Indian Institute of Science

Design of Photovoltaic Systems

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NPTEL Online Certification Course

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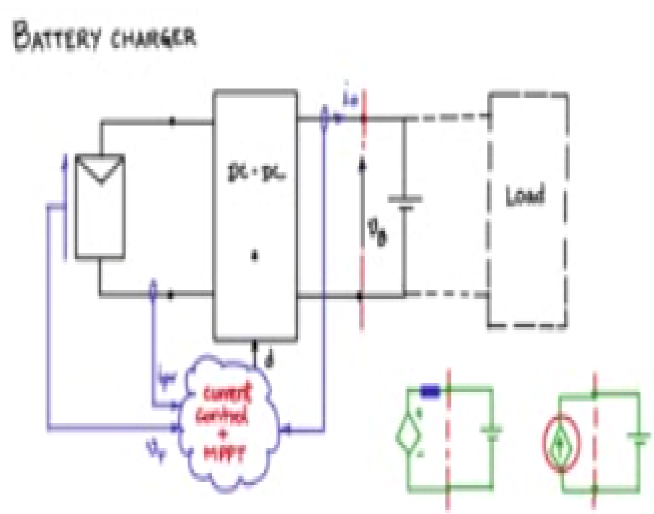

Let us now discuss the battery charge circuit where MPPT is integrated inbuilt into the charge of scenario. So let us consider this PV module or a PV array and this PV array is connected to a DC-DC converter and an output of the DC-DC converter is connected to a battery that needs to be charged. So you say this is the DC-DC converter it has a control input D the duty cycle input,. The voltage across terminals of the Dc-DC converter output is connected the battery and therefore the output of the DC-DC converter the voltage is fixed by the battery, because the batteries are source.

Across the battery you may have a load connected like this, so you have a load connected like this. Now how do we charge the battery. The terminal voltage is VD and this voltage is defined, then what would be the current charge current, so let us say we want to put the peak power from the panel into the battery, now let us say PM is the peak power, PM/VB will give you the IB, the peak power that is going out of the DC-DC converter.

So IB can be controlled by controlling the duty cycle, because VB is fixed and therefore, power can be controlled by controlling the duty cycle as VB is fixed. So that is the strategy that we want to adopt, sense this control, sense this current I0 which is flowing out of the terminals of the DC-DC converter. And use that as a feedback you also provide the PB current IPB, and also the terminal voltage of the PV, VB which will be used for sensing the power that is being drawn from the PV module.

Now what is the control algorithm that you need to put in here, let us consider this boundary here, the terminals of the DC-DC converter to which the battery is connected. Now normally if you consider this terminals and the battery is connected here, all this portion, PV source, DC-DC converter can be considered as a controlled source. Now let us say if it is a controlled voltage source +n- like this.

If you have a controlled voltage source you cannot parallel to voltage sources, because there is no impedance in between and there can be huge circulating current which can blow something in the control voltage source. So whenever you are having control voltage source you need to have a series impedance which will limit the current.

So if you are having the control voltage source have a series in particular this is tone possibility but you do not want to control the voltage because the battery voltage is fixed you can directly control the connect in fact the control voltage source with the series impedance and if the impudence is inductive non dissipative not to form a control current source itself.

So what can be also done is across this boundary where you have the battery you have control source and that control source you make it has a controlled current source it had the inbuilt impendence necessary impendence in build within it so that there will always be a current limit current source and the voltage sources can be connected in parallel so we will follow this model and that is what we will introduce into this control algorithm which is at current controller.

Plus the current controller reference will be obtained from the constrain that we want to take maximum power out of the PV so plus MPPT maximum power point tracking both will be included into this and we will see how we will do that and we can choose DC-DC appropriate DC-DC convert it could be buck most or buck most converter the control logic will remain same similar.

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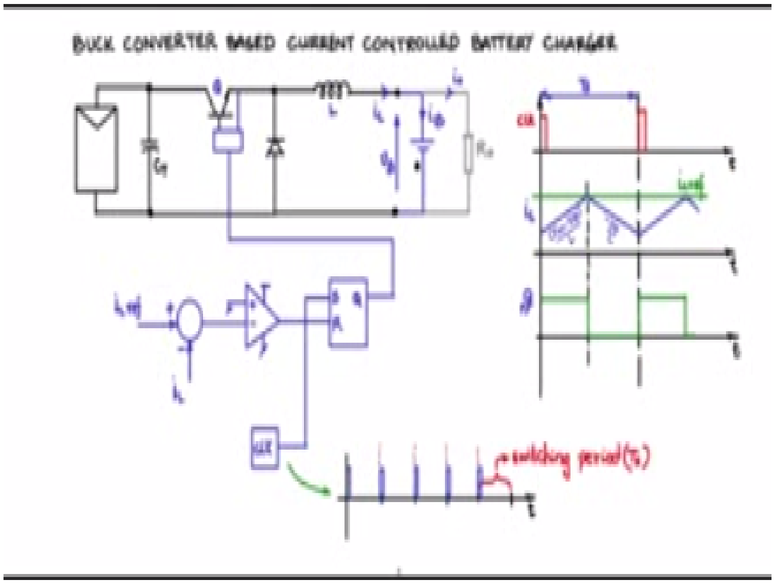

Let me draw and discuss the schematic for a buck converter based current controlled battery charge, now what it basically means is that the PV module or the PV array is interfaced with a buck converter which will charge the battery, so let us draw the circuit schematic so you have the PV module PV panel connected to a buffer capacitor CT at the terminals.

And this is followed by a buck converter so I have a BJT switch now this BJT switch can be replaced with a max fries switch or an IGPT switch or a semi conductor switch followed by a diode and I have an inductor and following the indictor I am not going to place a capacitor insisted of the capacitor I will connect a battery desperation and across the battery you may have the load R0 like this.

So because the battery here fixes the potential across the output terminals of DC-DC converter the current row R0 is decoupled from the rest of the circuit operation so the current I0 through R0 is V battery by R0 now here you have the battery voltage VB we will call that has VB the current through the inductor is has shown here this will be the current through the battery IB and this current will be I0 which is flowing through the external load.

Now our point of interest is this current the current that is going to the battery load combine should be such that maximum power drawn from the PV array other PBM so let us draw the control scheme schema I have a comparative here plus minus so it compares the feedback signal with the reference signal I will call the feedback signal as IL so what I am going to feedback is the current pre call our discussion voltage VBB in constant because in the voltage source connected across terminal it is sufficient to feedback just the current and use that one to control the power and her you will have IL reference.

IL reference, reference for this now this error goes through a comparative so I will connect this to the minus terminal to the plus terminal I connected ground 0 of course there is cause of like comparator the output of the comparator goes to an SR latch, so I am going to connect the out to the comparator to the r reset pin of the SR latch there is a set in also and there is a q the output in of the SR latch, output of the pin of the SR latch is going to get connected to this get raise circuit or based raise circuit.

In this fashion so output of the SR latch q gets connected to the this drive circuit which will raises on or off so how does this operator and before that there is something we need to connected to the set in also, so we will let me have clock block so the clock output is connected to the set in of the SR latch, how does this clock look like so let me have the time so I will mark this ticks each of this sticks base is this switch in time period TS okay, so the clock is in this fashion at the beginning of every switching time.

Period you will have a very narrow very small duty cycle pulse coming like that at the same period the period being defined by this clock so this the moment this small duty cycle pulse comes to the set in it comes and sets the output of the latch on the raising it so you have the raising h so at the rising h PVC that a q is set and at every start of the period q is set and then switches on the transistors, now let us look at the various way from condense stand how this operates.

So I will draw the various access time maxes basically and I will divide this into two portions is the first cycle ES and is the latest cycle, so at the start of the cycle you have a small duty cycle pulse and that is this clock pulse and it happens every at every starting of the period now the moment this clock pulse is given it sets this SR latch Q is high moment Q is high there is based drive for the VJT or gear drive for the mass fit and this is on and VT gets connected and the inductor is charging up, the inductor current is growing. Now let me set some reference here let me for the moment set a reference which is constant okay, clock then I will set a reference which is constant iL reference.

So and Q is high it is providing the base drive or gear drive to this power-semi conductor switch and thereby the inductor current is integrating and has having a positive slope and that positive slope is vin-vb v battery/L so it keeps increasing in this fashion. $i_L$ref is higher than i_L this is $i_L$ref which is higher than i_L, so when $i_L$ref is higher than i_L the output this algebraic summer will be positive but that is connected to the negative of the comparator and the output will be low, the reset pin will be low no change on Q.

So it keeps increasing till the point 1 i_L reaches and crosses over $i_L$ref, so the output of the algebraic summer becomes negative and this becomes positive the reset becomes positive and therefore Q will reset and go low, the moment Q goes low there is no drive for this power-semi conductor switch it will switch off and the inductor will start freewheeling and start falling current will start falling.

So if you take this portion of the operation you will see that if you look at the output of the Q of the flip flop it would have been high till this point and then it resets, so during this period when this is low inductor is freewheeling you know the back convertor operation it is freewheeling this is connected to 0 because it is freewheeling like this and what is connected to the inductor is –v0/l or –v0 in this case is vb, -vb/l.

And then again at the new cycle there is clock coming in this will trigger the SR latch Q goes high the cycle repeats so you will have the inductor current rising and then at the point when i_L reaches $i_L$ref there is change in the slope so it keeps happening in this fashion. So observe that what are our current value you are setting $i_L$ref, $i_L$ref the inductor current and the current that this is going to be the battery load combine never exceeds the $i_L$ref.

So it is always below the $i_L$ref and gets controlled in this fashion and this is called current control it is as though every cycle there is a check for the current and the moment there is a over current within a cycle it is switched off and then again the power semi conductor switch is switched on the next cycle then it is on till the point when the current exceeds the references current and again it switches off so on it keeps doing a cycle by cycle there is an current limiting and therefore this is a very safe and fast method of doing battery charging through current control mechanism however there are some issues which will now discuss.

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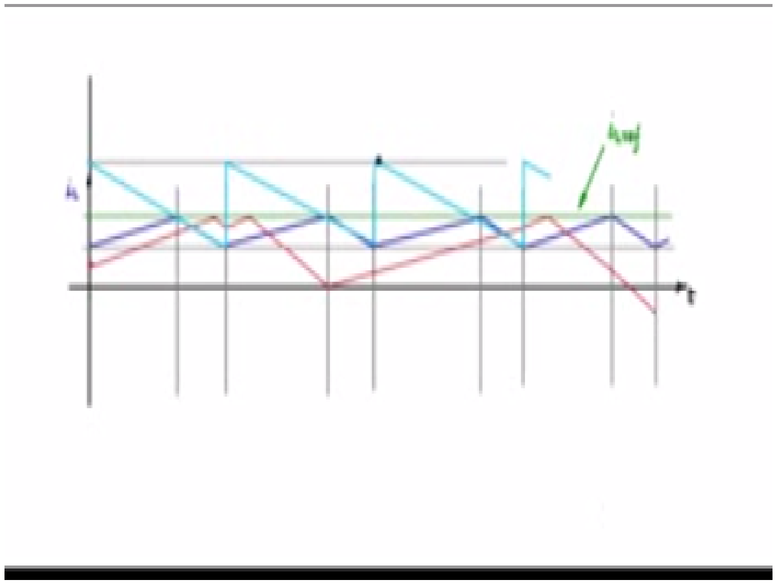

Consider the inductor current I will drop the time verses inductor current and I will keep the markings in such a way that is duty cycle is less than .5 I want to show few cycles now let us say this is one cycle, second cycle, third cycle, fourth cycle now these are the duty cycle gaps so in the first cycle duty cycle less than .5.

The second cycle same duty cycle less than .5 third cycle like that so let me mark the operator and bottom depth of the inductor so let me mark it like that and the inductor current will stay within this repel so during the time of this duty cycle vt inductor current is going to rise like this and during the time although 1-dt it is going to fall rise fall, rise fall so on.

Now this would be the normal expected steady state value of the inductor current now let us see what happens if there is a disturbance now I will introduce at disturbance here I will just obsolete the disturbance could have occurred due to any number of reason so if this disturbance occurs the inductor current will start on from here with the same slope v-vb/L so it go parallel to this line.

So let me draw to parallel to that line and then after it hits this top limit it will go parallel to the down slope of –vb/L then up slope down slope so on you see that progresses in this pattern and what eh is take away from this is that whatever there si the disturbance the disturbance finally decays to 0 and an it disturbance is removed.

And the normal inductance steady state value current flows not the example of the another case t verse IL now I am going to increase the duty cycle to beyond .5 same time period duty cycle is higher same time period duty cycle is higher and so on so when the duty cycle is greater than .5 what happens let me again mark the top and bottom of the inductor repel I will keep it same and what is the steady state normal expected value and the inductor current.

Let me first draw that so this will be v-vb/ this will be –Vb/L negative slope positive slope, negative slope positive slope, negative slope so on so this is the normal expected steady state value the inductor current under duty cycle greater than .5 also now here also like here we will introduce the disturbance the disturbance that occur due to whatever there is the reason.

So when you introduce the disturbance now from this point onwards it will start going parallel to this line, it will have the same inductor slow. So let us say it takes this line it hits the top value here that is i_l reference value then goes down rests again this is the time duration when the Q of the flip flop is low hits the time at the end of t_s when the clock again gives the small pulse and set the flip flop again it will rise then goes down continuous going down.

Here it will get reset so on and you see that the disturbances starts growing cycle by cycle it starts growing becomes unstable, so it never conversions to the expected steady state value of the inductor current. So when the duty cycle is greater than point 0.5 the inductor current will start diverging and it will not be stable when you do current control operation in this fashion where this is the i_l reference. The top of the inductor current drip is the higher reference, how do we solve this problem?

Let us seek a solution and try to find out and how do that and implement that? Let me consider where the problem case were formed, here the duty cycle is > than 0.5 and we see that if we give a disturbances, it keeps growing and leads to an unstable inductor current where form. Now this line here this top line here where the inductor current is comparing with that line is the higher reference line. So let me highlight that with a different colour and let me indicate that, so that is i_{lref} . so whenever the inductor current reaches i_{lref} and tries to cross that, then the error changes the direction becomes – and then resets the flip flop.

But that is not happening in the proper way when the duty cycle is > 0.5. Now let us ry to change the shape of this i_{lref} instead of being a straight flat line, let us introduced some slope. So what I will do is try to extent this access and let me draw a line which is having this same slope as the following slope of the inductor. Following slope of the inductor is – v_0/l or – v_b/ l for the case of the work convertor.

Sp we will try to use the same slope continue it upwards now this is, the slope line that we will use for this time period t_s we will repeat the same slope line for every time period, so using that as the marker let me repeat the same slope line for the next time period, then the next time period to and so on now this sort type of waveform will become the new IL ref so when you use IL ref of this nature you see something nice happening.

Now let us take the same disturbance and let me allow the inductor current to go parallel to what is suppose to be the steady state value so it goes parallel now hits the boundary here it hits the IL reference here and at this point it tries to across over and the comparator goes the error goes negative the comparator will output will see to it that the reset of the SR latch resets is asserted.

And resets the Q value so there by it will then start having a down slope and the down slope is going to be along the same parallel because the following slope for the inductive current is –v0/l or- vb/l in this case so you see that in just one switching cycle the error has been reduced so the error is from there on continuous to follow the steady state value so you see that any error quick converts and the error is removed within a switching cycle it is the beauty of having this type of a slopped slot truth shaped IL ref so you should give the slope here for the IL ref same as the following slope of the inductor current then your shape.

And the error will be removed within a cycle so how to give a slope now this was the old IL ref to the old IL ref you have to compensate and see that you have this kind of a slope so this is called slope compensation so current control slope compensation will give you the best results where even if there are errors the errors will be removed within a cycle and the system will be stable.

So this can aloes be proved mathematically what I have showed by graphs you can refer to literacy on DCC convertors or any of the NPT courses DCC convertors we shall now see how we can generate an IL reference which is of this form it should in this kind of sort out form and the slope is being same as the following slope of the inductor current once we generate that then our current controlled convertor is ready for performing battery charging operation with MPPT.