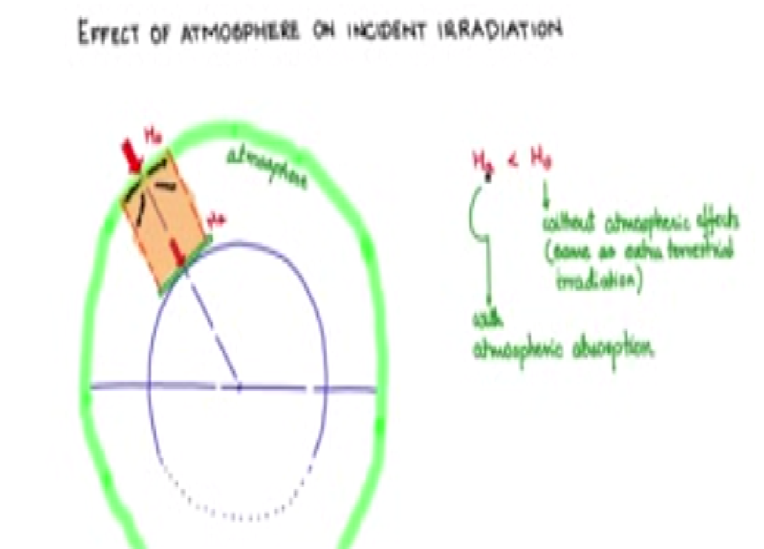
Indian Institute of Science

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)



Till now we had studied the incident energy on a flat surface at any locality on the surface of the earth and we had not considered the effects of atmosphere till now how our atmosphere plays a very important role key role in deciding the amount of energy that falls on a flat plate, now consider a globe like this I will draw an approximate globe and put the center of stars like that and I am drawing the equal equatorial plane and from the center I will draw a line through the place of interest like this is the zenith axis actually.

So this axis is actually the zenith axis that we have been seeing this is the latitude angle and this is the place of interest and at the place of interest let us place a horizontal flat plate, so I have placed a horizontal flat plate collector like this it could be a PV panel, now we have been estimating the energy that is falling on this flat plate collector and all this time we have been doing that without considering any atmospheric effects and therefore the incident energy here would be same as the extra-terrestrial energy which is significantly higher than with the effects of atmosphere coming into picture because the atmosphere significantly absorbs a major portion of the incident energy.

Now let me draw the outer atmosphere like this so in green so this is the outer atmosphere and the outer atmosphere is mostly ozone, so what I have actually shown in green would be the ozone layer and you have the atmosphere within up to the surface of the earth ozone low layer also plays a very important role in absorbing the high frequency incident radiation, so especially the ultraviolet and the higher frequencies of the visible radiation there is a quite significant absorption by the ozone layer.

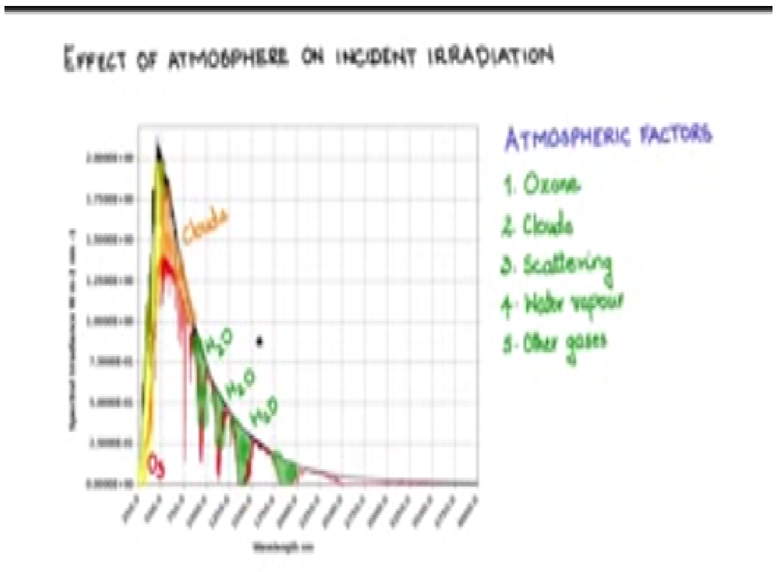
So you will find a dip in the incident radiation not only due to the ozone layer but also due to other effects like clouds you have water vapor and other gases so these how very great attenuation factor which will bring in a lot of attenuation in the incident radiation that will actually happen on this flat plate collector, now there is a vertical column of air mass now this is a vertical column of air mass and this is what is actually causing as an attenuating filter for this flat plate collector.

So what will be falling here now this is the incident radiation that is falling in the insulation that is falling at the outer atmosphere, so without at most the atmospheric effects we had considered H0 so it will be about almost equal to H0 because this distance is very small compared to the distances of the Sun from the center of the earth and therefore we can safely say that the incident energy here would be H0 so this insulation as it passes through the atmosphere.

So this would be H0 let us say incident energy in kilowatt hours per meter square per day as it passes through the atmosphere you will see a significant portion of it getting absorbed the ozone layer also will absorb the portion of the energy in fact the insulation corresponding to the ultraviolet frequency range and shorter wavelength energy energies are absorbed in the ozone layer and as you come down water vapor clouds aerosols dust they all will also cause attenuation and actually what will be following on the flat plate collector will be much smaller.

And that we will call it as HA is the incident energy on the flat horizontal flat plate collector with atmospheric effects and quite obviously H a will be less than H0 in kilowatt hour per meter square per day is actually the one without atmospheric effects which we have already dealt with and discussed there is no attenuation due to atmosphere and this is same as the extraterrestrial energy or the incident in store insulation that is occurring at the outer atmosphere or outside atmosphere of the earth whereas Ha is the incident energy on the flat plate collector with atmospheric effects or atmospheric acting as an attenuating filter with atmospheric absorption.

(Refer Slide Time: 07:05)



The picture here shows the spectral irradiance of the Sun this is the extra-terrestrial spectral in irradiance in watts per meter square per nanometer we have seen this graph earlier the x-axis is the wavelength in nanometers and the y-axis is the spectral irradiance Ps in watts per meter square per nanometer in order to study the effects of atmosphere on the instant irradiation this is a very good place to start the spectral irradiance that is incident at the edge of the outer atmosphere of the earth is something like this.

This is the extra-terrestrial irradiance and on what will happen when it goes through our atmosphere we expect that this spectral irradiance will go through a process of attenuation the atmosphere will act as an attenuating filter and you will see a vastly reduced spectral irradiance pattern after having gone through the atmosphere and that is what we will like to see and study if I superpose the spectral irradiance pattern after it has gone through the atmosphere after it is gone after it has gotten attenuated due to the various factors in the atmosphere.

We see the pattern something like this the one in red is the one which is with that atmospheric effect the one in black is the extra-terrestrial spectral irradiance and you see that there is a significant amount of attenuation after having passed through the atmosphere and this is the irradiance that is measured measurable at sea level on the surface of the earth after passing through the Earth's atmosphere we know that the factors that are affecting the energy incident at a horizontal flat plate collector at any given locality of the following one is the location.

And location we have 3 important parameters one is the latitude and we see that we have seen that having a significant effect on the incident radiation there is the longitude the Meridian it also has a significant effect in the sense that the diurnal changes are due to the longitudinal position and also the longitude indirectly as an effect in terms of the geographic conditions and profiles the third one is the height above mean sea level.

This also has an effect on the ultimate radiation that is incident on the flat plate collector the air mass amount of air or the volume of air in the vertical column above the location determines the amount of attenuation that one can expect when the radiation reaches the collector, so this also has a significant impact on the amount of energy that is going to be incident at the surface of the location.

Now the second important point is at time of day this is the hour angles we have seen it is effect the time of the year which is the declination we have seen its effect too and the angles of the collector tilled β we have seen this effect also note that all these all these factors that we have listed here are deterministic factors we can very accurately determine all these parameters and their effects on the incident radiation by using spherical geometry however the fifth important parameter that is what which we are going to discuss now is the local climate.

The local climatic conditions has a significant impact on the local atmospheric conditions and this in turn will have an effect on the attenuation capacities of the vertical column above the horizontal flat plate collector in a given locality, so this is not a deterministic it is probably stick in nature there is a lot of statisticalness that is involved in this.

However there is a kind of a repeating cycle that happens year after year on any given day and that is what we want to use to estimate the effect of the local climate on the attenuation of the spectral irradiance before it reaches the surface of the earth of the flat plate collector mounted at the surface of arc in a given locality there are various atmospheric factors that attenuate or absorb the spectral various components of the spectral irradiance one of the first and foremost factors is the ozone layer the top one layer absorbs primarily the high-frequency components.

So there will be significant attenuation in the low wavelength or the high frequency very high frequency spectral irradiance components so if you see these regions where I have shaded it with yellow met the dominant factor in the attenuation would be the ozone these are the high frequency component mostly in the ultraviolet to the higher visible range and if you go down in the frequency or higher in the wavelength there is attenuation due to other gases clouds carbon dioxide and also water vapor and you can probably see that there are some notches here deep notches.

Where attenuation in this band are very significant almost down to zero these notches where I have indicated by green are due to the water vapor content in the vertical column of air above the collector so you see that a major portion of the infrared portion of the spectrum irradiance components get eliminated get filtered out to the presence of water vapor of course it is it is not only here that water vapor access a absorber but even in these regions water vapor also is one of the factors to bring about absorption and attenuation of spectral irradiance components.

So therefore you can you can say that high-frequency components mainly ozone and then there is a water vapor content in these notches in the infrared region and also spread of distributed in the visible light region- in this orange shaded area and the orange shaded area here cloud cover dust scattering due to dust, so let me put in the little list out the factors clouds and scattering and the scattering maybe you go dust.

And other particulate materials which are matter which are suspended in the atmosphere then you have water vapor which is a very significant factor in absorption and therefore attenuation in the spectral irradiance and all the other gases in the atmosphere you know in which includes oxygen and the carbon dioxide also which absorbs a spectral irradiance some of the spectral irradiance components to some extent.