Indian Institute of Science

Design of Photovoltaic Systems

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NPTEL Online Certification Course

(Refer Slide Time: 00:19)

We have here a photovoltaic cell the symbol of a photovoltaic cell the terminal voltage V and the terminal current I that is supposed to flow out of the terminal a here is indicated and we also know we have seen before the equivalent circuit model of this photovoltaic cell and that is like this where you have this constant current source representing the photo current the photo current IP is basically directly proportional to the incident solar power.

This is primarily resource rest all other parameters are syncs dissipaters and we shall now try to study this equivalent circuit model a bit further and try to arrive at the equation for the terminal current with respect to the various parameters of the photovoltaic cell so using this model we shall further get some more insight into the photovoltaic cell which will be useful for selection choice of the photovoltaic cell.

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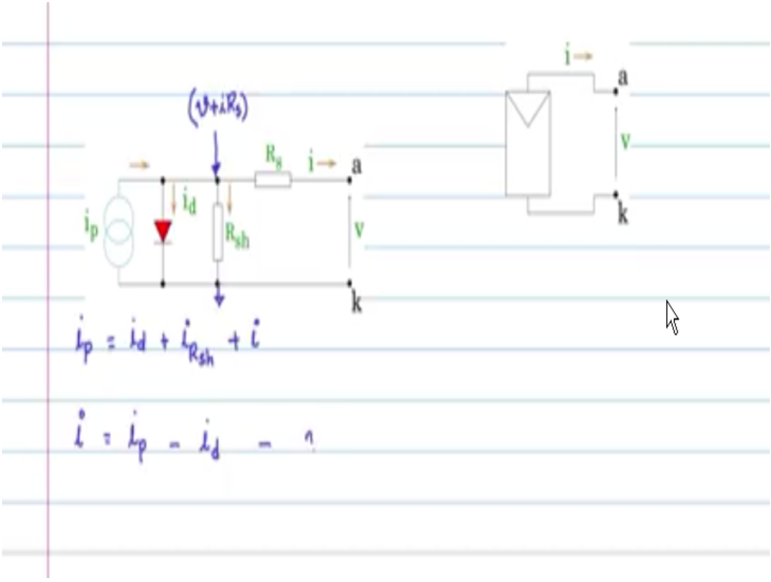

$$i_p = i_d + i_{R_{sh}} + i$$

$$i = i_p - i_d - ?$$

Let us clear someplace and position the equivalent circuit here the looking at the equivalent circuit the current Ip is equal to Id the diode current+ the current through the resistance R shunt+ the terminal current I if you consider this as the reference node the voltage at this node again can be seen that it is equivalent to V Plus this drop and this drop is having a potential which is positive here and negative here.

And therefore you have at this point V +iR_S therefore i flowing current flowing through R shunt is e plus IR s divided by R shunt rearranging we get the current terminal current which is IP -the diode current ID - the current flowing through R shunt which I can write as V +I *RS by R shunt now the diode current.

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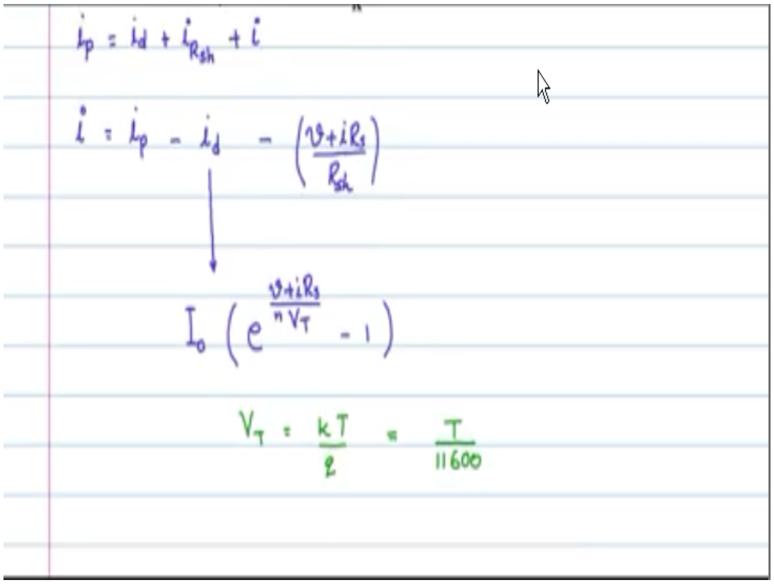

$$i_p = i_d + i_{R_{sh}} + i$$

$$i = i_p - i_d - \left(\frac{v+iR_s}{R_{sh}}\right)$$

$$I_0\left(e^{\frac{v+iR_s}{nV_T}} - 1\right)$$

$$V_T = \frac{kT}{q} = \frac{T}{11600}$$

We know from the P_N Junction theory can be written as I not which is the reverse saturation current e ^ voltage across the diode which is nothing but V + iR_S by an ideality factor n*VT-1 so this is the equator antique equation for the diode it comes from the P_N Junction theory which you will find it in any electronics the injunction chapter typical difference would be the integrated circuits electronics by Millman and how caves.

Now what is VT n and I^0, I^0 is the reverse saturation current VT is the Volt equivalent of temperature VT is the volt equivalent of temperature and given by Boltzmann constant into the temperature divided by Q, Q is electronic charge in coulombs K is the Boltzmann constant T is the temperature in degree Kelvin.

And if you substitute the Boltzmann constant electronic charge you will get this to be a value T by 11600 n is a parameter which is dependent upon the material and it has a value equal to 2 for silicon and it has values which are different for other semiconductor materials now I^0 itself called the reverse saturation current, reverse saturation current is also dependent on the material and the doping of the P and the N junctions not only that I^0 is dependent on temperature.

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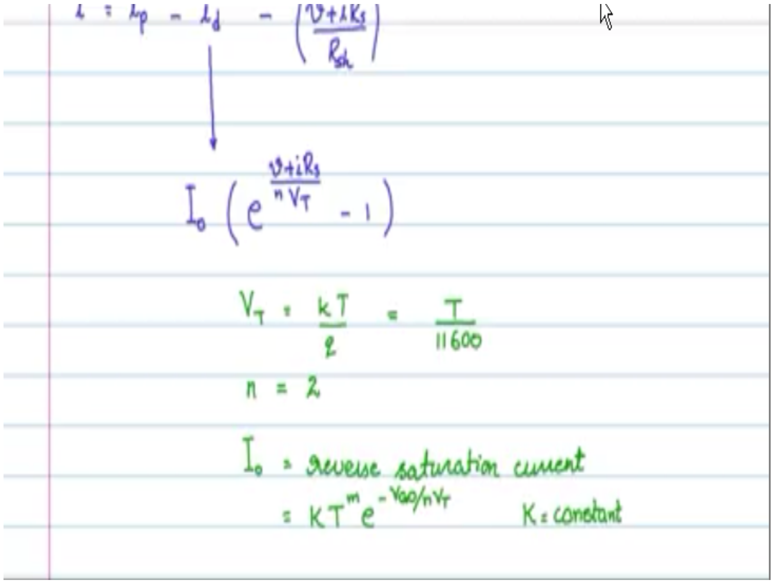

$$i = i_p - i_d - \left(\frac{v+iR_s}{R_{sh}}\right)$$

$$I_o\left(e^{\frac{v+iR_s}{nV_T}} - 1\right)$$

$$V_T = \frac{kT}{q} = \frac{T}{11600}$$

$$n = 2$$

I_o = reverse saturation current

$= KT^m e^{-V_{go}/nV_T}$ K = constant

So this is given by the following relation K T^m e-^{vgo}/n VT the same n VT coming into the picture here where K is a constant which depends upon the dimensions of the PN Junction and also the material properties and V_{go} is numerically the equivalent band gap energy in electron volts so V_{go} is basically the forbidden the band gap energy which is V_{go} in electron volts.

So this, this is again a numerical value which will come in there VT of course is known which is same as, as written about T/11600 n again is 2 for silicon T is the temperature in degree Kelvin some typical values are like this you have M which is equal to 1.5 for silicon and V_{go} varying from 1.16to 1.21 again depends upon the grade of purification whether it is electronic rate solar grade the solar grade for PV cells will be more closer to 1.16 volts.

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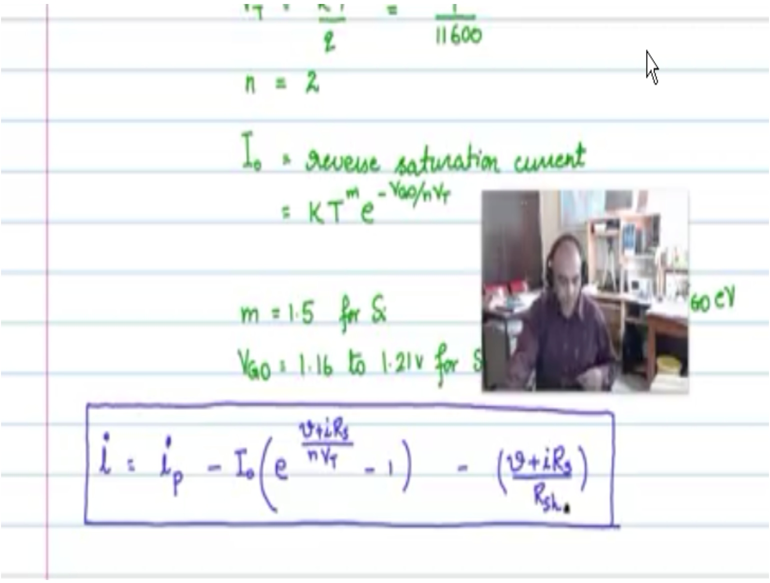

$n = 2$

I_0 = reverse saturation current

$= KT^m e^{-V_{G0}/nV_T}$

$m = 1.5$ for Si

$V_{G0} = 1.16$ to $1.21V$ for S

60 eV

$$\boxed{i = i_p - I_0\left(e^{\frac{v+iR_s}{nV_T}} - 1\right) - \left(\frac{v+iR_s}{R_{sh}}\right)}$$

So these are the typical values using which you can get the reverse saturation current for a particular PN Junction device the entire model of the photovoltaic terminal current can now be written as IP is the photocurrent the directly proportional to the incident solar radiation –I^0 to the power of V terminal voltage plus iR_s by n VT- the current flowing through the shunt resistance which is given like this.

So this would form the terminal current model of the PV cell and this can be obtained easily from the equivalent circuit as shown above so this equation of the current word of cohesion at this point you see that the terminal current I is a function of itself I appearing here in the equation so this means that this is an a causal equation which means that the present state of I is dependent on the present state of ix cell.

And therefore it is an algebraic equation and you can land up in problems when you do simulation however in practice you should understand that the diode is not an ideal diode it has junction capacitances and the junction capacitance across the diode will take care of the causality problems which means the voltage here will be a state and it will have history and memory and therefore the current here will not cause a problem.

If you simulate this particular circuit in spice the spice takes the real model of the diode along with the junction and diffusion capacitances whereas if you try to simulate this equation in Simulink and mat lab as an equation it will give you algebraic loop problems so for that what would can be done is to use a memory block history block pass this current.

I through history block I am used to calculate the terminal voltages here this would give some memory effect and can make the simulation work without problems however our analysis and selection of devices and to understand the PV cell this model is more than sufficient and we will use this model to understand the PV cell further and characterize it.