Power System Generation, Transmission and Distribution

Prof D.P.Kothari

Department Of Electrical Engineering

Indian Institute Of Technology, Delhi

Lecture No. # 23

Distribution Systems

Welcome to this lecture number 23 on Distribution Systems. So, far we have been talking on generation and transmission and distribution system has been getting a very raw deal, even in books you will hardly find a chapter or so.

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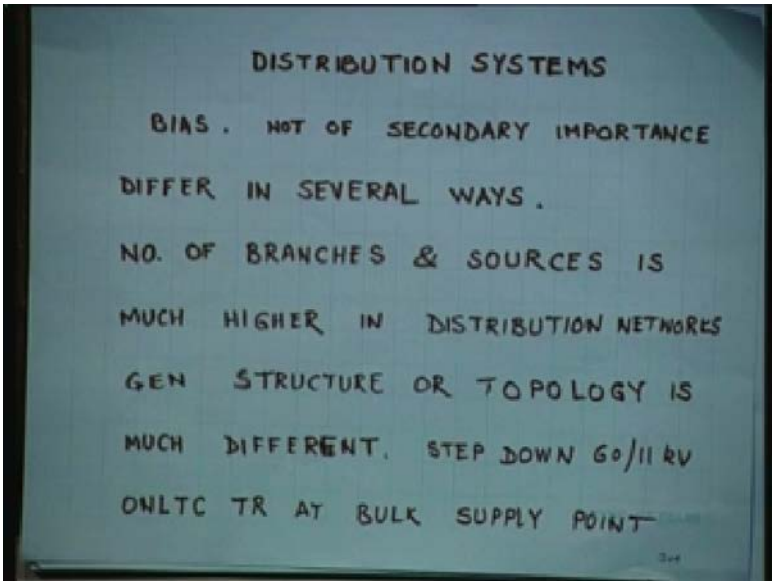

But let me tell you, there is a BIAS against it and it is definitely not of secondary importance, it is as important as generation at transmission, because it is a distribution that reaches out to consumers and customers industries and so it should not be neglected.

Of course, it differs from transmission systems in several ways; number of branches and source is much higher in distribution networks, general structure or topology is much different. Step down 60 to 11 k v on load transformer at bulk supply point.

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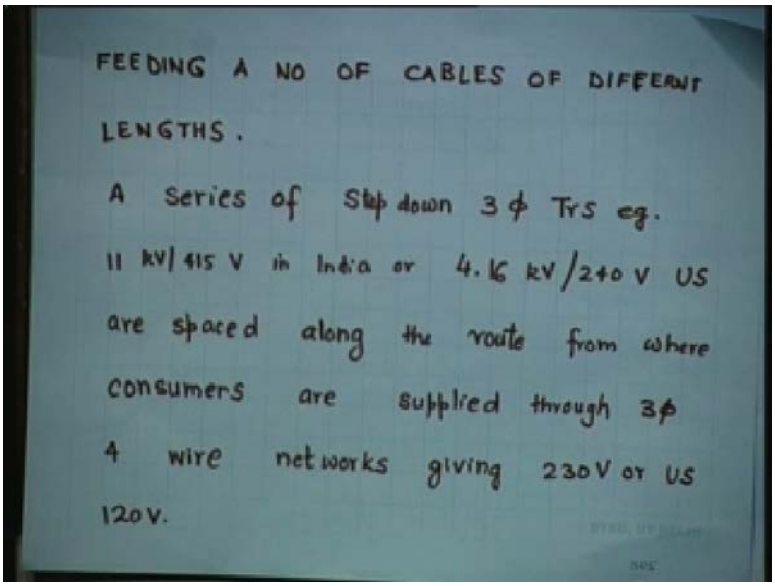

Feeding a number of cables of different lengths, a series of step down 3 phase transformers are required for example, 11 k v to 415 volts in India and in US, it is 4.16 k v to 240 volts, please remember they have 120 volt system, we have 240 volt system.

Now, it is spaced along the route from where consumers are supplied through 3 phase 4 wire networks giving 230 volt in India or 120 volt in US that is what is finally, required in domestic supply.

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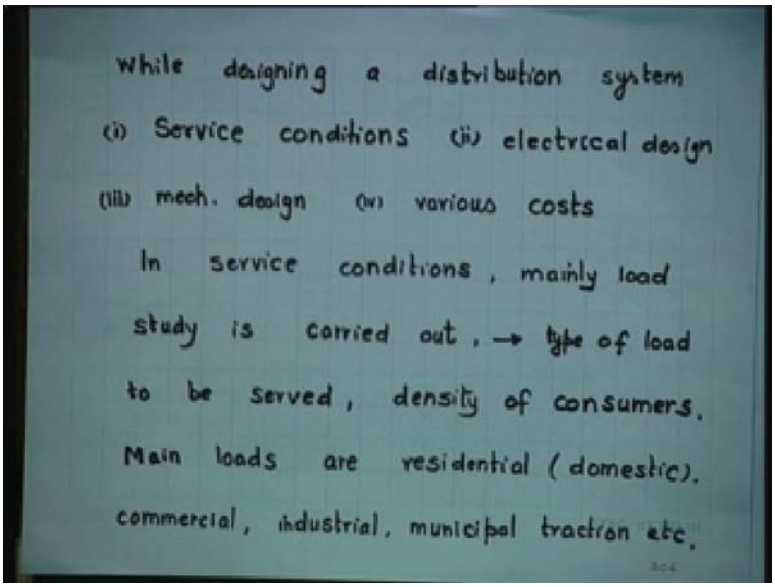

Now, while designing a distribution systems, what are the themes that one has to keep in mind, what are the service conditions, electrical design, mechanical design, various cost, whatever you may give, the cost factor you cannot ignore, whether you purchasing thing, whether you go anywhere, the cost is such a important factor. Even that is very important while designing a distribution system.

What is service conditions, mainly the load study is carried out is not quite loads flow study, but what sort of loads are there, which you have want to supply the power, is it any culture load, is it domestic load, is it you know, what you called industrial load or hesitate advertising load, neuron lights, codlings are easy to monuments you know, or hesitate here you want to put light or is it air port lighting scheme, which is entirely different.

So, type of load to be served, you have to study thoroughly in distribution system that much detail studies not required in transmission system, there you can lump them, density of consumer is very important, how many consumers are there at a given point. So, that the feeded design will depend on that; the number of transformers will depend on that; how much transformer will be you working for how much time, all these things are required, while designing a distribution system, which we never bothered while talking about transmission system. Meld out their residential domestic, a city like Delhi you have 1 crore population, you can one imaging the residential load itself.

Specially, when everyone is having all sets of gadgets at home vacuum cleaner, air drawer, you have iron, washing machine, ac, coolers, stores, ovens, micro waves and everything even saver, everything now you want to do needs a input of electric energy. Commercial load, I would not talk about advertisements, shops, malls, plazas, you know, all this need electric power.

Industrial, small scale industries, large scale industries, medium scale industries, is just or take a jockey. You know, we he has only just one motor, but that is a load; that is a small scale industry. Musical traction there are towns and cities in the world though very few number left now, where the tramp is still working in India, Calcutta is the only city where you have the tramp. Even today, Melbourne in Australia, San Francisco in USA and in Europe, there are certain cities where still the musical traction needs electric power.

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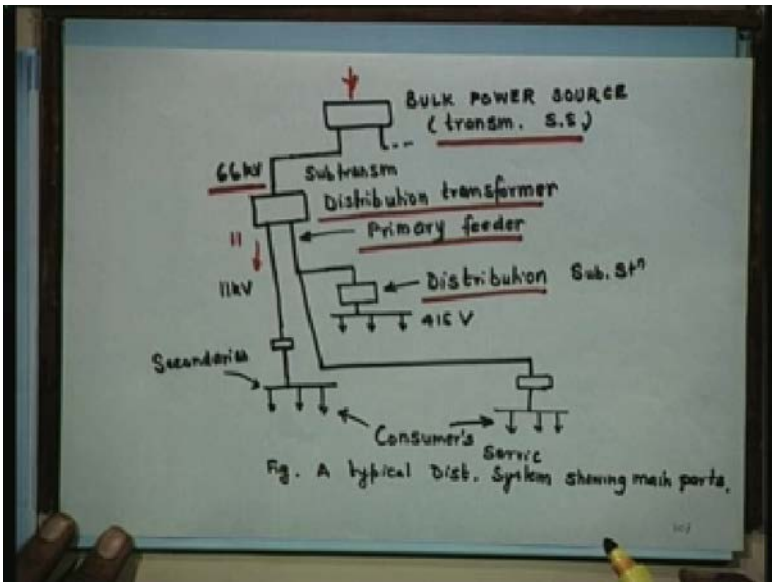

Now, I am go to show you a typical distribution system showing the main parts, this is the bulk power source, power is coming from the transmission system. Now, this is the transmission sub system; that is transmission substation, sub transmission the whole thing is known as sub transmission system. Transmission system we are not going to study now, we have been studying in earlier lectures.

Let us, it is 66 k v then this is the Distribution transformer, then there is the Primary feeder, this substation is called Distribution substation, the voltage is already loaded from 66 to let say 11 k v, then we have 415 volts, this is 66 to 11 and this was 11 k v, this is the secondary, these are the consumers, this consumers can be domestic, can be commercial, can be small scale industries, it is the big industry then the 11 k v directly is given to that. So, I think this is the self explanatory diagram all everything is quite, this is clear and this is what a normal distribution system will look like.

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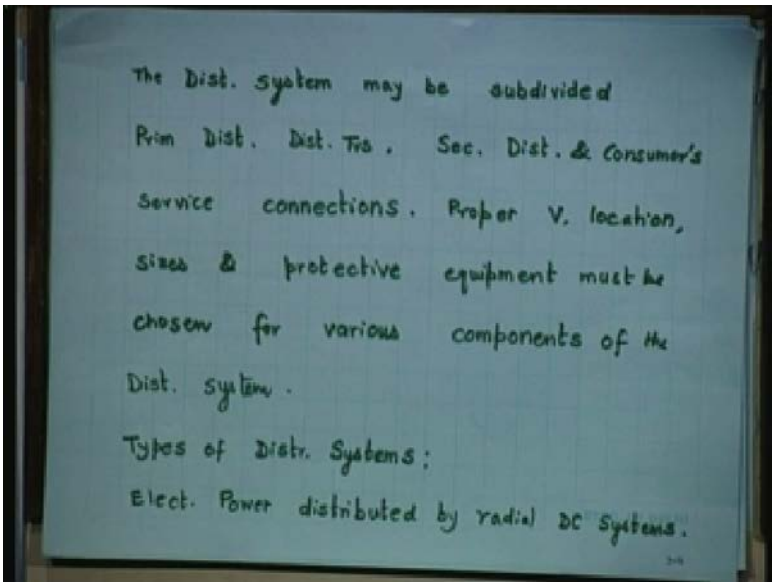

The distribution system may be sub divided. Primary distribution, distribution transformers we have seen ports, cities, where the transformers are placed. Secondary distribution and consumer service connections finally, the the power comes to your place, proper voltage is very important in any distribution system the voltage if it is not proper, your system would not work, your fridge would not work or you will have to put voltage stabilizer, which will normally do in India, everywhere you have to have voltage Stabilizer, you have to have a UPS system.

Location is important, where you have going to locate, just cannot electric pole anywhere you like and the transformer could not put anywhere you like and the entry point your house, your premises has to be really external to the premises, if you look and until your house and then reading, because billing has got to be done, metering has to be done.

So that is done, it has to be outside, it can be indoor, it has to be outdoor, the outdoor I do not mean away from your house some 50 kilometers or some. Now, it may be somewhere, where it is safe, it is protected and yet it is outside. So, that the guy can come from electric company or note down whatever you also note down, then protection is equally important, fuses and they must be chosen for various components of distribution system. As, it is protection of transmission system is important, as is the protection of generation system is important. So, equally if not more the distribution system protection is important.

For example, in transformer you have over flexing relays, what are the different types of distribution systems: electric power use to be distributed in olden days by radial DC systems, DC use to be very popular earlier, even Calcutta even now, you have DC power. If you go any house in Calcutta, you will find to have both AC and DC, so radial DC systems.

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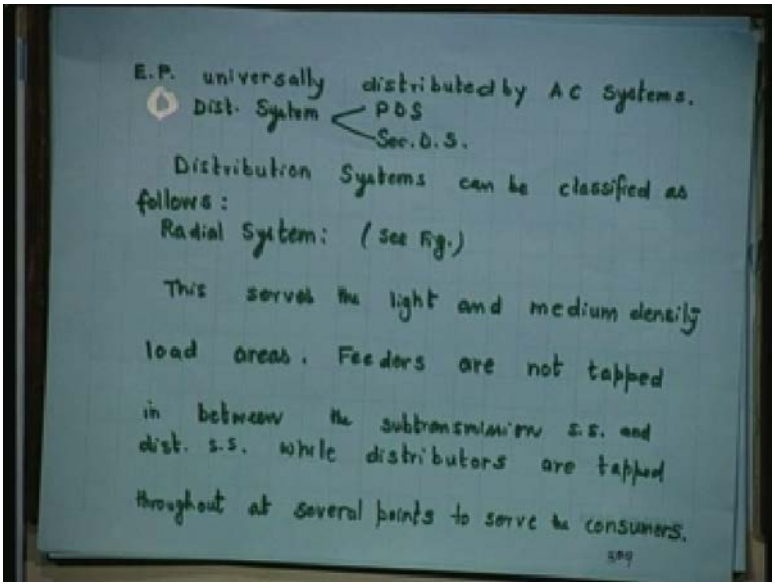

Electric power now in 21 century, is practically universally distributed by AC systems barring few exceptions, I have just talked about Calcutta, but distribution system can be divided in to two parts, categorized into two parts, primarily distribution system and secondary distribution system. For distribution systems can be classify as follows the radio system and lateral system, the normal system.

Now, the radial systems service the light and medium density load ores. Specially the lighting, the house, mainly house you have lighting. Feeders are not tapped in between the sub transmission sub system and distribution sub system. While, distributers are tapped throughout at several points to serve the consumers, this is to be properly designed very one topples which route you want to follow, which would be optimal to each meter of cable cost is not free.

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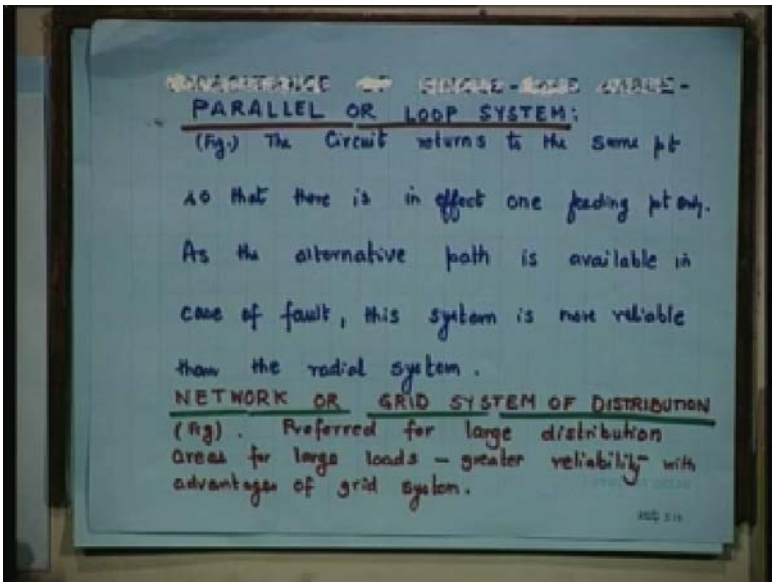

The other system is besides radial parallel or loop system: Now, the circuit returns to the same point. So, that there is in effect one feeding point only, loop completes on itself. As the alternative path is label in case of fault, this system is more relevant than radial system. If it is the fault you have to just wait for the remove on the fault or you have to resort to your inverter, alternative or non conventional energy sources if you have in that building.

Like, we have a photo will tight we have on add the energy building, the photo voltaic system use to be there will use to supply the committee rule. So, use to get power of the time before this 10 by power volts placed in place. So, this loops system is decidedly definitely more reliable than the radial system. Network or grid system of distribution this is the third. Before will go this, let me show the figure of parallel first, will come back to this.

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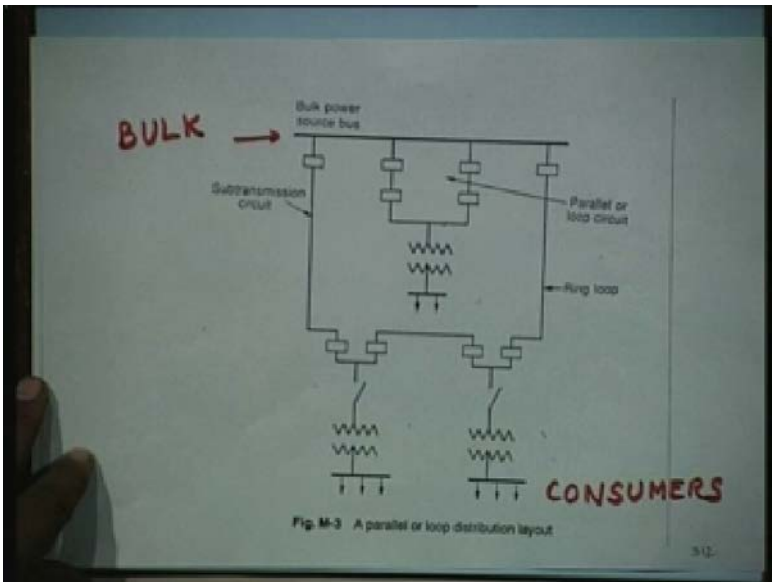

This is the parallel or loop distribution system. Here is the Bulk power source bus, BULK then these are the loop circuits, parallel circuits, sub transmission circuit, transformers, ring loop, again a transformer and these are CONSUMERS. If there is a fault here, you can even get power from here that is what I mean, when I say it is more reliable.

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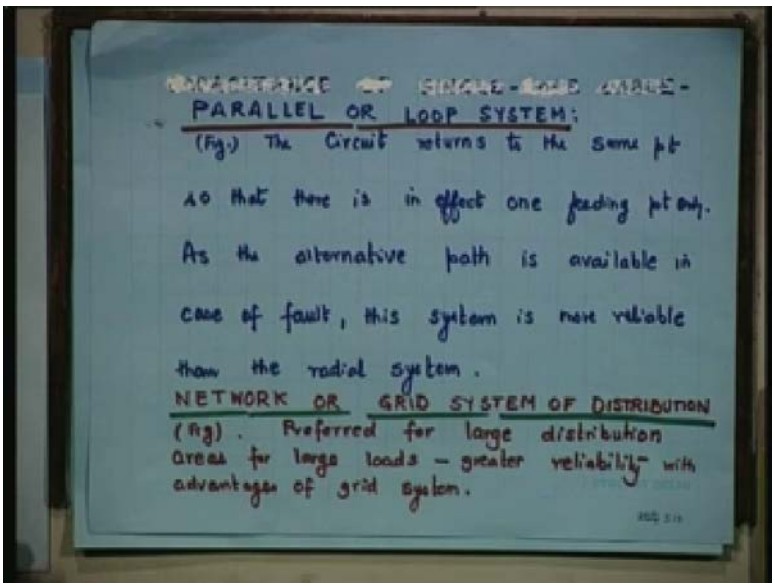

Come back to network or grid system preferred for the large distribution areas, large loads, role of Noida, role of greater Noida, now this is become a very dense area, lot of ,

lot of industries are there go to Faridabad prefer for large distribution areas for large loads greater reliability with advantages of grid system. It is practically a micro grid they call it, it is not a normal grid which we talk in a 11 bus 21 bus that is the whole country is around 1000 bus, but this is the micro grid and this is very strong grid, because in that New York, city of New York's, you cannot a flow to use power there, it will be the power goes as it need it went, some time back and there goes 18 hours to power. So, this system was got to be more reliable, more study.

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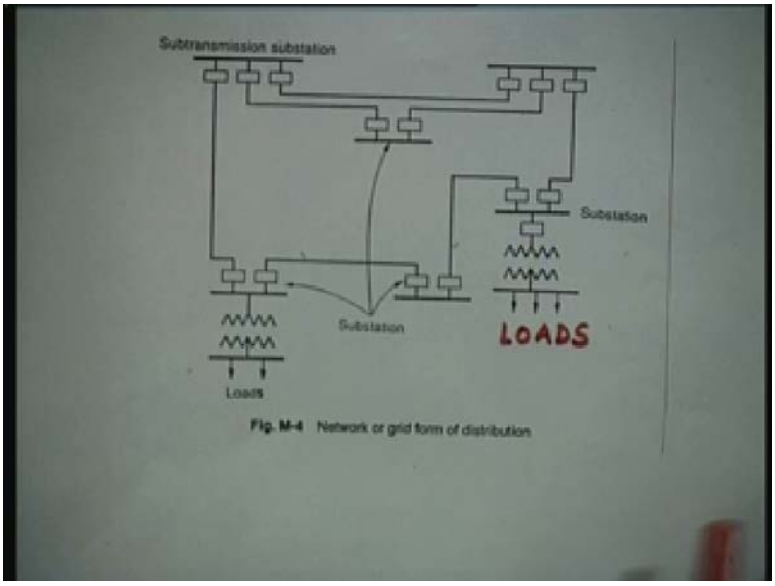

Let us to the figure, this looks like a transmission theory network. This is the sub transmission substation, it is the various substations everywhere, transformers and this are the loads and this are bigger loads, this are not smaller LOADS. As there give you an example, the BHUL factory is the bulk you know, consumer Haridhuvar for example, and that factory works factory, 24 hours.

So, you can guarantee them supplied for 24 hours. So, that the supply lines continue and you continue to get production. So, this is the network or grid form of distribution. So, if you cohesion comes draw or talk about network or grid form distribution talk this and to write this those lines, naturally this system gives better voltage regulation, as feeded like this small as compare to the regular distribution.

So, even in distribution all those factors, performers in dices or their deficiency for example, I do not know, whether you forgotten in machine codes, you might have

studied all the efficiency. So, we do not have any such term in transmission system, but here which which is the indicator, how well the distribution system is operating all the efficiency, you have to compute that, you have to calculate that, then you have to see, how much load is there for how many hours and then you have to find out those efficiency in some power supply.

And what is the quality of that power, what consumers fees or sees or comes across is the power that use supply to him, not power in singularly, not power in big substation called Bunking, they feel what power comes to your house, whether there was the flicker, whether bulbs 60 watt bulb is behaving like 40 watt bulb or is behaving like 100 watt bulb. So quality, power quality is very important in distribution system, because you are impression of your company is judged, is formed on the basis of quality of power that you get in your house, you are not bothered what power is coming out singularly, we generated in singularly that may be 50 hours that may be absolute for 100 k v, I am not bother about that I am the consumer forms impression based on the quality of power that you get in your premises.

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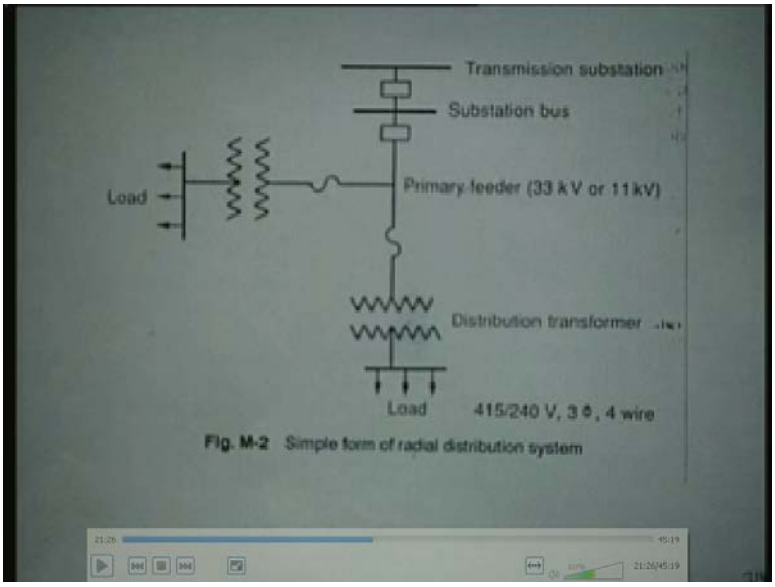

The earlier one, the simple formal radial again show you figure, here is the figure say how simple is this, this is form beginning of civilization when the electricity start it about 100 and now 15 volts and 20 volts at 18 with 6. So, isolated systems they where you know, there is the load, there is the generator, there is highly use to the distribution or

transmission, the thing which you are now coming back and circle is full and that is called Disperse power system.

So, they have been mention to you throughout the course of this wherever you are load is have a small generator, start generating, no transmission, highly distribution just it straight goes to the load and whatever quality you want to can maintain is your generator, is your system, you are not paying anything, you have already paid whatever you want it to pay, you can be maintain this system and fewer cost effects and if you happens to the wind and solar the fuel is also free, you do not have to pay any fuel cost for wind or solar or anything of that solve.

So, this is that simple form of a radial distribution system which is again coming back and becoming important thanks to the dispersed power systems and distributed power systems, if you want to more about these two topics, which is very important. Please read a book, by you know 1999 published IEEE. I have a book in Tamil and look at it if you want to do any project in that, because the future belongs to disperse system and distributed systems and of course, non conventional systems.

So, this substation bus is a transmission substation, primary feeder other 33 k v or 11 k v we have transform and load distribution transformer and load, which is 415 to 240 volt, 3 phase, 4 wire system, this is really coming back in full force, though it is less reliable as we said already, but then you can always built in reliability see that there are no faults and even a faults take place they get removed quick time.

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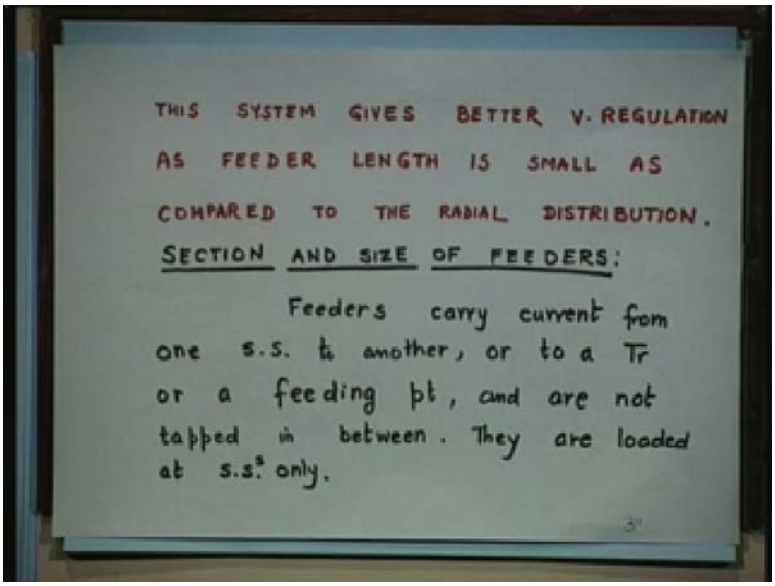

Now, we come to the last topic in distribution systems, what is this last topic, section and size of feeders, what do this feeders do, why they also important in distribution systems, because it is they who carry current from one substation to another or to a transformer or to a feeding point and are not tapped in between. They are loaded at substations only on repeatedly, when we use to study in a distribution system is to be 3 chapters, 4 chapters see the cottons books, only book good book available in distribution, which carries from first page to last page topics on distribution in by Gonen at distribution power system by Gonen, Gonen metro high book, otherwise there are only one chapter in each book.

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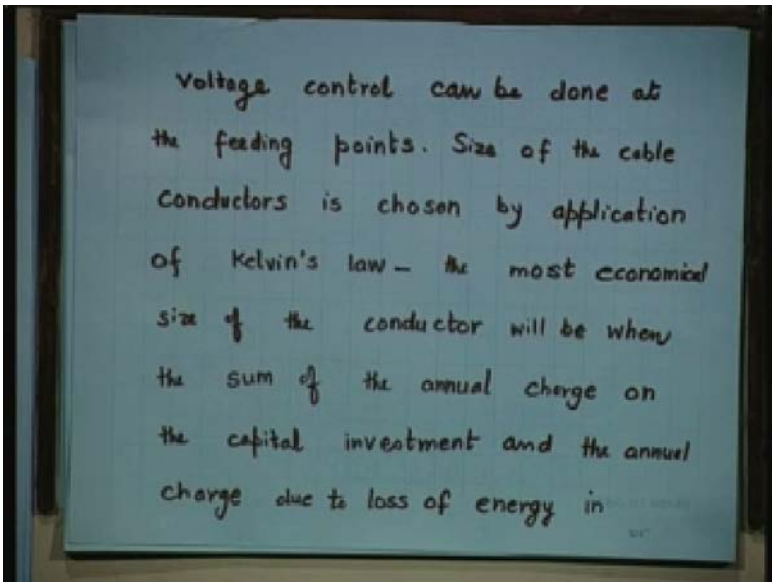

How do you to voltage control, at feeding points. Same methods you have to have those capacitors, inductors, or facts, this is the big familiar facts now, they were books available an facts, the recent book is by Matour and Varma very good book facts devices both Indians both settled in Canada.

Now, size of the cable conductors chosen by application of Kelvin's law, I am sure all of you must have learned Kelvin's law in some course or other still valid what does it gave, what does this law's state, it is talk about the most economical size of the conductor, it gives you more that is what is required, money. It saves you the money.

What should be the size that is given by computing an objective function, which consist of which comprises some of the annual charge on the capital investment and the annual charge that will due to loss of energy, these are the only two charges that a company has to pay.

What is the capital investment, how much money a particular person initially now to build that system; that is the capital investment and the annual charge, due to loss of energy other charges you get back, but you do not get back is loss of energy and this is the lot in India, you cannot ignore it, as if Kelvin sense it that something is going to go long in India. So, if a now this a law, otherwise this goes to any necessity to include this term and distribution system the losses are pretty high, 60 percent may be to the bad design is not that always practice there bat maintenance, why do you get a low this kilometer you know, in your car, old car, because it is in efficient inherently not that somebody is taking the petrol out, if it is your personal car.

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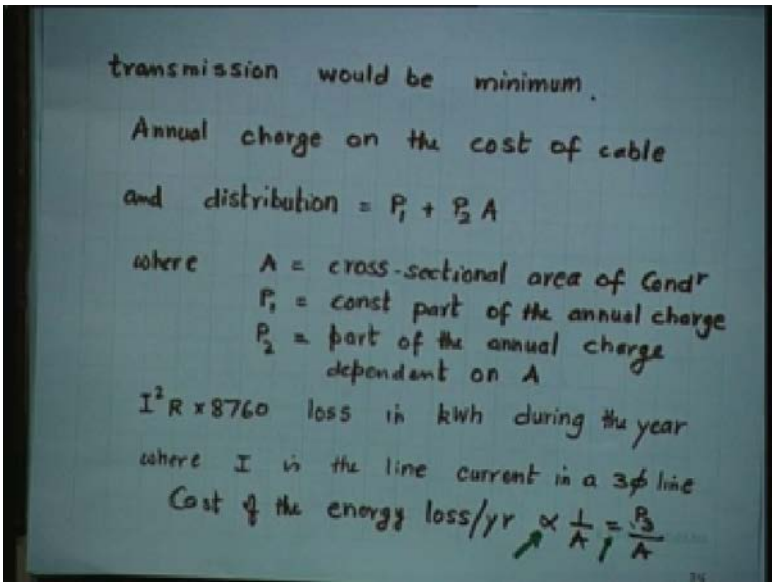

Now, this should be minimum, the two sums, summation of two terms that is what Kelvin law set, what is the annual charge in the cost of cable and distribution P 1 plus P 2 A, what is A, A is a cross sectional area of conductor it symbol of the cost.

What is P 1, the constant part of the annual charge, it includes salary, it includes deprecation, it includes sinking fund, it includes any rate that are would pay for the premises that you are occupying or taxes, municipal taxes any other expanses, which are constant you have to pay. Your own cost for the power you are consuming, do not think that is free, you have to put cost there also for example, if you have a medical shop and if you are consuming yourself some medicine do not think it is free, you already paid for it and you have to include it in expanses. So, will be any shop shop or restaurant, if you yourself start eating those samosa, do not think it is free.

And what is P 2 part of the annual charge dependent on a, what is the loss in Kilo Watt Hour during the year, I squared R into 8760, 8760 is the number of hours that you can have in year, I is the line current in 3 phase line. So, cost of energy loss per year is proportional to 1 by A, rest of the things are constant. Because R depends on rho l by A, rho is fixed once you fix the material; l is fixed once you fix the feeder or transmission line or distribution line. So, what is the variable is A that solve your allow to vary, rest things are given to you, it you to transmit power from this place to this place you have to

distribute power from this place to this place. So, like this fixed. If you want to change the sign of proportionality to equality you have to multiply by a constant, So P 3 by A.

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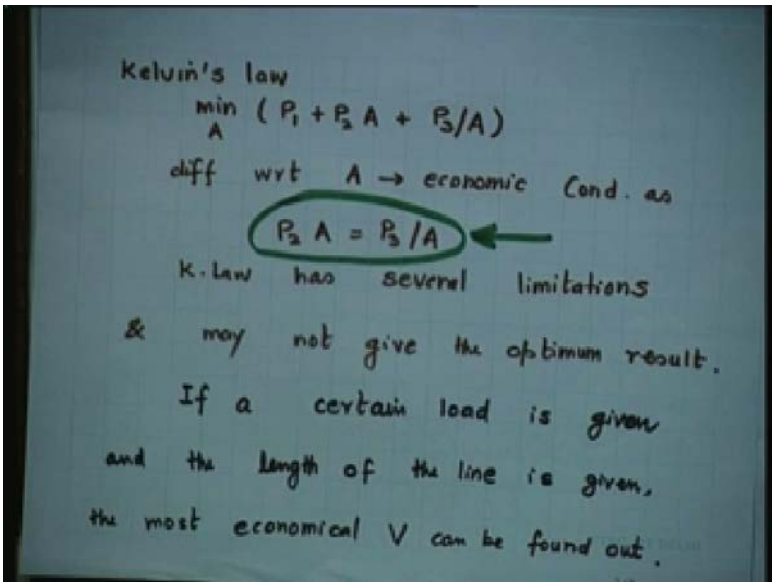

If I add, all these seats now. So, I get in Kelvin's law of minimization of P 1 plus P 2 in to A plus P 3 by A. Now, what is optimization problem when does this optimization started, optimization was not known till Second World War there was no optimization. There was no need choice, optimization only consume when there are only choices, otherwise where is the optimization, if only one train is going to your place there is no choice.

So, you cannot talk off optimization in the sense, which will take less time, which is a passenger train, which is the express train, which is Rajasthani, which will give you foot there is no choice. So, there is no optimization, if you have got admission only in energy that is no optimization, if you get admission in IITCU, you get electrical department, you get in career, you get in energy then you can choose, which one or if you get admission IIT Bombay, IIT Turkey, IIT Delhi, then you can choose, what you have got only in IIT Delhi there your choice. So, optimization only works when there are choices.

Now, here we have a choice, we can choose particular feeder, we can have a cross section, I was talking about this optimization started in Second World War while, because when Hitler force the war on the world in 1939 practically, whole world was

being ruled by England, there was no sunset. Now there is only sun set, sun never rises anywhere.

So, Hitler mean such in called a meeting of all is Engineers and Scientist in a big room like this or must be, much bigger this, ask them ladies and gentlemen as usual that time ladies where fewer in number, same train is still continuing, please stop working they were so happy of stop working, but they have worried, whether is sending as to front to fight the war, the next sentence is spoke out start working in Military Operations Research (MOR), I do not want my people to die in the war unnecessary, I do not want to spend money unnecessary though I am the biggest empire in the world, but still I do not want to this hardly earn money to spend like this.

So, give me a strategy feared to how many friends, I should open people say Hitler would have one if he has not open too many friends, which you could not managed. So, he gave them instruction and he use to keep you know, real time monitoring and control of the war position without computers. The first computer, as I said was invented or was created in 1948 in where I has told you that the, went there and that computer was called Baby computer and it occupied this space and still is to there in it is working.

So, without computer they were suppose to do real time monitoring and control and the the engineers, the scientist started working on developing an optimization technique. It is so happen, the war was over the technique was still not found out and the first technique was found out was linear programming by a in 1945 in the war was over. Thanks to the atom bombs, atom bombs there will be no war would have continue.

So, this linear programming was what, in any optimization process you have to have three things, objective function, how do you start, where do you end and what path follow step size, suppose you want to start from m's and you want to come to IIT at what step you should ask question, where is that suppose you ask in you will say you have already left have to be high. So, you may ask in Green Park, you may ask in Arvindo and then of course, close to IIT and you will find IIT. So, what should be step size, when do you stop, stopping criterion, starting criterion, how do you start, where do you start with what value do you start.

So, linear programming means objective function was linear their constrains where also linear and the answer was there and there was guarantee that answer will be there you

have to only compute on corners that was the simplex method, this method which we are following here is the age old method of calculus that first derivative should be 0 and that will give you optimum and if you have to worry whether it is a minima or maxima examine, second derivative if it is minus maxima, if it is plus it is minima.

So, if you differentiate this equation is P 2 to A, we get the economic conductor as P 2 A is P 3, this is the condition in your obtain this you can do it home. So, very simple calculation and see you get this answers; however, Kelvin's law has several limitations and hence, it is no longer used, this is just for your education that are talked about it and it may not give you global optima, it may give you local optima. If a certain load is given in the length of the line is given, the most economical voltage can also be found out at what voltage you should distribute power that also you have find out.

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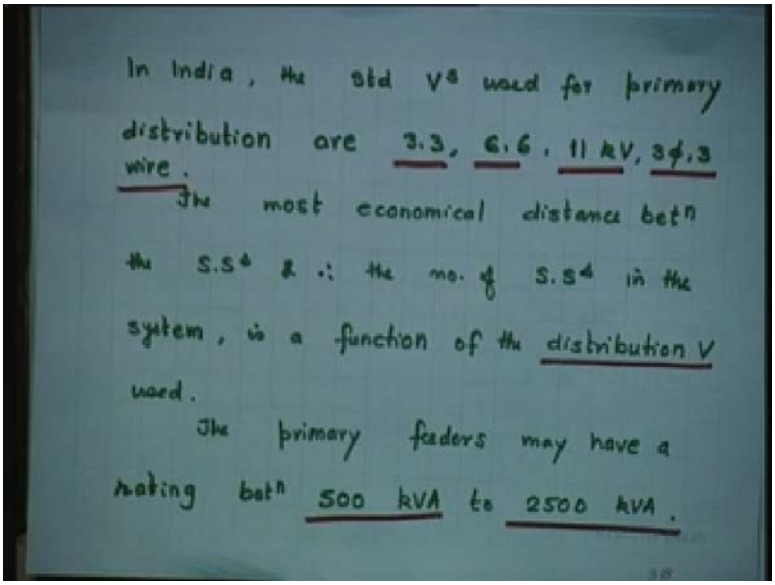

In India, the standard voltages used for primary distribution are 3.3 all are k v, 6.6, 11 k v, 3 phase, 3 wire system. The most economical distance between substations and therefore, number of substations in the system is a function of distribution voltage used and it is another optimization problem. In IIT, I do not know, how many of you know, how many substations are there, did you ever bother to find out, one is your symbol that is hospital and one is near block 4, one is… So, they are so many substations, now you can study, why they are there, how they are choices have been selected, what is the total demand of IIT Delhi, how the power is supplied, this is the gain and optimization

problem, which can be taken as an M. Tech theses. The primary feeders may have a rating between 500 KVA to 2500 KVA; this is the range in which the primary feeders can be there.

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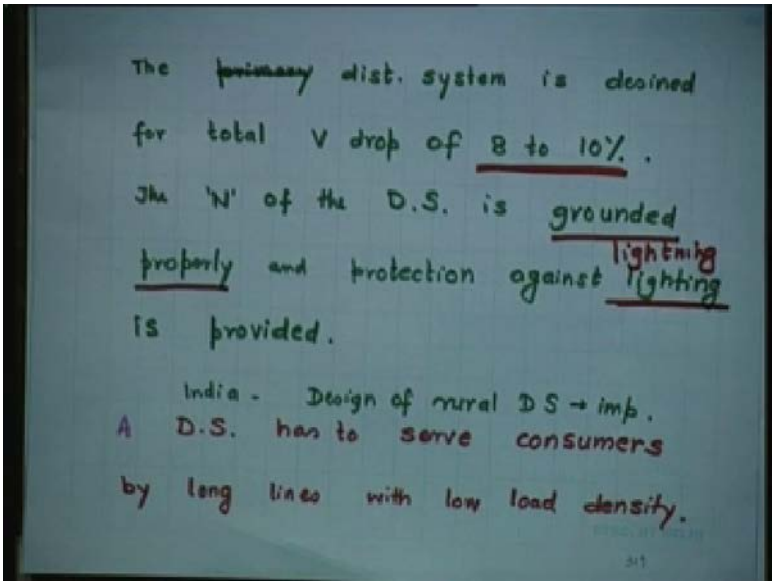

The distribution system is designed for a total voltage drop of 8 to 10 percent, not more than that; this is the voltage regulation I am talking. The neutral of the distribution system is grounded properly thoroughly. So, that there is the protection against light, lighting, not lighting, but lighting. India design of rural distribution system is very important, why Mahatma Gandhi use to save India leaves in villages 80 percent population still leave in the rural and and all of them need power, all of them do irrigation, out of all of them need power for their pumps.

A distribution system has to serve consumers by long lines with low load density while, the all across India, the villages have started and you have to carried those distribution lines sometimes deep in to the villages and density is very low certain villages have only 100 only 1000 there is one the near Argentina for only 180 people are living for which the war was flat between England and Argentina in 1982, I do not know whether you have only 180 persons were living in that place.

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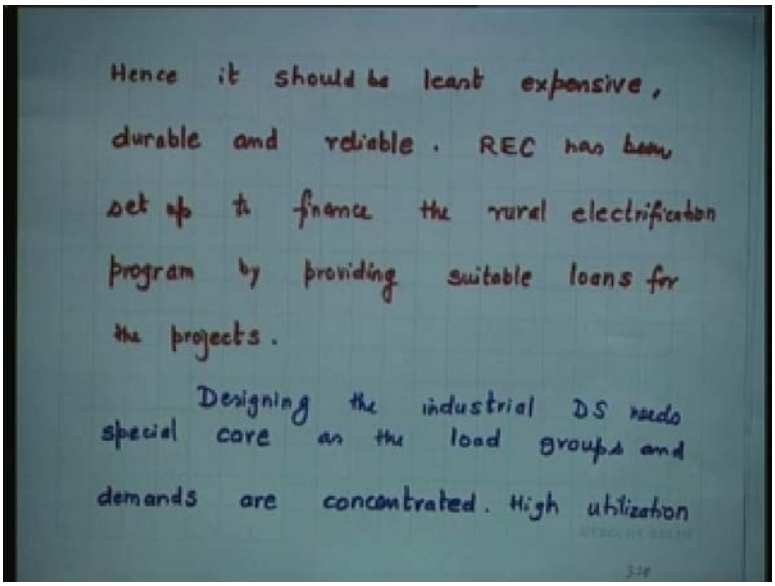

Hence, it should be least expensive, durable and reliable. REC has be not Regional Engineering College, Rural Electrification Corporation has been set up to finance this Rural Electrification Program long back by government of India by providing suitable loans, soft loans with low interested, as it is now we are passing through low interested receipt, but this interest is still lower, almost it is free for the projects. Designing the industrial distribution system needs special care, as the load groups and demands are concentrated.

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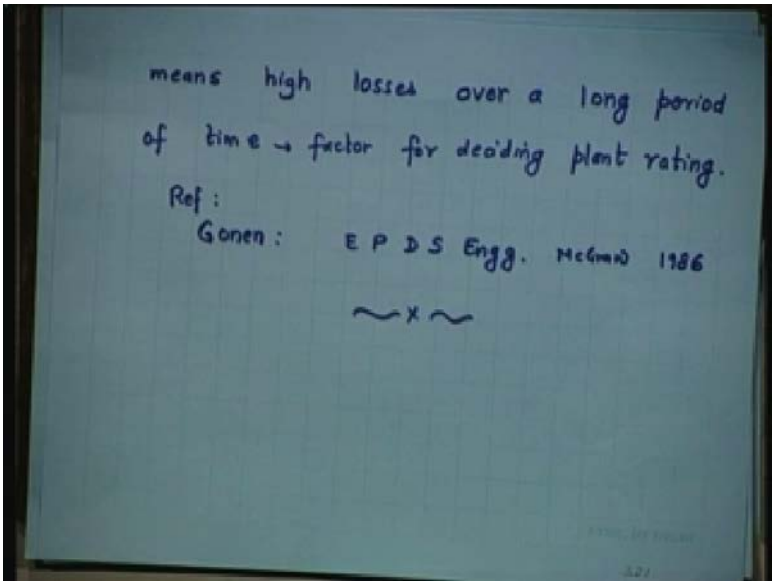

High utilization means high losses, over a long period of time. So, these are very important factor for deciding, designing plants, what should be the plant rating, as I told you the reference book is Gonen, which is the best book, the title is Electrical Power Distribution System Engineering McGraw Hill New York 1986. There is many Indian books as well my , it is in fourth edition that is the wonderful book written by a practicing engineer, not many practicing engineers write books and you can have a look and that book also.

So, this is what is distribution system all about it is very important, as important in transmission and generation system, we need to take power to all villages, we have not yet electrified or energized all the villages in India, how many villages are there in India? 700000. Now out of 700000, 85 percent villages have been electrified and some of them this say in light and wind, the only lines are passing through them, then there is no power.

Our challenge is to take power to them, take power to every Indian wherever he or she is and then only we can say that really similarly, the Prime Minister that you know, road plant to take roads to all the villages to interconnect the India through proper roads well built roads and if roads are not possible than IIT rule, he is working on project cheaper road road ways. So, that you can go any hilly areas from one place to another, where perhaps roads cannot be built or it will be too costly and that is why you find there are no railing states like Jammu and Kashmir still it become only go up to Jammu and may be Udaipur not up to Sri Lanka any way.

So, ladies and gentle men with this we finish our distribution system. Now, the next topic will be AGC - Automatic Generation Control, which is very important and there is the first topic and the only topic which cares for which getters for frequency of the system, we have been talking about voltages, we have been talking about power factors, but we have already talked about, how to keep frequency constant within the plus minus 0.5 hertz.