

An Education Set Of Power Electronics: AC/DC Converters

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Abstract

Ac/dc converters have a wide range of applications from small rectifiers to large high voltage direct current (HVDC) transmission systems. They are used for general-purpose power supplies, power conversion systems, electro-chemical process, many kinds of motor drives and many other applications. Ac/dc converters are one of the most important topic for power electronics engineering. This paper presents an educational graphical user interface (GUI) for simulation of various topologies of power electronic ac/dc converters. The educational GUI is developed by using the GUIDE tool of MATLAB, which acts as a front-end interface that can be used for teaching as well as learning. This package can be considered as a virtual laboratory or a useful learning tool for the power community.

Key words: AC/DC Converter, Power Electronics, GUI

An Interface Program for Three-Phase Transformer Design

Özet

Ac/dc konverterler, küçük güçlü doğrultuculardan yüksek gerilimli doğru akım iletim sistemlerine (HVDC) kadar birçok kullanım alanına sahiptir. Bunlar, genel amaçlı güç kaynakları, güç dönüşüm sistemleri, elektro-kimyasal işlemler, motor sürme sistemleri ve birçok uygulamada kullanılmaktadır. Ac/dc konverterler, güç elektroniği mühendisliğindeki en önemli konulardan biridir. Bu çalışma, birçok farklı topolojiye ait ac/dc konverterlerin simülasyonu için eğitim amaçlı bir arayüz sunmaktadır. Bu arayüz programı, MATLAB GUIDE kullanılarak geliştirilmiştir; GUIDE, öğrenme ve öğretme için de kullanılacak en son tür bir arayüz geliştirme MATLAB eklentisidir. Bu çalışmada geliştirilen arayüz programı, güç sistemleri ile ilgilenen topluluk için sanal bir laboratuvar olarak düşünülebilir

Anahtar Kelimeler: AC/DC Konverter, Güç Elektroniği, Arayüz

1. Introduction

Ac/dc converters constitute the largest segment of power electronics that interface to the electric utility system today. The history of these converters extends nearly one hundred years, and they are often defined as classical power electronics. Ac/dc converters, the rectifiers, come in many types and can variously be classified as uncontrolled versus controlled, single-phase versus multiphase (usually, three-phase), half-wave versus full-wave, or phase-controlled versus pulse with modulated. Uncontrolled rectifiers are based on power diodes; in phase controlled rectifiers SCRs are used; and pulse with modulated rectifiers require fully controlled switches, such as IGBTs or power MOSFETs [1-5].

In the sense of teaching pedagogy, the traditional treatment of all fields of engineering tends to be highly theoretical and mathematical with heavy emphasis on equation derivation and algorithmic development. Such an approach is convenient from the instructor's point of view but may not be beneficial to the students. Simulations often enrich modern education in all areas [6-8]. Various simulation packages are being widely used to design and simulate electrical and electronic circuits' behavior. However, each of these simulators has their own merits and demerits, limitations either from the analysis point of view or from economical considerations. These simulators also require the user to be proficient in designing the circuits and need deep training to be familiar with. Important demands for education are visualization of the

simulation results and the interactivity of the simulation. The student should have the ability to influence parameters and/or conditions during the simulation and thereby see the effects of these variations immediately in his simulation. GUI based interactive simulations are an effective way to go deeper inside a problem [9-11].

Due to increasing demand, the power conversion systems are becoming more and more complex in their structure. As a result of this, it is essential to make computer aided simulations before setting up the power electronic system. In this paper an educational GUI for simulation of various topologies of power electronic ac/dc converters has been presented. An attractive and flexible GUI is built benefiting from the facilities offered by the Matlab programming language. Matlab implements GUIs through GUIDE (Graphical User Interface Development Environment). The developed GUI, no need for any circuitry design, is a user-friendly tool and gives the basic understanding of most commonly used ac/dc converter topologies, so it can be considered as a learning aid system for students to get a comprehensive understanding of power electronic converter operations. Various parameters are made available for the user to change and see their impacts on the converter performance through its waveforms.

2. Material and Method

Matlab is a matrix-based software for scientific and engineering numeric computation and visualization. Matlab is chosen as the programming tool primarily because of simple GUIs, immediate graphics facilities, built-in functions, the possibility of adding user-written functions, interactive mode of work, simple programming and its wide availability on computing platforms. These factors make Matlab an excellent language for teaching and a powerful tool for research and practical problem solving.

A GUI is a user interface program built with graphical objects such as buttons, text fields, sliders and menus. In fact, these definitions are well known for almost all computer users. Applications that provide GUIs are generally easier to learn and use since the person using the application does not need to know what commands are available or how to use them.

GUIs assure the communication process between the user and the system's inference engine. Matlab implements GUI through GUIDE which allows the user to create figure windows containing graphical objects [12]. Matlab also provides the user some built-in templates on which the user can develop further. The user can place graphical objects by drag-and-dropping them on the figure window and modify the default properties of these objects such as foreground and background colors, font types and sizes by invoking the Property Editor. When the user saves this figure, Matlab generates two files: one with .fig extension containing the graphical objects and the other with .m extension. In the second file, the user has to write the Matlab code in callback routine, which is associated with each of the graphical objects. This code will be executed each time when the graphical control is activated.

All controllable electrical switching devices can be used for contact-free switching or continuous control of electrical energy. Depending on the type, the switches can be uncontrolled, semi-controlled, or fully-controlled. The classical ac/dc converters use diodes, thyristors and power transistors as a power switch. In the callback routine (.m file), all of the power switches in question are assumed and modeled for ideal conditions (no internal resistance and inductance, no forward voltage drop). It is considered that the power system contains no harmonics (namely, pure sinusoidal). Power switching devices talked about are employed for controlling resistive, inductive or capacitive loads. Numerical solutions of dynamic models of the power circuits are performed with ODE45-ODE23S built-in functions in Matlab. ODE45, based on the fourth-fifth order Runge-Kutta pair, is a general-purpose single-step solver; and ODE23S is a single-step stiff system solver based on the Rosenbrock formulas. The calculation results, the rms value of the line current and the mean values of the load voltage and current, are also computed with 'trapz' built-in function. The calculation of THD is performed with 'fft' built-in function and classical THD formulas by supposing not to be used any filtering operation.

3. Demonstrative Examples

Basically, the developed GUI consists of two sets of programs. One set is responsible for the

main window; and the other is responsible for the selected ac/dc converter window. In this GUI a total of twenty-three ac/dc converters are investigated. Therefore, each of converters has its own window. The main window gives a list of all the ac/dc converters, displays the power circuitry&basic information of selected converter and allows the user to choose any of them to be examined. The power circuitry&basic information, positioned to bottom of the main window, is activated with push-button labeled with its own name. The main window,

displaying the power circuitry&basic information on three-phase voltage-source pwm controller with a freewheeling diode, is given in Fig.1. All of the power circuitries are formed with the Visio program, and imported and stored into Matlab program as a .gif image; the basic information is built with the static-text string property. All of the converters in question can be examined by using the push-buttons labeled with the symbol “>>” positioned to right of the converter type.

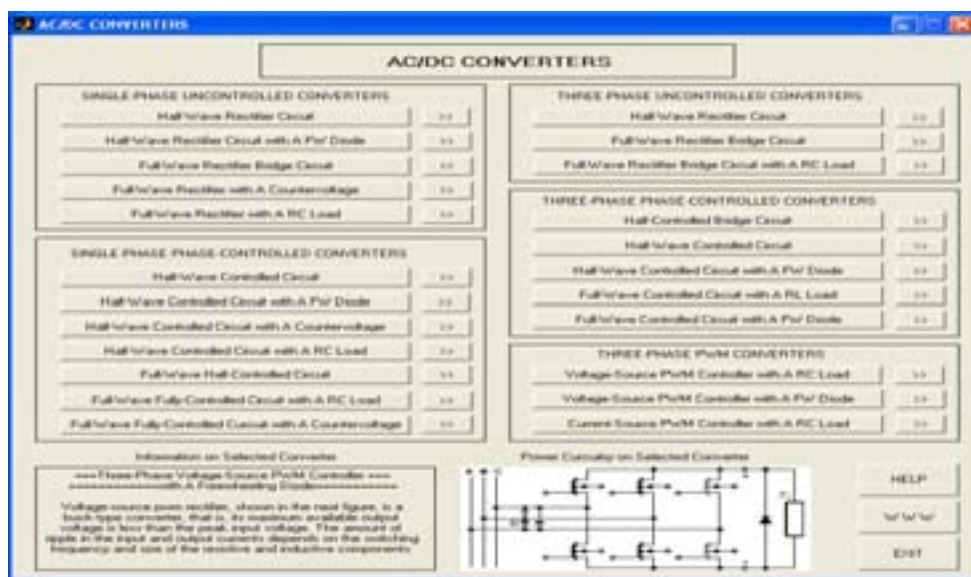


Figure 1. The main window of the GUI

At any time the user can run all of the converter types independently and compare with each other. When the user selects the converter type to simulate by pressing “>>”, an individual window showing the circuit specifications will pop-up. Depending upon the nature of the selected converter type, the user needs to enter the required data. Naturally, the required data will be different from each other. As soon as the user enters the required data and presses RUN&SAVE button available in the window, the figure windows positioned to right of the window show the waveforms such as power system voltages-currents, load voltages-currents and etc. At the end of the simulation, the data of the waveforms seen on the screen are saved as a .dat file into where the GUI is positioned. The .dat file will be used at following process. The push-button named with CALCULATE calculates the rms value and total harmonic distortion (THD) of the line current and the

mean values of the load voltage and current by using the saved .dat file. The HELP button gives relevant information on ac/dc converter and its usage. The menus and toolbar located to top of the window can be used for classical window operations such as saving, copying, printing, zooming and etc.

Because of the limited space, only four-demonstrative examples are given in this paper; those are single-phase half-wave controlled circuit with a freewheeling diode, three-phase full-wave uncontrolled circuit with a RC load, three-phase full-wave controlled circuit with a RL load, three-phase voltage-source pwm controller circuit with a freewheeling diode.

The individual window of single-phase half-wave controlled circuit with a freewheeling diode is given in Fig.2. In this figure, time profiles of line-load voltages-currents and freewheeling diode current are displayed for defined specifications (power system, firing

angle and load) in three-period time; and then, the calculations are made. To get detailed information on the voltage controller the HELP button can be used.

The individual window of three-phase full-wave uncontrolled circuit with a RC load is given in Fig.3. In this figure, time profiles of 3-phase line-load voltages-currents and capacitor current are displayed for defined specifications (power system, load) in three-period time; and

then, the calculations are made. Similarly, the HELP button can be used for getting help.

The individual window of three-phase full-wave controlled circuit with a RL load is given in Fig.4. In this figure, time profiles of 3-phase line-load voltages-currents and firing pulses are displayed for defined specifications (power system, firing angle and load) in three-period time; and then, the calculations are made.

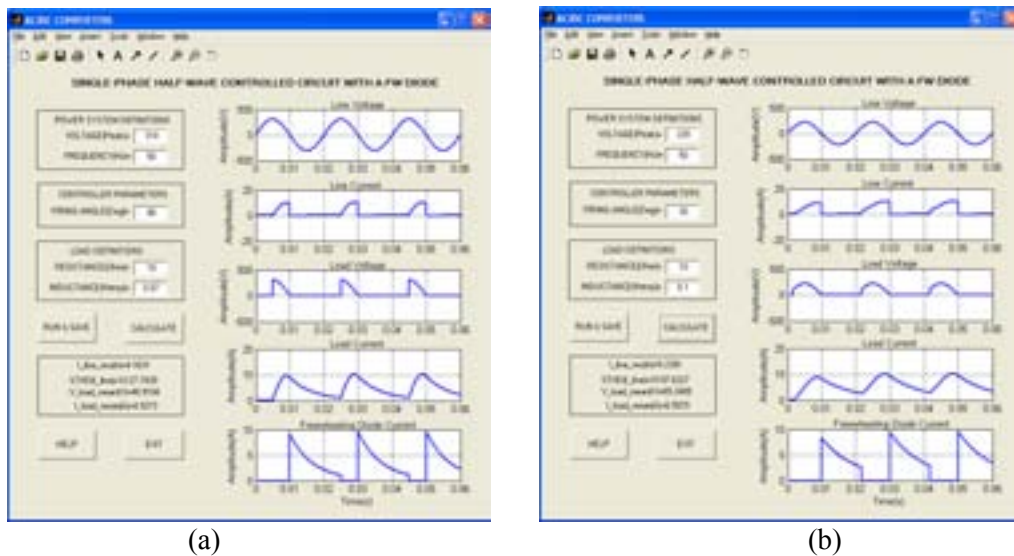


Figure 2. The individual window of single-phase half-wave controlled circuit with a freewheeling diode for different operating conditions, a) $V_p = 310V$, $L = 70mH$, $\alpha = 90^\circ$, b) $V_p = 220V$, $L = 100mH$, $\alpha = 30^\circ$

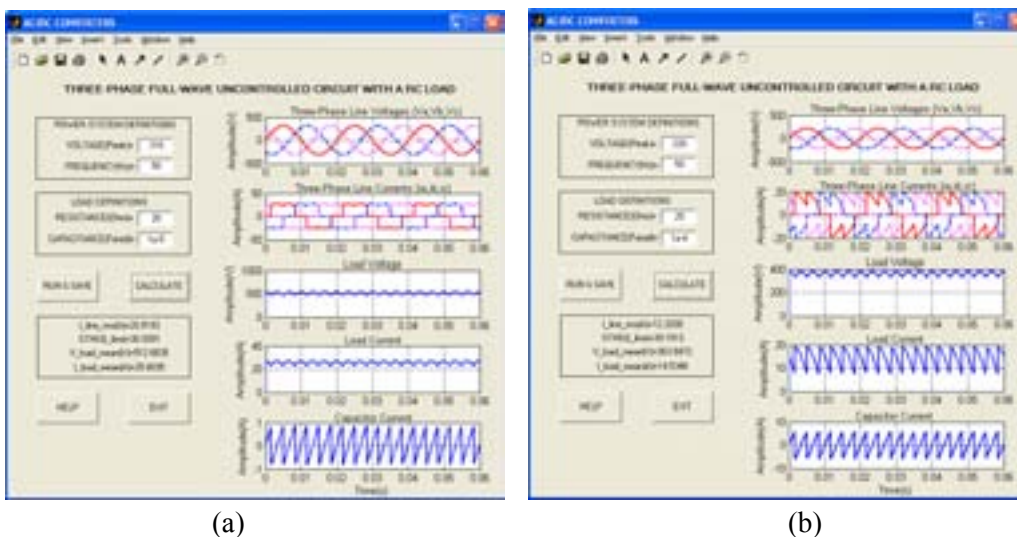
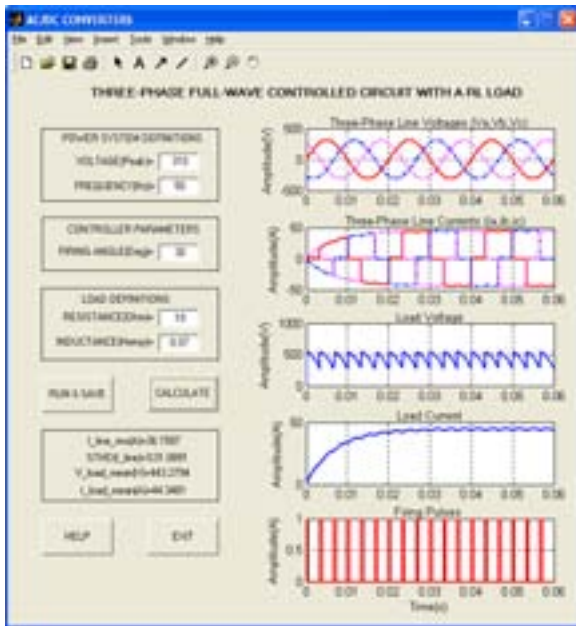
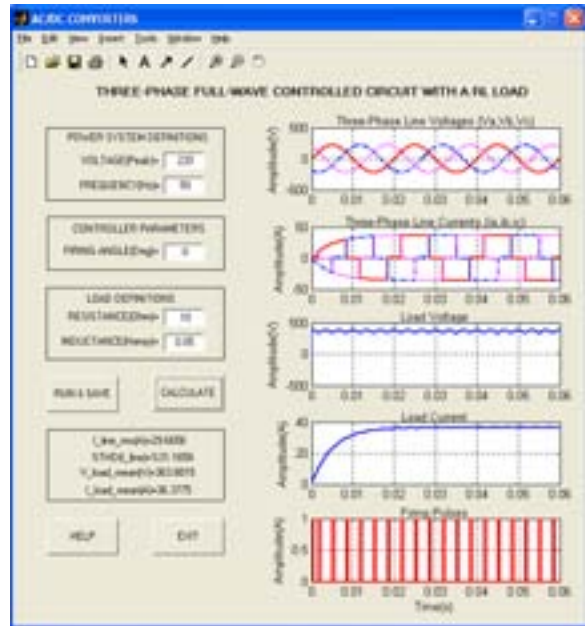


Figure 3. The individual window of three-phase full-wave uncontrolled circuit with a RC load for different operating conditions, a) $V_p = 310V$, $R = 20\Omega$, $C = 10\mu F$, b) $V_p = 220V$, $R = 25\Omega$, $C = 100\mu F$



(a)

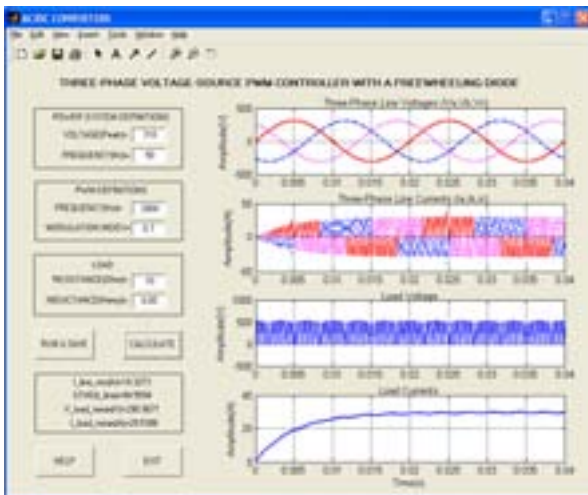


(b)

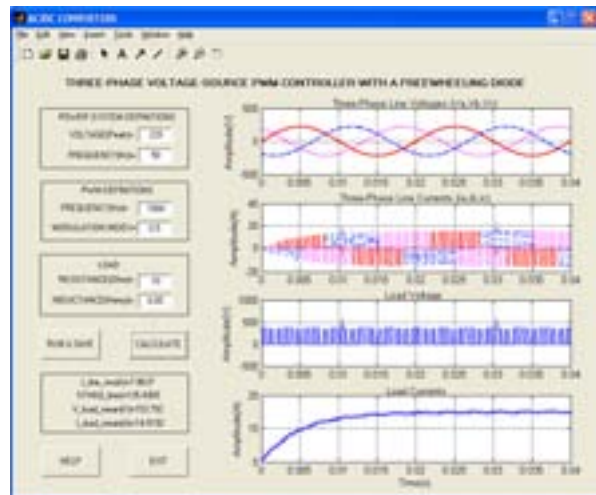
Figure 4. The individual window of three-phase full-wave controlled circuit with a RL load for different operating conditions , a) $V_p = 310V$, $L = 70mH$, $\alpha = 30^\circ$, b) $V_p = 220V$, $L = 50mH$, $\alpha = 0^\circ$

In the same way, the individual window of three-phase voltage-source pwm controller circuit with a freewheeling diode is given in Fig.5. In this figure, time profiles of 3-phase line-load

voltages and currents are displayed for defined specifications (power system, pwm and load) in two-period time; and then, the calculations are made.



(a)



(b)

Figure 5. The individual window of three-phase voltage-source pwm controller with a freewheeling diode for different operating conditions, a) $V_p = 310V$, $f_p = 2kHz$, $M = 0.7$, b) $V_p = 220V$, $f_p = 1kHz$, $M = 0.5$

4. Conclusion

This paper presents an educational GUI for simulation of various topologies of power electronic ac/dc converters. The educational GUI package, a different approach to power electronic education on a personal computer, provide a convenient tool so that many scenarios can be tried with ease. It also provides “a virtual laboratory” in which the user can chose the ac/dc converter type, enter the related converter parameters, view graphs of special parameters in time domain, and get the numerical results such as the rms value and total harmonic distortion (THD) of the line current and the mean values of the load voltage and current. This is very helpful for better understanding. The user needs only an elementary knowledge of power electronic circuitry in order to use this educational GUI.

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