Indian Institute of Science

Design of Photovoltaic Systems

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NPTEL Online Certification Course

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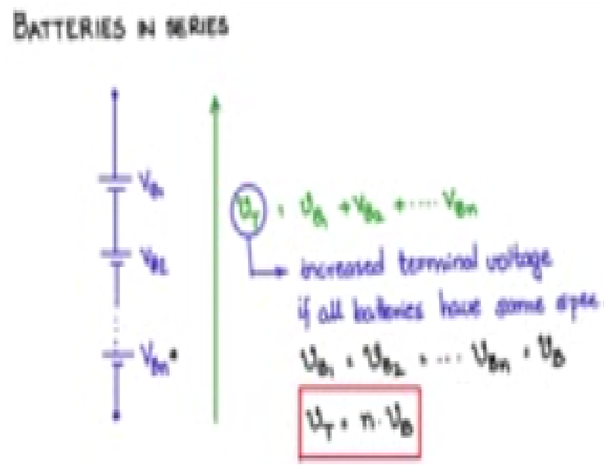

In photovoltaic based applications batteries play a very important role, and most of the times the batteries are not single, there are multiple batteries and they may be either connected in series or in parallel. Batteries connected in series are used to enhance the terminal voltage and battery is connected in parallel are used to enhance the terminal current, which I do not consider these batteries and series and see what is the problems, because you will encounter batteries connected in series or parallel in many of the applications, photovoltaic based applications.

So let us say that we have set of batteries connected in series like this. And across the terminals let us say what is the terminal voltage when each of the battery is having voltage VB1, Vb2, VBn there are n batteries. And the terminal voltage Vt is given by Vb1+Vb2+ so on to Vbn. Now consider this terminal voltage what is the advantage, this terminal voltage has increased, so if you want to have increased terminal voltage many of the applications where the load demands the high terminal voltage, so that for the same power the current is lesser and thereby, the i^2 or losses will be reduced.

So in many applications the systems will try to have a higher terminal voltage or DC+. So this series connection of batteries aid in that situation, so it results and increased terminal voltage. Now if all the batteries have the same spec then Vb1 = Vb2 = Vbn that is each of the battery will have the same voltage and let us call that one as Vb. And Vd will be equal to N times Vb, so this would be the nice simple relationship.

However, the picture is not as nice and simple as it seems even if the batteries have the same spec, even if they are all same batch coming from the same factory VB1 will not be equal to VB2 will not be to VBM they will be different they will be charged differently and they will have deferent terminal voltages so under such conditions how do we make a balance of charge balance in putting the charge to all the batteries and there by improve the battery capacity.

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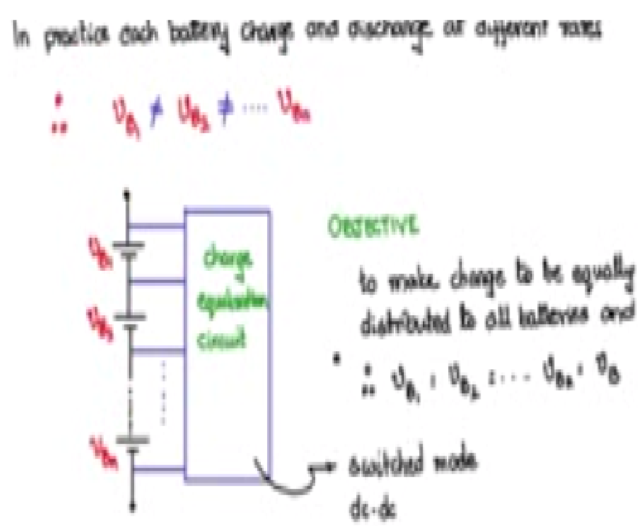

So therefore in practice each battery will charge and discharge at different rates and therefore VB1 ≠ VB2 ≠ other battery voltages and therefore we need something to do this charge balancing where each of the battery will get the required amount of charge so that the voltages will balance out and be = now that has to be done only by means if some electronics so let us say that we have some electronic system and we will sense the voltages across the battery in this fashion.

And we will build the charge equalizations circuit so this charge equalization circuit is suppose to take care of making the charge distribution among all the batteries in such a manner that all the batteries get equal amount of charges and the battery voltage will be the same each of them so that is the main objective so let us put down the objective to make charge to equally distributed to all batteries in the series connection and therefore make VB1 = VB2 = VBN = VB and discharge equalization circuit is primarily a switched mode DC- DC converter and how to build this charge equalization circuit we will shortly see.

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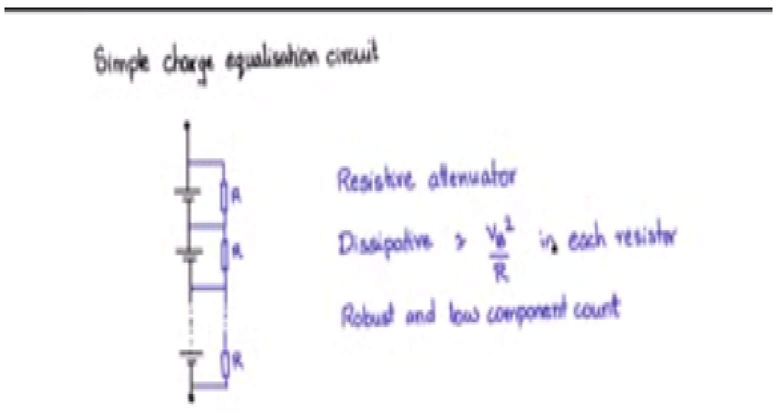

Let us look at a simple charged equalization circuit so let us have a set of batteries in series like this and across of each of the battery I will place a resisters across each battery I will place a resister so that around 2% of the load current flows through this, now if I make all the resistances R,R are equal and make all the resistances equal like this it forms a resistive attenuator branch so this is the resistive attenuator and this has a tendencies are that you λ here in the study state we will try to go towards equal voltage values across each of the resistor, however this method is highly dissipative.

So approximately V_{B2}/R see that each of the resistance is C the voltage of approximately V_B and the array so V_{B2}/R is the amount of power that gets dissipated into the resistor in each of the resistor, so that is one of the primary disadvantages otherwise it is very robust and has low component count and therefore very reliable so if it is a very low power circuit you can use this method otherwise if it is high power circuit this will not work out basically because of this issue.

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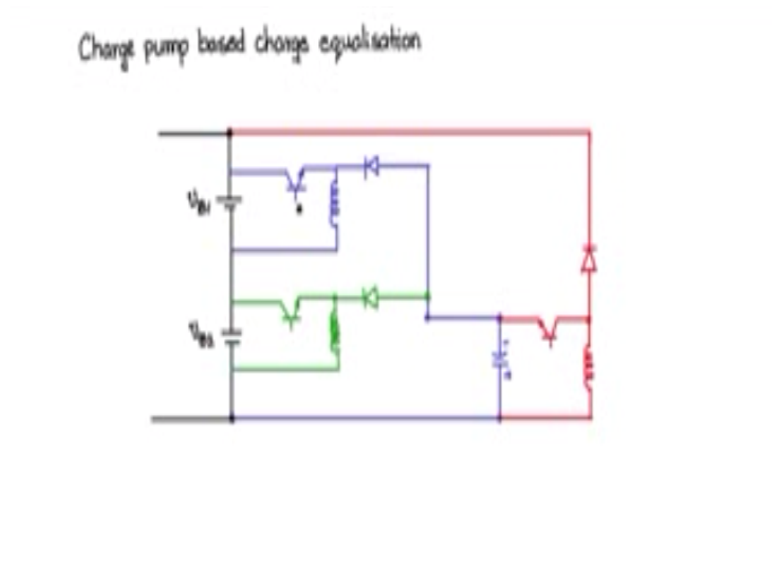

Let us now discuss the charge pump based charge equalization circuit which is based on fixed mode DC, DC convertors and therefore the efficiency will be much better than the case of simple resistive voltage dividers, so let me consider two batteries in series for simplicity rather than by taking up n batteries in series let us say I have just two batteries to be connected in series V_{B1} and V_{B2} on the left side the battery chargers are connected which will charger these batteries or it may be directly connected to a PV module or PV array which can directly charge the battery, now we say that these two batteries are not sharing the charge equally and therefore VB1 is different from V_{B2}.

But actually finally they should become $V_{B1} = V_{B2} = V_B$ now let us spoke some charge equalization circuit first I will consider VB1 let me put in as simple buck boost convertor here this is a buck boost convertor how does this operate when this transistor is on it removes charge from VB1 in this passion observed the cursor where this transistors is on from VB1 the charge is removed and stored into the inductor and then when this switches off the charge strode in inductor is flowing through in this fashion and then it has to come up through this, so we have to provide a path here, so let me put a capacitor a buffer capacitor here I am going to put a buffer capacitor here like this and complete this circuit in this fashion.

So now you see when this transistor is on charge from the vb1 is taken stored into the inductor in this fashion, when this is off inductor current continuous to flow in the same direction and it will flow in this fashion charges of this capacitance and into the through the diode into the inductor again, so while it is flowing see that the inductor is passing through other lower batteries and also this reservoir capacitor, this is called the reservoir capacitor.

So in this way charge can be removed from battery vb1 and it can be given to vb2 and also to this reservoir capacitor. Now let me consider the second battery vb2 and let me put the same back boost convertor circuit here also in this fashion, so observe here that when this transistor is on when will this transistor go on when it finds that vb2 is greater than terminal voltage by 2 so we have to since terminal voltage and if vb2 is greater than terminal voltage by 2 then I know that this is having excess charge I will turn on this transistor it will remove this charge store it into the inductor.

Then when I switch off this transistor during the 1-d doing the t-off period inductor current will continue to flow in this fashion it will go here charge up this reservoir capacitor and then come back and complete the circuit, so in this way individually each of the battery has a charge equalizer circuit like this it will DC, DC convertor like a back boost convertor where the charge can be removed and put into other battery, and charge from the lower batteries can be removed put it to the reservoir.

But when as a charge removed from the lower battery it can go into the reservoir how can it be put into the upper battery, so we need a charge pump so whatever is there in the reservoir we will pump it up and the pass it on here so let us see how we will weld this charge pump now this plus or minus node is that one and let us build up boost convertor here so I will have transistor and inductor like this so plus the this capacitor plus terminal connect to the inductor to this boost transistor.

And then goes to the divot to the terminal plus of the battery set terminal state so let me put this divot and an connect it like that so now you see this operations operate when let us say the voltage across this capacitor is more than particular value then we will switch this we will switch this will stored the charge here and this inductor and this is switching off.

The charge goes once up in and into the plus terminal of the battery set and in that way it starts percolating down again and this way he steady state the charge the batteries will get equalized because this is closed control system the each of the battery voltage is sensed terminal voltage is sensed and I am checking per each of the battery voltage with respect to the terminal.

So if there are n batteries terminal voltage divided by n should be each battery volute is the battery voltage exceeds that then charge is removed from that so that is the simple concept that is used for driving this transistors so whenever the battery voltage is greater than terminal voltage divided by n then this transistor is enabled for switching like that for each transistor.

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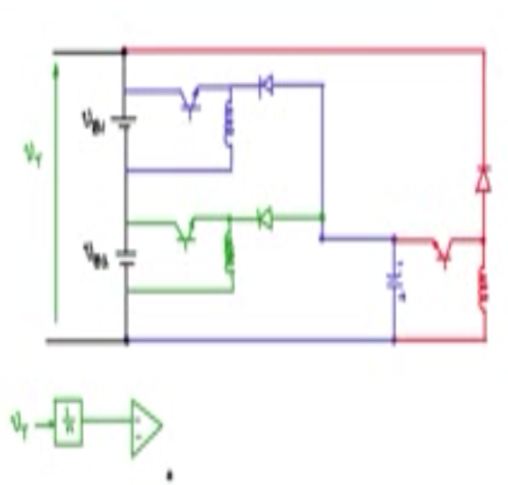

Let us now see how we will give the based wire signals for these three BJT's of course always note that wherever I use BJT's always use this now we will call this one as terminal voltage vt and vt is pass through again of 1/n to provide an output which is vt/n so where n is the number of batteries connected in series so in this case n is to there are two batteries connected in series so vt passes through 1/2n output will be vt/2 now this is compared with the comparator.

So let us say that one of the inputs is V_{p1}which is connected to the + terminal, Vt/ n, Vt/ 2 here is connected to the – terminal. The output okay I will also connect for the other battery, so let us say V_{b2} and V_{bn} so both are connected similarly, Vt/ n in this case Vt/ 2 is connected to the – terminal of the 1 comparator, – terminal of the other comparator also.

The + terminal is connected to the V_{b1} batteries and soul gat, so you need to have battery voltage censor and then V_{b2} batteries sensed voltage is given to + terminal. You could use differential amplifiers and then obtain may be 2 and may be 1 respectively. And the output of the comparators is given to 2 gates, so comparator 1 is given one of the terminals to the gate comparator 2 is given to another gate.

And a clock is given to the other terminal, so the n gate is acting like a gating block, so this clock is having continuously also being generated in this fashion of a particular duty cycle. So how does this operate? When V_{b1} > Vt/n or Vt/2 in this case, this goes high. So when this goes high this input is enabled clock passes through and that is given to this transistor so this transistor will be clocked at this frequency and this comparator act as gating or the enabling signal.

Now when this goes low even if the clock is present this is going low and this will swift off whenever the battery voltage is lesser than VT/N likewise for battery two also whenever the battery two goes more than VT/N that enables this AND gate and that will enable switching pulses to be passed on to this transistor now for this reservoir capacitor and the boost charge pump I will call this an CR and this as voltage VCR measured in this direction.

So I will use a comparator minus and plus in this fashion where for the minus I will use a VCR set asset value for VCR a reference value some voltage beyond which I want to pump up the charge and this is we measured value or the voltage across VCR obtained from differential amplifiers and this will be passed through a gating through AND gate act as a gating signal and clock is pass through the other input of an AND gate the output of the AND gate is given to this BJT thus enabling switching out this BJT.

And acting as a charge pump so in this way this charge pump base equalization circuit operates you can connect any number of batteries in series with the same circuit getting duplicated so this is a very efficient way of doing charge balancing especially for very high power level.