Indian Institute of Science

Design of Photovoltaic Systems

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NPTEL Online Certification Course

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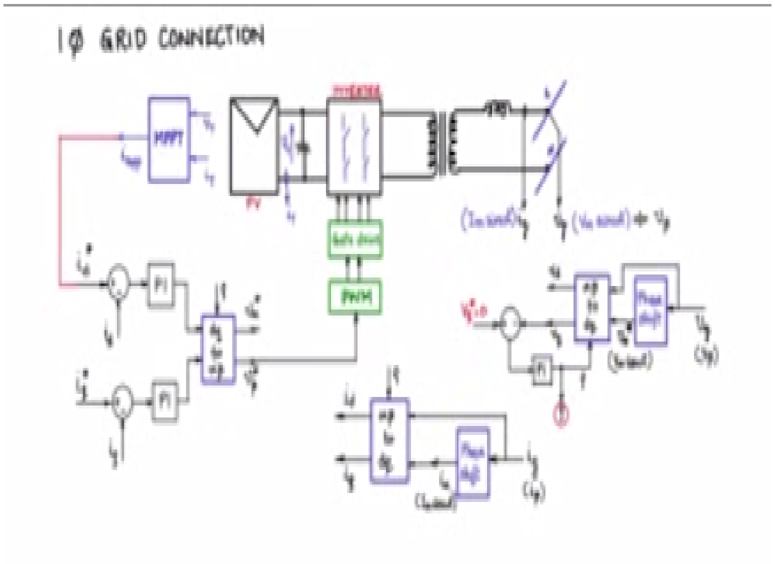

Let us now discuss the single phase grid connection as the PV module is being interface to a single phase grid, let us first draw the topology of the PV module being connected to a single phase grid. The PV module terminals being buffered is connected to a single phase inverter which is consisting of a bridge having four switches full bridge having four switches and from this center of this bridge arms we will connected to a single phase transformer like this and the secondary side of the transformer is connected to an inductor and through the inductor is connected to the line neutral of the grid for single phase grid.

So this is the basic topology of the single phase grid which we have discussed earlier, this PV and this is the inverter let us name this parts, now the gate drive here unlike the three phase case we need to drive only four switches so let us have four gear drives and the signals for then gear drive or coming from a PWM module. The PWM module will give two signals depending upon the type of the PWM which will be used for driving these four switches.

Let us now sense the current that is flowing through the inductor into the grid that we are pumping into the grid we will call it as ig and let us also measure the phase voltage have a line and neutral and I will call that one as vg that is the grid voltage, grid voltage vg is vm sinωt it of course contains lot of harmonics but let us say that vg is vm sinωt and ig we wanted to the im sinωt that is we would like to inject the current into the grid at unity power factor.

So the moment you say this is vm sinωt this is im sinωt this is actually iβ, this is vβ there is no vα or iα so we have to generate it, we have to create the α component so that it willfit into the α,β co-ordinate axis. Let me consider a phase shifter block, so let us say this phase shifter block does the job of taking the input signal and shifting the phase by 90° we will see how we can realize that but that is the objective of this phase shifter block.

So to the input of the phase shifter block I will give ig, ig which is considered as iβ because it is a sinωt and the output of the phase shifter block will give you iα so after this im sinωt is pass through the phase shifter block it will become im cosωt shifted by 90°. Now I have iα and I have iβ also so which I can pass it to a transformation this is α,β to dq which will give me id and iq, so now I have this id and iq which are dc quantities due to this αβ to dq transformation there is a ρ input which has to be given so we will provide that ρ input.

Now what is that ρ, ρ is the angle between the αβ co-ordinate axis in the dq co-ordinate axis I will come to I will come and discuss later on how we will generate this ρ. Now that I have let us say id and iq the dc quantities of the current I will now have a control mechanism like this so I have id*, id just like in the case of three phase and the error is passed through a PI controller. Similarly, I will have another control mechanism for iq*, iq is fed back and I will have a PI controller.

So we will see what we have to set for id* and iq* id is basically this transformed current which is given here iq is this transformed current which is given here, coming ultimately from any input measurement. Now this PI these two PI outputs will be passed through a transformation this PI controller outputs will represent voltages which need to given to the PWM to control their inverter, so this would be a dq to αβ transformation it also needs ρ information ρ which is the angle between the dq axis and the αβ axis.

The output of this will be v_α^* or reference v_β^* and these two will act as a reference for the PWM generation it means this, this will be given as the signal for comparing with a triangle and generate the pulses for giving it to the gate drive. Now we do not need to use both v_α^* and v_β^* see that vg here is vm sinωt which is v_β, now ig is also i_β vg is v_β that is a β axis components we have, we generated the α axis components by this phase shift, we generated i_α and then the id and iq where obtained. So we need to use only the β axis components α axis components where created just to provide us the transformation, so that we could go into the dq domain that is the dc domain so that you could so set point control.

So here we will use only one of this which is v_β here for now because we are taking this as vm sinωt.vm cosωt so we will use that. Now this will go to the PWM it will generate the PWM signals gate drive and then it will drive the current pump the current into the grid, now this current ig which is being pumped into the grid is the one which is actually being controlled because these are current controllers and we are doing current control, we need to set these references before we set these references let us see how we are going to get this row these two rows.

Let me use another phase shifter the input to that is vg which is v_β and I will use αβ to dq transformator, the phase shift output is going to give me v_α because it has shifted it by 90° which is vm cosωt this was vm sinωt and I can use vg here so this will give me v_β and v_α and I will pass it through αβ to dq which will give me vd and vq and this will have a row input, so how do I get this row input I will setup a control system here, I will have a reference and the feedback point is vq the converted transformed vq, the output of that the error is given to a PI block the output of the PI block is given as ρ to this αβ to dq transformation just like as we did in the three phase system.

Now this v_q^* here I am setting it to 0 then eventually this control mechanism will operate in such a way that this PI controller being high gain controller will make this error 0 which means vq will become 0 match with the v_q^* and therefore we can say that the ρ is at such an angle that the dq axis is aligned along the vd which is the voltage space vector. So once it is aligned along vg then I can set commands to the current set points or the current references.

So I would not like to have any quadrature component of the current I would like to inject only active current which means in phase current so therefore iq has to set to 0 there should not be any quadrature component then the current space phaser will become in line with the voltage space vector which will be in line with the dq axis of the rotating dq axis co-ordinate system just like in a three phase system.

So we will set iq* to be 0 and id* whatever value that is being set here will be the amplitude of the current that will be actually pumped in here which is directly proportional to the power being pumped into the grid because the voltage is fixed by the grid. So therefore, id* set point should actually have the output of the MPPT control algorithm.

So therefore, I will set up this MPPT block now this is vd the terminal voltage of the PV I will measure also id the current through the PV we will have a MPPT block the inputs are vt and it power will be calculated and a MPPT algorithm can be used to obtain an output which will be proportional to imPV current at maximum power point and that will be given as a set point to id*, so output of the MPPT will determine id* and id will try to match that meaning the current that is flowing here could corresponds to the, will correspond to the maximum power point of the PV panel.

Thereby achieving MPPT integrated MPPT control and grid connection, so this would be the entire block diagram for a single phase grid connected inverter. Now what about this two phase shift blocks, how will you make the phase shift I will just tell that now right now.

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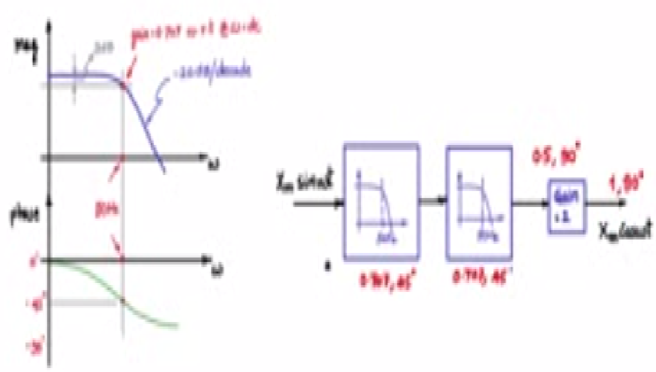

Let us now see how we obtain the 90° phase shift, so consider this graph where the x-axis is ω frequency not time. Now this graph has magnitude as the y axis and this graph has phase as the y axis, now consider a first order filter now first order filter will have a magnitude verses ω plot something like this, this slope is -20dp/decade and find out the 3dp point below the flat portion of the magnitude curve that is 3dp below the magnitude at ω which is dc.

So this is the 3dp below point, now at this point the gain is 0.707 with respect to the flat portion. Now that the frequency, take this vertical line which cuts the frequency and look at the phase curve the phase at that 3dp point will be 45° so this is 0°-45° eventually this phase curve will reach 90°. So for us the grid frequency is very stable it varies between 49.5 to 50.5 Hz which is a very small margin it is more or less 50Hz.

So this line should be add frequency which is 50 Hz, the we can say now at this point the gain is 0.707 with respect to ωdc or the flat portion of this magnitude curve. Now we can say that if I have this first order filter and at 50Hz it is so designed that it is having a gain of 0.707 or an angle of 45° then I will use two such first order filters each providing 45° if I am biasing in that fashion designing in that fashion where the 3dp point is at 50Hz then this first order filter will give gain of 0.707 and 45° shift another first order filter will give again a 0.707 45° shift overall I will have a 0.5, 0.707 into 0.707 will be 0.5 gain and 90° shift.

Now pass this through a gain block, gain of 2 and I will get 1 gain same as the input and with the 90° shift, so if I am having xm sinωt they format the input it pass through and at the output here you will get xm cosωt, so this is how you will generate a 90° phase shift the one that I had indicated here this and this, so with this, this entire single phase grid connected inverter topology can be implemented.