A Web-Based System for Transformer Design

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Abstract. Despite the recent use of computer software to aid in the design of power supply components such as transformers and inductors, there has been little work done on investigating the usefulness of a web-based environment for the design of these magnetic components. Such an environment would offer many advantages, including the potential to share and view previous designs easily along with platform/OS independence. This paper presents a web-based transformer design system whereby users can create new optimised transformer designs and collaborate or comment on previous designs through a shared information space.

1 Introduction

Despite the recent use of computer software to aid in the design of magnetic components [3], to date there has been little work done on investigating the usefulness of a web-based environment for magnetic component design. Such an environment would offer many advantages, including the potential to share and view previous designs easily along with platform and operating system independence. This paper proposes a web-based prototype for magnetic component design. The system is based on an existing transformer design methodology [1], and is implemented using a web programming language, PHP. Magnetic component material information and designs created by students and instructors are stored in a MySQL database on the system server. It will therefore be possible for users of this system to collaborate and comment on previous designs through a shared information space. We will begin with a summary of existing methods for transformer design, followed by details of the system design, and finally an overview of the web-based implementation.

2 Related Research and Other Systems

2.1 Transformer Design Methodologies

The basic area product methodology [4] often results in designs that are not optimal in terms of either losses or size since the method is orientated towards low frequency

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transformers. A revised arbitrary waveform methodology was proposed [1] that allows designs at both low and high frequencies, and is suitable for integration with high frequency winding resistance minimisation techniques [2].

The selection of the core is optimised in this methodology to minimise both the core and winding losses. The design process can take different paths depending on whether a flux density constraint is violated or not. If the flux density exceeds a set limit (the saturation value for a particular core material), it is reset to be equal to this limit and one path is used to calculate the core size; otherwise the initial flux density is used and a different path is taken to find the core size.

2.2 Previous Windows-Based Packages

Many magnetic design companies have used computer spreadsheets to satisfy their own design needs and requirements. They thus tend to be solely linked to a company and its products, and remain unpublished as their content is only of interest to their direct users and competitors. Some of the limitations of these spreadsheets include: difficulties in incorporating previous designer expertise due to limited decision or case statements; non-conformity with professional database formats used by manufacturers; problems with implementing most optimisation routines due to slow iterative capabilities and a reduced set of mathematical functions; basic spreadsheet input mechanisms that lack the features possible with a customised GUI.

A computer aided design package has previously been developed [3] for the Windows environment based on the arbitrary waveform methodology [1]. This package allows the design of transformers by both novice and expert users for multiple application types through "try-it-and-see" design iterations. As well as incorporated design knowledge and high frequency winding optimisation, the system allows access to customisable or pre-stored transformer geometries which were usually only available by consulting catalogues.

Other systems such as [6] provide more detailed information on winding layouts and SPICE models, but lack the high frequency proximity and skin effects details of [3]. Another Windows-based package has recently been released [7] which allows the comparison of designs based on different parameters. Some companies have also advertised web-based selection of magnetic components [8]; however these tend to be online spreadsheets and therefore suffer from the problems previously mentioned.

3 System Design

All of the information and associated programs of the system reside on a web server, and any user can access the system using a web browser through the appropriate URL. The inputs to the system are in the form of specifications such as desired voltage, current, frequency, etc. The output from the system is an optimised design for the specifications given. Fig. 1 shows the steps taken in creating and managing a design.

The system is comprised of the following elements: a relational database management system (RDBMS); a web-based graphical user interface (GUI); optimisation techniques; a repository of knowledge; and a shared information space. We will now describe these in some more detail.

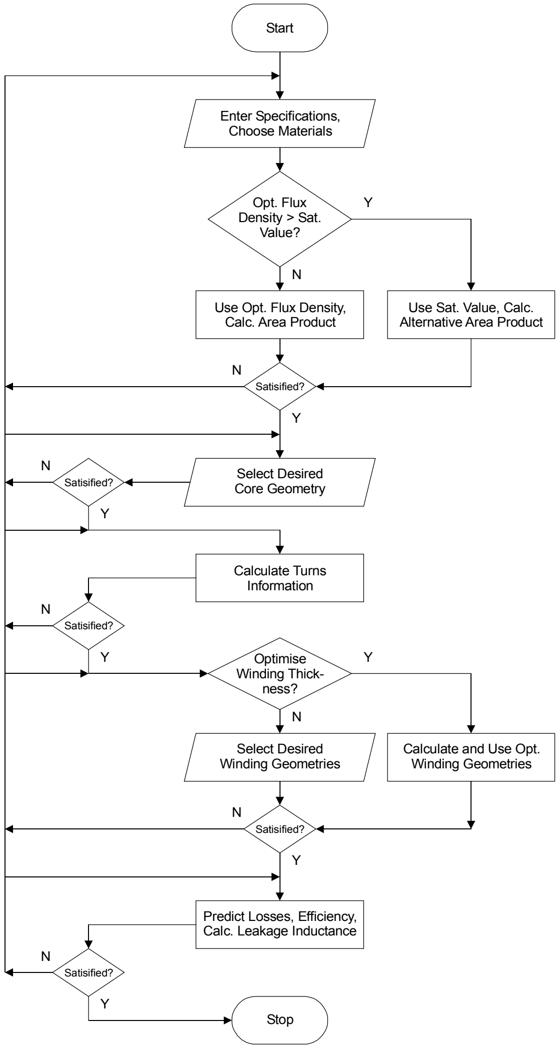

Fig. 1. Flow chart of design steps

3.1 Relational Database Management System

In transformer design, huge amounts of core and winding data have to be managed for effective exchange of information between various design stages. The magnetic designer should not get lost in the data management process as their concentration on the real design problem may be affected. A RDBMS can be used to save designers from having to search through books with manufacturer's data or from manipulating data themselves with lower level external programs. All transformer core and winding data is accessible using the sophisticated database storage and retrieval capabilities of a relational database engine incorporated into the design application.

The database contains the following tables of data: *designs* (where each saved design is identified by a unique *design_id*); *designers* (users of the system); *areas* (consisting of parent areas which contain child areas for related sets of designs); *comments* (each relating to a particular *design_id*); *cores* and *windings* (either read-only items added by an administrator or modifiable items created by a particular designer); and tables for core and winding materials, shapes, manufacturers and types.

3.2 Web-Based Graphical User Interface

In our system, we require over 250 HTML objects and form controls for interaction with the user; these include text boxes for both inputs and calculated outputs, labels describing each text box, radio buttons and checkboxes for selection of discrete or Boolean variables, option group menus, graphs of waveforms, etc. Proper categorisation and presentation of data in stages is our solution to the problem of organising this data in a meaningful way, whereby images identify links to the distinct steps in the design process, and only information related to a particular step is shown at any given time.

Some of the main GUI features incorporated in the system are: numbered and boxed areas for entry of related data in "sub-steps"; input and output boxes colour-coded according to whether data entry is complete, required, or just not permitted; scrollbars for viewing large tables of data in small areas; and pop-up message windows for recommendations and errors.

3.3 Optimisation Techniques

The performance level of an engineering design is a very important criterion in evaluating the design. Optimisation techniques based on mathematical routines provide the magnetic designer with robust analytical tools, which help them in their quest for a better design. The merits of a design are judged on the basis of a criterion called the measure of merit function (or the figure of merit if only a single measure exists). Methods for optimising AC resistance for foil windings [2] and total transformer loss [1] are implemented in the web-based system; these variables are our measures of merit.

3.4 Repository of Knowledge

A "repository of knowledge" is incorporated into our system, to allow a program design problem to be supplemented by rules of thumb and other designer experience. In the early design stages, the designer generates the functional requirements of the transformer to be designed, and the expertise of previous users can play a very important role at this stage.

For example, on entry of an incompatible combination of transformer specifications, the designer will be notified by a message informing them that a design error is imminent. The system will also suggest recommended "expert" values for certain variables. Although such a system is useful for novices, it can also be used by experts who may already know of certain recommended values and who want to save time setting them up in the first place.

3.5 Shared Information Space

The system allows collaboration between users working on a design through a shared information space, with features similar to those of a discussion forum. Designs are filed in folders, where each folder may be accessed by a restricted set of users. To accommodate this, user and group permissions are managed through an administration panel. Access to design folders is controlled by specifying either the users or the groups that have permission to view and add designs to that folder. Users can comment on each design, and can also send private messages to other users.

4 Implementation and Testing

A popular combination for creating data-driven web sites is the PHP language with a MySQL database, and this was chosen for the implementation of the system. PHP is a server-side scripting language that allows code to be embedded within an HTML page. The web server processes the PHP script and returns regular HTML back to the browser. MySQL is a RDBMS that can be run as a small, compact database server and is ideal for small to medium-sized applications. MySQL also supports standard ANSI SQL statements. The PHP / MySQL combination is cross-platform; this allowed the development of the system in Windows while the server runs on a stable BSD Unix platform.

A typical PHP / MySQL interaction in the system is as follows. After initial calculations based on the design specifications to find the optimum core size (as mentioned in section 2.1 and detailed in [1]), a suitable core geometry is obtained from the `cores` database table using the statement:

```
$suitable_core_array = mysql_query("SELECT * FROM cores
WHERE (core_ap >= $optimum_ap AND corematerial_id =
$chosen_corematerial_id AND coretype_id = $cho-
sen_coretype_id) ORDER BY core_ap LIMIT 1");
```

where the names of calculated and user-entered values are prefixed by the dollar symbol ($), and fields in the database table have no prefix symbol.

Fig. 2 shows the user interface, with each of the design steps clearly marked at the top and the current step highlighted (i.e. “Specifications”). An area at the bottom of the screen is available for designer comments.

The underlying methodologies have previously been tested by both the authors [1] and external institutions [5]. Design examples carried out using the system produce identical results to those calculated manually. The system is being tested as a computer-aided instruction tool for an undergraduate engineering class.

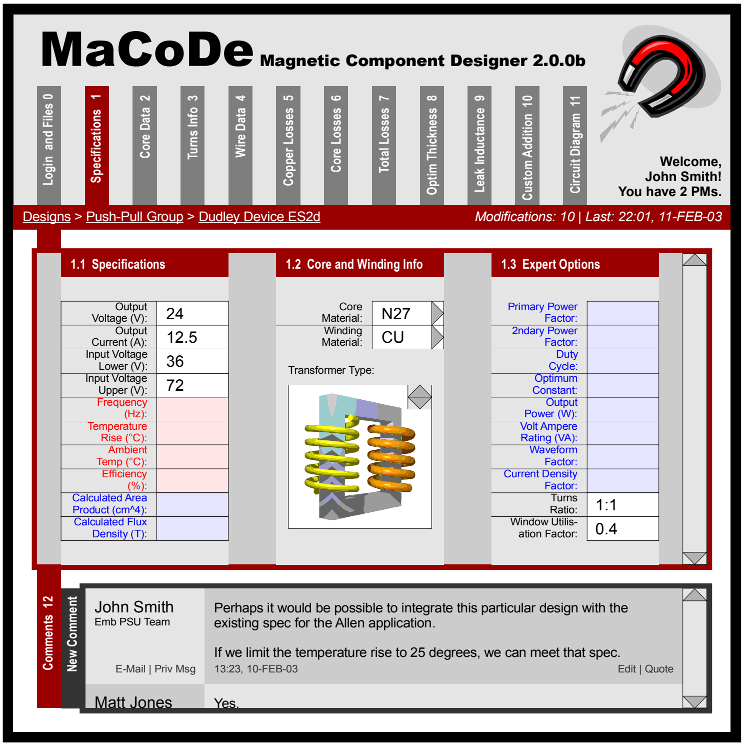

Fig. 2. Screenshot of web-based system

5 Conclusions and Future Work

With the current trend towards miniaturisation in power converters, the magnetics designer should now expect accurate computer aided techniques that will allow the design of any magnetic component while incorporating existing techniques in the area of web-based collaboration. This paper presented a web-based transformer design system based on a previous methodology. This system is an improvement on previous automated systems because: previous designer expertise and optimisation routines are incorporated into the design method; database integration avoids the need for consultation of catalogues; and a user-friendly interface, with advanced input mechanisms, allows for collaboration among users where designs can be shared and analysed. This system can be further developed for more transformer applications, and with a revised methodology the system could also be updated to incorporate inductors and integrated planar magnetics.

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