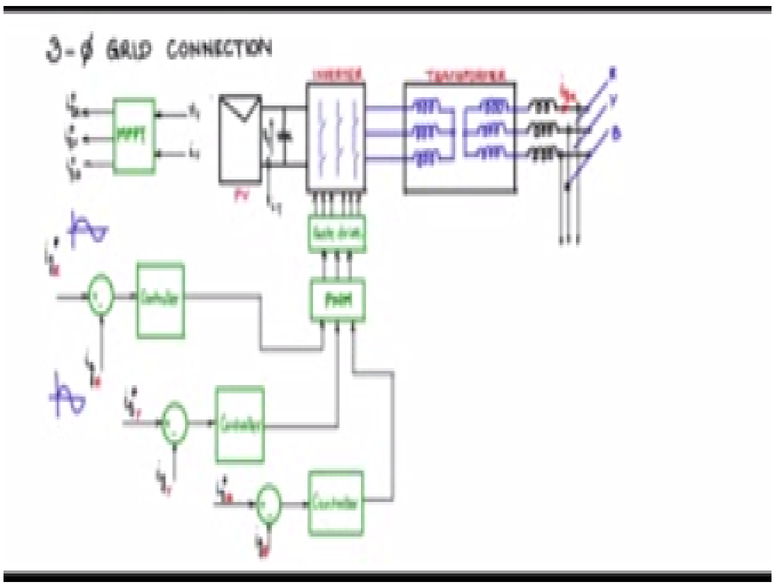
Indian Institute of Science

Design of Photovoltaic Systems

Prof. L. Umanand
Department of Electronic Systems Engineering
Indian Institute of Science, Bangalore

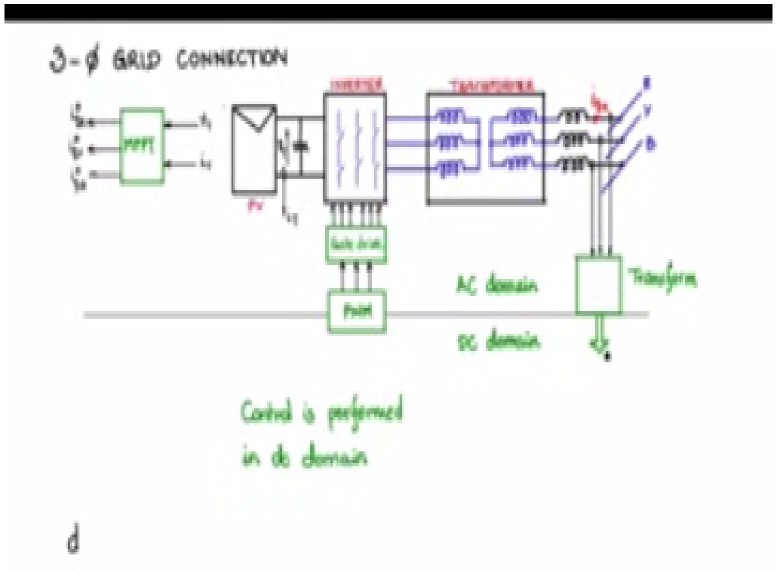
NPTEL Online Certification Course

(Refer Slide Time: 00:18)



So this in this 3 phase grid connection system we would like to replace all these control blocks and we would like to have all the variables in the control, controller region as DC. How do we do that? Because all the signals that you are sensing are AC signals, how to go about doing this transformation.

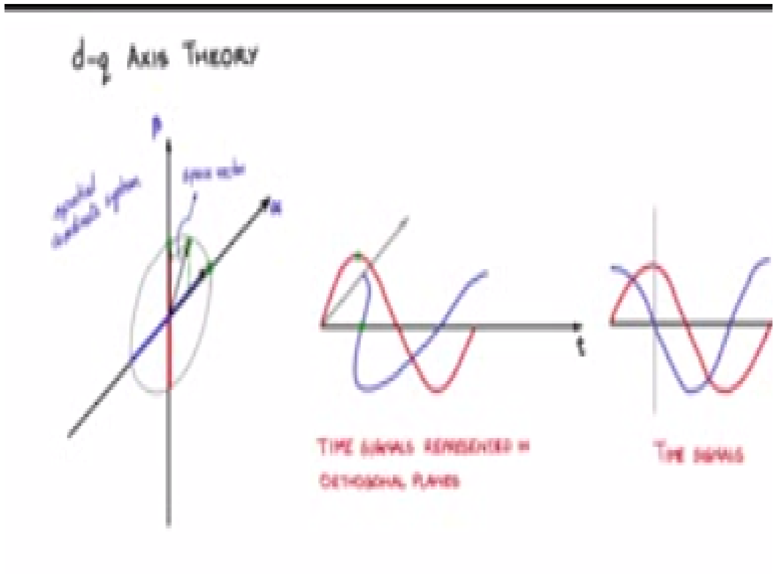
(Refer Slide Time: 00:40)



So let me remove this and let me draw a line above the line all the variables on AC we know the line I want to convert all the signals through some transformation where it becomes DC here. So that is the AC domain and this region will be the DC domain, so I will put a transfer meter and convert all these signals let us say the currents that you are sensing are sinusoidal signals and after you pass it through this transformation, what we call frame transformation the variable here even the current variable here will appear DC.

So to the controller as the variables are appearing DC I can now make a set point controller now that would give a much better response and the controller will also be simpler and have a better bandwidth and better performance.

(Refer Slide Time: 02:20)



To do that we will discuss this dq axis theory there is this dq axis theory whereby it is a transformation principle where you can convert AC signals into DC AC sinusoidal signals into DC and then operate upon the DC values and then back again transform it into the AC domain where they will become AC signals, so this process of transforming from AC domain to DC domain DC domain to AC domain is what is popularly known as dq access theory which we will see now.

Consider an axis here like this I will not name it now I will name it later just consider an axis here and consider a time axis here as shown and another time axis also I am drawing here by the side of it now let me draw a sine wavelike this on this time axis, likewise I will repeat that time wave on this time axis to now here not only am I drawing a sine wave I will also have a cosine wave Cos way so let me mark and draw a sphere like this. As the sine wave is evolving with time at every instant of time it is having a value.

And project that value on to this axis that we trio first, so if you see that there will be a projected image on this axis as time evolves and that will be in this region depending upon the amplitude of this sine wave. Now I will draw another orthogonal axis like this I will still not give this also a name I will give that later but it is an orthogonal axis, so this sign was placed on a plane which is vertical I will how a horizontal plane like this and on that horizontal plane I will place this cos wave like this.

So you have to imagine the cos wave is placed on the horizontal plane, the sine wave is placed on the vertical plane so they are placed on two orthogonal planes just like you did for the sine wave as the time is evolving the cost wave the projection of the cos wave is seen on this axis this orthogonal axis as we are seen as I have shown here. So in a cycle as the cos waves as a evolved like this you will see the projection as a line on this axis like this.

Consider the cause ensign signals here now assume that this line vertical line gray shaded line is moving with time along like this I am going to move this great shaded line at different points in time I am going to sweep it in the time axis, so let us say at this point in time let us say this is 0 let us see what is the projection when it is here at this point the sine wave value is 0 the COS wave value is maximum. So if you look at it the sine wave value is 0 it is projection is on this axis it will be here the cost wave magnitude is maximum and on this plane its maximum it is projection is here.

And I will put a mark here to represent the Victorial sum of the this point on this coordinate axis and also this point on this coordinate axis, now I will shift this reference line right like this now at this point in time the sine and the cost values are like this at the point of intersection. Now if you take the sine which is on the vertical plane the point corresponding point is here and on the horizontal plane the corresponding point for the Y is here both is at the same time now project that on to project the cost point on to this axis project the sine point on to the vertical axis.

And you will see that those two combined and the resultant will be a vector like this, so this would be a cost value this is a sign value and therefore this would-be $\sqrt{}cos^2$ + sine square the angle which is 1 if both the sine and cos our unit signs and unit causes. Now I have moved this reference line further and I see that here the cause time signal is at 0 at this point and the sine time signal is at maximum.

Now coming back to this orthogonal plane representation you will see that the cost signal has reached 0 in the horizontal plane the sine signal has reached maximum on the vertical plane and now you project the sine signal onto this axis project the cost signal onto this axis then you will see that because the cost ignore value is 0 the resultant marker will be there and the vector will be at this point. Here again because signal is having 0 sine signal is having a maximum value if they are unit sine and unit cosine.

Then the max value will be 1 so you see that the vectors are all amplitude 1 amplitude 1 amplitude 1 so on and if we proceed you will see that it will start moving along this locus the tip of the vector will move on this locus and the radius of this circle will be 1 it will in fact be a circle because every other intermediate point can be reached by $\sqrt{\cos^2\theta}$ plus sine square θ which will be so this coordinate axis which I have here, this coordinate axis is a spatial coordinate system.

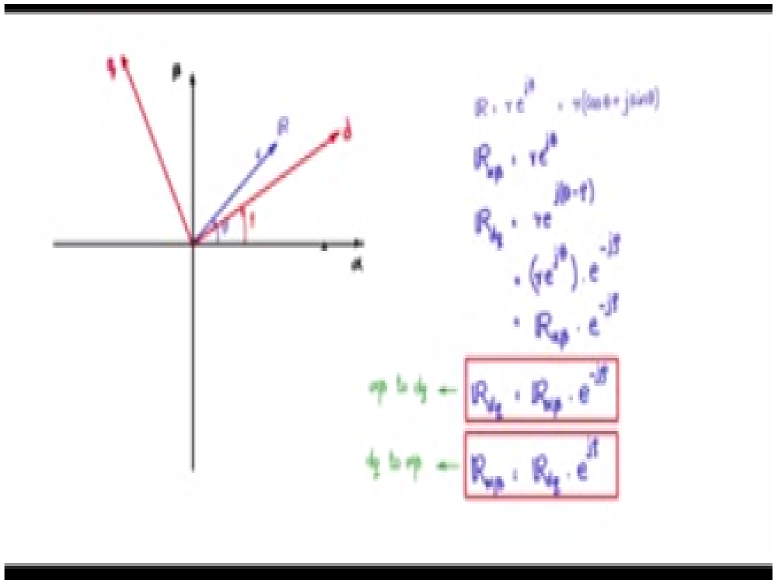
I will now call this axis by a symbol named α axis and this vertical axis we will call it as the β axis, so this coordinate system is not connected with time both these axes are not dependent on time they are just two axis orthogonal axis in space therefore it is called the spatial coordinate system. Because they just represent projections of sometime signal and because these are vectors in the space coordinate system these are called space vectors these vectors at a very instant of time which are forming a circle here and continuously rotating they are called space vectors.

This signal which we started with these two signals the sine and the cosine which are evolving along time they are time signals and these time signals were then put into two different flavoring or two different planes the sine signal was put-on the vertical plane and the cost signal was put on the horizontal plane. So here the time signals are represented in orthogonal planes, so two time signals then these time signals were represent in orthogonal planes here also the axis of evolution of the time axis and then we projected the instantaneous amplitude on to a spatial quality system α β axis.

And we saw that the projected equivalent resultant vector had an amplitude of 1 provided these two waves were sine and cosine waves of unit amplitude and this vector kept rotating continuously with the time evolution it started along the A axis and in 90^0 it reached the β axis when the sine has reached the maximum and then as time progresses this vector completes a complete circle. So once the sine wave has progressed and completed 1 complete cycle this vector the space vector has started from the α axis and made a complete circle and come back to the A axis again.

So what we have achieved the takeaway is that time signals are now converted into a space vector, the time signals can now be represented as a spatial vector or a space vector space vector rotating in space. Now this is the concept that we would be using to convert AC signals to DC

(Refer Slide Time: 13:58)



Consider the AB chord spatial coordinate system I have also and I have β consider a vector in this spatial coordinate system this is a space vector, now let the space vector have an amplitude R and it is at an angle θ, so in this fashion and this space vector can be represented Victorial form has all like this. Now this arm can be written as amplitude e to the power of J θ in polar form is nothing but R cos θ plus J sine θ in this fashion.

Now this is the representation of this are using the variables R and θ now consider another coordinate system and I am calling that 1 as the D axis and the Q axis D and Q are orthogonal this is another coordinate system having the same origin only it is displaced from the α-β coordinate system by an angle ρ. Now in this new DQ coordinate system how do we represent this same R in terms of the α-β representation? Now the vector R in the α-β coordinate system is represented as re to the power of J θ same as here.

Now this are in the DQ coordinate system can be written as re to the power J θ minus ρ this is Θ minus ρ is this angle and I can write it as J θ into e to the - J ρ now or e to the J θ is nothing but the α-β representation I will write it as α β representation into e - J ρ so ρ here is the only variable coming into the picture and that ρ is the displacement of the new coordinate system from the world coordinate system or I should say the displacement of the DQ coordinate system from the α-β coordinate system sousing only the displacement angle of the two coordinate system.

You can write the representation of the vector in the DQ coordinate system is = representation vector in the α-β coordinate system into transform factor e to the power of - J ρ this is 1 thing or I can say representation of α β representation of R in the A B coordinate system is given by representation in the DQ coordinate system into a transformation factor e $^{J \rho}$ so here it is - J ρ here is J ρ. So 1 is the forward transformation another is the reverse transformation so this first 1 is α β to DQ α β to DQ transformation the second 1 is DQ to α β transformation reverse transformation so these are the two transformations that we will be using to go back and forth what we are going to do is this vector.

We saw was a vector which was rotating in a circle and then we will make DQ also to synchronize with R and keep rotating so the vector is rotating in a circle it is going at speed ω T so the angle θ is going at ω T we will make a row also go at ω T so it looks as though D is following this vector R synchronously then the angle between R and D will be same at every instant of time though both are rotating. So if some1 were to jump on to this DQ axis and then they are sitting on here and viewing always the projection of this R vector onto the D axis is a constant projection of our vector under the Q axis is a constant.

So instant by instant you will see that there is no change as long as R does not change and you will for some1 sitting on the D axis everything is seen as DC once the person jumps back onto the α β axis this is rotating and then for everything will be seen as a sine and a cosine wave. So this is the principle that comes into being and this is how we convert AC signal to DC and then do the controller control action here and then jump back so all the controllers are kept in the DQ axis reference axis which is rotating at ω T R at the rotating at the same speed as the R vector, so this is the DQ axis theory principle let us consolidate with few conversion equations and then we can write down the block diagram.