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

In order to estimate the solar insulation and the energy in kilo watt our per m^2 per day following at a given locality on the earth surface we need to understand the earth centric view point and the parameters related to it and therefore I will briefly review the earth centric view point and its related parameters before going in to the max for estimation of the solar insulation at a given place.

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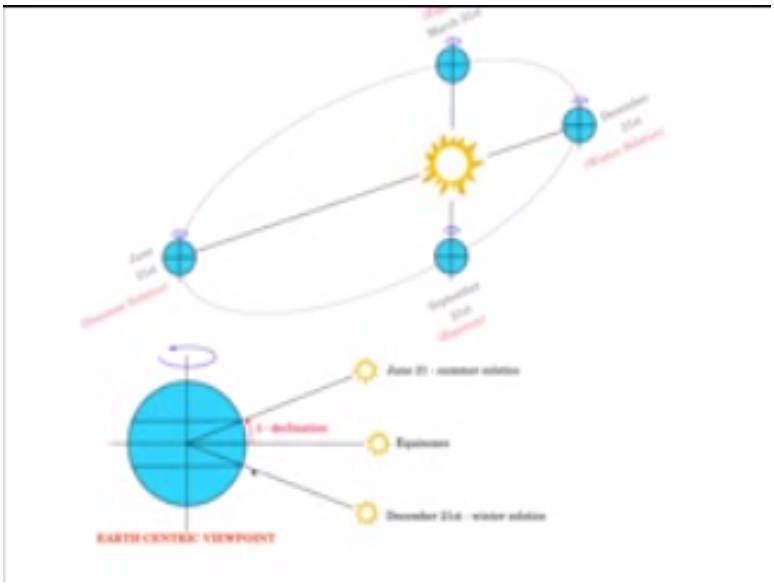

Consider that in absorber is well remote from both the earth and the sun he will see that the earth revolves around the sun in a elliptical orbit something like this with the sun position within the ellipse and earth goes around along this elliptical path let us position the earth like this, this is the equator and this is the poll axes absorb that the poll axes is stilted from the vertical by around $231/2^0$. The earth is spindling about its poll axes continuously as it is revolving around the sun this spindling effect is what is going to give the diagonal effects the day and the night.

Now let us say this position occurs on 21st March I will talk about this later but for now let us say at this position it is occurring every year on 21st March. Now the earth is continuously spindling and moving along on this path on the elliptical path and let us say it comes to this position, and at this position I will mark it by again another picture the earth spindling with the same tilted axes and this occurs on June 21st every year. Progressing further in time the earth take this path and then reaches another important point here and that occurs every year September 21st of course some literature say September 22nd this has September 23rd but for easy remembrance I will keep it at September 21st.

And then going further along you will see that this is another important point and I will mark that by another picture of the earth and this occurs every year on December 21st March 21st and September 21st these positions are call the equine axes because the sun is in the equatorial plane it directly is in line with the equator. When I show you the earth centric view point you will see that the sun is allying itself along the equatorial plane and this line joining these two this call the equine aux line.

Now this position is call the summer solve sties for the northern hemisphere it is the longest day that will occur on June 21st and you will see that the sun allying more towards the northern hemisphere and the line passes through the 23 and 1/2 ^{0} latitude which is the tropic of cancer. And in the southern hemisphere it is doing that likewise on this side this is called the winter soled sties and this occurs on December 21st every year and you see that the sun allying itself along this line where it touches the latitude tropic of capriccio which is -23 and half degrees in the southern hemisphere.

So it is some of our southern hemisphere and for the northern hemisphere it will be the winter, the line connecting the two sale sties point the summer solves style and the winter solve sties is called these solve sties line. And the line connecting the two equine aux is called the equine aux line, I have mentioned that the extra terrestrials solar insulation is rarely constant it varies between 1.33 to 1.41 kw /m^2 so typically for this positions of the earth points along the electric orbit the following insulation values at data values or available. So at the winter sols sties point it is 1.41kw / m2 and at the summer sols sties point it is 1.33kw /m2.

At the September equine aux it is 1.36kw/m2 and at the March equine aux it is 1.38kw/m2 apparently the shape the elliptic orbit and the nearness of the earth to the sun would probably

have brought about this small change in the value of the insulation. In this view the absorber is neither on earth or the sun is away from both these planetary bodies let us move towards an earth centric view point in order to get the insulation at a point on the surface of the earth.

We have the pole axes the polar axes tilted at 23 and half degrees from the vertical so let us try to shift it and make the implore axes vertical and that would give you a better visualization for the urgent review point. So when we till the entire figure by 23 and half degrees you see that the polar ax for the earth appears vertical and this will become the base is for the earth centric view point.

Now the earth a bit enlarged is like this you have the equatorial plane this is the tropic of cancer and the tropic of Capricorn the earth will rotate about its polar axes. Now absorb this line the line here going along and join to the center of the earth so the line join the center of the earth to the center of the sun, now that is this line and on 21st June it appears to a person on the earth it appears the sun is relatively in this position like this with respect to the earth. Then if you go along and look at the winter solve sties you see that it is the sun is align in the southern hemisphere.

So it move it looks as though the sun as moved down and it is aligned in this fashion to the center of the earth and it is cutting the surface of the earth had to tropic of Capricorn at -23 1/2 ^{0} gratitude. And for both the equine access the sun align itself along the equatorial plane in this fashion, so for a person standing on the earth let us say person standing here the equator it would appear as though the sun is moving in this fashion annually. So June 21st it is it would have reach the maximum point and northern hemisphere cutting the surface at 23 ½^{0} north which is a tropic of cancer.

And then moving down it reaches the September 21st equine aux which is align along the equatorial plane and then has this continues you will see that it reaches the December 21st winter sun sties which is align along this it is summer for the southern hemisphere, and then has this continues to move of like that you will see that this again start to move up the sun is ascending and reaches the March 21st equine aux and so on the cycle repeats year after year.

Now this is called the earth centering view and this is the view that we will be using for calculating the insulation at any given latitude on the earth surface. One important angle that I want to introduce here is the angle between the equatorial plane and the line joining the center of

the earth and the center of the sun that is this angle this angle is called declination and it is denoted by the symbol δ remember this the δ are the declination is th4e angle between the equatorial plane and the line joining the center of the earth and center of the sun at any given time and day of the year. So the re-click declination angle where is from plus 23 ½ ^{0} to -23 ½ $^{0.}$

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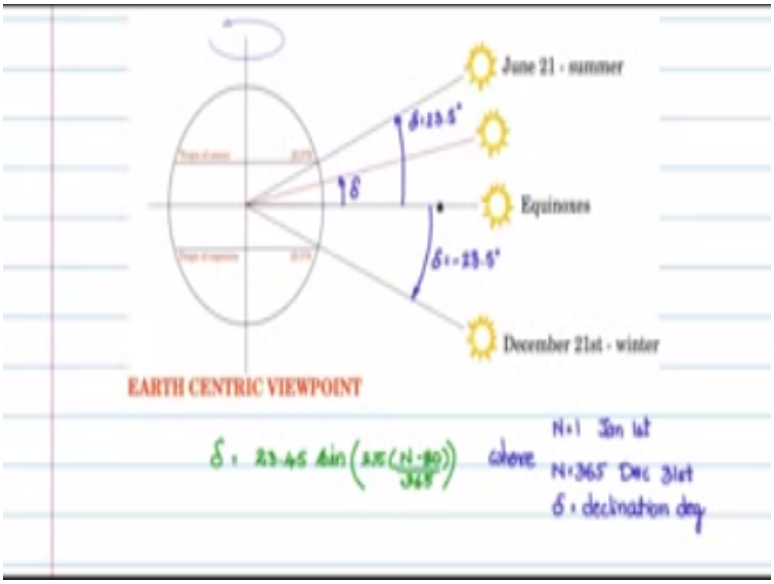

Let us look at the model for the declination δ from the earth centric view point so this is supposed to be the earth this is the polar axes it is rotating about the polar axes and we saw that the moment of the sun over the year is in this fashion the sun reaches a height where the line joining the center of the earth and the sun cuts the 23.5^{0} in at latitude north which is the tropic of cancer. And then as the sun swings to the winter all sties point it intersects the latitude tropic of Capricorn which is 23 ½^{0} south.

And it is the equine aux is here during March 21st and September 21st now consider an arbitrary point here the sun is a on some day at this position the line joining the sun and the earth is here indicated in red this angel is called δ which is the declination so this is the variable and has the sun is moving along in this arch the value of the δ keeps changing it reaches a max value here which is 23.5^{0} and the mean value will be corresponding to this and that will be declination value of -23.5^{0} because it is going in the clock wise direction from the equatorial plane.

Now how to go about obtaining a model for this variable δ so if you look at the movement of the sun so now take for example the equine aux let us say March 21st it starts here then goes up June 21st then starts coming down September 21st then still going further down December 21st coming

up again March 21st so this movement is one cycle this has a resemblance to assign where if you look at the δ function as a function of time over the year function of the day number over the year from 1 to 365 it has a very close resemblance to the sign wave.

So one very good model would be based on then sign function let us make some space let me push it up so that we have some space here let me push this up okay now δ can be written as 23.45 x sign 2π N- 80 /365 has shown here, where N = 1 on January first N = 365 on December 31st this is a empirical formula which seems to fit the δ with very close accuracy you can get 0.1% accuracy with respect to actual values that you would find in a femurs data or the almanacs.

The δ declination is given in degrees absorb that here 80 would represent in terms of number of days starting from Jan 1st 80 would be 80th day would be 21st of March so somewhere at the equine aux so when N is 80 sign 0 so you have δ 0 it starting from here as N is increasing 81, 82, 83 so on goes up here and then comes back and returns again back on up March 21st to this point so the sign wave we shifted in such way that N = 80 it is 0 starting at this point and also at the equine aux the September equine aux.