Indian Institute of Science

Design of Photovoltaic Systems

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NPTEL Online Certification Course

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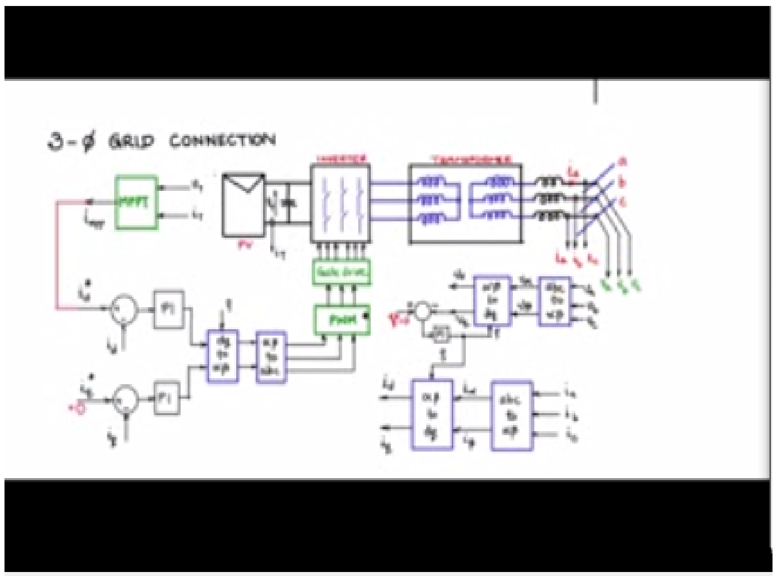

Another important Block in this topology is the PWM block we have not discussed about this for three-phase we normally use a space vector PWM method and let me describe to you how this is done.

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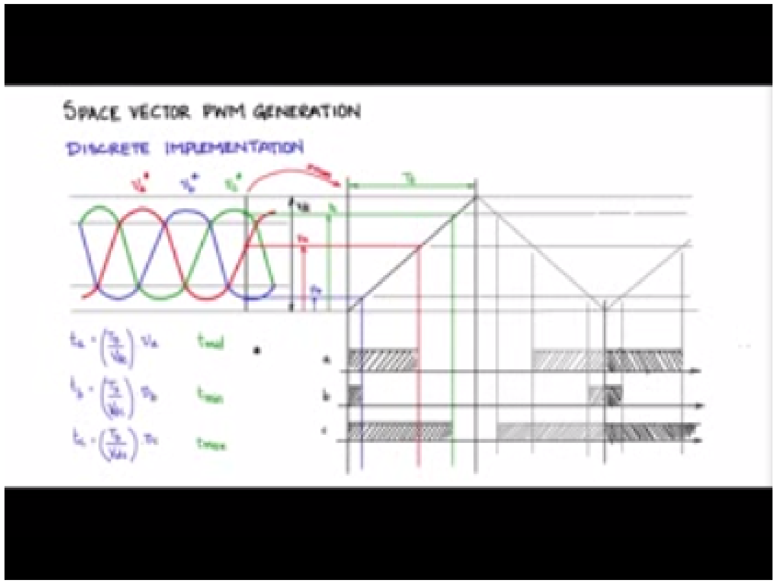

Most of the control logic the DQ transformation the PWM VI controllers all are implemented in the digital domain mostly in microcontrollers and DSP processors so therefore it is important that we try to understand the space vector PWM the discrete implementation version later I will talk to you about the analog implementation also if you want to implement it using op amps.

So here to the input of the PWM we have three inputs VA VB reference we see rough so that is our starting point we have three phase reference voltage signals and the output would be pulse width modulated signals to that gear drive let us now generate the three phase reference signals we a star V B star B C star and I will try to do it in this in this way simple.

So now you have we stopped we B star and V C star so these are the three phase reference signals that are going as input to the pulse width modulator let me now mark the boundary of the modulation so this would be 100% modulation and that would correspond to the entire VDC of the bus the DC bus let me extend the extreme modulation limit line like this and let me shorten those lines so that I have some space here now let me have a window here now.

I am having this is the carrier signal is there in this one so this there is a triangle the three-phase AC signals are at 50 Hertz at lower frequency if it is motor drive but if it is for grid connected in inverters this is fixed at50 Hertz it will be more or less at 50Hertz but you could use the same space vector PWM generation what we are discussing even for motor drives where it could have this could have a varying frequency but for now consider that this is the grid frequency.

So these reference phases and Here I am having a triangle there is a small window where there are triangle carrier we will zoom it up and then see so we will zoom that so that we will be able to see what is in this narrow band that we have drawn so it consists of a triangular carrier which is like that so this time this time is TS one switching frequency period or carrier frequency P we will call that one as TS so is it because of this triangular this linear conversion the voltage can be converted.

To time because of this linear portion of your triangular waveform now we will mark the intersection point so the C which is the maximum now there is a intersection point there is an intersection point here for the VA waveform and there is an intersection point here for the VB waveform so let us extend that so that it cuts this voltage to time conversion ramp like that.

So this height is VA high time say this height will be VB height and this height up to this would be we see and we could say using a linear relationship TA is equal to the ratio the VDC will get converted to TS full period because of this linear graph so TS by VDC is the conversion ratio or transformation ratio into VA would give you a time corresponding to V TB is TS by VDC into VB would give a time corresponding to V then TC is TS for a VDC into.

We see would give a time corresponding to we see so if you drop down there so you will see that these times are PV ,TA and TC should be but there is some small modification I will come to that later but essentially the principle is that the voltage amplitudes are converted two times in the time scale by this converts a conversion ratio TS by VDC now let me draw the time axis signals here ABC which are supposed to be the output of the PWM.

Now we will this is a compare thing this is comparing with some kind of a counter this ramp triangle is nothing but a timer going up and down up down counter so anything below that let us make that high anything above that is low so let us say VB is the lowest this one so it will be high here and low elsewhere so team in let me say that TB is teaming because that is had at that instant at that instant where we are looking at that is the VB is the minimum at a minimum and we see is at the maximum and TA is a DI value teammate.

So let us now draw the PWM waveform so for the B it is cutting here so it will be high here and low elsewhere and for the A this is the A so it will be high until that point and for the C it will be high till this line here so let me hatch them so these can be extended further because this window has many triangles and I can also drop down the cutting points here so this is in dark because this is another TS period and third TS period so on.

So you can see depending upon the points where it cuts you will get the A it is mirror image because this up down counter this counts up linear ramp up linear ramp down linear ramp up keeps going in that fashion and following first let us finish the ABC so you see that it is like a mirror image and for the C phase also you will see as + width like this and then continue again up you will see that it continues without a seemed seamlessly without a break like this portion gets repeated here like that let me hatch that and this portion will get repeated here.

Because this is also uprising ramp we have drawn the uprising ramp here and the sea phase also comes in like that let me darken this so that you can make out a difference observe nice thing is that this is TS period this period TS that said this period is TS but as far as the switching is concerned you will see that there is no change in the switching state of the inverter when it is crossing the boundary so this remains high this remains high and this remains high soon also if there is a dump there will be a down slope here so this will continue to remain height.

So it looks as though the switching period switching of the switches is at half the frequency even though the carrier frequency is twice as much so therefore you will see that the switching losses are less so that is that one of the advantages of the space vector PWM so this way we can implement the space vector PWM this in fact would be the analog implementation just compare and then pass it through a comparator but the digital domain.

We need to give values numbers to a compare register and it will compare with this counter or timer and then make a port high or low depending upon the value compared value so how to calculate and give we have calculated DAT,BTC but observe that.

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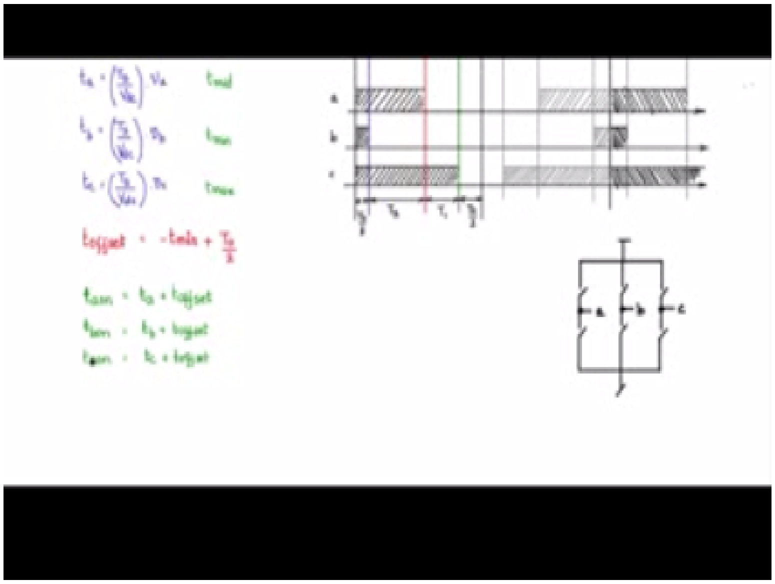

Let me draw this inverter scheme up the inverter like this so you are having the VDC across the inverter these are the 3R's of the inverter this is RBA RB RC so at the center points of this you will have the pick of points A B and C going to the load now if you observe this during this time A is high B is high C is high this is high this is high ,this is high all are connected high which means the space vector is 0 so this would be corresponding to 0 time another time is here in the same period TS period this is 0 ,0, 0 which means the switches are connected to all the lower switches.

Are connected 0 B 0 C 0 then also space vector is 0 so this time and this time or time durations during which the space vector is 0 so you can say that this is I am splitting it half an off T . by 2 and this is T .by 2 and from the maximum value phase to the mid value phase we call T 1 and from the mid value phase to the min value phase we call it as T so as the designation that we use in the space vector let me now indicate a problem.

To you see that this ABC phase wave form AC waveforms they are AC waveforms where the 0 is like this so above the 0 VA VBVC are positive below the 0 VA VB VC are negative so when you when I directly use this equation TA= T guess by VDC into VASTS by VDC into v BTS by VDC into VC TSS positive ad C is positive V a can be positive under some conditions can be negative under some conditions so you may get values of TA which are both positive and negative and in the time domain having a negative time value does not make much sense so we need to make a shift and we know the reason in the sense that we have taken centre point.

As the 0 this is a 0 we are saying this is - time is plus time what we do is we shift the 0 to this point this axis so basically what we are doing we are giving an offset so we make an offset down using the minimum value so I have a minimum value so I know this is the minimum value and this region out of the envelope both these regions out of the envelope is that time corresponding to T naught 0 space vector time we saw here this is T naught and it is T. this is the time corresponding to T. This is the time also corresponding to T .both – both together add up as 0 space vector time outside the envelope so this is T/2 we say T/2 and this is T min we said so team in here is negative .

So most of the time the teaming will be negative because when a wherever you make the window cut the minimum time will be in the lower than 0 so it will be negative so we just add this absolute value+ T . by 2 the whole DC will shift and the 0 line will come in here so we just add an offset to every calculation of T 80 BTC the offset value should be - T min + T. by 2the reason why I put - came in is T min value itself is negative- or -will become+ so you will have a ship now the actual value that you have to put.

To the compare register would be DA on will beta plus the offset all will be positive TB on will be TA ,TB+ t offset and TC on will be TC + T offset so this is the value that you will be sending to the comparator of your timer in your microcontroller or DSP.
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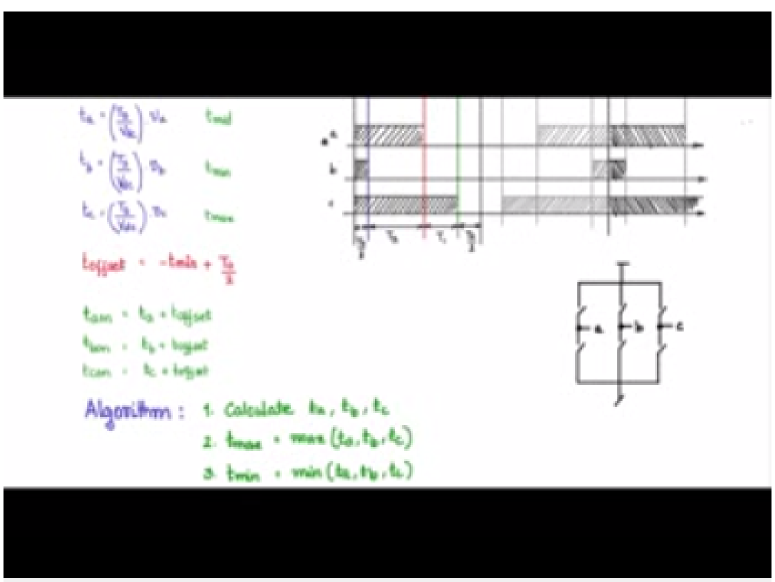

So let us just have a look at the algorithm that you would implement so first calculate T 80 BTC so the input is you are getting V A star will be star VC star from as input to your PWM block using that you can define as constants TS and VD V DC and TS the carrier frequency calculate TA BTC according to the equation that we just discussed the next calculate T max which will be max of T A BTC and then calculate T min which will be min of T80 be DC and fourth point will be calculate the effective.

Which is T max -demon this is basically the region within the envelope so T max minus T min will be this region so the region within the envelope is called the effective time the region out of the envelope is the region where space vector is zero that is T naught time and from the max value to mid value will be time corresponding to t1 from the mid value to min value is the time corresponding rotate so that is the nomenclature next calculate T naught which is TS we know is the carrier switching carrier period - T effective.

And then calculate T offset which is - T min +T naught by 2 and then finally calculate TA on TV on and TC on using this relationship and then use that one to load to the three compare registers of the timer and then that will count compare and then make the three digital ports up and down high or low depending upon the values so in this way you can generate this kind of a three-phase PFW waveform so here for every R for the top switch and the bottom switch you will give a ,A bar and when you give you A bar you do not just give one it just an inversion of a to the other device.

One you will give you another you will get a bar it is not just a plain inversion at the transition you will make a small time period called the blanking time period where both will be off for sometime because this has to account for the rise time and fall time of these practical switches so that is called the blanking time or the dead time in the literature so when you make the inversion you do not do a direct inversion and give it to the other a complementary switch you will have a delay mechanism built into your algorithm so you invert and then that goes high delay.

It and make it high so that the rise time and fall time will pass and there will not be a direct shoot through period where a huge current can flow so this is this is what is called the dead time intrusion and when in a real circuit when you are giving it two complementary switches these signals.