Design and Implementation of Web-Based Training Tool for a Single Switch Induction Cooking System Using PHP

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Introduction

All induction heating systems exploit the well-known electromagnetic induction prenomen: an AC current flowing through the heating coil generates a variable magnetic flux, thus causing eddy currents to occur in the load to be heated. Due to the Joule effect, the electrical energy caused by the induced current is converterted to heat. Induction heating is widely used in industry for melting, brazing and surface hardening applications. In recent years, with the availability of inexpensive transistor switches, it has become possible to apply for domestic cooking application as well.

Fig. 1 shows the induction cooking's block diagram. Rectified main voltage ensures the required dc voltage for medium frequency pulsating inverter. Power dissipation in device during switching transition, harmonics and radio frequency interferences can be reduced by using resonant switch network. Generated medium frequency square wave voltage or current is filtered by LC resonant tank.
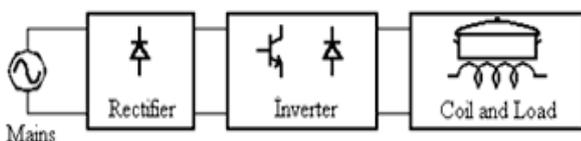

Fig. 1. Induction cooking block diagram

Induction cookers are a low-power induction heating systems with a maximum output power usually less than 3kW. A large number of inverter topologies have been developed in this area. The main inverter topologies used in induction cookers are resonant inverters, including full-bridge, half-bridge and single switch inverters. Single switch Class E resonant inverter (SSRI) seems to be the most popular induction cooking power source [1]. It is a simple, cheap, reasonable efficient inverter circuit with a

good power control range and it can cope with a wide range of loading conditions.

Simulation is increasingly being used in the power electronics design process to improve time to market, quality and predictability. Several papers proposed better induction cooker models for use in simulation and analysis[5].The current problem is no longer designing new topologies for a single inverter dedicated to one inductor, but to improve and optimize it [2] [3] [4]. However, most do not provide an easy-to-use model that is readily understood and applicable by design engineers. Also, many of the relationships between the various parameters demand further clarification, i.e., input voltage, maximum and minimum output powers, switching frequency, maximum rates of current and voltage that devices must withstand. Consequently, engineers are in strong need of more detailed and easy-to-use design tools. PSpice, MATLAB, Electronic Workbench, and other software packages have been used successfully for the development of such tools [6]. Unfortunately, most of these tools are limited to use on selected computers equipped with licensed software. Recognizing this limitation, several investigators have developed various tools making use of the Internet.

Web-based learning is an innovative approach to learning in which computer-based training is transformed by the technologies and methodologies of the Web [7], [8]. Delivering courseware over the Web has several advantages over computer based training methods [9], [10]. PHP (Hypertext Preprocessor) is a script language of the open-source used all over the world widely. It is a server-side scripted language which is ideal for the developing of dynamic web-based sites and applications. PHP procedures are located on the remote web server and are responsible for the computation process based on the received data and for the giving of the response to the request from the client. Among all the program languages, cooperates with MySQL best, and is also charge-free. With the release of PHP v5.0, its function becomes more powerful. Compared

with other languages, PHP is also easier. Besides, PHP can perform well in Linux and Unix system.

This paper aims to provide a PHP based design method of a SSRI for home cooking applications. Design specifications for the inverter are the input voltage (Vs), work coil parameters (Q, R_L, L_r), water mass (m) and required time for boiling (t). All other parameters need to be determined. The engineers should be able to use this tool from any computer connected to the Internet to verify design values, ask "what if" questions regarding their designs, and provide information and computational results for SSRI.

In this paper, we present a web-based tool for the engineer who is dealing with the induction cooking applications. With such a model, all the electrical quantities of the circuit can be computed. This design tool employs an intuitive and nonmathematical approach, allowing engineers to rapidly and efficiently learn the fundamentals, instead of wasting too much time on mathematical derivations and algebraic manipulations. The proposed tool is also usefull for distance learning and the person with disability problem as well.

Basic Inverter Operation

Induction heating cookware consists of two parts; a heating structure, which is composed of a heated plate and a heating coil, and an inverter which supplies high-frequency power to the heating coil. Detailed analysis of the proposed inverter system is given in the paper [11]. The operation over a switching period can be described by two circuit modes.

First mode begins when the switch is turned ON. With the initial conditions v_{C_r} (0)=0 and i_{L_r} (0)= $I_{L_r 2}$ The capacitor voltage and inductor current i_{L_r} at any time during the circuit mode can be written as

$$i_{L_r}(t) = \frac{V_s}{R_L}(1 - e^{-\tau \cdot t}) + I_{L_r 2}e^{-\tau \cdot t} , \qquad (1)$$

$$v_{C_r}(t) = 0 , \qquad (2)$$

where $\tau = R_L / L_r$ – the time constant of the R_L circuit. This stage continuous until S is turned OFF at $t=t_1$.

Second mode starts when S is turned OFF at $t=t_1$. Considering the loop formed by C_r, the source V_s, L_r and R_L, with the initial conditions v_{C_r} (0)=0 and i_{L_r} (0)= $I_{L_r 1}$ the corresponding equations are

$$i_{L_r}(t) = \left(\frac{\omega_0}{\omega}\right)(e^{-\alpha t})\left[\left(V_s - V_{C_r}\right)\left(\frac{C_r}{L_r}\right)^{1/2} Sin\omega t + I_{L_r 1}Cos(\omega t + \theta)\right], \qquad (3)$$

$$v_{C_r}(t) = V_s + \left(\frac{\omega_0}{\omega}\right)(e^{-\alpha t})\left[\left(V_{C_r} - V_s\right)Cos(\omega t - \theta) + I_{L_r 1}\left(\frac{L_r}{C_r}\right)^{1/2} Sin\omega t\right]; \qquad (4)$$

for the duration of resonant cycle, the constants α, ω and θ are given by

$$\alpha = R_L / 2L_r , \qquad (5)$$

$$\omega_0 = (L_r C_r)^{-1/2} , \qquad (6)$$

$$\omega = (\omega_0^2 - \alpha^2)^{1/2} , \qquad (7)$$

$$\theta = \tan^{-1}\left(\frac{\alpha}{\omega}\right) . \qquad (8)$$

Induction heating cookware consists of two parts; a heating structure, which is composed of a heated plate and a heating coil, and an inverter which supplies high-frequency power to the heating coil. Vessel type is a flat bottom, cylindrical shape and made of stainless steel. The vessel itself absorbs energy and spreads it to the water. Energy delivered to the water W_w is less then the energy absorbed by the vessel Wabs because of the efficiency. W_w will cause temperature rise of water.

$$\eta = \frac{W_w}{W_{abs}} . \qquad (9)$$

Time dependant temperature of water until boiling point can be found as

$$t_w = \frac{W_{abs}\eta}{mc} + t_{amb} . \qquad (10)$$

The power dissipated and time dependant energy delivered to the load is then

$$P_0 = f_{sw}V_s \int_0^{t_1} i_{L_r} dt , \qquad (11)$$

$$W_{abs} = P_0 t ; \qquad (12)$$

where t_w – temperature of water (K); m – water mass (kg); c – specific heat capacity of water (4190J/kg·K); t_{amb} – ambient temperature (K); t – operation time (s).

The average power delivered by the source, normalized by V_s^2 / Z_0 is given by

$$P_{n0} = \frac{P_0 Z_0}{V_s^2} . \qquad (13)$$

The switch in the inverter can be implemented by a unidirectional semiconductor controllable switch with an antiparallel diode.

Implementation

In designing an SSRI for home cooking application, given data would be the input voltage (Vs), work coil parameters (Q, R_L, L_r), water mass (m) and required time for boiling (t). All other parameters need to be determined. When user first accessed web site, index page will be displayed as shown in Fig. 2. Index page contains a form to enter design parameters and a circuit that shows entered parameters. PHP scripts used to calculate entered parameters. PHP GD library used to read characteristic curves and other drawings.
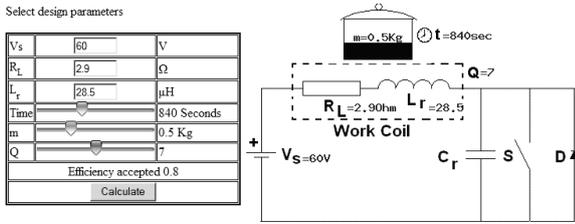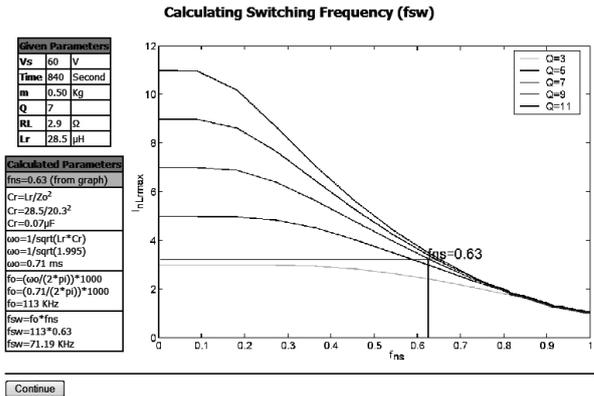
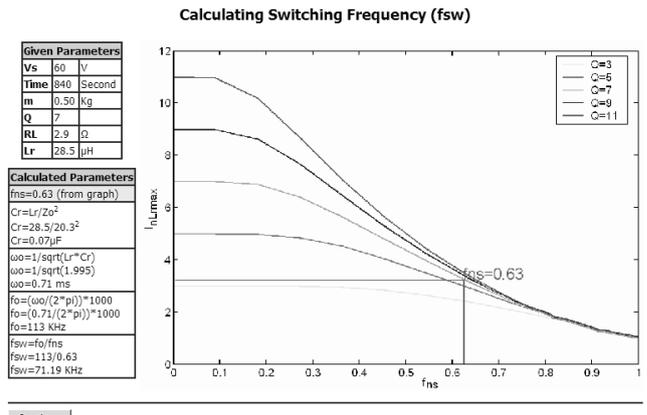**Fig. 2**. Index page of the SSRI desing web site

Slider components used to some form fields to make the tool easy-to-use and reduce mistakes. Added "title" properties of each field show a clue about fields when mouse move on a field. Water mass slider, which contains values (0.25, 0.50, 0.75, 1.00 and 1.25 Kg) has been used to choose water mass (*m*). Area of heated water mass indicator filled proportionally with value of m when user changed mass value.

JavaScript receives user inputs from the Web page, which are passed to PHP script to calculate and draw. Calculation results are then passed back to PHP page to show.

When the Calculate button is pushed, user goes to a set of characteristic curves step by step as seen in Fig. 3. Each graph has been obtained from previous study and validated by experiments. Fig. 3 (a) shows required power for boiling according to the entered user design parameters. By clicking the link Continue, normalised power and normalised peak load current can be obtained from Fig. 3 (b). Fig. 3 (c) shows the user normalized switching frequency which is depend on normalized peak load current and Fig. 3 (d) shows the normalized peak resonant capacitor voltage.
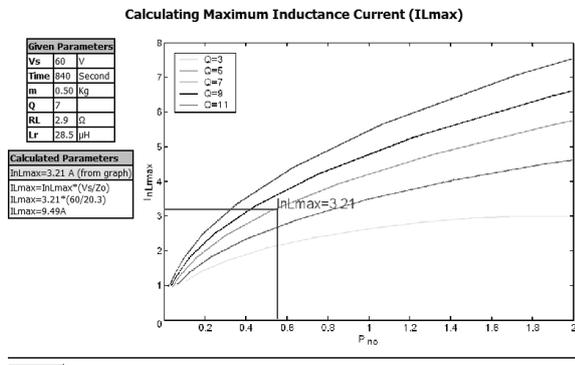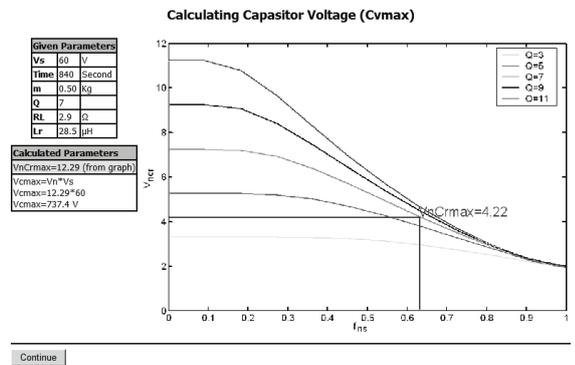

a)

b)

c)

d)

Fig. 3. Design graphs, given and calculated parameters windows of SSRI design tool a) Time vs. Po, b) Pno vs. InLmax, c) fns vs. InLmax, d) fns vs. VnCmax

Fig. 4 shows the calculated results of important design parameters. Using this interactive application, designers can design without lengthy and complex calculations via internet. Interactive application can use different combinations of design parameters again and again. The design results can be saved as an image file and use with other application such as Word etc. and can print whole page. Using Index page link, the user can go to home page of application to design with new parameters.
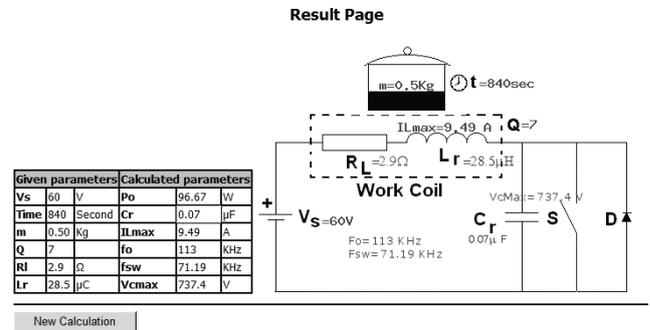

Fig. 4. Result page of the SSRI design tool

Conclusions

A practical design procedure for the small axisymmetrical induction heating cooker is proposed.

Good simulation results can be obtained for induction cooker by using the simple model presented here. This model was designed to be a learning tool to give those unfamiliar with induction cooker an opportunity to experiment with such a circuit.

The development and description of a Web-based design tool for SSRI is provided by means of PHP scripts. It was developed for engineers and students to use as a design tool for induction cooking systems. Although considerable work remains to be done, it is shown that Web-based education possesses many advantages for design engineer.

Calculation procedure has presented step by step using visual materials and results presented as a table and on the circuit. Interactivity properties of application provide designers can change possible values of design parameters and calculate different design.

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S. Yilmaz, B. S. Sazak, S. Cetin. Design and Implementation of Web-Based Training Tool for a Single Switch Induction Cooking System // Electronics and Electrical Engineering. – Kaunas: Technologija, 2010. – No. 3(99). – P. 89–92.

We present a new web-based design method of a single switch resonant inverter (SSRI) for home cooking applications. The tool was implemented using PHP scripts and is freely accessible through Web. Designing a SSRI for induction cooking application is a complex task. Design specifications for the inverter are the input voltage, work coil parameters, water mass and required time for boiling. All other parameters need to be determined. The proposed PHP based design tool will make it faster and easier for the engineer to obtain various design parameters. This design tool employs an intuitive and nonmathematical approach, allowing engineers to rapidly and efficiently learn the fundamentals, instead of wasting too much time on mathematical derivations and algebraic manipulations. A simple design procedure is given and a design example is presented for illustrative purposes. Application is tested local server and published at http://egitimproje.pau.edu.tr/induction/. Ill. 4, bibl. 11 (in English; summaries in English, Russian and Lithuanian).

С. Йылмаз, Б. С. Сазак, С. Четин. Проектирование и внедрение интернетного учебного пособия // Электроника и электротехника. – Каунас: Технология, 2010. – № 3(99). – С. 89–92.

Представлен новый интернетный метод проектирования резонансного инвертора одного переключателя (SSRI) для приложений домашней кулинарии. Программа была реализована используя PHP скрипты. Проектирование SSRI для индукционного применения приготовления еды является сложной задачей. Спецификации инвертора такие: входное напряжение, параметры работы катушки, масса воды и требуемое время для кипячения. Все остальные параметры должны быть определены. Инструмент основан на PHP и позволяет проектировать быстрее и прощеб а также получить различные параметры конструкции. Интерфейс программы интуитивный, что позволяет инженерам быстро и эффективно научиться основам, вместо того чтобы тратить слишком много времени на математические и алгебрические манипуляции. В иллюстративных целях приводится простой пример проектирования. Применение проверяется на локальном сервере по адресу: http://egitimproje.pau.edu.tr/induction/. Ил. 4, библ. 11 (на английском языке; рефераты на английском, русском и литовском яз.).

S. Yilmaz, B. S. Sazak, S. Cetin. Internetinės mokymo priemonės apie vieno jungiklio indukcinę virtuvinę viryklę sukūrimas naudojant PHP // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2010. – Nr. 3(99). – P. 89–92.

Pristatyta nauja buitinėms viryklėms skirto vieno jungiklio rezonansinio inverterio (SSRI) internetinio projektavimo priemonė. Programa sukurta naudojant PHP scenarijus ir yra nemokama. Indukcinei viryklei skirtą SSRI projektuoti sunku. Inverterio projektavimo pradiniai duomenys: įėjimo įtampa, darbiniai ritės parametrai, vandens masė ir reikalaujama užvirimo trukmė. Visus kitus parametrus reikia nustatyti. Siūlomas įrankis leidžia inžinieriui lengviau ir greičiau nustatyti trūkstamus parametrus. Programos sąsaja intuityvi, todėl inžinieriai gali greitai išmokti naudojimosi ja pagrindus. Pateiktas paprastas projektavimo pavyzdys. Programa išbandyta vietiniame serveryje ir gali būti prieinama adresu http://egitimproje.pau.edu.tr/induction/. Il. 4, bibl. 11 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).