Electrical Distribution System Analysis
Dr. Ganesh Kumbhar
Department of Electrical Engineering
Indian Institute of Technology, Roorkee

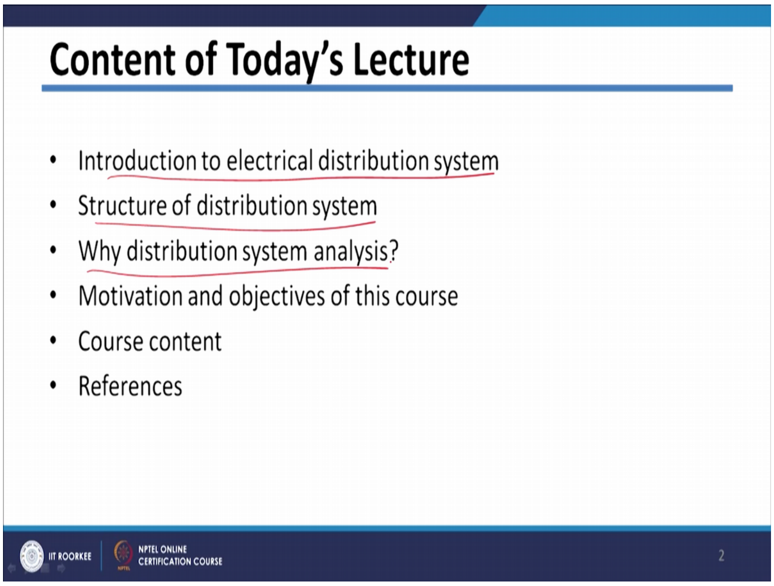
Lecture – 01
Introduction to Electrical Distribution System

Dear students, welcome to this course on Electrical Distribution System Analysis; myself Dr. Ganesh Kumbhar; I am working as a assistant professor in the department of electrical engineering IIT, Roorkee. This course is specifically designed at the electric course for the students of under graduate, post graduates and PhD who are working in the area of distribution system and smart grid.

This course will also be useful to the utility engineers who are working in this distribution sector. The basic power course system courses like power system analysis, power transmission and distribution, power system engineering, switchgear and protection are the basic prerequisite courses for this particular course.

In this particular first lecture will see following topics.

(Refer Slide Time: 01:26)

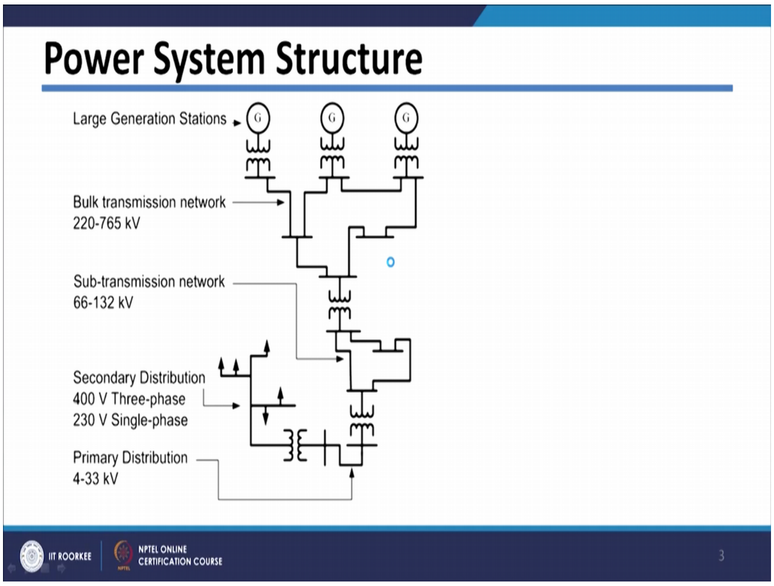


So, content of my today's lecture will be introduction to the electrical distribution system. So, I will introduce you to the electrical distribution system; then we will see the structure of distribution system. Basically distribution system is classified into 2 parts there is primary distribution system and secondary distribution system.

So, we will see the structure of this primary distribution system and secondary distribution system. Then we will see why distribution system in analysis is required? So, you might already study the power system analysis ah; however, this distribution system analysis will be different from earlier power system analysis. So, will try to find out what are these differences? Then we will see the motivation and objective of this particular course, then we will see the course content and then we will see the reference books required for this particular course.

As we have studied in our undergraduate courses; the power system can be divided into 3 parts.

(Refer Slide Time: 02:30)



That is generation, transmission, and distribution. So, if you see this figure generation is shown here and then this is nothing, but your transmission layer and then this is nothing, but your distribution part. Voltage level of the generation is around 11 kV to 25 kV. Now this voltages which are 11 to 25 kV will be stripped off to the transmission level that is 220 kV to 765 kV which is; which are the voltages for bulk transmission network. Then there will be step down to the sub transmission level the search transmission level is 66 kV to 132 kV.

Then it will be further step down to the distribution level. So, voltages at the distribution level or below 33 kV. Destination level can be divided into two parts that is primary distribution system and secondary distribution system. Primary distribution system will be having voltage level between 4 to 33 kV and secondary distribution system will be having voltages that is 400 volt three phase and 230 volt single phase.

And if you see the structural difference between your transmission network and distribution network, transmission network is basically inter connected means it will be find for mean some kind of low fear, but we see the structure of your distribution system, distribution system will be radial. So, it will be radial or weekly missed. Basic goals of your distribution system are listed here.

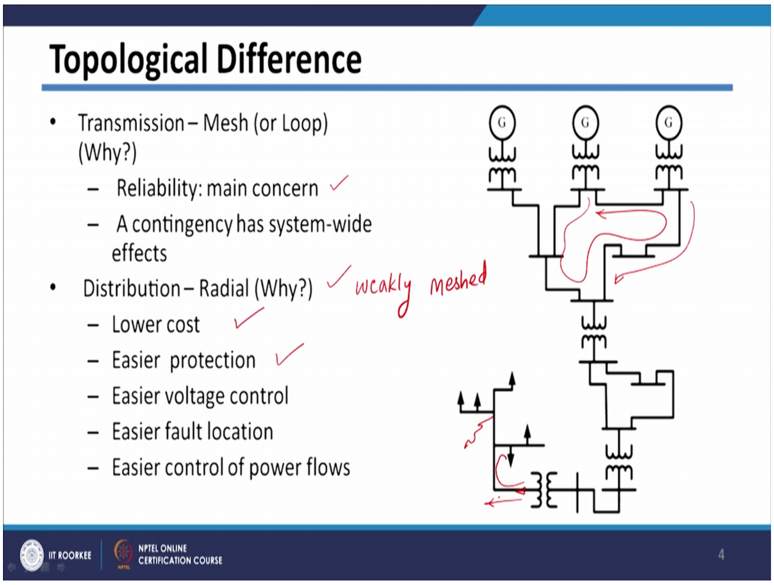
So, first goal it should be efficient; you should be efficient means losses in the distribution should be less as less as possible. We should deliver the customer the quality power means for your voltage should not contained any harmonics, it should not contain any sags swells or flickers.

Then we should provide a customer reliable power should be cheap to the customer. So, it should be economical and it should be secure power to the customer.

If you see the topological difference between your transmission and distribution network as I told you earlier, your transmission network is basically interconnected. So, as shown in this figure, you can see that it is forming some kind of lobe means of which is shown like this or you can say there will be actually one bus will be connected to many other buses which is forming inter connected kind of or loop kind of system.

This is basically done to increase the reliability of the system, because as we know all the generators are dispersed over wide distances and whenever there is contingences like few lines or few generators, if they go out of the system there is possibility that system and become unbalance. To avoid this stability issues into the system we want actually system to be inter connected or it is forming loop kind of loop of structure. Whenever there is some lines or some generators are out, the power will be still available from alternate route.

(Refer Slide Time: 06:21)

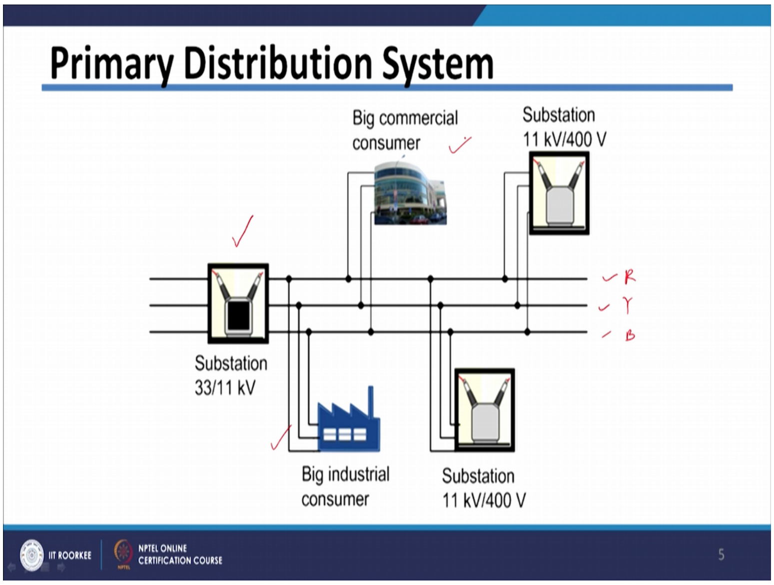


Your distribution system will be radial one radial means it will not be forming any kind of loop or it is kind of weakly mesh system. Weakly meshed means there will be only few loops unlike in case of transmission system. So, since transmission system is highly inter connected kind of system.

The basic reasons to make the distribution system radial are as follows; first is if you see the cost of the system called difference between interconnected system and this radial system, radial system will be very cheap, that is cost of the system will be very low. It is easier to protect, so protection system will be chief as well as easy to protect because you know that in this case if you see the radialty system the current will be actually having only one direction. So, whenever there is fall talker at some location; so the current will be fade from only one direction to the fault. So, in that case your protection will become easier.

Also since the power is flowing from one direction. So, voltage drop will be in one direction that is why voltage control will also become easier. Finding the fault also will become easier because power is flowing fault current as well as power their flowing from one direction, it is also easier to control the power flows.

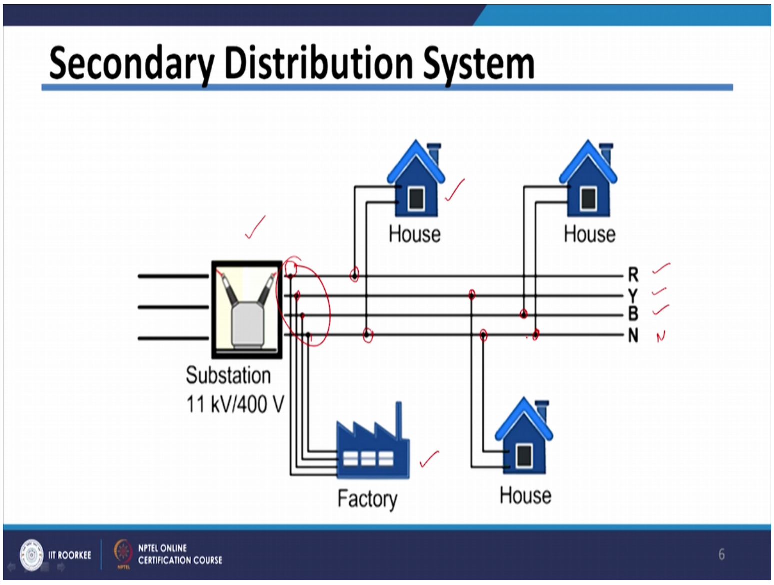
(Refer Slide Time: 07:57)



Now, if you see the structure of your primary and secondary distribution system which was seen earlier. The primary say distribution system basically consist of your 11 kV network, we also call it has HT level; High Tension lines. It starts from your 33 to 11 kV substation and it will be basically 3 phase 3 wire system.

So, there will be 3 wires R Y B at 11 kV level. This feeder will be basically connected to different substations which are 11 kV by 400 volt substations; there will be many sub substations will be connected to the speeder. We also provide power to bigger consumer like malls or big industrial consumers at 11 kV 3 phase level. So, there actually in shown in figure there is one in bigger industrial consumer which is taking power at 11 kV level and at 3 phases.

(Refer Slide Time: 09:09)



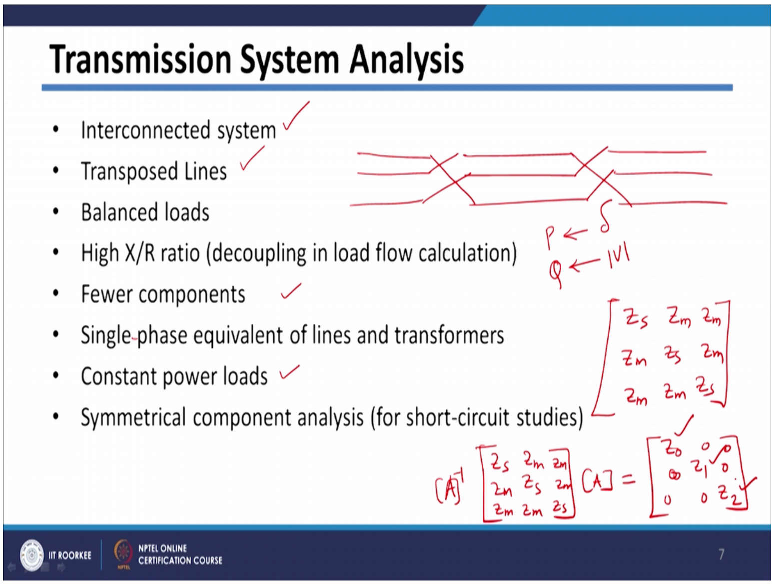
Similarly, there is one commercial consumer which is shown it here which is 3 phase; if you see the secondary distribution system secondary distribution system start with 11 kV by 400 volt substation and it is basically 3 phase 4 wire system. So, there is there are 3 phases R Y B and one neutral phase. So, 3 phase 4 wire system it will be providing power to the some big consumers as well as some domestic consumers like our houses.

So, we if you see here the factory which is little bit big consumer we are providing the power to this big consumer at 3 phase levels means all 3 phases are there with your neutral connection. And to our domestic consumers we if feed the power at single phase level.

So, if you see this house it is taking the power at R and N phase which is single phase R. Then if you see this house it is taking at power at Y and N phase and this house is taking power from B and N phase.

So, this is structure of your distribution system which is secondary distribution system.

(Refer Slide Time: 10:25)



Now, we will see transmission system analysis. So, basically in this particular slide we want to see what are the assumptions we are made, during the transmission system analysis. So, we know that the transmission system is basically interconnected kind of system. So, your algorithm should be such that this interconnection or loop kind of structure it will take into account.

Then we know that this transmission lines are basically transposed one; transpose means this lines will be changed at different location. So, every conductor of this line will be taking location of every other conductor. So, we know that transmission these lines will be transpose lines.

Then we know that actually loads are balance one generally at transmission level loads are balanced. Then we are we know that X by R ratio of transmission system will be very very high because of this X by R high ratio, we were decoupling is possible. Means your P and Q can be differently controlled. So, P can be control by just changing the angle delta which is basically phase angle difference between voltages at sending end and receiving end and Q can be control by voltage magnitudes.

So, as I told you because of this decoupling effect we can get decoupled kind of load flow algorithms. Then there are actually fewer components has if know only few components we need to model during the transmission system analysis; those are basically reactors and your transformers or may be some times capacitor banks.

Then as you remember during the modeling of transmission system load flow, we model it has a single phase equivalent, network; means lines as well as transformers will be modeled as single phase equivalents. Because of that we are not considered any individual connections of the transformers (Refer Time: 12:57) if it is delta star or star, star or delta, delta transformer, we modeled it as a single phase equivalent of them.

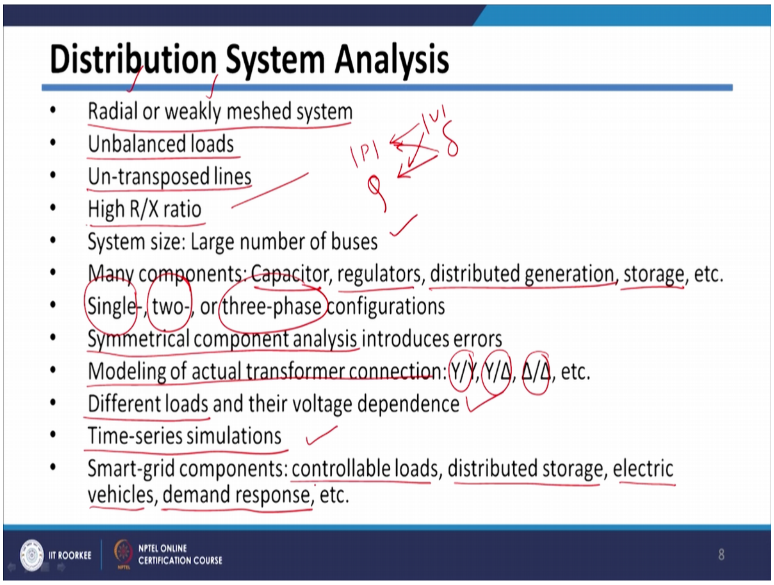
Then loads which you have modeled in transmission system we have consider them constant power loads. Means voltage dependency of the load we have not considered because of that at each iteration of load flow your power is remaining constant means we had not changed our power value is during load flow iterations.

Then symmetrical component analysis was possible; so we know that actually since lines are transposed, we get your because of transposition we know that yourself impedances of the line they will be equal. So, self impedance of all the 3 phases we know that it is going make a it equal to say Zs Zs Zs and mutual impedances between line also we make them equals; so Zm Zm Zm they are equal.

And we know that if you multi free and post multiply this metrics by A inverse which is symmetrical component transformation metrics and A matrix we if you multiplied by multiply to this impudent matrix which is Zm zm and diagonal entries Zs Zs Zs; we get only a diagonal metrics that is Z 0 Z 1 and Z 2.

Meaning of this your 3 network that is 0 sequence network, positive sequence network and negative sequence networks they are decoupled from each other.

(Refer Slide Time: 14:57)



Unlike this, if you go for distribution system analysis distribution system network as we discussed; it is radial or weakly meshed kind of network.

So, because of this structure we know that we can find out some algorithm which are simpler in nature than your transmission algorithm and specifically designed for your radial or weakly meshed kind of system. However, in case of distribution system your loads are totally unbalanced loads, your lines are un transposed your ratio of R by X will be higher.

Means you see the ratio is higher you cannot do the decoupling means there will be actually voltage magnet to do will also if make effect on your power as well has your delta will make effect on your Q. So, delta will make effect on both voltage will make effect on both the this quantities.

Also as compared to transmission network size of distribution system will be vey large ok. When we analyzing the transmission network the number of buses which we may have to considering is around 100 so, buses, but in case of distribution system the large distribution system I am talking about it will be around 1000s of buses; so system size is very large.

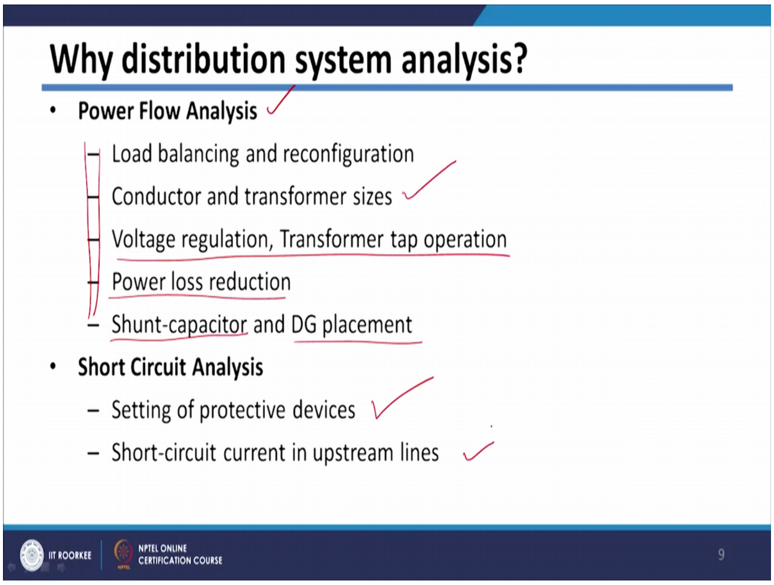
In distribution such system there are many component which are present like there will be capacitor, there will be regulators, there will be distributed generation, there will battery storage. Also if you see the structure of your distribution network, there will be some line which are actually single phase line, some lines which are 3 phase lines and some line which are actually 2 phase lines. Because of that we cannot do single phase equivalent analysis in case of distribution system. So, we need 3 phase analysis for distribution system.

Symmetrical component analysis also not possible because there are un transpose lines. So, this a 0 sequence, positive sequence and negative sequence networks will not be decoupled from each other. In this case since we are considering full 3 phase modeling your Y Y, Y delta or delta delta connections need to be actually modeled during the analysis of distribution system.

Loads in a distribution system are basically voltage dependent because of this voltage dependency of the load; the loads will change in each load flow iterations. So, that need to be considered while doing the load flow analysis. So, voltage dependency of the load needs to be taken into account.

Distribution system analysis will need time series simulations. So, we need to calculate load flow solution at difference time steps that is called a time series simulations. Also nowadays many smart grid components are coming into picture. And this smart grid components will make your distribution system analysis little bit complicated and those smart grid elements are controllable loads, distributed storage, but battery storage, electrical vehicles and demand response activities designed by utilities. So, because of them your distribution system analysis is important.

(Refer Slide Time: 19:09)



Now, we will see where the distribution system is required or where it is applicable or where it is used. So, as I told you the basic analysis is load flow analysis and short circuit analysis. So, load flow analysis is required for taking various decisions during operational stage of the distribution system as well has design stage of the distribution system.

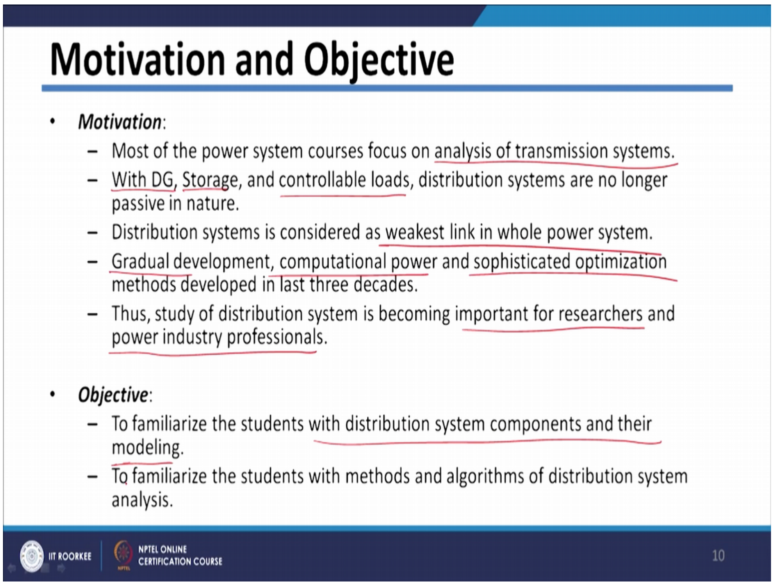
So, during the operational stage like load balancing or reconfiguration of the distribution system we need load flow analysis. During the design stage while we are selecting conductor size of the distribution conductors or transformer size is we go for we need to know the load flow solution.

Voltage regulation and tap operation during the operational stage we need result from load flow analysis, power loss reduction we need load flow analysis; then nowadays capacitor placement as well as DG placement, we need results from load flow analysis or load flow will be basically; it will be used during this different types of analysis.

Then short circuit analysis is required while during the settings for protective relates or during the relay coordination in a distribution system also to calculate short circuit current in the upstream network. So, we need actually result from short circuit analysis during this design stages.

Now, we will see what is the basic motivation and objectives for development of this particular course.

(Refer Slide Time: 21:01)



As we know most of the power system courses mostly focus on your transmission system analysis. And as we have seen in last 2 3 slide there are many components which are different the structure of distribution system is very different from your transmission system; we need to have separate algorithms or separate method for distribution system analysis.

We also know that nowadays with incorporation of distributed generation, battery storage, controllable load distribution system is no longer remaining passive in nature means distribution system is becoming active because of this; energy generation sources or energy storage sources which are present in your distribution system. Also distribution system is connect consider to be weakest link in whole power system because it is most loss making component. So, almost we can say 60 to 70 percent losses which happen in distribution system.

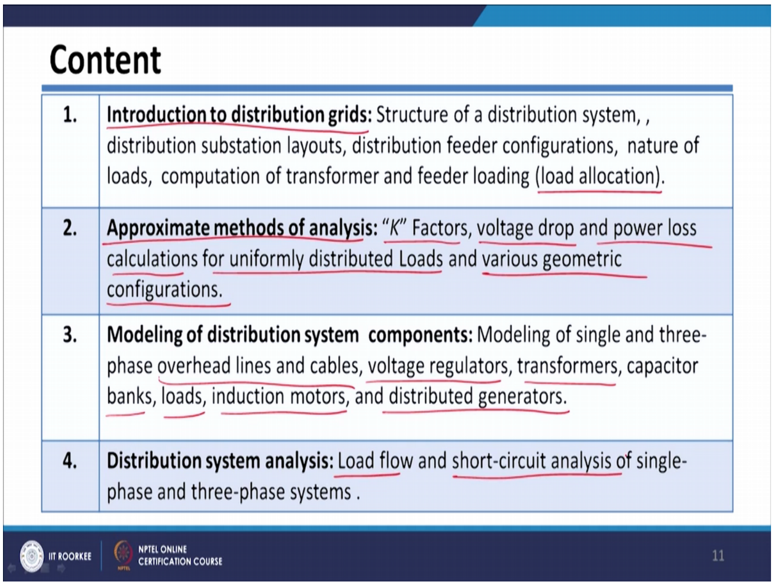
Also if you observe last 3 decades there is gradual development in computational power, there is gradual development in optimization algorithms. Now days there are many sophisticated algorithms are available for though optimization which can be used fuedering analysis purpose.

So, because of that this distribution system analysis is becoming very important for the researcher who are working in the area of distribution system and industry professionals which who are working in distribution sector. These results which we obtained from distribution system analysis will be quiet useful while making the decision during the operation as well as design stage of the distribution system.

Therefore, main objectives of this particular course are to familiarize the students with distribution system components and their modeling. So, first of part of this particular course we will see how to modeled different components of the distribution system and then second part of the distribution system the objective is to familiarize the students with methods and algorithms of distribution system analysis.

So, in this particular part we will introduce you various methods and algorithms which are very different from your transmission analysis algorithms for the distribution system analysis.

(Refer Slide Time: 24:13)



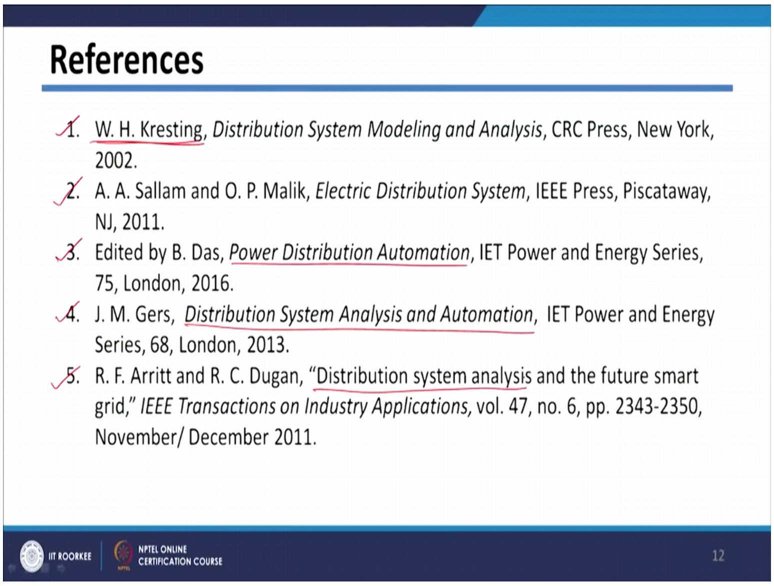
So, based on this based on this objectives the main content of this course is divided into 4 chapters; out of this first chapter is based on introduction to the distribution grid. So, basically in this particularly chapter we will see the structure of distribution system, distribution system substation layout, distribution feeder configurations, nature of loads, computation of transformer and feeder loadings that is nothing, but your load allocation.

Then we will see various approximate methods which are available for distribution system analysis. They are some method which are based on K factors will study then, the main aim of approximate methods is to get the voltage drop and power loss calculation on uniformly distributed load over the feeder.

Then we will see various geometrical load configurations, then in third chapter we will see modeling of distribution system components. In this modeling we will basically see modeling of single and 3 phase overhead lines and cables, then see will see the modeling of voltage regulator, transformer, capacitors banks, loads, induction motors and distributed generators.

In fourth chapter, we will see distribution system analysis. So, in this particular chapter will try to develop algorithms for load flow analysis and short circuit analysis which can be used for single phase as well as 3 phase systems. So, based on this content or the reference is for this particular course are listed here.

(Refer Slide Time: 26:07)



So, first is book by W H Kresting on Distribution System Modeling and Analysis.

So, to model the distribution system components we will be referring this particular book then there is book by Sallam and Malik Electrical Distribution System. So, this will be used for introduction to the distribution system as well as during the short circuit analysis of distribution system. Then there is book edited by Dr B Das on Power Distribution

Automation and this book will basically used while developing your algorithm for load flows and short circuit analysis.

Then there is book by J M Gers on Distribution System Analysis and Automation and then there is one paper by Arritt and Dugan which is Distribution System Analysis and Future smart grid. So, during the, your introduction section we will be using this particular paper.

Therefore, in this particular class we have started with introduction to the distribution system. Then we have seen the structure of distribution system, then we have seen motivation and objectives for this particular course. Then we will see we have seen that course content of this particular course and references.

Thank you.