A NEW TRANSMISSION EXPANSION PLANNING MODEL BASED ON AC LOAD FLOW

By

Kareem Mohamed Ibrahim Ali

A Thesis Submitted to the
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in Partial Fulfillment of the
Requirements for the Degree of
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In
Electrical power & machines engineering

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Under the Supervision of
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Key Words:
Transmission expansion planning problem, linear programming based model, mixed integer linear programming based model, mixed integer nonlinear programming using AC load flow, comparative study.

Summary:

Power system transmission expansion planning is one of the most important studies applied on the power grid; this study performs an important role in estimating the number of new transmission line which will be added to the network to achieve the loading conditions and technical constraints at target year with minimum cost.

More than one model can be used to perform this study. In this thesis we concentrate on a new model based on the AC load flow constraints equations, and compare the get results with the data get from the linear programming and mixed integer linear programming based model.

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List of symbols

a_k Constant coefficient for new line k

b_k Constant coefficient for new line k

b_k The imaginary part of the series admittance of line k

C_k Capital cost of line

C_{kj} Capital cost of step j associated with line k

C_g Cost of peaking generation system in LE/KVA

C_e Cost of unit energy in LE/KWA

F Objective function of any form

f_k Cost function of new line k

g_k The real part of the series admittance of line k

I_k Current flow on line k

I_{maxk} Maximum current flow on line k

I_{mk} The imaginary part of current flow I_k

I_{rk} The real part of current flow I_k

i Inflation rate

i_g Annual charge rate of generation system

g_i Constrained equations on the x variables with i=1,2,……….m

$\overline{K}$ Large positive value

$k1(i)$ Set of lines (existing and new) connected to bus i

$k2(l)$ Set of lines existing lines found in basic loop l

$k3(l)$ Set of new lines with basic loop l

LE Set of basic loops having only existing lines

L Number of basic loops

L_K Length of line k

l_s Loss factor

M Total number of lines (existing and proposed).

M1 Number of proposed lines

M2 Number of existing lines

N Number of buses (where bus N is the reference bus)

n Line life in years

nc(k) Maximum number of circuits associated with line k

Ns(k) The planning period of study (number of steps)

P_{kh}^{l} Power flow on segment l of step h of new line k

PL_k Annual energy loss cost associated with line k

PD_k Annual cost of demand loss associated with line k

PI_i Active power injected at bus i

PG_i Active power generated at bus i

PD_i Active power demand at bus i

$\mathrm{P_k}$ Real power flow on new line k

$\mathrm{P_{100+k}}$ Real power flow on line k in the opposite direction

$\mathrm{P_{maxk}}$ Maximum allowable power on line k

$\mathrm{P_k^i}$ The active power flow on line k from bus i

$\mathrm{P_k^j}$ The active power flow on line k from bus j

$\mathrm{q_k^i}$ The reactive power flow on line k from bus i

$\mathrm{q_k^j}$ The reactive power flow on line k from bus j

Q_k Reactive power flow on line k

QI_i Reactive power injected at bus i

QG_i Reactive power generated at bus i

QD_i Reactive power demand at bus i

QSi Reactive power injected from shunt reactive source existing at bus i, if any.

r_k Series Resistance of line k

$\acute{R_g}$ Reserve factor of generation system

S_k Apparent power flow on line k

S_{maxk} Maximum apparent power flow on line k

$\bar{S}_k$ Annual loss cost for unit power transmitted on line k

SD_k Annual demand cost for unit power transmitted on line k

S_{kj}^l Cost of unit power transmitted on segment l of step j of new line k

T Time in hours

V_{max} Maximum permissible voltage magnitude.

V_{min} Minimum permissible voltage magnitude.

V_i Voltage magnitude of bus i

V_j Voltage magnitude of bus j

w (h) Number of linear segments used for step h

$w(l)$ Number of new lines with basic loop l

x_{l_k} Series Reactance of line k per unit length

X_k Power or current flow on line k

X Set of variables of n dimension

Y_{ij} The magnitude of the element ijth of bus admittance matrix

Z_k Zero-one integer variable related to line k

Z_{kj} Zero – one integer variable associated with step j of line i

δ_{ijmax} Maximum angle permitted for line ij

δ_i Angle of voltage of bus i

δ_{max} Maximum line angle permitted

θ_{ij} The angle of transfer admittance between bus i and j

ABSTRACT

Present days power systems have a long stage and highly complicated transmissions systems which cost thousands of millions of dollars. Due to the steady annual growth rate, the expansion planning of these large size networks is a complicated nonlinear optimization problem .The solution of this problem using normal optimization tools has been made using nearly every type of these optimization tools, linear, nonlinear, integer and mixed integer programming techniques. The developed model for the application of each tool has its own merits and demerits. Normally, the DC load flow model has been utilized in all or most of these models.

In this thesis, two mathematical models has been presented to be solved by linear programming technique and mixed integer linear programming technique. The existence of the integer variables in the second case has proved to offer large advantages regarding both the cost function and the constrained equations .The capital cost of new lines is correctly simulated and the voltage loop equations containing new lines have been correctly simulated with the fact that a correct or highly accurate mathematical model has been reached .

In the last part of this thesis the AC load flow equations have been simplified and modified in order to replace DC load flow constrained equations by AC load flow one. This permits the considering of reactive power and bus voltage in the mathematical developed model. The AC load flow equations are the exact equations governing the power flow in the transmission system. Also bus voltage magnitudes constraints and stability constraints can be explicitly considered.

This mathematical model which depends on AC load flow gives the perfect planned network that satisfies all quality constraints imposed on the transmission system with the possible least cost .However, on the other side mixed integer - nonlinear programming technique is relativity difficult and consumes large computational time.