제 5 장 교류전압 제어기

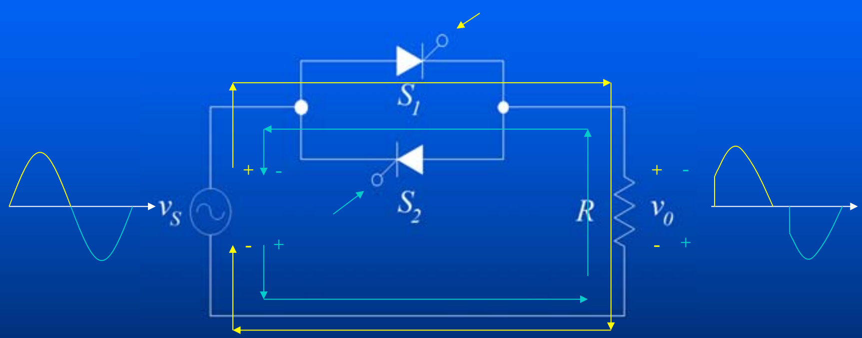
AC to AC Converter

AC→AC

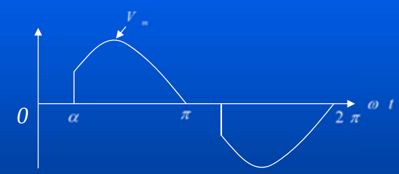
5.1 개요

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

5.2 단상 교류 전압제어기



5.2 단상교류전압제어기: 실효값



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

$$\boxed{\sin^2 x = \frac{1-\cos 2x}{2}}$$

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

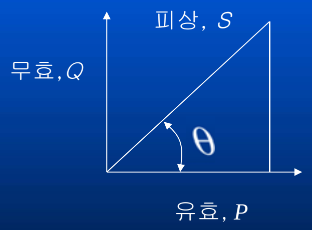
$$= \sqrt{\frac{V_m^2}{\pi}\left(\frac{\pi}{2} - \frac{\sin 2\pi}{4} - \frac{\alpha}{2} + \frac{\sin 2\alpha}{4}\right)}$$

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

5.2 단상교류전압제어기: 역률

- 역률(Power Factor)
  - 역률=유효/피상

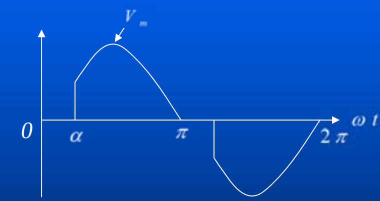
$$pf=\frac{P}{S}=\frac{V_{o,rms}}{V_{s,rms}}$$



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

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

5.2 단상교류전압제어기: 전류



- 평균값

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

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

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

- 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

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

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

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

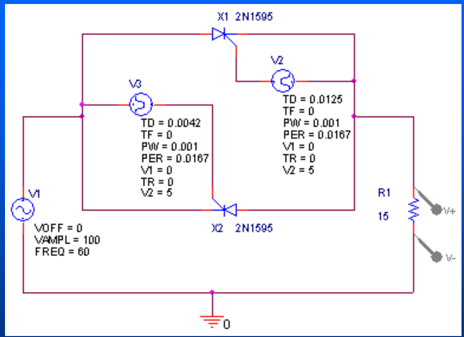
(d) 역률

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

(e) 전원전류의 실효값

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

예제 5-1(2) Pspice Simulation



- *Parameter*
  - ✓ $R=15\ \Omega$
  - ✓ $f=60$ Hz
  - ✓ $\alpha=90$
    - 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

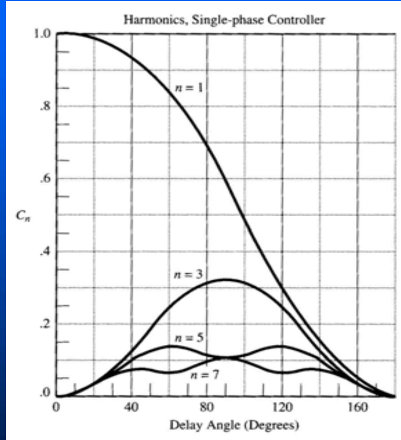
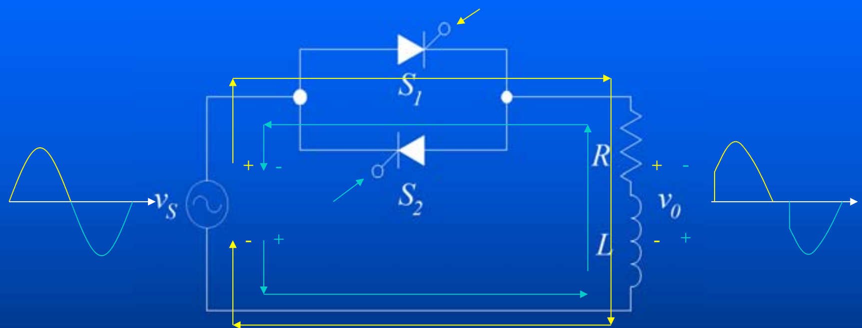


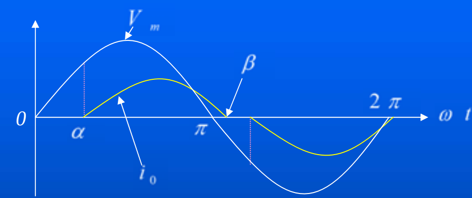
Figure 5.3 Normalized harmonic content versus delay angle for a single-phase ac voltage controller with a resistive load.

5.2 단상교류전압제어기: R-L 제어회로



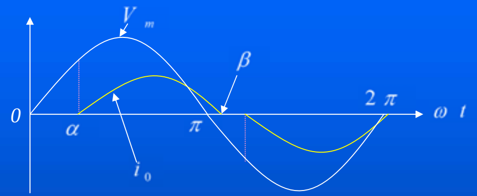
$$V_m \sin(\omega t) = R i_0(t) + L\frac{di_0(t)}{dt}$$

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



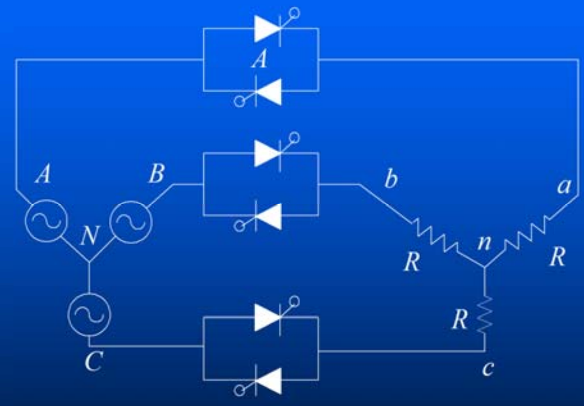
- 소호각(Extinction Angle)

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

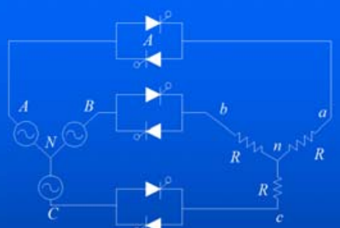
- 통전각(Duration Angle)

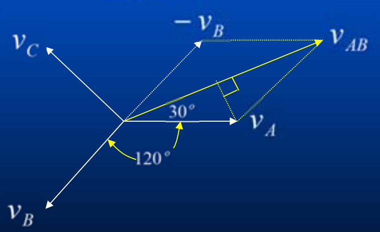
$$\gamma=\beta-\alpha$$

5.3 3상 전압조절기(Y 결선)



5.3 3상 전압조절기: 전압





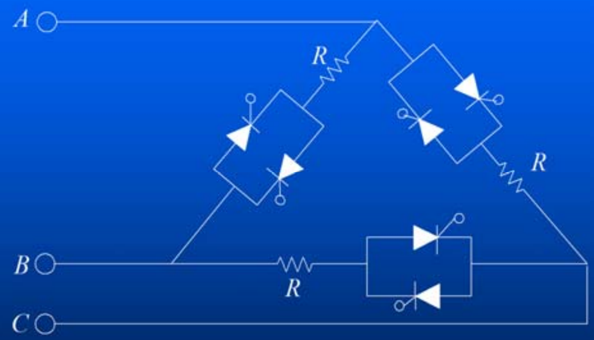
$$v_A=\sqrt{2}V\sin\omega t$$

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

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

$$\begin{aligned}v_{AB}&=2v_A\cos\left(30^o\right)\angle 30^o\\&=2v_A\frac{\sqrt{3}}{2}\angle 30^o\\&=\sqrt{3}v_A\angle 30^o\end{aligned}$$

5.3 3상 전압조절기(Δ 결선)

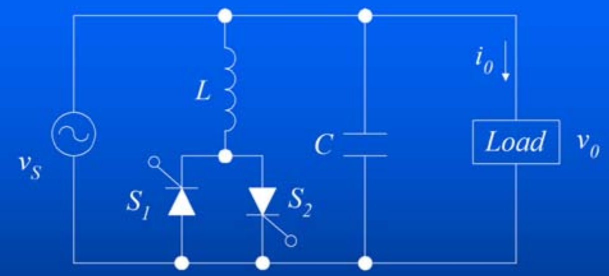


5.4 유도전동기 속도제어

- 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