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1 INTRODUCTION

The UPS of the SLC X-TRA product line are on-line, double conversion; the inverter supplies always energy to the load, whether the mains is available or not (according to the battery autonomy time).

Output always energized

The UPS output is energized even during mains failure, therefore in compliance with the prescriptions of EN 50091-1, the installer will have to identify the line or the plugs supplied by the UPS making the User aware of this fact.

This configuration guarantees the best service to the User, as it supplies clean continuously regulated power and guarantees the voltage and frequency will be stabilised at nominal value independently from mains status. Thanks to the double conversion, it makes the load completely immune from micro-interruptions due to excessive mains variation, and prevents damage to the critical load (Computer - Instrumentation - Scientific equipment etc.).

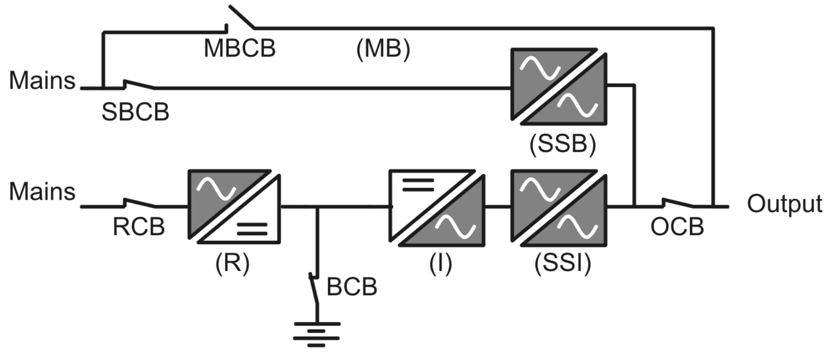


Figure 1 – UPS block diagram

The UPS is composed of three main sections: rectifier (R), inverter (I), static trasfer switch (SS). These sections will be described in the following chapters.

The final chapter includes the description of the various electronic boards installed inside the UPS as well as their block diagrams and programming instructions.

1.1 OPERATING STATUS

Final task of a UPS system is to protect the load from micro-interruptions, black-outs and various disturbances on the network, and guarantee a reliable supply also when internal faults occur. During normal operation the rectifier keeps the batteries in floating charge and provide energy for the inverter to supply the load through the static switch.

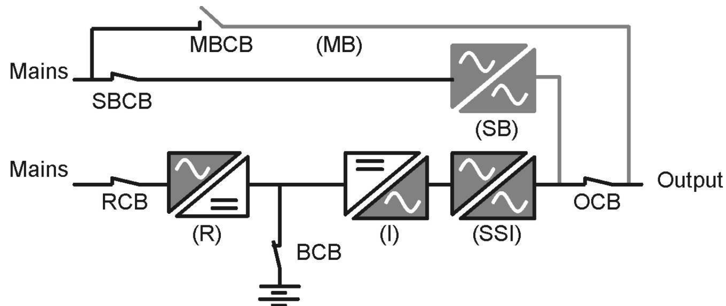


Figure 2 – Normal operation

In case of an inverter failure or an overload the load is automatically transferred, without interruption, to the by-pass static switch.

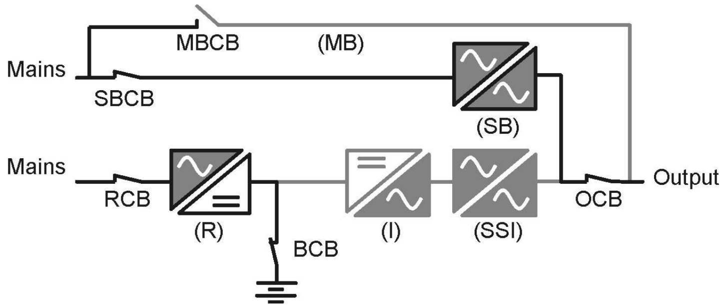


Figure 3 – Load supplied by by-pass

The inverter is the primary supply source, so when its voltage and frequency are in tolerance it synchronises with the by-pass line and the load is transferred again through the static switch.
In case of mains failure (or rectifier failure) the inverter draws energy from the battery for the specified autonomy time, after which the inverter is turned off.

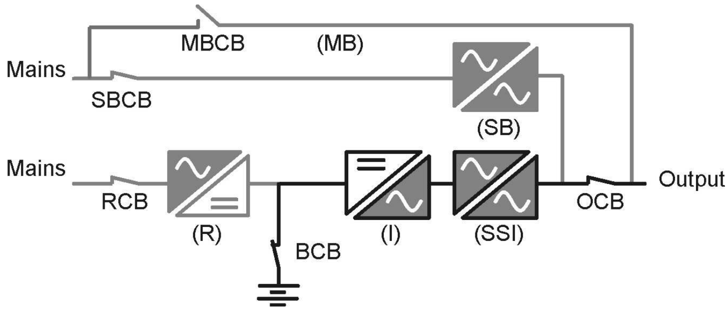


Figure 4 – Rectifier failure or mains failure

For maintenance operations it's possible to supply the load through the manual by-pass circuit breaker MBCB, connecting directly the by-pass line to the UPS output. During the manual by-pass procedure the load remains supplied, without any interruptions.

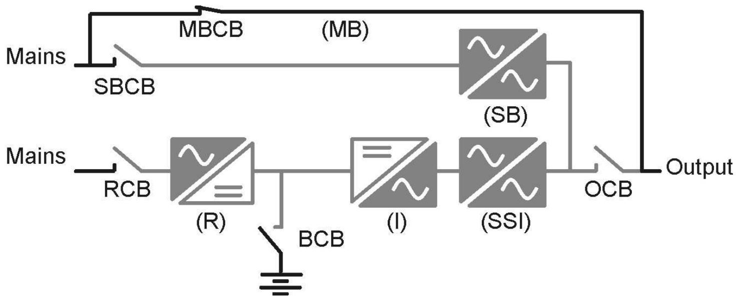


Figure 5 – Manual by-pass

2 DESCRIPTION OF THE SUB-ASSEMBLIES

2.1 RECTIFIER

2.1.1 General description

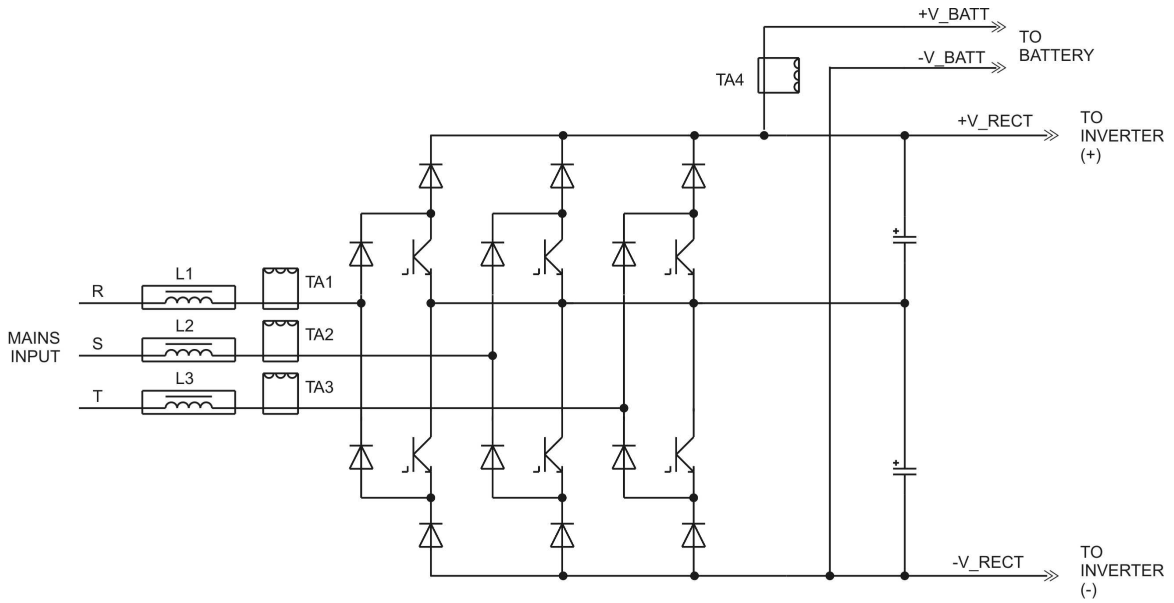


Figure 6 – Rectifier diagram

The rectifier battery charger is mainly composed of two separate sections:

- a diode rectification bridge;
- a IGBT booster bridge.

The diode bridge is made of thyristors instead of diodes, as the whole rectifier needs a controlled soft-start to pre-charge the capacitors in order to avoid sudden current spikes. The thyristors also work as de-coupling elements and avoid that high reverse voltage is applied to the IGBTs.

The IGBT and its series diode in the booster bridge are contained inside the same case; the diode is the component connected between Emitter and Collector of the second transistor contained in the IGBT pack (free-wheeling diode); on this transistor the Gate and Emitter connections are short-circuited.

Input capacitors are installed upstream the AC chokes, between the line conductors and the earth rod; their function is limit the high frequency harmonics generated during the commutation of the rectifier bridge, smoothing the input voltage waveform.

The electrolytic capacitors installed on the DC side are used to reduce the AC ripple on the DC voltage and provides energy to the inverter for a proper operation of the switching devices.

Current transducers are installed on the AC input and on the battery side for control purposes.

2.1.2 Control of the mains voltage

The mains voltage is controlled by the microprocessor according to the setting of the EEPROM parameters.

For each phase the following parameters are controlled:

- frequency;
- voltage RMS value;
- synchronization reference.

The resulting signals are combined together with the *PHSEQ_MAINS_OK* (control of the phase rotation).

Tolerance range of the AC input voltage

The tolerance range of the AC mains voltage (rectifier side) is +15% / -20%, referred to a nominal value of 230Vac (184 ÷ 265 Vac).

The electronic control of the rectifier remains locked to the mains only if the frequency and voltage derivative are within a certain tolerance range. In other words, if the variation of one or both the mains parameters (voltage and frequency) is too fast, the control "unlocks" and turns the booster bridge off.

The sensibility of the PLL can be adjusted to "LOW" in case the input voltage is quite distorted or not stable, so that the rectifier will remain in operation even in presence of bigger mains disturbances.

Verification of the mains voltage during first start-up

During first start-up the mains voltage is initially controlled by the board WRC-BRIDGE (PB295), until the microprocessor is started.

A fast mains sensor is also provided, which turns the rectifier off in case of sudden increase of the mains voltage above the higher limit.

- **E^2PROM parameters**

E2P Parameter	Description	Setting range	Standard
MAI_F_TL	Mains frequency tolerance [%]	1 …. 10	10 %
SEN_PLL	Sensibility of the PLL sensor	NORM LOW	NORM

2.1.3 Start-up management

The rectifier start-up is performed in two different phases:

1. start-up of the thyristor bridge;
2. start-up of the IGBT booster bridge.

The first phase is totally managed by the board WRC-BRIDGE (PB295) that controls the phase sequence and the tolerance range of the AC input voltage.

The board turns on two legs of the diode bridge and controls the soft-start by gradually increasing the DC voltage; this enables a controlled pre-charge of the DC capacitors bank so that the AC current increases constantly and slowly with no peaks.

At the end of the pre-charge process the thyristors are fully open, so they basically act like diodes, and the DC voltage reaches a value roughly equal to $V_{LL} \times 1{,}35$ (where V_{LL} is line-to-line voltage). At this point the power supply board is fully operational and supplies all the other boards so that the microprocessors are started and take control of the whole process.

The microprocessor controls that the DC voltage is within the tolerance range and starts the whole diode bridge by turning the remaining third leg on.

The IGBT bridge start-up (second phase) is completely managed by the microprocessor, that make the DC voltage increase up to the nominal value in a controlled manner. The "walk-in" time is adjustable.

Rectifier start-up after a mains fault (UPS in Normal operation)

The diode bridge start-up after a mains fault (the microprocessors have been running since the first start-up) is still controlled by the board WRC-BRIDGE (PB295), but the start-up consent is generated by the microprocessor board D-DSP (PB349). The command *REL_ON* defines when the WRC-BRIDGE will start to control the thyristors. Therefore, during the first UPS start-up the thyristors are started after a fixed time, the re-start delay after a mains failure is defined by the microprocessor (adjustable value).

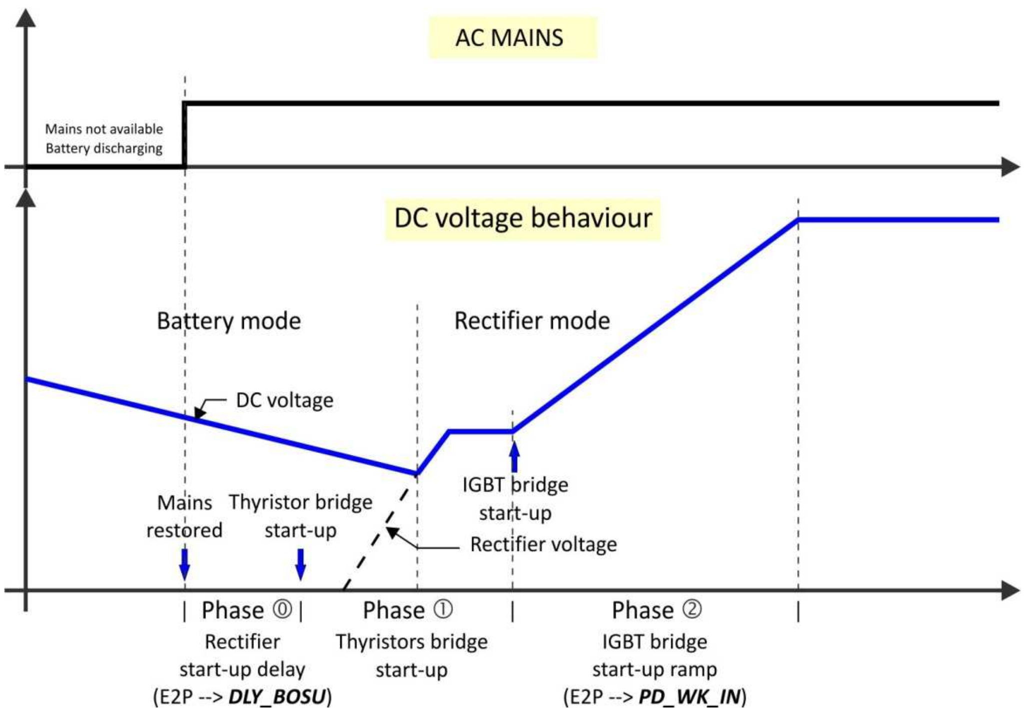


Figure 7 – Rectifier start-up characteristic

The adjustment of the start-up delay is quite important to define the re-start strategy of different devices connected to the same supply source, in order to avoid all the equipment to draw current at the same time.

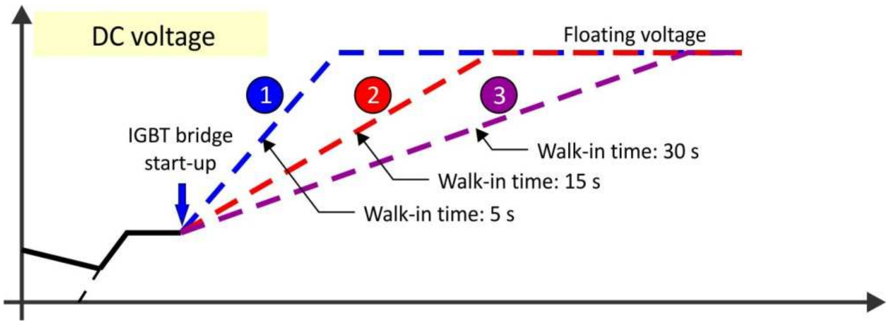


Figure 8 – Adjusting the walk-in time

The walk-in time can be adjusted in order to reduce the current derivative $^{di}/_{dt}$ so that the start-up has a softer impact on the supply source (normal AC supply or diesel generator).

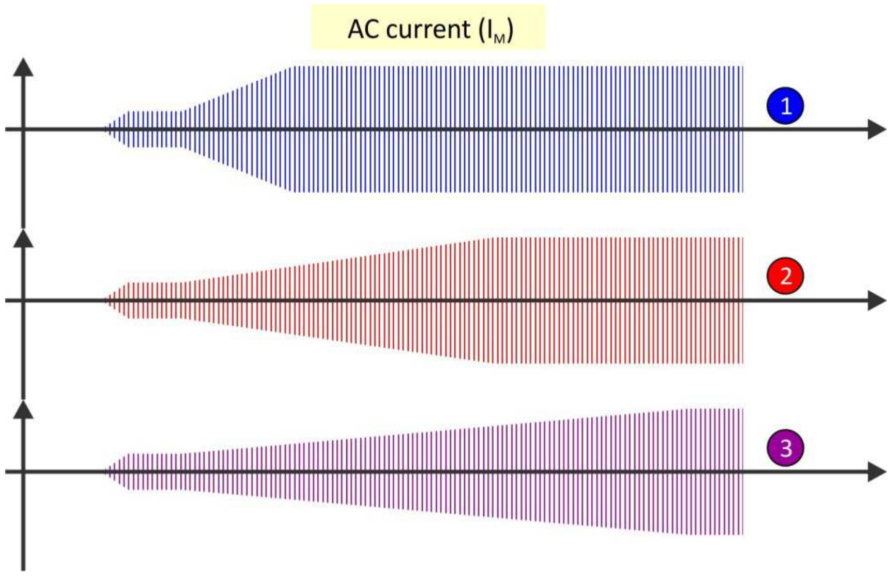


Figure 9 – Effect of different walk-in time on the AC current

– **E²PROM parameters**

E2P Parameter	Description	Setting range	Standard
R_V_FLOA	Floating voltage [V]	660 710	680 V
R_VDCNOM	Nominal battery voltage [V]	600 – 624	600 V
DLY_BOSU	Rectifier start-up delay [s]	1 300	1 s
PD_WK_IN	Rectifier walk-in time [s]	5 30	10 s

2.1.4 Acquisition of the control signals and measures

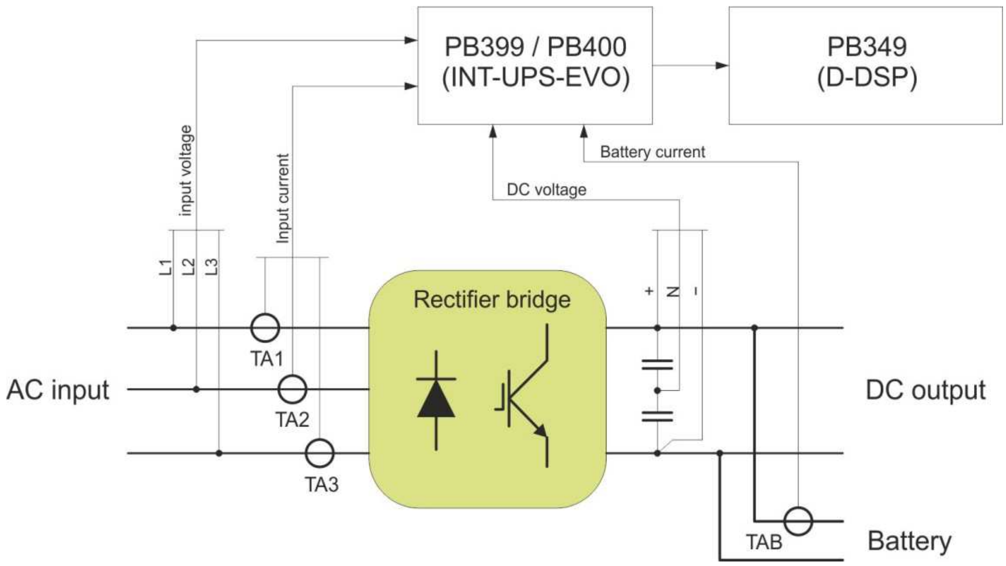


Figure 10 – Acquisition of the measures (rectifier section)

The rectifier/battery charger operation is controlled on the basis of the following control signals:

- input current, acquired through Hall-effect current transducers;
- input voltage, acquired through signal transformers in the INT-UPS-X-TRA board;

- DC voltage, acquired through Hall-effect transducers in the INT-UPS-X-TRA board;
- battery current, acquired through Hall-effect current transducers.

2.1.5 Management of the operating variables

During the booster operation the microprocessor keeps all the operating parameters under control and provide to activate the protections in case one or more parameters are beyond the acceptability range. In this case the booster is stopped (alarm A4) and declared faulty (alarm A3) only in presence of certain variables.

A list of the different variables that cause the booster stop is given below.

INPUT_FUSES_BLOWN (*)	The input fuses are blown.
Not (PLL_LOCKED)	The PLL is not locked.
ASYM_LOAD (*)	The DC voltage on the positive and negative capacitor banks is not equalized.
THERM_SWITCH_BOOST (*)	The thermal switch on the booster heat-sink has operated due to high temperature.
Not (MAINS_OK)	Problems on the mains voltage or frequency.
ERRORE_LOOP_TENSIONE (*)	The booster is unable to stabilize and control the DC voltage.
SV_TENS_INGRESSO	The AC input voltage is disturbed and exceeds the higher threshold (fast sensor).
SPEGNIMENTO_VELOCE	Fast shutdown due to sudden increase of the DC voltage above **780V**.
TERNA_ING_BILANCIATA	The three-phase input voltage is not balanced.

In case of booster stop owing to one of the variables marked with **(*)** the *Booster fault* alarm (A3) is also activated.

2.1.6 Management of the battery parameters

The battery general parameters can be set using the *E2P manager* software and are listed in the table below.

The battery recharging current depends on the rectifier rating and is specified in the technical specification. Therefore the current cannot be higher than the maximum value allowed, unless the DCM (Dynamic Charging Mode) is enabled. The maximum allowed charging current values on the basis of the UPS rating are listed below:

- 60-80-100kVA: **15 A**
- 125-160kVA: **20 A**
- 200kVA: **30 A**
- 250-300kVA: **40 A**
- 400kVA: **60 A**
- 500-600kVA: **80 A**
- 800kVA: **A**

The battery voltage is monitored during the discharge and a “END OF AUTONOMY” alarm is activated once the voltage drops below an adjustable threshold (LOBA_TH).

– E^2PROM parameters

E2P Parameter	Description	Setting range	Standard
BAT_PRES	Battery present	YES NO	YES
BAT_TYPE	Nominal autonomy [Ah]	1 9999	See *ecf*
N_B_BAT	Number of battery blocks	50 – 52	50
NOM_AUT	Nominal autonomy time [min]	1 1440	
MAX_BRC	Battery recharging current [A]	5 100	See *ecf*
LOBA_TH	Autonomy end alarm threshold [V]	530 580	540 V

2.1.7 Battery temperature control

The battery temperature probe is an optional item that allows the control of the temperature in the battery room. The battery charging voltage can be automatically adjusted on the basis of the ambient temperature, according to the recommendations given by all the battery manufacturers.

The charging voltage is reduced if the temperature increases, with a gradient of *–2mV/°C* per cell; the reference temperature, which the nominal charging voltage is referred to, is 20° C.

In order to enable the charging voltage compensation there's no need of any EEPROM setting; if the temperature probe is connected the microprocessor automatically recognizes the function.

EEPROM settings are provided in order to enable the battery temperature alarm. An alarm is activated if:

- T_{BAT} < LO_T_BAT
- T_{BAT} > HI_T_BAT

– E^2PROM parameters

E2P Parameter	Description	Setting range	Standard
BAT_ALL	Enables the battery temperature alarm	ENABLE DISABLE	DISABLE
LO_T_BAT	Minimum temperature [°C]	-13 .... +10	-13° C
HI_T_BAT	Maximum temperature [°C]	+15 .... +53	+53° C

2.1.8 Battery boost charge

The boost charge can be activated in case the battery is not of the sealed type and needs a higher charging voltage after the discharge.

It is a current-controlled charge, as it is activated if the charging current exceed a programmable threshold and de-activated when the current drops below a different programmable level.

The boost charge is enabled only if the mains fail for a time longer than a programmable value (*B_DT_MIN*). As the mains is restored the rectifier voltage set-point is still the floating charge value; the battery current is monitored for a time equal to *B_TIMED* and the rectifier switched to boost charge (set point → *R_V_BOOST*) if the current is still above the activation threshold *B_EN_CUR* when the time has elapsed.

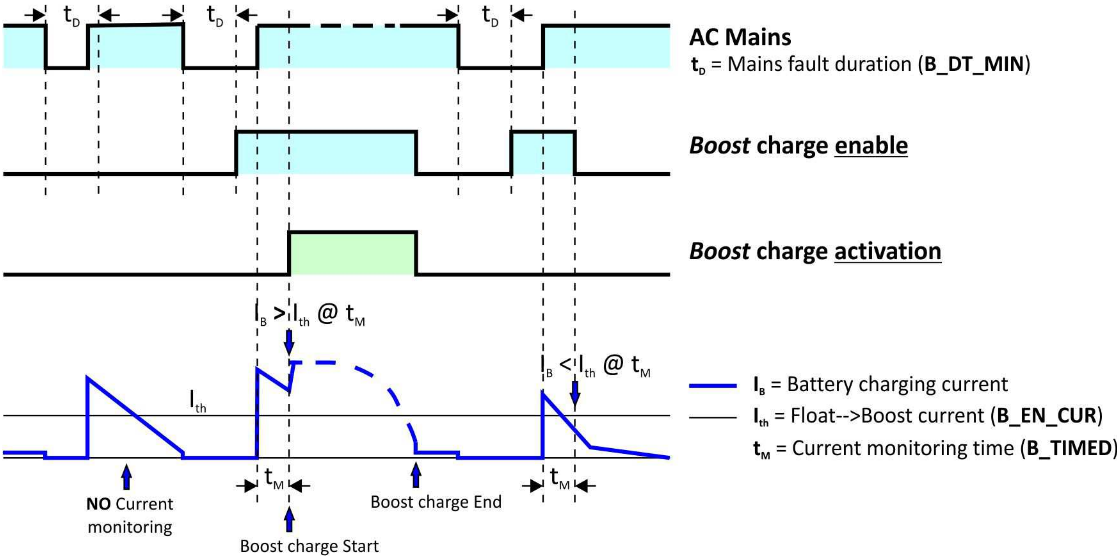


Figure 11 – Boost charge activation

The first phase of the charging process is performed at constant charging current (battery current limitation) and increasing voltage; once the voltage has reached the boost charge value the current starts to decrease. As it drops below the de-activation threshold *B_DI_CUR* for 30 seconds the boost charge process ends and the rectifier voltage switch back to the floating value.

During the boost charge the production of hydrogen increases significantly; the gas is discharged through the exhaust valve and does not affect the battery if the duration of the charge is limited (8 to 12 hours). In case the battery is subject to high voltage for a very long time the exhaust valve is not sufficient to discharge the hydrogen produced in excess, which remains inside the battery case causing overheating and bulging.

In order to avoid such occurrence a safety timer (*B_TIMES*) provides to stop the boost charge process even if the current is still above the de-activation threshold.

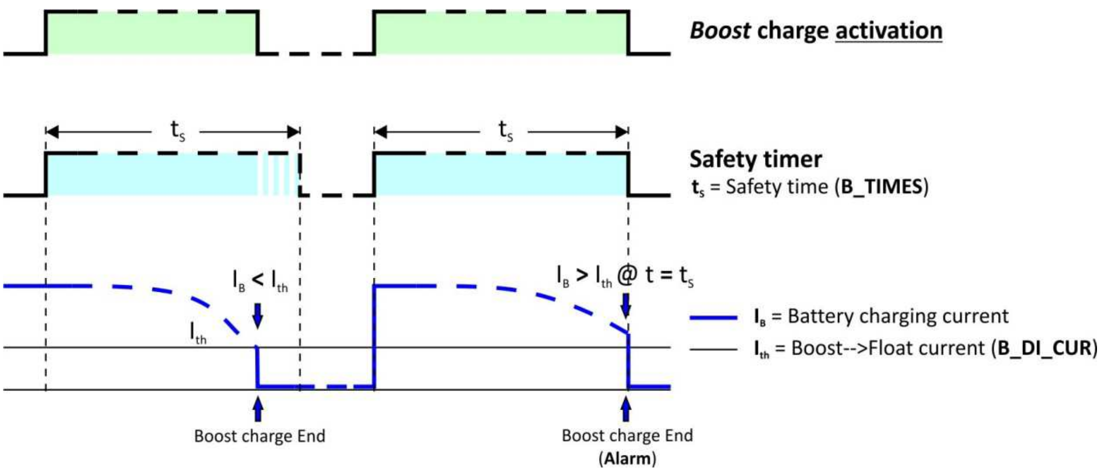


Figure 12 – Boost charge de-activation

– **E²PROM parameters**

E2P Parameter	Description	Setting range	Standard
F_BOOST	Enables the boost charge function	ENABLE DISABLE	DISABLE
B_DT_MIN	Mains failure timer [s]	1 50	1 min
B_EN_CUR	Float → Boost current threshold [A]	1 100	10 A (1)
B_DI_CUR	Boost → Float current threshold [A]	1 100	5 A (2)
B_TIMED	Boost charge start delay time [min]	1 5	1 min
B_TIMES	Safety timer [min]	10 1800	30 min
R_V_BOOST	Boost charge voltage [V]	680 752	700 V

(1) *B_EN_CUR* is normally set at 0,08 x C_{10} (C_{10} = battery rated capacity).
(2) *B_DI_CUR* is normally set at 0,03 x C_{10} (C_{10} = battery rated capacity).

2.1.9 Dynamic Charging Mode

As mentioned before the maximum battery recharging current depends on the rating of the UPS (i.e. it depends on the rating of the rectifier bridge). In case the battery needs a higher current for a proper charging it is possible to enable the Dynamic Charging Mode (DCM).

With DCM operation the rectifier works in power limitation mode, therefore additional current for the battery is only available if the UPS output power is lower than 100%.

The battery current behaviour versus the output load is represented in the diagram below.

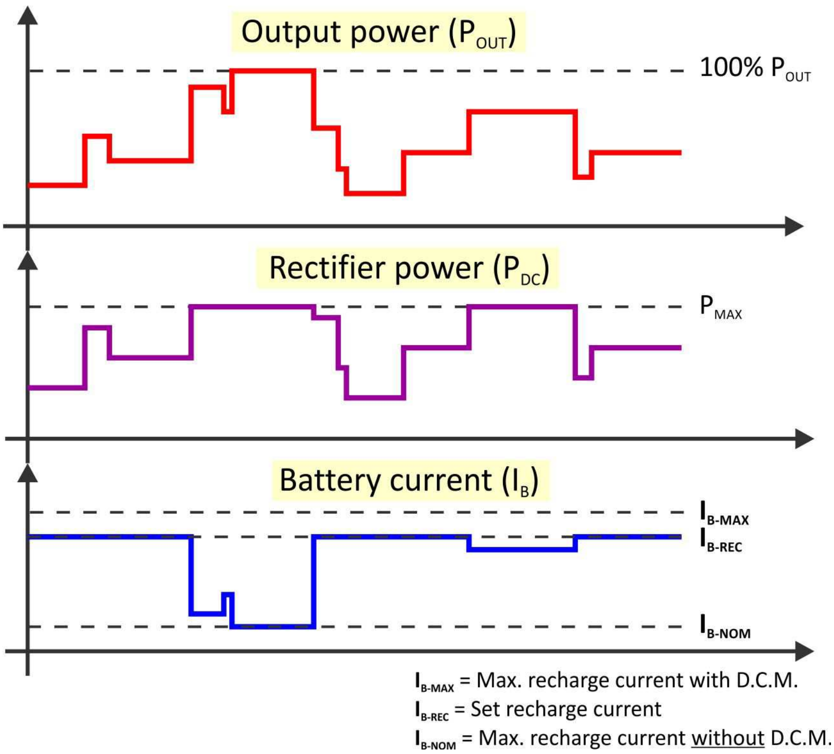
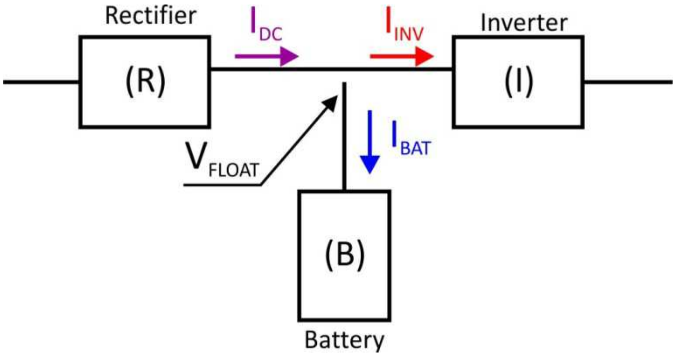


Figure 13 – Battery current during DCM operation



$$I_{DC\,(MAX)} = I_{BAT} + I_{INV}$$

$$I_{INV\,(MAX)} = \frac{P_{OUT}}{\eta_{INV}} \times V_{FLOAT} = const.$$

$$I_{BAT\,(MAX)} = I_{B-NOM} = const.$$

$$if \quad I_{INV} < I_{INV\,(MAX)} \quad then$$

$$\boldsymbol{I_{BAT\,(REC)} = I_{DC\,(MAX)} - I_{INV}}$$

Figure 14 – DCM equations

– **E²PROM parameters**

E2P Parameter	Description	Setting range	Standard
DCM	Enables the Dynamic Charging Mode	ENABLE DISABLE	DISABLE

2.1.10 Battery test

The battery test can only be performed if the E2P parameter *TEST_B* is enabled. Different programming options are available:

- Manual test → Launched by display
- Automatic test every 15 / 30 / 60 / 90 days

During the test the booster is stopped so that the rectifier voltage is reduced and the battery start to discharge. The discharge current depends on the output load, therefore the duration of the test and the voltage threshold under which the battery is considered defective can be adjusted. If the battery voltage reaches the value *BFAULTHR* before the counter *TBAT_DUR* has elapsed the test is stopped and the *Battery fault* alarm is activated.

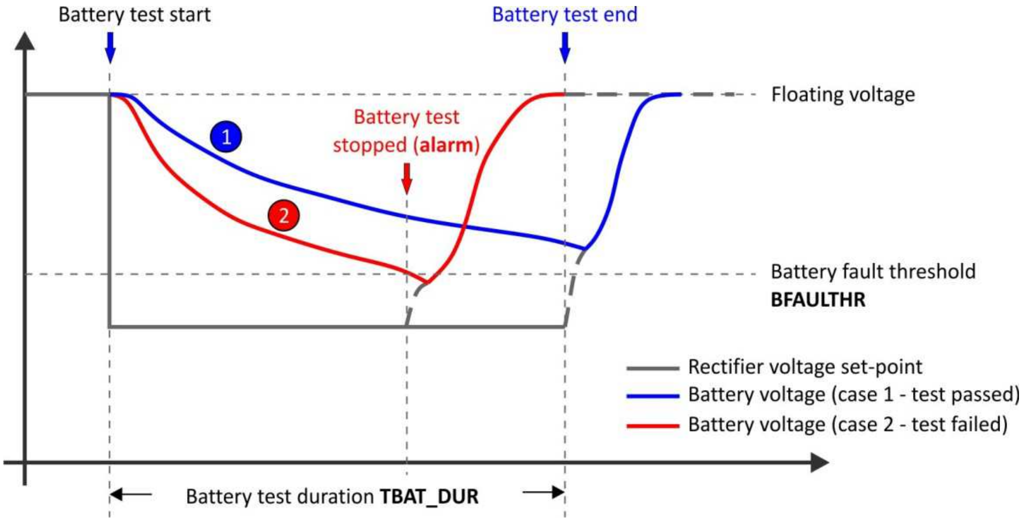


Figure 15 – Battery test

– E²PROM parameters

E2P Parameter	Description	Setting range	Standard
TEST_B	Enables the type of battery test	DISABLE MANUAL AUTO xx [(1)]	MANUAL
TBAT_DUR	Duration of the test [s]	20 21600	20 s
BFAULTHR	Test failed threshold [V]	570 630	570 V

(1) xx defines the days interval between two automatic battery tests and can be 15 / 30 / 60 / 90 days.

2.1.11 Diesel Mode

The Diesel Mode is enabled by a normally-closed contact connected to the UPS auxiliary terminals (see installation manual). When the contact is closed the rectifier works at reduced DC voltage in order not to recharge the battery; this operation allows to save some energy so that the diesel generator operation is more stable.

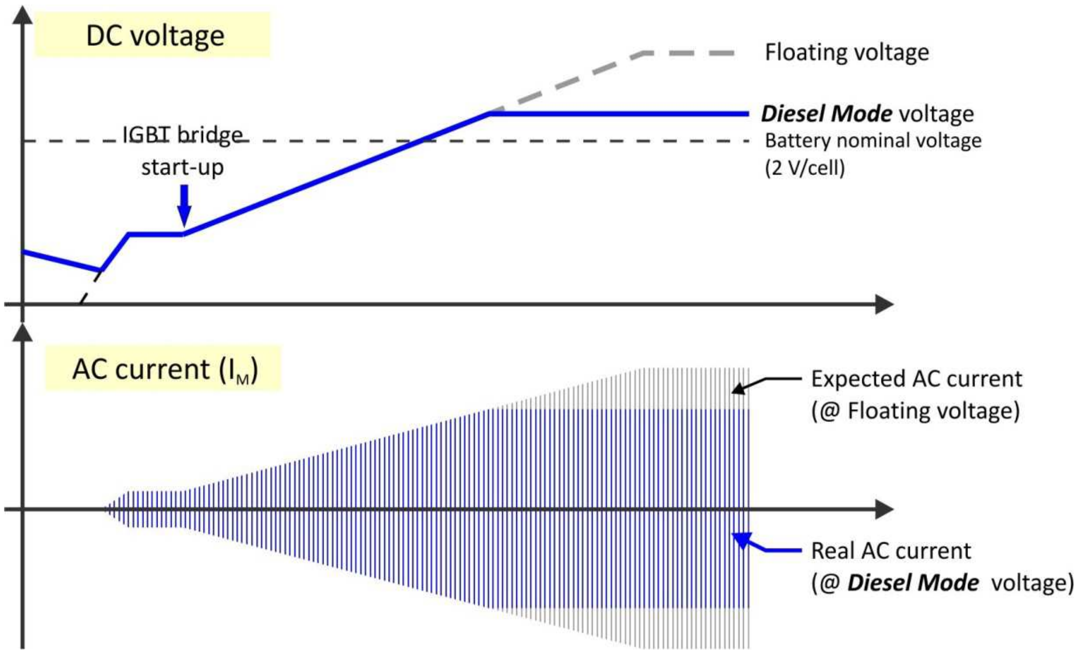


Figure 16 – Diesel Mode operation

– E²PROM parameters

E2P Parameter	Description	Setting range	Standard
DIESEL_M	Enables the Diesel Mode	ENABLE DISABLE	DISABLE
R_V_DIES	Rectifier voltage in Diesel Mode [V]	600 690	660 V

2.2 INVERTER

2.2.1 General description

The inverter is made up of six power blocks, controlled by the IGBT driver boards. The inverter bridge is connected to the transformer T1, which provides the galvanic insulation between the DC bus and the AC output. The transformer is provided with a leakage inductance that forms a low-pass filter with the output capacitors Cr-Cs-Ct; the filter provides to eliminate the high frequency harmonics from the output waveforms in order to reduce the distortion of the sine-waves.

Current transducers are installed after the inverter static switch thyristors to measure the output current; the feedback value is used in the overload protection algorithm.

The PWM generation and control are completely digital and managed by the microprocessor board PB349 on the basis of the current and voltage feedback values.

The current transducers installed on the inverter input section (DC side) are used to monitor the DC current and activate, when necessary, the output short circuit protection.

An additional protection for the inverter bridge is provided by fuses installed on the DC side, which are operated only in case of severe failure of the bridge itself.

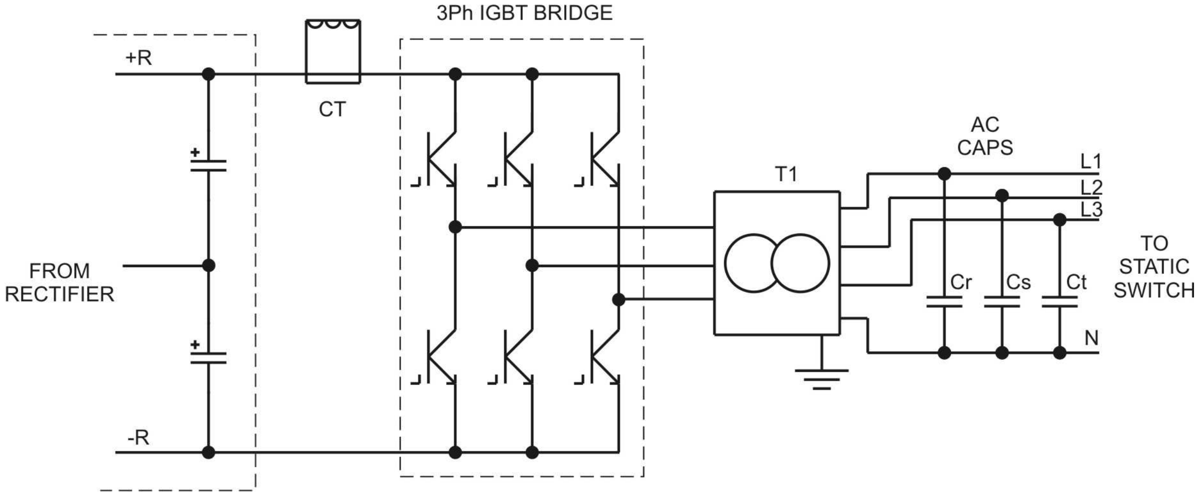


Figure 17 – Inverter diagram

2.2.2 Acquisition of the control signals and measures

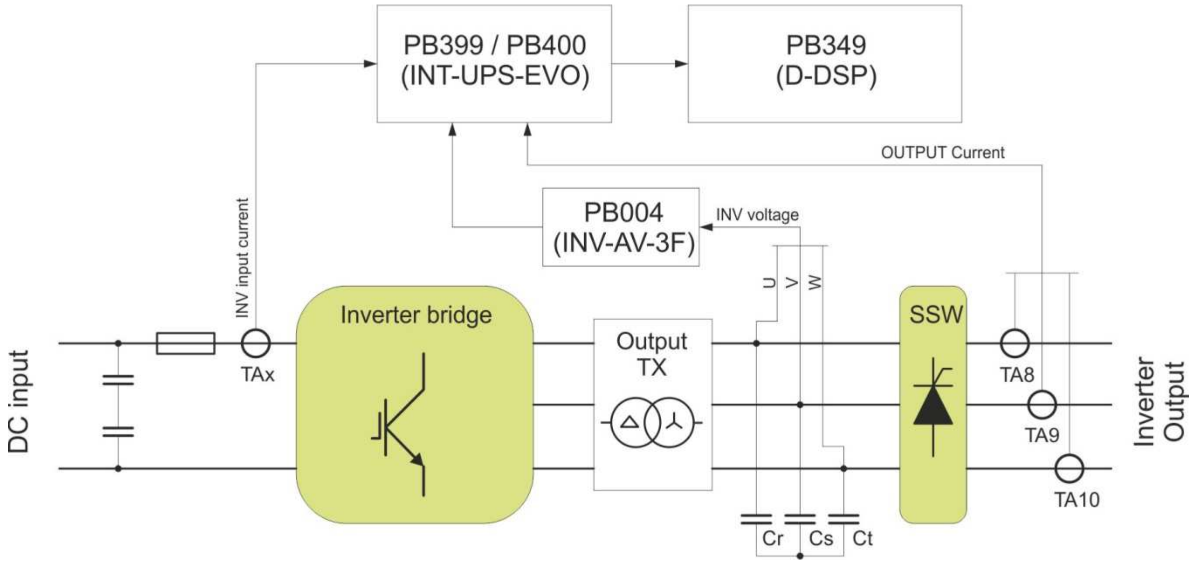


Figure 18 – Acquisition of the measures (Inverter section)

The inverter operation is controlled on the basis of the following control signals:

- input current, acquired through Hall-effect current transducers;
- output voltage, acquired through signal transformers in the INV-AV-3F board;
- output current, acquired through Hall-effect current transducers.

– **E²PROM parameters**

E2P Parameter	Description	Setting range	Standard
INV_V_NM	Inverter nominal voltage [V]	220 – 230 – 240	See *ecf*
INV_V_TL	Inverter voltage tolerance [%]	1 20	10 %

2.2.3 Management of the operating variables

During the inverter operation the microprocessor keeps all the operating parameters under control and provide to activate the protections in case one or more parameters are beyond the acceptability range. In this case the inverter is stopped (alarm A25) and the voltage declared out of tolerance (alarm A13).

The IGBT modulation is controlled by the variable CONAC, that is responsible for the inverter start-up and shut-down; its activation depends on the following conditions.

Not (DC_FUSES_BLOWN)	The inverter DC input fuses are blown.
Not (THERMO_SWITCH_INV)	The thermal switch on the inverter heat-sink or on the transformer has reached the maximum temperature.
Not (DESAT)	De-saturation pulse from the IGBT drivers.
Not (ELECT_FUSE_PROT)	Protection against excessive current on the inverter DC side.
Not (IMTERM)	Intervention of the thermal image algorithm after a sustained overload.
Not (ERROR_LOOP)	The inverter is unable to stabilize and control the AC voltage.
Not (SHORTCIRCUIT)	Intervention of the output short-circuit sensor.
Not (EPO_BUS)	Operation of the EPO switch.
Not (MBYP_STOP)	Operation of the manual bypass switch MBCB with the output switch OCB still closed.
Not (COMM_FAULT)	Internal communication fault.
CABLE_IN	Parallel cable not connected; effective only on parallel systems.
CONS_RAD_INV_ON	Enabling from the rectifier microprocessor; this parameter mainly depends on the FASTSHUTDOWN variable, which is activated when the DC voltage is beyond the upper or lower threshold for a very short time.

2.2.4 Overload management

The overload alarm is activated whenever the **active** power on one of the phases exceed the rated value. For a 300kVA UPS the maximum active power, according to the technical specification, is 240kW (power factor equal to 0,8); therefore the maximum active power for each phase is ${}^{240}/_{3} = \mathbf{80}\ \boldsymbol{kW}$.

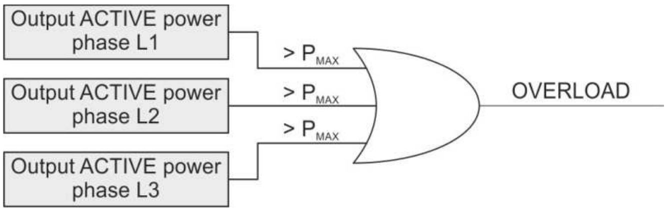


Figure 19 – Management of the Overload variable

As soon as a overload is detected the microprocessor activates the *thermal image* algorithm, which starts to count and evaluate the excess energy drawn by the load. This value is compared with a reference diagram and the inverter is stopped after a time that depends on the percentage of overload.

As soon as the inverter is stopped the static switch control transfers the load to the bypass line (if available).

- *If 100% ≤ Load ≤ 124% → Maximum time = 10 minutes*
- *If 125% ≤ Load ≤ 149% → Maximum time = 60 seconds*
- *If 150% ≤ Load ≤ 199% → Maximum time = 10 seconds*

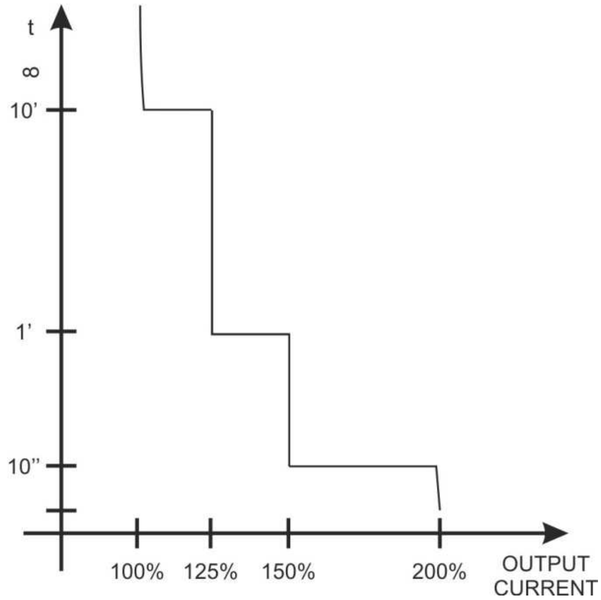


Figure 20 – Inverter overload characteristic

In case the output load exceeds 199% of the rated load the output short circuit protection is activated.

2.2.5 Output short-circuit protection

The short circuit protection depends on the feedback signal from the inverter input current transducers; the DC input current is proportional to the AC output current, so this signal can be used as well.

When the current exceeds the threshold a hardware protection activates a direct digital signal on the microprocessor (*PWM_TRIP*), which momentarily stops the inverter modulation.

The short circuit is managed in two different ways, depending on the presence of the bypass.

- If the bypass is available the PWM is stopped and the static switch logic commands the load transfer to bypass. The bypass should have enough current capability to operate the load's electrical protection (circuit breakers or fuses).
- If the bypass is not available the short circuit is supplied by the inverter, that limits the current to 200% for 100ms and then to 125% for 5 seconds. After this time has elapsed the inverter is definitely turned off and a time-out alarm is activated.

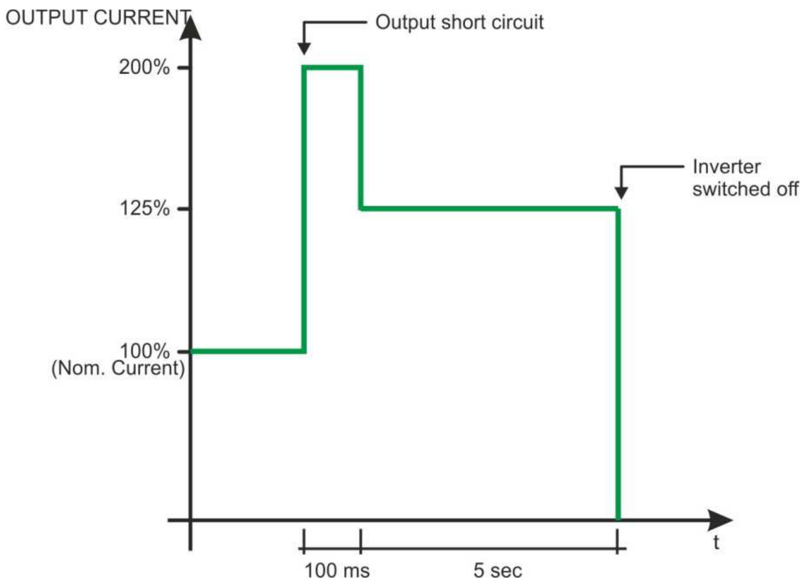


Figure 21 – Inverter short circuit characteristic

2.2.6 Management of the re-start after a complete battery discharge

When the battery is fully discharged and the DC voltage drops below the threshold (*INVOFFTH*) the inverter shuts down.

As the mains is restored the rectifier starts to charge the battery and the DC voltage gradually increases depending on the status of the battery. The UPS output supply can be restored in three different ways, depending on the setting of the variable *RST_DISC*.

– **Re-start from BYPASS**

This is the standard operation regarding the mode of restoring the UPS output supply after a full battery discharge.

The supply is restored immediately from bypass, as soon as the mains is available. The inverter is re-started only when the DC voltage exceeds the re-start threshold (*RSTA_INV*).

In case of power failure during this period of time the load is not supplied.

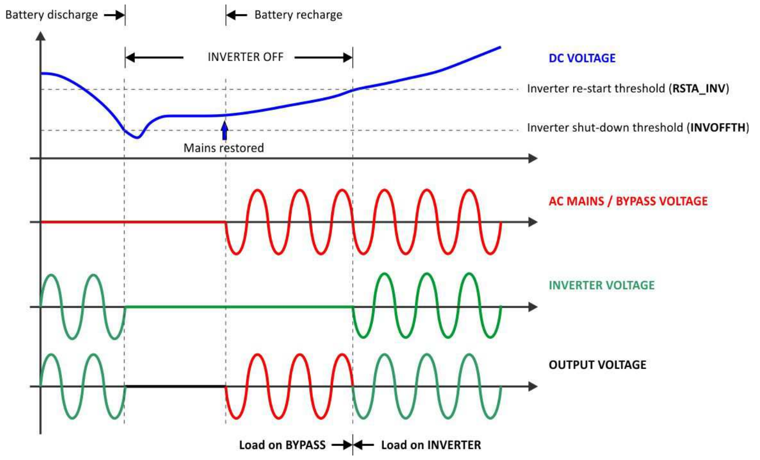


Figure 22 – Load re-supplied by bypass

– **Re-start from INVERTER**

The output supply is restored only when the DC voltage exceed the inverter re-start threshold (*RSTA_INV*) and the inverter is enabled to start. The threshold must be set in such a way that the battery had restored a sufficient capacity in order to sustain the inverter in case of short power failures after the re-start.

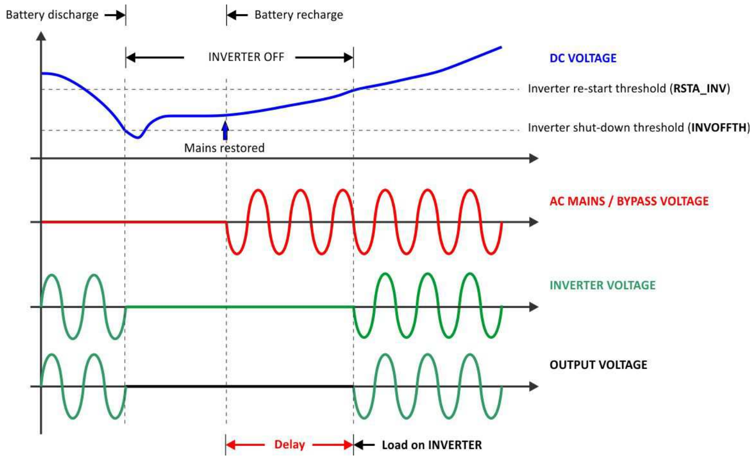


Figure 23 – Load re-supplied by inverter

Particular care must be taken on properly setting the inverter re-start threshold *RSTA_INV*.

After a discharge the battery has a “cushion” effect, so that the voltage increases as soon as the load is no longer applied. So, after the inverter has shut down, the battery voltage starts to rise and might exceed the *RSTA_INV* threshold even though the mains is still unavailable.

If this happens the inverter will unpredictably re-start and the AC voltage will be available at the UPS terminals for a certain time, that depends on how fast the battery voltage will drop below the inverter shutdown level. This effect might be very dangerous in case technicians are working on the UPS line.

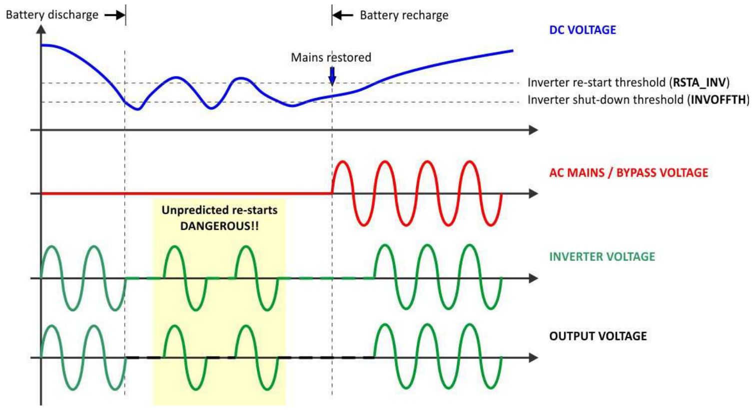


Figure 24 – Unpredicted re-start of the inverter

– **MANUAL Re-start**

For particular sensitive loads the operator may require not to re-start them automatically after a power failure; this is possible with the MANUAL re-start mode.

As soon as the DC voltage exceeds the inverter re-start threshold (*RSTA_INV*) the display shows a message and the inverter can be re-started manual by simply pressing a key.

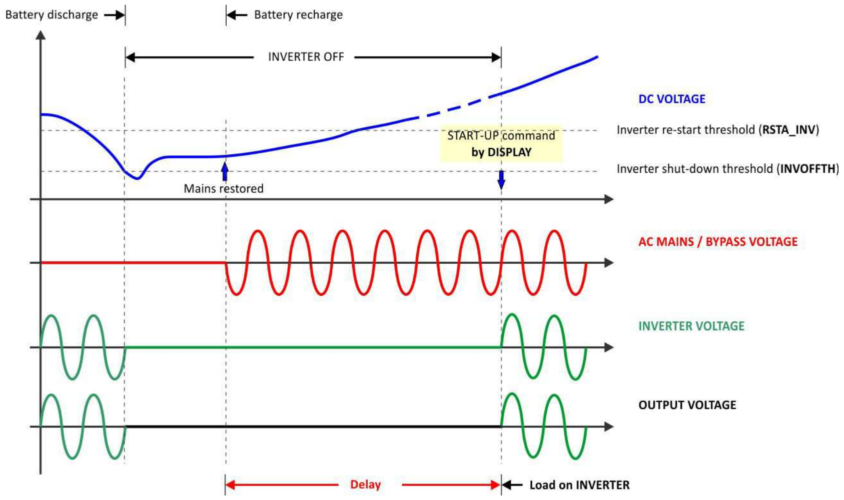


Figure 25 – Load re-supplied manually

– **E^2PROM parameters**

E2P Parameter	Description	Setting range	Standard
INVOFFTH	Inverter DC shutdown threshold [V]	490 520	496 V
RSTA_INV	Inverter DC re-start threshold [V]	530 644	644 V
RST_DISC	Load re-supply mode after inverter shutdown due to low DC voltage	BYPASS INVERTER MANUAL	BYPASS

2.3 STATIC TRANSFER SWITCH

2.3.1 General description

The three-phase emergency line is connected to the terminals 2-L1, 2-L2, 2-L3, 2-N; the by-pass line is energized by closing the input switch SBCB.

The static switch thyristors on the bypass line are protected by fast-acting fuses.

The control signals for the thyristors are generated by the microprocessor board and sent to the firing boards 2-SCRFIR, connected directly to the gate of the thyristors.

The control logic automatically transfers the load to the by-pass line in case of an inverter failure or overload. The manual by-pass switch MBCB connects directly the emergency line input to the load in case of UPS maintenance.

The bypass line can be:

- LOCAL → a bypass line for each UPS (standard configuration);
- SINGLE → a single bypass line for a group of UPS's in parallel;
- NOT PRESENT → typical configuration of a frequency converter.

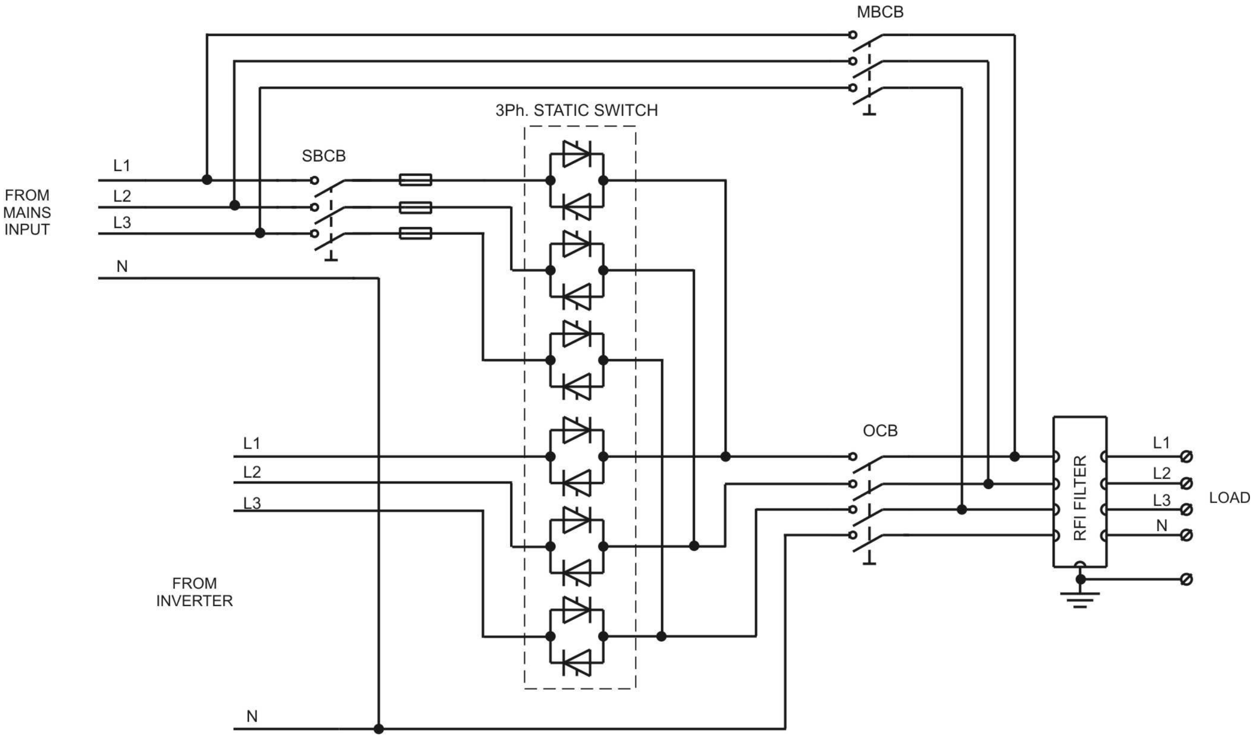


Figure 26 – Static switch diagram

2.3.2 Acquisition of the control signals and measures

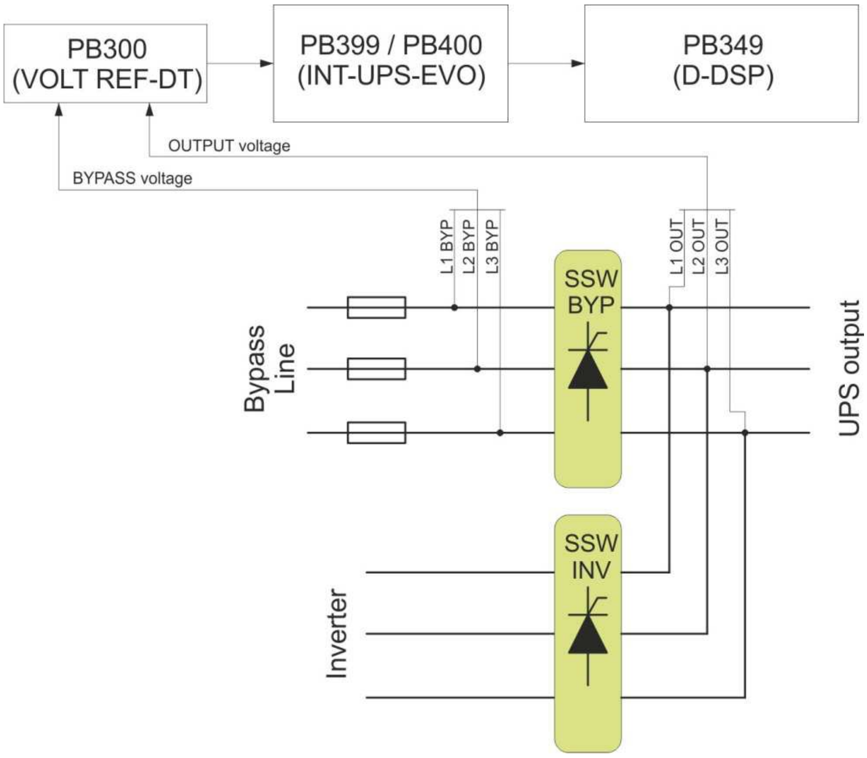


Figure 27 – Acquisition of the measures (Static Switch section)

The static switch operation is controlled on the basis of the following control signals:

- output voltage, acquired through signal transformers in the VOLT REF-DT board;
- bypass voltage, acquired through signal transformers in the VOLT REF-DT board.

– **E^{2}PROM parameters**

E2P Parameter	Description	Setting range	Standard
TIPO_BYP	Bypass configuration	LOCAL SINGLE NOT PRESENT	LOCAL
BYP_V_NM	Bypass nominal voltage [V]	220 – 230 – 240	See *ecf*
BYP_V_TL	Bypass voltage tolerance [%]	1 20	10 %
BYP_F_TL	Bypass frequency tolerance [%]	1 20	10 %
OUT_V_NM	Bypass nominal voltage [V]	220 – 230 – 240	See *ecf*
OUT_V_TL	Bypass voltage tolerance [%]	1 20	10 %

2.3.3 Control of the bypass voltage

The bypass voltage is controlled by the microprocessor according to the setting of the EEPROM parameters.

For each phase the following parameters are controlled:

- frequency;
- voltage RMS value;

- synchronization reference.

The resulting signals are combined together with the *PHSEQ_BYP_OK* (control of the phase rotation).

A fast voltage sensor is also provided, the associated variable is called *BYP_SV*. Each sample of the mains voltage, that is taken over a period, is compared with a reference table; if a certain number of consecutive samples are beyond the tolerance range the voltage is declared out of tolerance and the relevant alarm message is activated.

When the bypass voltage is good the variable *BYP_X_OK* is activated.

2.3.4 Control of the output voltage

The output voltage is controlled by the microprocessor according to the setting of the EEPROM parameters.

For each phase the following parameters are controlled:

- voltage RMS value;
- synchronization reference.

The resulting signals are combined together with the *COK_SV*, that is the fast voltage sensor for the output voltage. The operating principle of this sensor is equal to the one described regarding the bypass voltage.

When the output voltage is good the variable *COK_RMS* is activated.

2.3.5 Management of the operating variables

The static switch operates in three different conditions:

1) inverter static switch (SSI) closed and bypass static switch (SSB) open;
2) bypass static switch (SSB) closed and inverter static switch (SSI) open;
3) both static switches open.

The primary supply source is the inverter, therefore the control logic keeps SSI closed until the inverter voltage is within the tolerance range (*IOK_X*) and the output voltage is good (*COK_RMS*).

The transfer to bypass is commanded only if the bypass is available (*BYP_X_OK*) and for the following reasons:

- inverter shut-down (see 2.2.3);
- operation of the output voltage RMS and fast sensors (*COK_SV* and *COK_RMS*);

In the above said conditions, and in case the bypass is not available, the UPS opens the static switch and the output supply is interrupted.

The static switch also blocks in open mode in case of short circuit supplied by inverter for more than 5 seconds. In this case a logic reset is necessary to restore the normal operation.

2.3.6 Back-feed protection

The Back-feed protection prevents the inverter feeding power back to the mains in case of failure of the bypass static switch.

In order to achieve this function an automatic disconnection device is required; the FXS UPS uses a contactor which operation is controlled by the microprocessor board through a relay installed in the board BRIDGE_WRC (PB295).

The contactor opens whenever the bypass parameters are not within tolerance (*not BYP_X_OK*), so that there's a physical isolation between the inverter and the mains even in case of failure (short-circuit) of the bypass static switch thyristors.

3 UPS PARALLEL OPERATION

A parallel system is made up of at least two stand-alone units whose outputs are connected together. A stand-alone unit can be easily modified into a parallel one by simply installing the parallel interface board on each UPS and connecting all the units together with the BUS cable.

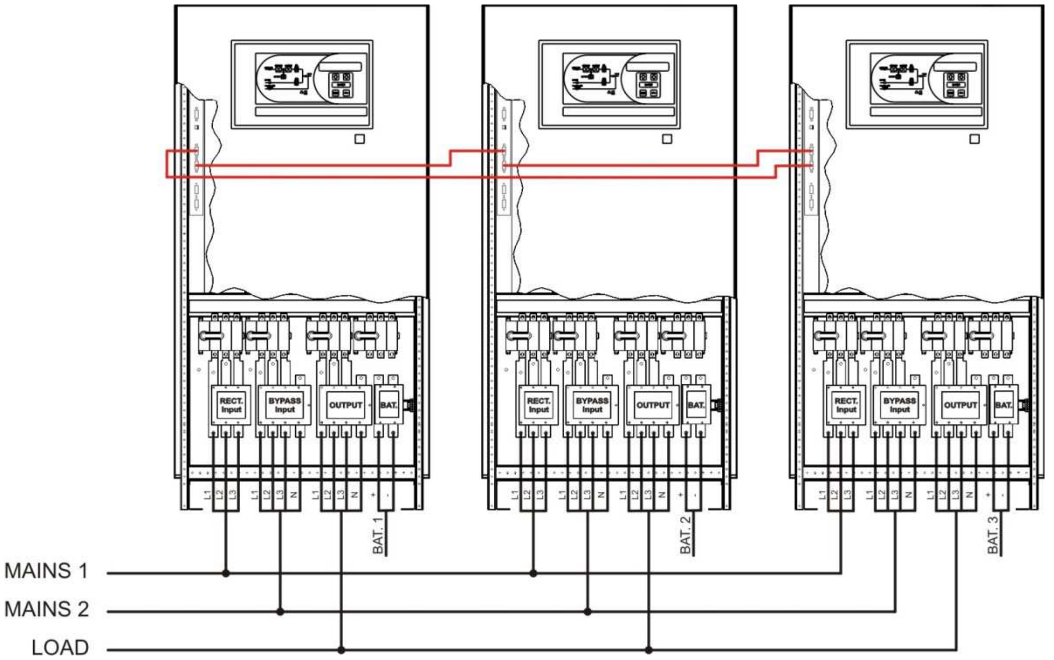


Figure 28 – Parallel connection

A loop connection is used for the BUS cable is order to have the whole system fully operational even in case of disconnection of one end of the cable (or in case one of the cables is cut).

3.1 SETTINGS FOR THE PARALLEL OPERATION

The operating parameters must be properly set on each UPS that forms the parallel system.

– **E²PROM parameters**

E2P Parameter	Description	Setting range	Standard
FLAG_PAR	Enables the parallel control	ENABLE DISABLE	DISABLE
TYPE_PAR	Parallel type (1)	AUTO POWER RED+x (4)	POWER
PAR_IND	Parallel index (2)	1 8	1
PAR_NUMB	Parallel number (3)	2 8	2

(1) Defines the redundancy logic.
(2) Total number of UPS's in the parallel system; the value must be the same for all the units.
(3) "x" is a number ranging from 1 to 7.
(4) Position of each UPS inside the parallel system; the value must be different on all the units.

3.2 REDUNDANCY LOGIC

The redundancy logic is defined by the EEPROM parameter *TYPE_PAR*. It basically defines how the parallel system must behave in case of failure of one of the unit; two different settings are possible.

- Red+x (x is the number of redundant units).
- Power parallel (no redundancy is provided).

3.2.1 Redundant parallel (Red+x)

When a parallel is system is declared "redundant" it means there is at least one UPS in excess for the actual load the system is supplying. A parallel redundant system made of 2 x 160kVA UPS's is normally used in an installation where the maximum load will never exceed 160kVA, so that one unit is capable of supplying the whole load by itself.

The following pictures show a parallel system made of 2 UPS's, the redundancy logic is set at **Red + 1**. During normal operation both inverters supply the load equally sharing the output current; in case of failure of one of the two inverters the load is supplied by the remaining inverter as the redundancy logic is still fulfilled.

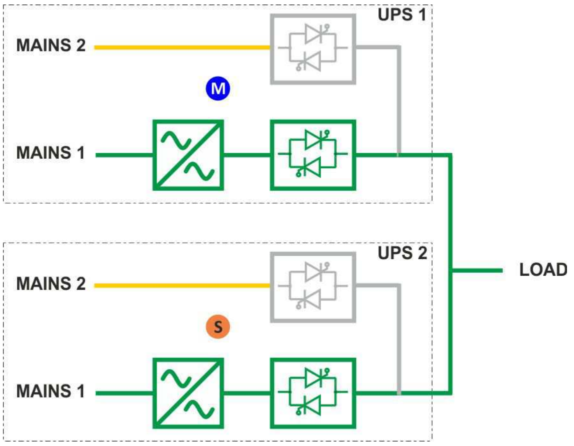


Figure 29 – Normal operation of 2 UPS's

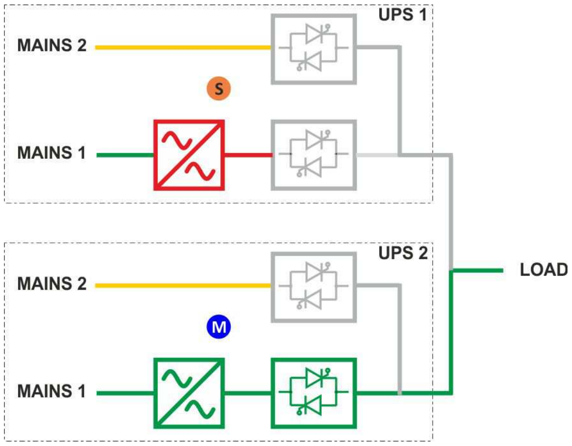


Figure 30 – Failure of inverter #1

In case of failure of the second inverter the whole load is transferred to bypass as the primary source is no longer available; the retransfer can only occur when at least one of the two inverters is ready to supply the load again.

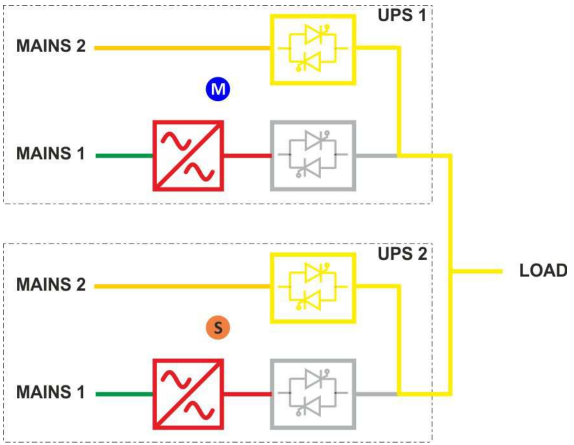


Figure 31 – Failure of both inverters

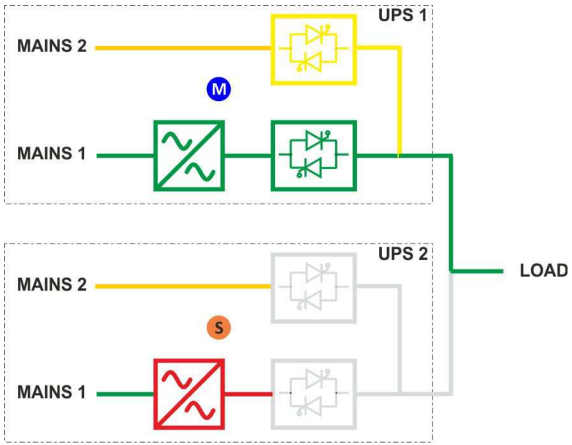


Figure 32 – Inverter #1 restores normal operation

A different case can be analyzed, where the redundant system is made of 4 UPS's and the redundancy logic is set as **RED + 2**. This means that each source (inverter or bypass) is considered available only when at least 2 out of 4 are available.

During normal operation the load is supplied by the primary source (inverter) until at least 2 of them are available.

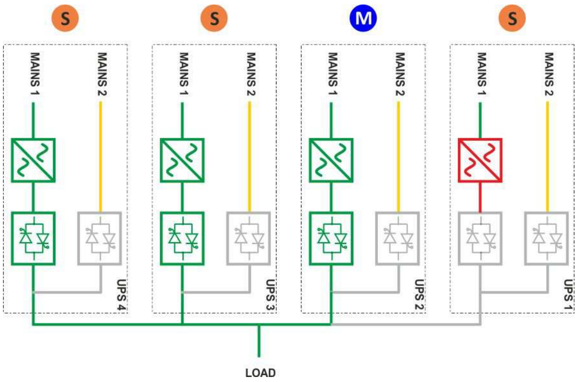


Figure 33 – Normal operation of 4 UPS's

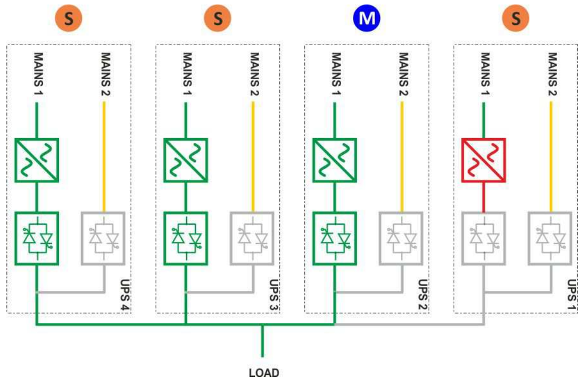


Figure 34 – Failure of Inverter #1

When the third inverter fails the load is transferred to bypass as only one inverter remains and the redundancy logic requires **at least** 2.

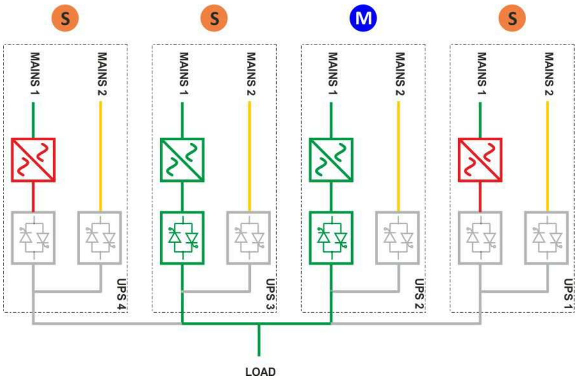


Figure 35 – Failure of 2 inverters

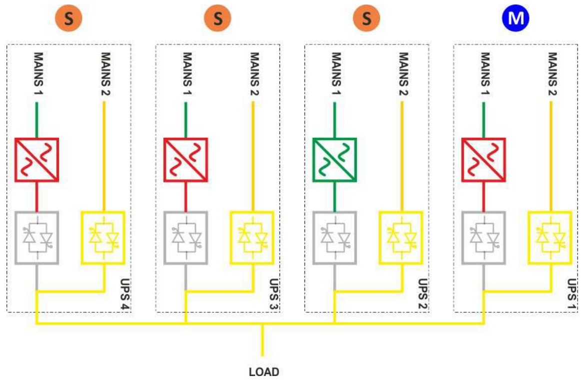


Figure 36 – Failure of 3 Inverters (Load → bypass)

Now the load is supplied by bypass, which is considered available as long as it is present on at least two units. If it is available on only one of the UPS the load is disconnected as the redundancy logic is no longer fulfilled.

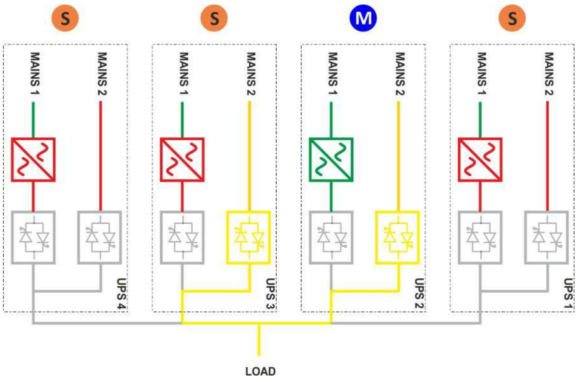


Figure 37 – Unavailability of 2 bypass lines

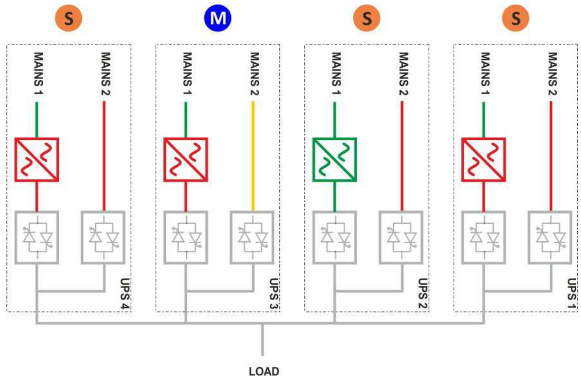


Figure 38 – Unavailability of 3 bypass lines

3.2.2 Power parallel

The power parallel is a particular case of redundant parallel *Rex+x*, where “x” is equal to zero. This means that all of the different inverters that compose the system, as well as all of the different bypass lines are considered as a single system. Failure or unavailability of one of the parts will make that section completely unavailable.

3.2.3 Automatic parallel

The *Automatic* parallel is a specific configuration of the operating parameters so that the microprocessor automatically defines the redundancy logic on the basis of the actual load.

When the load decreases the modification of the redundancy logic is performed after a certain time, defined by the EEPROM parameter *RIT_CRID*.

When the load increase the change of the redundancy logic is immediate.

Let’s imagine a parallel system made up of 3 x 100kVA.

1) Output load = 150kVA

- UPS required: 2
- Redundancy logic: **Red+1** (2 out of 3)

2) Load increases to 210kVA

- UPS required: 3
- Redundancy logic: **Power parallel** (no redundancy in case of failure of one source)
- Redundancy logic is <u>immediately</u> changed.

3) Load decreases to 80kVA

- UPS required: 1
- Redundancy logic: **Red+2** (1 out of 3)
- Redundancy logic changes from power parallel to Red+1 after the time *RIT_CRID*.
- Redundancy logic changes from Red+1 to Red+2 after the time *RIT_CRID*.

– **E^2PROM parameters**

E2P Parameter	Description	Setting range	Standard
RIT_CRID	Delay time for the change of the redundancy logic [minutes]	1 30	1 minute
ENALLOR	Enables the loss of redundancy control	ENABLE DISABLE	DISABLE

3.2.4 Loss of redundancy

On a redundant parallel system (Red+x) the logic is normally defined on the basis of the maximum load that can be connected on the UPS supply.

In case the load increases beyond the maximum acceptable value, so that the redundancy logic is no longer satisfied, the microprocessor can activate an alarm related to the “loss of redundancy”. This warns the operator that in case of failure of one of the units, the others will supply more load than what they are expected to do in normal conditions.

The alarm can be activated by enabling the EEPROM parameter *ENALLOR*.

3.3 MASTER/SLAVE LOGIC

The MASTER/SLAVE logic on a parallel system is mainly used to define the synchronization strategy.

It is well-known that all the units of a parallel system must stay steadily synchronized, that is the output voltage of all the units must have no phase difference.

In order to achieve this task the logic defines a MASTER unit, that creates the synchronization reference for all the other inverters, which are called SLAVE units.

One of the most important parameters, that defines which unit must take the lead as the MASTER, is the parallel index, that is set through the EEPROM parameter *PAR_IND*.

This number defines the priority on transmitting messages on the CAN BUS, so that the unit with the lowest number has the priority on all the others.

Therefore the MASTER is the unit, among those feeding the load, that has the lowest position (highest priority).

3.4 CURRENT SHARING CONTROL

The scope of the parallel control is to maintain the stability of the output variables and to react to the dynamic variations in such a way not to create any disturbances or malfunctions to the load. The block diagram of a parallel UPS system is shown in the following figure.

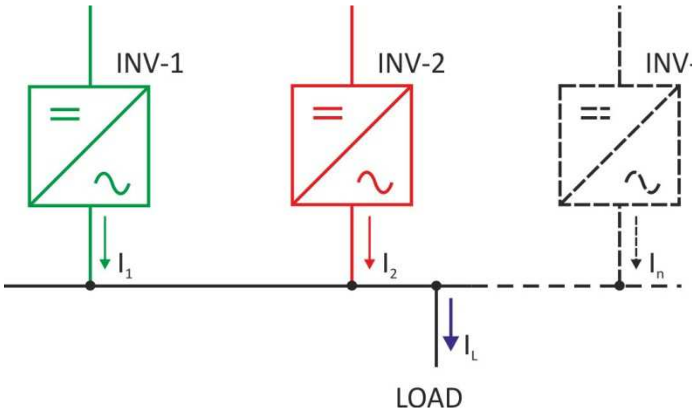


Figure 39 – Block diagram of a parallel system

The main task of the current sharing control is to equalize the output currents of all the units. Since we are dealing with an alternative variable (sine-wave in an ideal system) there are two parameters to keep under control: the module (amplitude) and the argument (phase displacement versus the output voltage).

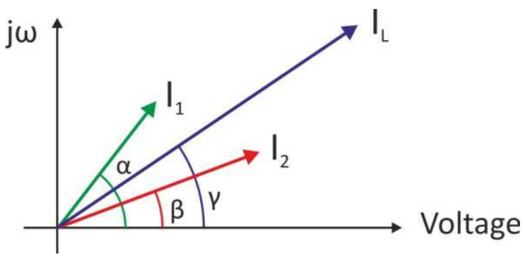


Figure 40 – Current vectors

The load current is a vector sum of different parts, each one with its module and argument.

$$\vec{I_L} = \vec{I_1} + \vec{I_2} + \ldots + \vec{I_n} \quad (1)$$

The current sharing control operates in order to fulfil the following conditions:

$$|\boldsymbol{I_1}| = |\boldsymbol{I_2}| = |\boldsymbol{I_n}| = \left|\frac{\boldsymbol{I_L}}{\boldsymbol{n}}\right| \quad (2)$$

and:

$$\boldsymbol{\alpha} = \boldsymbol{\beta} = \boldsymbol{\gamma} \quad (3)$$

Where “n” is the number of inverters that supply the load.

In order to equalize the magnitude and phase angle of the “local” current vectors, the microprocessor calculates the projections of the vectors on the real and imaginary axis, that’s to say the active and reactive components.

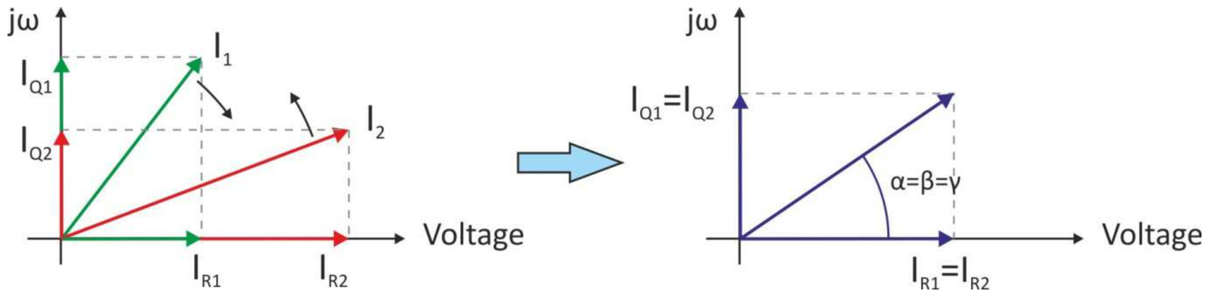


Figure 41 – Current vectors

The real and imaginary values of the currents are equalized by the control algorithm so that:

$$\boldsymbol{I_{R1}} = \boldsymbol{I_{R2}} = \boldsymbol{I_{Rn}} \quad \text{and} \quad \boldsymbol{I_{Q1}} = \boldsymbol{I_{Q2}} = \boldsymbol{I_{Qn}} \quad (4)$$

The equalities at (4) fulfil the conditions (2) and (3).

The inverter is a voltage generator and has no control on the output current, that only depends on the load. Therefore the only way to equalize the output current is by controlling the magnitude and phase angle of the output voltage.

The control signals for the inverter voltage are managed by a PI controller, that processes the resulting error signal of the comparison between the local output current (feedback signal from the output current transducers and the mean current.

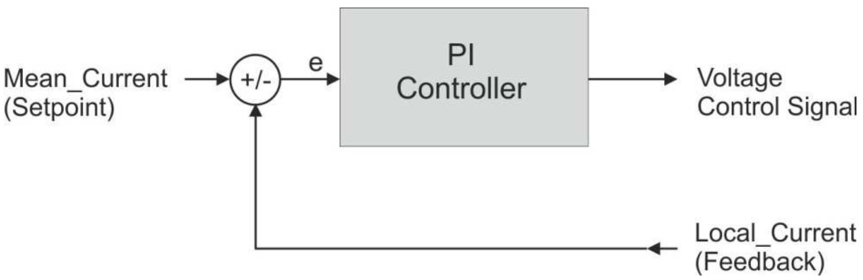


Figure 42 – Parallel PI controller

The mean current is calculated as follows:

$$\boldsymbol{I_{mean}} = \frac{\boldsymbol{I_1} + \boldsymbol{I_2} + \boldsymbol{I_3} + \cdots + \boldsymbol{I_n}}{\boldsymbol{n}} \quad (5)$$

Where “**n**” is the number of inverters that supply the load at each specific moment.

3.5 INFORMATION ON THE LCD

The LCD provides information on the actual status of the parallel system, regarding the settings and the data communication. The information about the parallel can be accessed through the menu INFO → PARALLEL. The information on the display can also be used as a first check for troubleshooting the unit in case of problems.

LCD display	Description
PARALLEL 2 / 4	Programmed position of the UPS (**2**) and total number of UPS's in the parallel system (**4**)
PARALLEL MASTER	Actual MASTER / SLAVE condition
PARALLEL 1 - [M] 2 - S 3 - S 4 - S PARALLEL 1 - M 2 - S 3 - S 4 - **[S]** PARALLEL 1 - [M] 2 - S 3 - **?** 4 - S	Current status of the parallel system and communication bus monitoring: - The numbers represent each UPS unit - The letters stand for MASTER (M) and SLAVE (S) - The brackets around a letter indicate which unit is currently being checked - A question mark next to a number indicates that there's no communication to and from that UPS unit
PARALLEL REDUNDANT + x	Parallel type
STATIST CAN SSW MSG RX: 32564 100.0%	Number of CAN messages and reception accuracy relevant to the static switches. Number rolling on all UPS units.
STATIST CAN INV SYNC RX: 15237 99.8%	Number of CAN messages and reception accuracy relevant to the synchronization signals. Number rolling on the SLAVE units only as the synchronism signal is sent by the MASTER.
STATIST CAN INV MSG RX: 9321 99.9%	Number of CAN messages and reception accuracy relevant to the operating status. Number rolling on all UPS units.

4 ADDITIONAL CONFIGURATIONS

4.1 ECO-MODE

The ECO-MODE is a particular configuration where the load is always supplied by the bypass line and the inverter is kept as a reserve supply source. In case of mains failure the load is transferred to inverter with a maximum time interruption of **10 ms**. As the mains is restored the load is transferred back to bypass after the adjustable delay time *ECO_TIME*.

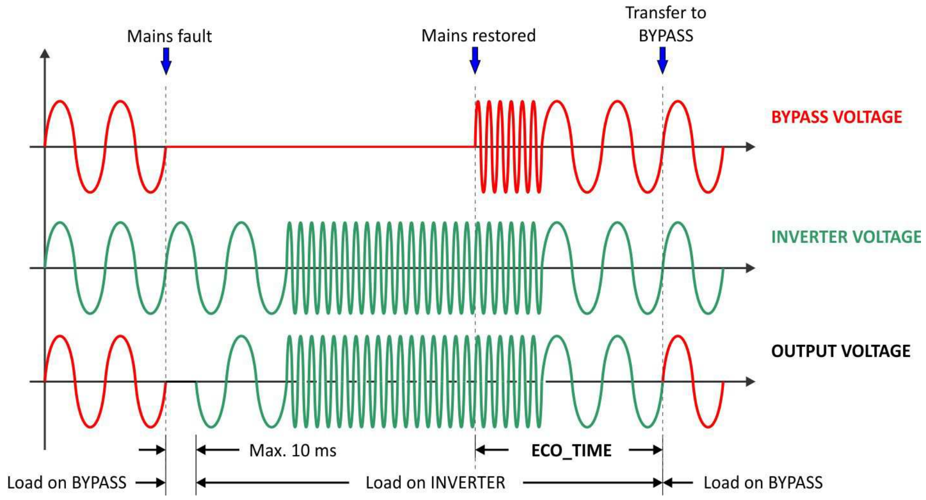


Figure 43 – Load transfer characteristic of the ECO-MODE configuration

– **E²PROM parameters**

E2P Parameter	Description	Setting range	Standard
ECO_MODE	Enables the ECO-Mode	ENABLE DISABLE	DISABLE
ECO_TIME	Re-transfer time from on-line to ECO mode	10 3600	10 s

4.2 LOAD-SYNC

The LOAD-SYNC configuration is used when there's the need of keeping different bus bars synchronized.

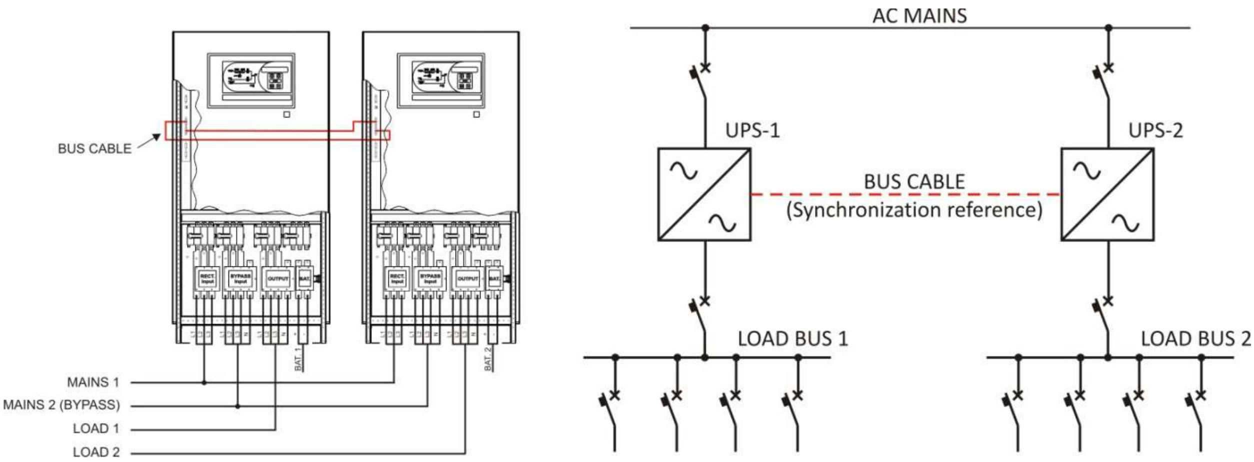


Figure 44 – LOAD-SYNC configuration

The configuration is very similar to the parallel as a bus cable must run through all the units that compose the LOAD-SYNC system and the interface board is the same as the parallel's. The communication messages are exchanged through the CANBUS.

The bypass line must be the same for all the UPS's as each unit behaves as being in stand-alone configuration, so each inverter is synchronized with the local bypass line.

– **E^2PROM parameters**

E2P Parameter	Description	Setting range	Standard
LOADSYNC	Enables the LOAD-SYNC Mode	ENABLE DISABLE	DISABLE

5 ELECTRONIC BOARDS

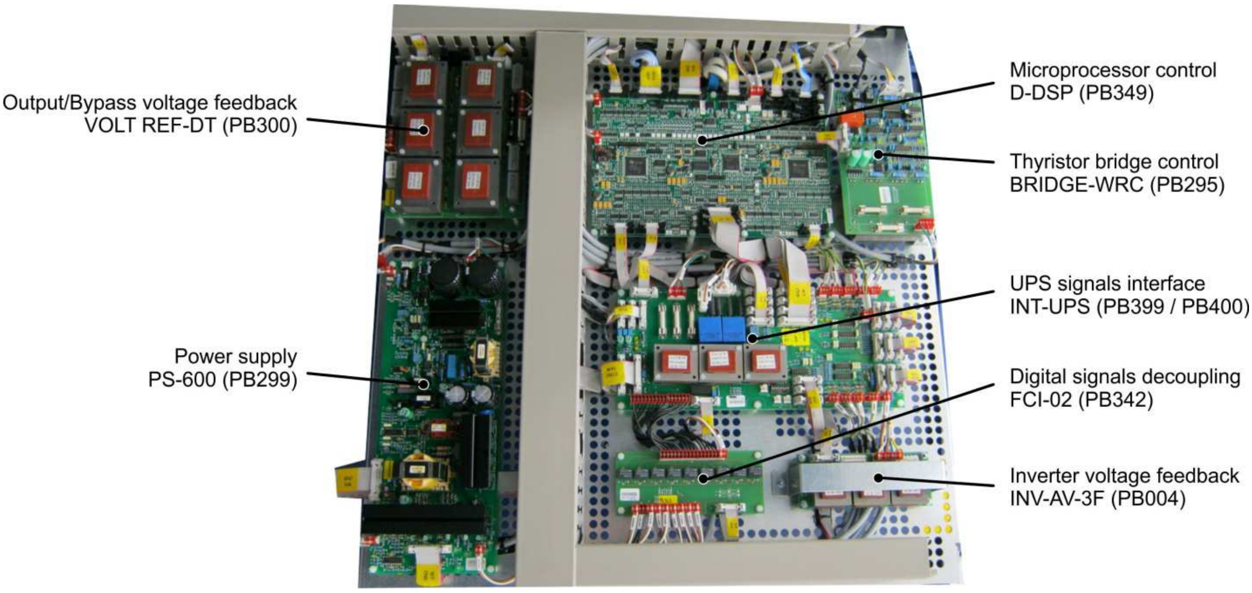


Figure 45 – Main control boards on the storm door

The electronic boards can be split in different groups, according to their specific function:

- power supply;
- control;
- signals interface;
- communication.

5.1 POWER SUPPLY (PB299)

The power supply board PB299 (PS-600) provides the DC stabilized power supplies for all the UPS' sections.

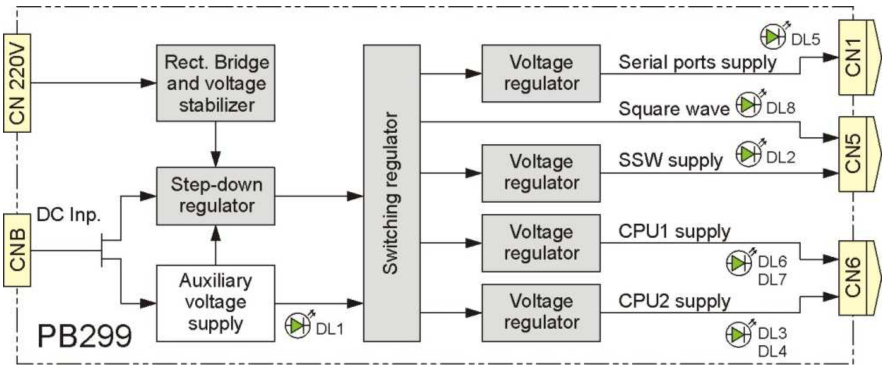


Figure 46 – Block diagram board PB299 (PS-600)

The DC input voltage from the inverter DC capacitors is connected to the connector CNB; a step-down regulator reduces and stabilizes the voltage and makes it available to the switching regulator. All the DC supplies are completely isolated from the input as they come from the secondary windings of a high frequency transformer. Additional voltage regulators stabilize the voltage at the values requested by the various sections.

Five supply sections can be identified:

- microprocessor 1 (CPU1);
- microprocessor 2 (CPU2);

- analogue controls;
- serial ports;
- IGBT drivers.

The following table lists the control LED's for the different outputs:

SECTION	LED		Value	Status
Internal supply	**DL1**		+12V	Steady ON
Analogue part supply	**DL2**	POS-SSW	+24V	Steady ON
CPU2 (POS) supply	**DL3**	POS-CPU2	+15V	Steady ON
CPU2 (NEG) supply	**DL4**	NEG-CPU2	−15V	Steady ON
Serial ports supply	**DL5**	+5SER	+5V	Steady ON
CPU1 (POS) supply	**DL6**	POS-CPU1	+15V	Steady ON
CPU1 (NEG) supply	**DL7**	NEG-CPU1	−15V	Steady ON
IGBT drivers supply	**DL8**	SQW-PS	35Vpp (Square wave)	Steady ON

5.2 THYRISTOR BRIDGE CONTROL (PB295)

The board PB295 (WRC-BRIDGE) controls the thyristor bridge, that is the first stage of the rectifier section.

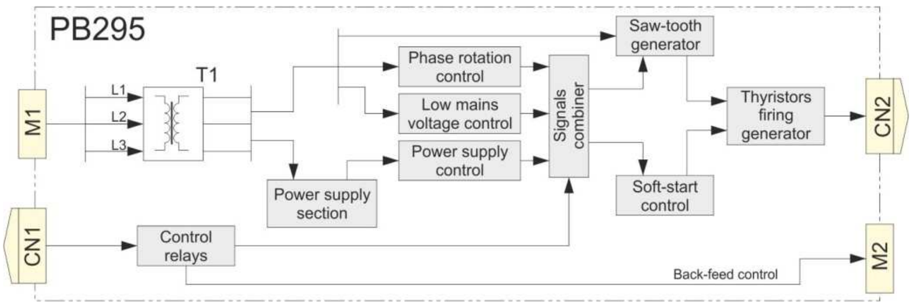


Figure 47 – Block diagram board PB295 (Thyristor bridge control)

The input three phase voltage is rectified and stabilized so that the board has its internal power supply section. The voltage is also controlled in terms of phase rotation and low RMS value; if all the parameters are within the range the control section starts to generate the thyristor firing signals.

– **Signals from the microprocessor board PB349**

The control relays inside the board PB259 are controlled by the microprocessor board PB349, that send the following signals.

PRECHARGE_ON The signal controls the relay RL1, which enables the thyristors control.

BRIDGE_ON The signal controls the relay RL3, which insert a DC signals in the thyristors control circuit, so that they work in diode-mode.

BACKFEED_ON The signal controls the relay RL4, which commands the back-feed contactor.

5.2.1 LED's table

The following table shows the meaning of the various LED's.

SECTION	LED	Colour	Status
Phase sequence control	**DL1**	**YELLOW**	Steady ON
Low mains voltage control	**DL2**	**RED**	Steady ON
Rectifier ON	**DL3**	**YELLOW**	Steady ON
Power supply control	**DL4**	**GREEN**	Steady ON
+12V supply	**DL5**	**GREEN**	Steady ON
-12V supply	**DL6**	**GREEN**	Steady ON
+12V relays	**DL7**	**GREEN**	Steady ON

5.3 MICROPROCESSOR CONTROL (PB349)

5.3.1 General description

The control board PB349 (D-DSP) manages the UPS operation and control all the communication interfaces

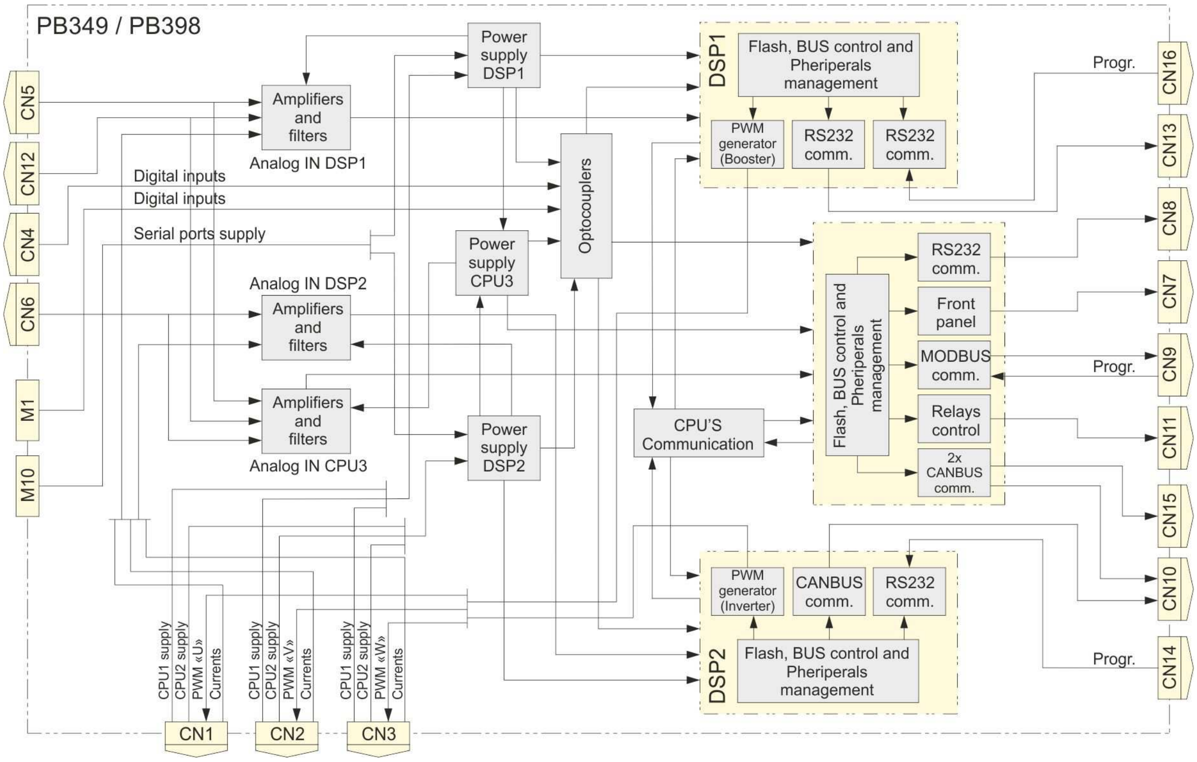


Figure 48 – Block diagram board PB349 (Microprocessor control)

The board uses two microcontrollers with integrated DSP, each provided with integrated A/D converters and BUSCAN interfaces for highly demanding industrial applications.

Another microcontroller with fast data processing capability is used to control all the user interfaces.

The three microprocessors control different sections of the UPS and communicate between each other through CANBUS interface. The basic functions are shown in the picture above.

5.3.2 Analogue inputs

All the analogue inputs (voltage and current measures) are directly connected to the microprocessor A/D converters. All the signals pass through the board PB399 (INT-UPS-FXS) or PB400 (INTH-UPS-FXS); each microprocessor acquires part of the analogue signals; then the signals are exchanged between the microprocessors through the communication section.

The following table shows all the analogue inputs managed by the control board and their path through the system (from the acquisition point to the control section).

Measure	Origin of the signal		PB399 / PB400 (INT-UPS-FXS)			PB349 (D-DSP)	
MAINS VOLTAGE (U)	F1 (U)	→	M5-1	CN7-4	→	CN5-4	DSP1
MAINS VOLTAGE (V)	F2 (V)	→	M5-3	CN7-5	→	CN5-5	
MAINS VOLTAGE (W)	F3 (W)	→	M5-5	CN7-6	→	CN5-6	
MAINS CURRENT (U)	TA1	→	M1	CN4-12	→	CN1-12	
MAINS CURRENT (V)	TA2	→	M2	CN5-12	→	CN2-12	
MAINS CURRENT (W)	TA3	→	M3	CN6-12	→	CN3-12	
DC VOLTAGE (POS)	DC CAPS	→	M7	CN7-9	→	CN5-9	
DC VOLTAGE (NEG)		→	M6	CN7-10	→	CN5-10	
BATTERY CURRENT	TA4 (1)	→	M4	CN4-13	→	CN1-13	
BATTERY TEMPERATURE	Temp. Probe	→			→	CN12-2	
BYPASS VOLTAGE (U)	PB300 (VOLT REF-DT)	→	CN10-4	CN7-1	→	CN5-1	CPU3
BYPASS VOLTAGE (V)		→	CN10-3	CN7-2	→	CN5-2	
BYPASS VOLTAGE (W)		→	CN10-2	CN7-3	→	CN5-3	
OUTPUT VOLTAGE (U)		→	CN10-5	CN11-1	→	CN6-1	
OUTPUT VOLTAGE (V)		→	CN10-6	CN11-2	→	CN6-2	
OUTPUT VOLTAGE (W)		→	CN10-7	CN11-3	→	CN6-3	
UPS TEMPERATURE	Temp. Probe	→			→	CN12-9	
INVERTER VOLTAGE (U)	PB004 (INV-AV-3F)	→	CN14-5	CN11-4	→	CN6-4	DSP2
INVERTER VOLTAGE (V)		→	CN14-4	CN11-5	→	CN6-5	
INVERTER VOLTAGE (W)		→	CN14-3	CN11-6	→	CN6-6	
INV. INPUT CURRENT	TA5 (2)	→	M8	CN4-2	→	CN1-2	
INV. INPUT CURRENT	TA6 (3)	→	M9	CN5-2	→	CN2-2	
INV. INPUT CURRENT	TA7 (4)	→	M10	CN6-2	→	CN3-2	
OUTPUT CURRENT (U)	TA8	→	M11	CN4-3	→	CN1-3	
OUTPUT CURRENT (V)	TA9	→	M12	CN5-3	→	CN2-3	
OUTPUT CURRENT (W)	TA10	→	M13	CN6-3	→	CN3-3	

(1) TA7 for 400-800 KVA
(2) TA4 for 400-800 KVA
(3) TA5 for 400-800 KVA
(4) TA6 for 400-800 KVA

5.3.3 Digital inputs

The digital inputs are all the voltage-free contacts managed by the control board; before they are acquired by the microprocessor they are de-coupled by means of relays (board PB342). A further de-coupling is provided by opto-couplers inside the control board. The signals are exchanged between the microprocessors through the communication section.

The signals acquired by the microprocessor board are shown on the *UPS Analyzer 2010* inside the relevant window.

5.3.4 LED's table

The following table shows the meaning of the various LED's on the board D-DSP.

SECTION	LED DSP1	LED DSP2	LED CPU3	Status
Microprocessor positive supply (POS-CPU)	**DLP1**	**DLP2**	**-**	Steady ON
Microprocessor negative supply (NEG-CPU)	**DLN1**	**DLN2**	**-**	Steady ON
SPI supply (+5V_SSW)	**DLSS**			Steady ON
CAN supply (+5V-CAN)	**LED14**			Steady ON
Serial ports supply (+5V-SER)	**LED15**			Steady ON
Microprocessor supply (NEG-CPU)	**LED3**	**LED8**	**LED12**	Steady ON
Microprocessor supply (+5V-CPU)	**LED4**	**LED9**	**LED13**	Steady ON
Microprocessor supply (3V3-CPU)	**LED5**	**LED10**	**-**	Steady ON
Microprocessor supply (1V9-CPU)	**LED6**	**LED11**	**-**	Steady ON
Microprocessor reset	**LED2**	**LED7**	**LED1**	OFF
Program running	**RUNDSP1**	**RUNDSP2**	**RUNMC**	Blinking

5.4 UPS SIGNALS INTERFACE (PB399/PB400)

The UPS interface board is the main interface between the microprocessor control board and the rest of the system. Two different boards are used, depending on the UPS model:

- PB399 (INT-UPS-FXS) → used on 60-300 kVA
- PB400 (INTH-UPS-FXS) → used on 400-800 kVA

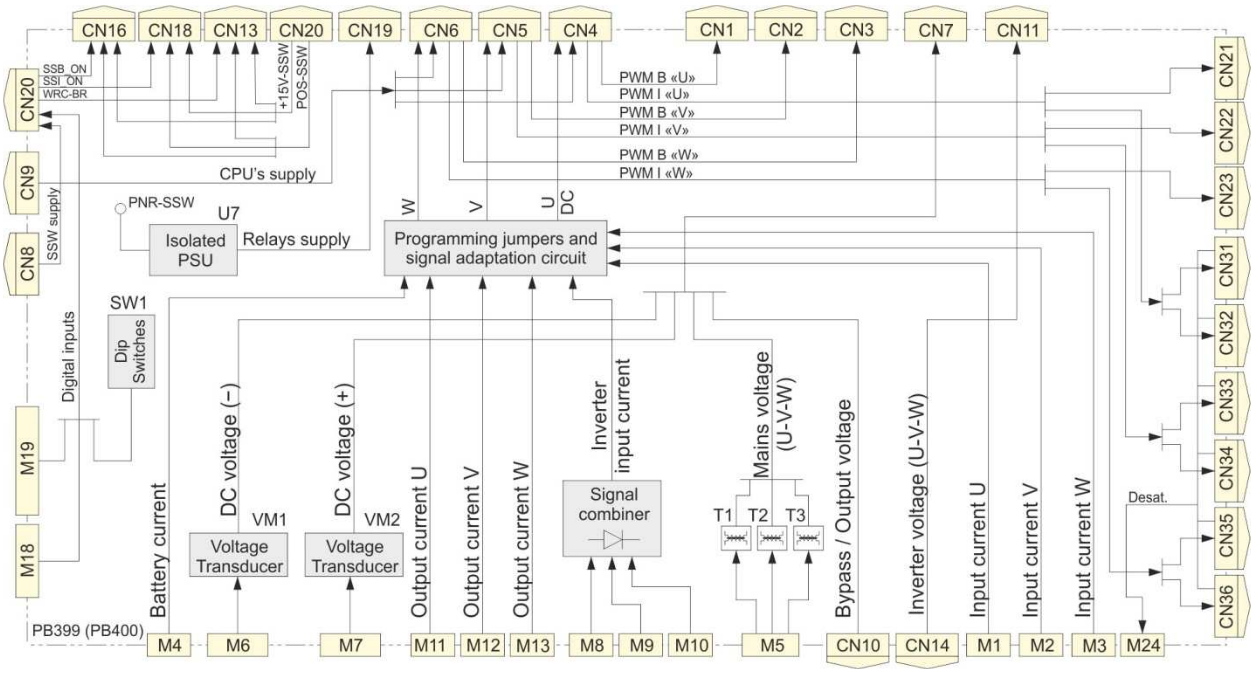


Figure 49 – Block diagram card PB364 (INT-PV)

Apart from transferring the main signals coming from other interface cards, it contains the following “active” parts:

- Mains voltage feedback: the transformers T1, T2 and T3 adapt the mains voltage to a value suitable for the control card.
- DC voltage feedback: the DC voltage is measured across the DC capacitors and then adapted by the voltage transducers VM1 (positive) and VM2 (negative).
- Analogue measures interface: all the analog measures are acquired by the board and transferred to the main control board. The summary table of all the interconnections is shown at paragraph 4.3.2.
- BOOSTER IGBT interface: the PWM signal for the booster IGBT's is generated directly by the microprocessor card and transferred to the drivers through the connectors of the board.

INT-UPS		DRIVER	
CN1	→	ID1	IGBT BOOSTER (L1)
CN2	→	ID2	IGBT BOOSTER (L2)
CN3	→	ID3	IGBT BOOSTER (L3)

- INVERTER IGBT interface: the PWM signal for the inverter IGBT's is generated directly by the microprocessor card and transferred to the drivers through the connectors of the board.

INT-UPS		DRIVER		UPS MODEL
CN21	→	DR1	IGBT INVERTER (U)	60-160kVA
CN22	→	DR2	IGBT INVERTER (V)	60-160kVA
CN23	→	DR3	IGBT INVERTER (W)	60-160kVA
CN31	→	DR1	IGBT INVERTER POS. (U)	200-800kVA
CN32	→	DR2	IGBT INVERTER NEG. (U)	200-800kVA
CN33	→	DR3	IGBT INVERTER POS. (V)	200-800kVA
CN34	→	DR4	IGBT INVERTER NEG. (V)	200-800kVA
CN35	→	DR5	IGBT INVERTER POS. (W)	200-800kVA
CN36	→	DR6	IGBT INVERTER NEG. (W)	200-800kVA

- Control LED's for the power supplies: all the power supplies generated by the board PB299 (PS-600) are available on the connectors CN8 and CN9. The supplies for the microprocessor card pass through the PB399 (PB400).

LED	Power supply	Status
DL1	NEG_CPU1	Steady ON
DL2	POS_CPU1	Steady ON
DL3	NEG_CPU2	Steady ON
DL4	POS_CPU2	Steady ON
DL5	PNR-SSW	Steady ON
DL6	POS-SSW	Steady ON
DL7	+15V-SSW	Steady ON
DL8	+12V-FCI	Steady ON

- Programming jumpers: the jumpers are used to adapt the current's signals to the dynamic range of the microprocessor, on the basis of the UPS rating.

Power rating	**JUMPER (JP..)**															
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**15**	**16**	**17**	**18**	**19**	**20**
60 kVA								●		●						
80 kVA								●		●						
100 kVA								●		●						
125 kVA		●		●		●		●		●	●		●		●	
160 kVA		●		●		●		●		●	●		●		●	
200 kVA		●		●		●		●		●						
250 kVA								●		●						
300 kVA								●		●						
400 kVA	●		●		●		●			●	●		●		●	
500 kVA	●		●		●		●		●		●		●		●	
600 kVA	●		●		●		●		●		●		●		●	
800 kVA																

● = Closed

- Dip switch: the dip switch SW1 is basically used for test purposes; all the switches must be set in position OFF for normal operation. The switch **3** of SW1 is used to set the UPS in TEST mode.

SW1	**3**
TEST mode	**ON**
NORMAL mode	**OFF**

The switch **1** of SW1 is effective only on parallel UPS; it is used to stop the UPS communicating on the parallel BUS. In this way the UPS can be completely tested as if it was a stand-alone unit.

SW1	**1**
CANBUS communication **stopped**	**ON**
CANBUS communication normal	**OFF**

5.5 INVERTER VOLTAGE FEEDBACK (PB004)

The inverter voltage is acquired by the board PB004 (INV-AV-3F), which contains three transformers to adapt the voltage to a value suitable for the control board. The feedback voltage is used either for the control loop and measuring purposes.

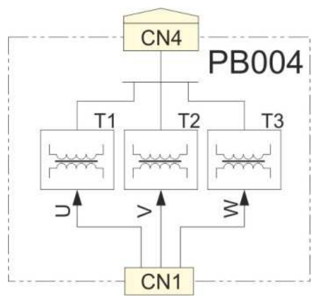


Figure 50 – Block diagram board PB004 (INV-AV-3F)

5.6 OUTPUT/BYPASS VOLTAGE FEEDBACK (PB300)

The output and bypass voltage feedback card contains six transformers, three for each sections, whose function is adapt the voltage so that it can be managed by the control board.

It also contains a power supply section that is used as a redundant source for the static switch thyristors. The outputs on the connector CN2 can be used to supply the cooling fans.

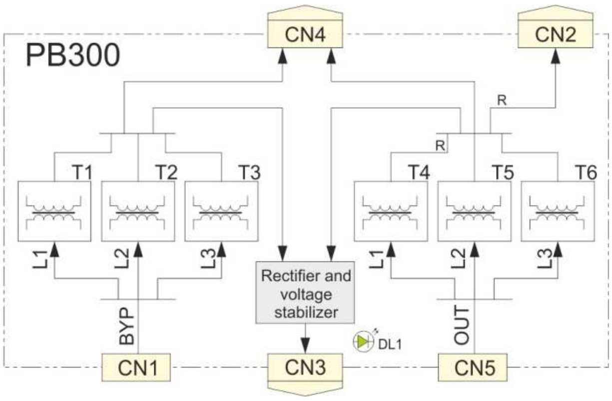


Figure 51 – Block diagram board PB300 (VOLT REF-DT)

5.7 DIGITAL SIGNALS DECOUPLING (PB342)

As mentioned previously, all the digital inputs (voltage-free contacts) are de-coupled before they are connected to the control board; this task is performed by the card PB342 (FCI-02).

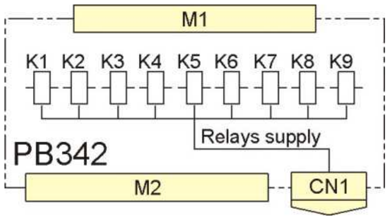


Figure 52 – Block diagram card PB342 (FCI-02)

Connection point on M1	Origin of the signal	Signal
1-2	Auxiliary contacts of: inverter input fuses, inverter heat-sink thermal sensor, transformer thermal sensor (1)	THERMO_SW1
3-4	Aux. contacts of the AC input fuses (rectifier)	THERMO_SW2
5-6	Thermal sensor on the **Booster** heat-sink (2)	THERMO_SW3
7-8	Auxiliary contact of: battery switch, battery protection fuse	BCB_AUX
9-10	Auxiliary contact of the output switch **OCB**	OCB_AUX
11-12	Auxiliary contact of the bypass switch **SW1**	BYS_AUX
13-14	Auxiliary contact of the manual bypass switch **MBCB**	MBYP_CLOSE
15-16	Auxiliary contact of the Emergency Power Off switch **EPO**	EPO_AUX
17-18	Auxiliary contact for Diesel Mode activation (option)	SPARE_IN2

(1) Only inverter input fuses and transformer thermal sensor on X-TRA **60-160kVA**
(2) Thermal sensor of the **static switch** heat-sink for X-TRA **200-800Kva**

5.8 IGBT DRIVERS

The PWM signal is transferred to the IGBT drivers through the main interface board PB364 (INT-PV).

The IGBT driver de-couples the PWM signal, which is transferred to an amplification section containing a de-saturation control system. The de-saturation alarm is managed by the main control board PB349 as a digital input.

The driver power supply is isolated by means of an internal circuit which rectifies and stabilizes the high frequency square wave coming from the power supply board PB299 (PS-600).

The board is also provided with an IGBT temperature control section that is used in case the IGBT is equipped with an internal temperature feedback. The temperature control is used in the 400-800 kVA range, where a PT100 sensor installed in the inverter heat-sink is connected to the driver board.

The IGBT drivers PB339 (ID3-03), PB350 (ID3-04) and PB394 (ID3-EH) have a single PWM input and are used to control maximum two IGBT's in parallel (single switch).

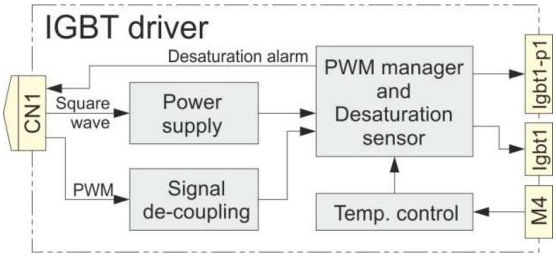


Figure 53 – Block diagram IGBT driver board (PB339-PB350-PB394)

The IGBT drivers PB246 (ID-HY) and PB352 (ID-TN) have two separate PWM inputs and are used to control two IGBT's in series (bridge leg). These cards don't have any temperature control circuitry.

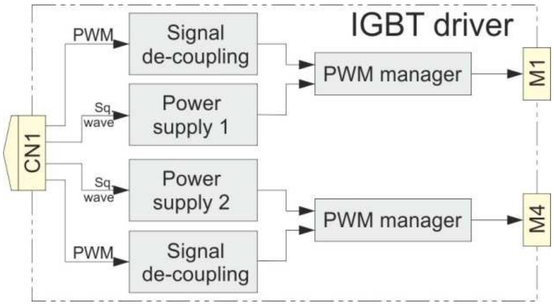


Figure 54 – Block diagram IGBT driver board (PB246-PB352)

5.8.1 IGBT drivers used in the FXS UPS series

The IGBT driver boards used in the FXS UPS series are listed in the table below.

Rated power [kVA]	Booster IGBT driver	Inverter IGBT driver
160÷100	3 x ID-HY (PB246)	3 x ID-HY (PB246)
125-160	3 x ID-HY (PB246)	3 x ID-TN (PB352)
200÷300	3 x ID-HY (PB246)	6 x ID-EH (PB394)
400	3 x ID-TN (PB352)	6 x ID3-03 (PB339)
500-600	3 x ID-TN (PB352)	6 x ID3-04 (PB350)
800	3 x ID-TN (PB352)	6 x ID3-04 (PB456)

5.8.2 Test points

The gate control voltage can be measured on test points as shown in the following pictures.

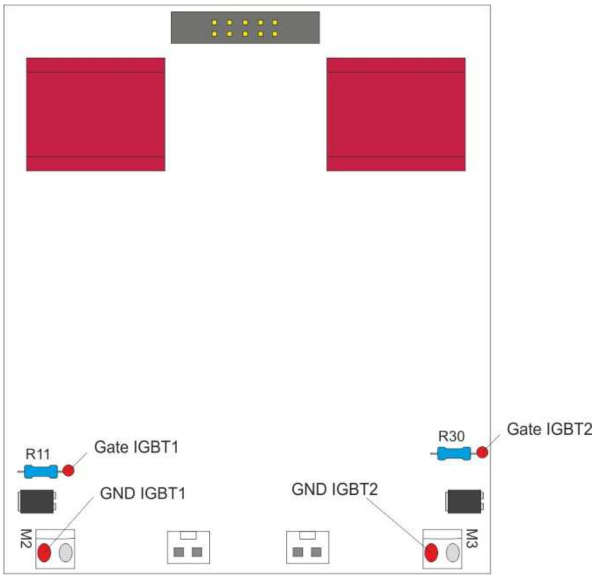


Figure 55 – Test points on PB246-PB352

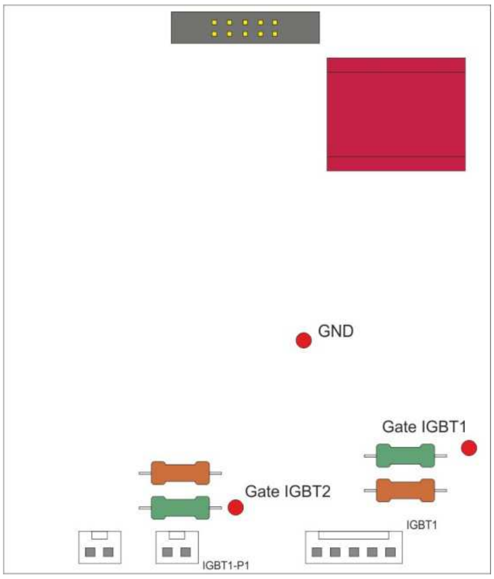


Figure 56 – Test points on PB339-PB350-PB394

5.8.3 LED's table

The following tables show the meaning of the various LED's on the IGBT driver boards.

– **LED's on PB246 / PB352**

SECTION	LED	Colour	Status
Modulation ON – section 1	**LD1**	**RED**	Steady ON
Modulation ON – section 2	**LD2**	**RED**	Steady ON
Power supply section 1	**LD3**	**GREEN**	Steady ON
Power supply section 2	**LD4**	**GREEN**	Steady ON

– **LED's on PB339 / PB350 / PB394**

SECTION	**LED**	**Colour**	**Status**
Power supply	**LD1**	**GREEN**	Steady ON
Modulation ON	**LD2**	**YELLOW**	Steady ON
High temperature on the heat-sink (>90° C)	**LD4**	**RED**	OFF [1]
Temperature on the heat-sink >65° C	**LD5**	**GREEN**	OFF [2]
Temperature on the heat-sink >75° C	**LD6**	**GREEN**	OFF [2]
Temperature on the heat-sink >85° C	**LD7**	**YELLOW**	OFF [2]
IGBT de-saturation	**LD8**	**RED**	Steady ON [3]

(1) The high temperature gives also a de-saturation pulse, so the LD8 is ON and the converter is stopped.
(2) The status of the LED depends on the current temperature of the heat-sink.
(3) The LED blinks at UPS start-up and is steady ON when the modulation signal is present. It blinks again only in case of IGBT de-saturation.

5.9 THYRISTOR DRIVERS

The thyristor driver boards are the directly connected to the thyristors and basically de-couple the firing signal generated by the microprocessor board PB349 (D-DSP) from the power section.

The control signal passes through a R-C filter and a high frequency transformer and is available on the board terminals G-K, where gate and cathode of the thyristor are connected.

LED's show when the firing signal is being sent to the thyristor.

The board PB016 (2SCR-FIR) is used for the control of the static switch thyristors (2x components for each card), while the board PB023 (RTF) is installed on the rectifier bridge and controls all 6 thyristors.