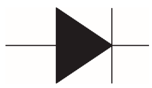
DC-power supplies

System voltage, often 230 or 400 V AC, is suitable for distributing electrical energy, but it frequently has to be converted to an appropriate voltage at the utilisation point, where alternating (AC) or direct (DC) voltage may be needed. Rectifiers are used to obtain direct voltage.

Rectifier connections

Rectifier connections convert alternating voltage/current to pulsating direct voltage/current by means of transformers, diodes, transistors and thyristors. Rectifier connections can have different pulse numbers. This means the number of unsmoothed pulses in the direct voltage per cycle in the alternating voltage.

Rectifier symbol



Diode symbol

Ripple

Depending on the nature of the load, different demands are made on filtration of the direct voltage or content of AC components (residual ripple). The residual ripple is the ratio between the effective value of the overlying alternating voltage with reference to the direct voltage on the output. (or "peak to peak" value of the alternating voltage, see figure). "Advanced" electronics such as burglar alarms and audio equipment typically make greater demands on the power supply than DC motors and contactor coils.

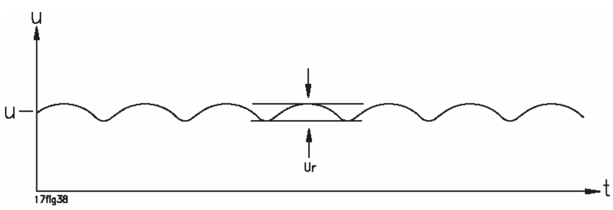
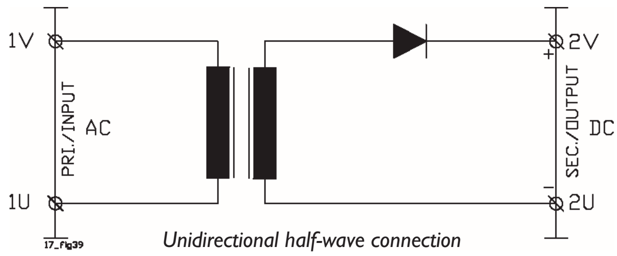


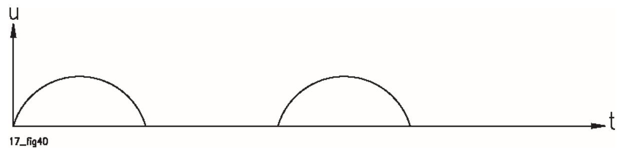
Illustration of ripple on the output's direct voltage. U_r is the residual ripple with reference to the DC voltage U on the output.

Unidirectional half-wave connection

This is the simplest of all rectifier connections. It uses a diode and a transformer. With a sine voltage at the transformer's secondary winding, the direct voltage at the load will consist of the positive half-cycles of the sine voltage. The ripple is 121%. This construction is not very widespread and does not form part of our product range.



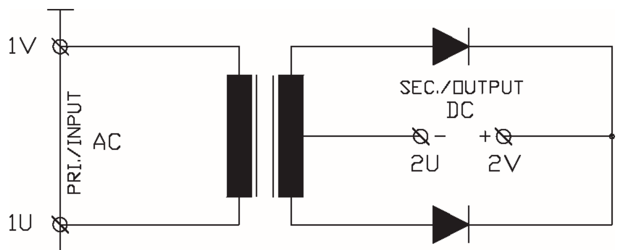
Unidirectional half-wave connection



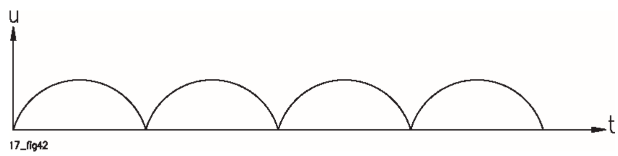
In the case of unidirectional half-wave connection the direct voltage consists of the positive half-waves of the sine voltage (one pulse per cycle).

Unidirectional full-wave connection

This construction uses two diodes and a feedback path for the current through a central terminal on the transformer's secondary winding. Each diode carries its own half-cycle. In the case of a sine voltage the direct voltage will consist of two positive sine half-waves for each electrical cycle. The direct voltage will be twice that for unidirectional half-wave connection in relation to the effective value of the alternating voltage. The ripple is 48%. This form of connection is used in some of our constructions of the LF-DC type.



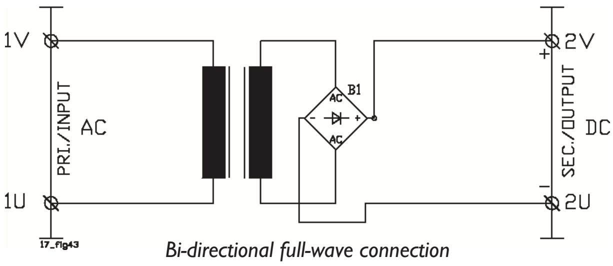
Unidirectional full-wave connection



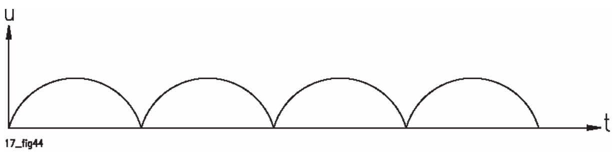
In the case of unidirectional full-wave connection the direct voltage consists of the two positive half-waves for each electrical cycle.

Bi-directional full-wave connection

This connection produces a direct voltage which is identical to unidirectional half-wave connection. The difference lies in the transformer's secon-dary winding and the rectifier valve. (Unidirectional full-wave coupling requires 41% more secondary copper, but manages with half the rectifier bridge and half the heat losses in the rectifier bridge. It is therefore preferred in the case of low output voltages). Bi-directional full-wave connection is to be preferred in the case of higher voltages and powers. This is probably the most widely used form of single-phase connection. Ripple is 48% without a filter. This is a design which we use in our transformer power supplies with 48% ripple. They can be used for DC contactors, solenoid valves and other equipment which can cope with the ripple voltage.



Bi-directional full-wave connection



In the case of bi-directional full-wave connection the trans-former's secondary windings carry current in the system's positive and negative half-cycles, i.e. in both directions (bi-directional).

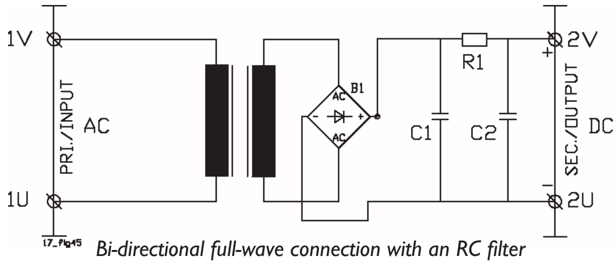
Smoothing

For many purposes direct voltage does not satisfy the requirements for low-ripple voltage. In such cases these requirements can be met by using a filter. The simplest alternative is the RC filter, consisting of a series resistor and a capacitor. This filter is only an option in the case of single-phase rectification and low powers. A better alternative is the LC filter, in which the series resistor is replaced by a reactor. In the case of high powers and controlled three-phase recti-fiers it is possible to improve the ripple ratio considerably by using a smoothing reactor on the direct current side.

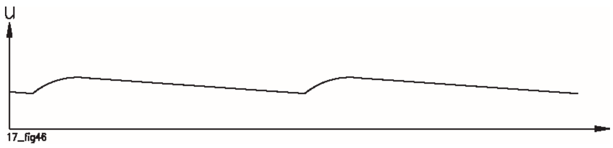
Stringent requirements with regard to low ripple can mean a substantial increase in cost.

The RC-C DC power supply is equipped with an RC filter and the maximum ripple is 5% RMS.

By fitting an RC filter in the bi-directional full-wave connection we obtain a design which we use in our power supplies with 5% ripple. Owing to their simple overload protection, DC power supplies with RC filters are ideal for PLCs, for example. Electronic power supplies can also be used for PLCs, but they have electronic short-circuit protection. This protection is so quick-acting that, in adverse circumstances, the power supply can pack up before the fuse blows. Electronic power supplies should therefore be avoided in situations where the selectivity of the installation must be maintained, e.g. PLC with several output connection fuses.

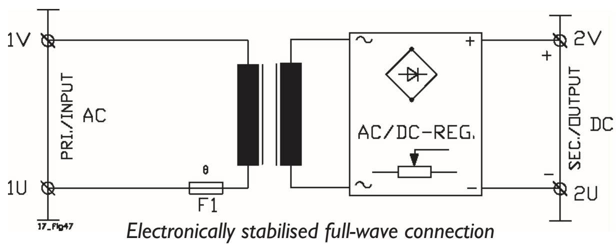


Bi-directional full-wave connection with an RC filter

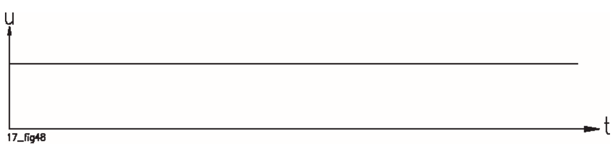


The direct voltage produced by bi-directional full-wave connection with an RC filter is a smoothed direct voltage.

This is a design which we use in our products with a stabilised output (max. 0.5% ripple). It has a short-circuit-proof output and is not very susceptible to supply voltage and load. It is ideal for electronics or other equipment which requires smooth, stable direct voltage. It can, in certain conditions, also be used as a constant voltage charger for batteries.



Electronically stabilised full-wave connection



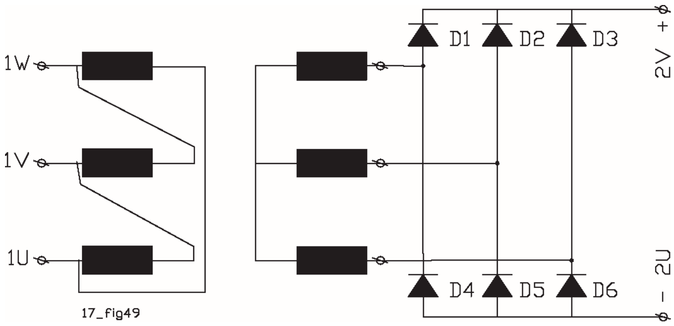
The direct voltage has max. 0.5% ripple in the case of electronically stabilised full-wave connection.

Rectifiers for high powers

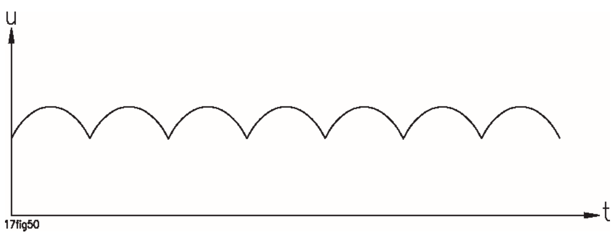
In the case of rectifiers for high powers the influence of undesirable harmonics on the system is a problem. It is therefore a good idea to make such rectifiers with a pulse number per system cycle that is higher than 6, preferably 12 or 24. A pulse number of more than 6 demands a special transformer design. Noratel has supplied many transformers and reactors to manufacturers of rectifiers of this type.

Bi-directional six-pulse connection

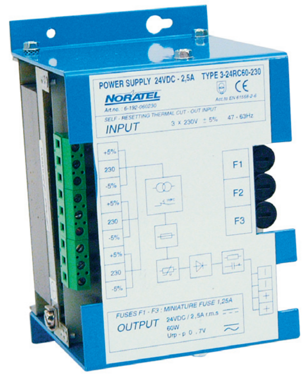
Rectifiers for high powers are generally based on a three-phase supply voltage, ensuring symmetrical loading of the system. Bi-directional six-pulse connection is the most widely used three-phase rectifier connection. In principle it is two uni-directional three-pulse connections in series, but in this case it is only necessary to use one transformer winding per phase owing to the diode connections. Anti-parallel connection is used for the two diodes in each phase. DC power supplies based on this method produce low ripple without using a capacitor/resistor. The typical ripple value is 4.2%.



Bi-directional six-pulse connection



In the case of bi-directional six-pulse connection the direct voltage consists of six pulses per system cycle

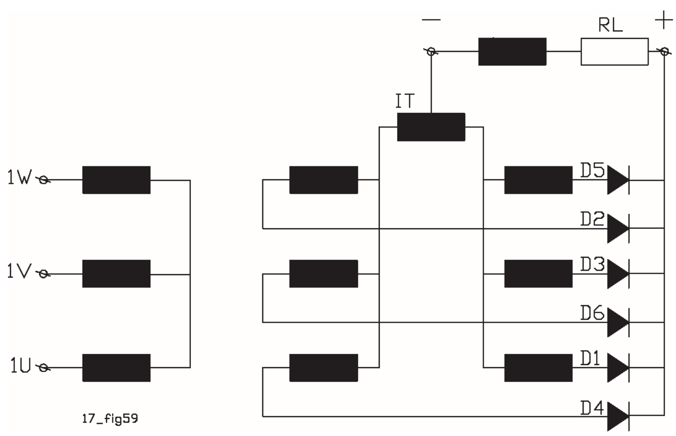


The 3RC-C power supplies have a three-phase supply voltage and the direct current has max. 5% ripple.

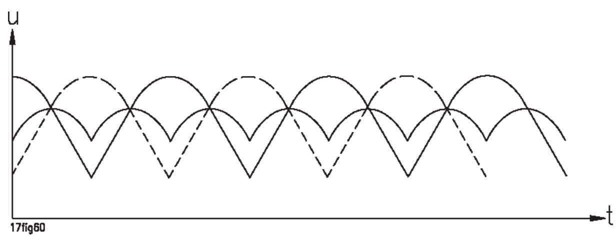
Unidirectional six-pulse connection

(with an interphase transformer)

This connection produces a direct voltage which is identical to that from bi-directional six-pulse connection. The primary side of the transformer is roughly the same for the two connections at the same power. The difference lies in the secondary winding and the rectifier valve. The secondary winding is divided into two and connected at the common neutral point, which is often used for the rectifier's minus tapping. The connection is unidirectional, resulting in a shorter conducting time per system cycle in the transformer's secondary windings. The secondary copper is therefore approx. 42% heavier than the primary copper. The transformer is therefore more expensive than an equivalent transformer in a six-point bi-directional connection. On the other hand, the rectifier valve is approximately half the size, and the losses in the rectifier valve are also halved. The interphase transformer is needed to even out the 30° phase displacement in the two secondary systems. This increases the conducting time in the secondary copper and diodes to 120° per system cycle. This connection is economical in terms of both acqui-sition cost and running costs in the case of low direct voltages and high currents.



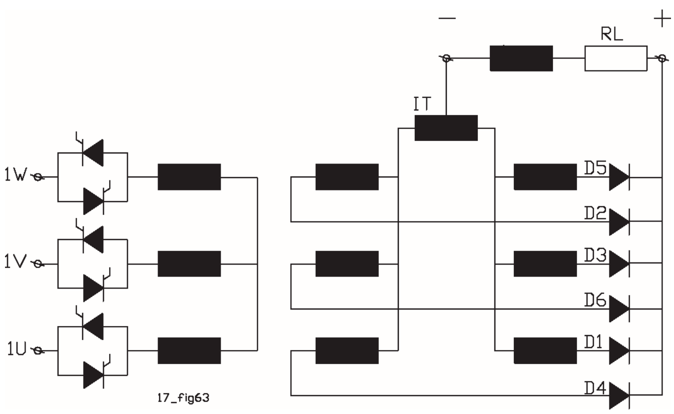
Unidirectional six-pulse connection with an interphase transformer (IT)



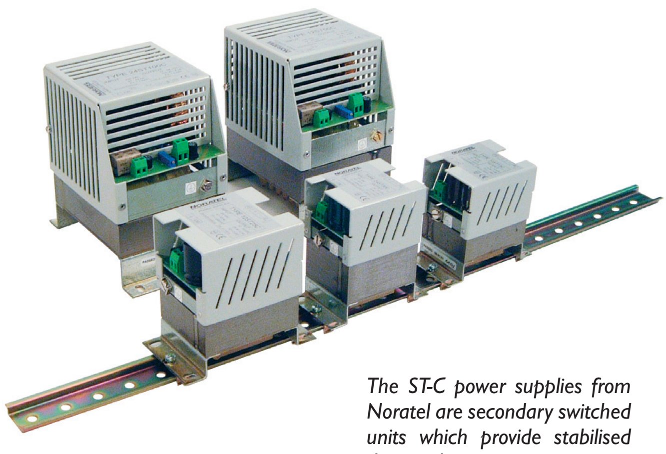
The direct voltage in the case of unidirectional six-pulse connection

Voltage/current-controlled rectifiers

An uncontrolled rectifier is often unusable because it has to meet the system's voltage variations and the demands which use of the rectifier makes on voltage/current control. Control can be implemented by, for example, replacing the rectifier diodes with thyristors or with transistors on the direct current side. In the case of low voltages and high currents it may be worth controlling the system voltage to the transformer with a primary thyristor controller. The below diagram shows a primary-controlled unidirectio-nal six-pulse connection with an interphase transformer.
This connection is widely used in galvano-rectifiers.



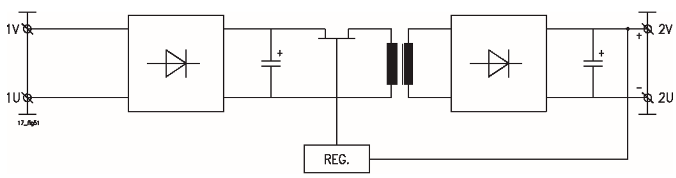
Primary-controlled unidirectional six-pulse connection with an interphase transformer (IT)



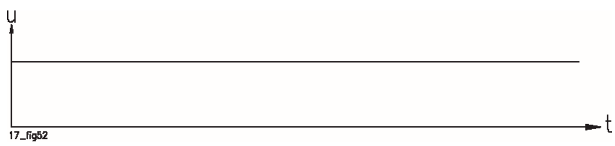
The ST-C power supplies from Noratel are secondary switched units which provide stabilised direct voltage

Switch mode

An increasingly common way of converting alternating voltage to controlled and stabilised direct voltage is to use electronic power supplies (switch mode), which work at a high frequency. The voltage is chopped up on the primary side, i.e. a primary-switched power supply. By varying the pulse width it is possible to control the transferred energy. By increasing the frequency it is possible to reduce the size of the transformer. The frequency is normally around 20-100 kHz, but frequencies of up 2 MHz occur. A primary-switched power supply has an efficiency in the regions of 80-95% and is about 75% lighter than other constructions. The switching in this construction generates interference/noise, and it is important for the power supply to be equipped with effective filters for its inputs and outputs. Installations containing solenoid valves, motors or other equipment which causes high current consumption for short periods can create operating problems for switch mode.



Schematic diagram of a switch mode power supply



The voltage from a switch mode power supply is stabilised

The DRA power supplies from Noratel are switch mode units which provide stabilised direct voltage