Indian Institute of Science

Design of photovoltaic systems

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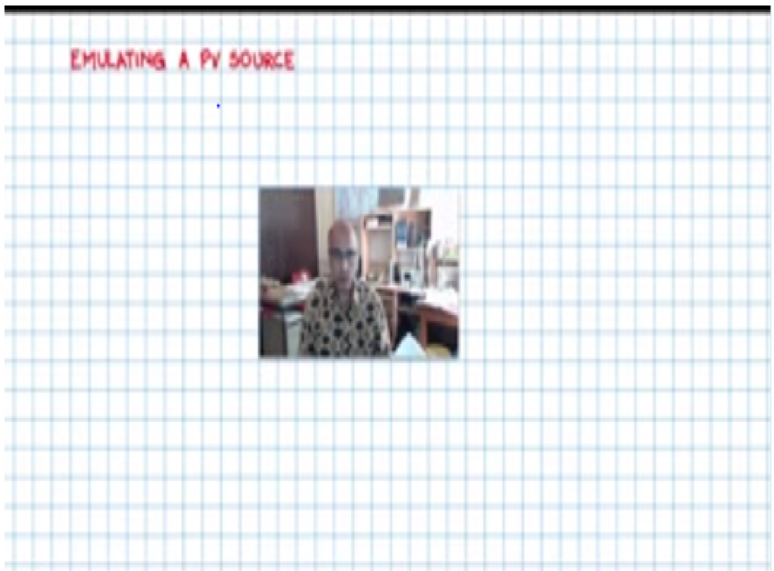

PV source emulation is very important when you are doing experimental work or even design work with circuits related to B resources you need to have a source which is stable and available all time of the day so that you can test your circuit you can perform your experiments and it should not be varying with the insulation dependent on the sunlight clouds rain and all those things in order for your circuit to function therefore having a stable source whenever needed any time of the day is very important if you have to do your experimentation and circuits and design.

With respected with respect to the PV source therefore we shall look at this problem and then see for the lab for you to work with a source which emulates PV source as best as possible we will try to demonstrate with a few psychotic samples and see how you can go about building them .
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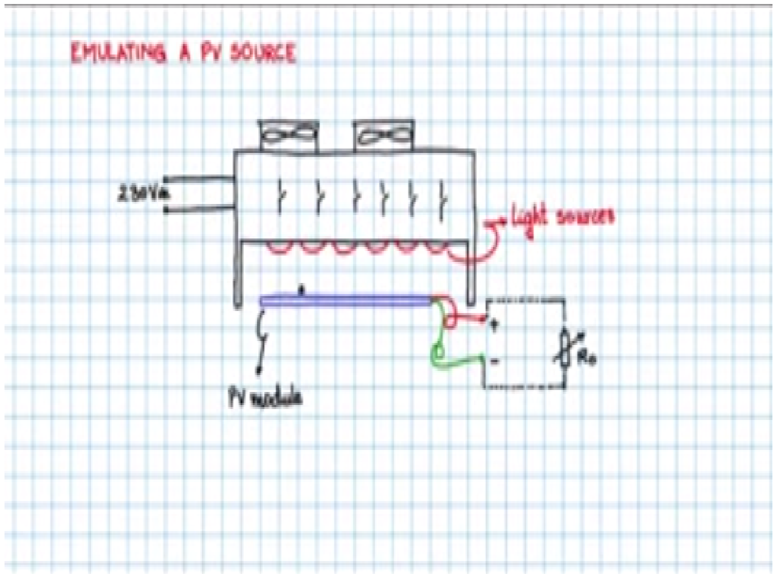

The simplest and the best way is to use the light source so let us take for example PV panels now let me consider this as a PV panel for PV modules and this PV module is having two wires coming out of it mark plus and _ across which you connect the load now this PV module has to be excited with light to deliver power and therefore we need to have some kind of an enclosure like this and this enclosures housing the buns so this is enclosure this is fan so that the bulbs.

When it becomes hot you need to remove the hot air and this enclosure is actually deriving power from 230 volts means and these are the bulbs which you see here and these bulbs are energized to throw light upon the PV module so that it can deliver power you can control the amount of light that falls on the PV module by controlling the intensity and the number of bulbs that are switched.

So these light bulbs are bulbs that you can choose which has a spectrum as close to the sunlight as possible now each of the bulbs or cluster of bulbs can have manual switches connected in this fashion such that only those particular bulbs are energized and the load is connected across the terminals of the PV panel in this fashion and the load R not is what you would like to drive now this is a very simple PV source but unfortunately this needs a PV modules and the PV module output is depend upon the area of exposure.

Which means if you want to go for very high powers you need a very large real estate and then a large bulb cover area so that you can suit them on and off under your control this is not such a feasible solution for very large powers for very small powers and small experiments this is fine but the ones who start going to higher powers greater than 1 kilowatt then you will have took at other electrical solutions.

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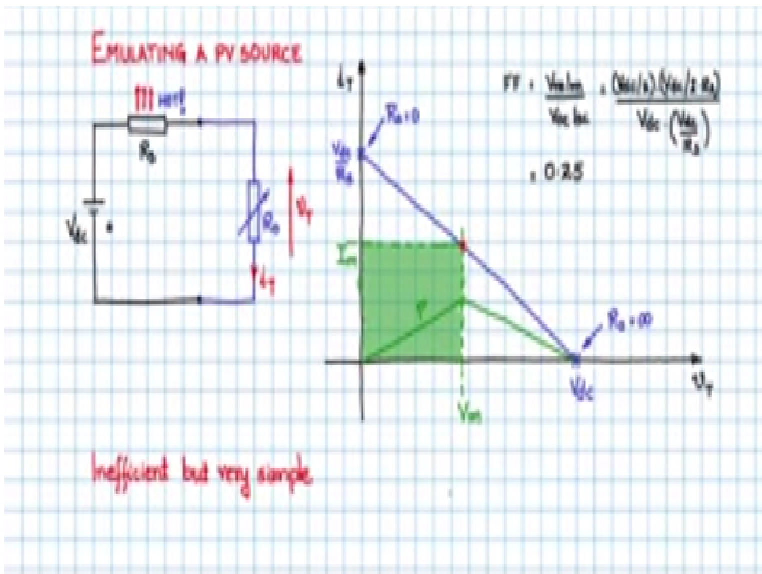

Let us now see how we can go about emulating a DB source by electrical means we think a simple DC source it could be a laboratory power supply or it could be a battery so let us say you take a battery and you connect in series a resistance we will name this battery as VDC and we renamed the resistor as RS so this combination VDC and RS together in series form the simplest PV source emulator across the terminals you will get a voltage VT and the current through the terminals that will look like quite similar to a PV source.

Let us connect now a load resistor across the terminals now I will call this load resistance or not and we will make the load resistance a variable resistance so that it can be varied from 0 to infinity or short circuit to open circuit the voltage across the terminals we will call that one as VT and there is current that flows through the terminals through or not and that we will call as a terminal current I T.

Now if we look at the characteristic IV characteristic then we will see that IV characteristic of this combination resembles that of the T V source and therefore we can call this as a simple PV source emulator so now let us draw the characteristic now x-axis I will call the x-axis as VT and for they-axis I will have I T now I will set our not to a very large value are not infinity meaning open circle.

So which means there is noncurrent flowing through the terminal I T is 0 when I T is 0 now I am talking of a point on the x-axis alone and what is VD as there is no current flowing there is no drop across borders as the whole VDC will come across the terminals and therefore VD will be VDC if you open circuit the output so I will put an operating point here and I will call that one as VDC.

So I have marked this operating point right this VDC the special thing here is that or not is infinite so open circuit next I will short-circuit I will go to the other extreme of are not I will short-circuit the terminals when you short-circuit the terminals VT becomes 0 which means then I am talking of a point on they-axis so I short-circuit this VT becomes 0 what is the current flowing through that VDC by RS so I will mark appoint another operating point and the value of that is VDC/ RS.

And the important character of this operating point is that R 0 is 0 short-circuit now are you very are not between these two extremes short circuit to open circuit you will see a series of points coming up like this in a linear fashion oat the midway point here I will mark and I will call that one as we and likewise the midway point will be I M so I M and V why do I call it I M Andrea because is the linear one at the midway point you will see that the product VM into I M will be maximum so power will be maximum here.

The product here VM into I am is Vinton I is 0 because voltage here is 0 even though the current is VDC by RS here at this operating point voltage is VDC current is 0 therefore you will get a triangular power curve P with the big power operating point here so this will be the peak power operating point no to the fill factor fill factor is VM I am this area as you see here this area divided by the total area as given by Vi C do I see so you can see fill factor which is equal to VM by by V was E is e

What is v m v m is halfway point of the x-axis VDC by 2 and what is IM halfway point on the y-axis which is VDC by 2 RS divided by VDC 4 v o C and VDC by RS 4 is C so if you workout you have 1 by 2 and 1 by 2 coming up here in here it is 0.25 the fee factor of this PV source emulator is 0.25 it is a very bad fill factor fill factors of PV panels should be a garden of 0.7 to0.8 for a reasonably good PV panel however TV source emulator is very simple and it will serve the purpose of doing experimentation at odd times even at night .

When you can get a steady t v source supply this TV source emulator is very inefficient why is it inefficient see there is are not flowing through this IT and always there will be I t square into RS drop power loss there is a I Tinto RS drop and I t-square and go Rs power loss in this resistance and that will make it pretty hot therefore it is inefficient even though it is very simple emulator so if it becomes hot there you have to build in mechanisms where you will have to remove the temperature.

So you may how to fix along with the resistance a forced cooling blower fan or something like that so this becomes the PV source emulator Avery simple PV source emulator no we will look at this DC supply I said wean use a battery but using a battery is not convenient because the battery haste be always kept charged and when it discharges you will have to find mechanisms or have another equipment to keep charging it and then keep the voltage at a nominal level however it would be very convenient if you get the power draw the power for this DC power supply.

Some a much more steady supply like the mains or the grid therefore we would like to replace this V DC source by an electronic version of DC generator already Z source where power is drawn primarily mainly from a grid or the mains supply so how do we go about doing this let us shift this circuit decide now this is what I want to replace so I will remove that and instead of that V DC source we will be having some electronic circuit here which will link up that we would like to draw power from the 230 volts grid the AC means.

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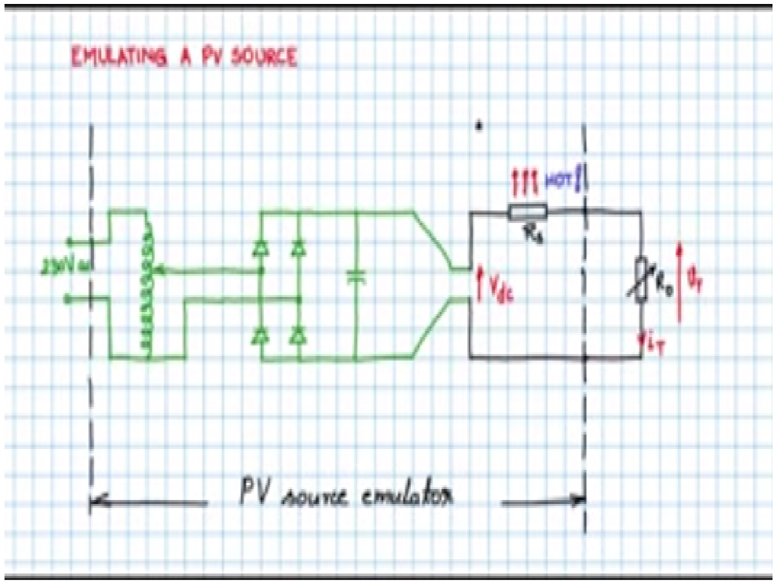

So let us draw transformer it is not a transformer it is an autotransformer so we would like to have an auto transformer there so that you can draw variable voltage from the grid and do that later the interface full bridge rectifier circuit so this is a full bridge rectifier you are familiar with this and we will place a capacitor filter full bridge rectifier with capacitor filter output and this will get connected to this point and that will become the DC source now you can see the portion of the system from here.

To here is what we will call as the p v source mo later and this is a simple circuit this is anautotransformereasily available in the lab the bridge rectifier you will get four bridge modules available to the market you can buy them put a capacitor across and then you have your VDC put a series of your start you have your total PV source emulator so this is a nice interesting circuit you can have you can use it anytime of the day and the load that you connect here can be used for testing a P V cell.

So in the in the end whatever experiment you are done you will finally test it with the actual PV source and if it works with the simulator most likely it will work with the PV source I will describe to you now a switched-mode DCDC converter based PV source emulator you see the previous circuit which was simple and easily could be implemented had one major drawback that is that it was very inefficient a lot of loss in the series resistance RS and not only direct the quality of the I characteristic was born it had only a sin factor of 0.5 but one major advantage with the previous circuit is that it was very simple easy to implement now here I will try to describe to you in a block schematic form the operation of the DC converter switched.

More DC converter being used as a PV source emulator faster the dc-dc converter output will have an IV characteristic similar to that of PV cell now let me draw the block schematic of this switched-mode DC converter.

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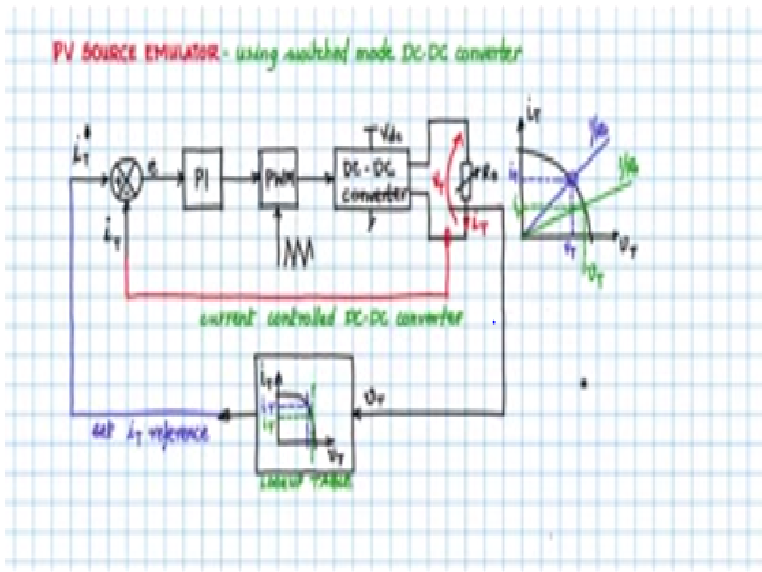

Which now behaves as a PV source emulator it is supposed to be a current controlled converter so the terminal current I T is supposed to be controlled so therefore I know how herewith me a reference ID reference the terminal current reference and terminal current feedback now these two on comparison leads to an error signal and this error signal is passed through controller which is a PI controller and output of a bi controller goes into a PWM block and this PWM block is applied with a triangle wave and output of that will be the duty cycle input to a DC converter.

Like this the DC converter is applied with VDC and output of the DC converter is supposed to emulate VB resource and that disconnected to a load or not like this I T as indicated here is what we are supposed to control so which means that I need to sense I T and then feed that back and get it control so what this block diagram mainly indicates is that if I set reference I T star and the error here passing through the PA controller freedom DC D C converter and all those things.

And this current terminal current being fed back in this fashion the job the VI controller is to make error 0which means that I T will be same as I T star which means I T is nothing but the terminal current flowing through the load which will become CMS IT starts now that is a current controlled DC converter now this basic topology is what we willies for making the p v source emulator now the DC converter being switched is a very high efficiency converter.

And therefore we will not have the loss as we saw in the gear in the earlier case or earlier model let me mark the output voltage like this as R et and let me also draw the V versus VD versus I Characteristic like this and we let us say this is the output characteristic that we expect across these terminals the actual characteristic that we expect across the terminals that we would see and this has a load R 0 and therefore the load 9 the one my are not line is like this with the operating point as shown here.

so at that operating point we see operating voltage VD and IT so this is the actual value of V Which you see here and the ID which is flowing through this now let us since VT and use that V D to provide the Dereference so what we do is how a lookup table of VD vs. and this look-up tables is the one which we will be using to generate the reference for IT so you see that in the lookup table VT is provided as the input it will check the independent axis and appropriately because the current IT to be given out.

So this ID is given out and fed to the reference so this way the setting for the IT references done now imagine that or not has changed or no this increased so increasing or not means the load line comes like this as shown in the green now the moment or not has increased IT into armed would be a higher value so you will see that VT these VT is like this now that is the VT and what is actually expected as I T is the horizontal so this is supposed to be the expected IT but right now the ID is here or not has change VT has become this now we should try to see the controller will bring back I'd.

Here now let us see now this VT has increased and that is given here and which means it will try to looking to the lookup table and see that the VT Falls there and waste on that VT and intersection of the IV characteristic of table you will get the new value of I T and this value of I T will be set as a reference here now this is a smaller lower value of I T and therefore this Irwell try to match this and therefore this load ID will try to match the new reference and therefore come and settle at this point.

So in this way for any value of R 0 this converter will track the IT and the in that way give you IV characteristic and Iracharacteristic as we have loaded into this lookup table so this lookup table is crucial the characteristic that your load into the lookup table is the one that will actually reflect here so you can you can play around with the lookup table in terms of insulation of the vivo T in terms of fill factors and all those things and actually get replica at output at the higher power level and this you can design it for any power level that you want.