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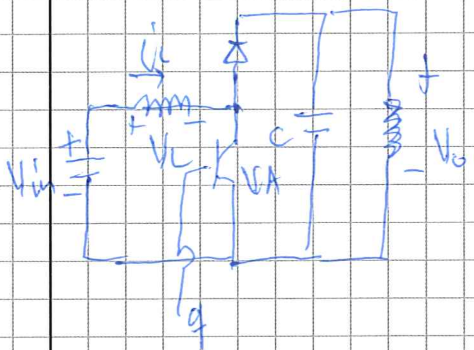
Emnekode : ENE 229

Kandidatnr. : 226

Dato : 23.05 -2017

Ark nr. : 1. av 10

Question 1 DC-DC Boost Converter



$L = 25\,\mu H$

$V_{in} = 12\,V$

$D = \frac{T_{on}}{T_s} = 0{,}4$

$f_s = 400\,kHz$

$P_o = 25\,W$

$T_s = \frac{1}{f_s} = \frac{1}{400\,kHz}$

$T_s = 2{,}5\,\mu s$

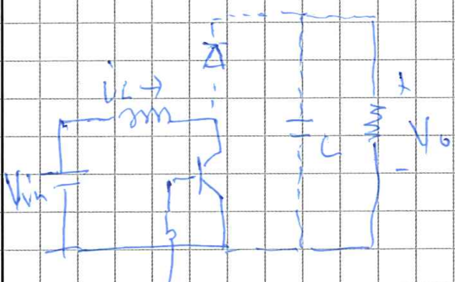
$\frac{V_o}{V_{in}} = \frac{1}{1-D}$

$V_o = \frac{V_{in}}{1-D}$

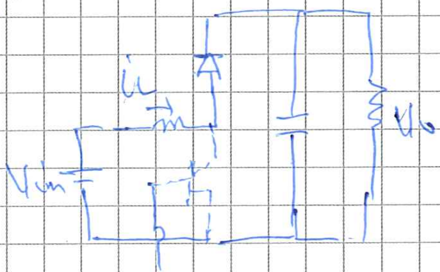
$V_o = \frac{12}{1-0{,}4}$

$= 20\,V$

a)



$q = 1$



$q = 0$

$T_{on} = D T_s = 1\,\mu s$

when $q = 1$ $V_A = 0$

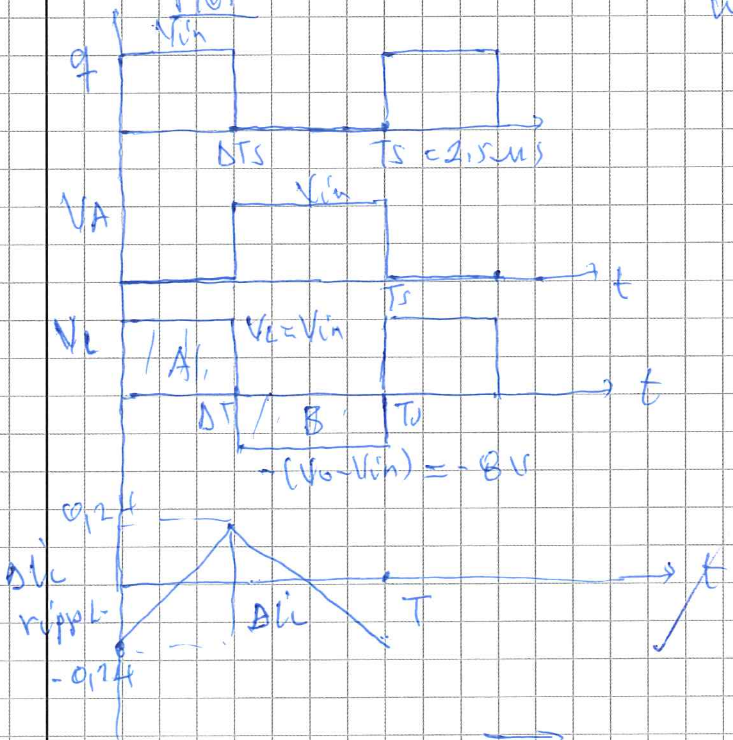
$q = 0$ $V_A = V_{in}$

when $q_1 = 1$ $V_L = V_{in}$

$q = 0$ $V_L = -(V_o - V_{in})$

$= -8\,V$

Plot



$\Delta i_L = \frac{V_{in} D T}{L}$

$= \frac{12 \cdot 0{,}4 \cdot 2{,}5 \times 10^{-6}}{25\,\mu H}$

Δi_L ripple $= 0{,}48\,A$

$I_L = I_{in} = \frac{P_{in}}{V_{in}} = \frac{25\,W}{12}$

$i_L = I_{in} = 2{,}08\,A$

$\Longrightarrow$

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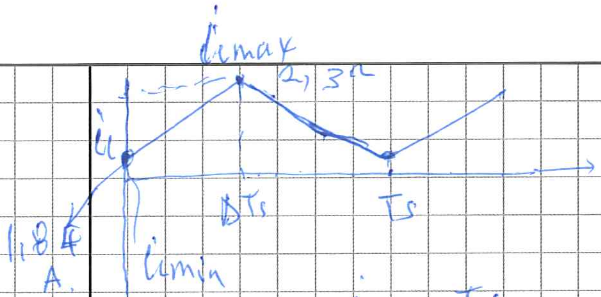


$i_{Lmax} = 2{,}08 + \frac{\Delta i_L}{2} = 2{,}32\ A$

$i_{Lmin} = 2{,}08 - \frac{\Delta i_L}{2} = 1{,}84\ A$

$i_L = I_{in}$ are the same.

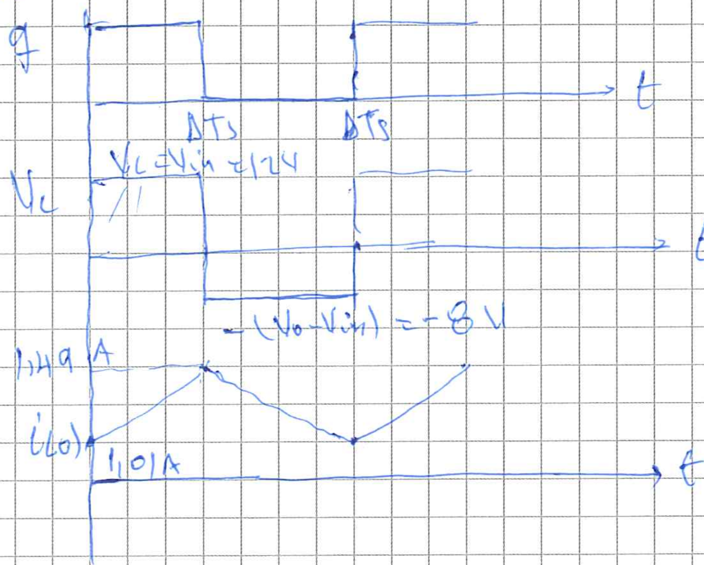
(b) $P_o = 15\ W$ $\qquad i_L = I_{in} = \frac{P_i/P_o}{V_{in}} = \frac{15}{12} = 1{,}25\ A$

Δi_L - ripple $= 0{,}48\ A$
↳ unchanged

V_{in} - is unchanged

Δi_L ripple $= \frac{V_{in} D T_s}{L} = \frac{12\ V \cdot 0{,}4 \cdot 2{,}5\ \mu s}{25\ \mu H} = 0{,}48$

Plot



$q = 1$ $\quad V_L = V_{in} = 12\ V$

$q = 0$ $\quad V_L = -(V_o - V_{in}) = -8\ V$

$i_{Lmax} = 1{,}25 + \frac{\Delta i_L}{2} = 1{,}49\ A$

$i_{Lmin} = 1{,}25 - \frac{\Delta i_L}{2} = 1{,}01\ A$

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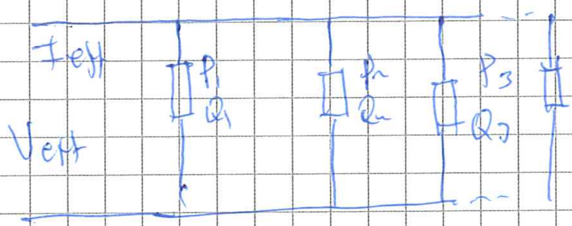
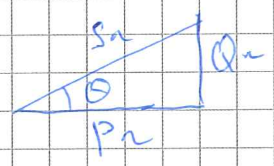
Question 2



$P_1 = 10\,kW$ $pf_1 = 1$ $P_2 = 20\,kW$ $pf_2 = 0{,}5$ lagging

$Q_1 = 0$



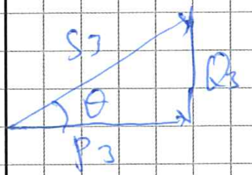
$\cos^{-1} 0{,}5 = \theta = 60°$

$\tan\theta = \frac{Q_2}{P_2}$

$P_3 = 15\,kW$, $pf_3 = 0{,}6$ lag

$Q_2 = \tan 60 \cdot 20\,kW$

$= 34{,}64\,kVAR$



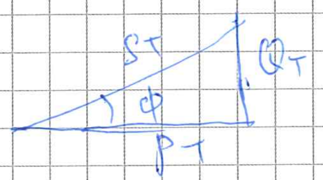
$\cos^{-1} 0{,}6 = \theta = 53{,}13$

$\tan\theta = \frac{Q_3}{P_3}$

$Q_3 = \tan 53{,}13 \cdot 15\,kW = 20\,kVAR$

So $P_T = P_1 + P_2 + P_3 = 10\,kW + 20\,kW + 15\,kW = 45\,kW$

$Q_T = Q_1 + Q_2 + Q_3 = 0 + 34{,}64\,kVAR + 20\,kVAR = \underline{54{,}64\,kVAR}$



$S_T = \sqrt{P_T^2 + Q_T^2}$

$= 70{,}785\,kVA$

$pf_T = \cos\phi = \frac{P_T}{S_T} = \underline{0{,}6357}$

$S_T = V_{ef}\, I_{ef}$

$I_{ef} = \frac{S_T}{V_{eff}} = \frac{70{,}785\,kVA}{6\,kV} = \underline{11{,}798 \angle -\cos^{-1} 0{,}6357}$

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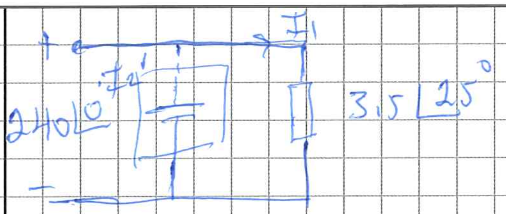
(b)



$Z = 3{,}5\angle 25°$

$Pf_1 = \cos 25 = 0{,}906$ lagging

$Pf_{improv} = 0{,}95$ lagging

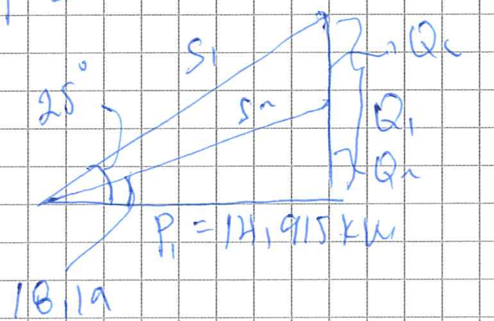
I_1 - Before capacitor is connected will be -

$$I_1 = \frac{240\angle 0°}{3{,}5\angle 25°} = 68{,}57\angle -25°$$

- Active power is always the same;

$P = V.I\cos\phi = 240 \cdot 68{,}57\cos(-25) = 14{,}915$ kW

$P =$



$\tan 25 = \frac{Q_1}{P}$

$Q_1 = \tan 25 \cdot 14{,}915$ kW

$= 6{,}955$ kVAR

$Q_2 = \tan 18{,}19 \cdot 14{,}915$ kW

$= 4{,}901$ kVAR

$Q_c = Q_1 - Q_2$

$= 6{,}955$ kVAR $- 4{,}901$ kVAR

$= 2{,}054$ kVar $\Rightarrow$ ~~205,4 VAR must be provided~~

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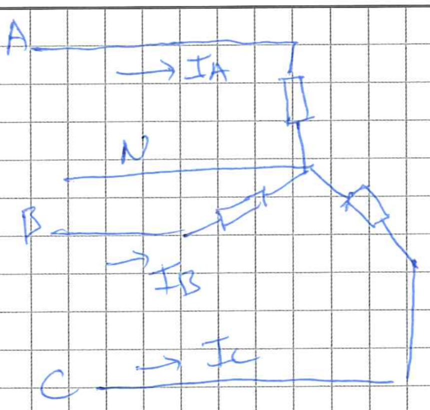
(c)



$V_{L-L} = 169,7\,V$

$V_{phase} = \frac{169,7}{\sqrt{3}} = 97,98\,V$

Y-connected line current is the Same as phase current

$Z = 20 \angle -30^\circ$

$V_{AN} = 97,98 \angle -90$

$V_{BN} = 97,98 \angle 30$

$V_{CN} = 97,98 \angle 150$

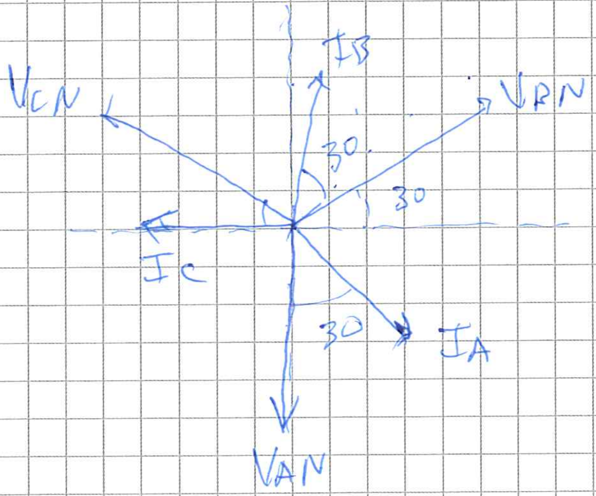
$I_A = \frac{97,98 \angle -90}{20 \angle -30^\circ}$

$= 4,899 \angle -60$

$I_B = \frac{97,98 \angle 30}{20 \angle -30} = 4,899 \angle 60$

$I_C = \frac{97,98 \angle 150^\circ}{20 \angle -30} = 4,899 \angle 180$

Phaser-Diagram



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Question 3

(a) Bus admitance matrix Y_{Bus} is formed by concidering KCL in the nodes of transmission line buses.

i.e
$$I_k = \sum_{k=1}^{n} Y_k V_k \quad (k = 1, 2, \ldots n)$$

n - is number of nodes

$$\begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ \vdots \\ I_n \end{bmatrix} = \begin{bmatrix} Y_{11} & Y_{12} & Y_{13} & Y_{14} & \ldots & Y_{1n} \\ Y_{21} & Y_{22} & Y_{23} & Y_{24} & \ldots & Y_{2N} \\ Y_{31} & Y_{31} & Y_{31} & Y_{34} & \ldots & Y_{2N} \\ \vdots & & & & & \\ Y_n & \ldots & & & & \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \\ \vdots \\ V_n \end{bmatrix}$$

$$I_{bus} = Y_{bus} V_{Bus}$$

. Admittance matrix Y_{Bus} is prefered in comparison to the bus impedence matrix Z_{bus} b/c normally buses are connected to one or two other buses, so when we deal with admittance matrix in the load flow studies it is simple and sparce where ~~on~~ some parts goes to zero, where as Z_{bus} is huge and can complicate the analysis.

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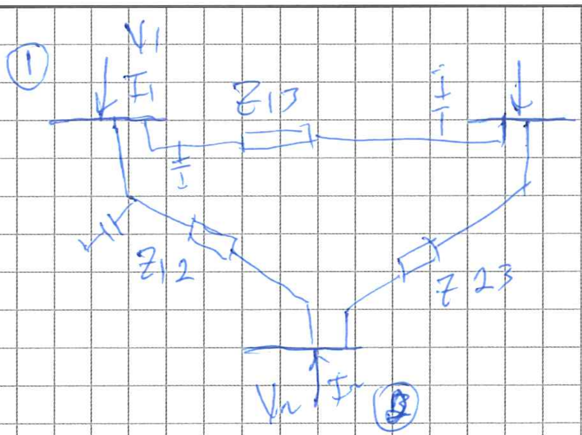
(b)



$V = 345\,kV$

$Z_{12} = 5{,}55 + j56{,}4\ \Omega$

$Z_{13} = 7{,}40 + j75{,}2\ \Omega$

$Z_{23} = 5{,}55 + j56{,}4$

$$Z_{12\,pu} = \frac{(5{,}55 + j56{,}4)\,100\,MVA}{(345k)^2} = 0{,}0047 + j0{,}0474\ pu$$

$$Z_{13} = \frac{(7{,}40 + j75{,}2)\,100\,MVA}{(345k)^2} = 0{,}0062 + j0{,}0632\ pu$$

$$Z_{23} = Z_{12} = 0{,}0047 + j0{,}0474\ pu$$

$$\begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} Y_{11} & Y_{12} & Y_{13} \\ Y_{21} & Y_{22} & Y_{23} \\ Y_{31} & Y_{32} & Y_{33} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix}$$

$Y_{11} = \frac{1}{Z_{12}} + \frac{1}{Z_{13}} = 3{,}61 - j36{,}56$

$Y_{12} = -\frac{1}{Z_{12}} = -2{,}07 + j20{,}89$

$Y_{13} = -\frac{1}{Z_{13}} = -1{,}54 + j15{,}67$

$Y_{21} = -\frac{1}{Z_{12}} = -2{,}07 + j20{,}89$

$Y_{22} = \frac{1}{Z_{12}} + \frac{1}{Z_{23}} = 4{,}14 - j41{,}78$

$Y_{23} = -\frac{1}{Z_{23}} = -2{,}07 + j20{,}89$

$Y_{31} = -\frac{1}{Z_{13}} = -1{,}54 + j15{,}67$

$Y_{32} = -\frac{1}{Z_{23}} = -2{,}07 + j20{,}89$

$Y_{33} = \frac{1}{Z_{13}} + \frac{1}{Z_{23}} = 3{,}61 - j36{,}56$

$$\begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 3{,}61 - j36{,}56 & -2{,}07 + j20{,}89 & -1{,}54 + j15{,}67 \\ -2{,}07 + j20{,}89 & 4{,}14 - j41{,}78 & -2{,}07 + j20{,}89 \\ -1{,}54 + j15{,}67 & -2{,}07 + j20{,}89 & 3{,}61 - j36{,}56 \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix}$$

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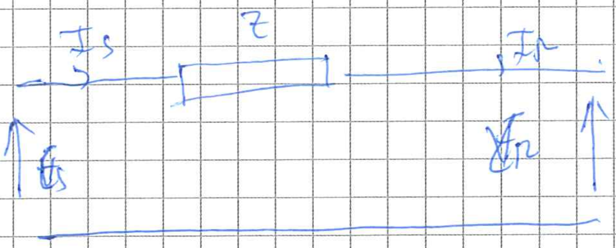
Question 4

(a) 3ϕ, 50Hz, load = 15 MW



$V_R = 10$ kV

pf = 0,8 lagging

$\phi_r = \cos^{-1} 0{,}8 = 36{,}87$

$E_s = E_r + IR\cos\phi_r + IX\sin\phi_r$

$Z = (0{,}02 + j0{,}65)\,20 = 0{,}4 + j13$

$P/\text{phase} = \dfrac{15\text{ MW}}{3} = 5\text{ MW}$

$P = V_R I_r \cos\phi \Rightarrow I_R = I = \dfrac{5\text{ MW}}{10k \cdot 0{,}8} = \underline{625}\ \underline{\angle -\cos^{-1} 0{,}8}$ A

$E_s = 10k\angle 0^\circ + 625\,(0{,}4 \cdot 0{,}8 + j13 \cdot 0{,}6)$

$= 10k\angle 0^\circ + 200 + j4{,}875$

$= 10{,}2 + j4{,}875$

$E_s = 11{,}305k\ \underline{\angle 25{,}55}$

Voltage regulation

$E_{r\,noload} = E_s$

$V_R = \dfrac{E_{r\,noload} - E_{r\,full\,load}}{E_{r\,full\,load}}$

$V_r\,\% = \dfrac{11{,}307 - 10}{10}\,100\,\%$

$= \underline{\underline{13{,}07\,\%}}$

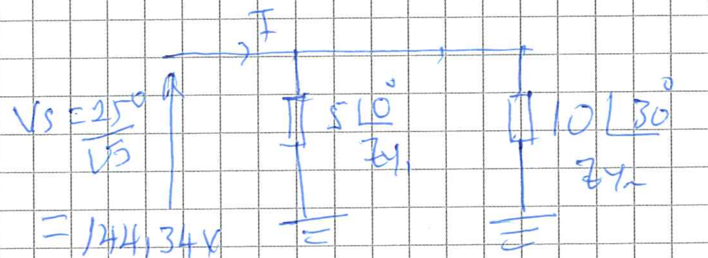
(c) 3ϕ, 3-wire $\quad V_{L-L} = 250\,V$

$Z_\Delta = 15\angle 0^\circ \qquad Z_Y = 10\angle 30^\circ$

Convert the Δ-load to Y-load

$Z_Y = \frac{Z_\Delta}{3} = \frac{15\angle 0}{3} = 5\angle 0^\circ$

By using single-line equivalent ckt



$Z_T = \frac{Z_{Y_1} \cdot Z_{Y_2}}{Z_{Y_1} + Z_{Y_2}}$

$= \frac{5\angle 0^\circ \cdot 10\angle 30^\circ}{5\angle 0^\circ + 10\angle 30^\circ}$

$Z_T = \frac{50\angle 30}{13,66 + j5} = \frac{50\angle 30^\circ}{14,55\angle 20,1}$

$= 3,44\angle 9,9$

So, combined pf $= \cos 9,9 = \underline{0,985}$

$P_{active} = 3 V I \cos\phi \qquad I = \frac{V\angle 0}{Z} = \frac{144,34\angle 0^\circ}{3,44\angle 9,9}$

$P_{active} = 144,34 \cdot 41,96 \cdot 0,985 \times 3 \qquad = 41,96\angle -9,9$

$= 17896,674$ watt

$\approx \underline{17,897\ KW}$

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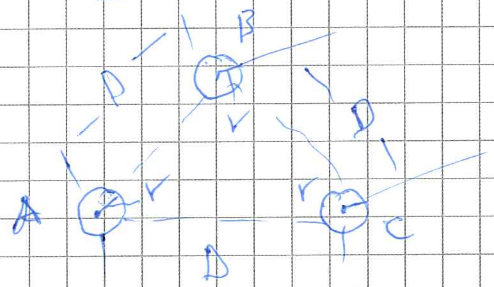
(d)

Conductors



Balanced condition

$I_a + I_b + I_c = 0$

If we take for the flux linkage of Conductor (A)

$\lambda_a = \frac{\mu_0}{2\pi} I_a \ln \frac{1}{r} + \frac{\mu_0}{2\pi} I_b \ln \frac{1}{D} + \frac{\mu_0}{2\pi} I_c \ln \frac{1}{D}$

λ_a - linkage due to the three conductors

$\lambda_a = \frac{\mu_0}{2\pi} I_a \ln \frac{1}{r} + (I_b + I_c) \frac{\mu_0}{2\pi} \ln \frac{1}{D}$

$I_a + I_b + I_c = 0$

$I_b + I_c = -I_a$

$\lambda_a = \frac{\mu_0}{2\pi} I_a \ln \frac{1}{r} - \frac{\mu_0}{2\pi} I_a \frac{1}{D} \rightarrow$

$\lambda_a = \frac{\mu_0}{2\pi} I_a \underbrace{\left(\ln \frac{1}{r} - \ln \frac{1}{D} \right)}_{} = \ln \frac{D}{r}$

$\lambda_a = \frac{\mu_0}{2\pi} I_a \ln \frac{D}{r}$

Inductance $L = \frac{\lambda_a}{I_a} = \frac{\frac{\mu_0}{2\pi} I_a \ln \frac{D}{r}}{I_a}$

So Inductance

$$L = \frac{\mu_0}{2\pi} \ln \frac{D}{r}$$