电力电子公式一览

Fourier Transform

$$f(x)=\frac{a_0}{2}+\sum_{n=1}^{\infty}\left[a_n\cos(nx)+b_n\sin(nx)\right]$$
$$a_n=\frac{2}{T}\int f(t)\cos\omega t\,dt$$
$$b_n=\frac{2}{T}\int f(t)\sin\omega t\,dt$$

DCDC

BUCK

电压变比

$$M=D \tag{1}$$

临界电流

$$I_{OB}=\frac{V_o}{2fL}(1-D) \tag{2}$$

DCM电压变比

$$\begin{gathered}M=\frac{2}{1+\sqrt{1+\frac{4I_o^*}{D^2}}}\\ I_O^*=\frac{I_O}{V_o/2fL}\end{gathered} \tag{3}$$

BOOST

电压变比

$$M=\frac{1}{1-D} \tag{4}$$

临界电流

$$I_{OB}=\frac{V_o}{2fL}(1-D)^2D \tag{5}$$

DCM电压变比

$$M=\frac{1+\sqrt{1+\frac{4D^2}{I_o^*}}}{2} \tag{6}$$

$$I_O^* = \frac{I_O}{V_o/2fL}$$

Cuk/Buck-Boost

电压变比

$$M = \frac{D}{1-D} \tag{7}$$

临界电流

$$I_{OB} = \frac{V_o}{2fL}(1-D)^2 \tag{8}$$

DCM电压变比

$$\begin{gathered} M = \frac{D}{\sqrt{I_O^*}} \\ I_O^* = \frac{I_O}{V_o/2fL} \end{gathered} \tag{9}$$

DCAC

上下方波的傅里叶变换

$$\begin{gathered} v(t) = \sum_{n=1,3,5}^{\infty} \frac{4V_D}{n\pi} sin(nwt) \\ \text{有效值} V_1 = 0.9V_D \\ \text{接} Z \text{阻抗} (R + wLj) \\ i_{a1} = \frac{4V_D}{\pi\sqrt{R^2+(wL)^2}} \sin\left(wt - \arctan\left(\frac{wL}{R}\right)\right) \end{gathered} \tag{10}$$

单脉波脉冲宽度调制

$$v_{ab}(wt) = \sum_{n=1,3,4}^{\infty} -(-1)^{(n+2)/2} \frac{4V_D}{n\pi} \sin\frac{n\theta}{2} \sin nwt \tag{11}$$

逆变器的性能指标

$$\begin{gathered} \text{谐波系数} HF_n = \frac{V_n}{V_1} \\ \text{总谐波系数} THD = \sqrt{\sum_{n=1,2,3}^{\infty} (\frac{V_n}{V_1})^2 - 1} \\ \text{畸变系数} \\ \text{一阶滤波} DF_1 = \sqrt{\sum_{n=2,3,4}^{\infty} (\frac{V_n}{nV_1})^2} \\ \text{二阶滤波} DF_2 = \sqrt{\sum^{\infty} (\frac{V_n}{n^2V_1})^2} \end{gathered} \tag{12}$$

$\sqrt{\sum_{n=2,3,4} \cdots}$

数据

BSPWM：0.707VD

方波：0.9VD

三相SPWM相电压幅值：0.5

三相SPWM线电压幅值：0.866

三相方波相电压幅值：1.1

ACDC公式

不控整流

1. 输出电压：
    1. 双半波：$\frac{2\sqrt{2}}{\pi}$
    2. 单相桥$\frac{2\sqrt{2}}{\pi}$
    3. 三相半桥$\frac{3\sqrt{6}}{2\pi}$
    4. 三相桥式$\frac{3\sqrt{6}}{\pi}$

单相相控整流电压

平均值

$$\frac{2\sqrt{2}}{\pi}V_s\frac{1+\cos\alpha}{2} \tag{13}$$

功率因数

$$PF=\sqrt{\frac{\sin 2\alpha}{2\pi}+\frac{\pi-\alpha}{\pi}} \tag{14}$$

电阻负载的电压有效值

$$V_s * PF \tag{15}$$

电阻负载的电流有效值

$$\frac{V_s}{R}PF \tag{16}$$

晶闸管的电流有效值

$$\frac{V_s}{2R}PF \tag{17}$$

三相相控整流电压

平均值

$$\frac{3\sqrt{6}}{\pi}V_s\cos\alpha \tag{18}$$

单相整流器导通角求取（有阻感性负载）（$\alpha > \phi$）

$$\tan(\alpha-\phi)=\frac{\sin\theta}{e^{-\frac{\theta}{\tan\theta}}-\cos\theta} \tag{19}$$

在有反电动势存在时单相相控整流器停止导电角

$$\sin\delta=\frac{E}{\sqrt{2}V_s} \tag{20}$$

单相桥相控整流时电流连续条件

$$L\geq\frac{\frac{2\sqrt{2}}{\pi}V_s}{wI_D} \tag{21}$$

换相整流区

m脉波整流电路

单相桥式m=2，核心在Vs=2Vs

两相半波m=2

三相半波m=3

三相全桥m=6

换相电阻

$$R=\frac{mwL}{2\pi} \tag{22}$$

换相重叠区角度

$$\cos\alpha-\cos(\alpha+\gamma)=\frac{wL_sI_D}{\sqrt{2}V_s\sin\frac{\pi}{m}} \tag{23}$$

有源逆变输出电压

$$\frac{3\sqrt{6}}{\pi}V_s\cos\beta-\frac{3wL_s}{2\pi}I_D*2 \tag{24}$$

电力电子公式推导

DCAC

上下方波的傅里叶变换

$$\begin{gathered}f(t)=\sum_{n=1,3,5}^{\infty}a_n\sin wt\\ a_n=\frac{2}{\pi}\int_0^{\pi}V_D\sin nwt\,d(wt)\\ a_n=\frac{4}{n\pi}V_D\end{gathered} \tag{25}$$

三相方波的傅里叶变换

$$\begin{gathered} v_{ab}(t)=\sum_{n=1,3,5}^{\infty} a_n \sin wt \\ a_n=\frac{2}{\pi}\int_{\pi/6}^{5\pi/6} V_D \sin nwt \, d(wt) \\ a_n=\frac{2\sqrt{3}}{n\pi} \end{gathered} \tag{26}$$

ACDC

不控整流平均输出电压计算

单相

$$V_o=\frac{1}{\pi}\int_0^{\pi}\sqrt{2}V_s \sin wt \, d(wt)=\frac{2\sqrt{2}}{\pi}V_s \tag{27}$$

三相

$$V_o=\frac{1}{\pi/3}\int_{\pi/3}^{2\pi/3}\sqrt{3}*\sqrt{2}V_s \sin wt \, d(wt)=\frac{3\sqrt{6}}{\pi}V_s \tag{28}$$

相控整流平均电压计算

单相

$$V_o=\frac{1}{\pi}\int_{\alpha}^{\pi}\sqrt{2}V_s \sin wt \, d(wt)=\frac{2\sqrt{2}}{\pi}V_s\frac{1+\cos\alpha}{2} \tag{29}$$

三相

$$V_o=\frac{1}{\pi/3}\int_{\pi/3+\alpha}^{2\pi/3+\alpha}\sqrt{3}*\sqrt{2}V_s \sin wt \, d(wt)=\frac{3\sqrt{6}}{\pi}V_s\cos\alpha(\alpha<60^o) \tag{30}$$

单相相控整流电压电阻负载的电压有效值计算

$$V_{rms}=\sqrt{\frac{1}{\pi}\int_{\alpha}^{\pi}[\sqrt{2}V_s \sin wt]^2 \, d(wt)}=V_s\sqrt{\frac{\sin 2\alpha}{2\pi}+\frac{\pi-\alpha}{\pi}} \tag{31}$$

单相相控整流电压电阻负载的功率因数计算

$$PF=\frac{P_{in}}{S_{in}}=\frac{P_{out}}{S_{in}}=\frac{V_{orms}^2/R}{V_{irms}I_{irms}}=\frac{V_{orms}^2/R}{V_sV_{orms}/R}=\sqrt{\frac{\sin 2\alpha}{2\pi}+\frac{\pi-\alpha}{\pi}} \tag{32}$$

单相整流器导通角求取（有阻感性负载）（$\alpha>\phi$）

原理

$$\begin{gathered} \sqrt{2}V_s \sin wt=L\frac{di_D}{dt}+Ri_D \\ when\ wt=\alpha,\ i_D=0 \\ when\ wt=\alpha+\theta,\ i_D=0 \end{gathered} \tag{33}$$

求解此方程组可得形式（齐次解+非齐次解）

$$\sqrt{2}V_s \sin(wt-\phi) \quad \ldots \quad A e^{-\frac{R}{L}t} \tag{34}$$

$$i_D = \frac{\quad}{Z} + Ae^{\ldots} \tag{34}$$

进而可以解得A, θ

$$\tan(\alpha - \phi) = \frac{\sin\theta}{e^{-\frac{\theta}{\tan\theta}} - \cos\theta} \tag{35}$$

在有反电动势存在时单相相控整流器停止导电角

易于理解，画一条线

$$\sin\delta = \frac{E}{\sqrt{2}V_s} \tag{36}$$

单相桥相控整流时电流连续条件

书上官方

取alpha处为时间坐标原点，在临界连续时有

$$i_D(wt = \pi) = 0 \tag{37}$$

而iD的计算为

$$\begin{gathered} L\frac{di_D}{dt} + Ri_D = \sqrt{2}V_s\sin(wt + \alpha) - E \\ i_D(wt = \pi) = 0 \\ i_D(wt = 0) = 0 \\ Ri_D + E = \frac{2\sqrt{2}}{\pi}V_s\cos\alpha \end{gathered} \tag{38}$$

故可解得临界连续时的电流为

$$i_D(t) = \frac{\sqrt{2}V_s}{wL}(\cos\alpha - \cos(wt + \alpha) - \frac{2}{\pi}\cos\alpha * wt) \tag{39}$$

电流平均值为

$$I_{Dmin} = \int_0^{\pi} i_D(wt)dwt = \frac{2\sqrt{2}}{\pi}V_S\frac{1}{wL}\sin\alpha \tag{40}$$

为使得什么时候都连续，取临界值$\alpha = \pi/2$

则

$$I_{Dmin} = \frac{2\sqrt{2}}{\pi}V_S\frac{1}{wL} \tag{41}$$

直接看$\alpha = \pi/2$

此时输出电压为0

$$L\frac{di_D}{dt} = \sqrt{2}V_s\cos(wt) \tag{42}$$

则

$$i_D = \frac{\sqrt{2}V_s\sin wt}{wL} \tag{43}$$

平均临界电流为

$$I_D = \frac{2\sqrt{2}}{\pi}\frac{V_s}{wL} \tag{44}$$

换相整流区

注意m为脉波数

原理

$$\begin{gathered}
v_1 = \sqrt{2}V_s\cos{(wt - \pi/m)} \\
v_2 = \sqrt{2}V_s\cos{(wt + \pi/m)} \\
v_D = \frac{1}{2}(v_1 + v_2) \\
\Delta V_S = \frac{1}{2\pi/m}\int_{\alpha}^{\alpha+\gamma}\frac{1}{2}(v_b - v_a)d(wt) = \frac{m}{\pi}\sqrt{2}V_s\sin\frac{\pi}{m}\frac{\cos\alpha - \cos{(\alpha+\gamma)}}{2} \\
I_D = \int_{\alpha}^{\alpha+\gamma}\frac{1}{wL_s}\frac{1}{2}(v_b - v_a)dwt = \frac{1}{wL_s}2\sqrt{2}V_s\sin\frac{\pi}{m}\frac{\cos\alpha - \cos{(\alpha+\gamma)}}{2}
\end{gathered} \tag{45}$$

则

$$\begin{gathered}
R_s = \frac{\Delta V_S}{I_D} = \frac{mwL_s}{2\pi} \\
\cos\alpha - \cos{(\alpha+\gamma)} = \frac{wL_sI_D}{\sqrt{2}V_s\sin\frac{\pi}{m}}
\end{gathered} \tag{46}$$