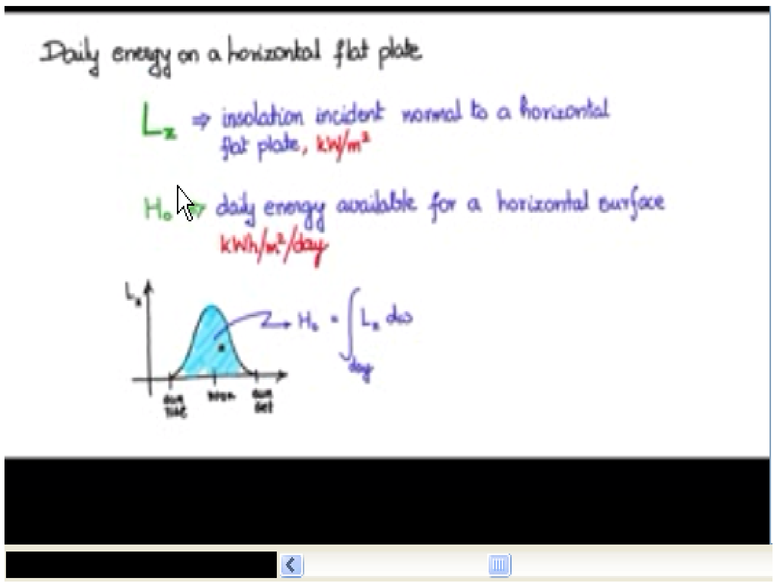
Indian Institute of Science

Design of Photovoltaic Systems

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

NPTEL Online Certification Course

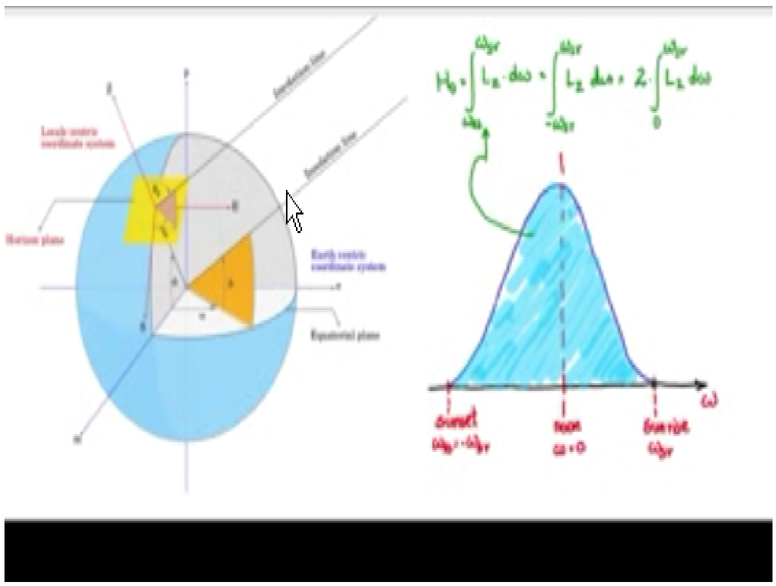
(Refer Slide Time: 00:17)



Given that we are able to obtain the insulation incident normally on a horizontal flat plate at any given latitude on the surface of the earth we need to find what is the daily energy that is incident on that horizontal flat plate we know that LZ is the insulation that is incident normally to horizontal flat plate placed at a given locality at some particular latitude now this is expressed in kilowatt per meter square this is the power per meter square now we need to find hedge not I am using a new symbol H dot represents the daily energy available for a horizontal flat plate please at a given point on the surface of the earth at a given latitude and this has units kilowatt hours per meter square per day let us draw an X and y axis.

The x-axis is the time of the day so let's say that is known and this point here is the Sun Rise and somewhere here let us have the Sun set and the y axis is LZ in kilowatt per meter square the insulation so if you draw the curve it will look something like this which we have seen earlier and the area under this curve is the integration of the NZ curve with respect to the time of the day or what we called our angle Omega so this area is H dot and it is integral of LZ overall our angles for the day or the complete day now this would give you the energy integral of kilowatt with time will give you the kilowatt hours.

(Refer Slide Time: 02:48)



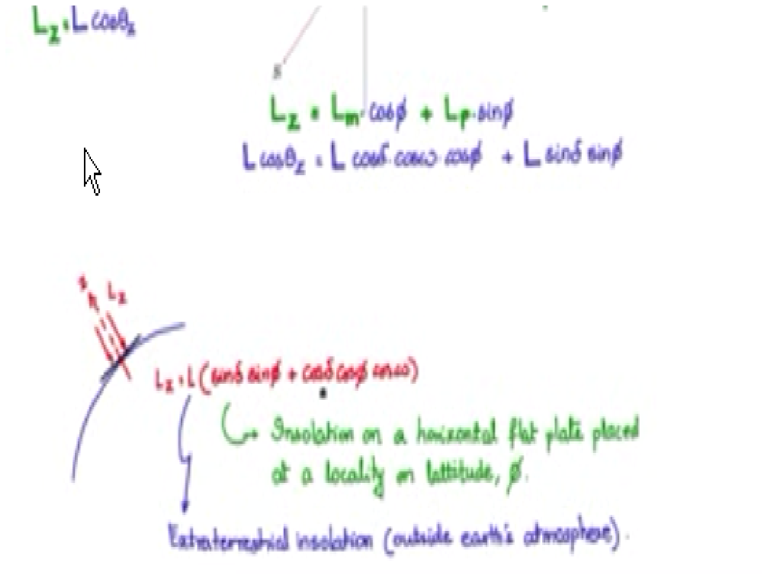
I have here the solar geometry coordinate system. And we have the hour angle here and I would like to integrate with respect to the hour angles to obtain the energy in kilowatt hour per meter square per day but for that we have to redefine the x-axis slightly differently like this so let me put the x-axis variable here and that is Ω represented by Ω and a vertical line here representing noon and at knoll Ω=0 so Ω=0means the projection of the insulation line is on the meridional axis and at Ω=0 would be the known for that meridian any our angle to the east of the original axis is considered positive.

And any our angle to the west of the meridional axis is considered as negative sunrise occurs on towards the east of the meridional axis and therefore sunrise is having an hour angle which is positive and sunset is having an hour angle which is negative so likewise we will indicate now when you want to indicate sunrise sun rise will be on the positive side of the noon so therefore sunrise will be located here and sunset will be located on the negative side so drawing that will draw sunrise and I am going to present sun rises ΩSR and sunset as ΩSS note that sunset the distance of the sunset sun set from noon.

And the distance of sunrise from noon or the same only difference is that Omega sunset is negative the negative angle however the value is the same as Ω SR and therefore you can write it as -ΩSR now if you draw the insulation curve it will look something like this and it is the area under this insulation curve that we are interested this insulation is kilo watt per meter square we want kilowatt hour per meter square so the area under the insulation curve is of interest to us and this is what we can obtain through integration.

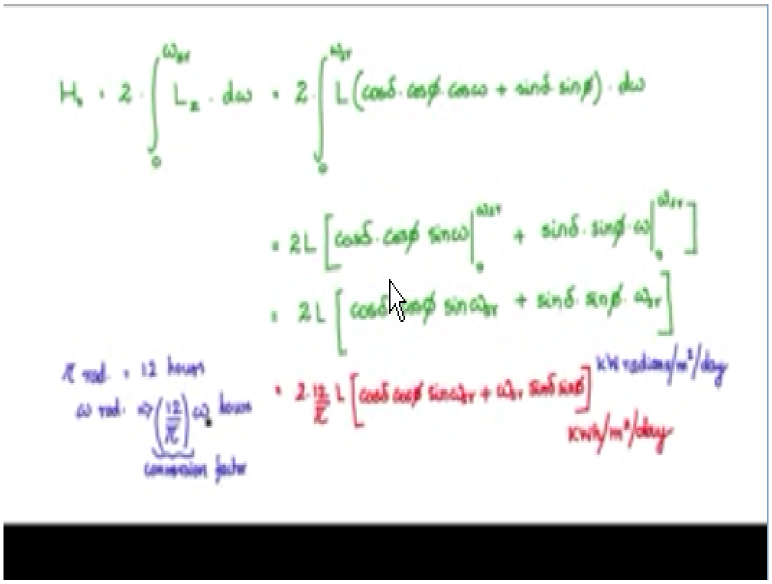
So on integration we would get H naught in kilowatt hour per meter square per day and that is integrated over the whole day from sunset to sunrise we will write it as Ω SS to Ω SR L Z into D Ω Now this can be rewritten as -ΩSR to ΩSR because sunset angle is same as sunrise angle with a negative sign and yes that with D Ω is a parameter and this can further be written simplified as 2 times integral 0 to Ω SR LZ D Omega this is because the distance from 0 to ΩSR is same as 0 to Ω SS so you can write it as 2 times 0 to Ω SR this curve is symmetrical about the new moon axis and note that the length of the day is 2 times ΩSR.

(Refer Slide Time: 6:39)



Let us now evaluate the daily incident energy on a horizontal flat plat eyes that is the insulation and we know the equation for that we have here the equation for L Z which is the insulation at normal incidence on the horizontal surface L is the extra-terrestrial insulation outside the Earth's atmosphere and this is the relationship with declination latitude and Omega playing a role now we will use this relationship in our equation

(Refer Slide Time: 07:27)

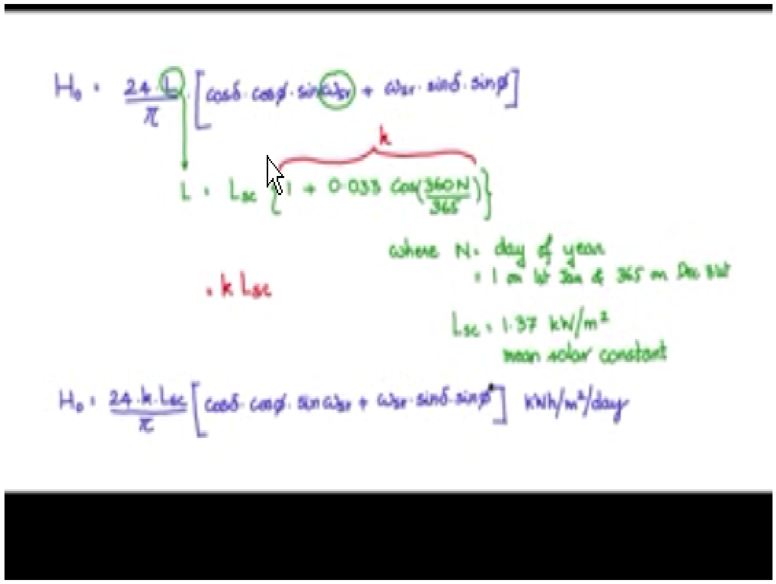


Equal to 2times 0 to Omega SR insulation extract insulation cos π cos Ω+sinδ sin π and sin and integration parameter is D Omega here is a radiance Omega this Omega is also in radiance so note that by integrating in this fashion you will get kilowatt radians per meter square per day but what we actually want to achieve in the end is kilowatt hours per meter square per day so later we will convert radians in two hours integrating we have sine cos Ω would become sine Ω cos and cos π or constant ZL is a constant.

And sine Ω where Omega has two limits which are 0 and Ω SR and sine δ and sine π are constants for a given latitude and time of year and Omega is omega which again has limits 0 to Ω SR and this is the integrated value and this will result in an Ω SR plus I Ω SR so this is the daily available energy incident on a horizontal flat plate Ω SR the hour angles are in radians therefore in this form it is kilo watt radians per meter square per day however we would like the energy units to be kilowatt hours per meter square per day.

So we will convert radians to hours the conversion factor goes like this we have PI radians getting converted in 12 hours are 2 radians in 24 hours and therefore Ω radians are covered in 12 by PI into Ω hours so this is the conversion factor which can be used for converting Ω in radians to hours so therefore if I multiply the entire if I multiply the entire H naught value obtained in kilowatt radiance per meter square with 12 π into all the things in the bracket Omega skin being in radians we will have kilowatt hour per meter square per day has the units naught.

(Refer Slide Time: 10:59)



The incident energy on a horizontal flat plate at a given latitude is given by this equation 24 L/π PI and a cos δ into cos π sine Omega SR cos SR sine Delta sine π now here there are two variables one is the CL the extra-terrestrial insulation and other is Omega SR the our angle at sunrise these two are still not determined we don't know how to evaluate that right now and as a result we cannot evaluate the value thought so let us see how we can go about getting an estimate of the extraterrestrial insulation.

And also the power angle at sunrise so let us take up the case of the extra-terrestrial insulation L now this L is given by an empirical relationship are obtained from measurements over many years so these this empirical relationship is available in the literature so let me write it down l SC solar constant 2 1 plus 0.03 3cos 360 N by 365 now this is the empirical relationship that will determine the extra-terrestrial insulation on a given day of the year en M is the day number where en is equal to is the day number of and 1 for January first and 365 for December 31stand NSC is the solar constant.

And mentioned it once before solar constant is a value equal to 1.3 7kilo watt per meter square is also called the mean solar constant and it is it is a constant value in the sense that it is not dependent on the position of the earth this again is the extra-terrestrial value now this and this relationship together can be putdown in this fashion let's say this is K and L can be written as K LSC now this can be substituted here and the whole equation can be written in this fashion H naught is equal to 24 k LS c by φ.

And cos δ cos Phi sine Omega SR plus Omega SR sine δ sine φ now this would be the entire equation for the energy available on a horizontal flat plate at a latitude for a given gains a daily computation so this kilowatt hours per meter square per day now here see this is known LSE the solar constant0.37 K is known given the day number the day of the year and δ the declination is known by latitude is known Ω SR is the sun rise angle we will look at how to find that one out and once that is known you should be able to evaluate the daily instant energy per meter square Per day.