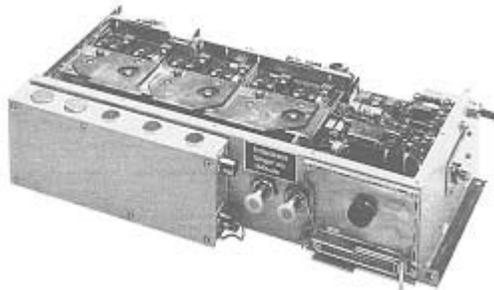
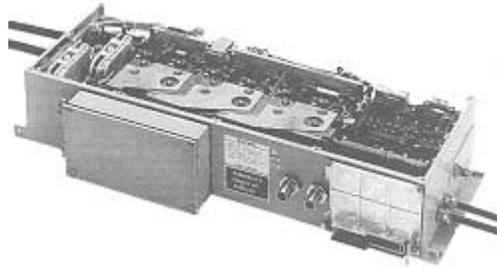


SIEMENS POWER INVERTERS

INSTALLATION MANUAL



SIEMENS POWER INVERTERS
Installation Manual

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METRIC MIND Engineering

Rev. 3.00w Feb 11 '2004
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The power inverters described in this
manual
are the product of Automobiltechnik
Division of
Siemens Corporation, Germany

Manufactured in Germany

Metric Mind Engineering
10645 SE Malden Street
Portland, OR 97266
(503) 680-0026

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Definition of "Caution" and "Warning" in this manual



(Caution) - designates potential danger to your hardware



(Warning) - designates potential danger to YOU



Even partially charged battery packs possess more energy than you may realize and may be lethal. Exercise extreme caution when working around any live circuit. As a general a rule of thumb, in dry environments voltage exceeding 36 volts may shock you. Higher voltage electric shock can cause burns, loss of breathing functions and consciousness, resulting in loss of balance, injury and possible death. Avoid working alone around high voltage circuits. Pay close attention to metal tools (non insulated wrenches or screwdrivers) while working on battery terminals. Dropping such a tool and shorting a string of batteries will result in sparks and possibly molten lead splatter, and can cause severe burns.

Some models of Siemens inverters and especially AC motors are heavy. Take precaution lifting them to avoid back or foot injury. Use of a hydraulic hoist, jacks, pulleys or another person's assistance is recommended for lifting them. Testing an unsecured motor may result in its sudden move and serious injury due to the high torque impact on the motor's case. For testing purposes always securely mount the base of the motor to a massive stationary surface.

Wherever in this manual a DC-DC converter mentioned, it applies to Simovert 6SV1 long or short inverter models only. Simotion model does not have integrated DC-DC converter.



Improper connection of the components and the use of the inverter for anything other than intended purpose may permanently damage internal circuitry and void your warranty. Never connect or disconnect any interface cables while system is running, i.e. ignition switch is in "ON" position and main contactors are closed. For Simovert 6SV1 models: never disconnect negative terminal of auxiliary 12V battery from the negative output of DC-DC converter (M6 bolt marked KL 31 on the metal case) while any power source including power from a PC through RS232C interface cable is applied. Always connect negative terminal of auxiliary 12V battery **directly, with dedicated 10mm² wire** to the KL31 terminal first and disconnect last. Avoid using any point on metal case as negative output of DC-DC converter, use M6 bolt specifically intended for this purpose. **Switching inverter off while -12V terminal of auxiliary battery is disconnected or makes poor contact to the KL-31 ground terminal WILL cause damage of inverter's interface board. Beware that this kind of damage is NOT covered by warranty repair, and lead-time to obtain spare interface board may be several weeks to several month.**

1 BRIEF THEORY OF OPERATION

1.1 The principle of the AC motor operation.

Following few sentences will very briefly describe the concept how an AC motor works. It is not intent of this manual to unveil full theory of its operation. Main focus will be on the inverter side. An AC induction motors require 3 phase sine wave voltage applied to the stator windings. For smooth operation each phase is 120° apart from the other two, and since windings are physically placed around in groups also 120° apart, the magnetic field generated by the windings can be seen as rotating around. The groups of windings are called "poles" and the same phase is applied to every winding belonging to the same group. The rotor usually is squirrel cage type having aluminum "turns" shorted at the ends so when the magnetic field crosses it, the current in the rotor turns induced. Magnetic field generated by this current reacts with rotating stator field, and the rotor starts rotate with some "electrical slip" (slower than the stator field for loaded motor). For an EV variable motor speeds and torque are necessary, so the task of the inverter is to generate variable (per driver demand) frequency and amplitude 3 phase voltage. The for accelerating, the frequency must be ahead of actual rotor speed, but only by as much as desired electrical slip at this moment allow. Therefore there are means to detect the actual rotor speed and feed this information (among other parameters) to the inverter. Inverter's software takes care of tracking all the input parameters and generates its output sine waves accordingly.

1.2 Sine wave synthesis.

Pure sine wave is analog signal, and inverter is digital piece of electronics. Therefore the sine wave generated (synthesized) by it is an approximation of the real sine wave shape. Each phase sine wave is synthesized using Pulse Width Modulation technique. The voltages are changing from zero to the maximum with variable duty cycles, but the current through the motor windings cannot change instantaneously, thus averaging the value over time. In the first approximation on fig.1 below the current at any instant is proportional to the average voltage within period "t", which, in turn is proportional to the duty cycle. Note that the period "t" between every pulse is the same, regardless of the pulse width. The frequency of these "carrier" pulses is about 6 kHz, and this is what can be heard from the motor at any speed. At higher sine wave frequency it takes fewer pulses to form the sine wave shape and resulting average "sine" wave become "jagged", more and more deviating from the sine shape and approximate the square one. This means more and more higher harmonics are present, which do not contribute to the mechanical torque generation. Therefore efficiency at these frequencies is lower and more energy is dissipated in the stator windings as heat. This also explains why the higher voltage - the better efficiency: aside resistive losses, at lower voltage to keep the current (thus the torque) the same, the pulses must be wider.

However at high current demands if they are already as wide as can be, adjacent pulses at the peaks will merge sooner, therefore with lower input voltage fewer pulses are available to form nice sine wave shape (more wasteful harmonics will be generated). On the picture below, to illustrate the point for simplicity only few pulses per one sine wave are shown.

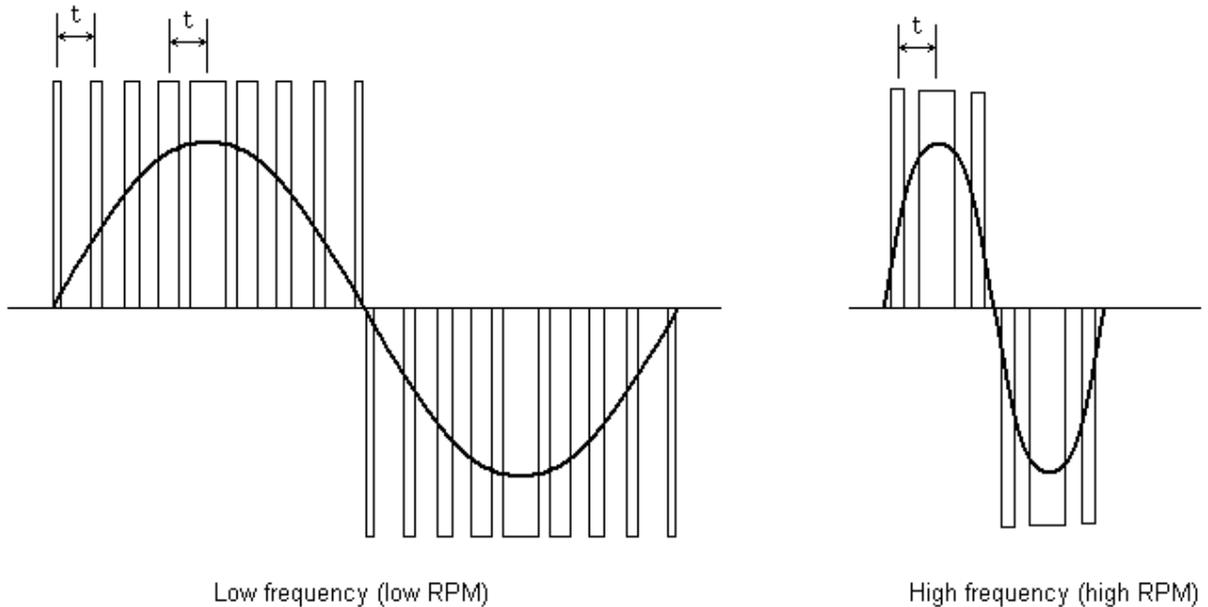


Fig.1

Simovert 6SV1 inverters are capable of synthesizing sine wave in 0.7...400 Hz range, which corresponds to max 12,000 RPM (no slip) for 4 pole motors. Granted, the motors themselves may impose additional mechanical limitations. Therefore, given the choice, it is advisable to run the motors at lowest RPM (tallest gear) provided the torque at the wheels is adequate for given driving conditions. The higher system voltage - the more advantage of doing so. This also prolongs the life of the shaft ball bearings and reduces losses in the gearbox. While it may be possible to cruise at 55 mph on the first gear at 10,000 rpm, the gearbox will become extremely hot and may fail prematurely, not to mention wasting to heat precious amp-hours stored in onboard battery. However, without low gears hill-climbing ability is greatly reduced. Also, on tall gears and very low motor RPM, motor current (and so its thermal losses) are higher to keep the same mechanical power, so there must be a balance. Monitoring battery current, voltage and power with provided software while cruising on different gears helps to find optimal gearing for given driving conditions.

2 INVERTER FEATURES

2.1 Main electrical specifications and options

Main Specifications

Parameter	Range or Value
Type	Three phase AC
Input DC voltage	110...350 VDC nom, 380V max
Input DC current	282 A max
Output AC current max	400 A peak (282 A rms)
Power stage insulation resistance	>400 kΩ
Regenerative braking	Yes
Programmable parameters	Yes
Integrated DC-DC converter output	60A continuous (90A for 3 min)
Cooling	Liquid (water or up to 1:1 ethylene glycol solution only)

List of implemented main features.

Implemented feature or function	User programmable?
Traction battery over charge / discharge protection	Yes, under- (driving) and over voltage (regen) limits
"Economy" power saving mode	Yes, with throttle potentiometer switch override
Cooling fan on / off temperature	Yes, both limits
Output current limit	Yes
Acceleration potentiometer (non)linearity and limits	Yes, software definable
Motor windings max temperature	No, implemented in hardware/firmware
Max motor shaft rotation speed	Yes, CW and CCW separately
Regenerative braking current	Yes, 2 modes
Motor current	Yes, drive and regen current limits individually
Overload protection	No, implemented in hardware/firmware
Thermal protection	No, implemented in hardware/firmware
Integrated DC-DC converter output current	No, hardware predefined, short circuit proof
Motor shaft rotation speed output signal	Yes, software scalable to match tach input
Start up self test	No, implemented in hardware/firmware
Fault indication	No, implemented in hardware/firmware
Start up lamp test	No, implemented in hardware/firmware
Default CW / CCW select	Yes
Forward / reverse select	Yes, by switch on the dash panel
Inverter Input over / under voltage protection	No, implemented in hardware/firmware
Accelerator pedal / Brake pedal priority	Yes, software definable
Start inhibit	Yes, 2 modes, by external contact or switch if enabled
Adaptation of drive characteristics to the motor or vehicle speed	Yes, software selectable
Intelligent drive start (pre-condition check and memorizing)	No, implemented in hardware/firmware
Emergency power off	No, implemented in hardware/firmware
Main contactors DC arcing suppression*	Magnetic arc suppressors
Dynamically displaying parameters on a PC in real time	Yes, available

*For lower power 1PV5105WS12 motors Kilovac EV200 contactors are used. These have no magnetic arc suppressors.

Main EV specific features

FOLLOWING FAILURES ARE DETECTED	MAIN CONTACTORS OPEN WHEN DETECTED?
Over voltage	Yes
Over current	Yes
Over temperature in the motor winding	Yes
Over temperature of the heat sink of the inverter or DC-DC converter	Yes
One or both motor winding temperature sensors failure	No
One heat sink temperature sensor failure	No
Both heat sink temperature sensors failure	Yes
Acceleration pedal cable failure	Yes
Braking pedal cable failure	No
Simultaneous selection of forward and reverse drive direction	No
Main contactors failure	Yes
Precharging circuitry failure	Yes
Power IGBT failure	Yes
Power supply driver board failure	Yes
Power supply failure	Yes
Current sensor failure	Yes
MPU failure (watchdog, check sum)	Yes
DC-DC converter failure	No

The difference between different models of inverter

Model	Simovvert 6SV Long	Simovvert 6SV Short	Simotion
Integrated DC-DC converter	Yes	Yes	No
Integrated main contactors	Yes	No	No

The power stage of the inverter is electrically isolated from the logic and control stage. (Isolation is factory tested at 1,5 kV). For this reason traction battery terminals and related instrumentation have to be isolated from the vehicle body. The metal housing of the inverter (also being negative DC-DC converter output) must be connected to the vehicle body (ground). This is achieved by connecting the M6 bolt (near DC-DC converter's positive output cable marked with kl.30) to the vehicle ground. Also the motor case has to be connected to the vehicle body.

2.2 Distinctive features

2.2.1 Forward/reverse operation

During operation three-phase AC current is generated and applied to the induction motor. Initial forward motor rotation direction is set through a programmable bit in the control register and stored in non-volatile memory. Forward and Reverse rotation direction is accomplished by switching two inverter control inputs (respectively FORWARD and REVERSE) to ground. There is no FORWARD or REVERSE rotation direction specific to the motor, so either CW or CCW shaft rotation direction can be chosen for FORWARD movement of the vehicle, and both work equally well.

2.2.2 Programmability of limit parameters

Many inverter parameters can be stored in internal memory (EEPROM) to define the limits of operation. These parameters include min/max input voltage (DC), max motor current (AC), max DC current (drive and regen current separately), max rotor speed, operating temperature limit and others. The default values usually satisfy the majority of applications, however most parameters may be read and changed via RS232 serial port, which also is used for diagnostic purposes.

2.2.3 Regenerative braking

All Siemens inverters are regenerative braking type, converting AC current generated by the motor to DC current for charging the traction battery. Braking action is initiated by applying +12V control signal to designated inverter's input. Brake lights switch is a convenient point to obtain this signal. Normally braking action is a two-step process. When the accelerator pedal is released, the inverter turns the AC motor into a generator with preprogrammed braking current (off-throttle regen). This action is similar to the exhaust braking action of an internal combustion engine. When the brake pedal is slightly depressed (so that brake lights come on, so +12V control signal is available, but mechanical disk brakes are not engaged yet), the inverter increases regenerative braking current to a new predefined value, increasing vehicle slow down rate, and thus wasting no kinetic energy. Further depressing the brake pedal won't affect the charging current as the regular braking action of the mechanical brakes takes place. There is an option to install a potentiometer on the brake pedal (similar to an accelerator potentiometer) to gradually increase brake current for finer control. This requires modification of the existing braking system to allow certain free pedal travel before the mechanical brakes are engaged, and unless done professionally, generally is not recommended.

2.2.4 Cooling

All Siemens inverters are water-cooled. This allows reduced inverter size and weight (no bulky heat dissipating fins needed) as well as elimination of the cooling fan noise and as well as waste of energy otherwise needed to run it. The existing vehicle cooling system can be used and small electric water pump is fitted to circulate water.

It is not necessary to run cooling water through the inverter for quick functionality checks. For Simovert inverters the fitting closer to the motor terminals cover is coolant inlet, and closer to X1 interface connector is coolant outlet. If external temperatures are expected to fall below 0°C (32°F), up to 1:1 mixture of ethylene glycol and water should be used only. Although due to high efficiency of the system heat output will not be nearly as much as from the internal combustion

engine, the coolant nevertheless can be routed through existing heater core to warm the cabin or used to warm the batteries (lead acid), further increasing overall efficiency of the energy use.

2.2.5 Thermal protection

Siemens inverters have built-in internal overheat protection circuitry and temperature sensors provided. However, for a long, reliable lifetime and the prevention of possible premature inverter failure, the recommended minimum flow rate should be sustained during operation.

2.2.6 Junction break-out box

To facilitate diagnostics and troubleshooting, a junction breakout box is provided. This box also contains the fuse for the inverter's logic and control circuits 12V power supply. One end of the harness cable ends with X1 female connector. The other end is split to two branches: one for connection of signal lamps, switches and controls on the dash panel, and the other for connecting acceleration (and optionally braking) potentiometer.

3 QUICK FUNCTIONALITY VERIFICATION ON THE BENCH

Upon arrival a test is recommended to insure functionality of the system. Wiring hook up depends on the inverter model and is described below. All systems are verified before shipment and all necessary components except the batteries are included. Acceleration potentiometer is fitted with temporary Molex connector suitable for testing, but this connector should not be used in a vehicle – the throttle potentiometer leads must be soldered and connections insulated to keep the moisture out. You will need only a main battery pack with 144VDC or more, and one separate 12VDC auxiliary battery. The "ignition" switch, rotation direction switch, "Start" pushbutton The main pack for testing purposes does not have to be consisted of high the capacity batteries, 6Ah...10Ah batteries string would be adequate.

Wiring hook up depends on the inverter model and is shown on the fig.2 (Simovert 6SV1 long and short inverter) and fig.3 (Simotion inverter).

3.1 Bench testing wiring hook up for Simovert 6SV1 long and short models.

Fig. 2. Bench testing wiring hook up (Simovert 6SV1 long inverter shown).

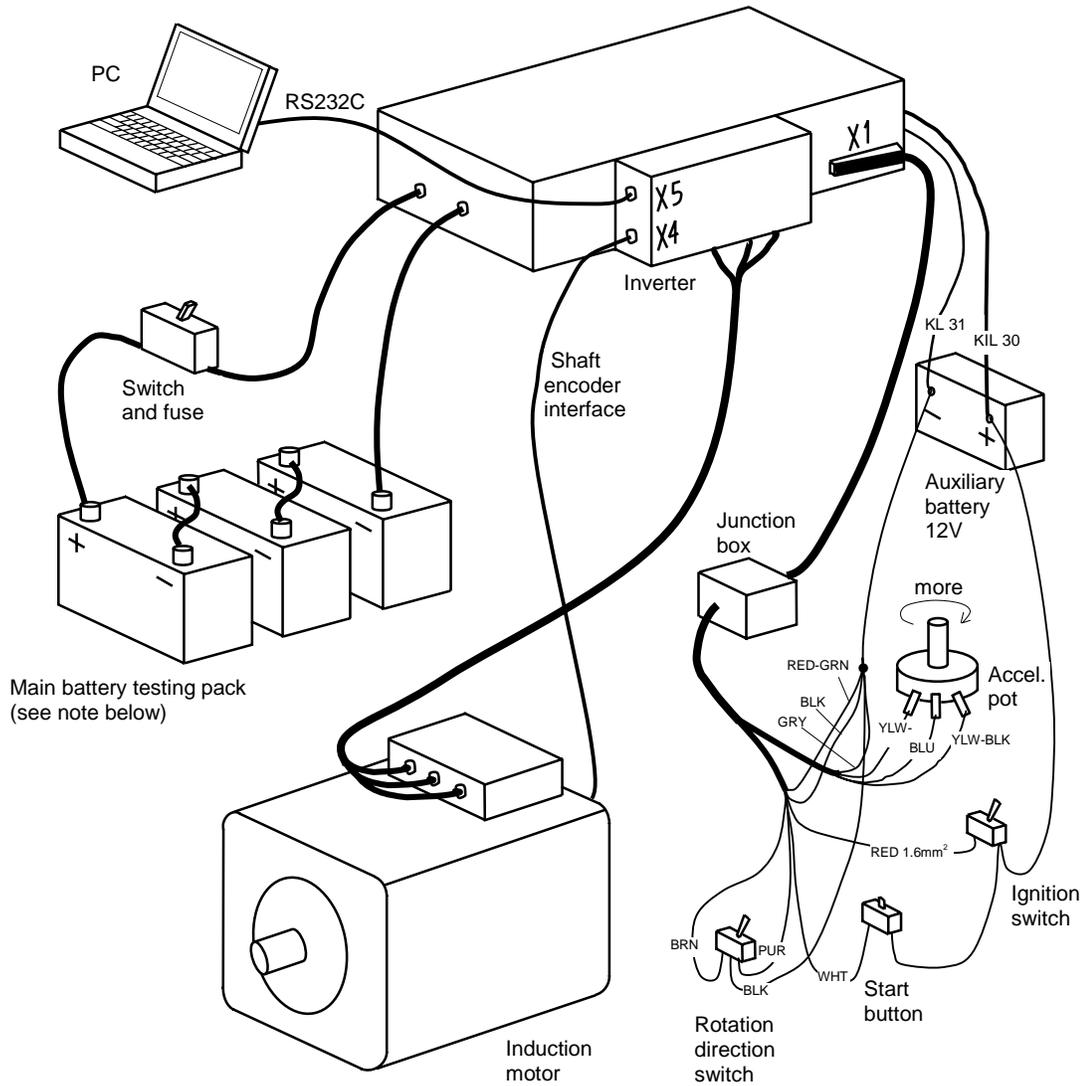
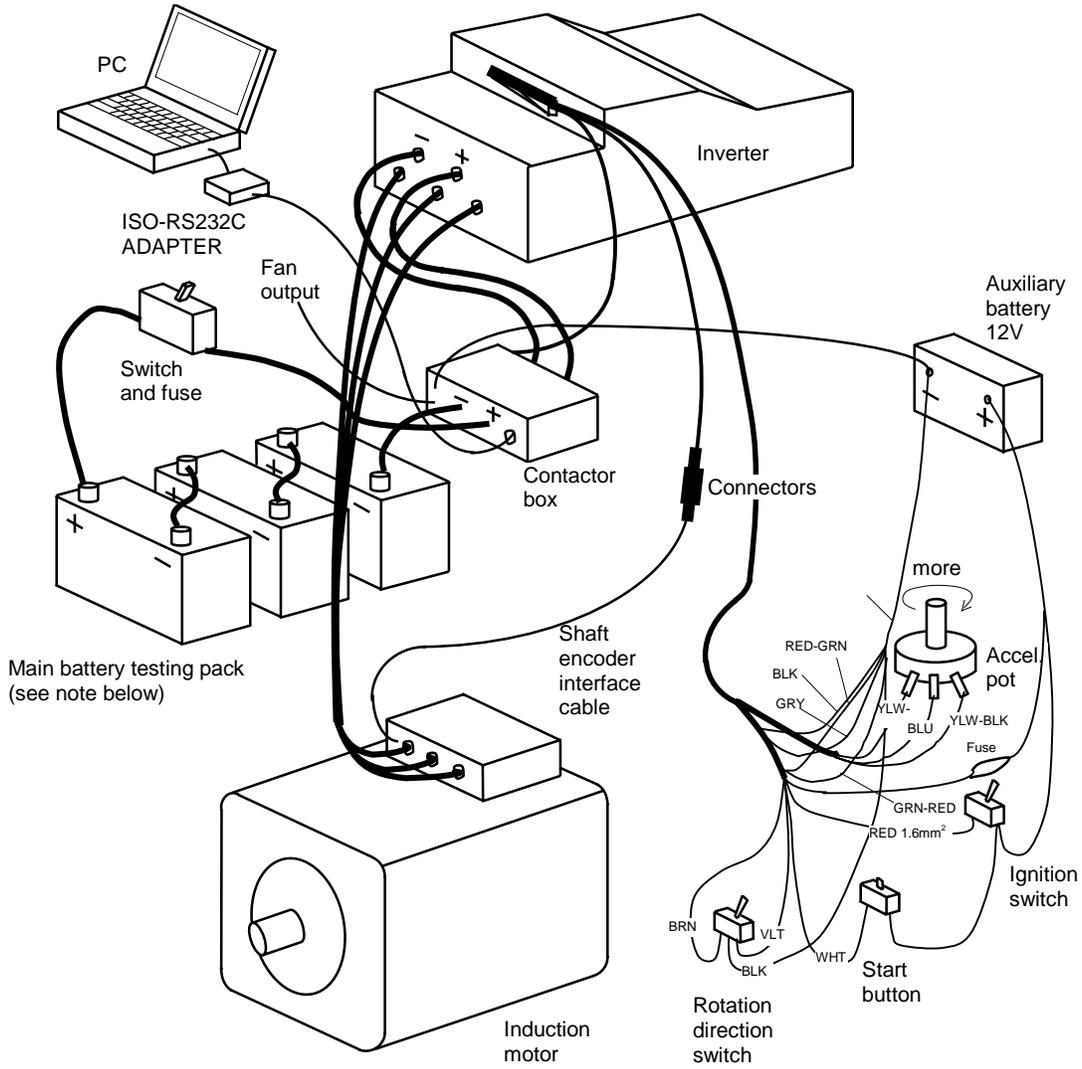


Fig. 3. Bench testing wiring hook up - Simotion inverter.



3.2 Step by step drive system testing procedure

3.2.1 The step-by-step initial hook up and bench testing procedure for Simovert 6SV1 long or short inverters:

- Connect the motor/inverter interface cable to the motor and X4 interface of the inverter
- Take off terminal compartment cover (long inverter - 4 screws, short inverter - 6 screws) and connect the motor power cables to the inverter (bolts with different size). The cable lugs can only be mounted to the bolts if the cable glands are properly mounted to the inverter housing. Don't use excessive force. If the motor power cables extended for testing purposes, the wires should be at least 6 mm².
- Plug in 35-pin female connector to X1 interface of the inverter. First place nose of the connector housing under corresponding hook on the mating male connector. Lower opposite end of the connector (where the cables come out) toward inverter until the metal locking spring snaps in place securing connection



- Connect -12V DC-DC converter output (M6 bolt on the metal case marked KL 31) with a **dedicated** wire at least 10 mm² directly to the negative terminal of auxiliary 12V battery. Ensure reliable connection by tightening M6 bolt, **do not** use metal case as -12V DC-DC output
- Make sure ignition switch is OFF, acceleration potentiometer wiper is at low end (turned CCW all the way, 0 speed position) and the drive direction switch is in neutral position¹
- Connect +12V DC-DC converter output black cable, (16 mm² marked KL 30), to the positive terminal of auxiliary 12V battery. A small spark due to the connection to discharged filter capacitor in the output of DC-DC converter is normal.



- LONG INVERTER ONLY:
 - Connect the main battery pack (144 VDC minimum²) to the inverter DC input (provided 50 mm² cables with lugs) through the 40A fuse and appropriately DC rated switch. Cables are marked "+" and "-". Observe battery polarity.
- SHORT INVERTER ONLY:
 - Connect two short cables coming from the contactor box (marked "+INV" and "-INV") to the inverter DC input in terminal compartment (marked "+" and "-". Positive terminal has larger diameter post;
 - Connect ground terminal of the contactor box (M6 bolt next to -INV cable) to the inverter's ground (KL 31 contact or -12V auxiliary battery).



- Connect the main battery pack (144VDC minimum ²) to the contactor box DC input (provided 50 mm² cables with lugs) through the 40A fuse and appropriately DC rated switch. Cables are marked "+BAT" and "-BAT". Observe battery polarity.

- Connect loose black wire (0.5 mm² with blue crimp-on connector) to the negative terminal of auxiliary 12V battery, and loose red wire (1.5 mm² with blue crimp-on connector) to the positive terminal of auxiliary 12V battery.
- Connect the SIADIS interface cable to the inverter (interface X5) and to the serial port of a laptop or PC ³.
- Hook up voltmeter to the auxiliary battery. The voltage must be above 12VDC.
- Boot laptop to DOS , and first copy to a new directory all contents of the floppy disk provided. CD to that directory and start the SIADIS program by typing: siadis <ENTER>. Alternatively you can run SIADIS off the floppy disk, but the computer must be booted from a hard drive. Working off floppy disk, some software functions may not be available.
- The message "Warning SIADIS customer version 2.05" will be displayed. Press the <ENTER> key.
- Turn on high voltage switch and make sure the high voltage is present. Put ignition switch to "ON" position. A slight buzzing sound may be heard from inside the inverter.
- Change default project name to your project name: hit <TAB> then left cursor key so your name appear in the "NAME" field, and press <ENTER>. Choose, 'Read inverter configuration' from the main menu.
- Choose , 'Display Instruments' submenu. Make sure AccPedRel parameter reads 0%, else main contactor won't close. If this is the case Acc_Ped_Min parameter will have to be adjusted to be about 0.2V below Acc_in voltage displayed on the screen and new value saved in EEPROM before proceeding.
- While drive direction switch in neutral position, push the start button. The main contactors will close with audible click. This turns on DC-DC converter as well, and auxiliary battery voltage should rise to about 14 VDC (may be higher with no load).
- Put drive direction switch to the "Forward" position and **slowly** turn throttle potentiometer. The motor shaft will rotate, indicating that the system works fine⁴. If the motor runs unloaded, it will run under load as well. To change rotation direction to reverse, first turn the potentiometer all the way CCW and wait for the shaft to stop. You can observe different parameters configured for display on the laptop screen.
- To shut down and disconnect inverter, first put ignition switch in "OFF" position. Main contactors will open. Turn off high voltage switch and disconnect main battery. Disconnect the rest of the components in reverse order.

3.2.2 The step-by-step initial hook up and bench testing procedure for Simotion inverters:

- Connect the motor/inverter interface cable (coming out of the 68 pole connector) to the motor.interface cable.
- Connect the motor power cables. L1 of the motor belongs to L1 of the inverter and so on (L2, L3). The different lug sizes prevent from wrong hookup.
- Connect the inverter plus cable (50 mm², black heat shrinking tube, cable lug with 10 mm hole) and the inverter minus cable (50 mm², black heat shrinking tube, cable lug with 8 mm hole) to the corresponding terminals in the inverter.



- Connect the M6 bolt on the MC box to the minus pole of the 12 V auxiliary battery. Use 6mm² cable. Ensure reliable connection.
- Connect the black wire (isolation stripped off, 0.5 mm²), to the minus pole of the 12 V battery
- Connect the 68 pole connector to the vehicle interface of the inverter: Pull the locking bar on the connector. Then carefully insert the connector. Support the connector with your hand and push the locking bar back. The connector is tightened to the vehicle interface. Don't use excessive force during this process.
- Make sure that the ignition switch (the one with two red wires) is in off-position (check this with the second pole of the two pole switch).
- Make sure that the forward direction switch (the one with violet and brown wires) is in off-position (check this with the second pole of the two pole switch). The main contactor can only be closed if the forward direction switch is in off-position.
- Connect the red wire (isolation stripped off, 0.5 mm²), to the plus pole of the 12 V battery
- Connect the red wire (isolation stripped off, 1.5 mm², connected with the ignition switch), to the plus pole of the 12 V battery.
- Connect the throttle potentiometer to the white Molex connector on vehicle harness.
- Connect the traction battery plus cable (50 mm², marked with red heat shrinking tube) and the traction battery minus cable (50 mm², marked with blue heat shrinking tube) to the main battery (about 150 VDC²).
- Connect the SIADIS interface cable to the interface on the main contactor housing. Connect small black box to the other end of the Siadis interface cable. Connect other end of black box to adapter cable and connect other end of the adapter cable to the laptop.
- Switch on the ignition switch.

- Hook up voltmeter to the auxiliary battery. The voltage must be above 12VDC.
- Boot laptop to DOS , and first copy to a new directory all contents of the floppy disk provided. CD to that directory and start the SIADIS program by typing: siadis <ENTER>. Alternatively you can run SIADIS off the floppy disk, but the computer must be booted from a hard drive. Working off floppy disk, some software functions may not be available.
- The message "Warning SIADIS customer version 3.11" will be displayed. Press the <ENTER> key.
- Turn on high voltage switch and make sure the high voltage is present. Put ignition switch to "ON" position. A slight buzzing sound may be heard from inside the inverter.
- Change default project name to your project name: hit <TAB> then left cursor key so your name appear in the "NAME" field, and press <ENTER>. Choose, 'Read inverter configuration' from the main menu.
- Choose , 'Display Instruments' submenu. Make sure AccPedRel parameter reads 0%, else main contactor won't close. If this is the case Acc_Ped_Min parameter will have to be adjusted to be about 0.2V below Acc_in voltage displayed on the screen and new value saved in EEPROM before proceeding.
- While drive direction switch in neutral position, push the start button. The main contactors will close with audible click.
- Put drive direction switch to the "Forward" position and **slowly** turn throttle potentiometer. The motor shaft will rotate, indicating that the system works fine ⁴. If the motor runs unloaded, it will run under load as well. To change rotation direction to reverse, first turn the potentiometer all the way CCW and wait for the shaft to stop. You can observe different parameters configured for display on the laptop screen.
- To shut down and disconnect inverter, first put ignition switch in "OFF" position. Main contactors will open. Turn off high voltage switch and disconnect traction battery. Disconnect 12V auxiliary battery and then the rest of the components.

¹ If these conditions are not met, inverter will not turn on when the "Start" button is pressed and the fault light comes on.

² If the system is pre-programmed per your specification, the main contactors will not close unless the pack voltage is within the limits defined by software (usually 90% of the nominal pack voltage).

These limits can be temporarily changed (the pack voltage must be 140V minimum) for quick functionality checking purpose without overwriting internal EEPROM. If MC won't close and you get "Recharge time >3 sec" error message, most likely high voltage for testing is not sufficient, or the leads are too long.

³ SIADIS comes with default communication configuration set to COM1 port at 9600 baud. If other port or speed is used, edit SIADIS.INI file accordingly. It was noticed that serial communications for some laptop models do not work with SIADIS software. The reason is that SIADIS serial communication protocol was written for the PC UART chip without data buffer such as 16550 or older (16450). In newer (Pentium and above) PCs and laptops the serial port may have no dedicated UART chip at all (Dell Inspiron laptops), or is implemented with more modern UART chip (16650, 16750, 16850). These chips have internal transmit and receive buffers which improves high speed communication, but confuses SIADIS. The older 386 or 486 laptops, and PCs are virtually guaranteed to work well because of UART with no buffer. Pentium class of PCs is more likely to present problems. For instance, your system was configured with old B/W Compaq Contura 386SX, while modern Dell Inspiron 3800 equipped with P-III 600 MHz but no dedicated UART, didn't work at all. If <No Communication> is displayed while system is ON, RS232C is connected and SIADIS configured and started, try to disable UART FIFO buffer with enclosed nofifo.exe utility or try different (older) laptop or a desktop.

Also, too much physical expanded memory may interfere with SIADIS. The solution is to waste some RAM by creating dummy RAM DISK, or use special utility provided on the floppy disk.

⁴ A slight cracking sound may be initially heard from inside the running motor. This sound is caused by fresh bearing grease being spread around, and will disappear in a few hours of operation. For safety, initially battery current is limited in software to 10A, which is plenty to test unloaded motor up to its maximum programmed RPM.



High voltage is present on exposed terminals (battery pack and motor power connection) during bench testing. Potential shock hazard exists – pay attention.



Never force +12V to the "Power Reduction", "Emergency Off", "Start Inhibit", "Regen Off" or "Forward/Reverse" inputs. Disconnecting them is enough; they have internal pull up means to maintain +12V for the logic board. Also, never disconnect any cable or interface (X1, X4 or X5) while system is running (ignition switch is on) and especially -12V terminal of auxiliary 12V battery. It was stated previously but must be stressed once more because despite multiple

warnings, several customers managed to damage their interface PCBs this way. PCB replacement is NOT free and even then, it may take long time to obtain spare one if they are out of stock.

4 INSTALLATION INSTRUCTIONS

4.1 Overview

Siemens inverters are designed for use in road vehicles and as such have water splash and dust proof construction. They can be mounted in any convenient position, but for proper venting of the cooling system, venting valve (near M6 bolt DC-DC negative output for Simovert inverters) has to be above the highest point of the cooling radiator or water pump. Also to prevent external damage, direct exposure to the road from the car underbody should be avoided. Length of the cooling water lines as well as power cables to the main traction battery and the motor should be considered for choosing the best place. M8 bolt size is used to mount the case of Simovert inverter and M6 for Simotion inverter. It is recommended to mount junction box in the same compartment where the inverter is located and have it easily accessible. Coolant should enter the inverter first and then flow to the motor (the cabin heater core or battery warmers if used, must be connected last in the cooling loop). For safety 300A circuit breaker in the positive cable from the traction battery is recommended.

Preferred position for the motor mounting is its terminal cover up, and either fitting can serve as either inlet or outlet. It is acceptable to mount the motor to the adapter plate rotated at any angle. In this case for proper air venting the lower fitting should be the coolant inlet, and the higher one - the outlet. Orientation of inverter mounting is irrelevant as long as there is no air trapped in the internal coolant plumbing.

4.2 Interface schematic

Simovert 6SV long inverter interface electrical schematic diagram is shown in fig.3.

See also appendix C section 6.2.1 for harness wiring identification information.

Simovert 6SV short inverter interface electrical schematic diagram is shown in fig.4.

See also appendix C section 6.2.2 for harness wiring identification information

Simotion inverter interface electrical schematic diagram is shown in fig.5.

Simovert 6SV long inverter X1 vehicle interface electrical schematic diagram is shown on fig.6.

See also appendix B 6.3.1 for pin assignment and functions.

Simovert 6SV short inverter X1 vehicle interface electrical schematic diagram is shown on fig.7.

See also appendix B 6.3.2 for pin assignment and functions.

Simotion inverter X1 vehicle interface electrical schematic diagram is shown on fig.8. See also appendix B 6.3.3 for pin assignment and functions.

All the EV components electrical schematic (Simovert long inverter) is shown on fig.9.

All the EV components electrical schematic (Simovert short inverter) is shown on fig.10.

All the EV components electrical schematic (Simotion inverter) is shown on fig.11.

Fig. 3. Simovert 6SV long inverter interface

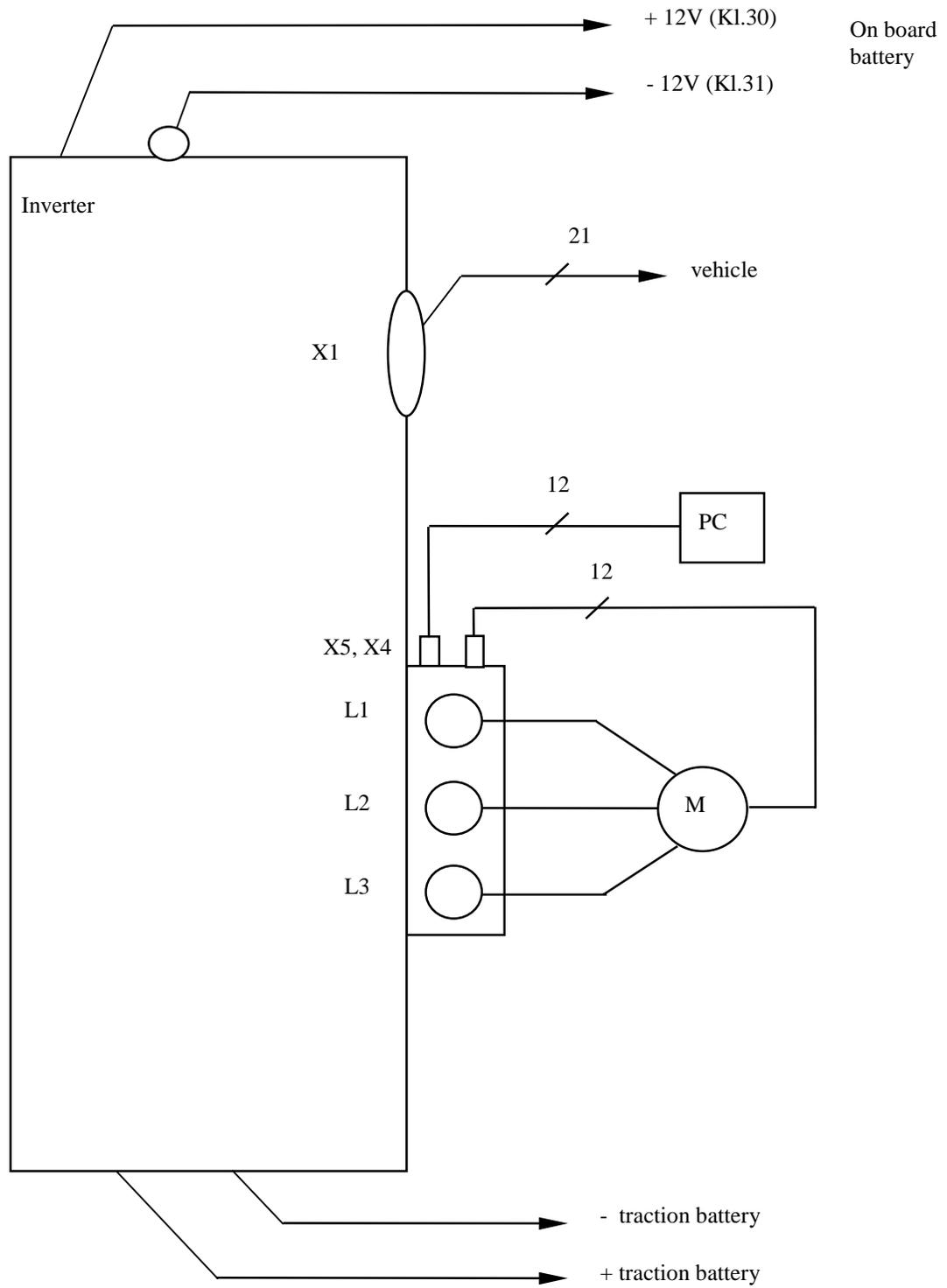


Fig. 4. Simovert 6SV short inverter interface

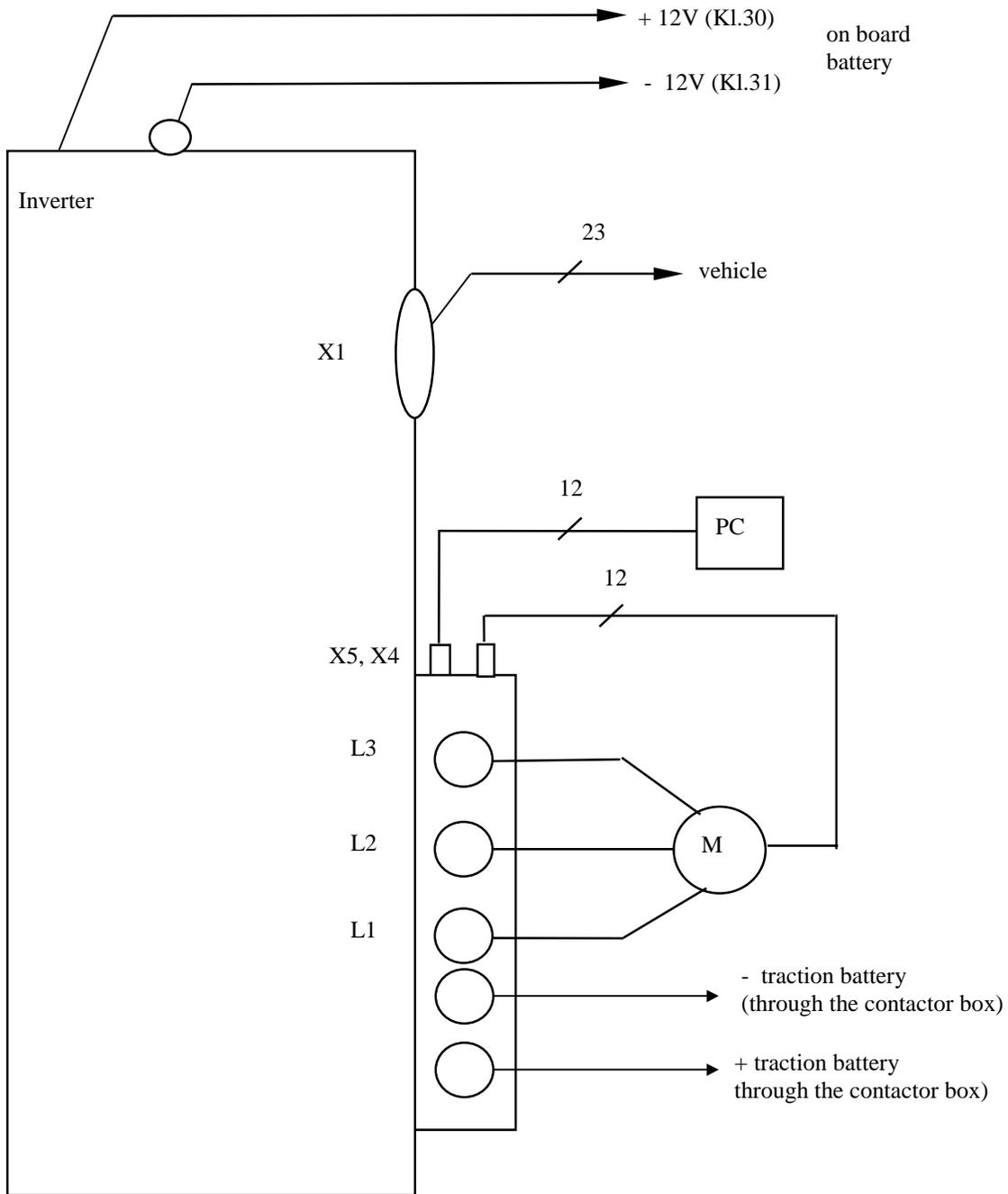


Fig. 5. Simotion inverter interface

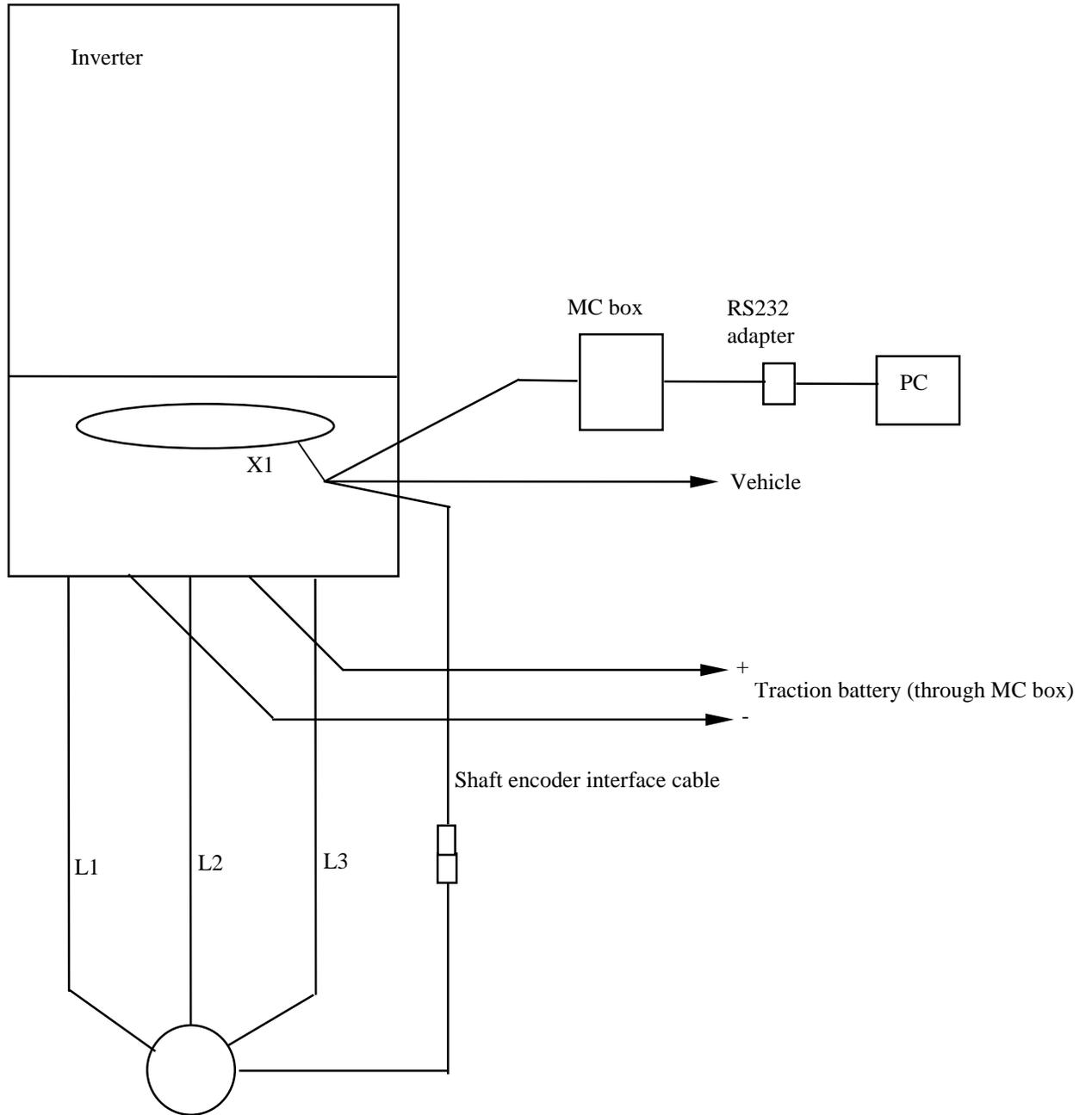


Fig. 6. Simovert 6SV long inverter X1 vehicle interface overview

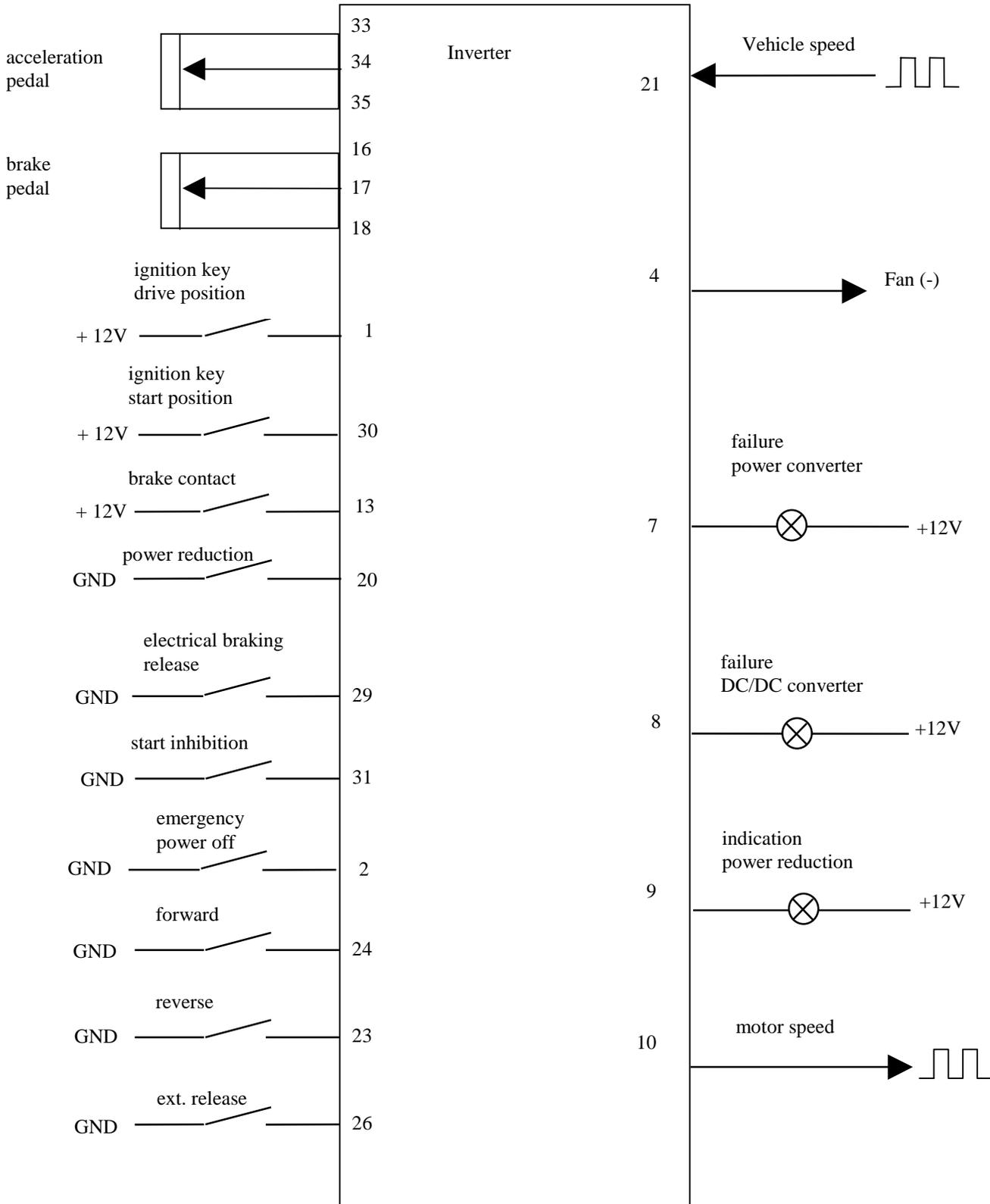


Fig. 7 Simovert 6SV short inverter X1 vehicle interface overview

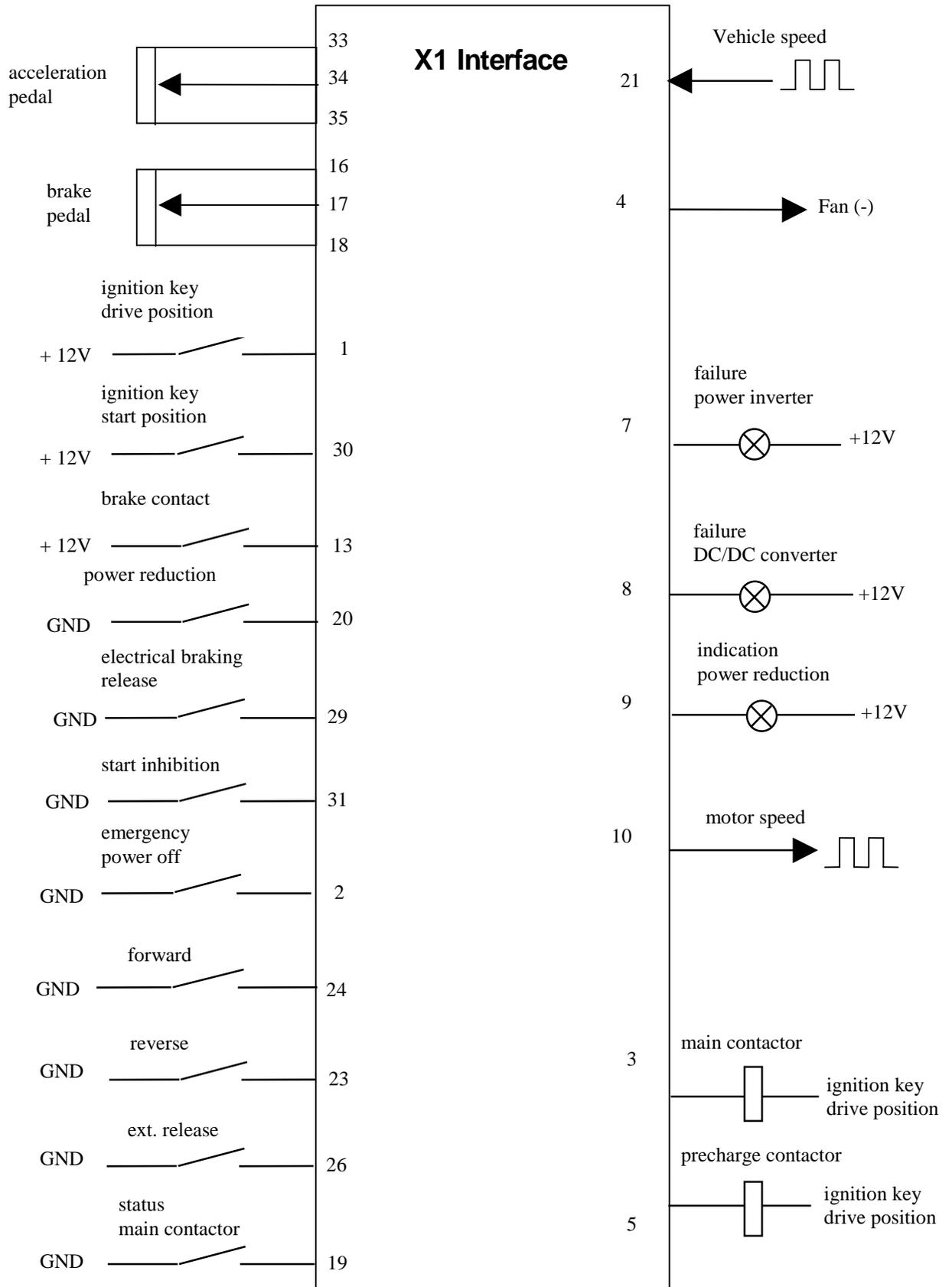


Fig. 8 Simotion inverter X1 vehicle interface overview

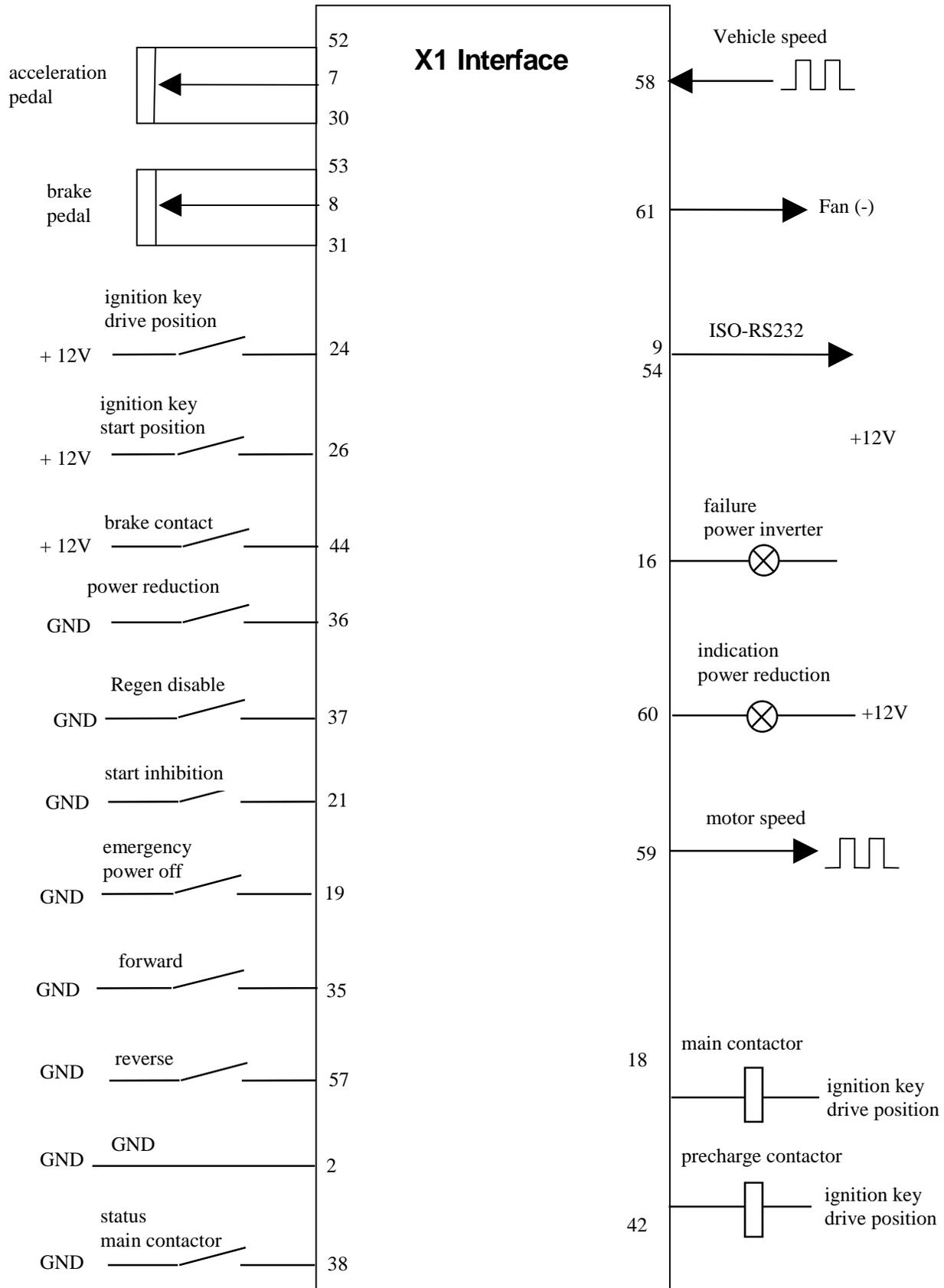


Fig. 9. Complete electrical schematic of an EV drive system using Simovert 6SV1 long inverter.
 (No charger connection shown).

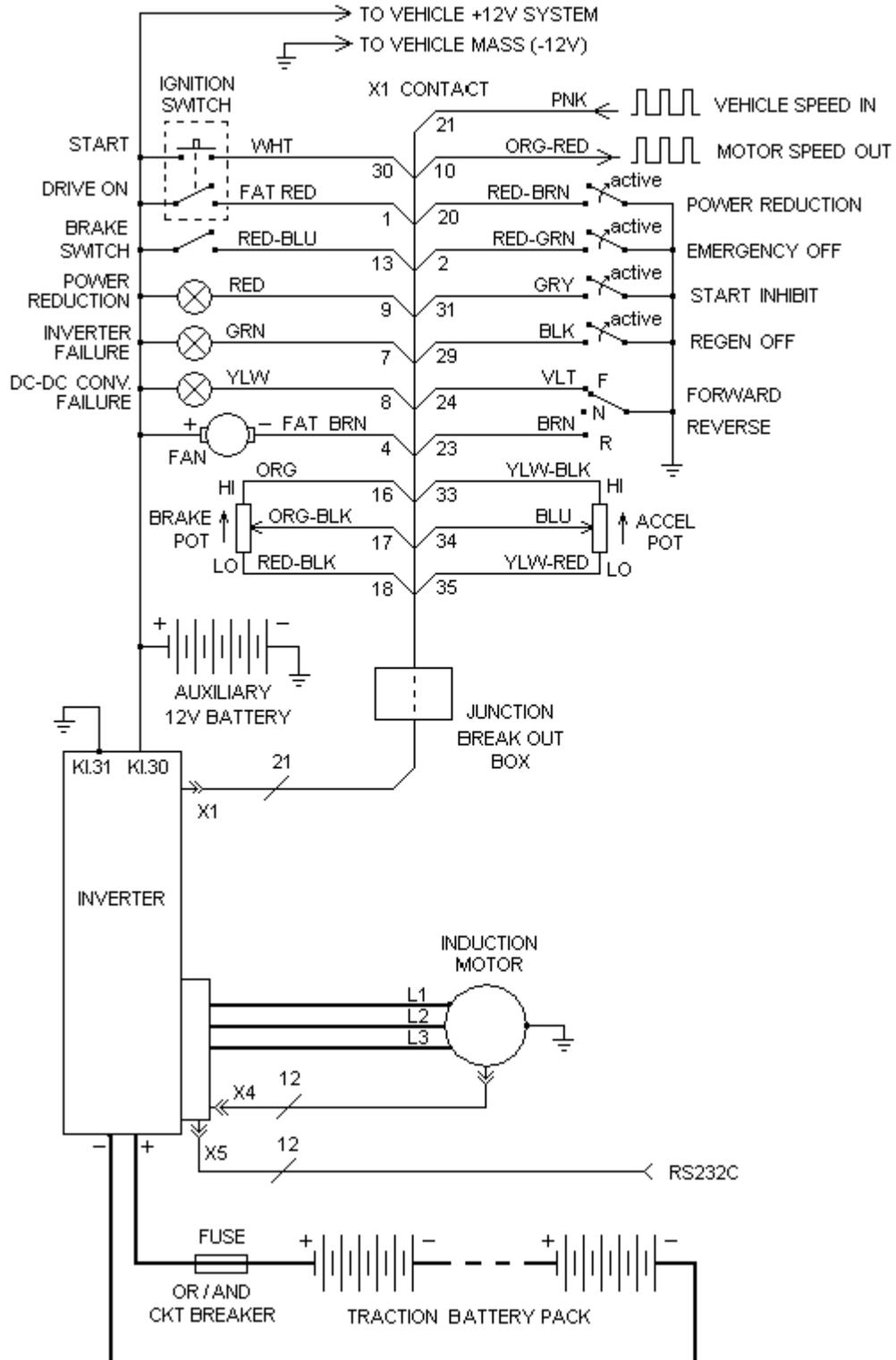


Fig. 10. Complete electrical schematic of an EV drive system using Simover 6SV1 short inverter.
 (No charger connection shown).

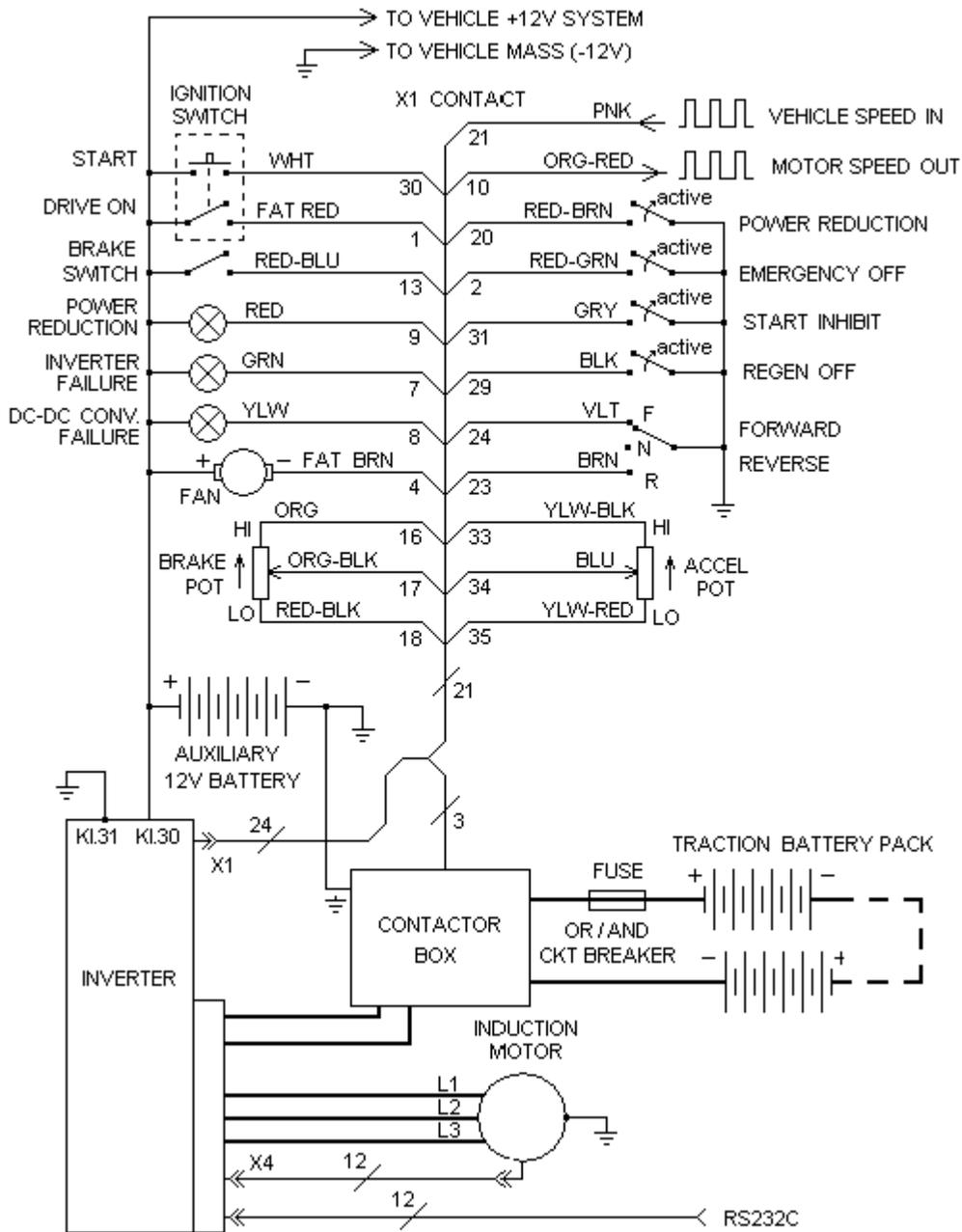
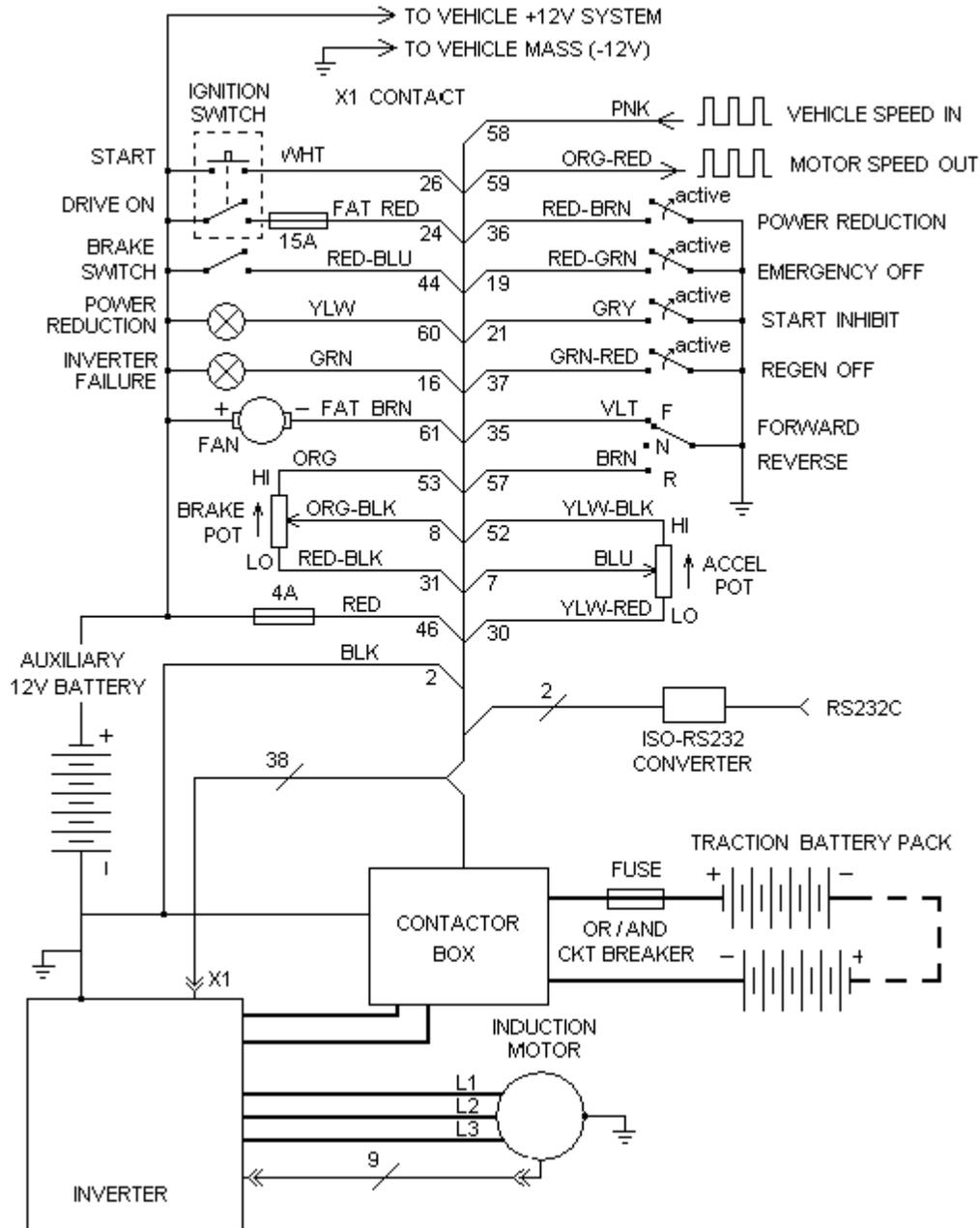


Fig. 11. Complete electrical schematic of an EV drive system using Simotion inverter.
 (No charger connection shown).



4.3 Wiring overview

NOTE: The cross-section of the encoder and temperature sensor cables of the motor is 0.22mm^2 . All other wires for connecting dash interface components (lamps and switches) should have minimum cross-section of 0.5 mm^2 .

4.3.1 Acceleration potentiometer connection

The accelerating potentiometer is the main controlling device and the reliability of the mechanical link to the accelerator pedal and electrical connection is critical for safe dependable driving. For the Siemens inverters, a special Bosch waterproof potentiometer assembly is used. This assembly consists of the potentiometer itself and a switching part - start switch and a kick-down switch. The kick-down switch can be used for full power demand while in current (thus power) reduced "economy" mode. This function is described in the section 7.2.14.1 (customer version only). The potentiometer terminals are high end (+5 V), central wiper and low end (0 V). When mounted, the wiper position is near one end of resistive element, which is the low end. As the accelerator pedal is depressed the wiper will slide from the low-end terminal toward high end. Thus the resistivity between the low end and the wiper is increased as the pedal is depressed. When the pedal is released, resistivity between wiper and low end is at its minimum. While working zone of the potentiometer will be less than its full possible wiper travel, initial and final positions (in $\text{k}\Omega$) can be specified to be 0% and 100% of the drive demand by the software.

Connect yellow/red wire from the breakout box to the potentiometer low end (brown wire), box blue wire - to the potentiometer wiper (white wire) and the box yellow/black wire - to the potentiometer high end (pink wire). The original white plastic connector of the potentiometer has to be cut off because it's not waterproof, and the soldering is recommended for the connection. Use heat shrink tubing for the soldering connections to make connection waterproof and corrosion free.

4.3.2 Brake light connection.

To signal inverter to switch to regenerative brake mode a 12V signal must be applied. In the existing electrical system of the car brake lights are usually grounded on one end and the brake switch connects 12V to the other "hot" end when the brake pedal is depressed. The red/blue wire from the junction box must be connected to the existing connection between brake switch and brake lights.

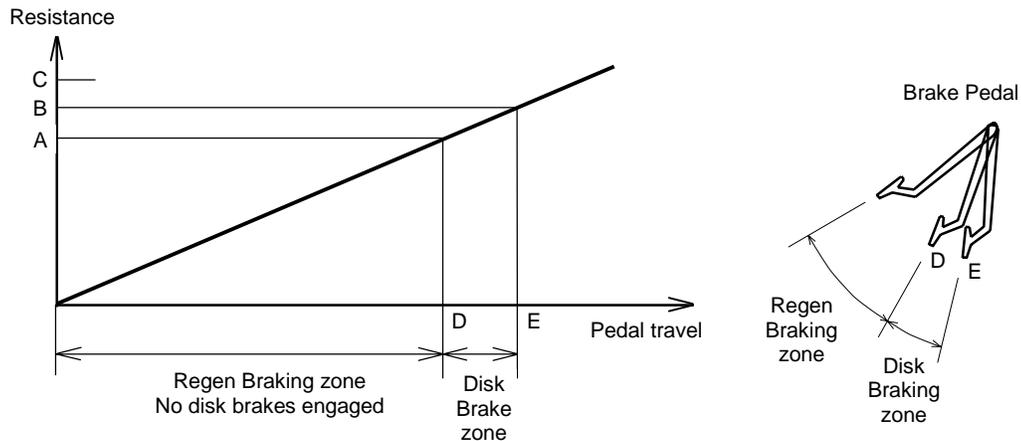
4.3.3 Optional brake potentiometer connection

Brake potentiometer allows fine control of regenerative brake action but requires alteration of existing system.



WARNING: Improper modification of the existing braking system may lead to the brake system malfunction.

The harness is pre-wired for the braking potentiometer use. If this option is desired, first free brake pedal travel (before brake pads engage with disks) must be provided. The brake potentiometer shaft must be linked to the pedal similar to accelerator potentiometer and accept full travel of the pedal including travel beyond regenerative braking zone (fig. 9) You may find potentiometers with linear sliding wiper movement more suitable than with rotating movement. Resistance can have any value between 1 k Ω and 5 k Ω . Like with accelerator potentiometer, the working zone of the braking potentiometer for regen will be less than its full travel, but initial and final positions (in k Ω .) are assigned to be 0% and 100% for regenerative action using maintenance software. Wires for the brake potentiometer are brought out of the break out box. Connect the red-black 0.5mm² wire from the breakout box to the low-end terminal of the braking potentiometer, the orange-black 0.5m m² wire - to the wiper (central) terminal, and the orange 0.5mm² wire - to the high end terminal.



- A – this resistance of the brake pot assigned by software to be 100% braking current demand
- B – any resistance above point A is ignored
- C – Maximum resistance of the pot itself
- D – Brake pedal position corresponding to 100% brake current demand
- E – Brake pedal position for fully engaged disk brakes

Fig. 9. Working zones of the brake pedal.

4.3.4 Optional speed sensor connection.

The max brake current (when the brake lights are on) can be adapted either to vehicle speed or motor speed. In case of adaptation to vehicle speed, a speed sensor is required. The sensor should have a binary frequency output signal. This signal is accepted by the control input of the inverter (pink 0.5mm² wire). The frequency of the signal is converted to the vehicle speed by the software. The correct conversion of the speed signal is given for frequencies between 0.7 and 150 Hz. Frequencies below 0.7 Hz are interpreted as standstill.

4.3.5 Shaft speed output connection

The motor shaft speed signal is available from the motor speed output and the frequency of the output square wave can be scaled up or down in software to match the requirement of the vehicle's tachometer. Connect the orange-red 0.5mm² wire from the break out box directly to the tachometer. This output is internally pulled up to +12VDC through a 4.7 kΩ resistor.

4.3.6 AC Motor connection.

There are three power cables connecting inverter to the motor. The connection cables have a copper size of 35mm². The contact posts on the inverter side are marked with L1, L2 and L3. They have different diameter - the thread sizes are M6, M8 and M10 respectively. Observe the torque when tightening the nuts on the posts. On the motor side posts are the same diameter and marked as L1, L2 and L3.

Connect supplied cable to the speed sensor connector on the inverter and the motor.

4.3.7 Cooling fan connection

The cooling fan (mounted behind radiator) comes on when the coolant temperature reaches default 40°C. ON and OFF temperatures are programmable. The "-" fan motor terminal is connected to the brown wire (1.5 mm²) from the break-out box. This is one contact from normally open relay mounted inside the inverter. Other relay contact is grounded inside, so brown wire gets grounded when relay is on (temp. has reached programmed max). Thus the "+" fan motor terminal must be connected directly to +12V. The maximum current may not exceed 10 A.

4.3.8 Traction battery connection

Since different models of inverter may or may not have integrated main contactors, connection will involve slightly different steps.

4.3.8.1 Simovert 6SV1 long inverter:

There are two cables for the traction battery coming out of the left side of the inverter and marked "+" and "-". Connect these to the respective battery terminals (one of the cables should have a circuit breaker and, optionally, shunt for instrumentation meters, see fig.3. If extension of these cables required, the cable copper size must be 50 mm². Since the traction battery is electrically isolated from the vehicle body (from inverter metal case), any instruments connected to the shunt or battery terminals have to be isolated from the vehicle body as well.

4.3.8.2 Simovert 6SV1 short inverter

Positive and negative traction battery cables coming out of the contactor box should be connected to the battery, fig. 4. If extension of these cables required, the cable copper size must be 50 mm². Since the traction battery is electrically isolated from the vehicle body (from inverter metal case), any instruments connected to the shunt or battery terminals have to be isolated from the vehicle body as well.

4.3.8.3 Simotion inverter

Positive and negative traction battery cables coming out of the contactor box should be connected to the battery, fig. 5. If extension of these cables required, the cable copper size must be 50 mm². Since the traction battery is electrically isolated from the vehicle body (from inverter metal case), any instruments connected to the shunt or battery terminals have to be isolated from the vehicle body as well.

4.3.9 DC-DC converter connection

Simovert SV6 inverters are equipped with an integrated DC-DC converter. The +12V output cable (coming from the right side of inverter) connects to the +12V terminal of the auxiliary 12V battery. The metal case of the inverter is -12V output and the M6 bolt marked "KL 31" (near +12V output cable) must be used as negative DC-DC output terminal. Connect negative terminal of



auxiliary 12V battery directly to this M6 bolt, and that point - to the vehicle body. The copper size cross section of the cables must be no less than 16 mm².

Do not rely on the vehicle body conductivity for connection of the negative terminal of auxiliary 12V battery to the inverter metal case. **Always use reliable direct 16 mm² wire connection between negative terminal of auxiliary 12V battery and M6 bolt marked "KL31" on the inverter case, and use separate cable from KL31 to the vehicle body. During bench testing always connect negative terminal of auxiliary 12V battery to the M6 bolt marked "KL31" on the inverter case first, and disconnect last. This is critical and not following these simple directions WILL cause inverter interface PCB damage.**

4.3.10 Water pump

Small 12V electric pump is usually used to circulate cooling liquid through the motor and inverter. The pump is independent of the inverter circuit and is not controlled by it. It must be wired such that it turns on as soon as the ignition switch is put in "ON" position. The water flow rate should be maintained at least 8 liters per minute (2.11 GPM). Cold water must flow into inverter first, and from inverter – to the motor. To achieve rated lifetime of the motor and inverter, the max inlet water temperature should not exceed 55°C (131°F) .If the inverter is at higher position than fill fitting, bleed the air out of inverter by opening the water valve on its side with a small square key (comes with the system).

5 MAINTENANCE

Siemens inverters have no serviceable parts inside, and once installed require no maintenance. The tightness of the bolts holding inverter in the vehicle should be verified occasionally. Ensure good electrical contact between inverter case and negative terminal of auxiliary battery as well as contact between inverter case and the vehicle chassis. Avoid allowing road dirt and moisture to get to X1, X4 and X5 interface connectors. Never pressure wash inverter from outside. Make sure of sufficient coolant flow and supply - expansion reservoir is recommended.

6 APPENDIXES

6.1 Appendix A. Tightening torque specifications.

Connection	Torque
Motor power cable – M6 nut	6 Nm ± 15%
Motor power cable – M8 nut	13 Nm ± 15%
Motor power cable – M10 nut	25 Nm ± 15%
Battery lugs and metal case in the vehicle M8 bolts	13 Nm ± 15%
DC-DC positive output converter lug – for M6x10 bolt and nut	10 Nm ± 15%
DC-DC negative output – M6x10 nut	10 Nm ± 15%

6.2 Appendix B. Interface connector pin assignment

6.2.1 Long inverter

Pin assignment of the 35 pin mating female connector for the vehicle interface (X1) of the SIMOVERT 6SV long inverter

Pin	Assignment	Standard function
1	power supply	Ignition key drive position
2	main contactors, ground	ext. GND / emergency power off
3	DO (5 A)	n.c. *
4	DO (10 A) + Di Low	Fan
5	DO (1 A)	n.c. *
6	DO (0,2A) + DI High	n.c. *
7	DO + DI High	Failure power inverter
8	DO + DI High	Failure DC/DC converter
9	DO + DI High	Indication, power reduced
10	DO + DI Low	Motor speed
11	CAN-Bus High	n.c. *
12	CAN-Bus Low	n.c. *
13	DI High	Brake contact
14	power supply, sensor	n.c. *
15	ground, sensor	n.c. *
16	power supply, sensor	Brake pedal
17	AI	Brake pedal, wiper
18	ground, sensor	Brake pedal
19	DI Low	n.c. *
20	DI Low (PWM)	Power reduction
21	DI Low (frequency input)	Vehicle speed
22	DI Low	n.c. *
23	DI Low	Reverse
24	DI Low	Forward
25	DI Low (PWM)	n.c. *
26	DI Low	n.c. *
27	diagnostic K-line	n.c. *
28	diagnostic L-line	n.c. *
29	DI Low	Electrical braking permitted
30	DI High	Ignition key start position
31	DI Low	Start inhibition
32	AI	n.c. *
33	power supply, sensor	Acceleration pedal
34	AI	Acceleration pedal, wiper
35	ground, sensor	Acceleration pedal

- Pins marked with n.c. must be left unconnected

6.2.2 Short inverter

Pin assignment of the 35 pin mating female connector for the vehicle interface (X1) of the SIMOVERT 6SV short inverter

Pin	Assignment	Standard function
1	power supply	Ignition key drive position
2	main contactors, ground	ext. GND / emergency power off
3	DO (5 A)	Main contactors
4	DO (10 A) + Di Low	Fan
5	DO (1 A)	Precharge contactors
6	DO (0,2A) + DI High	n.c. *
7	DO + DI High	Failure power inverter
8	DO + DI High	Failure DC/DC converter
9	DO + DI High	Indication, power reduced
10	DO + DI Low	Motor speed
11	CAN-Bus High	n.c. *
12	CAN-Bus Low	n.c. *
13	DI High	Brake contact
14	power supply, sensor	n.c. *
15	ground, sensor	n.c. *
16	power supply, sensor	Brake pedal
17	AI	Brake pedal, wiper
18	ground, sensor	Brake pedal
19	DI Low	Main contactors monitoring
20	DI Low (PWM)	Power reduction
21	DI Low (frequency input)	Vehicle speed
22	DI Low	n.c. *
23	DI Low	Reverse
24	DI Low	Forward
25	DI Low (PWM)	n.c. *
26	DI Low	n.c. *
27	diagnostic K-line	n.c. *
28	diagnostic L-line	n.c. *
29	DI Low	Electrical braking permitted
30	DI High	Ignition key start position
31	DI Low	Start inhibition
32	AI	n.c. *
33	power supply, sensor	Acceleration pedal
34	AI	Acceleration pedal, wiper
35	ground, sensor	Acceleration pedal

- Pins marked with n.c. should not be connected

6.3 Appendix C. Interface wire harness

6.3.1 Simovert Long inverter

X1 terminals and corresponding wires of the break out service box.

(SIMOVERT 6SV1 long inverter)

Pin (X1)	Standard function	Terminal	Wire 35 pin connector to break out box	Wire break out box to vehicle dash-board
1	Ignition key drive position	1	Red 1.5 mm ²	Red 1.5 mm ² fuse 16 A
2	ext. GND / emergency power off	2	Red/green 0.5 mm ²	Red/green 0.5 mm ²
3	n.c. *			
4	Fan	3	Brown 1.5 mm ²	Brown 1.5 mm ²
5	n.c. *			
6	n.c. *			
7	Failure power inverter	4	Green 0.5 mm ²	Green 0.5 mm ²
8	Failure DC/DC converter	5	Yellow 0.5 mm ²	Yellow 0.5 mm ²
9	Indication, power reduced	6	Red 0.5 mm ²	Red 0.5 mm ²
10	Motor speed	7	Orange/red 0.5 mm ²	Orange/red 0.5 mm ²
11	n.c. *			
12	n.c. *			
13	Brake contact	8	Red/blue 0.5 mm ²	Red/Blue 0.5 mm ²
14	n.c. *			
15	n.c. *			
16	brake pedal	9	Orange 0.5 mm ²	Orange 0.5 mm ²
17	brake pedal, wiper	10	Orange/black 0.5 mm ²	Orange/black 0.5 mm ²
18	brake pedal	11	Red/black 0.5 mm ²	Red/black 0.5 mm ²
19	n.c. *			
20	Power reduction	12	Red/brown 0.5 mm ²	Red/brown 0.5 mm ²
21	Vehicle speed	13	Pink 0.5 mm ²	Pink 0.5 mm ²
22	n.c. *			
23	Reverse	14	Brown 0.5 mm ²	Brown 0.5 mm ²
24	Forward	15	Violet 0.5 mm ²	Violet 0.5 mm ²
25	n.c. *			
26	n.c. *			
27	n.c. *			
28	n.c. *			
29	Electrical braking permitted	16	Black 0.5 mm ²	Black 0.5 mm ²
30	Ignition key start position	17	White 0.5 mm ²	White 0.5 mm ²
31	start inhibition	18	Gray 0.5 mm ²	Gray 0.5 mm ²
32	n.c. *			
33	Acceleration pedal	19	Yellow/black 0.5 mm ²	Yellow/black 0.5 mm ²
34	Acceleration pedal, wiper	20	Blue 0.5 mm ²	Blue 0.5 mm ²
35	Acceleration pedal	21	Yellow/red 0.5 mm ²	Yellow/red 0.5 mm ²

- Pins marked with n.c. may not be connected

6.3.2 Simovert Short inverter

X1 terminals and corresponding wires of the break out/main contactors box.
(SIMOVERT 6SV1 short inverter)

Pin (X1)	Standard function	Terminal	Wire 35 pin connector to break out/main contactors box	Wire break out/main contactors box to vehicle dash-board
1	Ignition key drive position	1	Red 1.5 mm ²	Red 1.5 mm ² 16A fuse
2	ext. GND / emergency power off	2	Red/green 0.5 mm ²	Red/green 0.5 mm ²
3	Main contactors	3	Violet/red 0.5 mm ²	
4	Fan	4	Brown 1.5 mm ²	Brown 1.5 mm ²
5	Precharge contactors	5	Yellow/green 0.5 mm ²	
6	n.c. *			
7	Failure power inverter	6	Green 0.5 mm ²	Green 0.5 mm ²
8	Failure DC/DC converter	7	Yellow 0.5 mm ²	Yellow 0.5 mm ²
9	Indication, power reduced	8	Red 0.5 mm ²	Red 0.5 mm ²
10	Motor speed	9	Orange/red 0.5 mm ²	Orange/red 0.5 mm ²
11	n.c. *			
12	n.c. *			
13	Brake contact	10	Red/blue 0.5 mm ²	Red/Blue 0.5 mm ²
14	n.c. *			
15	n.c. *			
16	brake pedal	11	Orange 0.5 mm ²	Orange 0.5 mm ²
17	brake pedal, wiper	12	Orange/black 0.5 mm ²	Orange/black 0.5 mm ²
18	brake pedal	13	Red/black 0.5 mm ²	Red/black 0.5 mm ²
19	Main contactors monitoring	14	Green/red 0.5 mm ²	
20	Power reduction	15	Red/brown 0.5 mm ²	Red/brown 0.5 mm ²
21	Vehicle speed	16	Pink 0.5 mm ²	Pink 0.5 mm ²
22	n.c. *			
23	Reverse	17	Brown 0.5 mm ²	Brown 0.5 mm ²
24	Forward	18	Violet 0.5 mm ²	Violet 0.5 mm ²
25	n.c. *			
26	n.c. *			
27	n.c. *			
28	n.c. *			
29	Electrical braking permitted	19	Black 0.5 mm ²	Black 0.5 mm ²
30	Ignition key start position	20	White 0.5 mm ²	White 0.5 mm ²
31	start inhibition	21	Gray 0.5 mm ²	Gray 0.5 mm ²
32	n.c. *			
33	Acceleration pedal	22	Yellow/black 0.5 mm ²	Yellow/black 0.5 mm ²
34	Acceleration pedal, wiper	23	Blue 0.5 mm ²	Blue 0.5 mm ²
35	Acceleration pedal	24	Yellow/red 0.5 mm ²	Yellow/red 0.5 mm ²

- Pins marked with n.c. may not be connected

6.3.3 SIMOTION inverter.

Description of the vehicle interface of the SIMOTION inverter (small MC box)

Pin assignment of the 68 pin connector for the vehicle interface (X1) and wire color of the vehicle harness.

Pin	Assignment	Standard function	Wire color	MC box signal cable	Motor signal cable
1	Converter housing GND	n.c. *			
2	Power supply GND	Vehicle chassis ground	Black		
3	Power supply GND	Vehicle chassis ground	Parallel to 2		
4	Analog GND	GND motor temperature sensor 1	Black		•
5	AI	Motor temperature sensor 1	Green		•
6	AI	n.c. *			
7	AI	Acceleration pedal, wiper	Blue		
8	AI	Brake pedal, wiper	Orange/black		
9	ISO 9141 L-line	SIADIS	Yellow	•	
10	CAN-Bus Low	n.c. *			
11	DI Low	Speed sensor U_{a1} **	Orange		•
12	DI Low	n.c. *			
13	DI (PWM) Low	n.c. *			
14	DI (frequency) High (8,2 k Ω)	n.c. *			
15	n.c.	n.c. *			
16	DO	Indication converter failure	Green		
17	DO	n.c. *			
18	DO	Main contactor (parallel to 63)	Orange	•	
19	main contactor GND	Main contactor GND / epo (parallel to 64)	Red/green		
20	DI Low	n.c. *			
21	DI Low	Start inhibition	Grey		
22	DI Low	n.c. *			
23	converter housing GND	n.c. *			
24	Power supply initial	Ignition key drive position	Red 1.5 mm ² with 15 A fuse		
25	Converter housing GND	n.c. *			
26	DI Low (analog)	Ignition key start position	White		
27	Analog GND	GND motor temperature sensor 2	Violet		•
28	AI	Motor temperature sensor 2	Blue		•
29	GND sensor	n.c. *			
30	GND sensor	Acceleration pedal, GND	Yellow/red		
31	GND sensor	Brake pedal, GND	Red/black		
32	GND motor sensor	GND motor position / speed sensor	Brown		•
33	Power supply motor sensor	Power supply motor position / speed sensor	Red		•
34	DI Low	n.c. *			
35	DI Low	Forward	Violet		
36	DI (PWM) Low	Power reduction (PWM or DI from BMS)	Red/brown		
37	DI Low	Electrical braking permitted	Green/red		
38	DI Low	Main contactor monitoring	Blue	•	
39	DO	DC/DC converter release	n.c. *		
40	DO	n.c. *			
41	DO	n.c. *			
42	DO	precharge contactor	Violet	•	

43	DI Low	n.c. *			
44	DI High	Brake contact	Red/blue		
45	DI Low (562kΩ)	n.c. *			
46	Power supply	+12 V on-board battery	Red with 4 A fuse		
47	Power supply	+12 V on-board battery	Parallel to 46		
48	Shield GND	Shield of motor signals	White connected to shield of motor signal cable		•
49	GND sensor	n.c. *			
50	AI (R _i ca. 100 kΩ)	n.c. *			
51	Power supply, sensor	n.c. *			
52	Power supply, sensor	Acceleration pedal power supply	Yellow/black		
53	Power supply, sensor	Brake pedal power supply	Orange		
54	ISO 9141 K-line	SIADIS	Green	•	
55	CAN-Bus High	n.c. *			
56	DI Low	Speed sensor U _{a2} **	Yellow		•
57	DI Low	Reverse	Brown		
58	DI (frequency) Low	Vehicle speed	Pink		
59	DO (switching 12 V)	Motor speed	Orange/red		
60	DO	Indication power reduced	Yellow		
61	DO	Fan	Brown	•	
62	DO	n.c. *			
63	DO	Main contactor (parallel to 18)	n.c. *		
64	Main contactor GND	Main contactor GND / epo (parallel to 19)	n.c. *		
65		n.c. *			
66	DO	n.c. *			
67	DI Low	n.c.			
68	DI Low	External release	n.c. *		

* Pins marked with n.c. must be left unconnected

** For a clockwise direction of rotation of the motor when driving forwards the pins for the speed sensor signals U_{a1} and U_{a2} have to be swapped.

DI Low ⇒ pull up is installed in the inverter

DI High ⇒ pull down is installed in the inverter