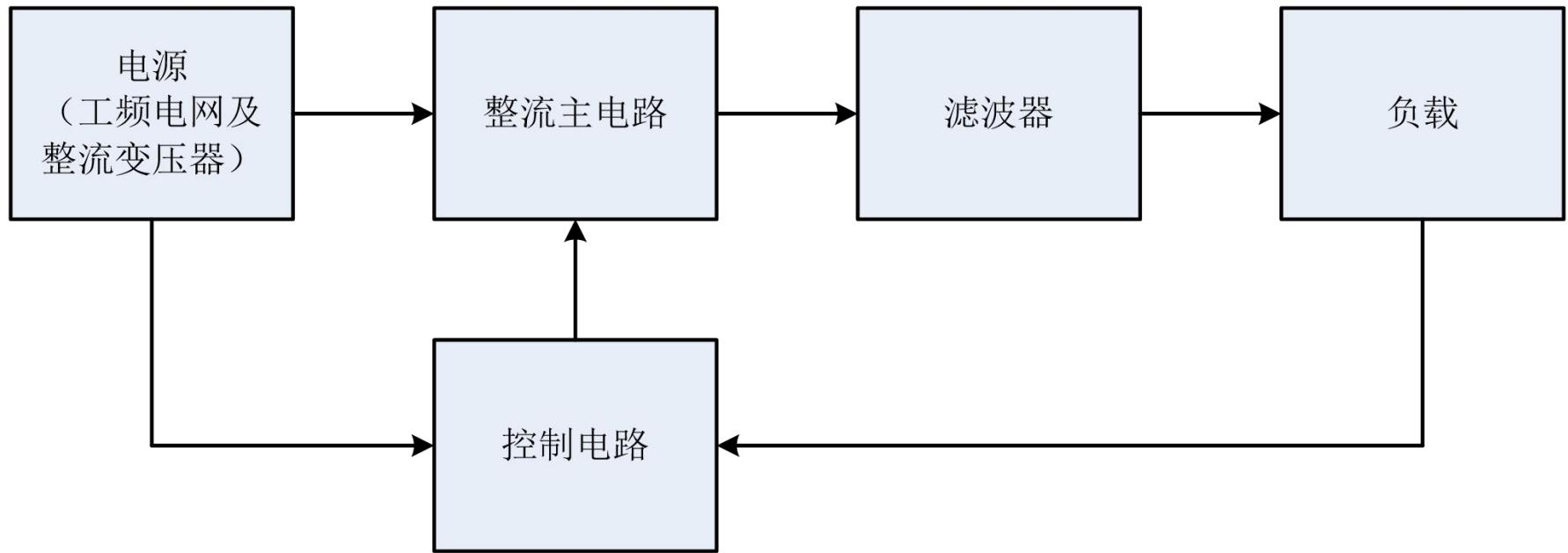


# 可控整流电路的一般结构

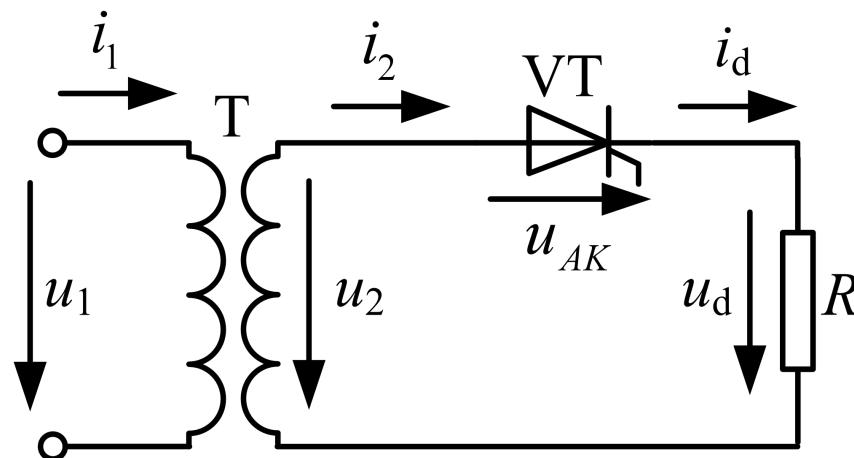


# 1.3 单相半波可控整流电路

- ❖ 交流侧接单相电源
- ❖ 重点注意：工作原理（波形分析）、定量计算、不同负载的影响。

## 1.3.1 电阻负载

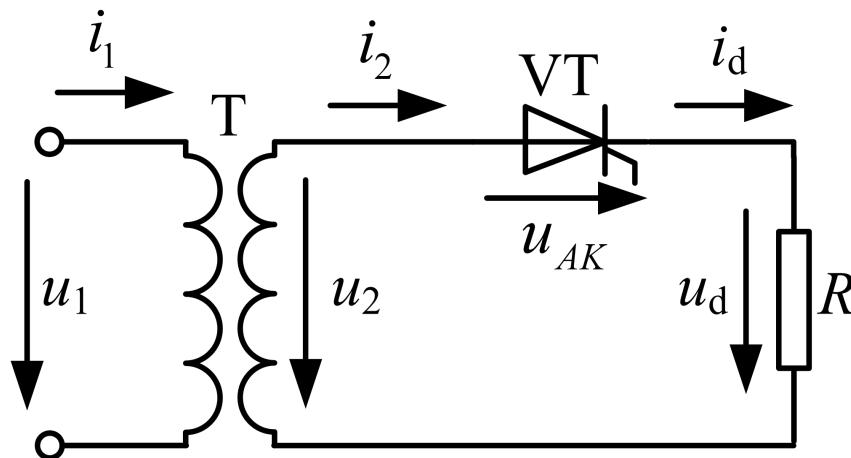
- 变压器T起变换电压和隔离的作用；
- 电阻负载的特点：电压与电流成正比，两者波形相同。



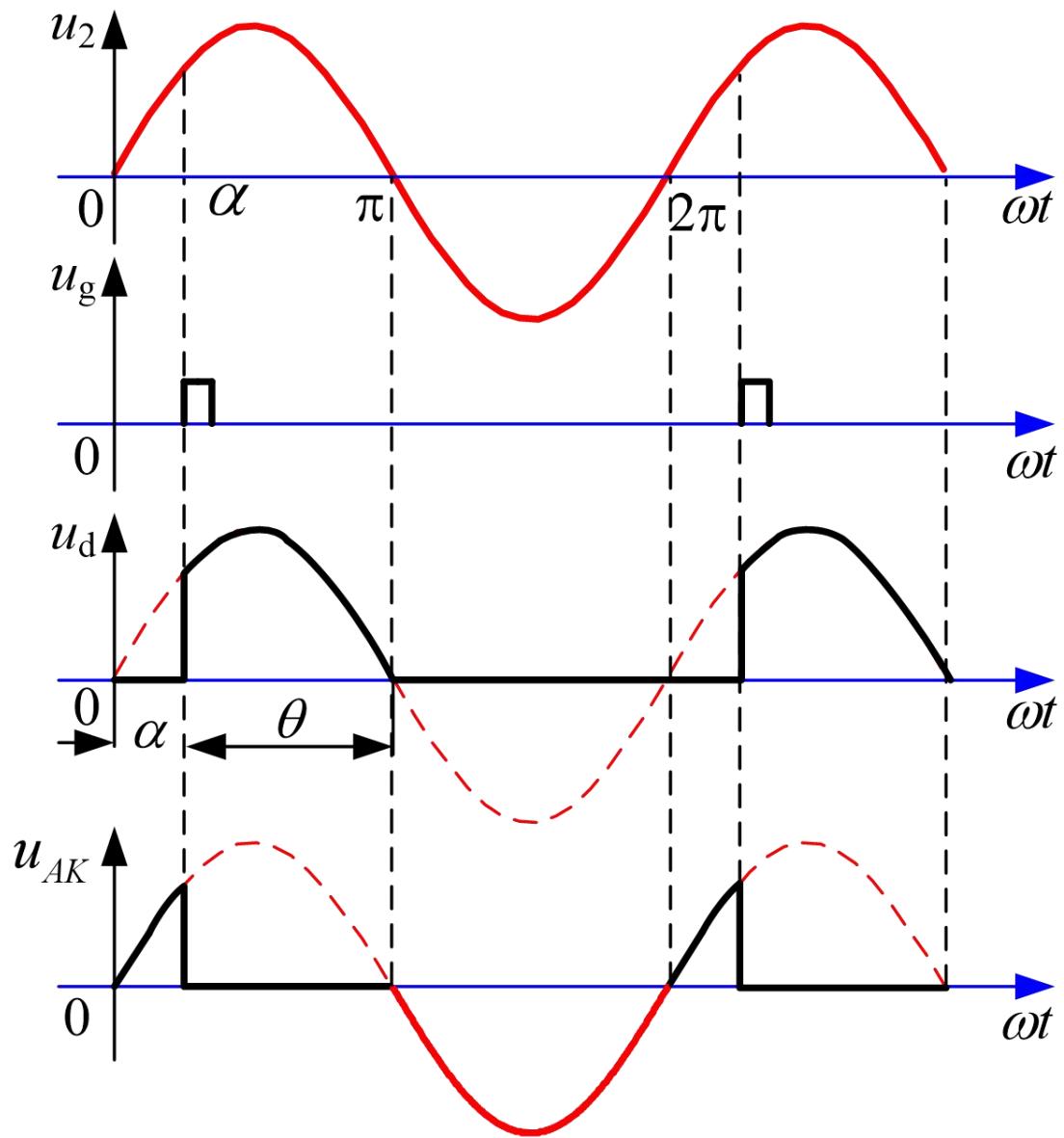
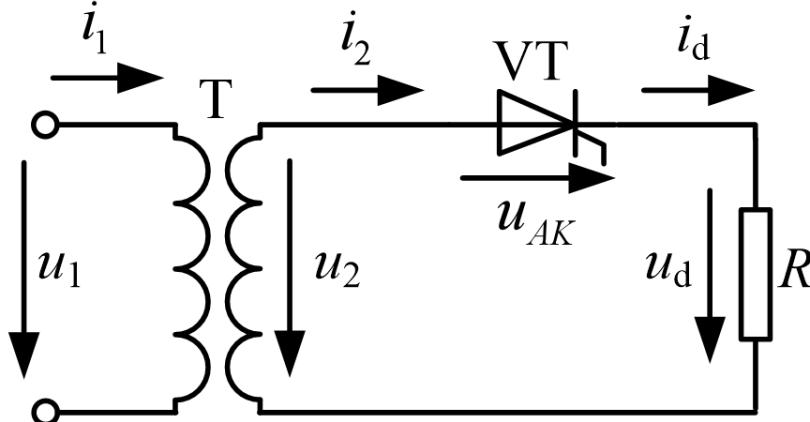
## 1.3 单相半波可控整流电路

理想晶闸管假设：

- 正向和反向阻断时电阻为无穷大，漏电流为零
- 正向导通时管压降为零
- 开通和关断瞬时完成
- $du/dt$ 、 $di/dt$ 承受能力为无穷大

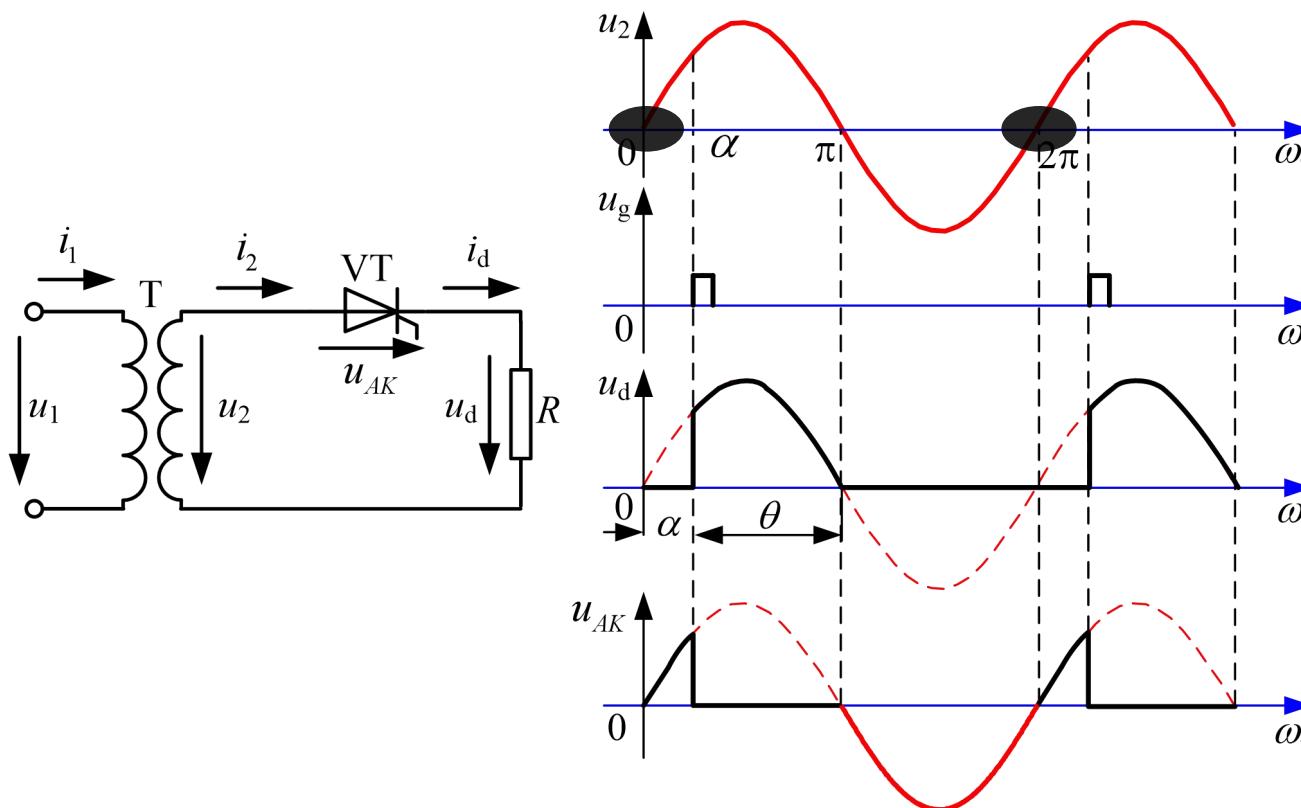


# 单相半波可控整流电路及波形



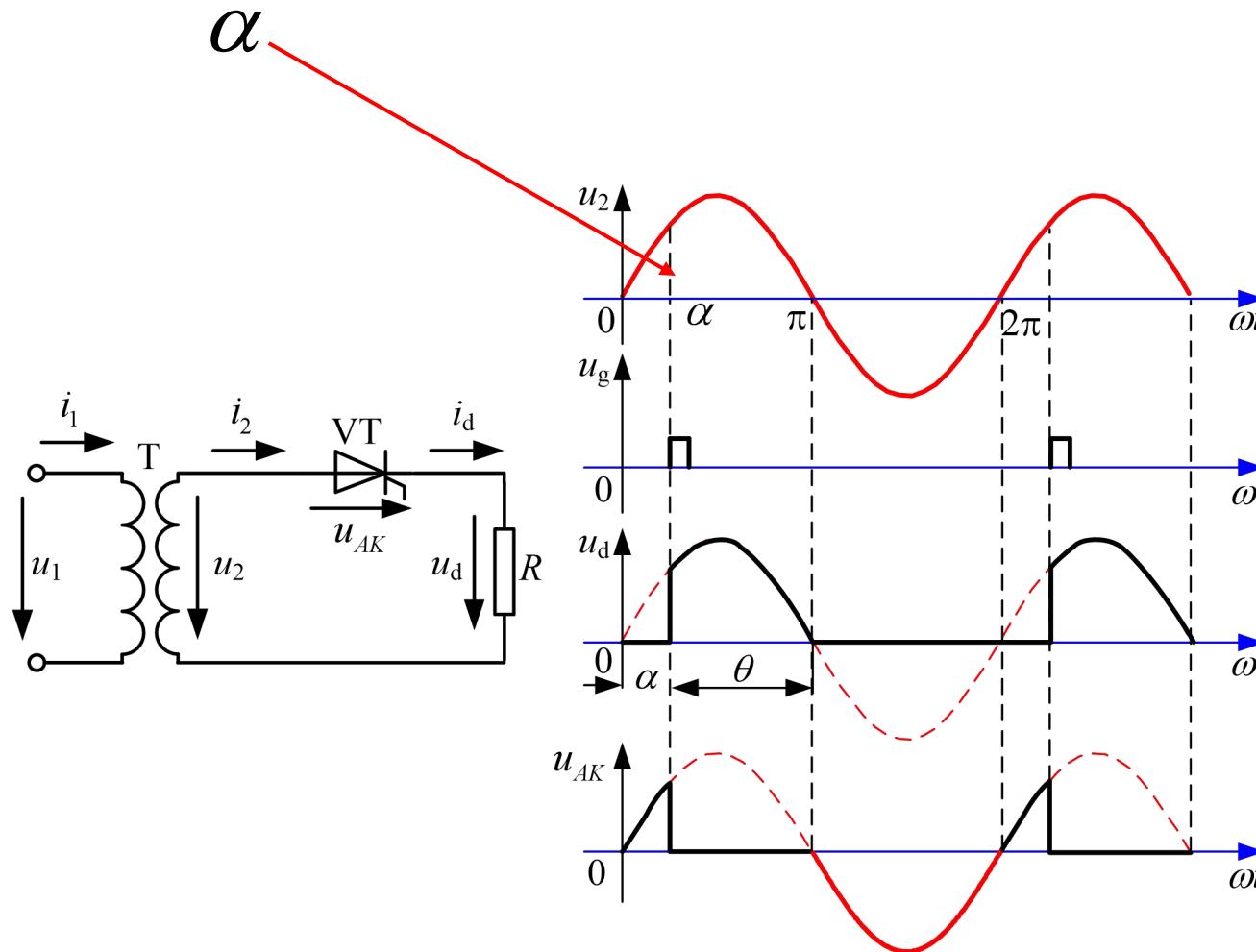
# 自然换流点

- 如将晶闸管换为二极管，则二极管开始流过电流的时刻称为“**自然换流点**”。
- 此电路中，交流电压由**负电压过零**的时刻即为自然换流点。



# 延迟角

- 从自然换流点算起至触发脉冲出现时的延迟角度称为“**延迟角**”。



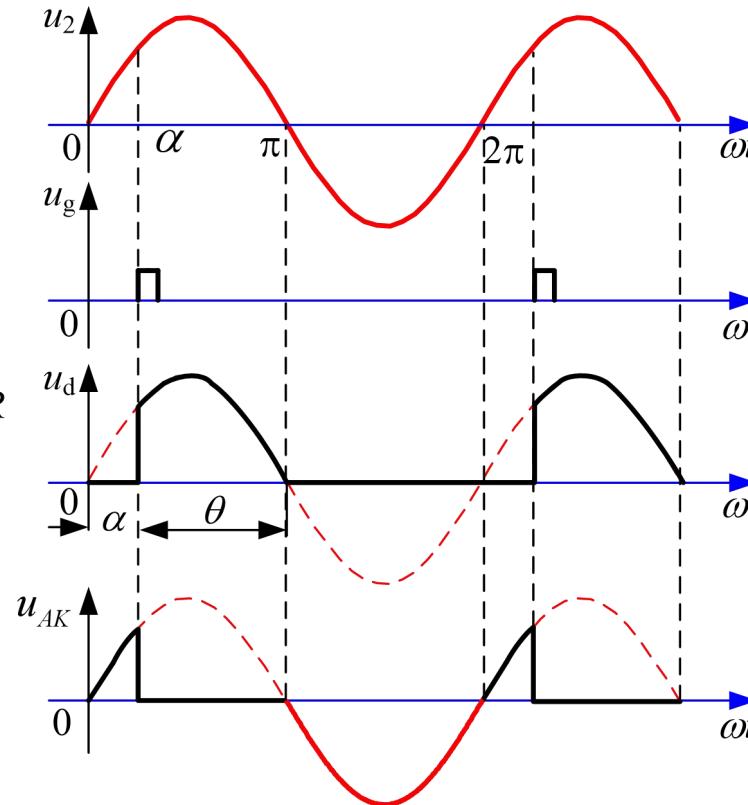
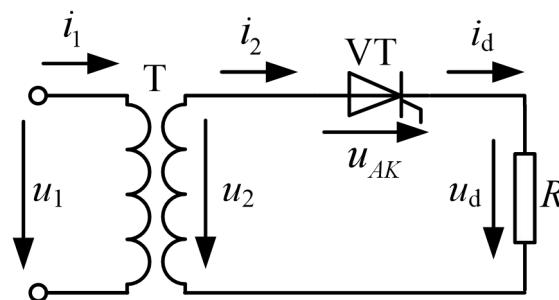
# 原理分析

## ➤ $0^\circ \sim 180^\circ$ , 晶闸管正向偏置

- ◆ 如果门极有触发电压, 则导通
- ◆ 如果门极无触发电压, 则阻断

## ➤ $180^\circ \sim 360^\circ$ , 晶闸管反向偏置

- ◆ 不论有无门极触发电压, 均阻断

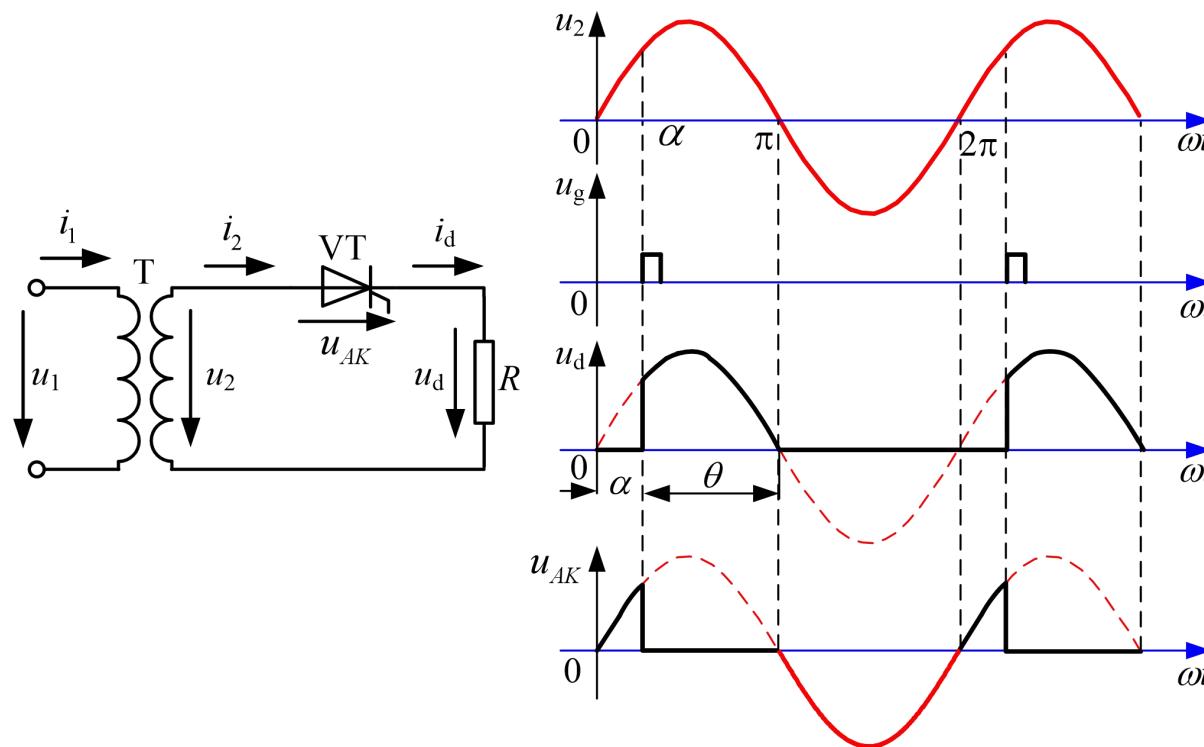


# 原理分析

- 不同的  $\alpha$  对应于不同的电压输出波形
- 改变  $\alpha$  便可改变输出电压  $u_d$  的大小。

移相范围：

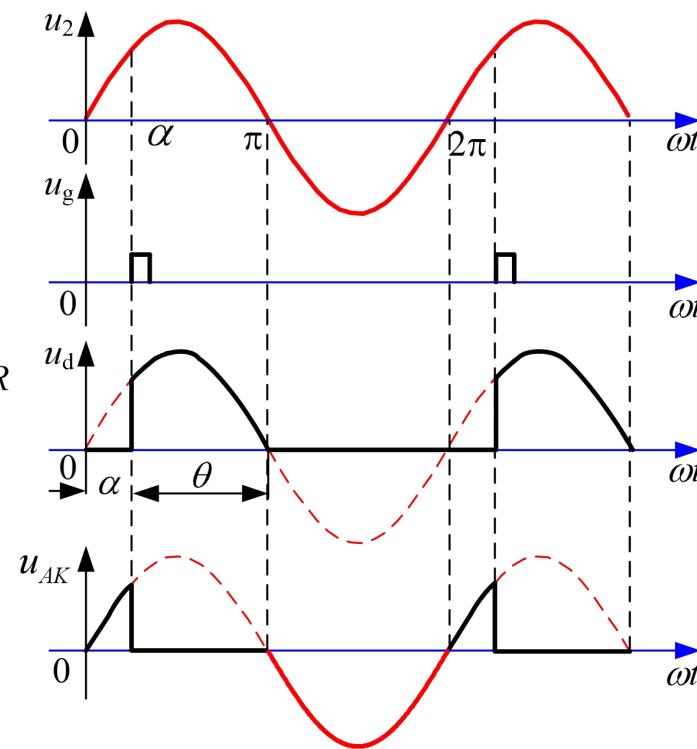
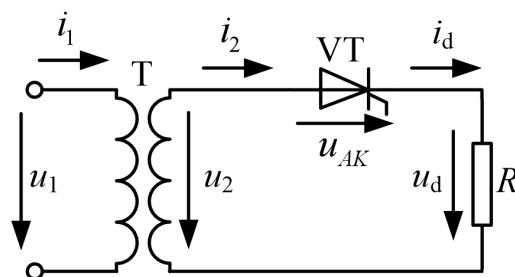
- 能使输出电压从最大到最小的延迟角的变化范围
- $180^\circ$



# 导通角

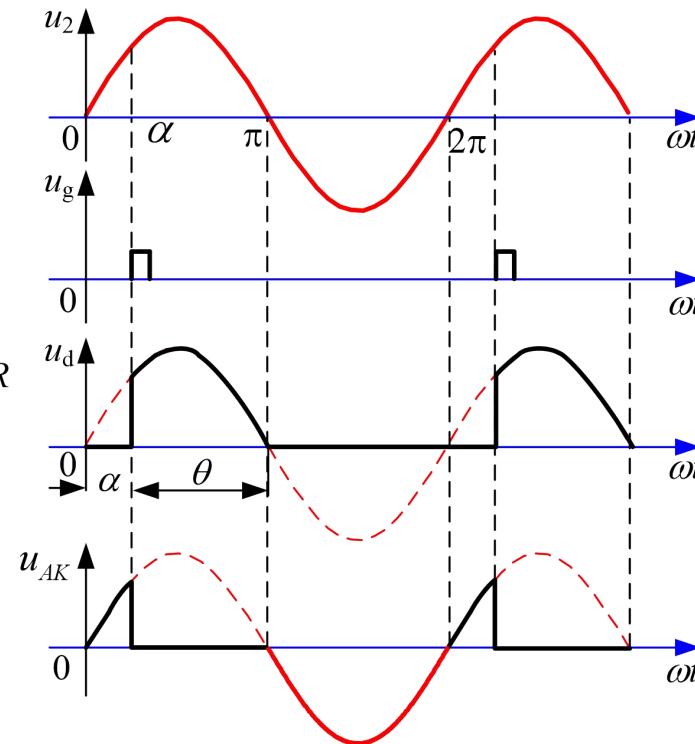
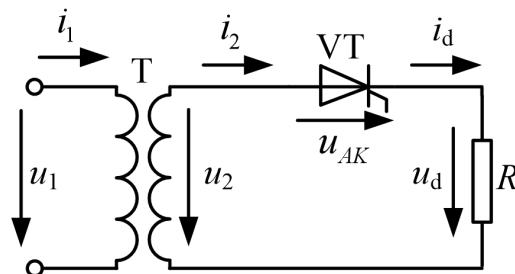
➤ 在一个周期内晶闸管导通的角度

$$\theta = 180^\circ - \alpha$$



# 概念总结

- 自然换流点
- 延迟角
- 移相范围
- 导通角

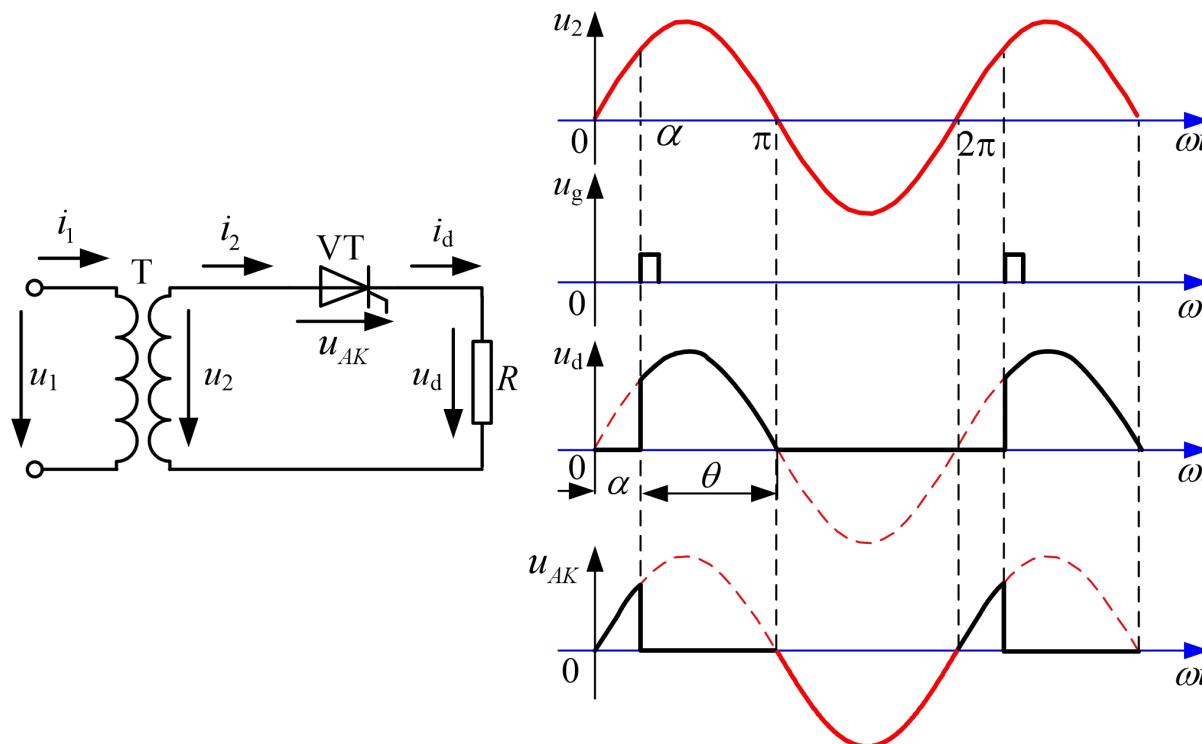


# 数量计算

## ➤ 整流电压平均值

$$U_d = \frac{1}{2\pi} \int_{\alpha}^{\pi} \sqrt{2} U_2 \sin \omega t d\omega t = \frac{\sqrt{2}}{2\pi} U_2 (1 + \cos \alpha)$$

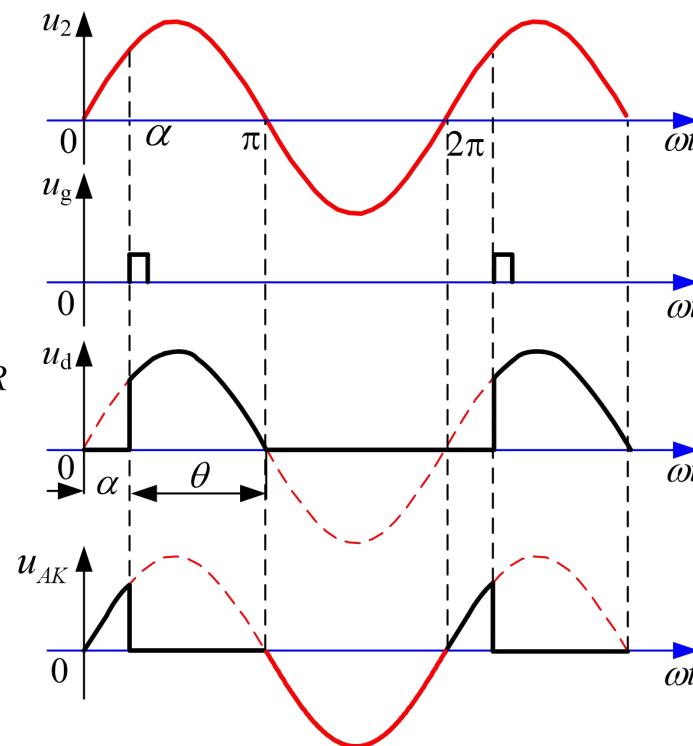
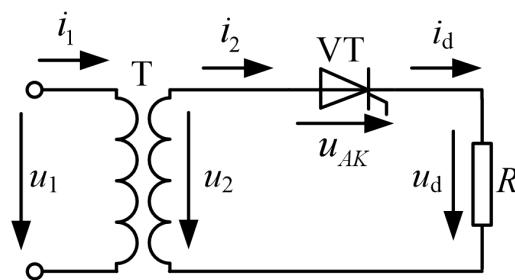
$U_2$ 为变压器次级相电压的有效值



# 数量计算

## ➤ 负载电流平均值

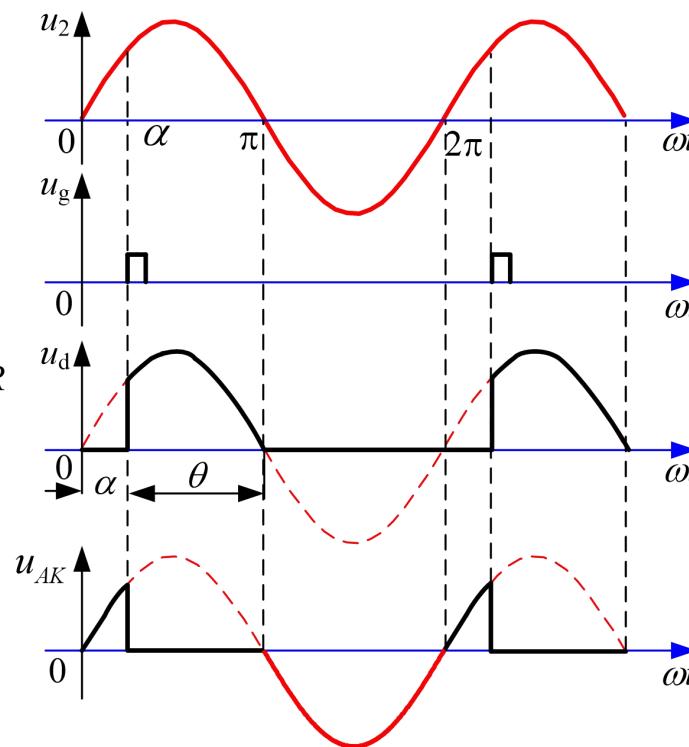
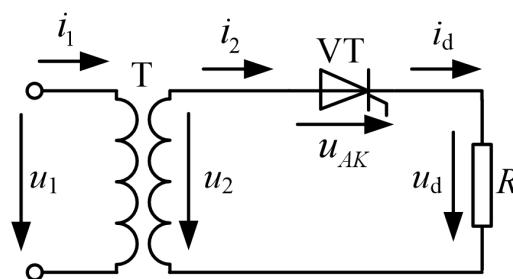
$$I_d = \frac{U_d}{R} = \frac{\sqrt{2}U_2}{\pi R} \frac{1 + \cos \alpha}{2}$$



# 数量计算

## ➤ 流过晶闸管的电流有效值

$$I_{VT} = \sqrt{\frac{1}{2\pi} \int_{\alpha}^{\pi} \left( \frac{\sqrt{2}U_2}{R} \sin \omega t \right)^2 d\omega t} = \frac{U_2}{R} \sqrt{\frac{1}{4\pi} \sin 2\alpha + \frac{\pi - \alpha}{2\pi}}$$

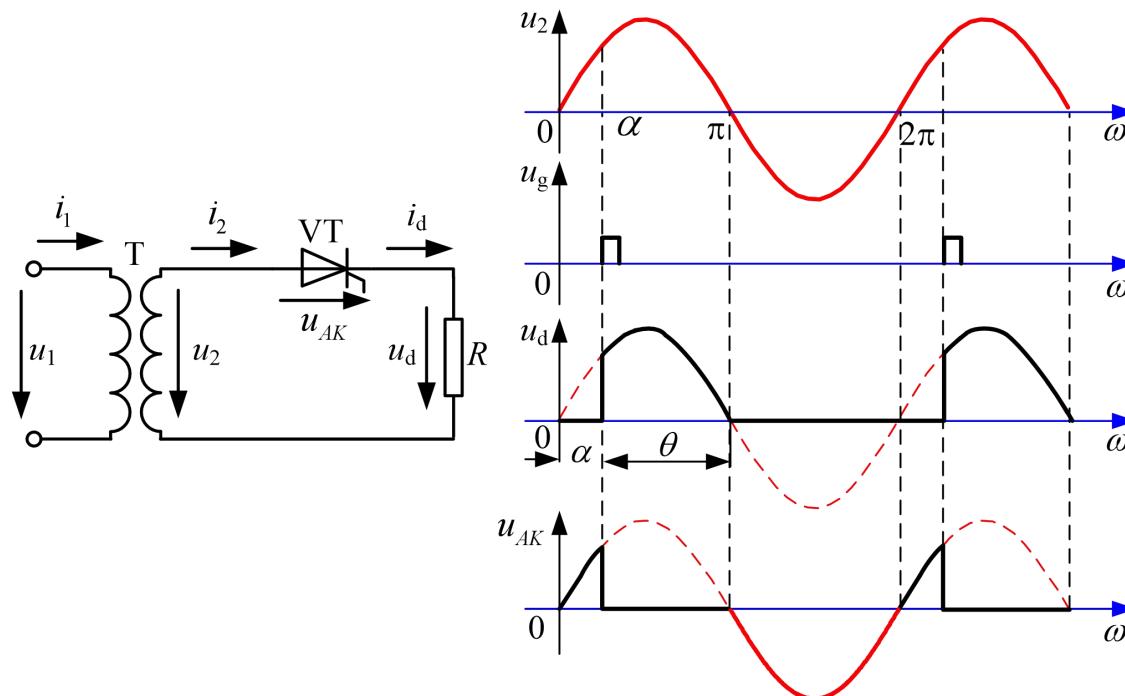


# 数量计算

## ➤ 波形系数

$$K_f = \frac{I_{VT}}{I_d} = \frac{\sqrt{\frac{\pi}{2} \sin 2\alpha + \pi(\pi - \alpha)}}{1 + \cos \alpha}$$

$\alpha = 0$ 时,  $K_f = \frac{\pi}{2} = 1.57$ , 与前述结论一致。



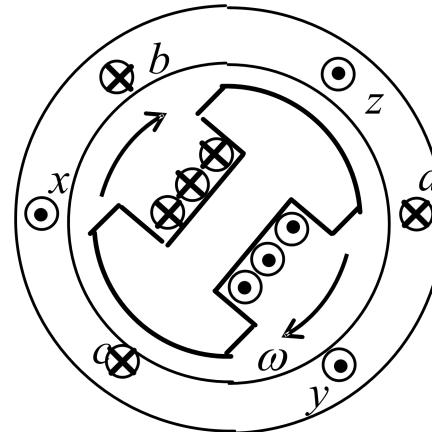
## 例1.2

单相半波可控整流电路，交流电源为220V直接接在电源上（不用电源变压器）；负载为电阻，输出直流电压50V，直流电流15A。试选择晶闸管电压定额及电流定额。

### 1.3.2 电阻电感负载

典型的阻感负载：

- 发电机励磁绕组
- 电磁铁线圈
- .....



阻感负载的特点：

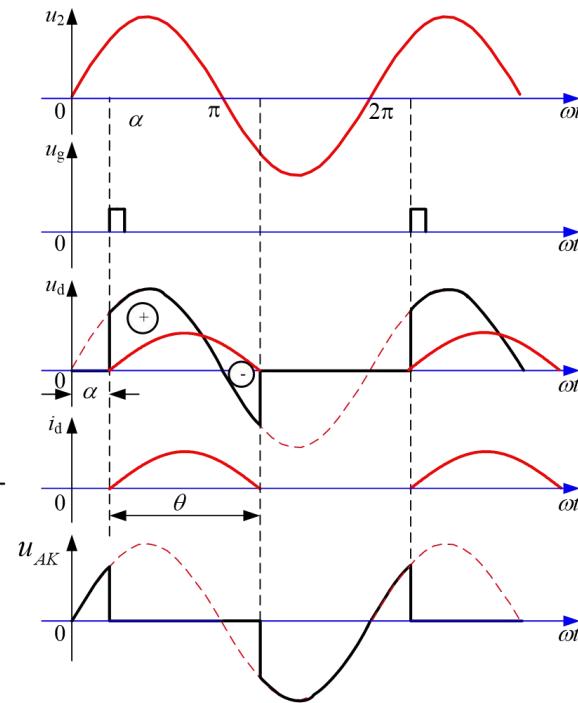
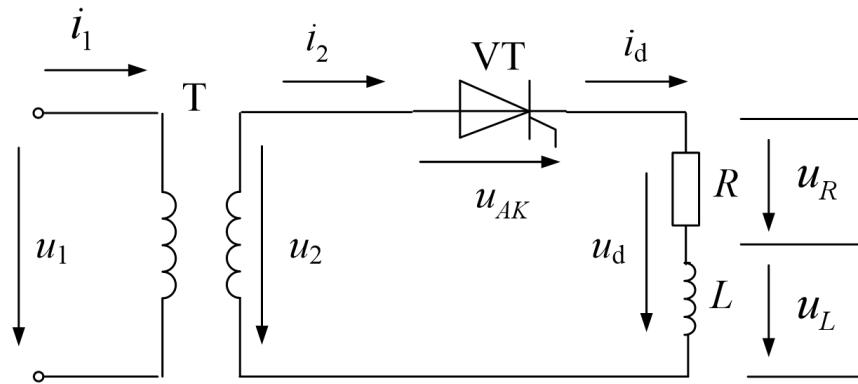
- 电压与电流不再成正比，两者波形不再相同

## 1.3.2 电阻电感负载

$$u_2 = u_L + u_R = L \frac{di_2}{dt} + i_2 R$$

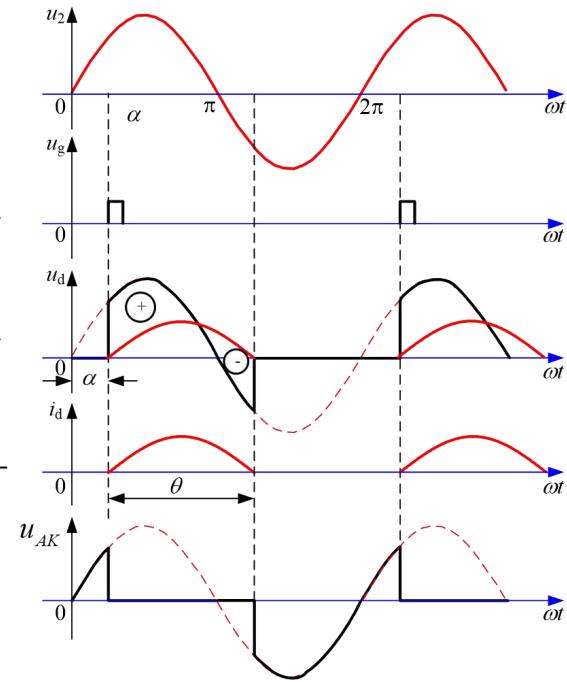
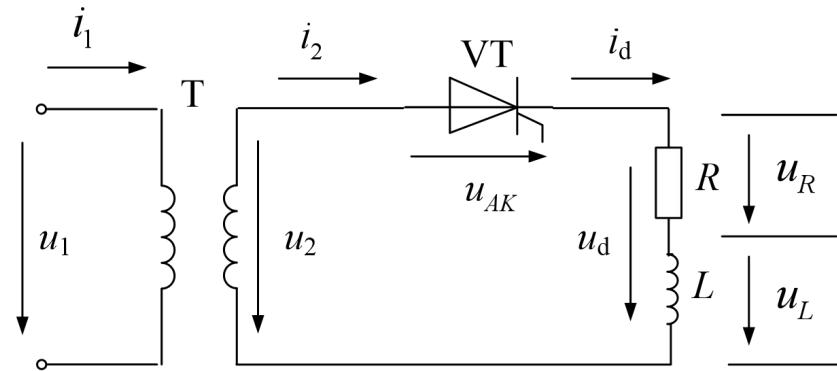
$u_L$  — 电感端瞬时电压

$u_R$  — 电阻端瞬时电压



## 1.3.2 电阻电感负载

- a处，电流不能突变， $i_2=0$ ,  $u_R=0$ ,  $u_2=u_d$ 。
- 电流逐渐上升
- 电流变化率为0时，电感中能量最大
- $u_2$ 进入负半周时，电感中能量仍旧继续释放  
**(晶闸管不关断)**
- 电感能量释放完毕，电流*i<sub>2</sub>*降为0，晶闸管关断

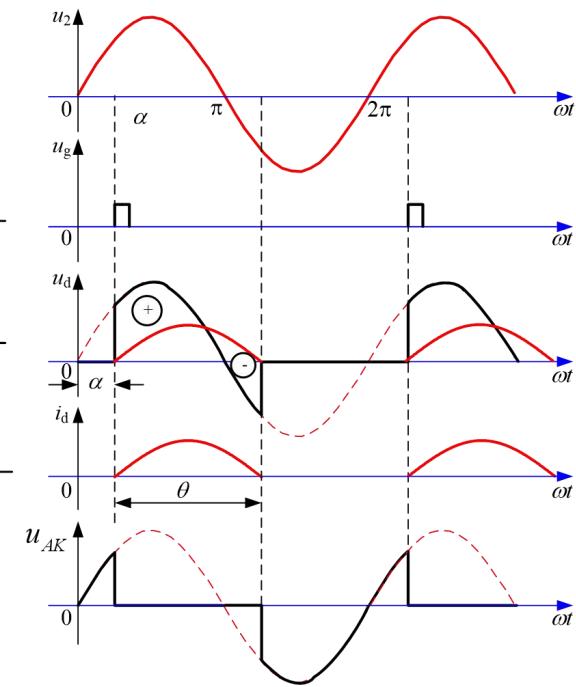
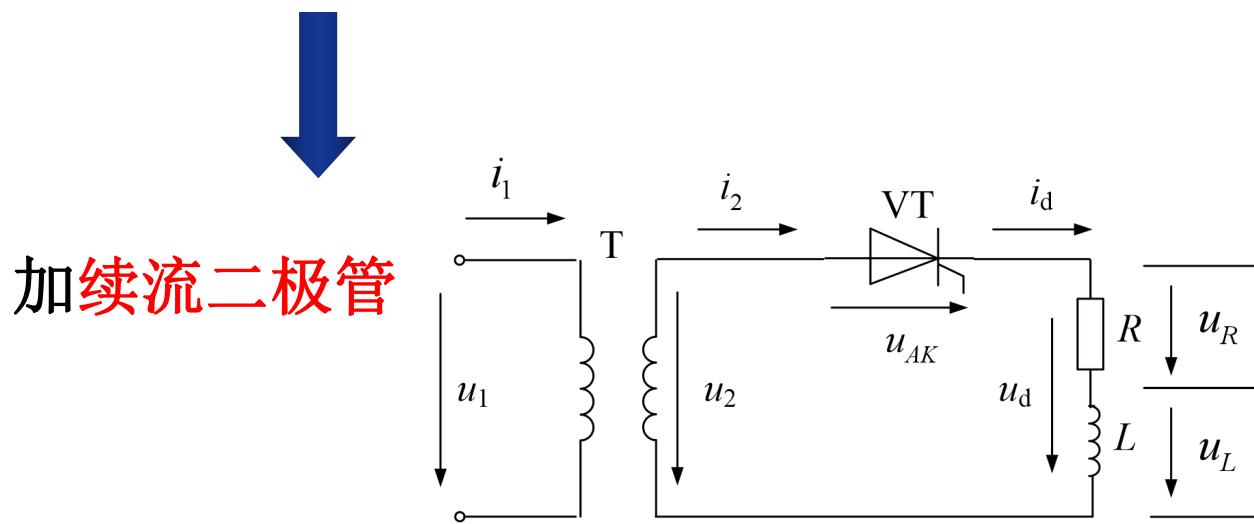


## 1.3.2 电阻电感负载

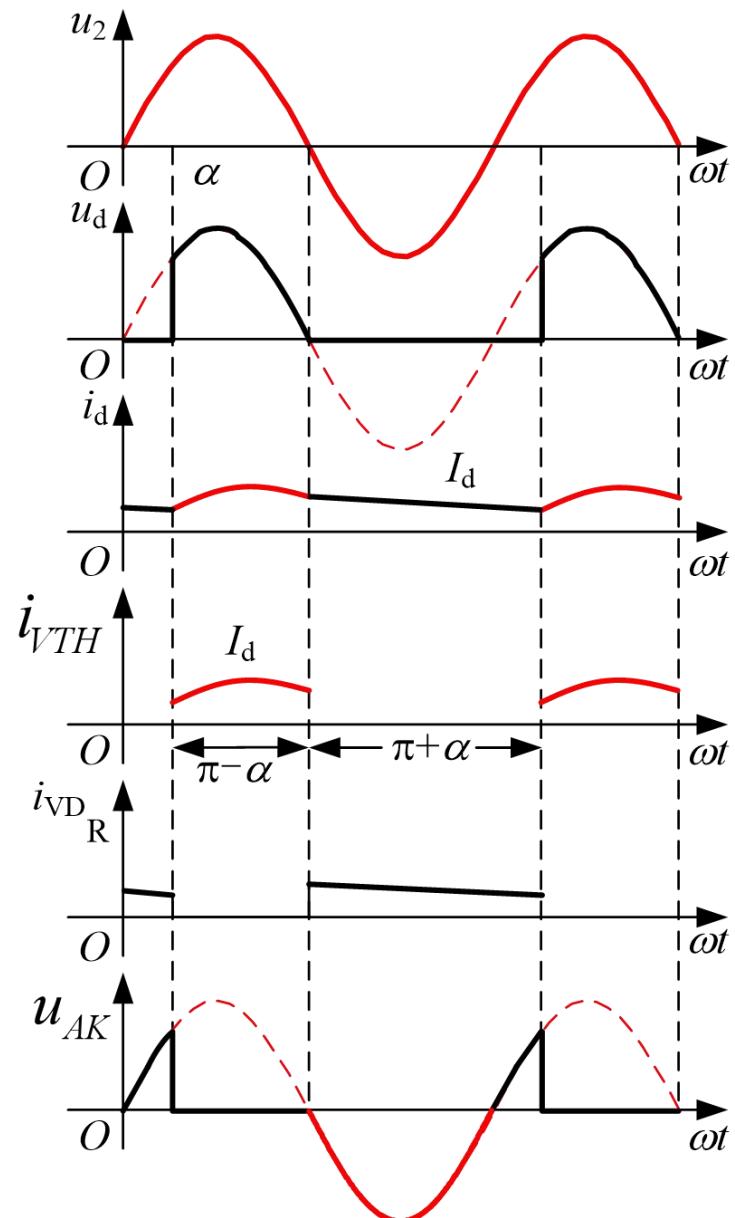
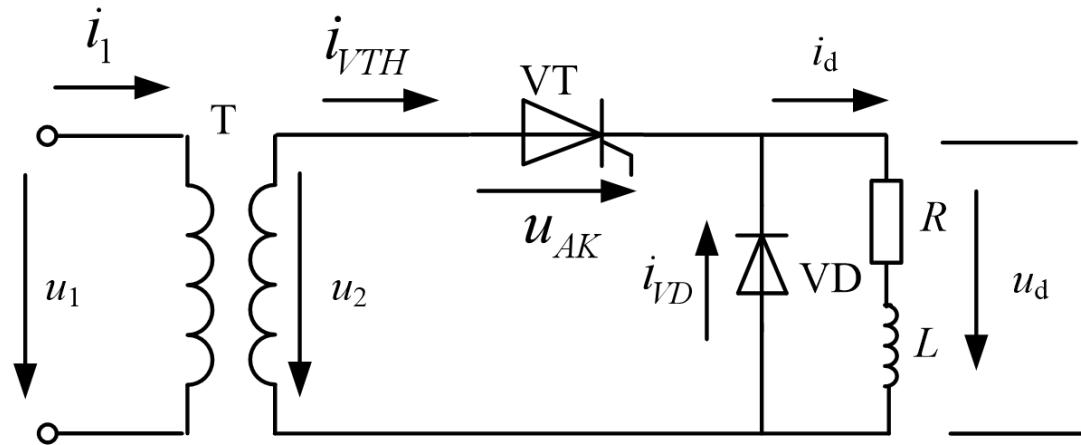
输出平均电压

$$U_d = \frac{1}{2\pi} \int_{\alpha}^{\alpha+\theta} \sqrt{2}U_2 \sin \omega t d\omega t = \frac{\sqrt{2}U_2}{2\pi} [\cos \alpha - \cos(\alpha + \theta)]$$

- 导通角越大，  $U_d$  越小。
- 电感远远大于电阻时，  $U_d=0$

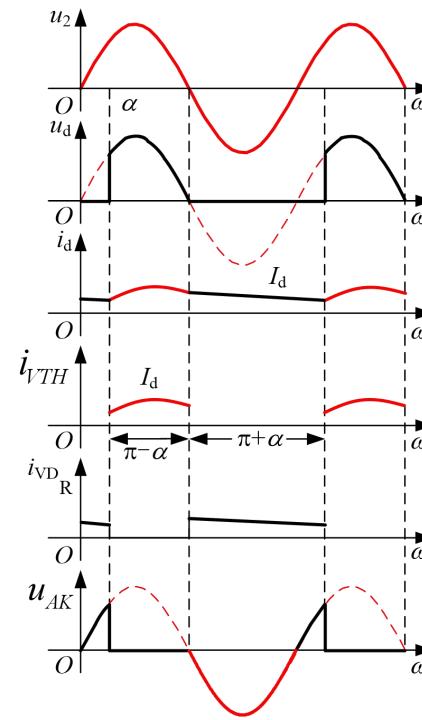
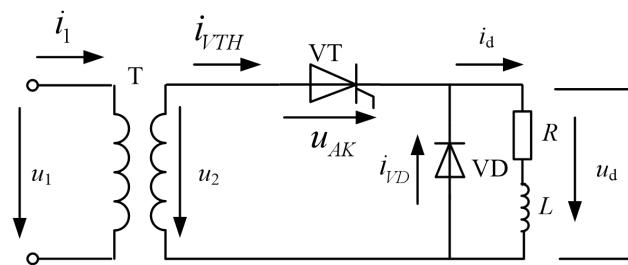


### 1.3.3 带续流二极管的电阻电感负载



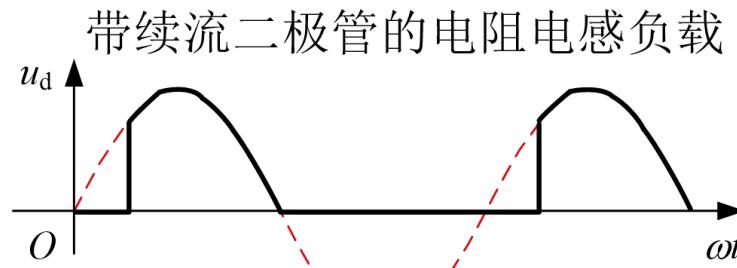
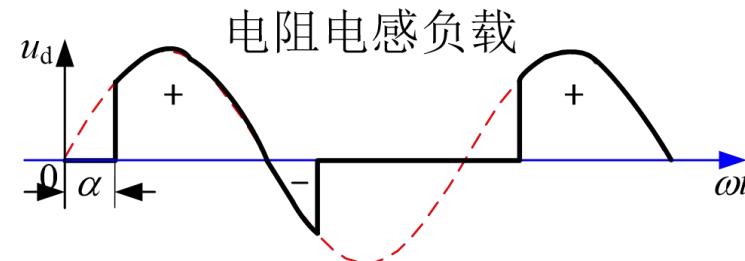
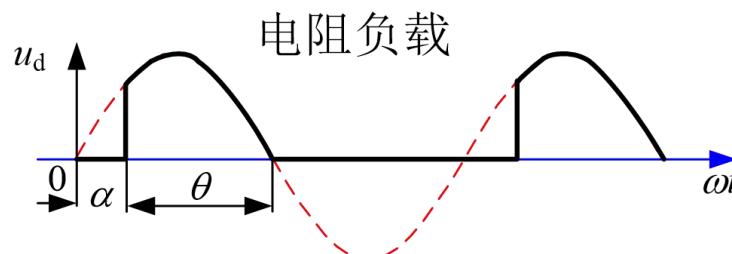
### 1.3.3 带续流二极管的电阻电感负载

- $\alpha$  到  $\pi$  区间，续流二极管不起作用
- $\pi$  后，续流二极管导通，晶闸管关断，电感通过电阻和续流二极管释放能量， $u_d = 0$
- 当电感足够大时，电流的脉动很小，近似于一条水平直线

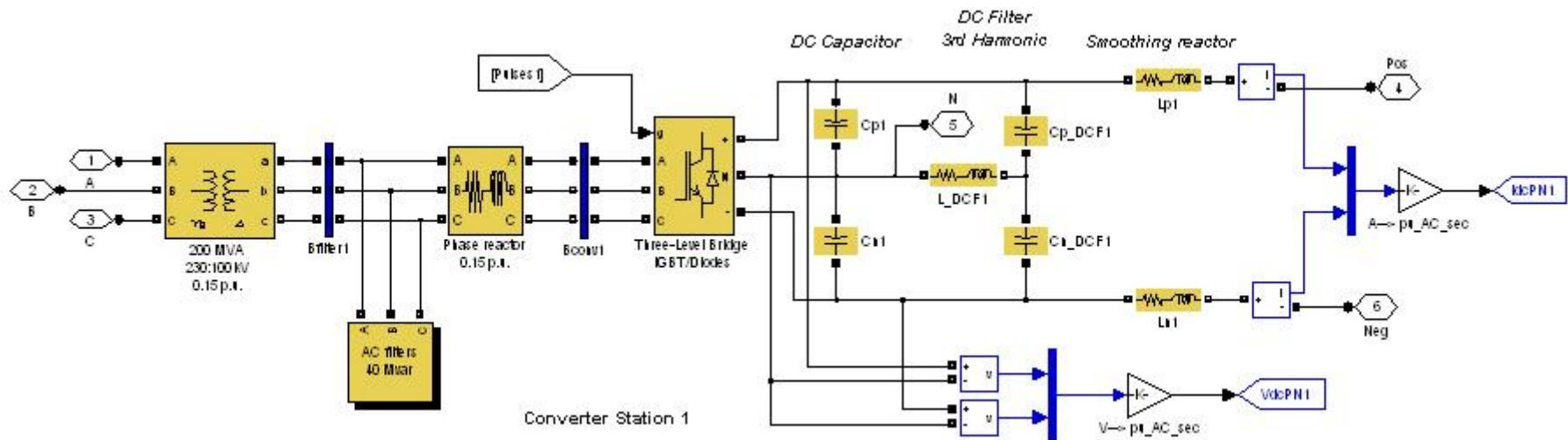
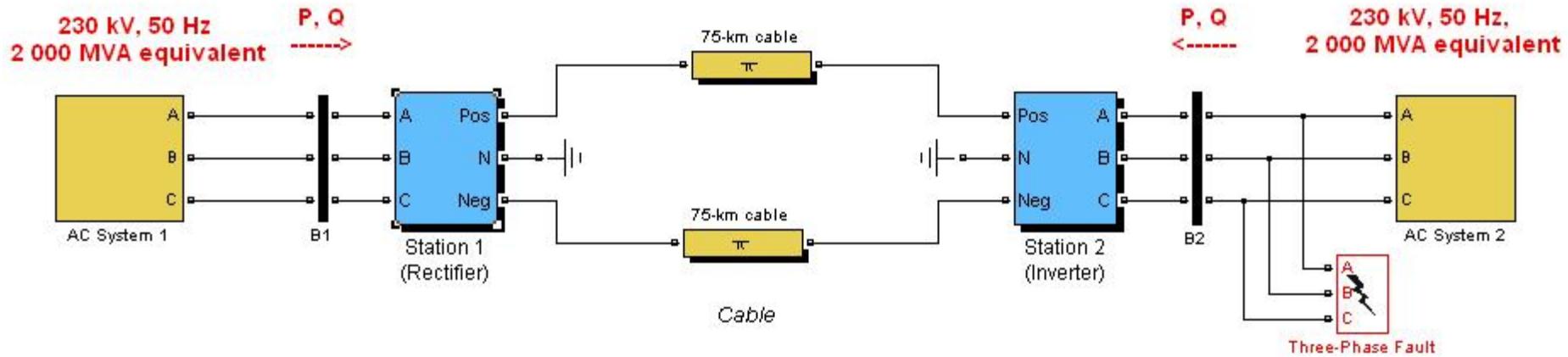


### 1.3.4 电容性负载

- 以上变换中，输出直流电压均存在不同程度的**纹波**。
- 电容有滤波作用（**两端电压不能突变**）。
- 电容性负载可在一定程度上消除纹波。



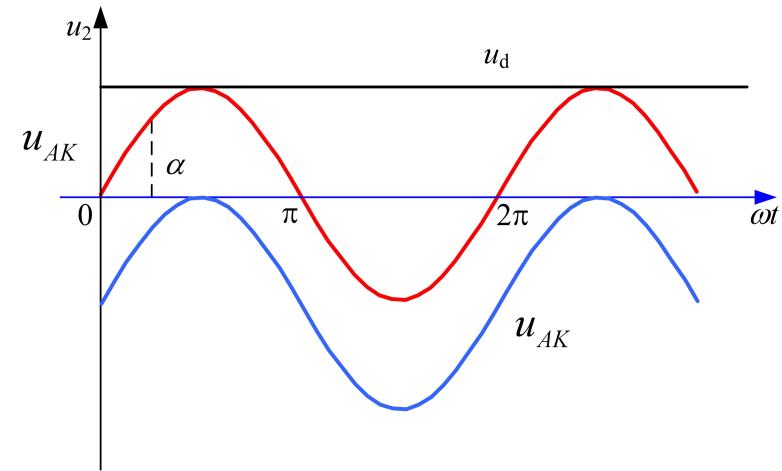
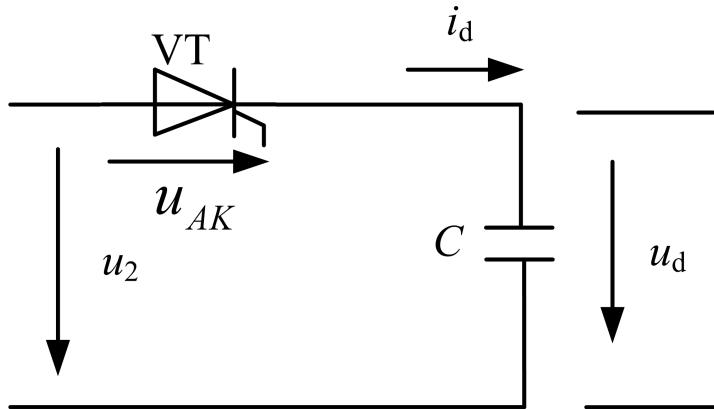
# 电容性负载例 (HVDC)



## 1.3.4 电容性负载

### 1) 电容负载

- VT触发后，电容就不断充电，达到电源峰值
- 电流为零
- 元件承受耐压为电源峰值电压的2倍



## 1.3.4 电容性负载

### 2) 电阻电容负载

- 消除输出直流电压纹波
- 输出平均电压将比电阻负载时增大
- 输出平均电压的脉动值明显减少。电容越大，脉动越小。
- 移相范围变小

