled with the lift assembly and rotatably coupled with the barrel. The electric platform rotator motor is configured to drive a gear box using electrical energy provided by the energy storage device. The electric brake is configured to activate to prevent relative rotation between the barrel and the structural support member. The electric brake is configured to receive electrical energy from the energy storage device and control signals from the controller and activate in response to receiving the control signals from the controller. The gear box is configured to receive a rotational input from the motor and provide a rotational output to rotate the barrel and the platform assembly relative to the structural support member that fixedly couples with the lift assembly.

(8) The lift assembly can include multiple lower members, multiple upper members, a jib arm, and an electric linear actuator. The multiple lower members pivotally couple at their first ends with the fully electric turntable and pivotally couple at their opposite ends with a first upright member. The multiple upper members pivotally couple at their first ends with the first upright member, and pivotally couple at their opposite ends with a second upright member. The jib arm is pivotally coupled at a first end with the second upright member and coupled at an opposite end with the platform assembly. The electric linear actuator is pivotally coupled at a first end with one of the lower members and pivotally coupled through a trunnion mount with one of the upper members. The electric linear actuator is configured to extend or retract to drive the one or more upper members to pivot relative to the first upright member. The electric linear actuator is configured to receive power from the energy storage device and control signals from the controller to operate to extend or retract to raise or lower the lift assembly.

(9) The trunnion mount can include a collar, and a pair of protrusions. The collar is configured to clamp with an outer periphery of the electric linear actuator. The pair of protrusions extend outwards from opposite sides of the collar and pivotally couple with the upper members.

(10) The base assembly further includes a laterally extending frame member, and multiple lockout electric linear actuators. The laterally extending frame member is pivotally coupled with the base. The base is configured to rotate about a longitudinal axis relative to the laterally extending frame member. The multiple lockout electric linear actuators are coupled to at least one of the laterally extending frame member or the base and configured to consume electrical energy supplied by the energy storage device to extend and retract. In a first mode of operation, the controller is configured to control the lockout electric linear actuators to permit rotation of the base relative to the laterally extending frame member through a first range of motion. In a second mode of operation, the controller is configured to control the lockout electric linear actuators to limit rotation of the base relative to the laterally extending frame member to a second range of motion

smaller than the first range of motion. The lockout electric linear actuator includes a body slidably coupled to a rod and an electric lockout motor that controls movement of the rod relative to the body. In the second mode of operation, the controller is configured to control the electric lockout motor to extend the electric linear actuator until the lockout electric linear actuator engages the laterally extending frame member.
(11) The electric linear actuator includes a motor controller configured to monitor a flow of electrical energy supplied to the electric motor. The controller is configured to determine that the electric linear actuator has engaged the laterally extending frame member when a current supplied to the electric motor exceeds a threshold current.
(12) Another implementation of the present disclosure is a fully electric lift device, according to an exemplary embodiment. The fully electric lift device includes a base assembly, a lift assembly, a platform assembly, multiple tractive elements, an energy storage device, and a control system. The lift assembly is coupled with the base assembly and configured to be driven by an electric linear actuator to perform a lifting function. The platform assembly is positioned at a top of the lift assembly and is configured to be raised or lowered as the lift assembly performs the lifting function. The multiple tractive elements are rotatably coupled with the base assembly and configured to be driven by an electric wheel motor to perform a driving function. The control system includes a controller configured to operate the electric wheel motor and the electric linear actuator to perform the driving function and the lifting function using power drawn from the energy storage device. The lift assembly and the multiple tractive elements use only electrical energy as a power source to perform the lifting function and the driving function.
(13) The fully electric lift device can be a fully electric telehandler or a fully electric boom lift.
(14) The fully electric lift device can further include a steering system. The steering system is configured to drive the multiple tractive elements to pivot to indicate a turn of the fully electric lift device. The steering system includes a linear electric steering actuator, and a steering knuckle. The linear electric steering actuator is pivotally coupled to the base at a first end, and fixedly coupled with an arcuate steering member at a second end. The steering knuckle is rotatably coupled with one of the multiple tractive elements and pivotally coupled with the base. The arcuate steering member is pivotally coupled with the steering knuckle and is configured to drive the steering knuckle to pivot as the linear electric steering actuator extends and retracts. The arcuate steering member is shaped to provide clearance for a portion of the base as the linear electric steering actuator extends and retracts.
(15) The base assembly may include a base and a fully electric turntable configured to be driven to rotate relative to the base by an electric turntable motor. The fully electric turntable can include a ring gear, a reduction gear box, and an electric brake. The ring gear is rotatably coupled with the base through a slewing bearing. The ring gear fixedly coupled with the lift assembly. The reduction gear box is configured to receive output rotational kinetic energy from the electric turntable motor and output rotational kinetic energy at an output torque to the ring gear to rotate the ring gear and the lift assembly relative to the base. The output torque is greater than the motor torque. The electric brake is configured to limit rotation of the ring gear when activated in response to receiving a control signal.
(16) The fully electric lift device may further include a platform rotator configured to pivot the platform assembly relative to the lift assembly. The platform rotator includes a barrel, a structural support member, an electric platform rotator motor, and an electric motor. The barrel is fixedly coupled with the platform assembly. The structural support member is fixedly coupled with the lift assembly and rotatably coupled with the barrel. The electric platform rotator motor is configured to drive a gear box using electrical energy provided by the energy storage device. The electric brake is configured to activate to prevent relative rotation between the barrel and the structural support member. The electric brake is configured to receive electrical energy from the energy storage device and control signals from the controller and activate in response to receiving the control

signals from the controller. The gear box is configured to receive a rotational input from the motor and provide a rotational output to rotate the barrel and the platform assembly relative to the structural support member that fixedly couples with the lift assembly.
(17) The base assembly can further include a laterally extending frame member, and multiple lockout electric linear actuators. The laterally extending frame member is pivotally coupled with the base. The base is configured to rotate about a longitudinal axis relative to the laterally extending frame member. The multiple lockout electric linear actuators are coupled with at least one of the laterally extending frame member or the base and are configured to consume electrical energy supplied by the energy storage device to extend and retract. In a first mode of operation, the controller is configured to control the lockout electric linear actuators to permit rotation of the base relative to the laterally extending frame member through a first range of motion. In a second mode of operation, the controller is configured to control the lockout electric linear actuators to limit rotation of the base relative to the laterally extending frame member to a second range of motion smaller than the first range of motion. The lockout electric linear actuator includes a body slidably coupled to a rod and an electric lockout motor that controls movement of the rod relative to the body. In the second mode of operation, the controller is configured to control the electric lockout motor to extend the electric linear actuator until the lockout electric linear actuator engages the laterally extending frame member.
(18) Another implementation of the present disclosure is a fully electric lift device, according to an exemplary embodiment. The fully electric lift device includes a base, a lift apparatus, an energy storage device, and a controller. The lift apparatus is coupled with the base assembly and includes multiple lower members, multiple upper members, and an electric linear actuator. The multiple lower members are pivotally coupled at their first ends with the base and pivotally coupled at their opposite ends with a first upright member. The multiple upper members are pivotally coupled at their first ends with the first upright member and at their opposite ends with a second upright member. The electric linear actuator is configured to extend or retract to raise or lower the lift apparatus. The energy storage device is configured to provide electrical energy to the electric linear actuator. The controller is configured to operate the electric linear actuator to raise or lower the lift apparatus.
(19) The multiple lower members, the base, and the first upright member form a first four-bar linkage. The multiple upper members, the first upright member, and the second upright member form a second four-bar linkage. The first upright member and the second upright member maintain a particular orientation as the lift apparatus is raise or lowered.
(20) The electric linear actuator is pivotally coupled at a lower end with one of the lower members and pivotally coupled with one of the upper members through a trunnion mount.
(21) The trunnion mount can include a collar, and a pair of protrusions. The collar is configured to clamp with an outer periphery of the electric linear actuator. The pair of protrusions extend outwards from opposite sides of the collar and pivotally couple with the upper members.
(22) 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 DRAWINGS
(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** is a perspective view of a fully electric boom, according to an exemplary embodiment.

(3) FIG. **2** is a perspective view of a portion of a base assembly of the fully electric boom of FIG. **1**, according to an exemplary embodiment.
(4) FIG. **3** is a perspective view of a portion of a base assembly of the fully electric boom of FIG. **1**, according to an exemplary embodiment.
(5) FIG. **4** is a perspective view of a steering system of the fully electric boom of FIG. **1**, according to an exemplary embodiment.
(6) FIG. **5** is a perspective view of the steering system of the fully electric boom of FIG. **1**, according to an exemplary embodiment.
(7) FIG. **6** is a perspective view of the steering system of the fully electric boom of FIG. **1**, according to an exemplary embodiment.
(8) FIG. **7** is a perspective view of a portion of the steering system of the fully electric boom of FIG. **1**, according to an exemplary embodiment.
(9) FIG. **8** is a perspective view of a portion of the steering system of the fully electric boom of FIG. **1**, according to an exemplary embodiment.
(10) FIG. **9** is a perspective view of a portion of the steering system of the fully electric boom of FIG. **1**, according to an exemplary embodiment.
(11) FIG. **10** is a perspective view of a portion of the steering system of the fully electric boom of FIG. **1**, according to an exemplary embodiment.
(12) FIG. **11** is a top view of the steering system of the fully electric boom of FIG. **1**, according to an exemplary embodiment.
(13) FIG. **12** is a front view of the steering system of the fully electric boom of FIG. **1**, according to an exemplary embodiment.
(14) FIG. **13** is a perspective view of a turntable of the fully electric boom of FIG. **1** including an electric turntable motor, a gear box, a transmission, and a ring gear, according to an exemplary embodiment.
(15) FIG. **14** is a side view of a gear interface between an output shaft of the gear box and the ring gear of the turntable of FIG. **14**, according to an exemplary embodiment.
(16) FIG. **15** is a side view of a gear interface between an output shaft of the gear box and the ring gear of the turntable of FIG. **14**, according to an exemplary embodiment.
(17) FIG. **16** is a side view of a gear interface between an output shaft of the gear box and the ring gear of the turntable of FIG. **14**, according to an exemplary embodiment.
(18) FIG. **17** is a perspective view of a lift assembly of the fully electric boom of FIG. **1**, according to an exemplary embodiment.
(19) FIG. **18** is a perspective view of a platform rotator of the fully electric boom of FIG. **1**, according to an exemplary embodiment.
(20) FIG. **19** is a perspective view of the platform rotator of FIG. **18**.
(21) FIG. **20** is a perspective view of the platform rotator of FIG. **18**.
(22) FIG. **21** is a side view of the platform rotator of FIG. **18**.
(23) FIG. **22** is a top view of the platform rotator of FIG. **18**.
(24) FIG. **23** is a top view of the platform rotator of FIG. **18**.
(25) FIG. **24** is a diagram of a side view of a boom arm of the fully electric boom of FIG. **1**, according to an exemplary embodiment.
(26) FIG. **25** is a perspective view of the boom arm of the fully electric boom of FIG. **1**, according to an exemplary embodiment.
(27) FIG. **26** is a perspective view of a portion of the boom arm of the fully electric boom of FIG. **1**, according to an exemplary embodiment.
(28) FIG. **27** is a perspective view of a portion of the boom arm of the fully electric boom of FIG. **1**, according to an exemplary embodiment.
(29) FIG. **28** is a perspective view of a trunnion mount of an electric linear actuator of the boom arm of FIG. **24**, according to an exemplary embodiment.

(30) FIG. **29** is a perspective view of a trunnion mount of an electric linear actuator of the boom arm of FIG. **24**, according to an exemplary embodiment.
(31) FIG. **30** is a sectional view of the trunnion mount of the electric linear actuator of FIGS. **26-29**, according to an exemplary embodiment.
(32) FIG. **31** is a perspective view of the trunnion mount of FIG. **29**.
(33) FIG. **32** is a perspective view of a jib arm of the fully electric boom of FIG. **1**, according to an exemplary embodiment.
(34) FIG. **33** is a perspective view of the electric linear actuator of FIGS. **28-29** and **31**, according to an exemplary embodiment.
(35) FIG. **34** is a perspective view of the electric linear actuator of FIGS. **28-29** and **31**, according to an exemplary embodiment.
(36) FIG. **35** is a perspective view of an electric linear actuator that drives the jib arm of FIG. **32**, according to an exemplary embodiment.
(37) FIG. **36** is a perspective view of the electric linear actuator of FIGS. **28-29**.
(38) FIG. **37** is a perspective view of an axle actuator of the fully electric boom of FIG. **1**, according to an exemplary embodiment.
(39) FIG. **38** is a front view of the base assembly of FIG. **2**, according to an exemplary embodiment.
(40) FIG. **39** is a front view of the base assembly of FIG. **2**, according to an exemplary embodiment.
(41) FIG. **40** is a front view of the base assembly of FIG. **2**, according to an exemplary embodiment.
(42) FIG. **41** is a front view of an axle actuator of a fully electric boom, according to an exemplary embodiment.
(43) FIG. **42** is a front view of an axle actuator of a fully electric boom, according to an exemplary embodiment.
(44) FIG. **43** is a front view of a base assembly of a fully electric boom including an axle lock out assembly, according to an exemplary embodiment.
(45) FIG. **44** is a front view of a base assembly of a fully electric boom including an axle lock out assembly, according to an exemplary embodiment.
(46) FIG. **45** is a front view of a base assembly of a fully electric boom including an axle lock out assembly, according to an exemplary embodiment.
(47) FIG. **46** is a block diagram of a control system for operating a fully electric boom, according to an exemplary embodiment.

DETAILED DESCRIPTION

(48) 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.
(49) Overview
(50) Referring generally to the FIGURES, a fully electric boom is shown, according to various exemplary embodiments. The fully electric boom includes a platform assembly, a lift assembly, and a base assembly. The base assembly supports the lift assembly and the platform assembly. The platform assembly is positioned at a top end of the lift assembly. The lift assembly can include one or more articulated arms that are hingedly coupled with each other. The one or more articulated arms are configured to be driven to pivot by electric linear actuators. As the articulated arms pivot, the lift assembly increases or decreases in height, thereby raising and lowering the platform assembly.
(51) The base assembly include a turn table and a base. The turn table is rotatably coupled with the base. The lift assembly is rotatably coupled with the turn table. The turn table is driven to rotate

relative to the base assembly by an electric turn table motor. The base assembly also includes one or more tractive elements. The tractive elements each include an electric motor configured to drive the corresponding tractive element. The tractive elements can be independently driven by the corresponding electric motor. The base assembly includes a steering system. The steering system includes an electric linear actuator that extends and retracts. An end of a rod of the electric linear actuator is fixedly coupled with an end of one or more arcuate/curved steering members. The one or more arcuate/curved steering members are pivotally coupled with a steering knuckle of the tractive element. An end of the housing of the electric linear actuator is pivotally/rotatably coupled with the base. The electric linear actuator can be extended or retracted to pivot the corresponding tractive element for a turn.

(52) The electric turntable motor is rotatably coupled with a gear box. The gear box receives rotational kinetic energy from the electric turntable motor and outputs rotational kinetic energy with a higher torque. Depending on the orientation/configuration of the electric turntable motor and the gear box, a transmission can be used to transfer the rotational kinetic energy into an axis that is substantially parallel to an axis that a ring gear of the turntable rotates about (e.g., using bevel gears). In other embodiments, the transmission or the gear box includes a worm and the ring gear is a worm gear.

(53) The fully electric boom can include energy storage devices (e.g., batteries). Any of the motors, electric linear actuators, etc., of the fully electric boom can receive electrical power from the energy storage devices. A controller is configured to receive user inputs from one or more human machine interfaces and operate any of the motors, electric linear actuators, etc., of the fully electric boom. The controller may generate control signals for any of the electric motors, electric linear actuators, etc. The controller can also monitor feedback (e.g., voltage feedback, current feedback, etc.) from any of the electric linear actuators, electric motors, etc.

(54) The fully electric boom can include a boom arm and a jib arm. The boom arm is configured to lower and raise by one or more electric linear actuators. The jib arm is coupled to an end of the boom arm and is configured to rotate and pivot the platform assembly. The jib arm includes a platform rotator that pivotally couples the platform assembly with the jib arm.

(55) The platform rotator pivotally couples the platform assembly with the jib arm. The platform rotator can include a barrel formed by two portions that couple with the platform assembly. The barrel can fixedly couple with one or more structural support members that protrude outwards from the platform assembly.

(56) The barrel is supported on either side (e.g., an upper side and a lower side) by structural support members that extend from the end of the jib arm. The barrel can slidably interface with the structural support members. The barrel and the structural support members are configured to rotatably or pivotally couple with each other.

(57) The platform rotator includes an electric motor, a brake, and one or more gear boxes. The electric motor is configured to drive the one or more gear boxes to pivot the barrel relative to the structural support members that support the barrel. The one or more gear boxes can be reduction gear boxes that increase the output torque provided to the barrel. The brake can be an electric brake that transitions between an activated state and a deactivated state. When in the activated state, the brake facilitates restricting relative rotation between the barrel and the structural support members that support the barrel.

(58) The electric motor and the brake of the platform rotator can receive electrical energy from the batteries of the electric boom. The electric motor and the brake can be operated by a controller in response to the controller receiving a user input from a human machine interface. The controller can operate the electric motor to pivot/rotate the platform assembly in either direction. The controller may transition the brake into the activated state to facilitate locking a current angular position of the platform assembly.

(59) The fully electric boom can include a boom arm and a jib arm. The boom arm can include

lower members, upper members, and two upright members. The lower members are pivotally coupled with the turntable at a lower end. The lower members are pivotally coupled at an upper end with a first one of the upright members. The upper members are pivotally coupled at a lower end with the first upright member, and pivotally coupled with the second upright member at the upper end. The jib arm is pivotally coupled with the second upright member. The lower members can pivot about the lower end to raise and lower the first upright member. The upper members can pivot about their lower ends to raise and lower the second upright member and the jib arm.
(60) An electric linear actuator is pivotally coupled at a lower end with one of the lower members. The electric linear actuator is mounted with a trunnion mount to one of the upper members at an upper end. The trunnion mount includes a collar that surrounds a cylinder of the electric linear actuator. The collar can be a single-piece clamping collar or a two-piece clamping collar. The collar includes protrusions that extend radially outwards and pivotally couple with apertures of one of the upper members. The trunnion mount facilitates using an electric linear actuator with a longer overall stroke length. The electric linear actuator can be operated to pivot the upper members about their bottom ends, and thereby raise/lower the second upright member.
(61) Another electric linear actuator can be pivotally coupled at a lower end with the turntable and pivotally coupled with one of the lower members with a trunnion mount. The electric linear actuator can be operated to extend and retract to pivot the lower members about their lower ends.
(62) The electric boom further includes an axle lock out system configured to selectively limit rotation of the axle assemblies relative to the chassis. The axle assemblies are configured to rotate relative to the chassis about a longitudinal axis. A pair of electric linear actuators (i.e., axle actuators) are coupled to the chassis on opposites sides of the longitudinal axis. The electric linear actuators extend downward from the chassis to engage the corresponding axle assembly. During a driving mode of operation, the axle actuators permit free rotation of the axle assembly. In some embodiments, during the driving mode, the axle actuators are held in a retracted configuration to permit the axle to rotate through a first range of motion without contacting the axle actuators. In other embodiments, during the driving mode, the axle actuators engage the axle assemblies, but are configured to extend and retract freely (e.g., with minimal resistance) such that the axle assembly can rotate through the first range of motion.
(63) During an operating mode, the axle actuators limit rotation of the axle assemblies to a second range of motion smaller than the first range of motion. In embodiments where the axle actuators are held in the retracted position during the driving mode, the axle actuators are extended until they engage the axle assembly. A controller may determine that the axle actuators have engaged the axle assembly in response to the current supplied to each actuator reaching a threshold current. Once the axle actuators have engaged the axle assembly, the axle actuators may lock to a fixed length. In embodiments where the axle actuators extend and retract freely during the driving mode, the axle actuators may lock to a fixed length in response to entering the operating mode.
(64) Advantageously, the fully electric boom does not use any hydraulic systems, hydraulic pumps, engines, internal combustion engines, etc. to perform the respective functions of the various motors and actuators. All of the motors and actuators are fully electric. Other systems use electric motors to rotate pumps of various hydraulic systems. The fully electric boom facilitates a quieter, more environmentally friendly, more efficient lift device.
(65) Electric Boom
(66) Referring to FIG. **1**, an electric lifting apparatus, an electric telehandler, an electric boom lift, a towable electric boom lift, a lift device, a fully electric boom lift, etc., shown as electric boom **10** includes a base assembly **12** (e.g., a support assembly, a drivable support assembly, a support structure, etc.), a platform assembly **16** (e.g., a platform, a terrace, etc.), and a lift assembly **14** (e.g., a boom lift assembly, a lifting apparatus, an articulated arm, a scissors lift, etc.). If electric boom **10** is a telehandler, platform assembly **16** can be replaced with a fork apparatus, a bucket apparatus, a material lifting apparatus, a mechanical lifting apparatus attachment, etc. Electric

boom **10** includes a front end (e.g., a forward facing end, a front portion, a front, etc.), shown as front **62**, and a rear end (e.g., a rearward facing end, a back portion, a back, a rear, etc.,) shown as rear **60**. Lift assembly **14** is configured to elevate platform assembly **16** in an upwards direction **46** relative to base assembly **12**. Lift assembly **14** is also configured to translate platform assembly **16** in a downwards direction **48**. Lift assembly **14** is also configured to translate platform assembly **16** in either a forwards direction **50** or a rearwards direction **51**. Lift assembly **14** generally facilitates performing a lifting function to raise and lower platform assembly **16**, as well as movement of platform assembly **16** in various directions.

(67) Base assembly **12** defines a longitudinal axis **78** and a lateral axis **80**. Longitudinal axis **78** defines forwards direction **50** of electric boom **10** and rearwards direction **51**. Electric boom **10** is configured to translate in forwards direction **50** and to translate backwards in rearwards direction **51**. Base assembly **12** includes one or more wheels, tires, wheel assemblies, tractive elements, rotary elements, treads, etc., shown as tractive elements **82**. Tractive elements **82** are configured to rotate to drive (e.g., translate, steer, move, etc.) electric boom **10**. Tractive elements **82** can each include an electric motor **52** (e.g., electric wheel motors) configured to drive tractive elements **82** (e.g., to rotate tractive elements **82** to facilitation motion of electric boom **10**). In other embodiments, tractive elements **82** are configured to receive power (e.g., rotational mechanical energy) from electric motors **52** through a drive train (e.g., a combination of any number and configuration of a shaft, an axle, a gear reduction, a gear train, etc.). Tractive elements **82** and electric motors **52** can facilitate a driving and/or steering function of electric boom **10**.

(68) Platform assembly **16** is configured to provide a work area for an operator of electric boom **10** to stand/rest upon. Platform assembly **16** can be pivotally coupled to an upper end of lift assembly **14**. Electric boom **10** is configured to facilitate the operator accessing various elevated areas (e.g., lights, platforms, the sides of buildings, building scaffolding, trees, power lines, etc.). Electric boom **10** uses various electrically powered motors and electrically powered linear actuators to facilitate elevation of platform assembly **16** (e.g., relative to base assembly **12**, or to a ground surface that base assembly **12** rests upon).

(69) Platform assembly **16** includes a base member, a base portion, a platform, a standing surface, a shelf, a work platform, a floor, a deck, etc., shown as deck **18**. Deck **18** provides a space (e.g., a floor surface) for a worker to stand upon as platform assembly **16** is raised and lowered.

(70) Platform assembly **16** includes various members, beams, bars, guard rails, rails, railings, etc., shown as rails **22**. Rails **22** extend along substantially an entire perimeter of deck **18**. Rails **22** provide one or more members for the operator of electric boom **10** to grasp while using electric boom **10** (e.g., to grasp while operating electric boom **10** to elevate platform assembly **16**). Rails **22** can include members that are substantially horizontal to deck **18**. Rails **22** can also include vertical structural members that couple with the substantially horizontal members. The vertical structural members can extend upwards from deck **18**.

(71) Platform assembly **16** can include a human machine interface (HMI) (e.g., a user interface), shown as HMI **20**. HMI **20** is configured to receive user inputs from the operator at platform assembly **16** to facilitate operation of electric boom **10**. HMI **20** can include any number of buttons, levers, switches, keys, etc., or any other user input device configured to receive a user input to operate electric boom **10**. HMI **20** can be supported by one or more of rails **22**.

(72) Platform assembly **16** includes a frame **24** (e.g., structural members, support beams, a body, a structure, etc.) that extends at least partially below deck **18**. Frame **24** can be integrally formed with deck **18**. Frame **24** is configured to provide structural support for deck **18** of platform assembly **16**. Frame **24** can include any number of structural members (e.g., beams, bars, I-beams, etc.) to support deck **18**. Frame **24** couples platform assembly **16** with lift assembly **14**. Frame **24** may rotatably or pivotally coupled with lift assembly **14** to facilitate rotation of platform assembly **16** about an axis **28** (e.g., a centerline). Frame **24** can also rotatably/pivotally couple with lift assembly **14** such that frame **24** and platform assembly **16** can pivot about an axis **25** (e.g., a centerline).

(73) Lift assembly **14** includes one or more beams, articulated arms, bars, booms, arms, support members, boom sections, cantilever beams, etc., shown as lift arms **32**. Lift arms **32** are hingedly or rotatably coupled with each other at their ends. Lift arms **32** can be hingedly or rotatably coupled to facilitate articulation of lift assembly **14** and raising/lowering of platform assembly **16**. Electric boom **10** includes a lower lift arm **32***a*, a central or medial lift arm **32***b*, and an upper lift arm **32***c*. Lower lift arm **32***a* is configured to hingedly or rotatably couple at one end with base assembly **12** to facilitate lifting (e.g., elevation) of platform assembly **16**. Lower lift arm **32***a* is configured to hingedly or rotatably couple at an opposite end with medial lift arm **32***b*. Likewise, medial lift arm **32***b* is configured to hingedly or rotatably couple with upper lift arm **32***c*. Upper lift arm **32***c* can be configured to hingedly interface/couple and/or telescope with an intermediate lift arm **32***d*. Upper lift arm **32***c* can be referred to as “the jib” of electric boom **10**. Intermediate lift arm **32***d* may extend into an inner volume of upper lift arm **32***c* and extend/retract. Lower lift arm **32***a* and medial lift arm **32***b* may be referred to as “the boom” of electric boom **10**. Intermediate lift arm **32***d* can be configured to couple (e.g., rotatably, hingedly, etc.), with platform assembly **16** to facilitate levelling of platform assembly **16**.
(74) Lift arms **32** are driven to hinge or rotate relative to each other by electric actuators **34** (e.g., electric linear actuators, linear electric arm actuators, etc.). Electric actuators **34** can be mounted between adjacent lift arms **32** to drive adjacent lift arms **32** to hinge or pivot (e.g., rotate some angular amount) relative to each other about pivot points **84**. Electric actuators **34** can be mounted between adjacent lift arms **32** using any of a foot bracket, a flange bracket, a clevis bracket, a trunnion bracket, etc. Electric actuators **34** are configured to extend or retract (e.g., increase in overall length, or decrease in overall length) to facilitate pivoting adjacent lift arms **32** to pivot/hinge relative to each other, thereby articulating lift arms **32** and raising or lowering platform assembly **16**.
(75) Electric actuators **34** can be configured to extend (e.g., increase in length) to increase a value of angle **74** formed between adjacent lift arms **32**. Angle **74** can be defined between centerlines of adjacent lift arms **32** (e.g., centerlines that extend substantially through a center of lift arms **32**). For example, electric actuator **34***a* is configured to extend/retract to increase/decrease angle **74***a* defined between a centerline of lower lift arm **32***a* and longitudinal axis **78** (angle **74***a* can also be defined between the centerline of lower lift arm **32***a* and a plane defined by longitudinal axis **78** and lateral axis **80**) and facilitate lifting of platform assembly **16** (e.g., moving platform assembly **16** at least partially along upwards direction **46**). Likewise, electric actuator **34***b* can be configured to retract to decrease angle **74***a* to facilitate lowering of platform assembly **16** (e.g., moving platform assembly **16** at least partially along downwards direction **48**). Similarly, electric actuator **34***b* is configured to extend to increase angle **74***b* defined between centerlines of lower lift arm **32***a* and medial lift arm **32***b* and facilitate elevating of platform assembly **16**. Similarly, electric actuator **34***b* is configured to retract to decrease angle **74***b* to facilitate lowering of platform assembly **16**. Electric actuator **34***c* is similarly configured to extend/retract to increase/decrease angle **74***c*, respectively, to raise/lower platform assembly **16**.
(76) Electric actuators **34** can be mounted (e.g., rotatably coupled, pivotally coupled, etc.) to adjacent lift arms **32** at mounts **40** (e.g., mounting members, mounting portions, attachment members, attachment portions, etc.). Mounts **40** can be positioned at any position along a length of each lift arm **32**. For example, mounts **40** can be positioned at a midpoint of each lift arm **32**, and a lower end of each lift arm **32**.
(77) Intermediate lift arm **32***d* and frame **24** are configured to pivotally interface/couple at a platform rotator **30** (e.g., a rotary actuator, a rotational electric actuator, a gear box, etc.). Platform rotator **30** facilitates rotation of platform assembly **16** about axis **28** relative to intermediate lift arm **32***d*. In some embodiments, platform rotator **30** is between frame **24** and upper lift arm **32***c* and facilitates pivoting of platform assembly **16** relative to upper lift arm **32***c*. Axis **28** extends through a central pivot point of platform rotator **30**. Intermediate lift arm **32***d* is also configured to

extend/retract along upper lift arm **32***c*. Intermediate lift arm **32***d* can also be configured to pivotally/rotatably couple with upper lift arm **32***c* such that intermediate lift arm **32***d* pivots/rotates about axis **25**. Intermediate lift arm **32***d* can be driven to rotate/pivot about axis **25** by extension and retraction of electric actuator **34***d*.

(78) Platform assembly **16** is configured to be driven to pivot about axis **28** (e.g., rotate about axis **28** in either a clockwise or a counter-clockwise direction) by an electric motor **26** (e.g., a rotary electric actuator, a stepper motor, a platform rotator, a platform electric motor, an electric platform rotator motor, etc.). Electric motor **26** can be configured to drive frame **24** to pivot about axis **28** relative to upper lift arm **32***c* (or relative to intermediate lift arm **32***d*). Electric motor **26** can be configured to drive a gear train to pivot platform assembly **16** about axis **28**.

(79) Lift assembly **14** is configured to pivotally or rotatably couple with base assembly **12**. Base assembly **12** include a rotatable base member, a rotatable platform member, a fully electric turntable, etc., shown as turntable **70**. Lift assembly **14** is configured to rotatably/pivotally couple with base assembly **12**. Turntable **70** is rotatably coupled with a base, frame, structural support member, carriage, etc., of base assembly **12**, shown as base **36**. Turntable **70** is configured to rotate or pivot relative to base **36**. Turntable **70** can pivot/rotate about central axis **42** relative to base **36**. Turntable **70** facilitates accessing various elevated and angularly offset locations at platform assembly **16**. Turntable **70** is configured to be driven to rotate or pivot relative to base **36** by an electric motor, an electric turntable motor, an electric rotary actuator, etc., shown as turntable motor **44**. Turntable motor **44** can be configured to drive a ring gear that is rotatably coupled with base **36** to produce relative rotation of turntable **70** relative to base **36**. Lower lift arm **32***a* is pivotally coupled with turntable **70** (or with a turntable member **72** of turntable **70**) such that lift assembly **14** and platform assembly **16** rotate as turntable **70** rotates about central axis **42**. In some embodiments, turntable **70** is configured to rotate a complete 360 degrees about central axis **42** relative to base **36**. In other embodiments, turntable **70** is configured to rotate an angular amount less than 360 degrees about central axis **42** relative to base **36** (e.g., 270 degrees, 120 degrees, etc.).

(80) Base assembly **12** includes one or more energy storage devices (e.g., capacitors, batteries, Lithium-Ion batteries, Nickel Cadmium batteries, etc.), shown as batteries **64**. Batteries **64** are configured to store energy in a form (e.g., in the form of chemical energy) that can be converted into electrical energy for the various electric motors and electric actuators of electric boom **10**. Batteries **64** can be stored within base **36**. Electric boom **10** includes a controller **38** configured to operate any of the electric motors, electric actuators, etc., of electric boom **10**. Controller **38** can be configured to receive sensory input information from various sensors of electric boom **10**, user inputs from HMI **20** (or any other user input device such as a key-start or a push-button start), etc. Controller **38** can be configured to generate control signals for the various electric motors, electric actuators, etc., of electric boom **10** to operate any of the electric motors, electric actuators, electrically powered movers, etc., of electric boom **10**. Batteries **64** are configured to power any of the electrical motors, sensors, actuators, electric linear actuators, electrical devices, electrical movers, stepper motors, etc., of electric boom **10**. Base assembly **12** can include a power circuit including any necessary transformers, resistors, transistors, thermistors, capacitors, etc., to provide appropriate power (e.g., electrical energy with appropriate current and/or appropriate voltage) to any of the electric motors, electric actuators, sensors, electrical devices, etc., of electric boom **10**.

(81) Batteries **64** are configured to deliver power to electric motors **52** to drive tractive elements **82**. A rear set of tractive elements **82** can be configured to pivot to steer electric boom **10**. In other embodiments, a front set of tractive elements **82** are configured to pivot to steer electric boom **10**. In still other embodiments, both the front and the rear set of tractive elements **82** are configured to pivot (e.g., independently) to steer electric boom **10**.

(82) Base assembly **12** can include one or more laterally extending frame members (e.g., laterally extending structural members) and one or more longitudinally extending frame members (e.g., longitudinally extending structural members).

(83) Base assembly **12** includes a steering system **150**. Steering system **150** is configured to drive tractive elements **82** to pivot for a turn of electric boom **10**. Steering system **150** can be configured to pivot tractive elements **82** in pairs (e.g., to pivot a front pair of tractive elements **82**), or can be configured to pivot tractive elements **82** independently (e.g., four-wheel steering for tight-turns).
(84) Base assembly **12** can include an HMI **21** (e.g., a user interface, a user input device, a display screen, etc.). In some embodiments, HMI **21** is coupled with base **36**. In other embodiments, HMI **21** is positioned on turntable **70**. HMI **21** can be positioned on any side or surface of base assembly **12** (e.g., on the front **62** of base **36**, on the rear **60** of base **36**, etc.)
(85) Referring now to FIGS. **2-3**, base assembly **12** includes a longitudinally extending frame member **54** (e.g., a rigid member, a structural support member, an axle, a base, a frame, a carriage, etc.). Longitudinally extending frame member **54** provides structural support for turntable **70** as well as tractive elements **82**. Longitudinally extending frame member **54** is pivotally coupled with lateral frame members **110** (e.g., axles, frame members, beams, bars, etc.) at opposite longitudinal ends of longitudinally extending frame member **54**. For example, lateral frame members **110** may be pivotally coupled with longitudinally extending frame member **54** at a front end and a rear end of longitudinally extending frame member **54**. Lateral frame members **110** can be configured to pivot about a pivot joint **58**. Pivot joint **58** can include a pin and a receiving portion (e.g., a bore, an aperture, etc.). The pin of pivot joint **58** is coupled to one of lateral frame member **110** (e.g., a front lateral frame member **110** or a rear lateral frame member **110**) or longitudinally extending frame member **54** and the receiving portion is coupled to the other of longitudinally extending frame member **54** and lateral frame member **110**. For example, the pin may be coupled with longitudinally extending frame member **54** and the receiving portion can be coupled with one of lateral frame members **110** (e.g., integrally formed with the front lateral frame member **110**).
(86) In some embodiments, longitudinally extending frame member **54** and lateral frame members **110** are integrally formed or coupled (e.g., fastened, welded, riveted, etc.) to define base **36**. In still other embodiments, base **36** is integrally formed with longitudinally extending frame member **54** and/or lateral frame members **110**. In still other embodiments, base **36** is coupled with longitudinally extending frame member **54** and/or lateral frame members **110**.
(87) Base assembly **12** includes one or more axle actuators **56** (e.g., electric linear actuators, electric axle actuators, electric levelling actuators, etc.). Axle actuators **56** can be linear actuators configured to receive power from batteries **64**. Axle actuators **56** can be configured to extend or retract to contact a top surface of a corresponding one of lateral frame members **110**. When axle actuators **56** extend, an end of a rod of electric levelling actuators can contact the surface of lateral frame member **110** and prevent relative rotation between lateral frame member **110** and longitudinally extending frame member **54**. In this way, the relative rotation/pivoting between lateral frame member **110** and longitudinally extending frame member **54** can be locked (e.g., to prevent rolling of longitudinally extending frame member **54** relative to lateral frame members **110** during operation of lift assembly **14**). Axle actuators **56** can receive power from batteries **64**. Axle actuators **56** receive control signals from controller **38**. Axle actuators **56** receive electrical power (e.g., to extend or retract) from batteries **64**.
(88) Steering System
(89) Referring now to FIGS. **4-12**, steering system **150** is shown in greater detail, according to an exemplary embodiment. Steering system **150** is configured to pivot tractive elements **82** to perform a turn. Steering system **150** includes one or more frame members, control arm assemblies, hub assemblies, knuckles, etc., shown as steering knuckle **106**. Tractive elements **82** are rotatably coupled with steering knuckle **106**. Tractive elements **82** are configured to rotate relative to steering knuckle **106** about axis **190**. Tractive elements **82** can frictionally interface with a ground surface and thereby drive electric boom **10** as they are driven to rotate by electric motors **52**.
(90) Steering knuckle **106** is configured to rotate/pivot relative to laterally extending frame members **102**/**104** about axis **120** to facilitate steering of electric boom **10**. Steering knuckle **106**

can rotatably couple with laterally extending frame members **102**/**104** with a bearing. Electric motor **52** can be configured to pivot with steering knuckle **106** as steering knuckle **106** rotates about axis **120**. Steering knuckle **106** is driven to pivot about axis **120** by a tie rod, a control arm, a rigid member, etc., shown as steering member **192**. Steering member **192** includes a first arcuate member **108*a*** and a second arcuate member **108*b*** (e.g., curved members, bowed members, arching members, etc.). Arcuate members **108** can have a generally arcuate shape, a curved shape, a constant-radius curved shape, a non-constant radius curved shape, an angled shape (e.g., two straight or curved portions angularly offset), etc. Steering member **192** is configured to pivotally couple with a connecting portion **112** of steering knuckle **106** about axis **111**. Steering member **192** can be coupled with an elongated member, a cylinder, a pin, a rod, etc., shown as pin **202** that extends between first arcuate member **108*a*** and second arcuate member **108*b*** through a corresponding aperture of connecting portion **112**. In some embodiments, pin **202** is fixedly coupled with arcuate members **108** and is rotatably coupled with an aperture/bore of steering knuckle **106**. In other embodiments, pin **202** is fixedly coupled with steering knuckle **106** and is rotatably coupled with apertures/bores of arcuate members **108**. First arcuate member **108*a*** and second arcuate member **108*b*** each include a connecting end **196**, respectively. Connecting end **196** can include an aperture, bore, hole, etc., that extends therethrough and is configured to couple with pin **202**. In some embodiments, a bearing (e.g., a sleeve bearing, a ball bearing, etc.) is disposed in the aperture of connecting portion **112** and is configured to couple with pin **202** that extends between first arcuate member **108*a*** and second arcuate member **108*b***. The pivotal/rotatable interface between steering knuckle **106** and first and second arcuate members **108*a*** and **108*b*** facilitates relative rotation between steering knuckle **106** and steering member **192** about axis **111**.
(91) Electric motor **52** is configured to drive tractive element **82**. Electric motor **52** can be mounted between laterally extending frame member **102** and laterally extending frame member **104**. Laterally extending frame members **102**/**104** are end portions of one of (e.g., a front, a rear) lateral frame member **110**. Lateral frame member **110** can extend along substantially an entire lateral width of electric boom **10**. Lateral frame member **110** provide structural support between tractive elements **82** and base assembly **12**. Lateral frame member **110** extends along lateral axis of electric boom **10**.
(92) Steering member **192** has a generally arcuate shape and extends between electric actuator **122** (e.g., an electric linear actuator, a linear electric steering actuator, etc.) and steering knuckle **106**. Steering member **192** is configured to couple with a rod, a cylinder, an extension member, a push rod, etc., of electric actuator **122**, shown as rod **126**. Steering member **192** can be fixedly coupled with an end portion, a connecting portion, a clevis, an attachment portion, etc., of rod **126**, shown as end portion **130**. Rod **126** is configured to extend and retract relative to a body, a housing, a frame, a main member, an outer member, etc., of electric actuator **122**, shown as body **124**. Rod **126** can be received therewithin body **124** of electric actuator **122** and driven to extend and retract by electric motor **132**. Electric motor **132** may be configured to interface with a gear that drives a drive nut (not shown). The drive nut may drive rod **126** to extend or retract.
(93) End portion **130** of rod **126** is configured to be received therebetween first arcuate member **108*a*** and second arcuate member **108*b***. First arcuate member **108*a*** and second arcuate member **108*b*** can be substantially parallel to each other and extend outwards between electric actuator **122** and tractive element **82**. End portion **130** can be fixedly coupled with first arcuate member **108*a*** and second arcuate member **108*b***. In some embodiments, end portion **130** is fixedly coupled with first arcuate member **108*a*** and second arcuate member **108*b*** with fasteners **128** (e.g., bolts, rivets, screws, etc.) that extend therethrough. In some embodiments, two or more fasteners **128** are used to fixedly couple end portion **130** of rod **126** with steering member **192** (i.e., with first arcuate member **108*a*** and second arcuate member **108*b***). In other embodiments, end portion **130** of rod **126** and steering member **192** are integrally formed, welded, etc., or otherwise fixedly attached.
(94) The fixed connection between end portion **130** of rod **126** and steering member **192** prevents

rotation between rod **126** and steering member **192**. Advantageously, this facilitates reducing transverse loads being applied to electric actuator **122**. This can reduce the likelihood of any of the internal components of electric actuator **122** failing due to excessive transverse loads/forces.

(95) Electric actuator **122** is configured to pivotally couple with longitudinally extending frame members **142**. Longitudinally extending frame members **142** extend longitudinally outwards from lateral frame member **110**. Longitudinally extending frame members **142** can extend from a centerpoint of lateral frame member **110**. Longitudinally extending frame members **142** can extend outwards (e.g., in forwards direction **50**) from lateral frame member **110**. Longitudinally extending frame members **142** can be removably coupled with lateral frame member **110** (e.g., with fasteners), integrally formed with lateral frame member **110**, or otherwise connected/coupled with lateral frame member **110**. Electric actuator **122** is disposed between longitudinally extending frame member **142***a* and longitudinally extending frame member **142***b*. Body **124** of electric actuator **122** can be positioned between longitudinally extending frame member **142***a* and longitudinally extending frame member **142***b*.

(96) A pin **198** may extend at least partially (or entirely) through an aperture of electric actuator **122** and corresponding apertures of longitudinally extending frame members **142**. Electric actuator **122** is configured to pivot, swivel, rotate, etc., about axis **180** relative to longitudinally extending frame members **142**. As electric actuator **122** extends and retracts, electric actuator **122** may pivot about axis **180** in either direction. Axis **180** can be defined as extending through pin **198**. Pin **198** can be fixedly coupled with electric actuator **122** and configured to rotatably couple with bearings, mounting members, rotatable coupling members, etc., shown as coupling members **200**. Coupling members **200** can be disposed on outer sides of longitudinally extending frame members **142**. For example, coupling member **200***a* may be disposed on an upper or outer surface of longitudinally extending frame member **142***a*, while coupling member **200***b* is disposed on a bottom or outer surface of longitudinally extending frame member **142***b*. Pin **198** can be slidably coupled with an aperture, bore, hole, etc., of body **124** of electric actuator **122**. In other embodiments, pin **198** is fixedly coupled with the bore of body **124**. In still other embodiments, pin **198** is slip fit with an inner surface of the bore of body **124**. Pin **198** can be rotatably coupled with coupling members **200**. Coupling members **200** can each include a bearing (e.g., a ball bearing, a roller bearing, a sleeve bearing, etc.) configured to couple with pin **198**. Coupling members **200** can be coupled with longitudinally extending frame members **142**.

(97) Longitudinally extending frame member **142***a* and longitudinally extending frame member **142***b* can be substantially parallel to each other and define a receiving area therebetween. The receiving area is configured to receive body **124** of electric actuator **122** therebetween. Pin **198** may extend through at least a portion or substantially an entirety of the receiving area defined between longitudinally extending frame member **142***a* and longitudinally extending frame member **142***b*.

(98) As electric actuator **122** extends (e.g., rod **126** extends relative to body **124**), electric actuator **122** may rotate about axis **180**. Likewise, steering knuckle **106** and steering member **192** rotate relative to each other about axis **111**. Similarly, when electric actuator **122** retracts (e.g., rod **126** retracts relative to body **124**), electric actuator **122** may rotate about axis **180** and steering knuckle **106** and steering member **192** rotate relative to each other about central axis **111**. In this way, extension and retraction of electric actuator **122** can drive the rotation/pivoting of steering knuckle **106** about axis **120** to turn tractive element **82**. Electric actuator **122** can receive power for extending and retracting from batteries **64**. Electric actuator **122** can receive control signals that indicate a degree of extension or retraction (and thereby indicate a degree of turn of tractive elements **82**) from controller **38**. Controller **38** may provide electric actuator **122** with the control signals that indicate the degree of extension or retraction in response to receiving a user input from HMI **20**, or any other user input device of electric boom **10**. Controller **38** operates electric actuator **122** to extend or retract to indicate a direction of turn of electric boom **10**.

(99) Electric motors **52** can also receive power from batteries **64** to drive tractive elements **82**.

Electric motors **52** can receive a control signal from controller **38** to operate (e.g., a desired speed).
(100) Arcuate members **108** have a curved shape such that when tractive elements **82** are pivoted to their angular extremes (e.g., a sharpest turn possible, when electric actuator **122** is fully extended, etc.), steering member **192** does not contact electric motors **52**. This facilitates sharper turns of electric boom **10** without steering member **192** contacting electric motors **52**.
(101) Referring particularly to FIG. **8**, electric boom **10** can include a shield, a guard, a planar member, etc., shown as guard member **131**. Guard member **131** can protrude outwards from electric boom **10** in a direction of travel of electric boom **10**. Guard member **131** provides a barrier for objects in front of electric boom **10** such that electric actuator **122** does not contact the objects as electric boom **10** is driven. Electric boom **10** can include a front guard member **131** and a rear guard member **131** disposed at opposite ends of electric boom **10**. Guard members **131** can protrude outwards along longitudinal axis **78** in either forwards direction **50** or rearwards direction **51**. For example, a front guard member **131** may protrude outwards in forwards direction **50** from front **62** of base assembly **12**. Likewise, a rear guard member **131** may protrude in rearwards direction **51** from rear **60** of base assembly **12**.
(102) It should be noted that while only one tractive element **82** is shown pivoted/rotated by steering system **150**, any or all of tractive elements **82** of electric boom **10** can be similarly configured. For example, steering system **150** can include a similar and symmetric electric actuator **122** at an opposite side (e.g., a right/left side) of base assembly **12** that steers tractive element **82** at the opposite side. In some embodiments, steering system **150** is positioned on an outwards facing side of lateral members **110** (e.g., a forwards facing side of a front lateral frame member **110**, a rearwards facing side of a rear lateral frame member **110**). In other embodiments, steering system **150** is positioned in an inwards facing side of lateral members **110** (e.g., an inwards facing side of a front lateral frame member **110**, a front facing side of a rear lateral frame member **110**).
(103) Turn Table
(104) Referring now to FIG. **13**, turntable **70** (e.g., a swing drive) is shown in greater detail, according to an exemplary embodiment. Turntable **70** includes a gear, shown as ring gear **608**. Ring gear **608** includes a bearing, shown as slewing bearing **614**. Slewing bearing **614** is configured to interface with a cylindrical protrusion **616** of base **36**. Cylindrical protrusion **616** and base **36** are integrally formed with each other. Cylindrical protrusion **616** is configured to couple with an inner surface (e.g., an inner race) of slewing bearing **614**. Slewing bearing **614** can be press fit, slip fit, fastened (e.g., with a keyed interface) with cylindrical protrusion **616** of base **36**. Ring gear **608** includes teeth **618** along an entire perimeter of an outer surface. Ring gear **608** can be a spur gear, a helical gear, etc., or any other gear.
(105) Ring gear **608** can couple with turntable member **72**. Ring gear **608** can be removably coupled with turntable member **72** (e.g., with fasteners, rivets, bolts, etc.) of turntable **70**. Turntable member **72** rotates as ring gear **608** is driven to rotate by turntable motor **44**. Turntable motor **44** can be a stepper motor, a reversible motor, a brushless motor, etc. Turntable motor **44** can operate in forwards or reverse (e.g., operate to provide rotational kinetic energy in a clockwise direction or a counter-clockwise direction).
(106) Turntable motor **44** is an electric motor configured to receive electrical power from batteries **64**. Turntable motor **44** can be a component of motor assembly **602**. Motor assembly **602** can be mounted (e.g., coupled, removably coupled, connected, fastened, etc.) to base **36** or to turntable member **72**. If motor assembly **602** is coupled to (e.g., mounted on) base **36**, turntable motor **44** is configured to provide rotational kinetic energy to ring gear **608** to rotate ring gear **608** relative to base **36**. Similarly, if motor assembly **602** is coupled to turntable member **72**, motor assembly **602** rotates with turntable member **72** as turntable member **72** rotates. Motor assembly **602** can be mounted to either turntable member **72** (or any other member that rotates with ring gear **608**), or can be mounted to base **36** (or any other member that is coupled to base **36**).
(107) Motor assembly **602** includes a gear box **604** (e.g., a speed reducing gear box, a reduction

gear box, a torque increasing gearbox, etc.). Gear box **604** can include any gears (e.g., planetary gears, helical gears, spur gears, bevel gears, etc.) that transform the torque provided by turntable motor **44**. Turntable motor **44** includes a drive shaft (not shown) that is rotatably coupled with one of the gears of gear box **604**. Gear box **604** is configured to increase the torque provided by turntable motor **44** before the rotational kinetic energy is provided to ring gear **608**. For example, turntable motor **44** may output rotational kinetic energy having a torque T.sub.1 and a rotational velocity ω.sub.1. Gear box **604** is configured to be driven by the driveshaft of turntable motor **44** and output rotational kinetic energy at a torque T.sub.2 and a rotational velocity ω.sub.2 where T.sub.2>T.sub.1 and ω.sub.2<ω.sub.1. Gear box **604** either outputs the rotational kinetic energy with torque T.sub.2 and rotational velocity ω2 directly to ring gear **608** or to another gearbox, shown as transmission **606** (depending on the configuration/orientation of motor assembly **602**). Transmission **606** is configured to receive the rotational kinetic from gear box **604** and transfer the rotational kinetic energy into another axis. For example, if turntable motor **44** outputs rotational kinetic energy at the driveshaft about axis **612** (where axis **612** passes through the center of the driveshaft of turntable motor **44**) and ring gear **608** is configured to rotate about axis **42** (where axis **42** and axis **612** are perpendicular to each other), transmission **606** can transfer the rotational kinetic energy from axis **612** to axis **42**.

(108) In other embodiments (as described in greater detail below), axis **612** and axis **42** are substantially parallel to each other and transmission **606** is not needed. In such configurations, gear box **604** can include an output gear mounted to an output shaft (e.g., press fit, mounted with a keyed interface, etc.) that meshes with teeth **618** of ring gear **608**. In such a configuration, the output gear can be any of a spur gear, a helical gear, etc.

(109) Transmission **606** can include any gear configuration to transfer the rotational kinetic energy output by turntable motor **44** to a perpendicular axis. For example, transmission **606** can include bevel gears or a worm (e.g., a screw). If transmission **606** includes a worm, ring gear **608** can include worm gear teeth (e.g., ring gear **608** is a worm wheel).

(110) Turntable motor **44** can receive electrical power from batteries **64** through an electrical connection, wires, an electrical harness, etc., shown as power wires **610**. In some embodiments, wires **610** includes a wired connection between turntable motor **44** and controller **38** such that controller **38** can provide turntable motor **44** with control signals (e.g., to operate turntable motor **44**).

(111) Motor assembly **602** can include a turntable brake **620** (e.g., an electric brake). Turntable brake **620** can be positioned at the output driveshaft of turntable motor **44** between turntable motor **44** and gear box **604**. Turntable brake **620** can lock the output driveshaft of turntable motor **44** by frictionally restricting the output driveshaft of turntable motor **44** from rotating. Turntable brake **620** can include electric actuators and a brake pad (e.g., drum brakes) that lock the output driveshaft of turntable motor **44** from rotating. In other embodiments, turntable brake **620** is a magnetic brake.

(112) Turntable brake **620** can be configured to lock the output driveshaft of turntable motor **44**. In other embodiments, turntable brake **620** is configured to lock an output driveshaft of gear box **604**. Turntable brake **620** can receive electrical power from batteries **64** and control signals from controller **68**. In other embodiments, turntable brake **620** is configured to directly interface (e.g., mesh) with ring gear **608** to restrict rotation of ring gear **608** when activated.

(113) In some embodiments, turntable motor **44** and gear box **604** are configured to interface with a gear box for a turntable of a hydraulically powered boom. For example, gear box **604** can increase the torque output by turntable motor **44** such that the primary mover for turntable **70** of a boom that is not fully electric can be replaced with turntable motor **44** and gear box **604**.

(114) Referring now to FIGS. **14-16**, various embodiments and possible configurations of turntable motor **44** and gear box **604** are shown. FIGS. **14-16** show various embodiments of transmission **606** to transfer rotational kinetic energy from gear box **604** to ring gear **608**. It should be

understood that the present disclosure is not limited to the configurations and embodiments shown, and that other configurations of turntable motor **44** and gear box **604** are possible to drive ring gear **608**. Output driveshaft **634** is the output driveshaft of gear box **604**.
(115) In one embodiment, output driveshaft **634** of gear box **604** includes a worm **622** (FIG. **14**). Worm **622** is configured to mesh with a worm gear (e.g., a worm wheel). Ring gear **608** can be a worm gear and mesh with worm **622**. Output driveshaft **634** rotates about axis **612** and the rotational kinetic energy is transferred to ring gear **608** which rotates about axis **42**. Turntable motor **44** can be operated to rotate in either direction, thereby rotating ring gear **608** in either direction (e.g., clockwise, counter-clockwise) about axis **42**. Motor assembly **602** can be mounted (e.g., removably coupled, fixedly coupled, etc.) to base **36**.
(116) In another embodiment (FIG. **15**), output driveshaft **634** is rotatably coupled with a bevel gear **624**. Bevel gear **624** meshes with another bevel gear **626**. Bevel gear **626** is mounted to a shaft **628** that includes a gear **630** (e.g., a spur gear, a helical gear, etc.). Gear **630** meshes with teeth **618** of ring gear **608**. While not shown, shaft **628** can mount with base **36** (e.g., at a bearing). It should be understood that any other configuration of bevel gears can be used to transfer the rotational kinetic energy of turntable motor **44** from axis **612** to axis **42**.
(117) In another embodiment (FIG. **16**), axis **612** of output driveshaft **634** is substantially parallel with axis **42** of ring gear **608**. A gear **632** (e.g., a spur gear, a helical gear, etc.) can be rotatably coupled with output driveshaft and mesh with teeth **618** of ring gear **608**.
(118) Advantageously, turntable **70** can be driven to rotate by turntable motor **44** without using any hydraulic systems or internal combustion engines. Turntable motor **44** is a fully electric motor and can provide sufficient torque to rotate turntable **70**.
(119) Platform Rotator
(120) Referring now to FIG. **17**, upper lift arm **32***c* (e.g., the jib arm) can be a telescoping arm that receives intermediate lift arm **32***d* therewithin. Intermediate lift arm **32***d* is configured to extend or retract relative to upper lift arm **32***c* to increase or decrease an overall length of the jib arm.
(121) Intermediate lift arm **32***d* can be pivotally coupled with a four bar linkage, a member, a bar, etc., shown as support assembly **754**. Support assembly **754** is pivotally coupled with intermediate lift arm **32***d* at a first end and supports platform assembly **16** at an opposite end. Support assembly **754** of lift assembly **14** can be configured to rotate platform assembly **16** about axis **25**. Support assembly **754** can be coupled with platform assembly **16** through platform rotator **30**. Platform rotator **30** is configured to pivot/rotate platform assembly **16** about axis **25**. Support assembly **754** can be driven by electric actuator **34***d* to pivot/rotate platform assembly **16** about axis **25**.
(122) Referring now to FIGS. **18-21**, platform rotator **30** is configured to couple with a support member **702** of platform assembly **16**, and a support member **700** of lift assembly **14**. Platform rotator **30** is configured to rotate support member **702** (and therefore platform assembly **16**) about axis **28** relative to support member **700** of lift assembly **14**. Support member **702** can be a portion of frame **24**. In other embodiments, support member **702** is integrally formed or removably coupled (e.g., with fasteners) with frame **24** of platform assembly **16**. Support member **700** can be an end portion of support assembly **754** or an end member of the jib arm.
(123) A support member, protrusion, structural support member, support portion, etc., shown as structural member **704** extends from support member **702** of platform assembly **16**. Structural member **704** is coupled with a housing portion, barrel, casing, cylinder, shell, structural member, etc., shown as housing member **708**. Housing member **708** can function as both a housing member that encloses internal components of platform rotator **30** (e.g., gears, shafts, bearings, etc.) and also provides structural support to pivotally couple platform assembly **16** with lift assembly **14**. Housing member **708** can be a tubular member. Housing member **708** may be integrally formed with structural member **704**. Structural member **704** couples (e.g., fixedly) housing member **708** with support member **702** of platform assembly **16**.
(124) Another support member, protrusion, member, structural support member, support portion,

coupling member, etc., shown as structural member **718** extends from support member **702** of platform assembly **16**. Structural member **718** is coupled with a housing portion, barrel, casing, cylinder, shell, structural member, tubular member, etc., shown as housing member **720**. Structural member **718** may be the same as or symmetric to structural member **704**. Likewise, housing member **720** may be the same as or symmetric to housing member **708**. Housing member **720** can be integrally formed with structural member **718**. Structural member **704** may extend from a lower portion of support member **702**, while structural member **718** extends from an upper portion of support member **702**.

(125) Housing member **720** and housing member **708** can include an inner volume, a space, etc., therewithin for containing internal components (e.g., gears, bearings, shafts, etc.) of platform rotator **30**. Housing member **720** and housing member **708** can be removably coupled with each other to define an inner volume therewithin. Housing member **720** and housing member **708** can include a rim, ledge, protrusion, periphery, annular protrusion, etc., shown as annular member **760** and annular member **762**. Annular member **760** can be integrally formed with housing member **720**. Likewise, annular member **762** can be integrally formed with housing member **708**. Annular member **762** and annular member **760** can extend along an entire perimeter of housing member **708** and housing member **720**, respectively.

(126) Housing member **720** and housing member **708** can couple with each other at annular member **760** and annular member **762**. Annular member **760** and annular member **762** can include corresponding apertures, holes, bores, openings, etc., that extend along an entire perimeter of annular member **760** and annular member **762**. The apertures can be spaced apart along the perimeter of annular member **760** and annular member **762**. The apertures of annular member **760** and the apertures of annular member **762** can be aligned with each other and receive fasteners **764** therethrough. In this way, housing member **720** and housing member **708** can be removably coupled by fasteners **764**.

(127) A support member, protrusion, structural support member, support portion, coupling member, etc., shown as structural member **714** extends from support member **700** of lift assembly **14**. Structural member **714** can be integrally formed with support member **700** of lift assembly **14**. In other embodiments, structural member **714** is removably coupled with support member **700** of lift assembly **14**. Structural member **714** can extend from an upper portion of support member **700**.

(128) Structural member **714** is coupled with a housing portion, barrel, casing, cylinder, shell, structural member, tubular member, etc., shown as upper support member **724**. Upper support member **724** can be integrally formed with structural member **714**. Upper support member **724** can have a generally circular outer periphery or a generally cylindrical shape. A bottom surface of upper support member **724** can slidably couple with an upper/top surface of housing member **720**. Upper support member **724** and housing member **720** are configured to pivot/rotate relative to each other about axis **28**. Upper support member **724** and housing member **720** may be co-axial with each other about axis **28**.

(129) Upper support member **724** can define an inner volume, an inner space, an inner area, etc., for partially or completely enclosing internal components of platform rotator **30**. Upper support member **724** can be adjacent and above housing member **720**. Upper support member **724** is coupled with a housing, casing, shell, etc., shown as motor housing **716**. Motor housing **716** can be removably coupled with upper support member **724** (e.g., via fasteners).

(130) Motor housing **716** includes an inner volume, inner space, inner area, etc., for containing and enclosing electric motor **26**. Motor housing **716** can function as both a housing member (e.g., enclosing electric motor **26** therewithin) as well as a structural member (e.g., electric motor **26** can be fixedly coupled/mounted to an inner wall of motor housing **716**).

(131) A support member, protrusion, structural support member, support portion, coupling member, etc., shown as structural member **730** extends from support member **700** of lift assembly **14**. Structural member **730** can be integrally formed with support member **700** or can be removably

coupled with support member **700** (e.g., with fasteners).

(132) Structural member **730** is coupled with a housing portion, barrel, casing, cylinder, shell, structural member, tubular member, etc., shown as bottom support member **732**. Bottom support member **732** can be a structural support member that is adjacent (e.g., below) housing member **708** and provides structural support to housing member **708**. Bottom support member **732** can slidably interface with housing member **708**. Bottom support member **732**, housing member **708**, housing member **720**, and upper support member **724** may all be co-axial with each other about axis **28**.

(133) Housing member **720** and housing member **708** can be supported therebetween upper support member **724** and bottom support member **732**. Housing member **720** and housing member **708** are configured to pivot/rotate together about axis **28** relative to upper support member **724** and bottom support member **732**.

(134) Motor housing **716** includes a connecting portion, a port, an electrical connecting portion, etc., shown as connector **758**. Connector **758** is configured to couple with an electrical wire, a hardness, a cord, etc., shown as electrical cord **710**. Electrical cord **710** can be coupled with connector **758** and provide electrical power to electric motor **26** therewithin motor housing **716**. Electrical cord **710** can also provide electrical power to brake **766**. Electrical cord **710** also facilitates communicable connection between electric motor **26**, brake **766**, and controller **38**.

(135) Electric motor **26** is configured to receive electrical energy through electrical cord **710** from batteries **64**. Electric motor **26** can be a rotary actuator, a stepper motor, a reversible motor, etc. Electric motor **26** is configured to drive housing members **720** and **708** to pivot/rotate about axis **28** relative to upper support member **724** and lower support member **732**, thereby rotating/pivoting platform assembly **16** about axis **28**. Electric motor **26** drives a shaft, shown as output driveshaft **740**. Output driveshaft **740** can be rotatably coupled with inner races of one or more bearings **742**. Bearings **742** can be any ball bearings, roller bearings, etc. Bearings **742** can be disposed at any location along output driveshaft **740**. For example, one of bearings **742** can be mounted in a bore, hole, aperture, opening, etc., of lower support member **732**. Another one of bearings **742** can be mounted in a bore, hole, aperture, opening, etc., of upper support member **724**. Likewise, another bearing **742** can be mounted in an aperture, bore, hole, opening, etc., of motor housing **716**.

(136) Platform rotator **30** can include a brake **766**. Brake **766** is configured to transition between an activated state and a de-activated state. When brake **766** is in the activated state, platform assembly **16** is restricted from pivoting about axis **28** relative to lift assembly **14**. For example, brake **766** can transition into the activated state to facilitate preventing relative rotation/pivoting between housing members **720** and **708**, and upper/lower support members **724** and **732**. Brake **766** can be any of an electro-magnetic brake, a frictional brake, etc. Brake **766** can be configured to facilitate restricting rotation of output driveshaft **740** of electric motor **26**. For example, brake **766** can receive electrical power from batteries **64** and control signals from controller **38** and use the electrical power received from batteries **64** to transition between the activated and the deactivated state. Brake **766** can transition between the activated state and the deactivated state in response to receiving control signals from controller **38**.

(137) Brake **766** can be mounted within an inner volume of any of motor housing **716**, upper support member **724**, housing member **720**, housing member **708**, lower support member **732**, etc. Brake **766** is an electrical brake that uses electrical energy/power from batteries **64** to transition between the activated state and the deactivated state.

(138) Electric motor **26** can provide rotational kinetic energy to pivot/rotate platform assembly **16** relative to lift assembly **14** through output driveshaft **740**. Platform rotator **30** can include internal gearing, shown as gear box **768**. Gear box **768** can be a reduction gearbox. For example, gear box **768** can receive an input torque T.sub.1 at an angular velocity ω.sub.1 and output a torque T.sub.2 at an angular velocity ω.sub.2 where T.sub.2>T.sub.1 and ω.sub.2<ω.sub.1. Output driveshaft **740** can be co-axial with axis **28**. In other embodiments, output driveshaft **740** is offset from axis **28**. Gear box **768** can provide the torque T.sub.2 about axis **28** to any of housing member **708**, housing

member **720**, structural member **718**, structural member **704**, etc., to drive platform assembly **16** to pivot about axis **28** relative to lift assembly **14**. In some embodiments, gear box **768** provides the torque T.sub.2 to a gearbox driveshaft that drives any of housing member **720**, housing member **708**, structural member **718**, structural member **704**, etc., to pivot about axis **28** relative to upper support member **724**, lower support member **732**, etc.

(139) Gear box **768** can include any gearing configuration/shafts to increase the torque provided from electric motor **26** before it is used to pivot platform assembly **16** relative to lift assembly **14**. In some embodiments, gear box **768** includes one or more planetary gear sets. In some embodiments, multiple planetary gear sets are used in gear box **768** with the output of one planetary gear set being provided as the input to another planetary gear set. Gear box **768** can be disposed within the inner volume formed by housing member **720** and housing member **708**. In other embodiments, gear box **768** is at least partially disposed within motor housing **716**.

(140) In other embodiments, multiple gear boxes **768** are used. For example, a first gear box can be disposed within motor housing **716**, while a second gear box is disposed within housing member **720** and housing member **708**.

(141) Brake **766** can be positioned between electric motor **26** and gear box **768**. In other embodiments, brake **766** is configured to interface with any gears, shafts, etc., of gear box **768**. For example, brake **766** can be configured to activate to facilitate preventing rotation/pivoting of an output shaft of gear box **768** that drives platform assembly **16** to rotate/pivot relative to lift assembly **14**.

(142) Referring now to FIGS. **22** and **23**, the operation of platform rotator **30** is shown in greater detail, according to an exemplary embodiment. Platform rotator **30** can operate (e.g., by operating electric motor **26**) to pivot platform assembly **16** about axis **28** relative to lift assembly **14**. Advantageously, platform rotator **30** is a fully-electric rotary actuator that does not require any hydraulic systems, engines, pumps, etc., to operate. Platform rotator **30** can operate using electrical power from batteries **64**. Platform rotator **30** can operate in response to receiving a control signal from controller **38**. Controller **38** may provide platform rotator **30** with control signals to pivot platform assembly **16** about axis **28** in either a clockwise direction or a counter-clockwise direction based on a user input received from HMI **20** and/or HMI **21**. Controller **38** can provide control signals to brake **766** to lock a current angular position of platform assembly **16** relative to lift assembly **14**. For example, an operator can provide a user input at HMI **20** and/or HMI **21** to rotate platform assembly **16** from the angular orientation as shown in FIG. **22** to the angular orientation as shown in FIG. **23**. The operator can then provide a user input at HMI **20** and/or HMI **21** to lock the current angular position of platform assembly **16** (e.g., to lock platform rotator **30** in the angular position shown in FIG. **23**).

(143) Boom and Electric Actuators

(144) Referring now to FIG. **24**, a portion of lift assembly **14** is shown, according to an exemplary embodiment. The portion shown in FIG. **24** (excluding jib arm **824**) may be referred to as “the boom” of electric boom **10**. The boom of lift assembly **14** includes an upright member, a coupling member, a linkage, etc., shown as upright member **802**. Upright member **802** is pivotally coupled with various members, boom arms, etc., shown as members **806-812**. Lower members **806** and **808** are pivotally coupled at a lower end with turntable **70** (e.g., at turntable member **72**). Lower members **806** and **808** can be substantially parallel with each other. Lower members **806** and **808** can be supported at one end by turntable member **72** and are pivotally coupled with turntable member **72**. Lower members **806** and **808** can be pivotally coupled with turntable member **72** at pins **826** and are configured to rotate about pins **826**. Lower member **806** and **808** are pivotally coupled with upright member **802** at an upper end with pins **818**.

(145) Upper members **810** and **812** can also be substantially parallel to each other. Upper members **810** and **812** are each pivotally coupled at a first end (e.g., a lower end) to upright member **802** with pins **818**. Upper members **810** and **812** are each pivotally coupled with upright member **804** (e.g., a

connecting portion, a coupling bar, etc.) at an opposite end (e.g., an upper end) with pins **818**.
(146) Lift assembly **14** includes an electric linear actuator, shown as electric actuator **814**. Electric actuator **814** is configured to receive electrical energy from batteries **64** and extend or retract to raise and lower lift assembly **14**. Electric actuator **814** is configured to pivotally couple at a bottom end with one of lower members **806** and **808**. In FIG. **24**, electric actuator **814** is shown pivotally coupling with lower member **806** with pin **822**. In other embodiments, electric actuator **814** is pivotally coupled at the bottom end with lower member **808**. Electric actuator **814** includes an outer cylinder **846** and an inner cylinder **828** (e.g., a rod, an inner member, etc.). Inner cylinder **828** is configured to extend/retract (e.g., linearly translate) relative to outer cylinder **846**. Outer cylinder **846** can receive inner cylinder **828** therewithin. Pivotally coupling electric actuator **814** with lower member **806** facilitates using an electric actuator with a longer stroke length.
(147) Electric actuator **814** is pivotally coupled with upper member **810** by trunnion mount **816**. In other embodiments, electric actuator **814** is pivotally coupled with upper member **812** using a trunnion mount similar to trunnion mount **816**. Electric actuator **814** extends beyond trunnion mount **816**. Advantageously, using trunnion mount **816** facilitates using an electric actuator with a longer extendable range. For example, trunnion mount **816** facilitates additional length of electric actuator **814** extending beyond trunnion mount **816**. The additional length corresponds to a longer range of extension/retraction (e.g., a greater stroke length), thereby facilitating a larger range over which upright member **804** can be raised/lowered.
(148) Electric actuator **814** can be extended to rotate upper members **810** and **812** about pins **818** at upright member **802**. Extending electric actuator **814** drives upper members **810** and **812** to rotate in a counter clockwise direction about pins **818** at upright member **802**, thereby raising upright member **804**. A member, an arm, a jib, an elongated member, etc., shown as jib arm **824** is coupled with upright member **804**. Therefore, as electric actuator **814** extends, jib arm **824** is raised with upright member **804**. Likewise, retracting electric actuator **814** drives upper member **810** and **812** to rotate in a clockwise direction about pins **818** at upright member **802**, thereby lowering upright member **804**. Jib arm **824** can be the same as or similar to upper lift arm **32***c*. Jib arm **824** can be pivotally or rotatably coupled with upright member **804**.
(149) Lower members **806** and **808** are configured to pivot about pins **826** to raise and lower upright member **802**. Lower members **806** and **808** rotate about pins **826** in a clockwise direction to raise upright member **802**. Likewise, lower members **806** and **808** rotate in a counter clockwise direction to lower upright member **802**. A mechanical stop can be used at pins **826** to restrict lower members **806** and **808** from rotating beyond a particular angular position in the clockwise direction. For example, lower members **806** and **808** may be prevented from rotating about pins **826** below a horizontal axis by the mechanical stop.
(150) Lower members **806** and **808** can be driven to rotate about pins **826** in either direction due to the extension and retraction of electric actuator **814**. In other embodiments, an electric actuator similar to electric actuator **814** (e.g., a linear electric actuator) is pivotally coupled with one of lower members **806** and **808** and is pivotally coupled with turntable **70**. The electric actuator can then be driven to extend and retract to rotate lower members **806** and **808** about pins **826** in a clockwise and a counter clockwise direction, respectively. The electric actuator can be mounted to one of lower members **806** and **808** using a trunnion mount similar to trunnion mount **816**.
(151) Any of members **806-812** can include multiple members spaced a distance apart. Electric actuator **814** can extend therebetween the multiple members. Upper members **810** and **812**, upright member **802**, and upright member **804** form a four-bar linkage, with upper members **810** and **812** being pivotally coupled with upright member **802** and upright member **804** at their ends. Likewise, lower members **806** and **808**, upright member **802**, and turntable **70** form a four bar linkage, with lower members **806** and **808** being pivotally coupled with upright member **802** and turntable **70** at their ends.
(152) Referring now to FIGS. **25-27**, the boom of lift assembly **14** is shown in greater detail,

according to an exemplary embodiment. Each of members **806-812** includes a pair of parallel bars, beams, members, etc., spaced a distance apart. For example, lower member **806** includes lower member **806***a* and lower member **806***b*. Lower member **806***a* and lower member **806***b* are parallel to each other and are spaced a distance apart. Lower member **806** includes support beams, structural members, etc., shown as cross members **842**. Cross members **842** extend between lower member **806***a* and **806***b* and provide structural support between lower member **806***a* and lower member **806***b*. Cross members **842** can be spaced a distance apart along substantially an entire overall length of lower member **806**. Cross members **842**, lower member **806***a* and lower member **806***b* can all be integrally formed with each other (or welded, or fastened, etc.). Each of members **806-812** can be constructed similarly to lower member **806**.

(153) Referring now to FIGS. **28-31**, trunnion mount **816** includes a collar, band, connector, etc., shown as collar **832**. Collar **832** surrounds substantially an entire outer surface, periphery, etc., of electric actuator **814**. Collar **832** can be clamped to the outer surface of electric actuator **814**. In other embodiments, collar **832** interlocks with the outer surface of electric actuator **814**, or can be frictionally interfaced with the outer surface of electric actuator **814**. In some embodiments, collar **832** is a clamping collar and is clamped to electric actuator **814** with fasteners **852**. Adjusting fasteners **852** increases clamping force provided by collar **832** to the outer surface of electric actuator **814**.

(154) Collar **832** can have an inner bore, hole, inner periphery, aperture, volume, etc., that receives electric actuator **814** therewithin. The aperture of collar **832** corresponds to the outer surface of outer cylinder **846**. In some embodiments, collar **832** is a one-piece clamping collar that is clamped to electric actuator **814** with fasteners **852**. In other embodiments, collar **832** is a two-piece clamping collar and is clamped to outer cylinder **846** with two sets of fasteners **852** (e.g., disposed at opposite sides of collar **832**). The two sets of fasteners **852** can be tightened to clamp the two pieces of collar **832** to outer cylinder **846** of electric actuator **814**.

(155) Collar **832** can include protrusions **834** that extend (e.g., radially outwards) from opposite ends of collar **832**. Protrusions **834** can be integrally formed with collar **832**. Protrusions **834** include pins, cylinders, protrusions, etc., shown as cylindrical protrusions **820**. Cylindrical protrusions **820** extend from either side of collar **832** and are configured to rotatably/pivotally couple with corresponding openings, apertures, holes, bores, etc., shown as apertures **836** of upper member **810**. When collar **832** is clamped with outer cylinder **846** of electric actuator **814**, electric actuator **814** can rotate/pivot about axis **838** of cylindrical protrusions **820** relative to upper member **810**.

(156) Protrusions **834** can be integrally formed with cylindrical protrusions **820**. In other embodiments, protrusions **834** of collar **832** are removably coupled with cylindrical protrusions **820** with fasteners **840**. Each of fasteners **840** can extend through a corresponding one of protrusions **834** and threadingly couple with a bore, aperture, hole, periphery, etc., of the corresponding protrusion **834**. Fasteners **840** can extend through a corresponding hole, aperture, opening, bore, etc., of a corresponding one of cylindrical protrusions **820** to removably couple cylindrical protrusion **820** with protrusion **834**.

(157) Referring now to FIGS. **33**, **34**, and **36**, electric actuator **814** includes an electric motor **844**, a brake **848**, and a gear box **850**. Electric motor **844** is configured to drive inner cylinder **828** of electric actuator **814** to extend or retract relative to outer cylinder **846** (and vice versa) by gear box **850**. Brake **848** is positioned between electric motor **844** and gear box **850**. Brake **848** is configured to lock electric motor **844** in response to receiving a control signal from controller **38**. Brake **848** can be any of a drum brake, an electromagnetic brake, etc.

(158) Electric motor **844** receives electrical power from batteries **64** and control signals from controller **38**. Electric motor **844** operates to extend or retract electric actuator **814** (e.g., to drive outer cylinder **846** and inner cylinder **828** to translate relative to each other). As electric actuator **814** extends or retracts to raise and lower lift assembly **14**, electric actuator **814** can pivot about

axis **838** of trunnion mount **816**.
(159) Referring now to FIGS. **32** and **35**, jib arm **824** is driven to rotate by electric actuator **34***c*. Electric actuator **34***c* can be the same as or similar to electric actuator **814**. Jib arm **824** is pivotally or rotatably coupled at one end with a member, support beam, structural member, etc., shown as upright member **860**. Upright member **860** is coupled with upright member **804**. Upright member **860** may be fixedly and/or removably coupled with upright member **804**. Upright member **860** is configured to raise/lower with upright member **804** as electric actuator **814** is operated to extend or retract.
(160) Electric actuator **34***c* is pivotally coupled at one end with upright member **860**. Electric actuator **34***c* can be pivotally or rotatably coupled with upright member **860** with pin **825**. Electric actuator **34***c* is configured to rotate/pivot about axis **856** in either direction (e.g., either clockwise or counter-clockwise) as electric actuator **34***c* extends or retracts to raise and lower jib arm **824**. Electric actuator **34***c* is rotatably or pivotally coupled at an opposite end with jib arm **824**. Electric actuator **34***c* can be rotatably or pivotally coupled at the opposite end with jib arm **824** with pin **854**. Electric actuator **34***c* is configured to pivot or rotate about axis **858** as electric actuator **34***c* extends or retracts to raise/lower jib arm **824**.
(161) Electric actuator **34***c* can include an outer cylinder **846** and an inner cylinder **828** (not shown). Outer cylinder **846** and inner cylinder **828** are driven to translate relative to each other as electric motor **844** of electric actuator **34***c* is operated. Electric actuator **34***c* includes a brake **848**. Brake **848** is configured to lock electric motor **844** of electric actuator **34***c*. Brake **848** of electric actuator **34***c* can be the same as or similar to brake **848** of electric actuator **814**. Brake **848** is configured to lock an output driveshaft of electric motor **844** of electric actuator **34***c*. Electric actuator **34***c* includes a gear box **850**. Gear box **850** of electric actuator **34***c* is configured to receive rotational kinetic energy from electric motor **844** of electric actuator **34***c* and drive outer electric actuator **34***c* to extend or retract (e.g., to drive outer cylinder **846** and inner cylinder **828** of electric actuator **34***c* to translate relative to each other). Gear box **850** of electric actuator **34***c* and gear box **850** of electric actuator **814** may be the same as or similar to each other. Gear box **850** of electric actuator **34***c* and gear box **850** of electric actuator **814** can be reduction gear boxes (e.g., gear boxes that receive input rotational kinetic energy at a first speed and a first torque, and output rotational kinetic energy at a second speed and a second torque, where the second speed is less than the first speed, and the second torque is greater than the first torque).
(162) Advantageously, lift assembly **14** can be operated to raise and lower platform assembly **16** using fully electric actuators (e.g., electric actuator **814**, electric actuator **34***c*, and optionally another electric actuator similar to electric actuator **814** that drives lower members **806** and **808** to rotate/pivot relative to turntable member **72**). Trunnion mount **816** facilitates using an electric actuator with a longer stroke length.
(163) Axle Lock Out System
(164) Referring again to FIGS. **2** and **3**, electric boom **10** includes a levelling system, axle oscillation control system, axle orientation control system, or axle position control system, shown as axle lock out system **1000**. Axle lock out system **1000** is configured to control the orientation of lateral frame members **110** relative to chassis **54** according to one or more modes of operation. Axle lock out system **1000** may limit a range of motion of each lateral frame member **110** or set (e.g., lock) the orientation of lateral frame members **110** in specific orientations (e.g., a level orientation).
(165) Referring to FIG. **37**, each axle actuator **56** includes an actuator body, housing, main body, or outer portion, shown as body **1010**, and a rod, manipulator, interface, or inner portion, shown as rod **1012**. Rod **1012** is received at least partially within body **1010** and is slidably coupled to body **1010**. Rod **1012** translates relative to body **1010** along an axis, shown as actuation axis **1014**. As rod **1012** translates, an overall length of axle actuator **56** varies.
(166) An electric motor, shown as motor **1020**, is configured to consume electrical energy and

provide mechanical energy (e.g., rotational mechanical energy, torque on a shaft, etc.) to extend and retract rod **1012** relative to body **1010** (i.e., translate rod **1012** along actuation axis **1014**). In some embodiments, motor **1020** is configured to provide rotational mechanical energy. Motor **1020** is coupled to a power transmission (e.g., gearbox, a gear drive, a belt drive, a leadscrew, etc.), shown as transmission **1022**, that is configured to transfer mechanical energy from motor **1020** to rod **1012** to move rod **1012** relative to body **1010**. Transmission **1022** may be configured to convert rotational mechanical energy to translational mechanical energy. In some embodiments, transmission **1022** is configured to have a mechanical advantage that facilitates moving rod **1012** with motor **1020** (e.g., with the torque output of motor **1020**). Transmission **1022** can include gearboxes, belts, screws, frame members, and/or any other components that facilitate the transfer and/or conversion (e.g., from rotation to translation) of mechanical energy. In some embodiments, transmission **1022** can be backdriven. By way of example, transmission **1022** may be configured to permit rotation of motor **1020** in response to a threshold compressive or tensile force on axle actuator **56**. In other embodiments, transmission **1022** cannot be backdriven. By way of example, transmission **1022** may include a mechanism, such as a worm gear drive or a ratchet, that only permits transmission of mechanical energy in one direction. In other embodiments, motor **1020** and/or transmission **1022** are omitted, and rod **1012** is actuated by motion of lateral frame member **110** relative to chassis **54**.

(167) As shown in FIG. **37**, motor **1020** is coupled to rod **1012** through a selective disconnect device or coupler, shown as clutch **1024**. Although clutch **1024** is shown positioned between motor **1020** and transmission **1022**, clutch **1024** may be positioned anywhere in axle actuator **56**. Clutch **1024** is configured to selectively couple motor **1020** to rod **1012**. Accordingly, when clutch **1024** is disengaged (e.g., deactivated, decoupled, disconnected, etc.), rod **1012** is free to move independent of operation (e.g., rotation) of motor **1020**. In the configuration shown in FIG. **37**, rod **1012** may fall freely downward when clutch **1024** is disengaged (e.g., unless brake **1026** is engaged, until hitting a mechanical limit, etc.). In other embodiments, clutch **1024** is omitted, and motor **1020** is constantly coupled to rod **1012**.

(168) Referring again to FIG. **37**, axle actuator **56** further includes a brake **1026**. Brake **1026** is configured to limit or prevent movement of at least one of rod **1012**, motor **1020**, and transmission **1022** (e.g., relative to body **1010**). Although brake **1026** is shown positioned between clutch **1024** and transmission **1022**, brake **1026** may be positioned anywhere in axle actuator **56**. Brake **1026** may impart resistive forces (e.g., friction) onto one or more components (e.g., by pressing a brake material against a surface) while still permitting movement if the resistive forces are overcome. Additionally or alternatively, brake **1026** may prevent movement of one or more components (e.g., entirely prevent, prevent movement past a certain point, by mechanically locking two or more components, etc.). Brake **1026** may act on any component of axle actuator **56**. By way of example, if brake **1026** is positioned downstream of clutch **1024**, brake **1026** may selectively prevent or limit movement of rod **1012** even when clutch **1024** is disengaged. In other embodiments, brake **1026** is omitted. In embodiments where transmission **1022** can be backdriven, brake **1026** may selectively prevent movement of rod **1012**, even under large external loading.

(169) In some embodiments, axle actuator **56** further includes a sensor **1030**. Sensor **1030** may be configured to provide an indication of a current extended length of axle actuator **56** and/or a distance between axle actuator **56** and lateral frame member **110**. Sensor **1030** may include one or more limit switches, potentiometers, encoders, ultrasonic sensors, LIDAR sensors, linear variable differential transformers, or other types of sensors. Sensor **1030** may be used for closed loop control over the position of rod **1012**.

(170) In some embodiments, axle actuator **56** further includes a motor controller (e.g., a voltage or current regulator, a motor driver, etc.), shown as motor controller **1032**. Motor controller **1032** may be operatively coupled to controller **38** and batteries **64**. Motor controller **1032** is configured to receive control signals from controller **38**. Based on the received control signals, motor controller

1032 is configured to provide electrical energy to motor **1020** at a desired voltage and/or current to control operation of axle actuator **56**. Motor controller **1032** may additionally provide feedback signals to controller **38** indicating an operational state of motor **1020**. By way of example, feedback signals may indicate a voltage, current, or frequency of the electrical energy supplied to motor **1020**.

(171) Referring to FIGS. **2**, **3**, and **38**, base assembly **12** includes four axle actuators **56**: two configured to control the front lateral frame member **110** and two configured to control the rear lateral frame member **110**. Although FIG. **38** illustrates only one lateral frame member **110**, it should be understood that this may represent the front lateral frame member **110**, the rear lateral frame member **110**, or both lateral frame members **110**. Each lateral frame member **110** includes a first portion, shown as main portion **1040**, and a second portion, shown as attachment portion **1042**. Main portion **1040** extends laterally below chassis **54** and rotatably couples to two tractive elements **82**. Attachment portion **1042** is approximately laterally centered relative to main portion **1040** and extends upward from main portion **1040** to receive pin **90**. Axle actuators **56** are positioned on opposite sides of pin **90** (and accordingly longitudinal axis **78**) and above main portion **1044**.

(172) Referring to FIGS. **38-40**, axle lock out system **1000** is shown according to an exemplary embodiment. In this embodiment, bodies **1010** are fixedly coupled to chassis **54**. In other embodiments, rods **1012** are coupled to chassis **54**. In some embodiments, bodies **1010** or rods **1012** are coupled to lateral frame member **110**. Axle actuators **56** are symmetrically located about longitudinal axis **78**. Actuation axes **1014** of axle actuators **56** are substantially vertical. Rods **1012** have ends that are substantially cylindrical and not coupled to lateral frame member **110**. When rods **1012** are extended, the end of rods **1012** move toward a pair of surfaces, shown as engagement surfaces **1050**, defined along a top surface of main portion **1044** of lateral frame member **110**. When rods **1012** engage engagement surfaces **1050** and clutch **1024** and/or brake **1026** are activated, rods **1012** limit rotation of lateral frame member **110**. Specifically, one of axle actuators **56** limits rotation of lateral frame member **110** about longitudinal axis **78** in a first direction, and the other axle actuator **56** limits rotation of lateral frame member **110** about longitudinal axis **78** in a second direction opposite the first direction. In other embodiments, bodies **1010** are fixedly coupled to lateral frame member **110**, and chassis **54** defines engagement surfaces **1050**.

(173) In FIGS. **38** and **39**, axle actuators **56** are shown in a fully retracted configuration. In this configuration, lateral frame member **110** has a maximum range of motion (i.e., an angle within which lateral frame member **110** is permitted to rotate). As rods **1012** extend, the range of motion is restricted. As shown in FIG. **6**, when both axle actuators **56** are contacting the respective engagement surfaces **1050**, the range of motion includes only a single position, and motion of lateral frame member **110** is prevented. A portion of rod **1012**, shown as engagement area **1052**, contacts lateral frame member **110**. The end of rod **1012** is cylindrical and has a fixed orientation. Accordingly, engagement area **1052** may be relatively small (e.g., a single point, smaller than the end of rod **1012**) in this embodiment, unless lateral frame member **110** is near the central position shown in FIG. **38**.

(174) In some embodiments, such as the alternative embodiment shown in FIGS. **41** and **42**, an adapter, foot, or swivel, shown as foot **1054**, is coupled to an end of rod **1012**. The foot **1054** has a bottom surface that can rotate freely relative to the rod **1012**. When foot **1054** engages engagement surface **1050**, the bottom surface of foot **1054** rotates to maximize engagement area **1052**, reducing the pressure on engagement area **1052**. Foot **1054** may include swivels, hinges, compliant materials (e.g., rubber, plastic, etc.), or other mechanisms that facilitate such rotation.

(175) Referring to FIG. **43**, the axle lock out system **1000** is shown according to an alternative embodiment. A first horizontal distance Di extends between the center of one of the axle actuators **56** and longitudinal axis **78**. A second horizontal distance Da extends between the center of the other axle actuator **56** and longitudinal axis **78**. In this embodiment, distance Di is less than

distance Dz. Accordingly, the moment effect of rod **1012** on lateral frame member **110** is different between the two axle actuators **56**. In other embodiments, distance Di and/or distance Da vary. In other embodiments, one of axle actuators **56** is omitted.

(176) Referring to FIG. **44** and FIG. **45**, the axle lock out system **1000** is shown according to an alternative embodiment. In this embodiment, axle actuators **56** are pivotally coupled to chassis **54** and lateral frame member **110** such that axle actuators **56** rotate about longitudinal axes **1060** and **1062**. Specifically, body **1010** includes a protrusion, shown as clevis **1064**, that defines an aperture configured to receive a pin to pivotally couple clevis **1064** to chassis **54**. Lateral frame member **110** includes a protrusion, shown as clevis **1066**, that defines an aperture. The aperture of clevis **1066** is aligned with a corresponding aperture defined by rod **1012** such that a pin can extend between both apertures to pivotally couple rod **1012** to clevis **1066**. In other embodiments, bodies **1010** are pivotally coupled to lateral frame member **110**, and rods **1012** are pivotally coupled to chassis **54**.

(177) When lateral frame member **110** rotates relative to chassis **54**, axle actuators **56** extend or retract and rotate about longitudinal axes **1060** and **1062**. Due to the coupling of devises **1064** and **1066** to chassis **54** and lateral frame member **110**, any rotation of lateral frame member **110** relative to chassis **54** has a corresponding rotation and change in length of axle actuators **56**.

(178) Controller **38** is configured to control axle actuators **56** to control an orientation of each lateral frame member **110** relative to chassis **54**. Controller may **38** provide control signals to motor controllers **1032** to control the flow of electrical energy supplied to each axle actuator **56**, thereby controlling the length of each axle actuator **56**. Controller **38** may utilize feedback from sensor **1030** and/or motor controller **1032** to determine a current orientation of lateral frame members **110** and/or a current length of each axle actuator **56**. Controller **38** may control each lateral frame member **110** independently, such that the ranges of motion of each lateral frame member **110** may differ.

(179) In some embodiments, axle lock out system **1000** is selectively reconfigurable between a first mode of operation (e.g., a driving mode, a movement mode, etc.) in which one or both lateral frame members **110** are permitted to rotate relative to chassis **54** and a second mode of operation (e.g., a stationary mode, an operating mode, an extended mode, a usage mode, etc.) in which rotation of one or both lateral frame members **110** is limited (e.g., prevented, reduced, etc.) relative to chassis **54**. In some embodiments, axle lock out system **1000** is further operable in a third mode of operation (e.g., a levelling mode, a leaning mode, etc.) in which lateral frame members **110** are brought into a specific orientation relative to chassis **54**. Controller **38** may change the current mode of operation automatically and/or in response to an operator input (e.g., through HMI **20** or HMI **21**, etc.).

(180) In some embodiments, it is desirable to operate axle lock out system **1000** in the driving mode while electric boom **10** is moving between different locations. The driving mode facilitates rotation of lateral frame members **110** based on the topography, shape, or contour of the terrain or support surface that electric boom **10** is traveling across. This facilitates retaining chassis **54** in a consistent orientation relative to the direction of gravity, smoothing the ride for the chassis **54** and/or operators of electric boom **10**. If both lateral frame members **110** were held stationary relative to chassis **54** while driving, lift assembly **14** and platform assembly **16** could experience rapid and/or large vertical movement based on the shape of the terrain.

(181) In the embodiment of axle lock out system **1000** shown in FIGS. **38-40**, axle actuators **56** may be retained in a retracted position (e.g., a partially retracted position, a fully retracted position, etc.) in the driving mode. In the retracted position, there may be space between one or both of rods **1012** and engagement surfaces **1050**, such that lateral frame member **110** has a first range of motion. The ends of the range of motion may be defined when one of engagement surfaces **1050** contacts rod **1012**. Alternatively, the range of motion may be defined by one or more other physical limits of lateral frame member **110** (e.g., contact between lateral frame member **110** and chassis **54**). Rods **1012** may be retained in the retracted position by brake **1026**, transmission **1022** (e.g.,

friction within transmission **1022**), and/or motor **1020**. By way of example, to brake the axle actuator **56** with motor **1020**, the leads of motor **1020** may be electrically coupled by a resistor such that motor **1020** resists rotation.

(182) In the embodiments of axle lock out system **1000** shown in FIGS. **38-40** and **44** and **11**, rods **1012** may be configured to travel freely with lateral frame member **110** in the driving mode. By way of example, motor **1020** may actively control rods **1012** to travel with the lateral frame member **110**. In such embodiments, motor **1020** may utilize feedback signals from sensor **1030** to determine a current length of each axle actuator **56** and/or an orientation of lateral frame member **110** relative to chassis **54** and control the length of axle actuators **56** to match the current orientation of lateral frame member **110** as lateral frame member **110** rotates. By way of another example, clutches **1024** may be disengaged such that rods **1012** travel freely relative to bodies **1010**. Rods **1012** may rest upon engagement surfaces **1050** or devises **1066** and be supported by lateral frame member **110**. Alternatively, transmission **1022** and/or motor **1020** may permit axle actuators **56** to be backdriven as lateral frame member **110** rotates.

(183) In some embodiments, it is desirable to operate axle lock out system **1000** in the operating mode while lift assembly **14** is being utilized. The operating mode may limit or prevent rotation of lateral frame members **110** relative to chassis **54** (e.g., once a desired orientation is achieved). This facilitates retaining chassis **54** in a consistent orientation relative to the direction of gravity, regardless of the operation of lift assembly **14**. If lateral frame members **110** were permitted to move freely relative to chassis **54** while lift assembly **14** moved, the change in location of the center of gravity of lift assembly **14** as the lift assembly **14** is operated (e.g., to manipulate a load such as an implement or work platform holding an operator) could cause the orientation of chassis **54** to shift.

(184) In the operating mode, controller **38** may control axle actuators **56** to reduce the range of motion of lateral frame member **110** relative to the range of motion in the driving mode. The range of motion of lateral frame member **110** in the operating mode may include one position (i.e., the lateral frame member **110** is fixed) or multiple positions (i.e., lateral frame member **110** is movable). In some embodiments, the range of motion in the driving mode includes the range of motion in the operating configuration. In other embodiments, the range of motion of lateral frame member **110** in the operating mode extends outside of the range of motion of lateral frame member **110** in the driving configuration.

(185) In the embodiment of axle lock out system **1000** shown in FIGS. **38-40**, when changing to the operating mode, controller **38** may first extend rods **1012** until rods **1012** reach an extended position. In some embodiments, the extended position corresponds to the position where rods **1012** contact engagement surfaces **1050** of lateral frame member **110**. In some embodiments, controller **38** operates motor **1020** in an extension direction and monitors the flow of electrical energy (e.g., the current, the voltage, the frequency, etc.) to motor **1020** (e.g., using motor controller **1032**). Controller **38** may determine that rod **1012** has contacted engagement surface **1050** based on a variation in the flow of electrical energy to the corresponding motor **1020**. By way of example, controller **38** may determine that rod **1012** has contacted engagement surface **1050** when the current drawn by motor **1020** exceeds a threshold current. In other embodiments, controller **38** utilizes data from sensor **1030** to determine when rod **1012** has contacted engagement surface **1050**. In yet other embodiments, controller **38** controls motor **1020** to extend axle actuators **56** for a predetermined period of time. In other embodiments, the rods **1012** are partially extended in the extended position, but not so much that rods **1012** contact engagement surfaces **1050**. This reduces the range of motion of lateral frame member **110** but permits some movement.

(186) In embodiments where rods **1012** are held in the retracted position during the driving mode, extension actuators **56** are held at a fixed length (e.g., locked) once rods **1012** reach the extended position. In embodiments where rods **1012** travel freely with lateral frame member **110** during the driving mode, extension actuators **56** are held at a fixed length as soon as axle lock out system

1000 enters operating mode. By way of example, controller **38** may engage clutch **1024** and/or brake **1026** to limit movement of rod **1012**. By way of another example, controller **38** may control motor **1020** to limit movement of rod **1012** (e.g., by electrically coupling the leads of motor **1020** through a resistor).

(187) In some embodiments, it is desirable to operate axle lock out system **1000** in the levelling mode prior to utilizing lift assembly **14**. While in levelling mode, controller **38** may operate axle actuators **56** to reorient lateral frame members **110** such that one or more elements of electric boom **10** (e.g., chassis **54**, turntable **70**, etc.) are in a desired orientation, such as substantially level (e.g., oriented substantially perpendicular to the direction of gravity). Once the levelling mode has succeeded in achieving the desired orientation, axle lock out system **1000** may be reconfigured into the operating mode to retain the chassis **54** or other element in the desired orientation.

(188) Control System

(189) Referring now to FIG. **46**, a control system **500** for operating electric boom **10** is shown, according to some embodiments. Control system **500** includes controller **38**, batteries **64** (e.g., energy storage devices), and the various controllable elements of electric boom **10**. The controllable elements of electric boom **10** include but are not limited to electric motors **52**, electric actuators **34**, electric actuators **122** (e.g., steering actuators), electric motor **26**, turntable motor **44**, and axle actuators **56**. The controllable elements of electric boom **10** can also include electrical lighting, sound emitting devices, etc.

(190) Controller **38** can receive user inputs from HMI **21** and/or HMI **20** and operate any of electric motors **52**, electric actuators **34**, electric actuators **122**, electric motor **26**, turntable motor **44**, and axle actuators **56** to operate electric boom **10**. For example, controller **38** may receive a user input from HMI **21** or HMI **20** to elevate platform assembly **16** and may operate electric actuators **34** to raise or lower platform assembly **16**. Likewise, controller **38** can receive a user input from HMI **21** or HMI **20** to rotate turntable **70** about axis **42** relative to base **36** and can operate turntable motor **44** to rotate turntable **70** based on the user input. Controller **38** can also receive a user input from HMI **21** or HMI **20** to drive or steer electric boom **10** and can operate electric motors **52** and electric actuator(s) **122** to drive and steer tractive elements **82**. Controller **38** operates any of electric motors **52**, electric actuators **34**, electric actuators **122**, electric motor **26**, and turntable motor **44** by generating control signals and providing the control signals to the various controllable elements to perform requested operations of electric boom **10**.

(191) Controller **38** can receive sensor inputs from sensors **510** of electric boom **10**. Sensors **510** can include proximity sensors, distance sensors, position sensors, etc. Sensors **510** can include any safety sensors that measure relative distance between electric boom **10** and objects. Sensors **510** can include sensors that monitor an approximate elevation of lift assembly **14**. In other embodiments, sensors **510** include temperature sensors configured to measure a temperature of batteries **64** to determine a condition of batteries **64**. Controller **38** can also receive feedback from any of electric motors **52**, electric actuators **34**, electric actuators **122**, electric motor **26**, turntable motor **44**, and axle actuators **56**. In some embodiments, the feedback information includes voltage or current indicative of a position (e.g., linear position, degree of extension, angular position, etc.) of any of the controllable elements, a speed (e.g., a speed of extension, a speed of rotation, etc.) of any of the controllable elements, etc.

(192) For example, the feedback received from turntable motor **44** can indicate a current angular position of turntable motor **44**. Controller **38** can use any of the feedback from electric motors **52**, electric actuators **34**, electric actuators **122**, electric motor **26**, turntable motor **44**, and axle actuators **56** to track, monitor, etc., angular or linear position of any of the controllable elements. In some embodiments, the feedback is received from a sensor associated with each of the controllable elements. For example, a position sensor can be mounted to each of electric actuators **34** to monitor a degree of extension or retraction of electric actuators **34**. Controller **38** can use any of the feedback information to monitor operations of electric boom **10** and to generate control signals for

the controllable elements.

(193) Controller **38** can monitor whether any of the controllable elements of electric boom **10** are operating properly based on the feedback received from the controllable elements. For example, controller **38** may receive feedback from any of the controllable elements (e.g., linear electric actuators of lift assembly **14**, turntable motor **44**, platform rotator **30**, etc.) and detect failure of any of the controllable elements based on the received feedback. In some embodiments, controller **38** notifies an operator regarding any failed controllable elements. For example, if controller **38** determines that electric actuator **34***a* is not operating properly, controller **38** can notify the operator by providing a message to the operator through HMI **20** and/or HMI **21**.

(194) Controller **38** can also monitor sensory information measured by sensors **510** to determine if any of the controllable elements (e.g., electric actuators **122**) are not operating properly. For example, if the sensory information from sensors **510** indicates that a particular one of electric actuators **122** (or any of the controllable elements) has not extended an expected amount, controller **38** can determine that the particular one of electric actuators **122** is not operating properly. Controller **38** can provide a notification to the operator through HMI **20** and/or HMI **21** regarding any detected failures of the controllable elements (e.g., any of the electric motors, any of the electric actuators, etc.).

(195) Electric boom **10** can also include one or more weight sensors configured to measure a load applied to platform assembly **16** (or forks, lifting apparatus, buckets, etc., if electric boom **10** is a telehandler). Controller **38** can receive sensor measurements from the weight sensors indicating the load applied to platform assembly **16**. Controller **38** can generate control signals for any of the controllable elements (e.g., electric actuators, electric motors, electric rotary actuators, etc.) of electric boom **10** based on the load applied to platform assembly **16**. For example, if the load applied to platform assembly **16** is greater than a threshold value, controller **38** can restrict operation of lift assembly **14**.

(196) Controller **38** can include a communications interface **508**. Communications interface **508** may facilitate communications between controller **38** and external systems, devices, sensors, etc. (e.g., sensors **510**, HMI **20**, HMI **21**, electric motors **52**, electric actuators **34**, electric actuators **122**, electric motor **26**, turntable motor **44**, axle actuators **56**, etc.) for allowing user control, monitoring, and adjustment to any of the communicably connected devices, sensors, systems, primary movers, etc. Communications interface **508** may also facilitate communications between controller **38** and HMI **21** and/or HMI **20** (e.g., a touch screen, a display screen, a personal computer, etc.) or with a network.

(197) Communications interface **508** can be or include wired or wireless communications interfaces (e.g., jacks, antennas, transmitters, receivers, transceivers, wire terminals, etc.) for conducting data communications with sensors, devices, systems, etc., of electric boom **10** or other external systems or devices (e.g., an administrative device). In various embodiments, communications via communications interface **508** can be direct (e.g., local wired or wireless communications) or via a communications network (e.g., a WAN, the Internet, a cellular network, etc.). For example, communications interface **508** can include an Ethernet card and port for sending and receiving data via an Ethernet-based communications link or network. In another example, the communications interface can include a Wi-Fi transceiver for communicating via a wireless communications network. In some embodiments, communications interface **508** is or includes a power line communications interface. In other embodiments, communications interface **508** is or includes an Ethernet interface, a USB interface, a serial communications interface, a parallel communications interface, etc.

(198) Controller **38** includes a processing circuit **502**, a processor **504**, and memory **506**. Processing circuit **502** can be communicably connected to communications interface **508** such that processing circuit **502** and the various components thereof can send and receive data via communications interface **508**. Processor **504** can be implemented as a general purpose processor,

an application specific integrated circuit (ASIC), one or more field programmable gate arrays (FPGAs), a group of processing components, or other suitable electronic processing components.
(199) Memory **506** (e.g., memory, memory unit, storage device, etc.) can include one or more devices (e.g., RAM, ROM, Flash memory, hard disk storage, etc.) for storing data and/or computer code for completing or facilitating the various processes, layers and modules described in the present application. Memory **506** can be or include volatile memory or non-volatile memory. Memory **506** can 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 application. According to some embodiments, memory **506** is communicably connected to processor **504** via processing circuit **502** and includes computer code for executing (e.g., by processing circuit **502** and/or processor **504**) one or more processes described herein.
(200) Electric motors **52**, electric actuators **34**, electric actuators **122**, electric motor **26**, turntable motor **44**, and axle actuators **56** can receive electrical power from batteries **64** to perform any of their respective operations. Controller **38** is configured to generate control signals for any of the controllable elements to perform their respective operation in response to receiving a user input from HMI **21** and/or HMI **20**. When the controllable elements receive the control signals from controller **38**, the controllable elements use the electrical power provided by batteries **64** to perform their respective operations.
(201) Controller **38** can receive a user input from HMI **21** and/or HMI **20** to raise or lower platform assembly **16** and generates control signals to cause electric actuators **34** to raise or lower platform assembly **16** (e.g., to raise or lower platform assembly **16** the amount desired/input by the user/operator). Likewise, controller **38** can receive a user input from HMI **21** and/or HMI **20** to rotate turntable **70** and can generate control signals for turntable motor **44** to rotate turntable **70** (e.g., to rotate turntable **70** the desired amount as input by the user/operator).
(202) Controller **38** can also generate and provide control signals to turntable brake **620** to restrict rotation of turntable **70**. Turntable brake **620** receives electric power from batteries **64** and actuates between an activated state and a deactivated state to restrict and allow rotation of ring gear **608**, respectively. Controller **38** may operate turntable motor **44** in response to receiving a user input from HMI **20** and/or HMI **21**. Controller **38** can receive feedback from turntable motor **44** indicating an angular position of turntable motor **44** or an angular speed of turntable motor **44**. In some embodiments, controller **38** receives sensory information from a turntable sensor that indicates an angular position of turntable **70**. In some embodiments, the user input received from HMI **20** and/or HMI **21** indicate a desired direction of rotation of turntable **70**. Controller **38** generates control signals and provides the control signals to turntable motor **44** to operate turntable motor **44** to rotate turntable **70** in the desired direction of rotation.
(203) Controller **38** can also provide control signals to electric actuator **814** to raise/lower the boom arm of lift assembly **14**. Electric actuator **814** is configured to use electric power from batteries **64** to operate electric motor **844**. Controller **38** can operate electric actuator **814** to extend or retract by operating electric motor **844** to operate in a forwards direction or a backwards direction. Controller **38** can operate electric motor **844** to cause electric actuator **814** to extend in response to receiving a user input from HMI **20** and/or HMI **21** to raise platform assembly **16**. Likewise, controller **38** can operate electric motor **844** to cause electric actuator **814** to retract in response to receiving a user input from HMI **20** and/or HMI **21** to lower platform assembly **16**.
(204) Controller **38** can also generate and provide control signals to electric motor **26** and/or brake **766**. Controller **38** can generate and provide the control signals to electric motor **26** to operate electric motor **26** in either direction, thereby pivoting platform assembly **16** about axis **28** in either direction. Controller **38** can operate electric motor **26** in response to receiving user inputs from an of HMI **20** and/or HMI **21**. For example, an operator can provide controller **38** with a user input to pivot/rotate platform assembly **16** in a clockwise direction at HMI **20** and/or HMI **21** (e.g., by

pressing a button, pulling a lever, moving a joy-stick, etc.). Controller **38** can operate electric motor **26** as long as the user input from HMI **20** and/or HMI **21** is received. In some embodiments, controller **38** can receive a user input from HMI **20** and/or HMI **21** to lock platform assembly **16** at a current angular position. Controller **38** can generate and provide control signals to brake **766** to lock platform assembly **16** (e.g., to activate brake **766**) at a current angular position in response to receiving the user input from HMI **20** and/or HMI **21**. Likewise, controller **38** can receive a user input from HMI **20** and/or HMI **21** to de-activate brake **766**. Controller **38** can generate and provide control signals to brake **766** to transition brake **766** into the de-activated state in response to receiving a user input from HMI **20** and/or HMI **21**.

(205) Advantageously, electric boom **10** is a fully-electric lifting device. All of the electric actuators and electric motors of electric boom **10** can be configured to perform their respective operations without requiring any hydraulic systems, hydraulic fluids, engine systems, etc. Other booms do not use a fully-electric system and require regular maintenance to ensure that the various hydraulic systems are operating properly. Electric boom **10** uses electric motors and electric actuators without requiring combustible fuels (e.g., gasoline, diesel), or hydraulic fluids. Electric boom **10** is powered by batteries **64** that can be re-charged when necessary.

Configuration of Exemplary Embodiments

(206) The present disclosure contemplates methods, systems, and program products on any machine-readable media for accomplishing various operations. The embodiments of the present disclosure may be implemented using existing computer processors, or by a special purpose computer processor for an appropriate system, incorporated for this or another purpose, or by a hardwired system. Embodiments within the scope of the present disclosure include program products comprising machine-readable media for carrying or having machine-executable instructions or data structures stored thereon. Such machine-readable media can be any available media that can be accessed by a general purpose or special purpose computer or other machine with a processor. By way of example, such machine-readable media can comprise RAM, ROM, EPROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium which can be used to carry or store desired program code in the form of machine-executable instructions or data structures and which can be accessed by a general purpose or special purpose computer or other machine with a processor. When information is transferred or provided over a network or another communications connection (either hardwired, wireless, or a combination of hardwired or wireless) to a machine, the machine properly views the connection as a machine-readable medium. Thus, any such connection is properly termed a machine-readable medium. Combinations of the above are also included within the scope of machine-readable media. Machine-executable instructions include, for example, instructions and data which cause a general purpose computer, special purpose computer, or special purpose processing machines to perform a certain function or group of functions.

(207) 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.

(208) It should be noted that the terms “exemplary” and “example” 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).

(209) 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.
(210) 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.
(211) Also, the term “or” is used in its inclusive sense (and not in its exclusive sense) so that when used, for example, to connect a list of elements, the term “or” means one, some, or all of the elements in the list. Conjunctive language such as the phrase “at least one of X, Y, and Z,” unless specifically stated otherwise, is otherwise understood with the context as used in general to convey that an item, term, etc. may be either X, Y, Z, X and Y, X and Z, Y and Z, or X, Y, and Z (i.e., any combination of X, Y, and Z). Thus, such conjunctive language is not generally intended to imply that certain embodiments require at least one of X, at least one of Y, and at least one of Z to each be present, unless otherwise indicated.
(212) It is important to note that the construction and arrangement of the systems 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 claim.

Claims

1. A lift device comprising: a chassis; a battery coupled to the chassis; a lift assembly coupled to the chassis and configured to selectively raise and lower a load relative to the chassis; a front axle assembly pivotally coupled to the lift assembly and configured to rotate about a longitudinal axis relative to the chassis and a rear axle assembly pivotally coupled to the lift assembly and configured to rotate about the longitudinal axis relative to the chassis; and a controller configured to control operation of a front electric linear actuator and a rear electric linear actuator according to a first mode of operation and a second mode of operation; wherein in the first mode of operation, the controller is configured to control the front electric linear actuator and the rear electric linear actuator to permit rotation of the front axle assembly and the rear axle assembly relative to the chassis through a first range of motion, and wherein in the second mode of operation, the controller is configured to control the front electric linear actuator and the rear electric linear actuator to limit rotation of the front axle assembly and the rear axle assembly relative to the chassis to a second range of motion.
2. The lift device of claim 1, wherein the front electric linear actuator and the rear electric linear

actuator each include a body slidably coupled to a rod and an electric motor that controls movement of the rod relative to the body, and wherein in the second mode of operation, the controller is configured to control the electric motor to extend the front electric linear actuator or the rear electric linear actuator until the front electric linear actuator or the rear electric linear actuator engages the front axle assembly or the rear axle assembly.

3. The lift device of claim 2, wherein the front electric linear actuator and the rear electric linear actuator each include a motor controller that monitors a flow of electrical energy supplied to the electric motor, and wherein the controller is configured to determine that the front electric linear actuator or the rear electric linear actuator has engaged the front axle assembly or the rear axle assembly when a current supplied to the electric motor exceeds a threshold current.

4. The lift device of claim 1, wherein in the first mode of operation, the front electric linear actuator and the rear electric linear actuator are configured to extend and retract freely as the front axle assembly and the rear axle assembly rotate relative to the chassis, and wherein in the second mode of operation, the controller limits extension and retraction of the front electric linear actuator and the rear electric linear actuator.

5. The lift device of claim 4, wherein the front electric linear actuator and the rear electric linear actuator each include a body slidably coupled to a rod and an electric motor that controls movement of the rod relative to the body, wherein the body is coupled to one of the front axle assembly or the rear axle assembly and the chassis, and wherein the rod is coupled to the other of the front axle assembly or the rear axle assembly and the chassis.

6. The lift device of claim 1, wherein the lift assembly is a boom assembly including at least one arm and at least one linear actuator configured to rotate the at least one arm relative to the chassis to selectively raise and lower the load.

7. The lift device of claim 1, wherein the lift device is a telehandler, and wherein the load is an implement.

8. The lift device of claim 1, wherein the lift device is a boom lift, and wherein the load is a work platform configured to support an operator.

9. The lift device of claim 1, wherein the first mode of operation is a transportation mode for when the lift device transports, and the second mode of operation is a usage mode for when the lift device does not transport and operates to raise and lower the load.