CONFIGURATION AND VERIFICATION INSTRUCTIONS

Integrated motor drive
IMD 100

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Contents

1. Introduction

This document describes how to mount, connect and perform initial start of the IMD at production. The initial start also includes upgrade of software and upload of parameters. It is assumed that a parameter file for the upload already exists. The manual described the standard way of installing the IMD.

It is recommended to fill out the verification check list (document no. 4189360022), and keep it with the turbines documentation in order to document the verification of the system.

It is possible to print this manual on a monochrome printer, though figures and illustrations are easier to understand if a colour printer is used.

Info

The screen images in this manual are based on the noted IMD Manager version. The manual will not be revised if a new version of the IMD Manager is available, but has no practical impact on the tasks described in this manual.

1.1 Conventions

The following conventions are used in this document:

Used in document	Description
`Monotype` font	Used when describing a path or text input in a machine human interface
	A yellow symbol illustrates hazard type (this symbol is an example for general hazard). There are different types such as electrical, chemical and so on.
Danger!	A signal word used to indicate an imminently hazardous situation, which if not avoided, will result in death or serious injury. (ISO 3864)
Warning!	A signal word used to indicate an imminently hazardous situation, which if not avoided, could result in death or serious injury. (ISO 3864)
Caution!	A signal word used to indicate a potentially hazardous situation, which if not avoided, could result in minor or moderate injury. (ISO 3864)
	A blue symbol illustrates a need for mandatory action. In this example read instructions. Other types of blue symbols exist and always indicate mandatory action.
	A symbol used to draw attention to extra information or an action that is not mandatory

1.2 Referenced documents

The following documents are referenced in this manual:

Document no.	Title
4189360022	IMD 100 configuration and verification checklist

2. Safety precautions

Attention

Company policy and local regulations regarding PPE must always be followed, regardless whether the PPE is shown in this manual or not.

2.1 Mechanical work

Use eye, hand and hearing protection

Use protection for eyes, hand and hearing, if the mounting holes for bolts and heat sink need to be made during production.

2.2 Electrical work

Disconnect power

Ensure that all power is disconnected when working with the IMD, except for during commissioning, testing and service.

Danger!

Risk of burns and electrical shock from short circuit, electrical arc and uninsulated wires.

Live work is not permitted, except for during verification, commissioning, and service.

Observe local regulation when working with electrical components.

Danger!

Risk of burns and electrical shock from short circuit, electrical arc and uninsulated wires.

Commissioning and maintenance work on this device may only be carried out by a qualified electrician.

When the IMD has been powered, there is a risk of stored energy even when the power is disconnected. Wait 5 minutes after the power is disconnected and verify zero energy according to company procedures on the outputs before performing any work.

Caution!

Risk of electrical shock from touch current if the protective earth is removed when the IMD is energized.

Do not remove the protective earth is removed when the IMD is energized.

2.3 Thermal precautions

Info

During operation, the IMD can reach high surface temperatures. The temperature levels depend on the ambient temperature inside and outside the cabinet.

Warning!

Risk of severe burns.

The heat sink of the IMD can reach high temperature.

Do not touch until the surface (see pos. 1 in Figure 1 on page 7) is cooled down.

Caution!

Risk of burns.

The sides of the IMD can reach medium high temperature.

Do not touch until the surface (see pos. 2 in Figure 1 on page 7) is cooled down.

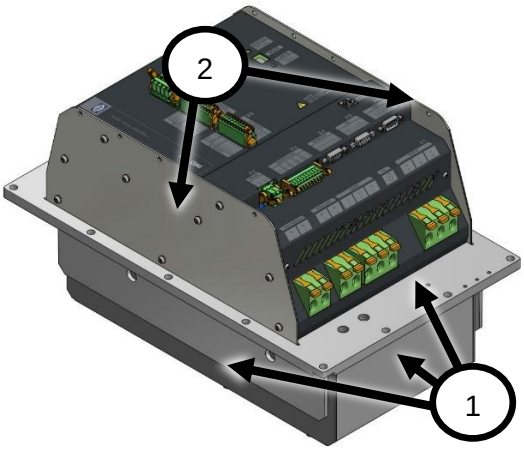


Figure 1 Hot surface areas

3. Avoiding damage to the IMD

Certain situations may result in product damage and should therefore be avoided by observing the precautions described in this section. These situations are not likely to occur under normal use of the IMD, but might occur in the lab or during service.

The situation list may not be comprehensive. Other, unknown situations that are not described in this section could occur.

3.1 Connecting the safe energy

Possible damage: Damage to internal power components.

How to avoid:

If the safe energy was disconnected from the SE terminals, the mains supply must be turned on before the safe energy is turned on.

3.2 Switching mains ON and OFF

Possible damage: DC-link Pre-charge circuit damaged due to repeated MAINS ON and OFF operations

How to avoid:

If the MAINS connections are switched ON and OFF more than once, wait 60 seconds before switching ON after switch OFF.

3.3 Overloading the ballast resistor

Possible damage: Ballast circuit ((switch or resistor) damaged due to overload.

How to avoid:

- The ballast resistor value is adequate for the DC-link Vmax.
- Never use single pulse longer than 1 s during safe energy test.
- Wait 10 minutes (at 25ºC) if the IMD is restarted and the ballast resistor has been loaded (hot)

3.4 Connecting the mains with overvoltage

Possible damage: Total damage to the IMD.

How to avoid:

The mains supply must never exceed the range specified in the Data sheet.

4. Configuration and firmware update

When the IMD is mounted and all electrical connection are made, the IMD needs to have the necessary parameters configured (customer specific), and possibly also firmware upgrade. The order of performing configuration and update does not matter.

4.1 Firmware update

There are two ways in which the firmware (FW) can be updated in the IMD:

1. **Update through the "Service" USB connector**.
2. **Update through CANopen**

The FW update in this stage is done through the "Service" USB connector no matter which method is going to be used later on, however, there is a difference in the files that are loaded to the IMD and how these files are loaded. Select the appropriate method in this section.

NOTE It will always be possible to update the FW through the "Service" USB connector. It is just a matter of which files are used in the update. However, if the procedure for future Service USB connector update is used, it will not be possible to update the FW through CANopen, without performing the procedure for future CANopen update first.

4.1.1 Updating firmware for future Service USB connector update method

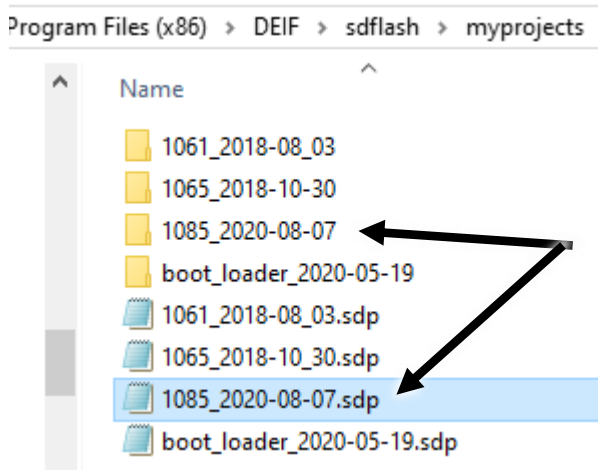
4.1.1.1 Prerequisites

- A computer with Spectrum Digital SDFlash program installed (including V3.3 SDFlash serial patch for flash programming, September 5, 2008), (http://emulators.spectrumdigital.com/utilities/sdflash/)

  Typically, the necessary USB driver will be found automatically if the computer is on-line. Otherwise, go to Silicon Labs home page and download the latest driver for CP210x USB to UART Bridge (http://www.silabs.com/products/mcu/Pages/USBtoUARTBridgeVCPDrivers.aspx).

  Info
  The links above were valid at the time when this manual was written. If the link does not work anymore, search for "`V3.3 SDFlash serial patch`" or "`CP210x USB to UART Bridge driver`".

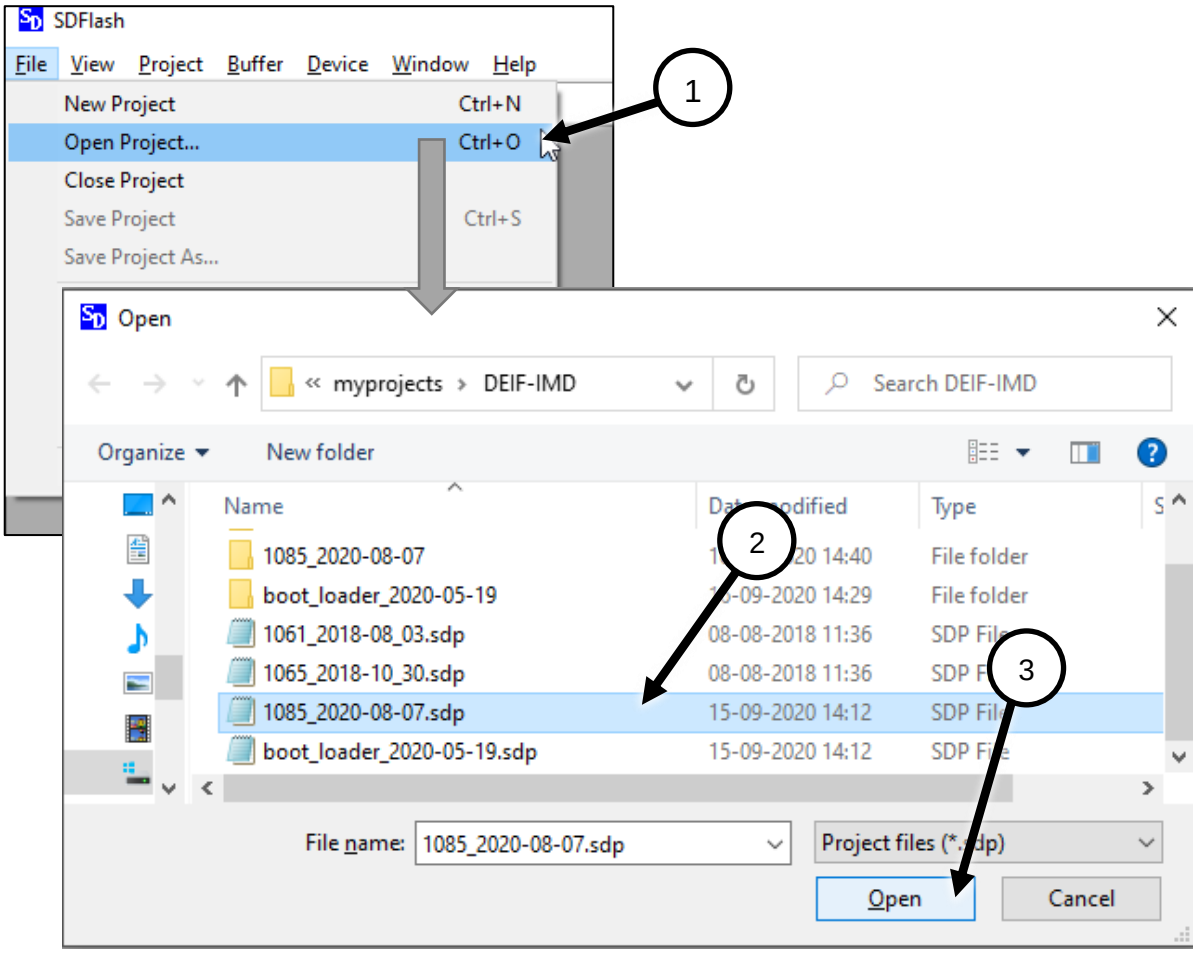
- The computer must be connected to the IMD with USB cable (male type A to male type B).
- Prepare the FW files for use:
  1. Copy the folder of the new FW.
  2. Paste the folder in the folder where other FW is located.
     If the FW files are located at their default location, go to `myprojects` folder in `sdflash` folder (where sdflash was installed) and paste the folder under `myprojects`.
     NOTE The files can be located anywhere. It is possible to brows to the location and sdflash remembers this location.
  3. Copy any of the .sdp files in the folder and paste it (the .sdp.
  4. Rename the .sdp file to the same name as the new FW folder:



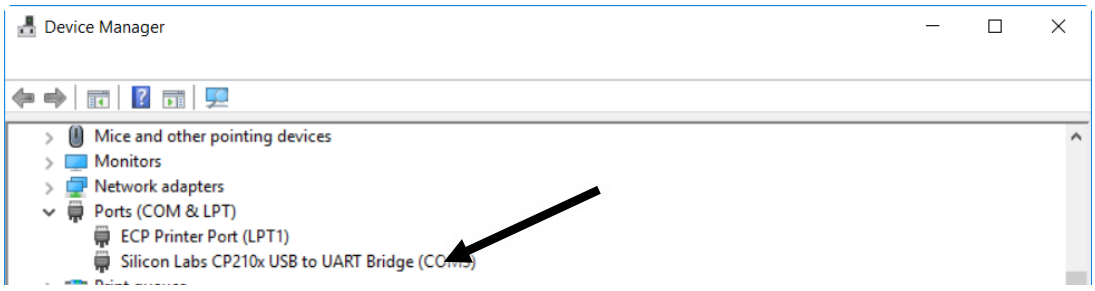
4.1.1.2 Updating firmware – USB FW

1. Before turning the power to the IMD ON (24 V DC if the IMD does not have built-in power supply, or 400 V AC if it does have a built-in power supply), ensure that the RFE input is OFF to prevent the IMD from starting the motor unintentionally.
2. Start the SDFlash if it is not started already.
3. Set the IMD into programming mode by doing the following:
   a. Turn the 24 V DC (or the 400 V AC if the DC power supply is built-in) off.
   b. Set the CAN ID switch to position 15.
   c. Turn the 24 V DC (or the 400 V AC if the DC power supply is built-in) on.

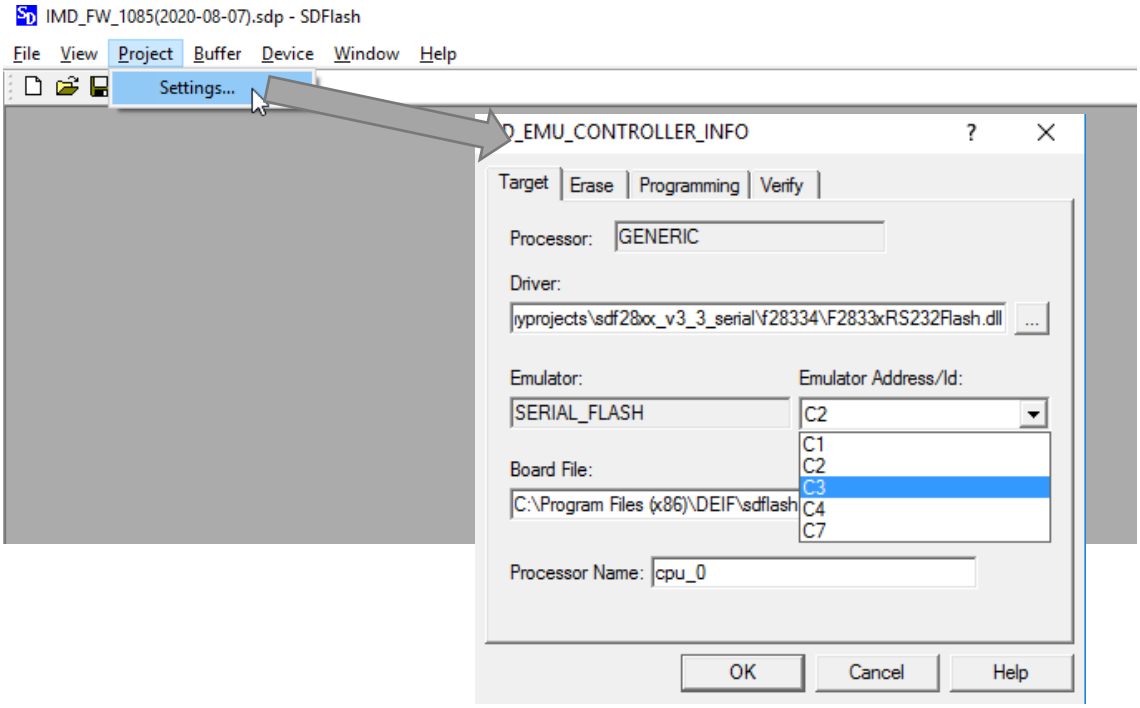
4. Click File→Open Project… (1), select and select the .sdp file that belongs to the FW that should be installed (2) and click Open (3):



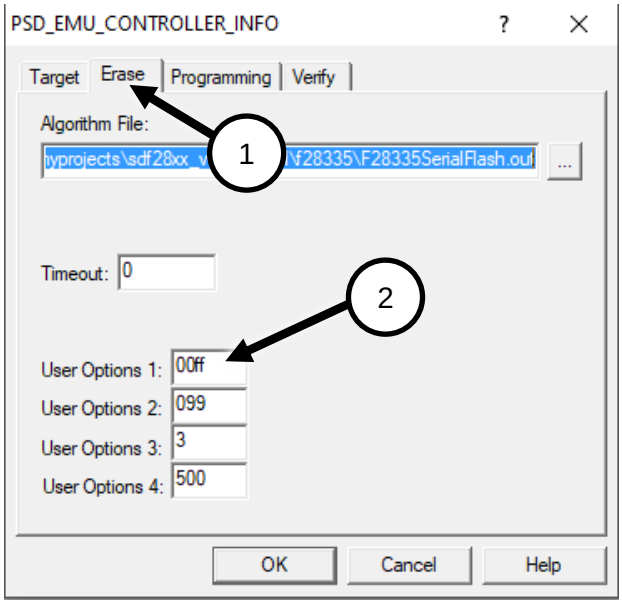
5. Skip this step if the used Com port is known.
Open the “Device manager” in the computer’s “Settings” and determine which com port is used for the USB connection (the look and name of the device manager may differ depending on the operating system). Only Com1, Com2, Com3, and Com4 can be used with the SDFlash, if another port is selected by the system, you will need to change it so one of the mentioned ports is used:



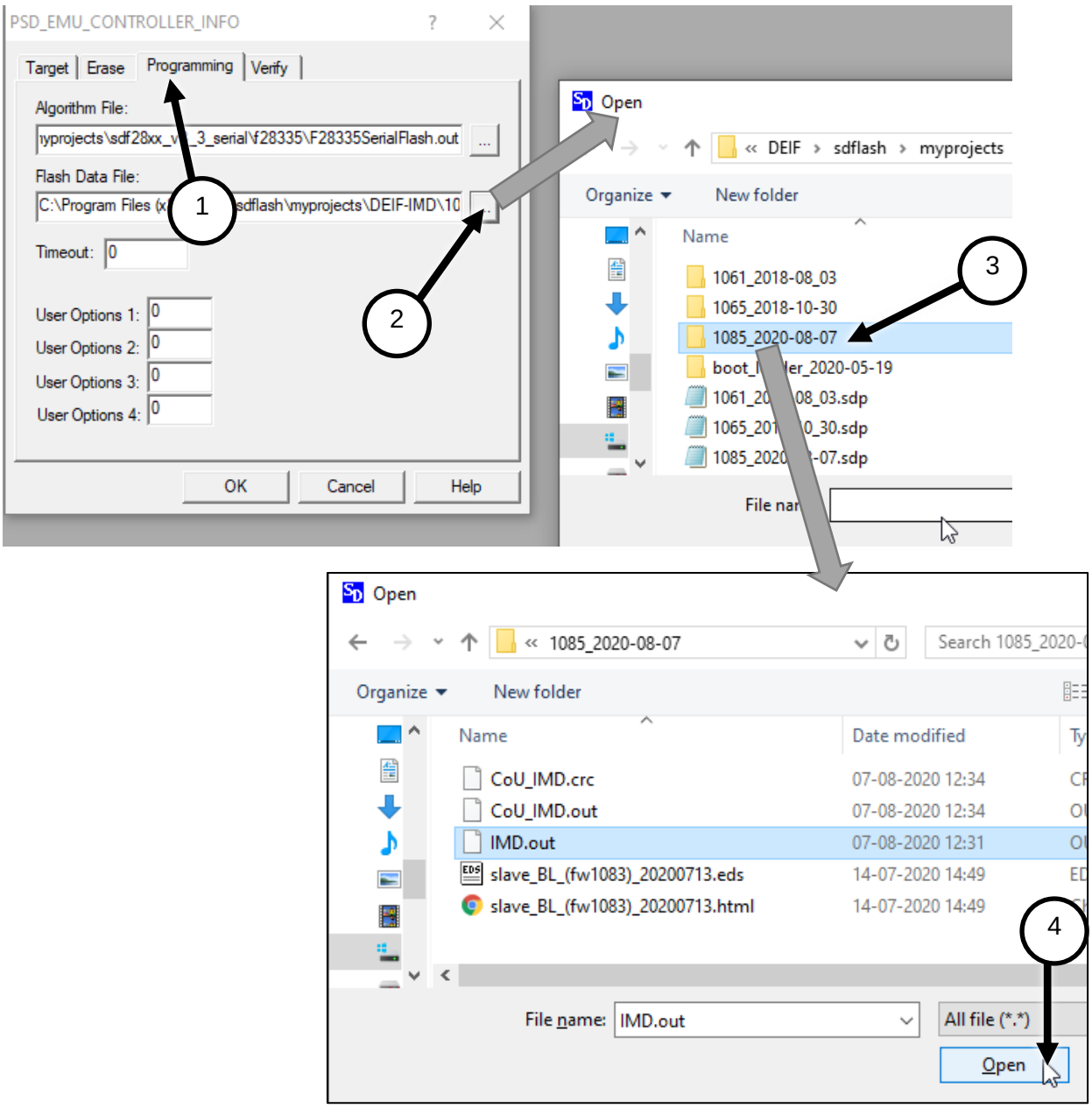
6. Click on Project →Settings… to open the Settings dialogue. Select the same com port as used in the device manager (COM1 → C1):



7. Click on the “Erase” tab (1), and ensure that “User Options 1:” is set to “`00ff`” (2):



8. Click on the “Programming” tab (1), then on the … button of the Flash Data File (2), double click on the FW folder (3), select the `IMD.out` file and click Open (4):

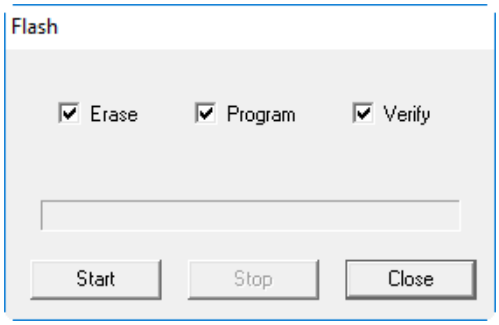


9. Click OK.

Info

If the com port or user option 1 was changed, you will be asked to save you project settings first, when attempting to upgrade the firmware in an IMD.

10. Click on Device → Flash… to open the upgrade dialogue:



11. Ensure that all three checkboxes are ticked and click Start.
12. When the programming cycle is completed, set the IMD back to normal operation mode:
    a. Turn the 24 V DC (or the 400 V AC if the DC power supply is built-in) off.
    b. Set the CAN ID switch back to its original position.
    c. Turn the 24 V DC (or the 400 V AC if the DC power supply is built-in) on. Note that the first startup after firmware upgrade might take longer (up to approximately 10 s).
13. The IMD is now updated.

Info

On rare occasions, The SDFlash program will show a “Connection error” after step **11** on page **15** is executed. In such a case, it is necessary to restart the whole process:

1. Close the SDflash program
2. Turn off the IMD
3. Start the SDflash
4. Turn on the IMD
5. Repeat com configuration, and the actions described in steps 4 on page 12 to 13 on page 15 .

4.1.2 Updating firmware for future CANopen update method

Updating firmware with CANopen files, requires that a bootloader is installed as well. Once the bootloader is installed any future updates can be done remotely through CANopen.

4.1.2.1 Prerequisites

- A computer with Spectrum Digital SDFlash program installed (including V3.3 SDFlash serial patch for flash programming, September 5, 2008), (http://emulators.spectrumdigital.com/utilities/sdflash/)

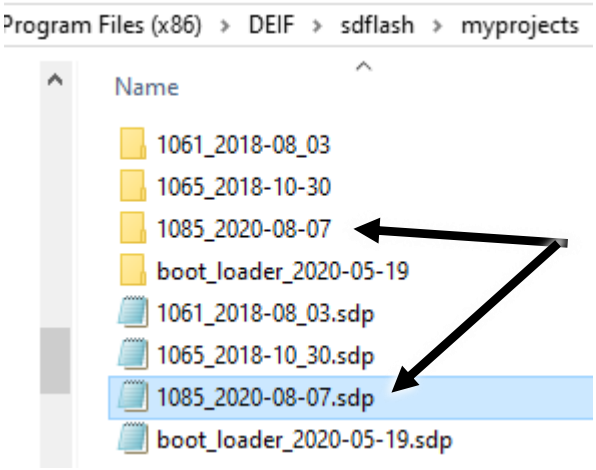
  Typically, the necessary USB driver will be found automatically if the computer is on-line. Otherwise, go to Silicon Labs home page and download the latest driver for CP210x USB to UART Bridge (http://www.silabs.com/products/mcu/Pages/USBtoUARTBridgeVCPDrivers.aspx).

Info

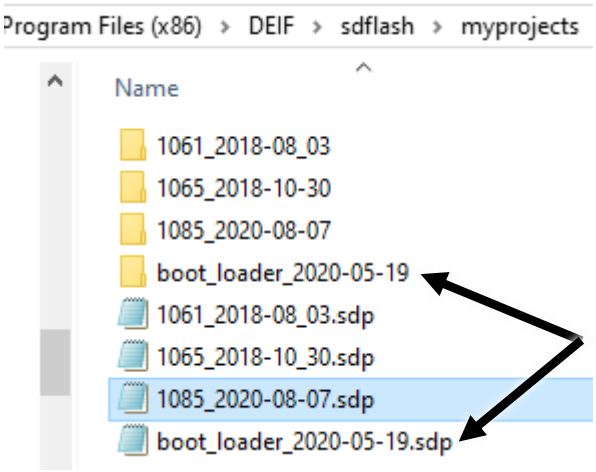
The links above were valid at the time when this manual was written. If the link does not work anymore, search for **“**V3.3 SDFlash serial patch” or “CP210x USB to UART Bridge driver”.

- The computer must be connected to the IMD with USB cable (male type A to male type B).

- Prepare the FW files for use.
  1. Copy the folder of the new FW.
  2. Paste the folder in the folder where other FW is located. If the FW files are located at their default location, go to `myprojects` folder in `sdflash` folder (where sdflash was installed) and paste the folder under `myprojects`.
     NOTE The files can be located anywhere. It is possible to brows to the location and sdflash remembers this location.
  3. Copy any of the .sdp files in the folder and paste it.
  4. Rename the .sdp file to the same name as the new FW folder:



  5. If there is no bootloader package in the folder, repeat the previous steps (1 to 4) for the bootloader:

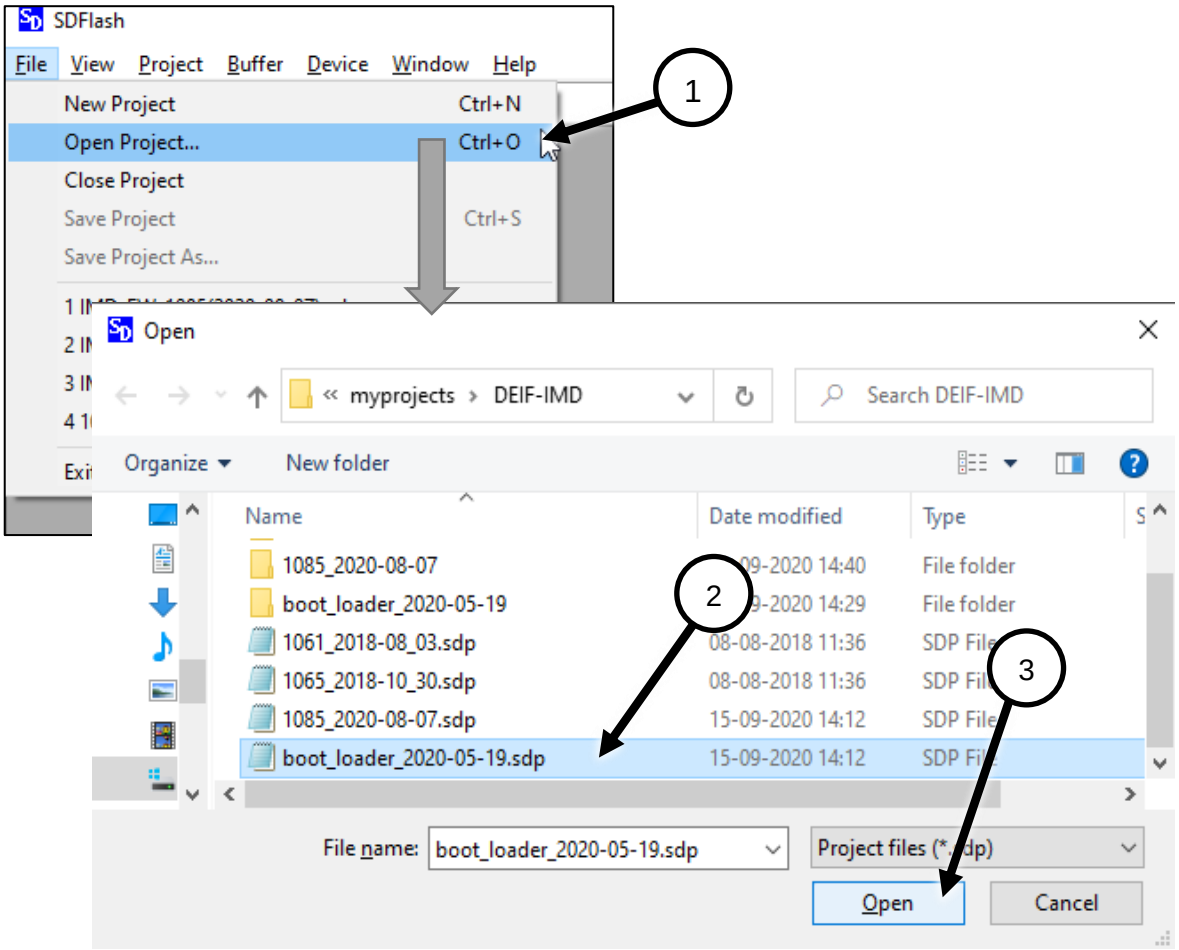


4.1.2.2 Updating CANopen bootloader file

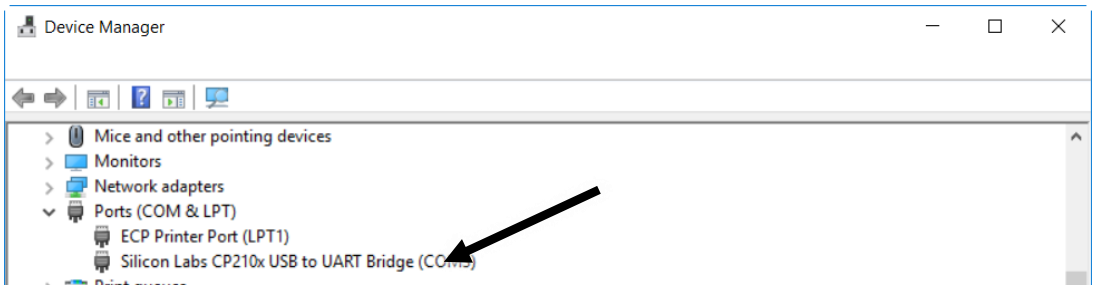
This task needs only to be done once, unless a newer bootloader version than the one already installed is available.

1. Before turning the power to the IMD ON (24 V DC if the IMD does not have built-in power supply, or 400 V AC if it does have a built-in power supply), ensure that the RFE input is OFF to prevent the IMD from starting the motor unintentionally.
2. Connect the computer to the IMD Service connector with USB cable (male type A to male type B).
3. Start the SDFlash if it is not started already.

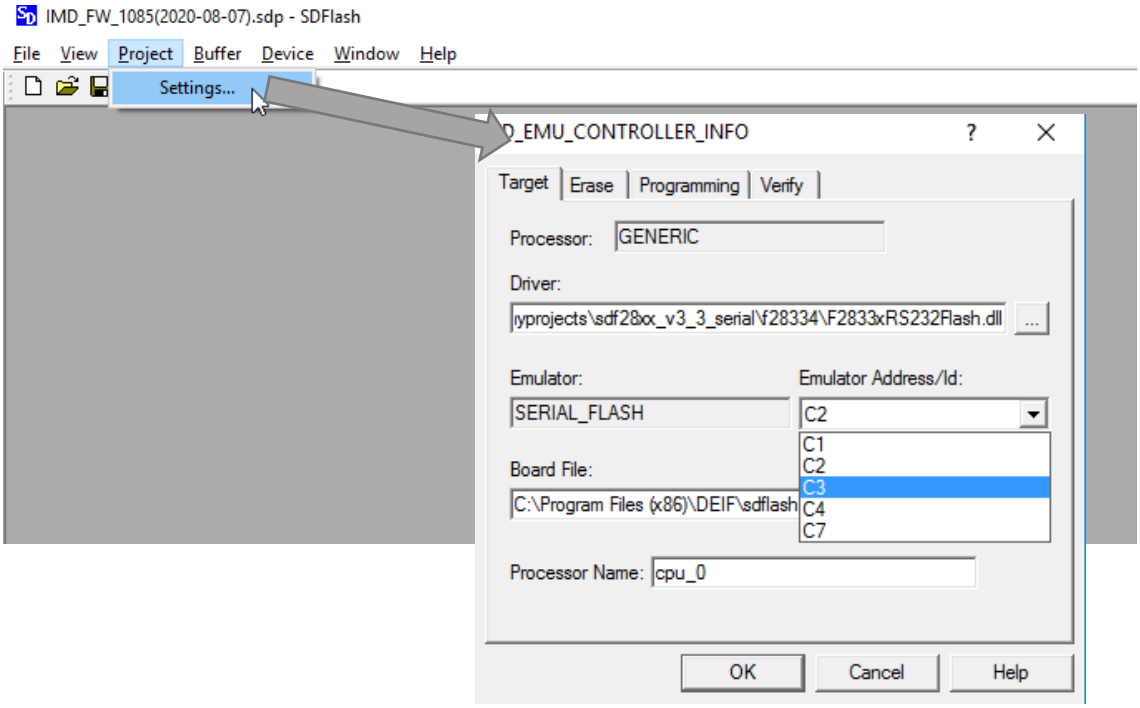
4. Click File→Open Project… (1), select and select the .sdp file that belongs to the bootloader package that should be installed (2), and click Open (3):



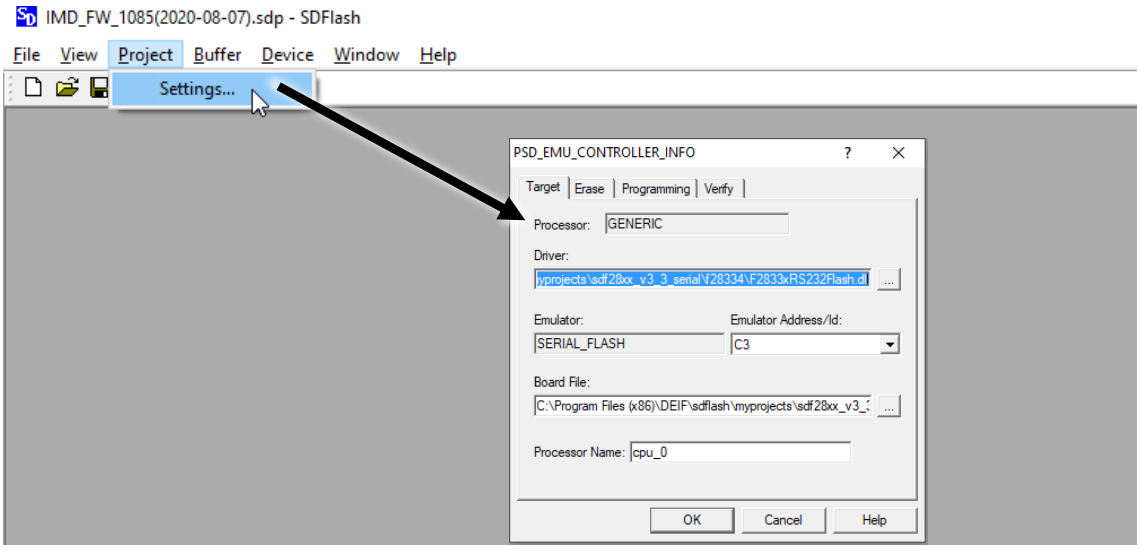
5. Skip this step if the used Com port is known.
Open the “Device manager” in the computer’s “Settings” and determine which com port is used for the USB connection (the look and name of the device manager may differ depending on the operating system). Only Com1, Com2, Com3, and Com4 can be used with the SDFlash, if another port is selected by the system, you will need to change it so one of the mentioned ports is used:



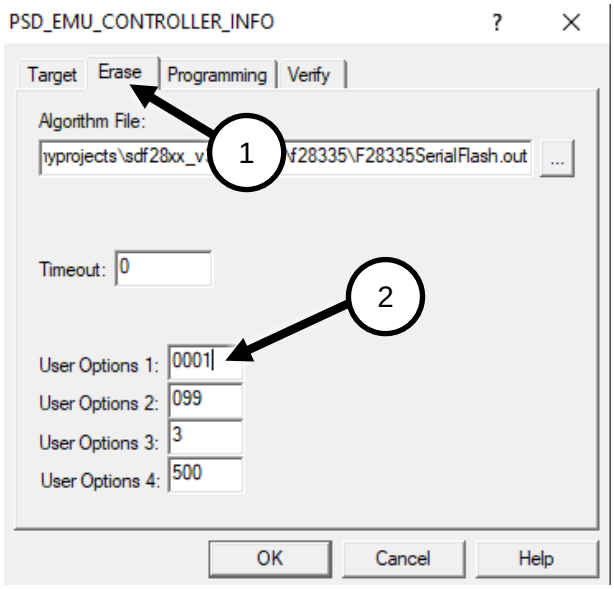
6. Click on Project →Settings… to open the Settings dialogue. Select the same com port as used in the device manager (COM1 → C1):



7. Click on Project →Settings… to open the Settings dialogue.

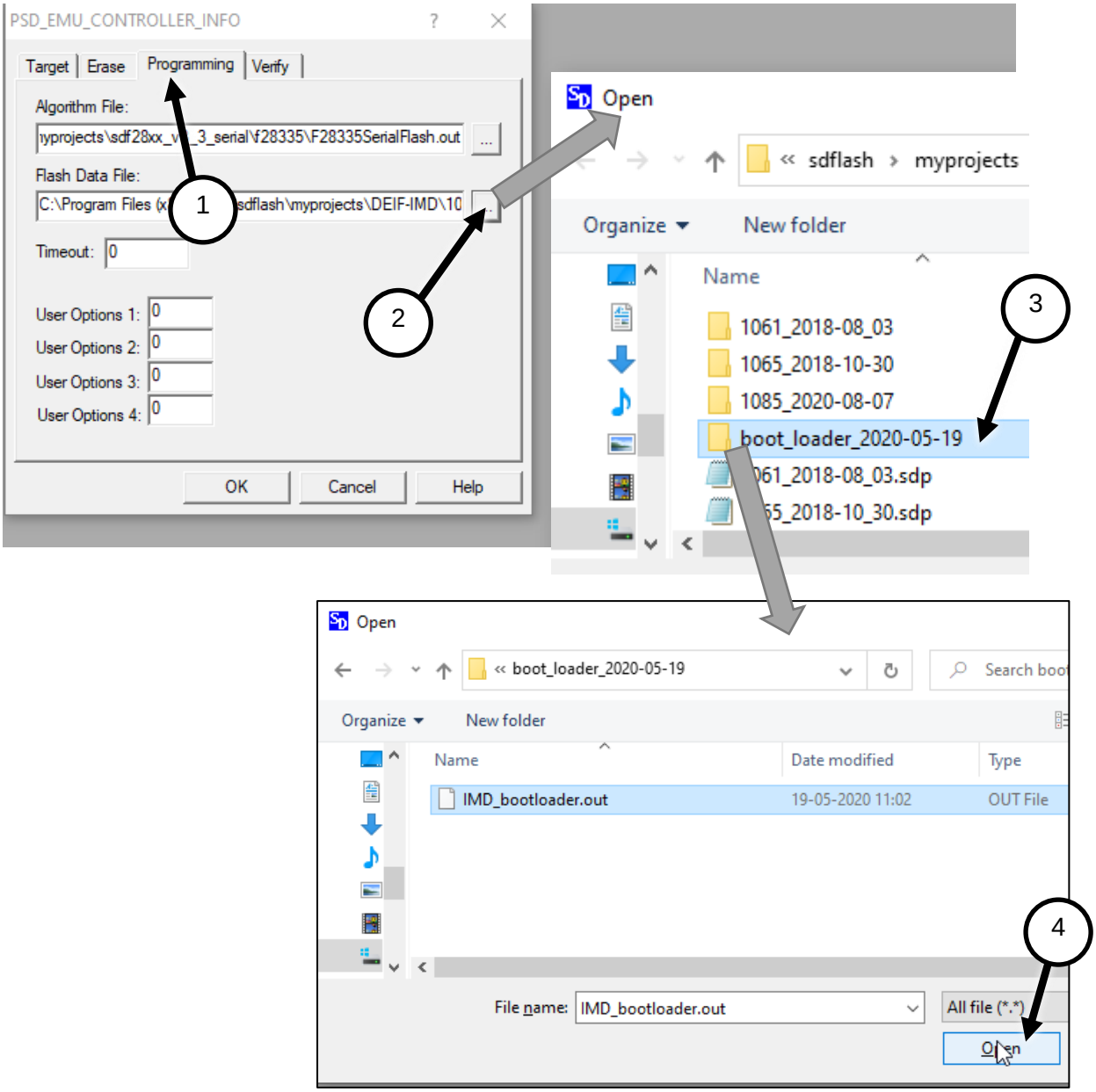


8. Click on the “Erase” tab (1), and ensure that “User Options 1:” is set to “0001” (2):



NOTE This step ensures that only the space allocated for the bootloader will be erased.

9. Click on the “Programming” tab (1), then on the … button of the Flash Data File (2), double click on the bootloader folder (3), select the `IMD_bootloader.out` file and click Open (4):

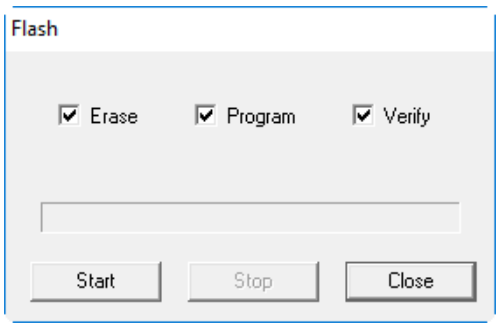


10. Click OK.

Info

If the com port or user option 1 was changed, you will be asked to save you project settings first, when attempting to update the bootloader in an IMD.

11. Set the IMD into programming mode by doing the following:
    a. Turn the 24 V DC (or the 400 V AC if the DC power supply is built-in) off.
    b. Set the CAN ID switch to position 15.
    c. Turn the 24 V DC (or the 400 V AC if the DC power supply is built-in) on.
12. Click on Device → Flash… to open the upgrade dialogue:



13. Ensure that all three checkboxes are ticked and click Start.
14. When the programming cycle is completed, click Close.
15. Skip this step if the FW is to be update as well.
    Set the IMD back to normal operation mode:
    a. Turn the 24 V DC (or the 400 V AC if the DC power supply is built-in) off.
    b. Set the CAN ID switch back to its original position.
    c. Turn the 24 V DC (or the 400 V AC if the DC power supply is built-in) on. Note that the first startup after firmware upgrade might take longer (up to approximately 10 s).
16. The IMD is now updated.

Info

On rare occasions, The SDflash program will show a “Connection error” after step **11** on page **15** is executed. In such a case, it is necessary to restart the whole process:

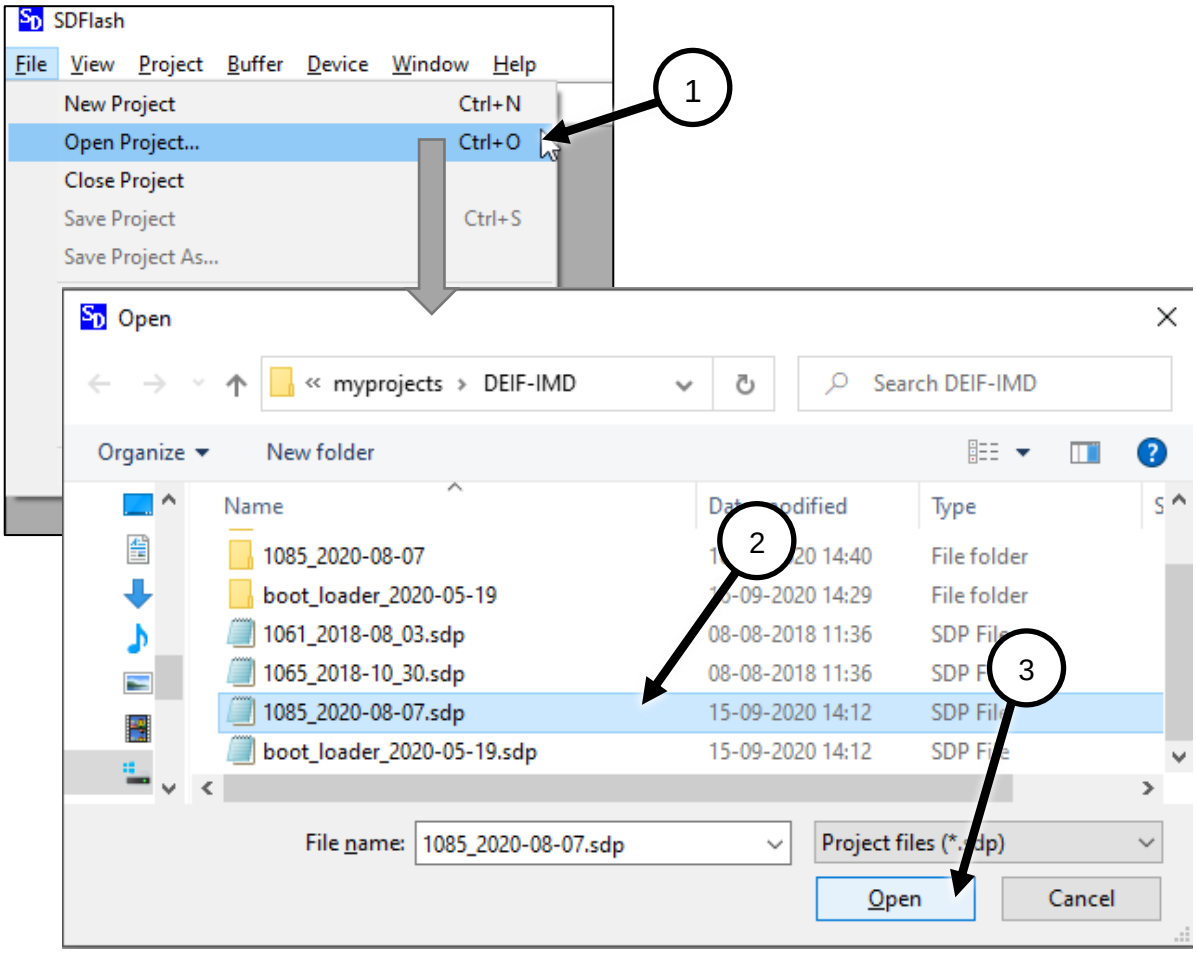
6. Close the SDflash program
7. Turn off the IMD
8. Start the SDflash
9. Turn on the IMD
10. Repeat com configuration, and the actions described in steps 4 on page 12 to 13 on page 15 .

4.1.2.3 Updating CANopen FW file

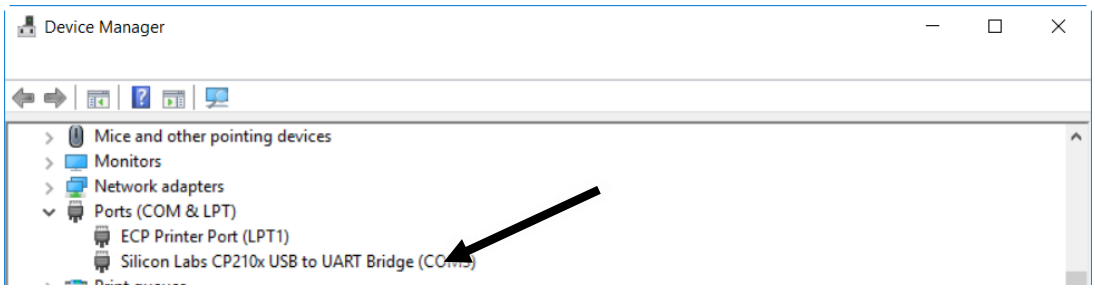
This procedure describes how to update the IMD FW in an IMD prepared for CANopen FW update, through the Service USB connector.

1. Skip this step if the SDFlash is started, and IMD is already turned on in programming mode
    a. Before turning the power to the IMD ON (24 V DC if the IMD does not have built-in power supply, or 400 V AC if it does have a built-in power supply), ensure that the RFE input is OFF to prevent the IMD from starting the motor unintentionally.
    b. Start the SDFlash if it is not started already.
    c. Set the IMD into programming mode by doing the following:
        i. Turn the 24 V DC (or the 400 V AC if the DC power supply is built-in) off.
        ii. Set the CAN ID switch to position 15.
        iii. Turn the 24 V DC (or the 400 V AC if the DC power supply is built-in) on.

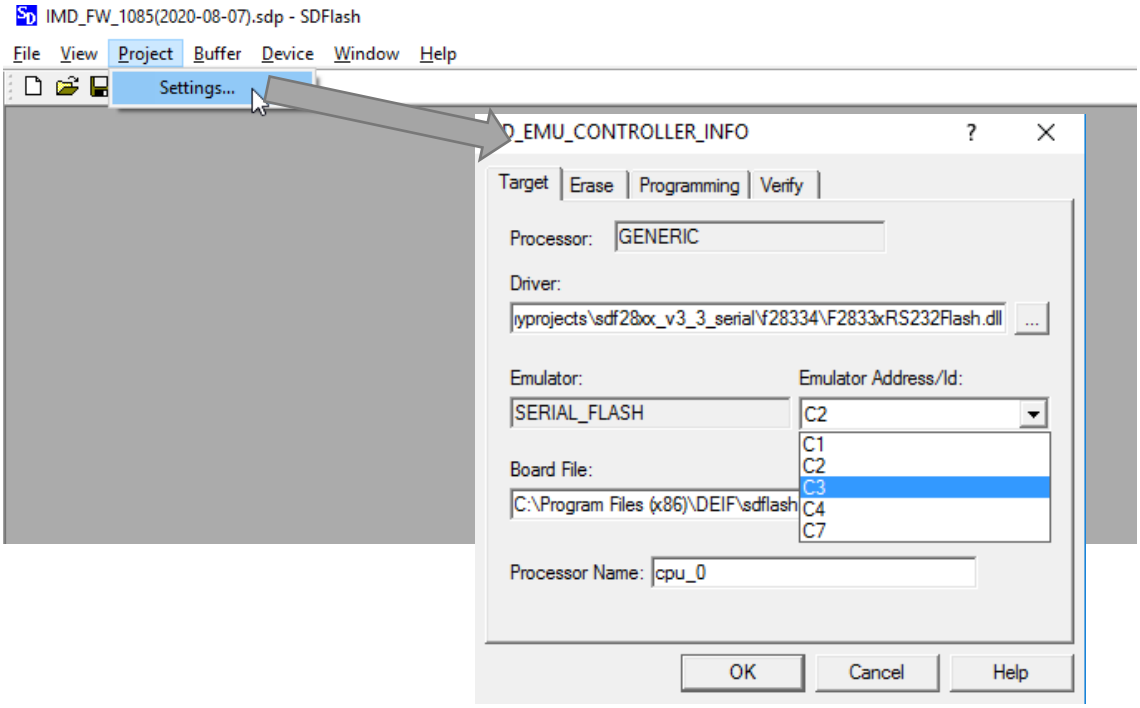
2. Click File→Open Project… (1), select and select the .sdp file that belongs to the FW that should be installed (2) and click Open (3):



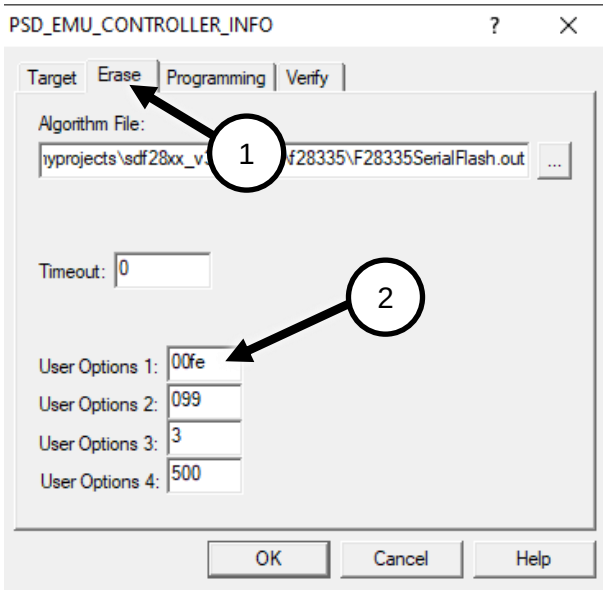
3. Skip this step if the used Com port is known.
Open the “Device manager” in the computer’s “Settings” and determine which com port is used for the USB connection (the look and name of the device manager may differ depending on the operating system). Only Com1, Com2, Com3, and Com4 can be used with the SDFlash, if another port is selected by the system, you will need to change it so one of the mentioned ports is used:



4. Click on Project →Settings… to open the Settings dialogue. Select the same com port as used in the device manager (COM1 → C1):

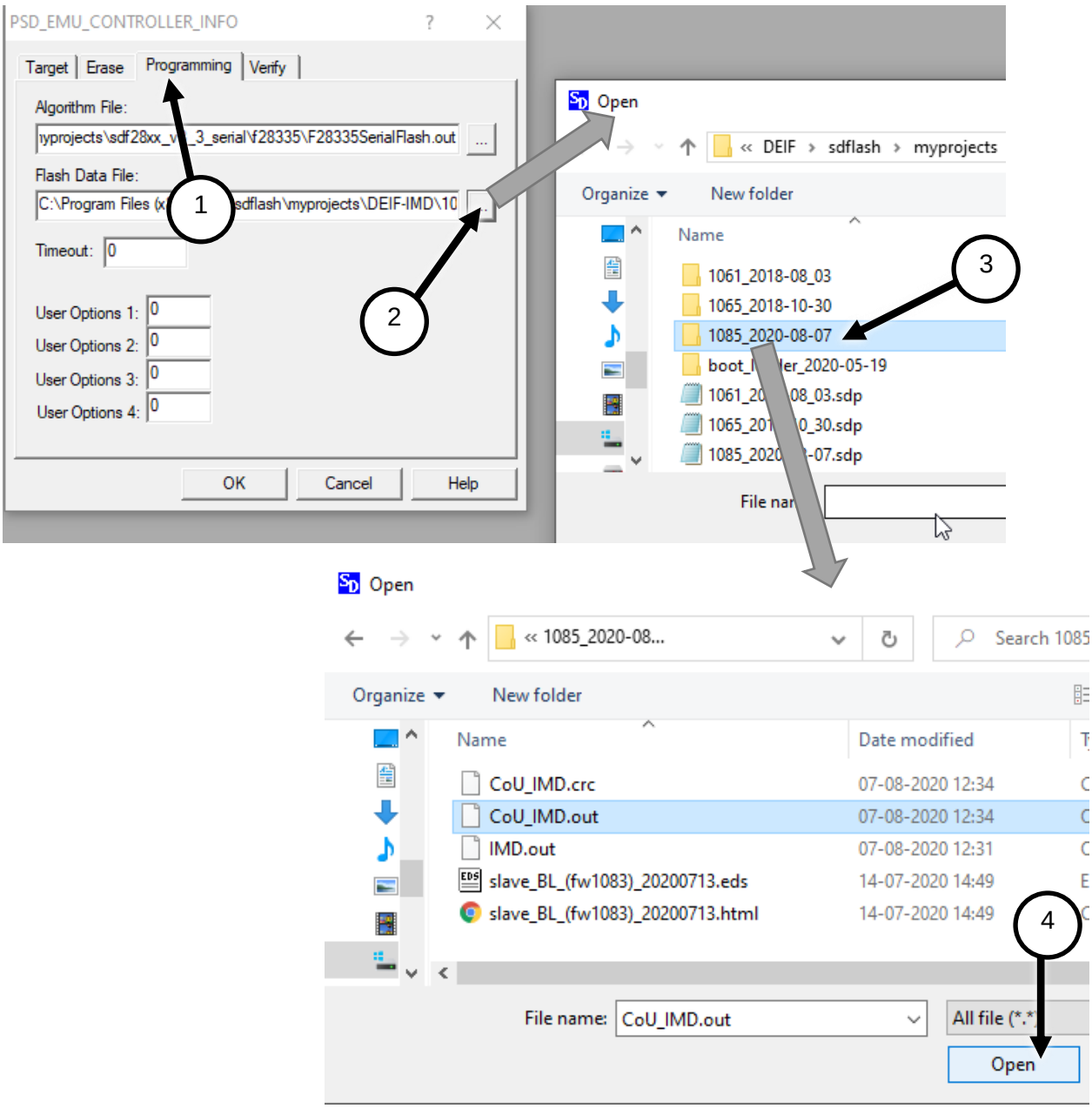


5. Click on the “Erase” tab (1), and ensure that “User Options 1:” is set to “`00fe`” (2):



NOTE This step ensures that the bootloader already installed will not erased.

6. Click on the “Programming” tab (1), then on the … button of the Flash Data File (2), double click on the FW folder (3), select the `CoU_IMD.out` file and click Open (4):

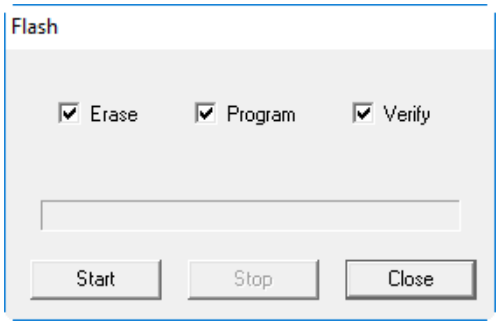


7. Click OK.

Info

If the com port or user option 1 was changed, you will be asked to save you project settings first, when attempting to upgrade the firmware in an IMD.

8. Click on Device → Flash… to open the upgrade dialogue:



9. Ensure that all three checkboxes are ticked and click Start.
10. When the programming cycle is completed, set the IMD back to normal operation mode:
    a. Turn the 24 V DC (or the 400 V AC if the DC power supply is built-in) off.
    b. Set the CAN ID switch back to its original position.
    c. Turn the 24 V DC (or the 400 V AC if the DC power supply is built-in) on. Note that the first startup after firmware upgrade might take longer (up to approximately 10 s).
11. The IMD is now updated.

Info

On rare occasions, The SDFlash program will show a “Connection error” after step **11** on page **15** is executed. In such a case, it is necessary to restart the whole process:

11. Close the SDflash program
12. Turn off the IMD
13. Start the SDflash
14. Turn on the IMD
15. Repeat com configuration, and the actions described in steps 4 on page 12 to 13 on page 15 .

4.2 Configuration

This section describes how to configure the IMD with a customer specific configuration.

4.2.1 Prerequisites

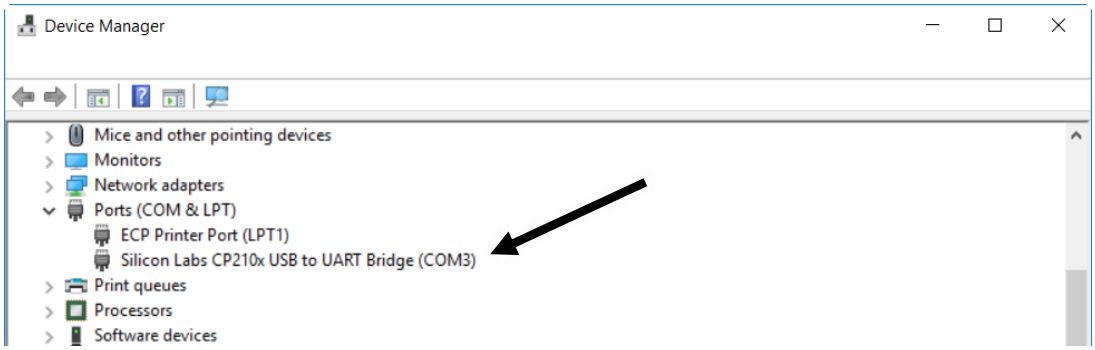
Before it is possible to upload new parameters the *IMD Manager* must be installed on a windows computer (XP or newer). See *IMD Manager installation instructions* for details.

- The configuration file (xxx.urf) is already made, and is available for the configuration.

USB cable (male type A to male type B) must be at hand.

1. Start the IMD Manager.

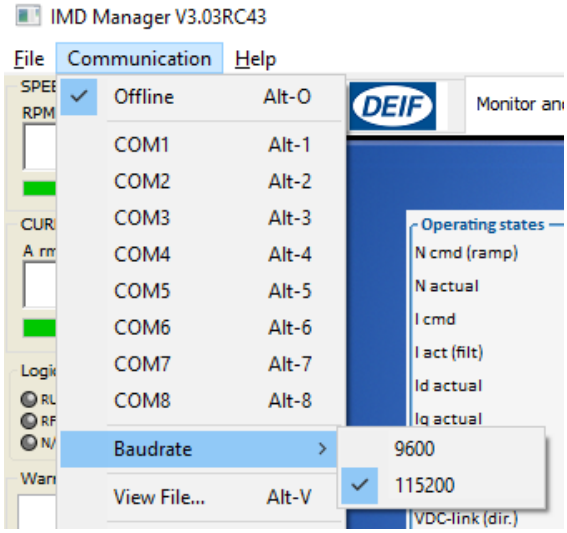
2. Open the “Device manager” in the computer’s “Settings” and determine which com port is used for the USB connection (the look of the device manager may differ depending on the operating system). Only Com1 to Com 8 can be used, if another port is selected by the system, you will need to change it so one of the mentioned ports is used:



Info

It is not possible to select the COM port in the IMD Manager before it is connected to an IMD.

3. Click Communication→Baudrate and verify that the baudrate is set to 115200:

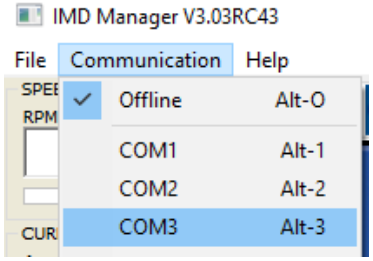


4. The IMD Manager is now ready.

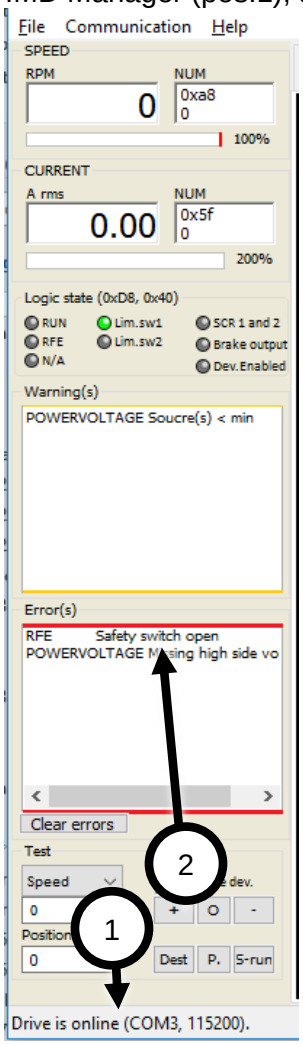
4.2.2 Configuring the IMD

1. Before turning the power to the IMD ON, ensure that the RFE input is OFF to prevent the IMD from starting the motor unintentionally.
2. Turn the power to the IMD on (24 V DC if the IMD does not have built-in power supply, 400 V AC if it does have a built-in power supply – configuring the charger requires 400 V AC).
3. Connect the computer to the IMD Service connector.

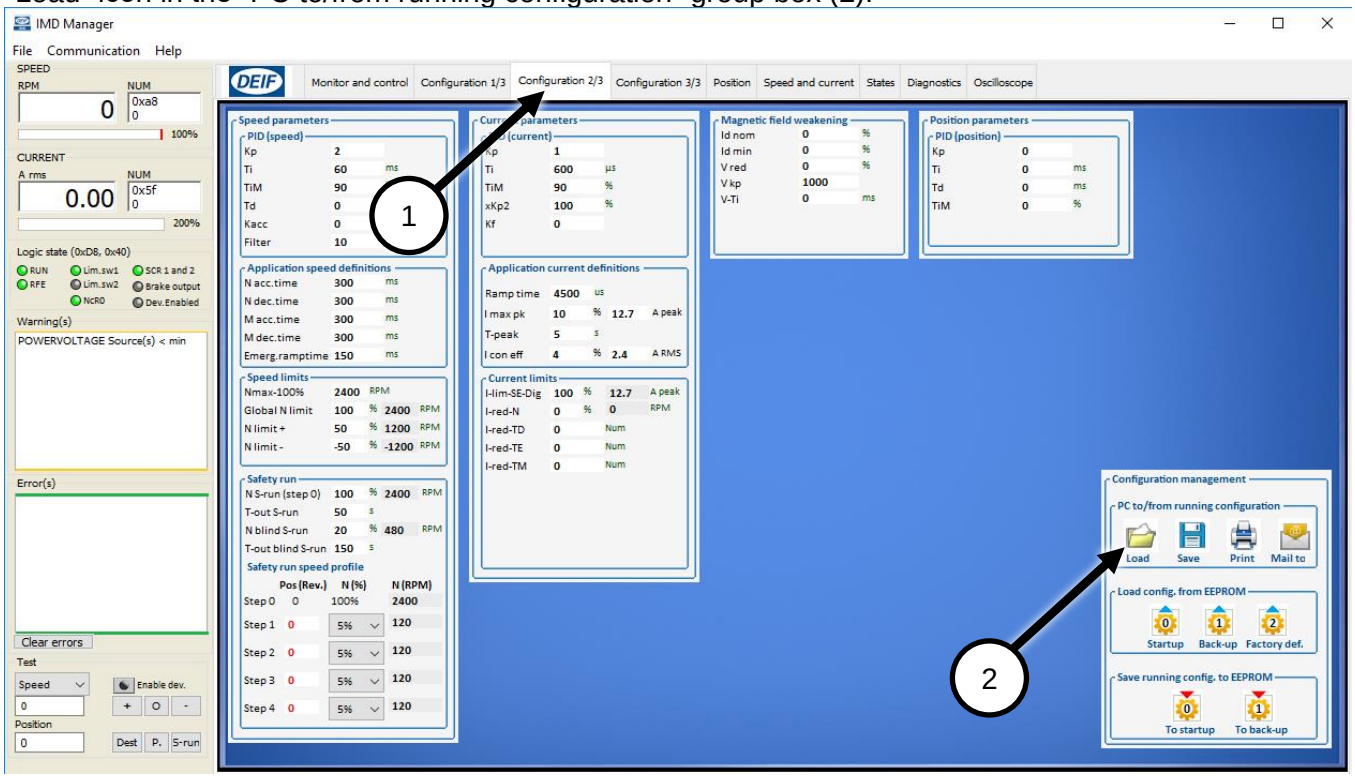
4. In the IMD Manager, select the same com port as used in the device manager (if the IMD Manager remains turned on it is enough to do this only once):



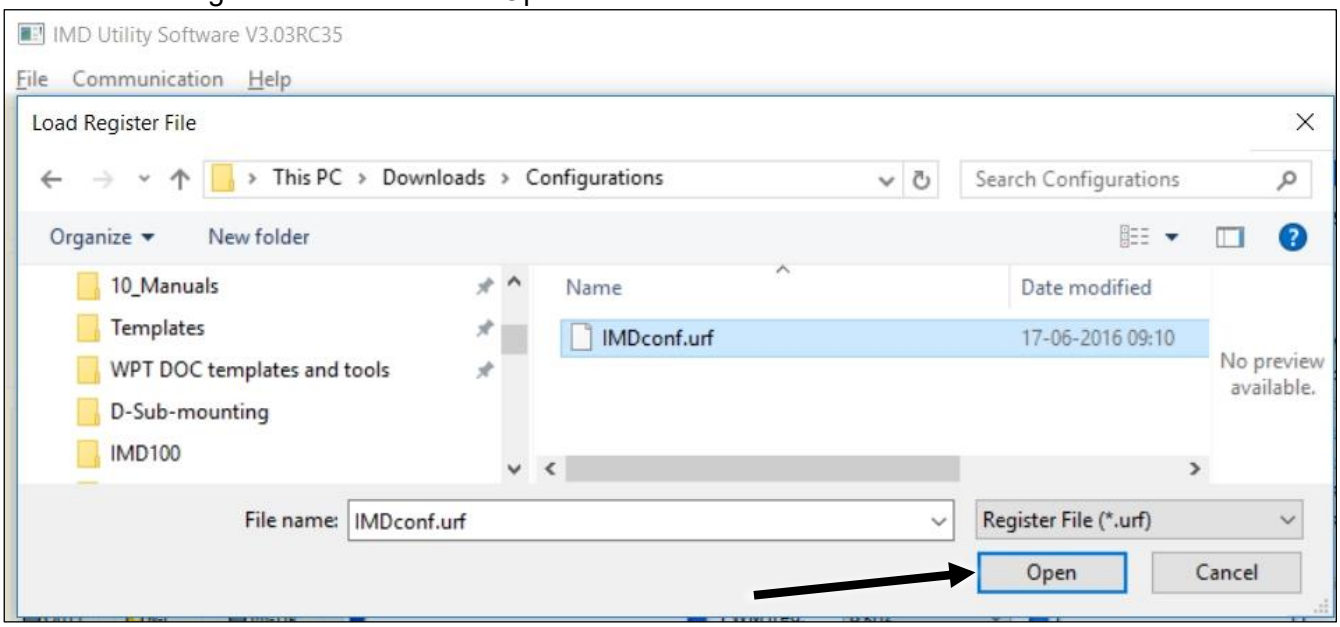
5. Ensure that the IMD is online by checking that “Drive is online” is shown at the bottom left of the IMD Manager (pos.1), and that RFE error is reported (pos.2), warnings can be ignored:



6. In the “Configuration 2/3” tab (1), upload the parameter file (xxx.urf) to the IMD by clicking on the “Load” icon in the “PC to/from running configuration” group box (2):

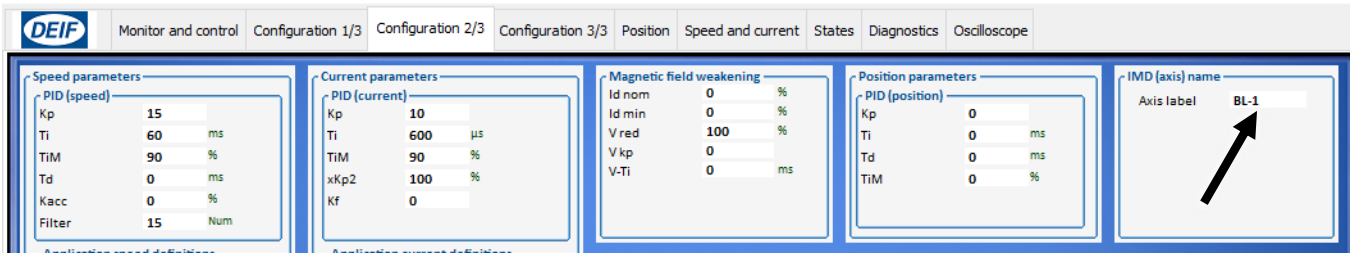


7. Locate the configuration file and click “Open”:

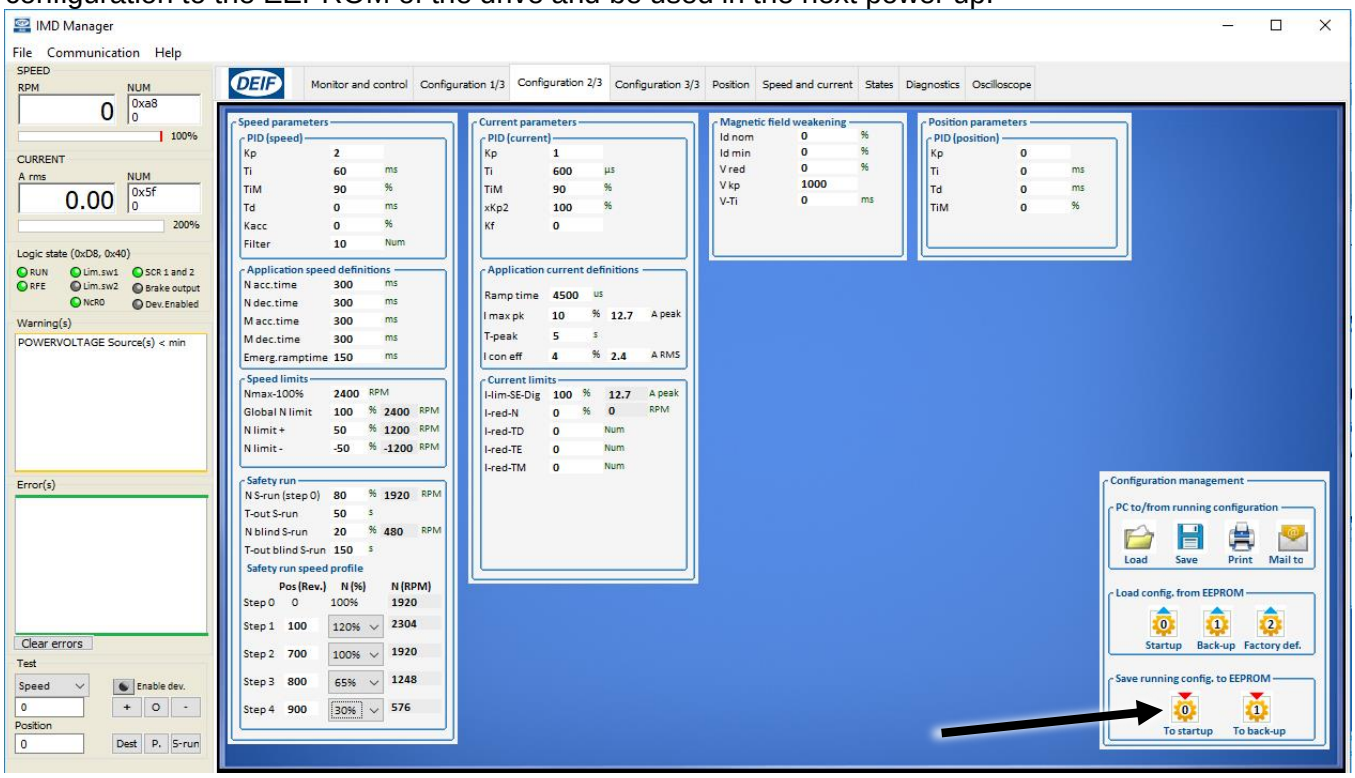


8. Wait a few seconds and you will see the parameters in the IMD Manager have changed. The new parameters are now uploaded to the IMD.

9. In the “IMD (axis) name” group, enter a name (maximum 4 characters) for the IMD according to the customer specific documentation (this step is optional):



10. In the “Save running configuration to EEPROM”, click on the “To startup” icon to save the new configuration to the EEPROM of the drive and be used in the next power up.



11. The IMD is now configured with the customer specific parameters.

5. Installation verification

Verification of the installation can be done in various ways, and is also depended on where the verification is done and how many of the interfaces are connected to the IMD at the time of verification.

This section describes a way to verify the installation, though it cannot be a complete description since this will depend on the application in the specific turbine, as well as the situation in which the installation is verified.

It is recommended to perform the verification of the installation described in this section before shipping the electrical/pitch system from the production. For troubleshooting see section 6 on page 47.

The verification is described as one list of tasks, which is broken into functional groups. Tasks, not deemed to be relevant can be omitted. Other tasks need to be further defined in details (for example, which digital inputs to test and how to change the level of these), consult the applicable verification/test information.

5.1 Prerequisites

The described procedure requires the following:

- The IMD is fully installed with all connections to the motor, brake, resolver, limit switches and so on
- It must be possible to turn the RFE input ON and OFF in order to perform the verification
- It must be possible to turn any used connections to digital inputs on and off, if full verification is required
- The IMD firmware is updated if necessary
- The IMD is configured with customer specific parameters
- A computer with IMD Manager installed and running

5.2 Verification

Danger!

Risk of burns and electrical shock from short circuit, electrical arc and uninsulated wires or terminals.

This verification procedure requires work with live circuit with voltage up to 860 V DC and 400 V AC, and may only be carried out by skilled personnel.

When the IMD has been powered, there is a risk of stored energy even when the power is disconnected. Wait 5 minutes after the power is disconnected and verify zero energy according to company procedures on the outputs before performing any work.

Caution!

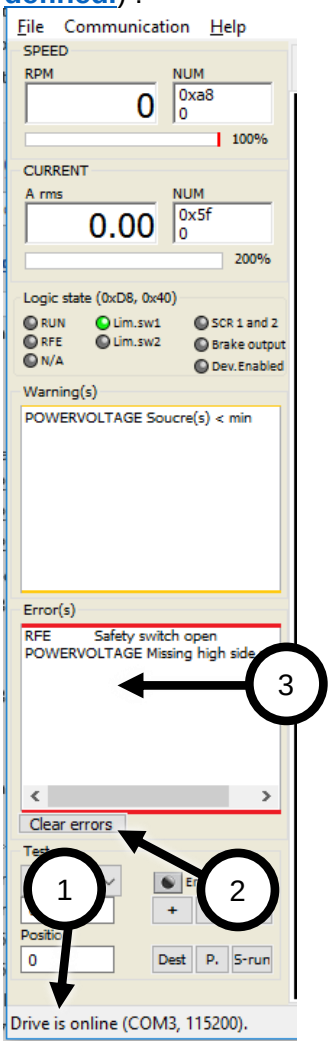
Danger of hand and limb crush from to moving objects.
Be careful when the motor or other mechanical parts are moving.

5.2.1 Turning on power and checking errors

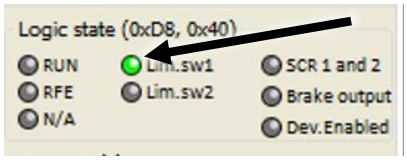
Attention

It is important that the Mains (400 V AC) is turned on before the safe energy is connected in order to prevent damage to internal power components. See also section 3 on page 8 for information about how to avoid damaging the IMD.

1. Before turning the power to the IMD ON, ensure that the RFE input is OFF to prevent the IMD from starting the motor unintentionally. Ensure that the safe energy is turned OFF.
2. Ensure that at least one limit switch is activated.
3. Turn the power to the IMD on (24 V DC if the IMD does not have built-in power supply, or 400 V AC if it does have a built-in power supply).
4. Connect the computer to the IMD Service connector. Ensure that the IMD is online by checking that "Drive is online" is shown at the bottom left of the IMD Manager (pos.1). It is assumed that the COM port in the IMD Manager is already configured (from the IMD configuration step 4 on page 27) Click on "Clear errors" (pos.2) and verify that only RFE error is reported (pos.3). If any other errors or warnings are shown, evaluate whether they should be shown due to missing inputs/sensors or AC power (see section **Error! Reference source not found.** on page **Error! Bookmark not defined.**) :



5. Verify that at least one limit switch is on (does not matter whether it is Lim.sw 1 or Lim.sw 2):

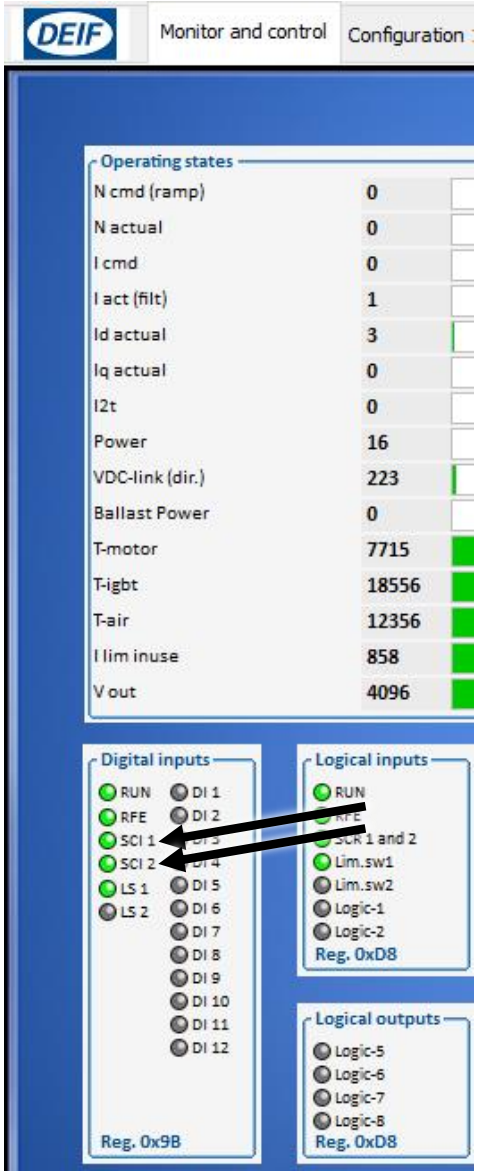


Info

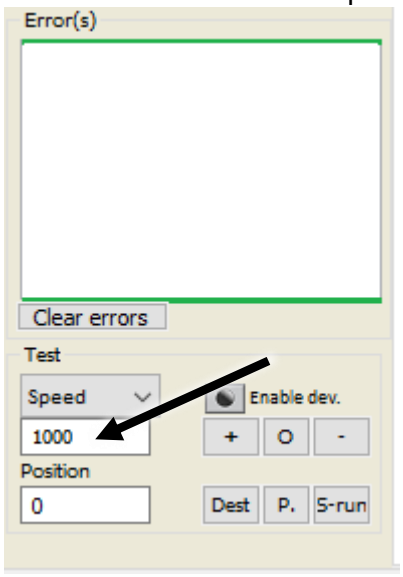
If no limit switch is activated when the IMD starts or shortly after (depending on the configured safety-run timeout) the IMD will enter an error state where enabling the device will not be possible.

5.2.2 Verifying safety-chain inputs and motor control function

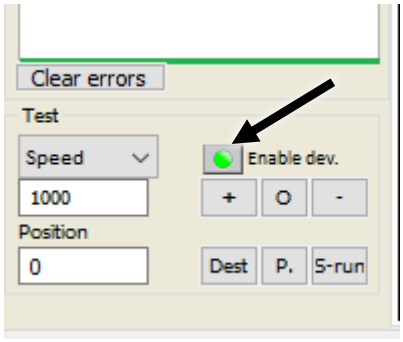
6. If the 400 V AC supply is not turned on already, turn it on.
7. Ensure that the signal to RUN input is high.
8. Activate RFE, click on “Clear errors” button, verify that the “RFE open” error is not shown anymore.
9. Reset the safety-chain.
10. Click on “Monitor and control” tab. Verify that both SCI 1 and SCI 2 (safety-chain inputs) are on:



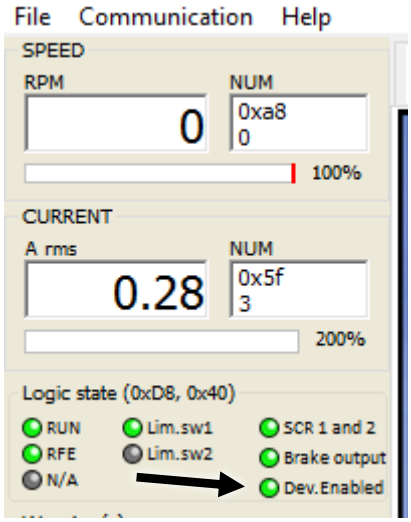
11. Enter `1000` in the Test→Speed field:



12. Click on “Enable dev.” button. Verify that it changes to green.

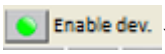


13. Verify that the Dev.Enabled LED has changed to green.

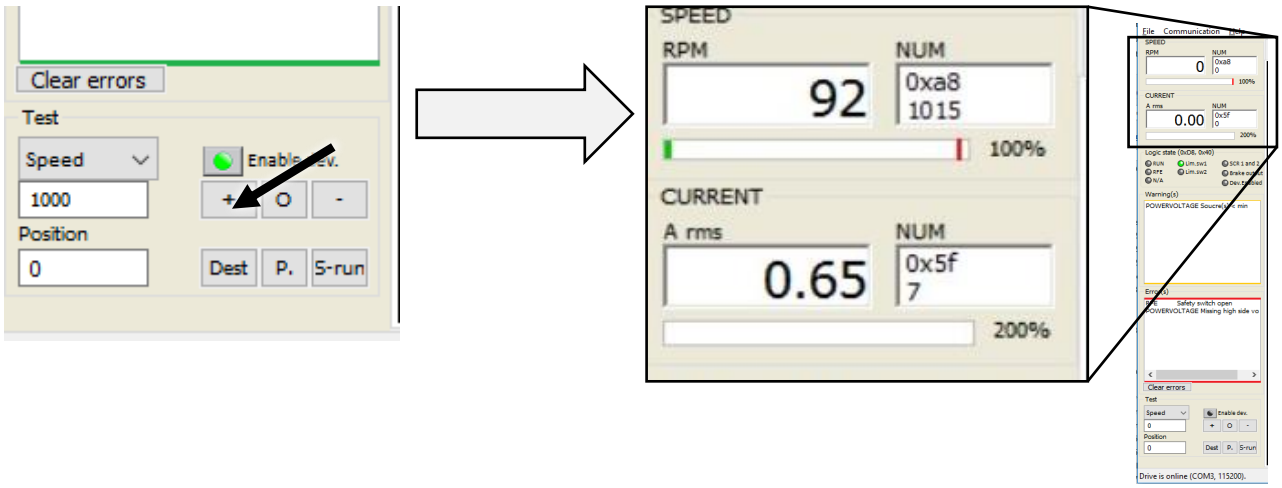


14. Click on “+” button, verify that the motor turns (RPM changes to a non-zero value and the motor can be heard turning)

Attention

Pay attention to the RPM. Disable the drive (click on the “Enable dev.” button 

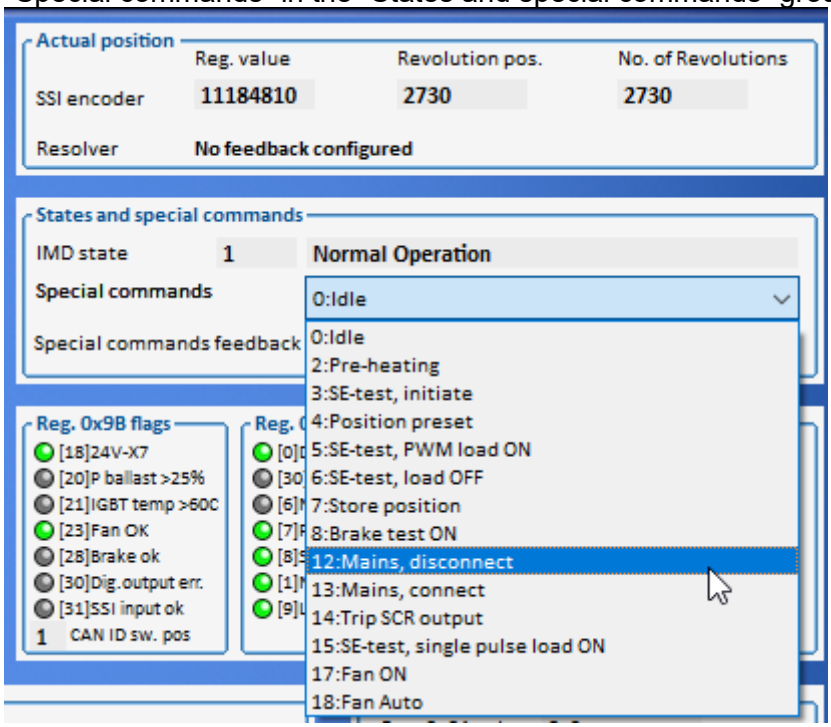
) if the motor starts racing away or is unstable in any other way.



5.2.3 Verifying safe energy connection

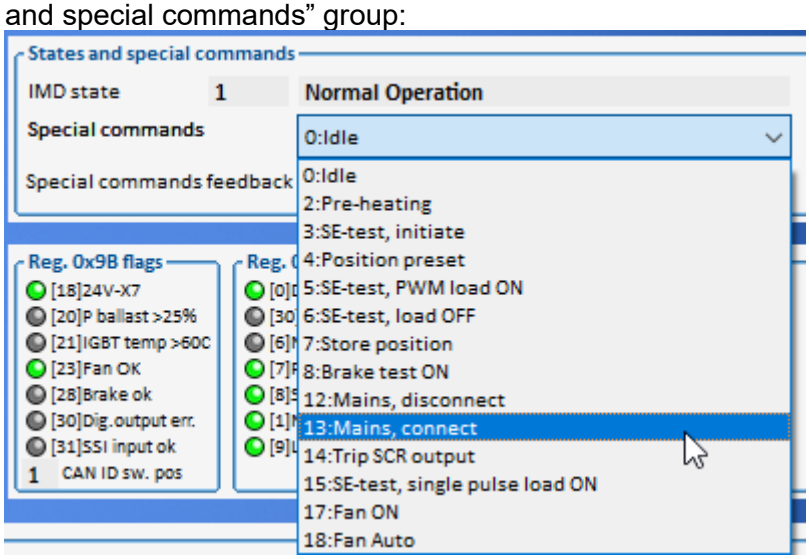
NOTE Skip this section if no safe energy source is connected to X1.

15. While the motor is still turning, disconnect the mains by selecting “12:Maines, disconnect” in the “Special commands” in the “States and special commands” group:

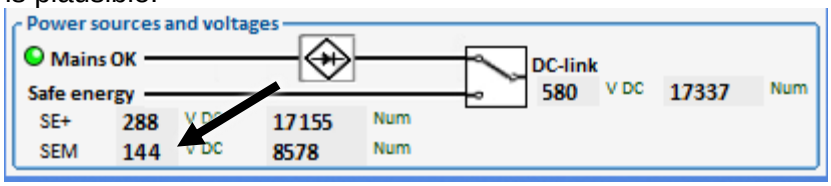


16. Verify that the motor continues to turn.

17. Reconnect the mains by selecting “13:Maines, connect” in the “Special commands” in the “States and special commands” group:



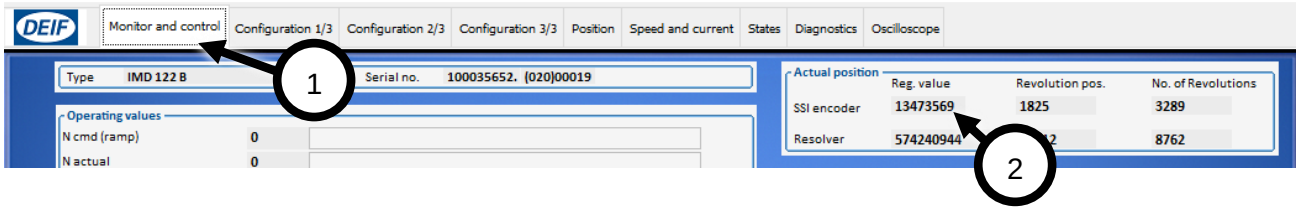
18. If the SEM connector is connected to the mid-point of the safe energy, verify that the shown voltage is plausible.



5.2.4 Verifying SSI function

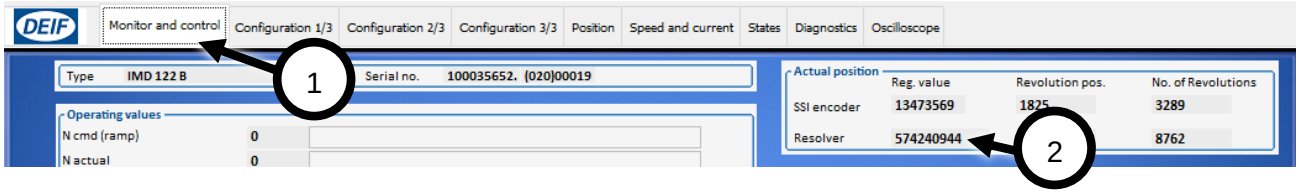
Prerequisites: The SSI encoder and motor must be mechanically connected.

19. While the motor is turning click on “Monitor and control” tab (pos.1), verify that the number in the Reg. value (pos.2) of the SSI encoder is changing:



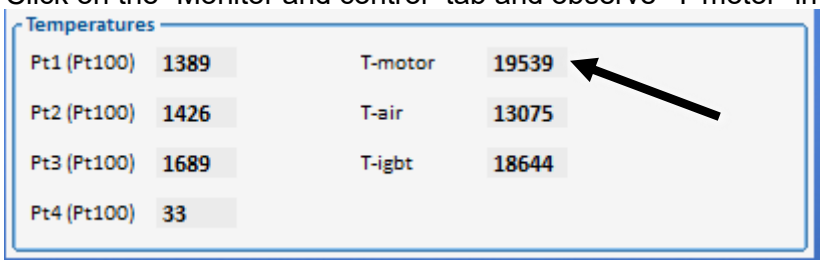
5.2.5 Verifying resolver function

20. While the motor is turning click on “Monitor and control” tab (pos.1), verify that the number in the Reg. value (pos.2) of the resolver is changing:

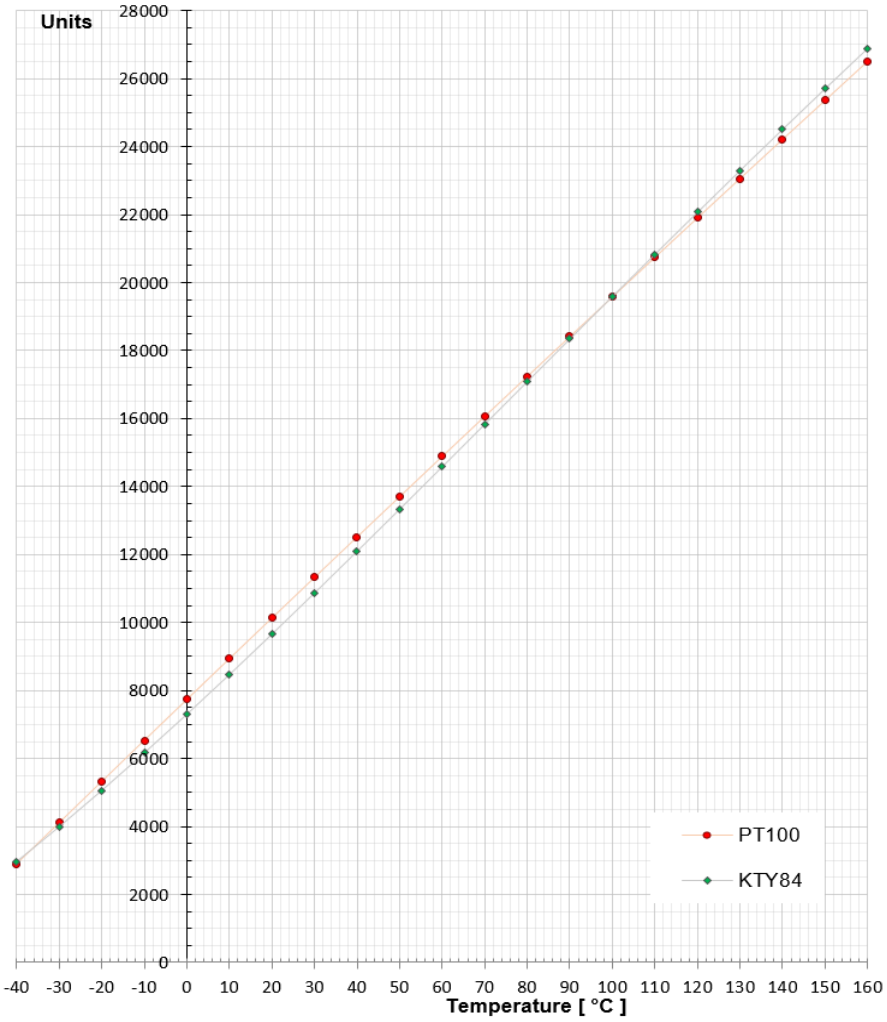


5.2.6 Verifying motor temperature connection

21. Click on the “Monitor and control” tab and observe “T-motor” in the “Temperature” group.



22. For KTY84 and PT100, verify that the value (in units) for the motor temperature is plausible. Use the following chart to estimate the value:



Info

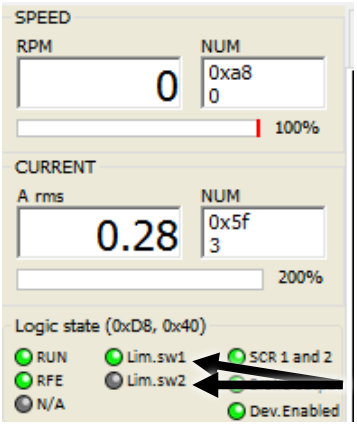
This check is not meant as a test of the sensor’s accuracy. A plausible value is ± 20 Cº within the estimated temperature. A value above 30000 most likely means that there is no sensor connected to the temperature input.

If a PTC temperature sensor is used, verify that that the T-motor is between the following values (assuming normal working temperature):

Number of PTCs in series	Raw values
1	100 to 7800
3	100 to 28800

5.2.7 Verifying limit switches function

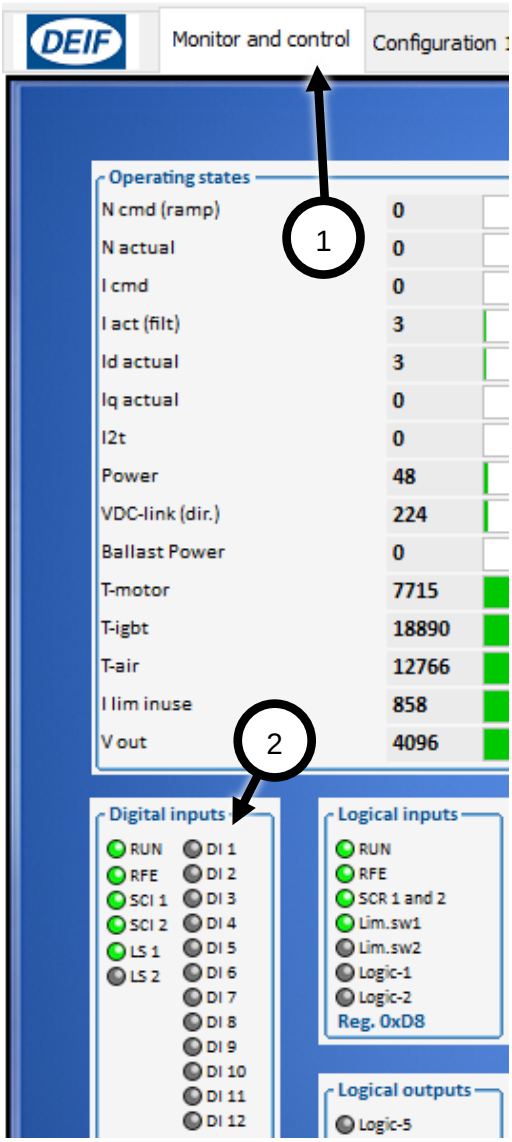
23. Ensure that when the limit switches LED icons change state when they are activated (it depends on the specific application whether the limit switches are N.O or N.C):



5.2.8 Verifying digital inputs

Prerequisites: In order to be able to verify a digital input it must be possible to change the input level of the interface connected to the digital input.

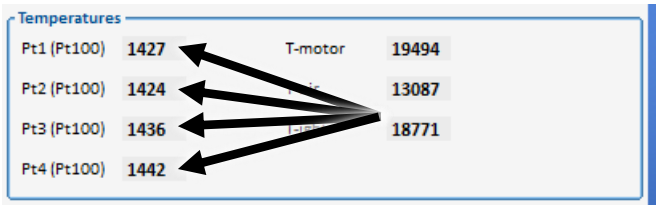
24. Click on the “Monitor and control” tab (1). Observe the “Digital inputs” group (2).



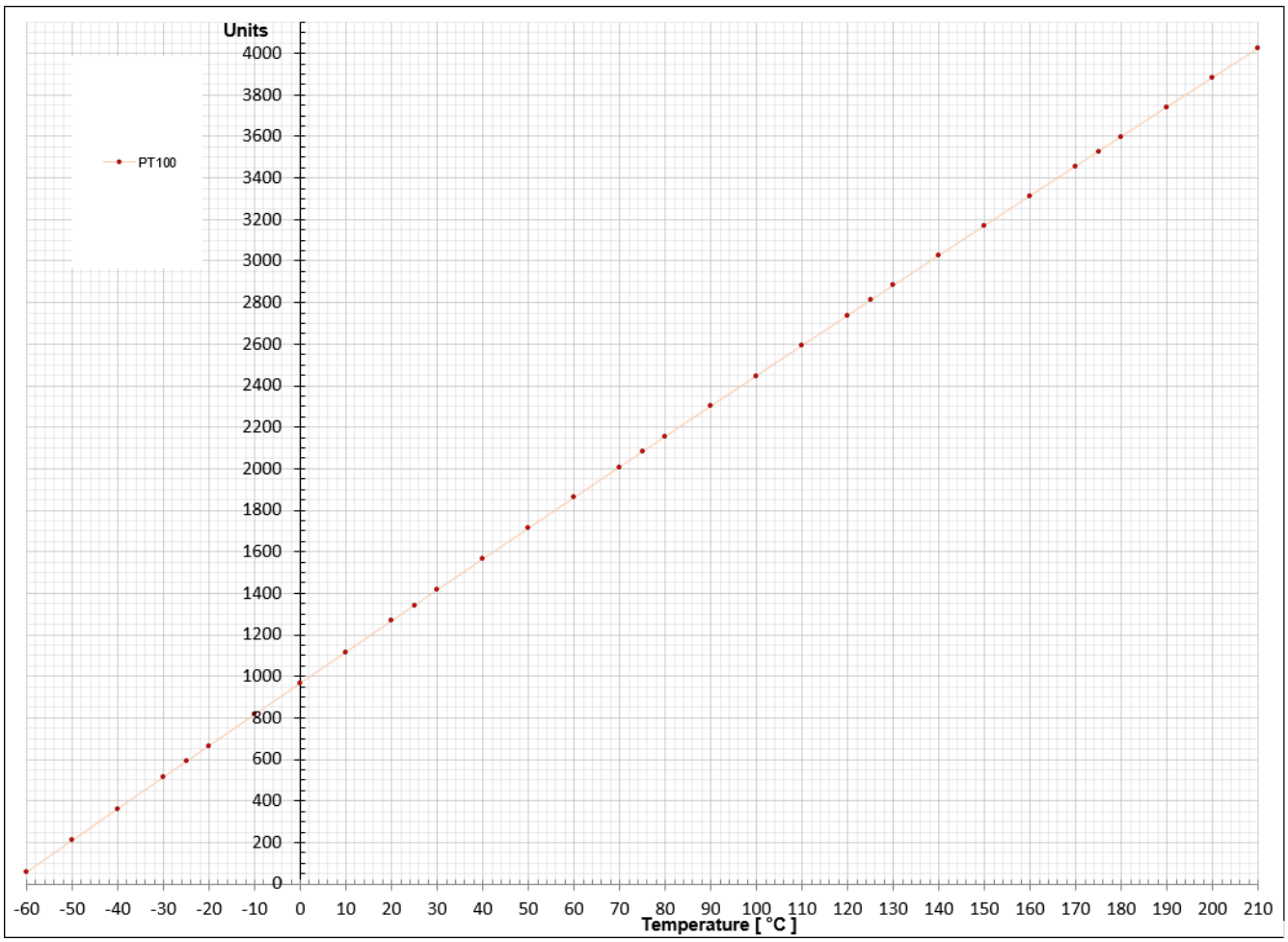
25. Change the level of the interface of a digital input and verify that the LED indication for that input changes accordingly.

5.2.9 Verifying temperature sensors (Pt100) functions

26. Click on the “Monitor and control” tab and observe “Pt100-x” in the “Temperature” group.



27. Verify that the values (in units) for the connected sensors are plausible. Note that the values given are in 12 bits resolution. Use the following chart to estimate the value:



Info

This check is not meant as a test of the sensor's accuracy. A plausible value is ± 20 Cº within the estimated temperature. A value above 4000 most likely means that there is no sensor connected to the temperature input.

5.2.10 Verifying the fan function

The fan function is verified differently depending on the IMD HW version.

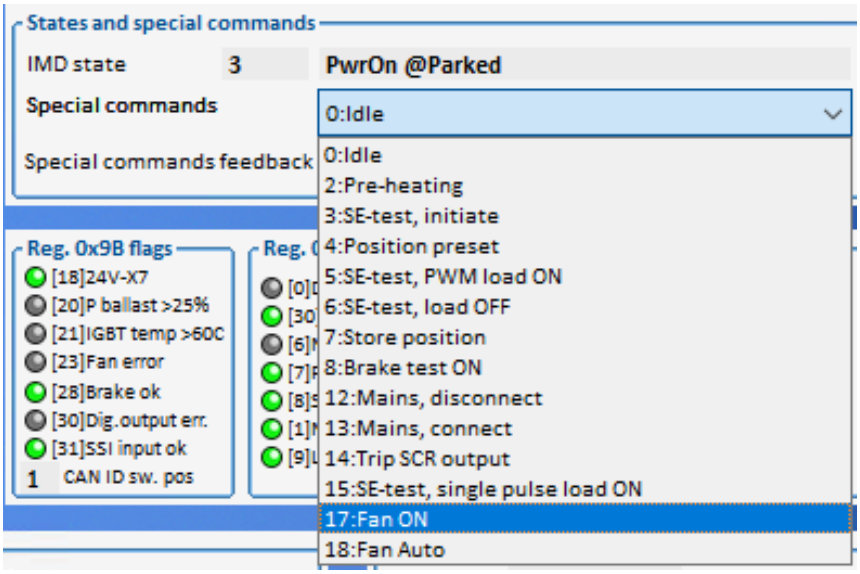
5.2.10.1 Verifying the fan function – IMD 122/135 C

Info

The description in this section only applies to IMD122/135 C.

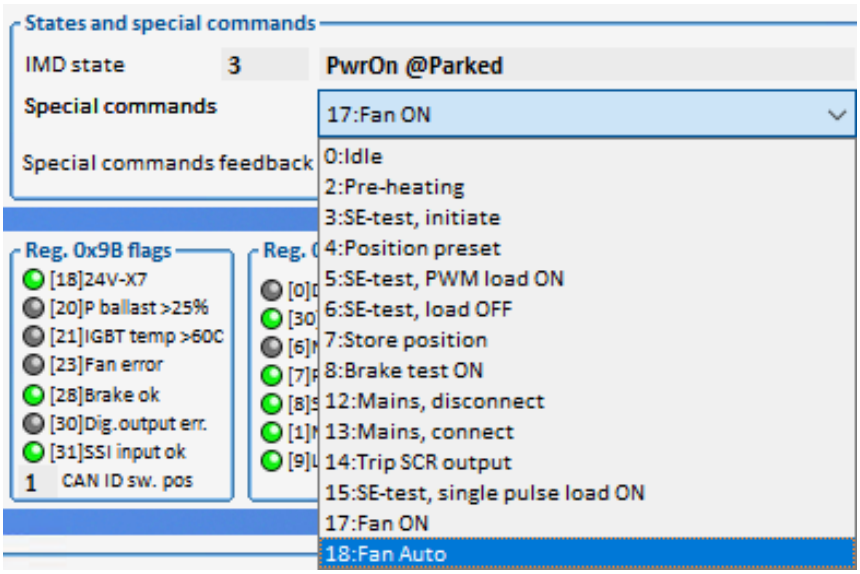
Description for IMD122 B can be found in section 5.2.10.2 on page 41.

28. Select “17:Fan ON” in the “States and special commands” in the “Monitor and control” tab. The IMD turns the fan on.



29. Verify that the fan at the back of the IMD (outside the cabinet) is turning and does not make an unusual noise (for example if the cover touches the fan), and that the fan’s wind direction is into the heatsink.

30. Select “18:Fan Auto” in the “States and special commands” in the “Monitor and control” tab. The fan will be back to automatic control.



5.2.10.2 Verifying the fan function – IMD 122B

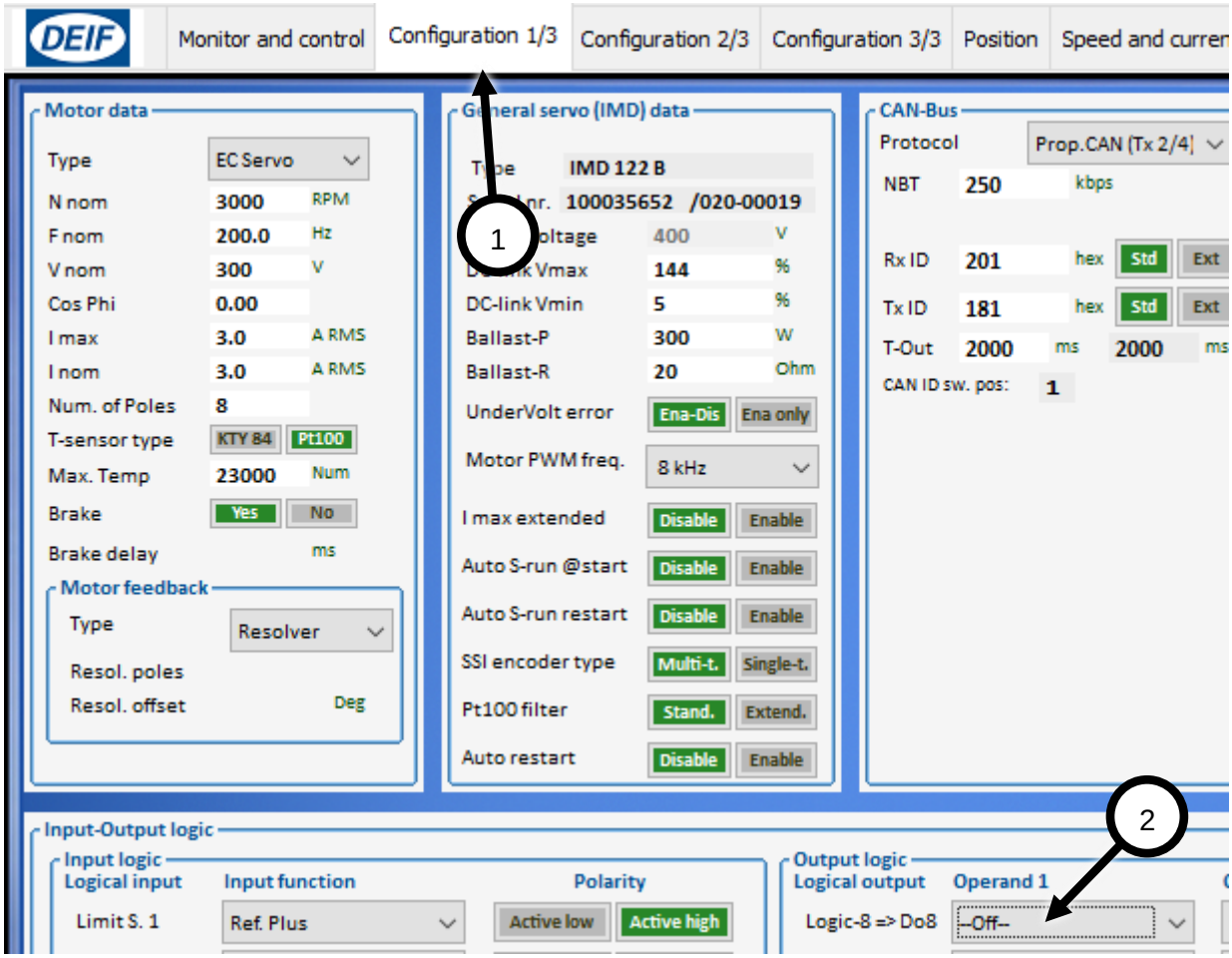
Info

The description in this section only applies to IMD122 B.

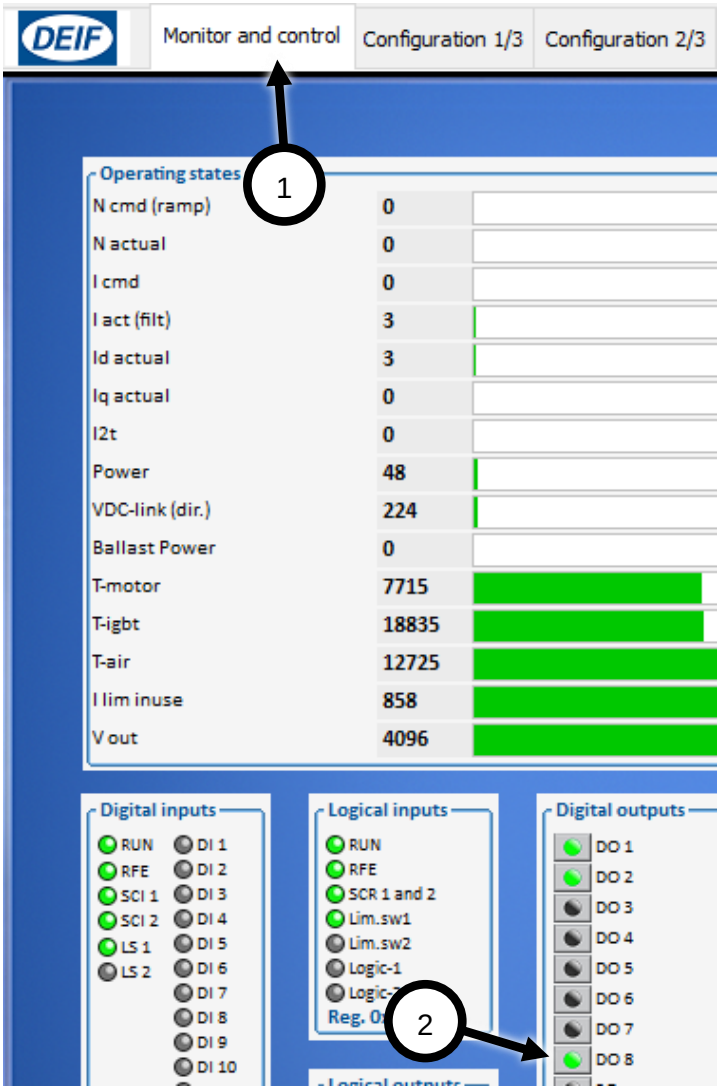
This description is valid when the fan is connected to DO8 (see IMD 100 installation instructions).

Description for IMD 122/135 C can be found in section 5.2.10.1 on page 40.

31. Click on “Configuration 1/3” tab (1). Select “—Off—” as Operand 1 for “Logic-8=>Do8” (2):



32. Click on the “Monitor and control” tab (1). Click on “Do 8” button (2) to turn the fan on (if another output was used for the fan, click on the corresponding icon).



33. Verify that the fan at the back of the IMD (outside the cabinet) is turning and does not make an unusual noise (for example if the cover touches the fan), and that the fan’s wind direction is into the heatsink.

34. Click again on “Do 8” button on the “Monitor and control” tab, to turn the fan OFF. It is not necessary to put the “Logic-8=>Do8” settings in the Logic tab back. When the settings are not saved, the original settings will be restored when the IMD starts again.

5.2.11 Verifying digital outputs

The digital outputs can be manually turned on and off in the “Digital outputs” group in the “Monitor and control” tab.

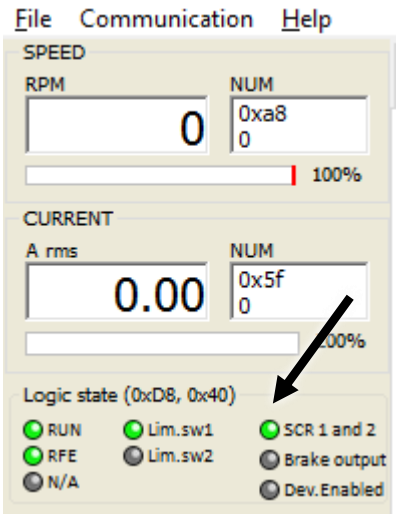
35. Do 5 to Do 8, might be mapped to from the “Logic” group in the “Configuration 1/3) tab. In such a case, disable the mapping: Click on “Configuration 1/3” tab and select “—Off—” as operand 1 for the appropriate logic output.
    122 B only: If any logical output was configured for the fan, reconfigure that output for the fan operation.

36. Click on the button for the relevant output to turn it on or off.

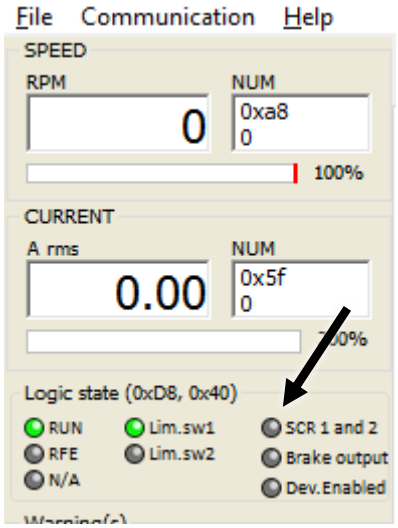
5.2.12 Verifying safety-chain output (SCR)

It is assumed that the emergency stop switch is connected to RFE input.

37. Verify that SCR 1 and 2 is on:

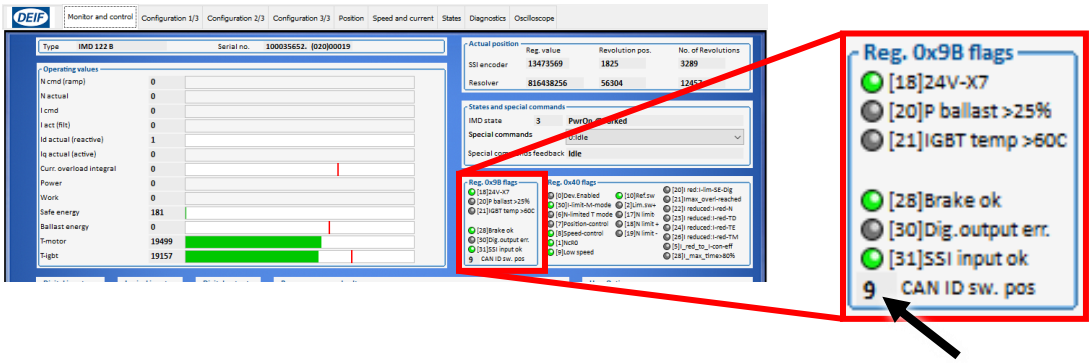


38. Activate the emergency stop switch. Verify that SCR 1 and 2 is turned off. Verify (depending on the specific function of SCR 1 and SCR 2 in the turbine) that the safety chain signal is turned off (verification of the wiring to X8-7 to X8-10).

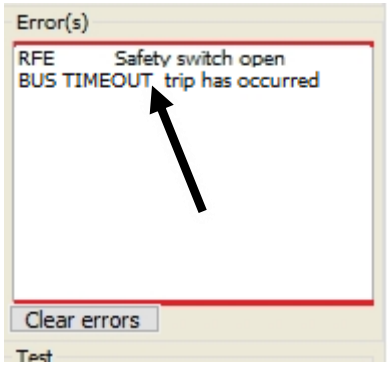


5.2.13 Verifying CAN/CANopen communication

39. Verify in the “Monitor & control”, “Reg. 0x9B flags” group that the CAN ID switch on the IMD front panel is sat to the correct position according to the documentation:



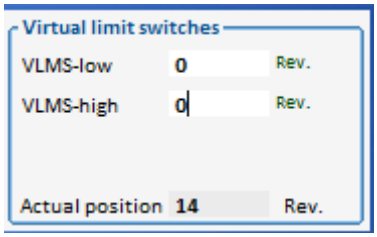
40. Ensure that the application SW is running. Pull out the CAN communication cable from X6. Verify that a BUS TIMEOUT error appears in the Error(s) field in the IMD Manager:



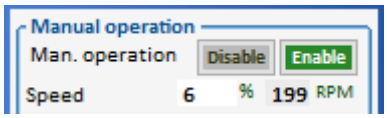
5.2.14 Verifying manual operation

NOTE Skip this section if no manual operation is used for the IMD (no connections to X9 terminals 15, 16 and 17).

41. Set “VLMS-low” and “VLMS-high” to zero in “Configuration 1/3”, “Virtual limit switches” group (if not already configured to zero):

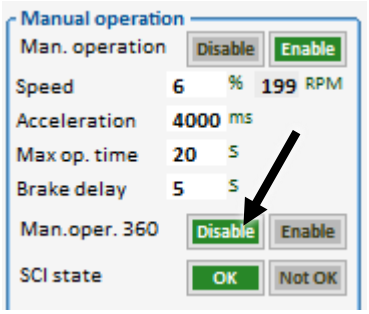


42. Verify that Man. operation is enabled in “Configuration 1/3”, “Manual operation” group:

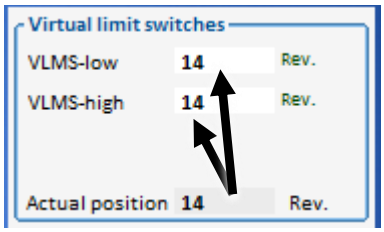


43. Set the switch connected to X9/17 (DI 12) ON.
44. Activate the switch connected to X9/15 (DI 10). Verify that the motor is turning. Deactivate the switch.
45. Activate the switch connected to X9/16 (DI 10). Verify that the motor is turning the other way. Deactivate the switch.
46. If virtual limit switches are used and a switch is connected to X9/14 (DI 9), verify manual operation 360:

a. Verify that “Man.oper.360” is disabled in “Configuration 1/3”, “Manual operation” group:

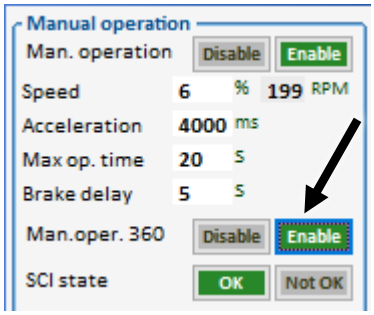


b. Set “VLMS-low” and “VLMS-high” to the same value as the “Actual position” in “Configuration 1/3”, “Virtual limit switches” group:



c. Activate the switch connected to X9/15 (DI 10). Verify that the motor is turning only one revolution and then stops.
Deactivate the switch.

d. Enable “Man.oper.360” is disabled in “Configuration 1/3”, “Manual operation” group:



e. Set the switch connected to X9/14 (DI 9) ON.

f. Activate the switch connected to X9/15 (DI 10). Verify that the motor is turning.
Deactivate the switch.

g. Set the switch connected to X9/14 (DI 9) OFF.

47. Set the switch connected to X9/17 (DI 12) OFF.

5.2.15 Verifying 24 V DC output (IMD with internal power supply option only)

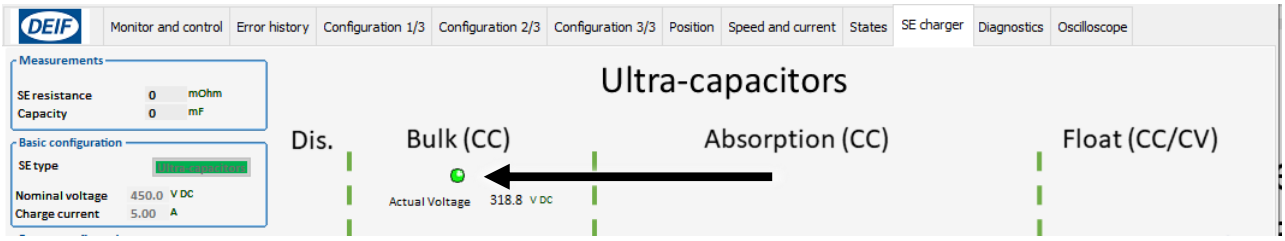
NOTE Skip this section if no external load is connected to X7.

48. If there is an external power supply (backup) connected to X7, switch the power supply OFF.
49. Measure voltage with a voltmeter on X7/1 and X7/4 and verify 24 ± 2.5 V DC.
50. If an external power supply was switched OFF, switch it ON again.

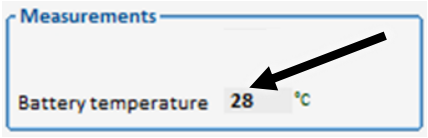
5.2.16 Verifying Safe Energy charger (IMD with built-in charger option only)

NOTE Skip this section if there is no charger in the IMD, or if no safe energy source is connected to X1.

51. Click on the “SE charger” tab in the IMD Manager.
52. Verify that the charging process (green LED) is not in disabled stage (must be in either Bulk, Absorption, or Float stages). The following example is from an Ultra-capacitor SE type:



53. Lead acid batteries only: If temperature compensation is used, verify that the temperature shown in the “Measurements” group is plausible:



5.2.17 Verification completion

54. Turn off the power to the IMD. The verification is now complete.

6. Troubleshooting

Problem	Possible causes	Remedy
“Enable dev.” button does not turn green	• An error is still active • Safety-chain inputs (SCI 1 and SCI 2) are not correct	• Remove error cause and click “Clear errors” button • Check wiring from the safety-chain
Dev. Enabled is not on (green)	• Either RUN (X9-2) is not high or an error is active	• Remove error cause and click “Clear errors” button • Check RUN connection
Motor doesn’t move Motor turns the wrong way “RACEAWAY” error is shown	• Wiring to the motor is wrong	• Check the wiring between the motor and the IMD
Motor doesn’t move on SE	• One or both wires to SE are defective or not connected • The SE is not charged • A cell is defective	• Check the SE wires • Check if the SE source is charged • Check if all cells are OK. Testing the cells must be performed with load.
SSI doesn’t show movement when the motor is turning.	• Connection to the SSI sensor is bad • The SSI sensor doesn’t work.	• Check the wiring to the SSI sensor • Replace the sensor
Resolver value doesn’t show movement when the motor is turning.	• Connection to the resolver is bad • The resolver doesn’t work.	• Check the wiring to the resolver • If necessary, replace the resolver
Motor temperature does not show right temperature	• The wrong sensor is configured as motor temp. sensor • The connection to the sensor is bad	• Configure the correct sensor (KTY or PT100) • Check the wiring to the sensor
Lim.sw x does not change state	• Bad connection in the limit switch or X9 • 0 V is missing in X9 • Limit switch is defect	• Check the wiring • Check the wiring (X9-9/18) • Replace the limit switch
DI x does not change state	• Bad connection • 0 V is missing in X9	• Check the wiring • Check the wiring (X9-9/18)

Problem	Possible causes	Remedy
Temperature sensor does not show right temperature	• The wrong sensor is used (not Pt100) • The connection to the sensor is bad	• Use the correct sensor • Check the wiring to the sensor
Fan doesn't work	• Wrong wiring to the fan • The fan cover is bent	• Check the wiring to the fan • Replace or straighten the fan cover
Digital output does not work	• Bad connection • 0 V or 24 V is missing in X8	• Check the wiring • Check the wiring (X8-11/20)
CAN communication does not work	• CAN ID is not correct • Wiring or termination is wrong • IMD is using wrong communication speed	• Set the CAN ID switch in the correct position. • Check in the CAN parameters in "Configuration 1/3" tab that the Rx and Tx IDs are correct • Check the wiring and termination resistors • Check in the CAN parameters in "Configuration 1/3" tab that NBT is sat to the correct speed
Safety run timeout	• No limit switch is defined as Ref Plus • Bad or wrong connection to the limit switch • The limit switch is defective	• Check that Limit S. 1 or Limit S. 2 is defined as Ref Plus in the in "Configuration 1/3" tab, "Input function" • Check the wiring to the limit switch • Replace the limit switch if necessary
Charger not charging (IMD 122C or later mounted with SE charger option)	• The IMD is not equipped with the charger option • No safe energy source is connected, wrong polarity, or defective wire • No valid SE charger configuration • The charger is in Setup mode	• Check on the label that the SE Charger is included in the options. • Check wiring to the safe energy source • Check in the IMD manager that the charger configuration is valid • Check in the IMD manager that the charger is not in Setup mode

7. Errors and warnings

The IMD has two ways to report faults: Errors and warnings:

	Cause and action	Reset
Warning	Normal parameter limits are beginning to be crossed. No immediate action. If not addressed, some warnings might escalate to errors after a timeout.	Automatically reset when the cause is removed.
Error	Severe violation of limits, causing a safety chain trip, and either an immediate motor stop or initiating a safety run.	Reset is done either from the controller, another USB device, or using the IMD Manager tool. From the application SW or another USB device, writing any value to register 0x8E resets errors. Reset is not possible if the cause is not removed.

Both errors and warnings are displayed on the IMD display and the IMD Manager tool.

7.1 Error list

When an error is active it is displayed in the IMD Manager tool in the “Error(s)” field. Following is a list of errors:

Table 1 Error list and description

IMD display / Error bit no.	IMD Manager Error(s) field	Safety run performed	Error description
0	BADPARAS	No	Checksum (CRC) error when reading parameters from EEPROM. This error can only be reset by a power-cycle (OFF-ON) of the IMD.
1	POWER FAULT	No	A fault condition related to the IGBT module is detected.
2	RFE open	No	RFE (Rotational Field Enable) input is in low state.
3	BUS TIMEOUT	Yes	This error can be caused by three reasons: • Timeout has occurred on the CAN-bus. Timeout period defined in ms in register CAN_TIMEOUT (0xd0). The bus time out error is enabled after the CAN bus has reached operational state. • Communication error with the built-in charger (after the communication was initialised at start-up). • Communication error with the built-in charger (option). When resulting from this reason, the error is generated automatically after warning 3 has been active during the Charger timeout period and not cleared.

IMD display / Error bit no.	IMD Manager Error(s) field	Safety run performed	Error description
4	FEEDBACK	Yes	Bad or no motor feedback signal. The resolver circuit detects a fault.
5	UNDERVOLTAGE	No	DC link voltage is lower than DC-link Vlow or DC-link Vmin.
6	MOTORTEMP	Yes	Motor temperature too high. Motor-temperature reached the limit specified in *M-temp.* This error can be reset after the motor had cooled down.
7	DEVICETEMP	Yes	IMD temperature too high. This error can be reset after the IMD had cooled down.
8	OVERVOLTAGE	Yes/No	DC-link voltage upper limits (HW DC-link overvoltage or DC-link Vmax) exceeded.
9	I_PEAK	No	The current to the motor exceeded the peak current limit for more than 8 ms.
A	MOTOR OUTPUT	No	The motor speed and direction cannot be controlled. The motor either races at full speed or cannot move. This error can be caused by four reasons: • Non coherent parameter configuration. • Mismatch between the direction from the drive and direction from the motor feedback. • The phase sequence (W, V, U) is wrong. • At least one of the phases from the IMD to the motor is disconnected.
B	CHARGER		Error in the charger (option). This error is generated automatically after warning B has been active during the Charger timeout period and not cleared. There are a number of charger errors that caused the warning that was escalated to the error. Possible errors are listed in section 7.1.1 on page 51. The active errors can be determined by reading the charger error register.
C	HIGHVOLTAGE	Yes	HIGHVOLTAGE warning was on more than approximately five seconds.
D	PRE_CHARGE	Yes	Pre-charge circuit failure. Mains power cannot be connected to DC link.

IMD display / Error bit no.	IMD Manager Error(s) field	Safety run performed	Error description
E	HW-ERROR	No	Hardware component failure. Multiple reasons can cause this error. For example: • An internal supply voltage has failed • Internal communication to power-module has timed out • The controller has detected a power-module error-condition • The internal current measurement has failed Determination of the precise reason can only be done by experts, possibly also using the errors log.
F	BALLAST	Yes	This error can be caused by two reasons: • Ballast resistor overload. The ballast resistor load has exceeded the configured value (Ballast-P). This error can be reset after a timeout has elapsed. • Hardware failure in the ballast circuit or resistor

7.1.1 Charger (option) errors

If the built-in charger option is mounted in the IMD, the following errors can be read from the charger warnings register:

Error bit no.	Error text	Error description
0	OPENCIRCUIT	The charger detected open circuit. No safe energy source is connected, or a wire is broken.
1	SHORTCIRCUIT	The SE output is short-circuited. For lead acid this error is raised when the SE voltage is less than 20% of nominal while charging.
2	CHARGERTEMP	The internal temperature of the charger is too high.

7.2 Warning list

When a warning is active it is displayed in the IMD Manager tool in the “Warning(s)” field. Following is a list of warnings:

Table 2 Warning list and description

Warning bit no.	IMD Manager Warning(s) field	Warning description
0	BADPARA	Parameter error. This warning can be caused by the following reasons: • Deceleration ramp too long when “Run” signal is deactivated • Calculation of motor-parameters gives an unlikely result
1	Warning 1	Not used
2	Warning 2	Not used
3	COMCHARGER	Communication error with the built-in charger (option). If this warning persists for the Charger timeout period, and the IMD is configured to escalate charger warnings to error, error 3 will be generated. Sending “clear errors” every 8 seconds will delay error generation (until clearing errors is stopped) if the warning persists.
4	FEEDBACK	Unstable resolver signal. This warning is also active during blind safety run.
5	POWERVOLTAGE	Safe energy voltage is lower than SE Vmin.
6	MOTORTEMP	--Motor temperature high. Motor-temperature reached 87.5% of the limit specified in *M-temp*.
7	DEVICETEMP	IMD temperature high. Internal components temperature exceeded 72 ºC.
8	Warning 8	Not used
9	I_PEAK	Digital output driver is overheated
A	Warning A	Not used
B	CHARGER	Error in the charger (option). There are a number of charger errors that caused the warning that was escalated to the error. These can be determined by reading the charger error register. If this warning persists for the Charger timeout period, and the IMD is configured to escalate charger warnings to error, error 3 will be generated. Sending “clear errors” every 8 seconds will delay error generation (until clearing errors is stopped) if the warning persists.
C	HIGHVOLTAGE	Ballast resistor is on too long (> 100 ms) while the Mains is ON. If the pitch controller does not act for more than 5 seconds, a HIGHVOLTAGE error is generated, and the warning is reset.
D	Warning D	Not used

Warning bit no.	IMD Manager Warning(s) field	Warning description
E	HW-warning	This warning can be caused by the following reasons: • Current offset too high (too far from zero) • Pt100 measurements are wrong, measured value cannot be trusted • DI 10, 11 or 12 is high when not in manual operation mode (and manual mode is enabled).
F	BALLAST	The ballast resistor load is over 50% the configured maximum value.

7.2.1 Charger (option) warnings

If the built-in charger option is mounted in the IMD, the following warnings can be read from the charger warnings register:

Warning bit no.	Warning text	Description
0	BATTEMP	The battery temperature is more than 10ºC outside charging temperature limits (-20ºC to 50ºC). Lead acid only.
1	TEMPCHANNEL	The defined temperature sensor channel is not valid.
2	VinLOW	The input voltage from the DC-link is below 270 V DC.
3	Vin-VseLOW	The input voltage from the DC-link is not at least 15 V DC higher than the SE voltage.
4	LOWCURR.	The output current is too low compared to setpoint.

7.3 Errors log

The IMD has an error log containing up to 20 entries. The log is a rolling log using “First In First Out” principle, which means that it always contain the latest 20 errors generated by the IMD, with the latest error at the top. The log entries are available in the IMD Manager and through CAN/CANopen. Each entry contains the following parameter values at the time the error occurred (see description of the register in the Integration manual for details):

Information	Register	Description
IMD state	0x02	The state of the IMD
T-IGBT	0x4A	The numeric representation of the IGBT temperature
N act (filt)	0xA8	The filtered actual speed value in units
N cmd ramp	0x32	Speed command after ramp in units
I act (filt)	0x5F	Actual filtered current value in units
DC-link voltage	0xEB	The filtered voltage of the DC-link in units
Drive status	0x40	Bit map representation of the state of the internal flags

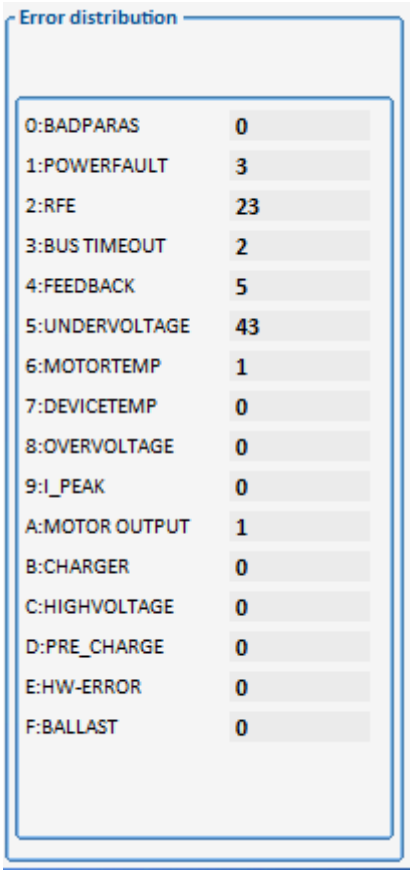
Information	Register	Description
Logic in block	0x9B	Bit map representation of the state of digital inputs and some internal flags
Out block	0x98	Bit map representation of the state of digital outputs
Power board status	0x63	Status of the power board
Actual current limit	0x48	The current limit used at the time
Special command	0x03	The values of the special commands register. If a command was executed, the register contains the feedback for the command.
Error register value	0x8F	Active errors at the time the error occurred
ID	N/A	Special ID information for the error
Timestamp 1 (Device enabled)	N/A	A relative time stamp (seconds) for the entry indicating the time elapsed since the last time the device enabled flag was set
Timestamp 2 (power)	N/A	A relative time stamp (seconds) for the entry indicating the time elapsed since the last power on of the IMD
Timestamp 3 (life)	N/A	A relative time stamp (seconds) for the entry indicating the time elapsed since the IMD was delivered from the factory, or if the IMD is older, since the first time a firmware supporting error history was installed. This time counter only counts time when the IMD 24 V DC supply (external or internal) is on. For IMDs that were delivered with FW older than 1-08-0 (first FW with error log) the life time stamp is relative to the time when the first FW supporting error log was installed on the IMD.

The last error further contains the following parameter values at the time the error occurred (Extra info):

Information	Register	Description
Actual position	0x6D	The actual position based on the resolver and rounds count
Actual position SSI	0x6F	The actual position based on the SSI encoder count
1st error in power board	0x94	First error (code) on power board since last clear error command.
Ballast energy counter (L) and Current overload integral (H)	0x45	Values of Ballast energy counter (low 16 bits), Current overload integral (High16 bits),
SE voltage	0x66	Numeric value of the safe energy voltage
SE mid-point voltage	0x61	Numeric value of the safe energy mid-point voltage
T-air	0x4B	Numeric value of the air temperature inside the IMD
(dbg) *temp	0x9A	Dynamic pointer register used for debug by DEIF engineers
(dbg) *ptr1	0xB8	Dynamic pointer register used for debug by DEIF engineers
(dbg) *ptr2	0xBA	Dynamic pointer register used for debug by DEIF engineers
(dbg) ptr1	0xB7	Dynamic pointer register used for debug by DEIF engineers

Information	Register	Description
(dbg) ptr2	0xB9	Dynamic pointer register used for debug by DEIF engineers

The error log also contains a distribution representation of all errors occurred during the “Elapsed time:life” (the time elapsed since the first FW supporting error history was installed), showing how many times each error appears in the log:



8. Revision history

Apart from editorial changes the following changes have been made in this revision:

Date	Revision	Changes
2020-09-25	C	• “Firmware update” section in “Configuration and firmware update” updated • “Turning on power and checking errors” updated • “Connecting the safe energy” in “Avoiding damage to the IMD” updated • “Charger (option) warning” in “Warning list” updated
2019-06-29	B	• Based on IMD Manager version 1.0.5.0 • Referenced documents section added • Error and warning lists updated • Screen pictures updated • Ny procedure for SSI encoder and resolver verification • New procedure for PTC temperature sensor • New procedure for fan verification in C version • New procedures for verifying manual operation, 24 V DC output, SE charger, and SE measurements • “Error and warning lists” section renamed to “Errors and warnings” • “Errors and warnings log” section added to “Errors and warnings” section • Troubleshooting updated
2016-12-22	A	This is the first version of the document. This manual is based on IMD Manager version 1.0.0.0.

9. Product user documentation

The IMD product has an extensive user documentation, targeted towards different audience and product use stages.

The following documents are part of the user documentation:

Table 3 IMD user documentation

Document	Target audience	Content
IMD 100 datasheet Document no.: 4921260015	Buyers and technicians of customers	Describes relevant specifications and give an overview of the IMD functions
IMD 100 function description Document no.: 4189360013	Mainly technicians and engineers of customers.	Describes the functions of the IMD. Gives the reader an understanding of the purpose of the IMD in a system, and which functions can be utilised in a pitch system. The functions are described so that the reader can understand what each function is used for.
IMD 100 integration manual Document no.: 4189360015	Engineers at customer R&D department	Describes how to integrate the IMD in a pitch system. Gives extensive knowledge about: IMD SW (parameters and how to achieve specific functionality) How to create customized parameter file for use in production Requirements for external interfaces/components
IMD Manager installation instructions Document no.: 4189360018	Engineers at customer R&D department, as well as commissioners and service personnel	Describes how to install the IMD Manager. The IMD Manager is an application used to configure and control the IMD using the Service USB connector.
IMD Manager user manual Document no.: 4189360019	Engineers at customer R&D department, as well as commissioners and service personnel	Describes how to use the IMD Manager. The IMD Manager is an application used to configure and control the IMD using the Service USB connector.
IMD 100 installation instructions Document no.: 4189360005	Technicians at production site where the IMD is mounted in the cabinet/hub	Describes how to mount, connect and perform initial start, test, and configuration (using a configuration file) of the IMD at production.
IMD 100 initial configuration and verification manual Document no.: 4189360016	Commissioners or other personnel with similar qualifications, as well as service personnel (for SW upgrade)	Describes how to upgrade the IMD SW, how to load configuration file, and how to verify the IMD installation to the possible extent.

Document	Target audience	Content
IMD 100 service and maintenance manual Document no.: 4189360017	Service and warehouse personnel	Describes preventive (scheduled) and corrective maintenance of the IMD, as well as storage requirements.
IMD 100 installation checklist Document no.: 4189360021	Technicians at production site where the IMD is mounted in the cabinet/hub	Installation tasks with check boxes to document the tasks done during installation
IMD 100 configuration and verification checklist Document no.: 4189360022	Commissioners or other personnel with similar qualifications, as well as service personnel (for SW upgrade)	configuration and verification tasks with check boxes to document the tasks done during configuration and verification
Addendum to installation manual Document no.: 4189360023	Integration and installation personnel	Describes the how to replace a pitch drive when the IMD is equipped with Retrofit wiring harness var.1

The IMD 100 documentation is written anticipating an OEM (original equipment manufacturer) product use-cycle in a wind turbine. The envisioned cycle is described in the following figure. The description also explains the tasks, who is expected to execute the task, the location where the execution takes place and the supporting DEIF documentation for the task. Many details in these tasks depends on the actual implementation, which is why the IMD documentation will never stand alone.

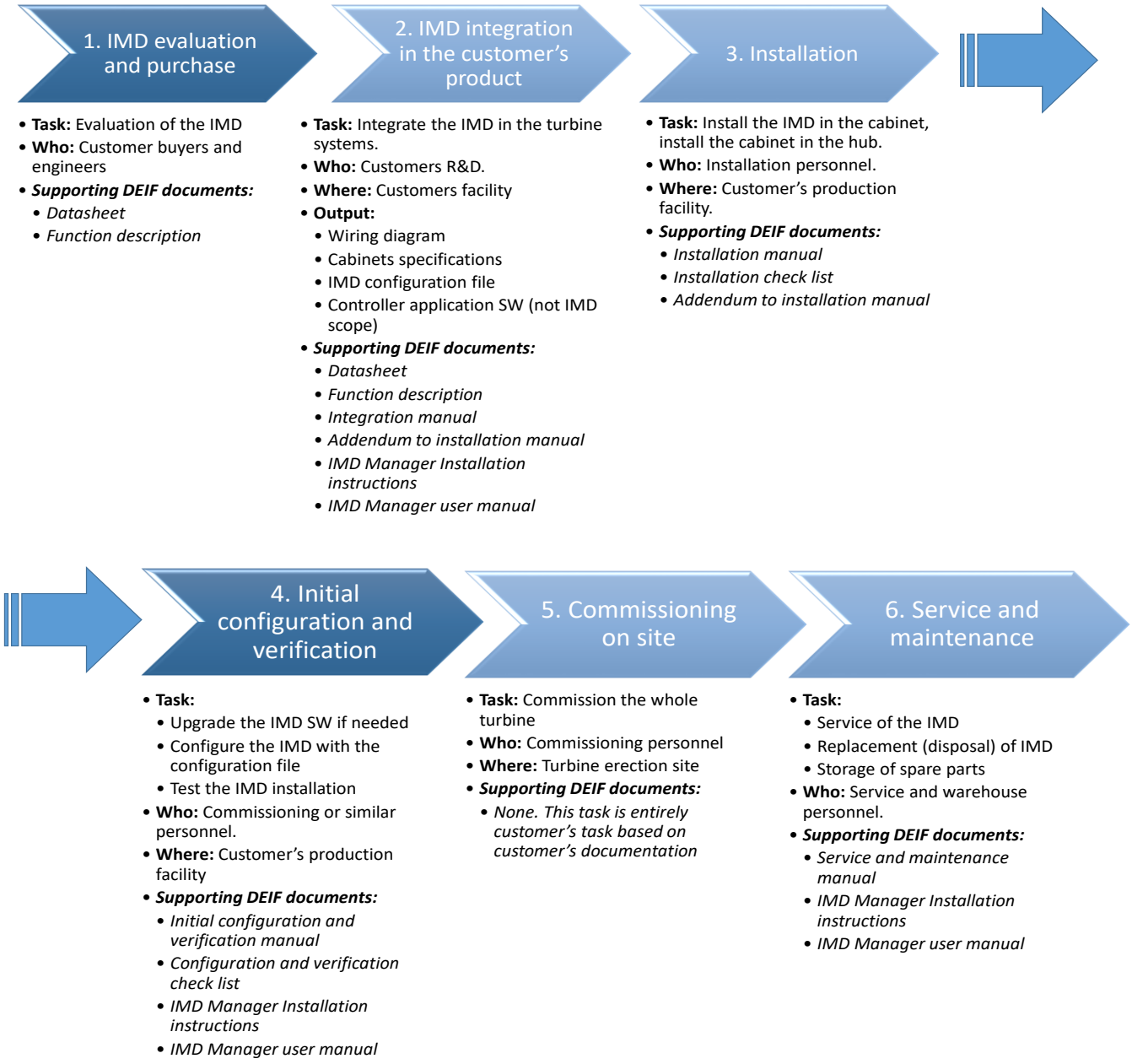


Figure 2 Tasks and documentation overview

The described product use-cycle might not apply as is for all customers, but the tasks are universal and can therefore be adapted. For example, if the SW upgrade, configuration and verification is done during the turbine commissioning, the applicable documentation can be used at this stage instead of a separate stage at the end of production.

10. Glossary

10.1 Terms and abbreviations

CAN	Controller Area Network (communication protocol)
IMD	Integrated Motor Drive
SCI	Safety-Chain Input
SCR	Safety-Chain Relay
SE	Safe Energy
SSI	Synchronous Serial Interface
USB	Universal Serial Bus

10.2 Units

Unit	Unit Name	Quantity name	US unit	US name	Conversion	Alternative units
A	ampere	Current				
ºC	degrees Celsius	Temperature	ºF	Fahrenheit	$T[ºC] = \frac{(T[ºF] - 32º) \times 5}{9}$	
g	gram	Weight	oz	ounce	1 g = 0.03527 oz	
Hz	hertz	Frequency (cycles per second)				
kg	kilogram	Weight	lb	pound	1 kg = 2.205 lb	
m	metre	length	ft	foot (or feet)	1 m = 3.28 ft	
mA	milliampere	Current				
mm	millimetre	Length	in	inch	1 mm = 0.0394 in	
ms	millisecond	Time				
RPM	revolutions per minute	Frequency of rotation (rotational speed)				
s	second	Time				
V	volt	Voltage				
V AC	volt (alternating current)	Voltage (alternating current)				
V DC	volt (direct current)	Voltage (direct current)				
W	watt	Power				
Ω	ohm	Resistance				