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REFACE EDITOR-PUBLISHER

Transformers have been designed and widely used for energy transfer, measurement, protection, electrical isolation and signal coupling over the last century. Most transformer designs were for low frequency operation, where in spite of a long history of low frequency transformer theory and design, many stray field problems have not been resolved so far. On the other hand the operating frequency of many switched mode power supplies has significantly increased to several hundreds of kHz and in some cases up to a few MHz. However, in the MHz region several problems arise related to both the windings and standard core materials. Therefore, the recent use of coreless transformers is an alternative to transformers with a core for some applications.

In the particular case of power transformers, they are keys and costly components in networks and the failure of a transformer can have an essential impact on safety, reliability and cost of electrical supply. Their maintenance, or more generally – managing their life, with improved reliability and reduction of scheduled outages becomes more and more important due to economic pressure. Both users and manufacturers play important roles in these stages and hence close cooperation between them is essential in achieving success in life cycle management. Recent catastrophic black-outs have exposed major vulnerabilities in existing generation, transmission and distribution systems. Severe under-investment, ageing technology and conservatism in the approach to innovation are being blamed and have created a situation where reliability of the entire system is under question. Resources need to be directed into technologies that have the potential to improve the integrity of the system; high temperature superconductivity has such potential. It also has a positive environmental impact by significantly reducing the losses as well as size and weight of the power devices.

The interest in increasing operational frequencies remains alive since there are two important trends influencing the development of transformers: the miniaturization and the increase in transmitted power density. Therefore, power applications of high frequency products comprise transformers in switch-mode power supplies, power chokes and electronic lamp ballast devices. The latter includes transformers for wind power plants, contact-less chargers for electrical cars (safety !) and contact-less energy transmission to robotic arms (unlimited twisting in all directions).

The demand for power materials running under higher operating frequencies can now be met by highly advanced materials like ferrites. Metallic powders and amorphous metals are also becoming increasingly important for use in this area.

Solutions for measuring currents and voltages needed for protection and monitoring in power systems are achieved using instrument transformers. New solutions such as electronic instrument transformers (sensors) are being successfully employed. Because of their superior technical performance, current and voltage electronic transformers (sensors) are expected to have in future an increasingly important role in MV systems. In this area of instrument transformers, problems of propagation of disturbances to secondary circuits occur depending on the design features. While the principle of operation of instrument transformers is the same as power transformers, the problems concerned with the design are quite different.

The advances in computational tools are promoting the development of sophisticated modelling software for the solution of, non-linear, 3D fields has supported the design of transformers in the last few decades. However, it is not always accompanied by relatively inexpensive, simple and rapid engineering methods, which are being established for regular industrial design use.

This monograph offers invaluable information for designers and users of transformers to overcome some of the difficulties highlighted above. This material has been supplied and compiled by an international group of outstanding transformer experts who met at ARWtr'04 in Vigo-Spain (<http://webs.uvigo.es/arwtr04>). You will also find in this monograph a wide range of subjects including: contemporary economic, design, diagnostics and maintenance aspects of power, instrument and high frequency transformers collected directly from the authors into 22 chapters, which have never before been published all together.

It is hoped that anyone working with transformers will find this invaluable material. Theory and mathematics have been kept to a minimum so that one can find out how to overcome many practical problems.

Vigo, July 12, 2006

Xose M. López-Fernández



GENERAL INTRODUCTION

This monograph "Transformers in practice" is the latest presentation of the contemporary state of art in the field of modern transformers, written by some of the best world experts, gathered at the Advanced Research Workshop on transformers ARWtr'04 in Vigo, Spain. Lectures delivered by invited Key Speakers were divided into three main Sections: I. High Frequency Transformers (Chairman Prof. B. Ertan, Turkey), II. Power Transformers (Dr M. Kazmierski and Prof. J. Turowski, Poland) and III. Instrument Transformers (Prof. E. Lesniewska-Komezka, Poland).

The authors of this publication are leading international researchers in the presented topics and that the integrity of their contributions is beyond any doubt. This publication provides an invaluable reference for every designer, who should look at a problem from his own position as well and from considerations of his local economical and technical circumstances.

A Short History of the Transformer

Electromagnetic transformers, which are objects of this book, have a long tradition. This tradition should be considered in order to correlate the impressive achievements of past generations with significant progress in the design and construction. The main imperative at the beginning this history was to create new ideas, adequate theory and effective processing. The economic aspects of manufacturing were less important. Nowadays, particularly over last few decades, growing economic pressure and liberation of the electricity market are forcing utilities to seek new ways of asset management and cost/risk assessment. Not only the initial cost but the Life Cycle Cost, i.e., the operating costs (loss evaluation, maintenance and outage costs) are becoming a top priority in asset management. All this leads to reliability considerations at each stage of transformer manufacturing including reliability of the total system in which the transformer operates.

The history of the transformer started probably from *Michael Faraday's* first single solid iron core transformer 1831 and *Ruhmkorff's* coil 1848 as a first HV single column, solid iron transformer, first single-phase 15 kVA, 1500/300 V transmission line transformers 1883 of *K. Ziperowski, M. Déri and O. Bláthy* (Ganz Budapest) and others. Hungarian specialists were the first (1885) to have used the technical term **transformer**. It was then adopted the world over.

However, the first real industrial 3-phase 15 kVA, 1500/300 V power transformer was built and patented in 1891 by a Polish nobleman *Michal Doliwo-Dobrowolski*, born in Petersburg and working in AEG Berlin. Since *Doliwo-Dobrowolski* there has been 115 years of transformer history. There has been much research and development of this device - from magnetic and electric circuits, cooling, HV insulation systems, noise and vibration, power losses in active and non-active components, processing, testing, maintenance, monitoring, economy, reliability, etc., The most modern construction of transformers based on (1987) discovery of High temperature superconductors by Nobel Prize winners *Pole J. Bednorz, and Zwiss K A. Müller* is also an important milestone.

Advanced Research Workshop on Transformers ARWtr'04

Advanced Research Workshop on transformers ARWtr'04 was held in Vigo Spain, sponsored generously by the Spanish and Portuguese Companies, and Spanish and Autonomous Community of Galicia Government. ARWtr'04 was excellent and important technical event in the field of electromagnetic transformers. Since the International Summer School of Transformers - ISST'93 held at Technical University of Lodz, Poland, the ARWtr now includes new important topics of High Frequency Transformers and Instrument Transformers. Nevertheless this Power Transformer Section remains as the most important part of this monograph covering many complex aspects of transformer engineering.



Transformers in practice

The ARWtr'04 (<http://webs.uvigo.es/arwtr04>) was attended by 109 specialists, including 34 from universities, 75 from private institutions (Industries and Research Centres) from 20 countries. In all 21 lectures, 16 contributions from participants were delivered.



ARWtr'04 organisers, speakers and participants. Vigo, October 30, 2004.

(<http://webs.uvigo.es/arwtr04>)

This workshop held, under the auspices of the Spanish and Portuguese CIGRE Study Committee A2 (Transformers) and UNESCO-UNISAPAR Poland, was an important milestone in the history of international transformer conferences. It is especially valuable, because of participation of many specialists from industry and power utilities of many countries and continents. Discussions held during the workshop were of high scientific and professional level. The successful organization of the workshop is yet another significant contribution at international level of the organizers, viz. Department of Electrical Engineering University of Vigo and Institute of Mechatronics and Information Systems, Technical University of Lodz, former Institute of Electrical Machine and Transformers.

Thanks are expressed to Sponsors *Spanish Ministry of Science and Technology, Xunta de Galicia, Vice-chancellor R&D University of Vigo, ARTECHE R&D Department, EFACEC –Porto, ABB Power Technology, Spanish Red Eléctrica (REE), Portuguese Red Nacional (REN)* and others Institutions for their financial and organisational support.



The **ARWtr** meetings will be continued in the future organised by Prof. Xose M. López-Fernández, who is working in the organization of ARWtr'07, which will include interesting and inspiring international sessions on relevant and emerging topics.

The Editors would welcome any comments and advice from any other experts in this field.

Editors



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