# Improved Cable Ampacity Calculations by Combining the IEC Standard with the Finite Element Technique

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## *ABSTRACT*

*The IEC Standard 60287 provides analytical equations for calculating continuous cable current ratings (based on an approximate thermal model), which are still widely adopted by the electricity industry. The problem with the cable external thermal resistance ($T_4$) calculations of this standard is that they are inaccurate due to the inherent assumptions and inflexible due to the limited cable installation conditions that can be modelled. The authors have developed computer software combining the finite element method, a modern, flexible, and accurate numerical technique, together with standard calculations to provide improved accuracy and extended capabilities for performing high voltage power cable rating calculations.*

## *KEYWORDS*

Cable Ampacity, Current Rating Calculations, Finite Element Method.

## INTRODUCTION

The current rating of power cables depends on the cable construction, the cable systems design, and the installation conditions. The calculation of a current rating involves utilising an appropriate thermal model that incorporates heat generation inside the cable due to electrical losses and heat transfer through thermal resistances of the cable and of the external environment to determine an operationally temperature-limited current. Whilst it is a complex problem to solve, obtaining accurate ratings is imperative during the design.

The IEC Standard (60287) series provides analytical equations for calculating cable current ratings. The IEC standards for cable current rating calculations continue to be widely adopted because: 1. They are adapted for common cable types and installation methods. 2. They are reasonably accurate, which leads to reliable, current ratings for new and existing cable circuits. 3. They ensure consistency, dependability, and comparability of current ratings determined by different bidders, providers, or suppliers for stakeholders. The IEC standard calculations are somewhat complicated to implement and ambiguous in parts. Recently CIGRE Technical Brochure (TB) 880 [4] was released to address the ambiguities.

The finite element method (FEM) is a numerical approach for solving the heat transfer model for cable current ratings, which has fewer assumptions and provides greater flexibility.

The problem we are addressing is the IEC standards make assumptions in the external thermal resistance ($T_4$) calculation that are often inaccurate. For example, the analytical methods provided for buried cables are restricted by the following assumptions: 1. The ground surface is isothermal when it is not; 2. The cable surface is isothermal when it is not; and 3. The superposition principle applies when it does not. A recent research and development project by National Grid (NIA_NGET0082) [6] advised the isothermal ground surface assumption results in over-rating for cables buried shallower than 1 meter, including those installed in surface troughs.

We have addressed the problem by developing computer software that combines the IEC standard methods with numerical FEM. The benefits of our solution, which we will explain, are that consistency with TB 880 is maintained and more accurate current rating calculations are achieved that also extend beyond the limitations of the IEC standards for both continuous and dynamic ratings.

In this report, calculations are in accordance with the latest IEC 60287 standards. Modelling was performed using the commercially available software which includes a module based on FEM.

## COMBINED IEC AND FEM CALCULATIONS

### Benefits and Capabilities

A new cable current rating calculation algorithm combining the IEC (60287) standard equations with numerical modelling has been developed. The finite element method has been used to effectively improve the accuracy and extend the capabilities of the IEC standard methods.

A FEM-based software module with an interactive user interface provides the following highlighted features:

- Model an unlimited number of rectangular areas (zones) of different thermal resistivity.
- Model an unlimited number of circuits of different cable types.
- Non-isothermal ground surface calculations considering convection by air with velocity.
- Calculate the current rating of cables installed in filled troughs.
- Compute steady-state current rating or operating temperature.
- Transient analysis, cyclic loading, and emergency ratings are supported.

### Algorithm

The new algorithm combines the IEC standard method with FEM calculations and is suitable for all cable types that are installed in buried environments. It is also computationally efficient, and its validity has been confirmed through the undertaking of hundreds of finite element simulations.

The algorithm uses the IEC 60287 standard for calculating the loss and internal cable thermal resistances (these methods are well-documented by CIGRE TB 880) but computes the external thermal resistance of the cable environment ($T_4$) using FEM, and finally, the current rating is obtained using the standard IEC current rating equation presented earlier.