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Evaluation of Proximity Heating Effects in Power Cables

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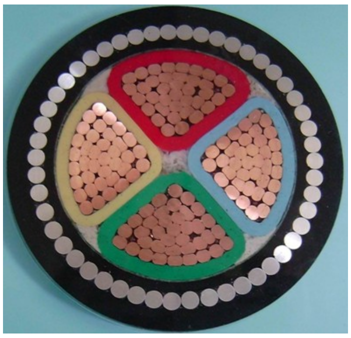

Researchers at Dublin Institute of Technology (DIT) have developed a new modelling system for evaluating the two- and three-dimensional heating effects in power cables due to harmonic distortion and proximity field effects. The approach provides the basis for implementing Voxel modelling systems to investigate proximity effects for a range of configurations with applications to the design of power cables, cable trays and ducts, inter-connections, busbar junctions and transformers, for example.

The applications of this technology include:

- Electromagnetic Compatibility (EMC);
- electromagnetic emissions generated by equipment;
- investigation of voltage and current distortions present in supply systems;
- load current distortion in installations connected to the supply system;
- effects of harmonics that create or add to existing distortion;
- heating effects generated by proximity effects including thermal diffusion.

Overview

Under ideal circumstances, in the built environment, electrical power supply voltage and current waveforms should be sinusoidal. However, this is very seldom the case due to the proliferation of non-linear loads. Examples of non-linear loads are those containing switched mode power supplies, reactors and electronic rectifiers/inverters. Such loads produce complex current and voltage wave forms and simple spectral analysis of these wave forms shows that they can be represented in terms of a fundamental power frequency plus other wave forms at integer and non-integer multiples of this frequency. These harmonics produce an overall effect called 'Harmonic Distortion' which can give rise to overheating in plant equipment and the power cables supplying them leading to reduced efficiency, operational life time and, on occasions, failure.

Being able to accurately model harmonic proximity effects in the design of cables, junctions, transformers and electrical appliances in general is particularly important in the design of electrical installations with regard to simulating heating effects. It is important to be able to simulate potential 'hotspots' in the built environment and check that heating effects conform to international standards especially with regard to the effect of higher order harmonics. This is because the heat generated is proportional to the square frequency of the harmonic.

Advantages

- **3D Geometry –** The simulator is based on a three-dimensional Voxel modeling system.
- **Material Properties –** The simulator includes variations in physical parameters including the electrical and thermal conductivity and the magnetic permeability.
- **Visualization –** The computed output fields can be visualized in both two- and three-dimensions.
- **Harmonics –** The simulator considers the effects of all harmonics present in the AC waveform.
- **Proximity Effects –** The simulator identifies 'hot-spots' due to proximity hearting effects.
- **Thermal Diffusion –** The simulator includes the effects of thermal diffusion.
- **Rating Factors –** The simulator compares the solutions obtained with international rating factors.

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Technology Description

Alternating Current (AC) power systems are subject to distortion by harmonic and inter-harmonic components which affect the supply voltage and load currents. Over the last few decades, harmonic distortion in power supplies has increased significantly due to the increasing use of electronic components in industry and elsewhere. Being able to accurately model harmonic proximity effects in the design of cables, junctions, transformers and electrical appliances in general is particularly important in the design of electrical installations with regard to simulating heating effects. It is therefore necessary to be able to simulate potential 'hotspots' in the built environment and check that heating effects conform to international standards especially with regard to the effect of higher order harmonics.

The phenomenon of both the skin and proximity effects, although recognised as reducing the ampacity of cables, has not yet evolved into a set of de-rating tables that can be easily applied on a day to day basis in engineering design. The problem in quantifying harmonic heating effects is that they are a function of frequency. The greater the harmonic distortion present, the larger the number of harmonics present. Each harmonic current generates its own individual heating effect and thus, a harmonic rating factor has to be taken into account for a large number of individual elements. Further, in general, proximity effects tend to be understated because the effect on extraneous metalwork including metal enclosures such as cable trays and metal cladding on cables, has, to date, not been fully considered either experimentally or in the Standard International Electrotechnical Commission 60287-1-1. It is for this reason that the simulator presented here has been developed.

Stage of Development

The technology includes an operational prototype demonstration system developed using MATLAB. Dublin Institute of Technology is seeking partners and collaborators to licence the technology, or work to develop it further to meet specific commercial applications.

J M Blackledge and K O'Connell

Prof. Jonathan Blackledge is the Science Foundation Ireland Stokes Professor at Dublin Institute of Technology. He holds a PhD in theoretical physics from London University and a PhD in mathematical information technology from Jyvaskyla University. He has published over 200 scientific and engineering research papers, authored 12 books and supervised over 200 research (MSc/PhD) graduates working in both an academic and commercial context.

Eugene Coyle is Head of Research Innovation and Partnerships at the Dublin Institute of Technology. His research spans the fields of control systems and electrical engineering, renewable energy, digital signal processing and ICT, and engineering education and he has published in excess of 120 peer reviewed conference and journal papers in addition to a number of book chapters. He is a Fellow of the Institution of Engineering and Technology, Engineers Ireland, and the Energy Institute.

Kevin O'Connell was previously Head of the Department of Electrical Services Engineering until his retirement in September 2010 and is now a PhD student at Dublin Institute of Technology working with Professor Jonathan Blackledge and Professor Eugene Coyle. He recently obtained the Best Paper Award for his paper entitled 'Cable Heating Effects due to Harmonic Distortion' presented at the World Congress on Engineering 2012 (WCE2012) held at Imperial College, London in July 4-6, 2012.

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