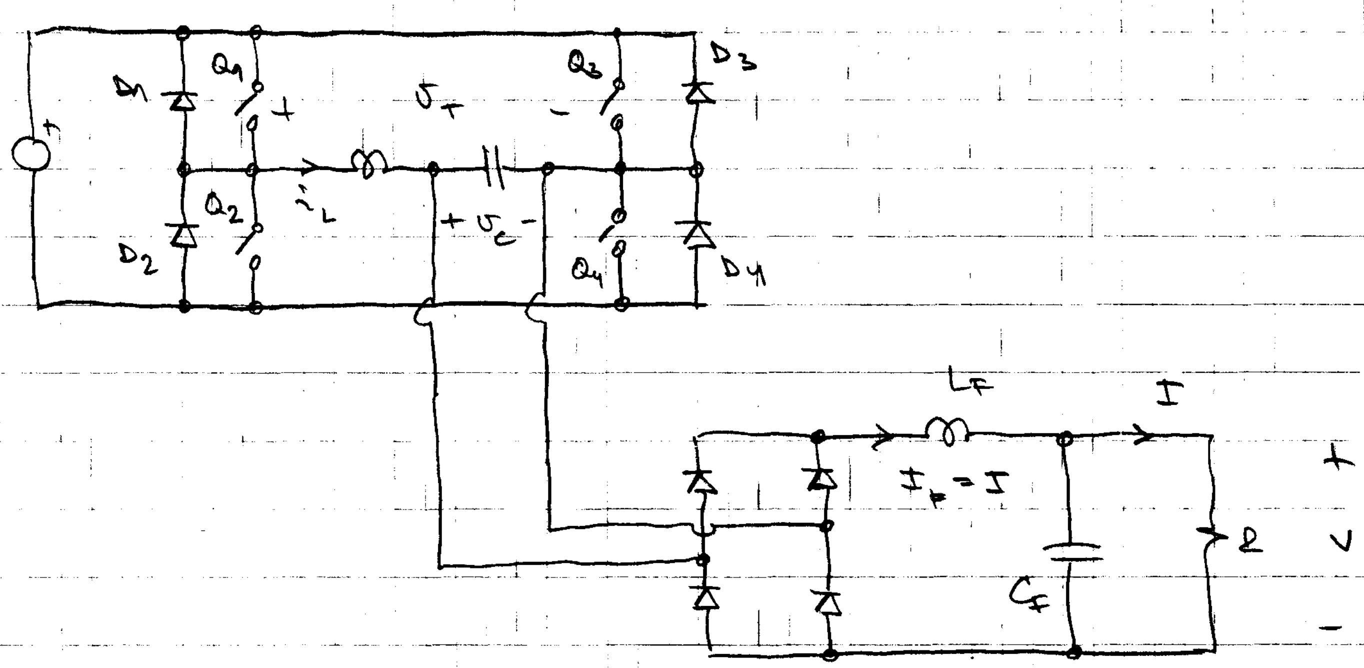
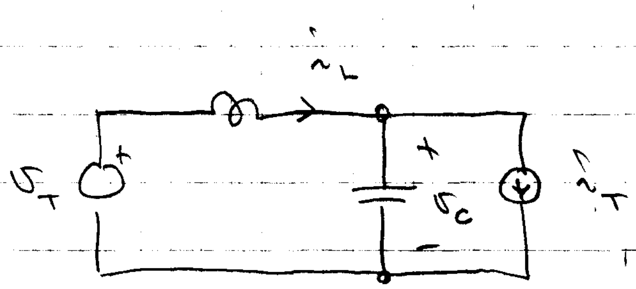
Parallel Resonant Converter



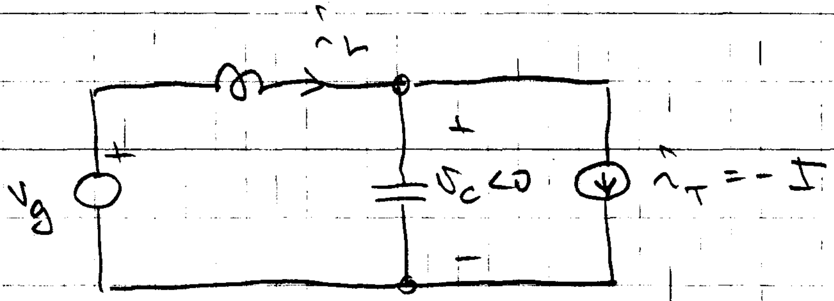
$$I_F = I$$

$$V = \overline{|v_C|}$$

interval	V_T	M_T	I_T	J_T	v_C
1	V_g	$+1$	$-I$	$-J$	$-$
2	V_g	$+1$	$+I$	$+J$	$+$
3	$-V_g$	-1	$+I$	$+J$	$+$
4	$-V_g$	-1	$-I$	$-J$	$-$

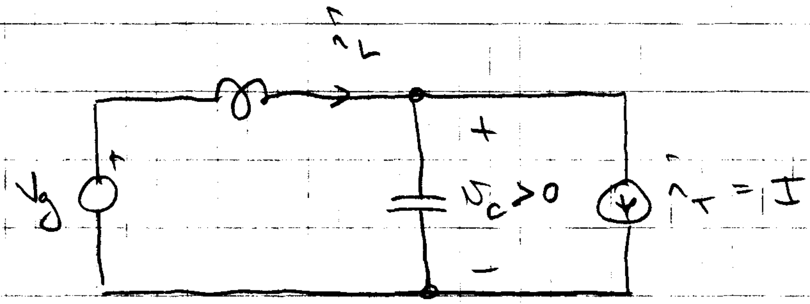


1



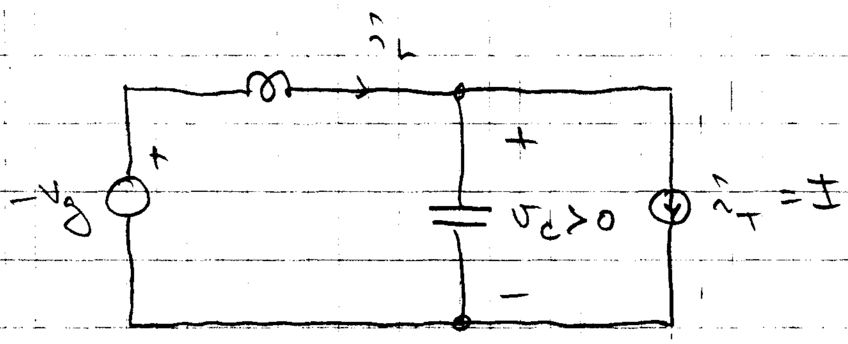
Q1, Q4 / D1, D4 $\quad 0 < \omega_0 t < \alpha$

2



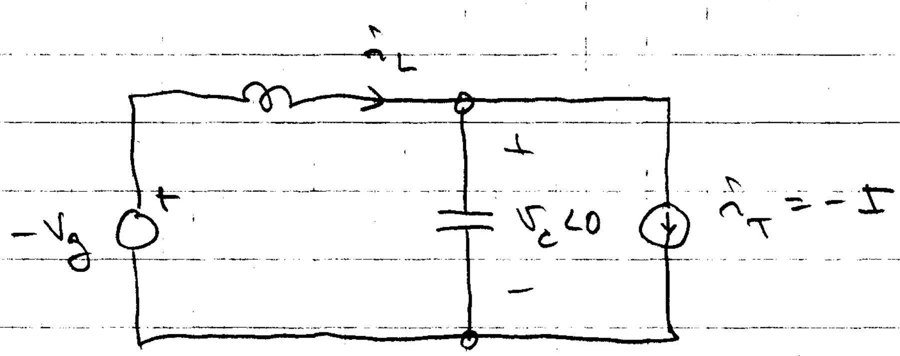
Q1, Q4 / D1, D4 $\quad \alpha < \omega_0 t < \alpha + \beta = \gamma$

3

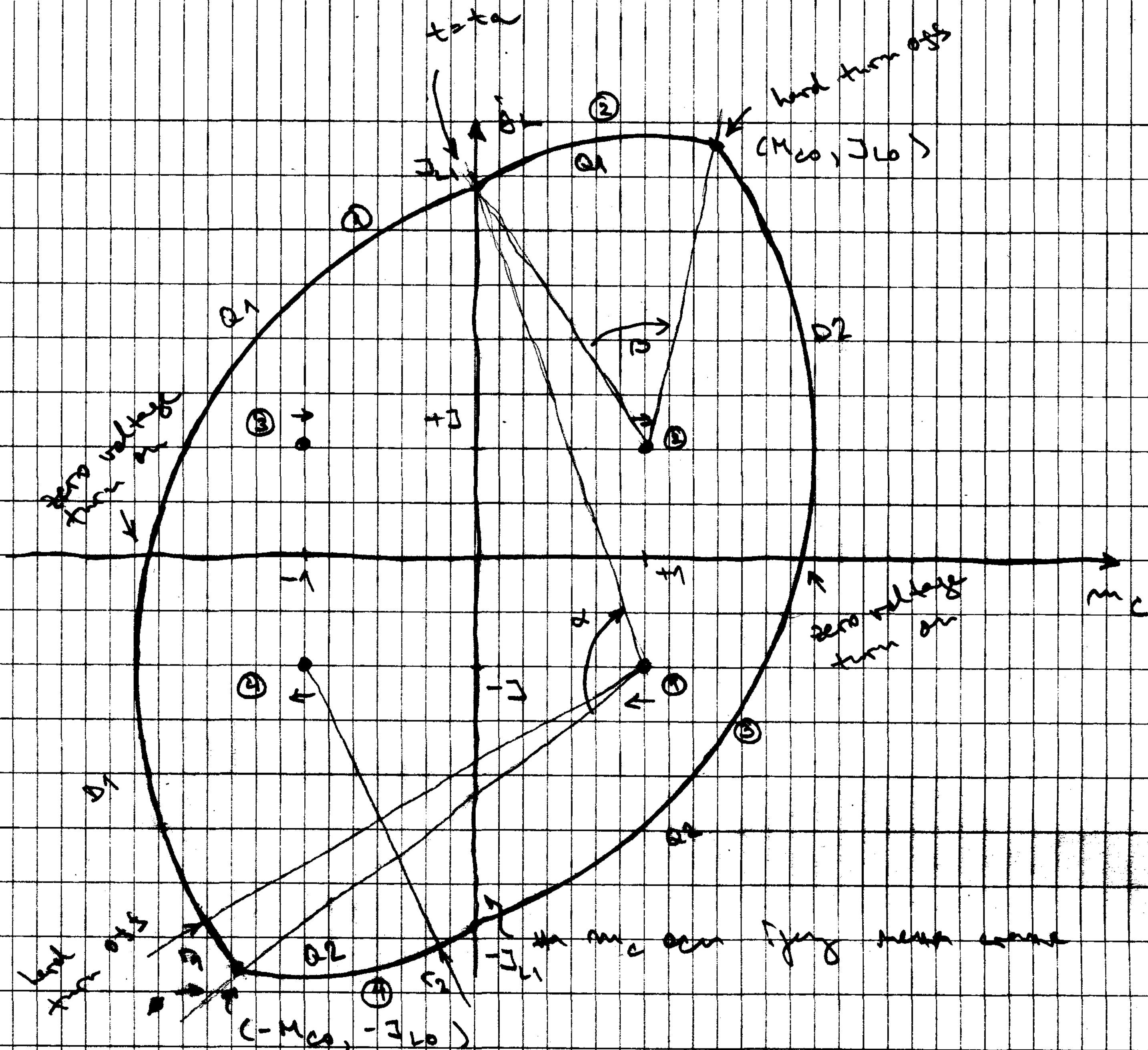


Q2, Q3 / D2, D3 $\quad \gamma < \omega_0 t < \gamma + \alpha$

4



Q2, Q3 / D2, D3 $\quad \gamma + \alpha < \omega_0 t < 2\gamma$

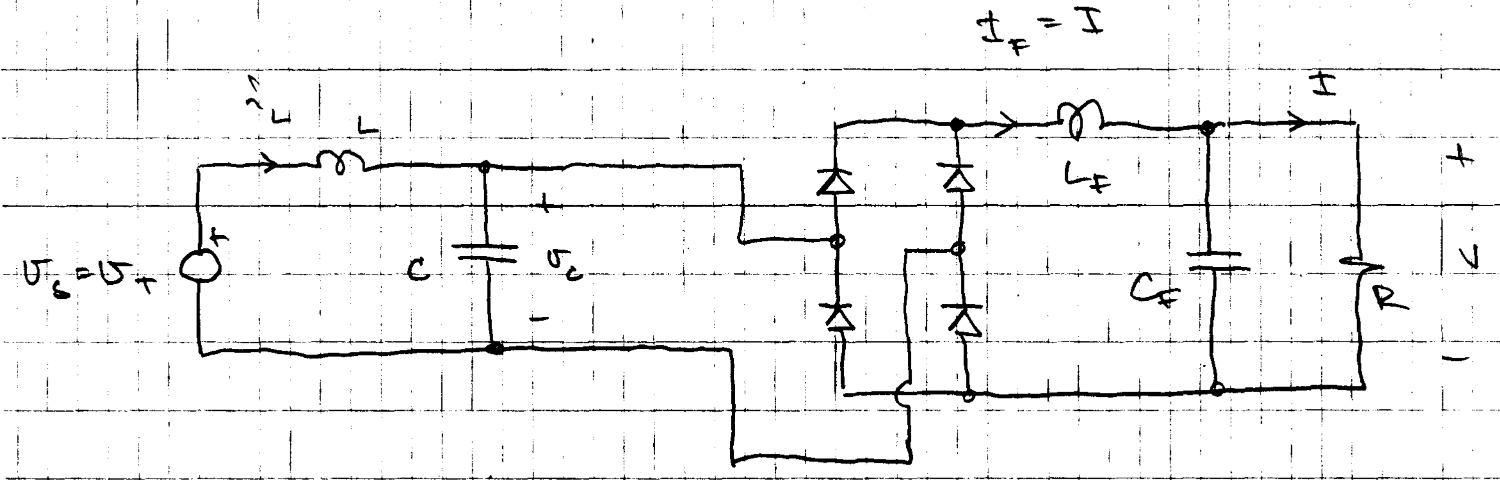


① - центар за леву комутацију

④ - центар за леву комутацију

② - центар за десну комутацију

③ - центар за десну комутацију



$$V = \overline{|v_c|}$$

$$V = \frac{2}{T_s} \int_{t_a}^{t_a + \frac{1}{2} T_s} v_c(t)\, dt$$

$t = t_a$ – [illegible] v_c

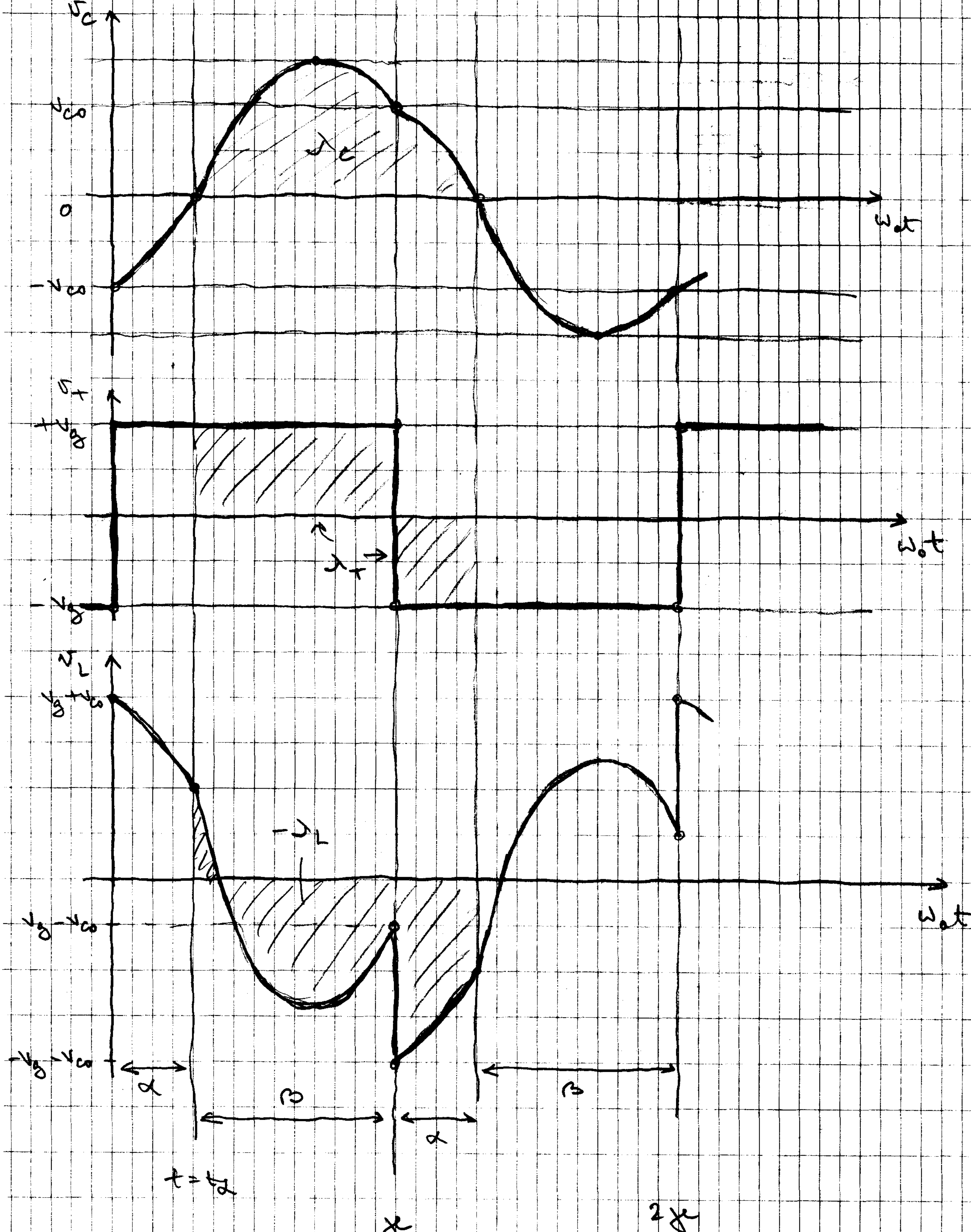
$$V = \frac{2}{T_s} \lambda_c$$

$$\lambda_c = \int_{t_a}^{t_a + \frac{1}{2} T_s} v_c(t)\, dt$$

$$\lambda_c = \lambda_T - \lambda_L$$

$$\lambda_T = \int_{t_a}^{t_a + \frac{1}{2} T_s} v_T(t)\, dt$$

$$\lambda_L = \int_{t_a}^{t_a + \frac{1}{2} T_s} v_L(t)\, dt$$



vC
vC0
0
-vC0
ω0t
vT
+Vg
-Vg
VL
Vg+vC0
Vg-vC0
-Vg-vC0
α
β
t = t2
π
2π

$$V = \frac{2}{T_s}\left(\lambda_T - \lambda_L\right)$$

λ_T - [illegible]

$$\lambda_T = V_g\left(\frac{1}{2}T_s - 2t_a\right)$$

$$\lambda_T = V_g\left(\frac{\beta}{\omega_0} - \frac{\alpha}{\omega_0}\right)$$ – са [illegible]!

$$\lambda_T = V_g\,\frac{\beta-\alpha}{\omega_0}$$

$$\lambda_L = L\left(-2I_{L1}\right)$$

$$V = \frac{2}{T_s}\left(V_g\,\frac{\beta-\alpha}{\omega_0} + 2LI_{L1}\right)$$

$$\frac{V}{V_g} = M = \frac{2}{T_s}\left(\frac{\beta-\alpha}{\omega_0} + \frac{1}{\omega_0}\cdot 2\underbrace{\omega_0 L}_{R_0}\cdot\underbrace{\frac{I_{L1}}{V_g}}_{J_{L1}}\right), \quad T_s\,\omega_0 = 2\gamma$$

$$M = \frac{1}{\gamma}\left(\beta - \alpha + 2J_{L1}\right)$$

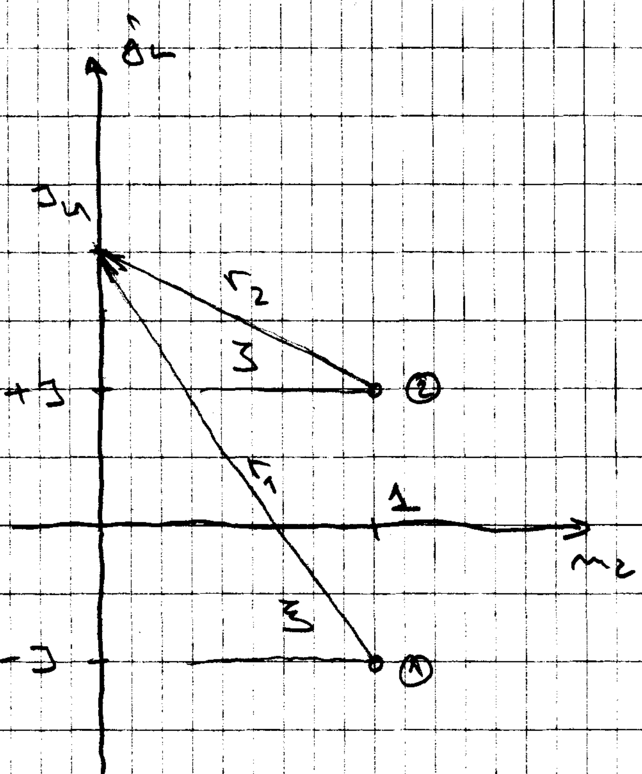
$$M = \frac{2}{\gamma}\left(\frac{\beta-\alpha}{2} + J_{L1}\right)$$

$$\boxed{\frac{M\gamma}{2} = (\varphi + J_ц)} \qquad (0)$$

$$\boxed{\varphi \stackrel{деф}{=} \frac{\beta - \alpha}{2}}$$

– Геометрија: заменити $J_ц$, β и α са J и γ

① одредимо r_1 и r_2



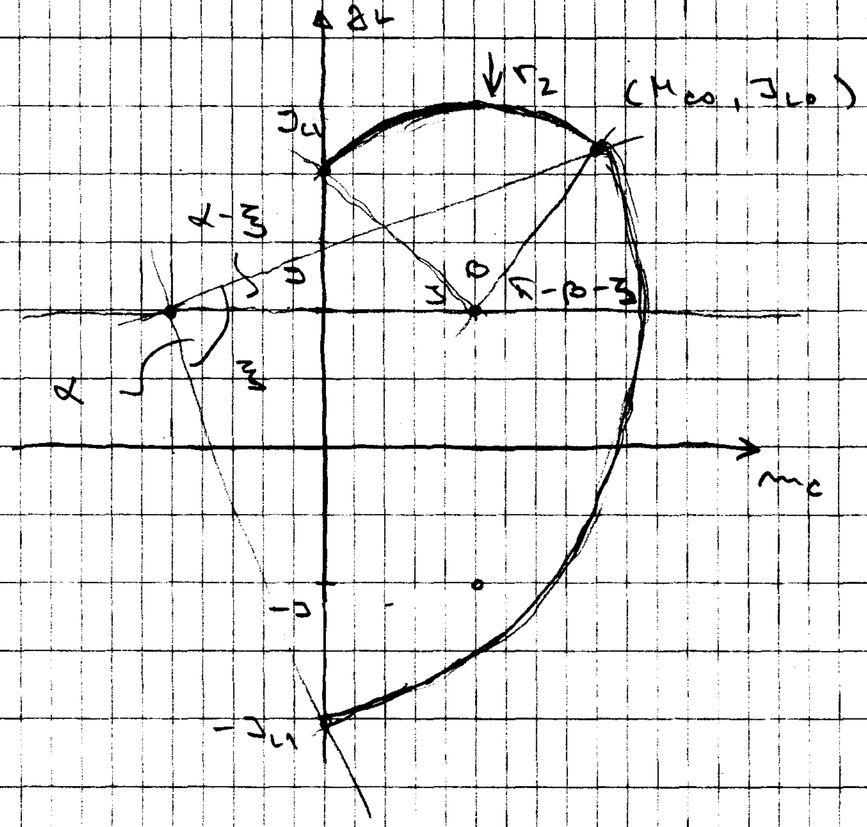
$$r_2 \sin\zeta = J_ц - J \qquad (1)$$

$$r_2 \cos\zeta = 1 \qquad (2)$$

$$r_1 \sin\xi = J_ц + J \qquad (3)$$

$$r_1 \cos\xi = 1 \qquad (4)$$

② одредимо граничне услове за J_{L0}



$$J_{L0} = J + r_2 \sin(\pi - \beta - \xi)$$

$$\underline{J_{L0} = J + r_2 \sin(\beta + \xi)} \qquad (5)$$

$$\underline{J_{L0} = J + r_1 \sin(\alpha - \xi)} \qquad (6)$$

$$r_2 \sin(\beta + \xi) = r_1 \sin(\alpha - \xi)$$

$$r_2 (\sin\beta \cos\xi + \cos\beta \sin\xi) =$$

$$= r_1 (\sin\alpha \cos\beta - \cos\alpha \sin\beta) \qquad (7)$$

елімінуємо $r_2\cos\xi$, $r_2\sin\xi$, $r_1\cos\xi$, $r_1\sin\xi$ користати (1) - (4)

$$\sin\alpha - (J_{L1} + J)\cos\alpha = \sin\beta + (J_{L1} - J)\cos\beta \qquad (8)$$

маємо, де $\frac{\alpha+\beta}{2} = \frac{\gamma}{2}$, $\frac{\beta-\alpha}{2} = \varphi$

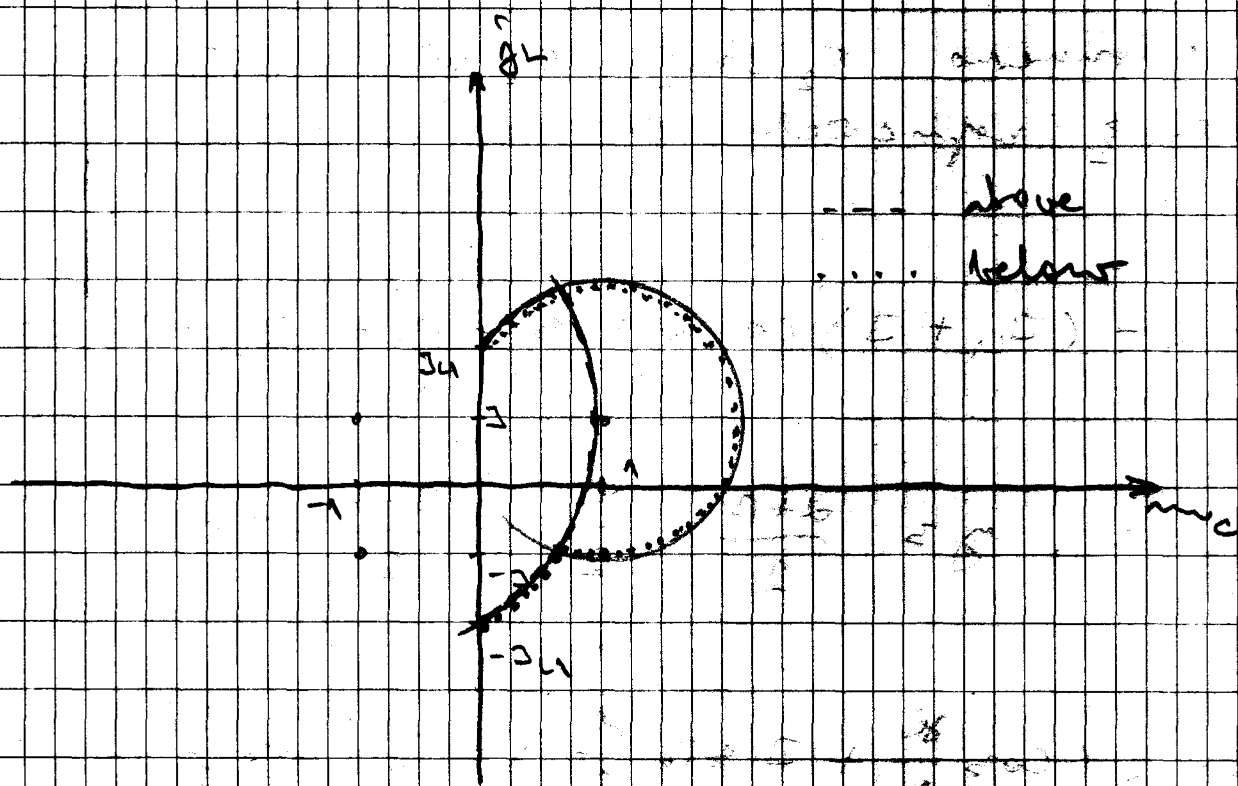
$$-\sin\varphi\left(\cos\frac{\gamma}{2} + J\sin\frac{\gamma}{2}\right) = J_{L1}\cos\frac{\gamma}{2}\cos\varphi \qquad (9)$$

③ обчислимо граничне число ~~на~~ M_{co}

$$M_{co} = 1 + r_2\cos(\pi - \beta - \xi)$$

$$M_{co} = 1 - r_2\cos(\beta + \xi) \qquad (10)$$

$$M_{co} = r_1\cos(\alpha - \xi) - 1 \qquad (11)$$



--- above
... below
j4
j
-1
1
-j
-j4

из треугольника

$$1 - r_2 \cos(\beta + \xi) = r_1 \cos(\alpha - \xi) - 1$$

$$\cos\varphi \left(\cos\frac{\gamma}{2} + J \sin\frac{\gamma}{2}\right) = J_{L1} \cos\frac{\gamma}{2} \sin\varphi + 1 \qquad (12)$$

из (12) и (9) исключаем $J_{L1} \cos\frac{\gamma}{2}$

$$\cos\varphi = \cos\frac{\gamma}{2} + J \sin\frac{\gamma}{2} \qquad (13)$$

$$\boxed{\varphi = \pm \arccos\left(\cos\frac{\gamma}{2} + J \sin\frac{\gamma}{2}\right)} \qquad (14)$$

above resonance $\varphi = \frac{\beta - \alpha}{2} < 0$

below resonance $\varphi = \frac{\beta - \alpha}{2} > 0$

зачем?, когда сильно

$$\varphi = \begin{cases} -\arccos\left(\cos\frac{\gamma}{2} + J\sin\frac{\gamma}{2}\right) & 0 < \gamma < \pi \quad \text{(above)} \\ \arccos\left(\cos\frac{\gamma}{2} + J\sin\frac{\gamma}{2}\right) & \pi < \gamma < 2\pi \quad \text{(below)} \end{cases} \tag{15}$$

$$J_u = -\frac{\sin\varphi}{\cos\frac{\gamma}{2}} \tag{16}$$

$$J_{lo} = -(J^2 - 1)\,tg\,\frac{\gamma}{2} \tag{17}$$

$$M_{co} = -\frac{J\sin\varphi}{\cos\frac{\gamma}{2}} \tag{18}$$

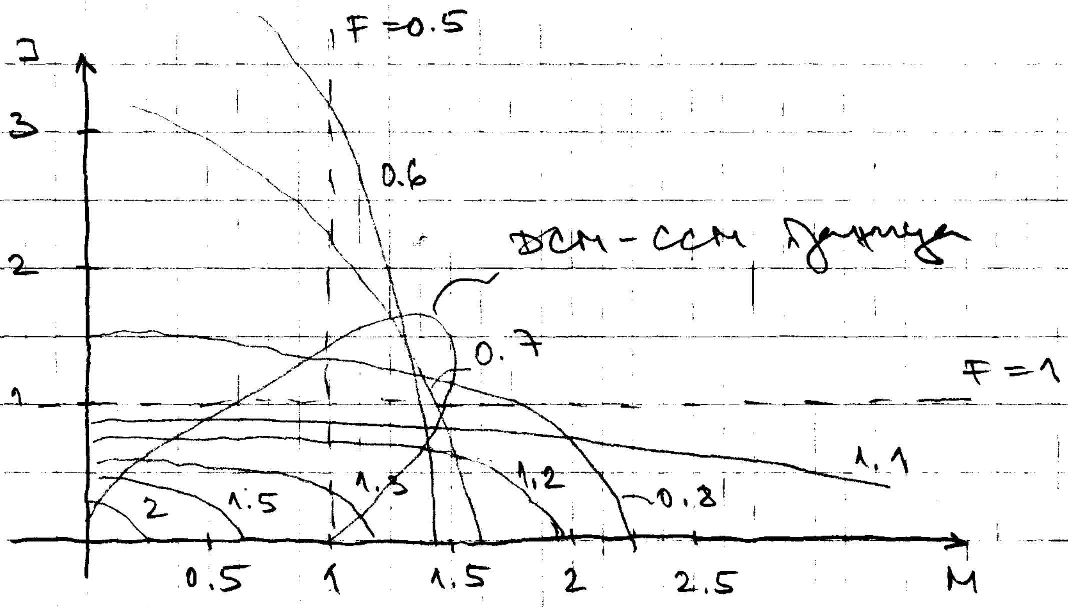
заменом (16) у (0)

$$\boxed{M = \frac{2}{\gamma}\left(\varphi - \frac{\sin\varphi}{\cos\frac{\gamma}{2}}\right)} \quad - \quad (17)$$

(ово је $M(J,\gamma)$, т. ј. $M(J,F)$, експлицитно, без интеграла.

Иначе – highly transcedental

– излазне карактеристике $J(M)$ F – параметар,



апроксимација елипсама

$$\frac{M^2}{a^2} + \frac{J^2}{b^2} = 1$$

$$a^2 = M^2\Big|_{J=0} = \left(1 - \left(\frac{2}{\gamma}\right) \operatorname{tg} \frac{\gamma}{2}\right)^2$$

⌞ open-circuit voltage

$$b^2 = J^2\Big|_{M=0} = \left(\frac{1 - \cos\frac{\gamma}{2}}{\sin\frac{\gamma}{2}}\right)^2$$

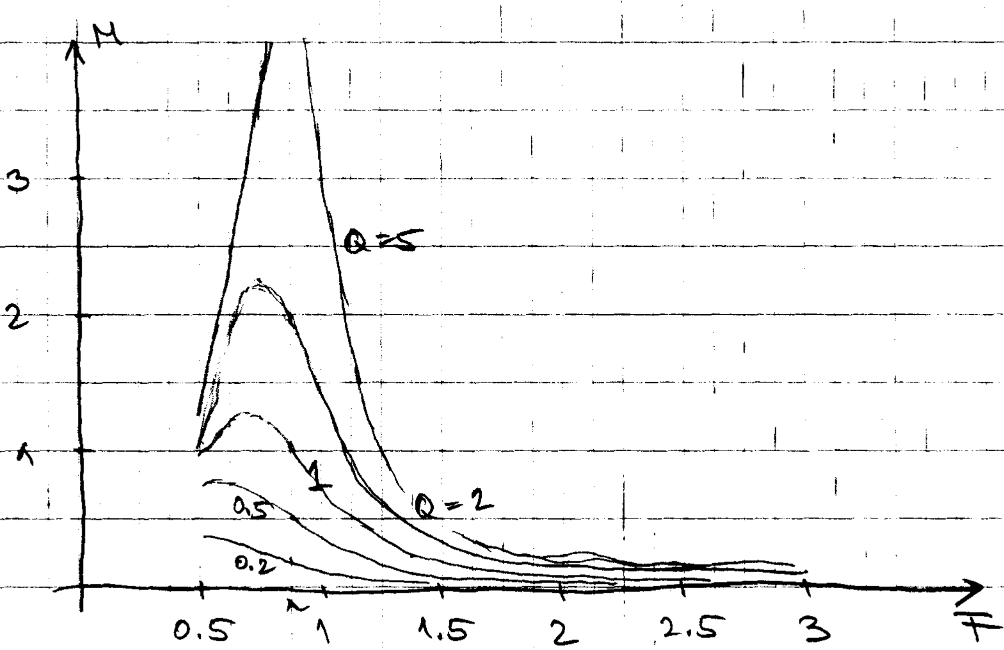
⌞ "short"-circuit current

Control Plane Characteristics $M(F)$, Q - param

$$Q = \frac{R}{R_0} \quad (\text{parallel!})$$

$$J = \frac{M}{Q}$$

$$M = \frac{1}{\sqrt{\frac{1}{a^2} + \frac{1}{Q^2 b^2}}}$$



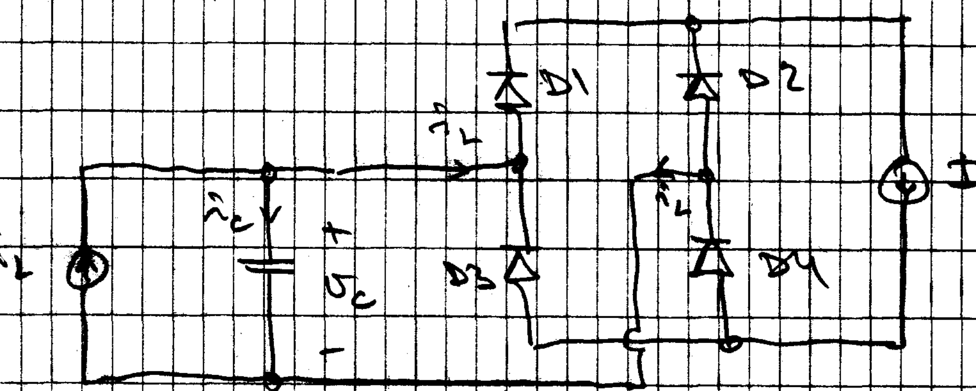
[illegible]

Discontinuous Conduction Mode

- идеално SRC, кад је напон кондензатора нула - све 4 диоде у једну воде

- дешава се и између и после резонансе ако је инвертор оптерећен

- разматрање:



$v_C(0) < 0$ - увек

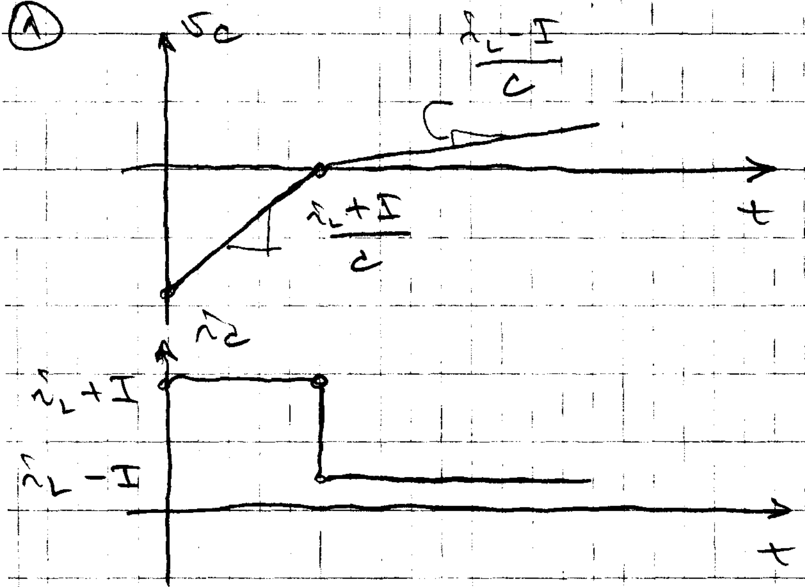
i_L = const током комутације

ситуације

① $i_L > I$

② $i_L < I$

1



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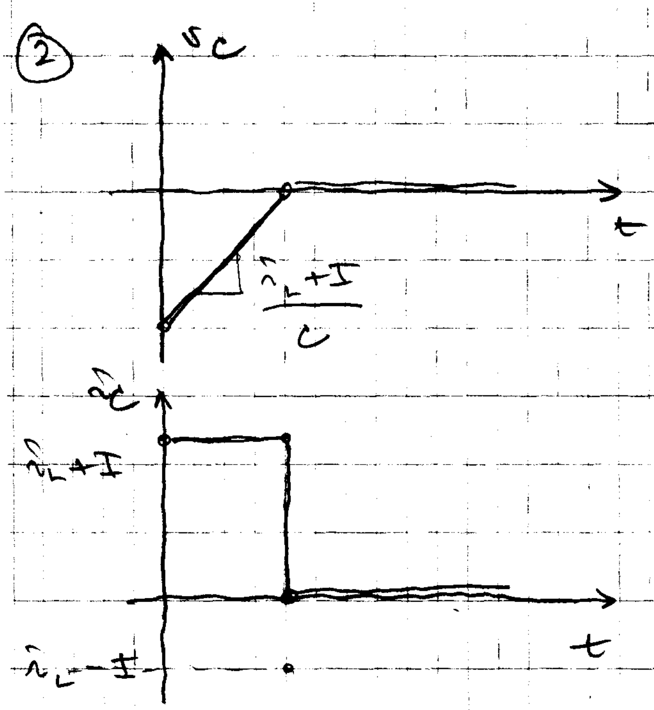


негативно i_C, $v_C < 0$, требају нам двосмерно само две диоде воде!

$$i_{D1} + i_{D2} = I \qquad i_{D1} = i_{D3} + i_L$$

$$i_{D3} + i_{D4} = I \qquad i_{D4} = i_{D2} + i_L$$

сингуларни систем

додајем симетрију

$$\left.\begin{aligned} \hat{\rho}_{D1} &= \hat{\rho}_{D4} \\ \hat{\rho}_{D3} &= \hat{\rho}_{D2} \end{aligned}\right\}$$ због изотропности према R-ом

$$\hat{\rho}_{D1} + \hat{\rho}_{D2} = I$$

$$\hat{\rho}_{D1} - \hat{\rho}_{D3} = \hat{\rho}_{L}$$

$$\hat{\rho}_{D1} - \hat{\rho}_{D2} = \hat{\rho}_{L}$$

$$2\,\hat{\rho}_{D1} = I + \hat{\rho}_{L}$$

$$\hat{\rho}_{D1} = \hat{\rho}_{D4} = \frac{1}{2}\left(I + \hat{\rho}_{L}\right)$$

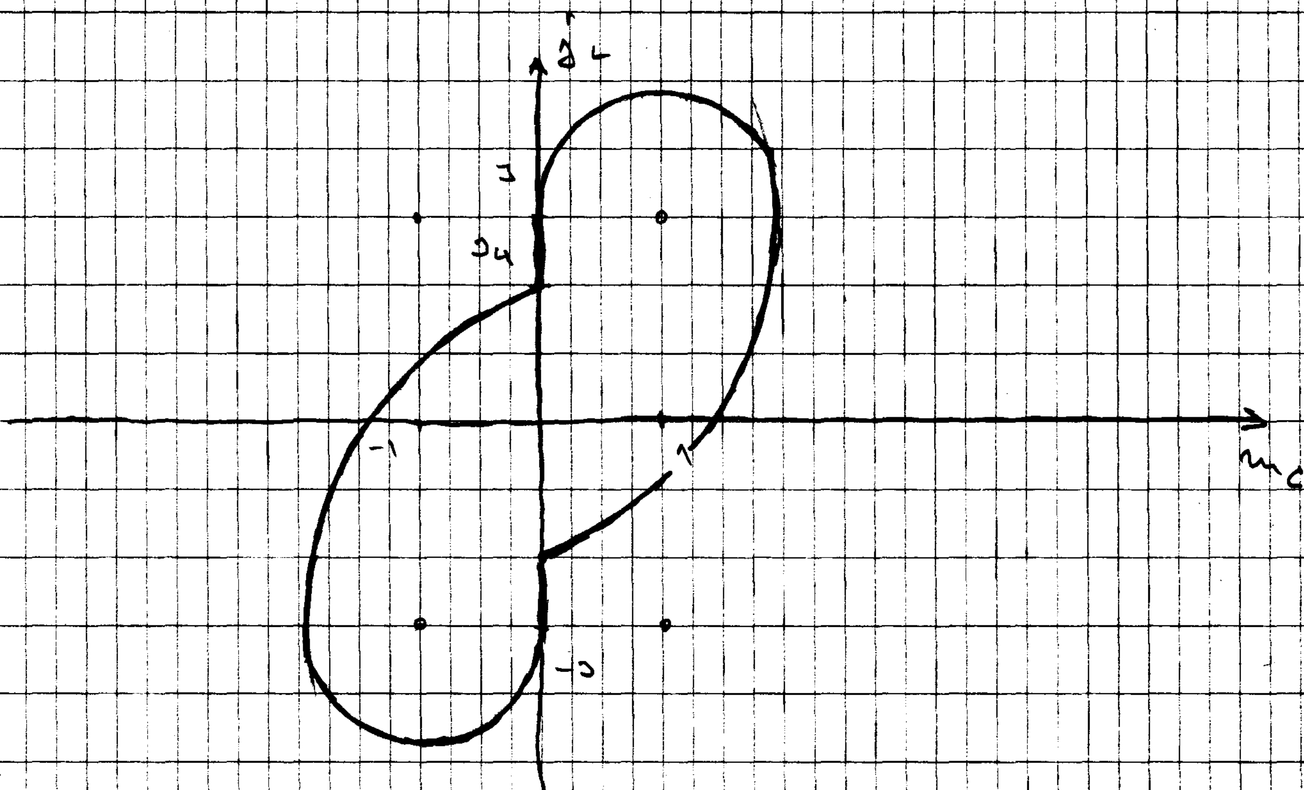
$$2\,\hat{\rho}_{D2} = I - \hat{\rho}_{L}$$

$$\hat{\rho}_{D2} = \hat{\rho}_{D3} = \frac{1}{2}\left(I - \hat{\rho}_{L}\right)$$

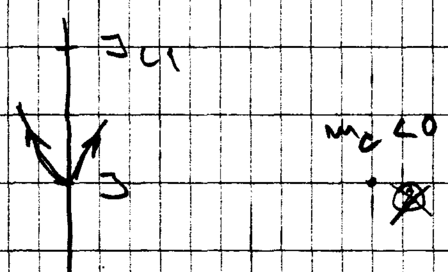
$\hat{\rho}_{L} < I$ – све $\hat{\rho}_{D} > 0$!

Мада све док $\hat{\rho}_{L}$ не пређе преко I !

– фазна далба



не може



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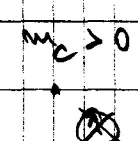


Q2 Q3 одб.,
не може ускор
да – 1

гранична маржа $m_c = 0$ $J_{c1} < |\dot{J}_c| < J$

CCM - DCM boundary

$J_{L1} < J$

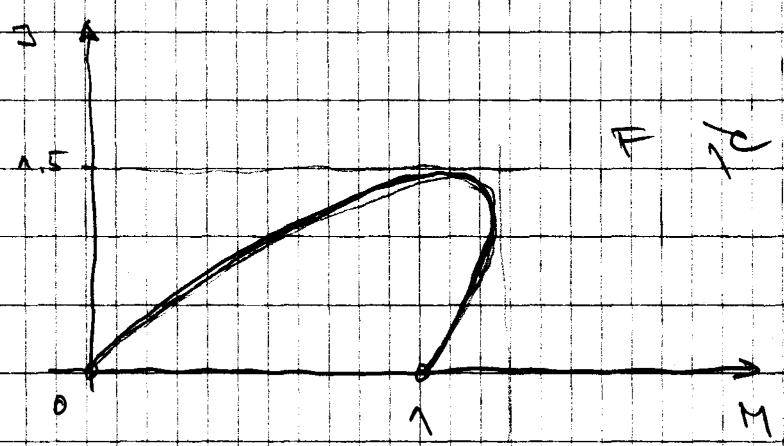
$J > J_{crit}$ за DCM

$J < J_{crit}$ за CCM

$$J_{crit} = -\frac{1}{2}\sin\gamma + \sqrt{\sin^2\frac{\gamma}{2} + \frac{1}{4}\sin^2\gamma}$$

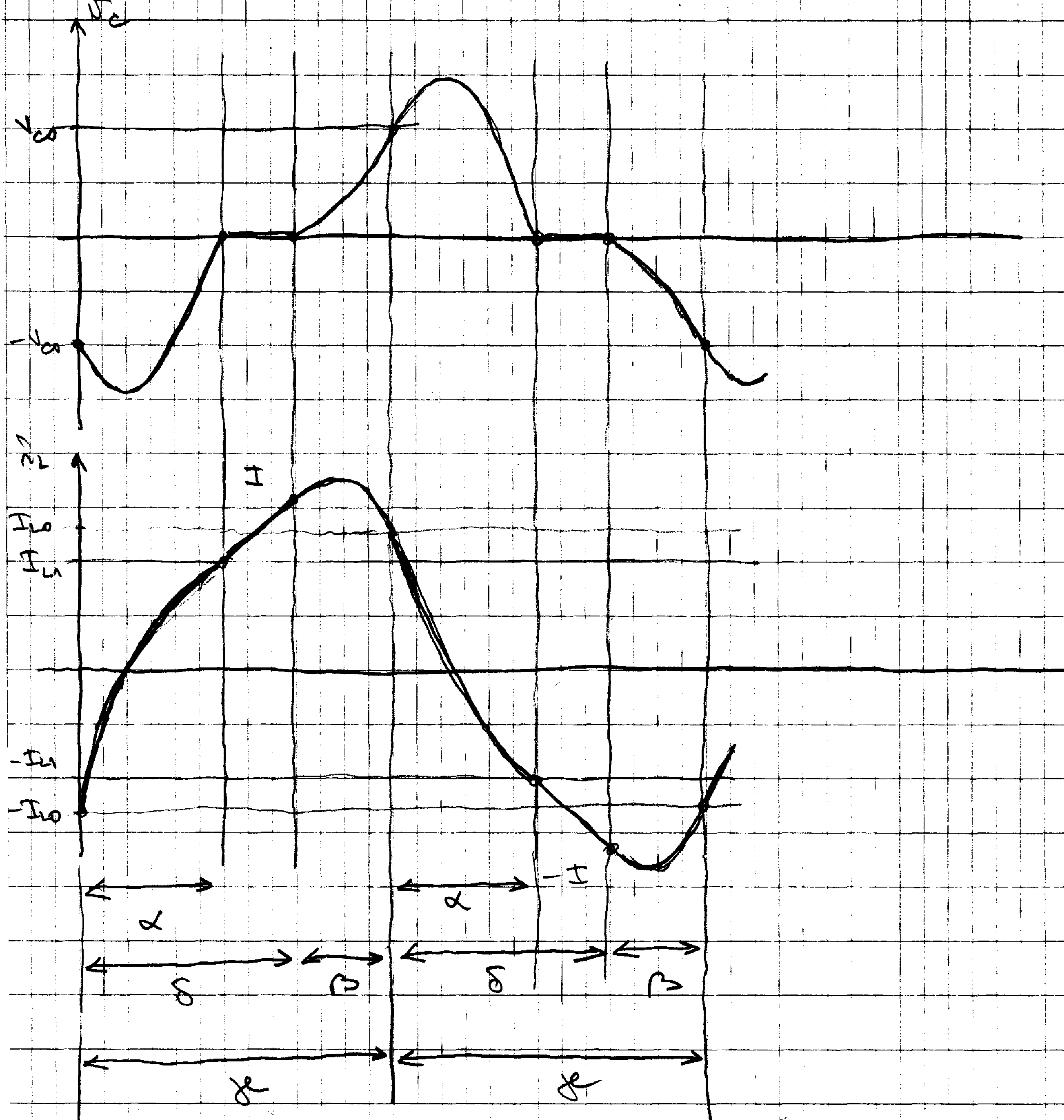
$$J_{L1} = -\frac{\sin\varphi}{\cos\frac{\gamma}{2}} \qquad \varphi = \ldots$$

+ пускане



F/C характеристика

Решение за DCM



једначине:

$$M_{co} = 1 - \cos\beta$$

$$J_{co} = J + \sin\beta$$

$$\cos(\alpha+\beta) - 2\cos\alpha = -1$$

$$-\sin(\alpha+\beta) + 2\sin\alpha + (\delta-\alpha) = 2J$$

$$\beta + \delta = \gamma$$

$$M = 1 + \frac{2}{\gamma}(J-\delta)$$

- не може се решити аналитички, мора нумерички