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QUICK START MANUAL FOR POWERMASTER INVERTER
Pikakäyttöönotto-ohje PowerMASTER-invertterille

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Bachelor's Thesis
LUT School of Energy Systems
Electrical Engineering

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ABSTRACT

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The restrictions for greenhouse emissions, the rise of the oil price and the fall of the battery price have made electric drivetrains a better option for vehicles as well as heavy-duty machines. Controlled electric drive systems are used more and more in electric drivetrains. The different types of electric motors are being used more so controlling is needed. By using the controlled electric drive system, it is also possible to achieve greater overall process efficiency. It is achieved with accurate speed and torque control.

Visedo is an electric drivetrain manufacturer from Lappeenranta, Finland. Visedo manufactures drivetrains for heavy-duty machines, marine vessels and commercial vehicles. PowerMASTER is an inverter manufactured by Visedo. It can be used for example for controlling electric motors or to create a standalone microgrid. More and more customers need help with installing and using their inverters. There is a product manual available for PowerMASTER inverter, but a more hands-on manual was needed. The quick start manual described in this Bachelor's Thesis was created for this need.

The basic idea for the quick start manual was to create an easy step-by-step guide for installing and using the PowerMASTER inverter. The manual was created by first installing the inverter with the help of product manual and then by using the inverter with PowerUSER application to control an electric machine. Inverter was installed and used without prior experience to find the possible mistakes in installing and using the inverter. The Visedo engineers also helped when needed. A step-by-step guide for electrical connections, liquid-cooling connections, motor controlling and parameters setup was created as result.

Keywords: connection manual, control manual, drive control, electric drive system, electric drivetrain, inverter, PowerMASTER, PowerUSER, Visedo

TIIVISTELMÄ

Lappeenrannan teknillinen yliopisto
LUT School of Energy Systems
Sähkötekniikka

Aleksi Sirviö
Pikakäyttöönotto-ohje PowerMASTER-invertterille

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Jatkuvasti kiristyvät rajoitukset kasvihuonekaasupäästöissä, öljyn hinnan nousu sekä akkuteknologian hinnan lasku ovat tehneet sähköisestä voimalinjasta yhä paremman vaihtoehdon niin ajoneuvoissa kuin työkoneissakin. Ohjattujen sähköisten voimalinjojen määrä on kasvanut, sillä erilaisten käytettyjen sähkömoottorityyppien määrä on lisääntynyt. Ohjatulla voimalinjaratkaisulla voidaan myös saavuttaa parempi prosessin kokonaishyötysuhde. Parempi hyötysuhde saavutetaan tarkalla pyörimisnopeus- tai vääntömomenttisäädöllä.

Visedo on lappeenrantalainen yritys, joka on erikoistunut sähköisiin voimalinjaratkaisuihin erityisesti raskaissa työkoneissa, laivoissa sekä kaupallisissa ajoneuvoissa. PowerMASTER on Visedon valmistama sähköisissä voimalinjoissa käytetty invertteri. Sillä voidaan esimerkiksi ohjata moottoria sekä muodostaa irrallinen mikroverkko. Yhä useammat Visedon asiakkaat tarvitsevat apua invertteireidensä asennuksessa ja käyttämisessä. PowerMASTERille on saatavilla tuotemanuaali, mutta käytännönläheisemmälle manuaalille syntyi tarve. Tähän tarkoitukseen kehitettiin pikakäyttöönotto-ohje PowerMASTER-invertterille, joka on esitelty tässä kandidaatintyössä.

Pikakäyttöönotto-ohjeen lähtökohtana oli tarjota helppo vaiheittainen kuvaus PowerMASTER-invertterin asennukseen sekä käyttöön. Ohje tehtiin asentamalla ensin invertteri tuotemanuaalin avustuksella ja sitten käyttämällä invertteriä PowerUSER-applikaatiolla sähkömoottorin ajamiseen. Invertteri asennettiin ja sitä käytettiin ilman aiempaa kokemusta, jotta mahdolliset asennus- ja käyttövirheet tulisivat esille. Tarvittaessa invertterin asennuksessa sekä käytössä auttoivat kuitenkin Visedon insinöörit. Kokonaisuutena muodostui ohje, joka kuvaa vaiheittain invertterin asennuksen ja käyttämisen. Ohjeessa on kuvattu sähköisten kytkentöjen tekeminen, jäähdytyksen asentaminen, moottorin ohjaus sekä tarvittavien parametrien asettaminen.

Avainsanat: invertteri, kytkentäohje, käyttöohje, sähkömoottorikäyttö, PowerMASTER, PowerUSER, sähköinen voimalinja, Visedo

Contents

Abbreviations and Symbols

AC	alternating current
AFE	active front end
BEV	battery electric vehicle
CAN	controlled area network
DC	direct current
DOL	direct on-line
IM	asynchronous induction motor
PM	synchronous permanent magnet motor
PWM	pulse width modulation
SRPM	synchronous reluctance assisted permanent magnet motor
VSI	voltage-source inverter

f	factor
R	reference value
V	value

Subscripts

act	actual
min	minimum
dec	decimal format

1. INTRODUCTION

Electric drivetrains are becoming more and more popular as greenhouse emission restrictions are becoming stricter. For example in the US battery electric vehicle (BEV) sales have grown from zero to 72 000 sold units in just six years. As the price of gasoline is estimated to rise and the price per kWh of Lithium Ion battery packs is estimated to fall the BEV's are increasing their popularity also in the future (Brennan, J. W. & Barder, T. E. 2017).

Electric drivetrains are in addition being used more and more in heavy-duty hybrid vehicles to reduce their fuel consumption and greenhouse emissions. While the fuel consumption is reduced, maximum output torque is also increased as electric machine is added. The electric machine can also regenerate energy while braking to increase the overall efficiency of the vehicle. In addition, the hybrid duty gives possibility to easily emphasize for example fuel economy or emissions by just adjusting power management plan (Grizzle, J.W., Kang, J.-M., Lin, C.-C. & Peng, H. 2003).

1.1 About Visedo

Visedo is electric drivetrain manufacturer from Lappeenranta, Finland. Visedo was founded in 2009 and its main mission is to end pollution through electrification. Visedo manufactures electric drivetrains for heavy duty hybrid vehicles, electric powered marine vessels and commercial vehicles (Visedo 2017).

1.2 Electric drive system

Electric drive systems can be noncontrolled or controlled. The most common type of a non-controlled electric drive system consists asynchronous induction motors (IM) with direct-on-line (DOL) starting. These types of systems cannot be controlled other than completely shutting down the motor by opening network contactors. (Hrabovcocá, V., Pyrhönen, J., & Semken, R. S. 2016.).

In the controlled electric drive systems, it is usually possible to control the speed, the force production, the acceleration, the deceleration and the movement's direction of the electric machines. This makes it possible to optimize for example industrial processes and that is the reason why controlled drive systems are gaining ground from the non-controlled ones (Hrabovcocá, V., Pyrhönen, J., & Semken, R. S. 2016). Typically controlled electric drive systems consist 6 main parts: an electric supply, a rectifier, a DC-link, an inverter, an electric machine and a load. Depending on the setup a separated rectifier can be used if there are multiple drive controls in the system. In the multi-drive systems, a common DC-link is usually used for all the inverter units as can be seen in the Figure 1.1. Gearing can be used to adjust the rotating speed of the machine to the required rotating speed of the load (ABB 2011).

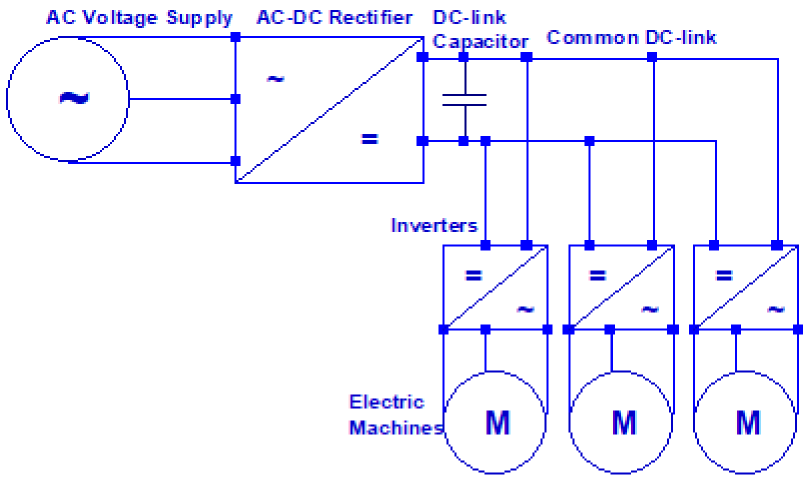

Figure 1.1 Electrical drive system with three electric machines and inverters. A common DC-link has been used. The DC-link voltage is rectified from the AC voltage supply with a rectifier.

The electric drive systems have several benefits compared to other drive systems, such as hydraulic engines, pneumatic drives and combustion engines. The electric drive systems have wide power range and therefore they can be used in many different tasks. Available speed range is wide and no gearboxes are therefore usually needed. The electric power systems require significantly less maintenance than for example combustion engines. The control abilities of the electric drive systems are also excellent and all this comes with very little acoustic noise (De Docker, R. W., Pulle, D. W. J., Veltman, A. 2016.)

1.3 Drive controls

Drive control is a device that controls electric machines based on frequency and voltage regulation. In case of a direct current (DC) drive control only the voltage is regulated. Pulse width modulation (PWM) is a widely applied principle for electric power conversion in drive controls. For example, in a voltage-source inverter (VSI) drive the DC voltage in the DC-link of the drive is converted into a desired type three-phase alternating current (AC) voltage with PWM. Vector-control is a controlling principle that has become more popular in the drive controls due to increasing amount of different motor types in electrical drive applications. It uses space vectors to model the transients of an electrical machine to increase the accuracy of the control (Hrabovcocá, V., Pyrhönen, J., & Semken, R. S. 2016.).

In a typical AC drive control the AC voltage of the network is rectified to DC voltage in the DC-link with a diode bridge. The DC voltage is then converted to AC voltage with desired frequency and amplitude with six controlled switches which carry out the pulse width modulation. If vector-control is used, controller uses feedback from the motor to make the PWM work more accurately (Hrabovcocá, V., Pyrhönen, J., & Semken, R. S. 2016.).

Visedo PowerMASTER inverter has two DC connections and one three-phase AC connection so it can convert the voltage only from AC to DC or vice versa depending on setup. As the PowerMASTER uses DC voltage when driving an AC motor it requires a separate rectifier when used in the AC network. (Visedo 2016a). The basic idea of the used components in the PowerMASTER to convert the voltage can be seen in the Figure 1.2.

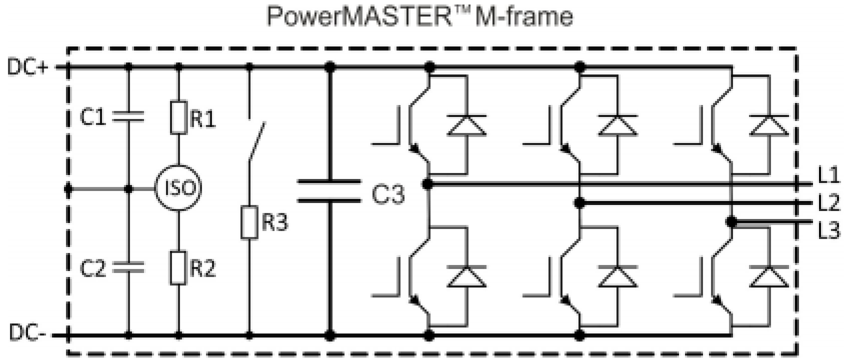

Figure 1.2 The basic components used in a PowerMASTER inverter for converting the voltage.
R1, R2 = Resistor between DC-link plus and minus busbar and the device frame.
R3 = Resistor between DC-Link plus and minus busbar.
C1, C2 = Capacitor between DC-link plus and minus busbar.
C3 = Capacitor between DC-link plus and minus busbar. (Visedo 2016a).

PowerMASTER inverter can be used for speed and torque control of an electric machine. In addition, PowerMASTER inverter can be used to convert AC voltage generated in generator use to DC voltage. PowerMASTER can also be used as an active front end (AFE) or to create a standalone three phase microgrid (Visedo 2016a).

The controllable electric motor types of PowerMASTER inverter are synchronous permanent magnet motors (PM), asynchronous induction motors (IM) and Visedo-made synchronous reluctance assisted permanent magnet motors (SRPM). The control principle of the motors is rotor flux oriented current vector control (Visedo 2016a).

1.4 Electric machines

Electric machine is a machine that converts electrical power to mechanical power or vice versa. The main active parts of an electric machine are rotor and stator. The main passive parts of an electric machine are bearings, the body of the stator, stator shaft and terminal box. Air cooled electric machines have also a fan in the N-end for cooling. The most important electric machine types are asynchronous, synchronous and DC machines. The first two machine types are AC machines. There are also several special electric machine types. The electric machine can be called as an electric motor or a generator depending on if the machine drives or is driven (Aura L, Tonteri A. J. 1996).

Torque in AC motors is generated with rotating magnetic field in the three phase windings of the stator. Motor is asynchronous or synchronous depending on if the rotor rotates with same speed as the magnetic field or not. The difference between the rotor speed and magnetic field speed is called slip (Aura L, Tonteri A. J. 1996).

The used example machine in this manual is Pannacotta, a prototype of Visedo PowerDRUM. It is a liquid-cooled SRPM. The main benefits of this motor type are smaller dimensions, lighter weight and higher efficiency. The typical applications for such motors are traction use in vehicles, propulsion use in marine vessels and generator use in hybrid vehicles or marine vessels (Visedo 2016b).

1.5 Goal of this study

The goal of this study is to produce a quick start manual for customer use to help the customers to connect and test their PowerMASTER inverters on their own. As more and more PowerMASTER inverters are being sold to different customers Visedo service has to help the customers more and more with basic questions. This manual aims to help the customers with the basic questions relating installing and using the inverter by offering a step-by-step guide how to complete the installation and start-up. As the more detailed product manual is available on the Visedo website this manual will cover only the most basic subjects relating installation and use of PowerMASTER inverter.

1.6 Research questions

The research questions for the manual are:

- How is a PowerMASTER inverter connected to a DC-link and an AC motor step-by-step?
- How should the cooling and the grounding be done?
- Which tools and parts are needed for the connections?
- Which things are easily done incorrectly during the installation?
- How can the motor model and safety limits be set in PowerUSER and how to define them?
- How can an electric motor be controlled with the PowerMASTER inverter by using PowerUSER application?

The study how the PowerMASTER inverter is installed and used is performed by first installing the inverter with the help of the PowerMASTER product manual and then by using the inverter according to the instructions given by an experienced engineer. The process is completely documented. It is necessary that the study is performed by an inexperienced person so that all needed information for the installation and use is gathered. The mentioned research methods have been chosen to gain as authentic as possible view on the first installation and use process done by a customer. Currently there are no detailed manuals about using PowerUSER application, so the experienced engineers that have learned how to use the application are the only available source.

2. CONNECTING INSTRUCTIONS

First, the PowerMASTER inverter was connected with the help of the product manual at the test laboratory of Visedo. While the inverter was installed, it was possible to ask for help in any unclear situations from the test engineer team of Visedo. The product manual was used as little as possible to find the possible incorrect actions. The connections were checked to be correct afterwards by a test engineer. The instructions have been written so that they will guide the installation process step-by-step.

In this manual PowerMASTER inverter is connected to a DC-link, to an AC motor, to the grounding, to a low voltage DC signal connection and to a computer. Always check that there is no voltage left in the common DC-link or in the DC-link of the inverter before installing or removing the high-voltage cables.

2.1 Installing procedure and required tools

The installing procedure for the PowerMASTER inverter for testing the device is described in the Table 2.1. The inverter is not mounted in this procedure.

Table 2.1 The installing procedure for the PowerMASTER inverter. The installing procedure does not include the mounting of the inverter.

Order number	Description
1	prepare the installation place
2	connect liquid cooling system
3	connect the grounding
4	connect high voltage cables
5	install connection box lid
6	connect signal connectors

The required tools and parts for the installation of the inverter are listed in the Table 2.2. Parts included with the inverter are also indicated. Depending on the control method of the inverter and the compressing method of the hoses Visedo Power Series Service Cable and ratchet torque wrench may be needed.

Table 2.2 The required tools and parts for installing the Visedo PowerMASTER inverter. Parts included with the inverter can be noticed from the “x provided” text, where the x describes the amount of the provided parts. *Needed if the control method is serial connection. ** Needed if hose clamps are used.

Amount(pcs)	Description
2	hose clamp or hose clip
2	hose, internal diameter of 19 mm, length depending on installing position
6	12mm hexagon bolt with M8 thread (5 provided)
6	D8 washer (5 provided)
6	D8 spring washer (5 provided)
10	25 mm Torx screw (10 provided)
5	M25 x 1.5 EMC cable gland (5 provided)
5	30-70 mm^2 high voltage cable with shielding, length depending on installing position
1	30-70mm^2 grounding cable, length depending on installing position
6	cable lug with M8 hole, size to match the size of the cables
5	shrink tube for the high voltage cables
1	low voltage signals cable with X1-connector
1	low voltage DC supply, voltage between 7-33 V
1	25mm Torx screwdriver
1	6mm T-handle
1	torque key with a turnkey head
1	30mm key to adapt the cable glands
1	cable skinning knife
1	crimping tool for cable lugs
1	Visedo Power Series Service Cable*
1	ratchet torque wrench fitting the hose clamps**

2.2 Liquid cooling

Hoses with 19 mm internal diameter fit to the ¾” inlet and outlet of the inverter. Use hose clamps or hose clips to compress the joints. Use water/glycol mixture with 50% or less glycol or pure water with corrosion inhibitor for the cooling of the inverter. The temperature of the coolant must be between -40 and +65 ºC, the coolant flow must be at least 10l/min and the maximum operating pressure for the cooling system is two bars. Always check that there are no air pockets in the cooling system (Visedo 2016a). Installed liquid cooling is shown in the Figure 2.1.

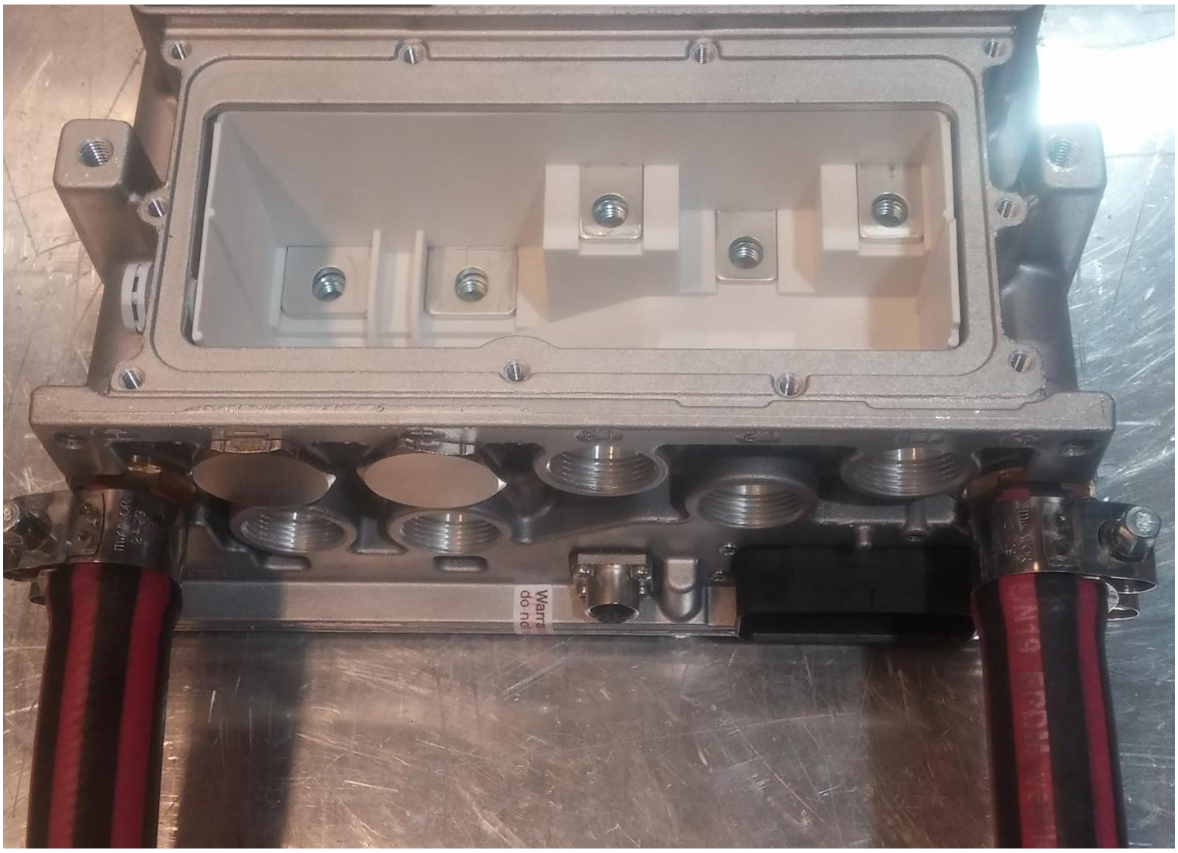

Figure 2.1 Liquid cooling installed on PowerMASTER inverter. Use hose clamps or clips to compress the joints.

2.3 Grounding

Next connect the inverter to the ground from a marked grounding point shown in the Figure 2.2 or from the frame of the inverter. Use grounding cable with inner cross-sectional area equal to the cross-sectional area of the high-voltage cables. Tighten the cable with M8 bolt, D8 washer and D8 spring washer with 15 Nm tightening torque as shown in the Figure 2.3. The best grounding level is achieved if the frame of the inverter is also directly connected to the ground. Grounding points must comply with national and local industrial safety regulations and/or electrical codes (Visedo 2016a).

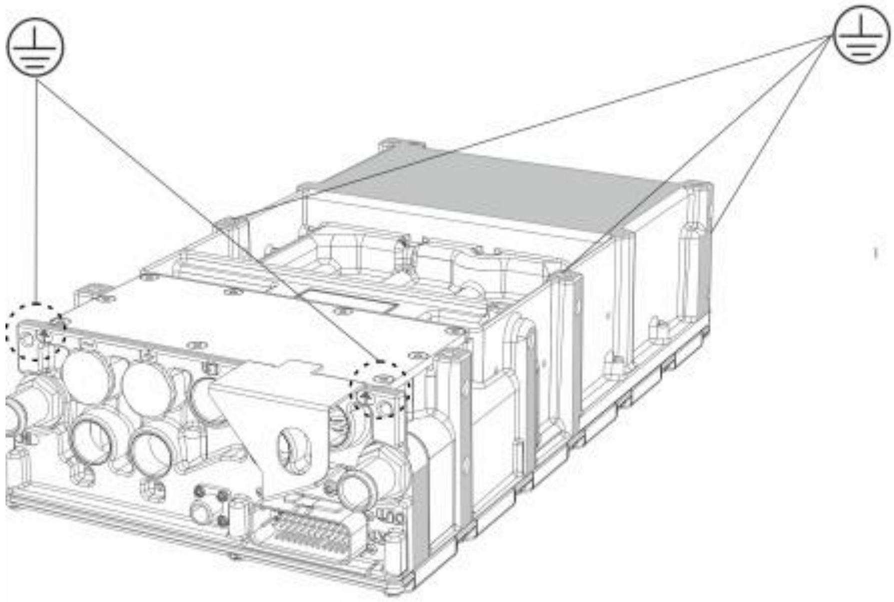

Figure 2.2 The grounding points of the PowerMASTER inverter. Connect the inverter to the ground from at least one grounding point to ensure good grounding level (Visedo 2016a).

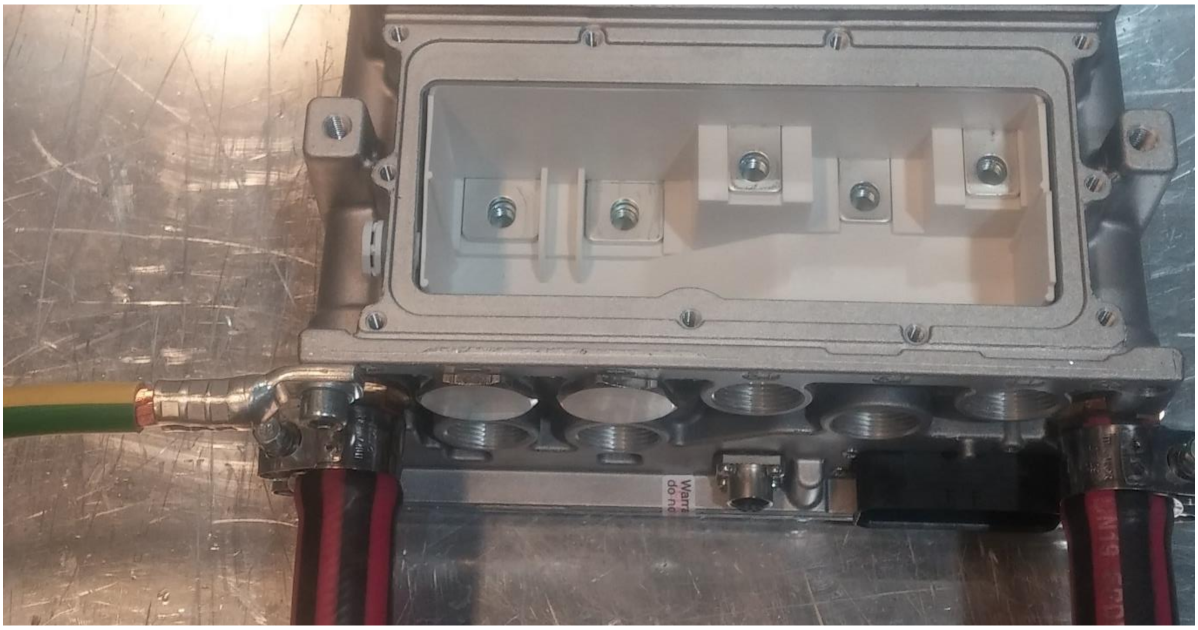

Figure 2.3 PowerMASTER inverter with grounding cable connected. The grounding cable must have at least the same inner cross-sectional area as the high-voltage cables. The inverter is also grounded through the metal base.

2.4 Connecting high-voltage cables

It is recommended to use IP67/68 rated, 360° shielded cable glands, such as the original EMC cable glands provided, and single core automotive rated screened cable, such as Radox Elastometer S, for high-voltage connections. The cross-sectional area of the copper cable can be 35mm^2, 50mm^2 or 70 mm^2 depending on the required maximum current. The cable lugs and the cable glands must be assembled according to the instructions. Always check that the cable lugs fit from the M25 holes of the inverter before making the cables. Cable shields must be connected to the ground also from the other end of the cables (Visedo 2016a).

First, remove the hexagonal piece from the BlueGlobe-sealing as shown in the Figure 2.4. If the cross-sectional area of the cable is $70mm^2$, remove also the inner piece of the rounded sealing inside the cable gland.

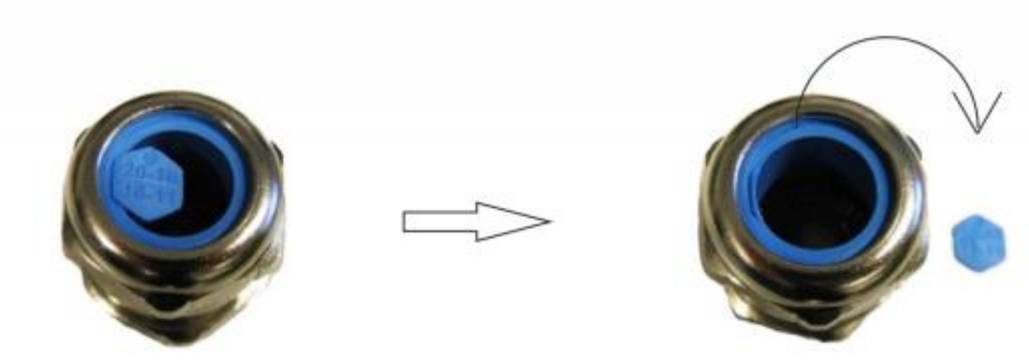

Figure 2.4 BlueGlobe cable gland used in the PowerMASTER inverter. Remove the hexagonal piece from the sealing (Visedo 2016a).

Cut the cable sheath at the distance of 60mm from the end of the cable. Pull the cut part of the sheath 10 to 15 mm so that braid screen is visible as shown in the Figure 2.5. Do not remove the cable sheath completely and do not cut the braid screen of the cable. If the inner sheath is damaged, or if the braid screen is notably damaged, cut the cable and repeat the process.

Figure 2.5 High-voltage cable with braid screen visible. Do not completely remove the cable sheath before the cable gland is installed (Visedo 2016a).

Insert the cable gland on the braid screen of the cable with slight turning motion and push the cable gland against the sheath of the cable. Next remove the cable sheath and cut the braid screen 10mm from the bottom of the cable gland as shown in the Figure 2.6.

Figure 2.6 High-voltage cable with cable gland installed. Push the cable gland against the sheath of the cable and cut the braid screen 10mm from the bottom of the cable gland (Visedo 2016a).

Cut a piece of the inner cable sheath from the end of the cable with same length as the body of the cable lug. Insert the cable inside the cable lug body and crimp the lug twice in different places as shown in the Figure 2.7.

Figure 2.7 High-voltage cable with the cable lug installed. Cut a piece of the inner cable sheath from the end of the cable with same length as the body of the cable lug, insert the lug and crimp it in two different places (Visedo 2016a).

Lastly cut a piece of shrink tube and shrink it over the cable. Shrink tube should be on the braid screen and on the cable lug as shown in the Figure 2.8.

Figure 2.8 High-voltage cable with shrink tube on the braid screen and on the cable lug (Visedo 2016a).

The high-voltage cable order in the PowerMASTER inverter is shown in the Figure 2.9. It is also indicated on the frame of the inverter.

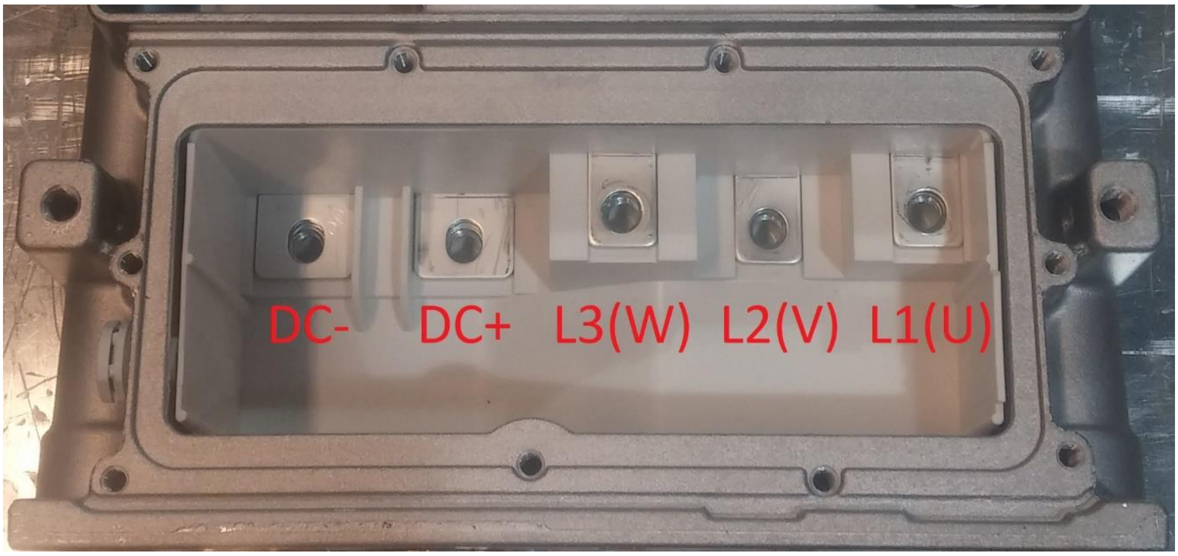

Figure 2.9 High-voltage cable order in PowerMASTER inverter.

First put the DC minus cable through the leftmost hole. Then connect the cable lug with M8 bolt to the left most place inside. Use both washer and spring washer to tighten the cable lug with light torque so that the cable can be still adjusted. Next install the cable gland. Attach the two shield parts together by rotating them and rotate them then to the inverter. Use a torque key with a turnkey head and a 30mm key to adapt the cable gland to tighten it up from the cap of the gland with 15 Nm torque. Then use 15 Nm torque to tighten the cable lug and make sure that the cable lug will not move to any direction. Put the DC plus cable through the hole next to the minus and connect it in the same way as the minus cable.

Next connect the three motor cables in the same way as the DC cables. Easiest way is to first connect the middle one and then the other two. Connect U to L1, V to L2 and W to L3. The correct cable order in the example case shown in the Figure 2.10 is DC-, DC+, W, V and U.

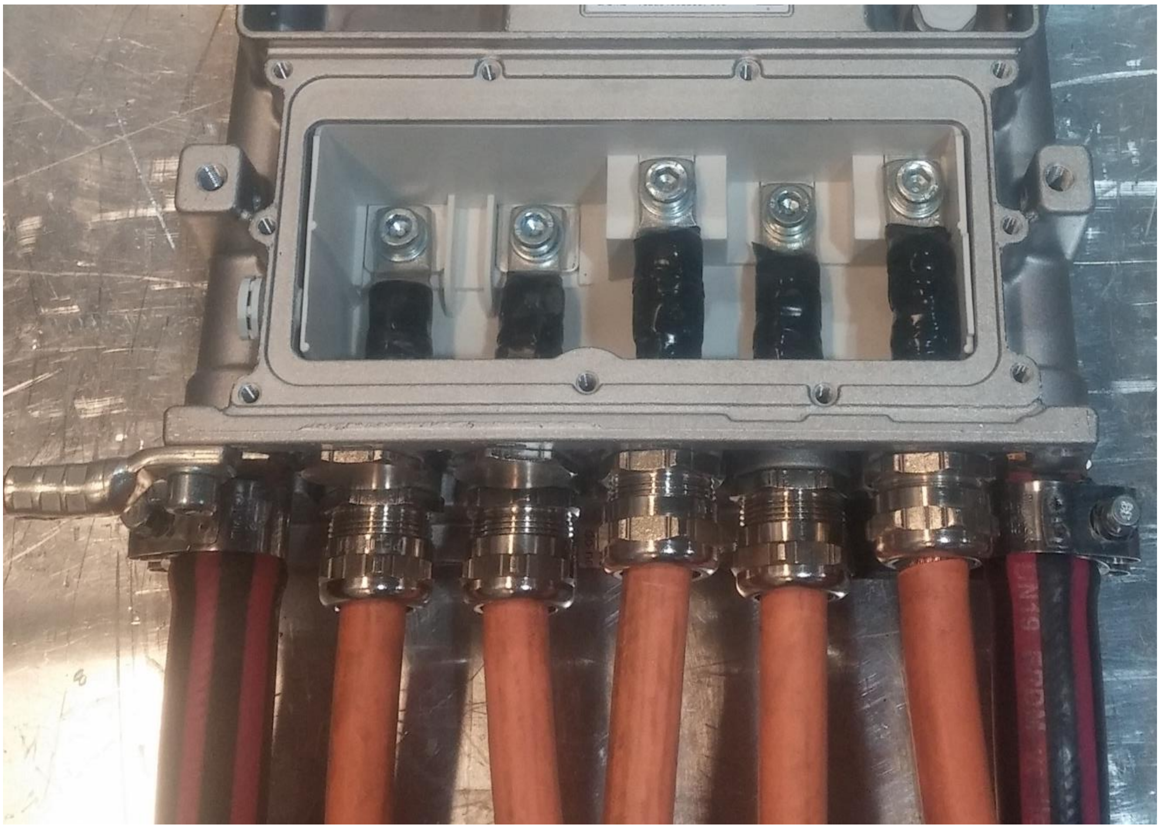

Figure 2.10 Tighten up high-voltage cables. The cable order from left to right: DC-, DC+, W, V and U.

2.5 Installing connection box lid

Seal all the unused cable inlets and insert the connection box lid. Use 25mm Torx screw-driver to install the lid with 10 Torx screws. Use 4 Nm tightening torque. The installed connection box lid can be seen in the Figure 2.11.

Figure 2.11 PowerMASTER with connection box lid installed. Use 10 Torx screws to install the lid and use 4 Nm tightening torque.

2.6 Connecting signal connectors

X1 is a low voltage control signal connection. The voltage range for the low voltage connections is from 7 to 33 V DC. The minimum pins that need to be connected in the connector to power the inverter are VIN_P (1), POWER_ON (2), #STOP_2 (3), VIN_N (13) and #STOP_1 (24). The numbers indicate the pin numbers of the connector. VIN_N is connected to DC- and other four are connected to DC+. If the inverter is controlled with controlled area network (CAN) software, also the CAN pins have to be connected. For CAN A connection, the pins are CANH_A (8), CANL_A (9) and GND_CAN_A (20) and for the CAN B CAN_H_B (32), CAN_L_B (33) and GND_CAN_B (21) (Visedo 2016a). More detailed information can be found from the product manual of the PowerMASTER M-frame inverter.

X1 connector can be inserted only in one way as there is a plastic connection lock on the other side of the connector. The lock can be seen in the Figure 2.12. Connect the X1 connector to the black connector on the right side of the connection end lock side up. As the X1 connector is completely connected, a click-sound can be heard from the connection lock. When removing the connector, first lift the connection lock of the connector up and then pull the connector out. Do not use excessive force when installing the connector.

Figure 2.12 The 35-pin X1 connector used in connecting PowerMASTER inverter for low voltage signal connection. The plastic locking system is on the top of the connector.

The maintenance connector interface uses a RS-485 connector and an USB connector to connect the inverter to a computer. The connector is needed if the inverter is controlled with serial connection. Use Visedo Power Series Service Cable (PSSC) to ensure reliable connection. The RS-485 connector can also be inserted only in one way, as there is a small overhang inside the connector. The overhang can be seen in the Figure 2.13. Insert the connector to the left side of the X1 connector. After the signal cable has been inserted in correct way, the metal part of the cable can be rotated to lock the signal cable into the inverter. Tighten the cable until the end of the spiral with light torque.

Figure 2.13 The RS-485 connector used in maintenance connector interface. It is used to connect a PowerMASTER inverter to a computer with serial connection. There is a small overhang inside the connector and a metal spiral on top of the connector.

The complete installation of the inverter is shown in the figure 2.14. Always check the connections before using the PowerMASTER inverter.

Figure 2.14 The complete installation of the PowerMASTER inverter without mounting the inverter.

3. CONTROLLING THE POWERMASTER INVERTER

After the PowerMASTER inverter had been installed, the actions that need to be done with PowerUSER application to get the motor running were showed by Antti Summanen, the commissioning engineer of Visedo. The actions were then repeated and documented step-by-step. Finally, PowerUSER was used to get the motor running. The controlling was also tested with CAN. Again, the instructions have been written so that they will guide the controlling process step-by-step.

PowerUSER is an application used for controlling and measuring all Visedo products. PowerUSER can be downloaded from the Visedo website.

3.1 Setting the safety limits in PowerUSER

After the inverter has been connected to the computer with the maintenance connector, select serial connection and the correct USB serial port from the Settings as shown in the Figure 3.1. If the inverter is connected with CAN, select CAN or use CAN software to control the inverter. The light in the bottom right corner starts to blink green and the text next to it changes to Serial or CAN Connection when the connection has been established.

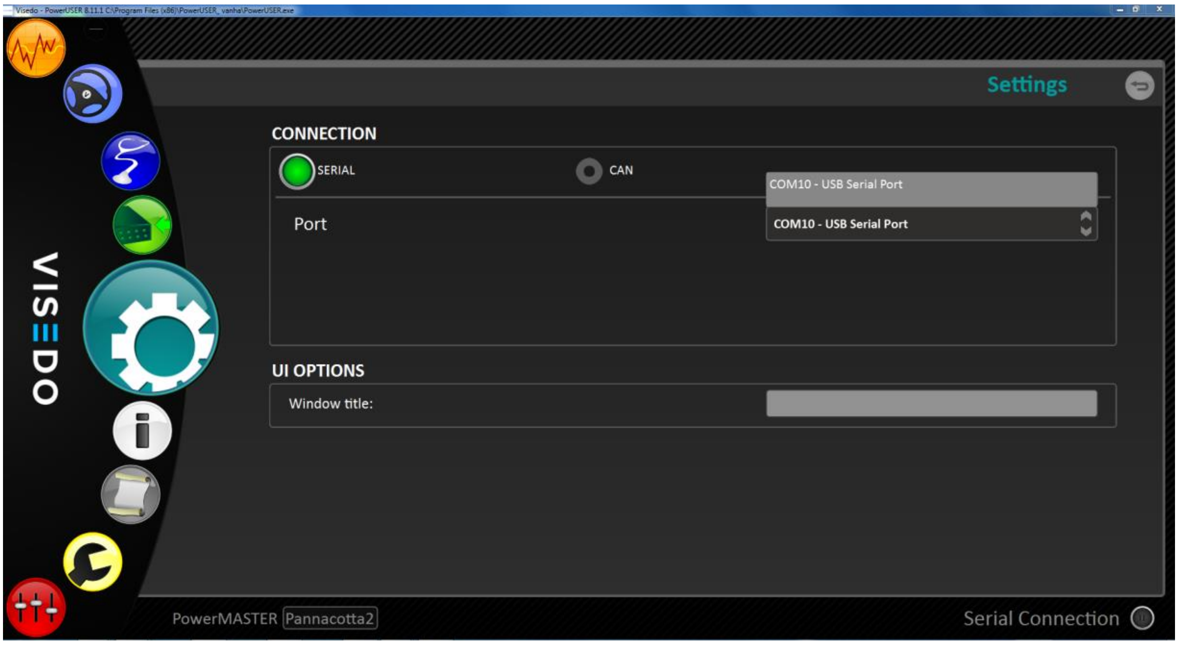

Figure 3.1 PowerUSER connection settings. Connection can be set up for example with serial or CAN connection.

Next step is to set the control position of the PowerMASTER inverter to local. From the Parameters menu, select powermaster_application and double click the control_position. From there, select 1 – Local as shown in the Figure 3.2. Now the inverter is controlled locally. The control mode of the motor can be changed below from control_mode when the control position is local. There are three control modes where to choose from: speed, torque and DC-voltage. For normal motor use choose speed control. If the motor is used as a generator with another motor, use torque or DC-voltage reference.

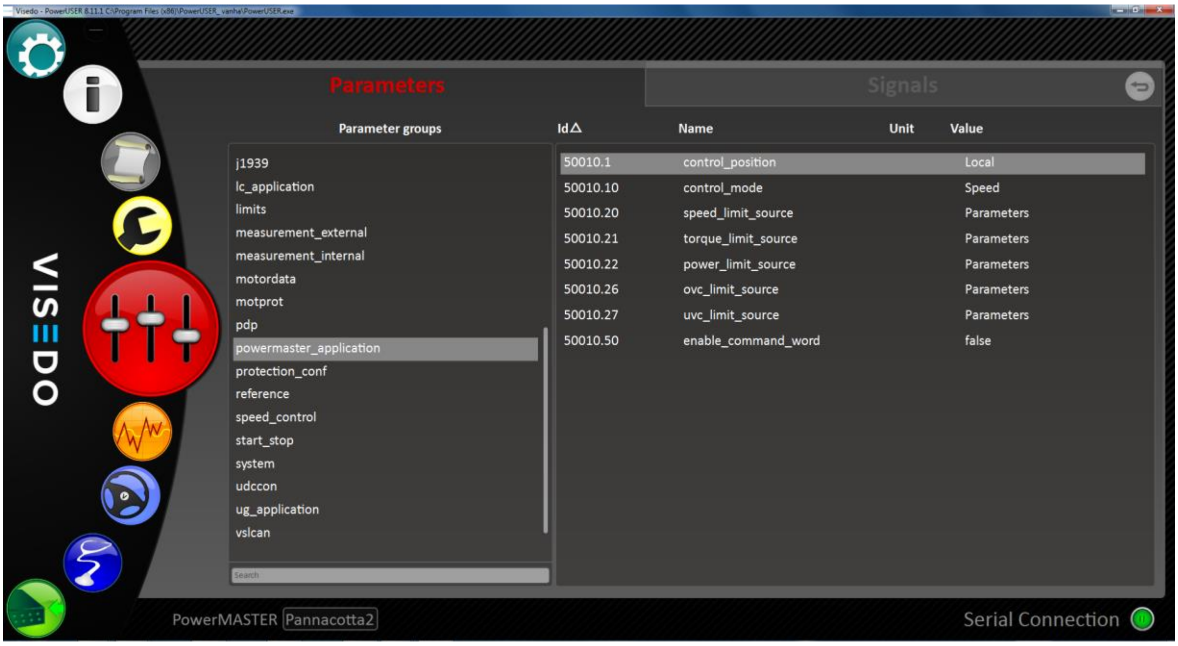

Figure 3.2 Control position and control mode parameters in PowerUSER. Use local as control position and speed as control mode.

After the control position has been chosen, parameter limits for safe use have to be set. Select limits from the parameters list shown in the Figure 3.3. Depending on the controlled motor and used inverter model the limits can be different. PowerMASTER inverter rated values depend on the model, for example nominal values for 300kW model are 48-850 V for DC voltage, 32-500 V for AC voltage, 0-580 Hz for frequency and 350 A for RMS current. These values can be found from the rating plate on top of the inverter as shown in the Figure 3.4. These values must not be exceeded.

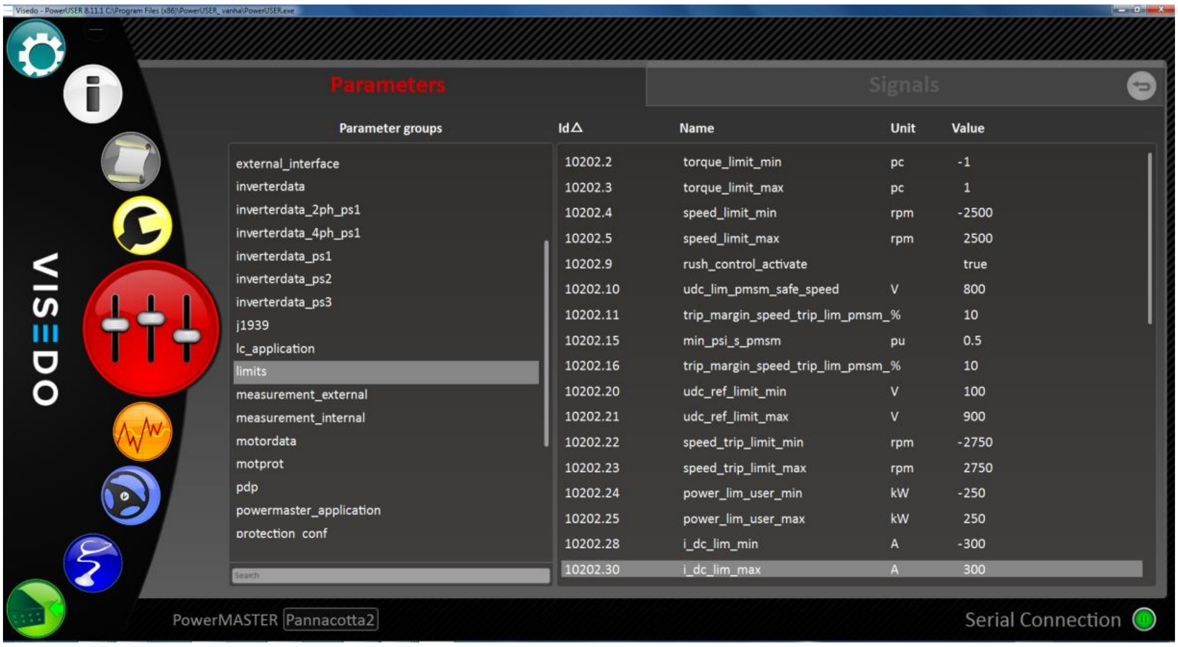

Figure 3.3 Limit parameters in PowerUSER. Always check the maximum values from the rating plates of the motor and inverter.

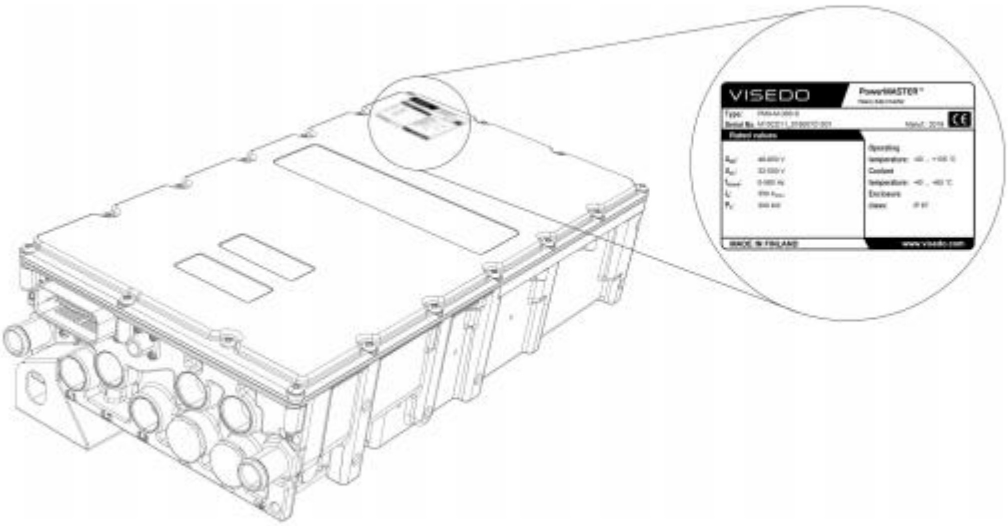

Figure 3.4 Rating plate placement in the PowerMASTER inverter. Do not exceed the rated values (Visedo 2016a).

Current limit can be for example 10000 A, so the Powerstage current limit is used instead. Torque limits torque_limit_min and torque_limit_max set the torque limit in pc-scale, where 1 means the nominal torque of the motor. For example, limits of -1 and 1 can be used so higher than nominal torque cannot be set as reference. Positive values rotate the motor clockwise and the negative values counterclockwise. Changing the cable order may change the rotating directions. Speed limits speed_limit_min and speed_limit_max should be set according to the highest desired motor rotating speed. The speed trip limits speed_trip_limit_min and speed_trip_limit_max can be set for example 10% higher than the speed limits. Also, the power limits power_lim_user_min and power_lim_user_max and the current limits i_dc_lim_min and i_dc_lim_max should be set to match safe values for the system.

3.2 Setting the motor parameters in PowerUSER

Select motordata on the Parameters list and change the motor parameters to match the controlled motor. From motor_type, set the motor type to Induction motor or to Permanent magnet synchronous motor. Insert the nominal voltage, frequency, speed, current, power and power factor of the controlled motor to the next six values. These values can be found from the rating plate of the motor. Motor manufacturers should be able to provide also the more specific values for the motor, such as im_rs for the induction motor. These values should be also checked and changed if possible. Depending on the used unit type, select Per units or SI-Values from parameter_units. This selects the used unit type, so only SI- or per unit values are needed. The motor parameters shown in the Figure 3.5 are set for 90kW PowerDRUM. The parameters must be set so that the inverter can control the motor as accurately as possible.

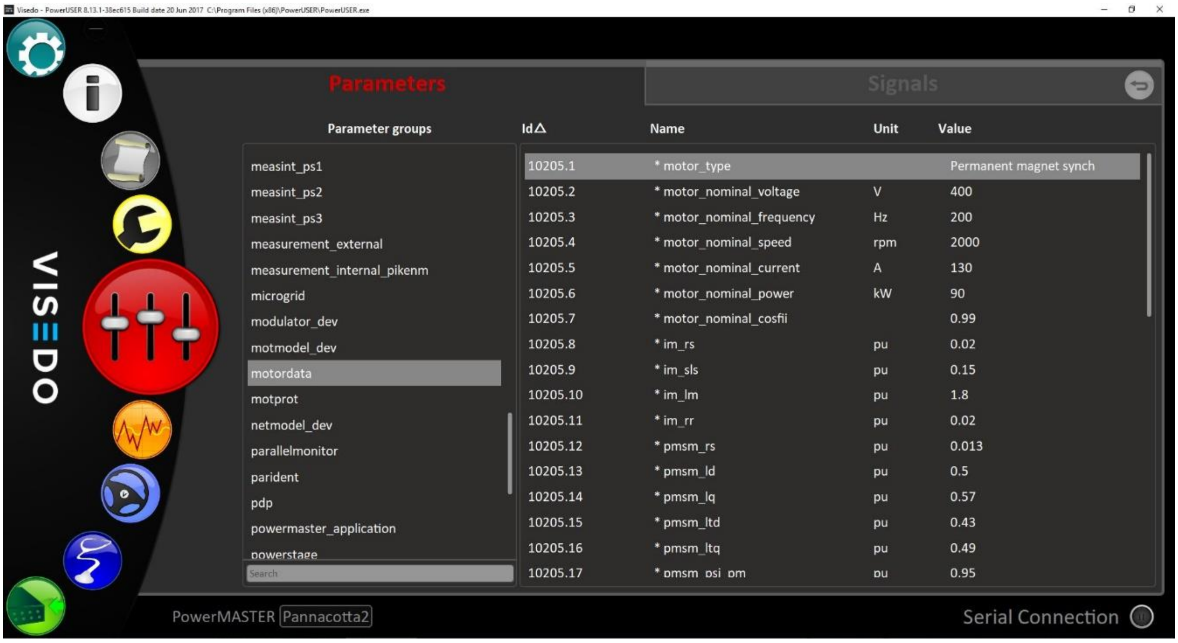

Figure 3.5 Motor parameters in PowerUSER. Change at least motor type and the first six motor parameters to be according to the rating plate of controlled motor. Change also the more specific values below if they are available.

3.3 Controlling the motor with PowerUSER

After the limits have been set go to Signals and select powermaster_application. Control mode can be changed also from here. Depending on the control mode PowerUSER will use speed, torque or DC voltage reference. Rotating direction can be changed by using positive or negative speed reference. When the reference value has been set motor can be started by changing run_command to true. The motor can be then stopped by changing run_command back to false as shown in the Figure 3.6.

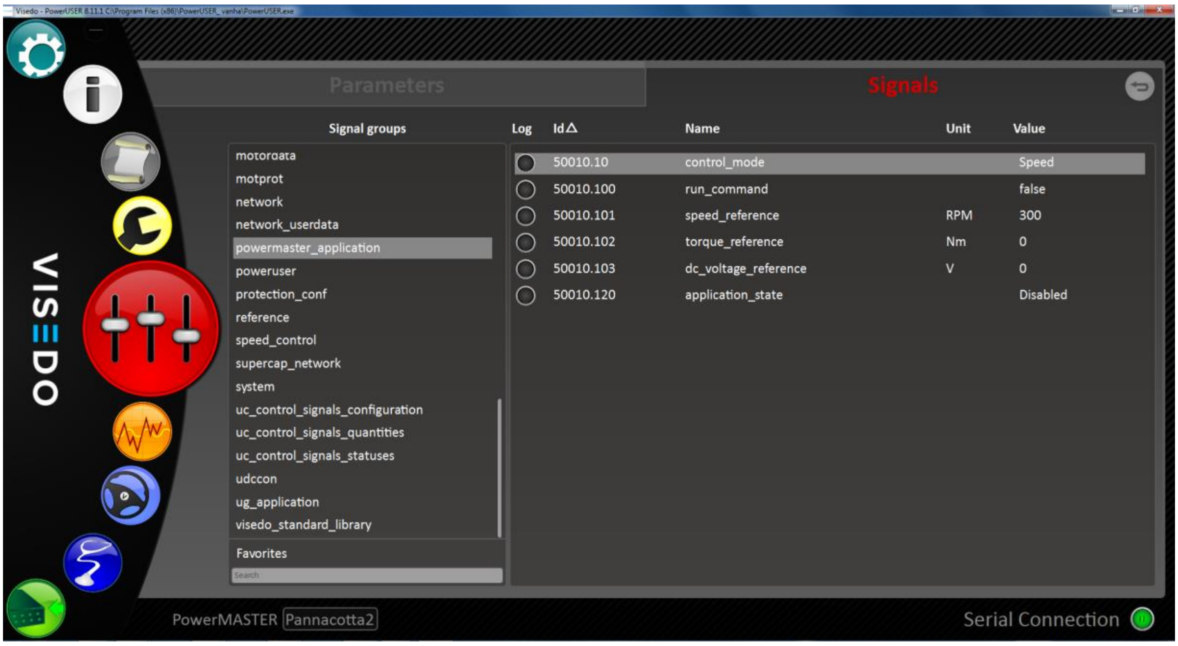

Figure 3.6 Reference signals in PowerUSER. Set the speed reference to speed_reference input. Motor can be started by changing run_command to true and stopped by changing it back to false.

3.4 Logging data with PowerUSER signal logger

The motor signals can be logged to the signal logger by clicking the black circle under the Log column in Signals menu. The circle turns yellow once the signal logger is active. The logger has to be started from the logger screen by clicking the green run button on the left bottom corner.

Several signals can be logged at the same time. All values that can be logged can be found from the Signals menu. Run command and reference values can be changed directly from the logger screen by double clicking them. They will then also change in Signals menu. Logged signals can also be taken away from the logging screen by clicking the green button next to the reference signals or by right-clicking the signal and choosing remove from logging. After the signal capture has been done it can be stopped by clicking the stop button from the right bottom corner of the signal logger as shown in the Figure 3.7.

Figure 3.7 Signal logger in PowerUSER application. Logger can be started by clicking run on the right bottom corner and stopped by clicking the same button. Logged data is from a motor start and a stop with 300 RPM reference speed.

3.5 Fault situations

If the motor trips and the application state becomes tripped, change run_command to false and check the error messages from the Faults as shown in the Figure 3.8. Red messages are faults and yellow messages are warnings. If there are red messages in the Faults, stop using the inverter and contact Visedo service for more information.

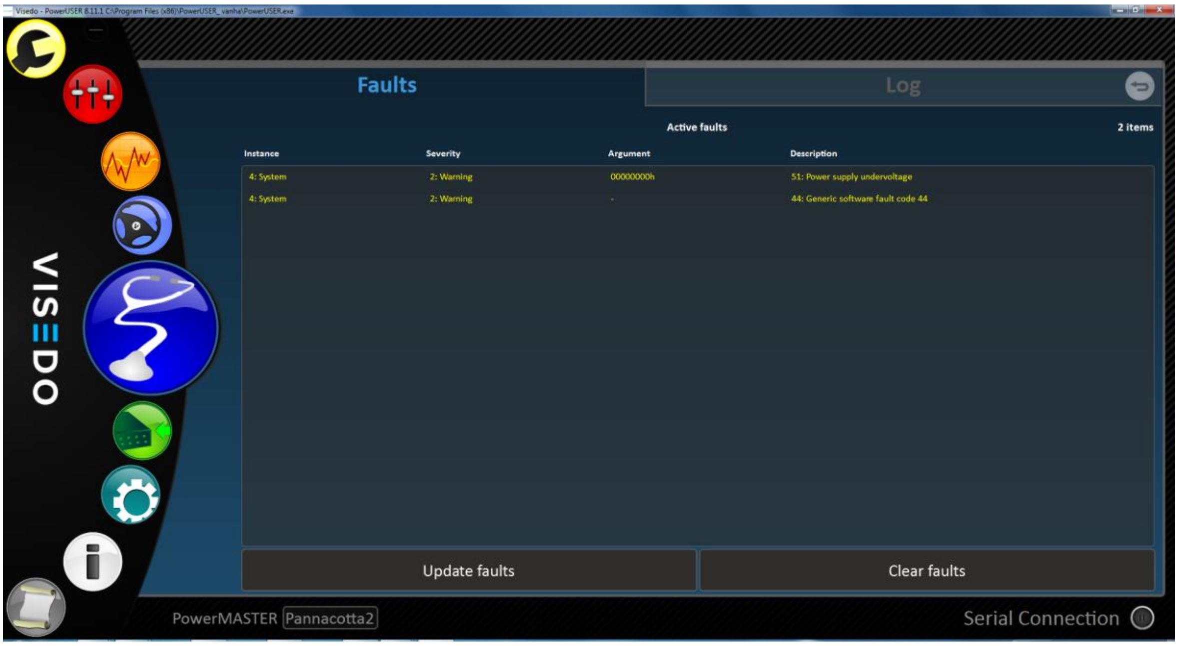

Figure 3.8 Fault list in PowerUSER application. Yellow messages are warnings and red messages are faults.

If the inverter needs to be rebooted, reboot the device from Firmware update screen shown in the Figure 3.9 by clicking reboot device and then reboot.

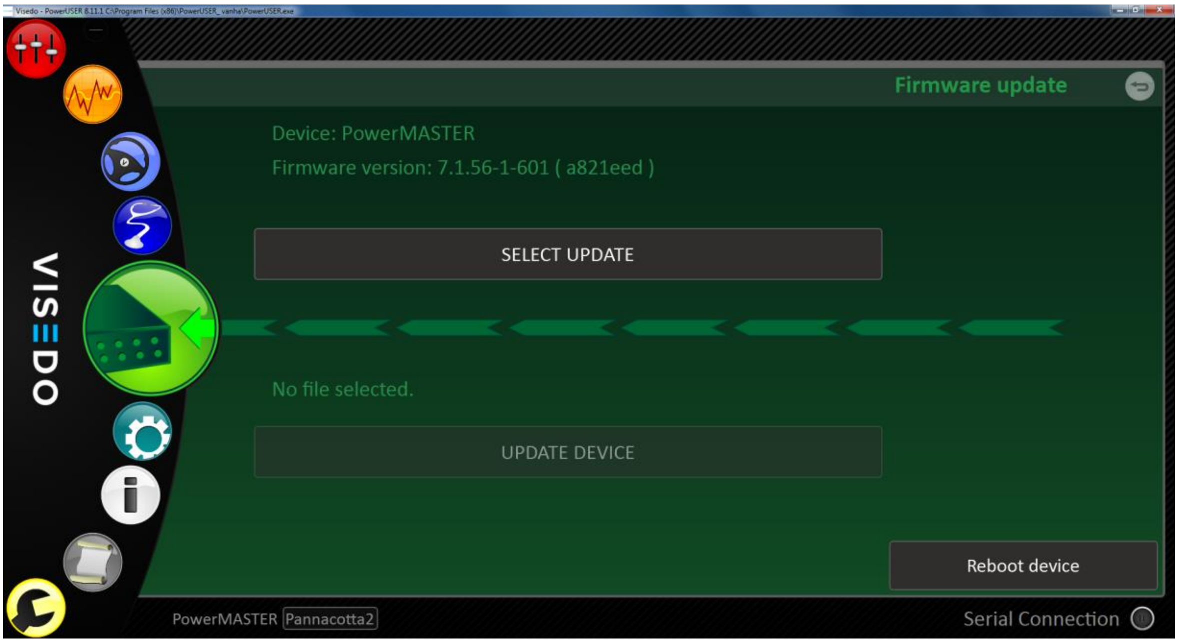

Figure 3.9 Firmware update screen in PowerUSER. The PowerMASTER can be rebooted by clicking the reboot device button and then clicking reboot.

3.6 Controlling the PowerMASTER without PowerUSER

The PowerMASTER inverter can also be controlled without PowerUSER with CAN messages. The inverter supports CANopen or SAE J1939 messages depending on the installed software. Next the inverter is controlled with J1939 messages, but the CANopen messages work in the same way, only the messages change. The used CAN software in this example is PCAN-View, but another CAN software would do as well. The default bit rate for the CAN is 250 kBit/s.

Depending on the input messages, the ID, the data and the cycle time of the message change. The transmit message window in PCAN view can be seen in the figure 3.10. The ID consists the priority of the message, a parameter group number (PGN) and the address of the management computer. The priority is 0C in all messages sent to PowerMASTER, the PGN varies depending on the command and the address is 27 as default. The order for these is always the same, first the priority, next the PGN and then the address. The cycle time and the data also depends on the command. The cycle time has to be shorter than the timeout time given.

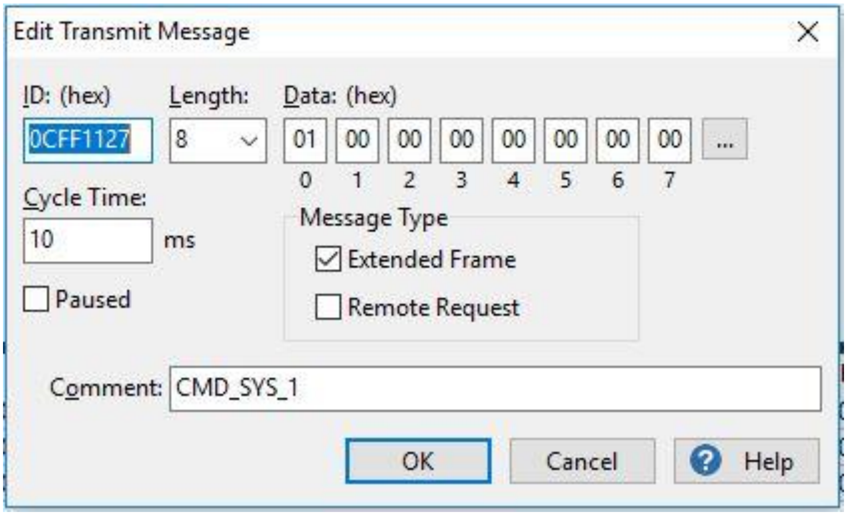

Figure 3.10 Transmit message edit window in PCAN-View software. ID consists the priority, the PGN and the source of the message. Cycle time has to be shorter than the timeout time.

CMD_SYS_1 is a message that contains two functions. First two functional bits are for resetting the fault messages and the second two are for enabling the motor control. The motor control can be enabled by switching the bits from 00 to 01 and vice versa. The fault reset works in the same way, so faults can be cleared by changing the bits from 00 to 01. The data in the message has to be in hexadecimal format, so the data has to be converted. The binary data used in the PowerMASTER control consists always eight digits, first bits are zeroes if all bits have not been used. As there are four unused bits in the CMD_SYS_1, the first four bits are 0000. The binary message 0000 0001 can be converted to hexadecimal message 01 for example by using binary hex converters. The data can be then inserted to the PCAN-View as shown in the figure 3.10. As the timeout for this message is 50 ms, 10 ms cycle time has been used. By sending the message the motor control is enabled and run_enable is changed to true as shown in the figure 3.11. The changes apply to the network signal group in PowerUSER.

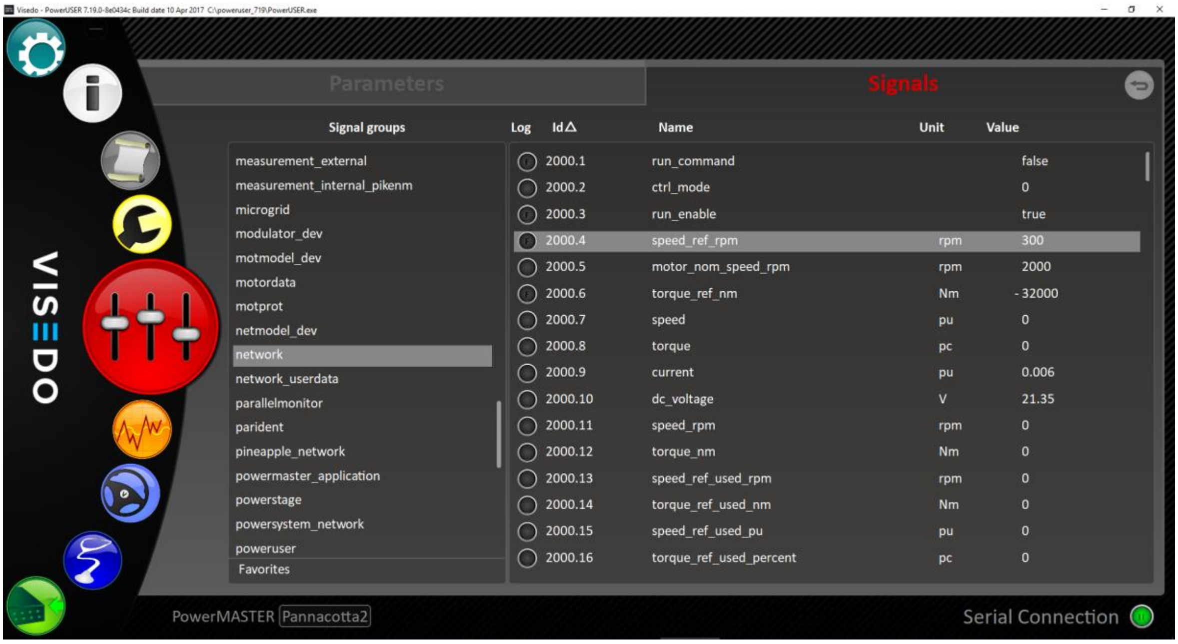

Figure 3.11 Network Signal group in PowerUSER. As SAE J1939 message has been sent, run_enable has changed to true.

The next needed message is CMD_MOT_1. Now the PGN is FF21 and the priority, timeout and source remain the same. CMD_MOT_1 uses six bits, first two for the run command of the motor and the last four are for the control mode of the motor. Speed control can be selected with 00, motor torque control with 01 and DC-Link voltage control with 02. The motor run command can be changed on with 01 and off with 00. Again, the bits have to be converted to hexadecimal data. If the motor run command is enabled and the control mode is speed, the message in binary format is 0001 0000 and in hexadecimal format 10.

The last message needed to get the motor running is CMD_MOT_2. PGN for it is FF22, timeout is 500ms and other data remains the same. Now there are 16 bits for four different reference values. First 16 are for the speed reference, the next 16 are for the torque reference, the next 16 for DC-link voltage reference and the last 16 for the power reference. There are different factors, minimum values and maximum values for all these reference types. For the speed control, the factor is 0.5, the minimum value is -16064 RPM and the maximum value 16064 RPM. Now, the input data in decimal format can be calculated with following formula:

$$R_{dec} = \frac{(R_{act} - V_{min})}{f}, \tag{3.1}$$

where R_{dec} means the reference message in decimal format, R_{act} means the actual reference, V_{min} means the minimum value for the reference and f means the factor. Now, if the speed reference value is 300 RPM, the reference message in decimal is 32 728 by using equation (3.1). In hexadecimal format, this is 7F D8. When sending the data to PowerMASTER, the hexadecimals have to be inverted to be D8 7F as the bytes of one reference value are sent in inverted order. All the messages above can be seen in the figure 3.12.

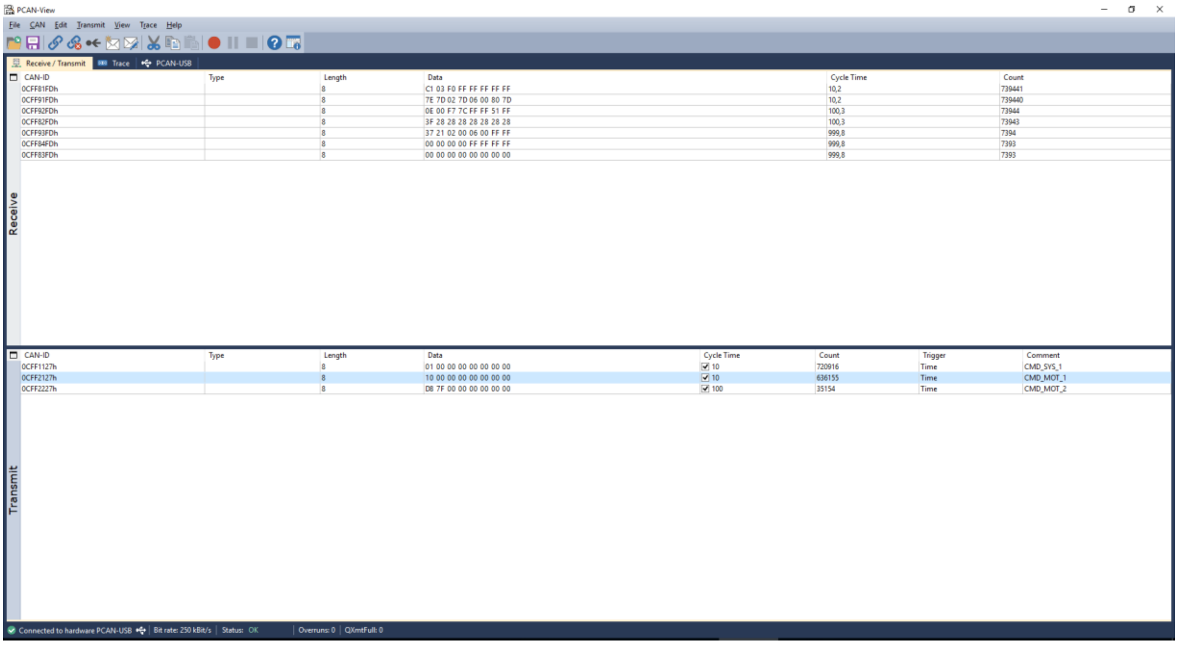

Figure 3.12 Receive and transmit message window in PCAN-View. The three sent messages are in the Transmit category.

As can be seen from the transmit messages in the figure 3.12, the speed reference has been chosen as the reference type and it has been set to 300 RPM, motor control has been enabled and run command has been changed to true. Now, in the PowerUSER these changes can be seen in the Network Signal group as shown in the figure 3.13. As the inverter unit was not connected to the motor at this point, the measured values shown in the figure 3.13 should be ignored.

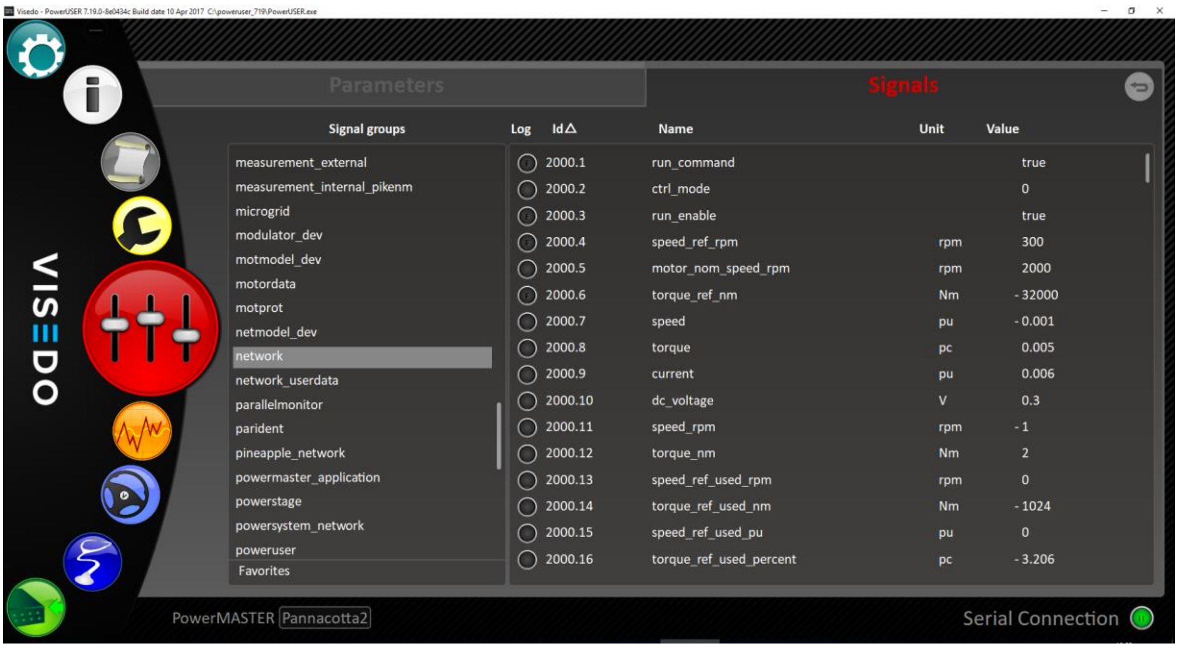

Figure 3.13 Network Signal group after CMD_SYS_1, CMD_MOT_1 and CMD_MOT_2 messages have been sent. Inverter tries to drive the motor with 300 RPM reference speed. The motor is not connected so the measured data should be ignored.

Also for example speed limits can be set with CAN messages in the same formula. All the messages can be found from the PowerMASTER communication manual. In addition, the CANopen messages can be found there.

4. CONCLUSION

The PowerMASTER inverter was installed and it was used to control an electric motor. The installation and use were completely documented, but some of the documentation had to be redone later to achieve better usability for the manual. Basics for CAN controlling were also added later as CAN is used by many customers for controlling the inverter.

The manual achieved good usability level as targeted. The step-by-step style was right choice for this type of manual and purpose. Answers were found to all the research questions thanks to the research style and help from the experienced engineers. Only time will tell if this manual can help most of the customers to use their devices or not. All-in-all it can be said that the research was successful and it achieved the set targets. Even though this manual was targeted for customer use, it can also be used in the training of the new engineers at Visedo.

The next steps to develop the quick start manual would be the addition of microgrid controlling and active front end use. Also, more specific guide for generator use could be added. From the installation side, smart mounting of the inverter would be one of the useful things to add. In addition, using multiple inverters at the same time and using the inverter in more complicated setups would be good to add not only for the customers, but also for new engineers at Visedo.

This manual was however aimed to be a quick start manual, so adding too much content would possibly reduce the usability of the manual. At the moment, the usability of the manual is probably close to the maximum. The additional things should be therefore added to a separate manual concentrated in controlling the inverter, for instance.

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