ALTERNATIVE DESIGN OF FOUNDATIONS SUBJECTED TO UPLIFT FOR TRANSMISSION LINE TOWER

PURUSHOTHAMAN NAIR S/O NARAYANAN NAIR

UNIVERSITY TECHNOLOGY OF MALAYSIA

Dedicated to my late father, beloved mother, loveliest wife S.Gouri and dearest daughter P.Yasunthra who inspired me until the completion of this study and at times I had to turn down their entertainment schedule just to continue my study.

ACKNOWLEDGEMENT

I thank God for giving me strength to complete this thesis. Many people made this thesis possible. First of all, I would like to extent my greatest thank you to my project supervisor, Dr. Nurly Gofar for her effort and concern.

I would like to express my gratitude to Ir. Wong Chung Hoo (General Manager of TNB Transmission – Asset Development Department), En. Suhaimi Ishak (Chief Engineer – Major Project), Asset Development Department managers En. Mohd Zahid Hj. Abu Bakar, En. Mohd Shukri Rahimi Zainal Abidin, Ir. Megat Kamil Azman Megat Ruskamarani, En. Kumar Mariappan, En. Mohd Azhar Ahmad, En. Mohd Halil Harun (Engineering and Design), En. Mansor Rohani (Transmission Technology Sdn. Bhd), 275kV Melaka – Kelemak Project Team, Ir. Selvem Ramen (Opus International, Wellington, New Zealand) and all other TNB staff and also TNB transmission line contractor's staff for the encouragement and support in writing this project report and also throughout my master program.

Finally, I would like to thank all those who have contributed, either directly or indirectly to the preparation, research and compilation of this project report.

ABSTRACT

Transmission line is a medium to carry power loads from one station to another station, therefore; it is one of the most important projects in power business. An efficient design of foundations for transmission line towers has always been a challenge for the engineers due to the variety and cyclic nature of the loads. Foundations especially for the four legged type are subjected to combinations of all types of loads i.e: compression, uplift, torsion and shear. The current practice of non-shored excavation for the construction of the transmission tower foundation does not comply with the safety regulation. Thus, the main objective of this study is to evaluate current design practices for standard undercut foundations (1 Undercut and 2 Undercut) for transmission line projects undertaken by TNB. Furthermore, alternative foundation design and their performance will be in term of safety and concrete volume. The study is based on an ongoing project i.e a 275Kv Transmission Line from Melaka to Kelemak. In this research, drilled shaft was identified as alternative foundation for transmission line towers. Even-though the construction cost is higher than the conventional method, but drilled shaft can eliminate or reduce unsafe act and unsafe condition thus will reduce the incidents or near misses. Furthermore drilled shaft also comply with the requirement of FMA and OSHA which was identified as a main objective of this study.

ABSTRAK

Menara talian penghantaran ialah struktur yang di bina untuk membawa arus elektrik dari suatu pencawang (PMU) ke pencawang (PMU) yang lain. Rekabentuk asas menara (kebiasannya berkaki empat) yang effisien sentiasa menjadi cabaran kepada jurutera-jurutera rekabentuk disebabkan oleh kepelbagaian beban yang ditanggungnya. Menara penghantaran terdiri dari beberapa jenis yang berbeza dan direkabentuk mengikut ketinggian dan keupayaan menara tersebut menanggung beban rentang kabel (weight span), beban mampatan (compression load), beban angin (wind load) serta beban terangkat (uplift load). Pembinaan asas menara yang dipraktikkan kini tidak memenuhi kehendak perundangan atau Akta Keselamatan dan Kesihatan Pekerjaan dimana tupang atau penghadang lubang korekan asas tidak disediakan disebabkan saiz terutama bagi asas biasa (tanpa cerucuk) kelas 1 Undercut dan 2 Undercut yang terlalu kecil (1 meter x 1 meter sahaja). Objektif utama kajian ini adalah untuk menganalisa kaedah rekabentuk sediada dan mencadangkan asas alternatif serta memenuhi kehendak perundangan dan Akta Keselamatan dan Kesihatan Pekerjaan. Perbandingan kuantiti konkrit dan kos serta penilaian keselamatan di tapakbina bagi kaedah yang sediada dan kaedah alternatif juga dikaji. Kajian ini dijalankan keatas projek talian atas 275kV dari PMU Melaka ke PMU Kelemak yang kini dalam pembinaan. Shaf gerekan (drilled shaft) dikenalpasti sebagai asas alternatif bagi menara talian penghantaran. Hasil kajian mendapati kos pembinaan bagi kaedah alternatif ini meningkat jika dibandingkan dengan kaedah sediada tetapi dari aspek keselamatan pula kaedah alternatif ini dapat mengurangkan risiko kemalangan serta dapat mengurangkan keadaan-keadaan merbahaya dan perilaku merbahaya serta insiden hampir (near misses). Shaf gerekan (drilled shaft) juga memenuhi kehendak perundangan dan Akta Keselamatan dan Kesihatan Perkerjaan (FMA dan OSHA) dan memenuhi objektif utama kajian ini.

TABLES OF CONTENT

LIST OF TABLE

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

Achievement of construction industry is a symbol of development for every country. Billions of ringgit is spent annually on Malaysian construction industry by both government and private sector. Basically there are two types of construction or development; for public purposes (infrastructure, utilities and health development) and for commercial purposes (commercial buildings and business developments). In the past few decades, the electric power industries in Malaysia have been developing power transmission system to follow up with the rapid growth of the power demand.

Tenaga Nasional Berhad (TNB) is the entity that is responsible to supply electricity to its customers mainly publics in Peninsular Malaysia with the least disruption to the system. A significant annoyance to the public is when important projects are not completed in a timely manner. Transmission line is a medium to carry power loads from one station to another station, therefore; it is one of the most important projects in power business. The interruption in transmission line system affects the countries economic growth.

An efficient design of foundations for transmission line towers has always been a challenge for the engineers due to the variety and cyclic nature of the loads. Foundations especially for the four legged towers are subjected to combinations of all types of loads i.e: compression, tension, torsion and shear. The cyclic nature of the loads further complicates the situation. Available design parameters proposed by different researches are mostly based on the monotonic loading conditions and are not directly applicable for tower foundations.

Safety is a concern in the construction of transmission line foundation. In the field of transmission line structural design, the Electric Power Research Institute has sponsored research studies directed towards the implementation of new safety concepts for the design of transmission line structures (e.g. Criswell and Vanderbilt, 1987). Parallel research and development efforts in this field have also been undertaken by the ASCE Task Committee on Structural Loadings (Task Committee on Structural Loadings, 1991) and the IEC Technical Committee 11 (IEC, 1991).

There is also clear trend toward adopting more rational and consistent methods of addressing safety in construction field. By improving the control of safety in the design process, the number of over designed foundations and the potential high cost of failure or repair associated with foundations having low levels of safety can be minimized. Furthermore, the incompatibility between structural and foundation design procedures can be avoided. At present foundations for transmission line structures are designed using the conventional global factor of safety approach (Kulhawy, et.al., 1983; Joint Committee of IEEE and ASCE, 1985).

The first transmission line in Malaysia was built in 1927 which was carrying 33kV voltage from Bangsar Power Station to Gombak Lanes and surrounding areas within city, and followed by first 66kV transmission line from Bangsar Power Station to

Klang. The first 66kv transmission line built by CEB was from Bangsar Power Station to Connaught Bridge Power Station in 1952. In 1953 the Connaught Bridge Power Station was fully completed with transmission line connecting Bangi, Seremban and Melaka. It is also the start of National Grid System; this followed by first 132kV transmission line between Connaught Bridge and Cameron Highland's Sultan Yussoff Hydro Station was built in 1963 by CEB. Then in 1970 the first 275kV transmission line was built between Tuanku Jaafar Power Station to Kuala Lumpur. Then in 1994 National Grid System was strengthened by 500kV transmission line system from Gurun, Kedah to Pasir Gudang, Johor. Currently 275kV (1000MVA) grid is under construction especially Central Area Grid Reinforcement Project which will strengthened the electricity system in Klang Valley.

Foundation for transmission line in Malaysia can be classified in three groups: normal standardized pad footing, pile foundation or pile cap and rock foundation. Standardized pad footings have been designed for several foundation conditions. The range of likely foundation conditions are represented by five main categories termed Foundation Class Number based mainly on soil strength, and described in terms of the ultimate bearing capacity, ultimate passive pressure and bulk density. Most transmission line towers in Malaysia are constructed on standard pad footing foundation. Pile foundation or pile-cap is used or constructed when the bearing capacity of soil is below 100kPa. Rock foundation is constructed when the hard stratum or rock layer was at shallow depth where the soil weight and frustum soil weight cannot resist the uplift capacity.

For the standard pad footing, the size of excavation is between 1 and 2 m depending on the bearing capacity of the soil, while the depth is 4 m. Thus, there is a very limited working clearance for the workers to do the foundation work. One regulation stated by Factories and Machinery (Building Operations and Works of Engineering Construction) (Safety) Regulations, 1986, (Part XII) (FMA) and OSHA (Occupational Safety and Health) Act 1994 regarding the construction of transmission

line foundation is that all excavation which exceeds 1.5 m depth shall be shored to prevent collapsed of excavation wall. However, TNB has not been enforcing the use the shored excavation for the standard pad foundation, thus safety is a concern.

There are several cases recorded where the excavated wall collapsed but not any death cases recorded to date. There are also space constraints especially if transmission line is constructed at city area where there are lot of infrastructure relocation needed due to excavation works, thus will increase the cost of construction.

1.2 Problem Statement

As mentioned above, the FMA and OSHA have regulated that all excavation which exceeds 1.5 m shall be shored to prevent collapsed of excavation wall since 1994. Despite of the regulation, TNB has been practicing a non-shored excavation for the construction of the line transmission foundation since 1976, and still practicing it up to now. The dimension of footing 1 undercut and 2 undercut is only 1.0 m x 1.0 m with 4 m depth of excavation, thus there is very limited working clearance to do reinforcement installation and concreting in the pit. The standard foundations is designed in such way mainly to reduce the volume of concrete thus to reduce the cost of construction.

Due to the fact that the standard foundation size is not meeting the FMA and OHSA requirements, an alternative design for foundation of transmission line should be considered. However, no study has been done so far to determine alternative design for this standard foundation (1 undercut and 2 undercut). It is therefore important that a thorough analysis is carried out to identify alternative design which is safe and cost effective.

1.3 Objective

The main objectives of the study are as follows:

1) To study the current design practices for transmission line towers foundation based in Malaysia.
2) To identify alternative design for transmission towers foundations in cohesive soil.
3) To evaluate performance of the alternative design in term of safety and volume of concrete (cost).

1.4 Scope of Study

This study was confined to the following scopes:

1) This study only focus on the standardized undercut foundations on cohesive soil for 275kV transmission line projects undertaken by TNB.
2) The field data (safety performance) and design data (soil parameters, soil investigation data, loading data and other related design data) for these studies were collected from 275kV transmission line project from PMU Melaka to PMU Kelemak.
3) This study is to focus on the writer's own design work and compare with existing design for selected case study (275kV Transmission Line PMU Melaka to PMU Kelemak) only.

REFERENCES

Adams, J.I., and Hayes, D.C., (1967). The uplift Capacity of Shallow Foundations. Ontario Hydro Research Quartely 19.1

Alexander J. Verstraetan.(1987). "Steel Pile Foundations For Transmission Line Towers, as Used in Western Europe", Proc. 2nd Int. Conf. of Deep Foundation Institute, Luxemberg.

Baldwin, J.D., Manthei, J.M., Rothbart, H. and Harris, R.B. (1971). Causes of delay in construction industry, Journal of Construction Division, ASCE, 97(CO2) p 177-187.

Balla, A., (1961) The Resistance To Breaking Out of Mushroom Foundations For Pylons. Proc 5th Int.Conf. Soil Mechanic and Foundation Eng.1

Been, K., Clark, J.I., & Livingstone, W.R. (1993) Verification & Calibration Studies for New CAN/CSA- S472 Foundations of Ofshore Structures, Canadian Geotechnical Journal, 30(3), p 515-525.

Bolton, M. D. (1981) Limit State Design in Geotechnical Engineering", Ground Engineering, 14 (6), p 39-46.

Bowles J.E,(1988).Foundation Analysis and Design 4th Edition. Mc. Graw Hill Int.

Crisswell, M.E & Vanderbilt, M. (1987) Reliability-Based design of Transmission Line Structures Methods, Report EL-4793(1), EPRI, Palo Altoi, 473 p.

DiGioia, A. M., Jr. & Rojas-Gonzalez, L. F., "Application of Reliability-Based Design Concepts to Transmission Line Structure Foundations', Paper 90 SM 307-9 PWRD, IEEE Power Engineering Society Summer Meeting, New York, 1990, 7 p.

DiGioia, A. M., Jr. & Rojas-Gonzalez, L. F (1991) Application of Reliability-Based Design Concepts to Transmission Line Structure Foundations: Part II, Paper 91 WM 091-9 PWRD, IEEE Power Engineering Society Winter Meeting, New York, 7p.

Hansen, J. B (1965) Philosophy of Foundation Design: Design Criteria, Safety Factors & Settlement Limits, Symposium on Bearing Capacity & Settlement of Foundations, Duke University, Durham, 1 -13.

Kulhawy, F.H., (1984) ASCE Drilled Shaft Standard: University Perspective", Analysis & Design of Pile Foundations, Ed. J. R. Meyer, ASCE, New York, p. 390 – 395.

Kulhawy, F. H., Trautmann, C. H., Beech, J. F., O'Rourke, T.D McGuire, W., Wood, W. A., Capano, C. (1983) Transmission Line Structure foundations for Uplift-Compression Loading, Report EL-2 870, Electric Power Research Institute, Palo Alto, 1983, 412 p.

Meyerhof. G. G (1970) Safety Factors in Soil Mechanics, Canadian Geotechnical Journal, 7(4), Nov 1970, 349 – 355.

Meyerhof G. G. (1970) Safety Factors & Limit States Analysis in Geotechnical Engineering", Canadian Geotechnical Journal, 21 (1), Feb 1984, 1-7.

Smith G.N, (1982),Mechanics For Civil and Mining Engineers, 5th Edition' Granada Pub.

Smith, G. N.(1981)Probability Theory in Geotechnics – An introduction", Ground Engineering, 14 (7), pp. 24 -34.

Lambe, T.W. & Silva, F. 1988. The determination of soil strength for stability analysis. Proc. 13th Southeast Asian Geot. Conf., Taipei.

Orchant, C. J., Kulhawy, F. H., & Trautmann, C. H., "Reliability-Based Foundation Design for Transmission Line Structures: Critical Evaluation of In-Situ Test Methods", Report EL-5507(2), Electric Power Research Institute,Palo Alto, 1988, 214 p.

Task Committee on Structural loading (J. D. Mozer, Chair), Guidelines for Electrical Transmission line Structural Loading, Manual & Report on Engineering Practice 74, ASCE, New York, 1991, 139 p.