A Computer Based Study of Transmission Loss Evaluation

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This paper is concerned with the process of evaluating transmission losses as proposed by O.I. Elgard, Kron and Yung-Chung Chang. Wei-Tzen Yang, Chun-chun Lui. Computer programmes were prepared on these methods and subsequently compared on a standard four-bus system. Transmission loss considerations have often proved to be important in the planning of future systems in particular regard to location of plants and the construction of transmission lines. Computers have brought a sea change in all walks of life including the operation, control and maintenance of power systems. The computing and analytical techniques are of increasing value ot the electric utility engineering since systems have tended to become progressively complex as they expand. Computer study was essential as the transmission loss evaluation using computers has facilities like reliability, accuracy, simplicity, directness, rapid execution and reduction in time. The losses are necessary to be determined as the cost of producing energy and as the price of installing new generating plants are increasing. By adopting suitable measures and control these losses can be diminished considerably.

Introduction

An engineer is always concerned with the cost of product and services. For a power system to return a profit on the capital invested, proper operation is always necessary. Rates fixed by regulatory bodies place extreme pressures on power companies to achieve maximum efficiency of operation and to improve efficiency continually in order to maintain a reasonable relation between cost of a kilowatt-hour in the face of constantly rising prices for fuel, labour, supplies an maintenance. [1].

With the development of power systems and the interconnections of companies for purposes of economy interchange, it is necessary to consider the incremental fuel costs along with the transmission losses. This consideration has resulted in the fuel savings upto one hundred dollars per year per megawatt. Another point in the operation of interconnected systems is the determination of transmission losses for the purposes of billing in various interconnections. The revenue to be gained by properly billing for these losses can be a very large sum. [2]. The advantage claimed in the equal transmission method is that the method requires only small computer memory, it is easy to make a programme of the method and sometimes, it is essential to develop a reliable algorithm also. This furnishes a flexible and accurate method of taking

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Into account the various rapidly changing system conditions in the plant and in the transmission system.

ANALYSIS

The transmission loss (2) may be closely approximated by the means of a transmission loss formula of the form:

$$P_L = \sum_m \sum_n P_m B_{mn} P_n$$

Where B_{mn} = transmission loss formula coefficients.

P_m, P_n = Soruce loadings.

The other formula includes linear terms and a constant term in addition to the quadratic term

$$P_L = \sum_m \sum_n P_m B_{mn} P_n + \Sigma B_{no} P_n + B_{oo}$$

This is formula allows more flexibility relating to the manner in which each individual load varies with the total load. The energy losses in a power system are classified according to the following criteria (3,4):

a) Utility of the power network

b) Voltage level.

- losses in the transmission system
- losses in the distribution system

c) Type of cause

- Physical losses
- Black losses

It is to be noted that about 2/3 of losses are due to physical losses and 1/3 black losses. Losses on the transmission system are a function of wheeling, generation and load expressed by the equation (5):

$$L_S = f\,(W,G,L)$$

Where L_S = transmission losses, W = Wheeling (imports, exports), G = Generation, L = Load. Wheeling includes imports, exports and wheeling for others through the transmission system. Losses in the distribution and radially operated sub transmission system are a function of load, VARs, resistance and voltage profile as represented by eq: $L_S = f\,(P, Q,V,r)$ where L_S = Losses, P = Power output, Q = VAR output, V = Voltage, r = resistance. If voltage and resistance remains constant, VARs are proportional to load. The various methods of transmission loss evaluation are:

1. Current Distribution Factor Method

The B – coefficients for the transmission loss are (6):

$$P_L = B_{11}P_1+^{2}B_{22}P_2+2^{2}B_{12}P_1P_2$$

Where given as:

$$B_{11} = \frac{\Sigma_b\,(\alpha_{b1})^2 Rb}{|V_1|^2 \cos^2\phi_1}$$

$$B_{22} = \frac{\Sigma_b\,(\alpha_{b2})^2 R_b}{|V_2|^2 \cos^2\phi_2}$$

$$B_{12} = \frac{\Sigma_b\,(\alpha_{b1})\,(\alpha_{b2})\,R_b}{|V_1|\,|V_2|\,\cos\phi_1 \cos\phi_2}$$

Assumptions:

1. The ratio X/R for all the transmission line is same.
2. The phase angle of all load currents is same.

Incorporating above assumptions, the load currents and branch currents become in phase and hence the current distribution factors become real.

2. Method Proposed by Elgard

Elgard (7) made the following assumptions for estimation of transmission losses

1. $Z = R + j X$
2. $_{PL} << P_{G1}, P_{G2}, P_{D1}, P_{D2}$
3. $S^2 >> R^2$
4. $|V_1| = |V_2| = |V|$
5. $\sin\delta = \delta$ and $\cos\delta = 1 - (½)\,\delta^2$
6. $(IC)_1 = \alpha + \beta P_{G1}$

   $(IC)_2 = \alpha + \beta P_{G2}$

The PL can be given by an expression PL = $\delta^2 \frac{R}{X^2}$ where δ is the power angle.

3. Kron's Method:

Kron's circuit transformation (8) involves straightforward matrix operations. The first transformation expresses load currents in terms of generator current and second transformation expresses generator currents in terms of generator real power outputs.

The necessary assumption to achieve the first transformation to achieve the first transformation that the load current at any buss current be linearly related to total load current. The assumption for the second transformation is that the reactive output of the generator be linearly is related to its corresponding real power output.

It is to be demonstrated that if $i_{old} = Ci_{new}$ where c is the matrix of transformation and if the power is to remain invariant, the new set of voltages is given by

$$e_{new} = c_t^* e_{old} = c_t^* z_{old}\, c\, i_{new}$$

and the new set impedances is given by

$$z_{new} = c_t^* z_{old}\, c$$

The transmission loss equation may be given as:

$$P_L = \sum_{i=1}^{k} \sum_{j=1}^{k} P_{Gi} B_i P_{Gj} + \sum_{i=1}^{k} B_{io} P_{Gi} B_{oo}$$

The B – terms are called loss coefficients. The units of loss coefficients are reciprocal megawatts when the three phase power P_{Gi} to P_{GK} are expressed in megawatts in which case P_L will be in megawatts. The units of B_{oo} match those of P_L while B_{io} is dimensionless.

3. Sensitivity Factor method:

The generation shift distribution factor (GSDF) and line outage distribution factor (ODF) (9,10) are two most important sensitivity factors. These sensitivity factors to compute line flows remain popular for properties like linearity and rapid computation the assumptions of the proposed method are:

1. The ration R_m / X_m for each transmission line is much smaller than unity.
2. The voltage magnitude at every bus is in per unit.
3. The angles across transmission lines are small.

The GSDF reflects the generation shifts to line follows and can be calculated by

$$A_{m,i} = \frac{\partial P_m}{\partial P_{Gi}} = \frac{X_{li} - X_{ki}}{X_m}, \quad m=1,..\ NL$$

Where, 1 and k are initial bus and terminal bus of line m respectively. The new line flows after shifts can be expressed in an incremental form as:

$$P_m = P_m^{O} + \sum_{i=1}^{NG} A_{m,i}\, \Delta P_{Gi}, \quad m = 1,\ ..\ NL$$

The solution accuracy of GSDF is guaranteed only when system generation remains unchanged. The Generalized Generations Shift Distribution Factor (GGDF) overcomes this limit as it calculates line flows in the integral form given by

$$P_m = \sum_{i=1}^{NG} D_{m,i}\, P_{Gi}, \quad m = 1,\ldots NL$$

$$D_{m,i}\ (GGDF) = D_{m,r} + A_{m,i}$$

$$D_{m,r} = \frac{P_m - \sum_{i=1,\ i \neq r}^{NG} A_{m,i} P_{Gi}}{\sum_{j=1}^{NG} P_{Gj}}$$

$D_{m,r}$ denotes the GGDF for line m due to generation of reference bus. Programs for these methods have been developed and transmission loss is calculated using these three methods. Results are as under (p.u.):

Current Distribution	**Kron's**	**Sensitivity Factor**
Factor Method,	**Method**	**Method**
P_L = 0.2050	0.0934	0.00980

Conclusion

Transmission loss was minimum when calculated through sensitivity factor and maximum when calculated using current distribution method. Kron's method has proved to be better than current distribution method but is complicated, lengthy and time consuming as it applies transformation of frames of references.

The Sensitivity Factor Method avoids many limitations associated. The method is fast, linear and can handle line outages. The method avoids the use of complicated reference frame transformations based upon Kron's analysis. The method is easy to implement and is well suited to on-line dispatch applications.

Reference Book:
Power And Energy For Sustainable Growth
Proceedings All India Seminar, February 20-21, 2003