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An evaluation of the environmental burdens of present and alternative materials used for electricity transmission

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Abstract

This paper describes research using life cycle analysis assessment techniques to determine the environmental impacts associated with the use of present and possible alternative materials utilised in all aspects of high voltage electricity transmission. The study focuses on the National Grid system in England and Wales, where the majority of high voltage electricity is transmitted through steel and aluminium conductors supported above the ground by mild steel lattice type towers. A major aspect of the study is to address the effects of different corrosive environments to which the tower materials are exposed: namely rural, industrial and coastal locations.

Keywords: Conductors; Transmission towers; Electricity transmission; Life cycle analysis; Overhead line

1. Introduction

The National Grid is responsible for the transmission of electricity across England and Wales. This typically is achieved through the use of 400 mm^2 steel/aluminium cross-section conductors supported above the ground by 50 m high transmission towers, similar to Fig. 1 [1]. With an increasing company-wide environmental awareness, along with recent compliance to ISO 14001 [2], National Grid is continually striving towards a more environmentally sound method of electricity transmission.

To enable high voltage electricity transmission to take place, many different materials are required. For example, National Grid are currently operating some 7500 route kilometres of overhead line throughout England and Wales, which alone represents a considerable volume of steel and aluminium. In addition, if the transmission towers and insulators are also considered, it can be seen that a significant quantity of materials is being processed. The materials and manufacturing processes used to produce the necessary transmission equipment impose environmental impacts.

A detailed appreciation and understanding of the main environmental burdens can be obtained by undertaking a life cycle assessment (LCA) on the integral parts of the towers, conductors and insulators. In addition to the consideration of those materials and processes currently used, there are potential alternatives that may impose fewer environmental burdens than their traditional counterparts. By evaluating these associated burdens in relation to electricity transmission, National Grid will possess a more in-depth knowledge of their own products and have an opportunity to rationally consider alternative materials or processes.

1.1. Life cycle assessment (LCA)

LCA is becoming an increasingly popular tool for environmental management. Rather than focusing purely on waste produced or emissions created at the manufacturing stage of a product, LCA goes much further in determining all the environmental burdens created through the entire life cycle of a product. LCA evaluates the environmental burdens of a product from the extraction of

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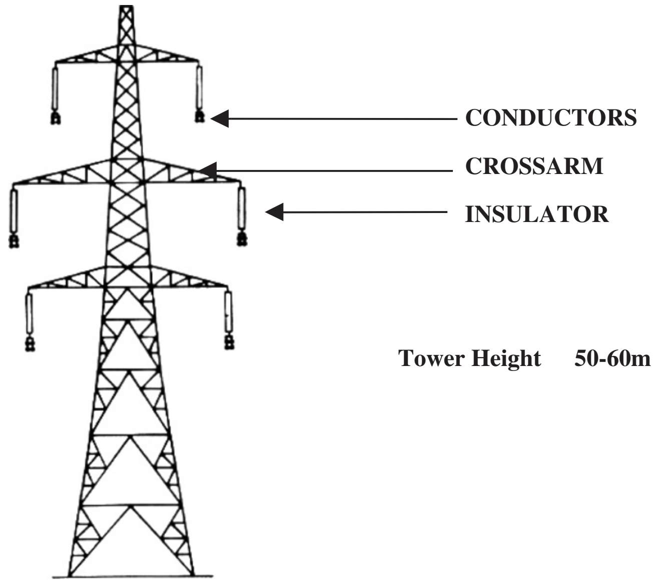

Fig. 1. Standard 400 kV Tower used on the National Grid System (ACSR: Aluminium conductor, steel reinforced).

its raw materials right the way through to its disposal or recycling. It involves cradle-to-grave analysis of production systems and provides comprehensive evaluations of all upstream and downstream energy inputs and environmental emissions. It should be noted, however, that LCA can be costly and time consuming and so its use as an analysis technique in both the public and private sector is limited.

LCA differs from other environmental analysis tools primarily in the way in which the boundary between 'systems' and environment is drawn. More familiar tools like Environmental Impact Assessment concentrate on a process or a specific site [3]. A considerable amount of research has been undertaken in the last few years to develop LCA methodology. There are three main foci for this work: the Society for Environmental Toxicology and Chemistry (SETAC) [4], various EU-funded projects, and the International Standards Organisation (ISO). Since the late 1980s, SETAC has been organising LCA conferences and workshops. Its booklet "Guidelines for Life-Cycle Assessment: 'A Code of Practice'" [5] provide guidelines on the general use of LCA, whereas ISO more recently introduced a series of documents aimed at providing general principles for conducting, reviewing, presenting, and using LCA [6–9].

Although LCA may offer the benefits outlined above, it also has some drawbacks. It is a relatively complex tool and, because of the technical content, can have high initial costs. These costs can be considered in terms of the time and effort that is required to perform a LCA. Time and effort both equate to monetary units within any company and, therefore, a financial input is required. Since data quality also introduces uncertainties in LCAs [10,11], various tagging systems have been suggested for signalling data quality, and database formats put forward to standardise data collection and facilitate compilation of common data sets [10].

LCA has been used in many industrial applications, particularly where steel is concerned. The steel industry is gaining valuable experience with LCA to reduce the environmental impact and also energy usage [12]. The recycling of galvanised steel has also been addressed [13] in an attempt to determine the most environmentally sound option between the recycling and landfill of zinc. As well as looking at one material, LCA can also be used to draw comparisons between different materials used for the same application. There have been numerous studies performed in an attempt to evaluate which materials impose fewer burdens for a given application [14–16]. Amato [13] drew the conclusion that the comparative LCA of steel and concrete-framed office buildings showed very little difference in the burdens, whereas Johnsson [14] undertook a comparative LCA on wood, vinyl and linoleum floor coverings and concluded that wood clearly created the least impacts.

1.2. Aims and objectives

This study is concerned with a reduction in the environmental impacts of towers, conductors and insulators, focusing on a detailed LCA, which can be used to influence and support any decisions made in relation to the re-design of these components. This may involve changing their appearance or size and, in doing so, may require the use of alternative materials which could effectively decrease the environmental burdens imposed.

The study also encompasses the geographical locations of transmission towers. Three classes of geographical environment are used within the transmission industry, as follows:

- Non-polluted (rural).
- Polluted (industrial).
- Coastal.

Due to the different corrosive characteristics, each environment will have different effects on the lifetime of towers and lines over the service life and, hence, the environmental burdens created.

2. The LCA approach

To assist in the LCA, a computer software package (TEAM, 1997) was used [17]. The software allows the user to input all the major stages of a product's life cycle, and, using a comprehensive database, simulates the associated outputs and environmental burdens. For the individual case studies regarding conductors, towers and insulators, the system boundary will encompass the life cycle of the product from extraction of raw materials through to its use in the field.

The functional unit of all of the case studies was relative to the standard National Grid expected lifetime, which is 85 years for a transmission tower. The functional units for