Operation and Planning of Power Distribution Systems

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Lecture - 28
Multi-objective planning incorporating sectionalizing switches and tie-lines

In this part of the lecture we will finish that Power Distribution System Planning ok. So, this is the last part of this power distribution system planning that is 5th module and only in my next lecture I will show you another new paradigm of distribution system planning. But in this part of the lecture this is the last lecture ok.

Now, in this part I will talk about a distribution system planning model where we have proposed a new reliability index ok. And this is a kind of multi objective optimization problem where the objective functions are; one is of course, as similar to the last problem that is the total cost optimization or minimization of total investment and operational cost.

And another objective would be the reliability objective. So, up to this last lecture, we consider the reliability objective or the objective function which is basically considered to improve the reliability or to enhance the reliability is minimization of total interruption cost ok. But in this part of this lecture I was talking about new reliability index which is not taught to you so far. And it is formulated for a specific purpose and it is applicable only for this distribution system planning problem. In fact, it is devised only for solving this distribution system planning problem so that the planned network would have certain degree of reliability ok.

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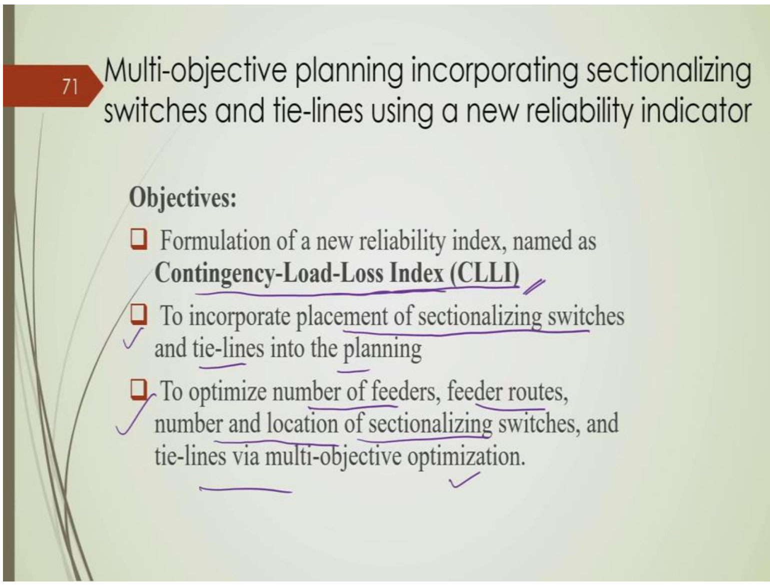

And this new reliability index is called contingency-load-loss index; contingency-load-loss index. It is proposed in one of the papers which I will show you after a few while. And also in this planning model, we have incorporated this placement of sectionalizing switches and tie-lines into the distribution system planning problem. So far, whatever we have discussed, this distribution system planning problem is solved to determine the feeder routes and branch conductor sizes ok. And in this part of this problem along with this determination of feeder routes and branch conductor size or distribution line conductor size, we have additionally considered the location for sectionalizers.

In fact, if you could remember my lecture on module 2, you can remember what is called sectionalizer. It is used to sectionalize a distribution feeder into different parts and thereby it improves the reliability. Now, the question is how a sectionalizer placement improves the reliability? In order to understand that, this new reliability index is proposed ok and along with the sectionalizing and tie-lines we optimize the number of feeders, feeder routes number and location of sectionalizing switches already I mentioned and the tie-lines and this everything is done via multi objective optimization approach ok. So, before I show you; before I show you the whole multi-objective optimization planning approach, let me talk about something called this contingency-load-loss index and how do we compute that index and how this index is designed or is formulated to assess the reliability of a distribution feeder ok.

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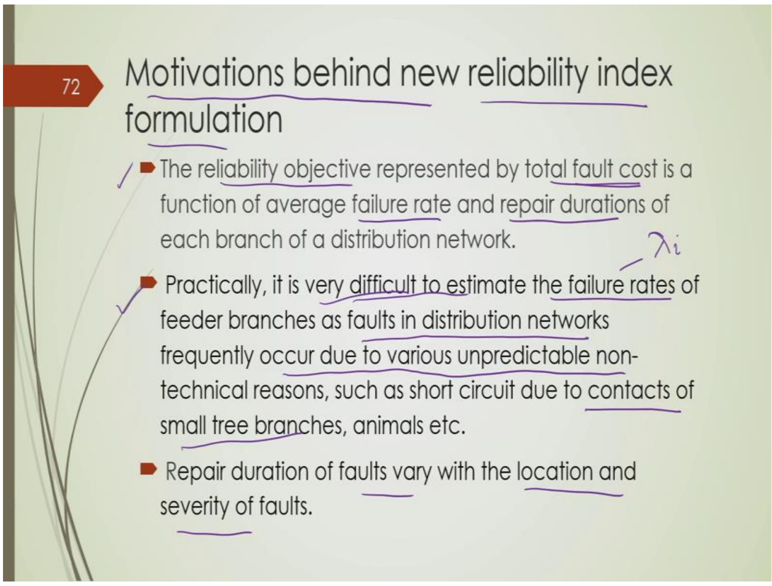

So, before I go to that formulation, let us understand the motivations behind this new reliability index formulation. In fact, you have seen in my module 3, I discussed the various types of reliability indicators ok. And the obvious question is instead of using one of them what is the need to propose or to formulate a new reliability indicator ok.

So, let us see what the motivations are; what are the motivating factors! So, first one is that you have seen the reliability objective represented by total fault or introduction cost which we have done last 2 lectures in the planning model; it is basically a function of this failure rate and repair duration of each branch of a distribution network.

In fact, we have studied this many reliability indices and most of them are functions of this failure rate or repair duration. In fact, many of them, not, most of them particularly those are, these rely energy based reliability indices. For example, that energy not supplied that ENS or expected energy not supplied. So, these indices are function of failure rate and repair duration.

However, it is very difficult to estimate this failure rate of this feeder branch as faults in distribution networks frequently occurred due to various unpredictable non technical reasons. This is again I discuss during this reliability module that most of the faults of distribution networks occurred due to non technical reasons. Non technical reason means either they are weather related faults or animal related faults.

So, weather related faults are for example, these contacts of small tree branches with the live conductor because most of the distribution networks are of overhead conductors. So, due to one tree bunch suddenly touches touching this particular live conductor it may create a fault path. And thereby the network whole network would be faulty. Now the question is nobody can predict when it happens.

Similarly, there are some faults which are animal related. Some animal suddenly touched, it may be rat or it may be squirrel or different types of animal including snakes, suddenly touched the insulators of the live conductors and thereby creates a short circuit path. So, most of the time, this faults are often cleared within few micro seconds and so.

Sometimes they are not cleared, but these are the examples of non-technical faults or interruptions and most of the distribution networks suffer from this type of non-technical faults ok. And thereby, it is very difficult to estimate this failure rate what should be the failure rate and what should be the repair duration we can do.

So, we can determine this failure rate based upon our experience based data by recording this fault data for last few years and so, but it may not be too accurate; it may not be too accurate to consider that because most of the faults are of no or of non technical faults.

And repair duration of the faults also will vary with the location and severity of the fault. So, therefore, this failure rate which is represented by lambda and this repair duration these are some parameters which cannot be predicted prior to the design of a network ok; prior to, because again you have to understand that in this planning process we are trying to develop, we are trying to design a network ok.

Now, for a design network what would be the failure rate for a particular branch of the conductor? Due to this type of non-technical reason, it is difficult to predict ok; it is difficult to estimate. So, therefore, this becomes the motivation factors for proposal of a new reliability index which does not need this type of data that is failure rate and repair duration ok. And that is what the concept of contingency-load-loss index.

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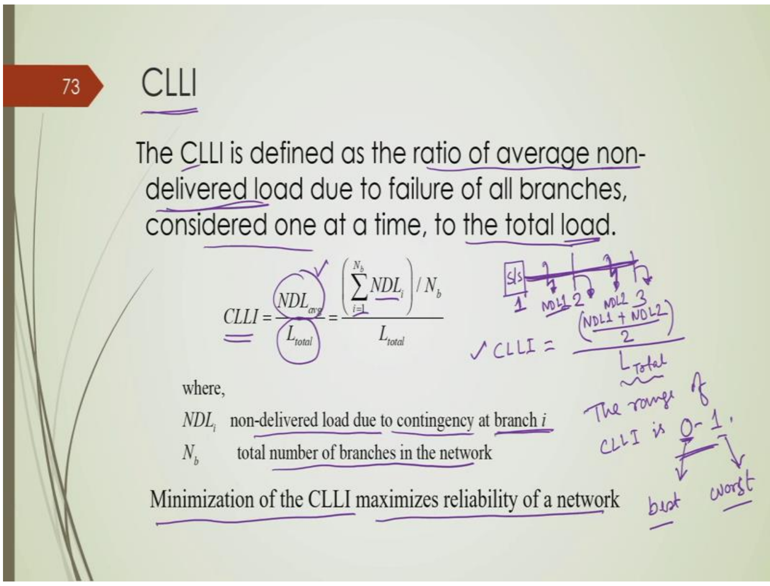

So, it is defined as the ratio of the average non delivered load due to failure or fault of all the branches considered one at a time to the total load; to the total load. So, we have assumed that there is no simultaneous failures of distribution lines or distribution branches or rather this simultaneous failures of distribution lines or distribution line branches is ignored here and we assume that this index is computed based upon the fault of a distribution line or a distribution branch occurring one at a time ok.

And we determine that what should be the non-delivered load. Non-delivered load means; how do you define this non-delivered load? Non-delivered load means the load which needs to be curtailed or which needs to be shed due to this fault ok; due to this fault and which cannot be delivered. In fact, those loads which cannot be delivered due to this fault. And which fault? This is basically a branch or line fault and we assume that each of the line fault is of independent and this occurs one at a time that means, one at a branch or one at a line.

I will show an example how to compute this index for a typical distribution feeder and how it improves the reliability or how it measures; not improves it how measures the reliability ok. It is a ratio of non-delivered load to the total load demand; to the total load demand and this load demand etc. We considered as the peak load demand of course because this planning is certain parameter which is done considering peak load demand data ok.

Now, how do you compute this average non-delivered load? This is by considering this one branch failure at a time; NDLi stands for non delivered load due to this fault or contingency at distribution line or distribution branch i ok or for distribution line or ith distribution branch.

And N b is total number of branches or total number of lines of a distribution network. So, if we have a distribution feeder having two line sections, this is, suppose, substation, this is node 1 or bus 1 and this is node 2 and this is node 3; these are of course, load buses as you know. Now, in order to determine the CLLI of this particular feeder section what we need to do? We need to first determine what is that CLLI due to this failure or fault in this particular line section.

Suppose this gives some data like NDL 1 and due to this branch fault suppose non delivered load is NDL 2. So, what we will do, in order to compute this CLLI we first determine the average non delivered load. So, that is equal to NDL 1 plus NDL 2 divided by 2; 2 is the number of lines or number of branches here we have 2 lines; one is connecting bus 1 or node 1 to node 2 another is connecting node 2 to node 3.

So, we have 2 lines. So, we considered that one line fault at a time; we did not consider the simultaneous faults both the lines ok. So, we considered that line fault 1 at a time and we accordingly determine that how much load would not be delivered due to the fault of this particular line as well as this particular line and we will make a average we will make a mean of that ok. And this divided by total load demand L total will give you that the value of this contingency load loss index.

In fact, this denominator is basically to normalize this data ok and that is why this CLLI will always vary in between 0 to 1. So, the range of the CLLI the range of CLLI is 0 to 1. So, it can be 0 or it can be 1; 0 means there is no non delivered load at all which is not possible of course, because due to fault certain non delivered load would be definitely there. So, 0 is not possible, but it is possible that CLLI can be 1 if due to the branch fault or due to the line fault the total load of a particular feeder section is curtailed or is set is to be said at. So, that is something that is one should understand.

So, 0 means it is the best reliable network and CLLI equal to 1 means it is the worst reliable network ok. So, these two are the two possible extreme cases ok. So, minimization of CLLI would be the our goal so as to maximize the reliability of a network ok. So, here is some quantitative example, where is one quantitative example to understand the computation of this index that is CLLI ok.

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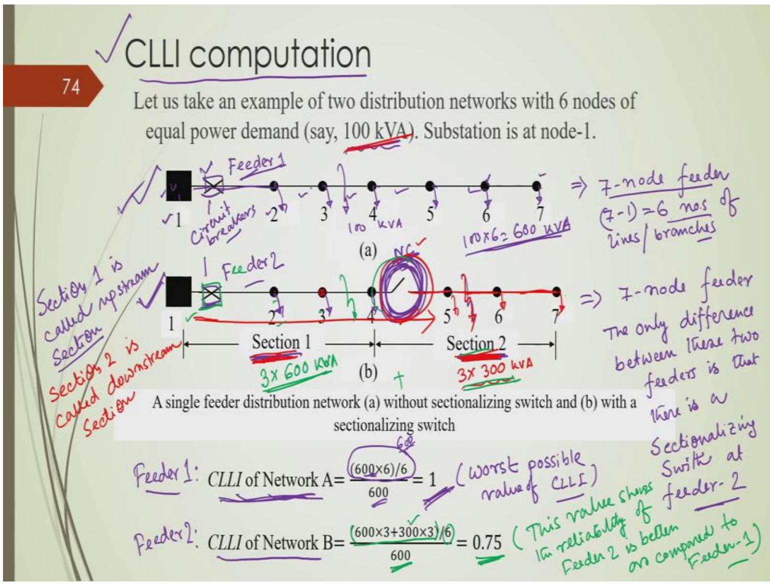

So, here we have considered a feeder section this is 1 feeder let us say feeder 1 and this is another feeder ok. Both of the feeders are having same number of nodes. So, these are this is a 7 node system 7 node feeder and this is also an example of 7 node feeder the only difference between this feeder 1 and feeder 2 is that there is a sectionalizer here there is a sectionalizer very close to this node 4 in this feeder 2. So, that is the only difference.

So, the only difference between these two feeder is that there is a sectionalizer or sectionalizing switch at feeder 2 ok. So, here we have a sectionalizing switch. Now what is the purpose of the sectionalizing switch? It sectionalizes this feeder that is feeder 2 into 2 sections 1 is section 1 another is section 2 ok.

And it is normally closed switches and it is similar to an isolator, for example it is not a breaker which can interrupt or which can make the circuit on load condition, rather it is an example of similar to this isolator which can be operated at no load condition ok.

So, both the feeders are located in the substation. So, these are the main circuit breakers. So, these are the main circuit breakers and normally you know the circuit breakers are located in a substation only ok. Now what is the impact of having a sectionalizer here in this particular feeder? Let us examine and this examination will be doing with this computation of this CLLI index ok.

Now, what we will do? We will compute this CLLI for this network A or feeder 1 or feeder 1 and we will also compute this CLLI for network B or feeder 2 ok. Now in order to compute the CLLI of feeder 1, it is assumed that this power demand of all these nodes, here we have 1 substation and rest 6 nodes; 1, 2, 3, 4, 5, 6 nodes, are of load nodes and each of the load nodes are having a certain peak demand and we assume that they are having uniform peak demand of 100 kVA ok.

So, each of the nodes of having 100 kVA peak demand; 100 kVA peak demand ok. Now let us consider this feeder 1 what we will be doing in order to compute this CLLI? We will assume that there will be no simultaneous branch failure or line failure and we also assume that each of the line failure event would be independent ok.

Now, here you can see in this particular feeder we have because it is having 7 numbers of nodes and it is a radial feeder. So, it will have 7 minus 1 that is 6 numbers of; 6 numbers of lines or branches ok. So, you can see that in between this node 1 to node 2 there is a branch in between 2 to 3; there is a another branch, similarly 3 to 4 another branch and so on. So, we have 6 numbers of branches.

Now, what will happen if there is a fault in any of the branch? What would be the impact to the feeder? Since we do not have any other interrupting device in this particular feeder if there is any of the fault which might be here in between node 6 to node 7 or which might be anywhere ok, this will result in the interruption of this circuit breaker because the circuit breaker is the main interrupter for this particular feeder and thereby all these nodes; all these nodes would be isolated to the substation ok. And there will be a loss of total loss of the load ok.

And since each of this load is associated with 100 kVA of load demand, due to fault of any line branch, it may be here as I have shown, or it may be here, as well ok, it will cause an uniform load curtailment or load loss that will be equal to this total number of load demand which is equal to 100 multiplied by 6 that is 600 kVA. So, due to any particular section fault whole load would be lost ok.

And since we have 6 numbers of line of the branches, so, total loss of the load due to this faults or interruption in one in any of this or each of this line 1 at a time will be 6 multiplied by 600 and if we take the average of that if we take the mean of that this will be 6 multiplied by 6 divided by number of branches that we have or number of lines we have that is 6. So, this will be rather 600. So, this gives you 600 and this is normalized with the total load demand which is also 600 and thereby the CLLI for this particular feeder section would be equal to 1 and that is the worst possible value of CLLI alright.

So, for feeder 1 or this network A here it is mentioned network A our CLLI what we got as 1 ok. Now let us examine that what would be the value of the CLLI for feeder 2? In order to compute this CLLI for the feeder 2, which is having one sectionalizer at this particular point, that is in between this nodes 4 and 5, and it is assumed to be at the vicinity of node 4 what would be the change of the CLLI that is something interesting to find ok. Now, since we have 2 sections here due to the presence of the sectionalizer, any fault or any branch fault of this section 2, for example, if there is a branch fault here or if there is a branch fault here, this will lead to the interruption of the circuit breaker, but once it is sensed that it happens to be at section 2, what we can do? We can open this sectionalizer and thereby you we can isolate this faulty part from this particular feeder. And we can keep the load supply to this node 2, 3, and 4; to these nodes 2, 3, and 4 we can keep intact ok. So, any fault of this section 2 can be isolated by opening of the sectionalizer/sectionalizing switch and thereby keeping its upstream section healthy. So, this here section 1 is called upstream section and section 2 is called downstream section because power always flow from power always flows from substation to the all nodes in a unified direction ok. And thereby this section 2 is the downstream section of section 1 and section 1 is basically upstream section of the section 1. So, any fault in the downstream section would be isolated by this particular sectionalizer and thereby its upstream section can be kept as healthy. And that is what the purpose of having sectionalizer; that is what the purpose of having sectionalizer.

In fact, a small time it will be faulty the whole feeder till we isolate this sectionalizer; till we isolate this faulty section and thereby keeping this upstream section which is healthy section isolated from the faulty section ok. So, what will happen what will be the non-delivered load if there is a fault in this particular section 2 at any of the branch of this section 2; that will be equal to the total load demand of that particular section.

And here we have 3 you know loads, each of having 100 kVA demand. So, here we have all together 300 kVA of loss of load due to fault of any of the section fault of any of the section. And we have 3 sections 1 is in between any of the section I should say any of the line or any of the branch in a particular section because in this particular section that is section 2 we have 3 branches; one is connecting node 4 and node 5 another is connecting node 5 and node 6 another is connecting node 6 and node 7.

So, we have 3 sections and for fault in any of this section will create a loss of 300 kVA of the load. So, total non-delivered load due to this fault of any of these branches or any of these lines in the section is 3 multiplied by 300 kVA ok. However, in the upstream section that is in section 1 if there is any fault at any of the branch either it is a branch connecting node 3 to node 4 or node 2 to node 3 or node 1 to node 2 if there is a fault at any of the section either there is a fault at here or the fault at here or at fault at here so, impact will be same, impact will be same. What would be the impact? Impact would be the total loss of the load because this is then the circuit breaker will trip and isolate the whole feeder from the fault and thereby there will be total loss. Because there is no way to keep this supply of this 5, 6, 7 which are the downstream nodes or which are located in the downstream section, healthy, because power will always flow from the substation to this. Under this particular feeder configuration there is no way to skip this section 2 energize ok. And therefore, for this type of branch failure we will cause the total loss of the load. So, there would be loss of 600 kVA of the load and we have 3 branches here 1 is connecting node 1 to node 2 another is connecting node 2 to node 3 another is connecting node 3 to node 4. So, there will be 3 multiplied by 600 kVA of non delivered load. And here we have 3 multiplied by 300 kVA of non delivered load.

So, once we add these 2 we will get total non delivered load which is shown over here shown over here and since we have total 6 numbers of branches or lines here, we divide it by 6 in order to find the average non delivered load. This is again normalized with the total load demand and once you do so, it will be lower than 1 because the obvious reason there it is 300 multiplied by 3 and it is coming out to be 0.75.

So, it shows that this value this value shows the reliability of feeder 2 is better as compared to feeder 1 ok alright. Because as I said that, lower value of CLLI would be preferable or we our goal would be to minimize the value of the CLLI in order to maximize the reliability of the whole network and that is exactly done here.

And one thing you can also understand that if there is any fault in the downstream section and if there is a sectionalizer, we sectionalize this downstream and upstream section; then we can isolate the downstream section through the sectionalizer, but if there is any fault in the upstream section there is no way to keep or no there is no way to restore the supply of the nodes who are located which are located in the downstream section; that is something one needs to understand very clearly.

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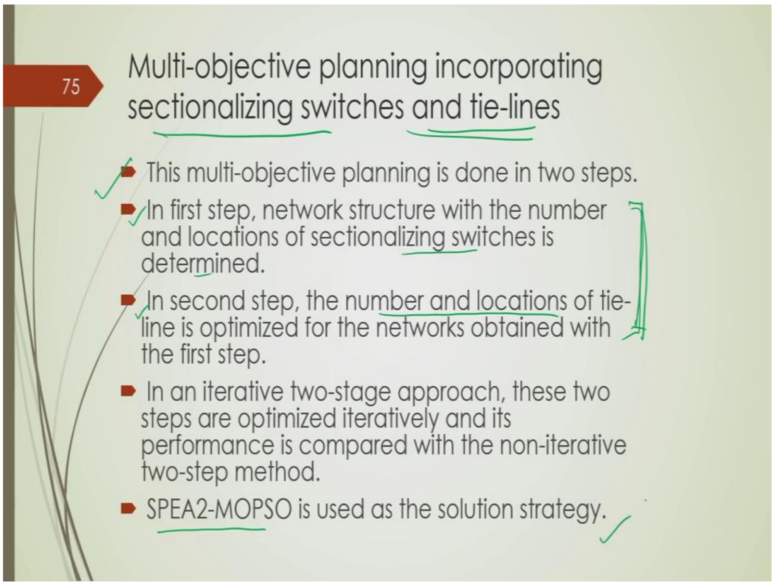

Now, again our goal of this multi-objective optimization is to locate the sectionalizer as well as tie-lines ok. So, what in order to do so? We propose a multi-objective planning model and, in fact, we propose 2 models; in one model, we determine this network structure; it is a two step model. We determine this network structure and along with this location of the sectionalizer in the first step of optimization and there is a next step that is the second step of optimization, this is used for determination of the number and locations of the tie-lines ok.

So, this is a kind of sequential two-step optimization; in one step, we are determining these feeder routes, number of feeders, and the number and locations of the sectionalizer. And in another step that is the next step and that will be sequential step, we determine the locations of the tie-lines ok. And that is why it is a sequential case type of optimization.

And here we have proposed two case two cases; in one case there will be an iterative two-step optimization in which this after first step optimization, we will perform the second step optimization and this will be repeated in different iteration this is called iterative two-step optimization.

And another is non-iterative in which one the first step of optimization would be done before and then after completion of the first step of optimization we will perform the second step optimization. So, non-iterative optimization is basically completely sequential optimization approach, but iterative is something that will be iteratively done this first step and second step ok.

And we use this strength parallel to evolutionary algorithm 2 based multi-objective particles swarm optimization which we proposed in the last planning model itself. In fact, last two planning models as the solution strategy ok.

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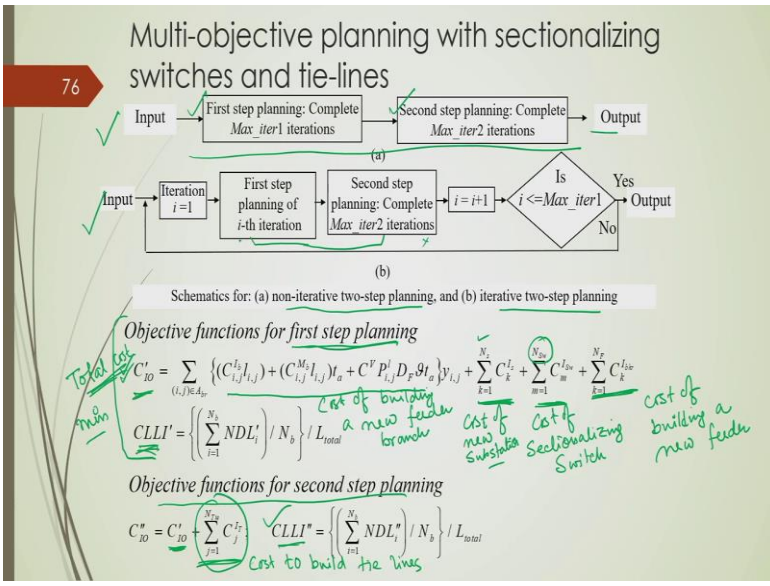

Now, here you get the flow chart this is you know non iterative 2-step planning model; this is non iterative 2-step planning model where this first step planning model; planning optimization is done after that second step optimization is done. So, this is a sequential 2 step first step followed by the second step.

And in iterative 2 step planning model this is flowchart. So, we first we determine this you know we perform this first step optimization followed by second step optimization and this is iteratively done ok. And that is why it is not a sequential optimization ok; this is not a sequential optimization.

Now, let us see, what are our objective functions for performing these two planning approaches! So, these are the objective functions for first step planning or both when both the iterative and non-iterative approach. This is the first objective function for the first step of optimization; one is the total cost.

So, this one is total cost by minimizing which we are basically minimizing both the objective functions simultaneously and the minimizing of total cost you know will give you economy will provide you an economical network. Whereas, this CLLI is as you have seen in the last slide it is an example or indicator to measure the reliability of the network by minimizing that we will get a reliable network ok.

So, these are the two objective functions. So, it is a bi-objective or two-objective optimization problem where we have two different objective functions and as we have seen that cost and reliability traditionally will conflict each other conflict with each other and therefore, we need to follow some multi objective optimizations approach to solve this ok.

Now, this total cost includes that the cost of this new feeder section. So, here we have considered this similar objective functions we have formulated before. But apart from that, we consider that the cost of these sectionalizers or sectionalizing switches needs to be added which is this feeder section. So, this gives cost of sectionalizer or sectionalizing switch and this section is basically the cost of building a new feeder this section is cost of building a new feeder branch and this one is basically cost of new substation or yeah new substation.

So, depending upon the number of substation, we will always have one substation only. So, this will be the cost of new substation and of course, the CLLI already I explained what it what is it. So, this C IO that is the total investment and operational cost; it provides the total cost involved in developing a whole network and also this network will consist of the sectionalizers ok. And in second step planning, because in second step planning, our goal is to place these tie-lines, we can determine the location of tie-lines once we get this topology of the network. We get the network topology or network structure. So, the second step optimization, there is an added term which is due to the cost of locating a tie-line or cost of building a tie-line ok.

So, this total cost in addition to that this cost component is there which is due to the addition of this. So, this is cost to build tie-lines and other you know objective function is same that is CLLI ok CLLI with tie-line; CLLI dashed double dash means CLLI is determined after consideration of tie-line and CLLI 1 dash is representing the CLLI after consideration of sectionalizer ok.

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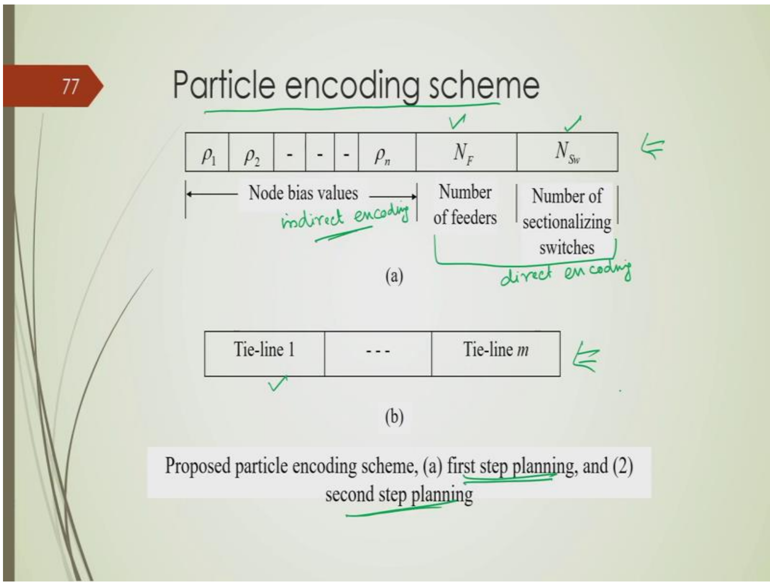

So, these are particle encoding scheme to encode the information of this all this problem variables to a particle and this is a type of indirect encoding. So, it is a combination of indirect encoding. So, this part is basically indirect encoding by decoding which we can get a network structure or network topology whereas, this is a part which where we will follow this direct encoding ok.

So, whatever you will get at this particular section this gives you total number of feeders and whatever you will get at this section this gives you total number of sectionalizers or sectionalizing switches ok. This particular encoding decoding scheme is used for first step planning and this is for used for second step planning. In second step planning our goal is to determine the tie-lines look; in fact, tie-lines location. So, these are use direct encoding process ok.

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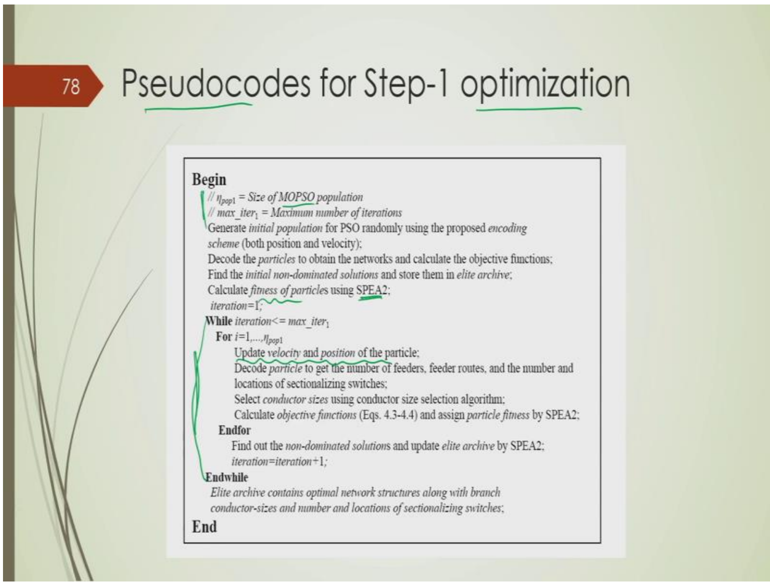

Now, this is the pseudo codes for the step 1 optimization; it is exactly similar to before we use this multi-objective particle swarm optimization. You also use strength Pareto evolutionary algorithm for assigning the fitness of the particle and rest of the things are exactly similar to the what previous.

So, this is the main iterative loop; this is the main iterative loop where we iteratively update the solution by updating the velocity and position of each of the particle in a particular population size in a particular population ok. And population size and maximum iteration these are the two things these are the two parameters we will specify much before we execute this loop ok.

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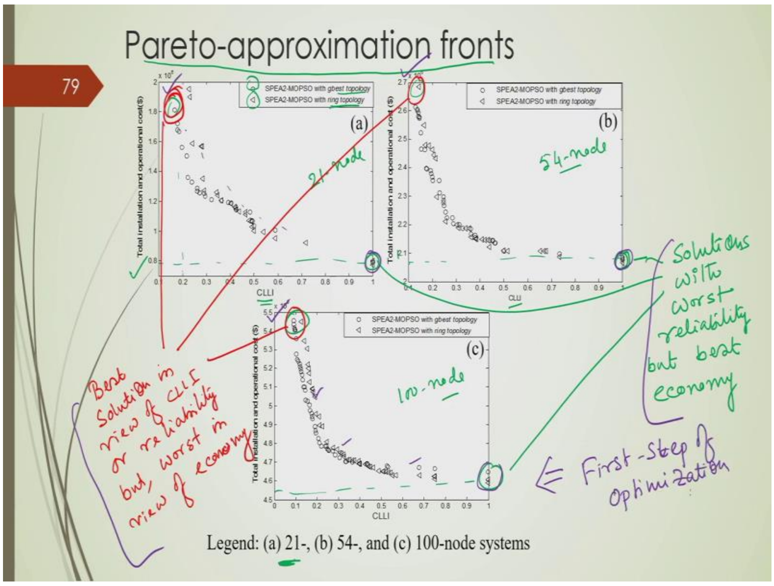

Now these are the solutions; these are the Pareto approximation solutions that we got from this multi-objective optimization approach and this is the result of 21-node system; this is for 21-node system; this is for 54-node system and this is for 100-node system. Again we got basically two Pareto approximation fronts in each of the system; one is marked with this circle; another is marked with triangle.

And these are you know by modifying this right selection mechanism of SPEA 2 MOPSO; one is followed by gbest topology; another is for ring topology; these are different topology used to select the leader or used to select a guide or use to select a global best. One needs to understand these particle swarm optimizations in order to understand this whole philosophy ok.

Now, one you can see that this highest value of CLLI we got 1 and lowest value of CLLI we got at somewhat lower value means less than 0.2. And here also we got you know lowest value of CLLI is somewhat in between 0.1 to 0.2 and highest value is of course, 1. So, these are 2 extreme solutions for all this different Pareto fronts and this solutions are basically this solutions are solutions with worst reliability because they are having CLLI value equal to 1, but best economy; why best economy? Because, this corresponds to the lowest value of the cost. In fact, this corresponds to the lowest value of the cost which you can see. And similarly, these solutions are the best solution in view of CLLI or reliability, but worst solution worst in view of economy ok. So, this is something that already I explained in my last lecture that these two are the extreme solutions; one is best solution in view of the economy; another is best solution in view of reliability and all other with the intermediate values of this economy and reliability ok.

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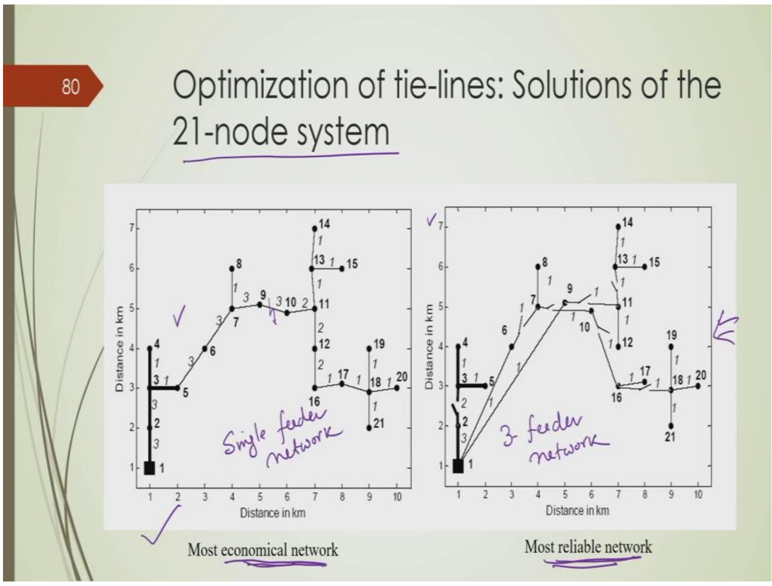

Now, here you can see this slide gives that for 21-node system this is the network topology which obtained which is most economical network that is. In fact, this network that is this corner solution which is having the lowest value of the cost which is associated with the lowest value of the cost and these are single feeder network as you can see there is no sectionalizer here. So; obviously, the CLLI of this most economical network would be equal to 1 the so that if there is any fault of any of the branch it will cause the total loss of the load ok.

But if you look at this right hand side this network topology; this is the case of most reliable network which are shown over these this corner solutions; this corner solutions. So, best solution in view of the reliability and this is of a 3-feeder network. This shows this is a 3-feeder network; 3-feeder network. So, this is a single feeder network and this is a 3-feeder network with many sectionalizers located in different parts of the network and this sectionalizers and this feeders definitely cause lowest value of CLLI ok.

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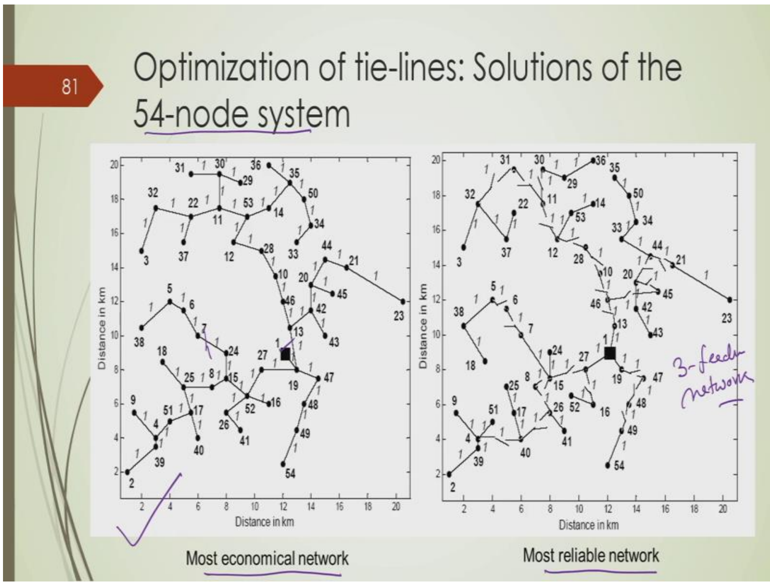

And same thing, we obtained for other system. This is for 54-node system. This is most economical network. This is again a single feeder network and here it is a most reliable network; it is of a 3-feeder network; 3 feeder network. So, here why you are getting these 3-feeder network as the most reliable? Because, we have assigned that total number of feeders should not exceed 3 here ok. If you assign it to 5 then you may get a network with having 5 feeders and so on. And here you can see this in the most economical network there is no sectionalizer anywhere. So, if there is any fault at any part of the network it will cause you know not the total loss of energy, but it will cause the total loss of yeah it is a single feeder network. So, it will cause the total loss of the supply. Similarly, here if there is any fault in any branch it will not cause the total loss of the supply or total loss of the load.

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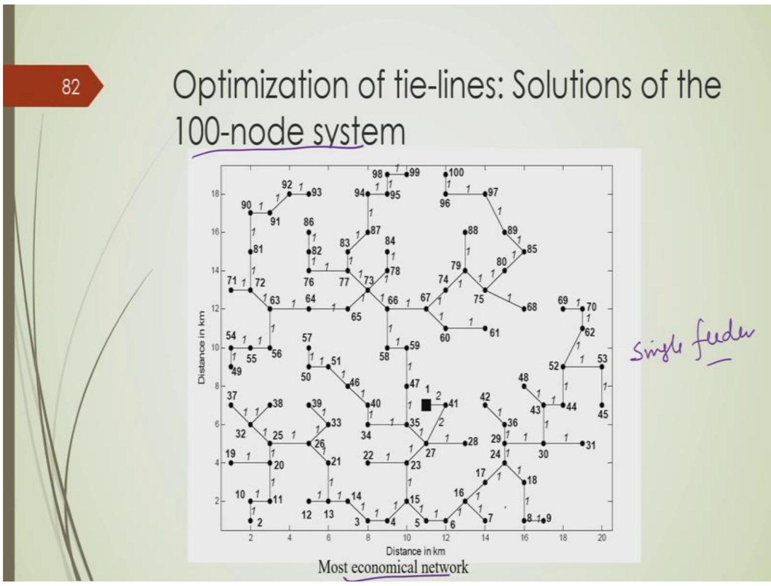

Similarly, here you know, this is the result we got from 100-node system. It is also a single feeder network that you can see and it is a case of most economical network where there is no sectionalizer anywhere. So, if there is any fault at any point of this or any branch of the network it will cause the total loss of the supply or total loss of the load.

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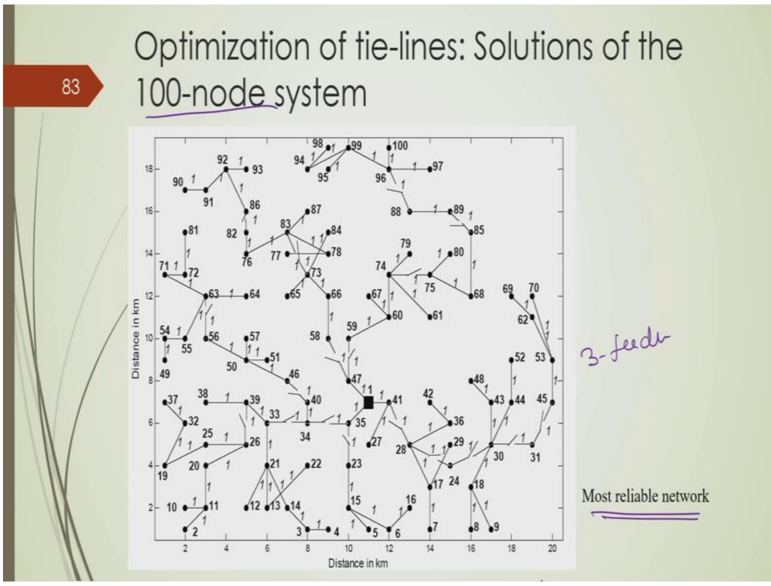

But this is the network topology, we got as most reliable network, it is again a 3-feeder network having many sectionalizers located in different parts of the network. So, if there is any fault in any feeder section it will never cause the total loss of the supply ok.

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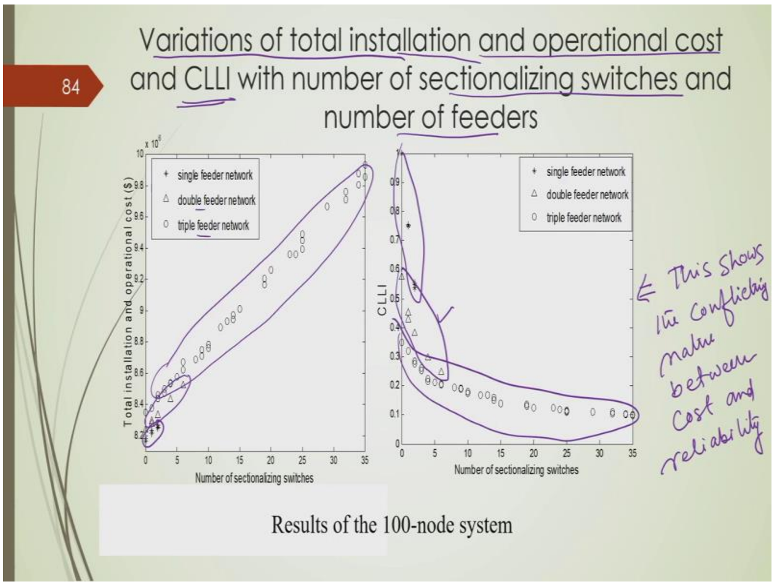

So, here we give one comparison to show that how this variation of in total cost that is total installation or in operational cost or total investment cost and this other reliability of objective that is CLLI, how these two objectives vary with different number of sectionalizing switches and different number of feeders that we get in the solution.

In fact, the solutions that we get in this Pareto front each solution is having one specific number of feeders and a specific number of sectionalizers which we got through this optimization process. So, if we just differentiate the solutions in view of the number of feeders in view of the number of sectionalizers then how their the cost will vary. So, here you can see for single feeder network; it is number of sectionalizers which are very less the solutions having single feeder and sectionalizers are very less and the cost will be the lowest.

Similarly, for a double feeder network, the sectionalized number of section these are the number of sectionalizers and cost is slightly increasing. And for triple feeder network, these are the numbers of sectionalizers and the number of sectionalizers increasing the total cost will also increase and it is exactly opposite nature of the fact that you will get in CLLI for single feeder network. You can see value of CLLI are pretty high and for double feeder network; these are this layer and for triple feeder network; these are this layer.

And this two, you know, the objective of providing these two characteristics is to show the conflict-ness. So, this shows the conflicting nature between cost and reliability ok. So, this is just to show how this cost and reliability will conflict with each other. And thereby we need to consider simultaneous optimization of both the objectives in a multi-objective optimization approach.

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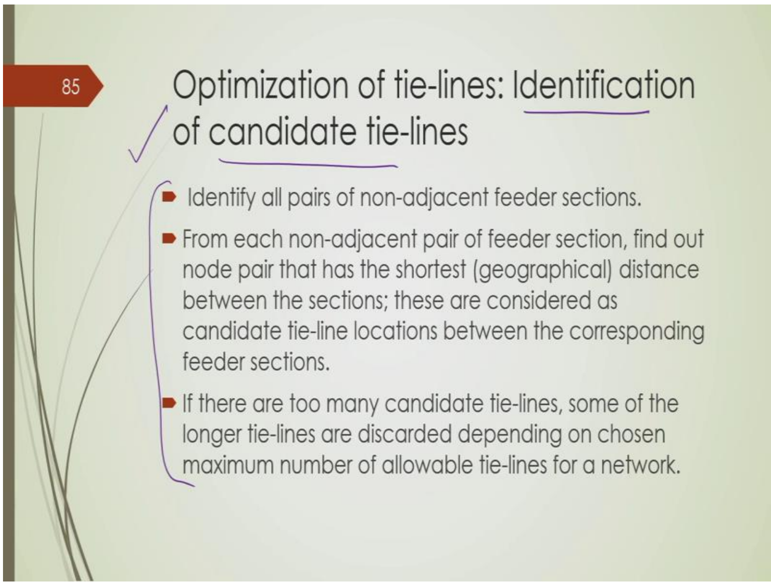

So, this is the next step of optimization. So, previously, these are the results of the first step of optimization that we got; these are the results of first step of optimization first step of optimization ok. So, after this first step of optimization we can determine the network topology number of feeders and the location of the sectionalizers etc., from this particular network structure we can find out the candidate locations for tie-lines in order to find the best location for the tie-lines in the next step of optimization ok.

So, this is exactly done in that particular slide. So, this is how we use some heuristic idea in order to find these candidate tie-lines/the potential tie-lines and this is only possible if we get the network topology. So, without that we cannot find the potential tie-line locations or candidate tie-lines location ok.

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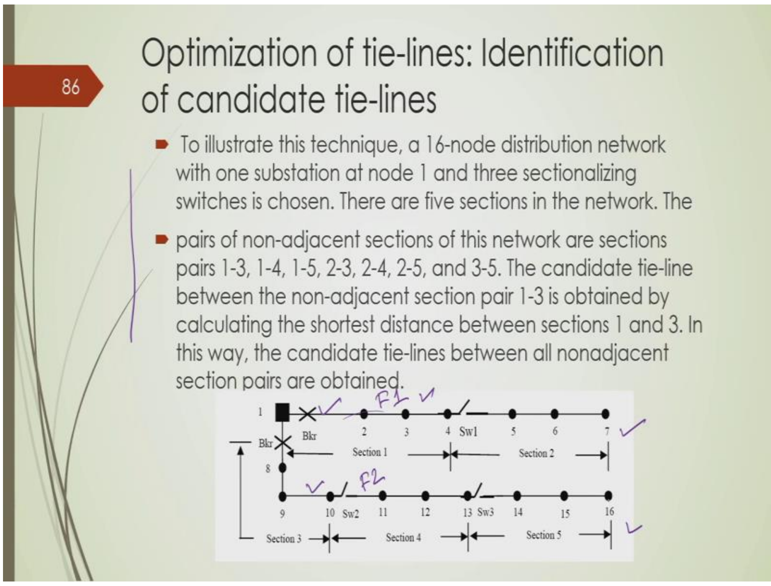

In fact, as we have seen, this is this figure shows that, suppose, we have two feeders; one is this feeder; another is this feeder. So, this is suppose feeder 1; this is suppose feeder 2 and we have 1 sectionalizer in the feeder 1 and 2 sectionalizers in feeder 2. So, we have total 2 sections in feeder 1 and 3 sections in feeder 2. So, we find out the adjacent nodes from one particular section to other so that we can find out the candidate locations for the tie-lines. So, we can make tie-lines between these two feeders by connecting any 2 nodes and this is done by determination of the adjacent nodes of one particular section to other ok.

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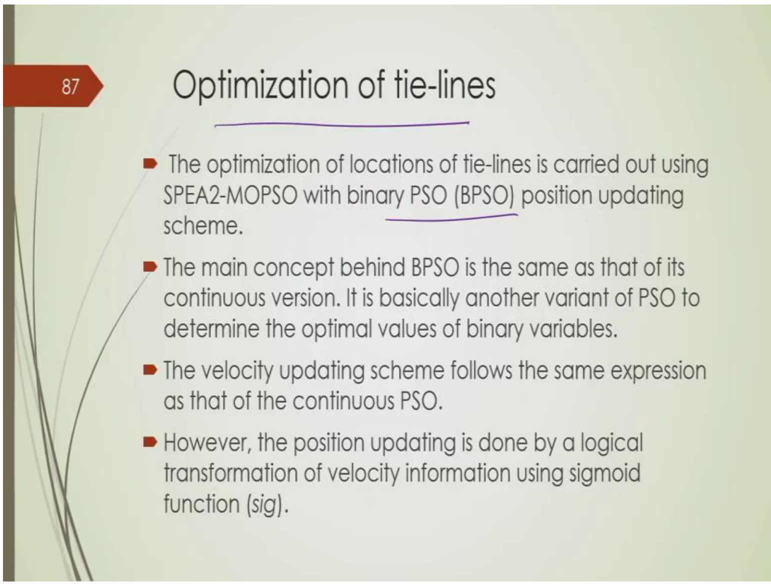

And then we optimize this tie-line location again by considering a multi-objective optimization approach and here we consider binary PSO which is another variant of PSO which is applicable when your decision variables or problem variables are of binary ok. And this binary PSO literature one can find out.

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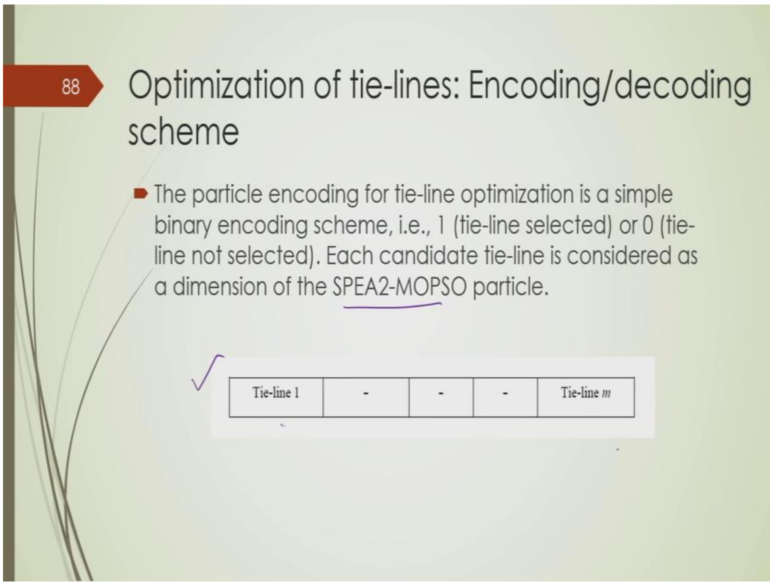

And with this binary PSO, we determine the locations of the tie-lines. So, here this is how we encode this particle information; here all the candidate tie-lines are determined and they are put in a particle section and accordingly we assign either 1 or 0 to each of this section and thereby selecting this which candidate tie-lines we should consider for final implementation ok.

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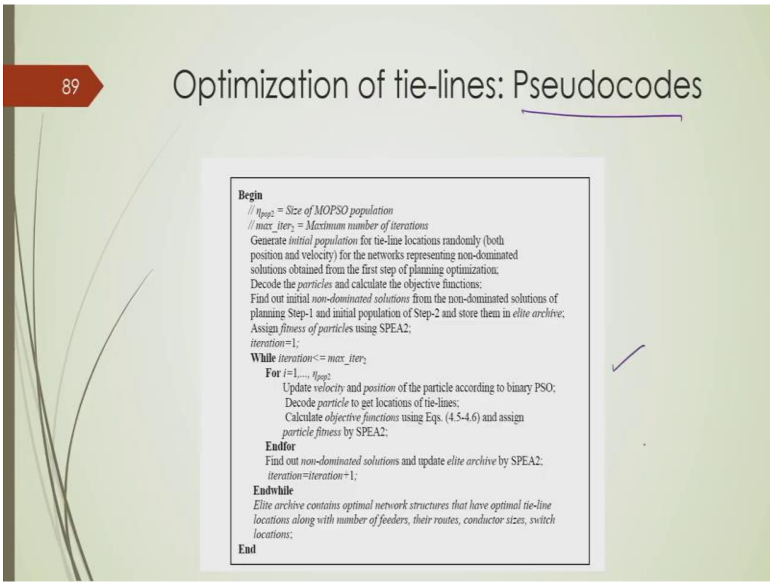

This is the pseudo code again for the second step of planning.

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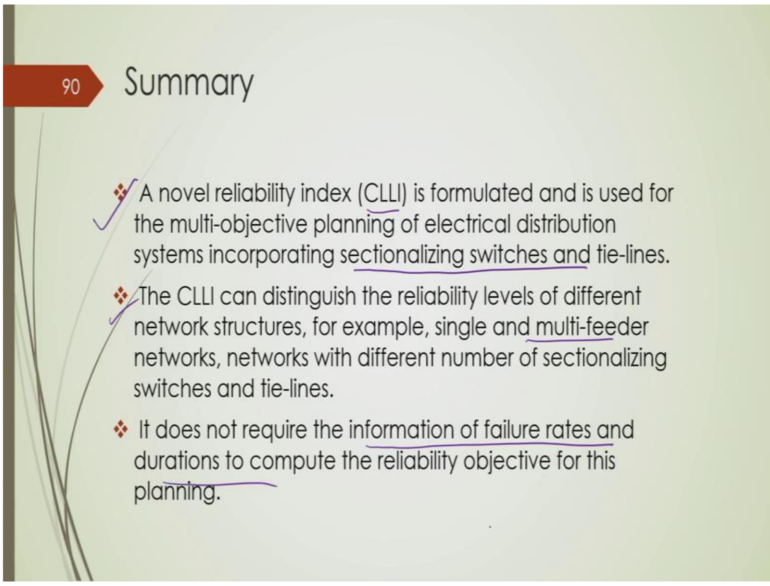

And then we get the location of the tie-lines; these results are not shown.

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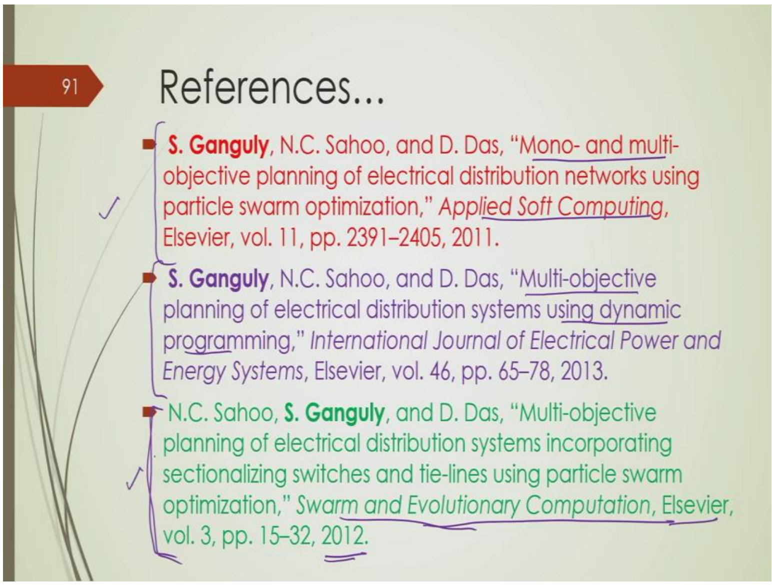

In order to find this result, one needs to go through these papers which are published in this journal Swarm and Evolutionary Competition, Elsevier in 2012 ok. Now, in summary, in this particular lecture, what we did, we propose a novel reliability index and which can be applicable when we do not have the data of this failure rate and repair duration ok for a particular feeder section or particular branch ok. And we implement this CLLI as one of the objectives to determine the locations of sectionalizing switches and tie-lines as well. And also to determine this number of feeders in a network and most important part of this is this index does not need this information of failure rate and repair duration to compute the reliability, but it can assess the reliability so that we can differentiate one network topology with other ok. So, the detailed result if one can find in this particular paper and in this particular paper; we can get this single objective and multi-objective planning models which we discussed before ok. This is published in again one Elsevier journal, i.e., Applied Soft Computing. And in this particular paper, one should get the idea of dynamic programming and how it is extended to solve a multiobjective optimization approach to determine the feeder topology and conductor sizes for a particular distribution network.

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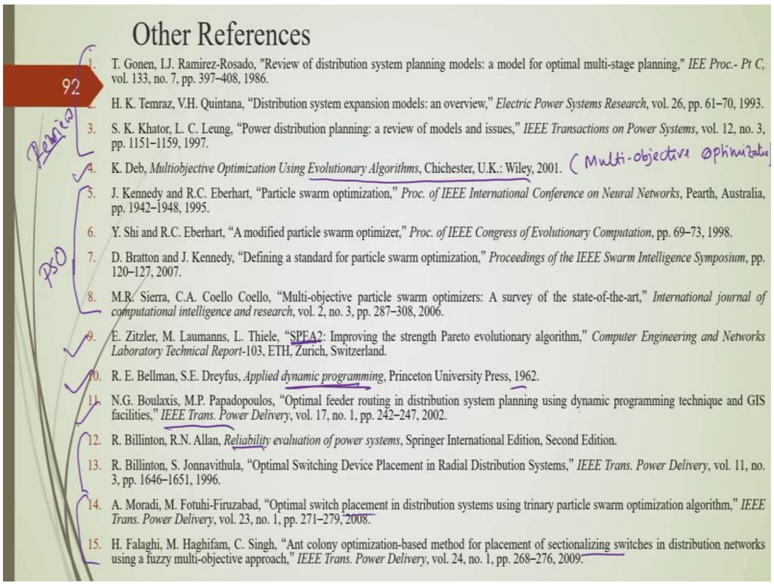

So, these are my works only; apart from that there are many references one can find out. So, these first 3 references are review papers on distribution system planning; these are published long time ago. This book essentially gives you idea of multi-objective optimization; multi objective optimization and this paper gives you the idea of PSO particle swarm optimization and this is for understanding this strength Pareto evolutionary algorithm. This is for understanding this dynamic programming; this is a book and this dynamic programming is previously implemented only once before us in this particular paper. This gives you the idea of the reliability; idea of the reliability and this gives you the idea of this optimal switch placement that is sectionalizing switch placement in a distribution network. But apart from that, I also would like to tell you that most of this data of particularly 21-node system and 100-node system data, we got from the archival of an author which is acknowledged over here.

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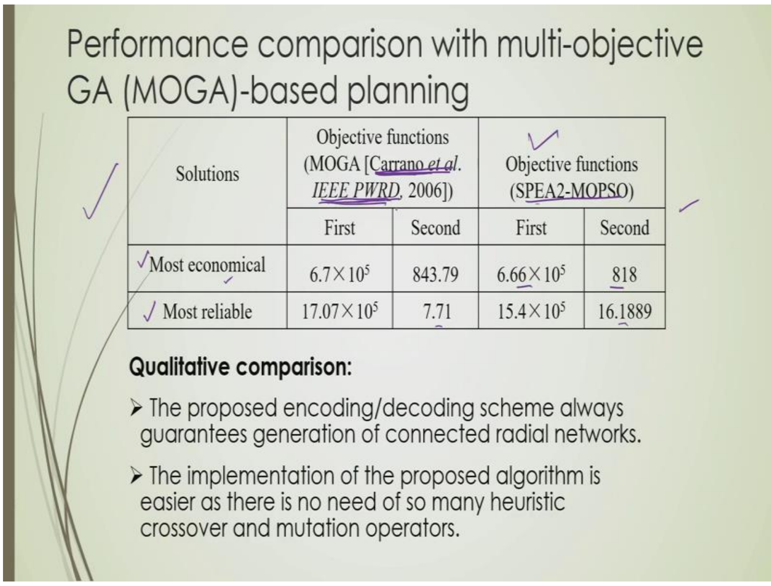

This is basically published by Carrano etc., all in IEEE power delivery, IEEE transactions of power delivery 2006. So, one needs to contact this author in order to get this detailed data for 21-node and 100-node system. And for 54-node system, 182-node system, these data you can get in the reference of one of the papers in the three references I have shown to you ok.

So, that is in this reference one can get the data related to 21-node and 100-node system and in this node particular paper one can get the similar system data and we have acknowledged the source of the data. So, one can also contact this author to find this data ok. So, with this I will complete this part of the lecture.

Thank you for your attention.