Indian Institute of Science

Design of Photovoltaic Systems

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NPTEL Online Certification Course

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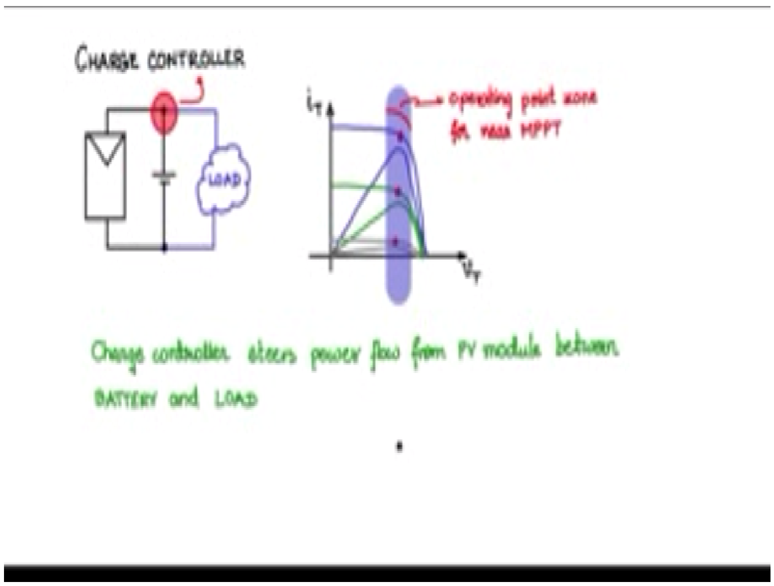

Let us now discuss the charge controller, it is an important PV battery and load interface. So if we consider a PV panel or PV module and to that we have a direct connection of the batter like this. So we discussed about this direct connection of the battery if the PV panel and battery are compatible, then you do not need any further electronics. However, the PV panels are not used generally to only charge the batteries.

They are operated to although supplying to the load and most of the time the PV panels are supposed to be operated at maximum power of point. So in general you would also have the load which is connected across the PV panel. Now consider the IV characteristic, Vt terminal voltage versus the current. Now if you have a IV characteristic like that and I will draw the PV also with the same color, and say that the operating point the peak power point optimally should be near here.

Now let us say the insulation of change, insulation of change means there will be a change in the short circuit operating point, and let us say you have another cup, the VOC point where is logarithmically, so you will not see that much of change has compared to the short circuit operating point. So I have this IV curve changed IV curve for the new insulation and the PV curve.

And the optimal desired operating point would be somewhere corresponding here. So let me mark that point. Now it is still further different insulation, I have an operating point like this. So if you see the locus of the peak power points or the locus of the maximum power points, the operating points will be along somewhere in this, almost vertical near vertical line. So if I draw bad like this, this bad would be the zone of operation will be the zone of operation for P power point or maximum power point zone of operation.

In this region of operating point you would be at near MPPT and that is sufficient for most of the applications, because of slight flatness in the hill of the power versus V curve. If we now say that the region of the operating points would swing in this narrow band near the peak power operating point, then obviously all these operating points are not suppose to be used, because you will be rate below the peak power operating point.

And likewise, on this side also these operating points are not suppose to be used. So if the operating point has to hold around here direct connection will not work, direct connection of the battery here will not work, you need to have some electronics here, which will properly manage the power flow from the PV to the battery, from the DV to the load between the battery and the load and all those things.

So you need a unit there and that unit is called the charge controller, because it controls the flow of charge and controls this, it steers the flow of charge. So the main job of the charge controller is that it steers the power flow from the PV module between the battery and the load.
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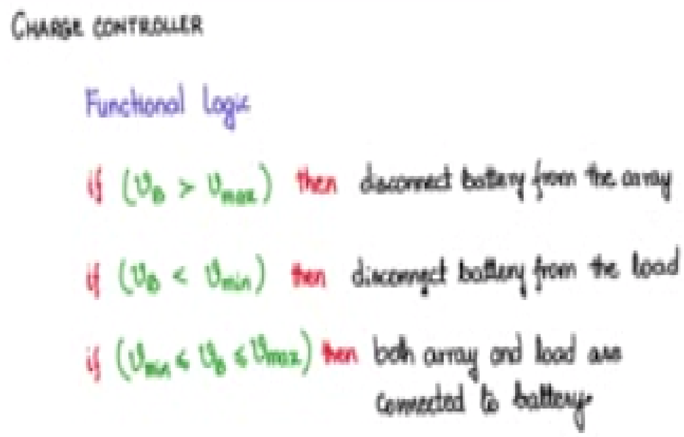

Before we discuss the circuit of the charge controller let us understand the functional logic of the charge controller. How does the charge controller behave, how does the charge controller function. Consider this condition when the battery voltage is above pre set max v max voltage we will pre set this voltage then the battery voltage is greater than that then we save to the battery is in the charged condition when the battery has reached the charged condition we would like the battery to discharge into the load only and not get any more further charge from the Vp panel, so at that time you can disconnect the battery from the PV array and connect it only to the load.

So the condition would be disconnect battery from the array only the PV array but let it be connected to the load, now if the battery voltage is less than a pre defined Vmin v minimum voltage let us defined this, so the battery voltage is less than that we do not want it to discharge any further but we still need to take charge from the PV panel then disconnect the battery from the load so you know that the battery is not go to discharge into the load but it is still connected to the PV panel which means that it can charge up from the PV panel.

Another 3rd condition if the battery voltage is in between V min and V max the pre set per defined minimum and the max voltage than during that condition both the PV and the load can be connected to the battery and they all will be operating within the zone of the maxiuamum power point of the IV characteristic of the pan so under that condition both the PV array and the load or connected to the battery so this is the simple functional logic of almost all charge controllers.

So measured to the charge controllers will follow this logic and let us try to see understand this logic and build the circuits schematic for this.

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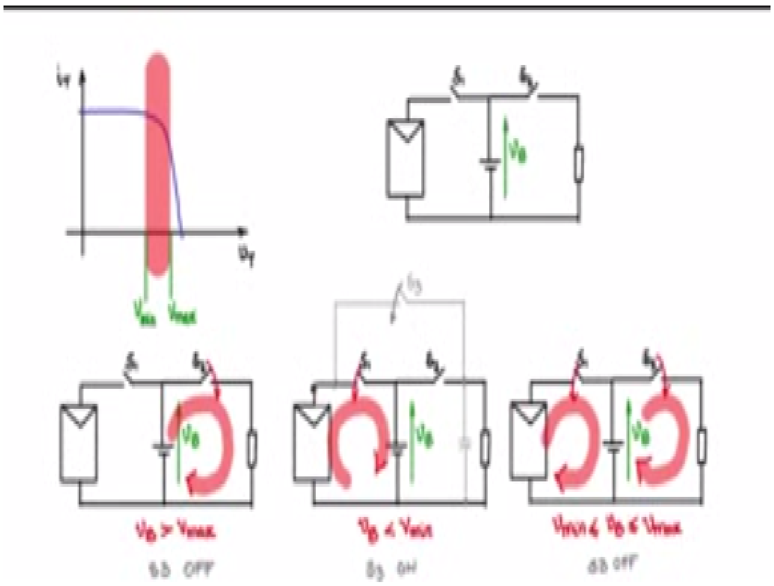

Let us now put the functional logic into the form of a brief circuit schematic conceptual schematic by trying to understand what this V min and V max are from the point of view of the IV characteristic now let me have this VT versus IT and I have this characteristic and we set that we would like to operate in the MMPT zone so zone a region of the asset of operating points here which are near MMPT.

Now this lower voltage point we will defined it has V min and the higher voltage point we will define it has V max now if the battery voltage is within this than the PV panel battery and the load or contend if the battery voltage is less than this than you know that the battery is not in the charged condition and therefore the battery has to get disconnected from the load so fro battery voltage less than this battery has to get disconnected to the load it will get directly connected to the PV panel.

So it will be charging with almost the full PV panel current and in this region above v max we do not want the battery to charge any further we do not want the operating pointer any further to this side and we will connect the battery to the load and disconnect the battery form the PV panel, so that so the logic so now let us draw the conceptual circuit let me have the switch battery and connect it like this now let me have another switch and connect the load in this fashion.

So let me call this has S1 and let me call this switch has S2 s2wicth two now this voltage is the battery voltage VB so this is VB so this is the conceptual schematic now let us see the various mode we had put 3 conditional statements one is on the wade battery voltage is greater than V max when the battery voltage is less than V_{min} and the battery voltage is in between so just let us see how this conventional schematic words in this three modes, so in the first mode here let us define V battery greater than V_{max} so doing the mod 1 V battery would be greater than V_{max} we saw in the condition that if.

$V_B > V_{max}$ and disconnect battery is on the array so that is the condition that we have applied, so we should connect the battery only to the load because battery is fully charged let it discharge to the load and let it not get further let this B open, so the battery will the PV panel will not charging the battery but the battery on the other hand will continue to discharge from the low, so that is what is indicator in this flow of the current here in the second mode we had the condition battery voltage we need < Vmin.

So the battery voltage is < Vmin meaning it is in this region the battery voltage which means the operating point will be somewhere here, so we need the battery to charge up so which means we need switch as want to be on and S_2 to off and therefore only S_1 will be connected and the battery will be connected to the PV panel and get charged in this condition here we see that the load is not having in connection either to the battery or to the PV panel load will not be satellite with power.

Do you want this let me get back to that after the final condition the third condition, so here in the third condition we say battery voltage is in between V_{min} and V_{max} $V_{min} < = V_B < = V_{max}$ so the battery voltage is on between these two wireless so after that condition it is which means that it is in the zone of near MBPT so all will be connected both S1 will be connected and S2 will be connected and there will be current flow in both the load the battery from the TV source now I am coming back here.

And I would like to state back during the time of this mod 2 and battery is less than Vmin it is now connected to the PV panel PV panel is charging the battery which mean the operating point is somewhere here, the load is not having any our source connected to it what happens to the load, you could connect the load in this fashion and in various a perfect capacity here which will do some and I will call this as S3 so 1 can have this kind of a structure to see that during that time and the battery is low.

PV panel is charging up the battery and S3 is connected here and it is PV panel is also supplying to the load but understand that this S1 is a unidirectional current flow current will not flow out ot the battery and again through S3 into the load so that is one caution that you have to apply S1 is unidirectional switch then can be current flow one in this direction not in another direction and PV can supply a current at therefore the power to the load during this time so the condition is that same condition when $V_B < V_{min}$ S3 is on.

So we will say S3 is on and during this condition S3 does not come into the pictures so obviously S3 is off in this condition and that does not come into the picture so this is the modification that what can do during the time of this condition when the battery voltage is < Vmin then there can be some amount of power flow going into.

The load through the switch s3 provided s1 is a union directional switch. However, in most charge controller circuits you will not find s3 it will just be only s1 and s2 keep it simple we will be discussing the implementation of this circuit whereas most of the time the operating point will be hovering in this region both greater than the v_{max} and less than v_{min} condition is the extreme condition majority of the case it will be here and therefore it will be one of the switches s1 and s2, s3 will not come to the picture.

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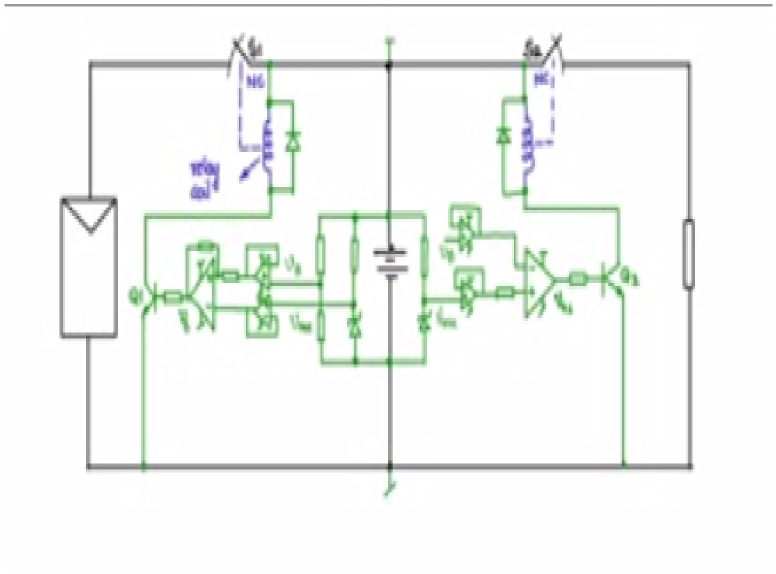

I have here the entire circuit schematic of the charge controller circuit, you see these two switches or relays they have relay coils associated the relay coils are actually turned on and off by VJT's that is 1 VJT here another VJT here and they are driven by op-amps and generators are basically used for setting the per set v_{max} and v_{min} limits. Now how does this circuit operate, let us reconstruct this circuit and you will understand how this circuit has come about.

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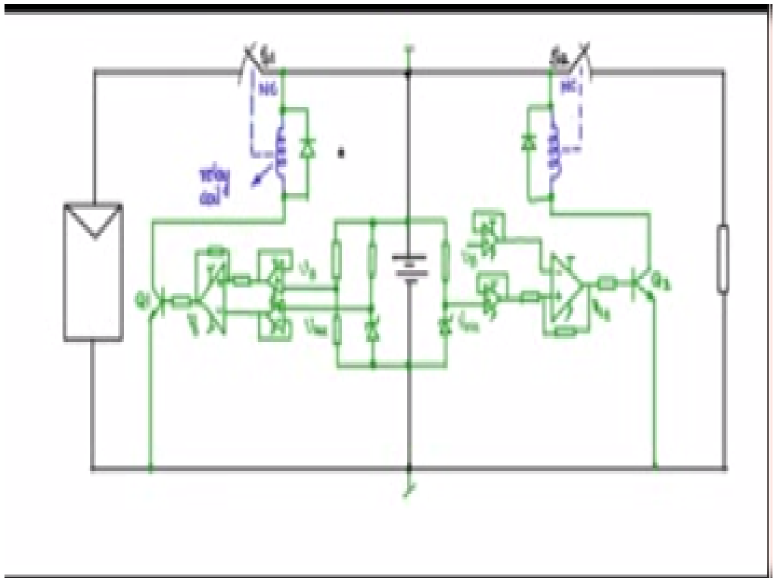

Let me start with occurring white board, you have the PV panel, PV array and the PV array is connected to the load or not and we also have the battery in between like this so this is the battery so this is how the circuit is, here we had one switch and there is another switch here let us place that so switch s1 and s2 and now we will make this both the switches normally closed, by normally closed means most of the time in operation we want both the switches to be on battery is between v_{min} and v_{max} and the operation is have that PV's applying both to the battery and to the load and battery is acting as a energy bar.

Switches s1 and s2 are relays they are driven by relay coils, so there is a relay coil here which will drive switch s1, so when this relay coil is energized then the switch s1 will be open, if this coil is not energized then that is the normal operating condition s1 will be closed, normally closed. Likewise relay s2 is energized by this coil and as for as one and the coil is energizeds2 is open and the coil is not energized s2 is closed normally closed.

So these are relay coils I will mark them here and I will indicate that this is any NC relay normally closed relay that is what it means under un-energized condition the switch is closed, so this is also NC. So let me now draw a resistance both the zener here and I will also put another two resistances like this so this midpoint here where order the midpoint of this attenuator will be considered as representing VB and the midpoint of this and the zener is considered as v_{max}.

So this attenuator here just a voltage division for this batter voltage will represent VB and from the battery because the battery voltage can be varying so I will need to take a fixed reference voltage so if I use a zener then this would be a fixed reference voltage and I will call that one as v_{max}. Now both this you buffer it with op-amp so let me pass VB through a buffer this is a voltage follower.

And v_{max} also I will buffer it the reason you buffer it is that this is high input impedance, input impedance is high output impedance is slow so any resistance that you use will not get affect the output side position of the circuit so one of these two I will give it to a comparator so I will pass Avb voltage value through as resistance and give it to the plus input the comparator and the minus input I will give the V max and the output the comparator I will pass a through a resistor to this input.

Now the output the comparator and the plus of the comparator I will put a resistance this is important because you need to give historicize between the upper drip point and the lower drip point I will explained that later now the base of the transistor is given by this op-amps for you connecting it to the collector is connected to this relic coil and the relic coil is analyzed by the battery.

So let beam have that this is this battery I will give this symbol and for the ground circuit, circuit ground imaginary ground I will give this symbol this is what is used for powering of the op-amps so I will power of this op-amps , power of this op-amps by the battery voltage I will call this oen as Q1 and this is we see control voltage see the relic coil has a larger resistance and the larger inductant also so when we switch of the relic there will be huge inductivity.

To prevent that you have a freewheeling divot here like this zone forget to put that otherwise your Vjt here will glow so put this revealing divot like this now you see how it operates now I have this potential Vb which is sensing the battery voltage and I have this V max which is a fixed voltage coming from the Zeon terminal buffet so this Vb this is VB max Vb*V max.

So whenever VB is greater than V max compare this is the comparator Vc goes high so in Vc goes high Q1 terms on when Q1 terms on there is a relic current going through this, this will open so our condition when Vb is greater than V max switch s1 will open so that the battery is only which charging to the load.

But one this switch opens out battery is whole is outputting the load and therefore there will be at drop in this potential because this drop in this potential this will come down and then probably become lower then V max and this will keep on switching this continuous chattering is not good for the relic so you put a hysteresis so that is why this is hysteresis is coming into the picture.

So the moment Vb goes greater then V max this will go high term this will open this voltage goes slightly low because it is supporting the entire load and even that goes slightly low because of this hysteresis there is a lower drip point only that goes one and below only if Vb goes below that lower drip point value as decided by this hysteresis components.

So again see the switch closing again so hysteresis very important here you start and put the appropriately now coming to the other portion of the circuit let me connect the resistance now this resistance and tenor is used for determining the other reference voltage with is v min so I will buffer that also and to the comparator.

So I will have power amps powered by the battery supply I will have the another buffer I do not need this buffer actually but I am just showing it for the completeness I could already always pick up Vb from here but anyway I will very use this vb output of that buffered this is V min so the output of V min I connect the resistor and these two I pass it into the comparator V min I give it to the positive of the comparator and the minus of the comparator I give the B.

And comparator is powered by the battery and the output of that is given to Vjt and as before the Vjt collector is connected to this relay a coil and you call this as Q_2 and this Vc_2 do not forget to put prevailing dio across the relay. Now this portion of the circuit how does it operate? When V_b goes less than Vmin V_b connected to the – terminal goes < V min this will go high and this goes high Q_2 goes on.

When Q_2 goes on this relay is energized, when this relay is energized S_2 opens, so when V_b goes < V min, we want S_2 to open according to our logic S_1 to be closed, so that the battery is getting charged, so that is the logic that works here. Here also we would like you to use hysteresis resources here, so you can connect a resistance between this and the output and have a hysteresis resist because as soon as this is opened there will a shoot up of this voltage and chartering will result.

Therefore it is good to connect a resistance across and put a hysteresis so that it will occur even if the voltage shoots up the again the trip will come back depending on the lower drip point and the upper drip point determine by this hysteresis. So in this way this charge controller circuits works, so whenever the Vb is > than the Vmax you will see that this will open out, this will continue to remain closed and whenever Vb is < Vmin look at this polarity, this will open out, this will remain closed.

So when Vb is between Vmin and Vmax both Vb is < Vmax and Vb > Vmin both these are off and S_1 and S_2 are closed. So now that is the logic that we want. And the all the electronics here are powered by the battery voltage so therefore if you do not need any other extra power supply apart from the battery voltage the battery voltage is compatible, if the battery voltage is very large and you will have to have a small DC convertors to generate this power supply which you are using for this and the relays.

Instead of the switches S_1 and S_2 being a relays you can also replace them with our semi conductor devices, you could use Vjt also but most of the time the system the circuit is in operating in the operating zone near the MPPT, therefore S_1 and S_2 will be on and therefore this relay coils are not energized Q_1 and Q_2 are off there is not current flowing through the Q_1 and Q_2, so least amount of the power being drawn during the condition of MPPT which will be the majority of the time period that this system will be in that zone of operation.

And therefore this is a pretty efficient circuit and the relay will come into picture only under the extreme operating conditions when VB is going greater than v match and when VB is going less than VN only than the operation of this switches come into the picture otherwise they are not in the picture so only then the operation of the relays will come in and the number of cycles of operation will be very low it will come for many years.

Because the relays have greater than 10,000 cycles of operation so it will lost many years so therefore this is a operating using with relay a pretty useful circuit simple circuit and very inexpensive let us say that we would like to replace the relay with a power semi conductor switch like VJT so let me erase this portion of the circuit and replace the switch by a power BKT and I am using a PNP because I am putting a PNP on the high side and I can do really side switching so let me put an resistance like this.

And I need a resistances here between the base and the ammeter and one more modification here we need to give VB to this and VMAX to here so now the logic will okay you see van you see that v max is given to the positive VB is given to the negative so normally VB is less than

VMAX so therefore this is high Q1 is on and base current flows this will be on now when VB goes greater than VMAX negative goes high than plus this will go low Q1 will switch off there is no base derive this will switch off.

So when VB is greater than VMAX we want this to switch off and then we want battery to discharge into the load so that way you replace the relay with the power semi conductors switch also instead of a p PNP transistor you can use a P channel most 2 I will leave it to you to do the replacement of this with power semi conductors switch like a PNP transmitter or a P channel most and appropriately adjust the logic here.