Development of Knowledge Based Expert System for Power Electronics Design

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Introduction

Power electronics circuits are usually quite simple in form, but their design and implementation requires wide and sophisticated knowledge, which must be continually updated as the technology improves. Power electronics engineers must be expert in many areas such as thermal domain, circuit and system packaging and circuit protection. Therefore it is usually not possible for the design engineer to come up with an optimum circuit and a right device.

The use of wide range of power electronics circuits through different disciplines (industry, aerospace, military, etc.) has made it necessary for the researcher to facilitate the design, the implementation and the use of these circuits for the different applications. In addition, the difficulties in understanding and designing power electronics circuits, especially for the non-expertise person has led to the development of computer tools that help users in these tasks. Such tools (e.g. ECAP, ASTAP SCEPTRE, SPICE...) are very useful and user friendly that make the complicated tasks easier. Database modules for different devices enhance them. Since they have been introduced, power electronics has emerged as an important discipline in electrical engineering. The functions they provide are remarkably considerable, particularly in the design and analysis of the circuit behaviour as well as in the simulation tasks. This simulation could replace the need of the real implementation of the circuit and hardware testing during the design phase.

On the other hand, these powerful commercial power electronics design and simulation packages that are capable of performing extensive calculation quickly and accurately, offer little assistance as teaching and learning aids. The designers of these tools assume that the user is knowledgeable enough in subject, and is able to select and apply the know-how properly. This is true for the experts and frequent electronics engineers, but the beginners have to consult continuously the manuals and references to be able to use these packages. Because of this drawback of such packages in delivering more teaching information and the amount of expertise required by them, researchers have tended to the development of expert tools that facilitate the tasks for the user and provide more flexible and much amount of knowledge. In such tools based on expert system, the user, which is assumed less knowledgeable, is guided step by step till he reaches his conclusions. In addition, it is essential in these tools that the user can question the system to determine which rules are crucial in determine answers.

Although there has been a tremendous advances in expert systems development in many areas (medicine, environment, economics, etc.), there is still a lack in the power electronics area. However some research are being carried out in this area for specific circuits [1, 2, and 3] and as a learning tool and knowledge base [4]. A framework for automatic design of switching power converters was developed [7], where a converter modelling technique was introduced. This technique permits the systematic representation of power converters in a way suitable for implementation in computer programme. An important tool was also developed for power electronics circuit design [5, 6]. The drawback of this tool is the need of many packages to develop and to operate; such as HUMBLES expert system shell, HSPICE, semiconductor library and the Smalltalk-80™ system, which is a 4th generation language.

The present tool is interfaced only with the PSPICE package and is developed using a high level programming language (3rd generation language enhanced by 5th generation language features). It assumes that the user has some knowledge about power electronics converters' circuits. Nevertheless, the tool can guide the user by prompting messages and help instructions till the required circuit is achieved, or the cancelling of the process. Though, the tool is interfaced with the *Pspice* simulator, it introduces an interactive interface with the user starting from the selection of a specific application until arriving to the optimum topology with all parameter values and switches. The topologies are stored in the knowledge base as schematic files, allowing the Schematic to be able to display the resulted circuit. The system architecture, the knowledge base representation and the inference engine are developed in this work.

Materials and Methods

Expert system can be developed with different types of programming languages, rating from artificial intelligence (LISP and PROLOG) to standard procedural languages (FORTRAN, PASCAL...). They can even be developed with forth generation languages such as Lotus 1-2-3 [8]. In this work Visual Basic has been chosen as a development tool. Hence two major questions may rise in this purpose. Why the artificial intelligence (AI) languages were excluded? And Why Visual Basic among the other non-AI languages was chosen?

For the first question, the implementation of AI language require more memory on personal computer and may not give the programmer the suitable control they need to conserve memory. AI languages also, require specialized training even for experienced programmers in traditional language [9]. Because of its easy development environment and visualization facilities, Visual Basic was chosen where the "Visual" part refers to the method used to create the graphical user interface (GUI). Rather than writing numerous lines of code to describe the appearance and location of interface elements, it is simple to add pre-built objects into place on screen. In addition, Visual Basic application is based on objects; hence it offers a smooth way to construct the application using object-oriented paradigm. This paradigm is becoming popular in artificial intelligence.

The first concept in designing the GUI is that it should be flexible enough to permit the user to navigate through the system easily and thus facilitate the access to the different functions provided by the system. These tasks are accomplished efficiently using Visual Basic as a programming tool for its visualisation features at the design time and the virtual separation of the source codes. Using an instance of the multiple document interface (MDI) form helps in gathering all the needed forms, frames and other controls applications under one form in a Windows-style application. The MDI form is enhanced by a menu bar, status bar and toolbar where many useful functions are associated. Figure 1 shows the developed GUI. As it can be seen, many functions are offered within the menu bar and tool bar such as, the menu *Start* which contains two submenus, *Start With Circuit* and *Start With Application*. Menu *Circuit* contains the type of converters available such as DC to DC and DC to AC Converters. The user needs only to navigate through the system to discover other important functions.

Results and Discussion

The developed system constitutes of many modules interact with each other. As the user interface is a fundamental segment in any expert system, an attractive and flexible graphical user interface (GUI) was built benefiting from the facilities offered by Visual Basic programming language. This GUI consists of menu, toolbar, and other features. The interaction module is an essential part within the graphical user interface. It assures the communication process between the designer and the system's inference engine. Constitute of simple controls, such as Combo boxes and message boxes, the interaction module leads the designer along a smooth way to insert his specifications and requirements. These requirements have to be matched against the system's knowledge base. This process is the task of the inference engine module.

In rule-based systems, the inference engine is totally separated form the knowledge base. However, for an object oriented-based system the inference engine is not completely separated from the knowledge base, as the latter is represented as objects having various methods and properties. These methods and properties constitute the kernel of the inference engine. Figure 2 represents block diagram describing the inference engine process flow. After the user selects the application of the circuit or the type of conversion, a matching process is launched to come out with the topology that meets the requirements. Based on these requirements, the circuit parameters such as the input and/or output filter elements have to be calculated. Meanwhile, optimal switches are to be selected from switching devices database. The choice of certain switches is based on their ratings as well as on their prices. If many switches satisfy the requirements, the cheapest ones are chosen regardless of their manufacturers. At the end of the process the user is given all these switches (satisfying the requirements), where he could change the optimal switches if his concern is more on the manufacturer than the price. The results of this process are sent to the interfacing module, which constructs the final circuit and displays it within schematics environment of *Pspice* simulation package.

The knowledge base constitutes of two parts. The switching devices database, which is a collection of various types of devices (power diodes, SCRs, IGBTs and MOSFETs) with their ratings. These devices are organized under one library accessible by the system. To avoid the mismatch between *Pspice* and the system, this library contains only the devices that can be found in *Pspice* library (version 5.3). This module is enhanced by various functions, such as adding and/or removing some devices. The second part that makes up the knowledge base is the converter topologies. This portion of knowledge is represented within the system using object-oriented paradigm. The objects are modeled in class modules. Because this model doesn't allow the total separation of the knowledge from the inference engine, the inference engine invokes the class methods and properties whenever needed to infer conclusions or assert facts. Two types of knowledge have been introduced. Modular knowledge, which consists of most common topologies, based on their types (DC/DC, DC/AC, DC/AC and AC/AC converters). Each type contains the ordinary circuits such as buck converter under DC/DC type. Each type represents on object (class module), whereas a subclass designates the ordinary circuit. The subclass can inherit the properties and methods of the parent class. In addition it can convey its own properties and methods. This knowledge is accessible by the inference engine from the "*Type of Converter Selection*" module. The heuristics topologies are the second type of the knowledge. Although this knowledge can be encompassed under one type of the four types of conversion, it's more convenient to separate it because it has no regularity (methods and properties) as the standard ones. Most of this knowledge has been collected from several articles and papers. This segment of knowledge is organized and represented within the whole module based on the application, whereby it is accessible by the inference engine from the "*Application Selection*" section. Each topology represents an independent object (class module) with its own properties and methods. The interaction between several objects (classes) is accomplished by the message passing technique.

The explanation module is designed to guide and help the user to find out: how the results have been achieved, and general information about the circuit topologies and switching devices. In fact, the first point is inclusive in the interaction module. From the communication process, the user can know how certain results have been reached. A help module was developed to accomplish the second point. This module gathers basic information, formulas and some topologies for each type of converter. This knowledge is accessible from the general menu. Currently, only a framework of this module has been completed. Relevant information has to be gathered and collected from various books and articles and then coded into this module. This module can be considered as a learning aid system for power electronics converters.

Conclusions

A computer aid system was designed and developed. The main function of such system is to guide the design engineer to come out with the right topology and specifications of the converter circuits. An inference engine was implemented to manipulate the knowledge base. According to the user requirements, the tool acts as an expert system for making decision. Many converter topologies were included into the knowledge base of the system. These topologies range from the dc-dc converters to ac-ac converters. It is the function of the inference engine to find the suitable topology that matches the user entries. Benefiting from the object oriented programming and the design visibility features of Visual Basic programming language; an attractive user interface is developed to interact between the user and the system. Furthermore, a library module consisting of more than 600 switching devices with their specifications was included to allow the user to navigate for the suitable switch. A help module that explains how to use the system and gathers information about power electronics converters was also built.

Benefits from the study

Prototypes of power electronics converters have been developed for various applications. Database of circuit topologies and power semiconductor devices has been developed linked to the expert system.

The study also accounted for few journal papers and many have been presented at international, regional and national conferences.

Benefits of the study also included training of several postgraduate students.

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