Indian Institute of Science

Design of Photovoltaic Systems

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NPTEL Online Certification Course

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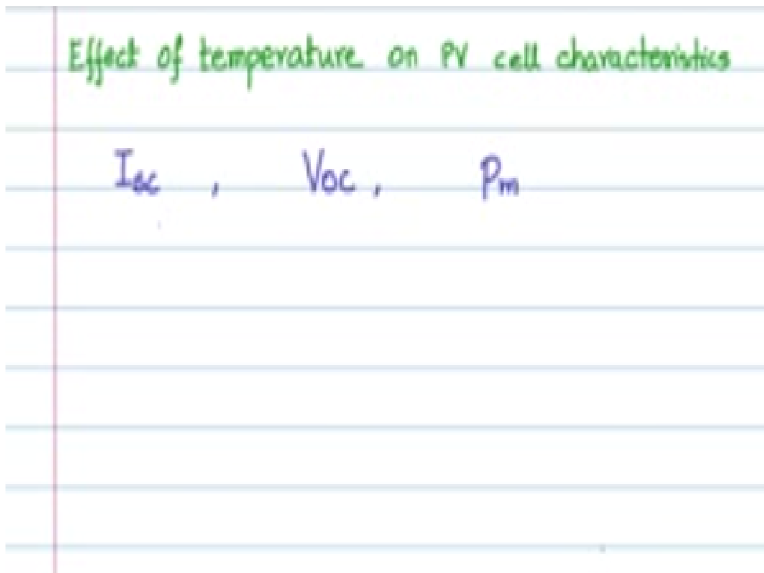

In this clip let us look at the effect of temperature on the PV cell characteristics there are 3 important parameters one is I_{SC} the short circuit current and then you have the Voc open circuit voltage and you have Pm the max power of the Pv cell or the peak power of the Pv cell now how does these 3 important parameters vary with temperature let us now have a look at the data sheet and see what are the number and what are the values they give.

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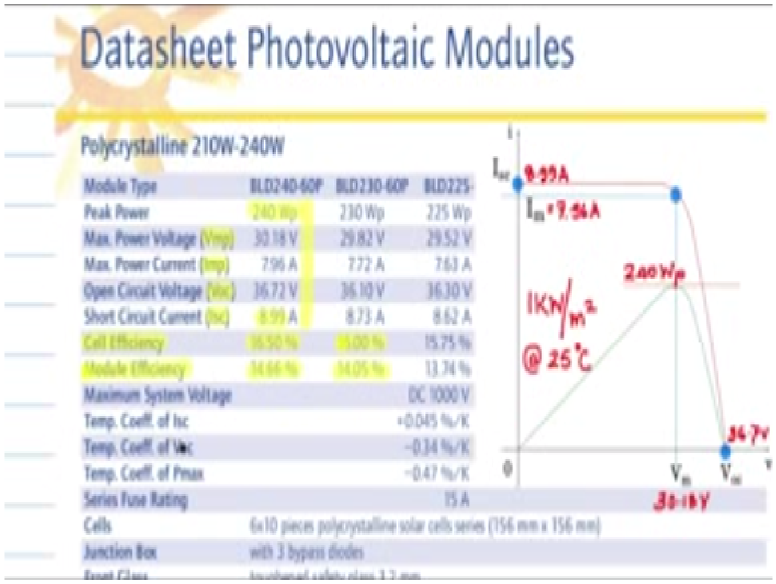

Here in this data sheet you see here there are 3 parameters temperature, coefficient of Isc short circuit current temperature coefficient of Voc temperature coefficient of P max these are the 3 parameters that we would be discussing now see the temperature coefficient Yac is + 0. 045 %/ degree Kelvin and the temperature coefficient of Voc is – 0.34%/ degree k which means that as the temperature increases Voc will decrease same way P max this is understandable because the temperature coefficient of Isc is positive temperature coefficient of Voc is negative the temperature coefficient of power which a product of current and voltage will also be negative.

And that is given as – 0.47%/ degree K, so let us study bit on how these temperature coefficients come about and what is there relationship with respect to temperature.

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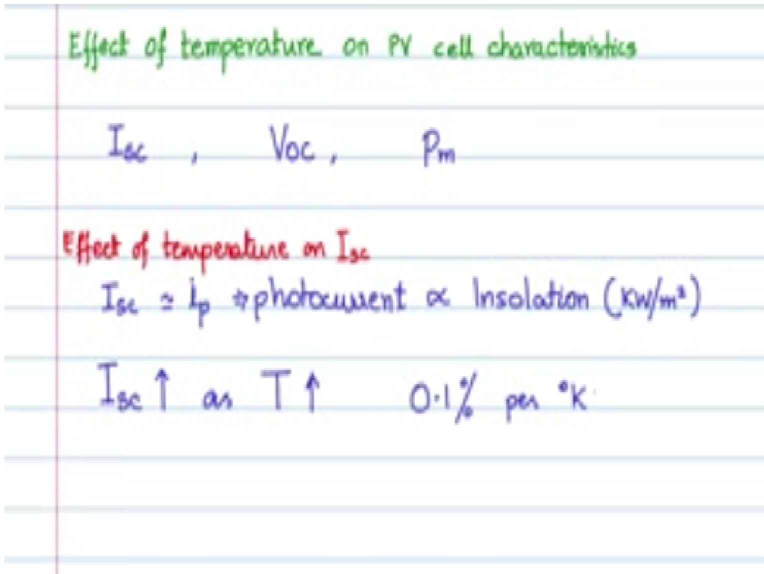

With regard to Isc we know that we have see an earlier clip that Isc is approximately = to the photo current Ip which is the photocurrent and the photocurrent is directly proportional to the isolation is nothing but the power / m^2 of the incident solar radiation so if you see this from this relationship with increase in temperature what will happen to Isc with increase in temperature the photocurrent will increase.

Why should the photocurrent increase the band gab energy reduces the band gab energy was 1.16 electron volts and it will come down and this will allow more wave lengths electrons to jump into the conduction band any way for there are more free electrons and as result more phtoo current and therefore higher value of Isc short circuit current so in summary for the short circuit current the short circuit current Isc increases as temperature increases. And this is very small value it is around 0.1% / ^{0}K or / ^{0} C/ silicon.

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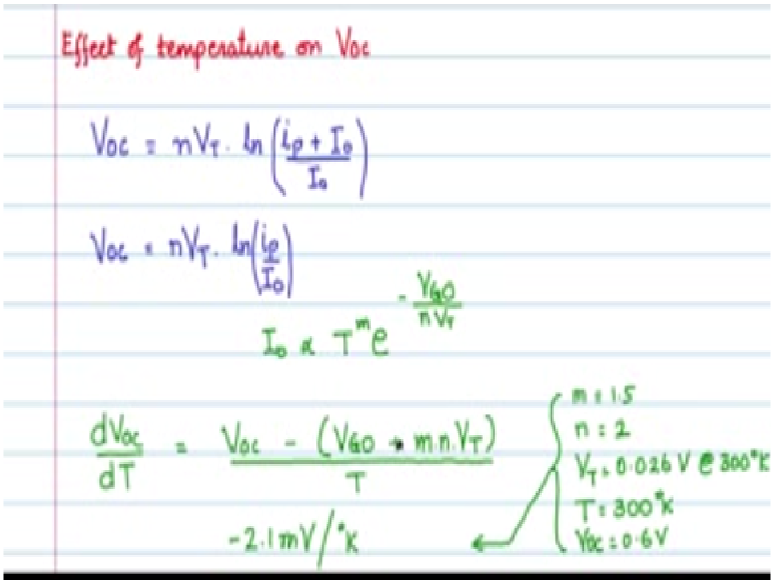

We pick of to the effect of temperature on Voc the open circuit voltage we seen the relationship of Voc with the photocurrent which is given like this and we have seen this equation earlier in another video clip so it is given as this relationship where this is nV_T n is to for silicon V_T is the voltage equivalent of temperature logarithm of Ip the photo current I0 is the reverse saturation current by I0 if you take I0 very small compare to the photocurrent then we can say Voc is = nV_T logarithm of Ip of / I0 the reviser saturation current.

So apparently if you look at this equation it is not directly evident that Voc will decrease if temperature increases however you should note that V_T is a function of temperature where as T/ 11600 I0 is also a function of temperature it is an exponential function of temperature so considering I0 and V_T effect together you will see that Voc is inversely proportional to temperature the reverse saturation current I0 is proportional to temperature to the power of m e^{VG0} recall V_G0 was the numerically voltage equivalent of the band gab energy by an V_T
So you see the dependence of I0 on temperature and substituting this and then trying to find dVoc / dT we get dVoc/ dT as Voc – V_G0 + mnV_T hole over T so you see that for a given temperature we can calculate the rate Voc will change with temperature now if we take values typical values for silicon let us say for silicon m = 1.5 n = 2, V_T = 0.026 mv or 26 v @ 300^0 k how take temperature as 300^0 k and you will and Voc as 0.6 v or a certain cutting voltage.

And you will see that if you apply all these to the above formula you will get approximately – 2.1 m V / ^{0} K what it means that for every cell an junction P variation of the open circuit voltage Voc with temperature is – 2.1mV/ ^{0} K 1^0 C rising temperature will make Voc to fall by 2.1mV how did we get this equation I will quickly run through the derivation you can use the pass mode and try to study how the relationship is with effect of temperature of Voc came about.

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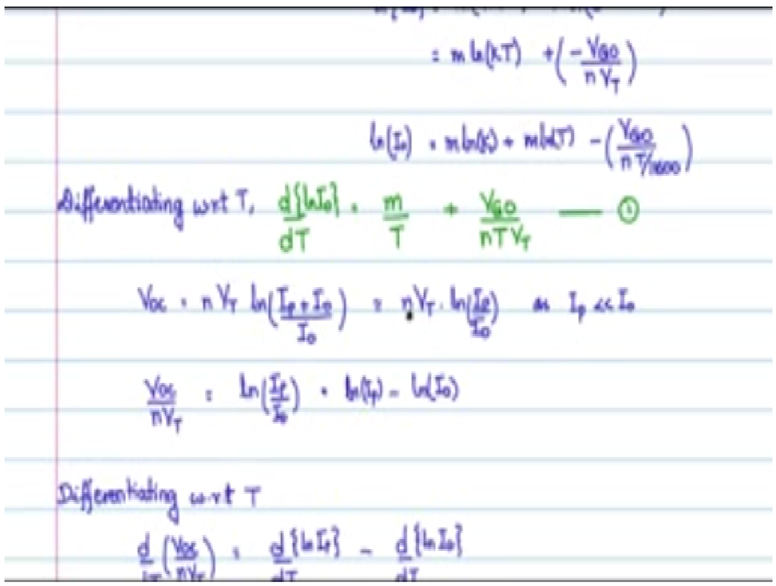

So here I have the derivation for dVoc / dT the derivation is simple but I am not going to explain every step I will just run through it you can use the pause mode on the video clip and read it at your convinces the reverse saturation current V so was five was given by $I0 = K\ T^{m}\ e^{-VG0/nVT}$ where G_0 is the numerically voltage equivalent of the van gab energy m is 1.5 for silicon n is 2 for silicon and V_T the temperature equivalent to the voltage.

Now for this equation take dL logarithm and you will see that it falls into this kind of a relationship and logarithm of I0 is given like this then this equation you differentiate with respect to temperature T so differentiating with respect to temperature you will land up with m / T + V_G0/ nTvT so keep this equation a side next come to the Voc relationship we say that Voc is = nV_T logarithm of Ip + I_0/I_0 and if we take Ip greater than much greater than I0 you will see that it is equal to nV_T log of $I_T/\ I_0$ and this the relationship that falls as the next step.

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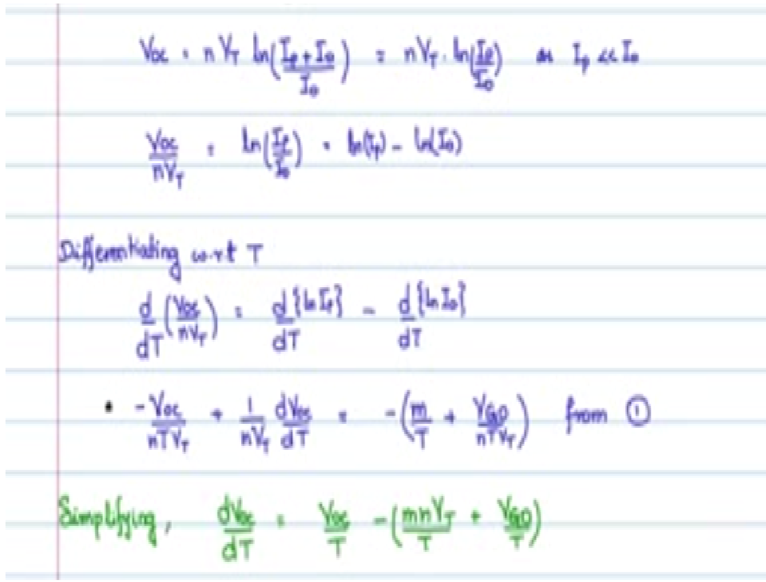

Now differentiate that differentiating this equation with respect to temperature you get d/ dT Voc / nV_T dT/ log of IT – d/ dT log of I0 now d/ dT log of I0 we have all ready derived here so we can directly substitute this value here d/ dT of log of IT is 0 assuming that the variation is good negligible come compare to variation and I0, so as you are having numerator as you are having 2 terms Voc dependent on temperature and VT dependent on temperature splitting it up single product rule. You get this relationship and then simplifying.

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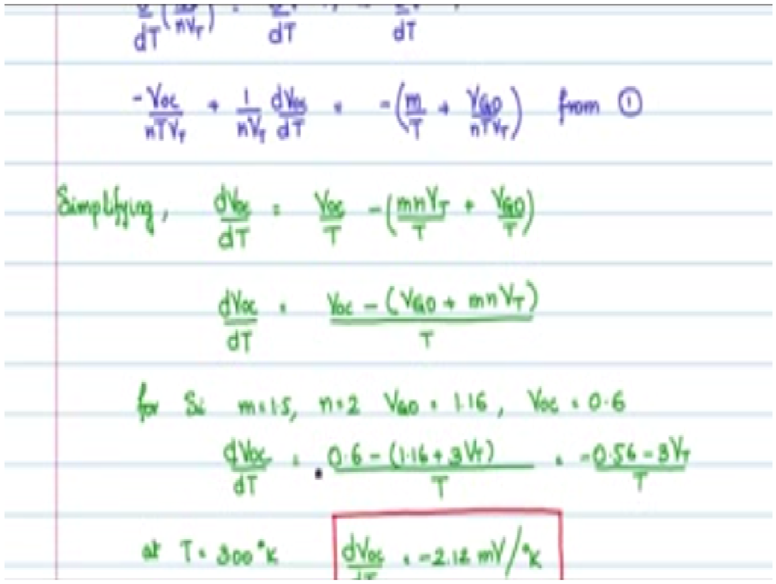

You will see that dVoc / dT = Voc – V_G0 + mn V_T/ T and this is what I had mentioned earlier the see weather almost inverse proportionality of Voc with T now for silicon if you substitute m = 1.5 n = 2 V_G0 = 1.16 electron volts and Voc 0.6 you will land up with T voc / dT as this value and for a temperature of 300 ^{0} K the rate at which Voc changes it – 2.120 v / ^{0} k which mean that for very degree rising temperature open circuit voltage falls by approximately 2mv.

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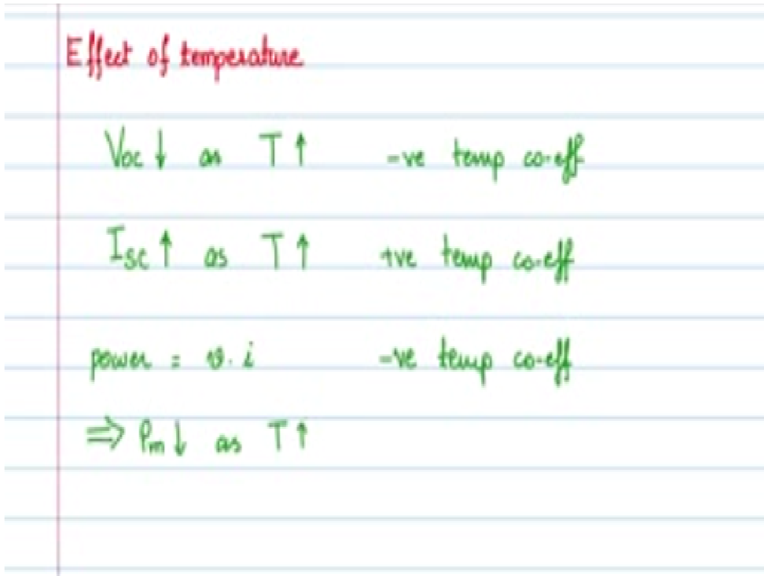

Therefore in the case of Voc we see that Voc will decrease as temperature increases per as in the case of short circuit current Isc we saw that Isc increases as temperature increases and in the case of power being a product of v x i as Voc is having a negative temperature coefficient and Isc is having a positive temperature coefficient so this is negative temperature coefficient this is positive temperature coefficient.

Power will also have a negative temperature coefficient this means this would imply that Pm would decrease as temperature increases so these are the main effects that you would see on the Pv cell parameters due to variation in temperature.

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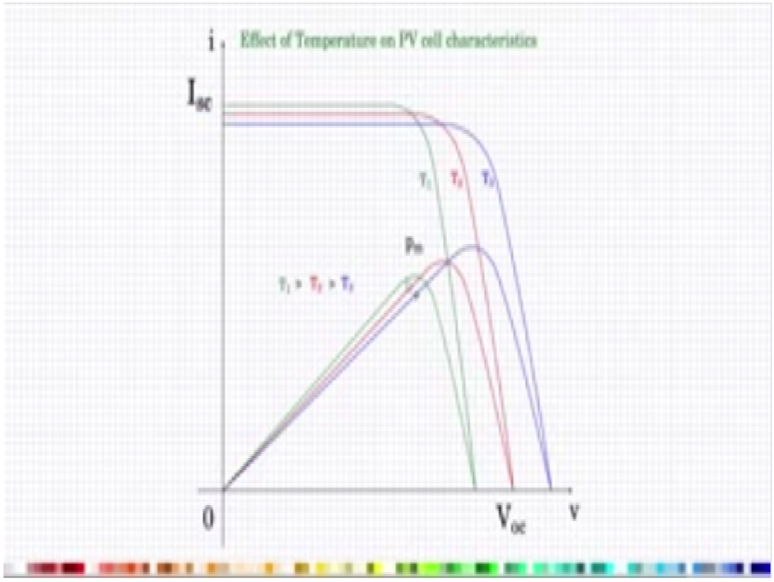

Consider this Iv characteristic of a Pv cell and let us study the effete of temperature on the cell characteristic we have this Iv curve taken x standard insulation on 1 kv / m^2 and standard temperature of 25^0 c now let us say the temperature increases and the temperature incases form 25^0 C TO 40^0 c what is the effect on the cell now let me make a duplicate of this curve let me change color to green and super impose the changed curve the Isc will vary slightly and it will increases with increase in temperature that is what we studied.

And what happens to Voc would decrease with increasing temperature and it will decrease in inverse ratio so the changed characteristic Pv cell characteristic curve would look like this the one show in green so as temperature increases the characteristics shifts in this manner now consider the temperatures replaced with variables T1 and T2 where T2 is the lower temperature and T1 is the higher temperature now what would happen and how will the curve look like if we have 3^{rd} curve which is set at a temperature T3

Such that T1 is> than T2 > T3, T3 is a lower temperature much lower than T1 and T2 so we would expect the curve of a Voc to be on this side of T2 the red line and for Isc because the temperature is lower we would expect it will be low the red lien so this is the curve that is excepted for the Interviewee: characteristic which is set a temperature T3 now looking at the our curve now this is the power curve for the T3 curve.

And this is the peak power that the service get low of giving at temperature T3 now a temperature T2 and T1 the corresponding power curves or like this and you see that the peak powers or decreasing so as the temperature is increasing you will see that the peak powers reduce like this is also calibrating what we just studied that Voc decreases with increase in temperature Isc short circuit current increases with temperature and it is product the peak power decreases with temperature.