Indian Institute of Science

Design of Photovoltaic Systems

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NPTEL Online Certification Course

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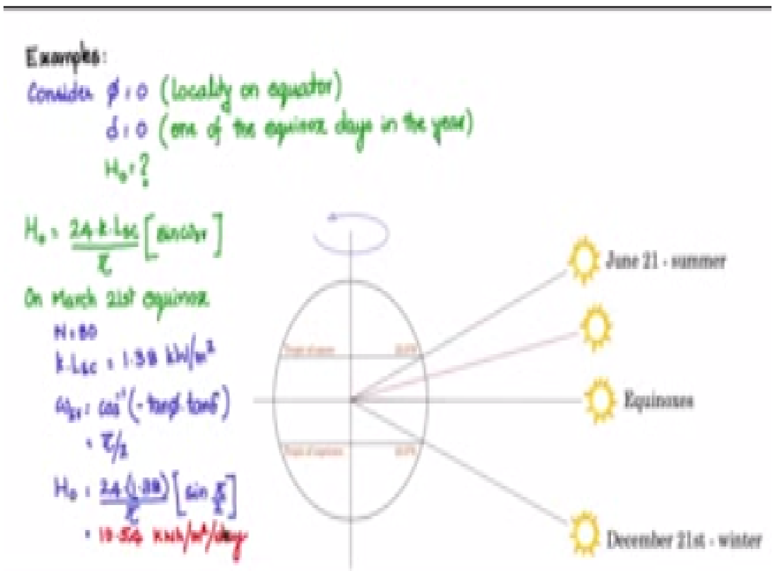

Let us now consolidate our understanding of energy on a horizontal flat plate at a locality, so we will try to calculate through some examples and try to get some inside on this topic. For ready reference I am keeping here the picture of the earth centric view point that will make you easy to understand the problem that I will be suggesting right now. So for now consider a simple case where the attitude is equal to 0 what does it mean that the place is located on the equator.

So now the locality is located on the equator very simple case and now let me make it further simple by taking declination is equal to 0, what is the declination you know that this is the insulation line the line joining the center of the earth to the center of the sun and angle that this insulation line makes with the equatorial plane is called the declination. So if you set declination is 0 which means the sun is along the equatorial plane and this occurs only on two days in a year and that and those days are the equinoxes days.

So therefore declination 0 would mean one of the equinoxes days in the year there are only two equinoxes this one occurs on 21st March called the spring equinox and the other occurs on 21^{st} September and it is called the autumn equinox. So we can consider one of the equinoxes days and let us say for this example we will take March 21^{st}. So now the problem is what is H_0 what is the daily incident energy at the locality ϕ=0 on the equator on an equinox day on a horizontal flat plate.

So let us calculate compute H_0 24k l_{sc}/π[sin ωsr] this comes from the equations that we have derived cosϕ cos δ will be 1 because ϕ and δ are 0 and the second term ωsr sinϕ sinδ will be 0 because again ϕ δ are 0 and sin ϕ/ sin δ are 0. So now here we need to know K so let us compute kl_{sc} and we need to know ωsr then we will be able to compute H_0. So if we consider March21st equinox and counting from first of Jan n=1 on first off Jan and if you start counting from first of Jan 21st March will turn out to be n=80 and with n=80 K can be calculated and k l_{sc} can be calculated and you can see that it comes out to 1.38 kW/m^2.

And ωsr is given by $\cos^{-1}$of -tanϕ tanδ, so this we know ϕ=0 we know δ=0 ,tanϕ tanδ is 0 and therefore $\cos^{-1}$ of the 0 is π/2 by 2 so ωsr the sun rise our angle is π/2 so we know ωsr and therefore we can calculate H_0 which is 24x1.38$kW/m^2/\pi$[sin π/2]. Now this turns out to be 10.54kWh/m^2/day, now this value is the energy per m^2/day that is incident on a locality located on the equator ϕ=0 and it is evaluated on one of the equinoxes days δ=0 and also must be noted that there are no atmospheric effects.

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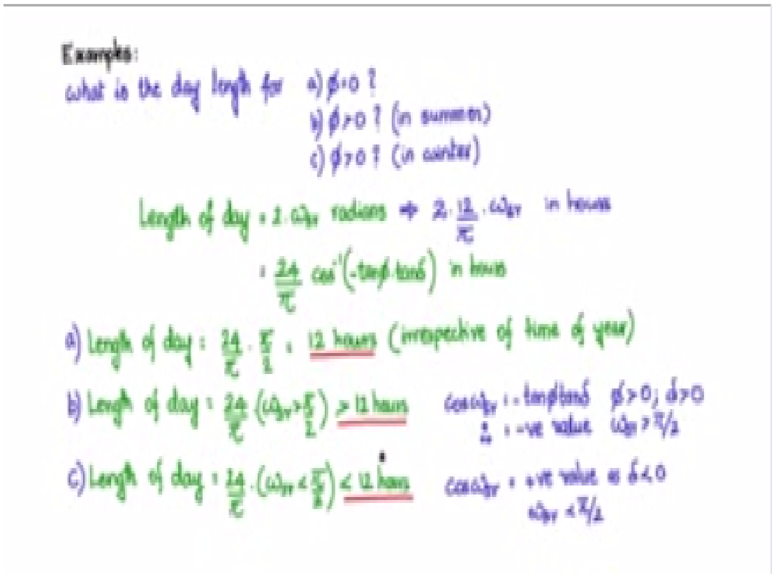

Let us take another interesting example, let us say we want to find the length of the day in a given time of the year, so let us say for the case a latitude is equal to 0 which means that the locality is on the equator ϕ=0 what is the length of the day. Second case we can say latitude to the north of the equator latitude greater than 0, north of the equator and during summer in the northern hemisphere and case C let us say latitude greater than 0 which is a place in the northern hemisphere and winter in the northern hemisphere under these conditions what is the length of the day for each of these conditions. Now let us see how we go about calculating that one, we know the length of the day is two times the sunrise hour angle, 2 ωsr and is expressed in radians as ωsr is in radians.

However if you want to express it in hours the of the day it is more convenient to express in hours we say it is 2x12/π we saw this conversion factor into ωsr which now will give you the length of the day in hours. So this gives you 24/π ωsr which is $\cos^{-1}$ (-tan ϕ tan δ) this would be the length of the day expressed in hours. Now let us take up case a, in case a here we are talking of trying to find the length of the day at a place located on the equator and it could be any time of the year.

So for π=0 the length of the day is given by 2ωsr are in hours we use this relationship 24/π and $\cos^{-1}$ (-tan ϕ tan δ) ϕ is 0 and therefore $\cos^{-1}$ of 0 is π/2 and you will get 12 hours, so the length of the day is 12 hours 6 to 6 so this 12 hours length of day is irrespective of the value of δ here. So therefore it is irrespective of the time of the year, so tan δ, δ can be any value from 0 to + $23^{1/2}$

or 0 to -$23^{1/2\circ}$. If I_0 which if the place is located at the equator this product term is 0 and therefore you will always find the length of the day is 12 hours irrespective of the time of the year but it is not so at all latitudes it is very, very specific to the equator.

So consider case B, now in case B we need to find the length of a day of a place which is to the north of the equator, any place above the equator and in summer in the northern hemisphere which means the declination angle δ is positive and the sun the insulation line is having an angle which is positive with respect to the equatorial plane. Now in such a case here now consider the cos ωsr the sunrise angle, so you see that cos ωsr is given by -tanϕ tanδ, now ϕ is greater than 0 we know that that is positive and δ is greater than 0 because it is summer in the northern hemisphere.

So in both these are greater than or positive cos ωsr will be a negative value, so cos ωsr is the negative value then ωsr is in the second quadrant and therefore you will have it as greater than π/2.l Therefore you see that the value, the length of the day is given by 24/π ωsr value greater than π/2 for this particular case which will result in the length of the day being greater than 12 hours.

So for latitudes in the northern hemisphere in summer you will see that they have the length of the day greater than to 12 hours and that is why in summer the northern latitudes we will see will have sunlight even late into the night. Now for case c, the length of the day is given by a similar relationship only thing is that we are talking of a place located in the northern hemisphere, north of the Equator but it is winter time in the northern hemisphere which means the declination is negative.

So under that condition you know that cos ωsr will become positive value because δ becomes lesser than 0, if it is winter the northern hemisphere it is somewhere in the southern hemisphere and the declination is negative value. And therefore ωsr will be a value which is less than π/2 and now applying this here we will see that value is equal to 24/π ωsr value which is less than π/2 and as a consequence the length of the day will be less than 12 hours.

So therefore you see that for the same latitude in the northern hemisphere above the equator in summer it is greater than 12 hours in winter it is less than 12 hours and these are the important take a ways. For a place on the equator irrespective to the time of the year the length of the day is always 12 hours for a place on the north of the equator during summers in the northern hemisphere the length of the day is greater than 12 hours and the length of the day is less than 12 hours for the northern hemisphere latitudes during winter. Similar corollaries can be obtained for places located to the south of the equator also.