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Power Supply Systems for

Passenger Coaches

Type testing

International Union of Railways

Leaflet to be classified in volumes:

V - Transport stock
VI - Traction

Amendments

Preliminary remarks:

Obligatory provisions are preceded by an asterisk: *.

The double vertical line (II) in the margin denotes amendments made on the date shown at the foot of the page.

Enforcement of this leaflet is governed by the provisions listed under "Application" at the end of the document.

Note

This leaflet forms part of a set which also includes:

- Leaflet 550 - Power supply installations for passenger stock
- Leaflet 550-1 - Electrical switch cabinets on passenger stock
- Leaflet 552 - Electric power supply for trains taken from the train cable
- Leaflet 553-1 - Air-conditioning equipment in coaches - Standard tests
- Leaflet 555 - Electric lighting in passenger rolling stock

Contents

0 - General

0.1 - The following test programme is a standard programme for testing the power supply systems of fully-fitted passenger coaches. It does not replace the type testing of sub-systems. Other systems may be tested simultaneously.

0.2 - To enable type testing to proceed without interruption, insulation testing in accordance with the regulations of the railway concerned and comprehensive functional testing of the systems of the vehicle as a whole should be carried out beforehand.

0.3 - Measurements of power consumption at the limits of the required outdoor temperature range should, for practical reasons, be made in a climatic chamber in conjunction with type testing of the air-conditioning system in accordance with Leaflet 553-1.

0.4 - The purpose of type testing is not only to demonstrate correct functioning according to specification under the various operating conditions, but also to check whether the systems are of energy-saving design.

0.5 - The method for providing proof of compatibility with electrical power supply systems for diesel locomotives in accordance with Leaflet 626 has still to be specified.

1 - Conduct of tests and explanatory notes

1.1 - Testing with various train bus voltages

The train bus voltage should be varied within the limits of the range Umin2 and Umax2A as specified in Leaflet 550. The following specific evaluations should be made:

1.1.1 - Function for all Un, together with the associated voltage forms and frequencies for which the coach systems are designed.

1.1.2 - Umax2A

Allowance should be made in accordance with Leaflet 550, §4.2 for the distortion of the curve shape with a.c. voltage.

- Function
- Cos and/or (Leaflet 500, §4.2)
- Heating of the critical design components after an operating period of 1 hour
- Switching on and off of the power supply and loads:

  . behaviour of the switching elements
  . voltage peaks in train bus and on-board supply system
  . starting currents (Leaflet 550, §4.11)

With a.c. voltage, the voltage should be switched on at the zero crossing.

1.1.3 - Umin2

Switching on and off of the power supply and loads (Leaflet 550, §4.11).

1.1.4 - Harmonics

Limit values in accordance with Leaflet 550, section 5.

Measuring procedure in accordance with *APPENDIX 1.*

1.1.5 - Input impedances

Limit values for d.c. voltages in accordance with Leaflet 550, section 5. Measuring procedure in accordance with *APPENDIX 1.*

1.2 - Power requirement and energy consumption

The power requirement and energy consumption of the entire electrical systems of the vehicle and of individual conversion elements and loads shall be determined.

1.2.1 - Extreme outdoor temperature Te

- Power input on switching on the vehicle power supply for preheating and precooling at Un with main lighting switched on. The vehicle should have reached beforehand an internal temperature Ti which ensures maximum power when switching on.
- Power requirement of the vehicle systems in normal operation with main lighting switched on for

  . Un,
  . Umax2,
  . Umin1.

- Efficiency of the inverter connected to the train bus as a function of loading at

  . Un,
  . Umax2,
  . Umin1.

- Power requirement and energy consumption of individual loads at Un

  . air-conditioning system
  . lighting
  . clean water heating
  . effluent heating

- Power consumption at Un and with lighting switched off for

  . preheating (switching on until ambient temperature Ti reaches 20°C)

  . precooling (switching on until ambient temperature has reached the value of the control characteristic)

  . normal operation (without occupants, all temperature controls in mid-position)

  . normal operation (with occupants, all temperature controls in mid-position)

1.2.2 - Outdoor temperature Te between 10°C and 25°C

Energy consumption shall be recorded as a function of Te with and without occupancy.

1.3 - Battery charging

1.3.1 - Charging voltage with charged battery

- With battery loads
- With battery loads and with minimum consumption in the three-phase system
- Without battery loads
- Without battery loads and with maximum consumption in the three-phase system

1.3.2 - Harmonic content of the charging current with

- Charged battery
- Discharged battery

1.3.3 - Current limitation with discharged battery

1.3.4 - Residual charging current in float charging mode

1.3.5 - Behaviour of the charging voltage when intended to be dependent on battery temperature

1.4 - Behaviour of the load when dependent on battery voltage

1.4.1 - Rising battery voltage (switching on the power supply)

Voltage at which loads are connected or are released for connection.

1.4.2 - Falling battery voltage (switching off the power supply)

- After switching off the charging voltage, determining voltage and period of time
  - . at which main loads are disconnected,
  - . at which all main loads are disconnected and only the emergency lighting is still switched on,
  - . at which the emergency lighting is also disconnected.

1.4.3 - Protection of lead-acid batteries against freezing

After 5 hours' discharge with lighting in accordance with Leaflet 555, §9.7 and outside temperature of 20°C, check whether the electrolyte density level reached guarantees protection against freezing.

The minimum value of electrolyte density shall be specified by the supplier.

1.5 - Switching on the power supply systems at minimum battery voltage

1.6 - Other energy conversion components

Behaviour in conformity with contract, as based on specification.

1.7 - Other electro-technical equipment

Behaviour in conformity with contract, as based on specification.

2 - Testing and measuring procedures

2.1 - Test facilities

For testing the electrical and air-conditioning systems, special test rigs are required. These should be equipped as follows:

- building with reasonable temperature to protect staff working there against wind and weather,
- track with illuminated inspection pit,
- test apparatus for insulation testing of systems with rated voltages of: 1000 V, 1500 V, 3000 V,
- power supply systems with adequate power for functional and performance testing of the systems with the necessary voltages and the associated voltage forms and frequencies,
- connection for compressed air supply,
- connection for electrical operating equipment.

2.2 - Test chamber

Testing of the electrical part of the vehicle's air-conditioning system in cooling mode requires a test rig in a chamber equipped as described under 2.1 above, where the temperature can be set and held constant at a value within the temperature range +24°C to +32°C (it is not necessary for this room to have a cooling system).

2.3 - Measuring instruments

The accuracy of the measuring instruments shall be at least that of class 0.5.

Measuring programme for interference currents and input impedances of static inverters in passenger coaches

1 - Purpose of the measuring programme

To ensure that the interference currents and input impedances of static inverters conform to the criteria of UIC Leaflet 550,

- the interference current generated by the inverter and
- the input impedance of the inverter

are to be measured.

Measurement of the interference current should take place in the frequency band of 1 to 10,000 Hz, and that of the input impedance in the frequency band 50 to 10,000 Hz.

UIC Leaflet 550 contains limit values

- for the interference current, for all supply voltages and
- for the input impedance only for supply with d.c. voltage.

During the tests, the inverter should be operated in all ranges of the supply voltages and loads for which it is designed.

The behaviour of the supply source in terms of its influence on the measured results should be recorded.

The measurements are all to be made at stable operating points of at least 2 minutes' duration. Transient effects during switching, of less than 2 seconds' duration, shall not be taken into account.

2 - Measuring set-up

Since the tests will be conducted at high voltage, it will be necessary to take the prescribed safety measures. The definition of these safety regulations is not within the scope of the present leaflet.

2.1 - Measurement signals and measuring sensors

The following are measured:

- the input current of the inverter i,
- the input voltage of the inverter u.

The measuring sensors should be connected as close as possible to the inverter input.

The (dynamic) amplitude range of the input signals is:

- between around 50 A and around 0.5 mA; i.e. around 100 dB for the current;

- between around 4000 V and 0.22 V (-70 dB based on 700 V); i.e. around 85 dB for the voltage.

The frequency range of the measurement signals is:

- 0 to 10,000 Hz.

In view of the large dynamic range, the sensors for measuring voltage and current deserve close attention. It is recommended that the use of active measuring sensors be restricted to the measurement of direct current, d.c. voltage components, and perhaps the low-frequency spectrum.

For measuring a.c. voltage and alternating current components it is preferable to use passive inductive sensors with air gap.

Since current transformers are often provided with a large aperture for the cable through which the current to be measured flows, account should also be taken of the influence of the sensor mounting on the accuracy of the measurements. Influences such as, for example, eccentric or non-vertical cable passages may be avoided by producing beforehand a geometrically accurate cable passage and including it in the calibration process.

2.2 - Measuring set-up

The processing of the measured signals leads to further limitations on accuracy. Since the majority of measuring and processing instruments operate over only a limited signal range, it is not possible to amplify the lowest signal level at will.

For the impedance measurement, an attempt can be made to overcome this problem by making the incoming signals as large as possible. This is not possible for the interference current measurement; here the whole of the frequency range to be avoided may be split into frequency bands which can be analysed separately. The purpose of this breakdown into frequency bands is to increase the dynamic range in each of the bands. Large frequency components are filtered out, while for the smaller frequency components, more amplification is possible.

The following breakdown is recommended:

- 0 Hz to 500 Hz
- 500 Hz to 1,000 Hz
- 1,000 Hz to 5,000 Hz
- 5,000 Hz to 10,000 Hz

The spectral content of the signal is then determined for each separate frequency band in the course of interference current measurement.

The typical measuring set-ups for interference current and impedance measurements are shown in Figures 1 and 2.

In principle it is not necessary to use a tape recorder. If a tape recorder is used for record-keeping, attention should be paid to the limitation of the measuring dynamics.

In all cases it is recommended that the measuring set-up be kept to the necessary minimum.

2.3 - Frequency analysis

Frequency analysis can be done using a spectrometer or on the basis of an FFT algorithm and a computer with the measured values.

The frequency analysis should be so designed that the amplitudes of the spectral components can be determined as accurately as possible. It should be possible to limit the maximum relative error tolerance to 0.1 to 0.2 dB by "flat-top" filtering. A rectangular window is used, in which all samples have the same weighting.

2.4 - Noise level

For each voltage, the noise level of the measuring set-up should be checked both immediately before and also directly after measuring. For this purpose a noise measurement is carried out. This involves recording the level of the measuring signals under maximum loading and minimum voltage, with all measuring inputs shorted out.

The noise level should be recorded. In every case there must be at least 10 to 20 dB between the highest noise level in any of the frequency bands and the lowest signal to be measured in that frequency band.

Where the frequencies are divided into narrow bands centred on the frequencies of the signals, the noise should be measured in the narrow band.

2.5 - Calibration of the measuring apparatus

Before and directly after measurement, the entire measuring set-up must be calibrated. The calibration signal is transmitted as close as possible to the start of the measuring chain, but at least at the output of the sensors for input current and input voltage. The sensor itself should be calibrated once a year, and the calibration records form part of the complete measurement report.

In principle, calibration takes place at the same frequencies as for the measurements.

The amplitudes at which calibration is to be made correspond to the values of the criteria for interference current set out in the UIC leaflet.

2.6 - Accuracy of measurement

Factors which may affect the accuracy of the results are:

- the method of measurement
- the sensors
- the filters
- the spectral analysis
- the calibration
- the setting of the supply voltage
- the setting of the inverter load.

With precise calibration, the effect of filtering and spectral analysis on overall accuracy can be eliminated. It should be possible to limit the effect of the remaining factors so that measuring accuracy at all frequencies is better than 2 dB. At low frequencies, accuracy of more than 0.5 dB must be achievable.

3 - Supply source

3.1 - D.c. voltage supply

The absolute maximum value of the internal impedance of the supply source at all frequencies in the frequency range to be tested should not exceed 1% of the input impedance of the inverter. For d.c. voltage feed the rule for the input impedance in numerical form for frequencies between 0 and 10,000 Hz is:

$Z < 0.008\ f$

with Z in Ohms and f in Hz.

3.2 - A.c. voltage supply

The ratio of the voltage difference of each of the harmonic components of the voltage over the internal impedance of the supply source to the supply voltage itself may be regarded as a measure of the effect of the internal impedance of the supply source. It is required that the harmonics in the spectrum of the supply voltage are at least 70 dB less than the basic wave.

3.3 - Interference voltages from the supply

In the case of direct current, in order to reduce both the level of interference voltage and also the impedance of the supply source, a smoothing filter may be connected between the supply source and the inverter. With an a.c. voltage supply, the filtering-out of undesired interference voltage is also possible to a limited extent.

In practice, however, it is not possible to avoid interference frequencies of greater or lesser strength being generated by the supply source itself.

In the measurement of the interference components generated by the inverter, the components generated by the supply source may interfere and even lead to incorrect conclusions. It is therefore important to establish in advance what frequency components are generated by the supply source and to what extent. This check is made using a resistive load, which represents the same load to the supply source as that of the inverter. A comparison of the spectra of the supply current in the case of resistive loads and loading by the inverter provides the desired check. Should the behaviour of the supply source give cause to do so, the check with resistive load should also be made with partial resistive load and at reduced voltage.

3.4 - Approval of the supply source

The required check of the internal impedance of the supply source and of the interference components generated by the supply source may be carried out in conjunction with the proof of conformity of the supply source. The report of the conformity test should be adjoined or refer to the report of the inverter measurement.

4 - Input voltage

The measurements should be made under stationary conditions at the following voltages, which are taken from UIC Leaflets 552 and 600:

Minimum voltage: Umin2	900 V d.c. 1800 V d.c. 700 V, 16 2/3 Hz 1050 V, 50 Hz
Maximum voltage: Umax2	1950 V d.c. 3900 V d.c. 1200 V, 16 2/3 Hz 1740 V, 50 Hz

The mains frequency for supply with a.c. voltage is not expressly prescribed but should remain within the tolerance limits shown in UIC Leaflet 600:

- For 16 2/3 Hz: minimum 16 1/6 Hz, maximum 17 Hz;
- For 50 Hz: minimum 49 Hz, maximum 51 Hz.

The mains frequency which occurs shall be recorded during the measurements.

In addition to the voltage limit values referred to above, measurement should also take place at the rated values of the supply voltage, in accordance with UIC Leaflet 552:

- 1500 V d.c.
- 3000 V d.c.
- 1000 V, 16 2/3 Hz
- 1500 V, 50 Hz.

The interference current criteria in UIC Leaflet 550 apply to stationary conditions. In principle, the supply and load conditions last for a certain period of time, during which several measurements may be conducted in order to obtain an average value. The minimum period of time is set at 2 minutes. After a change in condition there should be a 2 seconds' pause before the first measurement is made.

It is likewise appropriate to carry out a test under transient conditions: the interference spectrum is then determined 2 seconds after a switching event in a period of 2 seconds or over a total of 4 spectra.

5 - Loading of the inverter

A distinction should be made between three types of output circuits:

- d.c. voltage
- battery charging
- a.c. or three-phase voltage.

The load to be applied depends on the type of output circuit.

With reference to the performance specification of the inverter, two special operating conditions are also defined:

- no-load running of the inverter,
- overloaded inverter.

5.1 - D.c. voltage output

Three values are defined for the load; they are expressed by the resistance values $R_{cc\ max}$, $R_{cc\ nom}$ and $R_{cc\ min}$

- Minimum load = maximum load resistance $R_{cc\ max}$, intended to simulate the situation of zero load on the inverter in a vehicle.

The output at zero load is defined as 15% of the maximum load.

- Rated load = nominal load resistance Rcc nom, intended to simulate the design load in the vehicle.

50% of maximum output is chosen for the nominal load.

- Maximum load = minimum load resistance $R_{cc\ min}$, conforming to the permitted maximum output of the inverter, i.e. 100% output.

5.2 - Battery charging output

If the inverter to be tested has an output for charging a battery, then this battery should also actually be connected.

If under normal operation the control electronics are powered by the battery, then all tests should be performed under this condition.

If the battery output also supplies other loads, then these should similarly be applied; these loads are defined as $R_{batt\ max}$ (15%), $R_{batt\ nom}$ (50%) and $R_{batt\ min}$ (100%).

5.3 - A.c. voltage or three-phase voltage output

The apparent output power S is converted, with the aid of the nominal operating factor λ for the output system, into an operating output

$P = \lambda \times S$

The inverter is subjected to a purely resistive load. Here too a distinction is made between the load resistances $R_{ac\ max}$ (15%), $R_{ac\ nom}$ (50%) and $R_{ac\ min}$ (100%). If there is no clear specification for the output factor, then the value $\lambda = 0.8$ is assumed.

If the frequency of the a.c. and three-phase voltage output can be varied, then measurements are made at five frequencies, distributed over the whole of the available frequency range, under nominal voltage and load conditions.

In principle, the load to be applied for each measurement is distributed evenly over all available outputs. In testing with switching phenomena, the entire variation may also be applied to the output with the maximum power (often the three-phase output).

5.4 - Unbalanced inverter load

The measurements with unbalanced load of the three-phase voltage system supplied by the inverter should be made at rated supply voltage and under maximum load conditions. The unbalanced load corresponds to the maximum permitted unbalanced load for the inverter as defined in its specification.

6 - Sudden voltage and load changes

The tests involving sudden changes in load and voltage are intended to establish that any instabilities which may occur, generated by the change in state of the inverter, do not lead to the interference current limit values being exceeded. The following sudden changes in load and voltage (1) should be taken into account in the tests:

- Under nominal load conditions:
  - voltage steps of 100 V up and down with 1500 V d.c. supply;
  - voltage steps of 200 V up and down with 3000 V d.c. supply;
  - voltage steps of 100 V up and down with a.c. voltage supply.
- Under nominal supply conditions:
  - step load changes of +25% and -25% around the rated load (set at 50% of the maximum value).

1) Drastic change of voltage amplitude from one pseudo-constant value to another pseudo-constant value.

7 - Interference current measurements

Interference current measurements should be made in accordance with Table 1.

Table 1: Interference current measurements

Test	Supply voltage	Load
1.1	Maximum	Maximum
1.2	Maximum	Maximum
2.1	Nominal	No-load running 1)
2.2	Nominal	Minimal
2.3	Nominal	Nominal
2.4	Nominal	Maximum
2.5	Nominal	Overload 1)
3	Nominal	Unbalanced load
4.1	Nominal + Δu	Nominal
4.2	Nominal - Δu	Nominal
5.1	Nominal	Nominal - ΔR
5.2	Nominal	Nominal + ΔR
Variation of output frequency with changes in output voltage 2)		
6	Nominal	Nominal

1) State as defined in the inverter specification
2) Only if the output frequency of the inverter is variable

8 - Impedance measurements

8.1 - Supply source

There are in principle two methods of applying the voltage and current for measuring the input impedance of the inverter:

- Parallel feed: the supply source is connected in parallel to the inverter,
- Series feed: the supply source is connected in series to the inverter.

The two methods are illustrated in Figs. 3 and 4. The use of series feed is recommended.

A choice may be made between the supply of only one frequency or of several frequencies simultaneously.

It is advisable to supply only one frequency in each case. In order to reduce measuring error, the frequencies generated by the inverter should be avoided. Likewise the natural frequency of the input filter should not be used, in order to rule out filter resonance and possible sub-standard functioning of the inverter.

So far as the magnitude of the supplied currents and voltages is concerned, there are two restrictions, which may be formulated in general terms:

- Voltage and current should be high enough to permit accurate measurement;
- The voltage and current applied should be low relative to the supply voltage and supply current (≤ 3%).

8.2 Measurement and evaluation

The test conditions during impedance measurement should be as shown in Table 2.

Table 2: Measurement of input impedances

Test	Supply voltage	Load
1.1	Nominal	Minimum
1.2	Nominal	Nominal
1.3	Nominal	Maximum
2.1	Maximum	Maximum
2.2	Minimum	Maximum

The frequencies used in measuring the input impedance of the inverter are determined as follows:

- By a definition in the inverter specification

- By a frequency selection in the range 50 to 10,000 Hz

The basis for determining these frequencies is that adequate frequencies should be tested logarithmically in the entire frequency band of 50 to 10,000 Hz. To achieve this, four frequencies should be selected from each decade at regular intervals. If it is found from the measurements already made that symptoms of resonance are occurring, then the number of measuring points in the vicinity of the resonances should be increased so that a detailed picture of the pattern of the impedance is obtained. This applies especially where the impedance is lower around the resonance point (series resonance) and the impedance value according to the criteria of UIC Leaflet 550 is not reached.

Exactly as in the case of measurement of the interference currents, the measuring time is at least two minutes. During this time several measurements can be made, from which the average value may then be calculated.

In view of the fact that supply from only one frequency in each case is to be preferred, and that the measuring set-up should be no more extensive than is necessary, the evaluation should be made on the basis of spectral analysis.

9 - Record of measurement

A record of the measurements should be made, to include:

- The results of the supply source conformity test;

- A brief description of the inverter tested and of the operating conditions tested for this inverter;

- The result of calibration of the measuring set-up: impedance and interference current together with records of the calibration of the various measuring sensors;

- The measuring set-up used for the interference current measurement;

- The results of the interference current measurement including the noise measurement made for checking purposes; these results to be set out in the form of a comparison between measured result and criteria laid down in UIC Leaflet 550;

- The measuring set-up used for the impedance measurement;

- The results of the impedance measurement; these results are combined with the criteria laid down in UIC Leaflet 550, so that a simple comparison between measurement and criterion is possible.

Figure 1: Interference current measurement
Test set-up for type testing

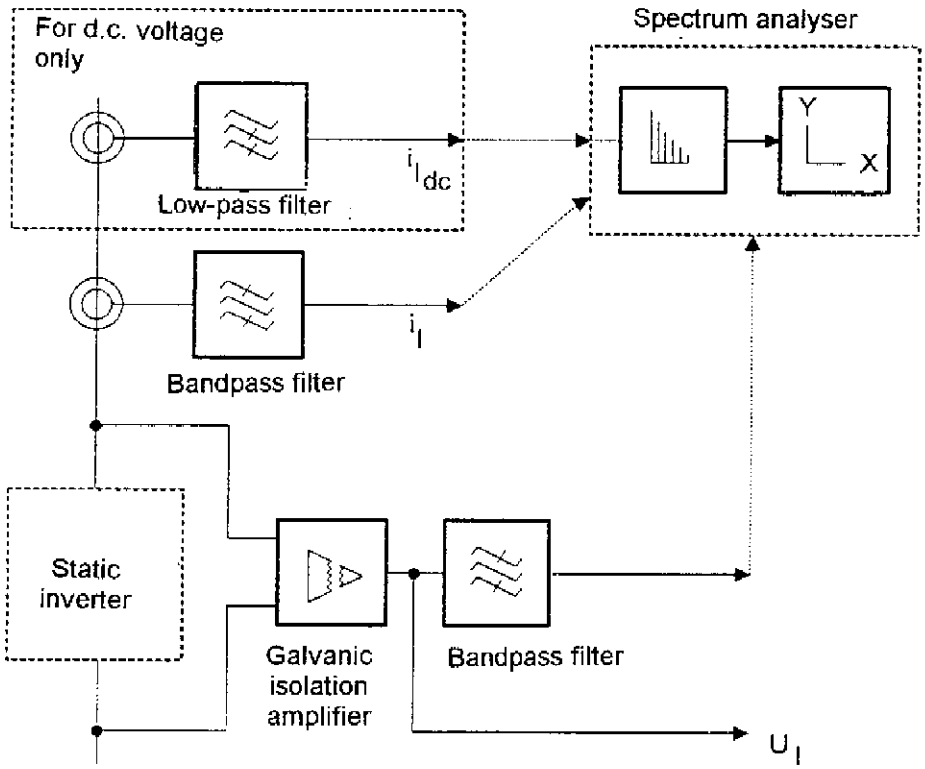


Figure 2: Measurement of input impedance
Test set-up for type testing

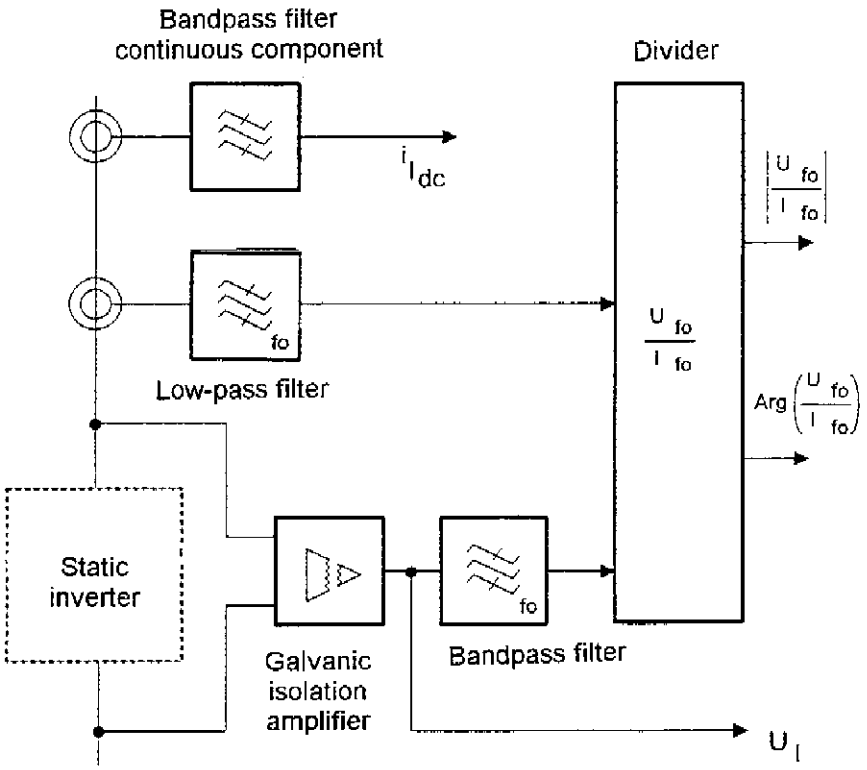


Figure 3: Parallel feed

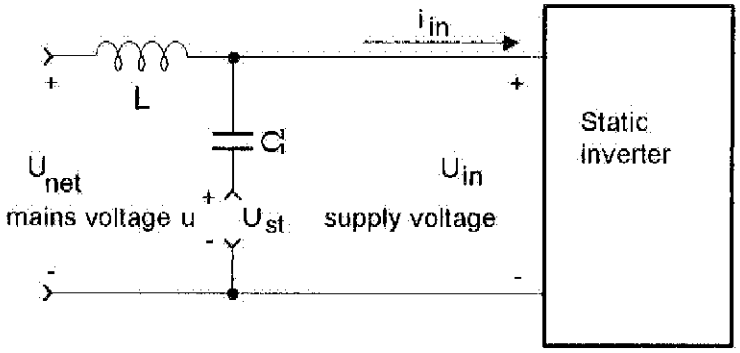
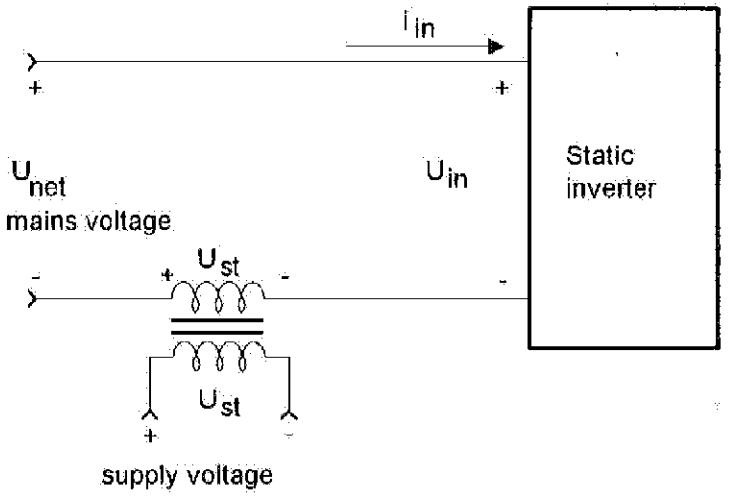


Figure 4: Series feed



Application

With effect from 1 January 1994.

All UIC members.

Record references

Heading under which the question has been studied:

- *Question 5/R/FIC* - Item 8.3 - Approval of Leaflet 550-2.

"Power supply systems for passenger coaches - Type testing".

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