

Chapter 1

Introduction

1.1 Background

The space required for building safe and reliable electrical power lines has become an increasing problem in South Africa, as it has internationally. Since the tall structures visually affect the surroundings and use up wide servitudes (up to 80 meters for $765kV$), land owners are more hesitant to accommodate these lines.

Visual impact and land requirement is considerably less for double circuit ($765kV$) configuration structures compared with multiple circuits at lower voltages ($400kV$). Figure 1.1 shows this effect for equivalent electrical power transfer. Thus, the requirement to minimize visual impact and reduce tower footprint is the main motivation behind the development of the $765kV$ and $400kV$, double circuit alternating current (AC) transmission lines.



Figure 1.1: Effect of multiple power line circuits in a single corridor. The corridors transmit equivalent electrical power. Left: A corridor with four $400kV$ circuits. Middle: A corridor with two $765kV$ circuits. Right: A corridor with one $765kV$ double circuit.

Because there is an increase of electrical constraints (ground clearance and phase-to-phase clearance), multiple conductor bundles, higher reliabil-

ity and the necessity to limit foundation footprints, there is a tremendous load increase on structural members from tower load conditions (*IEC 60826 - Design criteria of overhead transmission lines* 2003).

The conventional use of standard angular hot-rolled sections for tower members (bracing members, leg members, etc.) presents a limiting factor, owing to the high loads and constraints. Furthermore, the required axial forces encountered with double circuit transmission towers exceed the load carrying capacity of the standard angular members, when a compact tower with low visibility is required. Power line towers built with circular hollow sections (CHS) can withstand the increased load capacity, while providing a small footprint, with a low visual impact. Korea's First 765-kV Double-Circuit Line. [ON-LINE] Available at: http://www.tdworld.com/overhead_transmission/power_koreas_first_kv/. [Accessed 02 October 2012]

1.2 Aim of this research

The aim of this research is to design and build a power line tower using circular hollow sections, and through the process, prove that current design software, current design standards, and current manufacturing techniques can successfully be implemented to develop towers with a small footprint and a low visual impact.

1.3 Research objectives

In order to achieve the aim of this research, the following objectives have been identified:

- I Perform a comprehensive literature review on the current design practices; the various cross sections available that could be used in power line tower design and also determine which of the cross sections will actually outperform the conventional angle cross sections. An important aspect of the literature review is to identify current connection design standards used to join hollow cross section members.

- II Generate a 3D model of the test tower and propose practical connection layouts.

- III Design and analyse the proposed circular hollow section tower top based on typical tower load conditions.
- IV Fabricate and test the new circular hollow section tower top.

It should be mentioned at the outset of this research that certain aspects of the tower design process will not be considered here. They are:

- I The process of determining the geometry of transmission line towers. The geometry of transmission towers is not primarily driven by structural parameters, but is determined through a comprehensive electrical analysis of the electrical system, considering conductor configuration (delta, vertical, horizontal etc.), conductor bundles, electrical clearances, magnetic field levels, and reliability, to name only a few.
- II This research will not consider the specific design process of transmission line towers; instead it will rather focus more on practical implementation of circular hollow sections. The reason for this is that, through the electrical analysis, it was shown that the vertical double circuit tower is the best solution for distributing large quantities of electrical energy.
- III Not all the load cases usually considered for designing power line towers are considered in this research. It is usual to consider a large number of load combinations affecting a family of structures. Only four critical load cases are considered.

It is important to the author that this research serve as a guide to practicing engineers who intend to use circular hollow sections in power line tower design; specifically changing the mindset of traditional designers that good alternatives exist and, under a controlled environment, welds are not all that bad.

1.4 Outline of dissertation

The proposed design and manufacturing processes will be demonstrated with a test tower (figure 1.2). The test tower consists of the top sections of a small

power line tower. It contains all the connection types of a full tower, but it is cheaper to manufacture because it is smaller. The complexity of the tower is sufficient to demonstrate and validate the design process.



Figure 1.2: Picture showing the fabricated tubular test tower.

The test tower is designed using current design standards and Prokon structural analysis software. Prokon is a finite element analysis (FEA) software package currently used by civil and structural designers in the South African market. This is locally developed software with training and support capabilities. The software is used to calculate the forces in each member. The calculated forces are then used together with the design standards to find suitable connection- and member geometry.

The design of critical parts of the tower is verified using a complete three-dimensional FEA software package, Ansys. The tower is fitted with strain gauges and forces simulating actual load conditions are applied to the tower. The measured stresses are compared with the calculated stresses in order to validate the design process.

The chapters that follow will firstly consider current design practices of angle iron transmission structures; secondly, circular hollow sections (CHS) are compared with various standard cross sections in order to highlight the advantages of circular hollow sections; thirdly, standard strength formulae for hollow sections are reviewed. Thereafter, the 3D modeling and manufacturing processes are discussed, followed by the analysis (analytical and numerical) of the tower. The theoretical results are then compared with physical test data in order to validate the design process.