Indian Institute of Science

Design of Photovoltaic Systems

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NPTEL Online Certification Course

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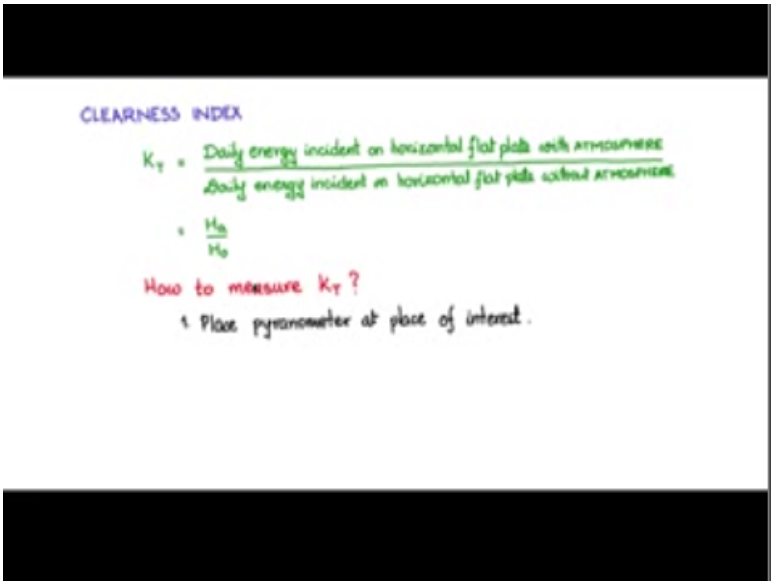

Let us now find out the way to estimate the clearance index KT is nothing but the ratio of the daily energy incident on a horizontal flat plate collector with atmospheric effects with atmosphere is divided by daily energy incident on horizontal flat plate collector without atmosphere now this is equal to the daily energy incident horizontal flat plate with atmosphere we have been using the symbol Ha.

And the daily energy without atmosphere and we have been using the symbol Ho now Ho can be computed it is determinable by means of closed form solution and all these needs is input like the latitude the locality and you can accurately compute it using 3d geometry with reasonably with accuracy however Ha is the energy with atmospheric effects and that is difficult to calculate but we can measure it so if we measure Ha and calculate Ho and we get the accurate current value of KT at any event place.

So now how to we do that how do we measure KT first what we do is place a pyronometer at the place of interest now what is pyronometer? Pyronometer is an instrument that can measure insulation so it is used in all solar based experiments and then it is based on thermal principles it has a thermal coil and by means of the cbay affect it converts the incident radiation to electric voltage value and the voltage value gives us the measure of the incident insulation. Now let me show you the pyronometer which we give you an idea of what it is and you will understand what I mean by pyronometer

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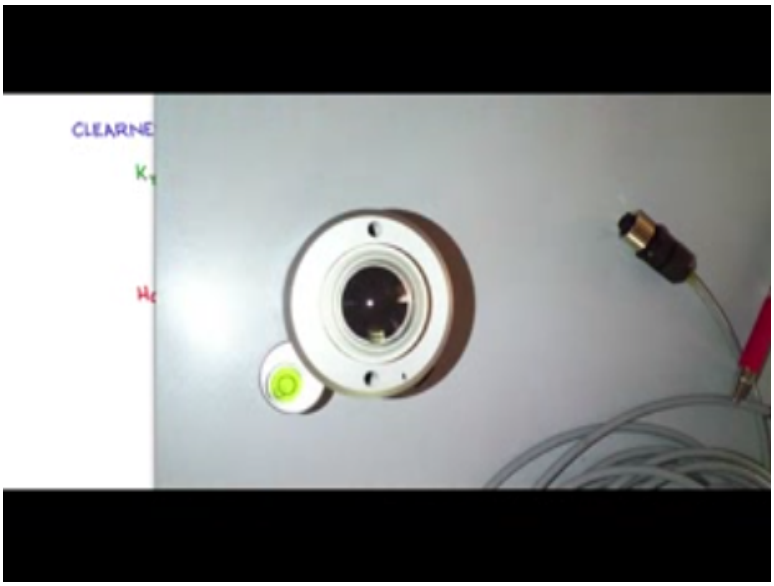

Look at this equipment this is pyronometer you see that a glass bulb on top and inside there is a black item now that is thermopile now the radiation falls on the thermopile and gives to the thermopile and that becomes the hotspot and the pyronometer body is the cold junction and there will be hot junction and the cold junction and there will be the temperature gradating between the hot junction and cold junction give voltage based on the effect.

Now through this wire we will be able to measure the voltage using a millimeter now this pyronometer, or thermo couple can measure so it is let me open this out and you will look at the name plate so you see here name plate indicates and when it is 0volts output is 0volts and if the output is 10volts and the output is 2000watts per meter square of course the insulation from the sun will not exceed 1000watts per meter square so you will get almost 5volts from these now if

you look at right here you will see this green spot here that is nothing but spirit level an item mechanism which will do the job of positioning the pyronometer horizontally at a place.

And then allow it to measure the radiation and it will give you an output towards in a voltage which is in a direct measure of the insulation and the units of in watts the pyronometer is an expensive piece of equipment so handle this with care.

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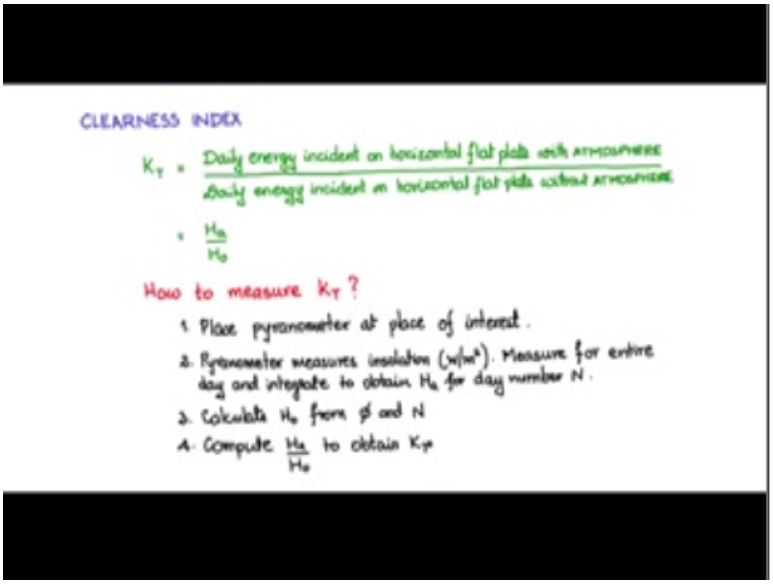

So now having placed the pyronometer it gives the measure of the insulation in watts per meter square measure for the entire day and integrates the values and you will get Ha in meter square per day so this would mean you would get the Ha for that a number N so this Ha value in kilo watt hour in meter square if the energy that you would have got for that particular day of the year you could do that for every day of the year to get the value of Ha of the year and if you do for many years and you will get a statically history based on an idea of that climatic condition.

And atmospheric absorption during various times of the year and various years next let us compute Ho value we know how to do this if we have the latitude and the day number we can compute Ho after that we take the ratio of Ha to Ho and this will give you the KT value to you so this clearance index value remember for that specific value of a Ha if Ha has been computed for number and KT value is value for that particular day number.

So if you want to have KT to which takes into account into historic data that Ha itself should take into account the statically mean of all the Ha values of previous years too and you will get the KT value which as an better representation on the climate atmospheric effects

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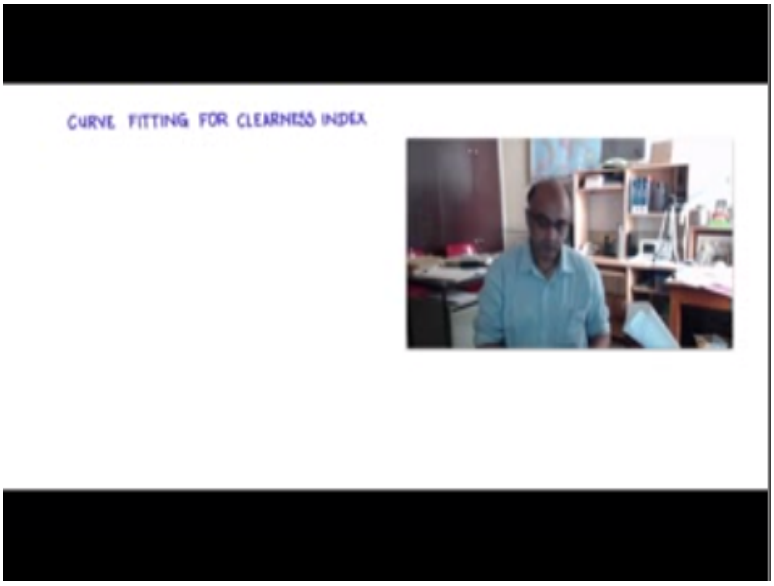

Computing for clearance index see generally measurement of clearance index for a particular place on a particular day as we saw before measuring Ha however if you want to find the clearance index of the place the measurement as not been done and in such a case how do we go about finding the clearance index computing is a very nice solution here even if we have measured data of few latitudes we can make a model such that for any given latitude about in the neighbor of the place measurements have been carried out we can find the clearance index using the model so that is what we attempt to do we let us say how data collected for few of the latitude in different parts of the country.

And we will why do we make model to give the clearance index estimate equation then we can find the clearance index for any latitude or any place in the neighbor of the places where we have measured data available now find the clearance index let us first proposed a model.

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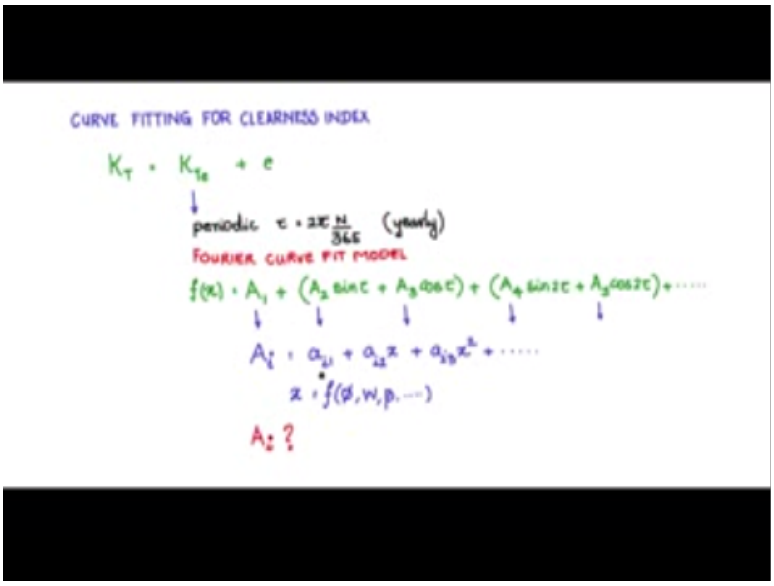

KT is given by KT estimate this is the KT estimate equation for me to formulate now plus the error so off course when we do an estimate it there will be an error and therefore KT actually deviating from the estimate equation or the estimated value of KT will be deviate from the actual measure value of KT by some error. So let us see what is the best KT estimate that we can arrive it which will give minimum error so one important charatertic of this clearance index is that it is periodic so it has the periodic interval of one year 365 days.

And therefore we use our four year series with τ from the period of 2πn/365 n varies from 1 to 5 or the angle 4 year series fundamental angle can be represented in the fraction so this would give a yearly period and we are okay with using the four year curve fit now let us choose this particular KT at some function f(x)a1+(a2sinτ+a3cosτ)+(a4sin2τ+a3cos2τ).

So this is the four year series model use which are having the fundamental harmonic of the fundamental x is contained in all the coefficient parameter so Ai =ai1+ai2x+ai3x where is a function of which are related to the atmospheric conditions on its latitudes=f(ϕ,w,p)so however jump now is to find Ai what are these coefficient value of those model.

And each coefficient value is spilt into a function called x of this polynomial form and if x is function of latitude and so on so this is the model that we most of to have fit we get an estimate equation for a clearance index KT now let us see how we are getting model for clearance index we use the simple model to understand how we going to obtain in the model and then I will show the four accurate model for using a 12 series from within the country

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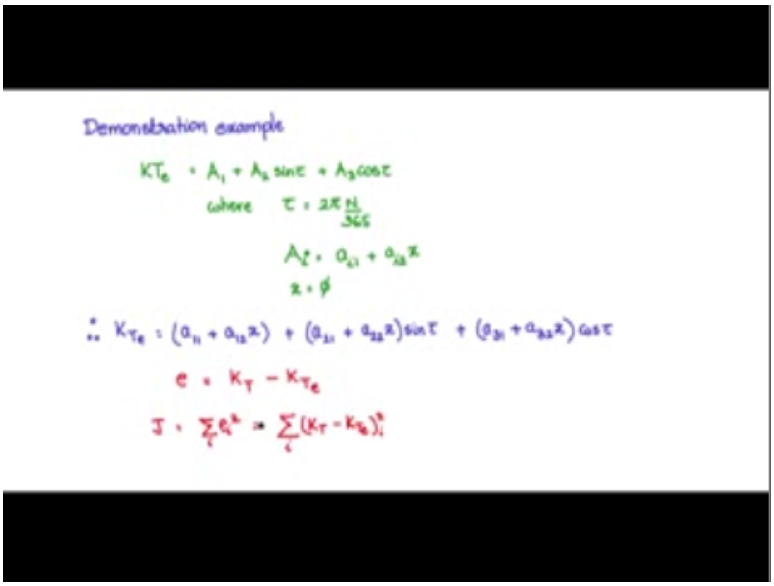

Let us go through an demonstration example and let us take a very simple model and we see how we know about obtaining the model and then later I will expand it and extend it to a once more accurate and model and we will see how we estimate equation and for the clearance index so let us say KT is the estimate clearance index based on estimate equation which is of this form A1+A2sinτ+a3cosτ.

So it is a simple equation I have just taken the fundamental harmonic where is 2Л*n/365 of course it need not necessarily be in this form it could also be a pay shifted form we will look at this mode when we are considering the exact model now our job is to find out what are these coeffient now this coefficient Ai themselves are of these form ai1+ai2*x where x is just simply the latitude x can be the function of latitude water vapour so on so forth as we said before other atmospheric effect but here in this simplistic problem we will take x as just plane latitude.

And we have taken the coefficient upper cases I as ai1+ai2x just up to the first order poly nominal now let us see how we go about obtaining the various coefficient parameters so therefore now KTe can be written as using these form format into these coefficient here you will get a11+a12x+a21+a22x*sinτ+a31+a32x*cosτ so this is the clearance index estimate equation and we don't know what a1,a12,a21,a31 are it is now our job to find out these coefficient and plug in these coefficient only then there is estimate equation becomes complete.

And you can use it for another place latitude x and error is given by KT this is the measure at clearness index minus the KT estimated index and our job is to find these coefficient in such a way it will give the KT value such that the error will be a minimum now the error square will be the minimum so let's say J is $\delta ei^2 = \delta kt\text{-}k^2$ estimate now this is the square of the error and we want to minimize the square of that error so what we will do now is said δj/δa11/δj/δa12/δa/δa21/δj/δa22/δja31/δja320 individually and when you equate each to 0 individually we will have six equation 6 unknowns and later if you simultaneously solve that out you will get the values of a12,a21,a22,a31,a32 so on.

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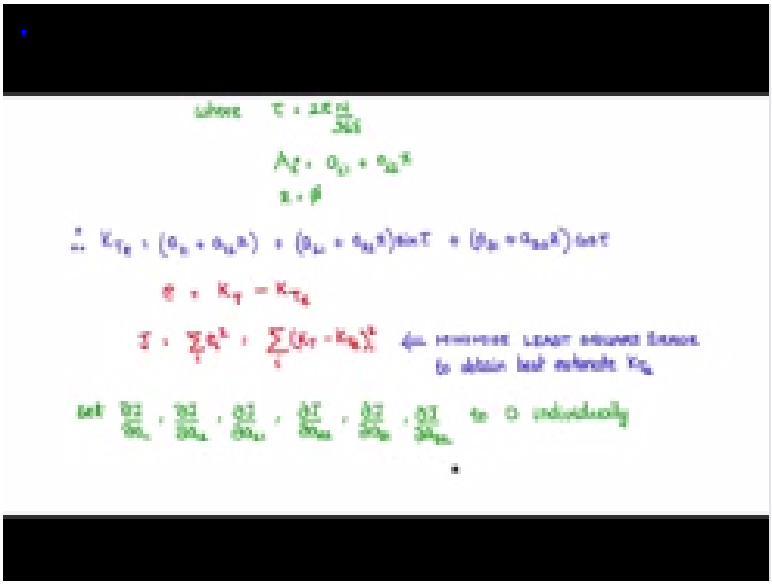

Now we have the estimate equation here we know the J the function to minimize this KT-KT estimate now this is what we would like to minimize this is the error square so that you get the minimum square error or the least square error so δj/δa11 is nothing but -2σ over all eyes KT-Kte and this is set equal to 0 so now we will do it for the other parameter term δj/δa12-2σ overall eyes KT-KTe*x 1&2 as x as a coefficient so this you set into 0 likewise if you do 21 here it as a coefficient σδ so therefore when you differ ate you will have δi set to 0.

And 22 you will have KT-KTi*xisinδi=0 as because x sin then for the a31 and a32 you will have costx as multiply factor here we will write that down we make some space a31=-2σKT-ktecosy

setting equal to 0 let me make more space δj/δa32 is -2σ.KT-KTE x cos of y said equal to 0 now these are the 6 equations that you have KTis a measured quantity xiδi or input quantities KTE the parameters A11 to A32 are unknown you know 6 unknowns 6 equations you should be able to measure you should be able to calculate.

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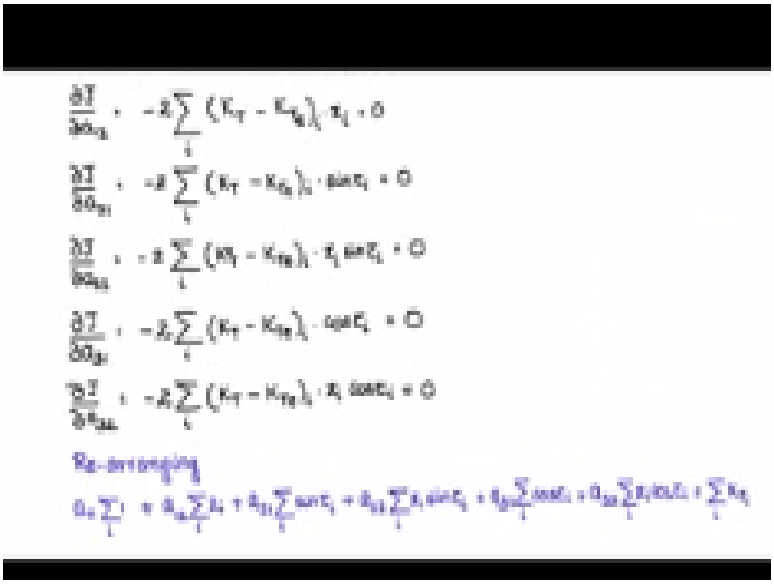

So what we do next is rearrange you have a11σ1+a12xi+a21σia22+a31cos(y)+a32=δKTi so this is coming from actually this 1st equation expanding KT comes to the right side and expanding KTE you will get all these things like wise if you expand the other terms I will just run through you can do that for all the terms so the second term here you will see that xiKTI now that's what xiKTi and KT estimate into xi and that is what comes in here.

You have the Xi component coming here everywhere other actor so likewise the third term so on so I will just run through it and you can work it out and case later on and so on all the six equations now these six equations can be expressed in matrix form and put in matrix form like this so you have matrix component parameters the coefficient parameters a11,12,21,22,31,32 6 coefficient component parameters and that equal to σKTi σxiKti σδiKti σsinKTi,σcosKTi these are so this is the matrix representation you have the six set of equation represented the matrix form this matrix here.

Which is shown blank contains the coefficient of theses equations like xi,sini,xsini,δ,cosi so on all these things will get populated here and these values can be calculated and here this particular column vector can be calculated because we know KTI,xi,sini,and the only set of unknown will be this column vector a11,a21,a22,a31,a32 and you have six unknowns.

And 6 equations which you can calculate easily. Now we need to look into the input data now this input data is needed because we need to know the are these values what is KTi? What is xi? What is sini? and what are all the various elements of this coefficient array so normally you have to get set of input data measure data and you should get as many as possible so that you get very good results so I represents the number of data more the better we need 5 the latitude we need the day number n we need to compute h0, ha, kt the clearance index.

And you need x,sin,cos these are the values which you need if you have to compute this matrix and this matrix and five is something given input n is also a given input h0 is computed based on JI and n ha is measured using pyrometer which we discussed while back KT is computed using ha and h0 computed using N axis computed using 5 and atmospheric parameters likewise sin,cos compute once you have all these data you can solve for a11,a12,a21,a22,a31,a32 and so on and obtain the values of this.

And note that this is a onetime computation you are not doing it dynamically every time this you compute it one time using a effect of data that has been measured by anybody and using that day you have arrived that this coefficient values which will go into the clearance in estimate equation the clearance index estimate equation can now be written as a11 which we have found out+a12x+a21+a22x and to sin +a31+a32x*cos so this becomes the estimate equation and this equation you can save it and keep it at one place or put it as script file in a program.

And then use it for finding out the clearance index at any latitude by substituting it within x and then computing the value through this estimate equation and the latitude value that you use need not be the one for which the measurement data has been made available it could be any other attitude also within the neighborhood which will fit into which will fit into that geographical occasion.

And because of the equation it will give you a various good estimate now if you go back and look at the steps to estimate HAT this is what ultimately you want the incident energy on flat plat

collector at any given place with atmospheric effects HAT so we saw that we need to have the latitude number delta angle you can estimate h0 you can estimate hot estimation of KT was differed that's what we wanted to do it last and then we have now mapped where you can estimate KT for any given latitude day number we will use this top of an equation then we find rd which is HOT/HO estimate RT and calculate HAT as RT*KT*HO

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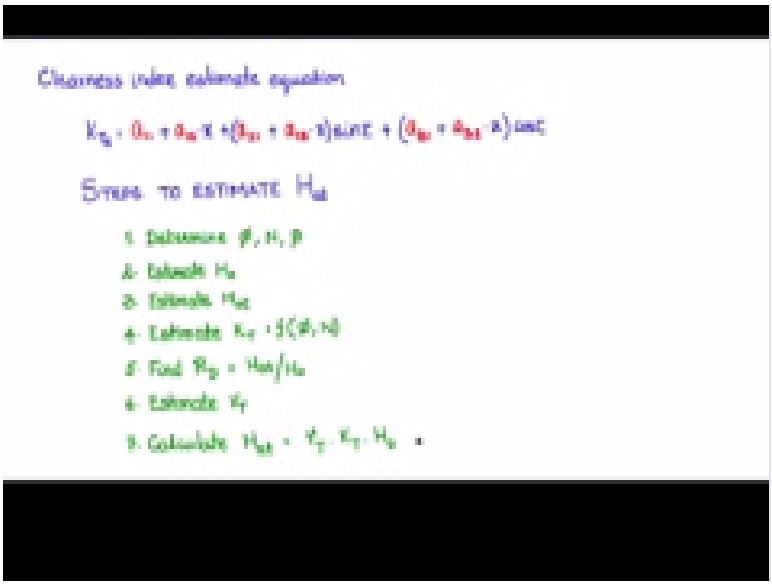

Let us now discuss a model for India it is based on measurements taken from 12 cities and towns from various parts of the country so the model goes like this the estimate equation is of this form a1+a2sin+a3sin2+a4sin3 so we go up to the 3 harmonic and then we have cost terms also a5cos,a6cos2+a7cos now this is the model frame work this a four year series model we need to estimate what is a1,a2,a3,a4,a5,a6,a7 based on atmospheric parameters so where how do we find the various parameters first.

Let us take that is the yearly period instead of taking 2Л*n/365 we shall take 3Л*n-18/365 this gives much better lower mean square error then the Aare o0f this form $ai1+ai2+ai3x^2+aix4w+ai5w^2$ w is water vapour content in the vertical column of the locality we have included that into the effects of the coefficient component of ai and what is x is 5 so this set off definition give a very good accuracy of the estimated clearance index now how to get the water vapour content of course new can do a measurement of water vapour content look at metal cal size and obtain them.

But again this is the tough thing to do we need to go have it integrated into the model therefore again like clearance index we make a sub four year series model to estimate w so w is of the form g1+g2+sing3+g4sin+gcos+g6cost+g7cost where are of the form gi1 +gi2 xgi3x^2 where x is the latitude as defined here now this would give you the entire model so first what you do given the latitude we estimate this portion that is water vapour content because you need to know the latitude.

And the find then water vapour content can be estimated from this estimate equation then this can be plugged in here to define the Ai and then that can be used to estimate the clearance index by plugging it in here. So this is the model that we have used to find the clearance index at any place within the country it is reasonably good model accurate within 15% and which is sufficient for design because we are any way being conservative and we are designing the photovoltaic panels. So this model we can put it as script file within the octave and mat lab and execute it to obtain KTe.