FOUR TYPE INPUT VOLTAGE STATIC CONVERTER FOR SUPPLING AUXILIARY SERVICES ON RAILWAY WAGONS

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Abstract. *The modernization of the railway wagons for passengers able to operate the international traffic of European countries are focused on the static converters for auxiliary services. Those converters are supplied through an internal link with four ranges of voltage: 1500 Vac, 50Hz; 1000 Vac, 16 2/3 Hz; 1500 Vdc; 3000 Vdc.*

DESCRIPTION OF OPERATION PRINCIPLE

This convertor have the input voltages specified in the following table:

Table 1

Current	Voltage (Vrms)						Frequency
Nature	Maine	Minimum 10 minutes	Minimum permanent	Maximum permanent	Maximum 5 minutes	Disconnect superior	Hz
Mono-phase	1500	1050	1140	1650	1740	1860	48…52
	1000	700	800	1150	1200	1250	16.. 17.5
D.C.	1500	900	1000	1800	1950	2050	-
	3000	1800	2000	3600	3900	4050	-

The outputs of such converters usually are:

28 Vdc for accumulators and control equipment, with respect for temperature range, charging current (70…100Adc) and overall current (200…250Adc);

3x400Vac, 2…50 Hz, 15…30 kVA for induction motor of air conditioning systems;

3x400Vac, 50 Hz, 10…45 kVA for heating resistors;

230 Vac, 50 Hz for various devices as fans, water heaters, dust cleaners, coffee filters, shavers.

Figure 1 presents the power diagram of the converter. The convertor is fed in from the main power line of the train with one of the four input voltages according to Table 1, and according to the European country traversed by the railway car.

The input voltage is connected to the terminals (hubs) 1X1 and 1X2. The voltage passes firstly through a separator 1 which is opened / shut (ON/OFF) when opening and closing the door no. 1 from the convertor that activates it. This separator can break the load circuit if it is necessary.

The output voltage from separator 1, through an IT 11 fuse and a contactor 12 is applied to a diode bridge rectifier 13, the rectified voltage is filtered by an inductance 14 and by two marked capacitors 15 and 16, which assure a small output dc ripple even in case of supplying the converter with 1.000 Vac-16 2/3 Hz.

The voltage on the capacitors 15 and 16 is applied to a mono-phased inverter 19 of PWM type made with IGBT transistors that function at a frequency higher than 200 Hz, usually of 300 Hz.

The inverter produces output impulses with variable width and constant frequency and supplies through a block of contactors 22 that belongs to the selector 5, the primary winding of a mono- phased transformer 23. This primary winding of the transformer has two sections which can be connected in series or in parallel depending of the type of the input voltage applied on the input of the convertor.
Thus, if the input voltage is 3.000 Vdc, the contact 22a is shut and the two sections, of primary windings are connected in a series circuit and in this way it will be maintained the same voltage on the secondary winding of the transformer as in case of the other three input voltages when the two sections of the primary winding will be connected in parallel through the contacts of connection 22b.

The secondary winding of the transformer supplies a diode bridge rectifier, thus obtaining an output-regulated voltage of 650 Vdc.

The rectified voltage is filtered by an inductance 25 and by a capacitor 27 which together form a power filter that assures the filtering for the input stage internal dc regulated link of the convertor. The voltage from the capacitor terminals 32 and 33 is then applied to a PWM three-phased inverter numbered 34, which is made with IGBT transistors.

At every start up of the inverter this produces an output low voltage of 20 Vac with a frequency of 1Hz, and, afterwards both the voltage and the frequency increase automatically so the ratio U/f is kept constant and stops at a voltage of 3 x 400 Vac- 50 Hz

The frequency's increasing speed depends on the compressor ac motor rated power, and the inverter will receive the start up command with a low frequency at every necessary start up of the compressor from the cooler device, in order to obtain the air conditioning. If the frequency's increasing speed is chosen correctly, the compressor ac motor will have a maximum starting current of 2In. In this way the current shocks from the power converter are limited at optimal values, taking into account the fact that the power of the compressor ac motor has a significant importance in the entire power of the convertor.

The output voltage from the inverter passes through a LC filter 37, so that the output three-phased voltage will have a sinusoidal form and limited harmonic components, no more than 15%. The output voltage is measured with a voltage transducer 38.The drive 45 receives input signals from a control panel 46 made of one or more DSP's.

The inverter's starting is possible only if the converter starts-up too, and this produces a low output voltage of 20Vac at a frequency of 1Hz; the voltage and the frequency will then increase automatically so that U/f is constant and stops at the voltage rating of 3 x 400 Vac- 50 Hz.

The output voltage from the inverter passes through a filter LC-47 so that the output three-phased voltage would have a sinusoidal form and limited harmonic components, no more than 15%. Generally on this output there are connected the heating resistors situated under the windows and the ventilators of the heating / cooling / ventilating device which are started-up according to momentary needs through a direct connection, but the current shocks are low, as the ventilator's power are of maximum 1kW. The output voltage from the inverter 53 is then applied to a voltage reducer transformer 56, and then it passes through a filter LC-57 so that the output voltage would be of sinusoidal form and have the limited harmonics, no more than 15%.
The output voltage has the nominal value of 230 Vac-50Hz and it is measured by a voltage transducer 58. The voltage from the condenser terminal's 62 and 63 is applied to a mono-phased inverter of high frequency, higher than 10 kHz, 64, made with IGBT transistors or HEXFET, commanded by a mono-phased inverter drive protected against short-circuit 65 and controlled from a regulating and control block 66 based on DSP technology.

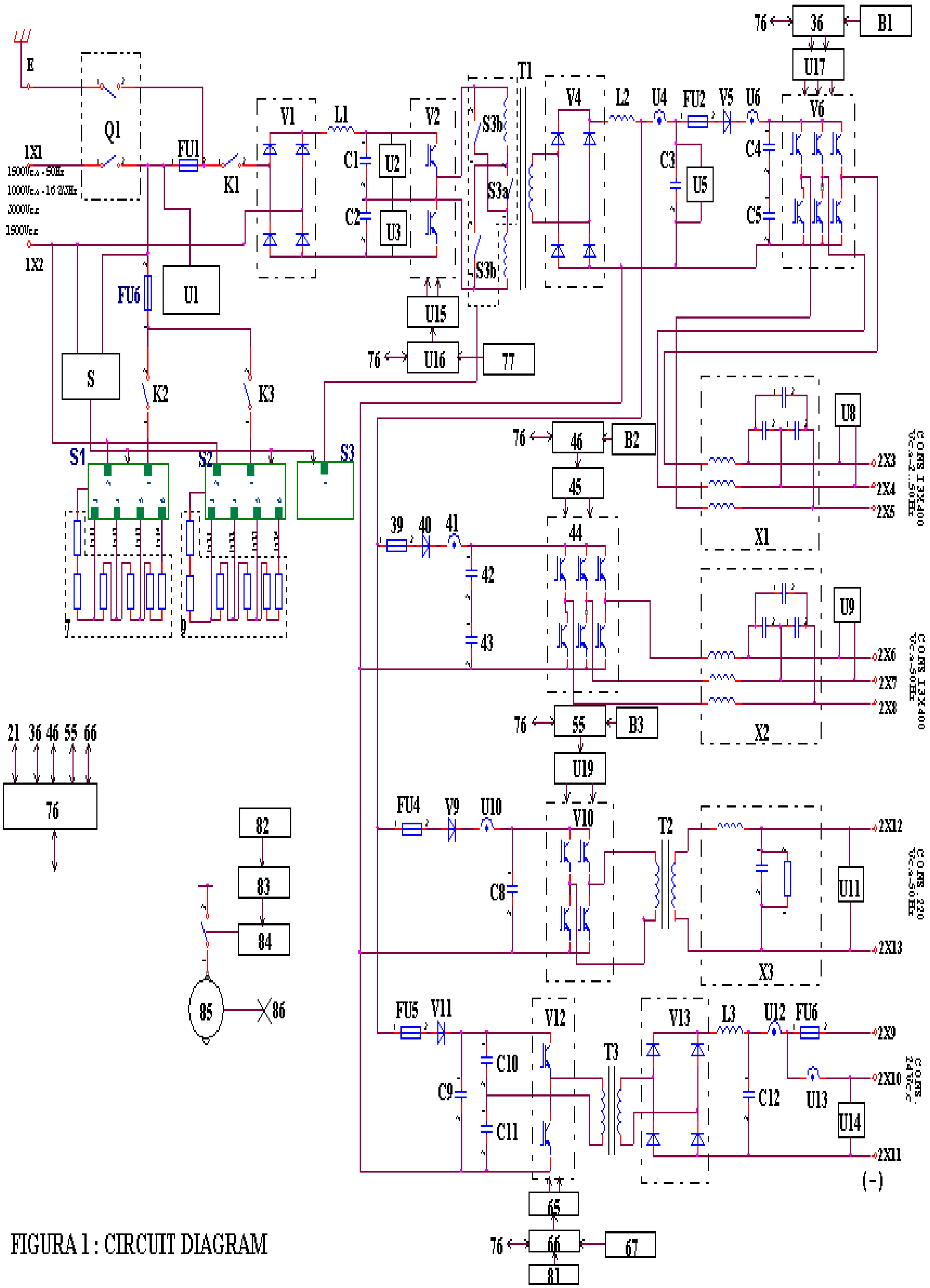

FIGURA 1 : CIRCUIT DIAGRAM

Legend Fig.1

separator	1	temperature transducer	67
contactor	3, 4, 12, 84	diagnose block	76
input voltage selector	5	thermo-contact	77, 78, 79, 80, 81,82
power contacts from input voltage selector	6,8,22	fuse	29, 39, 49, 59, 73
heating resistor battery	7,9	sense diode	30, 40, 50, 60
voltage sensor	10	three-phase PWM inverter	34, 44
high voltage fuse	2, 11	three-phase filter	37, 47
rectifier bridge	13, 24, 69	mono-phase PWM inverter	53
filter choke	14, 25,70	mono-phase transformer	56
filter capacitor	15, 16, 27, 32, 33, 42 43, 52, 61, 62, 63, 71	LC filter	57
voltage transducer	17, 18, 38, 48, 58,75	high frequency mono-phase PWM inverter	64
mono-phase PWM inverter	19	high frequency mono-phase transformer	68
driver	20,35,45,54,65	thermo-contact	77, 78, 79, 80, 81,82
control unit with µP	21,36,46,55,66	logical command fan	83
power transformer	23	fan	85-86
current transducer	26, 31, 41, 51, 72, 74		

The output voltage of the inverter depends on the accumulator's battery temperature, which is measured by a temperature transducer 67. The mono-phased inverter 64 supplies on the primary winding of a voltage reducer mono-phased transformer 68, and the voltage from the secondary winding is applied to a rectifier bridge 69.

The output voltage from the rectifier is sent to a small dimension filter LC-70, 71; it is finally received by consumers, fed in with a nominal voltage of 24 Vdc. In this way the control block 66 through the driver 65 assures the command of transistors from the mono-phased inverter 64, so that the load current of the battery of accumulators would not exceed a given value.

While normal functioning, when the converter supplies the battery of accumulators with a current lower than the maximum current rating, for instance of 80A, the applied voltage for the accumulator battery and for the auxiliary services consumers fed in with a nominal voltage of 24 Vdc will depend on the battery's storage temperature and will be in conformity with the conditions stipulated in Table2.

With every coupling of the converter or during every cutting off of the voltage from the main power-line, the output voltage will have the values presented in the maximum voltage column from the above table, but it can be switched to a floating voltage if the load current of the battery is lower than the admitted cross current of 10 A.

The correction of the battery charging voltage is performed according to the temperature of the battery with a coefficient of 0, 06 V/°C, as detailed in Table 2.

At every start of the converter the output voltage is maintained at the maximum value until the charging current of the battery decreases below 10Adc. After this charging period the output voltage will referee to the floating voltage.

Table 2

Temperature (^{0}C)	Battery's floating voltage value (V)	Maximum Voltage (V)
40	25,56 +/- 2 %	27,7
20	26,75 +/- 2 %	28,2
-25	29,46 +/- 2 %	30
-33	29,90 +/- 2 %	31,3

If the temperature transducer 26 is short-circuited or interrupted, the converter will supply the voltages according to the temperature of + 20ºC. On each heatsink that has transistors installed for the main inverter, on tri-phased and mono-phased inverters, temperature transducers and thermo-contacts 77, 78, 79, 80, 81 are also mounted.
Moreover there is also a temperature transducer that measures the air's temperature from the converter 82, and transmits the temperature's value to a logic temperature block 83; if the temperature exceeds the maximum permitted limit, it will give an off command of the module (will *give the 'OFF' signal*) to contact 84, which supplies one or more electrical motors *85*, which is /are connected to one or more ventilators 86.
The power supply provides the supply of two heating assemblies under the car (6 and 8) having one of the input voltages through a separator that can brakes the current, two contactors (3 and 4) and a thermal fusible 2. The resistors in the assembly are serial connected when the main voltage is 3,000 Vdc and they are all series-parallel connected when the main voltage is 1,500 V and parallel for 1.000 V, by a voltage selector (5, 6, and 8).
Figure 2 presents the logical scheme of signals from the regulating and control block 21, made with one or more microprocessors.
The signals collected from the voltage transducers 17 and 18 are converted into digital signals adapted for digital-to- analogue converters 87 and 88.
The digital signals from the converters are summed up in the summing block 89 and thus the output signal from this block is sent to a digital voltage regulator 90 as a basic reaction as to the width and rapidity.

The values of the voltage reference amplitudes, that can have 600 V and a frequency of 300 Hz, are collected and introduced by means of programming from a laptop into a referential block 91, the value of the output voltage from the block 91 is admitted into the regulator with a positive signal.

The voltage from the voltage transducer 28 enters an analogue-to-digital converter block 92, the digital signal from the converter's output is transmitted to an averaging block 93, which intermediates the value received for a duration of 10...20 ms; when the inverter functions with a frequency of 300 Hz, the output digital signal from this block is admitted as an additional reaction in the voltage regulator 90, and this reaction depends on the voltage drops caused by the source on the inverter 19, the transformer 23 and the inductance 25.

The digital output voltage from the regulator comes through a logical block 94 together with frequency's value from the block 91, and the logical block 94 sends the command signals to the command drive 20 of the inverter's transistors, if there are no abnormal situations in the source.

The voltage arrived from the current transducer 26 enters the analogue / digital converter 95, then passes into an input hysteresis block 96; the current supplied by the inverter having a maximum value; then into a delay block 97, the delay depending on the input value; if the current surpasses a certain admitted value the input signal will transmit a blocking alert to the logical block 94, thus inducing the blocking of the main inverter's functioning 19.

From the voltage sensing block IT-10 a signal arrives and notifies the existence of an input voltage, out of the four possible, existing voltages. If the signal is zero, the voltage-sensing block 98 sends a

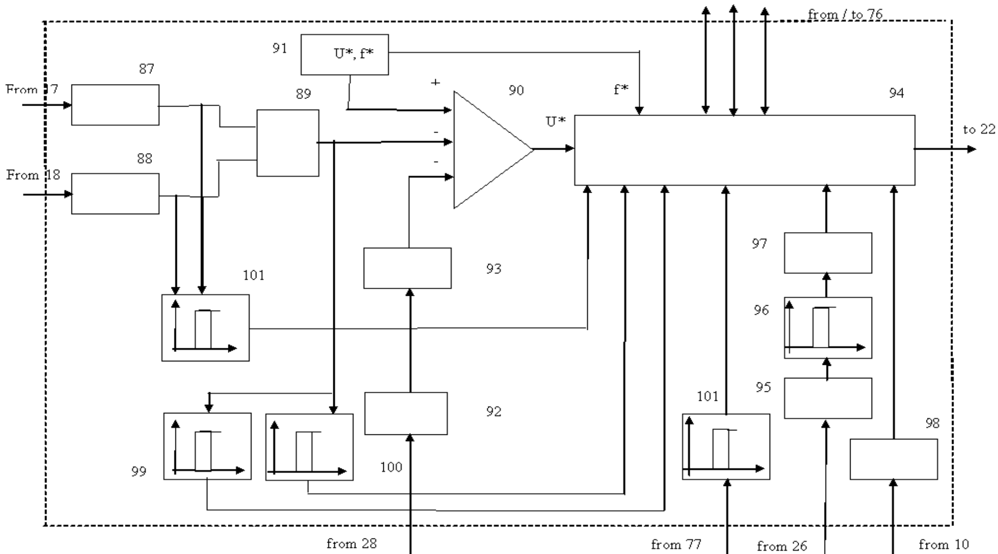

Fig. 2

blocking signal to the logic block 94, thus cutting off the functioning of the inverter 19.
A digital value is sent from the summing block 89 to the input hysteresis block with minimum network voltage 99 that sends a blocking signal to the logical block 94 if the input voltage of the source is lower than 700 V.

The same way, a logical hysteresis block with a maximum voltage of 100 V, which receives a signal also from the summing block 89, sends a blocking signal to the logical block 94 if the input voltage in the source is higher than 4.050 V.

From the converters 87 and 88 leaves a signal of minimum voltage to the input hysteresis block 101, which will also carry away a blocking alert into the main logical block 94 cutting off the inverter functioning if the voltage, from one of the marked condensers 15 and 16 supplying the main inverter 19, is lower than the minimum admitted value.

CONCLUSIONS

This solution for the high voltage inverter concerning in high voltage IGBT technology is efficient, reliable and cost effective assuring together with high voltage transformer of the convertor designed with two primary windings an excellent performance above all input voltages conditions and no matter the loadings on the outputs. As well the modular construction of the different output modules which deliver 24Vdc, 3x400Vac 50 Hz, 230Vac 50 Hz and 485 Vac 50 Hz assures a total interchanging operability, easy maintenance and flexibility by means of the same type of independently control units which are based on the same DSP platform and the diagnose software.

REFERENCES

[1]. UIC 550 OR :97, Installations pour l'alimentation en energie electrique du matériel a voyageurs.
[2]. Invention patent – A / 00511 / 11.06.2003 OSIM-Romania