DIRECTIONAL CONSIDERATIONS FOR EXTREME WIND CLIMATIC EVENTS IN THE TRANSMISSION LINE DESIGN

ANYAKA, B. O.
Department of Electrical Engineering
University of Nigeria, Nsukka.

ABSTRACT
This paper takes a look at the importance and role of probability concepts structural design of transmission line. The reliability of transmission structure is clearly a function of the maximum loads that may be imposed over the useful life of the structure. These loads are, more often than not, caused by the extreme atmospheric events to which the line is exposed. Because the extreme wind speed and direction are impossible to predict exactly, and any prediction is subject to uncertainties, the reliability of the line may be assumed only in terms of the probability that the available strength will be adequate to withstand the lifetime maximum load. A spatial interpolation approach was used to correlate the meteorological wind speeds data. The statistical analysis of the data results in a Gumbel Type 1 distribution. Sample fit plot, directional wind speed plots and probability density function plots are also presented.

1. INTRODUCTION
Transmission lines form a vital component of any electric power system. They carry electrical energy from generating stations to the load points. During its operating life, a line will be subjected to an almost infinite variety of climatic events such as wind storms and varying temperatures. When a line is subjected to a climatic event, its response takes the form of stresses and displacements in each of its components. That response is called the load effect, which depends not only on the climatic event, but also on the actual configuration of the line. The traditional transmission line design process involves sizing of component to withstand a few carefully selected combinations of wind velocity and temperature. Once the components have the strength to withstand the loads produced by the few selected combinations, they are expected to have sufficient strength to resist most of the severe climatic events to which they will be subjected [1].

In the current design calculations of wind loads for overhead transmission and distribution lines the annual or weekly extreme wind is always assumed to act at a right angle to the line. This is a conservative assumption, which may result in unnecessarily expensive designs with the reliability values much higher than required. The difficulty in utilizing directional characteristics of the extreme wind events arises from the lack of credible data bases. Even though the meteorological stations usually record the speed and directions of high winds, these parameters apply at the sites where the data art obtained. The data stations will not generally be located along the route of a transmission line, and it will therefore be necessary to interpolate the design wind to the transmission line route from the estimation at the data locations [1]

In this paper, we will examine the effect that the inclusion of the distribution of wind directions has on the design span of the transmission line.

2. AN INFLUENCE OF WIND DIRECTION ON EXTREME WIND LOADS FOR OVERHEAD POWER LINES

It is intuitively obvious that both the loading on the line conductor and the resulting forces acting on the towers are greater when the winds blow in the direction normal to the line than when they come from any other direction. As it happens strong winds have usually preferred direction of movement resulting from environmental and geographical circumstances [2]. It is important to note that if the designer had his or her choice, all the transmission lines would preferably run in the same direction. However, it is quite unfortunate at least from the transmission line designer's point of view, that when our ancestors settled in certain areas and when power generating stations were and could be built, these circumstances were not taken into consideration. Therefore, the most the designer can do now is to take the available directional information into account when designing an overhead line.

A straight forward procedure for analyzing line loadings, taking into consideration wind directions, was proposed by Krishnasamy [2], The approach is clearly stated in the design methodology of this paper.

FREQUENCY OF RIGHT OF WAY LOSSES CAUSED BY TORNADOES

When there is a requirement for the transportation of large amount of electrical power between two given points electrical utilities often build several transmission circuits along the same right of way (ROW).Economy (the cost of land) and public demands are the main reasons for this practice [3] From the reliability point of view, however, it would be much more expedient to have the circuits built along different ROWs, since this would certainly reduce the chance of all circuits being lost at the same time as a result of the same extreme atmospheric event. The potential loss of all circuits on a common ROW is great interest to power system planners and analysts. Quite often, the permanent loss of towers and conductors comes about through high winds or tornadoes activity.

4. DESIGN METHODOLOGY

In the analysis of the line loadings, the wind direction was taken into account. The approach is to separate extreme wind data into several convenient directional sectors and then obtain the probability distribution functions of the winds in each of the sector. After which, possible line orientations are defined. Then for each orientation loadings, analysis is performed, taking into account directional wind information, as described in krishnasamy [2]. Wind speed data obtained from the meteorological section of the Nigerian Civil Aviation Lagos were used for analysis.

5. DESIGN OF THE LINE SPAN

In order to obtain a reasonably accurate estimate of wind directions, the 360^0 circumference was divided into 16 sectors and eight different line orientations as shown in fig. 1 and table 1.

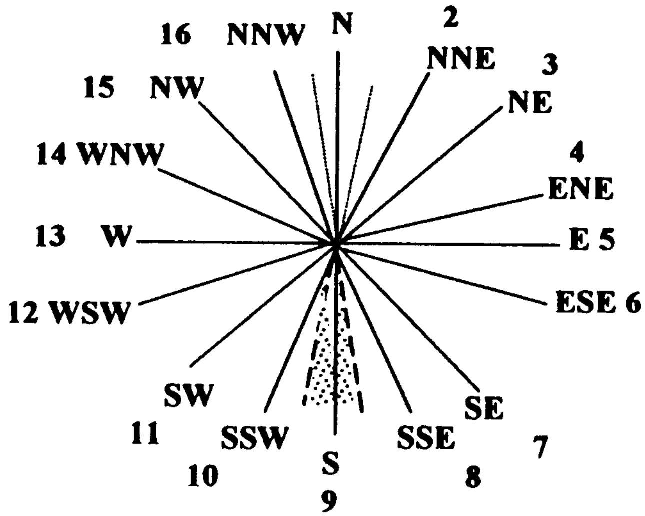


Fig.1 sixteen section orientations for extreme wind speed

TABLE 1 EIGHT LINE ORIENTATION FOR EXTREME WIND SPEED VALUES

LINE	N-S	NNE-SSW	NE-SW	ENE- WSW
ORIENTATION	E-W	ESE- WNW	SE-NW	SSE-NNW

Using Fig. 1 and the weather data from the meteorological station, eight sets of directional annual extreme wind speeds were obtained. The statistical analysis of the annual extreme wind speeds by direction and the annual extreme wind speeds normal to line orientation results in a Gumbel Type 1 distribution for each of the eight sets of directional extreme wind speed data. A sample fit for the NE - SW direction is shown in Fig. 2. A set of eight directional wind speed plots are shown in Fig 3, along with a comparable plot of non-directional extreme wind speeds.

The results of the annual extreme wind speeds normal to line orientation were summarized in the form of appropriate probability density function as shown in Fig4. The probability distributions of the line loadings were computed and the results are shown in Fig. 5

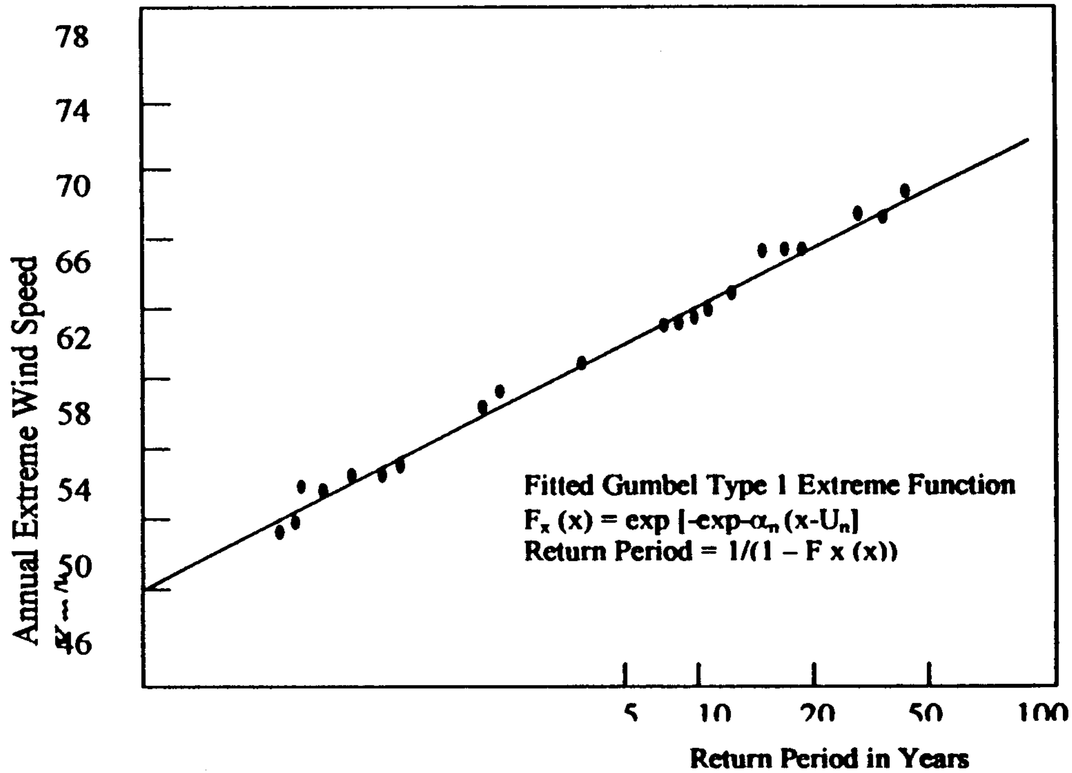


Fig. 2 Set of Annual Extreme Wind Speeds in NE-SW Direction fitted by Type 1 Asymptotic Extreme Value Distribution

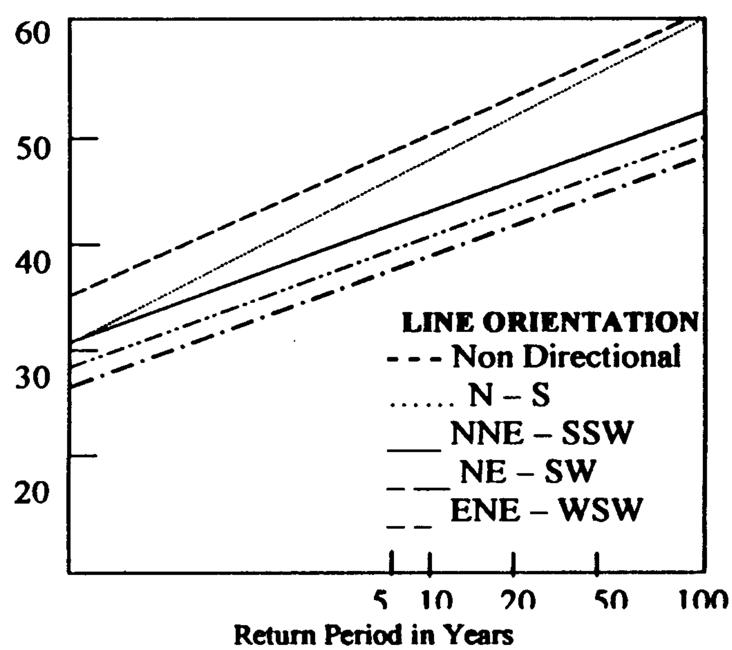
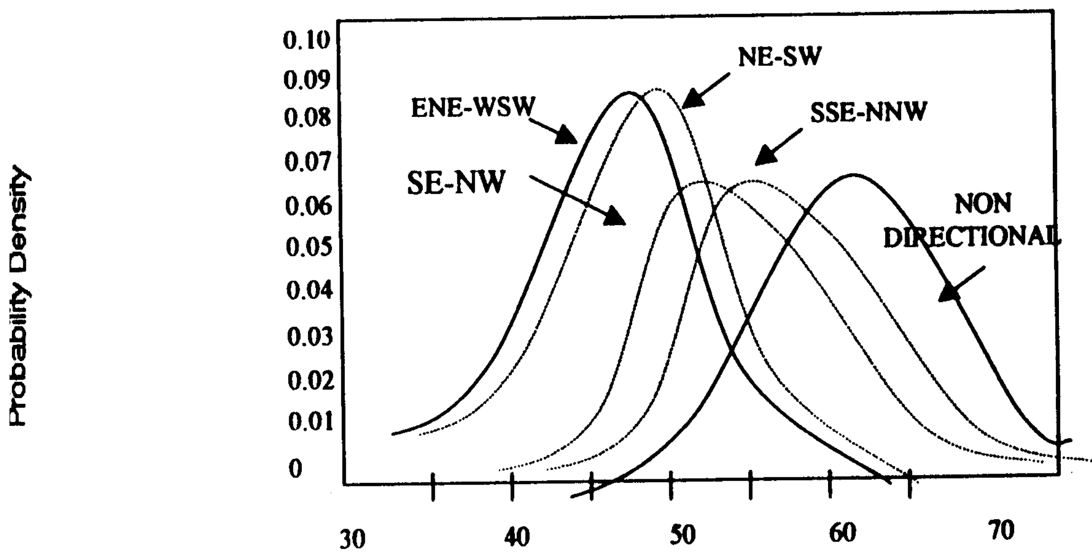


Fig. 3 Annual Extreme Wind Speed plots by Line Orientation

6. COMPUTATION OF THE ALLOWABLE SPAN LENGTH

To compute the allowable span length, the procedure proposed by Krishnasamy [2] as shown in Fig. 6 was used. Fig. 6 represents two PDF functions of extreme winds load corresponding to two different span lengths. The allowable design load at the end of each arm shown in Fig. 6 includes consideration of simultaneous loads on the tower. The shaded areas represent, of course, the probability of tower failure in each of the two cases.

Sample calculations were conducted for a double-circuit 500KVA lattice type tower For each of the eight line orientations, interactive calculations of conductor loading caused by the extreme wind conditions were performed by varying the span lengths to obtain a critical span length resulting in the probability failure equal to 0.01 (100 year return period). Four conductor bundles (each having a 24.13mm diameter) for the six phases were considered in all computations. For comparison purposes, an additional computation was carried out for the non- directional wind distribution.



Extreme Mean Wind Speed (km/h)

Fig.4 probability Density Functions of the Extreme Winds Speeds for typical line orientations

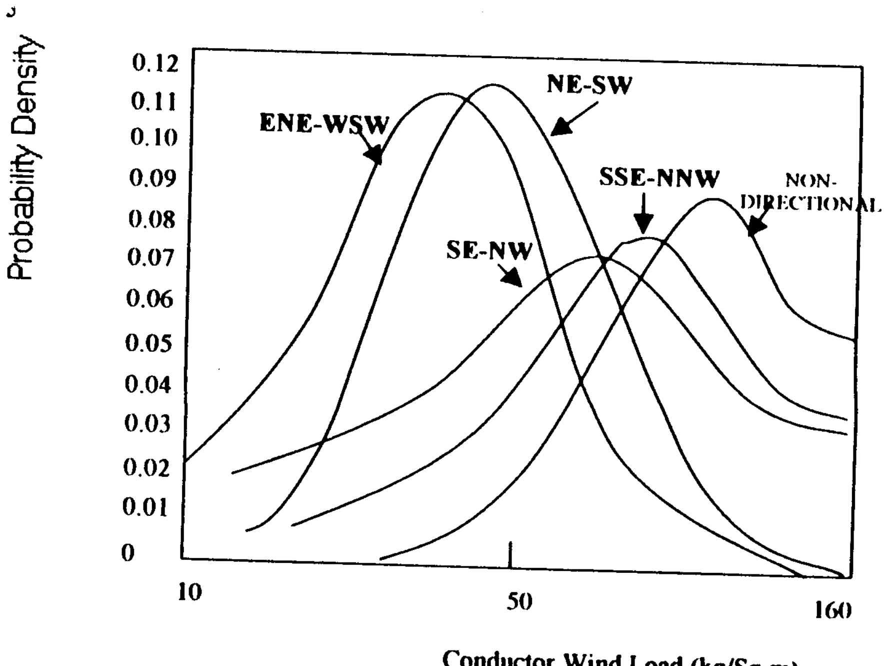


Fig. 5 Probability Density Functions of the Extreme Wind Loads for Typical line Orientations

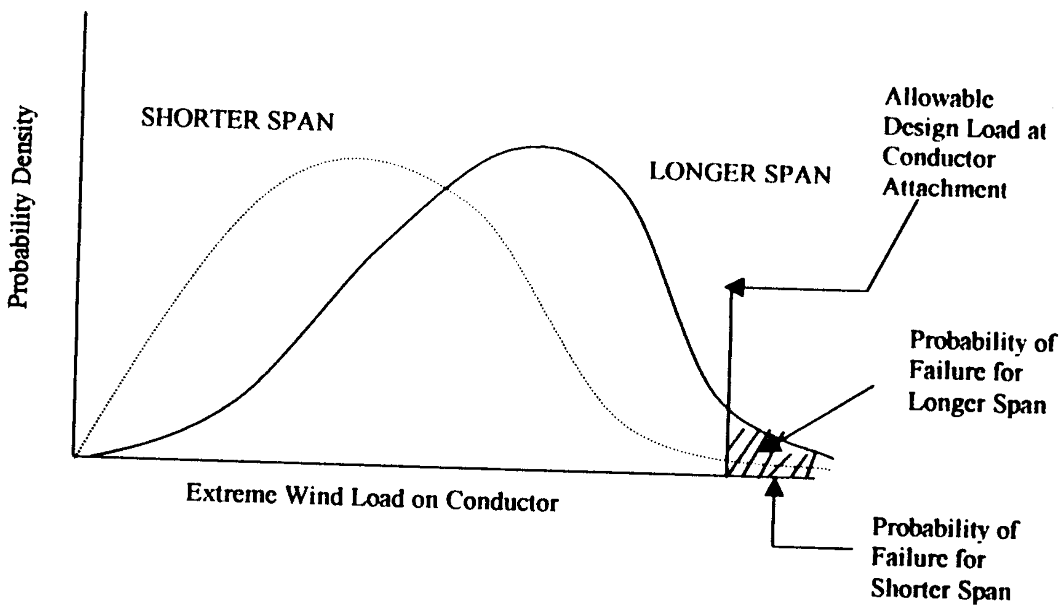


Fig. 6 Concept of the Probability of Tower Failure under Transverse Wind Loads

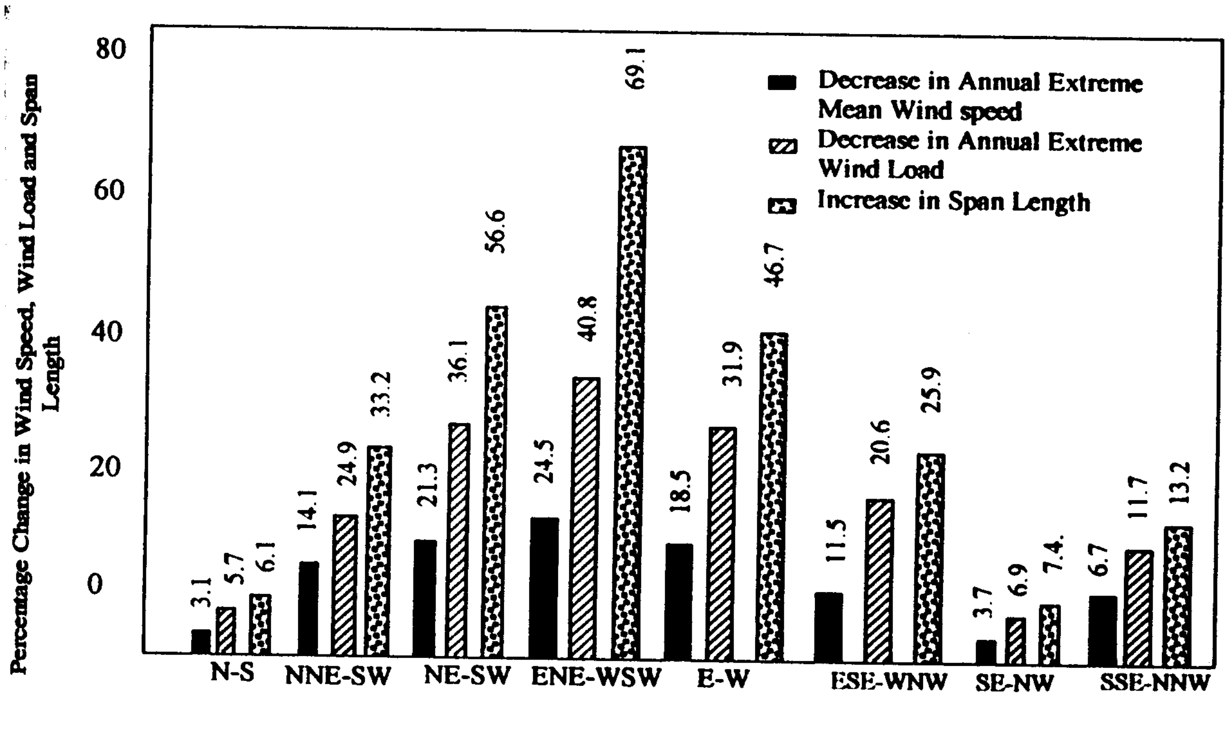


Fig. 7 Change in Annual Extreme Wind Speed, Wind Load, and Span Length for Different Line Orientations

CONCLUSION

A probability consideration for structural design of high-voltage electric transmission lines taking into account the wind direction was examined. As can be observed from Figs. 4 and 5, the mean values of the non-directional wind speed and loading are always greater than the corresponding values in directional cases. In all eight directional cases, the critical span length was also higher than in the non-directional case. The relative decreases in the mean wind speed and the line loading as compared with the non-directional case, together with the relative increase in the critical span length, are shown in Fig. 7. In Fig. 7, we can observe that if the proposed line were to run in the ENE-WSW direction, the design span length could be almost 70% longer than the design span length obtained with directional information not taken into account. Thus, the saving in the line construction costs could be significant if the effect of the wind direction were taken into account in the calculation of the design wind load.

REFERENCES

[1] Ghannoun, E., and Orawiski, G. Reliability Based Design of Transmission Lines According, to Recent Advances by IEC and ClGRE, in Probability Methods Applied to Electrical Power Systems, Edited by S. Krishnasamy, Pergamon Press, Oxford, England, pp. 125 - 136. 1987

[2] Krishnasamy, S. G. Assessment of Weather Induced Transmission Line Loads on a Probability Bases, IEEE Trans, vol. PAS-104 No.9, pp 2510 - 2514. 1985

[3] Peyrot, A.H and Dagher, H.J. Reliability-base Design of

transmission lines, J. Struct. Eng, ASCR, vol 110 No .11, pp 2758-2775 1984.

[4] Mozer, J.D Digioa, A.M, and phlman, J.C. practical code format for probability- based Design of Transmission structures in probabilistic Methods Applied to Electric power systems, Edited by S. Krishnasmy pergamon press, Oxford, England,pp89-99,1987.

[5] Nigeria Civil Aviation Lagos Statistical Meteorological data Book, 1990-2003.

[6] Krishnasamy S.G. Ford, G.I and Orde, C.L predicting the structural performance of transmission Line, Updated by Reconducting, IEE trans. Vol PAS-100,No. 5, pp. 2271-2270.198.

[7] Electric Power Research Institute (EPRI) Reliability-Based Design of Transmission Line Structure Final Report, vol 1-Methods. Reports, EPRIEL-4793.1987a

[8] Electric Power Research Institute (EPRI) Reliability – Based Design of Transmission Line Structure: Final Report. Vol 2 Appendixes. Report EPRII.4793.1987b

[9] Elliogwood B.R. Mac Gregor, J.G. Galambo.I.V and Cornell. C.A Probability- Based Criteria Load Factors and Load Combination 1 Stuct. Div. ASCE Vol.108. No. S15. Pp 978-995 1982

[10] Anders G.J. Daneno, P.I and Neudorl F.G Computing of Frequency of Right of Way Losses Due to Lornadoes, IEFE Trans Vol. PAS 103, No.9, PP 1675-2080.1984

[11] ASCE Committee on Electrical Transmission Structures. Guidelines for Transmission Line Structural Loading. American Society of Civil Engineering. New York 1984