Power System Generation, Transmission and Distribution

Prof. D.P.Kothari

Department of Electrical Engineering

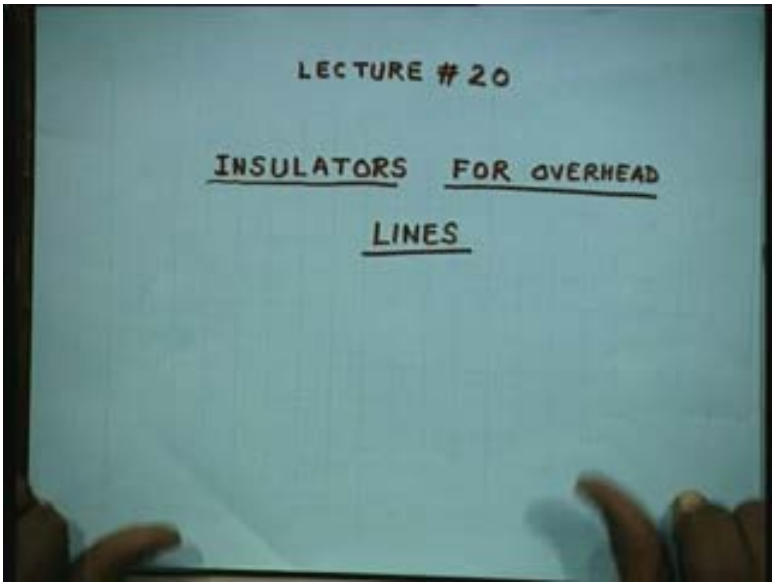
Centre for Energy Studies

Indian Institute of Technology, Delhi

Lecture No. # 20

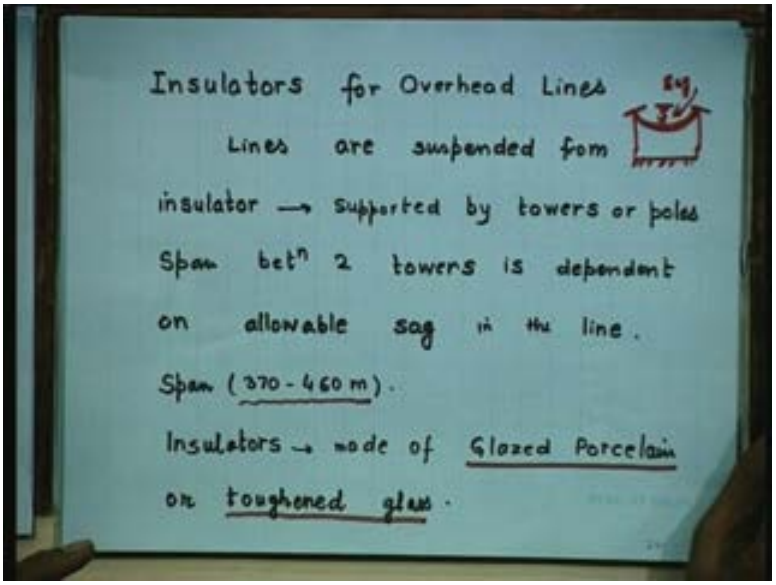
Insulators for Overhead Lines

(Refer Slide Time: 01:03)



Welcome to this lecture 20 which is on Insulators for overhead lines. Now all of you must have seen. In fact, while travelling in a train or while going to any country side the transmission lines and this various blackish looking objects which are insulators. If where why do we need insulators, because lines are life. So, they should not come in contact with the poles, with towers, with the transforms. So, what we do? We suspend lines from insulators.

(Refer Slide Time: 01:51)



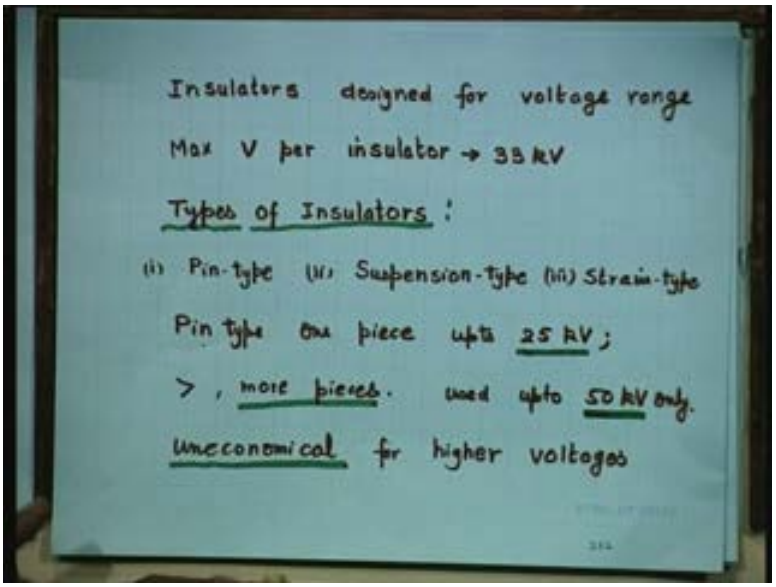
Now insulators are required for overhead lines and all those conductor is suspended from insulator, and which is supported by towers or poles depending on the voltage. If it is a very high voltage, extra high voltage then they are towers. You must have seen towers in open space, while travelling etcetera. Poles you can see even inside the city, even inside the campus. Span between two traverses is a very critical factor, there is a economics involved in it. You cannot have a tower after every 4 feet, but you cannot have a tower after every 4 kilometer also.

So, what is that ideal span which you should have between 2 poles, between 2 towers. It is a very important topics in design of transmission lines, and you are request to read t n d hand book transmission and distribution hand book by wresting house. If you need to go into details of tower design, if this topic is cover there. However, I can tell you the moolmenthra which guides this is the span between the 2 towers is depended on allowable sag in the line. I hope you understand this sag, this wire is cannot remain tight all the time, it will slowly get loosing, and a sag will form.

I will show you the figure here, like this, it will be… This is ground, this is pole, and this is conductor and it will be like this, and this is the called sag. Now this sag should not the so much that the wire touches the ground. It will be highly on desirable and safe, and it can cause accidents. So, the span roughly comes about 370 to 460 meters, less than half kilometers. Insulators are made of Glazed porcelain or toughened glass; these are the

two main materials which are used to make insulators, because they have an ideal properties of an insulator.

(Refer Slide Time: 04:52)



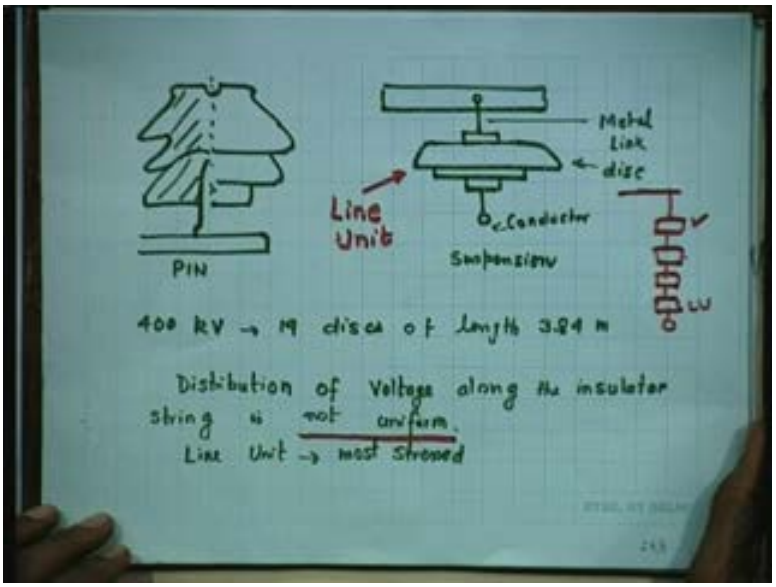
Now insulators are designed for a given range of voltages. Voltage where is from 220 volts domestic to 765 K V or 800 K V in India. Outside it is certain 100 K V, we not gone beyond there is no necessity. The If at all western world want to reduce use of energy and not increase, because they have already reached the limit, beyond which then yes you can go, because there doing everything have using electric energy, nothing is left where electric energy is not used. So, and there population is almost constant are decreasing.

So, there demand is not likely to go up at all the maximum voltage per insulator is 33 K V insulator is designed for 33 K V. You may ask me question, what happens in the voltage is more than 33 K V? Well we repeat that we have several insulators rather having one. Some modular like if you need more then we go for more 1 mega volt, 1 volt, 10 volts, 100 volts depending on what is the cell size in photo volatize even in power plants, big power plants. You do not have 1 unit of total capacity, you may have 5 units of 100 mega volts each, you may have 5 of 200 mega volts each even 12 units 6 on is east bind and 6 on west bind.

Types of isolators: there are only three types; so for, pin type, suspension type and strain type. Pin type one piece is up to 25 K V, if it is more you have more pieces, but it goes

only up to 50 K V. Why why not more? It becomes uneconomical for higher voltages pin type.

(Refer Slide Time: 07:51)

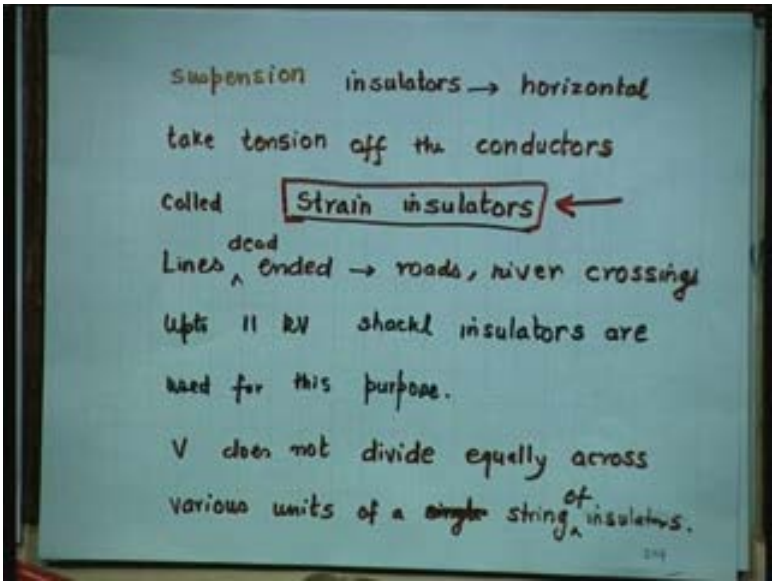


Now this is the two diagrams the left hand side is pin type and right hand side is suspension type. Well there are repetitions of these units if required; I have shown just 1 unit for space constraint. Otherwise the whole slide will be full of this, and this is a metal link, this is the disk and here is the conductor. Since conductor is suspended. This insulator is called suspension insulator. Suppose we have 400 K V transmission line, which you have in our country, then we can have 19 disk of length 3.84 meter each. So, is a structure. You may not see it will goes it is in you know 400 KV line one pass through from which of new Delhi you know that will pass somewhere in isolated areas.

Distribution of voltage along with isolated string unfortunately is not uniform, this is the main problem. Which unit is most strained or stressed? Closes to the conductor, and that is that unit is called line unit. Since in this figure there is only one. So, this is called line unit. And this is more stressed, suppose there are 4 units...

This is the least stress, this is more than that most this is the line unit. This is the foal string in suspended type insulator. Well you can have a simple mathematics in show that indeed it is a line unit which is the most stress, you can see any book...

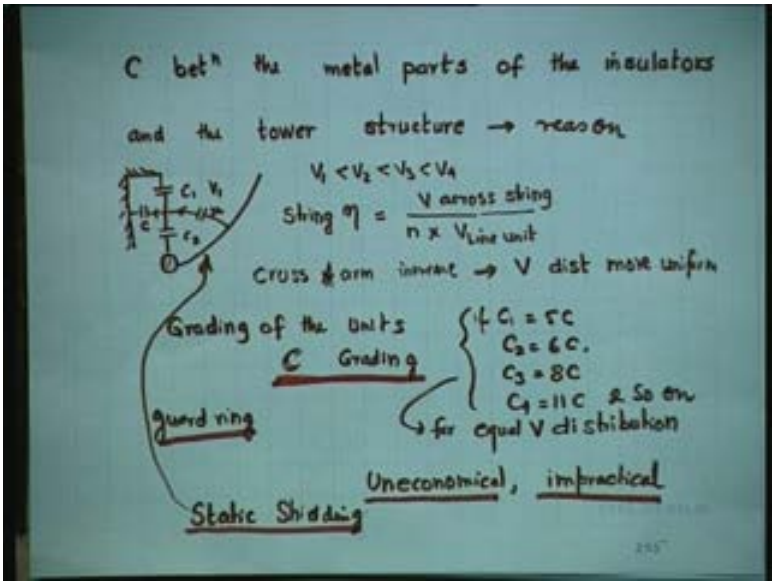
(Refer Slide Time: 10:21)



When suspension type insulators or kept in horizontal position, rather a vertical position that is called strain insulator. This is the special variety like here slight bus. They take the tension of the conductors, then they are used since they are special conductors and insulators they are used in special situation. What are those special situations? Dead ended lines, roads, river crossings, bridges, and so on... where ever you feel that this is the end. You cannot take the line further, up to 11 K V shackl insulators are used for this purpose. Now voltage does not divide equally across various units of string, of insulators as a capacitor changes from each unit to each unit.

That is why voltage does not get, suppose the total over all voltage is V 400 K V. Now this is whole units will not have a 100 K V each across it. It will be 70, 90, 180 and then 220, something like that... So, the lowest unit being the most stressed, that is the mini. V 1, V 2, V 3, V 4 is not equal; V 1 is less than V 2 is less than V 3 is less than V 4, V 4 is across the line unit.

(Refer Slide Time: 12:42)



Capacities between the metal parts of the insulators, and the towers structure is main reason. Same thing I told you V 1 is less than V 2 is less than V 3 is less than V 4. How none uniformly the distribution is given by an index. What is that index? That is called string efficiency, there are you be must solve many problems in a under graduate, where they ask you to calculate string efficiency. String efficiency is defined as voltage across string divide by n times V line unit, and it is the total number of insulators. Conductor is always one.

In 2 V across line unit, which is maximum and that is why efficiency will be less than 100 sorry less than yeah less than 100. Higher efficiency, but how can you mechanically achieve this? High resting efficiency, by having a larger longer… However, every good thing in life is at a price, a price a two piece more cost in convenience to the public, and there is no space, just there is no space. You may be certain houses nearby, train may be going nearby or telephone lines are going interaction radio interference and so on.., but definitely if you can achieve that you will have a voltage distribution more uniform.

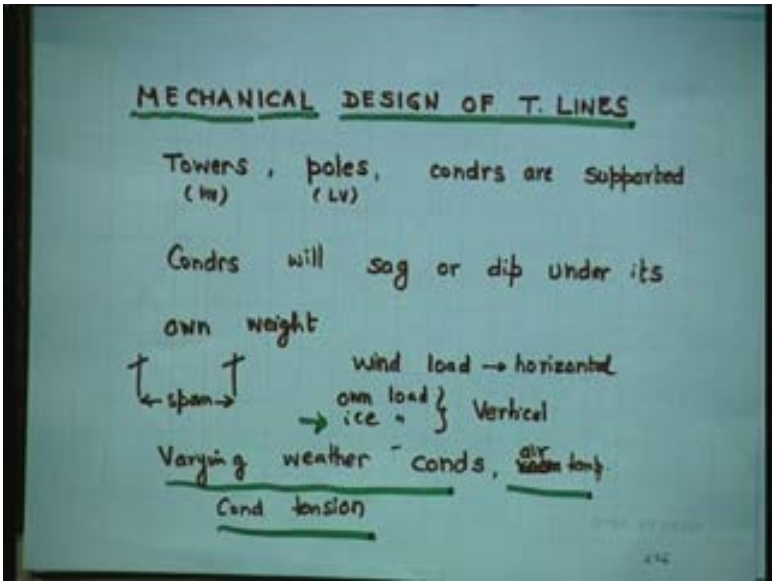
What is grading of units? The process by which you can achieve this equalization is called grading of units. If you do that, what happens? If C 1 is 5 time capacitance, C 2 becomes 6, C 3 becomes 8, and C 4 becomes 11 and so on... Remember we have talked about 19 piece suspension insulators, by the time you reach seen 19. It may be some 120 C. So, it looks so ugly, each unit is so, different than other.

And it is not a question of looking ugly, what about the inventory? What about the in now of the replacement? Stand by unit, you have to have each unit once chamber. Which is very bad, who will spend some what money? Where is the space to store all this unit just, because you want to equalize the voltage, but if you do this this method of grading is called capacitance grading. If you tall do the adamant is no problem a lot of money, lot of space, I will store than… money is no problem. Then such a method is called capacitance grading.

This is a part of and you will have a perfect voltage distribution, equal distribution. Otherwise there is a second method, because the first method is uneconomical impractical. You cannot have a 19 different sizes of units if looks so hot, suppose you have to have cheat over in front of your house if all three have different sizes different shape, different look something wrong with this man. You know you you cannot do that...

So, we have another method called static shedding guarding this is the guarding, and you have connections here and you whatever values of this x y z you can compute that will see to it that voltages are equal, exactly equal. This is much more practical than the earlier method, and this is this was being used in practice. I think with this we finished this topic of insulators sky's are limit you can born were reading about it my aim here is only to briefly introduce the topic of your knowledge. So, that if anybody ask you question about insulators, you should be fresh answer. Now next we go for mechanical design of transmission line.

(Refer Slide Time: 18:19)

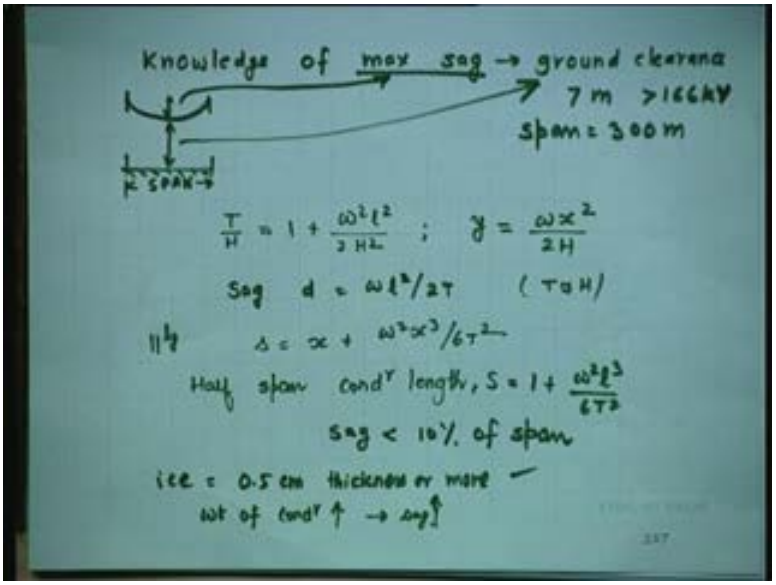


Mechanical design means, what is not electrical. Electrical design is separate, where you are decided the number of conductor bundles, the currents, the pi model, t model, regulation, R factor, up loses, power carrying capability that is it so, electrical design. What is mechanical design? Mechanical design means for high voltage you have to design towers, for low voltage you to design poles, and these structures support the conductors.

Now why there is a sag in conductor. It is weight, it is not wet less, you are not in space you are still surrounded by atmosphere and so, there is the gravity and gravity pulls every one below. So, these conductors are no exception and there is sag or dip under its own weight. Here is that figure which are drawn earlier also called span. Now wind also place a part here; wind load x urgently, and its own load x vertically. Now in winters in certain countries ice is also formed. Maybe in India we do not have that problem, bargain Badhrinath, Kidharnath, Kashmir Lake it was hilly areas. I do not think there is a no is no does not fall in most part of the India is no snow fall in Delhi, nobody has said that the trip today there was snow fall in Delhi.

When a snow falls its gets deposited on conductors and that it increases the rate of the country and that is why it is written here ice load. This is why I written here varying weather condition, varying air temperature. So, conductor tension will also varying, we will , then there is a problem sag will varying...

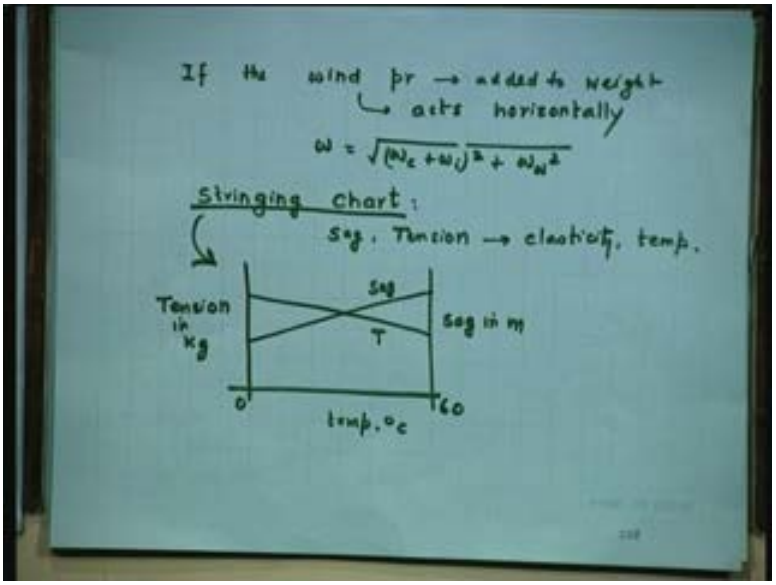
(Refer Slide Time: 21:21)



Why do you need knowledge of sag? Maximum sag, we need to have minimum ground clearance. Otherwise, it will cause accidence like library has a copy. The span is the 300 meters, this is the span. Now you can write these equation as to earlier T is the tension, H is the horizontal tension 1 plus omega is square, guys square and square 1 to x square y equal to omega x square 2 H, and sag is given by omega l square 2 T. T is roughly equal to H, this quantity is very small. So, the sag is not sag span span is x plus omega square x cube 6 T square.

Infect it is half this span, if you remember. What you did in your under graduate, see half span half span conductor length is 1 plus omega square l cube by 6 T square. Span should be less than 10 percent of span. Span is 300 meters sag should not we more than 30 meters, otherwise there is something wrong. How much ice can be there? 0.5 centimeters thicknesses are more then, we say you have there is the ice and should consider that ice. What will happen because of ice forms surround conductors the weight will go up weight will go up side will go up, because sag is sizely, because of weight if the conductors would have been wet less there any side...

(Refer Slide Time: 23:52)



If you add wind pressure, to the weight which x urgently. The equivalent weight of the conductor is given by w c plus w i whole square, what is w c conductor weight? What is w i ice weight? Square plus w w is wind. Now there are places in India where this is no wind, almost stand still some summer days if you get up early in the morning, nothing not even in the trees moving at all… so, that is if it condition where like with this not there. Infect the whole country is divided into 15 agro climatic zones. If you have we in the students of atmospheric science is in this institute you are all learned more about this storms, ocean graphing you know. Sea storms, earth quacks if very earth quacks engineering is a separate branch is a very important branch.

So, is a atmospheric science is… so, here also atmospheric science place a great role, and the whole country is divided into 15 agro climatic zones and we are in same year it zone tomorrow somebody may ask you Delhi is under which zone. Delhi is under semi arid it is not arid; arid is Rajasthan you know that is the desert. What is stringing chart? Does anybody remember? If you have ask the stringing chart in an interview that is given do that very knowing this… you are knowing, Good. So, at least one gentle man was knowing.

It if you plot tension and sag on two vertical axis y axis, what is is temperature in degree centigrade always mention units temperature can be Fahrenheit, temperature can be Kelvin, temperature can be degree centigrade or degree Fahrenheit. So, temperature and

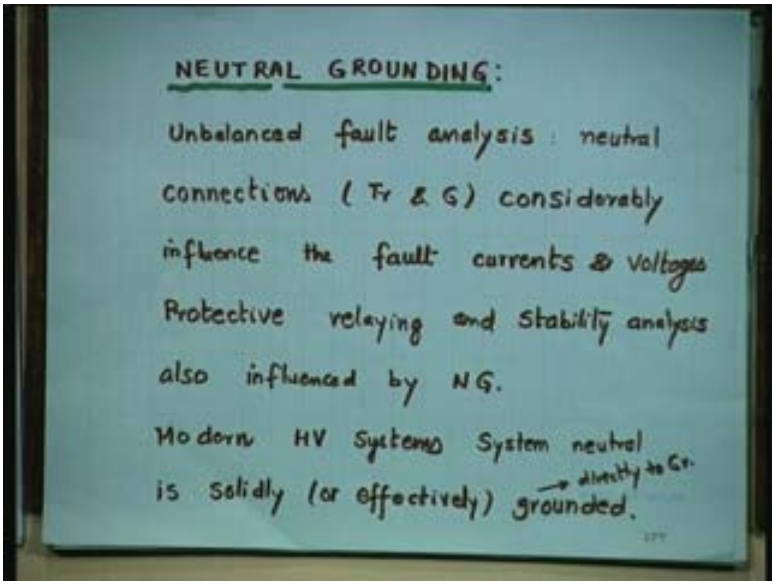
degree centigrade 0 to 60, because beyond 60 it is highly, unlikely the temperature will be on the earth where we live. Infect in Iraq, when temperature crosses 50 degree centigrade they declared to be holiday is the standard rule in middle list.

The moment temperature crosses 50 degrees even here the schools are close before time if the summer is severe, instead of fifteenth May they closes from first May. May it has government has done. And the reveres happen in winter, if the winter is too severe they may delay opening of schools after Christmas, because they do not want young children to be expose, to this in of the vagaries of the weather.

I do not know whether we know in our days in village when they we want to chute we need twist prove what on the bench, when rainy season. So, it is all wet where we site chute. So, this tension in kilogram and sag in meters are plotted like this which temperature tension drops, sag increases which is quite understandable that is the expansion in the conductor. Expansion means more side, but luckily the difference is not much though I have not scaled it the way it is scaled x axis, y axis are not scaled, but you can see this string in chart in wasting house look are any designed book on power system; this one very book on powers designed by Begum Muthrey.

So, that is a take person who passed his life time in Canada, then you went to I T control and now I do not know where is he must be above 70. So, that book gives you a very good account of power system designed. People may not like such course is, but they are the course is which are more practical, because this is what you do if you join b h c l n t p c power grade you have to all the time think of designing new system are improving the existing system. With this really gentle man we also finish our sag, and tension part of this lecture.

(Refer Slide Time: 29:11)



The third capsule in this is on grounding neutral grounding. Especially we are more interested in grounding is a very important topic is in electrical engine. In any circuit you to first see you where is the ground, water grounded even while doing practical you see where is what is ground. This very important from safety point of you that is why we have a all those things like neutral and ground, especially when you are done fault analysis in your under graduate. You must have I had teach after one on symmetrical components, one on balance for an, another on unbalanced or unsymmetrical.

What is wrong in unbalanced operation? That is more practical say we we often said that this is not showing a balanced brevier form there must be some participation we must I got a later from home or something some news which is not good. So, he got he or she gets part of are some one must banking are must quarrel with somebody, you know that is why you show different behavior on that day. So, it is an unbalanced operation. So, why power system show unbalanced operation, because take place otherwise, while show unbalanced approaching, if you see in your houses the supplies given in such a way that there is the balanced.

One facer one facer one facer and ultimately its overall balanced. Unit tagged distributed work in a balanced way if you are head of the department, you do not just load one particular technician or one particular teacher yeah you teach all the courses, others

enjoy. Know it tries to balance everybody get 6 hours per week or 3 hours per week in a center, in the part time 6 hours per week .

So, they are doing we are trying to achieve a balance, we say in practice it is a very balancing as an administrator. What are different types of the keep on happening all the time right l g, l l, l l g, all l l l l that is three faces? You can design a system if you bank up on which is fall proof; that means, no fall take place is it worth it is not worth their own bean exceeding life if there is no fall there is no need and such a system will be very very costly, very very undesirable it is like very in a space shout in the winter.

So, that you do not get catch cold know then, you will be feeling there is the space and at all moving in that when who diffuses bomb you know the bomb squad they wear such dresses. Only they wear on earth the space shuttle you know even they go. So, we we take picas ion we I am not saying that do not take any picas ion all this are thing rounding is what it is a step in that direction. So, that normally do not take place, if I tell the take place you are safe nothing happens to the system, you know while there is a fuse in houses, while there is a fuse in any device, because that is of weakest link; at if that is so cheap, a fuse wire is almost almost free of cost.

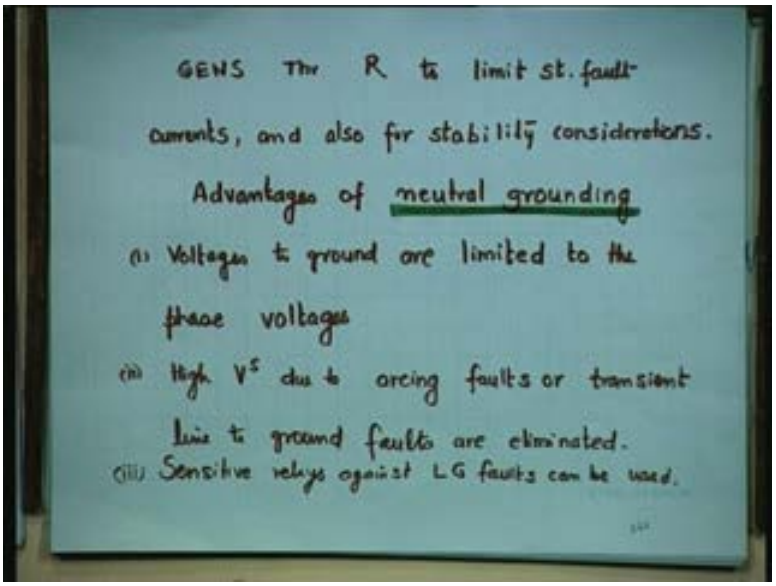
So, it is easy to replace what happens in our hostels, they put such a thick wire whole fuse go there, because nobody wants to go his room his in winter when they use heaters which is not allowed, because that load is not provided for, but student use heaters. I am told in old real winters now there is hardly in winter. So, unbalanced fault analysis neutral connection is very important. How neutral is connected? If it is a balanced neutral current is not there…

So, all transformers are generators have neutral and it is properly grounded, and they considerably in place the fault current and voltages. Voltage is changed, volts narrow is change. Protective relaying and stability analysis also influenced by neutral grounding. How do you ground a neutral is an art, modern high voltage systems, system neutral is solidly are effectively grounded. What you mean by solid grounded, effectively grounded? It is directly grounded something like, direct online starter is no starter, any motor less than 5 horse power you do not need any starter.

Why we need starter? A starting current is 5 time the full of current, I starting is equal to 5 times full load current, but that 5 times full load current is not large enough… if the

capacity of the motor is less. So, we can tolerate that much amount of current, but it was 100 horse powers, 25 horse power we starts slowly and through starter. Can we start as starter, it can be auto transformer, and it can be anything. Similarly, here when we talk about solidly grounded or effectively grounded, what are needs? I need it is grounded directly to the ground. There is nothing in between, there is no resistance, there is no reactance, and there is no capacitance, which is just a big thick wire. There are specialized books written on grounding you can see that I will given the references.

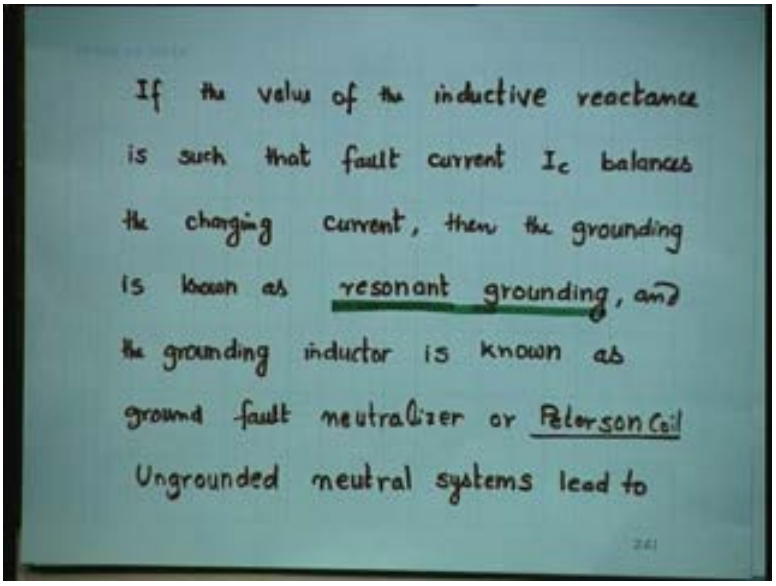
(Refer Slide Time: 36:23)



Generators are grounded through registers to limit the fault starter fault fault current static fault current are there is all static fault current are dynamic fault currents. So, which is not varying from also for stability considerations, it is always better to ground through registers. What are the advantages of neutral grounding? Why should we do that, because any grounding needs money, extra circuit voltages to ground are limited to the phase voltages, high voltages due to arcing faults or transient line to ground faults or eliminated poor voltages, we are solving the problem of poor voltages.

Sensitive relays against l g faults can be used line to drawn. Now relays are numerical relays, computer relays gone are the days of electro mechanical relays, static relays, solid state relays. Now we have electronic relays, computer relays or a numerical relay that is using software.

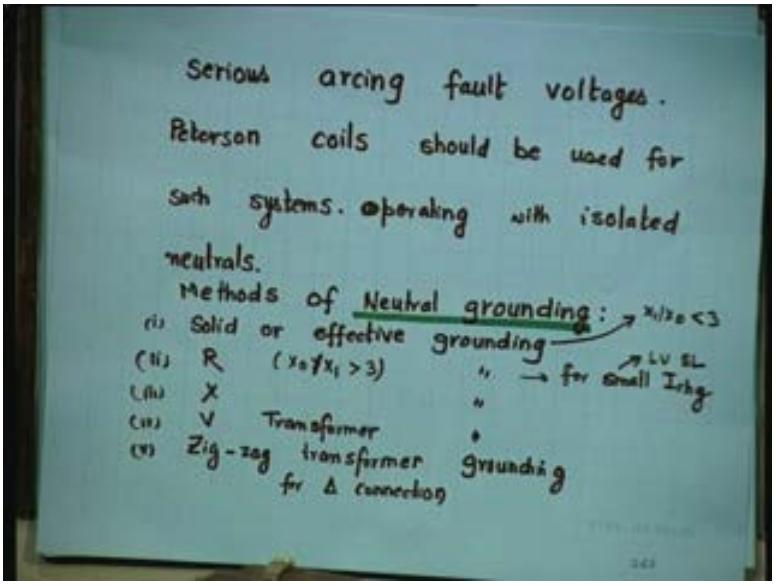
(Refer Slide Time: 38:18)



If the value of the inductive reactance is such that the fault current I c balances the charging current, then the grounding is known as resonant grounding. So, if somebody asks you what is resonant grounding... Then the value of inductive reactance x l, we such that the fault current I c balances the charging current, and the grounding inductor such a inductor is a put in between neutral and ground is a given a special name in the literature. Which is called Peterson coil, very important coil and is normally asked in interviews, what is Peterson coil? We should not look this way and that way I do not know sir, and I will read it sometime...

And we are neutral systems lead to suppose you leave neutrals un grounding what happens you not to save money for Peterson coil is the arcing, fault routings that is more important. So, this may lead to serious arcing fault voltages.

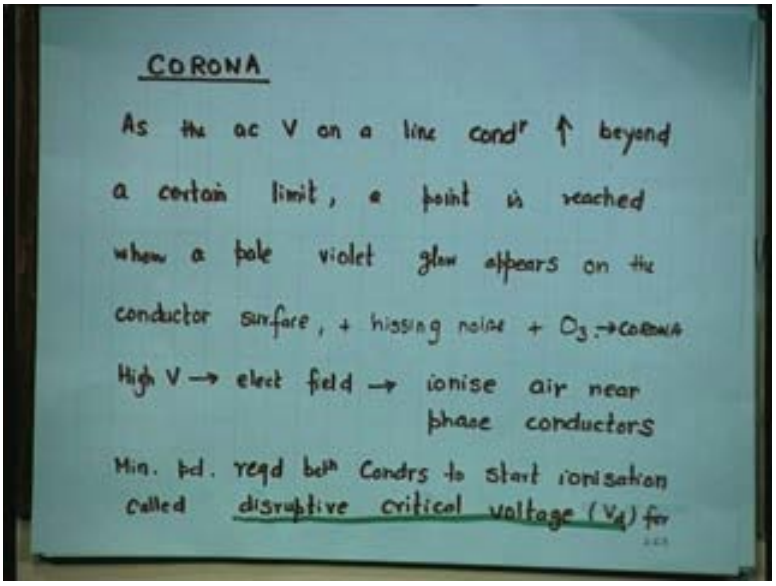
(Refer Slide Time: 39:55)



Serious arcing fault voltages will be there, if you do not ground neutrals. Peterson coil should used for such systems, operating with isolated neutral. What are the five different methods for neutral grounding? There are five methods, any one solid or effective grounded from where we started this story. This is or it is effective if x 1 by x 0 is less than 3. What is x 1? Positive sequence reactors, what is x 0? Zero sequence reactance, normally 0 sequence is very high it is 2.5 times the positive or negative sequence reactance this you must learn any of fault chapters. And if you would want to use registers, when the condition is x 0 from x 1e is more than 3.

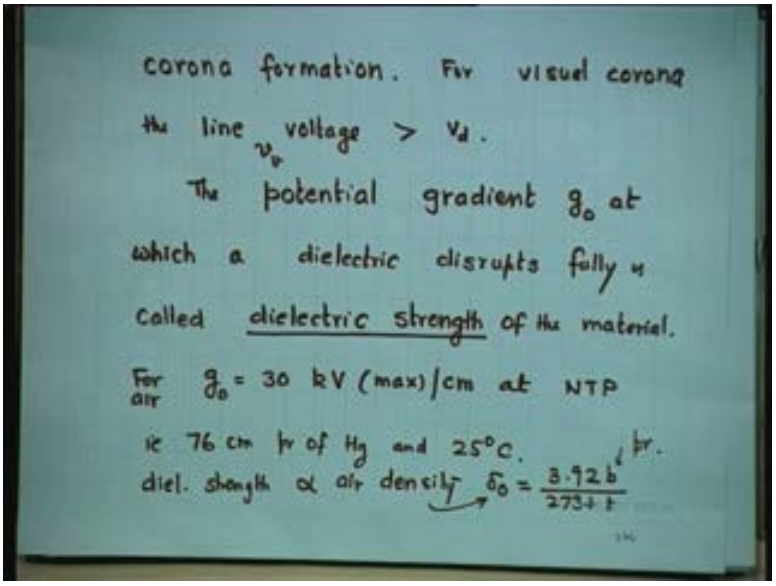
For small eye charging, low voltage short line; S L is short line, L V is low voltage. Short line means no no point networks, no capacitance less than 100 kilometers 80 miles; reactance use also for grounding V is voltage transformer for grounding we use zigzag class transformer grounding. What is zigzag transformer? Where ever there is the delta connection, there is no neutral available as such there you to use this zigzag transformer where ever there is the delta connect ion and delta connection is the practical connection is not a theoretical idea or a fusion...

(Refer Slide Time: 42:40)



Another important topic corona, you must a word of corona, as the A C voltage on a line conductor increases beyond a certain limit. A point is reached when a pale, violet, glow appears on the conductor surface. What is of the glow? Pale, violet, glow; with accompanied by hissing noise, and store it as there is ozone also coming along with it. So, it is a cheap long attack and conductors. There is a glow, there is a noise and there is a gas formation, which ozone are high voltage will always have an electric field this electric field, what as a do? It ionizes air near the phase conductor. Minimum potential difference required between conductors to start ionization is called disruptive critical voltage. That is the minimum potential difference required to start this process is called V d.

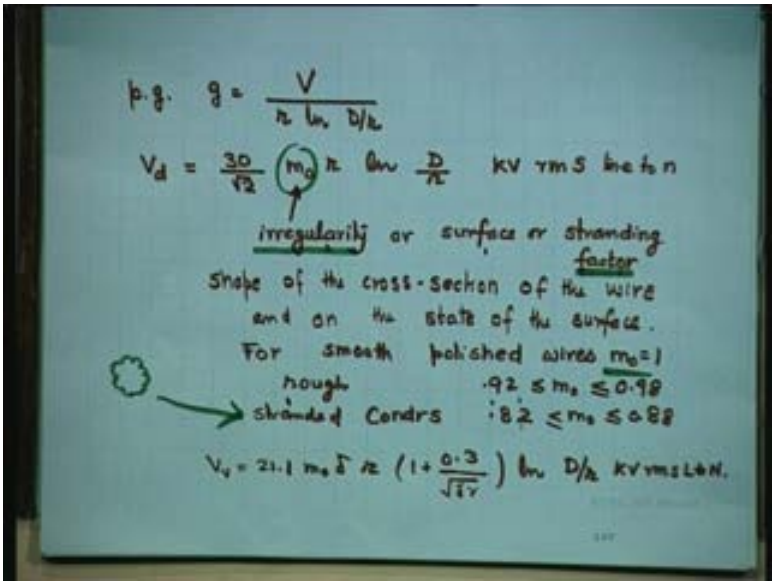
(Refer Slide Time: 44:35)



And when that potential difference is a reliable we say coronas form. As we have to see that corona there it will be still go ahead and that is called visual corona, and the line voltage must exceed this V d and that line is also called V V virtual corona. The potential gradient g 0 at which a dielectric disrupts, fully that is dielectric strength of the material is spoil that is called dielectric strength of the material that gradient. What is that the dielectric strength of the material? The potential gradient g 0 is called dielectric strength, of material at which point at which a dielectric disrupts fully. What is the value for air? Such a value is 30 K V maximum peak or centimeter at N T P - Normal Temperature and Pressure; the pressure is same to 76 centimeter of mercury at 25 degree centigrade. So, dielectric strength is proportional to air density air density is defined as 3.92 b upon 273 plus t that is absolute temperature capital T, b is a pressure...

Right...

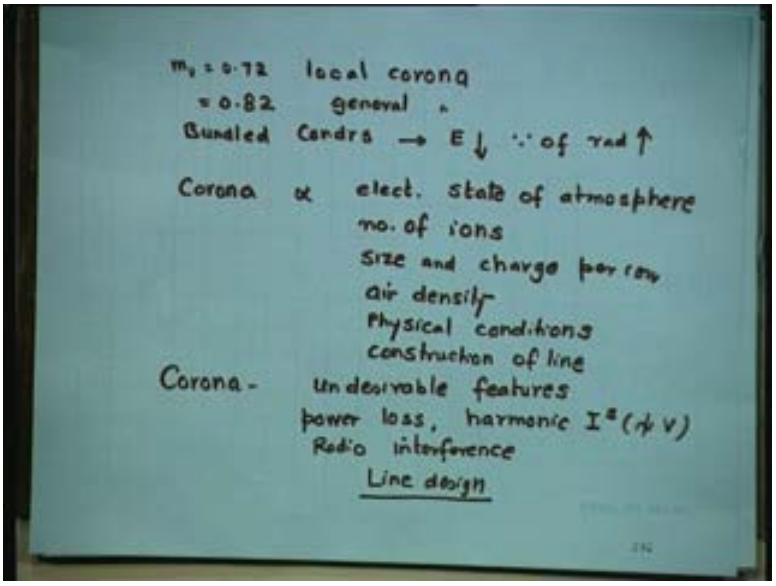
(Refer Slide Time: 46:33)



Potential guidance is V upon r l and D by r. So, V d the the disruptive voltage is 30 by square root to why root to to be read r m s it was maximum m 0 or l n d by r K V r m s line to neutral. This m 0 is called regulative factors or surface or stranding factors three names are there regulative factor is a noun and adjectives are irregularity surface stranding; three all three mean the same thing. Shape of the cross section of the wire and on the state of the surface, for smooth polished wires m 0 is 1, chances of corona is minimum if it is smooth yes higher voltage. That is why chances are low, but if it is rough then m 0 where is between 0.9 to 0.98, if it is standard, then 0.82 m 0 0.88 standard means like this...

Starts smooth so, v v is 21.1 what is 21.1? 30 by root 2 root, 2 is 1.41, root 3 is 1.772 1.7 is enough do not go beyond and 0 delta are 1 plus 0.3 upon under root delta r right, l n d by r K V r m s line to neutral again for n v 0.72 local corona, if it is 0.82 general corona.

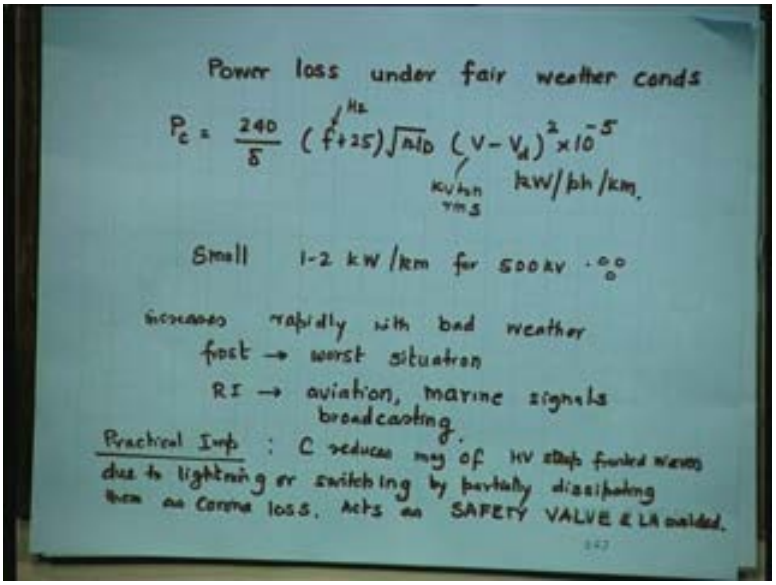
(Refer Slide Time: 49:05)



Why do use general conductors? If you recall one of the answers which we gave for using, conductors use to reduce the chance of corona, because the E goes down therefore, radius goes up yes… and corona is proportional to electrical state of the atmosphere, number of ions size, and charge per ions, air density, physical conditions, construction of line these are all the factors you have to mention there moment of the question is least the factors on which corona formation depends.

Now corona is not something which you will welcome. You see, well I am coming to that normally the undesirable features of corona that always present menus whatever happens there is the power loss, there is the harmonic currents, which is not proportional to voltage is not sigh which is non harmonic currents is non certain voltage and radio interference. So, while designing line you must consider corona.

(Refer Slide Time: 50:38)



How do get the power loss due to corona? Peaks formula, lets come to peaks formula. Power loss under fear by their condition is given by Pc Pc is power loss due to corona 240 by this is an empirical formula. This is no derivation given by a gentlemen called peek p w k f is the hurts 25 or by D v minus V d whole square 10 east minis 5 kilovolt per phase per kilometers. This is K V to neutral r n s luckily the power loss is very small, hardly 1 to 2 kilo volt per kilo meter for 500 KV is the bundle conductor.

It increases rapidly with bad weather weather there is bad the corona loss increases, you can no longer ignore it, if it is the fast. So, worst condition that can happen for conductors. Which normally it comes in us and any cold countries, what is array? Not regressive imprisonments it is radio interference, aviation, marine signals, broadcasting all gates of effected, because of corona. As the young lady was talking about good points about corona there is something good out of any it will also, you must our write you must our written essays on the benefits of war.

What is war do? It improves new technology is bring is in, but the first second world war there is no atom bomb, there is no need. So, practical importance is corona reduces magnitude of high voltage steep for take this to do lightning or switching by partially dissipating them as corona loss. Thus it access the safety wall, and you made no you may not have any safety device like lightening or extract lie is not last angels, but lightening

or esterase avoided because of corona. So, it acts as a safety. So, that is a people ask you what is the practical importance of corona right yes.

So, with this we finish today's lecture any point you want to have anything you want to race and queries any suggestions yeah ground yeah. Getting confuses sir. You tell the same and if you are register between them will not say people are not it need not, but it always are 0.Yes of course, it is the reference point. So, it is a reference point so, what not practical. No it is a chain basis. So, you cannot use line line is only dc systems there is basically asked in another time compare the copper required if 2 wire, 3 wire, 4 wire, etcetera etcetera … use to many regular question in universities. Sir, what is local current and general current know? That is we are only touch the topics.

So, that you do not forget them that very important topics, do not get last into bigger topics like economic properties in stability they are more practical they are very much a practical in a these things it was take all the times about why you it can be used in looser system? Why you are always to over like neutral system? This will talk after the class.