1 a) a 3φ TL deliver 200 MVA at 220 kV over a distance of 75 km. The loss in MW is not to exceed 2,8 % of the rated line in MVA. Resistivity of the conductor $2{,}84 \cdot 10^{-8}\ \Omega m$

$S_{loss} = 200\,MVA \cdot 2{,}8\% = 5{,}6\ MVA$

$I_{line} = \frac{S}{\sqrt{3}\ V_L} = \frac{200\ MVA}{\sqrt{3} \cdot 220\ kV}$

$I_{line} = 524{,}86$

$R = \frac{S_{loss}}{3\ I^2} = \frac{5{,}6\ MVA}{3 \cdot 524{,}86^2} = 6{,}776\ \Omega$

$R = \frac{\rho \cdot L}{A} \Rightarrow A = \frac{\rho \cdot L}{R}$

$A = \frac{2{,}84 \cdot 10^{-8}\ \Omega m \cdot 75\,000\ m}{6{,}776\ \Omega}$

$A = 0{,}000314\ m^2 = 3{,}14\ cm^2$

$\left(\frac{D}{2}\right)^2 \cdot \pi = \pi\ cm^2$

$D = \sqrt{4} = 2\ cm$

Emnekode : ENE 229
Kandidatnr. : 507
Dato : 27/05-19
Ark nr. : 2 av 14

1 a) 50Hz-3Φ line with horizontal spacing 12 m. Bundle with conductors is 0,25 m, and radius 1 cm. Calculate inductance and reactance

$$GMD = \sqrt[3]{12 \cdot (2 \cdot 12) \cdot 12} = 15,12\ m$$

$$GMR_L = \sqrt[3]{1 \cdot 0,7788 \cdot 25 \cdot 25} = 7,866\ cm$$

$$GMR_C = \sqrt[3]{1 \cdot 25 \cdot 25} = 8,55\ cm$$

$$L = 0,2 \cdot \ln \cdot \frac{15,12}{0,07866} = \underline{\underline{1,0517\ mH/km}}$$

$$X_L = 2\pi \cdot 50 \cdot 1,0517\ mH/km = 330\ m\Omega/km$$

$$C = \frac{2\pi \cdot 8,85 \cdot 10^{-12}}{\ln \frac{15,12}{0,0855}} = \underline{\underline{0,0107\ \mu F/km}}$$

$$X_C = \frac{1}{2\pi \cdot 50 \cdot 0,0107\ \mu F/km}$$

Emnekode : ENE 229

Kandidatnr. : 507

Dato : 27/05-19

Ark nr. : 3 av 14

1c) 50 Hz - 200 km long TL has a

$Z = 30 + 100j$ and $Y = 0{,}001j$ ℧

$P_r = 100$ MW at 220 KV (line to line) with 0,9 PF lagging. find V_s, I_s, PF and Power

$$|I| = \frac{100\ MW}{0{,}8 \cdot 220} = 568{,}18\ A$$

$$\theta = \cos^{-1}(0{,}9) = 25{,}84°$$

$$I = 568{,}18 \angle -25{,}84\ A$$

$$\begin{bmatrix} V_s \\ I_s \end{bmatrix} = \begin{bmatrix} \left(1 + \frac{ZY}{2}\right) & Z \\ Y\left(1 + \frac{ZY}{4}\right) & \left(1 + \frac{ZY}{2}\right) \end{bmatrix} \cdot \begin{bmatrix} V_R \\ I_R \end{bmatrix}$$

$$\begin{bmatrix} V_s \\ I_s \end{bmatrix} = \begin{bmatrix} 0{,}95 \angle 0{,}9 & 104{,}4 \angle 73{,}3 \\ 0{,}0009 \angle 90 & 0{,}95 \angle 0{,}9 \end{bmatrix} \cdot \begin{bmatrix} 220\,KV/\sqrt{3} \\ 568{,}18 \angle -25{,}84 \end{bmatrix}$$

$$\begin{bmatrix} V_s \\ I_s \end{bmatrix} = \begin{bmatrix} 173900 \angle 11{,}3 \\ 469{,}8 \angle -27{,}98 \end{bmatrix}$$

$$V_s = \sqrt{3} \cdot 173900 \angle 11{,}3 = 301{,}203 \angle 11{,}3\ KV$$

$$I_s = 469{,}8 \angle -27{,}98\ A$$

iii) $PF = 11{,}3 + 27{,}98 = 39{,}28$

$PF = \cos(39{,}28) = 0{,}774$

iiii) $S = V \cdot I^* = 301{,}203 \angle 11{,}3\,K \cdot 469{,}8 \angle -27{,}98\,A$

$$S = 141{,}5 \angle 39{,}28\ MVA$$

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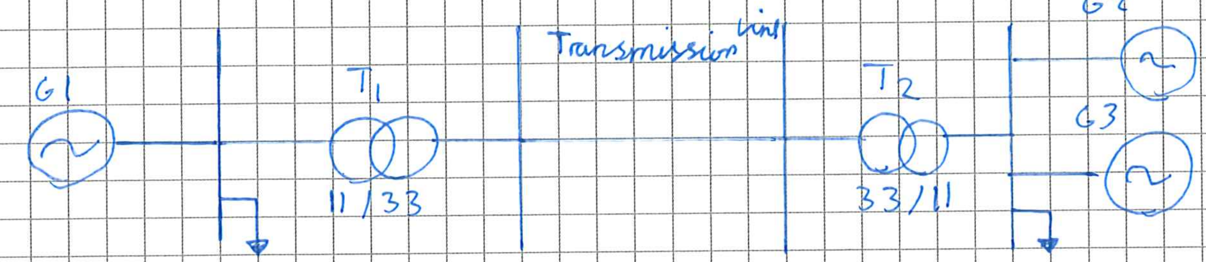
Emnekode : ENE 229

Kandidatnr. : 507

Dato : 27/05-19

Ark nr. : 4 av 14

2a)



$X_{G1} = 1{,}6 \cdot \frac{30}{11^2} = \underline{0{,}396\ PU}$

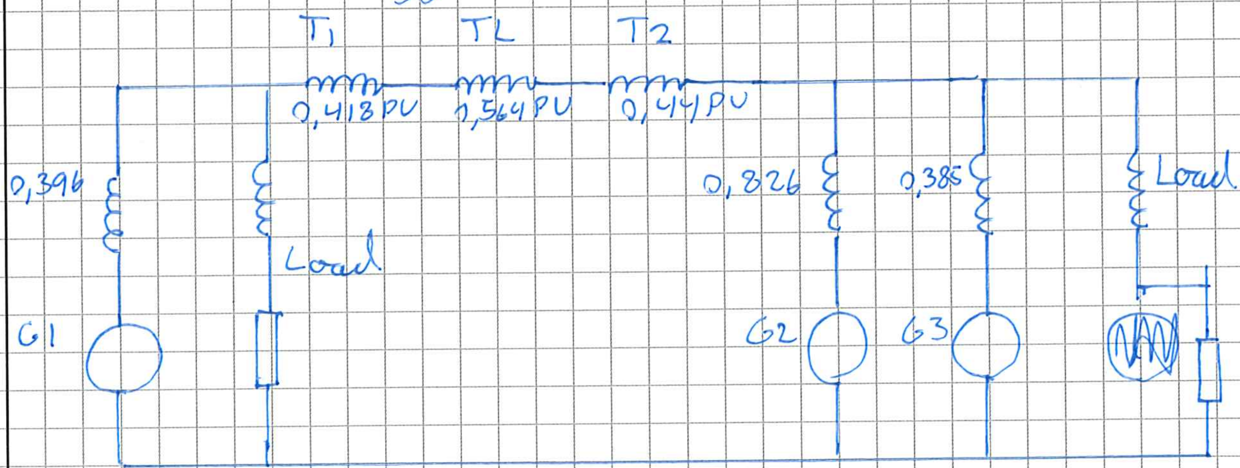
$X_{G2} = 1{,}2 \cdot \frac{30}{6{,}6^2} = \underline{0{,}826\ PU}$

$X_{G3} = 0{,}56 \cdot \frac{30}{6{,}6^2} = \underline{0{,}385\ PU}$

$X_{T1} = 15{,}2 \cdot \frac{30}{33^2} = \underline{0{,}418\ PU}$

$X_{T2} = 16 \cdot \frac{30}{33^2} = \underline{0{,}44\ PU}$

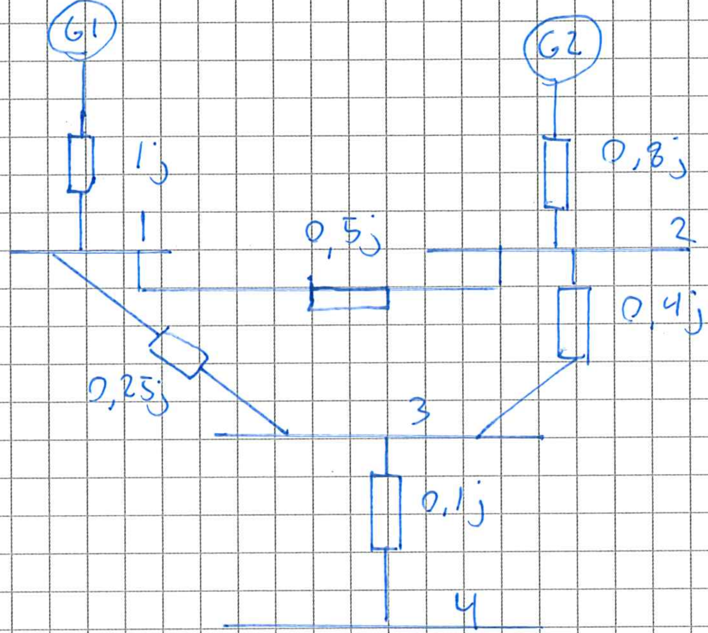
$X_{TL} = 20{,}5 \cdot \frac{30}{33^2} = \underline{0{,}564\ PU}$



UNIVERSITETET I AGDER

Emnekode : ENE 229
Kandidatnr. : 507
Dato : 27/05-19
Ark nr. : 5 av 14

2 a) b)



Find the Y bus

	Z	Y
G1	1j	-1j
G2	0,8j	-1,25j
Line 1-2	0,5j	-2j
Line 1-3	0,25j	-4j
Line 2-3	0,4j	-2,5j
Line 3-4	0,1j	-10j

$$Y_{bus} = \begin{bmatrix} Y_{12}Y_{13}+Y_{G1} & -Y_{12} & -Y_{13} & 0 \\ -Y_{12} & Y_{12}Y_{13}+Y_{G2} & -Y_{23} & 0 \\ -Y_{13} & -Y_{23} & Y_{13}Y_{23}Y_{34} & -Y_{34} \\ 0 & 0 & -Y_{34} & Y_{34} \end{bmatrix}$$

$$Y_{bus} = \begin{bmatrix} -7j & 2j & 4j & 0 \\ 2j & -5,75j & 2,5j & 0 \\ 4j & 2,5j & -16,5j & 10j \\ 0 & 0 & 10j & -10j \end{bmatrix}$$

3 a

Generator delivering 1PU and $V_t = 1$ PU.
Voltag at infinity bus $V_b = 1\angle 0°$ PU

i) Calculate the terminal voltage angle and current fed into infinite bus

$$P = \frac{E_A \cdot V_b}{X} \sin\delta \Rightarrow$$

$$\sin\delta = \frac{P \cdot X}{E_A \cdot V_b} = \frac{1 \cdot 0{,}35}{1 \cdot 1} = 0{,}35$$

$$\delta = \sin^{-1}(0{,}35) = 20{,}5$$

$$E_a = V_b + X_j I \Rightarrow I = \frac{E_a - V_b}{X_j}$$

$$I = \frac{1\angle 20{,}5 - 1\angle 0°}{0{,}35j} = 1 + 0{,}18j$$

ii) Calculate the generator internal voltage

$$E_A = V_b + X_j I = 1 + 0{,}6j \cdot (1 + 0{,}18j)$$

$$E_A = 1{,}075 \angle 33{,}92 V$$

iii) Calculate the maximum power when both lines are healthy

P max when $\sin\delta = 1$

P max healthy $P = \frac{E_A \cdot V_b}{X} = \frac{1{,}075 \cdot 1}{0{,}6}$

$$P = 1{,}79 = P_{max} \sin\delta$$

~~P max = 1,79~~

UNIVERSITETET I AGDER

Emnekode : ENE 229
Kandidatnr. : 507
Dato : 27/05-19
Ark nr. : 7 av 14

3a

iv) Calculate the maximum power when one transmission line is open

$$P_{max\ fault} = \frac{E_A \cdot V_\infty}{x} = \frac{1{,}075}{0{,}85} = 1{,}264$$

$P_{max} \sin\delta = 1{,}264$

v) Plot the power angle curves

3b) 2-poles, 50 Hz generator has ratings 250 MVA with 0,8 PF lagging. Kinetic energy 1080 MJ. Generator delivering 60 MW with 8 electrical degrees to a load. Determine the acceleration when load is removed

$$H = \frac{\text{Kinetic energy}}{S\ \text{base}} = \frac{1080\ MJ}{250\ MVA} = 4,32\ MJ/MVA$$

$$\frac{2H}{\omega_s} \cdot \frac{d^2\delta}{dt^2} = P_m - P_e \Rightarrow \frac{d^2\delta}{dt^2} = \frac{\omega_s}{2H} \; P_m - P_e$$

$$\frac{d^2\delta}{dt^2} = \frac{2\pi \cdot 50}{2 \cdot 4,32} \cdot \frac{60}{250} = 8,72\ rad/s^2$$

$$= 83,3\ rpm/s$$

$$= 500\ deg/s^2$$

$$\frac{d^2\delta}{dt^2} = 8,72\ rad/s^2$$

$$\delta = \frac{1}{2}(500\ deg/s^2)\, t^2 + 8\ deg$$

UNIVERSITETET I AGDER

Emnekode : ENE 229
Kandidatnr. : 507
Dato : 27/05-19
Ark nr. : 9 av 14

3 c

Two generators of 200 MW and 600 MW operate at 60 Hz. The system load increase by 150 MW when both of the operate at half of their capacity. A frequency falls to 49,6 Hz. Generators share the load increase proportional

i) What should be their individual regulations

$$P_1 = 150\ MW \cdot \frac{200\ MW}{800\ MW} = 37{,}5\ MW$$

$$P_2 = 150\ MW \cdot \frac{600\ MW}{800\ MW} = 112{,}5\ MW$$

$$R_1 = -\frac{\Delta f}{P_1} = -\frac{(-0{,}4)}{37{,}5\ MW} = \underline{0{,}0106\ Hz/MW}$$

$$R_2 = -\frac{\Delta f}{P_1} = -\frac{(-0{,}4)\ Hz}{112{,}5\ MW} = \underline{0{,}00355\ Hz/MW}$$

ii) What should the regulations be if expressed in PU?

$$R_{1\,PU} = \frac{0{,}0106\ Hz/MW \cdot 200 MW}{50\ Hz} = \underline{0{,}0426\ PU}$$

$$R_{2\,PU} = \frac{0{,}00355\ Hz/MW \cdot 600 MW}{50\ Hz} = \underline{0{,}0426\ PU}$$

UNIVERSITETET I AGDER

Emnekode : ENE 229

Kandidatnr. : 507

Dato : 27/05-19

Ark nr. : 10 av 14

4 Boost converter $L = 100 \mu H$

$V_{in} = 15\,V$ $D = 0{,}5$ $P_o = 30\,W$ $f_s = 150\,KHz$

a) Calculate and draw control signal Q, inductor current and voltage and diode current.

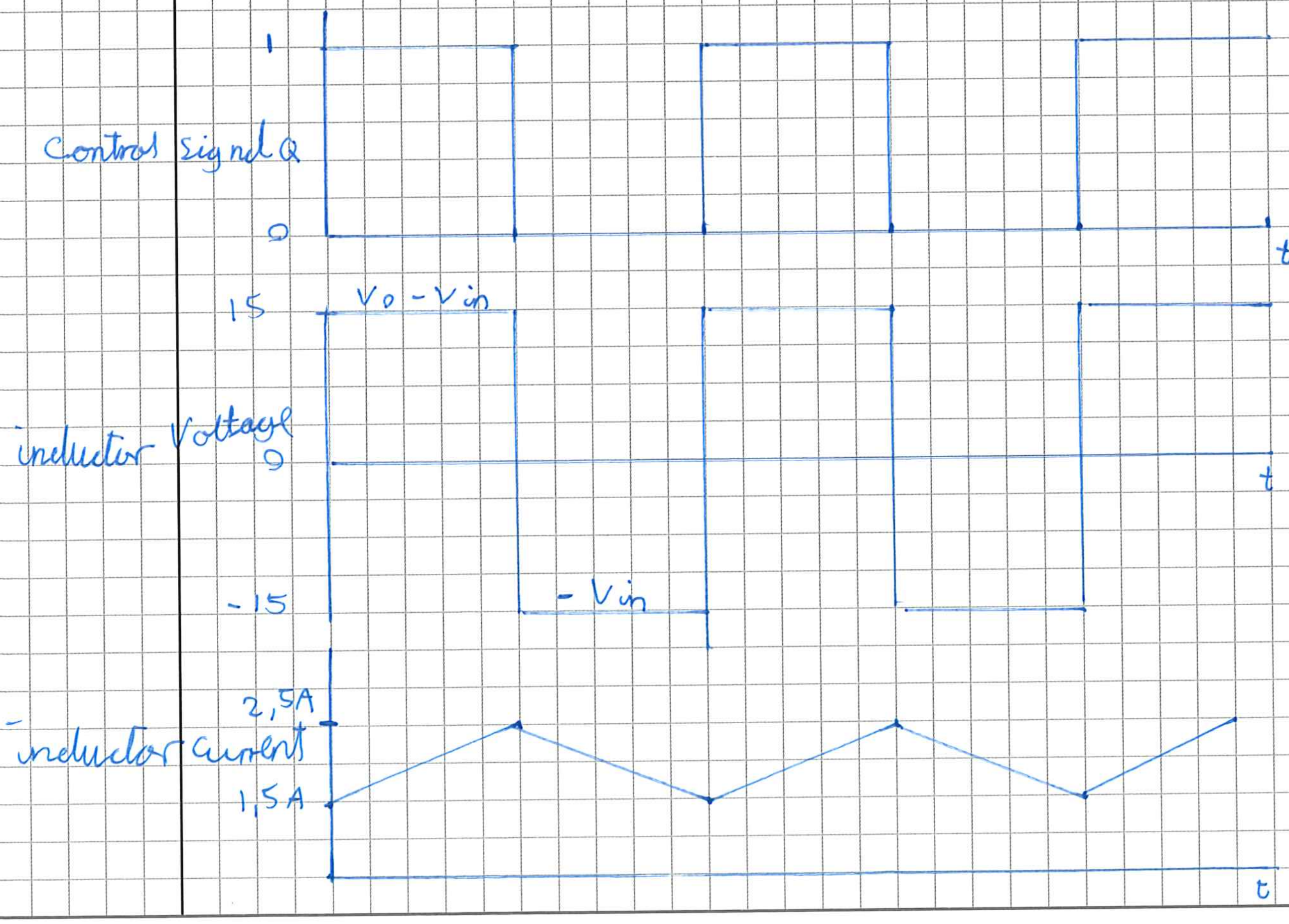
ideal boost converter => $P_o = P_{in}$

$$P_{in} = I_{in} \cdot V_{in} \Rightarrow I_{in} = \frac{P_{in}}{V_{in}} = \frac{30}{15} = 2\,A$$

$$V_o = \frac{1}{1-D} \cdot V_{in} = 30\,V$$

$$I_o = \frac{P_o}{V_o} = \frac{30\,W}{30\,V} = 1\,A$$

$$\Delta i_L = \frac{1}{L}(V_o - V_{in})(1-D)\frac{1}{f_s} = 0{,}5\,A$$



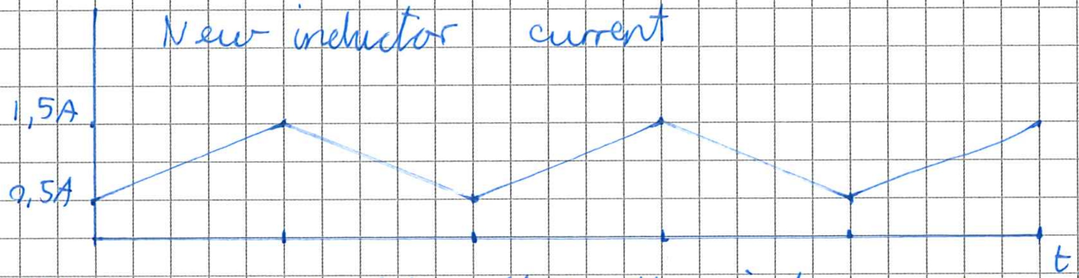
Emnekode : ENE 229
Kandidatnr. : 507
Dato : 27/05-19
Ark nr. : 11 av 14

Diode current

b) if $P_o = 15\,W$, draw the inductor current waveform

$$I = \frac{P_1}{V_1} = \frac{15W}{15V} = \underline{1A}$$

New inductor current



The power don't affect the ripple, so the ripple in both cases are the same.

c) In the boost converter, the output load is changing, calculate the critical value of the load P_o wich the converter enters discontinuous

$\Delta i_L = 0,5\,A$

$$I_{crit} = \frac{\Delta i_L}{2} = 0,25\,A$$

$\underline{P_{o\,crit} = 0,25A \cdot 30V = 7,5\,W}$

4 D

Calculate the ~~value~~ Critical value of the inductance L wich the converter will enter discontinious mode at Po = 5 W.

$I_{crit} = \frac{P_o}{V_o} = \frac{5W}{30V} = 0{,}167\ A$

$\Delta i_L = 2 \cdot I_{crit} = 0{,}33\ A$

$\Delta i_L = \frac{1}{L}(V_o - V_{in})(1-D)\frac{1}{f_s}$

$L = \frac{1}{\Delta i_L}(V_o - V_{in})(1-D)\frac{1}{f_s}$

$L = 150\ \mu H$

UNIVERSITETET I AGDER

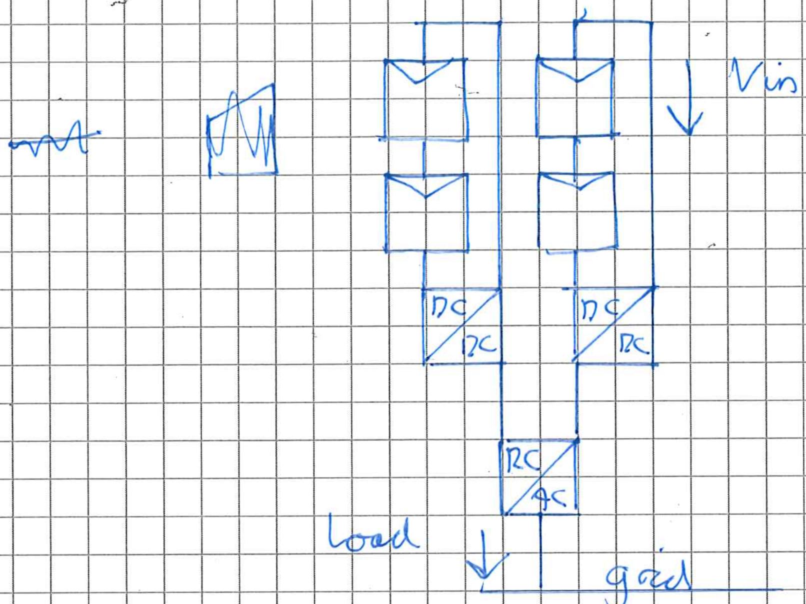
Emnekode : ENE 229

Kandidatnr. : 507

Dato : 27/05-19

Ark nr. : 13 av 14

a



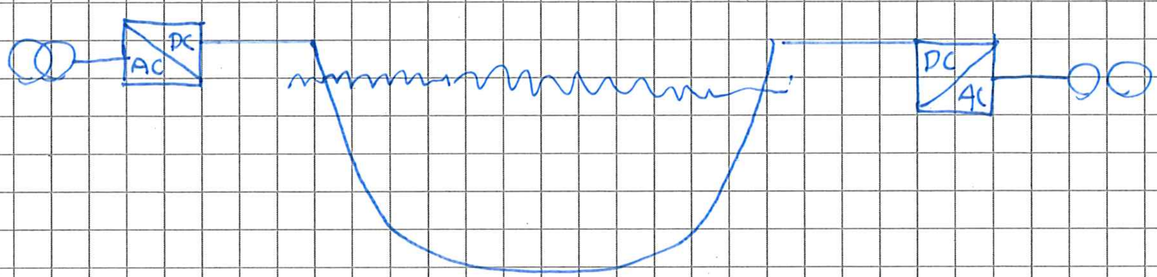
Multstring system. Using MPPT to adjust the load to ~~maxi~~ get the most power out of the panels. Converters make sure that the voltage output one the panels are on the same voltage level.

UNIVERSITETET I AGDER

Emnekode : ENE 229
Kandidatnr. : 507
Dato : 27/05-19
Ark nr. : 14 av 14

5

C) Draw a simple diagram of underground HVDC. What is the main advantage using HVDC



The main advantage using HVDC is it just Ω loss, you don't need to compensate with capacitors.

D) Write four voltage control methods used in electricity grid.

- DC/DC converter, used in solarpharms to get all the panels to operate/deliver sam voltage level. Multi string
- AC/AC converter, transformer (Up/down voltage)
- DC/AC inverter and DC/AC rectifiers used in HVDC lines and control units in wind turbines type 3 and 4.

E) 4 techical solutions for Re

- Storage, (hydro, batteries, .
- Stronger grid systems, Lines with other countries
- Use hydro power when there is no wind and sun.
- Lower cost for materials/converters. Also better control on new wind turbines/solar panels.