Indian Institute of Science

Design of Photovoltaic Systems

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NPTEL Online Certification Course

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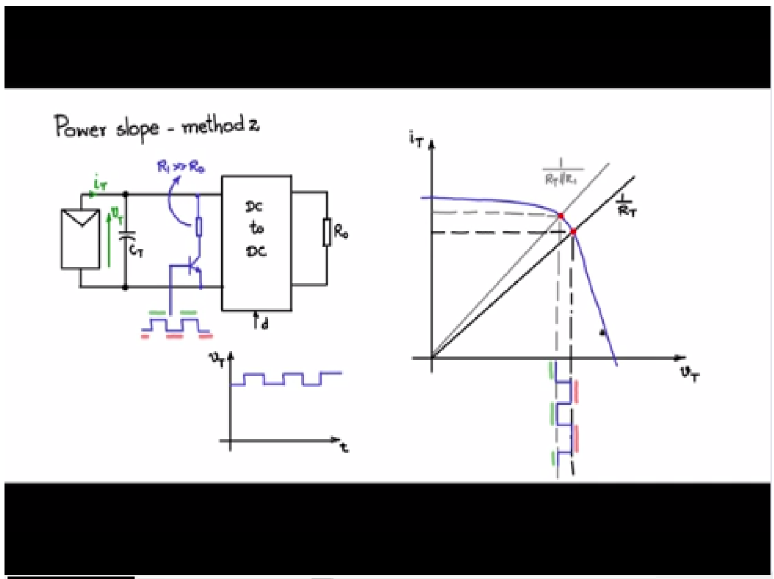

In the power slope method 1that we discussed there are derivatives dit/dvt, dit/dtr, dvt/dt, and it is generally not easy to obtain derivatives. And therefore, literature has some solutions where you can do the power slope method without actually taking derivative of a signal. So that is what we are going to see. Let us first have the basic circuit topology that is a PV module connected to the load R0 through a DC to DC converter having duty cycle of the control input.

Now there is a buffer capacitor we will put buffer capacitor slightly on this side leaving some space to the right of the buffer capacitor because I want to introduce something here. Now here I will introduce two components one is okay, let us mark this VT and IT, now let me put a component here a resistance and that resistance is connected to the ground through this power switch BJT or a mass fed or an IGBT.

Now what signal do you give to base or gate of this power semiconductor switch? So it will be pulse to form something like this not necessary it should pulse, but it can be even a linearly wearing wave shape, a triangle wave shape or any such thing or in such a cases will go through the leaner region. But it is easy to give a pulse of a form, so we will just have a look at the concept with this type of a wave shape given to the BJT here.

So the BJT is actually acting like a switch. Now let us see how this operates, let us give this resistor a name and let us call that one as R1, and remember that R1 is a very large value this much, much larger than the input impedance that is presented by the DC-DC converter and much larger than this R0. So actually this is acting like an additional load of the buffer capacitance, the buffer capacitance is supporting DC-DC converter +Ro as the load to that now we have added the additional load.

But it is very small additional load whenever the BJT is turned on R1 comes across the terminals. Now what is the effect on the characteristic IV characteristic of the panel? So you have VT and you have IT, let me draw the IV curve. Now let us say this is not there in the picture, R1 is not in the picture when the transistor is off, then Ro when you take it on to the input side as a function of D you will see RT.

So let us say RT is something like that 1/RT. Now when this switch is on when this is high, so during that time the switched on R1 comes across the terminals of the PV panel. So you will see that it will take a line like this a load line will take a load line like this it will be RT parallel R1. Now RT parallel R1 will be corresponding to a load which is lesser than RT, and therefore this load line moves towards the short circuit depending upon the value of R1.

Now for this operating point let me draw vertical down straight down like this, and for this operating point also I will draw a vertical line straight down like this. Now let me consider this on-off periods during the time when this is high the BJT is on R1 gets connected. So during the time this is high R1 gets connected, then this is load line and the corresponding VT terminal voltage is this.

And during the time this is off R1 is not in the picture and only RT that is presented to the PV panel and to this load line this is the operating point and the corresponding VT is this line. So if you see the VT swings between these two lines as shown, so if I say during this period green during the green period here the switch is on which means it will be corresponds to this values of VT and during the period when it is low switch is off it will corresponds to this portions.

So the VT will be something like this and likewise there will be a variation in the current also. So let as look at the VT verses time curve, so the VT versus time curve will look something like this that there will be a ripple and there will be a ripple in VT, and also there will be a ripple in it and then there will be a ripple in the power P which is =V x IT, VT x IT, and we will use this ripple to actually give a distinction or trying to find the point where the maximum power occurs.

And that is how we will try to use this ripple to find the maximum power point. Now let us look about how we will go about doing this using this ripple as a distinguishing feature for identifying the maximum power point.

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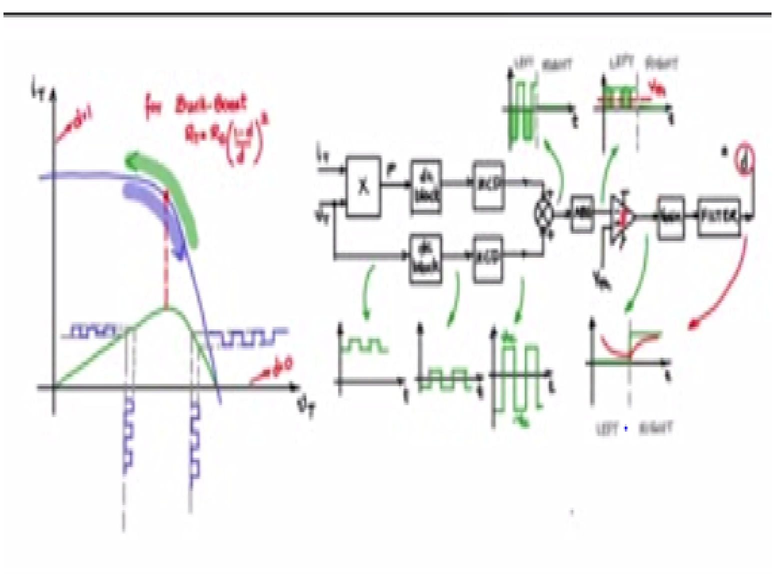

Now consider the static characteristic IT versus VT and the power versus VT this is the power versus VT. And let me consider a vertical line here representing a particular operating point and let me draw the vertical and the horizontal line, this point here would represent an operating point at a given instant and the corresponding extinction to the IV curve here. So now here what I am going to do now is a super impose on the voltage.

Now this is the 0 of the voltage and if you look at it on this voltage which is supposed to be a DC I will super impose a ripple, how do you super impose a ripple just like we discussed earlier, I am going to use a resistive switcher, and introduce this ripple. Now let me take the peak amplitude of the ripple projected on to the power curve and then extended on to the horizontal. So whenever the voltage ripple increases the power ripple also correspondingly increases, as you can see.

So on this slope, where the slope is positive on the left side of the peak this is the peak power point on the left side of the peak power point where the slope is positive whenever there is an increase in the voltage ripple there will be an increase in power ripple too. So the power ripple in the voltage ripple will be in phase. Now on the right side of the peak power point the slope is negative.

So let us have a representative operating point line here having the vertical and horizontal. And as before I will introduce the ripple on a voltage and if I extent the ripple amplitude you will see that there is an inversion already. So whenever the voltage is increasing the power is decreasing and the voltage is decreasing power increases. So you will see that here, because of this negative slow there is an inversion the voltage and the power ripples are out of phase.

So we would be using this information on one side of the operating point the power ripple and the voltage ripple are in phase, the other side of the operating point the voltage and the power ripples are out of phase. And indirectly we are measuring the slopes, so this is also a power slope deduction. But here we are using the d/dt no differentiation action is coming into picture, we need the power variable, we need the voltage variable power variable is obtained by multiplication.

Now let us see in a block schematic way how to build this system. So let me have a multiplier block, the input of the multipliers are IT and VT, so you are measuring the panel current and the panel terminal voltage, and the output of that would be the power. And you are taking the power and the voltage these two are the quantities that we like to process. So first let me process it by removing DC.

So you pass it through a DC block circuit, so when you remove the DC, so you will see that here before the DC block circuit the values of the voltage and power signal will be something like this, so there will be a DC plus on that there will be a ripple. The power signals will be also something like this similar except the ripple will be either in phase or out of phase depending upon which side of the peak power point the current operating point is.

So after it passes through the DC block how will the wave form look like? So the DC is removed, so this will come down, so you will see that the average value is 0 you will only have the ripple content. Now is the ripple content that we would like to process even on the power side after you remove the DC block if you remove the DC from the power form you will a similar such wave from here to the except for the phase change.

Then after we DC block we will pass it through the 0 pass detector XCD is the 0 cross detector, the reason that we pass through the 0 cross detector is that what I have shown as an iso-rectangular wave form need not be it can be triangular or it can have smoother rise and fall, and therefore, you need to pass it through a 0 crossing detector, so that you will get well defined short wave forms.

So let us see after the 0 crossing detector you will see that I will have well defined wave forms like this basically this wave form going from –VCC to +VCC, that will be +VCC will be –VCC. So next we will add the signal obtained from the power signal and the signal obtained from the voltage signal, we will add them up what do you expect? So you see that if the operating point is on the left side of the peak power point, the power ripple and the voltage ripple are in phase.

So this and this will be in phase, so it will be added up and if this because this is already saturated it will be the same way. If suppose the operating point had been on the falling slope that is a negative slope region to the right of the peak power point, you will see that these two on adding will becomes zero. So when the voltage is positive the equivalent power signal value will be negative, when the voltage is negative here the power signal value will be positive.

So when you add it will result in a 0 value. So therefore, we can see that we have two regions one is if the operating point is on the left side of the power curve peak power point and the operating point is on the right side of the peak power point, so if operating point had been any were in the left side of the peak power operating point on the positive slope you will see that these two will add up because they are in phase and you have still this kind of a wave shape.

Now if suppose the operating point was on the right side of the peak power point the phases of the voltage and power are opposite they will subtract and you will have 0. Now next what we do is pass this wave shape through an absolute value circuit, so that all this negative portion will bring it up and rectify basically. So let us draw the output of the area circuit absolute value circuit again for the left side operating point and the right side operating point.

So on the left side when this gets the rectified you see this it is a constant value, so actually you will see that this portion gets rectified absolute value were this portion absolute value here. This will remain 0, the right side portion. Now this value I can now set a threshold V threshold and then pass it through a comparator like this, so I will set a V threshold the comparative and the output going from either VCC or 0.

Now this wave form is given here, now you see that whenever this is high the output is 0, whenever it is low during this period the output is high. So if you drop that portion you will see that I will again mark left and right left operating point, and right operating point, you will see that there is an inversion whenever it is high during the left side it is high output will be low, and during the time when it was low and it was right side of the operating point it becomes high.

Now this I will pass it through a gain block so that it would become 0 to 1 rather than 0 to VCC or make it 0 to 1, and then pass it through the filter And the output of the filter is what I will give to the duty cycle input control input of the DC-DC converter, one should note that the filter output is actually pass through a PWM block, and then given to the duty cycle input of the DC-DC converter which is interfacing with the PV panel.

Here I will just show the directly at the filter output, because the filter output is directly proportional to the duty cycle. But in actually there will be in between a PWM block before you give to the duty cycle input of the DC-DC converter.

Now what would be the filtered wave form like, so let me superimpose this. So the filter wave form will fall down here when it is 0, and then rise up gradually with the time constant like this. Now this is actually representing the duty cycle. Now consider the converter which is the buck boost converter, the buck boost converter we saw that the range of the buck boost converter is the entire IV curve in the first quadrant.

So $Rt = Ro(1\text{-}D/D)^2$, and here when D the load line corresponding to the vertical axis the short circuit operating point D=1 the load line corresponding to the X-axis VT axis open circuit point D =0. So in between you have the various load lines for different values of D. Now consider this when the operating point was on the left means the left of the peak power point somewhere here the operating point is there.

So when it is there you see that the duty cycle is decreasing, duty cycle is decreasing you will see that the operating point is moving like this to the right. It is moving to the right, so let us say this is the peak power point and the operating point is moving to the right. So it has crossed the peak power point and then gone into this negative slope region.

The movement that has gone to the negative slope region the gain output is high 1, and the filter output is trying to rise towards that value 1, or the duty cycle is trying to rise which means that this is again going back the operating point is now moving left. So you will see the operating point moving thus and crossing the peak power point.

So if we control this window, this window you can control by putting the proper value of results here. So you can make a big window or a small window so that this will be moving right left, right left, around the peak power operating point or the maximum power operating point and thereby achieving maximum power point tracking.