제 5 장 교류전압 제어기

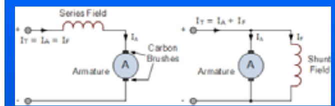
AC to AC Converter

AC→AC

5.1 개요

- 교류전력을 직접 변환
- Light Dimmer, Small Power Induction Motor 등에 사용
- 종류
  - Phase Control 방식
  - Integral Control 방식

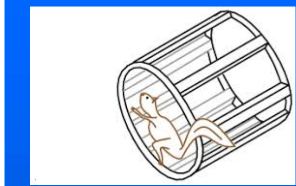
전동기의 종류

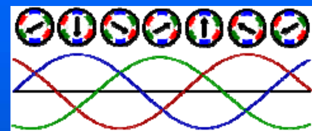


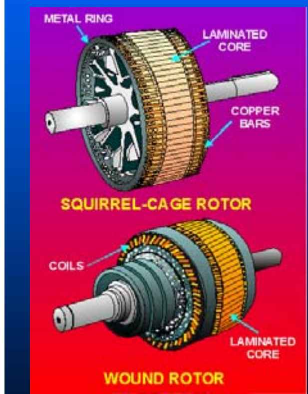
$$N = \frac{120f}{P}(1-s)[rpm]$$

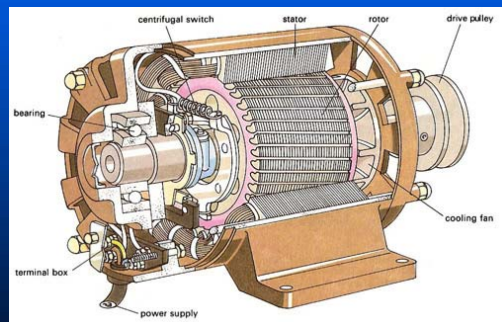
- 직류
  - 분권(shunt): 회전자와 계자 병렬, 정속도
  - 직권(series): 회전자와 계자 직렬, 회전력 (torque)
  - 복권(compound)
- 교류 단상: 회전자계가 발생하지 않음
  - 분상기동, 콘덴서 기동, 반발기동
- 교류 3상: 회전자계가 발생
  - 유도전동기(induction): slip이 발생
    - 암페어의 법칙: 회전자에 자계 유도
    - 농형(squirrel cage): 5kw 이하
    - 권선형(wound) : 5kw 이상
  - 동기전동기(synchronous): 동기속도

3상 유도전동기

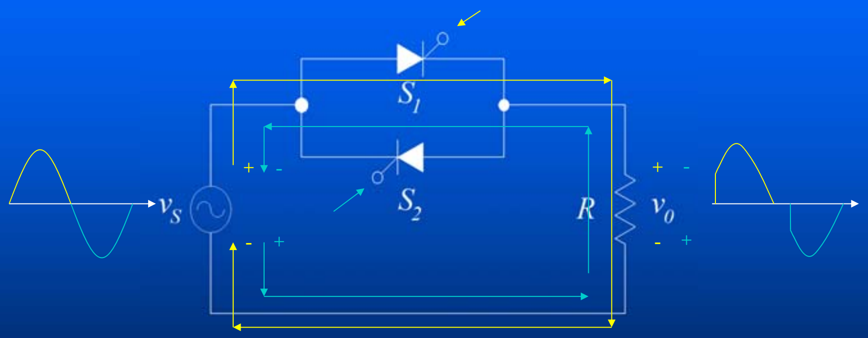




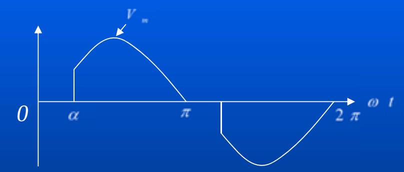




5.2 단상 교류 전압제어기



5.2 단상교류전압제어기: 실효값



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

$$\left(\sin^2\omega t = \frac{1-\cos 2\omega t}{2}\right)$$

$$= \sqrt{\frac{V_m^{\,2}}{\pi}\left[\frac{\omega t}{2} - \frac{\sin 2\omega t}{4}\right]_{\alpha}^{\pi}}$$

$$= \sqrt{\frac{V_m^{\,2}}{\pi}\left(\frac{\pi}{2} - \frac{\sin 2\pi}{4} - \frac{\alpha}{2} + \frac{\sin 2\alpha}{4}\right)}$$

$$= \frac{V_m}{\sqrt{2}}\sqrt{\left(1 - \frac{\alpha}{\pi} + \frac{\sin 2\alpha}{2\pi}\right)}$$

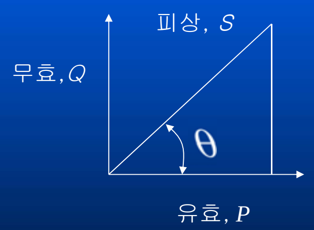
5.2 단상교류전압제어기: 역률

- 역률(Power Factor)
  – 역률=유효/피상

$$pf = \frac{P}{S} = \frac{V_{o,rms}}{V_{s,rms}}$$

$$= \frac{\frac{V_m}{\sqrt{2}}\sqrt{\left(1 - \frac{\alpha}{\pi} + \frac{\sin 2\alpha}{2\pi}\right)}}{\frac{V_m}{\sqrt{2}}}$$

$$= \sqrt{\left(1 - \frac{\alpha}{\pi} + \frac{\sin 2\alpha}{2\pi}\right)}$$



5.2 단상교류전압제어기: 전류

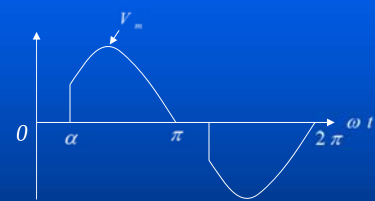
- 평균값

$$I_{SCR,avg} = \frac{1}{2\pi}\int_{\alpha}^{\pi}\frac{V_m}{R}\sin\omega t\, d(\omega t)$$

$$\int \sin dt = -\cos t$$

$$= \frac{V_m}{2\pi R}\left[-\cos\omega t\right]_{\alpha}^{\pi}$$

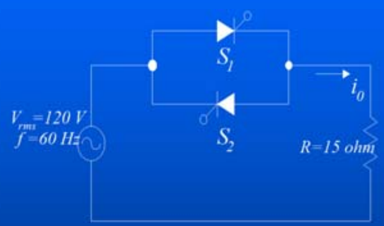
$$= \frac{V_m}{2\pi R}(1+\cos\alpha)$$



- 실효값

$$I_{base} = \frac{V_{S,rms}}{R}$$

예제 5.1 저항부하를 가진 단상제어기(1)



(a) 500 W를 공급하는 지연각

$$P = \frac{V_{0,rms}^2}{R}$$

$$V_{0,rms} = \sqrt{PR} = \sqrt{(500\times 15)} = 86.6V$$

$$V_{0,rms} = \frac{V_m}{\sqrt{2}}\sqrt{\left(1-\frac{\alpha}{\pi}+\frac{\sin 2\alpha}{2\pi}\right)}$$

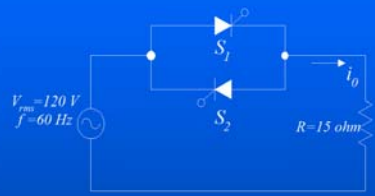
$$\therefore 86.8 - 120\sqrt{\left(1-\frac{\alpha}{\pi}+\frac{\sin 2\alpha}{2\pi}\right)} = 0$$

$$\alpha = 1.54\,rad = 88.1^o$$

(b) 전원전류의 실효값

$$I_{0,rms} = \frac{V_{0,rms}}{R} = \frac{86.6}{15} = 5.77\,A$$

예제 5.1 저항부하를 가진 단상제어기(2)



(c) SCR 전류의 실효, 평균값

$$I_{SCR,rms} = \frac{I_{0,rms}}{\sqrt{2}} = \frac{5.77}{\sqrt{2}} = 4.08\,A$$

$$I_{SCR,avg} = \frac{V_m}{2\pi R}(1+\cos\alpha)$$

$$= \frac{\sqrt{2}(120)}{2\pi(15)}(1+\cos(88.1)) = 1.86\,A$$

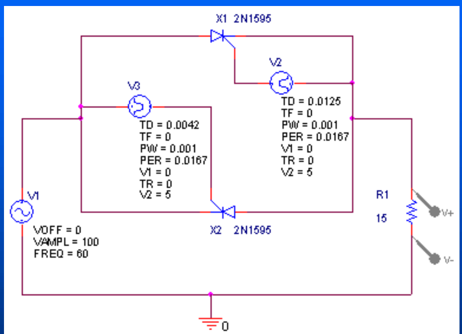
(d) 역률

$$pf = \frac{P}{S} = \frac{500}{(120)(5.77)} = 0.72$$

(e) 전원전류의 실효값

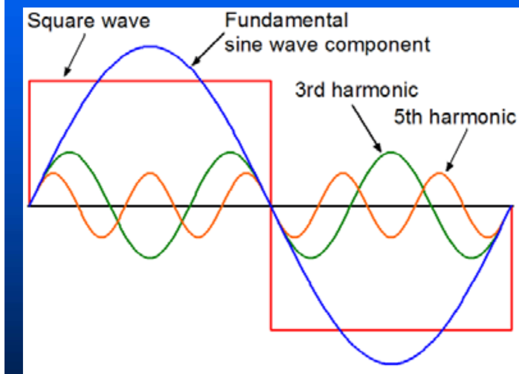
$$I_{base} = \frac{V_{S,rms}}{R} = \frac{120}{15} = 8.0\,A$$

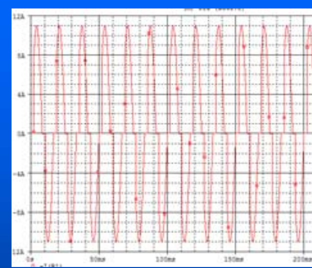
예제 5-1(2) Pspice Simulation

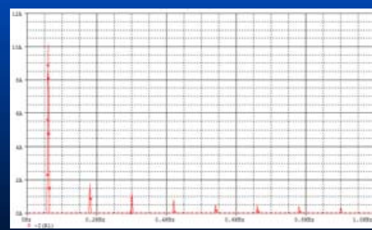


- *Parameter*
  - ✓ *R=15 Ω*
  - ✓ *f=60 Hz*
  - ✓ *α= 90*
    - *- TD1:0.0042(1/240)*
    - *- TD2:0.0125(3/240)*
  - ✓ *PW=0.001*
  - ✓ *V_m=100V*
  - ✓ *Transient Step =0 50 ms*
- *Find: i, i_{avg} , P*

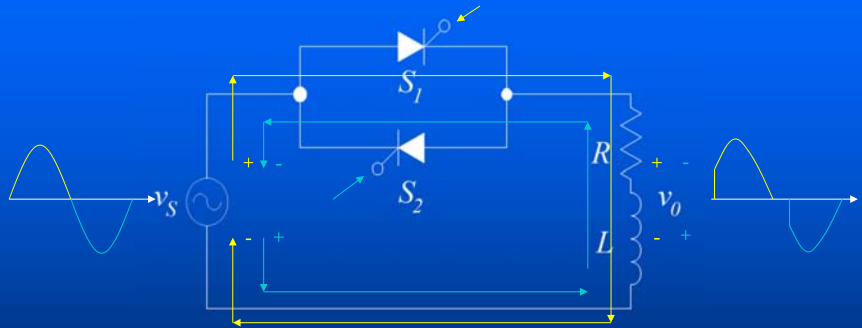
5.2 단상교류전압제어기: 고조파





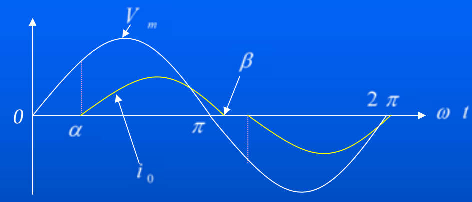


5.2 단상교류전압제어기: R-L 제어회로



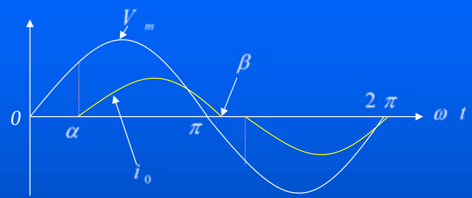
$$V_m \sin(\omega t) = Ri_0(t) + L\frac{di_0(t)}{dt}$$

5.2 단상교류전압제어기: R-L부하 전류



$$i(\omega t) = \begin{cases} \dfrac{V_m}{Z}\left[\sin(\omega t-\theta)+\sin(\alpha-\theta)\cdot e^{-\frac{(\alpha-\omega t)R}{\omega L}}\right] & at\ \alpha \le \omega t \le \beta \\ 0 & otherwise \end{cases}$$

5.2 단상교류전압제어기: R-L부하 통전각



- 소호각(Extinction Angle)

$$i(\beta) = 0 = \frac{V_m}{Z}\left[\sin(\beta-\theta)+\sin(\alpha-\theta)\cdot e^{-\frac{(\alpha-\beta)R}{\omega L}}\right]$$

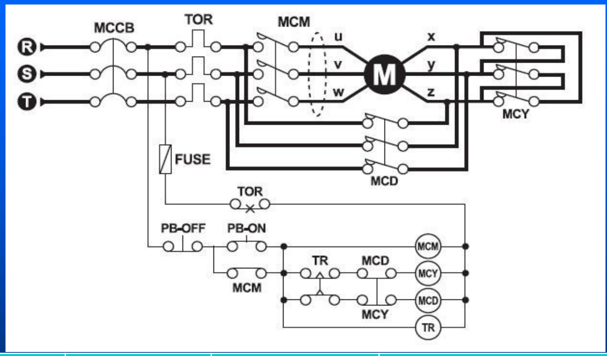
- 통전각(Duration Angle)

$$\gamma = \beta - \alpha$$

3상회로

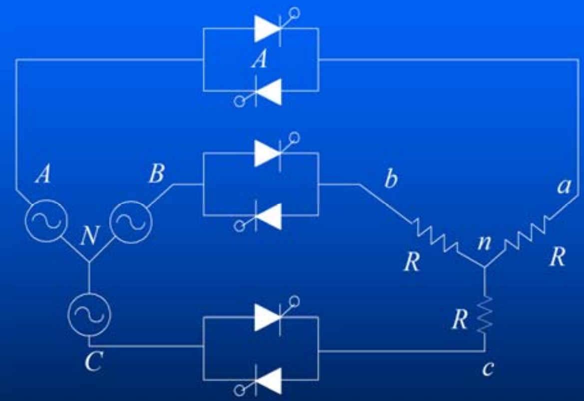
결선	선간전류	선전류	전력
Y	$\sqrt{3}$ × 상전압	상전류	$\sqrt{3}$ × 상전압 × 상전류
Δ	상전압	$\sqrt{3}$ × 상전류	$\sqrt{3}$ × 상전압 × 상전류

Y-Δ 기동법

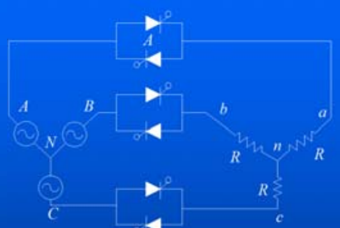


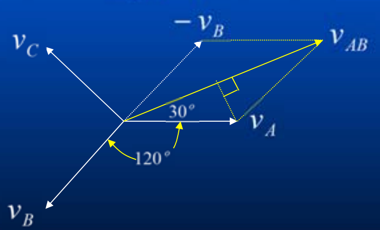
결선	선간전류	선전류	전력
Y	$\sqrt{3}$ × 상전압	상전류	$\sqrt{3}$ × 상전압 × 상전류
Δ	상전압	$\sqrt{3}$ × 상전류	$\sqrt{3}$ × 상전압 × 상전류

5.3 3상 전압조절기(Y 결선)



5.3 3상 전압조절기: 전압





$$v_A = \sqrt{2}V \sin \omega t$$

$$v_B = \sqrt{2}V \sin\left(\omega t - \frac{2\pi}{3}\right)$$

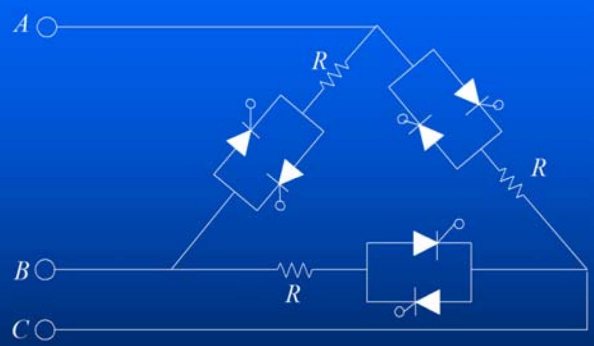
$$v_C = \sqrt{2}V \sin\left(\omega t - \frac{4\pi}{3}\right)$$

$$v_{AB} = 2v_A \cos(30^o)\angle 30^o$$

$$= 2v_A \frac{\sqrt{3}}{2}\angle 30^o$$

$$= \sqrt{3}v_A \angle 30^o$$

5.3 3상 전압조절기(Δ 결선)

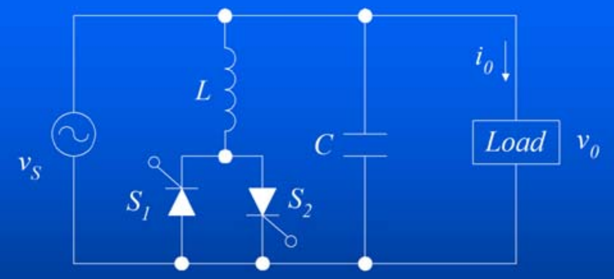


5.4 유도전동기 속도제어

- 전압제어(Voltage Control)
  - 1차 전압제어
  - Squirrel-cage(농형)
- 전압-주파수제어(Voltage /Frequency Control)
- 주파수 제어(Frequency Control)

$$N = \frac{120f}{P}(1-s)$$

5.5 정지형 무효전력제어



- L의 가변에 의한 역률 보상
- Load의 값에 따라 효율적으로 무효전력 관리