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USING THE GROWTH MODELS FOR OPTIMISATION OF ENERGY DISTRIBUTION SYSTEMS

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1- Introduction

Energy distribution systems were developed in the recent years due to increasing population, new technologies and load demand. Alternative technical arrangements are made trouble to choose the best construction. On the other hand, system costs are affected for the new design and operating. That is, for a new distribution design or operation of an exist system, both technical and economical constraints must be consider.

Today, the present planning is done more sensitively using various statistical methods and computer aided approaches depending on the new technology developments. Some parameters depend on system design must be considered correctly. If some of them change yearly, these changes must be included in the calculations such as load, inflation, etc. If this work is not done, then the system design may be insufficient. For example, if load growth is not considered correctly, then the system design will be affected from this situation because of operating losses.

The purpose of this paper is a brief summary of reference [1]. Annual growth factors of load, loss factor and energy costs were considered to obtain the sufficient system design. So, all the cost expressions depend on these factors can be obtained correctly. Moreover, these factors were modeled in twenty-seven cases by the considered three models in "Present Worth Analysis" formulations. These cases can be used in such as exact cost expressions, optimum system design, selection of the optimum design amongst the others [2,3,4,5,6], etc. in energy distribution systems.

2- Method

The total cost (TC) expressions of an energy distribution system are composed by two basic part: "Fixed costs" and "Variable Costs". Fixed costs (FC) are related to the investment costs. Variable costs (VC) are operating costs. In other words, operating costs are the cost of energy due to I^2R losses. The cost of investment is the largest cost component and it depends purchase cost, taxed, insurance, depreciation, operation and maintenance, etc.

Since operating costs change from year to year, it is necessary to consider them over the expected lifetime (N) of the system. Therefore total cost of a system can be written by the following formula:

$$TC = FC + \sum_{n=1}^{N} OC_n \qquad (1)$$

In the following parts annual growth rates must be considered, growth models and using these models in calculations will be presented for a distribution system. The expressions are derived by the Present Worth Analysis formulations because of its simplicity using in optimization techniques.

2.1- Growth Models

Load growth in distribution systems is an unavoidable situation due to increasing population, increasing consumption, using new technologies, migrations, etc. To obtain an efficient and economic system design in distribution substation transformers, high voltage primary feeders, distribution transformers, low voltage feeders and service lines the load growth must be estimated.

The system experiences growth in load factor due to many reasons such as increase in load diversity with load growth, increase in energy consumption per kW connected load with time, measures taken by the utilities to flatten load curves for improving system efficiency and to curb the growth in peak demand, etc. Due to depending on the load factor, loss factor also increases with load factor.

On the other hand, cost of energy also increases with time depends on inflation. When the energy losses are chanced by the $I^2.R$, the cost of energy losses is subjected to the increased energy cost year by year.

In the next part of the study, considering the proceeding situations Sm, LF and EC will be modeled by the yearly growth rates gs, glf and gec using in three cases [1,2].

- There is no growth.
- There is a linear relation amongst the annual growth rates.
- There is a nonlinear relation amongst the annual growth rates.

In the first case:

$$\begin{aligned} Sm_n &= Sm_o \\ LF_n &= LF_o \\ EC_n &= EC_o \end{aligned} \qquad (2)$$

In the second case :

$$\begin{aligned} Sm_n &= Sm_o.[(1+(n-1).gs] \\ LF_n &= LF_o.\ [(1+(n-1).glf] \\ Ec_n &= EC_o.\ [(1+(n-1).gec] \end{aligned} \qquad (3)$$

In the third case :

$$\begin{aligned} Sm_n &= Sm_o.(1+gs)^{n-1} \\ LF_n &= LF_o.(1+glf)^{n-1} \\ EC_n &= EC_o.(1+gec)^{n-1} \end{aligned} \qquad (4)$$

Where

Sm_n : Maximum apparent power for nth year, assuming end of year values, MVA.
LF_n : Annual loss factor for nth year, assuming end of year values.
EC_n : Energy cost for nth year, assuming end of year values, $/kWh
Sm_o : Initial maximum apparent power for the first year, MVA
LF_o : Initial loss factor for the first year.
EC_o : Initial energy cost for the first year.
gs : Annual growth rate of peak load.
glf : Annual growth rate of loss factor.
gec : Annual growth rate of energy cost.

2.3- Using the Growth Models

In the cost expressions that are expressed by subscript n; Sm, LF and EC are easily modeled by using with (2-4) in the following manner:

- The best model that shows the growth trend is chosen.
- The annual growth rate that is being used is determined.
- The weighted cost of capital is taken into account as the interest rate.

That the three cases that determined in the preceding part amongst the three terms are revealed twenty-seven different possible arrangements. If there are two terms, this number is 9; if there is only one term, there will be three arrangements.

That the constant case of Sm, LF and EC is shown by (C), the linear modeled case (L) and the nonlinear modeled case (N) is shown at Table 1 in twenty-seven different possible arrangements [1].

Variable costs, in the other words, operating costs depend on Sm, LF and EC are rewritten in the following formula to show using the growth models:

$$OC_n = k1.\sum_{n=1}^{N} Sm_n^2.LF_n.Ec_n.q^n = k1.k2.T_{cn} \tag{5}$$

Where

k1 : The other fixed multipliers of the operation costs.
k2 : The multiplier of $Sm_o.LF_o.EC_o$
q^n : $(1+i)^{-n}$
i : interest rate
T_{cn} : Case number shows which case is considered amongst the twenty-seven cases.

From table 1, the suitable model is chosen considering the problem and then its corresponding form (2-4) is substituted in the cost expressions with subscript n as (5). At the end, the case number cs is determined and for this number, the sum of the series T_{cn} are constituted in the cost equations. So, the expressions are obtained by depending on the annual growth rates. In reference [1], these twenty-seven cases were obtained with the generalized expressions for Sm, LSF and EC. Therefore, required T_{cn} values can be taken from there.

CASE	Sm	LF	EC
1	N	N	N
2	N	N	C
3	N	C	N
4	N	C	C
5	N	L	L
6	N	L	C
7	N	C	L
8	N	N	L
9	N	L	N
10	L	L	L
11	L	L	C
12	L	C	L
13	L	C	C
14	L	N	N
15	L	N	C
16	L	C	N
17	L	L	N
18	L	N	L
19	C	N	N
20	C	L	L
21	C	L	N
22	C	N	L
23	C	N	C
24	C	L	C
25	C	C	L
26	C	C	N
27	C	C	C

Table 1- Twenty-seven Case For Annual Growth Rates Used In The Models [1].

Here, for example, the first case of table 1 is given. In the case, all the terms are modeled by the nonlinear model. Using (4) and (5)

$$OC_n = k1.\ Sm_o^2.\ LF_o.\ Ec_o.\ \sum_{n=1}^{N} (1+gl)^{2(n-1)}.(1+glf)^{n-1}.(1+gec)^{n-1}.(1+i)^{-n} \qquad (6)$$

and for cs=1, that is T_1 from reference [1] substituting in (6)

$$OC_n = k1.\ Sm_o^2.\ LF_o.\ Ec_o.\ (q-q^{N+1}.g1^{2N}.g2^{N}.g3^{N}) / (1-q.\ g1^2.\ g2.\ g3) \qquad (7)$$

is obtained. Where

g1	: 1+gs
g2	: 1+glf
g3	: 1+gec
k2	: $Sm_o^2.\ LF_o.\ Ec_o$
T_1	: $(q-q^{N+1}.g1^{2N}.g2^{N}.g3^{N}) / (1-q.\ g1^2.\ g2.\ g3)$

3- Conclusion

The purpose of this paper is a brief summary of reference [1]. Using of annual growth rates of load, loss factor and energy cost is presented and modeled by means of the three model for planning and design of distribution systems. So, all the cost expressions depend on these factors can be obtained correctly. Moreover, these factors were modeled in twenty-seven cases by the considered three models in "Present Worth Analysis" formulations. These cases can be used in plenty of calculation for distribution systems such as primary feeder costs, low voltage feeders' costs, distribution transformer's costs, etc. Besides, these are also used for both determining the optimum cable sizes and norm transformer values amongst the others. The conclusions obtained by these cases are useful for all the optimization methods like as linear, integer, mixed integer, nonlinear, dynamic optimization, etc.

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