RECTIFIERS (AC/DC CONVERTERS)

1. Uncontrolled Rectifier

The dc output voltage of a rectifier should be as ripple free as possible. Therefore a large capacitor is connected as a filter on the dc side. This capacitor gets charged to a value close to the peak of the ac input voltage.

In such diode rectifiers, the power flow can only be from the utility ac side to the dc side.

Increasingly, the trend is to use the inexpensive rectifiers with diodes

1.1. Pure Resistive Load

There is no phase difference between i and Vd for (+) alternance.

For Single Phase half wave rectifier for R Load

$$V_d = \frac{1}{2\pi}\int_0^{\pi} V_m \cdot \sin(\omega t)\cdot d(\omega t) = \frac{1}{\pi} V_m = \frac{\sqrt{2}\cdot V_{ph}}{\pi} \text{ Volt}$$

V_{ph} = Phase voltage , V_m = Max value of phase voltage

For Single Phase full wave rectifier for R load

$$V_d = \frac{1}{\pi}\int_0^{\pi} V_m \sin(\omega t)\cdot d(\omega t) = \frac{2 \cdot V_m}{\pi} = \frac{2\cdot\sqrt{2}\cdot V_{ph}}{\pi}$$

For Three Phase half wave rectifier for R load.

$$V_d = \frac{1}{2\pi/3}\int_{-\pi/3}^{\pi/3} V_m \cdot \cos(\omega t)\cdot d(\omega t) = \frac{3\sqrt{3}}{2\pi}\cdot\sqrt{2}\cdot V_{ph}$$

For three phase full wave Rectifier for R Load

$$V_d = \frac{1}{\pi/3} \int_{-\pi/3}^{\pi/3} V_m \cdot \cos(\omega t) \cdot d(\omega t) = \frac{3\sqrt{3}}{\pi} \cdot \sqrt{2} \cdot V_{ph}$$

2. CONTROLLED RECTIFIER

Output voltage can be controlled from positive max., to min. value. The converter dc current can not change direction. A converter of this type can operate in only two quadrants.

The positive values of Vd-Id imply rectification mode which the power is transferred from ac to dc side In inverter mode, Vd becomes negatif but Id is still positive and the power is transferred from dc to ac side.

In some applications such as in reversible-speed dc motor drives with regenerative braking, the converter must be capable of operating in all four quadrants. This is accomplished by connecting two two-quadrants converter in antiparallel.

For Single phase and half wave rectifier with resistive load.

$$V_{d\alpha} = \frac{1}{2\pi} \int_{\alpha}^{\pi} V_m \cdot \sin(\omega t) \cdot d(\omega t)$$

$$= \frac{1}{2\pi} \cdot \sqrt{2} \cdot V_{ph} (1 + \cos\alpha)$$

For single phase, half wave rectifier with inductive load

$$V_{d\alpha} = \frac{1}{2\pi} \int_{\alpha}^{\pi+\alpha} V_m \cdot \sin(\omega t) \cdot d(\omega t)$$

$$= \frac{1}{2\pi} \cdot \sqrt{2} \cdot V_{ph} \cdot (\cos\alpha + \cos\alpha) = \frac{\sqrt{2} \cdot V_{ph}}{\pi} \cdot \cos\alpha .$$

for $\alpha < \frac{\pi}{2}$, $V_{d\alpha} > 0$ Rectifier mode

for $\alpha > \frac{\pi}{2}$, $V_{d\alpha} < 0$, Inverter mode.

If the circuit losses are omitted, the input and output powers are equal.

$$P_i = P_o = V_d \cdot I_d \cdot \cos\alpha$$

P_i = input power
P_o = output power

For one power switch

$$I_{TAV} = \frac{1}{q} \cdot I_d$$

q = number of phase

$$I_{Trms} = \sqrt{\frac{1}{q}} \cdot I_d$$

I_{TAV} = Average value of the thyristor current

I_{Trms} = Rms value or effective value of thyristor current

V_{DRM}, V_{RRM} = Positive and negative breakdown voltage for each power switch

$V_{DRM}, V_{RRM} > \sqrt{2} \cdot V_{ph}$ for single phase

$V_{DRM}, V_{RRM} > \sqrt{6} \cdot V_{ph}$ for three phase

The generalized equation for all kind of rectifiers

$$V_d = s \cdot \frac{q}{\pi} \cdot \sqrt{2} \cdot V \cdot \sin\frac{\pi}{q}$$

$$V_{d\alpha} = V_d \cdot \cos\alpha .$$

s = Cofficient   s = 1 for half wave and uncontrol
s = 2 for full wave.

q = number of phases

V = supply voltage

to convert the single phase to two phases system

Single phase	=	Two phases
V_f = 220 V.		V_f = 110 V
q = 1		q = 2.

DC/DC CONVERTERS (DC CHOPPERS)

Basic Specifications of DC-DC CONVERTERS.

- The control is linear.
- The output value is varied as average value.
- There are ripples both input and output side.
- Forced-commutation is needed
- They are high frequency circuits.
- Usually for lower power levels and high frequencies MOSFET, for the power and frequency values above middle level ones, IGBT is prefered.

STRUCTURES OF DC CHOPPERS.

FOR A QUADRANT DC Chopper

Resistive load

I_o = output current = U_q/R — i = lower case for instant value

$I_q = i_T = i_d$ — i_d = DC supply current.

$i_D = 0$ — i_D = Diode current

$$U_q = \frac{1}{T_p}\int_0^{T_i} U_d \cdot dt = \frac{T_i}{T_p},\ U_d = a \cdot U_d = D \cdot U_d$$

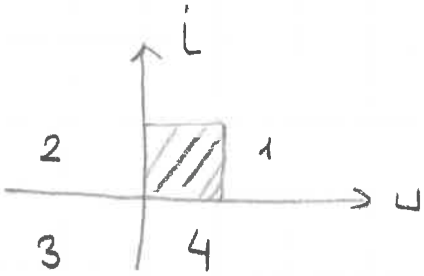
$0 \le D = a < 1$ $\qquad 0 \le U_o \le U_d$

Inductive Load

$i_q = i_T + i_D$

$I_T = a \cdot I_q$

$I_D = (1-a)\, I_q$



The aim of using diode is to protect the circuit elements from excessive back-emf due to inductor.
Output voltage is uni-directional and positive.

TWO QUADRANT DC CHOPPER

$$U_o = \frac{1}{T}\left[\int_0^{T_{on}} U_d \cdot dt + \int_{T_{on}}^{T} -U_d \cdot dt\right]$$

$$U_o = \frac{1}{T} U_d \left[T_{on} - (T - T_{on})\right]$$

U_o = Output Voltage of chopper

$$U_o = \frac{1}{T}(2 \cdot T_{on} - T) U_d = (2\lambda - 1) \cdot U_d$$

$$U_o = (2\lambda - 1) \cdot U_d$$

$$0 \leq \lambda \leq 1$$

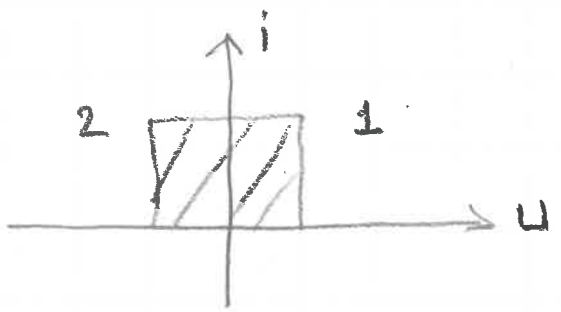
$$-U_d \leq U_q \leq U_d.$$

for $\lambda < \frac{1}{2}$, $U_q < 0$ negative operation mode

for $\lambda > \frac{1}{2}$, $U_q > 0$ positive operation mode

for $\lambda = \frac{1}{2}$ $U_q = 0$

for $\lambda = 1$ $U_g = U_q$



The energy flow is from supply to load when the transistor is on-state. But it is from the load to the supply when the diode is on-state.