Power supply systems

Three-phase half-wave rectifier.

The circuit arrangement and the time-diagram of the main quantities of this rectifier are shown in fig. 2.1. The primary winding could be in a star connection or in a delta connection. The secondary winding is in a simple star connection.

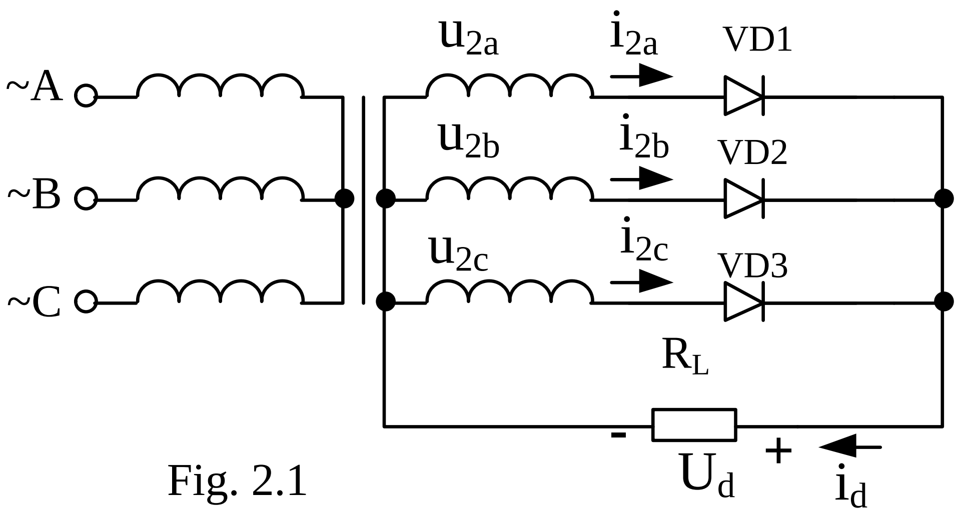


Fig. 2.1

Three-phase half-wave rectifier

It could be seen from the shown circuit diagram that each supply phase is connected to the load via a diode, and as in all half-wave connections, the load current is returned to the supply neutral. With the poly-phase connections, the time interval between the relation in the load waveform are shorter than for single phase connections, and also in practice they usually supply larger loads having heavier inductance. The net result is for the ripple content of the load current to be less.

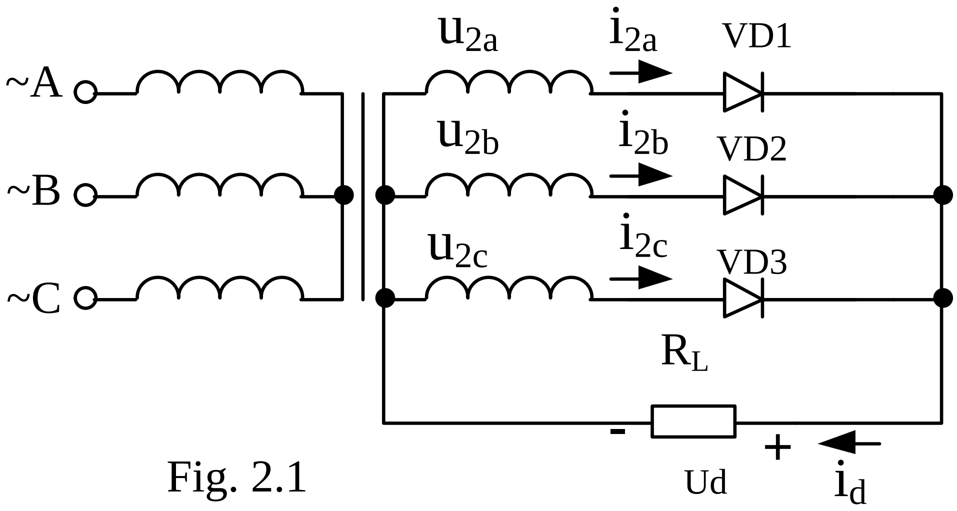


Fig. 2.1

Three-phase half-wave rectifier

The circuit functions in a manner such that only one diode is conducting at a given instant, that one which is connected to the phase having the highest transitory value of the voltage. This results in the output voltage Vd having the waveform of the top of the successive phase voltage. While is the most positive phase, diode VD1 conducts but, directly e_b becomes more positive than e_a the load current is transferred from diode VD1 to diode VD2.

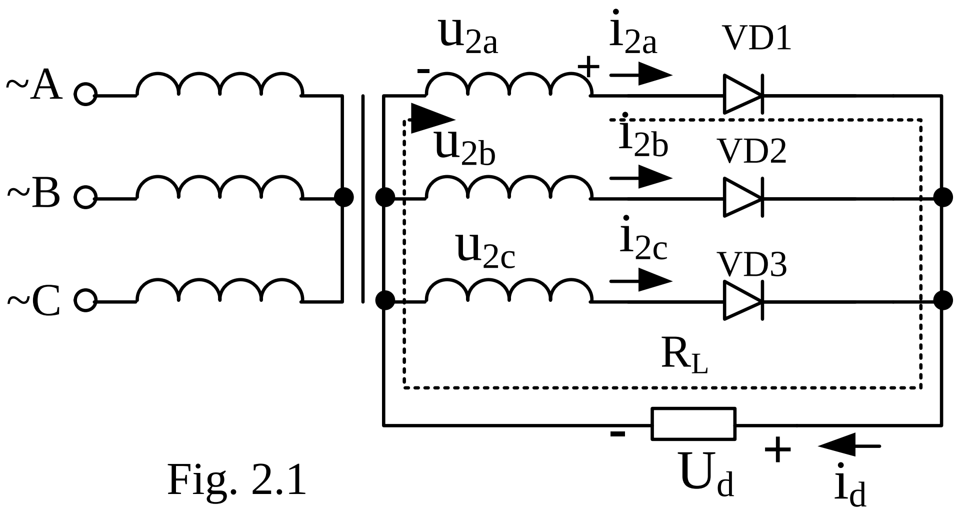
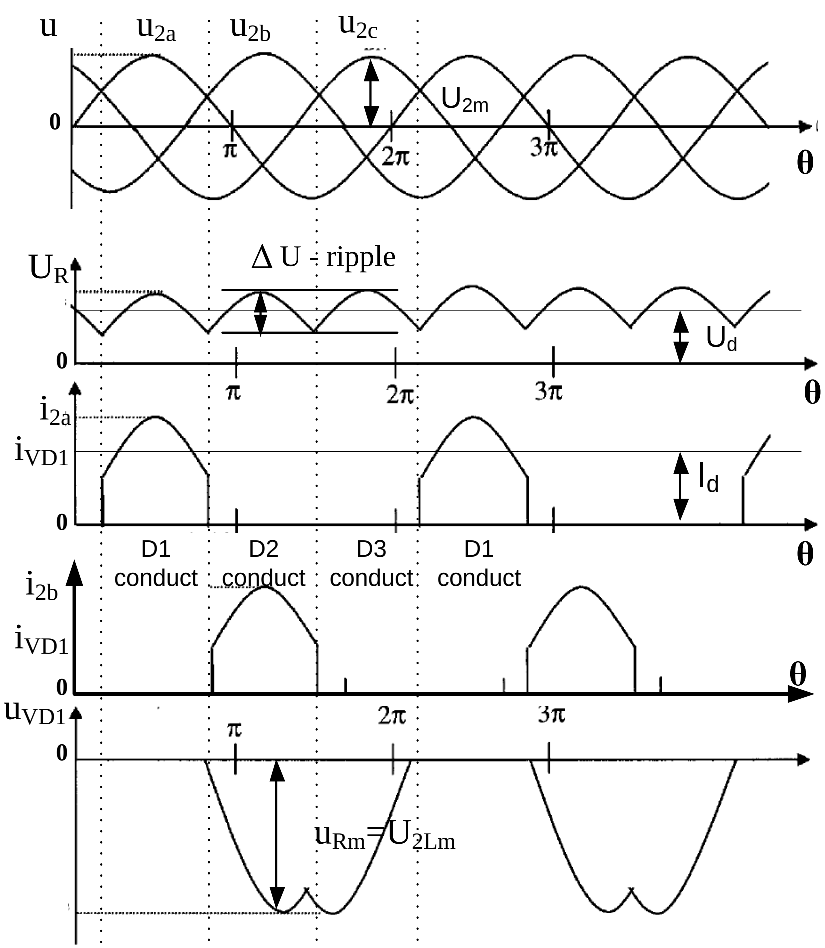


Fig. 2.1

Three-phase half-wave rectifier



Confirmation of the instant of commutation can be seen by examining the diode voltage waveform u_{VD1}, which goes negative directly u_a has a transitory value below u_b , hence diode VD1 turns off. The transitory value of the load voltage varies between the maximum value of the phase voltage and half this value, and it also repeats itself three times per cycle, this having a three pulse characteristic. Comparison of the output voltage of this rectifier and the single-phase connections shows that the tree-phase half-wave rectifier has a much smaller ripple. The main relationship for this rectifier are given by the following expressions:

Three-phase half-wave rectifier

The average value of the output voltage is:

$$Ud = \frac{1}{\frac{2\pi}{3}} \int_{-\frac{\pi}{3}}^{\frac{\pi}{3}} U_{2m} \cos\theta d\theta = \frac{3}{2\pi} \int_{-\frac{\pi}{3}}^{\frac{\pi}{3}} U_{2m} \cos\theta d\theta = = \frac{3}{\pi} U_{2m} \sin\frac{\pi}{3}$$

$$U_{2m} = \frac{Ud}{\frac{3}{\pi}\sin\frac{\pi}{3}} = 1,21Ud \qquad U_2 = \frac{U_{2m}}{\sqrt{2}} = 0,855Ud$$

The maximum (peak) reverse voltage across the diode is: $u_{Rm} = U_{2Lm} = U_{2m}\sqrt{3} = 2,1Ud$

The average current flowing through the diode is: $I_{Fav} = \frac{Id}{3}$

The maximum (peak) current flowing through the diode is: $I_{Fm} = I_{2m} = \frac{Id}{\frac{3}{\pi}\sin\frac{\pi}{3}} = 1,21.Id$

The standard transformer power according to which the core of the transformer should be dimensioned is :

$$Ptr = \frac{P_1 + P_2}{2} = \frac{1,27 + 1,47}{2} Pd = 1,37Pd$$

where Pd=Ud.Id

Three-phase full-wave rectifier

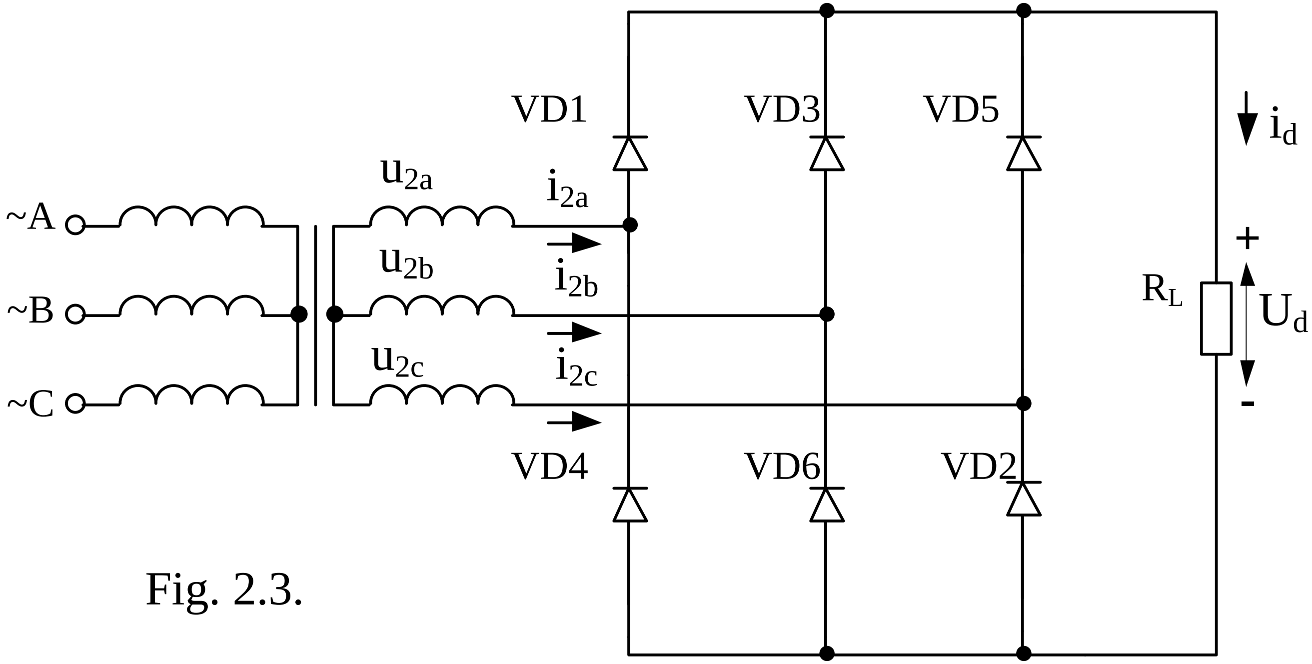
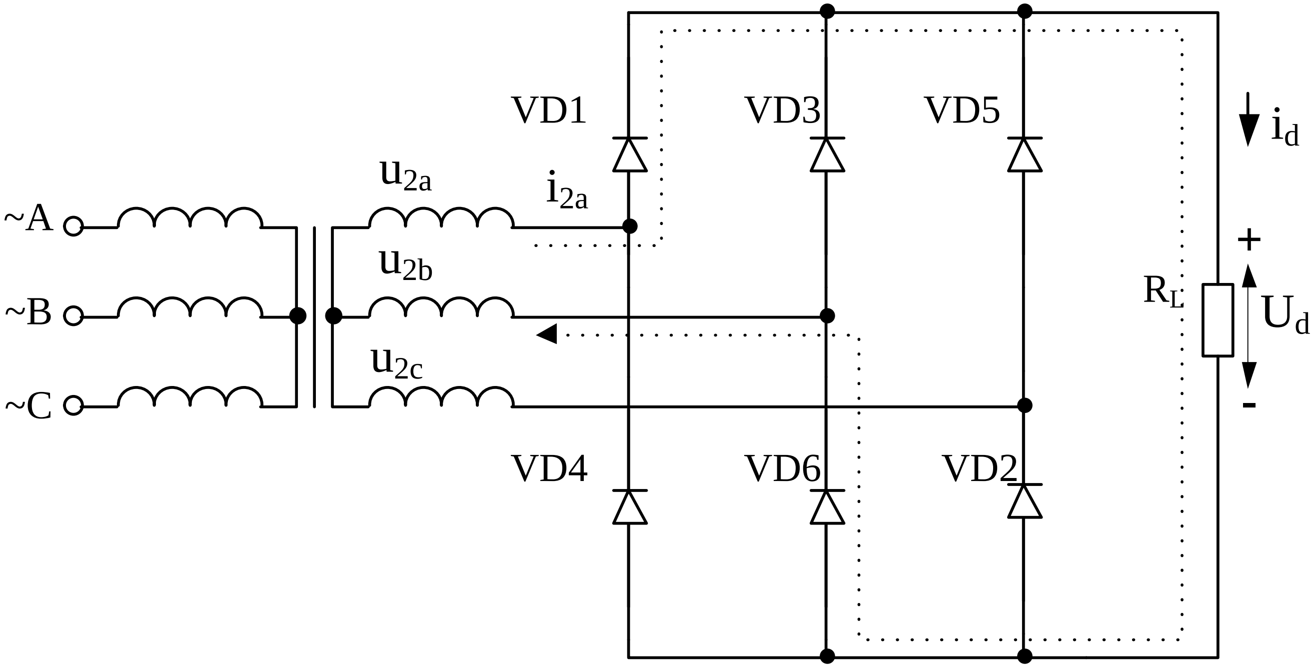


Fig. 2.3.

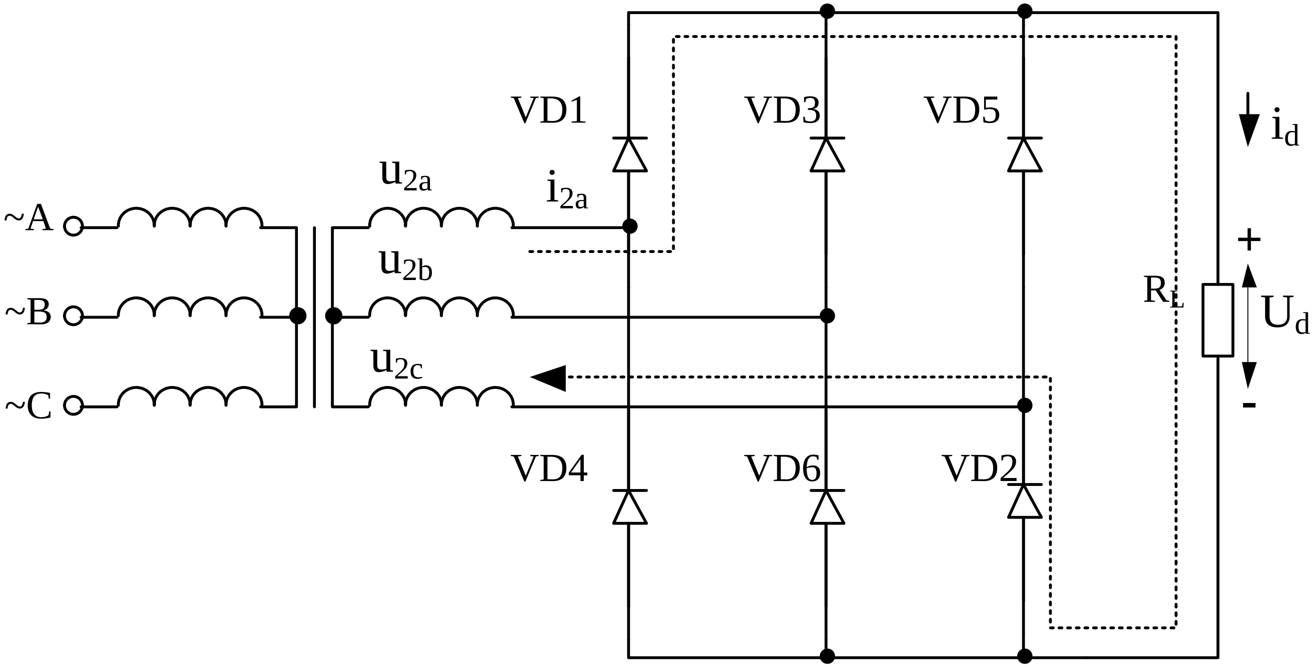
Three-phase full-wave rectifier

The circuit connection layout is shown in fig. 2.3, while the waveform of the main quantities are shown in fig. 2.4. This rectifier actually consists of two three-phase half-wave rectifiers, the pulse number being six. The load is fed via a three-phase half wave connection, the return current path being via another half-wave connection to one of the three supply line, no neutral being required. The transformer winding could be connected as star – star or delta – star, or star-delta, or delta-delta. The devices VD1, VD3, VD5 have a common cathode and form the **cathode group** of diodes, while VD2, VD4, VD6 have a common anode and form the anode group of diodes. Two diodes conduct at each instant, one from the cathode group of device, the other from the anode group.

Three-phase full-wave rectifier



Three-phase full-wave rectifier



Three-phase full-wave rectifier

The diode belonging to the cathode group of devices and conducting is that which is connected to the most positive phase voltage in a given instant. The diode belonging to the anode group of devices and conducting is than which is connected to the most negative phase voltage in the given instant. This means that when u_a is the most positive phase voltage diode VD1 conducts, and during this period first u_b is the most negative with diode VD6 conducting until v_c becomes more negative when the current in diode VD6 transfers (commutates) to diode VD2. The load voltage flows in turn six sine-wave voltages during one cycle, these being u_a-u_b, u_a-u_c, u_b-u_c, u_b-u_a, u_c-u_a, u_c-u_b, all having the maximum (peak) value of the line voltage, that is $\sqrt{3}$ times the phase voltage.

Three-phase full-wave rectifier

The diode current waveforms reveal that each diode conducts the full load current for one third of a cycle, the order of commutation determining the numbering of the diodes in the circuit. The diode voltage u_{VD1} waveform can be determined as the difference between the phase voltage u_a and the voltage at the common cathode relative to the supply neutral. The peak reverse voltage appearing across the diode is the maximum (peak) value of the line voltage. The a.c. supply current is symmetrical. The expression giving the main relationships for this rectifier are as follows:

Three-phase full-wave rectifier

The average value of the output voltage is:

$$Ud = \frac{1}{\frac{2\pi}{6}} \int_{-\frac{\pi}{6}}^{\frac{\pi}{6}} U_{2Lm} \cos\theta d\theta = \frac{U_{2Lm}}{\pi} \frac{6}{\pi} \sin\frac{\pi}{6}$$

therefore $U_{2Lm} = \dfrac{Ud}{\frac{6}{\pi}\sin\frac{\pi}{6}} = 1,05Ud$ $\qquad U_{2m} = \dfrac{U_{2Lm}}{\sqrt{3}} = 0,606Ud$

The maximum (peak) reverse voltage across the diode is: $u_{Rm} = U_{2Lm} = 1,05Ud$

The average current flowing through the diode is: $I_{Fav} = \dfrac{Id}{3}$

The maximum (peak) current flowing through the diode is: $I_{Fm} = I_{2m} = \dfrac{Id}{\frac{6}{\pi}\sin\frac{\pi}{6}}$

The standard transformer power according to which the core of the transformer should be dimensioned is : $P_{tr}=P_1=P_2=1,05P_d$ where $P_d=Ud.Id$

Three-phase full-wave rectifier

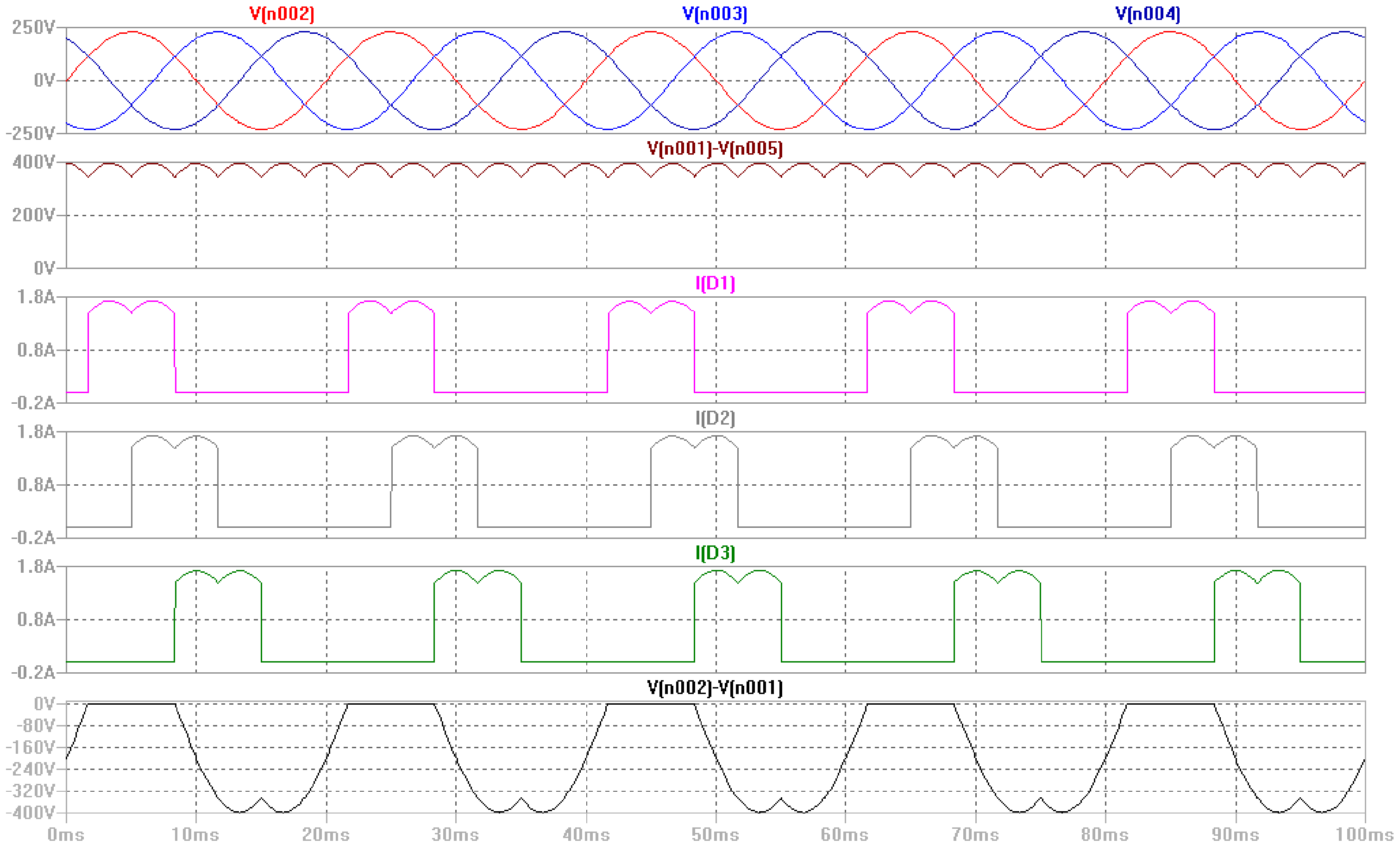
The r.m.s. value of current flowing through the secondary transformer winding is:

$$I_2 == 0,817 Id$$

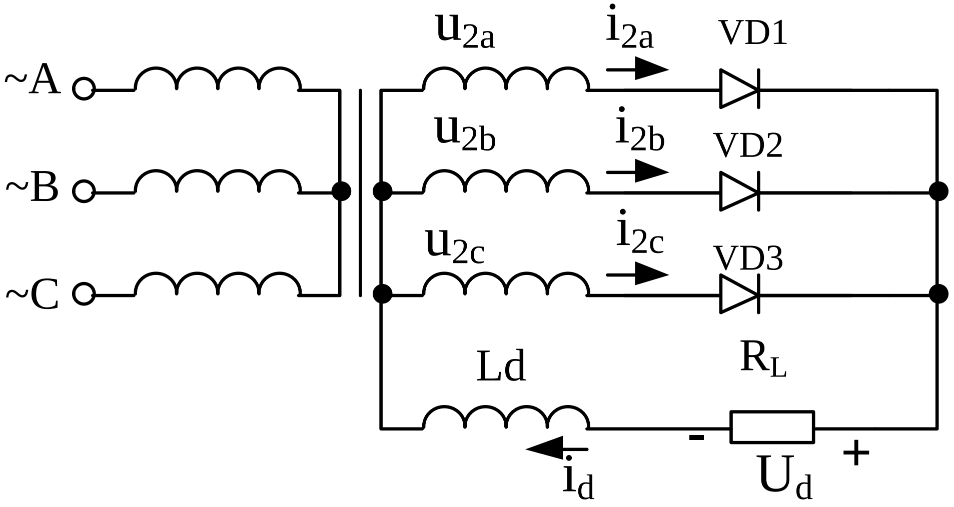
The r.m.s. value of current flowing through the primary winding is : $I_1=n.I_2$,where $n= w_2/w_1$

The coefficient 1,05 in the previous expression show that the rectifier is the most efficient one. The three-phase bridge rectifier has the smallest ripple of the output voltage among the other rectifiers and the ripple frequency is six times the mains frequency. The three-phase bridge rectifier can be applied for middle and high levels of the output power.

Three-phase full-wave rectifire



Three-phase half-wave rectifier with inductive load (RL-load)



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