Operation and Planning of Power Distribution Systems
Dr. Sanjib Ganguly
Department of Electronics and Electrical Engineering
Indian Institute of Technology, Guwahati

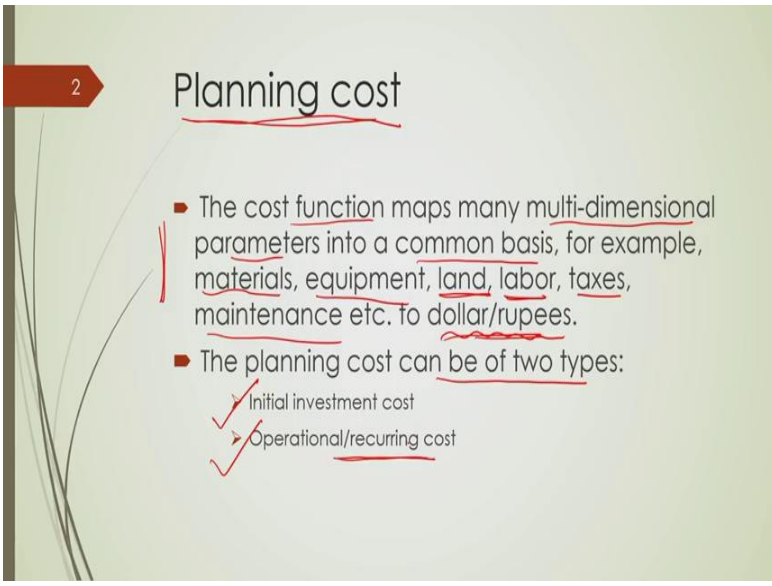
Lecture - 24
Power distribution system planning: Economic aspects

In today's lecture I will start a new module which is Power distribution system planning ok; and today this is part 1 of this module. It is a very short module; it is a very short lecture, although this module is very vast or very big. But, in this particular lecture, I will basically focus on this Economic aspects of power distribution system ok.

And in this economic aspect, I will basically discuss some of the economic parameters which we normally use in power systems planning or power distribution system planning. So, in order to understand the power distribution system planning models which I am going to discuss from next lecture onwards, one needs to have an understanding of some of the financial parameters ok.

Although they are not related to our electrical engineering, but these are required to understand this power distribution system planning models ok. So, some of the important financial parameters, I am going to discuss in today's lecture ok.

(Refer Slide Time: 01:54)



So, let us start. So, basically in my next lecture onwards you will see that power distribution system planning is essentially an optimization problem in which we will optimize certain objectives ok. And, one of the main objectives is to minimize the cost of whatever is associated in planning of a distribution network.

For example: if I wish to construct a new distribution network, I need to plan that network and this planning process is essentially an optimization process. Because, whatever we will be planning that planning should be economically feasible, otherwise nobody will accept the planning ok and nobody will invest, nobody will wish to invest money in that particular planning.

So, in order to make one planning economically feasible, one needs to formulate certain optimization problem, one needs to formulate certain optimization problem. And, in this optimization problem one essential component is minimization of investment and operational costs ok.

Now, what do you mean by investment cost? Investment cost means if I want to construct a new distribution line, I need to put lot of money to install this substation or inside the substation to install the power transformers; to install this different bus schemes; or to install whichever is associated to build this particular substation ok.

So, building a substation is essentially a planning which needs certain amount of money, and this money will come from this investment of a particular financial stakeholder ok. Now, in order to build a whole distribution network similar to the substation construction, we need to invest money to construct the feeders.

We need to invest money to construct this overhead or underground distribution lines. And, we need to also invest money to install these distribution transformers, and from distribution transformers to the consumers premises whatever lines we require, that is called secondary distribution lines.

Now, from a substation end to the customer end, in order to build a distribution network infrastructure, we need to construct many things which need some investment which needs money. And, this investment is called this capital investment ok and apart from this capital investment money is also required in order to run this distribution network over a period of time and that periodic expenditure is called operational expenses or operational expenditure.

So, in a typical planning process, we do optimize this investment cost and operational cost ok. And, we have different planning models which I am going to show you in the next lecture in which different types of optimization problems are formulated; and these are solved ok. So, different features are included, based upon that we have a very voluminous literature on power distribution system planning ok.

So, in today's lecture I will particularly focus on some of the financial parameters which one should know before they try to understand these different planning models ok. So, as I said, any type of planning will involve a cost, a cost function because it is essentially an optimization problem; and that cost function is called as planning cost ok.

So, this cost function maps multi-dimensional parameters into the common basis, that common basis is basically the money or cost and that is represented by either in dollar or whatever currencies we use in different countries ok. So, here for simplicity, I will use this dollar as the currency. So that means, it requires certain amount of money and apart from this planning and its implementation, we have many other entities, with that we can construct a particular distribution network.

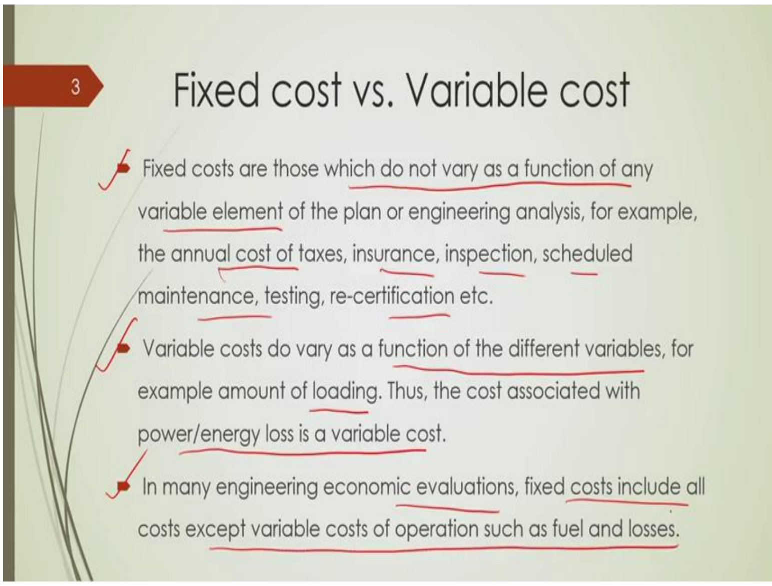
And with these multi-dimensional entities, we bring all these multi-dimensional entities into a common basis or we map them in a common basis and that common basis is our dollar for this planning ok. So, we have many parameters like we need many materials, we need many equipment, we need land of course, to install the substation and we need to purchase this land. One needs to purchase this land and we will have several other requirements which also need money.

We need labour cost, we need government taxes, we need maintenance cost all these things at different-different entities or different-different parameters ok. We bring all this to a single common basis form, and that is basically this money or the dollar or rupees for our Indian scenario. So, ultimately we need this dollar or rupees or euro whatever you can say in order to do all these activities, in order to install a distribution network in a particular area ok.

And so, ultimately we translate all these different multi-dimensional parameters into a single basis that is called dollar or rupees. And, this planning cost can be also of two types: one is called initial investment cost; another is operational or recurring cost ok. So, suppose I need to build a new distribution network in a certain locality ok. So, what sort of cost will involve in this process? So, there are various cost as I explained and this cost can be categorized this cost components can be categorized into two broad areas.

One is called capital investment cost which is a onetime cost or maybe it is a periodic cost, but ultimately it is a single time investment cost. And, another is called that operational cost which is basically function of time and this is a recurring cost. So, this is in initial investment case cost; of course, non-recurring cost and whatever others costs which are time varying, we can categorize as recurring cost or operational cost ok.

(Refer Slide Time: 10:55)

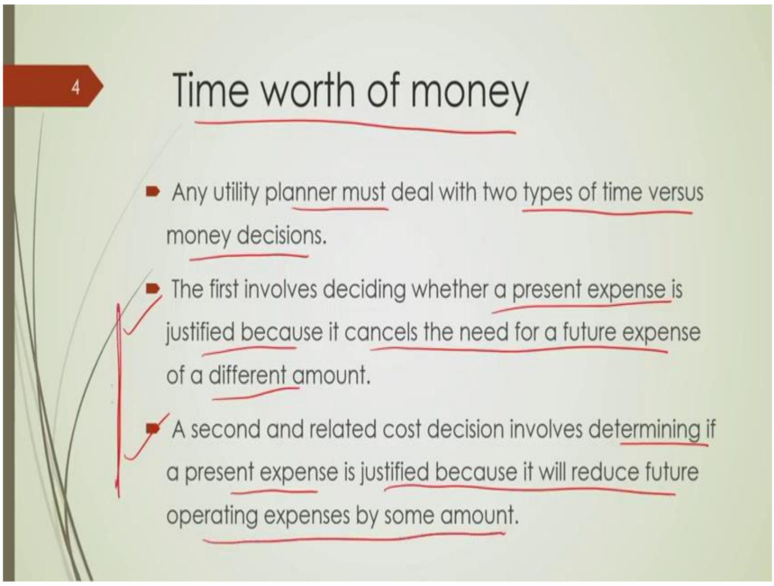


So, what are the fixed costs? So, fixed costs are those which do not vary as a function of any variable element ok. For example, annual cost of taxes, insurance, inspections, scheduled maintenance, etc. So, these are the fixed costs we require every year; and variable cost which will vary with certain variables.

For example, this loading in a typical substation loading will vary from one year to another year and according to this loading there are some cost components which will also vary. For example, the cost associated with the energy loss ok.

So, if your loading varies, your cost of energy loss will also vary ok. So, power loss or energy loss which is one of the cost components of variable cost which is one of the cost components under this recurring cost ok. Now, in many engineering economic evolutions fixed costs include all costs except this variable cost such as fuel and losses ok. So, whichever are variable cost apart from those cost, all other cost will include as fixed cost ok.

(Refer Slide Time: 12:28)



Now, next is another important thing that I am going to discuss that is time worth of money ok, that which means that any utility planner must deal with two types of time versus money decisions ok. First one deciding whether a present expense is justified because it cancels the need of future expense.

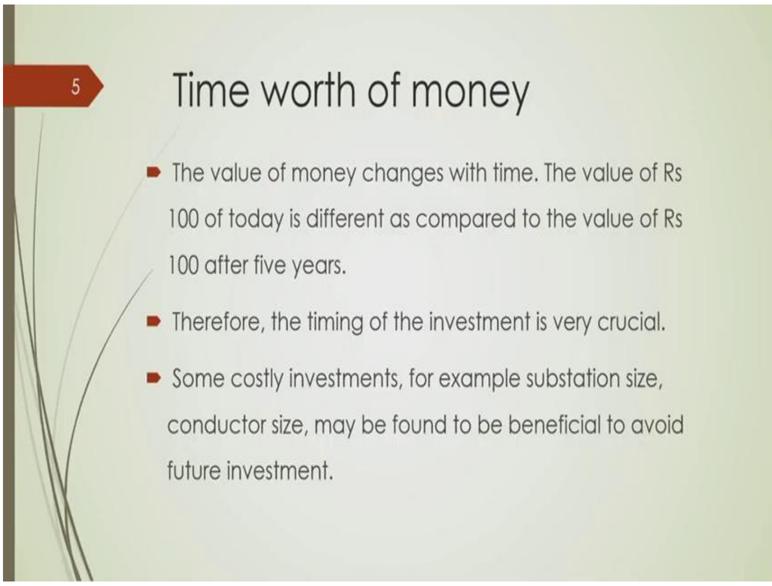
Second decision involves determining whether a present expense is justified because, it will reduce the future expense by some amount. So, these two I will explain with some illustrative examples that I have. For example, I can tell you there are many decisions that we have in order to plan a network, a plan means it is planning an implementation in order to plan and in order to plan and construct a network.

For example: I have an example later on I will show you suppose I build a substation ok. So, when you build a substation there are several decisions that one needs to take and one of the decisions is how many number of power transformers I will be locating in a substation ok. And, that planning decision is basically taken based upon the future loading of the substation and that how much loading may happen or will appear in near future ok.

And, this type of planning is usually called long term planning that I build a substation which will work for let us say 10, 15 years of a period or even more than that, 20 years or 25 years. Now, there are many possibilities that I can take a decision that I will install two transformers, two power transformers of let us say some capacity 10 MVA or 20 MVA, 25 MVA each ok.

And now the question is should we install two transformers at the very beginning of the construction of the substation or I should start with a one power transformer at the initial few years, then I will add another transformer as a capacity addition of the substation. So, those type of decisions are normally taken by considering time worth of the money ok. So, I have a very good example that I will show you ok.

(Refer Slide Time: 15:32)



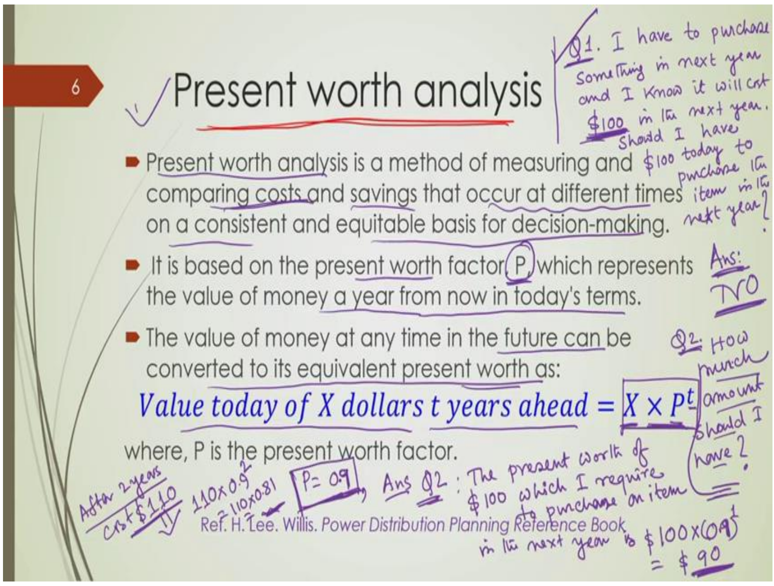
So, the question is actually one needs to understand that the value of money changes with time, it does not remain fixed with time. It means that suppose I have 100 rupees with me today at today at this moment ok, 100 rupees or 100 dollar ok; will it have will it mean that it has the same worth after five years? The answer would be certainly no ok.

So, if we have some amount of money at this present moment that does not mean that it will have the same value, same worth after five years ok. And therefore, one needs to understand the timing on the investment which is very important that when should we invest, when should we invest that is very important ok. So, this is a typical type of financial parameter. But, in order to understand this, different planning models even we the electrical power system engineer, we needs to understand those things ok.

So, that is what I was talking about. Some of the investment decisions like substation size, conductor size; these are taken based upon this future scenario that I may construct a substation with one 10 MVA one 10 MVA power transformer. But, whether that capacity would be enough after 10 years that I need to see first.

And if it is not so, then I have to either take the decision of capacity addition during that type and which would be probably the costlier option, other if we compared, if we take the decision to install two similar transformers right now or not, those analysis should be done prior to the start of the construction of a network ok.

(Refer Slide Time: 18:08)



Now, in order to understand in bit finer way; so, let us study this present worth analysis ok. So, this present worth analysis is an important tool, it is an important tool. It gives you the answer of many decisions, it gives you answer of many decision. For example, suppose I have two questions, I have two questions. Question 1 is I have to purchase something in next year ok and I know it will cost let us say dollar 100 in the next year ok.

So, this is question 1, that I have to purchase something in the next year and I know that it will cost dollar 100 in the next year. Then the question is should I have dollar 100 today to purchase the item in the next year? So, this is the question that I have to purchase an item in the next year and I know that it will cost rupees 100 in the next year.

Now, should we have rupees 100 today so that I can purchase it next year? This answer would be; obviously, no answer would be; obviously, no; I should not require to have 100 dollar today so that I can purchase an item which will cost 100 dollar in the next year, I should not. Then how much amount we should have? So, the next question is Q 2 is how much amount should I have?

So, if the answer of the first question is no, that I do not require to have 100 dollar at this present time at today at this instant of time, in order to purchase an item which will cost 100 dollars in the one year after that or in the next year ok. So, if this answer is no, then the question is how much amount should I have? Ok. Should we have rupees should we have 90 dollars, should we have 95 dollars, should we have 110 dollar or how much?.

So, that answer we can get if you know this present worth analysis. Now, what this present worth analysis is? This present worth analysis is a method of measuring and comparing costs, measuring and comparing cost and saving that occur at different times on a consistent and equitable basis for a decision making.

Because, in a planning you have to understand that if I need to plan for construction or for installation of a distribution network, there are many things, there are many decisions which I need to take time to time. One example, I already gave you that what should be the rating of the power transformer. Then the next question is only one power transformer will it be enough to supply all this load which will appear in the next 10 years or 15 years, then I have to answer this question.

So, there are many possible questions that will come ok and in order to answer this effectively I need to bring all these different values of money in different years to a common form and that form is basically present form. That I may have to take a decision that I need an investment one in 5th year of my planning or in 7th year of my planning. Now, what would be the value of that investment in the present time, that is called this analysis i.e., present worth analysis. So, it gives the present worth of any money which we need in next 5 years or which we need next 10 years ok.

And, we have a factor called present worth factor, it represents this value of money a year from now in today's term ok. So, the value of money at any time in the future can be converted to the equivalent present worth. Any value of money which I require in future can be converted to equivalent present worth and that process of converting any future investment or any future cost required to this present value is called this present worth analysis.

For example, as I said, I need to invest rupees or I need to invest this 100 dollar one year after and then how much money should I have; so, that I can purchase that item ok. So, in order to understand that I have to bring this a 100 dollar that amount to the equivalent present form, that what is the present worth of that particular money.

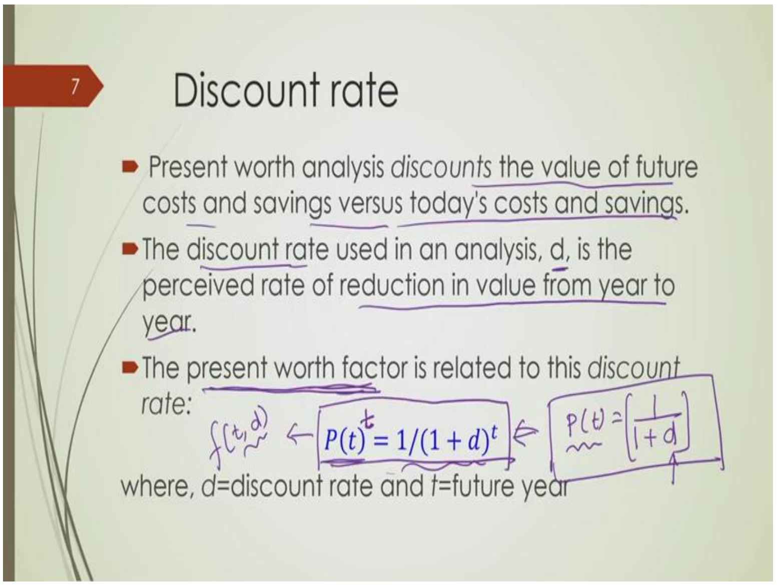
And, that is basically done by this equation that value of X dollar in terms of time is basically X multiplied by this P to the power t, where P is basically this present worth factor and t is basically this year in which that investment is required ok.

So, suppose this P is basically equal to 0.1 ok. So, I can find out that answer of this question 1. So, then answer of question 2 is that how much amount I should require I should have; so, that I can purchase an item which will cost 100 dollar in the next year or after one year ok. So, the present worth of 100 dollar, the present worth of 100 dollar which I required to purchase an item in the next year is 100 multiplied by this P which is given 0.1 that is 0.1 to the power t, t is here 1 to the power 1. So, this gives you 90 dollar. So; that means, if we have 90 dollar at this present time then and if present worth factor is considered to be 0.9, then I should have this 90 dollar, a 90 dollar with me. So, that I can spend 100 dollar to purchase the item which will cost 100 dollar after one year ok. So, I need not to have 100 dollar at this moment, if I have 90 dollar it is sufficient. Why it is sufficient? Because, this 90 dollar if I invest somewhere which will return assuming that it gives a return of some percent and that return itself will make this 90 dollar to 100 dollar; so, that I can purchase this item ok.

So, basically; that means, an item which will cost 100 dollar from a year after, its present worth is 90 dollar; assuming that this P is basically 0.9 ok; P is basically 0.9. And, this is the expression by which we can bring down any quantities to its present worth. For example, if instead of this you know 100 dollars, suppose I can say that I want to purchase I an item after 2 years, and I know that after 2 years its cost will be let us say 110 dollar ok.

Now, what would be the present worth of this, that particular item at this present worth? It would be equal to 110 multiplied by this P to the power t that is 0.9 multi to the power 2 that is 110 multiplied by 0.1. So, it will give some amount ok. So, if we have some amount this amount at this moment, then I will be able to purchase an item which will cost 110 dollar after 2 years ok. So, that is what one should understand that is what I want to convey in this particular slide.

(Refer Slide Time: 29:41)



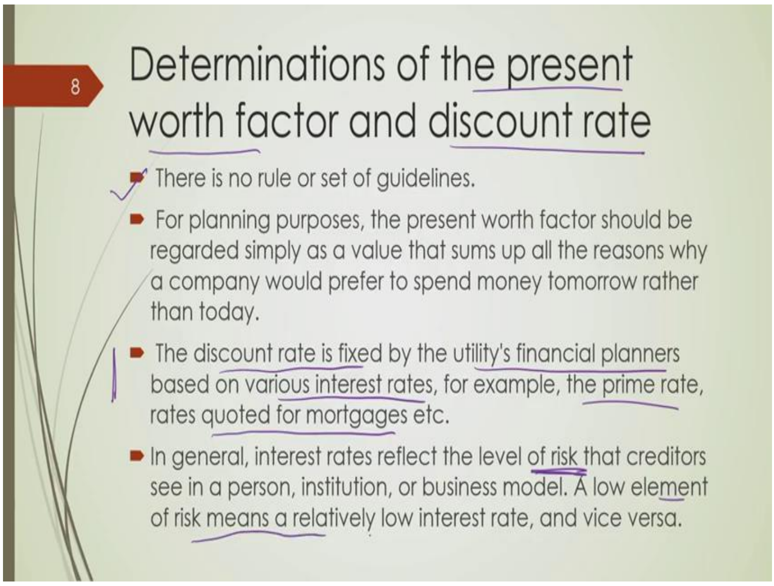
Now, the next question is how we decide this present worth factor, that how much it value you should consider? This present worth factor is basically function of another parameter which is called discount factor. So, this present worth factor, it is time varying of course, you can see. So, it is basically function of time as well as one parameter that is called discount factor ok or discount rate; discount rate.

So, this present worth analysis, discounts the value of future cost, and saving versus today's cost and savings ok. So, this discount rate is used as an analysis that is represented by this variable d which is perceived as the rate of the reduction of the value from a year to a year ok. So, it gives the value of this present worth factor P ok. And what is that relationship?

This is what the relationship; it is equal to 1 upon 1 plus d to the power t ok, 1 up on d to the power t. So, this is basically P to the power t itself there is an error. So, basically this P t is basically equal to 1 plus 1 upon d, one need to understand ok; and P t is your P to the power t will be equal to something like that, where d is basically discount rate.

So, if we know this discount rate, I can find out what should be the present worth factor and if I know this present worth factor, I can compute that what should be the value of money which I need let us say at t th year ok.

(Refer Slide Time: 31:44)



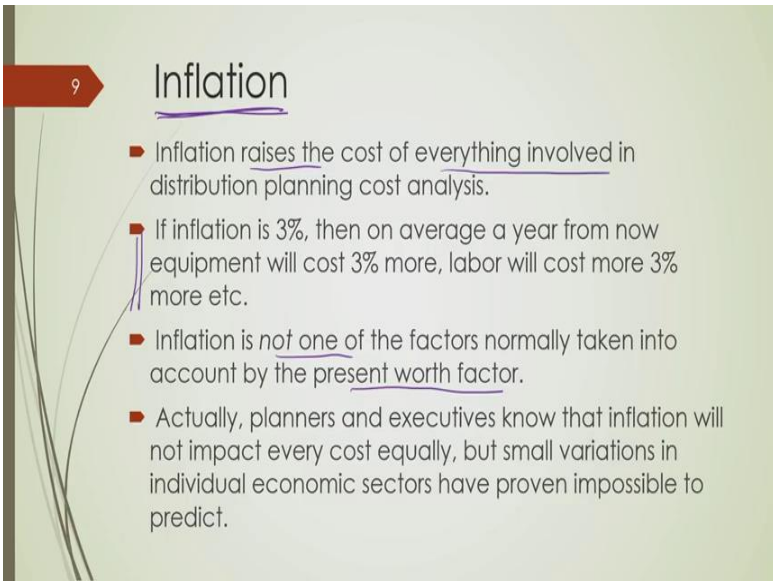
Now, next question is how do we determine this present worth factor and this discount rate? So, as you can see the first bullet point there is no uniform rule or set of guidelines available. So, that one can say that this is how we can decide that this would be the discount rate and once you know the discount rate, you can find out the present worth ok.

Now, how it is then determined? It is basically determined by this, by any particular companies financial planners ok. And, this discount rate is fixed by the utility's financial planners based upon various interest rates, for example, these prime rates, rates for mortgage etc.

So, there is a financial planner in a particular company which will basically decide that what should be the discount rate for a particular planning ok. And, once you get that discount rate, if it is 10 percent or 12 percent or whatever it is based upon that you can find out this present worth factor. And, based upon this present worth factor you can bring down the present worth of money of any future investment which is required ok.

Now, basically this discount rate also involves certain amount of risk ok. And, a low amount of risk means a relatively low interest rate or discount rate and vice versa. So, determination of discount rate involves certain amount of risk ok.

(Refer Slide Time: 33:36)



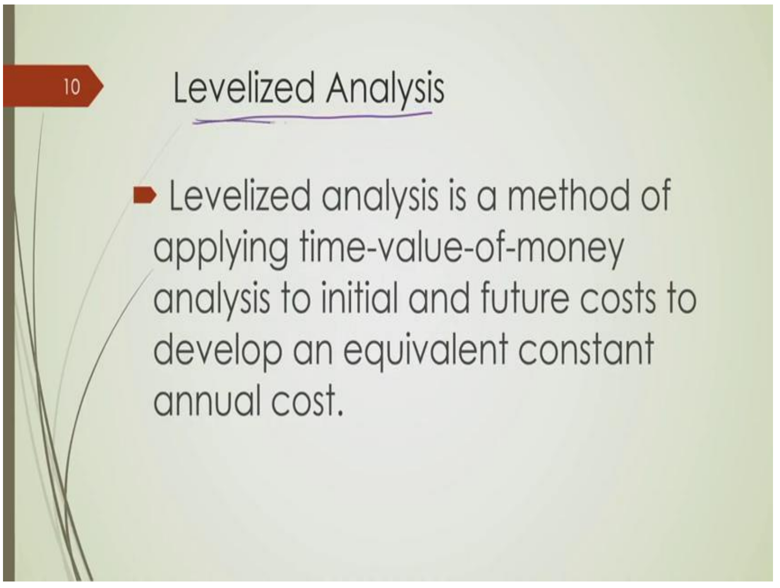
Also there is another financial parameter that everybody we know that is called inflation ok. So, inflation is basically responsible to raise the cost of everything involved in any type of planning ok. So, you know that this price of any equipment or any device will change from year to year and that change is basically due to this inflation. So, you know that government calculates one inflation rate at a given time ok.

So, but many times this inflation is not included into this computation of present worth factor, and sometimes this inflation is also included. Now, if this inflation is included then it is called inflation adjusted present worth factor and sometimes inflation is not included, because it is assumed that inflation will affect all these stakeholders in a uniform rate. So, if there is inflation of 3 percent, it means that equipment will cost 3 percent more, labour cost will be 3 percent more or whatever is associated with this planning will cost 3 percent more.

So, if there is a uniform change of this pricing, then it will not influence in the relative cost of the overall planning ok. And, in many of this distribution system planning models, this inflation rate is embedded into this computation of discount rate.

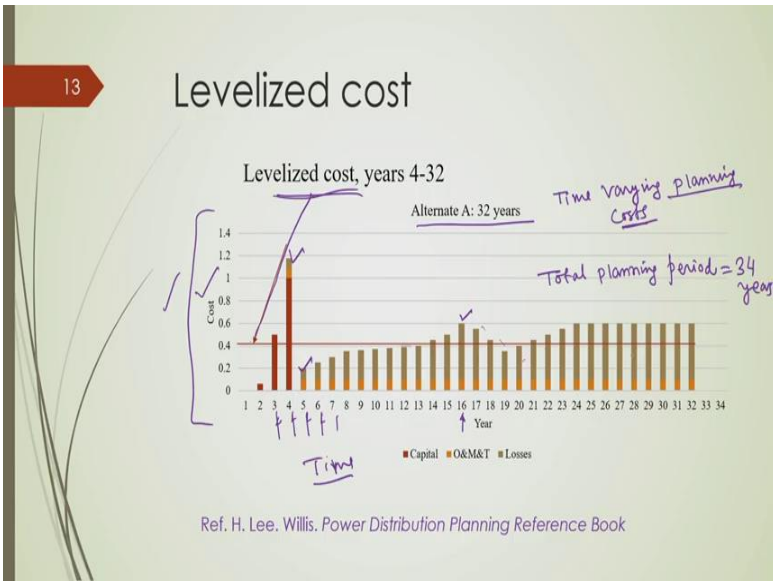
So that means, discount rate is computed in such a way that it considers certain amount of inflation into this account ok. So, this is how we need to understand about this inflation and discount rate. So, sometimes this present worth factor in some of the planning models; which I will show you later on, they embed this inflation rate into this present worth factor; and they call it as inflation adjusted present worth factor ok.

(Refer Slide Time: 36:04)



Now, I am going to another important financial analysis which is called levelized analysis or levelized cost analysis which is used to apply this time value of money to initial and future cost to develop an equivalent constant annual cost.

(Refer Slide Time: 36:34)

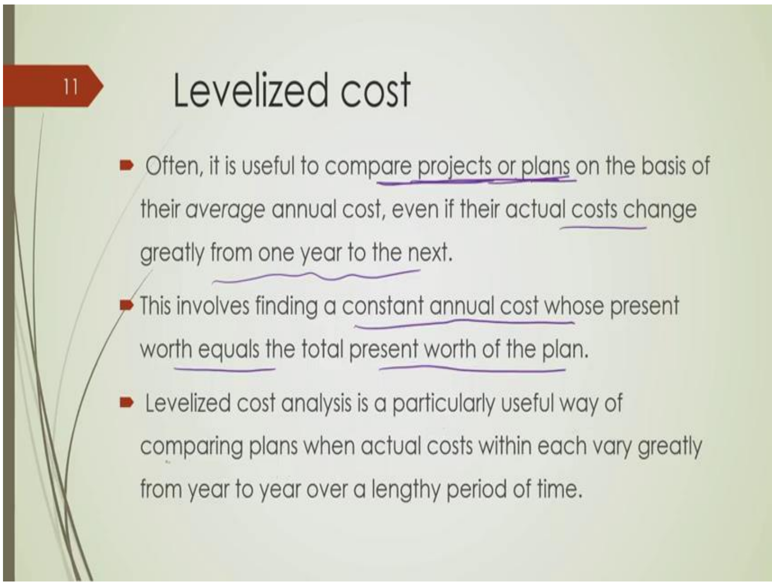


I will show you an example suppose this is what a planning of a particular building, a certain infrastructure in a power system. So, it is a time varying planning, time varying planning costs. Now, here you can see that this total, you know planning period is total planning period is equal to 34 years, and you can see the year to year this cost is varying.

So, the cost is highest at this 4th year, cost is it is lowest at 5th years, then slowly this cost is increasing and it is somewhere higher in 16th year, then again it is reducing and so on. So, these are basically time varying, this is your cost. So, these are time varying costs, time varying planning cost; time varying planning cost ok. Now, looking at this particular planning, it is very difficult to understand that how much annual cost you require so that we cope up with this planning ok.

And, most importantly, if I want to compare this planning with another planning which is having another set of time varying cost ok, how do we compare these two to planning alternatives? So, in order to bring them in a same platform, we use this levelized cost. This levelized cost, we will convert this time varying cost components in different future years to a constant cost. So, this is basically this levelized cost, i.e., constant annual cost by using which we can compare one planning alternative to another planning alternative ok. Now, how it is done; how it is done?

(Refer Slide Time: 39:03)

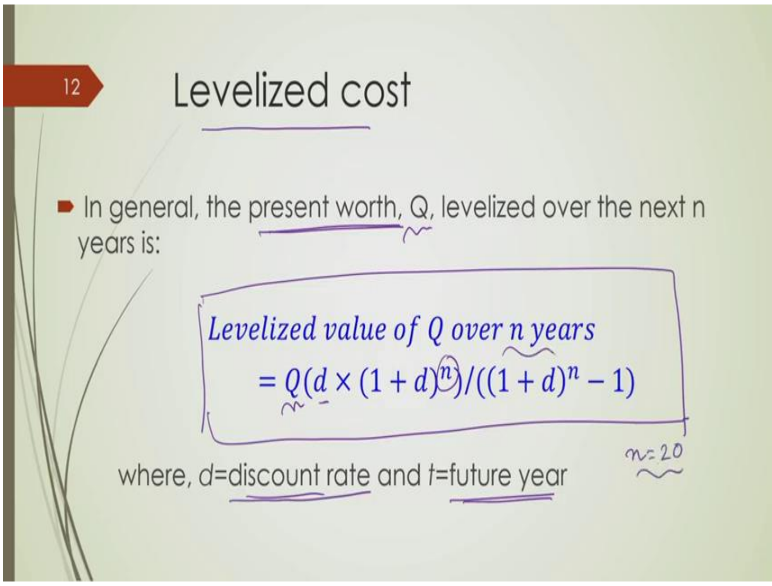


So, basically this levelized cost is useful as I said to compare different projects or plans. So, I have to construct suppose a distribution network; and I received let us say 3 to 4 planning alternatives, and I need to compare this planning. Now, how do we compare? Because, all these planning costs are time varying. So, one thing that I can do, I can bring all this future cost to this present worth cost and I can compare them.

And, also I can convert this present worth cost into a fixed annual cost, and then also I can compare ok. So, this levelized cost is basically the second one in which this present worth cost is converted to a constant annual cost; and by doing so, we can compare different alternative plans, with different projects ok even if their actual cost changes greatly from one year to another year ok. So, basically this levelized cost involves finding a constant annual cost whose present worth equals to the total present worth of the plan ok.

And levelized cost analysis is particularly useful in comparing different alternative plans to arrive at that which plan one should take for this implementation ok.

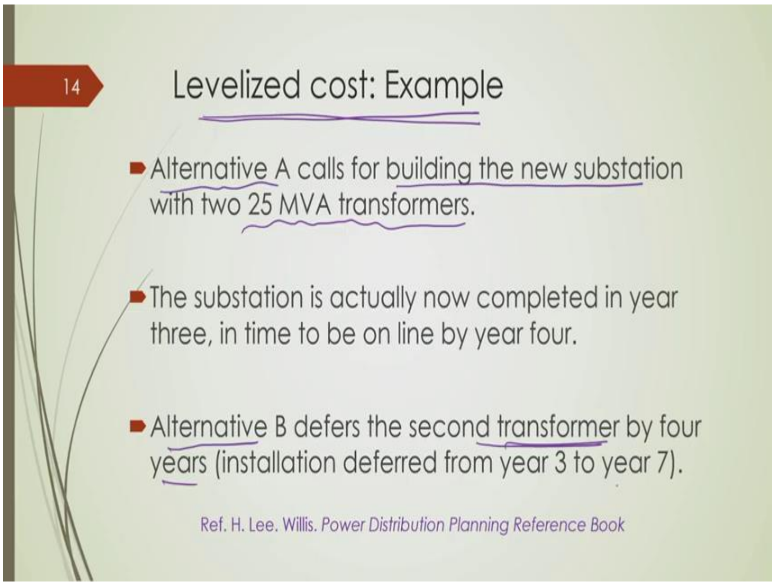
(Refer Slide Time: 40:32)



Now, how do we determine this levelized value or levelized cost? So, this is the expression through which we can derive this levelized cost, where you know that capital Q is basically present worth of a particular planning or time varying planning.

And small d as you know is discount rate and t is the years for the planning ok, here you know t is not given, instead of that n is given. So, n represents the number of years. So, if your n is equal to 20; that means, it is a plan for 20 years ok or planning horizon or planning horizon is equal to 20 years ok.

(Refer Slide Time: 41:27)

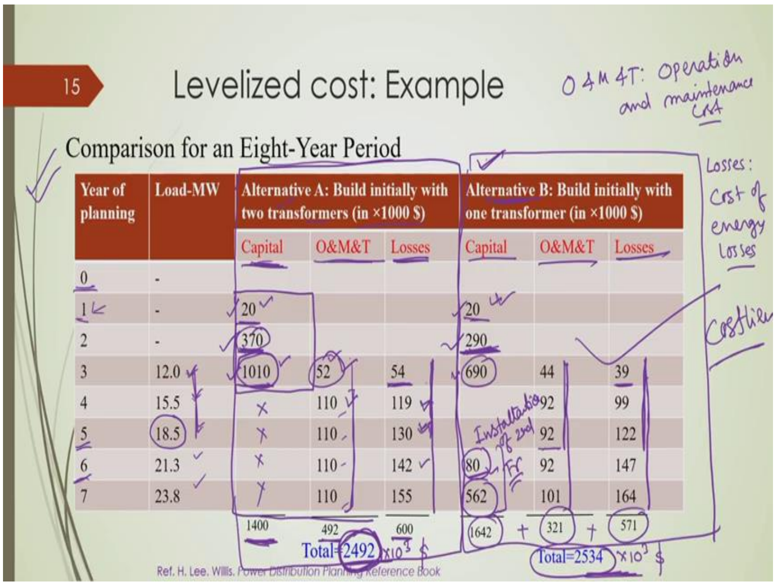


Now, I have two examples to illustrate how to determine this levelized cost ok. Now, the first example is building a substation, building a new substation. I have two alternatives: one is alternative A which means that is this alternative, I will take the decision that I will install two 25 MVA transformers at a particular time ok.

So, the idea is that I need to compare two planning alternatives, in one alternative I will consider that I will install two 25 MVA transformers at a time ok. And, in alternative B we in alternative B, we will defer the second transformer installation for four years ok and we will install it from year 3 to year 7 year, 3 to year 7.

So, that is the two alternatives we have or two possible planning alternatives that we have. In one alternative, I will take the decision that I will install two 25 MVA transformers at a time, another planning alternative is that I will defer one transformer installation by certain period of time that is four years ok.

(Refer Slide Time: 43:00)



And, this table gives your total eight years of this comparison ok. I will take it from this Lee Willis book, it gives a very good insight that particularly to understand this importance of present worth analysis, levelized cost analysis ok. Now, what this table is showing to you? This first column is the year of planning.

So, 0th year we will start construction of this particular substation, we will do this planning etc. Then, 1st year, we will basically start because at 0th year one needs to frame out this planning and then one needs to initiate land purchase etc and the 1st year we will start this construction ok. Now, this part is showing you this part is showing you the means alternative A, means we take the decision of building two transformers at a time ok.

And, this part is basically providing you this planning cost for alternative B, where we will defer this investment of one transformer to certain years ok. Now, in the 1st year you can see in we need these are the cost components, we have three cost components. One is capital investment cost, another is O, M and T, that is operation and maintenance cost.

So, this O, M and T is operation and maintenance cost and this one is basically third one, third column is representing the cost of energy losses. So, losses stand for the cost of energy ok.

Similarly, here also in alternative B, we have this capital investment cost, operational maintenance cost and cost of energy losses ok. So, we need same amount of capital investment cost in the 1st year in the both alternative plans that is 20 dollar each and you can understand that this is not 20 dollar, this is 20 multiplied by 1000 dollar. So, this is basically, all are equal to 20 multiplied by 1000 dollars.

So, that much we require as the capital investment cost those or 20000 dollar we require as a capital investment cost in both the planning alternatives in the 1st year. In the 2nd year, in alternative A, we require 370 multiplied by 1000 or 370000s of 370000s dollar as capital investment cost whereas, in alternative B, we require only 290000 of capital investment cost ok.

Now, why we require less amount of capital investment cost in alternative B? Because, in alternative B we took the decision that at that time at this 2nd year up to 3rd year, we will only install one transformer. So, it accounts for installation of only one transformer and associated equipment. So, its cost will be; obviously, lower as compared to this alternative A, where we take took the decision of installation of two transformers at a time ok.

So, in the 3rd year you can see in alternative A, all the two transformers are installed and it requires that much of capital investment whereas, in alternative B we have installed only one transformer. So, its cost will be less ok. So, its cost will be at this 40 percent or 30 percent less ok. Now, after this 1st, 2nd, and 3rd year, we have installed both the transformer in alternative way. So, there is no capital investment cost required after that ok.

So, total capital investment cost is 1400000 dollar ok and after installation of this two transformer, these are this operation maintenance cost and these are the operation maintenance cost and these are the cost of the losses, cost of the energy losses ok; which are also time varying depending upon that how much loading they are having. So, this loading, this column shows you this loading ok, this column shows you this loading and accordingly this cost of energy losses will also vary.

Similarly, in alternative B we have these are operational maintenance cost of one power transformer and these are the cost of energy losses for one transformer ok. Now, you can see up to this 5th year, when my load demand is 18.5 megawatt this alternative A which install two 25 MVA transformer. So, it does not have any problem. But, this alternative B, it has installed one 25 MVA transformer. So, if further load grows it needs to install another transformer in order to cope up with this additional load.

So, that is why in the 6th year, it decides to install another transformer which requires another capital investment cost of 80000 dollar and at 7th year 560000 dollar ok. So, this accounts for installation of the 2nd transformer; accordingly this way operation and maintenance cost and cost of energy losses will vary.

Now, if you compare this cost of energy losses in 3rd year of this alternative B and alternative A, you can see the cost of energy losses is higher in alternative A; in 5th in 3rd year as well as 4th year, 5th year and 6th year as and up to this you know 5th year. Because, only here in this alternative A, we have two transformers already we have installed and the loading is not much. So, they have to share this load.

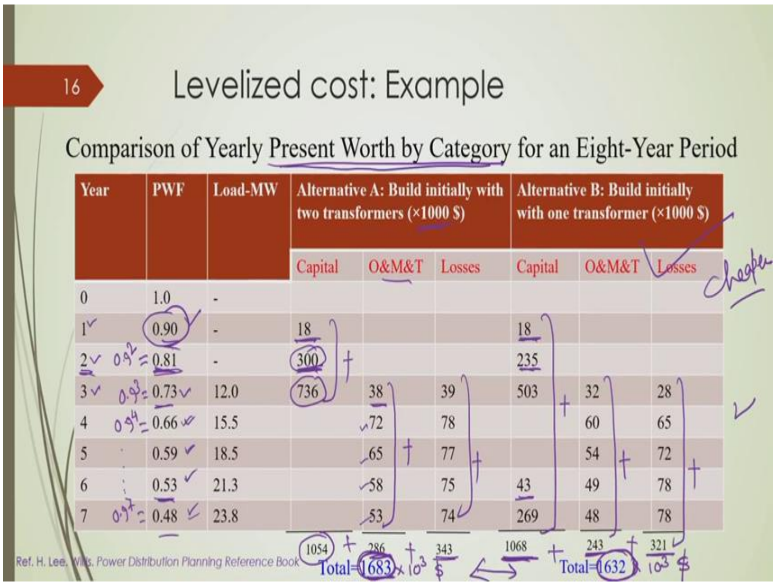
So, if loading is 12 megawatt; so, each of the transformer will share half of this loading. And, many times due to light load condition there will be this transformer will be very much lightly loaded which accounts for a higher amount of no load losses which makes the total and cost of energy losses higher as compared to alternative B, where we have only one transformer whose loading is; obviously, much higher whose loading is double than this alternative A ok.

Now, if you add up all this capital investment cost, operation maintenance cost and this cost of energy losses for alternative A, then you will get it is 2492 multiplied by 1000 dollar ok. So, that is the total cost we require, we did not consider any sort of present worth analysis at this time ok. Now, we do the same thing for by adding up this capital investment cost, operation maintenance cost and cost of energy losses for alternative B.

If you sum up all these three, then this will make the total of 2534 multiplied by 10 to the power 3 dollar ok. So, this is basically multiplied by 10 to the power 3 dollar and this is also multiplied by 10 to the power 3 dollar ok. Now, if you compare this total planning cost and this total planning cost; So, apparently you can see that this alternative B is much costlier in view of this particular total cost that we require ok. But, does it mean that this alternative B is really costlier? This you can understand with the present worth analysis.

So, here if you simply add up individual costs which occur in different time ok. So, this will not actually represent this total cost ok, because this 52000 dollar or this 110000 dollar occur in different times, they do not they do not occur in the same time. So, if you simply arithmetically add these two cost components which occurs at different times in a year then this will not reflect the actual cost ok.

(Refer Slide Time: 53:16)



So, in order to have this actual cost analysis, we will consider this present worth analysis present worth analysis ok. So, here we consider this discount factor as 0.9. So, present worth factor will be 0.9 at year 1 and at year 2, it will be 0.9 square. So, this will give you 0.81 and year 3, it will be 0.9 cube it will give you that much.

In year 4 it will be 0.9 to the power 4. So, this will be this and similar so on. So, this at year 7, this will be 0.9 to the power 7, this will give you 0.48 ok. So, these are the present worth factor which converts this future value of money to the present value ok. So, we need to multiply this present worth factor to all the cost components in order to bring them to the present worth or to the present value of the money ok.

And so, what we did we multiply 0.9 with this 20 and this 20 as well. So, what we will get? We will get 18 18. So, this is not 18, but this is 18 multiplied by 10 to the power 3; so, this is basically 18000 dollar.

Similarly, we multiply at year 2, we multiply 0.81 with all cost components which occurs at 2nd year, that is 370 and 290. So, if you multiply 370 with 0.81, it will give you 300; so, as this 235 ok. So, this shows you the present worth of this capital investment cost which is actually 370, but this 300 is basically representing this present worth value of this capital investment which is actually 370000 dollar after 2nd year ok, after year 2.

So, all these cost components are multiplied with their corresponding present worth factors and they brought down to the present worth ok. So, what we will get? This we get this total capital investment we require is 1054 multiplied by 10 to the power 3 and that we get by adding up these all these three capital cost investments, that we require in year 1, year 2 and year 3.

Similarly, we add all this operation and maintenance cost. These are present worth cost only, you can verify actual cost was 52, if you multiply 52 with this present worth factor that is 0.7, it becomes 38 ok. It is actually 38000, but here we have shown as 38. So, if you add up all these cost components. In fact, you can verify here, here you can see operation and maintenance costs are same over different year 4, year 5, year 6 and year 7.

But, when you multiply it with different present worth factors, they are different, they become 72, 65, 58 and 53. So, because you have different present worth values, present worth factor values ok. Now, after adding up, this will give you 286000 dollar for operation and maintenance cost, and 343000 dollar for cost of energy losses ok. And finally, if you sum up all these three, this will give you total present worth cost of this alternative plan that is 1683 multiplied by 10 to the power 3 dollar ok.

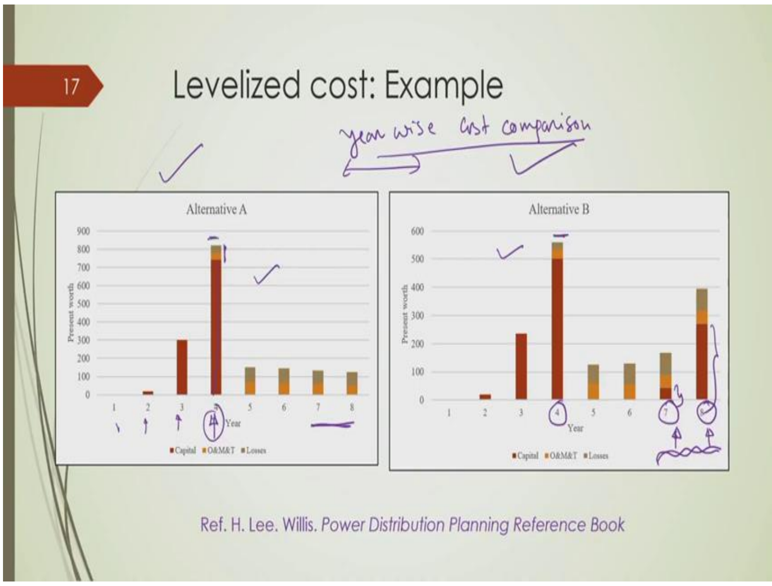
Similarly, if you multiply this capital investment cost, this capital investment cost of course, is the present worth cost. We got them from by multiplying this corresponding present worth factor from the actual cost. For example, you can see here you know for alternative B at 6th year, we need capital investment cost as 80000 dollar whereas, when you multiply it present worth factor of 0.53; it become 43 ok, 43000 dollar ok.

So, if you add up all these things, this will give you 1068 multiplied by 10 to the power 3. Similarly, if you add up all, you get 243, if you add up all these a cost of energy losses you get 321, then you add up all these three in order to get this total planning present worth planning cost which is 1632 10 to the power 3 dollar ok. Now, you can see if you arithmetically sum up all this planning cost, it is 2492000 dollar for this alternative A.

Whereas, if you sum up them with this present worth factor and this represent this present worth of this time varying investment decision, then, this value will come down to 1683000 dollar ok; similarly, here also, 16 1632000 dollar. Now, you compare these two plans or alternatively you can say the present worth values of these two alternative plans, one is 1683000 dollar, another is 1632000 dollar.

If you compare these two then; obviously, you can see this alternative B will be cheaper, this will be cheaper, this will be cheaper as compared to this alternative A. Whereas, if you simply add up arithmetically add up and compare then this will be costlier, this will be costlier ok. So, that is what the contradiction is, if you do not add this with present worth factor, whatever this actual cost you are getting that will not reflect the actual cost ok and that one needs to understand ok.

(Refer Slide Time: 60:02)

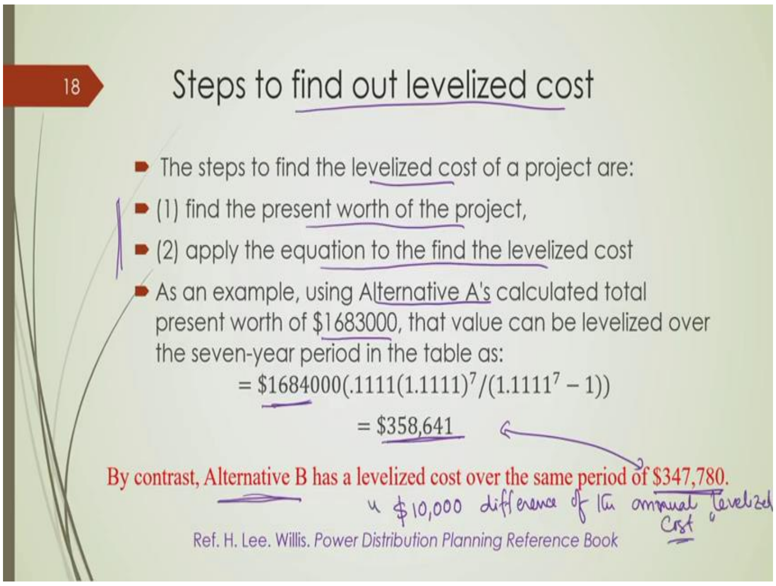


Now, from this present worth cost, we can eventually plot this you know alternative A and alternative B. So, in that plot you can see we have some portion of capital investment, we have some portion of operation and maintenance, we have some portion of cost of energy losses. So, this gives a glimpse of idea that which of the cost components will influence and how ok.

So, you can see in alternative way this 4th year, this is basically year wise cost total cost year wise, these are basically year wise cost comparison. And, you can see that in alternative A, at 4th year we have highest amount of dollar required or maximum value of the dollar required. And so, as this alternative B, but we have also need an 7th and 8th years higher value of this dollar ok.

And, because we install, why it is high compared to these two? Because, here we take the decision to install another transformer which accounts for considerable amount of capital investment cost ok, considerable amount of capital investment cost ok alright. Whereas, you know here, present worth cost is around 500, here present worth cost is much higher than that ok. So, these two are different scales that one needs to notice, although they look like same thing, but this is up to 550, here it is around 800 ok.

(Refer Slide Time: 61:46)

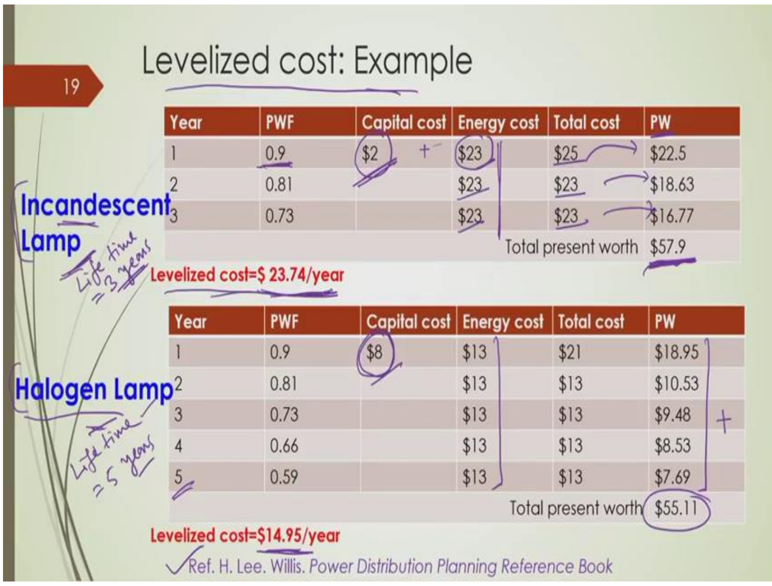


Now, from this present worth cost, we find out this levelized cost; this how to find out? These are the two steps, first you find out this present worth cost and then using this equation of this levelized cost, you convert it to this levelized cost. So, what we have done here? So, in alternative A, we have seen the total present worth cost is much 1683000 that much of present worth cost and if you convert it to this levelized value, this will give you that much that is around 358000 dollar ok.

By using the same type of analysis in alternative B, you will get this present worth, this levelized cost as around 347000 dollar. So, if you compare this and this you will get around 10000 dollar, difference of the annual levelized cost which is very important ok.

So, here you can understand that alternative B accounts for 10000 dollar less amount of levelized cost as compared to alternative A, which is basically significant amount. And, this helps you to choose which options should be economically more suitable ok.

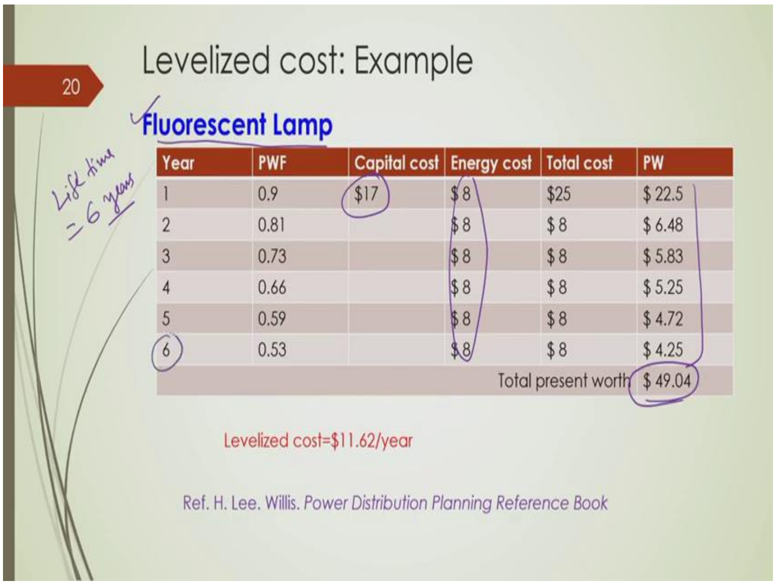
(Refer Slide Time: 63:29)



I have another example, short example which is also taken from this Lee Willis book, I sincerely acknowledge for that where I want to install this lighting of a particular area and I have three possible options. One is to have purchase an incandescent lamp, another is to purchase a halogen lamp, another option is to purchase a fluorescent lamp and all the options will give you same amount of light in illuminance ok.

Now, incandescent lamp its life time is 3 years. So, its life time it equal to 3 years because, different lamps you know their lifetimes are different, then halogen lamp this lifetime is equal to 5 years.

(Refer Slide Time: 64:26)



And, for this fluorescent lamp lifetime is equal to 6 years. So, they have different lifetimes and so as there are different purchase costs or different cost required to purchase. So, here you can see for purchasing incandescent lamp, we need only 2 dollar as capital cost ok, but it will account for this energy cost. That means, how much energy it will consume, if you convert it to the energy cost this will account for energy cost of 23 dollar in each year, each 3 year ok.

This is basically variable cost or recurring cost and this is what the capital investment or onetime cost ok. So, if you add up these two; so, total cost will be 25 dollar in the 1st year and 2nd year onwards 23 dollars ok. Now, if you convert this cost to the present worth factor by considering this present worth factor is 0.9. So, you get their corresponding present worth dollar ok and if you sum up all this present worth dollar, it will give you total present worth is around 57.9 dollar.

Now, with this present worth, if you can determine this levelized cost; you get this levelized cost for 23, around 23 dollar per year in a span of 3 years ok, after that we need replacement. Similarly, for halogen lamp also we need capital investment cost is 8 dollar; so, as the energy cost is lower than this incandescent lamp.

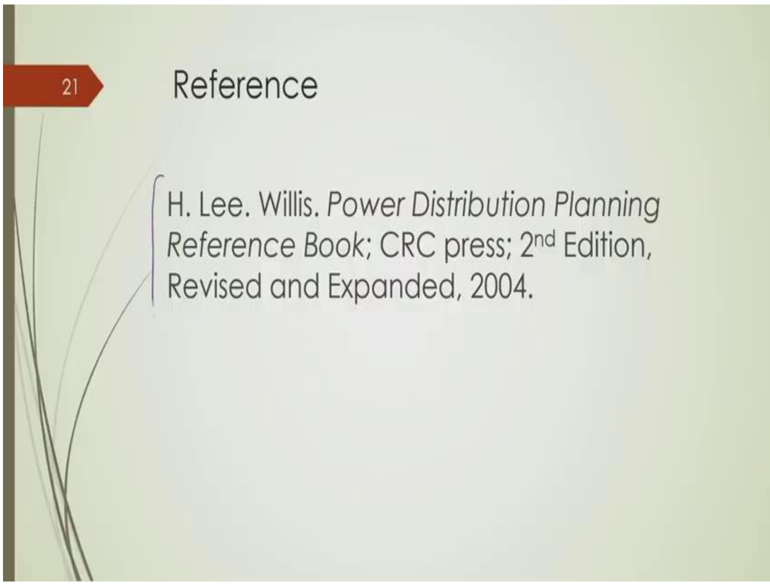
And, in similar way, you determine this present worth cost and if you sum up this total present worth cost; total present worth cost will give you around 55 dollar, this is for span of 5 years and levelized cost will be around 15 dollar per year.

So, if you compare this levelized cost and that levelized cost, you can see almost 10 dollar saving that you can get with this halogen lamp, whose capital investment cost is 4 times higher. It is actually 4 times of this incandescent lamp. So, just by looking at this capital cost you cannot decide that actual cost it will incur in future years ok. So, you have to do this present worth analysis as well as you have to do this levelized cost analysis.

Now, in further in the 3rd type that is fluorescent lamp, this capital cost is much higher; you can see as compared to this halogen or incandescent lamp it is much higher, but energy cost is significantly lower. And so, as the total present worth cost which is around 49 dollar ok and that is also for a span of 6 years, that is also that is something that one should notice, that is also for a span of 6 years.

So, when you convert this present worth to the levelized cost; you will get it around 11 dollar per year 11.6 dollar per year which is of course, significantly lower than this incandescent lamp and also lower than the halogen lamp. So, the main essence of the fact that I am trying to explain is that not only this capital cost looking at this capital cost one cannot take the decision that what particular decision what alternative decisions have to be selected. In order to do so, we need to find out this present worth analysis and finally, this levelized cost analysis ok.

(Refer Slide Time: 68:26)



So, these are the important things to initiate the understanding of power distribution system planning and with this I will finish this part of the lecture. And, I sincerely acknowledge this book H. Lee. Willis's book of Power Distribution Planning Reference Book ok, to have the idea, if one needs to have more understanding and different financial parameters you can go through this book ok.

Thank you.