Indian Institute of Science

Design of Photovoltaic Systems

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NPTEL Online Certification Course

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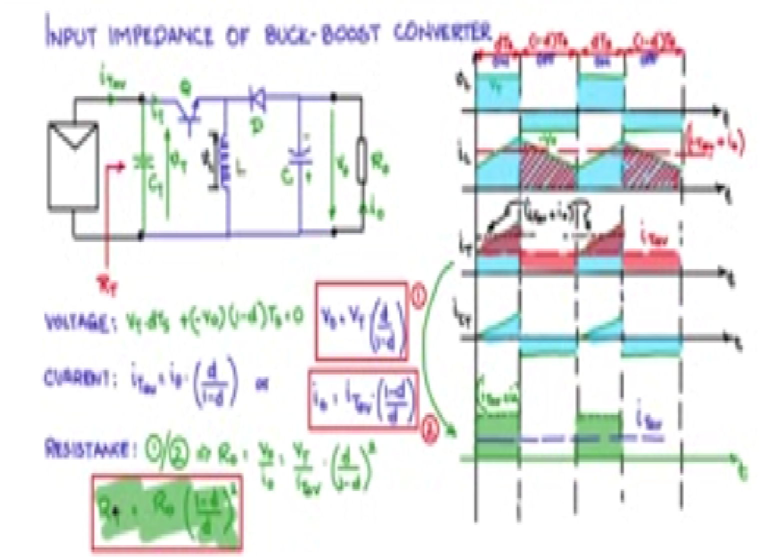

Let us now study the input impedance of a buck boost converter and see how we can regulate the input impedance of the buck boost converter through 2D cycle control and let us see it is effect on the Iv characteristic of the PV panel from the point of view of maximum power point tracking let us draw the buck boost converter interface to the PV panel so this is the PV module to this PV module let us introduce the buck boost converter the circular buck boost converter is like this it has there is a BJT power semiconductor switch again as I say the BJT can be replaced with a mass rate or IGBT.

And in series you have the inductor you have a diode cutter connected in this fashion a capacitor connected like this and this forms a boost converter to the terminals of the buck boost converter you have the load connected like this so this is R0 in the buck boost converter the voltage is reversed this is positive with respect to the other terminals upper terminal so the important terminal is positive like this and therefore V_0 is positive if measured in this fashion and I0 flows goes up as shown here.

So this is the character of the buck boost converter it does give you an inversion in the voltage polarity so that is C, D, L, Q and across the terminals like in the buck converter connecting capacitance C_T like this is compulsory is mandatory because of the switch present here on the input line the current through this is switched the current is not continuous and therefore the current through the PV panel also would not be continuous if you do not put the capacitor and along similar arguments that we made for the converter.

We need to put a capacitor here so that the current here from the panel is smooth and continuous and you can effectively take peak power from the panel at every instant of time, so we will call this V_T the voltage across the input terminal the input impedance R_T is as seen from the PV side from the PV panel side into the terminals it is like this, now this current here flowing into the collector of the BJT is called I_T the current here will be called I_T average like in the buck converter the collect the current through the capacitance the buffering current will be the i_{cd} current that will be flowing through this will have an average 0 this will have an average and this will be the switched current.

Let us know have the waveform access, so access 1 will be real access 2 is real the voltage across the inductor and the current through the inductor which we need we will have another axis to indicate the current I_T which is going through the switch and we will also see the current through the capacitor and also look at the reason why it becomes evident that we need to put the capacitor here so that we have an ID average flowing out of the PV panel now let us partition these waveform time axis into various time zones like this.;

And mark this first time zone as dTS1- dTS d is the duty cycle d is taking a value between 0 and 1this is one switching cycle 1 switching period TS second switching period dTS 1 – dTS so during dTS we are keeping the BJT Q here on so we say that is on during 1- dTS Q is off and so on dTS it is on 1 - dTS it is off let us consider the period dTS during the time and Q is on when Q is on you will see that there is a flow path for the current in this route not only that there is a current flow here the capacitor is discharging through the load.

So the capacitor will discharge through the load in this fashion, so you will see that this potential is at – V_0 observe that the polarity is negative as I told you this potential is – V_0 this potential is - V_T because Q is on this potential this potential will be same it will be +V_T it is - V_0 this is reverse bias so this out of the picture so you have one circuit here with a capacitor discharging in this fashion we have one circuit here with the current flowing through the inductor in this time.

Let us now write down the wave form during this period, so let us first look at the voltage across L so we will mark this V_L with the polarity of measurement in this fashion the common point of the probe is kept in this terminal and the measuring point is kept on this side as indicated by the arrow so across V_L at that point in time when Q is on this potential is same as this potential it is V_T diode is off out of the picture this is at ground potential also the voltage across the inductor is V_T.

So that is why we are going to draw a line like that constant V_T and this is what is going to appear across here and the current through L using that V_L = to L di L / d_T il is an integral of the voltage here, so it will rise linearly and this is iL as iL is same as the current through the BJT current through the power switch I_T is going to be a replica of iL we will look at i_{ct} much later let us finish the period periodic cycle waveform of all these 3 parameters and then later we will look at i_{ct}.

Now let us see what happens during 1 - dTs is time period and this is the time period when Q is off when Q is off I_T is 0 there is inductor current but the inductor current will continue to freewheel by making this diode on so it will freewheel in this arc and let us draw the path so the inductor current would prevail in this path with a part of it going through the load R_0 and another part going through the capacitance to charge it up in this fashion let us draw the waveforms for this part of the circuit during the period 1 – d x dS.

So if you look at the voltage across the inductor the inductor you see that Q is off the diode is on this is V_0 voltage with this negative so you have – V_0 coming across the inductor that is we V0 and this is negative portion this is the positive portion negative and positive portion should balance out so the average is 0 so during Inc for the inductor current during the on time we saw that the inter current is rising up and that was charging with a slope of V_T / L it will now discharge with a slope of – V_0 / l.

So it will discharge like this I_T will be 0 because Q is off there is no I_T current so this will remain 0 now for the next cycle also the same thing will repeat let me quickly write that down so that would be for V_L iL and I_T before we get to the input-output relationship between R_T and R_0 we need to do some analysis on this waveforms because we need some intermediate relationship which we will be using for finding the input output resistance relationship because we need to know what is I_D average and few other parameters.

Now consider the current that is flowing through this branch or the diode branch one of these so let me mark it there and if you look at the inductor current waveform observe the inductor current while the transfer while the transistor Q is on the inductor current goes in this direction and while it is off the inductor current goes in this direction, so which means this current there is contained within the inductor current waveform I shown hashed in this fashion here.

So that would be this portion would be the portion of the waveform that you will find if you prove here now that is actually composed of I_C current and I_0 current, so therefore it is I_0 + IC I_0 is the DC component an average component of the current I_C does not have an average component so it is a component of the current here which is an AC component without average so approximately I_0 would look like this plus IC would look something like this the sized portion of the current contributes an average value here of value I_0.

Here to there will be an average value the average value will I_T average so therefore the average value the inductor current will be I_T average as contributed by this portion and I_0 as contributed by this so this will be I_T average + I0 now consider I_T the current through the BJT so this value this line that have drawn here is the average value over switch the I_T waveform and that we have called it as ID average and that is what we expect to flow here I_T average this is the switch I_T and the buffer current is through C_T i_{ct}.

So let me draw the inductor average current like this so as we argued just before this portion is this line is a contribution of the average during dT and contribution to the average during 1- dT so therefore we have in the current averages I_T average + I_0 the value this line the average inductor current line is given by this relationship, so knowing that this value here cutting across through this linearly increasing Il waveform is I_T average + I_0 and as I_T during the dT portion is same as the inductor current.

We can say that the value that cuts across in between the linearly rising portion of the I_T waveform will be I_T average + I_0 so if you mark those average value you will see that that will be same as I_T average + I_0 both here and here same value as this so if I take this dotted black line every cycle that would give me a flat top rectangular wave shape let me redraw that down here and it will appear something like this and this has a flattop value of I_T + I_0 as I have indicated here.

This portion and this portion and there is an average value I_T have now this we can write it as I_T average is actually this peak value x 2D duty cycle I_T average + I_0 into d will give you the average value I_T average so if you simplify we get I_T average is = I_0 x d / 1- d so this is an important relationship we need, so this is the value I_T average in terms of I0 and d we need to know what is the value of the current the continuous current that is flowing out of the PV battle source.

From here it is easy to deduce the current flowing through C_T i_{ct} so you see this is average I_T average so if we make that as a zero line the current through the city is obtained directly from here so the portion above the I_T average line is the charging component and the portion below the discharging component and so on it repeats cycle by cycle, so this portion if we write it down separately here third portion like that you will see that i_{ct} will have wave shape something like this so during the dTS period there is current flowing through Q.

The average component the dC component is coming from I_T average the excess varying component is provided by C_T and during the 1 - dTS time when Q is of $I_{T\,0}$ so all the I_T average component is going into the C_T capacitor that is charging it up now we are ready to find out the voltage current and resistance relationships let us write down the voltage relationship input output voltage relationship we look at the inductor current waveform we know that we need to have a balance between the positive part and the negative part.

So within a cycle the positive part will balance of the negative part so V_T x dTS V_T x dTs + - V0 x 1 - dTS should be equal to 0 this implies that V0 = V_T d / 1 - d remember that we have chosen the measurement of V0 itself reverse if we have chosen it in the regular sense we would have got a - sign here this minus sign would not have been there.

So therefore V0 = V_T d / 1 – d is the input output voltage relationship of this converter now the current relationship the current relationship we have already seen I_T average we need I_T average and I0 I_T average is related to I0 in this following manner d / 1 –d we just now saw through this waveform or I will write I_0 = I_T average 1- d/ d, so this is the second relationship the rest of the relationship is obtained by the relationship 1 / 2 which will give you R0 which is equal to V_0 / I_0.

Which is equal to V_T / I_T average into d/ 1- d^2 V_T / T average is nothing but RT as seen from the input terminals the terminals of the PV module so therefore R_T is equal to R_0 this will come this side 1 – d/d^2 so this is the input output resistance relationship for the buck boost converter and we need to see how this effects the Iv characteristic of the PV module and what is the takeaway that we can get out of this particular relationship for the maximum power point tracking problem.

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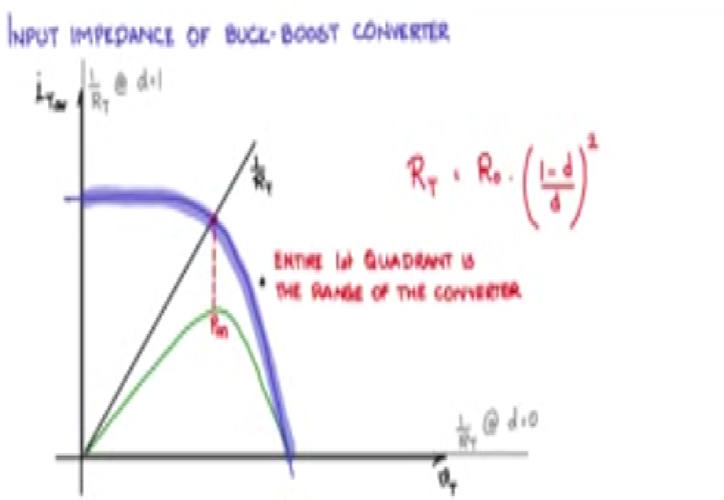

Now let us draw the Iv characteristic for the case of the buck boost convertor interfacing the PV module so let us draw the graph so you have the x-axis V_T the terminal voltage across the panel the y-axis is I_T average let me draw the Iv curve in blue in green you have the power versus V curve and I have a load line here 1/ R_T and at the point of intersection we have this operating point and when you drop it down it drops down to the power curve and that is Pm the maximum power.

So this is a maximum power operating point now for the buck boost converter interfacing the PV module R_T = R0 x 1- d/ d^2 so this is the relationship that we just now obtained now let us see what happens at d = 0 so when d is equal to 0 whatever may be the value of R_0 this works out to be infinity so RT will be infinity which means that it presents an open circuit to the PV panel, so the load line the virtual effective load line is along the x axis, so let us draw that so here you have 1 / R_T at T = 0.

Now d= 1 this is 1 this would be 1 and this is 0 so whatever may be the value of R_0 this works out to be 0 so RT is 0 implying that it is presenting a effective short-circuit across the terminals of the PV panel so which means it is along the y-axis so let us draw that and then mark it 1 / R_T at s = 1, so as d progresses from 0 here the load line from a horizontal value starts moving to a load line which is vertical which is having infinite slope at T = 1, so this means that all the points of the I_V curve in the first quadrant are reachable by the buck boost converter.

So this entire first quadrant portion of the Iv characteristic or possible operating points for the PV module and therefore obviously the P power point will definitely come within the range of the buck boost converter, so one of the main advantage of the buck boost converter is that it covers the entire first quadrant and any point on the Iv characteristic is reachable by the buck boost converter interface.

So this is the important takeaway entire first quadrant is the range of this converter, so for maximum point tracking from the point of your maximum power point tracking this would be a universal converter where any point can be reached for any insulation and any type of load.