EVROPSKÁ UNIE
Evropské strukturální a investiční fondy
Operační program Výzkum, vývoj a vzdělávání

MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY

6. Semiconductor converters

6.1 Classification of semiconductor converters

6.2 Fundamental principle of non-controlled and controlled rectifiers

6.3 Principle of AC voltage converter and inverter, applications

6.4 Frequency converter with voltage inverter: principle, characteristics, applications

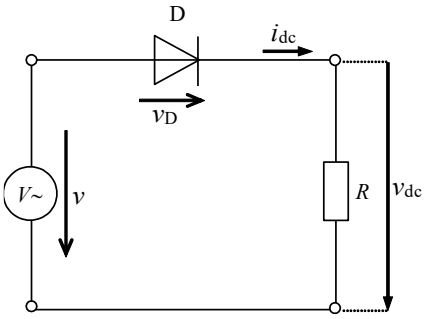
Doc. Ing. Stanislav Kocman, Ph.D.
January 2018

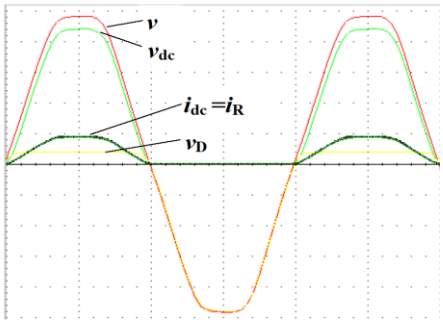
6.1 Classification of semiconductor converters

- rectifiers (used for a conversion of AC current into DC current)
  - non-controlled: with diodes, the output voltage is uncontrolled (constant)
  - controlled: with thyristors, the output voltage can be controlled (variable)
- AC controller (used for a controlling rms value of AC voltage)
  - with triacs: the output AC voltage variable or adjusted to a specific level
  - with thyristors: the output AC voltage variable or adjusted to a specific level
- choppers (DC to DC converter: used for a controlling value of DC voltage)
  - with transistors operating as switches, and diodes
- inverters (used for a conversion of DC current into AC current)
  - with transistors operating as switches, and diodes
  - with thyristors: for large power systems
- frequency converters (used for a controlling frequency of AC voltage)
  - direct (cycloconverter: output frequency is lower than input frequency)
  - indirect (output frequency variable, lower or higher than input frequency)
    - voltage-source inverter: input diode bridge, capacitor, transistor inverter
    - current-source inverter: input thyristor bridge, reactor, transistor inverter

6.2 Fundamental principle of non-controlled and controlled rectifiers

6.2.1 Single-phase non-controlled rectifier, half-wave rectification



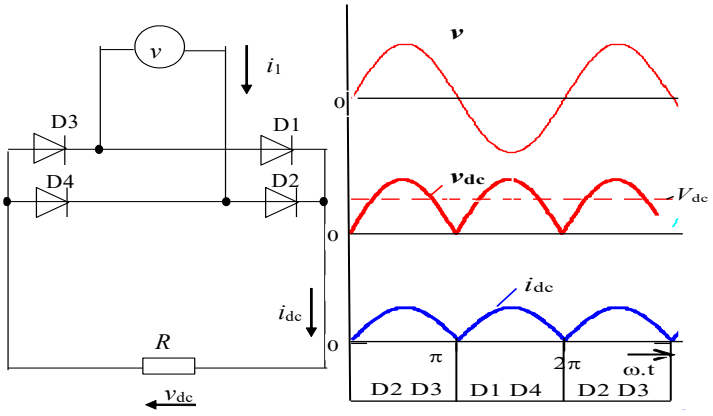


The half-wave rectification requires a single diode in a single-phase supply. One half of the input AC voltage wave is passed, while the other half is blocked causing pulsating direct voltage and current, which is unsuitable for many applications (https://en.wikipedia.org/wiki/Rectifier). The output voltage is constant, uncontrolled. The DC or average output voltage is calculated from (valid only for resistive load):

$V_{dc}=V_{av}=0{,}45 \cdot V$

To improve the output voltage, smoothing capacitor connected in parallel to the load is used (https://en.wikipedia.org/wiki/Rectifier).

6.2.2 Single-phase non-controlled rectifier, full-wave rectification



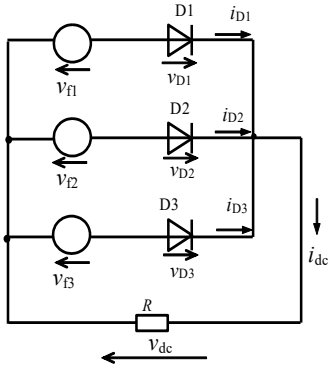
The full-wave rectification converts both polarities of the input voltage waveform to pulsating DC voltage and current. Four diodes in a bridge configuration are used. At each time two diodes are forward biased. The output voltage is constant, uncontrolled.

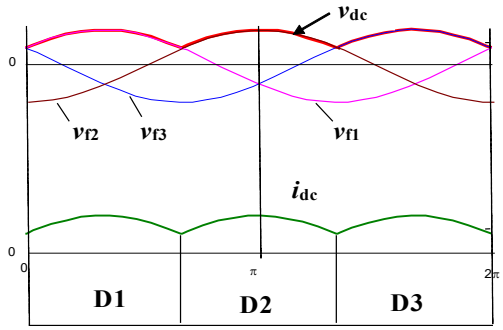
The DC or average output voltage is calculated from (valid only for resistive load):

$V_{dc} = V_{av} = 0{,}9 \cdot V$

To improve the output voltage smoothing capacitor connected in parallel to the load is used (G. Rizzoni: Fundamentals of electrical engineering).

6.2.3 Three-phase non-controlled rectifier, half-wave circuit

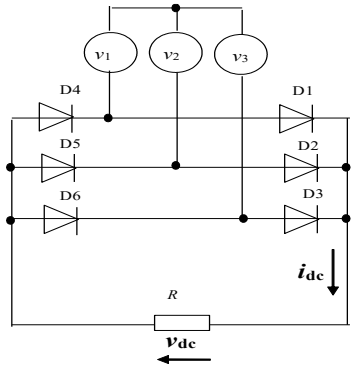


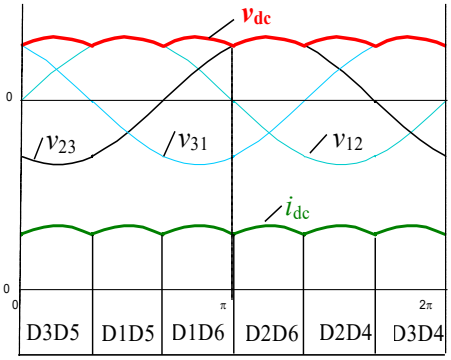


The three-phase, half-wave midpoint circuit requires three diodes, one connected to each phase. At each time one diode is forward biased. This is the simplest type of three-phase rectifier but suffers from relatively high harmonic distortion. The output voltage is constant, uncontrolled (https://en.wikipedia.org/wiki/Rectifier). The DC or average output voltage is calculated from (valid only for resistive load):

$$V_{dc} = V_{av} = 1{,}17 \cdot V_f$$

6.2.4 Three-phase non-controlled rectifier, full-wave circuit

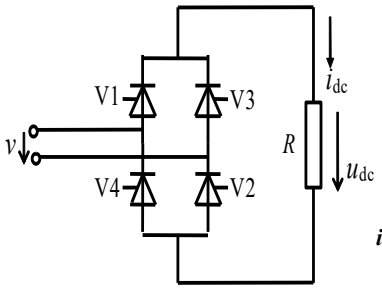


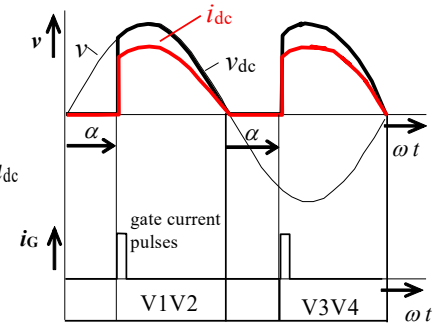


For the non-controlled three-phase bridge rectifier, six diodes are used. To each phase two diodes are connected. At each time two diodes are forward biased, one from the left group, the other from the right group. This rectifier is used in power technical applications. The output voltage is constant, uncontrolled. The DC or average output voltage is calculated from (valid only for resistive load):

$$V_{dc} = V_{av} = 2{,}34 \cdot V_f$$

6.2.5 Single-phase controlled rectifier, full-wave circuit





Thyristors are commonly used in place of diodes to create a circuit that can regulate the output voltage. Four thyristors in a bridge configuration are used. At each time two thyristors are forward biased are fired by gate current pulses (a firing angle α is defined). The DC or average output voltage is calculated from (valid only for resistive load):

$$V_{av(\alpha)} = V_{av} \cdot \frac{1 + \cos\alpha}{2} \qquad V_{av} = 0{,}9 \cdot V$$

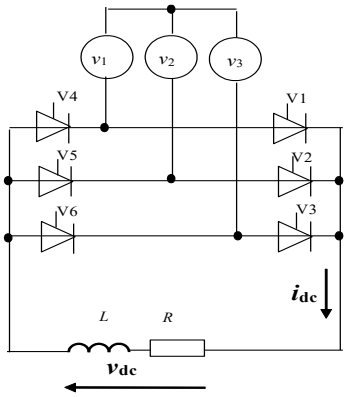
For a load with a resistor and a reactor with large inductance (ideally tends to infinity) the average voltage is calculated as:

$$V_{av(\alpha)} = V_{av} \cdot \cos\alpha$$

6.2.6 Three-phase controlled rectifier, full-wave circuit

For the controlled three-phase bridge rectifier, six thyristors are used. At each time two thyristors are forward biased and fired, one from the left group, the other from the right group. This rectifier is used in power applications, often with *RL* type of a load (https://en.wikipedia.org/wiki/Rectifier). For the load with large inductance (ideally tend to infinity) the average voltage is calculated as:

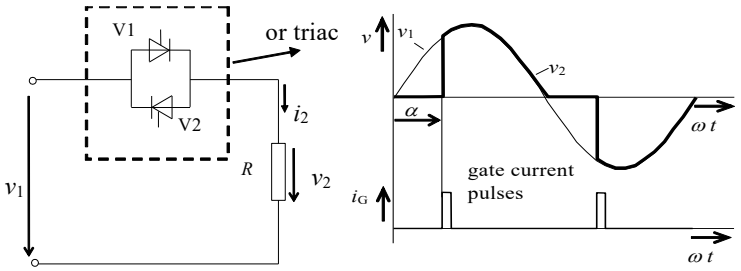
$$V_{av(\alpha)} = V_{av} \cdot \cos\alpha \quad V_{av} = \frac{3\sqrt{6}}{\pi} \cdot V_f$$



6.3 Principle of AC voltage converter and inverter

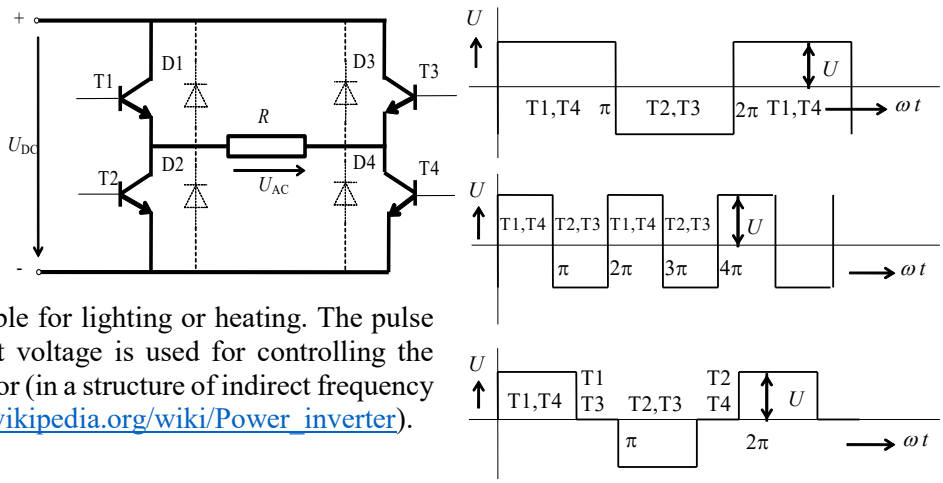
6.3.1 Principle of AC voltage converter

Using triac the alternating current and voltage can be switched and controlled rms value. This is commonly used for controlling the speed of motors in drilling and grinding machines, dimming lamps, and controlling electric heaters and domestic appliances (hair dryer, blender, chef machine, cooker).



6.3.2 Principle of AC voltage inverter

It is used for a conversion of DC current into AC current. The output voltage and frequency depend on the circuit design and switching strategy. The square wave of output voltage is suitable for lighting or heating. The pulse with modulated output voltage is used for controlling the speed of induction motor (in a structure of indirect frequency converter) (https://en.wikipedia.org/wiki/Power_inverter).



6.4 Frequency converter with voltage inverter: principle, characteristics

It is used in variable-frequency drive to control induction motor speed by varying motor input frequency and voltage. It consists of bridge diode rectifier for the conversion AC voltage into DC voltage, DC link with capacitor for smoothing DC ripple and providing a stiff input to an inverter, and the inverter with for the conversion to quasi-sinusoidal AC voltage with variable voltage and frequency. Used in drives of pumps, fans, extruders, conveyors, elevators (https://en.wikipedia.org/wiki/Variable-frequency_drive).

