Manual

For the electric propulsion system

SOLO Type 80400

Serial - No.	
Manufactured	

Aircraft - Type	.....
Registration	.....
Owner	.....

Log of revisions

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1. Description of the propulsion system

1.1 Components

The SOLO electric propulsion system type 80400 contains the following components:

Motor	EMRAX 208 HV with two resolvers for determination of RPM and position
Controller	SOLO Econtrol
Batteries	2 Batteries BM 384, Nominal Voltage 350V, 12 Ah
DCU	Central control unit for the display of operating data and warnings. (DCU = **D**isplay and **C**ontrol **U**nit) If the DCU shall be used with the display and the controls the unit has to be certified with the installation into the aircraft.
RFU	Control unit for extension and retraction (RFU = **R**etraction and **F**uses **U**nit)
IMD	Isolation monitoring device Bender iso 165c (IMD = **I**solation **M**onitoring **D**evice)
PRS	DC/DC Converter for the low voltage supply and charging of the 12V Batteries.
Charger	Charger for charging both HV-Batteries

All components are communicating with CAN-Bus. The CAN-Bus can be used for displaying operating data and warnings on a separate display unit.

The motor and the PRS (DC/DC Converter) are air-cooled. The controller can be water- or air-cooled.

The system can be operated with one or two batteries. The available power you can find in chapter 3.3

2. Technical Data

2.1 Motor

Dimensions	Diameter 208 mm Height 85 mm
Weight	9,1 kg
Efficiency	92 – 98 %

2.2 DCU (Display and Control Unit)

Dimensions for Installation in the panel	63 x 63 x 43 mm Cut-out 59 x 59 mm
Weight	145 g

2.3 RFU (Retraction and Fuses Unit)

Dimensions	130 x 80 x 31 mm
Weight	260 g

2.4 Controller (SOLO econtrol)

Dimensions watercooled	280 x 200 x 90 mm
Dimensions aircooled	300 x 200 x 150 mm
Weight for both versions	3,5 kg

2.5 Batteries (BM384)

Dimensions	725 x 347 x 82 mm
Configuration	69S4P Li Ion 18650
Battery Voltage	290V – 400V
Nominal Voltage	350V
Max. continuous current	60A
Capacity (depending on the load)	3,4 – 4,2 kWh
Weight	Ca. 25 kg

2.6 PRS (DC/DC-Converter)

Dimensions	120 x 83 x 55 mm
Weight	400 g
Supply- and output- voltage	290V – 400 V 12 – 14,3 V

2.7 IMD (Isolation monitoring device)

Dimensions	140 x 112 x 43 mm
Weight	220 g
Supply voltage	12 – 14,3 V

3. Operational data and limitations

3.1 Temperature limits

	Warning	Maximum
Motor	from 105°C	120°C
Controller	from 75°C	85°C
Batteries	from 63°C	70°C

3.2 RPM - limits

	Warning	Maximum
RPM	from 4000 RPM	4350 RPM

3.3 Power limits

With two batteries:

Max. Power	35 kW at 4000 RPM
Max continuous power	23 kW at 3600 RPM

With one battery:

Max. power	20 kW at 4300 RPM
Max continuous power	14 kW at 3000 RPM

4. Installation Instructions and torques

4.1 Motor

- The Motor can be mounted on the back side with 6 bolts M8. The screw-in depth is 20 to 25 mm (measured from the surface of the fastening flange). The torque is 20 Nm
- The propeller can be mounted with 6 bolts M8. The screw-in depth is 16 to 16,8 mm. The propeller should have a maximum diameter of 1400mm and a maximum mass of 2.5 kg.
- The torque is 20 Nm.
- The Tandem Resolver is connected to the controller with 5 wires each. The color coding and the dimension of the wiring are described in the wiring diagram attached to this manual.
- The Temperature sensor is connected to the controller with 2 wires. The color coding and the dimension of the wiring are described in the wiring diagram attached to this manual.
- The 3 high voltage connections (U, V, W) are connected to the controller. A shielded wire with a cross-section of 16 mm^2 must be used. This wire needs an orange Isolation. The maximal length is 2,5m.

4.2 Controller

- The controller can be water- or air-cooled.
- It can be mounted with 4 bolts M6 at the housing corners.
- The water-cooling must be able to lead away 1,2 kW. The coolant is water plus anti-freeze type G13. The mixture must be for at least – 25°C.
- The two wires of the high voltage batteries are connected by shielded wires with orange isolation. The cross section of the wires must be 16 mm^2 and the maximal length should not exceed 2.5m.
- The 3 high voltage wires to the motor (see above) are also connected to the controller.
- The Resolver cables, the wires of the temperature sensor and the connection to the DCU are connected by connectors. The cross sections and the color codes are described in the wiring diagram attached to this manual. The length of the cables should not exceed 2.5 m.

4.3 Batteries

- The 2 Batteries are installed in the motor bay. They each have a connector which automatically connects with the connector installed in the aircraft. In addition, they have a connection, which leads smoke away in case of a cell failure. This connection must lead smoke to the outside of the aircraft.
- The system can also be used with only one battery, but then the power will be reduced.
- The batteries can be charged inside or outside the fuselage.
- At the top of the batteries there is a red warning light which indicates that the high voltage is active in the system. Additionally, there is a green LED-indicator which shows the status of charge (SOC) of the battery.

4.4 Display and Control Unit (DCU)

- The DCU is usually installed in the instrument panel. The fixing threads are equal to a 57 mm diameter instrument, but the cut-out for the display is rectangular (59mm x 59 mm). The display is not part of the certification of the propulsion system and it has to be certified by the aircraft manufacturer with the installation.
- On the backside of the DCU there is a connector (SubD) which connects the DCU with the other components of the system. Dimensions of the wiring and connections must be taken from the wiring diagram. The max. length of the wiring can be 5m.

4.5 Retraction and Fuses Unit (RFU)

- The RFU can be mounted at any place of the aircraft. There are 4 mounting holes (6mm) at the housing.
- At the DCU there is a connector (SubD) for connecting the RFU with the other components of the system. Dimensions of the wiring and connections must be taken from the wiring diagram. The max. length of the wiring can be 5m.

4.6 Isolation and Monitoring Device (IMD)

- The IMD can be mounted at any place of the aircraft. There are 4 mounting holes (6mm) at the housing.
- At the IMD there is a connector (SubD) for connecting the RFU with the other components of the system. Dimensions of the wiring and connections must be taken from the wiring diagram. The max. length of the wiring can be 5m.

4.7 Power Rail Supply (PRS)

- The PRS can be mounted at any place of the aircraft. There are 4 mounting holes (3mm) at the housing.
- At the IMD there is a connector for connecting the RFU with the other components of the system. Dimensions of the wiring and connections must be taken from the wiring diagram. The max. length of the wiring can be 5m.

4.8 12 Volt Supply

- The system needs a 12V supply from a LiFePo-Battery, which can also supply the avionics in the aircraft.
- If the system is switched on, the PRS supplies the system with 5A max.
- In the Standby-Mode the 12V Battery can be charged from the High Voltage batteries with appr. 1.5A.

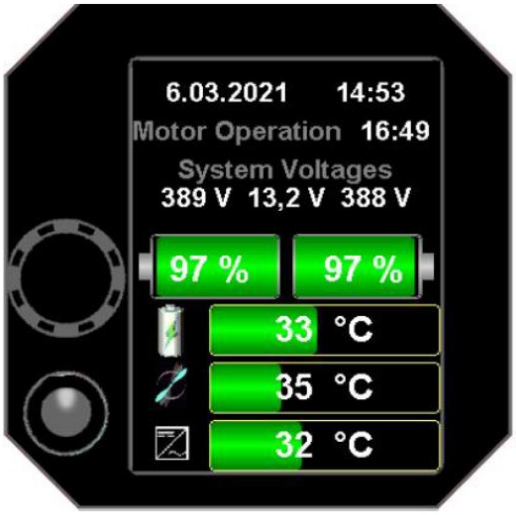
5. Operation of the system

5.1 Description of the display (DCU)

The DCU can display the following values. It is also possible to send these values via CAN-bus to external and alternative devices.

Command button

Extension and retraction switch



Actual date and time
Cumulative operation time of the motor
System voltage battery A, 12V supply and battery B
State of charge battery A and B

Battery temperature

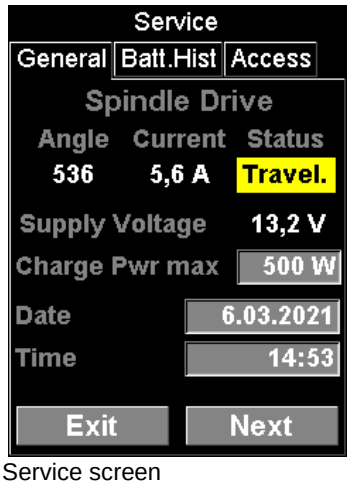
Motor temperature

Controller temperature

The system needs three elements for the operation:

- On/Off-switch in the panel to activate or shut off the system.
- A power controller
- A toggle switch to extend or retract the drive.

5.2 Service screen



Service screen

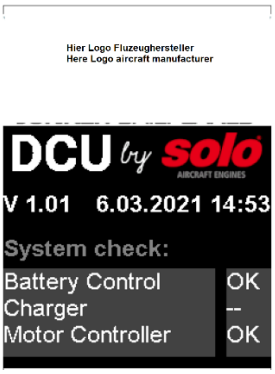
The service screen is activated by pressing the command button when the system is switched on.

In the service screen you can adjust date and time and the limit of the charging (500 or 1000W).
By clicking „Exit“ you can leave the screen. By clicking „Next“ you can switch to the next screen.
As long as the service screen is shown the pylon can be operated by the Extension and retraction switch manually.
During operation of the spindle drive the field angle shows a counting signal. The value shown is 0 for completely retracted and 1220 for completely extended. The value does not show the angle in degrees.

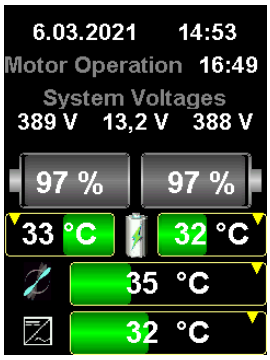
Aditionally the current for the spindle drive and the status is shown.
Bevore using the system it has to be calibrated after the assembly. Details are described in the Service Manual.

5.3 Description of various screens shown on the DCU

After switching on the system, the **Starting screen** is shown.
There you can see the date, the time, information about the present firmware and the status of the system self-check.

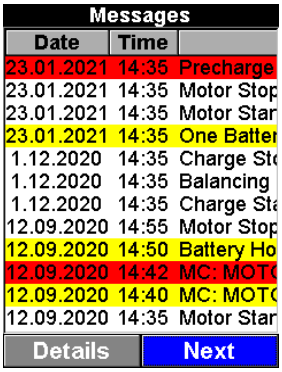


After a positive self-check the **Stand-by-screen** is shown. The high voltage batteries are not active and therefore shown in grey color.

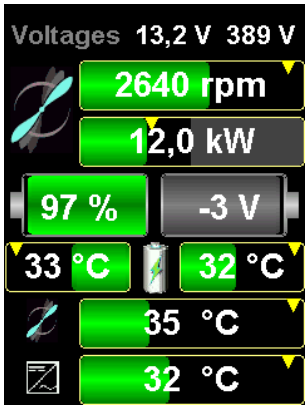


Now the system can be extended by pushing the Retract-extend-button upwards.
If you want to charge the 12V avionics battery you must push the Retract-extend-button downwards.

During the self-check you can activate the **message-screen**. There all stored messages with date and time can be seen. By clicking the button „Details“ by pushing the command button you can see more details of the messages. By pushing the command button again, you can leave the message screen.



If there is a difference in the voltage after charging the batteries the system has to be operated with one battery until the voltage of the two batteries is equal. A self-launch is only possible by using both batteries. This message is also shown by a warning message.



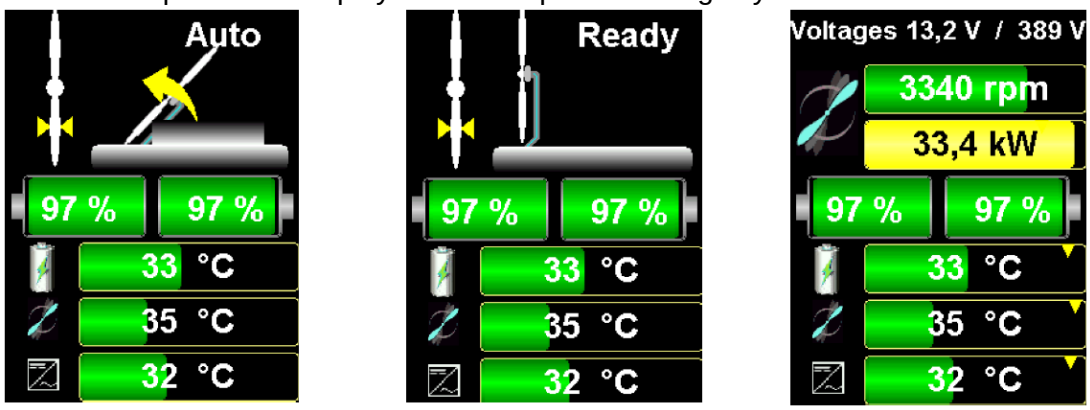
5.4 Normal operation of the system

Aktivating:

1. Switch on the system with the separate switch (12V supply).
2. The DCU shows the starting screen.
3. Self-check of the system. If all components are okay the DCU changes to the stand-by-screen.

Self launch:

1. To extend the motor and propeller push the toggle switch on the left side of the DCU upwards.
2. After the extension is complete the DCU shows „**Ready** “.
3. By rotating the command button clockwise, the power of the motor will be increased continuously until the maximum power is supplied. The DCU shows the RPM of the motor, the power supplied by the batteries, state of charge and temperature of the batteries, motor, and controller. If the warning values are reached the display shows the values in yellow color. If the limits are reached the DCU shows the values in red color and a failure message will be created.
4. At full power the display shows the power setting in yellow color.



Display of the DCU during normal self launch

Stopping the system:

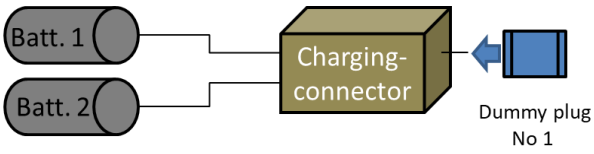
1. By a short push of the toggle switch at the DCU the power will be reduced.
2. The motor reduces the RPM and the propeller will turn in to the vertical position automatically. (This can be recognized by the two yellow arrows at the propeller symbol.
3. After the vertical position is reached the propeller mast is retracted automatically.
4. With the ON/OFF-switch in the panel the system will be shut off.

Use of the motor during flight:

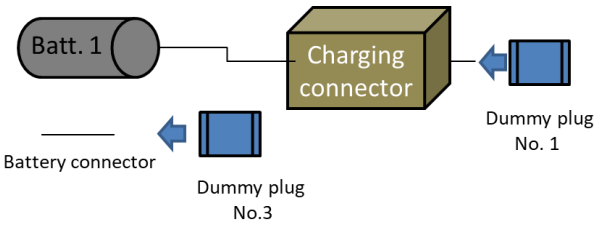
The use of the motor during flight is identical to the use for self-launch.
The system can be used with one or two batteries. With one battery self-launch is not possible, because the system reduces power automatically.

All free connectors must be secured with a suitable dummy plug (High voltage). Also the DCU checks all connections.

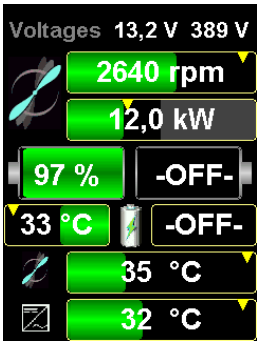
Use of the system with two batteries:
In the aircraft a charging connector is installed. This connector must be secured with dummy plug No. 1.



Use of the system with one battery:



If you are using the system with one battery only you will get the screen below and a warning message: One battery disconnected NO TAKE OFF



5.5 Charging the batteries

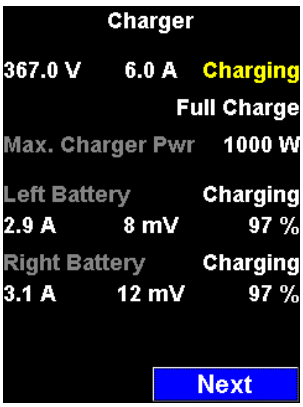
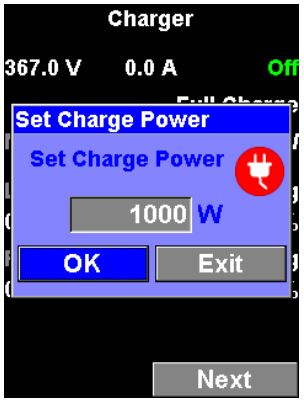
The batteries can be charged in the aircraft or taken out from the aircraft.
To reach a decent lifetime of the batteries it is recommended not to store them fully charged. For storage and transport a charge of 30% is recommended. If you need to discharge the batteries install them in the aircraft and do a ground-run. Charging is only possible between 5°C and 40°C.

5.5.1 Charging the batteries in the aircraft

First remove the dummy-plug from the charging connector. On one of the two cables of the charger the dummy-plug No. 2 must be fixed. As soon as the cable is connected with the charging connector, the charger can be switched on. The charger will supply 12V for the battery manager, the IMD and the DCU.

- All the components are started.
- The battery manager starts the charging mode. A red warning light will appear at the top of the batteries.
- The DCU and a green LED will show the charging.

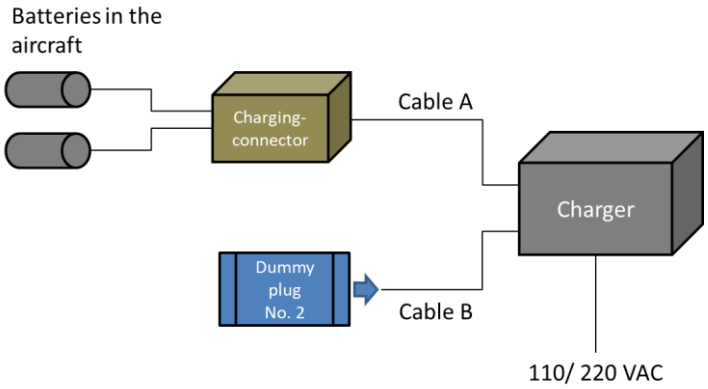
Within the first 20 seconds after switching on the charger it is possible to limit the charging current by following the screen on the DCU.

		
Anzeige des Ladezustandes	Für längere Lagerung der Batterien „STORE“ wählen	Ladeleistung 500W oder 1000 W möglich

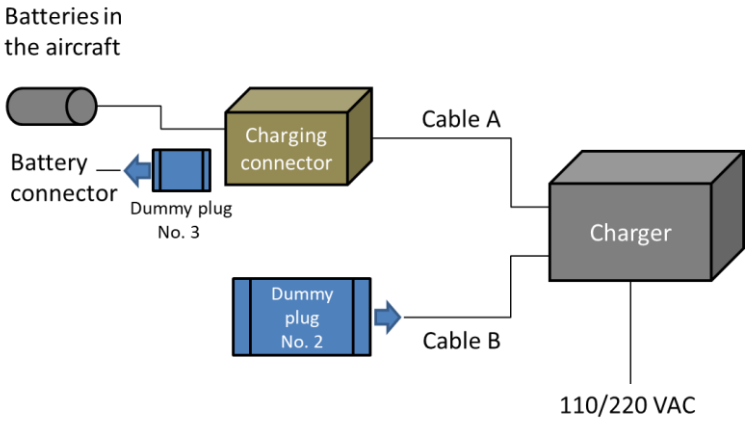
When the charging is complete:

- The battery manager will stop the charge.
- The DCU changes to the standby screen.
- The 12V supply and the charging of the 12V battery is still active.

Charging both batteries in the aircraft



Charging of one battery in the aircraft:
Charging one battery in the aircraft is also possible. In this case the dummy plug No. 3 must be connected.



5.5.2 Charging the batteries outside the aircraft

As soon as the charger is connected with the batteries and switched on, it supplies 12V for the battery manager.

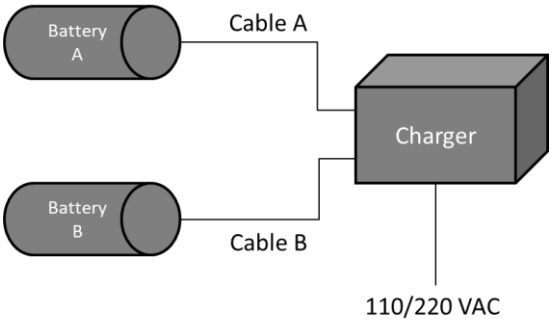
- The battery manager starts the charging. (The red light on top of the battery will go on)
- The LED bar will show the state of charge.

When the charging is completed:

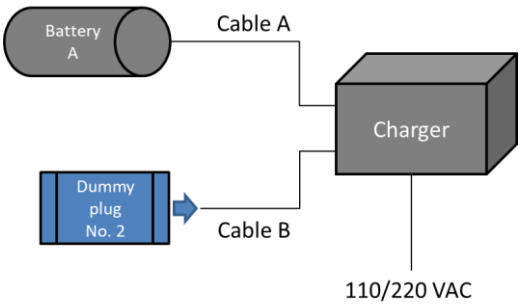
- The battery manager terminates the charging. The red light goes off.

Winter charging:
If the battery is not used for longer periods it is recommended, that the Winter mode is started. For this mode connect the batteries as described and push the toggle switch at the charger when you switch on the charger.

External charging oft two batteries



External charging of one battery



6. Maintenance instructions

6.1 Check before flight

- Switch on the system and extract the motor. If completely extracted switch off the system.
- Check if batteries are secured tight. If a water-cooled controller is installed check coolant level.
- Turn propeller by hand and check if there is a strange sound or it is difficult to turn.
- Switch on the system. The propeller must turn to the vertical position.
- If possible, do a ground run with little power.
- Retract system and switch off.

6.2 Check every 25 hours or after one year

4. Switch on the system and extract the motor. If completely extracted switch off the system.

- Check all nuts and bolts of the motor and the propeller.
- Check the wiring if there is wear or cracks in the isolation.
- Check all connectors for tight seat and condition of the locks.
- Switch on the system. The propeller must turn to the vertical position.
- Do a ground test run with full power.
- Retract system and switch off.

6.3 Check after 300 hours of use or 15 years of operation

This check may only be carried out by the manufacturer. To do this, all components must be sent to the manufacturer.

6.4 Preservation

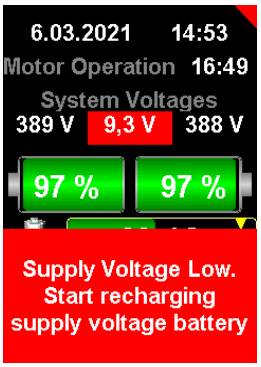
If the systemis not used fort wo or more months a preservation is not necessary. The batteries should be taken out from the aircraft and stored between 5°C and 20°C. The state of charge should be about 25% and also checked from time to time. The charger offers the possibility of a battery maintenance if the batteries must be stored for longer time.

7. Notifications

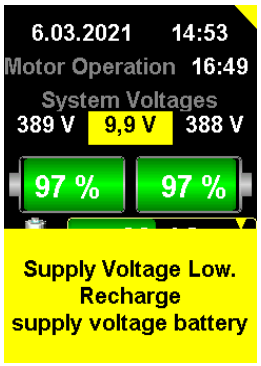
All notifications are stored in the DCU. They are classified and marked as follows:

	Background color	Audio warning
Warnings	Yellow	Beep for 1 second
Errors	Red	Continuous beep until the message is acknowledged

The notifications are shown on the DCU in the lower third of the display. They can be acknowledged by pressing the command button. In the upper right corner of the display a small triangle in the same color is displayed. This shows, that a notification was present.



Error message



Warning message

All notifications are stored in a flash memory. By pushing the command button, the display shows the next notification. Messages are shown in the lower part of the screen and are highlighted in red or yellow color.

If an error message occurs a continuous beep sounds until the command button is pushed. If a warning message occurs a beep sounds for one second.

7.1 Error Notification

Error message	Description, Action
Propeller overspeed !!! Reduce Power	RPM >4350 U/Min. Reduce power or speed
Supply Voltage too high!	Voltage exceeds 15,0 V. Wrong battery type used or voltage control inside PRS is damaged.
Interlock Circuit not closed!!! Check Connectors	During system startup the interlock circuit is not closed. Check connectors to charger and batteries
Battery DRAINED Connect Charger!	lowest cell voltage is < 2.5 V. No motor operation possible but keeps propeller vertical position.
All Batteries empty	Remaining motor operation time< 2Minutes
No Data from Charger	No CAN messages from charger.
No Data from Isometer	No CAN messages from isometer. Danger of electric shock.
Isometer defect	Selftest of isometer not successful. Danger of electric shock.
Isometer Ground Failure!	Isometer has bad connection to LV-ground rail. Danger of electric shock.
Insulation Problem!!!	Insulation between high voltage rail and low voltage rail below 100 kΩ. This is too low. Danger of electric shock.
No Data from RFU!	No CAN messages from RFU
No Data from Motor ontroller	No CAN messages from Motor Controller
No Data from Battery A	No CAN messages from left battery.
No Data from Battery B	No CAN messages from right battery.
Watchdog Reset	Detected error in software. DCU restarted automatically.
No Communication	CAN-Bus Fault. Check wiring.
Supply Voltage too low Start recharging supply voltage battery	Supply voltage is below 10,0 V. Switch on recharging process .
Retraction Mechanism Error	Several causes possible: - Current to spindle exceeds OEM-adjustable limit. - Spindle is switched on but there is no feedback. → Spindle seems to be blocked.

Retraction Mechanism Timeout! Spindle blocked?	Spindle was powered for more seconds that OEM-adjustable limit.
Precharge Timeout! Service Disconnect?	Voltage on high voltage rail does not reach battery voltage in time. Main relay cannot be closed.
Error messages from the controller	
MC: BAD PARAMETER	Damaged Parameter
MC: POWER FAULT	Overall message of hardware monitoring [1]
MC: RFE FAULT	Safety circuit faulty (only active with RUN)
MC: BUS TIMEOUT	CAN-Bus timeout
MC: FEEDBACK	Resolver signal faulty or missing
MC: POWER VOLTAGE	Power voltage missing
MC: MOTOR TEMP 1 Reduce Power Instantly!	Motor temperature too high (> 115 °C)
MC: DEVICE TEMP Power reduced	Device temperature too high (> 80°C)
MC: OVERVOLTAGE	Overvoltage (power voltage)
MC: I_PEAK	Overcurrent or strongly oscillating current detected
MC: RACEAWAY	Drive races (without command value, wrong direction)
MC: MOTOR TEMP 2	Motor temperature too high (second sensor) not used
MC: I Sensor	Current measurement error
MC: BALLAST	Ballast circuit overloaded

Error messages from the batteries	
BATTERY A: Modul Timeout Discharge Only Maintenance!	Error during selftest. Discharge only. Maintenance necessary.
BATTERY A: Cell connection Discharge Only Maintenance!	Error during selftest. Discharge only. Maintenance necessary
BATTERY A: Temperature Reg. Discharge Only Maintenance	Error during selftest. Discharge only. Maintenance necessary
BATTERY A: Cell Voltage Reg. Discharge Only Maintenance!	Error during selftest. Discharge only. Maintenance necessary
BATTERY A: No Module Data Discharge Only Maintenance!	Error during selftest. Discharge only. Maintenance necessary
BATTERY A: Battery TOO HOT Reduce Power !!!	Battery-Temperature > 70°C
BATTERY A: Battery Empty !!!	SOC < 3%
BATTERY A: Off! Precharge Error Check wiring and try again!	Only when charger is connected: Batman tries to precharge the power bus, but charger shows no voltage data.
BATTERY A: Off! Cell Overvoltage Reset Power Maintenance	Can only happen if charger is connected. Maintenance may be necessary
BATTERY A: Cell voltage difference. Maintenance Required	The battery cell voltage difference is higher that 50mV during boot time and the maximum cell voltage is higher that 4,0 V. Motor can be used after confirming the message

BATTERY A: Off! Charger Error Check Wiring	Can only happen if charger is connected. Reasons may be: - Communication problem between both batteries. - One battery is connected after power on
BATTERY A: Off! Cell Overvoltage New Precharge. Maintenance	At least one battery cell Voltage is higher than 4,2 V. Reset by a new precharge after problem is solved.
BATTERY A: Off! Cell Drained Connect Charger!	At least one battery cell voltage is below 2,3 V. It is possible to reset this state by a new precharge event
BATTERY A: Off! -Overcurrent- Reset Power	Hardware shutoff due to high current. Reset by power cycle
BATTERY A: Off! -Permanent Shutoff- Maintenance Required	Battery temperature > 85°C. Battery is permanently shutoff. Reset only by maintenance personal
BATTERY A: Current too high Decrease power setting immediately!	Battery current > 80 A. Maybe only one battery is connected to the power bus. Probably only one battery is connected unintentionally. Connect only one battery and check which one is working. Maintenance necessary
Error messages from the charger	
CHARGER: Hardware Error Remove Charger and try again	General hardware error. Can only be cleared by power reset.
CHARGER: Overtemperature	Charger too hot. Switch charger off until it cools down.
CHARGER: No Battery	Charger cannot detect valid battery voltage.
CHARGER: Communication Timeout	Charger didn’t receive control message for five seconds.

7.2 Warning notification

Warning messages	Description
Retraction Mechanism not calibrated. Service Screen!	Pylon angle does not correspond to spindle current, or pylon angle values are not valid.
Interlock Warning! Battery or Charger not Connected!	Connectors not fully closed.
Battery A not Connected	DCU does not get any data from Battery A
Battery B not Connected	DCU does not get any data from Battery B.
All Batteries low !	Remaining motor operation time < 5 minutes.
Battery voltage difference too high. NO TAKE-OFF !!!	Battery voltage difference is > 30 V. Battery with lower voltage is disabled, so no take-off is possible.
Battery Cell Voltage Low Motor LIMITED !	At least one battery cell voltage gets down to the low level.
Remove Charger !	If in standby motor operation is demanded but the charger is still connected.
Motor Current Limit! Temperature Motor Controller	Motor controller limits power to the motor. This message shouldn't show up in a system with correct parameter setup
Motor Current Limit!\ Motor Temperature	Motor controller limits power to the motor. This message shouldn't show up in a system with correct parameter setup
Motor Current Limit! Propeller Speedlimit	Motor controller limits power to the motor. This message shouldn't show up in a system with correct parameter setup
Supply Voltage Low. Recharge supply voltage battery	Supply voltage below 10,5 V
Insulation Resistance low. Check Insulation!	Insulation resistance between HV-rail and supply voltage rail below 200kΩ.
One Battery disconnected NO TAKE-OFF !!!	One battery operation. Battery power is limited to about 19 kW, so no take-off is possible.
CAN Buffer full	This message shouldn't show up in a system with correct parameter setup

Warning messages from the controller:

MC: WARNING_0	No device identification
MC: ILLEGAL STATUS	RUN signal disturbed, EMI
MC: MOTOR TEMP Reduce Power!	Motor temperature high (> 105 °C)
MC: DEVICE TEMP Power Reduced	Device temperature high (> 75 °C)
MC: insufficient Battery Power	Battery voltage too low to set the motor current that is rated.
MC: I_PEAK	Overcurrent 200%
MC: RACEWAY	Resolution range of the speed measurement reached
MC: 2.Supply Fail	12V second voltage supply missing
MC: Secondary Feedback Fail	Seconday resolver signal faulty or missing. Primary resolver signal active.
MC: BALLAST	Ballast circuit > 87 % overloaded

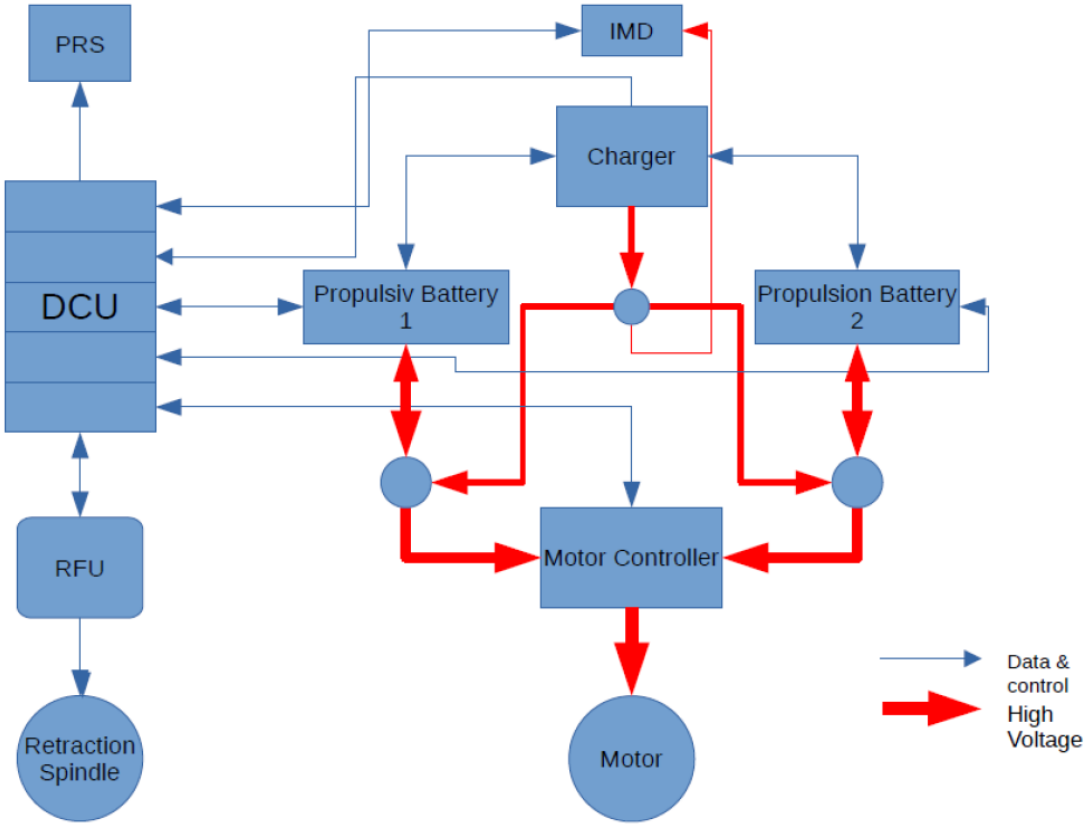
Warning messages from the Batteries:

BATTERY A: Battery Hot !	Maximum battery cell temperature > 60 °C
BATTERY A: Battery Low !	SOC < 10%
BATTERY A: Cell voltage difference too big. Connect Charger!!!	Battery cell voltage difference > 20 mV. Connect charger and let balancing process be finished.
BATTERY A: One or more Temperature Sensors failed	More than 5 temperature sensors are defect Maintenance necessary.
BATTERY A: Flash Memory Error Maintenance	No further effect. Maintenance necessary.
BATTERY A: Cell Monitor Chip too hot Balancing is paused.	Wait until chip is cooled down and balancing resumes.

Warnungen vom Ladegerät

CHARGER: No Power!	Charger not connected to the power grid. Charging process resumes automatically when power is back.

8 Wiring



Schematic description of the system

9 Power curve