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1. Introduction

1.1 Purpose

This document aims to describe the electrical requirements for machinery and electrical equipment validation. Its purpose is to be used externally by the suppliers, and internally by Lilium engineering, targeting the guidance towards the internal standardizations and homologations as well as to meet the current regulations and industry best practices. This document applies to the Electrical Compliance Organization of Lilium GmbH.

1.2 Scope

This document is applicable to the Lilium GmbH and its locations in Germany. It does not demonstrate a compliance to a Part 21 Annex I Subpart G requirement and therefore is out of scope to any external Part 21G Audit activity.

1.3 Definition of Terms

Term	Definition
CE marking / mark	Mark at the products that have the EC Declaration of Conformity
EC Declaration of Conformity	The Conformitè Europëenne (CE) Mark is defined as the European Union's (EU) mandatory conformity marking for regulating the goods sold within the European Economic Area (EEA)
Category	Classification of the safety-related parts of a control system in respect of their resistance to faults and their subsequent behaviour in the fault condition, and which is achieved by the structural arrangement of the parts, fault detection and/or by their reliability (ISO 13849-1:2015).

1.4 Acronyms

Acronym	Definition
OEM	Original Equipment Manufacturer
PL	Performance level
CAT	Category
SRP/CS	Safety–related part of a control system
LOTO	Lock Out Tag Out
RCD	Residual current device
IP	Ingress protection
EMC	Electromagnetic Compatibility
MAC	Machine Acceptance Checklist
HMI	Human Machine Interface
EKS	Electronic-Key-System
CNC	Computer Numerical Control

PLC	Programmable Logic Controller
I/O	Input/Output
OPC-UA	Open Platform Communications - United Architecture
vEFK	Verantwortliche Elektrofachkraft (Responsible electrician)

1.5 Reference to Other Documents

Document Ref	Document name
LG-EM-0100	Application of Lockout and Tagout devices
LG-EM-0101	Electrical Validation Management
LG-EM-0051	Electrical Compliance Organization
LG-EM-1002	Equipment or Machine Safety Acceptance Checklist
LG-EM-1000	Acceptance Form - Design Release Protocol
LG-EM-1005	Acceptance Form - Site Acceptance Test Protocol
LG-EM-1006	Acceptance Form - Factory Acceptance Test Protocol

1.6 Roles and Responsibilities

Role	Definition
Manufacturing Engineering – Equipment Acquisition engineer (ME EA engineer)	The Manufacturing Engineering – Equipment Acquisition engineer within the Lilium eAircraft Production Organization is the main key function role liable for the implementation of the guidelines stated in this standard.
vEFK for Machinery (VDE 1000-10.3.2)	The vEFK for Machinery is responsible for the machinery Health and Safety conditions, mainly regarding the electrical and control engineering.

2. General Conditions

2.1 Standards & Legislation

2.1.1 This specification does not remove the responsibility of the manufacturer to supply a machine/equipment whose design and construction complies with any legislation in force in the country of destination.

2.1.2 The manufacturer shall be responsible for notifying to Lilium of any contradictions between this specification and national legislation by using the deviation form.

2.1.3 All machinery/equipment shall be designed and built to international standards.

2.1.4 Where an international standard is not available or the national standard in the country of destination is an extension of the international standard, the national standard shall be used.

2.1.5 For machinery put into service within the EU, the OEM (Original Equipment Manufacturer) shall CE mark the equipment and provide the EC Declaration of Conformity. Where obtaining a CE mark is not possible, the OEM shall provide an EC Declaration of Incorporation. The OEM shall also gather all the documentary evidence required to form the Technical File; Calculations (EN ISO 13849-1/2: stating the PL, CAT), Risk Assessment, Diagrams/Projects (electrical, mechanical 3D, hydraulic, pneumatic, etc..).

2.1.6 Application of the following directives is fundamental to the machine design:

- The Machinery Directive (2006/42/EC)
- The Electromagnetic Compatibility Directive (2004/108/EC)
- The Low Voltage Directive (2006/95/EC)
- The Pressure Equipment Directive (97/23/EC)
- The Electromagnetic Fields (EMF) Directive (2013/35/EU)
- ATEX Directive (94/9/EC)
- RoHS 3 Directive (EU 2015/863)
- REACH Regulation

2.1.7 The following referenced documents are indispensable for the application of the aforementioned directives, including but not limited to. This list of international standards is not exhaustive and the manufacturer is responsible for applying all relevant standards.

- EN ISO 12100 – Safety of machinery – General principles for design — Risk assessment and risk reduction
- EN ISO 13849-1 – Safety-related parts of control systems – Part 1: General principles for design
- EN ISO 13849-2 – Safety-related parts of control systems – Part 2: Validation
- EN 60204-1 – Safety of Machinery – Electrical Equipment of Industrial Machines – Part 1: General Requirements
- EN ISO 11161 – Industrial automation systems – Safety of integrated manufacturing systems – Basic requirements
- EN ISO 10218-1 – Robots and robotic devices – Safety requirements for industrial robots (Part 1: Robots)
- EN ISO 10218-2 – Robots and robotic devices – Safety requirements for industrial robots (Part 2: Robot systems and integration)
- EN 1037 – Safety of machinery – Prevention of unexpected start-up
- IEC 62491 - Industrial systems, installations and equipment and industrial products – Labelling of cables and cores

- EN 61496 – Safety of machinery – Electro-sensitive protective equipment
- EN ISO 14119 – Safety of machinery – Interlocking devices associated with guards – Principles for design and selection
- EN ISO 14120 – Safety of machinery – Guards. General requirements for the design and construction of fixed and movable guards
- EN ISO 13857 – Safety of machinery – Safety distances to prevent hazard zones being reached by upper and lower limbs
- EN ISO 13850 – Safety of machinery – Emergency stop – Principles for design (ISO 13850:2006)
- EN ISO 13855 – Safety of machinery – Positioning of safeguards with respect to the approach speeds of parts of the human body
- EN 574 – Safety of machinery – Two-hand control devices – Functional aspects – Principles for design
- IEC 61310 – Safety of machinery – Indication, marking and actuation
- IEC 61310-1 – Safety of machinery – Indication, marking and actuation - Part 1: Requirements for visual, acoustic and tactile signals
- ISA 99 - Industrial Automation and Control Systems Security
- EN ISO 4413 – Hydraulic fluid power – General rules and safety requirements for systems and their components
- EN ISO 4414 – Pneumatic fluid power – General rules and safety requirements for systems and their components
- EN ISO 7010 – Graphical symbols – Safety colours and safety signs - Registered safety signs
- EN 349 – Safety of machinery – Minimum gaps to avoid crushing of parts of the human body
- IEC 61439-1:2020 - Low-voltage switchgear and controlgear assemblies
- EN 61010 - Safety requirements for electrical equipment for measurement, control, and laboratory use

The appropriate harmonized standard shall be selected, properly applied and listed in the Declaration of Conformity DoC.

Please note: Standards are subject to change, the most up to date Standards shall be always used.

2.2 Risk assessment & risk mitigation

2.2.1 The manufacturer or his authorized representative shall ensure a risk assessment is carried out to determine the Health and Safety requirements which apply to the machinery. The machinery/equipment shall then be designed and constructed taking account of the results of the risk assessment.

2.2.2 By the iterative process of risk assessment and risk reduction referred above, the manufacturer or his authorized representative shall:

- Identify the limits of the machinery/electrical;
- Identify the hazards;
- Estimate the risk;
- Select safeguard method;
- Determine performance level required;
- Implement safeguard.

2.2.3 The system level risk assessment along with the machine/equipment integration points identified shall be documented.

2.2.4 The manufacturer shall present the risk assessment to Lilium and might be requested to justify the assessments.

2.2.5 All safety-related parts of a control system (SRP/CS) shall be designed and constructed to achieve MINIMUM Category 3. All the safety guard devices (switches, E-Stop, Light curtain, Two-Hand-Control) must have its 2 channels entering in dedicated safety inputs, and all output safety circuits must be at the EDM (External device monitoring) circuit, integrating the feedback contact of the safety actuators (Contactors, Safety Pneumatic Valve, etc..) with the Reset button in series. Only well-tried components and well-tried safety principles according to ISO 13849-1 shall be used. Follow safety diagram example:

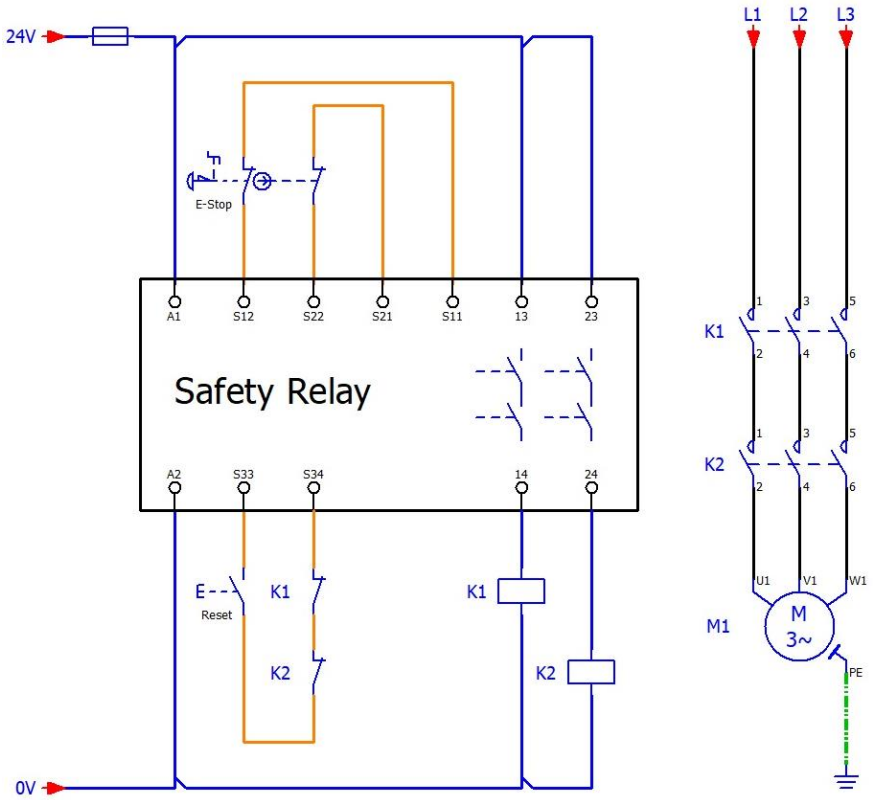


Figure 1 – Example Standard Safety Diagram

2.2.6 The OEM shall provide Lilium with all safety parameters used for safety-related design and the evaluation of control systems when presenting the risk assessment.

2.2.7 The manufacturer shall provide documentary evidence that the safety circuit has been verified. (Inspection Protocol).

3. Machinery/Equipment Safety Fundamentals

3.1 Design for Lock Out Tag Out (LOTO)

3.1.1 Machines/equipment shall be designed taking into consideration energy control and power lockout. The isolators (all energy sources) shall:

- Have a single point of isolation for each energy type.
- Be supplied with a suitable locking point (to use safety padlocks).
- Be installed between 500mm and 1800mm from the working surface.
- Be accessible outside enclosures or fixed guards.
- Be placed in proximity to each other where practicable.

3.1.2 Energy sources:

- **Electrical:**
  - Only one electrical power supply is allowed.
  - A lockable main disconnect switch shall be installed on the main electrical cabinet (side housing) which shall isolate all electrical energy within the machine. No rod type disconnect switch (cabinet mount) is allowed.
  - The main disconnect switch shall be black.
  - The main disconnect switch shall be mounted preferably at the right side, or front of the main electrical cabinet.
  - The main disconnect shall be mounted ideally 1500mm from the working surface.

Figure 2 – Main Disconnect Allowed

- **Hydraulics:**
  - Only one power unit, which is powered via the main electrical disconnect switch.
  - Shutdown shall be controlled when the electrical disconnect shuts down the hydraulic system. (Electrical Lockout).
  - **No hydraulic accumulators to be utilised**

- **Pneumatics**:
  - Only one compressed air supply.
  - A manual isolation valve shall be installed downstream of the main compressed air.

- **Lubrication**:
  - Only one automatic supply system for each type of lubricant - fed via the main electrical disconnect switch.

- **Coolant**:
  - Only one supply system.
  - - A manual isolation valve shall be installed downstream of the fluid inlet to isolate incoming coolant.

3.1.3 The manufacturer shall supply the LOTO placard and the editable electronic files.

3.1.4 The illustrated LOTO placard with sequential procedure to isolate and dissipate energy, and lock out the machine shall be hung at the machine/equipment.

3.1.5 The LOTO placard shall indicate all the existing residual energy sources, e.g., charged capacitors and time of discharge, trapped hydraulic and pneumatic energy, heat, gravity, magnetic, etc.

3.1.6 Any movement possible due to gravity shall be positively stopped before granting access through interlocked gates/guards.

3.2 Power On Requirements

3.2.1 The design of the machine shall be such that, at no time, removal, bypass, or inhibition of safety systems (safety interlocks, guards, safety monitoring switches) shall be necessary to undertake set-up, operation or maintenance tasks.

3.2.2 When necessary any set-up/maintenance/adjusts that promotes access to movements in which generate a hazardous condition; the control of this movements shall be done by an “Enabling Switch 3 position switch” and the limits of Speed (max. 200mm/s), Pressure, Power, Range, etc... shall be reduced as much as possible. Additionally, an E-Stop button must be reachable at that station.

3.3 Start-up

3.3.1 If the whole of the machine or system is not visible from any point of start-up; both audible and visual warning shall be given for a period of at least 5 seconds prior to machine start up (Audible alarm horns shall be a minimum of 90 dB).

3.3.2 During initial start-up or upon restarting after a stop for any reason, a person shall be required to manually perform at least two deliberate acts:

- Press Fault Reset button (blue) to reset the machine safety circuit (if in fault), AND
- Set mode to Automatic and press Auto Cycle Start button, OR
- Set mode to Manual and press a button for a particular function

E-Stop pushbutton activation or releasing shall not be deemed to count as an action

3.3.3 There shall be NO uncontrolled movement or trapped energy (pressure) after shutdown or restoration of energy to the machine using the means of isolation, opening of interlocked safety access gates or emergency stop situations (including loss of power).

- All pneumatic power shall be automatically removed, and stored energy shall be dissipated from the guarded zone (no trapped energy allowed) before any interlocked guard can be opened.
  - For vertical cylinder, a retention valve must be used, attached at the cylinder housing connection to avoid it to go down.
  - A progressive valve must be used to smooth the restore of energy.

3.3.4 No bypassing of the safety functions is allowed at any time. (e.g., light curtain).

3.3.5 All faults must be addressed at the HMI, and whenever practical instructions on how solve the problem.

3.4 Power Outage

3.4.1 In the event of an unexpected power failure or pressure drop, the system should remain in a safe state.

3.4.2 When the system is switched on again, no dangerous actions or movements may occur unexpectedly.

3.4.3 When the system is restarted, this event must be acknowledged with a reset button before the system returns to normal.

4. Required Documents

4.1 Documents to be provided by the OEM

4.1.1 Technical documentation with the following data:

a) general description of the machine and how it works;
b) overview of the drawing and circuit diagrams, as well as descriptions and explanations required to understand how the machine works;
c) operating instructions;
d) maintenance instructions;
e) bill of materials;
f) mechanical drawings, including detailed manufacturing drawing for tooling and respective interfaces;
g) simplified 3D machine layout;
h) machine layout, with a representation of utilities and power connection points;
i) description of the connection/installation requirements. (Protection requirement: Switch breaker or RCD type; cable cross section).
j) rigging and (un)loading instructions;

4.1.2 A copy of the EC Declaration of Conformity[1] (or EC Declaration of Incorporation[1], if applicable) with the information referred to in Annex II A to the Machinery Directive. The EC Declaration of Conformity must include:

List of applied standards (EU Official Journal on MRLs, presumption effect), at least listing (generally applicable for all machines/equipment):

- Machinery Directive (2006/42(EC) or Low Voltage Directive (2014/35/EU)
- DIN EN ISO 12100
- DIN EN ISO 13849-1 & 2
- DIN EN 60204-1
- DIN EN 61439-1 (when applicable)
- Electromagnetic Compatibility (EMC) Directive (2014/30/EU)

4.1.3 Printed (.pdf) safety program report, showing the full logic (Preferable in Blocks or Ladder).

4.1.4 Electrical Schematic backup file (EPlan P8).

4.1.5 When a customized machine with dedicated software is developed exclusively for Lilium, the portion of source code that is process related (in other words, that can be modified due to process changes or optimization reasons) shall be supplied, in English and with no password protection; same is valid for robots teaching program. Supplier shall include in the offer also, as an option, the remaining part of the source code.

4.1.6 Initial Electrical Test Report[1] (Protocol for commissioning based in the VDE113-1 / ISO EN 60204-1).

[1] These documents should be signed by the responsible person.

The documentation shall be delivered in the following media and languages:

Table 1 - Documentation media and language

Item		Language	Digital (USB flash disk)	Hardcopy
4.1.1	a), b), e), f) and j)	English	x	x
	c), d), h) and i)	English and German	x	x
	g)	English	x	
4.1.2		English	x	x
4.1.3		English	x	x
4.1.4		English	x	
4.1.5		English	x	
4.1.6		English	x	x

The machine naming on all documentation shall follow Lilium's standard machine number, to be supplied by Lilium's ME EA engineer during project kick-off.

5. General Specifications

5.1 Cabinet

5.1.1 All built-in devices at least IP2X (finger-safe).

5.1.2 The minimum ingress protection (IP) for the electrical enclosures shall be IP54.

5.1.3 All equipment/materials with CE marking.

5.1.4 All electrical components shall be in accordance with Lilium Homologated list (See appendix). Derogations/deviations can be applied with a formal approval of the Lilium Engineering Team.

5.1.5 Use only self-extinguishing materials (i.e., cables).

5.1.6 All distribution cabinets and terminal boxes (excluded Extra-low voltage) shall be marked with a warning sign W012 according to EN ISO 7010 (Electrical Warning “Flash”).

5.1.7 All distribution cabinets and terminal boxes shall be fitted with a sign of the voltage levels presented in it.

5.1.8 All the cabinets must have a lock that can only be opened with a unique key, yale type, 2 key copies for each cabinet.

5.1.9 As a minimum, all power cables and safety system cables shall be permanently tagged on both ends, according to wiring diagrams (IEC 62491). Supplier shall also include in the offer, as an option, single wire tagging for all other communication cables.

5.1.10 The electrical schematics supply should confirm to VDE 0040-1 with: overview plans (machine layout); circuit diagram; bill of materials; cabinet layout; wires with colors and cross section; components with: name, tag, function, brand and ordering code.

5.1.11 A minimum of 25mm clearance space shall be required between cabinet wire ducts and any component or terminal for ease of access.

5.1.12 The temperature inside the cabinets shall not exceed 40°C.

5.1.13 A heat load calculation is required to design the control cabinet air conditioning and shall be documented and provided to Lilium.

5.1.14 The cooling unit shall be controlled by a thermostat.

5.1.15 Control circuit shall be 24 VDC. The 0VDC potential shall be grounded to the main grounding of the cabinet.

5.1.16 At least 20% of the cabinet plate area must be kept free.

5.1.17 Heating limits for switch cabinets and expected short-circuit currents and short-circuit breaking capacity according to DIN EN 61439-1.

5.1.18 Main electrical enclosure doors shall be equipped with door stops / stays to avoid the door closing and making accidental contact with personnel and shall have a minimal opening angle of 90 degrees.

5.1.19 A metal A3-sized drawing pocket shall be fitted to the inside of the electrical enclosure door and shall be large enough to accommodate the electrical schematics.

5.1.20 The electrical enclosures that are bigger than 800x600mm shall have an internal light fixture with switch.

5.1.21 The operational cabinet shall have at least:

- HMI (please see list of standard components)
- Physical buttons (see chapter 7.3)

5.1.22 Electrical cables installed at the cabinet door shall be protected against damage (tubing, spiral wrap, etc.).

5.1.23 The exterior and interior of electrical enclosures shall be painted the same color as the machine (RAL 7035). The inside mounting plates shall be zinc galvanized plate to improve noise immunity and facilitate compliance with the EU EMC Directive.

5.1.24 Electrical equipment shall be mounted inside enclosures in accordance with EN 60204-1. Heavier or larger equipment, such as servo drives, shall be mounted at a height that facilitate easy removal and all resettable equipment shall be mounted between 400mm and 1800mm from the working surface.

5.1.25 Devices shall be grouped by function and voltage, keeping higher voltages away from lower voltage devices. Isolate analogue and other low-level signals to reduce induced noise.

5.1.26 A minimum of 1000mm clearance space shall be required in front of enclosures when doors are open.

5.1.27 Conductors shall be adequately secured and supported in accordance with EN 60204-1, to avoid mechanical stress on cables and connectors.

5.1.28 Non-electric components (e.g., pneumatic) and units shall not be fitted inside the housing of the electrical cabinets. Solenoid valves should be separated from the electrical equipment, e.g., in a separate compartment.

5.2 Field Wiring

5.2.1 All cabling and wiring shall be:

- Segregated by function where practical inside ducting (by use of metal barriers inside the ductwork) and on cable trays.
- When labelling is applicable, it shall be marked at each end by a durable and secure label in accordance with the documentation, in addition to the required colour coding
- Polyurethane (PUR) sheathed type cables shall be used for all applications.
- Where feasible a plug and socket arrangement shall be used at both ends of the flexible cable carrier.

5.2.2 Cables – Machine/Equipment to Cabinet. The cables shall:

- Be supported by cable trays/ducting from the terminal boxes at the machine/equipment to the main enclosure.
- Have extra length furnished and contained in the cable trays / ducting.
- Be identified and tagged with a unique number. The tag shall be located near the connector end of the cable.
- The mating socket on the enclosure shall be identified using a permanently fixed legend plate with the cable number on it.

- The mating socket/plug shall be coded with guide pins and bushes such that no reverse connection nor a different socket/plug connection is possible.

5.2.3 Remote I/O devices shall be used whenever possible.

5.2.4 Trunking systems and conduits shall be of a metal type, placed where possible to avoid mechanical damage. Floor mounted types shall be installed with walk-on covers.

5.2.5 Openings/termination on trunking and cable tracks shall be protected by appropriate edging (rubber, plastic) in order not to damage field wiring.

5.2.6 All spare conductors shall be run to terminals at each end and shall be clearly numbered and marked as spare.

5.2.7 Ideally power and control circuits conductors shall not be contained in the same multi-conductor cable. If contained, the power and control circuits shall be separated by groups in the terminals, and suitable barriers shall be provided (e.g. shielded cables).

6. Electrical Design and Build

6.1 Voltages, Wire Colours & Network

6.1.1 All equipment shall be designed to run with supply as specified below:

- Power:
  - Three-phase: 400V ±10%
  - Single-Phase (L+N): 230V ±10%
  - Frequency: 50Hz
  - Earthing System: TN-S network
  - The phase sequence of all low voltage systems: clockwise rotary field
- Compressed air:
  - Working pressure: 6 bar ± 0.5
  - Max supply pressure: 10 bar

6.1.2 All external power supply, including the protective earth system shall labelled (L1, L2, L3, N, PE).

6.1.3 All control circuits shall be 24VDC.

6.1.4 Transformers, rectifiers, and switch components shall not exceed 70% of the rated full load.

6.2 Machine/Equipment power feed requirements

6.2.1 The short circuit interrupting capacity of the main disconnect overcurrent protective device shall be indicated on the engraved plate affixed to the electrical enclosure.

6.2.2 Maintenance sockets to power programming devices shall be provided in the designated locations at the operator HMI cabinet. Sockets shall be protected by Residual Current operated Circuit Breaker (RCCB), maximum 16A with residual current of 30mA (preferred model: 5SV3321-4 from SIEMENS).

6.3 Earthing, Protective Earth and Functional Bonding

6.3.1 Preferably all grounding/bonding parts shall originate from the main grounding busbar with a proper cooper conductor cross section, without daisy chain. Parts that are not grounded must comply with the isolation class II (double insulation, reinforced insulation or by equivalent insulation) as described at 6.3.2.2 of ISO 60204-1. Metal enclosures or frames or mounting plates of electrical equipment, connected to the protective bonding circuit, may be used as protective conductors if they comply with the chapter 8.2.2 of ISO 60204-1.

6.3.2 All components shall be grounded in accordance with the manufacturer's instructions. All cabinets shall be earthed grounded.

6.3.3 The paint should be removed at the protective bonding conductor connection to the frame of the machine. The resistance of each protective bonding end/point until the main PE busbar shall be less than 0.5 Ohm.

6.4 Cables color coding

6.4.1 The cable color coding should follow as described in table below.

Table 2 – Cable color coding

Cable function	Cable color	Color marking
Cabinet Power Conductors 230/400 V	Black	BK
Neutral conductor N	Light Blue	LBU
Protective conductor PE	Green-Yellow	PE
AC Conductor L1 – (3 Phase External Circuits)[2]	Brown	BN
AC Conductor L2 – (3 Phase External Circuits)[2]	Black	BK
AC Conductor L3 – (3 Phase External Circuits) [2]	Grey	GY
Control voltage 24 V DC	Dark blue	BU
Control voltage 0 V DC	Dark Blue/White Stripe	BUWH
Low voltage 24-60 V AC	Grey	GY
Excepted circuits[3]	Orange	OG
Measurement signal (e.g., analog)	White	WH

[2] Motors, cabinet feeding, etc
[3] Orange must be used in the circuit that remains energized even after the LOTO procedure (i.e. main supply circuit before main switch, maintenance power outlets, etc) and safety circuits channels (E-stops, door switches, etc..). Orange spiral wrap tubing (Spiralwickelschlauch) should be used when technically the wires cannot be orange.

6.5 Indication And Signalling

6.5.1 The (status light) light column is mandatory for all machines, and through it the safety status of the machine shall be shown.

Table 3- Light Column

	Meaning	Solid	Flashing
Red	Emergency Situations	N/A	Hazard present, immediate action required (e.g. clear from machine)
Yellow	Abnormal situations	Impending situations[4] (Warning); Calibration / Maintenance	Running out material (starving), Machine on imminence to stop
Green	Machine Working	Running in automatic/cycle mode	Manual Mode, or Ready to start
Blue	Reset Needed	Safety Relay out	Process/Error Reset

6.5.2 The light column shall follow the color order above, with red on top and blue on bottom.

6.5.3 The light column shall be installed at a height of 2.5m measured from shopfloor to bottom (blue light) of light column.

[4] When an abnormal situation is imminent (as example the lower threshold of motor temperature is reached), the yellow light shall be turned on. When this abnormal situation escalates and machine comes to a halt (e.g. the higher threshold of this same motor temperature is reached and machine comes to a halt), one “Error” shall be triggered and the blue light shall be turned on and the accordingly actions shall be done before the machine be allowed to the reset and run again.

7. Controls Design and Build Processes

7.1 Project Milestones

7.1.1 The main Milestones shall be:

- Design approval & Materials list approval (mechanical, electrical, concept, etc..).
- FAT (Factory Acceptance Test - Manufacturer Site)
- Validation documents for the Authorization for shipment
- SAT (Site Acceptance Test - Lilium Site)
  - Final documentation submission

7.1.2 **Design Approval:** upon order placement, the manufacturer shall be contacted for periodic meetings to discuss design. At this stage, safety, build, interlocks, IT interface and the functional design shall be reviewed and documented. Preliminary drawings and system architecture diagrams should be provided during this meeting for general review.

7.1.3 **FAT**: during witness at the vendor site it will be checked: proof of functionality by either a conventional function test or simulation, performance, machine/process capability index, poka yoke(s), check of the completeness, verification against contractual requirements, and a portion check of the Machine Code MAC and PLC field signals I/Os shall be completed. Additionally, the Risk Assessment of the equipment shall be available to be presented to the Lilium engineering team. The machine shall be subject to a Stop Ship order if the requirements are not fulfilled, and a new FAT shall be scheduled.

7.1.4 **Authorization for shipment:** Authorization for shipment will only be granted after review of all documentation listed on items 4.1.1 to 4.1.3. Additional documentation might be requested by Lilium's ME EA engineer and agreed with supplier. The documentation shall be sent for approval at least 2 (two) weeks before the intended shipping date and Lilium will grant authorization no later than 1 (week) before the intended shipping date, as long as all requirements are fulfilled and FAT is approved.

7.1.5 **SAT**: at the Site Acceptance Test the main points checked at the FAT will be reviewed. Additionally, a production run will be performed, with a minimum number of manufactured pieces or working hours to ensure the repeatability and robustness of the equipment/machine.

7.1.5.1 **Final Documented Submission**: the final documentation, as built, shall be submitted after SAT for final approval. At this point, all software backups shall be made available (PLC, HMI, drives, cameras, hard drive images, nut runners, test parameters). Any subsequent changes shall follow the programmable safety permit to work process.

7.1.6 **Change Management and Programmable Safety Permit to Work**: after FAT, any programmable safety software modification shall be formally requested by the machine tool builder to Lilium's ME EA engineer, and the request shall be documented. Programmable Safety checksums shall be tracked and changes to the checksum that have not been authorised by Lilium's ME EA engineer will be regarded as a safety violation.

7.2 Deviations

7.2.1 If the manufacturer considers that due to technical reasons he cannot comply with any paragraph of this specification or cannot use all the LILIUM homologated components, then he shall submit a “REQUEST FOR DEVIATION" with a detailed TECHNICAL justification why the paragraph or component cannot be met. Any deviation granted shall apply only to the purchase order in question and shall not be considered as a permanent amendment to this specification. All requests for deviations shall be submitted in writing in the form at the appendix of this document to the Lilium’s ME EA engineer.

7.2.2 Deviations can only be granted by Lilium ME EA engineer. The manufacturer shall retain proof of deviation.

7.2.3 Any components used on a machine/equipment that are found not to be listed on the Lilium homologated list on which no deviation was granted shall be changed at no cost to Lilium and with no impact on the programme timing.

7.3 Operator Interface

7.3.1 There shall be at least one HMI on every station supplied. Any application deemed not to require an HMI shall be previously approved by Lilium.

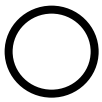
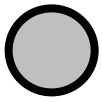
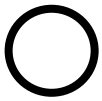
7.3.2 HMIs shall have the centre of the screen set between 1500mm and 1600mm above operating surface. At seated workstations place top of screen, no higher than 800mm above seat height.

7.3.3 Machine to machine interlock interface shall be displayed on the operator HMI.

7.3.4 All operator control cabinets shall display the language of the destination country (English and German for facilities in Germany), with the ability to select/switch to English via soft-key in a designated screen of the HMI.

7.3.5 The machine controls pushbutton shall be designed to function as described below.

Table 4 - Button Function

			LED		
	Function	**Color**	**On**	**Off**	**Flashing**
	Emergency stop	Red with yellow background [5]	**N/A**	**N/A**	**N/A**
	Stop	Black [6]	**N/A**	**N/A**	**N/A**
	Start	White [7]	Machine is running in automatic/cycle mode	Machine is stopped	Manual, Step-by-Step mode. Or moving to Home Position
	Reset	Blue	Reset needed - Safety relay or Safety Equipment deactivated	No action needed	Reset needed – Error, or Required action by the Operator [8]
	Move machine to Home position	Gray [6]	N/A	N/A	N/A
	Request access to the safety door/guard[9]	White [10]	Safety door unlocked	Safety door locked	Safety door locked - Operator prompt to unlock safety door

[5] Retentive mushroom head, turn to release, in red with yellow background. Used to stop the whole machine (or zone) as defined in the risk assessment.
[6] Opaque button (without LED)
[7] The start button LED follows the same logic as the green light in the light column.
[8] Example of required action by the operator: Running out of material, Overheating of component, Impending calibration, etc.
[9] To be installed at the point of use (on machine doors/guards), not with the main control panel.
[10] This button is optional, used when applicable, i.e. installed at machine doors in robotic cells.

7.3.6 The layout of the pushbuttons and HMI shall be as bellow:

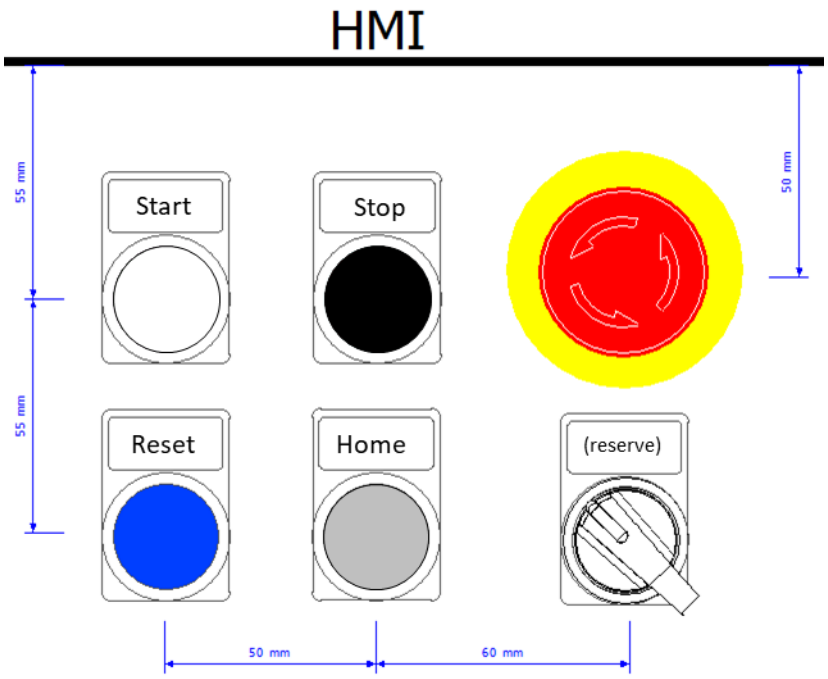


Figure 3 - Button Layout

7.4 System Design – General

7.4.1 All equipment shall be free from excessive machine vibration and shall be mounted as stated by the equipment manufacturer.

7.4.2 Only re-settable protection equipment shall be used. The use of fuses shall be previously approved by the Lilium ME EA engineer.

7.4.3 Electronic circuit breakers shall be selected for 24VDC circuits.

7.4.4 The manufacturer shall align and document any set-up or calibration procedures with Lilium.

7.4.5 All machine NC/drive axis shall be provided with a system that prevents movement unless the axis is within a safe working envelope. A safe procedure for referencing shall be provided, e.g., the axis should be correctly interlocked, and avoid any collisions.

7.4.6 Retentive memory shall be configured to prevent multiple cycling of equipment on an already finished component after the equipment is powered down and re-started.

7.4.7 Process equipment, automatic gauging and In-Process Test machine shall have its relevant configurable fields for pre-set values available for selection through a field in the HMI protected by EKS.

7.4.8 Where laser sensors are used, barriers shall be fitted to prevent the beams from passing through guarding. Operator exposure shall be avoided.

7.4.9 Where required a machine/work area lighting shall be 24VDC and IP67 rated.

7.4.10 Stations where the operator is required to press cycle start/complete at every cycle, the pushbutton shall be of a zero-force (e.g., capacitive) ergonomic type.

7.4.11 If machine requires warm-up cycles at start up (e.g. CNC machining centres), supplier shall program these in the equipment so that they are started at operator's choice but run fully automatic after that; they shall be stored in equipment's controller memory in a way that prevents unintentional deleting or modification.

7.4.12 The design risk assessments shall consider the safety of the design throughout all phases of the machine/equipment life cycle, i.e., transport, assembly & installation, commissioning, operation, tool change, model change, trouble-shooting, maintenance and dismantling & scrapping.

7.4.13 The machine shall be designed such that at no time shall the use of a safety interlock over-ride key or similar device be required for installation, set-up and commissioning or any maintenance task. Safety system inhibition is also strictly forbidden during machinery installation and commissioning.

7.5 Motors

7.5.1 An auxiliary contact from motor protection devices shall be used to show both overcurrent and short circuit trip indication. This information shall be used as inputs to the PLC and checked in the section of the sequence control software.

7.5.2 All motor control devices and circuits shall conform to Type 2 no damage coordinated protection in accordance with IEC 60947-4, e.g., the protection device is resettable.

7.5.3 Any motor driven by an inverter or any other motor greater than 15 KW shall be protected by thermistors. Where thermistor motor winding protection is provided, this shall be in addition to the required overcurrent protection device.

7.5.4 Three phase induction motors 35KW (50 HP) or greater shall be started by means of an electronic soft start or frequency inverter with adjustable ramp up times.

7.5.5 With the exception of approved servomotors, only IE3 premium efficient three phase AC motors shall be used (IEC 60034-30:2008).

7.5.6 In the event of failure of a clutch or brake system, the machine shall fault to a safe condition.

7.5.7 Each AC induction motor shall be sized to have a minimum connected load of 80 percent of the full load horsepower rating of the motor.

7.6 Energy Conservation (Only for Machinery)

7.6.1 The OEM shall incorporate automatic machine shutdown capability in the machine logic to reduce energy consumption. There are three stages to the standard LILIUM Production solution: Run-out, Rest Mode, and Energy Shutdown:

- Auto – Run-out: After 5 minutes of no machine activity, machines shall cycle any parts out of the machine, unless blocked.
- Rest mode: After 15 minutes of no machine activity, whether blocked or starved, the machine shall go into rest mode. In rest mode, the machine remains in cycle but shuts down as many motors/systems as practical for the given application.

- Energy Shutdown mode: After 2 hours of no machine activity, whether blocked or starved, the machine shall drop out of auto cycle and go into control off.

7.6.2 A machine in rest mode which becomes unblocked or fed a new part shall automatically start back into cycle.

7.6.3 Energy Conservation mode shall be switchable and configurable via machine HMI. A dedicated screen shall be made available at the HMI to edit the above mentioned time windows.

7.7 Programmable Logic Controller

7.7.1 Where the PLC manufacturer or the relevant software specification for a particular function or purpose designates an area of user memory, this shall be adhered to and not used for any other purpose.

7.7.2 Diagnostic faults of a critical nature, e.g., interlock faults that could cause immediate machine/equipment damage and safety interlock faults that could cause hazards to personnel, shall shut down the system as soon as they are detected, with an accurate diagnostic warning appearing on the HMI.

7.7.3 Machines shall not be in fault and still be performing a productive cycle. On faults that only stop the machine at the end of cycle, the fault bit shall only be high when the cycle stops.

7.7.4 The HMI of the machine/equipment shall provide full PLC diagnostics. All devices, systems, I/O bus system and point I/O module faults are to be detected and displayed on the HMI or other operator interface.

7.7.5 I/O racks (remote and local), processor racks and power supplies shall be installed and earthed (grounded) to meet the PLC manufacturers' specifications.

7.7.6 The auxiliary or monitoring contacts of circuit breakers shall be individually monitored to provide granular feedback.

7.7.7 I/O terminals shall each be identified with the terminal address number.

7.7.8 The software code shall:

- Have a text comment describing that element of code, in English
- Have abbreviations kept to a minimum, only used where necessary.
- Be written in ladder logic.
- Have a program structure arranged in a sequential format that follows the basic flow of the machine
- Have an associated fault message for each input and output.
- Have a timeout function and associated fault message for each motion.
- Be supplied with the source code and password for any protected block.

7.7.9 The machine shall have a 'Home Position' function, activated through the Grey Button to automatically move the machine safely to 'Home Position' and put all sequences in its initial step.

7.7.10 Fault messages shall include the relevant input/output related to the fault.

7.7.11 An Error Logbook shall be available at the HMI to track accruing events. These should be kept in a PLC Memory (retentive memory) for at least one week, and after it shall be stored in a database.

7.7.12 The PLC system shall incorporate 20% spare capacity of I/Os, 30% of memory, and at least 20% of possibility to be expanded with new modules.

7.8 Communication with enterprise systems

7.8.1 The controller shall have a dedicated ethernet port to communicate with enterprise level systems (Level 2 and 3 according to IEC 62264-3). This port is not part of the machine's control bus network. The port configuration, including but not limited to IPv4 address, default gateway, DNS server and firewall ports, shall be freely configurable through the machine HMI.

7.8.2 This ethernet port shall be available for connection by Lilium by means of a dedicated, minimum 4 ports, unmanaged switch, mounted in the machine cabinet. The 3 free ports of the switch shall be routed with patch chords to ports mounted to the outside of the cabinet: one port on the side of the main cabinet, for connection of a programming/maintenance device; and 2 ports on the top, for connection with enterprise systems.

7.8.3 The machine shall be able to communicate via OPC-UA protocol, acting as an OPC-UA server. All PLC/CNC software tags that are process related (e.g. axis positions, piece present, closed/open gripper) shall be made available in read mode via OPC-UA. Supplier shall share the OPC-UA tags mapping through an .xml file as part of the technical documentation.

8. Safeguarding and safety related devices

8.1 Programmable safety systems

8.1.1 Programmable safety-related control functions, including but not limited to safety interlocks, e-stops, overtravel switches, safety latches, light curtains, shall be designed to fail-safe.

8.1.2 The Safety Logic shall be password protected, and any change (including new devices installed) in the Logic must be accepted by Lilium.

8.2 Emergency stop pushbuttons

8.2.1 Emergency stop devices shall follow the requirements of EN 60204-1 (Safety of machinery. Electrical equipment of machines. Part 1: General requirements) and EN ISO 13850 (Safety of machinery – Emergency stop function – Principles for design).

8.2.2 Emergency stop pushbuttons shall be installed at all control cabinets that initiate motion, all operator posts (operational area designed to have a person) and where dictated by the risk assessment (taking into consideration normal operation, commissioning, maintenance, set-up, teaching positions).

8.2.3 Emergency stop devices shall be clearly identifiable, positioned such that they are readily accessible and capable of non-hazardous actuation by the operator and others who could need to actuate it.

8.2.4 Measures against inadvertent actuation should not impair accessibility.

8.2.5 Each emergency stop pushbutton shall be individually monitored by the PLC (using individual channels) and the machine shall be capable of identifying which emergency stop pushbutton is activated through HMI diagnostics.

8.2.6 One or more emergency stop devices (push buttons / pull-cord or power supply disconnecting device(s)), shall be installed such that at least one may be reached within 5 meters from any directly accessible point of the equipment.

8.2.7 Security torx/Torx TR shall be used on door safety interlocks, safety position switches and actuators.

8.3 Light Curtains

8.3.1 Status of light curtains and muting modules shall be monitored by the Safety PLC.

8.3.2 Device for testing (testing rod) the light curtain functionality shall be provided with a fixture and permanently chained to the machine, installed close to the light curtains for daily inspection.

8.3.3 Light curtain mounting shall allow for adjustments/alignment and provide physical protection.

8.4 Safety Laser Scanners

8.4.1 Safety laser scanners shall only be used with Lilium's ME EA engineer approval via deviation request.

8.5 Safety Mats

8.5.1 Safety mats shall only be used with Lilium's ME EA engineer approval via deviation request.

8.6 Safety Latches

8.6.1 Safety latches shall only be used with Lilium's ME EA engineer approval via deviation request.

8.7 Robots and Robot Systems

8.7.1 Limiting devices shall establish restricted spaces for restraint of robot motions. The limiting devices shall not cause additional hazards and be set such that the restricted space is as close as possible to the operating space.

8.7.2 Every robot shall be provided with Safe Operation/Safe Move programmable safety system unless the restricted space can be limited by mechanical hard stops and approved by LILIUM Controls Engineering via deviation request.

8.7.3 Robot spaces as defined by ISO 10218-1 shall be documented in the Controls electrical drawings and made available to the responsible Lilium's ME EA engineer aligned with the drawing submission milestones.

8.7.4 The machine builder shall provide documentary evidence on how the restricted space around the robot is established. It can be by either mechanical and electro-mechanical axis limiting devices or safety-rated soft axis and space limiting in accordance with EN 10218-1 clause 5.12.2 & 5.12.3. Where this function is performed by safety related parts of control systems this must be supported by EN 13849-1/2.

8.7.5 The robot control cabinet shall be located outside the safeguarded space, positioned to allow the operation of the pendant without being exposed, and with the robot in view.

8.7.6 Robot, end of arm tooling and other machine motions necessary for teaching robot shall be available at, and only initiated from the robot teach pendant. The machine HMI shall be disabled.

8.7.7 Requirements for multi-robot systems shall be discussed during the design phase with the responsible Lilium's ME EA engineer to agree:

- Control of the teaching method.
- Identification of the active robot.
- Interfaces between robots.

8.7.8 Cells where multiple robots exist, they shall be clearly identified so to avoid confusion when teaching or troubleshooting.

8.7.9 Only one person with robot teach pendant shall be allowed inside of a station cell. A second person may only be present if using an enable button (3 position switch, PLd Cat 3 minimum).

8.7.10 The Robot teaching/manual mode speed shall be limited to not exceed 200 millimetres/second.

Appendix – Deviation Form

The purchase of the machine is conditioned by the agreement with this document. Please check ☒ the appropriate box below, complete company details & sign, then email this page as a pdf.

☐ Yes, totally agreed

☐ Agreed with deviations/derogations (please, describe below)

Table 5 - Derogation Table

Item	Derogation

Name:
Company Name:

_____
Legal Representative Signature; Local; Date