Dedication

To my Family

Teachers

and Friends

Acknowledgment

I would like to express my deep gratitude and appreciation to my supervisor **Prof. Salih Elhadi** and **Mahmoud Ahmed** for sincere encouragement at the early stages of project and patient guidance throughout

My appreciation extends to my family, teachers and friends for the material and moral support without which this work would not have been accomplished.

ABSTRACT

RELIABILITY DESIGN OF STEEL TRANSMISSION LINE

A reliability design method for statically determinate steel transmission lines towers and poles is presented. The method is in a Load and Resistance Factor Design (LRFD) format. The nominal load and resistance values for design are obtained from the mean values of probability distribution functions describing wind speed, radial ice thickness and yield stress. The load and resistance involving the coefficient of variation of the above variables and a target reliability index. Several cases demonstrate that use of the equations results in steel line having an actual reliability index nearly equal to the target reliability index.

Current design of steel transmission line was investigated through reviews of the International Electrical Safety Code (IESC) and Design of Steel Transmission line structures. Load models and analysis procedures which are significantly better than current methods are discussed.

Probability of failure calculations by the methods of numerical integration and the design point method are discussed. The mathematical relationship between probability of failure and the reliability index is explained.

The analysis and design by computer program, using reliability method gives more safety and economical results.

ملخص البحث

رؤية جديدة لتصميم إنشاءات خطوط نقل القدرة الكهربائية بطريقة الوثوقية

تقدم هذه الدراسة طريقة لتصميم خطوط نقل الكهرباء الحديدية (أبراج خطوط النقل) بالطريقة الوثوقية بصورة أكثر سلامة وأماناً واقتصاداً.

في هذه الطريقة يكون عامل الحمل والمقاومة هما المشكل لبنية التصميم:

في التصميم تم استعمال القيمة الأسمية للحمل والمقاومة اللتان تم إيجادهما من القيمة المتوسطة لدالة التوزيع الاحتمالي والتي تصف سرعة الرياح وسمك الثلوج ومعامل جهد الإنهيار.

تم استخدام معامل التغير في المتغيرات أعلاه ومؤشر الوثوقية (قرينة الوثوقية) المحدد في الحمل والمقاومة في عدد من الحالات المدروسة أوضحت إن نتائج المعادلات التي تم تطبيقها في خطوط نقل الكهرباء الحديدية ذات مؤشر وثوقية حقيقي يقارب جداً مؤشر الوثوقية المحدد (المستهدف).

تصميم خط النقل الحديدي الذي بين أيدينا تم تحقيقه على ضوء كود السلامة العالمي للكهرباء وبناء خطوط النقل الحديدية تمت دراسة نماذج الحمل وطريقة التحليل والتي وجدت أحسن من طرق التصميم العادية في التصميم وطريقة التحليل وذلك بصورة ملموسة.

تمت دراسة احتمال الإنهيار بطريقة الوثوقية وطريقة تصميم النقطة كذلك تم توضيح العلاقة واظهار نواتج الدراسة بشكل أوضح بين احتمال الإنهيار ومؤشر الوثوقية لهازوفرلند في الدراسة.

وقد أوصت الدراسة باستخدام طريقة الوثوقية في التحليل للحمولات والمتانة لتصميم خطوط نقل الطاقة وهي بهذا تكون أوسع استخداماً لمراعاتها عوامل الحمولات والبيئة المختلفة في التصميم ليكون التصميم أكثر أماناً واقتصادية وتم إعطاء النتائج في جداول في كل مرحلة من مراحل الحل في الفصل الخامس والسادس وتمت المقارنة من حيث معقولية الحل مع كودات اخرى ونتائج اخرى وتم تدوين ذلك عبر رسومات توضيحية وكذلك اعطاء قيم احتمالية الانهيار ومقارنتها مع جداول سلاس وكانت مطابقة للحل لاعطاء احتمالية الانهيار وقرينة الوثوقية.

List of content

Chapter Three
The researche proplem

The towers under considertation (the case study)

Chapter Four
Analysis and Design of the Research

Chapter Five

Proposed Analyses and design by Reliability

Chapter Six
Discussions and Conclusions

List of Tables

Conversion Table

1 ft = 0.3048 mm
1 ksi = 6.895 x 10^6 N/m^2
1 kip/ft = 14.59 x 10^6 N/m^2
1 ksi = 6.895N/mm^2(MPa)
1 kip.in = 0.133 kN.m
1 kip = 4.448 kN.m
Kip / square inch (ksi) =0.895 megancwton/square meter
Kip / square inch (ksi) = 0.0895 Newtin / square mm

Kip / square foot=47.88 KN/square meter
Moments
Foot kip = 1.356 KN.m
Inch kip= 0.113 KN.m
ZEBR (Electric Unit):

controller KS0066 or equivalent 4.5 V for three controller
or 3.3V single power input controller

List of Figures

Name figure	Page. No

LIST OF SYMBOLS

Symbol	Definition
A	area;
a	constant;
b	constant;
c	constant representing an analysis;
C_D	drag coefficient;
COV	coefficient of variation;
cdf	cumulative distribution function;
C_1	constant;
C_2	constant;
D	diameter;
D_n	nominal dead load;
D_m	mean dead load;
d_g	diameter at pole groundline;
d_t	diameter at pole tip;
d_x	diameter at location x;
E	modulus of elasticity;
E_I	flexural stiffness;
E_m	mean modulus of elasticity;
e_k	k^{th} value of modulus of elasticity;
F_D	drag force;
$F_x(x)$(cdf)	cumlative distribution function value at point x;
$F_x^{-1}([0,1])$	inverse cdf function;
$f_x(x)$	probability density function value at point x;
g	a function;
H	horizontal load;
h	a distance or length;
I	ice thickness;
I_m	mean ice thickness;

Symbol	Definition
Ib	pound;
Wt/ft	weigth per foot;
ft-Ib	foot- pound;
mph	miles per hour;
sec	second;
hr	hour;
psf	pounds per square foot;
pcf	pounds per cubic foot;
in.	inch;
ft	foot.
W_R	reference wind speed;
W_m	mean wind speed;
W_{mh}	hourly average wind speed;
W_n	nominal wind load;
W_x	wind speed at heigth x;
W_k	k^{th} value of wind speed;
W_1	wind load on pole;
W_2	weight of pole;
X	a random variable;
$\bar{X}$	the vector $(X_1, X_2,..X_n)$;
X_d	design value of X;
X_{nom}	nominal value of X;
X_o	roughness length;
X	distance;
X_R	reference height;
y	deflection;
α_s	span factor;
α_i	M/EI at node i (chapter 3, Appendix C);
α_i	sensitivity factor (Chapter 4);
β	reliability index ;

Symbol	Definition
σ	standard deviation;
σ_i^N	standard deviation of the equivalent normal distribution for variable I;
γ	load factor;
γ_D	dead load factor;
P_{r_m}	mean wind pressure;
P_r	pressure;
P_2	exponent describing MOR residual variation;
P	power law exponent;
pdf	probability density function;
Q	stress (load effects);
Q_m	mean value of load effects;
R	resistance, modulus of rupture;
R_e	Reynold's number;
R_m	mean value of resistance;
R_n	nominal resistance;
r_k	k^{th} value of mobulus of rupture;
S	section modulus;
S_d	setting depth;
U_f	fastest-mile wind speed;
U_m	fastest-minute wind speed;
U_x	mode of random variable x;
V_E	COV of Modulus of elasticity
V_I	COV of ice thickness;
V_p	COV of wind pressure;
V_Q	COV of load effects;
V_R	COV of resistance, COV of modulus of rupture;
V_W	COV of wind speed;
V_x	COV of random variable X;
W	Wind speed;

List of Abbreviations (Notations)

NQDIS	Number of dead load distribution
Q mean	Mean of Q load
Q cov	Coefficient of Variation of Q load
Q LCDF	CDF at lower limit of Q load
Q HCDF	CDF at upper limit of Q load
NPDIS	Type of wind load distribution
Rp mean	Mean of land
RPCOV	Coefficient of variation of load
RPLOCDF	Cdf at lower limit of P load
RP HSDF	Cdf at upper limit of load
NDIVQ	Number of divisions between lower and upper of Q load
NMSDIS	Number of type of material strength (MOR) distention
RMSMN	Mean of material strength (MOR)
RMSCV	Coefficient of variation of material strength
SPI	Location opf parameter material strength
RSSLCDF	Cdf at lower limit materials strength
RSSHCDF	Cdf at upper limit of material strength (MOR)
QSTDV	Standard deviation of Q load
RDSTDV	Standard deviation of P load
RMSSTD	Standard deviation of material shingle (MOR)
RMESTD	Standard deviation of material s
Q1(I)	Discrete values quantized Q distribute a takes values from 1 to ND/VQ
PQ load (I)	Probability area associated with discrete values of quantized Q distribute I take values from to NDIVQ
PJ (J)	Discrete values of quantized planning takes value from 1 to NDIVP
P load (J)	Probability area associated with discreet values of quantized P distribute J takes values from 1 to NDIVP
NST	Number of Spans
B	Width Of Column
D	Depth of column
Mom	Moment
Dh	Area due to more
BH	Area sector due to vertical deflection
Moment	Second moment due to deflection
PFQ	Probability of failure freshen to more limit state
PFE	Probability of failure freshen more limit stale
EC	Modules of Elasticity in compression

Other Electrical Notations	
NESC	National Electrical Safety Code
OHGW	Overhead Ground Wire
GSW	Galvanized Steel Wire
OPGW	Optical Ground Wire
ACSR	Aluminum Conductors Steel Reinforced
IEEE	Institute of Electrical and Electronic Engineers
ASCE	American Society of Civil Engineers

Forwarding

Importance of the study:

The transmission line structures which carry conductors of electric current has an important part of the overall engineering efforts to solve energy problems especially in distribution field.

The purpose of this research is to provide a formal mathematical solutions and beside that our country Sudan is a huge country that have far distances between electricity production distances and distribution area, cities, industrial areas, therefore, thousands kilometers of transmission lines will be expected to take place in Sudan over the next score of years.

A growing percentage of that net work is being constructed of steel towers and poles.

The project objective

1. Study the design parameters covering the design (loads, resistance) to concepts of reliability.
2. Study the mathematical of structural analysis of steel transmission line towers.
3. Study methods of calculations the probability of failure including computer program.
4. Determination of the probability based values for parameters covering the design (new proposed method).

The project objective was stated as:

"The objective of this project is to apply a probability-based approach to the analysis/design of steel transmission structures. This approach will be used to predict structural performance of the transmission line system. While the complete development of a probability-based design method for steel transmission structures is very complex, practical and useful results can be obtained through a reasonable level of effort which is aimed at assessing the 'feasibility of application of the probability-based methodology. In addition, the much needed quantification of certain material resistance aspects of the problem of design of steel transmission structures will be accomplished.

Research methodology

This study presents a proposed reliability design methodology for statically determinate and indeterminate, steel transmission structures. Objectives considered in developing the methodology are described below.

The first step was to identify the loads acting on a pole, or tower to quantify the resistance offered by the structure, and to identify the various load and resistance factors that might be used in the LRFD equations. Loads are the consequence of physical phenomena such as gravity, wind, and snow and it was necessary to establish the probability distributions which describe these variables. Likewise, the probability distributions for yield stress and modulus of elasticity were determined. Finally, structural geometry and details were examined to see how they affect the resistance. This is the content of Chapter 2.

The second step was to develop an appropriate stress analysis method for steel transmission tower line. The assumptions made for both linear and nonlinear analyses are enumerated. Results for and example pole structure analyzed considering both linear and nonlinear behavior are given, and the results are compared.

The third step was to determine the current design methodology for steel poles and tower terms of the load, resistance and analysis concepts presented in Chapters and . This entailed reviewing recent editions of the National Electrical Safety.

Discussions of wind data, fluid mechanics equations for velocity and pressure, wind variation with height, and various wind load factors are also given.