(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
29 December 2016 (29.12.2016)

WIPO | PCT

(10) International Publication Number
WO 2016/205864 A1

(51) International Patent Classification:
G05D 13/00 (2006.01) *G05D 3/00* (2006.01)

(21) International Application Number:
PCT/AU2016/000222

(22) International Filing Date:
24 June 2016 (24.06.2016)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
2015902496 26 June 2015 (26.06.2015) AU

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report (Art. 21(3))*

(54) **Title**: CONTROL SYSTEM

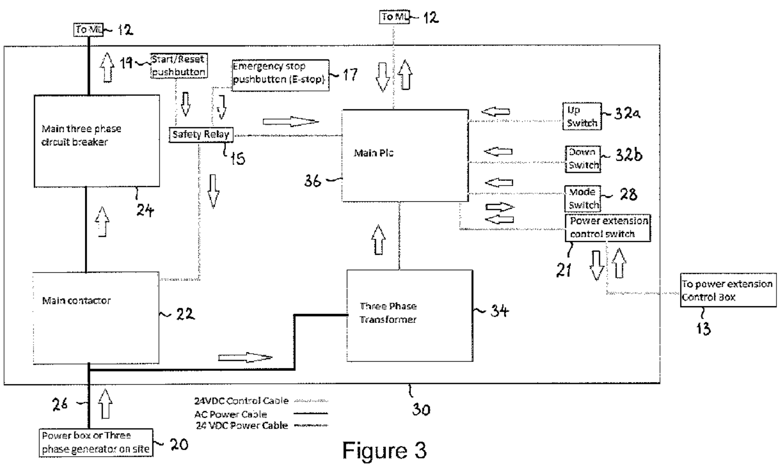

Figure 3

(57) Abstract: A control system for controlling the operation of a plurality of modular lifting units (12). The control system includes a power source (20) for providing power to each of the modular lifting units (12). A main control box connected between the power source (20) and the modular lifting units (12), comprises a mode switch (28) for switching the system between two control modes: a group mode, in which the plurality of modular lifting units (12) is controlled synchronously as a group; and, an individual mode, in which any one of the modular lifting units (12) is controlled independently of the other units. In group mode, synchronous movement of the modular lifting units is achieved by setting each unit to run at the same speed. The control system may also comprise one or more power extension control boxes (PECBs) (13) connected between an additional power source and a plurality of additional modular lifting units

WO 2016/205864 A1

"CONTROL SYSTEM"

Field of the Invention

The present invention relates to a control system for controlling a plurality of modular lifters and relates particularly, although not exclusively, to such a control system for lifting a building structure using a plurality of lifting jacks.

Background to the Invention

In co-pending International Patent Application No PCT/AU2014/000224, the contents of which are incorporated herein by reference, a method of constructing a multi-storey building structure is described. In the method of PCT/AU2014/000224 an upper storey of the building structure is first constructed at ground level, then lifted up to the required height, after which a lower storey of the building structure is constructed underneath. This building method achieves significant cost savings and improvements in safety when constructing a building structure, as it eliminates the need for installing scaffolding and working at heights during construction of the upper storey.

Lifting of the upper storey of the building structure is accomplished by employing a plurality of lifting jacks, adapted to be attached to the upper storey of the building structure and then operating the jacks simultaneously to apply a lifting force to the upper storey. Each of the lifting jacks described in PCT/AU2014/000224 comprises a motor/gear box unit which is operatively connected to a leadscrew to transfer rotational movement to the leadscrew. A means for controlling the speed of rotation of the leadscrew, in the form of a variable speed drive, is also provided. This allows the speed of the motor/gear box unit to be varied in accordance with the speed required at the time of elevating the building structure. The jack may also include means for stopping the rotational movement of the motor/gear box unit in an emergency. A rotary encoder may be incorporated in the motor/gear box unit of the jack to allow the position of the output shaft of the motor/gear box unit to be monitored.

PCT/AU2014/000224 also briefly describes the provision of a programmable logic controller (PLC) for controlling and monitoring the entire process of elevating and lowering the building structure. The PLC is provided to coordinate the processes carried out by all control elements of the jack, such as the means for controlling the speed of rotation of the leadscrew, means for stopping the rotational movements of the motor/gear box unit, and the position of the leadscrew according to the rotary encoder. The PLC is programmed to permit each of the jacks to be controlled independently of the others. Independently controlling each jack avoids the need to provide communication via, for example, cables or lasers between a master jack and the other jacks, thus facilitating the process for elevating the upper storey of the building structure.

Whilst the control system described in PCT/AU2014/000224 worked satisfactorily in some situations, there were problems with its implementation in other applications. In particular, because of the very low gearing of the jack the motor ran at high speed whilst the jack moved a very small amount. To get useful feedback for such a very low geared jack, a servomechanism, (sometimes shortened to “servo”), was employed to provide error-sensing, negative feedback. The servo devices employed were all shaft mounted encoders with a synchronisation card connected to a motor Variable Speed Drive (VSD). However the very high sensitivity or resolution, (number of pulses per second) of the servo devices meant that even the smallest differences were magnified. The constant variation compounded, and each adjustment made was then over-compensated for by the control system. Because the sensitivity was so high, the variable speed drive (VSD) caused the motor in the jack to switch on and off at very short intervals, while the VSD’s and synchronisation cards hunted for a consistent position signal. Under certain conditions the system became highly unstable.

The present invention was developed with a view to providing a more robust and reliable control system, capable of simultaneously controlling the operation of multiple lifting jacks during the elevation of a building structure. However it will be understood that the control system may also find useful application in other situations where multiple modular lifting units are required to be operated simultaneously to effect an elevating or lowering operation.

References to prior art in this specification are provided for illustrative purposes only and are not to be taken as an admission that such prior art is part of the common general knowledge in Australia or elsewhere.

Summary of the Invention

According to one aspect of the present invention there is provided a control system for controlling the operation of a plurality of modular lifting units, the control system comprising:

a plurality of modular lifting units;

a power source for providing power to each of the modular lifting units; and,

a main control box connected between the power source and the modular lifting units, the main control box comprising a mode switch for switching the system between two control modes: a group mode, in which the plurality of modular lifting units is controlled synchronously as a group; and, an individual mode, in which any one of the modular lifting units is controlled independently of the other units, and wherein, in group mode, synchronous movement of the modular lifting units is achieved by setting each unit to run at the same speed.

Preferably each modular lifting unit comprises a variable speed drive (VSD) for controlling the speed of an electric motor in the unit, and in group mode, synchronous movement of the modular lifting units is achieved by setting the VSD in each unit to run the motor at the same speed with no feedback from any part of the system.

Preferably the main control box further comprises a main controller, operatively coupled to the mode switch, for controlling the supply of electrical power to each of the modular lifting units. Typically the main control box also includes a main contactor which connects the power source to the modular lifting units via a three phase circuit breaker. Preferably the main control box also includes a power data logger for monitoring and recording electrical parameters for each of the modular lifting units. Preferably the main controller is a Programmable Logic Controller (PLC).

Preferably the control system further comprises a plurality of power extension control boxes (PECBs), when additional power sources are required and/or the number of modular lifting units exceeds a capacity of the main control box, each PECB being connected between an additional power source and a plurality of additional modular lifting units. Each of the PECBs is preferably under the control of the main control box.

According to another aspect of the present invention there is provided a control system for controlling the operation of a plurality of modular lifting units, the control system comprising:

a plurality of modular lifting units;

a power source for providing power to each of the modular lifting units;

a main control box connected between the power source and the modular lifting units, the main control box comprising:

a mode switch for switching the system between two control modes: a group mode, in which the plurality of modular lifting units is controlled synchronously as a group; and, an individual mode, in which any one of the modular lifting units is controlled independently of the other units; and, a main controller operatively coupled to the mode switch for transmitting control signals to each of the modular lifting units, the main controller also receiving feedback signals from each of the modular lifting units wherein, in group mode, synchronous movement of the modular lifting units is achieved by the main controller using the feedback signals received from each of the modular lifting units to supply power to, monitor and control the speed of the modular lifting units.

Preferably each modular lifting unit (MLU) comprises an encoder for sensing a lifting position of the unit and providing a feedback signal to the main controller. Preferably the encoder is connected to an actuator of the MLU, where useful load position can be monitored. Typically the encoder generates a predetermined number of pulses, according to a prescribed resolution, for each 360° of rotation of a motor/gear box in the MLU. Typically, the encoder is used to measure a lift-carriage movement on a lifting jack, relative to a stationary reference point. Preferably the encoder is an absolute encoder or an incremental encoder.

Advantageously each modular lifting unit further comprises a MLU controller for processing data received from the encoder and preparing the feedback signals. Preferably the MLU controller controls the operation of the modular lifting unit with reference to an algorithm within the MLU controller for controlling the MLU and/or transmitting the feedback signals to the main controller. In one embodiment each modular lifting unit comprises a variable speed drive (VSD) for controlling the speed of an electric motor in the unit.

Preferably each modular lifting unit also includes a load cell in order to measure the weight of a structure to be lifted and to monitor any change in load for the purpose of adjusting position.

Preferably the main controller comprises a Programmable Logic Controller (PLC) for controlling the supply of electrical power to each of the modular lifting units. Typically the main control box also includes a main contactor which connects the power source to the modular lifting units via a three phase circuit breaker.

Preferably the control system further comprises a plurality of power extension control boxes (PECBs), when additional power sources are required and/or the number of modular lifting units exceeds a capacity of the main control box, each PECB being connected between an additional power source and a plurality of additional modular lifting units. Preferably each PECB comprises a slave controller, operatively coupled to the main controller, for controlling the supply of electrical power to each of the additional modular lifting units. Preferably the slave controller is a Programmable Logic Controller (PLC). Preferably each PECB also includes a power data logger for monitoring and recording electrical parameters for each of the additional modular lifting units.

Advantageously the main controller monitors the actual position of each modular lifting unit (MLU) and adjusts the lifting by sending instructions to the MLU controller in each MLU. This enables the control system to synchronise and control the actual position of each modular lifting unit via adjustments in speed.

Preferably the main control box also comprises a wireless transmitter/receiver for transmitting and receiving wireless signals to/from the modular lifting units. Preferably each modular lifting unit also comprises a wireless transmitter/receiver for receiving control signals and transmitting feedback signals wirelessly to the main controller. Preferably each PECB also comprises a wireless transmitter/receiver for transmitting and receiving wireless signals to/from the main control box.

According to a further aspect of the present invention there is provided a method of controlling the operation of a plurality of modular lifting units via a main control box and a plurality of power extension control boxes (PECBs), each PECB being connected to the main control box and between an additional power source and a plurality of additional modular lifting units (MLUs) respectively, the method comprising:

detecting the number of PECBs; and,

providing feedback signals from each of the PECBs to the main control box.

Preferably the power extension control boxes (PECBs) are connected between various power sources, such as on-site generators or on-site power boxes or other power sources and the additional modular lifting units. Each PECB is typically controlled by the main control box. Preferably the main control box switches a main contactor inside each PECB ON or OFF in order to energise or de-energize the MLUs connected to each PECB respectively.

Advantageously each PECB sends a feedback signal or a series of feedback signals to the main control box to indicate if the main contactor in each PECB is working.

Preferably each PECB includes a data logging device, which records various electrical parameters, such as total current drawn, voltage per operation, amount of electrical disconnections, three phase unbalance situations, amongst others, that are then sent to a main controller in the main control box for future analysis.

According to a still further aspect of the present invention there is provided a method of controlling the operation of a plurality of modular lifting units via a main control box connected between a power source and the modular lifting units, the method comprising the steps of:

detecting the number of modular lifting units connected to a control network;

providing power to each of the modular lifting units in accordance with the method;

selecting one of two control modes: a group mode, in which the plurality of modular lifting units is controlled synchronously as a group; and, an individual mode, in which any one of the modular lifting units is controlled independently of the other units; and,

transmitting control signals from the main controller to the modular lifting units wherein, in group mode, synchronous movement of the modular lifting units is achieved by using feedback signals received from each of the modular lifting units to supply power to, monitor and control the speed of the modular lifting units.

Preferably each modular lifting unit (MLU) comprises an encoder and the method comprises the further steps of: sensing a lifting position of the unit and providing a feedback signal to the main controller. Preferably the encoder is an absolute encoder, or an incremental encoder.

Throughout the specification, unless the context requires otherwise, the word “comprise” or variations such as “comprises” or “comprising”, will be understood to imply the inclusion of a stated integer or group of integers but not the exclusion of any other integer or group of integers. Likewise the word “preferably” or variations such as “preferred”, will be understood to imply that a stated integer or group of integers is desirable but not essential to the working of the invention.

Brief Description of the Drawings

The nature of the invention will be better understood from the following detailed description of several specific embodiments of the control system, given by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a functional block diagram of a first embodiment of a control system according to the present invention illustrating the control topology;

Figure 2 is a functional block diagram of the control system of Figure 1 illustrating the power topology;

Figure 3 is a functional block diagram of a main control box in a second embodiment of a control system according to the present invention;

Figure 3.1 is a functional block diagram of a power extension control box in the second embodiment of a control system according to the present invention;

Figure 4 is functional block diagram of a modular lifting unit in the control system of Figure 3;

Figure 5 is a functional block diagram of a third embodiment of a control system according to the present invention illustrating the control topology;

Figure 5.1 is a functional block diagram of the third embodiment of a control system illustrated in Figure 5, including one or more power extension control boxes in the control topology;

Figure 6 is a functional block diagram of the control system of Figure 5 illustrating the power topology;

Figure 7 is a functional block diagram of a main control box in the control system of Figure 5;

Figure 7.1 is a functional block diagram of a power extension control box in the control system of Figure 5.1;

Figure 8 is functional block diagram of a modular lifting unit in the control system of Figure 5;

Figures 9, 9.1, 9.2 and 9.3 are a flowchart illustrating the steps implemented in the software programming for a main PLC in the control system of Figures 3 and 5;

Figure 10 is a functional block diagram of an alternative topology for the third embodiment of a control system according to the present invention illustrating the power topology; and,

Figure 11 is a functional block diagram of a main control box in the control system of Figure 10.

Detailed Description of Preferred Embodiments

A first embodiment of a control system in accordance with the invention, for controlling a plurality of modular lifting units 12, is illustrated in Figures 1 and 2. The control system comprises a main control box 10 for controlling a plurality of modular lifting units (MLUs) 12 connected in a daisy chain configuration. Optionally, the control system also comprises a plurality of power extension control boxes 13 for distributing the electrical power to additional modular lifting units 12 when the number of MLUs exceeds the limit the main control box 10 can distribute electrical power to. Each modular lifting unit 12 could be a lifting jack similar to that described in PCT/AU2014/000224, and comprises a variable speed drive (VSD) 14 for controlling the speed of an electric motor/gear box 16 (not shown in Figures 1 and 2) in the unit. Each modular lifting unit 12 is also fitted with a 24 volt interface relay 18.

The control system comprises one or more power sources 20 for providing electrical power for a plurality of the modular lifting units 12 (see Figure 2), and power cables 26 for delivering electrical power from the power source to each of the MLUs. A single main control box 10 may have a plurality of power cables 26 connected to it, each supplying power to a plurality of modular lifting units 12. One of more power extension control boxes 13 are optionally employed to distribute the electrical power to other MLUs via power cables 26 when several power sources are required to be used, as well as when the number of MLUs 12 in the operation exceed the maximum capacity of the main control box 10. In this embodiment the power source 20 comprises a plurality of 415 volt three phase generators or power boxes 20. The first three phase generator 20a is connected to a 415 volt three phase circuit breaker 24 and main contactor 22 in the main control box 10, (see Figure 3 in which main control box 30 is similar to the main control box 10) which connects to the modular lifting units 12 via power cable 26. Each power extension control box (PECB) 13 is likewise provided with a 415 volt three phase circuit breaker 24 and main contactor 22 (see Figure 3.1 in which PECB 33 is similar to the PECB 13). Each of the PECBs 13 is preferably under the control of the main control box 10.

The main control box 10 further comprises a mode switch 28 for switching between two modes: a group mode, in which the plurality of modular lifting units is controlled synchronously as a group, and an individual mode, in which any one of the modular lifting units is controlled independently of the other units. In group mode, synchronous movement of the modular lifting units is achieved by setting the VSD 14 in each unit, via the interface relay 18, to run the motor at the same speed with no speed feedback given to the main control box 10 from any part of the system other than control signals (limit switch signals and/or any other type of control signal from any other device) to stop the system in case the system reaches its maximum or minimum height.

Preferably the control box 10 further comprises two 24v DC switches 32a and 32b to switch the control system up and down respectively (see Figure 3). In group mode all the modular lifting units 12 perform synchronised movement when the 24v DC switches are switched up or down. In individual mode, each individual modular lifting unit 12 can be controlled without affecting the other units. This allows calibration of each modular lifting unit to a specific but different starting point. Because each modular lifting unit 12 is carrying a different load (weight), a different current is required to make all motors run at the same speed. Thus the VSD 14 in each unit changes the amount of current drawn by each motor depending on the load.

The use of the VSDs 14 alone to set the speed and adjust current to the motors 16, in of each modular lifting units 12, solved the prior art problem caused by the high sensitivity of the encoders/synchronisation cards, which caused the VSD to switch the motor in the jack to on and off at very short intervals, while the VSD's and synchronisation cards hunted for a consistent position signal. However this synchronised control was of relatively low accuracy only suitable for building structures capable of withstanding deflection of more than 25mm. For more accurate synchronised control of the plurality of modular lifting units, a second embodiment of the control system was developed.

A second embodiment of the control system in accordance with the invention, for controlling a plurality of modular lifting units 12, is illustrated in Figures 3 and 4. The principal difference between the first and second embodiments of the control system is that the main control box 30 of the second embodiment is provided with a main controller 36, as shown in Figure 3, and each modular lifting unit 12 is fitted with an encoder 38, as shown in Figure 4. In other respects the control system of the second embodiment is substantially the same as the first embodiment, and therefore the same reference numerals will be used to refer to the similar parts and these will not be described again in detail.

The main control box 30 of this embodiment comprises a main controller in the form of a Programmable Logic Controller (PLC) 36 for controlling the supply of electrical power to each of the modular lifting units 12 in order to control the speed of the motors amongst other functions. A safety relay 15 provides a safety mechanism which will switch off the main contactor 22 when an emergency stop (E-stop) pushbutton 17 is pressed in case of an emergency. Pressing the E-stop pushbutton 17 will cause an immediate stop of the system. A Start/Reset pushbutton 19 will reset the safety relay 15 when the E-stop button has been released and the emergency situation had been resolved. Once this is done, the safety relay 15 will switch the main contactor 22 ON as well as sending a signal to the main PLC 36 to indicate the system is in a non-dangerous status. A three phase transformer 34 provides 24v DC power for the main PLC 36 and control system. Once the safety relay 15 indicates that the system is in a non-dangerous status, the main PLC 36 can command the modular lifting units to go up or down by using the 24VDC control cable as well as controlling the power extension control box or boxes 13 if needed. A power extension control switch 21 is provided in the main control box 30 to control one or more power extension control boxes (PECBs) 33.

The PECB 33 of this embodiment, as illustrated in Figure 3.1, further comprises a 24VDC interface relay 23 which will turn the main contactor ON or OFF depending on a command from the main PLC 36 in the main control box 30. As mentioned before, the PECB or PECBs 33 will be used in order to distribute the electrical power when more than one power source is being used and/or when the number of modular lifting units 12 exceeds the maximum capacity that a control box can handle.

In order to overcome the prior art problems associated with using servo device in the modular lifting units, in this embodiment the main PLC 36 is employed to interpret the very high resolution feedback pulses from the encoder 38 and to subsequently control the motor speed via the VSD 14. A synchronisation card could only interpret the pulses but could not be configured to respond appropriately in controlling motor speed via the VSD. This was all due to the very high gearing and the high accuracy of the movement required.

Preferably the encoder 38 is positioned to be after the motor/gearbox 16 and is adapted to measure the actual actuator height (screw shaft of the jack) relative to a stationary point (jack base). This is a further difference with the prior art arrangement in which the encoder was mounted on the motor shaft (and fitted with a synchronisation card). In this embodiment the control system can accurately monitor the useful load position. The signals from the encoder 38 are received at a much slower rate than say from the shaft of a three phase motor running at 1410 RPM. The data processing functions performed by the main PLC 36, in order to interpret the feedback signals from the encoder 38 and determine the position of the modular lifting unit 12, is at a speed that will stop 'motor hunting'.

A third embodiment of a control system in accordance with the invention, for controlling a plurality of modular lifting units 42, is illustrated in Figures 5 to 8. As with the first and second embodiments, the control system comprises a main control box 40 for controlling a plurality of modular lifting units 42 connected in a daisy chain configuration, as shown in Figure 5. Optionally, one or more power extension control boxes (PECBs) 43 are also provided to distribute the electrical power among additional MLUs 42, as shown in Figures 5.1 and 6. Each modular lifting unit (MLU) 42 comprises a variable speed drive (VSD) 44 for controlling the speed of an electric motor/gear box 46 in the MLU, as can be seen most clearly in Figure 8. Each modular lifting unit 42 is also fitted with a 24 volt interface relay 48 and a MLU controller 50. In this embodiment the MLU controller is in the form of a Programmable Logic Controller (PLC) 50. The VSD 44 is used for controlling the ramp up/down set point speed of each modular lifting unit 42. This offers a constant draw of current that's accurately monitored through internal parameters.

Each modular lifting unit 42 is also supplied with an encoder 52 connected to an actuator, (after the motor/gearbox 46), where useful load position can be monitored. The encoder 52 generates a predetermined number of pulses, according to a prescribed resolution, for each 360° of rotation of the motor/gear box 46. Typically, the encoder 52 is used to measure the lift-carriage movement on a lifting jack, relative to a stationary reference point.

Preferably the encoder 52 is an absolute encoder. An absolute encoder is a position feedback device that reports absolute positional information. An absolute encoder generates a unique code for each position purchased via the number of pulses generated. When powered up, absolute encoders do not require a home cycle even if the shaft was rotated while the power was switched-off. The modular lifting units 42 are preferably portable lifting jacks that are needed to be powered off and on many times each week. Absolute encoders are the best product for this application. Typically the encoder 52 is fixed at the base of the MLU 42 (lifting jack), and one end of the encoder is fixed to the screw nut on the screw shaft of the lifting jack. The screw nut moves up the shaft, moving a lift carriage with it, when the shaft spins in the up direction. Alternatively the encoder 52 may be a magnetic tape encoder, linear encoder, tape draw encoder, wire draw encoder, Linear Variable Differential Transformer or any other device that allows the distance travelled by the MLU to be measured. Such devices can be of the incremental or absolute type, where the output can also be digital, analog or through a communication bus.

All the modular lifting units 42 (lifting jacks) will typically require a "zeroing" function to be performed pre-lift by a main PLC 60. The gear box ratio, along with other constant mechanical adders, ensures movement of the lift-carriages of each of the lifting jacks is around the same.

Typically the encoder 52 will allow a distance travelled by the lift-carriage to be measured with high resolution. The PLC 50 will compute this number and if needed alter the motor speed of the modular lifting unit 42 to address the issue of uneven weight distribution over the jack positions. Preferably each modular lifting unit 42 also includes a load cell 53 in order to measure the weight of the building structure to be lifted (see Figures 5 and 8). The load cell 53 will transmit the data to PLC 50 contained in each MLU 42, and the PLC will stop the operation when the load of the structure is higher than a rated lifting capacity that each modular lifting unit can carry.

The load cell 53 is also used to monitor changes to the load carried by the MLU 42. Such changes may occur if a MLU becomes "unhealthy" or "faulty", or the load changes due to environmental factors such as wind, or a MLU is not maintaining its position compared to other MLUs. The load cell can be used to adjust the position of the MLU, if necessary, to keep the load constant.

Some possible scenarios to be analysed are:

- the mechanical parts of the MLU wear and develop friction - this causes a higher level of current draw to keep the MLU elevating but the load remains the same. The PLC is programmed to report on the scenario by measuring speed, load, current draw and position and analysing this.
- Where multiple surrounding MLUs experience a change in load sharing the programed PLC reports on the scenario that confirms a

change in the load stability between MLUs. The program checks MLU positions and if each MLU has maintained its position compared to other MLUs, a failure in the structure or MLU attachment is reported.

- The load cell data is recorded and enables monitoring of hours, weight, total combined lifted weight and can be analysed to predict jack part maintenance intervals required to keep jacks healthy.

A wireless transmitter/receiver 54 provided in each modular lifting unit 42 enables wireless communication with other substations (modular lifting units 42), the power extension control boxes 43 and the main control box 40.

The PLC 50 in each modular lifting unit 42 will be used to:

- Supply a Modbus RTU network for the VSD 44, analogue network encoder 52 and load cell 53.
- Process the data received from the encoder 52 and VSD 44 against an algorithm (within the PLC) to amend the VSD speed or transmit data to a main PLC 60 via wireless communication.
- Communicate wirelessly with other modular lifting units 42 to analyse their data and act accordingly for a successful lift.

The control system further comprises one or several power sources 56 for providing electrical power for each of the modular lifting units 42, and power cables 58 for delivering electrical power from the main control box 40 and PECBs 43 to each of the modular lifting units 42, as shown in Figure 6. In this embodiment the power source comprises a 415 volt three phase AC generator 56 or, if needed, several other power sources such as other generators and power boxes 56a and 56b. The three phase AC generator 56a is connected to a 415 volt three phase circuit breaker 62 and main contactor 64 in the main control box 40 (see Figure 7). The main control box 40 activates the main contactor 64 which supplies the 415v three phase power to the motor in each modular lifting unit 42 via power cable 58. Main control box 40 also typically includes a power data logger 75 for monitoring and saving electrical parameters of a set of modular lifting units (MLUs).

The other generators and power boxes 56b and 56c are connected to a respective 415 volt three phase circuit breaker 62 and main contactor 64 in a respective power extension control box (PECB) 43 (see Figure 7.1). The PECBs 43 are used when multiple additional modular lifting units are needed to be supplied by power and/or total current consumption of MLUs is more than the current capacity of main control box 40. Each power extension control box 43 also comprises a main contactor 64 and a slave Programmable Logic Controller (PLC) 61 to receive and transmit data to main control box 40. A power supply provides 24v DC power for the slave PLC 61 and control system. The PECBs 43 activate the main contactor 64 which supplies the 415v three phase power to the motor in each modular lifting unit 42 via power cables 58. PECBs 43 also typically include a power data logger 75 for monitoring and saving electrical parameters of a set of modular lifting units (MLUs) 42.

The control system (24Vdc) typically has a machine safety system through a global E-Stop pushbutton 17 (see Figure 7) that is housed within the main control box 40 electrical enclosure. Provided the E-Stops are all in the correct position, 24Vdc can be activated through a start button 19, and the main contactor 64 which supplies the 415Vac three phase power to each motor in the modular lifting units 42.

The main control box 40 also comprises a main controller in the form of Programmable Logic Controller (PLC) 60 for controlling the supply of electrical power to each of the modular lifting units 42. A three phase transformer 66 provides 24v DC power for the main PLC 60 and control system. The control box 40 further comprises a mode switch 68 for switching the system between two modes: a group mode, in which the plurality of modular lifting units 42 is controlled synchronously as a group, and an individual mode, in which any one of the modular lifting units 42 is controlled independently of the other units. A wireless transmitter/receiver

70 preferably is provided in the main control box 40 for communicating wirelessly with each of the modular lifting units 42 and PECBs 43.

The main PLC 60 monitors the actual position of each modular lifting unit 42 and adjusts the speed by sending instructions to the VSDs 44 in each unit. This enables the control system to synchronise and control the actual position of each modular lifting unit (MLU) 42 via adjustments in speed. Control signals are received from, and transmitted to, each modular lifting unit 42 wirelessly, as shown in Figure 5. The VSD 44 in each MLU 42 changes the amount of current drawn by each motor depending on the load. The VSD speed is set by the MLU controller (PLC) 50 on board each MLU 42. Each MLU controller 50 monitors the position of the MLU via its encoder 52. The MLU controller 50 controls the on board VSD 44 as a slave, as shown in Figure 8. Each MLU controller (PLC) 50 in each MLU 42, in turn, acts as a slave to the Main controller (PLC) 60 in the main control box 40. This allows considerable more versatility in monitoring the maintenance, health of components, data log, position, load, response of each MLU 42. This combination of main controller 60 with multiple substation MLU controllers 50 enables the control system to effectively operate as a full SCADA (supervisory control and data acquisition) system.

Preferably the main control box 40 further comprises two 24v DC switches 72a and 72b to switch the control system up and down respectively. In group mode all the modular lifting units 42 perform synchronised movement when the 24v DC switches are switched up or down. In individual mode, each individual modular lifting unit 42 can be controlled without affecting the other units. This allows calibration of each modular lifting unit to a specific but different starting point.

Advantageously the main control box 40 is also provided with a Human Machine Interface (HMI) 74, for example a touch screen, to enable the PLC 60 to be programmed and reconfigured when required (see Figures 5 and 7). Preferably each of the modular lifting units 42 is also provided with a HMI 55.

The HMI touch screens enable a user to view meaningful control parameters of the various components of the control system (PLCs, VSDs, encoders, load cells). The user may tap the touch screen and dive deeper into adjusting a particular control parameter if needed, or resetting an internal error locally. Graphical buttons can be created to mimic a push button but the user has the option to create pages of buttons with a HMI touch screen.

The accuracy achieved when testing this embodiment of the control system was an error between a fully loaded and unloaded substation (MLU 42) of approximately 0.1mm. In addition, one of the principal benefits of the present control system is the ability to control the lifting of a horizontal plane to a very high level of accuracy. Testing has confirmed an accuracy of ±0.6mm between all MLUs.

An alternative topology for the third embodiment of the control system in accordance with the invention, for controlling a plurality of modular lifting units 42, is illustrated in Figures 10 and 11. Similar parts in this alternative topology are given like reference numerals as in Figures 6 and 7 and will not be described again in detail. In this alternative topology the control system comprises a main control box 80 for controlling a plurality of modular lifting units 42 connected in daisy chain configurations, as shown in Figure 10. A three phase AC generator 56a is connected to a 415 volt three phase circuit breaker 62 via a main contactor 64 in the main control box 80 (see Figure 11). The main control box 80 activates the main contactor 64 which supplies the 415v three phase power to the motor in each modular lifting unit 42 via power cable 58a. Main control box 80 also typically includes a power data logger 75 for monitoring and saving electrical parameters of a set of modular lifting units (MLUs). The data logger 75 records various electrical parameters, such as total current drawn, voltage per operation, amount of electrical disconnections, three phase unbalance situations, amongst others, that are then sent to a main controller (PLC) 60 for future analysis.

In this alternative configuration, instead of one or more power extension control boxes (PECBs) to distribute the electrical power among the MLUs 42, the main control box is provided with a plurality of extension contactors 84 and extension 415v three phase circuit breakers 82. Instead of slave PLCs in each PECB, the main controller (PLC) 60 directly activates the extension contactors 84 which supply 415v three phase power from a plurality of additional on-site power boxes or three phase generators 56b, 56c, 56c, etc., to the motor in each of a plurality of modular lifting units (MLUs) 42 via power cables 58b, 58c, 58d, etc. The power data logger 75 is also connected to each of the extension contactors 84, and monitors and records the various electrical parameters of the additional MLUs 42.

A method of controlling the operation of a plurality of modular lifting units, using the above control system, will now be described with reference to Figures 9 to 9.3. Figures 9 to 9.3 illustrate in flowchart form the method steps implemented by the software programmed into the main controller (PLC 30 or 60) in the second and third embodiments of the control system according to the present invention.

When the control system is switched ON the PLC 30 or 60 is energised at step 100 and then the system asks the operator if there are any power extension control boxes (PECBs) being used or needed for the current operation at step 102. If the answer is positive, the system switches on the contactor and starts scanning the network at step 104 to find how many PECBs are switched and connected. If X amount of PECBs are not yet connected, (X is a pre-set number depending on the application of the control system and MLUs), the necessary adjustment is made at step 105. Once it is detected at step 106 that X amount of PECBs are connected, the system energizes the MLUs at step 108. The system then commences scanning of the network (hardwired or wireless) at step 110 to detect how many, if any, modular lifting units (MLUs) 12 or 42 are connected to the network. If X amount of MLUs are not yet connected, (X is a pre-set number depending on the application of the control system and MLUs. Typically for lifting a building structure X = 4 minimum.), the necessary adjustment is made at step 111. When it is determined at step 112 that X number of MLUs are connected to the network, the operator enables the PLC to enter manual or local control mode at step 109. The operator will then proceed to the step of adjusting the starting height of each MLU 12 or 42 at step 113 (see Figure 9.1). The PLC interrogates the load cells in each MLU to check, at step 114, that the load on that MLU is within the safe working load. If any one of the MLUs is overloaded, (determined at step 116), the PLC will suspend further operations until an adjustment is made (step 118) to reduce the load to be within the safe limit of that MLU. This may mean including an additional MLU into the lifting operation to distribute the load.

Provided that all MLUs are operating within their safe working load, and the starting heights have been adjusted (step 113), the starting position of the encoder in each MLU is set to a zero position at step 115, in order to ensure that all the MLUs start at the same base line height. Then the required lift height for this job is entered into the PLC by an operator, via the HMI touch screen, at step 117. At step 119, the PLC determines on the basis of the detected starting height of all the MLUs whether the system can reach the set lift height. If not, then the starting height of the MLUs may need to be re-adjusted at step 113. If there is no problem with the set lift height, the operator then sets the lift parameters at step 120. The lift parameters include such factors as the actual lift position of each MLU, the wind conditions, the load, the control mode and motor parameters.

Once all the lift parameters have been entered at step 120, the operator enables the PLC to execute automatic (group) mode at step 122 (see Figure 9.2). At the same time, (step 124) the PLC commences a data logging operation, in which all data from the lift operation is automatically logged and stored by the PLC in its internal memory, at step 129 (see Figure 9.3). This data may also be transmitted to the company's main server for back-up. It will be kept as a record of the lift operation and analysed for any anomalies or significant events during the lift.

In automatic group mode the PLC commences the lift operation at 126, and continues to monitor the operation of all components in the network. This includes receiving feedback signals from the encoder in each of the MLUs providing an indication of the actual lift position of the MLU. If it is detected at step 128 that any of the operating parameters is about to, or actually does, fall outside pre-set limits, the PLC analyses possible scenarios at step 130 that would explain the anomaly, and may attempt to rectify the issue at step 132. However, it also continually monitors the situation, and if it determines at step 134 that the situation is not safe, the lifting operation is paused at step 136.

At step 133 it checks if the potentially unsafe situation has been rectified, and only if it is safe to re-start operation (step 135) will it continue the lifting operation at step 138. On the other hand, if it is determined at step 134 that the situation is still safe, then the PLC continues the lifting operation to the pre-set lift height at step 138.

Once it detects at step 140 that the MLUs have reached the pre-set lift height, it will conclude the lifting operation at step 142.

In each of the described embodiments the modular lifting units (MLUs) have been lifting jacks powered by an electric motor, similar to that described in PCT/AU2014/000224. However it will be understood that the MLUs could be any suitable lifting device, and are not limited to the electrically-powered lifting jacks of the described embodiments. For example, the MLUs could also be hydraulically- or pneumatically-powered lifting jacks, in which case the power source for the MLUs would be a compressor.

Now that several embodiments of the control system have been described in detail, it will be apparent that the described embodiments provide a number of advantages over the prior art, including the following:

(i) Accurate and stable lifting of a building structure using a plurality of lifting jacks (modular lifting units).

(ii) Improved control during synchronised operation of the modular lifting units to ensure that the building structure is not subject to deflection during lifting.

(iii) Ability to control the lifting of a horizontal plane to a very high level of accuracy, e.g. an accuracy of ±0.6mm between all MLUs.

(iv) More stable operation of the control system by using absolute or incremental encoders and on board controllers in the modular lifting units rather than servo devices.

(v) More versatile implementation due to use of wireless communication between the modular lifting units, and between the main control box and the modular lifting units.

It will be readily apparent to persons skilled in the relevant arts that various modifications and improvements may be made to the foregoing embodiments, in addition to those already described, without departing from the basic inventive concepts of the present invention. For example, other types of modular lifting unit could be employed, apart from the lifting jacks of the preferred embodiments. It will also be understood that other types of data processing device could be employed for the main controller and MLU controllers, apart from the Programmable Logic Controllers (PLCs) of the preferred embodiments. Therefore, it will be appreciated that the scope of the invention is not limited to the specific embodiments described.

Claims

1. A control system for controlling the operation of a plurality of modular lifting units, the control system comprising:

a plurality of modular lifting units;

a power source for providing power to each of the modular lifting units; and,

a main control box connected between the power source and the modular lifting units, the main control box comprising a mode switch for switching the system between two control modes: a group mode, in which the plurality of modular lifting units is controlled synchronously as a group; and, an individual mode, in which any one of the modular lifting units is controlled independently of the other units, and wherein, in group mode, synchronous movement of the modular lifting units is achieved by setting each unit to run at the same speed.

2. A control system for controlling the operation of a plurality of modular lifting units as defined in claim 1, wherein each modular lifting unit comprises a variable speed drive (VSD) for controlling the speed of an electric motor in the unit, and in group mode, synchronous movement of the modular lifting units is achieved by setting the VSD in each unit to run the motor at the same speed with no feedback from any part of the system.

3. A control system for controlling the operation of a plurality of modular lifting units as defined in claim 1 or claim 2, wherein the main control box further comprises a main controller, operatively coupled to the mode switch, for controlling the supply of electrical power to each of the modular lifting units.

4. A control system for controlling the operation of a plurality of modular lifting units as defined in claim 3, wherein the main control box also includes a main contactor which connects the power source to the modular lifting units via a three phase circuit breaker.

5. A control system for controlling the operation of a plurality of modular lifting units as defined in claim 3, wherein the main control box also includes a power data logger for monitoring and recording electrical parameters for each of the modular lifting units.

6. A control system for controlling the operation of a plurality of modular lifting units as defined in claim 3, wherein the main controller is a Programmable Logic Controller (PLC).

7. A control system for controlling the operation of a plurality of modular lifting units as defined in claim 1, wherein the control system further comprises a plurality of power extension control boxes (PECBs), when additional power sources are required and/or the number of modular lifting units exceeds a capacity of the main control box, each PECB being connected between an additional power source and a plurality of additional modular lifting units.

8. A control system for controlling the operation of a plurality of modular lifting units as defined in claim 7, wherein each of the PECBs is under the control of the main control box.

9. A control system for controlling the operation of a plurality of modular lifting units, the control system comprising:

a plurality of modular lifting units;

a power source for providing power to each of the modular lifting units;

a main control box connected between the power source and the modular lifting units, the main control box comprising:

a mode switch for switching the system between two control modes: a group mode, in which the plurality of modular lifting units is controlled synchronously as a group; and, an individual mode, in which any one of the modular lifting units is controlled independently of the other units; and, a main controller operatively coupled to the mode switch for transmitting control signals to each of the modular lifting units, the main controller also receiving feedback signals from each of the modular lifting units wherein, in group mode, synchronous movement of the modular lifting units is achieved by the main controller using the feedback signals received from each of the modular lifting units to supply power to, monitor and control the speed of the modular lifting units.

10. A control system for controlling the operation of a plurality of modular lifting units as defined in claim 9, wherein each modular lifting unit (MLU) comprises an encoder for sensing a lifting position of the unit and providing a feedback signal to the main controller.

11. A control system for controlling the operation of a plurality of modular lifting units as defined in claim 10, wherein the encoder is connected to an actuator of the MLU, where a useful load position can be monitored.

12. A control system for controlling the operation of a plurality of modular lifting units as defined in claim 11, wherein the encoder generates a predetermined number of pulses, according to a prescribed resolution, for each 360° of rotation of a motor/gear box in the MLU.

13. A control system for controlling the operation of a plurality of modular lifting units as defined in claim 12, wherein, the encoder is used to measure a lift-carriage movement on a lifting jack, relative to a stationary reference point.

14. A control system for controlling the operation of a plurality of modular lifting units as defined in any one of claims 10 to 13, wherein the encoder is an absolute encoder or an incremental encoder.

15. A control system for controlling the operation of a plurality of modular lifting units as defined in claim 10, wherein each modular lifting unit further comprises a MLU controller for processing data received from the encoder and preparing the feedback signals.

16. A control system for controlling the operation of a plurality of modular lifting units as defined in claim 15, wherein the MLU controller controls the operation of the modular lifting unit with reference to an algorithm within the MLU controller for controlling the MLU and/or transmitting the feedback signals to the main controller.

17. A control system for controlling the operation of a plurality of modular lifting units as defined in claim 9, wherein each modular lifting unit comprises a variable speed drive (VSD) for controlling the speed of an electric motor in the unit.

18. A control system for controlling the operation of a plurality of modular lifting units as defined in claim 10, wherein each modular lifting unit also includes a load cell in order to measure the weight of a structure to be lifted before and during the lift.

19. A control system for controlling the operation of a plurality of modular lifting units as defined in claim 9, wherein the main controller comprises a Programmable Logic Controller (PLC) for controlling the supply of electrical power to each of the modular lifting units.

20. A control system for controlling the operation of a plurality of modular lifting units as defined in claim 19, wherein the main control box also includes a main contactor which connects the power source to the modular lifting units via a three phase circuit breaker.

21. A control system for controlling the operation of a plurality of modular lifting units as defined in claim 9, wherein the control system further comprises a plurality of power extension control boxes (PECBs), when additional power sources are required and/or the number of modular lifting units exceeds a capacity of the main control box, each PECB being connected between an additional power source and a plurality of additional modular lifting units.

22. A control system for controlling the operation of a plurality of modular lifting units as defined in claim 21, wherein each PECB comprises a slave

controller, operatively coupled to the main controller, for controlling the supply of electrical power to each of the additional modular lifting units.

23. A control system for controlling the operation of a plurality of modular lifting units as defined in claim 22, wherein the slave controller is a Programmable Logic Controller (PLC).

24. A control system for controlling the operation of a plurality of modular lifting units as defined in claim 22, wherein each PECB also includes a power data logger for monitoring and recording electrical parameters for the additional modular lifting units.

25. A control system for controlling the operation of a plurality of modular lifting units as defined in claim 15, wherein the main controller monitors the actual position of each modular lifting unit (MLU) and adjusts the lifting by sending instructions to the MLU controller in each MLU.

26. A control system for controlling the operation of a plurality of modular lifting units as defined in claim 25, wherein the control system synchronises and controls the actual position of each modular lifting unit via adjustments in speed.

27. A control system for controlling the operation of a plurality of modular lifting units as defined in claim 9, wherein the main control box also comprises a wireless transmitter/receiver for transmitting and receiving wireless signals to/from the modular lifting units.

28. A control system for controlling the operation of a plurality of modular lifting units as defined in claim 27, wherein each modular lifting unit also comprises a wireless transmitter/receiver for receiving control signals and transmitting feedback signals wirelessly to the main controller.

29. A control system for controlling the operation of a plurality of modular lifting units as defined in claim 21, wherein each PECB also comprises a wireless transmitter/receiver for transmitting and receiving wireless signals to/from the main control box and the additional modular lifting units.

30. A method of controlling the operation of a plurality of modular lifting units via a main control box and a plurality of power extension control boxes (PECBs), each PECB being connected to the main control box and between an additional power source and a plurality of additional modular lifting units (MLUs) respectively, the method comprising:

detecting the number of PECBs; and

providing feedback signals from each of the PECBs to the main control box.

31. A method of controlling the operation of a plurality of modular lifting units as defined in claim 30, wherein the power extension control boxes (PECBs) are connected between various power sources, such as on-site generators or on-site power boxes or other power sources and the additional modular lifting units.

32. A method of controlling the operation of a plurality of modular lifting units as defined in claim 31, wherein each PECB is controlled by the main control box.

33. A method of controlling the operation of a plurality of modular lifting units as defined in claim 32, wherein the main control box switches a main contactor inside each PECB ON or OFF in order to energise or de-energize the MLUs connected to each PECB respectively.

34. A method of controlling the operation of a plurality of modular lifting units as defined in claim 32, wherein each PECB sends a feedback signal or a series of feedback signals to the main control box to indicate if the main contactor in each PECB is working.

35. A method of controlling the operation of a plurality of modular lifting units as defined in claim 30, wherein each PECB includes a data logging device, which records various electrical parameters, such as total current drawn, voltage per operation, amount of electrical disconnections, three phase unbalance situations, amongst others, that are then sent to a main controller in the main control box for future analysis.

36. A method of controlling the operation of a plurality of modular lifting units via a main control box connected between a power source and the modular lifting units, the method comprising the steps of:

detecting the number of modular lifting units connected to a control network;

providing power to each of the modular lifting units in accordance with the method;

selecting one of two control modes: a group mode, in which the plurality of modular lifting units is controlled synchronously as a group; and, an individual mode, in which any one of the modular lifting units is controlled independently of the other units; and,

transmitting control signals from the main controller to the modular lifting units wherein, in group mode, synchronous movement of the modular lifting units is achieved by using feedback signals received from each of the modular lifting units to supply power to, monitor and control the speed of the modular lifting units.

37. A method of controlling the operation of a plurality of modular lifting units as defined in claim 36, wherein each modular lifting unit (MLU) comprises an encoder and the method comprises the further steps of: sensing a lifting position of the unit and providing a feedback signal to the main controller.

38. A method of controlling the operation of a plurality of modular lifting units as defined in claim 37, wherein the encoder is an absolute encoder or incremental encoder.

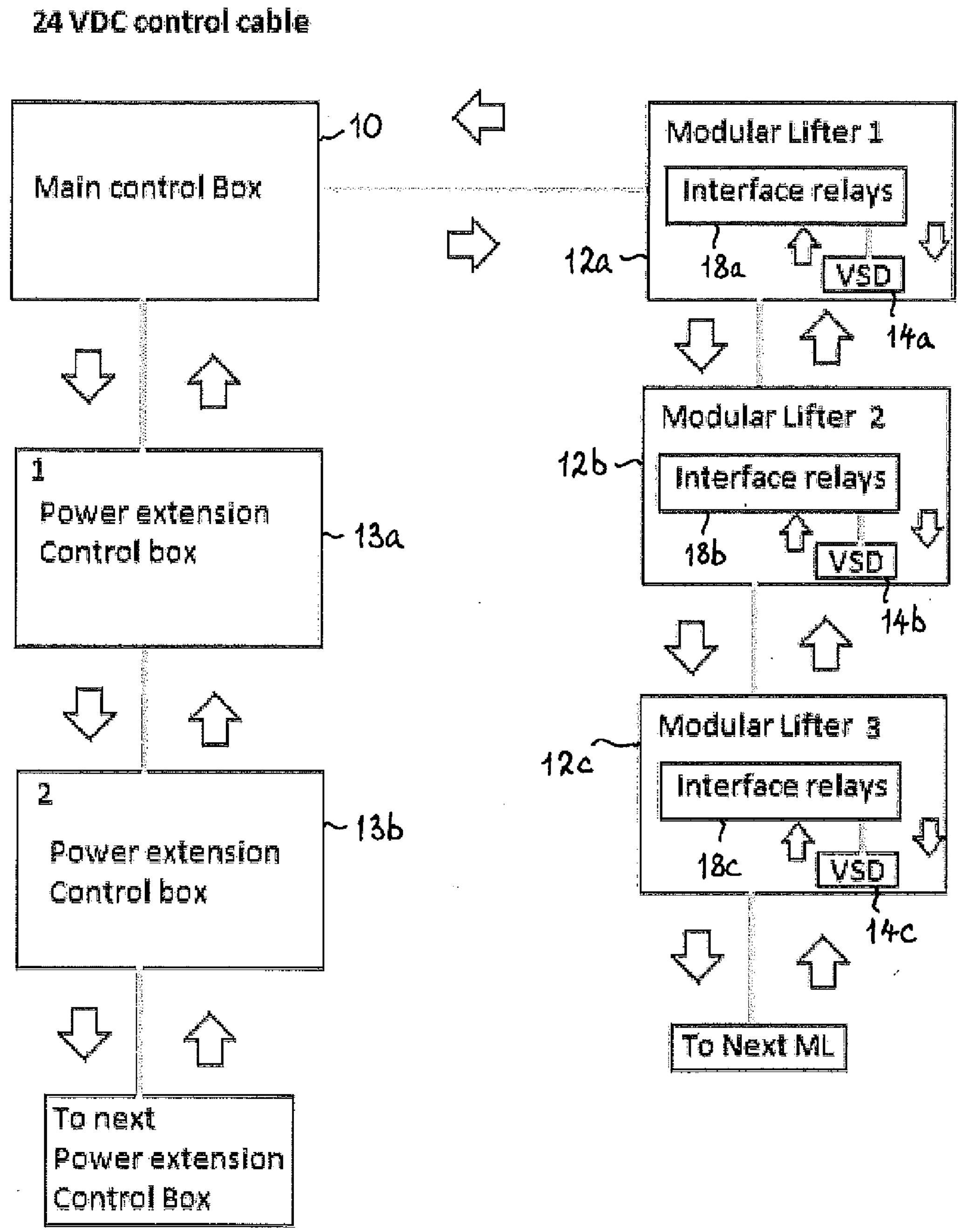
24 VDC control cable
Main control Box
10
Modular Lifter 1
Interface relays
12a
18a
VSD
14a
1
Power extension
Control box
13a
Modular Lifter 2
12b
Interface relays
18b
VSD
14b
2
Power extension
Control box
13b
Modular Lifter 3
12c
Interface relays
18c
VSD
14c
To Next ML
To next
Power extension
Control Box

Figure 1

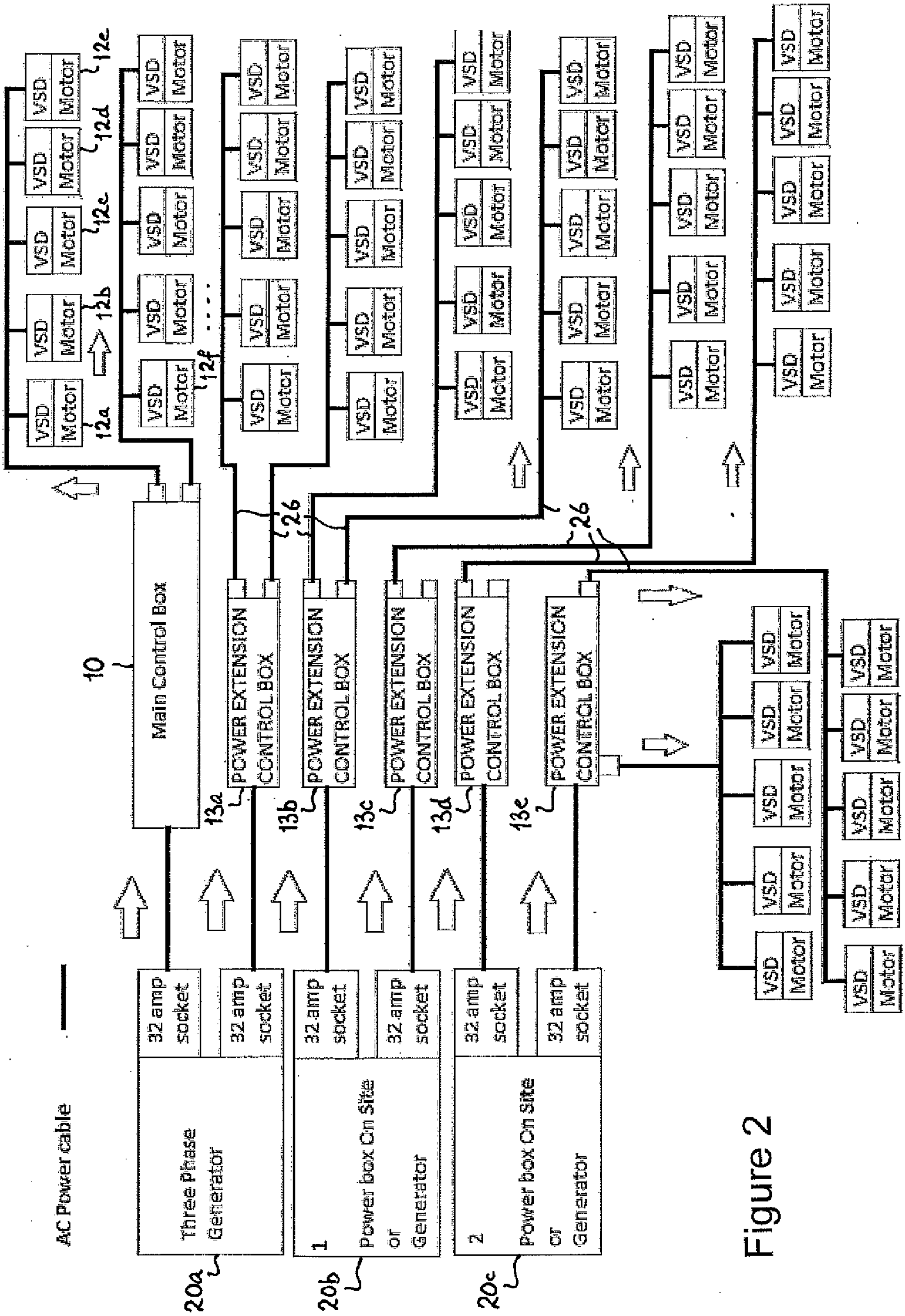
AC Power cable
Three Phase Generator
1 Power box On Site or Generator
2 Power box On Site or Generator
32 amp socket
Main Control Box
POWER EXTENSION CONTROL BOX
VSD
Motor
10
12a
12b
12c
12d
12e
12f
13a
13b
13c
13d
13e
20a
20b
20c
26

Figure 2

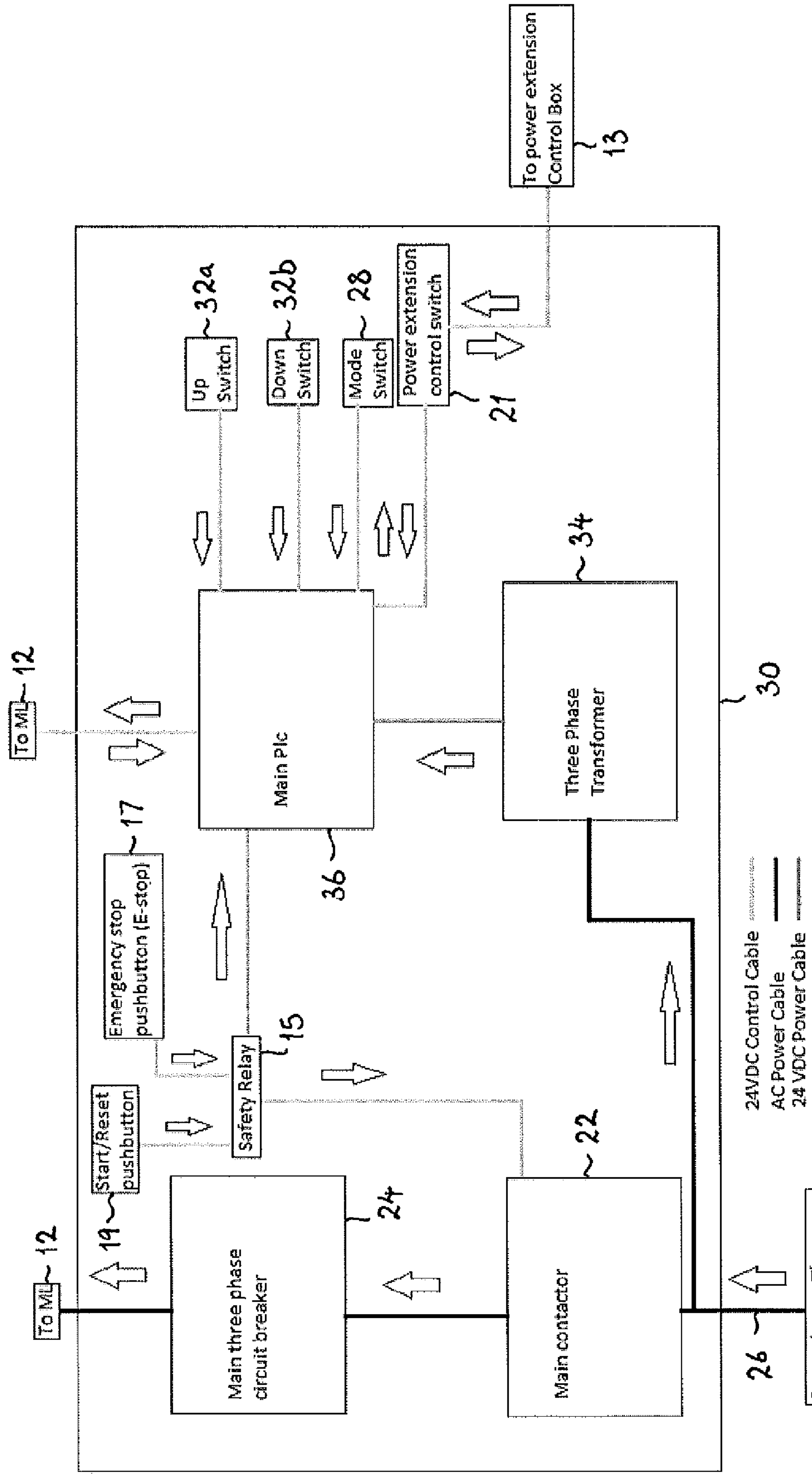
To power extension Control Box
13
Up Switch
32a
Down Switch
32b
Mode Switch
28
Power extension control switch
21
To ML
12
Main Plc
36
34
Three Phase Transformer
30
Emergency stop pushbutton (E-stop)
17
Safety Relay
15
Start/Reset pushbutton
19
22
24
To ML
12
Main three phase circuit breaker
Main contactor
26
Power box or Three phase generator on site
20
24VDC Control Cable
AC Power Cable
24 VDC Power Cable

Figure 3

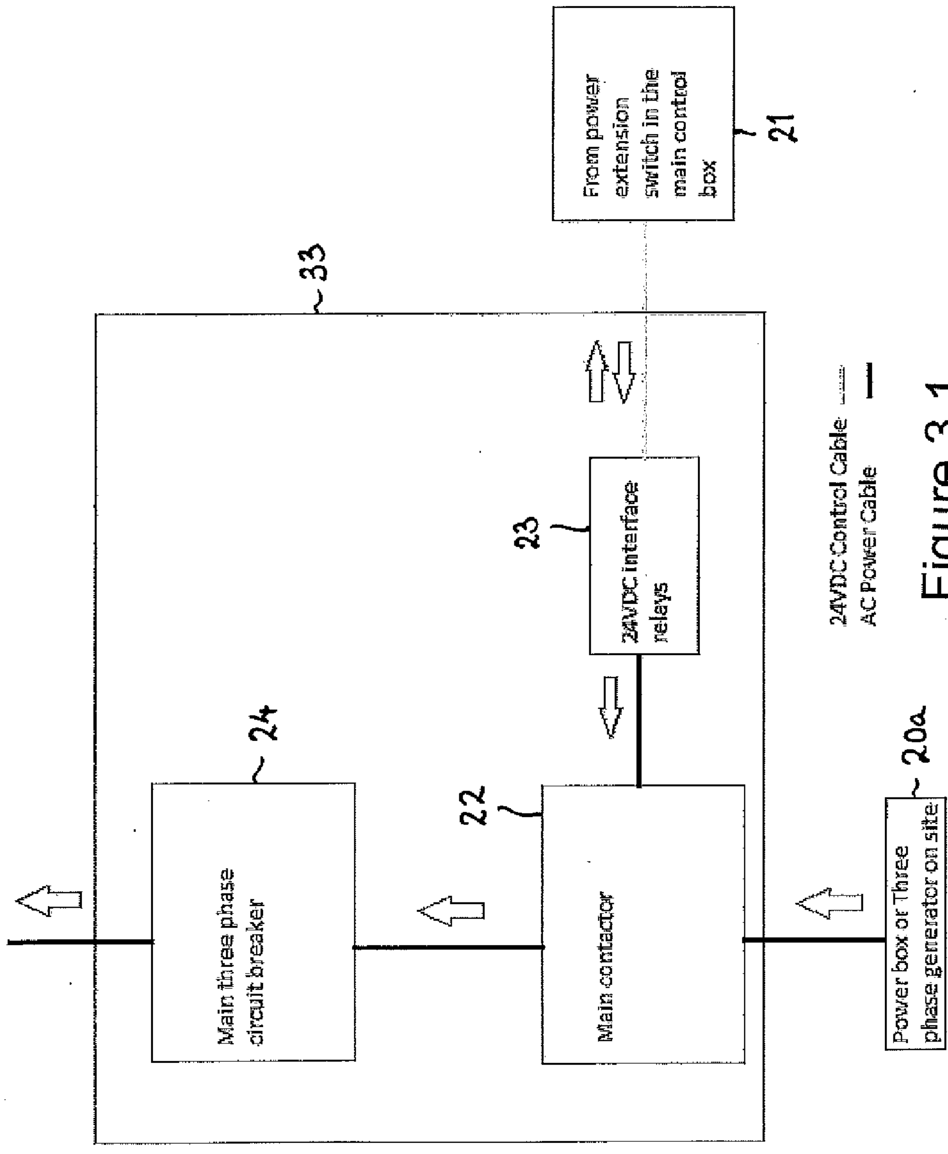
From power extension switch in the main control box
21
33
24VDC interface relays
23
Main three phase circuit breaker
24
Main contactor
22
Power box or Three phase generator on site
20a
24VDC Control Cable
AC Power Cable

Figure 3.1

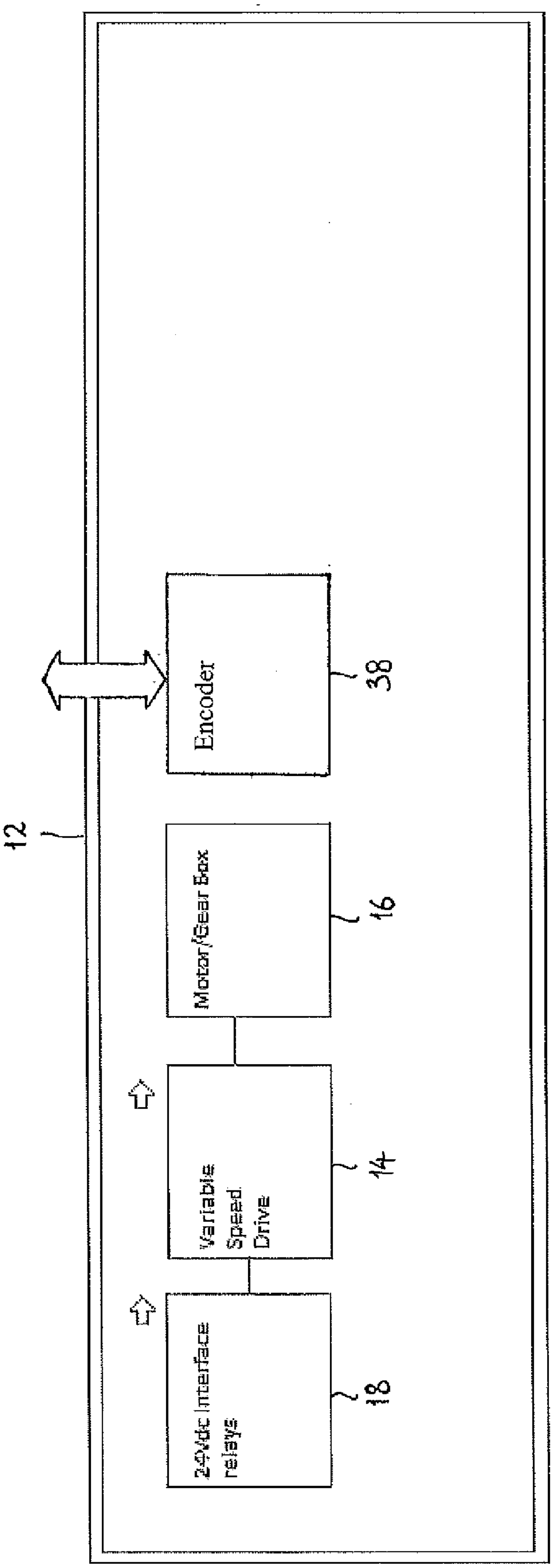
12
Encoder
38
Motor/Gear Box
16
Variable
Speed
Drive
14
24Vdc Interface
relays
18

Figure 4

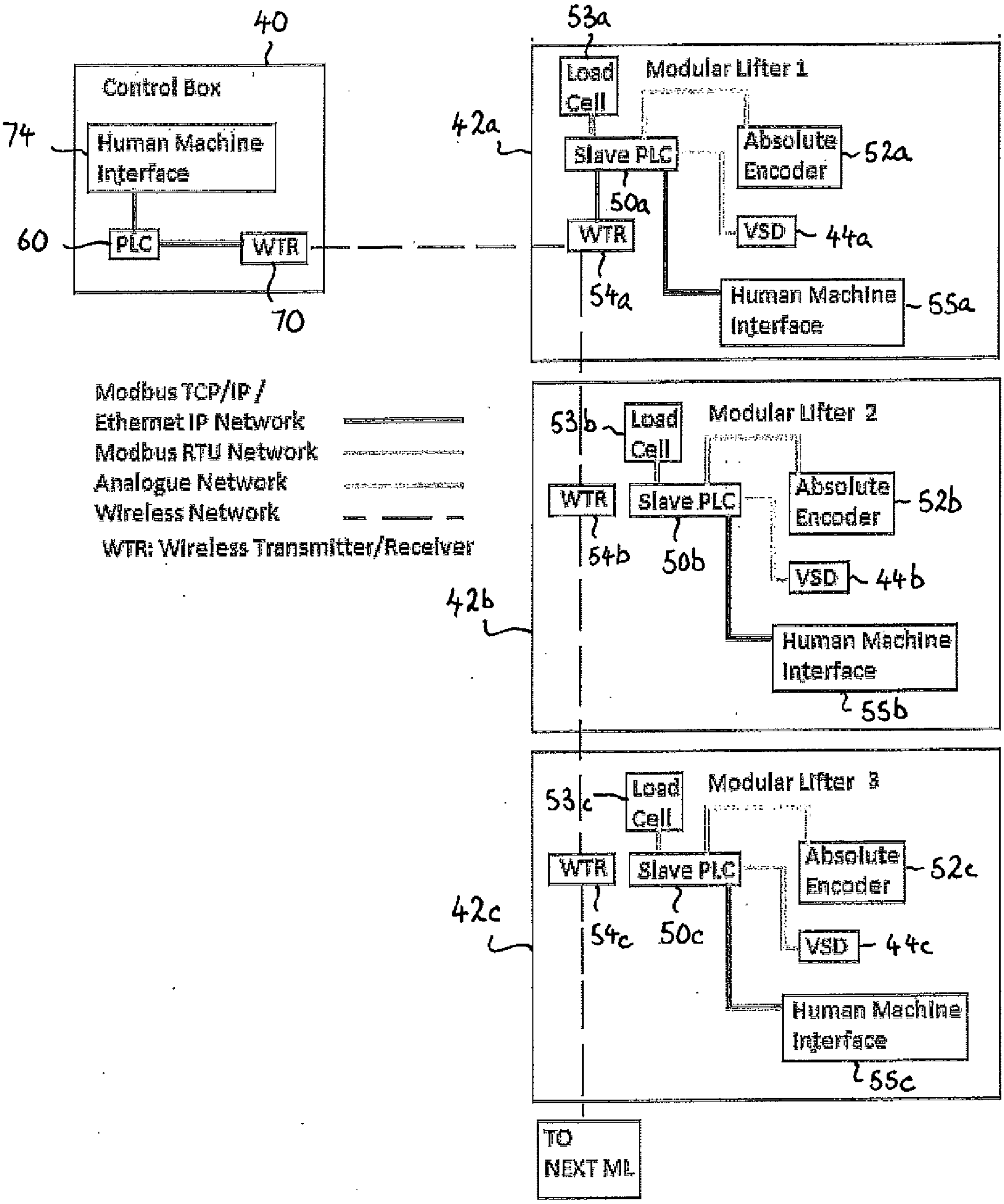
40
Control Box
74
Human Machine Interface
60
PLC
WTR
70
53a
Load Cell
Modular Lifter 1
42a
Slave PLC
Absolute Encoder
52a
50a
WTR
VSD
44a
54a
Human Machine Interface
55a
Modbus TCP/IP / Ethernet IP Network
Modbus RTU Network
Analogue Network
Wireless Network
WTR: Wireless Transmitter/Receiver
53b
Load Cell
Modular Lifter 2
WTR
Slave PLC
Absolute Encoder
52b
54b
50b
VSD
44b
42b
Human Machine Interface
55b
53c
Load Cell
Modular Lifter 3
WTR
Slave PLC
Absolute Encoder
52c
42c
54c
50c
VSD
44c
Human Machine Interface
55c
TO NEXT ML

Figure 5

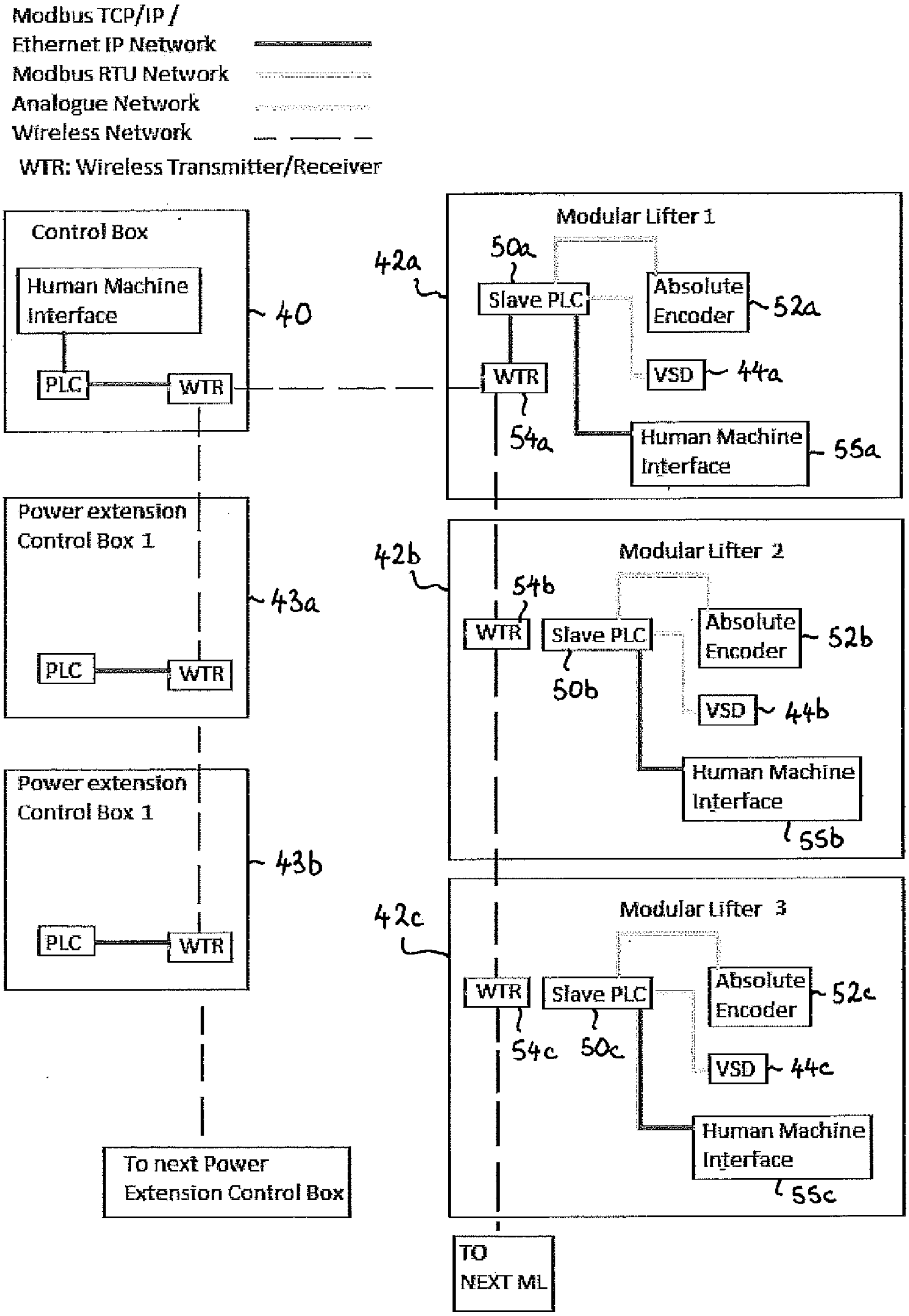
Modbus TCP/IP / Ethernet IP Network
Modbus RTU Network
Analogue Network
Wireless Network
WTR: Wireless Transmitter/Receiver
Control Box
Human Machine Interface
PLC
WTR
40
Power extension Control Box 1
PLC
WTR
43a
Power extension Control Box 1
PLC
WTR
43b
To next Power Extension Control Box
Modular Lifter 1
42a
50a
Slave PLC
Absolute Encoder
52a
WTR
54a
VSD
44a
Human Machine Interface
55a
Modular Lifter 2
42b
54b
WTR
Slave PLC
50b
Absolute Encoder
52b
VSD
44b
Human Machine Interface
55b
Modular Lifter 3
42c
WTR
Slave PLC
54c
50c
Absolute Encoder
52c
VSD
44c
Human Machine Interface
55c
TO NEXT ML

Figure 5.1

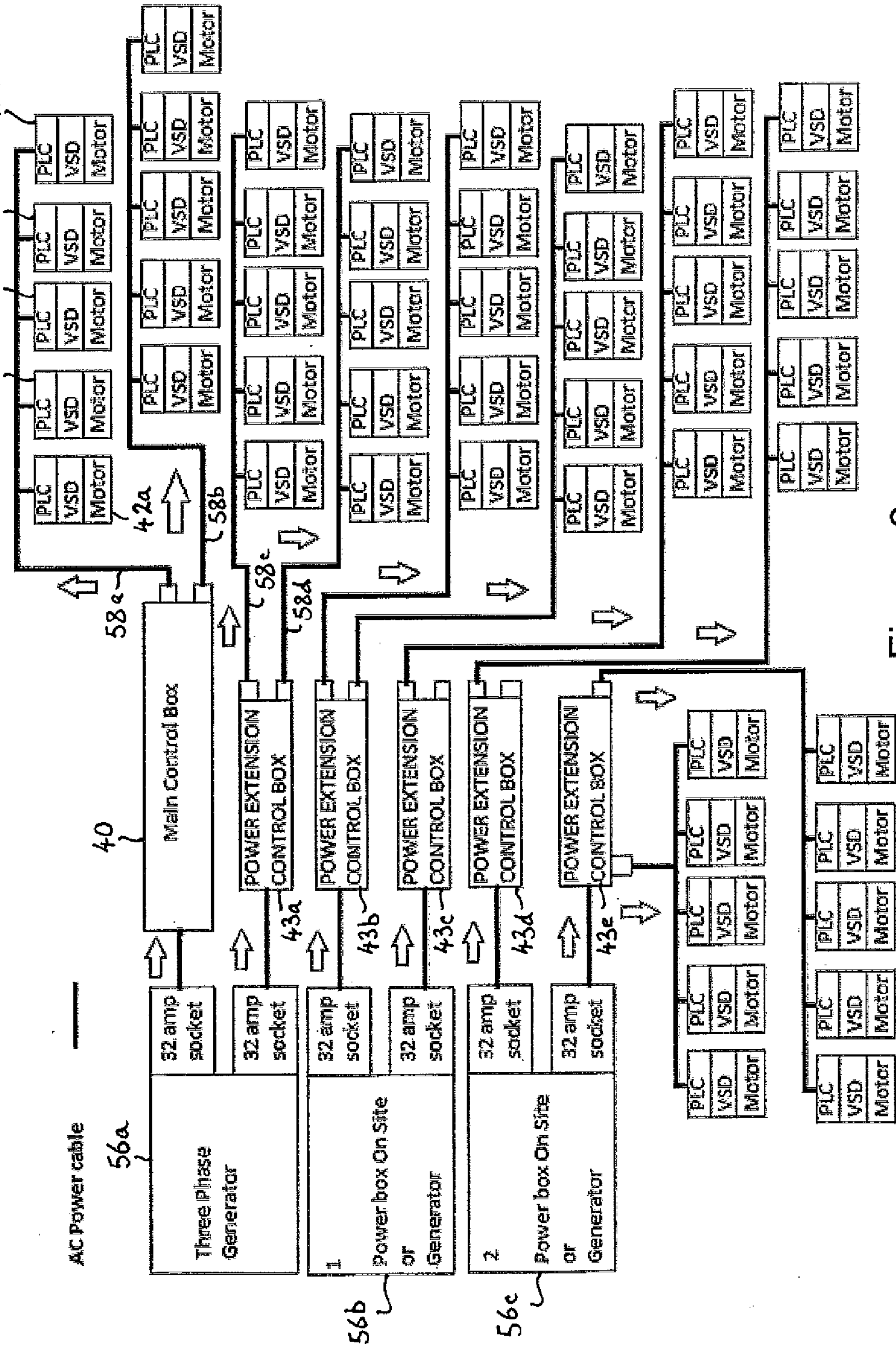
AC Power cable
56a
Three Phase Generator
32 amp socket
32 amp socket
1 Power box On Site or Generator
56b
32 amp socket
32 amp socket
2 Power box On Site or Generator
56c
32 amp socket
32 amp socket
40
Main Control Box
58a
58b
58c
58d
POWER EXTENSION CONTROL BOX
43a
43b
43c
43d
43e
42a
42b
42c
42d
42e
PLC
VSD
Motor

Figure 6

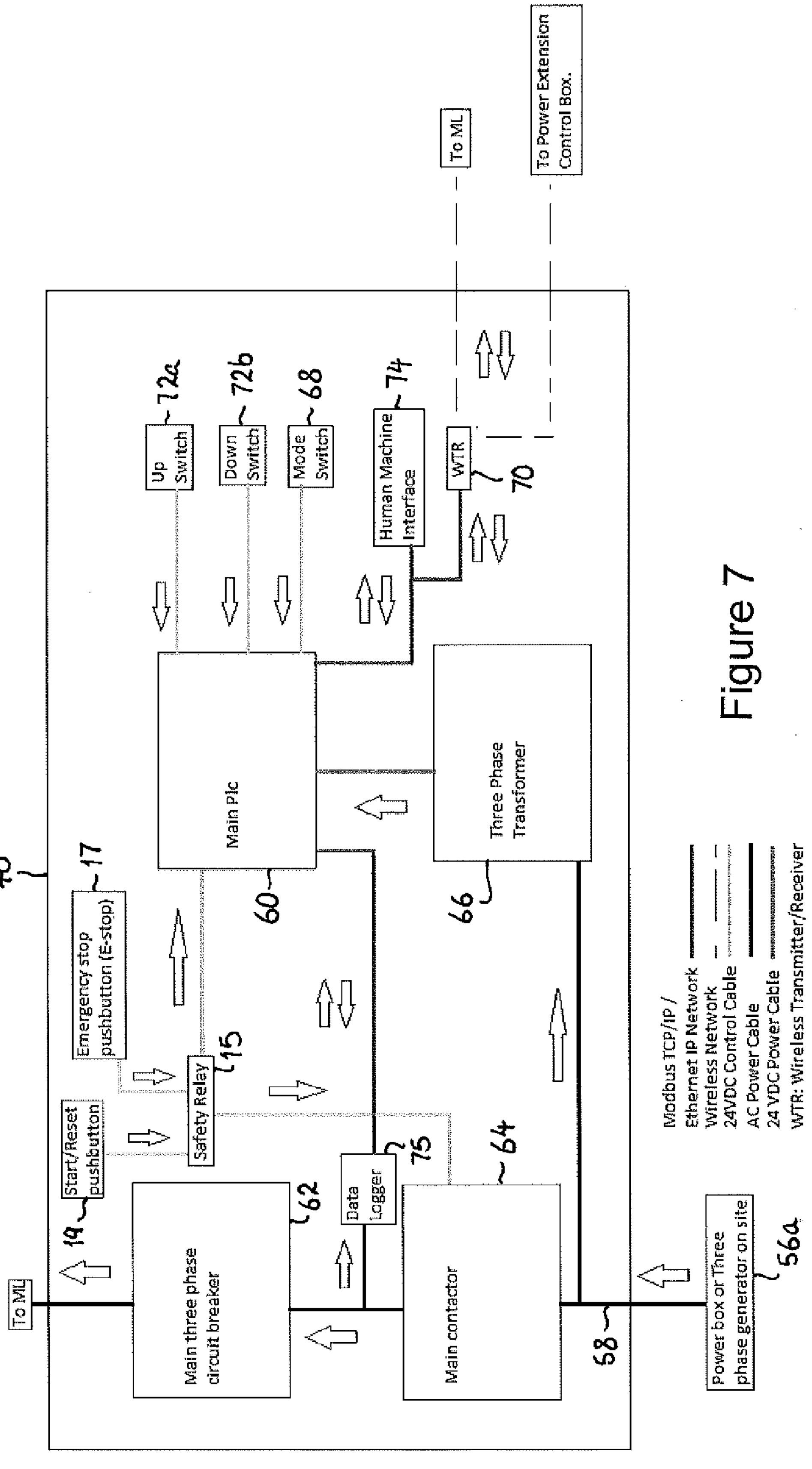
To ML
To Power Extension Control Box.
Up Switch
72a
Down Switch
72b
Mode Switch
68
Human Machine Interface
74
WTR
70
Main Plc
60
Three Phase Transformer
66
40
Emergency stop pushbutton (E-stop)
17
Safety Relay
15
Start/Reset pushbutton
19
Data Logger
75
Main three phase circuit breaker
62
Main contactor
64
To ML
58
Power box or Three phase generator on site
56a
Modbus TCP/IP / Ethernet IP Network
Wireless Network
24VDC Control Cable
AC Power Cable
24 VDC Power Cable
WTR: Wireless Transmitter/Receiver

Figure 7

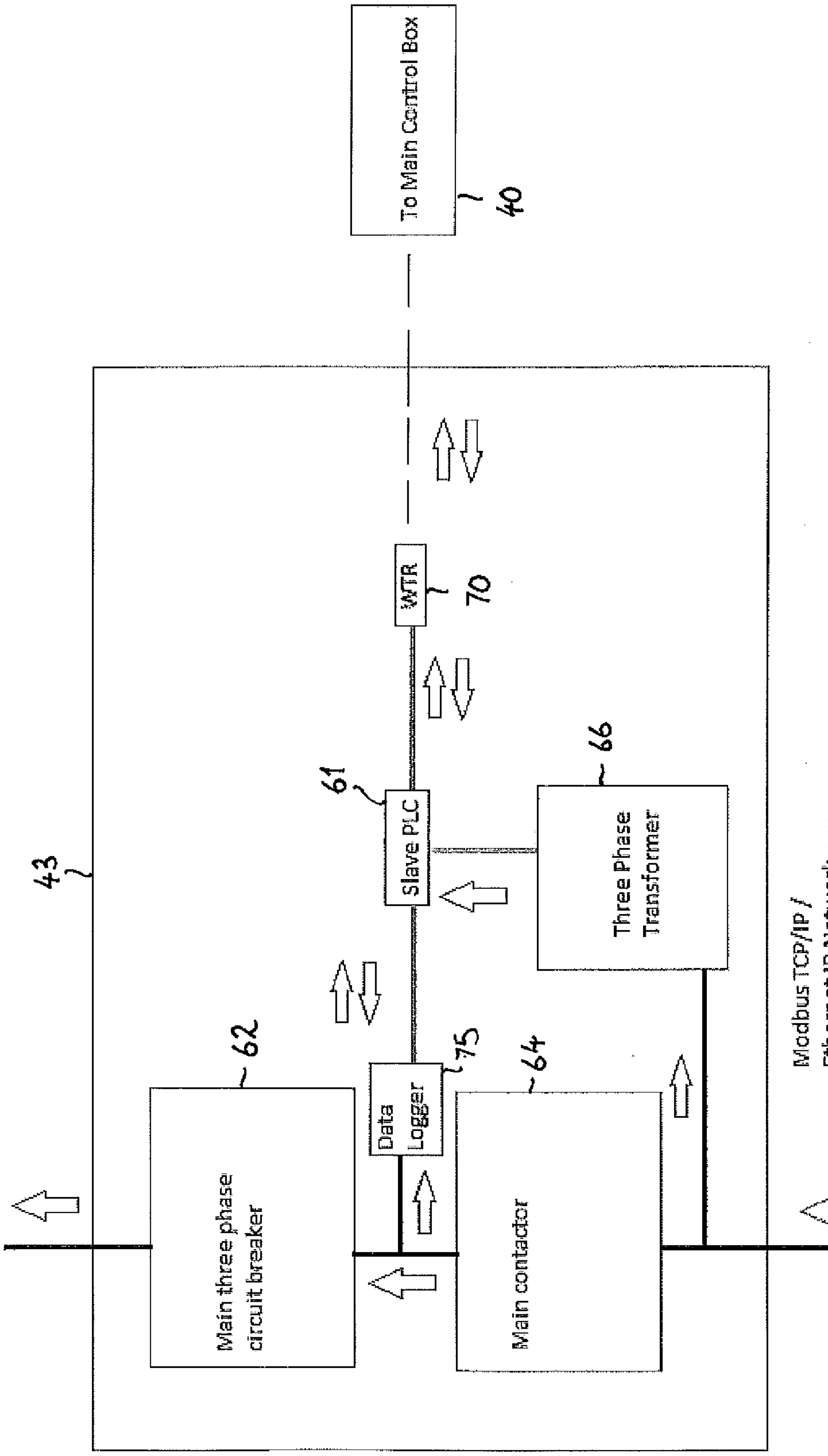
To Main Control Box
40
43
WTR
70
Slave PLC
61
Three Phase Transformer
66
Data Logger
75
Main three phase circuit breaker
62
Main contactor
64
Power box or Three phase generator on site
56b
Modbus TCP/IP / Ethernet IP Network
Wireless Network
AC Power Cable
24 VDC Power Cable
WTR: Wireless Transmitter/Receiver

Figure 7.1

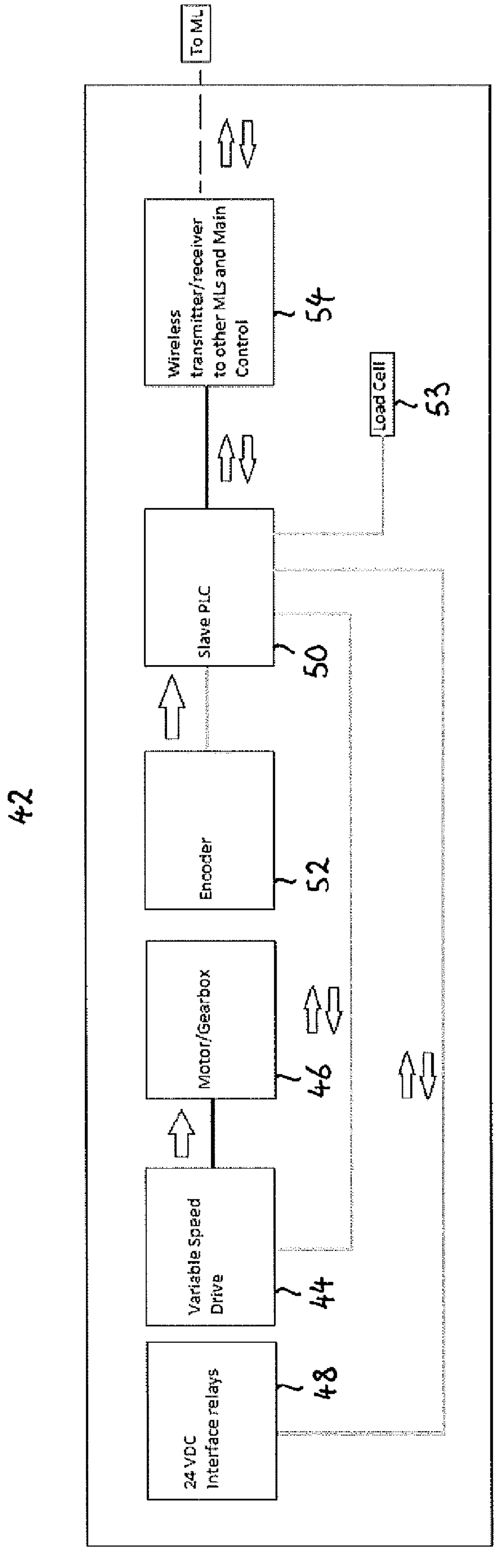

Figure 8

Modbus TCP/IP / Ethernet IP Network
Modbus RTU Network
Analogue Network
Wireless Network
WTR: Wireless Transmitter/Receiver

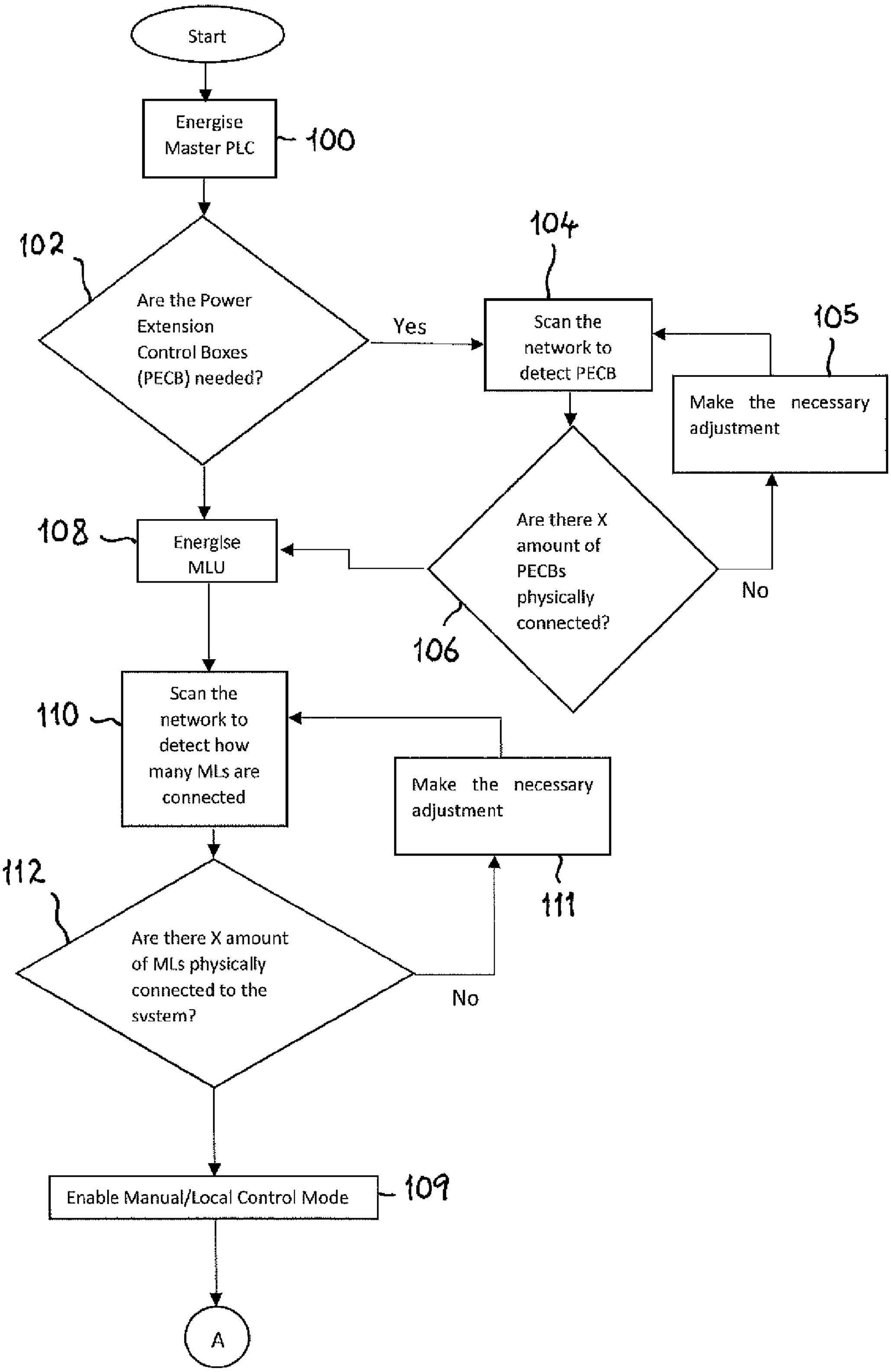
Start
Energise Master PLC
100
102
Are the Power Extension Control Boxes (PECB) needed?
Yes
104
Scan the network to detect PECB
105
Make the necessary adjustment
108
Energise MLU
Are there X amount of PECBs physically connected?
No
106
110
Scan the network to detect how many MLs are connected
Make the necessary adjustment
111
112
Are there X amount of MLs physically connected to the system?
No
Enable Manual/Local Control Mode
109
A

Figure 9

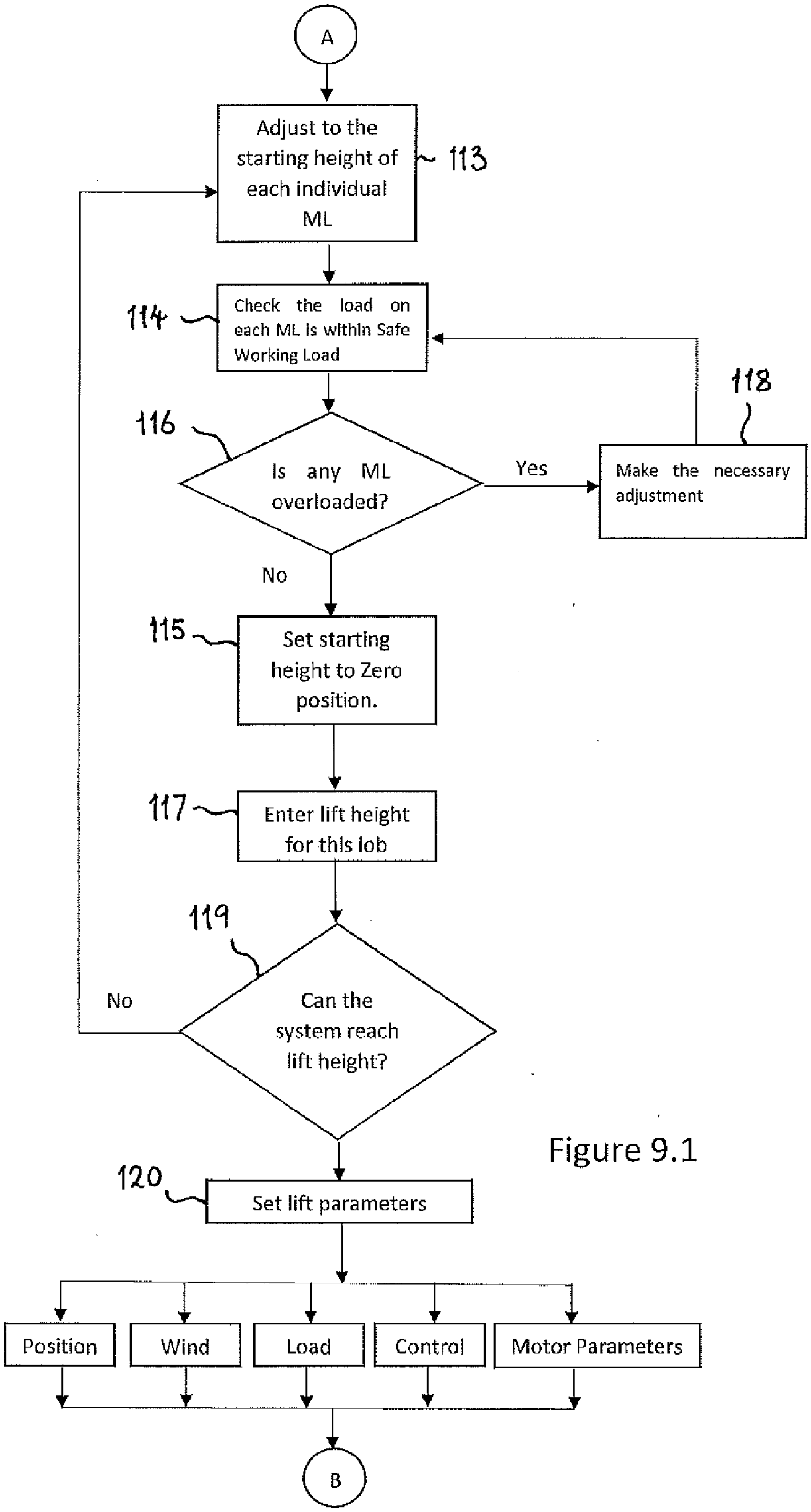
A
Adjust to the starting height of each individual ML
113
114
Check the load on each ML is within Safe Working Load
116
Is any ML overloaded?
Yes
118
Make the necessary adjustment
No
115
Set starting height to Zero position.
117
Enter lift height for this job
119
No
Can the system reach lift height?
120
Set lift parameters
Position
Wind
Load
Control
Motor Parameters
B

Figure 9.1

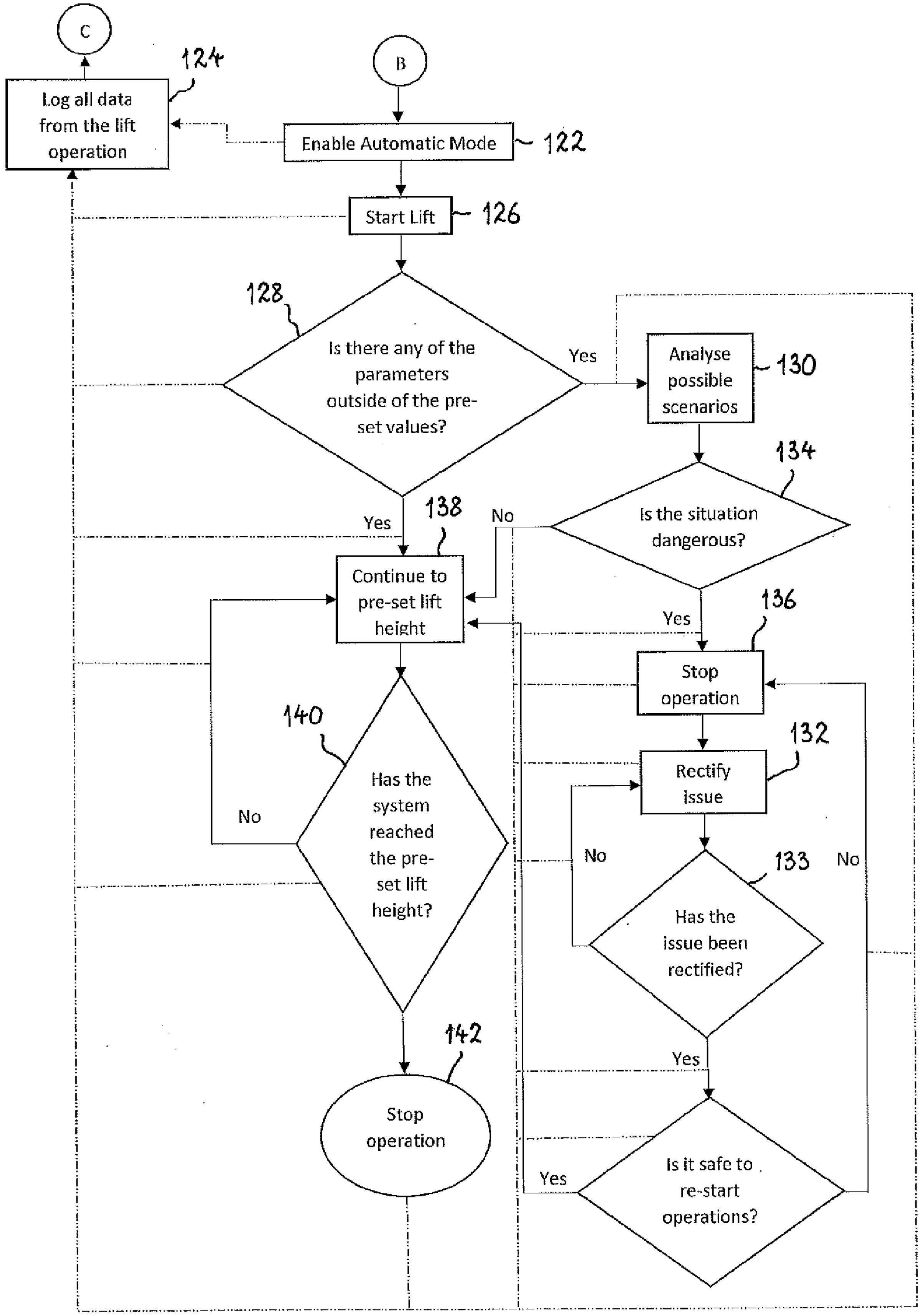
C
124
Log all data from the lift operation
B
Enable Automatic Mode
122
Start Lift
126
128
Is there any of the parameters outside of the pre-set values?
Yes
Analyse possible scenarios
130
134
Yes
138
No
Is the situation dangerous?
Continue to pre-set lift height
Yes
136
Stop operation
140
132
No
Has the system reached the pre-set lift height?
Rectify issue
No
133
No
Has the issue been rectified?
Yes
142
Stop operation
Yes
Is it safe to re-start operations?

Figure 9.2

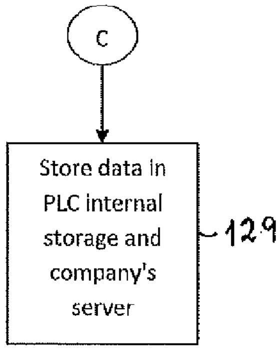
C
Store data in PLC internal storage and company's server
129

Figure 9.3

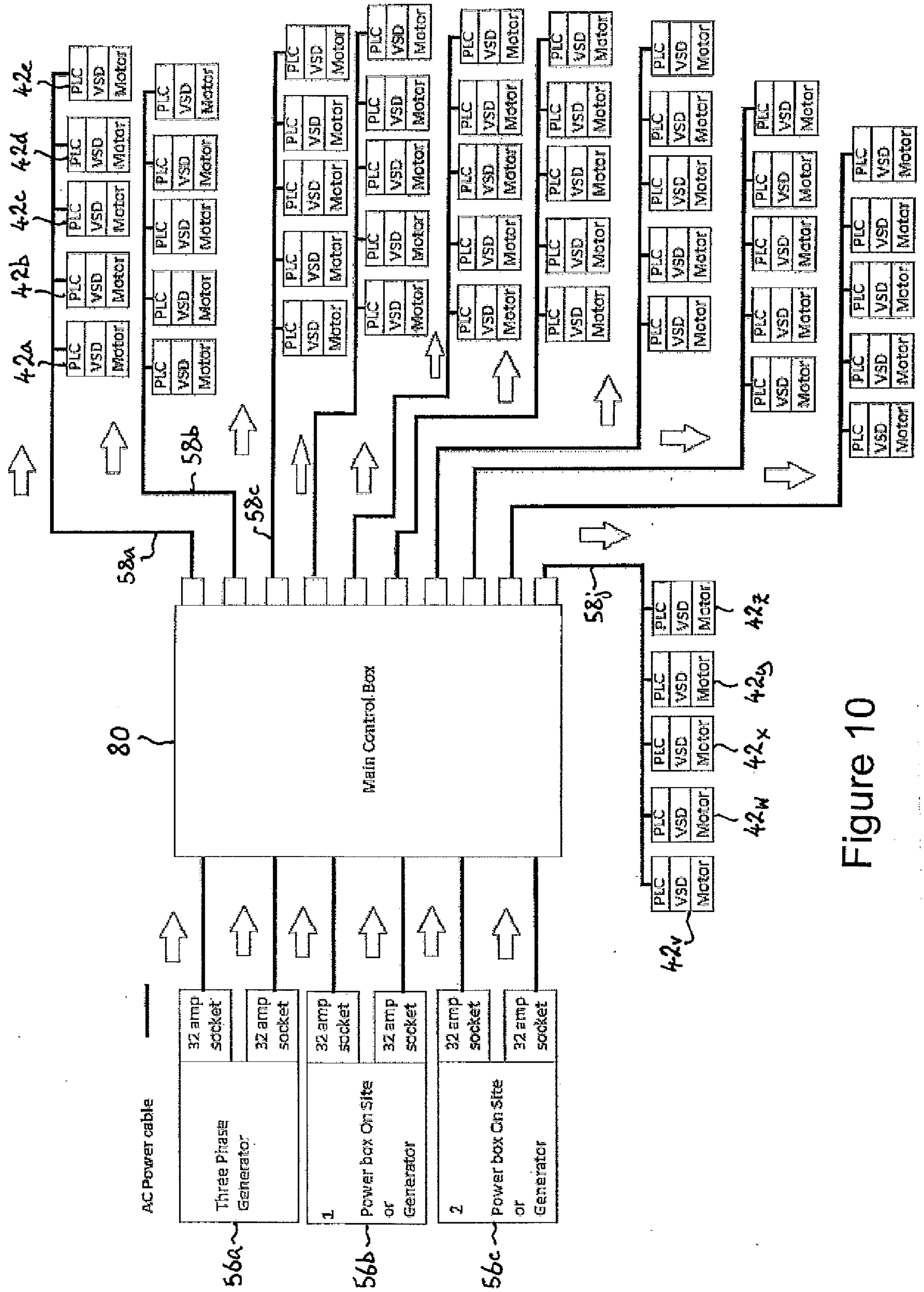
AC Power cable
Three Phase Generator
1 Power box On Site or Generator
2 Power box On Site or Generator
32 amp socket
Main Control Box
PLC
VSD
Motor
80
56a
56b
56c
58a
58b
58c
58j
42a
42b
42c
42d
42e
42v
42w
42x
42y
42z

Figure 10

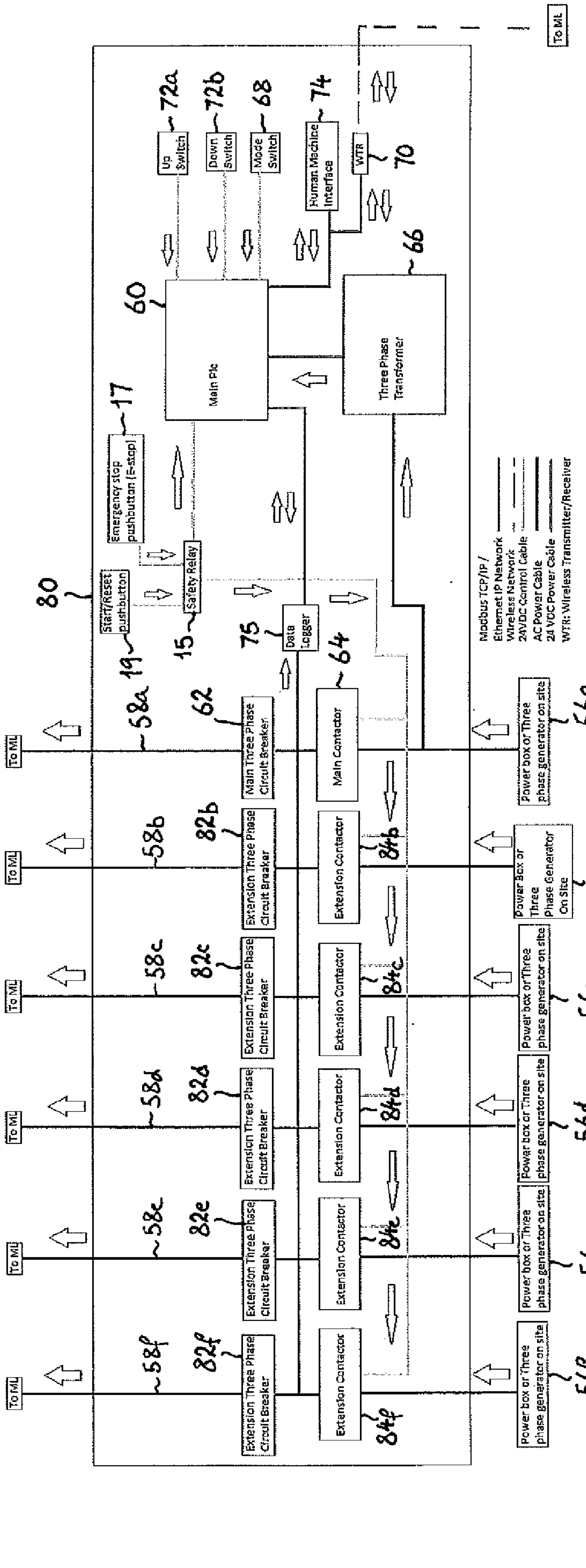
To ML
Up Switch
Down Switch
Mode Switch
Human Machine Interface
WTR
72a
72b
68
74
70
66
60
Main Plc
Three Phase Transformer
Emergency stop pushbutton (E-stop)
17
Safety Relay
15
Start/Reset pushbutton
19
80
Data Logger
75
64
62
Main Three Phase Circuit Breaker
Main Contactor
Extension Three Phase Circuit Breaker
Extension Contactor
Power box or Three phase generator on site
Power box or Three Phase Generator On Site
58a
58b
58c
58d
58e
58f
82b
82c
82d
82e
82f
84b
84c
84d
84e
84f
56a
56b
56c
56d
56e
56f
Modbus TCP/IP / Ethernet IP Network
Wireless Network
24VDC Control Cable
AC Power Cable
24 VDC Power Cable
WTR: Wireless Transmitter/Receiver

Figure 11

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2016/000222

A. CLASSIFICATION OF SUBJECT MATTER

G05D 13/00 (2006.01) G05D 3/00 (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Databases: EPODOC, WPIAP, Google/Google Patent/Google Scholar with keywords such as lift, modular, synchronise, feedback, group, variable speed, variable frequency, extension, encoding, detect, block, signal, device, multi, unit and like terms.

Title/Inventor/Applicant search in Espacenet/Auspat/IP Australia's internal database with various combinations of Philip Edward Jenner (inventor), control system (title) and UP FIRST CONSTRUCTION SYSTEMS PTY LTD (applicant).

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 September 2016	12 September 2016

Name and mailing address of the ISA/AU	**Authorised officer**
AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA Email address: pct@ipaustralia.gov.au	Selvam Kalymuthu AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No. 0262832467

INTERNATIONAL SEARCH REPORT	International application No.
C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT	**PCT/AU2016/000222**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6598859 B1 (KURECK et al.) 29 July 2003 Fig.1, 3, 6, Columns 3, 4, 6, 8 and 9	1-38
A	US 7219770 B2 (BAKER) 22 May 2007 Whole document	1-38
A	US 5625262 A (LAPOTA) 29 April 1997 Whole document	1-38

INTERNATIONAL SEARCH REPORT Information on patent family members	International application No. **PCT/AU2016/000222**

This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document/s Cited in Search Report		**Patent Family Member/s**	
Publication Number	**Publication Date**	**Publication Number**	**Publication Date**
US 6598859 B1	29 July 2003	US 6598859 B1	29 Jul 2003
		US 6956339 B1	18 Oct 2005
US 7219770 B2	22 May 2007	US 2005045429 A1	03 Mar 2005
		US 7219770 B2	22 May 2007
US 5625262 A	29 April 1997	US 5625262 A	29 Apr 1997
		CA 2180805 A1	04 Jul 1997
		MX 9606697 A	31 Jul 1997

End of Annex

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.