PASD

Assignment - 2

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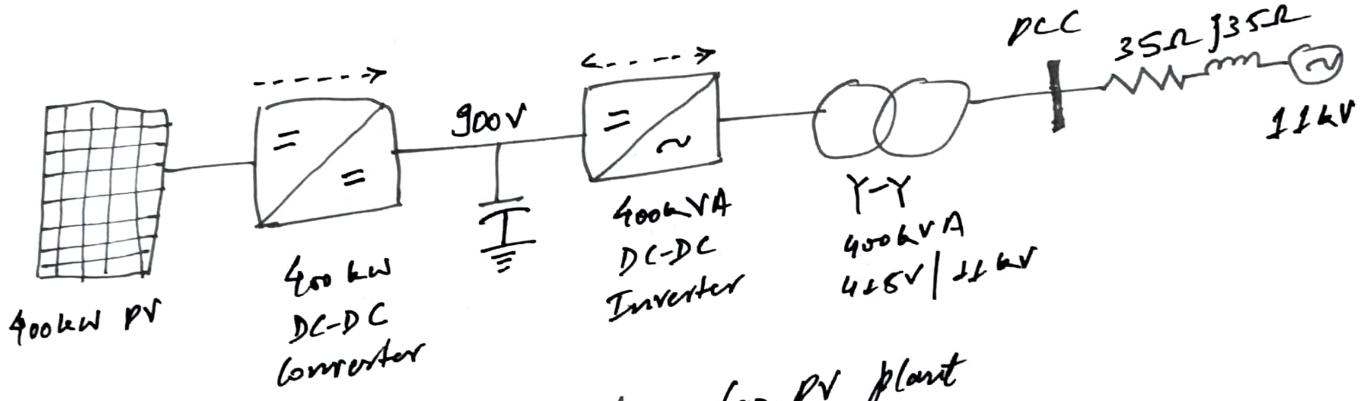


Grid Connected solar PV plant

Calculating energy & power imbalance

We take each time interval for which V_{pcc} remains constant and then find the active power supplied to the grid by multiplying V_{pcc} with active current. Active current is found by the formula $\sqrt{I^2-\Delta I_q^2}$ where I is the inverter current magnitude. Multiplying power with time gives the energy. We then subtract the power/energy supplied to the power grid from the power/energy generated (400 kW PV) to get the power/energy imbalance. V_{nom} is nominal PCC voltage & I_{nom} is the nominal current of the plant.

$t = 0$ to $0.3s$

$V_{pcc} = 0.15pu = 0.15\,V_{nom}$, $\Delta I_q = 1pu = I_{nom}$

Inverter current $I = 1.25pu$ (current $1.25pu$ till $1s$)

$\therefore$ Active current $I_q = \sqrt{I^2 - \Delta I_q^2} = \sqrt{1.25^2 - 1^2}\ pu = 0.75pu$

$= 0.75\ I_{nom}$

Active power to grid $= 0.15 \times 0.75 \times V_{nom} \times I_{nom} = 0.1125\ V_{nom} I_{nom}$

Energy to grid $= 0.15 \times 0.75 \times V_{nom} \times I_{nom} \times 0.3 = 0.03375\ V_{nom} I_{nom}$

$t = 0.3s$ to $1s$

$V_{PCC} = 0.45pu = 0.45\ V_{nom}$

from ΔI_q curve, $\Delta I_q = 1 - (V_{pcc} - 0.3) \times \frac{1}{0.85 - 0.3}$

$\Rightarrow \Delta I_q = 0.7273pu = \frac{8}{11} pu$

$I_r = \sqrt{1.25^2 - (8/11)^2}\ pu = 1.0166\ pu = 1.0166\ I_{nom}$

Energy to grid $= 0.320229\ V_{nom} I_{nom}$

$t = 1$ to $2s$

$V_{PCC} = 0.45\ pu = 0.45\ I_{nom}$

$\Delta I_q = 0.7273\ pu$, Now I is $1pu$.

$I_r = \sqrt{1^2 - \left(\frac{8}{11}\right)^2}\ pu = 0.6863pu = 0.6863\ I_{nom}$

Active power to grid $= 0.45 \times 0.6863\ V_{nom} I_{nom}$

$= 0.308835\ V_{nom} I_{nom}$

$t = 2s$ to $5s$

$V_{PCC} = 0.65pu = 0.65\ V_{nom}$

from ΔI_q curve, $\Delta I_q = 1 - (V_{PCC} - 0.3) \times \frac{1}{0.85 - 0.3}$

$\Rightarrow \Delta I_q = 1 - \frac{0.65 - 0.3}{0.85 - 0.3} = \frac{4}{11} pu = 0.3636\ pu$

$I_r = \sqrt{1^2 - \left(\frac{4}{11}\right)^2}\ pu = 0.9315pu = 0.9315\ I_{nom}$

Active power to grid $= 0.65 \times 0.9315\ V_{nom} I_{nom} = 0.605475\ V_{nom} I_{nom}$

Energy to grid $= 0.605475 \times 3 \times V_{nom} \times I_{nom} = 1.816425\ V_{nom} I_{nom}$.

Total energy supplied to grid = $V_{nom} \times I_{nom}$ (0.03375 + 0.320229 + 0.308835 + 1.816425)

= 2.479239 $V_{nom} I_{nom}$

After 5 s, the PCC voltage remains to the nominal value.
Energy supplied by PV during this time = 400 kW × 5 s
= 2000 kWs.

Now, $V_{nom} \times I_{nom}$ = 400 kW
Energy supplied to grid = (2.479239 × 400) kJ = 991.6956 kJ
∴ Energy Imbalance = (2000 − 991.6956) kJ
= 1008.3044 kJ

Now, maximum power imbalance occurs upon when the active power supplied to grid is min.
Minimum active power supplied to grid is during 0 to 0.3 s and has value of 0.1125 $V_{nom} I_{nom}$ = 45 kW.
∴ Maximum power imbalance = (400 − 45) kW = 355 kW

1(a) Peak power rating of DC-DC ~~to~~ bidirectional converter for interfacing energy voltage with DC bus is 355 kW.

1(b) Total energy absorbed by storage unit = energy imbalance
= 1008.3044 kJ.

The DC-DC bidirectional converter has voltage rating of (600 V ± 10%)/300 V. So low voltage side voltage can vary from 540 V to 600 V. Let us consider 10 supercapacitor units of 55 V, 130 F rating connected in series. Thus voltage across the combination = 550 V, which is within low voltage side rating of DC-DC bidirectional converter.

$\therefore$ Energy stored $= 5 \times 130 \times 55^2 = 1966.25\,KJ$

~~Energy stored~~

If we want the amount of energy that can be stored to be equal to energy unbalance, then:

$$\frac{1}{2}CV_1^2 + \frac{1}{2}CV_2^2 + \; - - - \; + \frac{1}{2}CV_n^2 = 1008.3044 \times 10^3$$

$$V_1^2 + V_2^2 + V_3^2 + - - - + V_n^2 = V_{total} \quad (n = \text{no. of supercapacitors})$$

Now, the supercapacitors are identical, so we assume $V_1 = V_2 = - - V_n = \frac{V_{total}}{n}$. Also, let $V_{total} = 600V$ then.

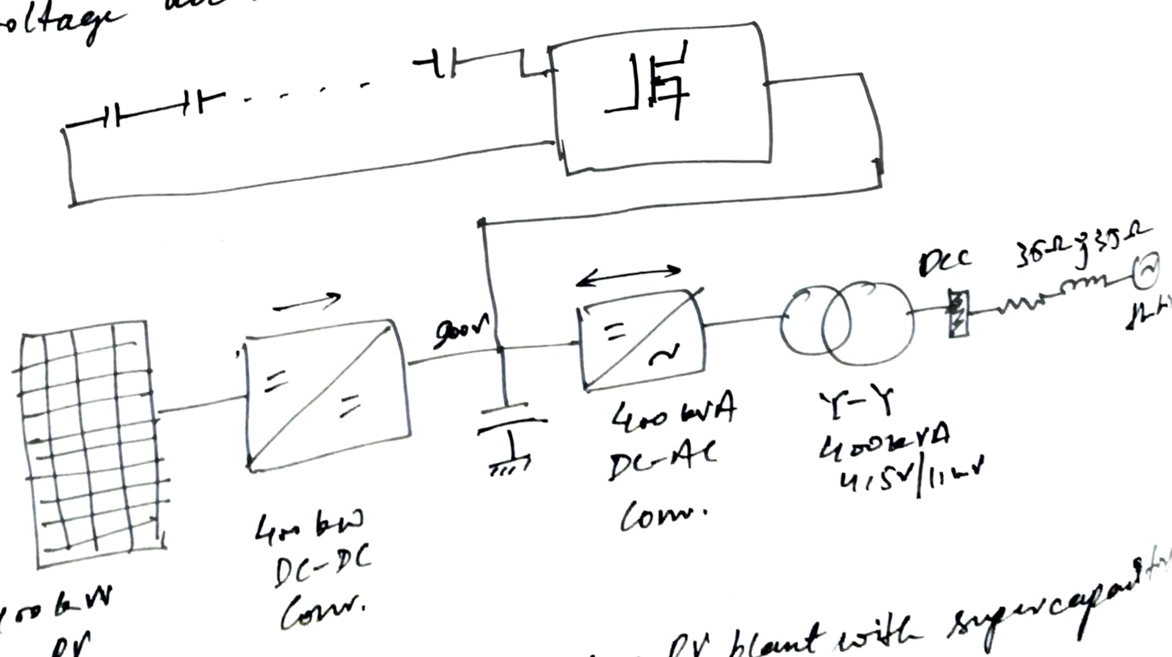
$$n \times \frac{1}{2} \times C \times \left(\frac{V_{total}}{n}\right)^2 = 1008.3044 \times 10^3$$

$$\frac{1}{2} \times 130 \times \frac{600^2}{n} = \quad "$$

$$\Rightarrow \quad n = 23.207 \approx 23$$

$\therefore$ 23 supercapacitors in series may be connected, with voltage across each being $\left(\frac{600}{23}V\right) = 26.09V$

1(c)



Grid connected solar PV plant with supercapacitor energy voltage.

Q. (a) We consider 2V, 400 Ah lead acid battery units with a 1/5 rate for safe charge / discharge, the battery can be charged / discharged by = 400/5 ie 80A current flowing for 5 hours.

Now charge flowing ~~rate~~ into the battery with a 80A charging current flowing for 5 seconds is : $2 \times 80 \times 5$ J = 800 J

Now, total energy to be stored = 1008.2044 J

let the number of batteries = n.

$$n \times 800 = 1008.2044 \times 10^3 \Rightarrow n = 1260.38 = 1260$$

let us consider 4 battery units in parallel. Number of such units for a total of 1260 batteries $= \frac{1260}{4} = 315$.

Each such combination of 4 battery units in parallel gives a voltage of 2V.

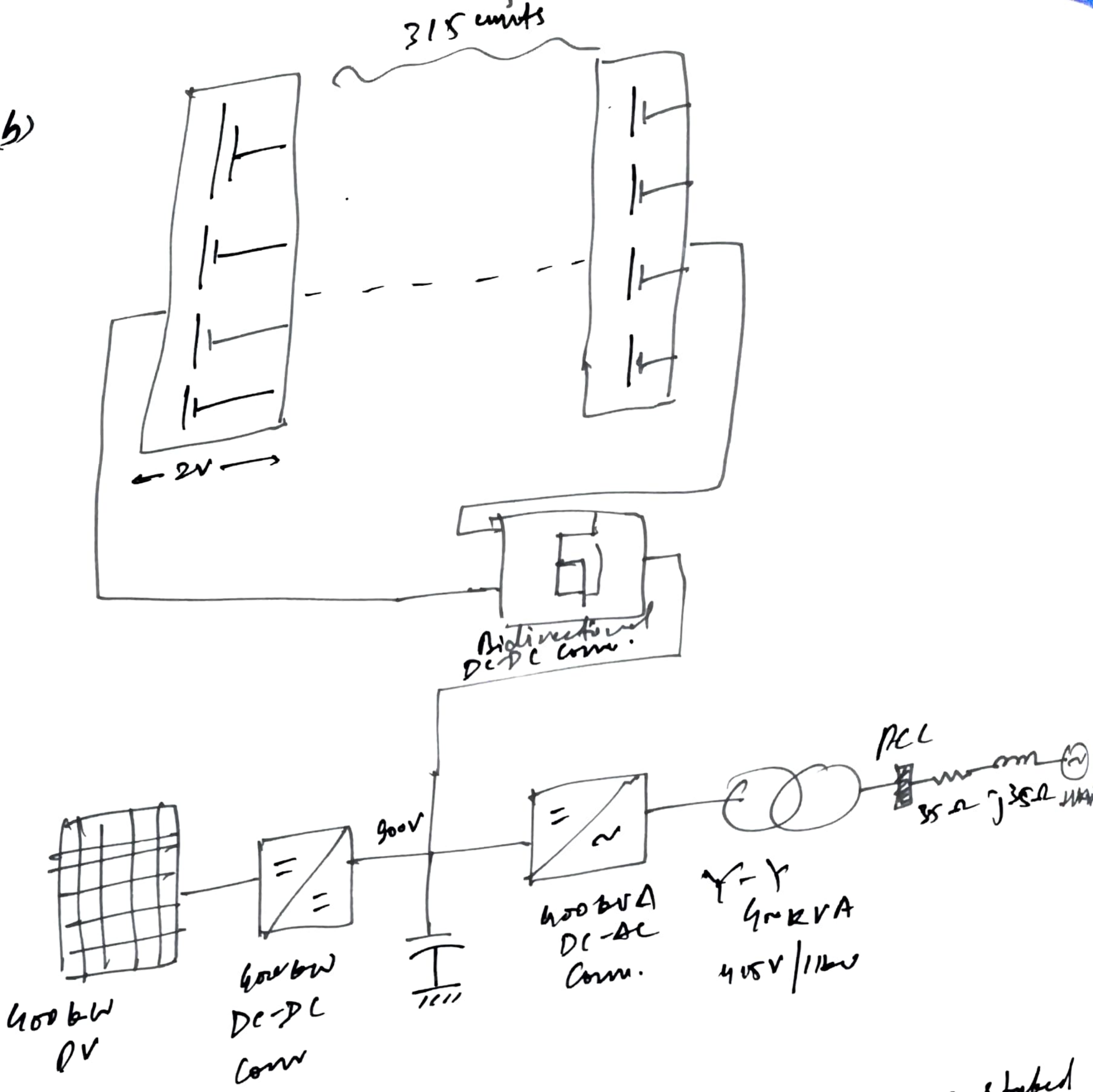
∴ 315 such combinations in series gives: 2×315V = 630V.

which is within range of voltage rating of DC-DC bidirectional converter.

Also, the maximum power from the batteries $= 1260 \times 2 \times 80$W
$= 201.6$ kW

which is less than peak power voltage of the DC-DC bidirectional converter.

2(b)



3. For supercapacitors fails, series of capacitors were stacked specially 23.
For battery units, we used a parallel combination of four batteries & connected 315 such units in series.
The total energy capacity for battery units ≈ 1008 kJ.
the supercapacitor is for model more ideal component than the battery lifetime & lifecycle is superior to batteries.
they have extremely high power & high current capability at a wide temperature range.

Moreover modelling of capacitor is easier as compared to that of battery. Hence simulation of capacitors become much simpler than those of batteries.