

Power Distribution System Planning: Economic Aspects

Dr. Sanjib Ganguly
Associate Professor, Department of EEE,
IIT Guwahati (Email: sganguly@iitg.ac.in)

Planning cost

- The cost function maps many multi-dimensional parameters into a common basis, for example, materials, equipment, land, labor, taxes, maintenance etc. to dollar/rupees.
- The planning cost can be of two types:
 - Initial investment cost
 - Operational/recurring cost

Fixed cost vs. Variable cost

- Fixed costs are those which do not vary as a function of any variable element of the plan or engineering analysis, for example, the annual cost of taxes, insurance, inspection, scheduled maintenance, testing, re-certification etc.
- Variable costs do vary as a function of the different variables, for example amount of loading. Thus, the cost associated with power/energy loss is a variable cost.
- In many engineering economic evaluations, fixed costs include all costs except variable costs of operation such as fuel and losses.

Time worth of money

- Any utility planner must deal with two types of time versus money decisions.
- The first involves deciding whether a present expense is justified because it cancels the need for a future expense of a different amount.
- A second and related cost decision involves determining if a present expense is justified because it will reduce future operating expenses by some amount.

Time worth of money

- The value of money changes with time. The value of Rs 100 of today is different as compared to the value of Rs 100 after five years.
- Therefore, the timing of the investment is very crucial.
- Some costly investments, for example substation size, conductor size, may be found to be beneficial to avoid future investment.

Present worth analysis

- Present worth analysis is a method of measuring and comparing costs and savings that occur at different times on a consistent and equitable basis for decision-making.
- It is based on the present worth factor, P , which represents the value of money a year from now in today's terms.
- The value of money at any time in the future can be converted to its equivalent present worth as:

$$\text{Value today of } X \text{ dollars } t \text{ years ahead} = X \times P^t$$

where, P is the present worth factor and t =future year.

Discount rate

- Present worth analysis *discounts* the value of future costs and savings versus today's costs and savings.
- The discount rate used in an analysis, d , is the perceived rate of reduction in value from year to year.
- The present worth factor is related to this *discount rate*:
$$P(t) = 1 / (1 + d)$$

where, d =discount rate.

Determinations of the present worth factor and discount rate

- There is no rule or set of guidelines.
- For planning purposes, the present worth factor should be regarded simply as a value that sums up all the reasons why a company would prefer to spend money tomorrow rather than today.
- The discount rate is fixed by the utility's financial planners based on various interest rates, for example, the prime rate, rates quoted for mortgages etc.
- In general, interest rates reflect the level of risk that creditors see in a person, institution, or business model. A low element of risk means a relatively low interest rate, and vice versa.

Inflation

- Inflation raises the cost of everything involved in distribution planning cost analysis.
- If inflation is 3%, then on average a year from now equipment will cost 3% more, labor will cost more 3% more etc.
- Inflation is *not* one of the factors normally taken into account by the present worth factor.
- Actually, planners and executives know that inflation will not impact every cost equally, but small variations in individual economic sectors have proven impossible to predict.

Levelized Analysis

- Levelized analysis is a method of applying time-value-of-money analysis to initial and future costs to develop an equivalent constant annual cost.

Levelized cost

- Often, it is useful to compare projects or plans on the basis of their *average* annual cost, even if their actual costs change greatly from one year to the next.
- This involves finding a constant annual cost whose present worth equals the total present worth of the plan.
- Levelized cost analysis is a particularly useful way of comparing plans when actual costs within each vary greatly from year to year over a lengthy period of time.

Levelized cost

- In general, the present worth, Q , levelized over the next n years is:

Levelized value of Q over n years

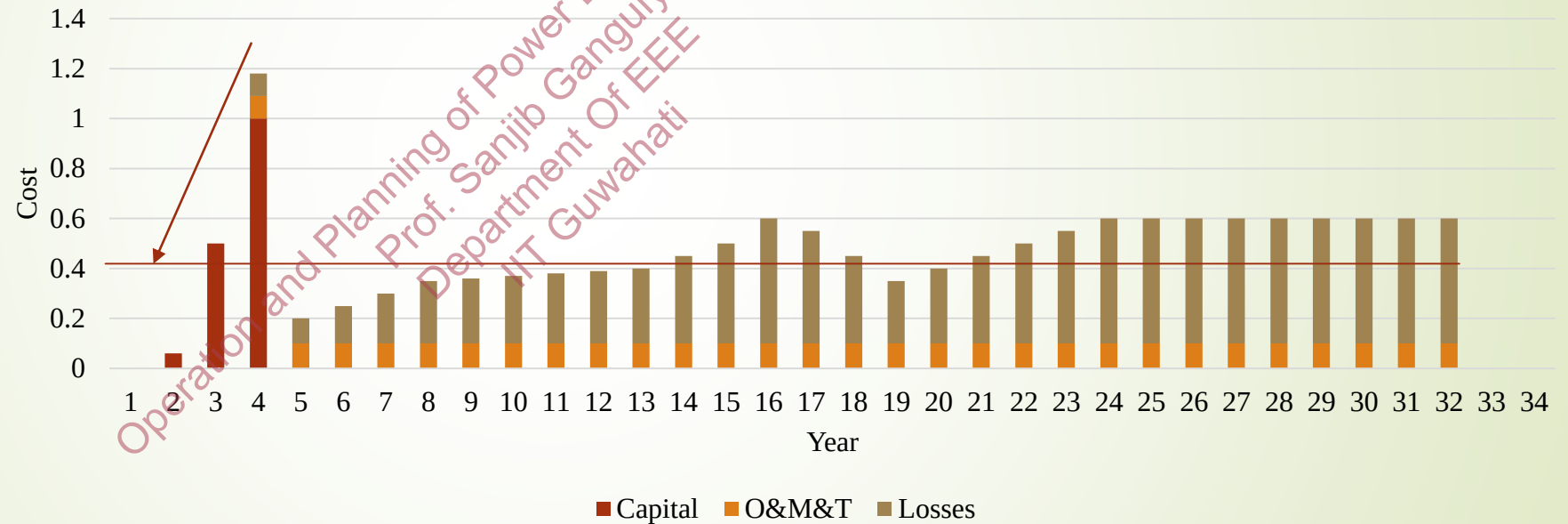
$$= Q(d \times (1 + d)^n) / ((1 + d)^n - 1)$$

where, d =discount rate and t =future year

Levelized cost

Levelized cost, years 4-32

Alternate A: 32 years



Ref. H. Lee. Willis. *Power Distribution Planning Reference Book*

Levelized cost: Example

- Alternative A calls for building the new substation with two 25 MVA transformers.
- The substation is actually now completed in year three, in time to be on line by year four.
- Alternative B defers the second transformer by four years (installation deferred from year 3 to year 7).

Levelized cost: Example

Comparison for an Eight-Year Period

Year of planning	Load-MW	Alternative A: Build initially with two transformers (in $\times 1000$ \$)			Alternative B: Build initially with one transformer (in $\times 1000$ \$)		
		Capital	O&M&T	Losses	Capital	O&M&T	Losses
0	-						
1	-	20			20		
2	-	370			290		
3	12.0	1010	52	54	690	44	39
4	15.5		110	119		92	99
5	18.5		110	130		92	122
6	21.3		110	142	80	92	147
7	23.8		110	155	562	101	164
		1400	492	600	1642	321	571
		Total=2492			Total=2534		

Levelized cost: Example

Comparison of Yearly Present Worth by Category for an Eight-Year Period

Year	PWF	Load-MW	Alternative A: Build initially with two transformers (×1000 \$)			Alternative B: Build initially with one transformer (×1000 \$)		
			Capital	O&M&T	Losses	Capital	O&M&T	Losses
0	1.0	-						
1	0.90	-	18			18		
2	0.81	-	300			235		
3	0.73	12.0	736	38	39	503	32	28
4	0.66	15.5		72	78		60	65
5	0.59	18.5		65	77		54	72
6	0.53	21.3		58	75	43	49	78
7	0.48	23.8		53	74	269	48	78

1054

286

343

1068

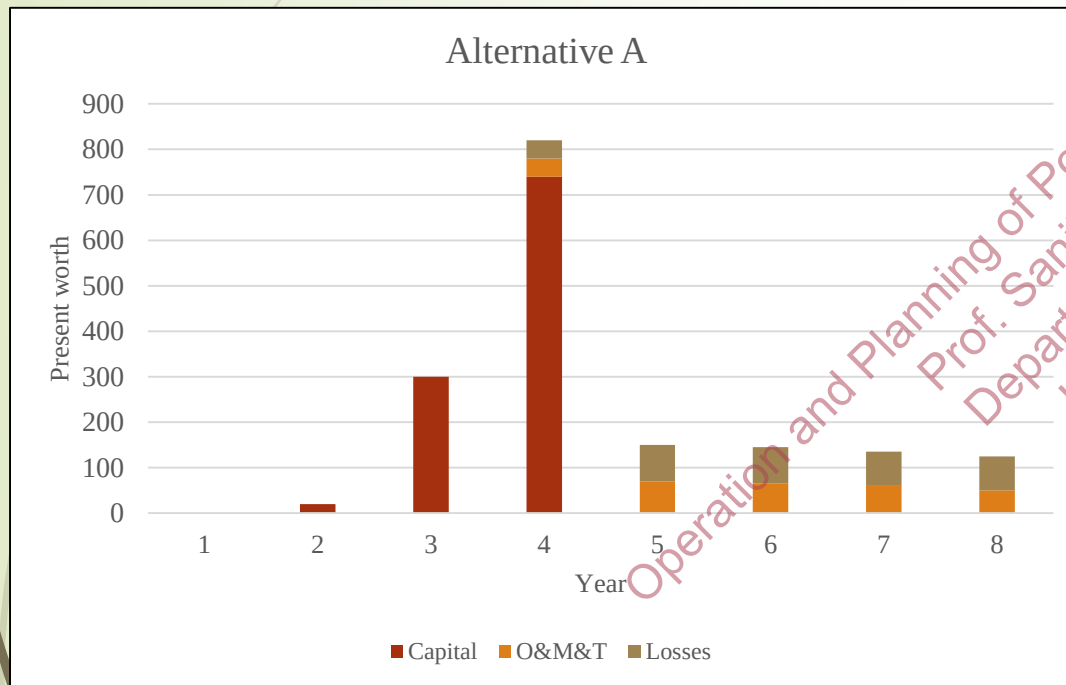
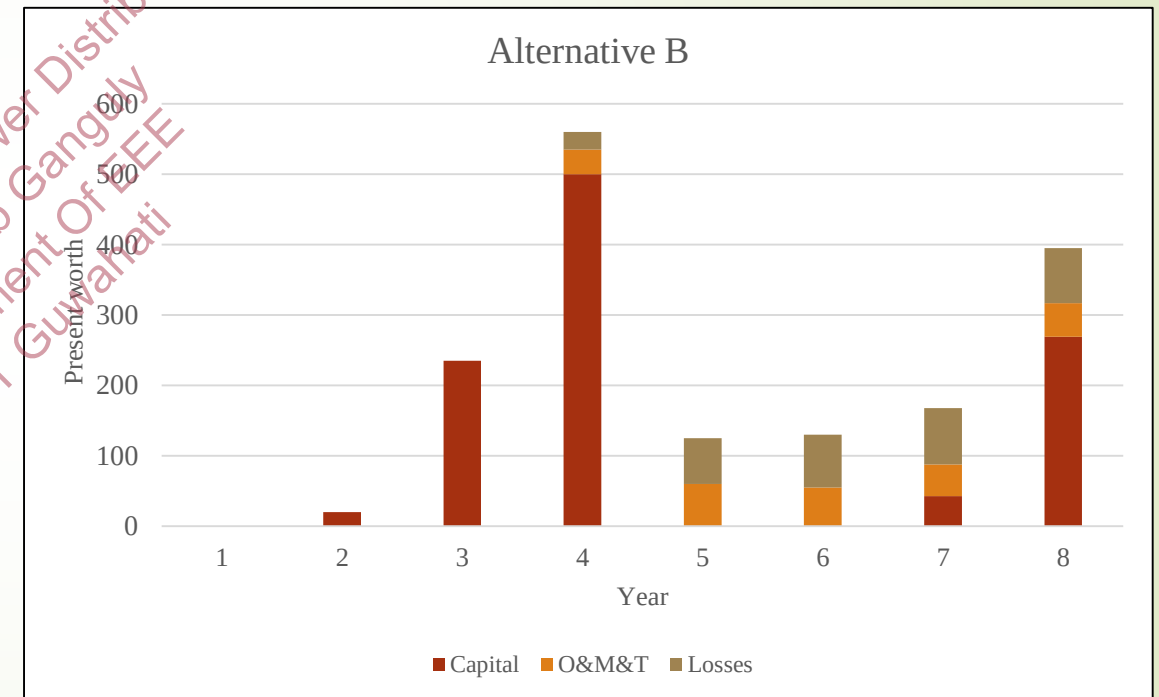
243

321

Total=1683

Total=1632

Levelized cost: Example



Ref. H. Lee. Willis. *Power Distribution Planning Reference Book*

Steps to find out levelized cost

- The steps to find the levelized cost of a project are:
- (1) find the present worth of the project,
- (2) apply the equation to find the levelized cost
- As an example, using Alternative A's calculated total present worth of \$1683000, that value can be levelized over the seven-year period in the table as:

$$\begin{aligned} &= \$1684000(.1111(1.1111)^7 / (1.1111^7 - 1)) \\ &= \$358,641 \end{aligned}$$

By contrast, Alternative B has a levelized cost over the same period of \$347,780.

Levelized cost: Example

Incandescent Lamp

Year	PWF	Capital cost	Energy cost	Total cost	PW
1	0.9	\$2	\$23	\$25	\$22.5
2	0.81		\$23	\$23	\$18.63
3	0.73		\$23	\$23	\$16.77
Total present worth					\$57.9

Levelized cost=\$ 23.74/year

Halogen Lamp

Year	PWF	Capital cost	Energy cost	Total cost	PW
1	0.9	\$8	\$13	\$21	\$18.95
2	0.81		\$13	\$13	\$10.53
3	0.73		\$13	\$13	\$9.48
4	0.66		\$13	\$13	\$8.53
5	0.59		\$13	\$13	\$7.69
Total present worth					\$55.11

Levelized cost=\$14.95/year

Levelized cost: Example

Fluorescent Lamp

Year	PWF	Capital cost	Energy cost	Total cost	PW
1	0.9	\$17	\$ 8	\$25	\$ 22.5
2	0.81		\$ 8	\$ 8	\$ 6.48
3	0.73		\$ 8	\$ 8	\$ 5.83
4	0.66		\$ 8	\$ 8	\$ 5.25
5	0.59		\$ 8	\$ 8	\$ 4.72
6	0.53		\$ 8	\$ 8	\$ 4.25
Total present worth					\$ 49.04

Levelized cost=\$11.62/year

Ref. H. Lee. Willis. *Power Distribution Planning Reference Book*

Reference

H. Lee. Willis. *Power Distribution Planning Reference Book*; CRC press; 2nd Edition, Revised and Expanded, 2004.

Operation and Planning of Power Distribution Systems
Prof. Sanjit Garuly
Department Of EEE
IIT Guwahati

Thank You....

Operation and Planning of Power Distribution Systems
Prof. Sanjib Ganguly
Department Of EEE
IIT Guwahati