



**NATURAL AND APPLIED SCIENCES**  
**ELECTRIC AND ELECTRONIC ENGINEERING**

Received: February 2008

Accepted: July 2008

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**AN EDUCATION SET OF POWER ELECTRONICS: AC/AC CONVERTERS**

**ABSTRACT**

Currently, four basic types of ac/ac converters have been used in industrial applications. These are phase controlled AC voltage controllers, cycloconverters, pwm controlled ac voltage controllers and matrix converters. This paper presents an educational graphical user interface (GUI) for simulation of various topologies of power electronic ac/ac 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.

**Keywords:** Electronic, AC/AC Converter, GUI, Power Electronics, Education Set

**GÜÇ ELEKTRONİĞİ EĞİTİM SETİ: AC/AC KONVERTERLER**

**ÖZET**

Günümüz endüstriyel uygulamalarında dört temel tip AC/AC konverter kullanılmaktadır. Bunlar, faz kontrollü ac gerilim kontrolcülerini, siklo konverterler, pwm kontrollü ac gerilim kontrolcülerini ve matrix konverterlerdir. Bu çalışma, birçok farklı topolojiye ait güç elektroniği AC/AC konverterlerin simülasyonu için eğitim amaçlı bir arayüz sunmaktadır. Bu arayüz programını, MATLAB GUIDE kullanılarak geliştirilmiştir; GUIDE, öğrenme ve öğretme için de kullanılabilir en son tür bir arayüz geliştirme MATLAB eklentisidir. Bu çalışmada geliştirilen arayüz programını, güç sistemleri ile ilgilenen topluluk için sanal bir laboratuvar veya kullanışlı bir öğrenme gereci olarak düşünülebilir.

**Anahtar Kelimeler:** Elektronik, AC/AC Konverter, Arayüz, Güç Elektroniği, Eğitim Seti



## 1. INTRODUCTION (GİRİŞ)

Ac voltage converters have a constant voltage ac supply input and incorporate semiconductor switches which vary the rms voltage impressed across the load. There are four basic types of ac to ac converters. The simplest ones, the phase controlled ac voltage controllers, allow controlling the output voltage only, while the output frequency is the same as the input frequency. The second one is the cycloconverter. In cycloconverters, the output frequency can be controlled, but it is at least one order of magnitude lower than the input frequency. In both the phase controlled ac voltage controllers and cycloconverters, the maximum available output voltages approach the input voltages. The third one is the pwm controlled ac voltage controller. Cutting out numerous slices of main voltage within each switching cycle of the converter can perform pwm control. Switching signal can be obtained by comparing an isosceles triangle carrier wave with a suitable dc voltage. The maximum available output voltage of pwm converter approaches the input voltage; and the output frequency is the same as the input frequency. The last one is the matrix converter. Because of having no inherent limits on the output frequency, matrix converters are most versatile, but the maximum available output voltage is about 15% lower than the input voltage [1, 2, 3, 4, and 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, 7, and 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, 10, and 11].

## 2. RESEARCH SIGNIFICANCE (ÇALIŞMANIN ÖNEMİ)

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/ac 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/ac voltage controller 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.



### 3. MATERIAL AND METHOD (MATERİYAL VE METOD)

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, interactive mode of work, immediate graphics facilities, built-in functions, the possibility of adding user-written functions, 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, which 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 object. 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/ac voltage controllers use thyristors and triacs as a power switch. New generation ac/ac voltage controllers, like matrix converters, require fully controlled power switches capable of conducting current in both directions (bi-directional). Such switches can be assembled from power transistors (MOSFET, IGBT, etc.) and diodes. 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. Power switching devices talked about are employed for controlling resistive, inductive or capacitive loads. The two principal load types of general interest in power electronics are the resistive and the inductive loads. That's why only the resistive and inductive loads are taken into account in the GUI. Numerical solutions of dynamic models of the power circuits are performed with ODE45-ODE23s built-in functions in Matlab. The calculation results, maximum and effective values of the load voltages and currents, are also computed with 'max' and 'trapz' built-in functions respectively.

### 4. DEMONSTRATIVE EXAMPLES (AÇIKLAMALI ÖRNEKLER)

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/ac voltage controller window. In this GUI a total of fourteen ac/ac voltage controller are investigated. Therefore, each of voltage controllers has its own window. The main window gives a list of all the ac/ac voltage controllers, displays the power circuitry&basic information of selected controller 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 full-wave ac/ac voltage controller, is given in Figure 1. All of the power circuitries are formed with the Visio program, and imported and stored into Matlab as a .gif image; the basic information is built with the static-text string property. All of the controllers in question can be examined by using the push-buttons labeled with the symbol ">>" positioned to right of the controller type.

At any time the user can run all of the voltage controller type independently and compare with each other. When the user selects the controller type to simulate by pressing ">>", an individual window showing the circuit specifications will pop-up. Depending upon the nature of the selected controller type, the user needs to input the required data. Naturally, the required data will be different from each other. As soon as the user inputs 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, load voltages&currents, pwm operation and reference signals. At the end of the simulation, the data of the waveforms are saved as a .dat file into where the GUI program is positioned. The .dat file will be used at following process. The push-button named with CALCULATE calculates the maximum and effective values of the load voltages and currents by using the saved .dat file. The HELP button gives relevant information on ac/ac voltage controller 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.

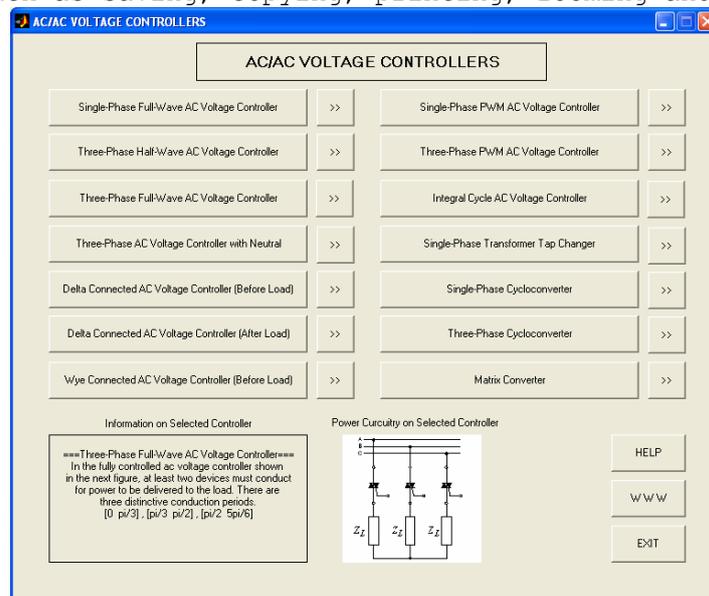
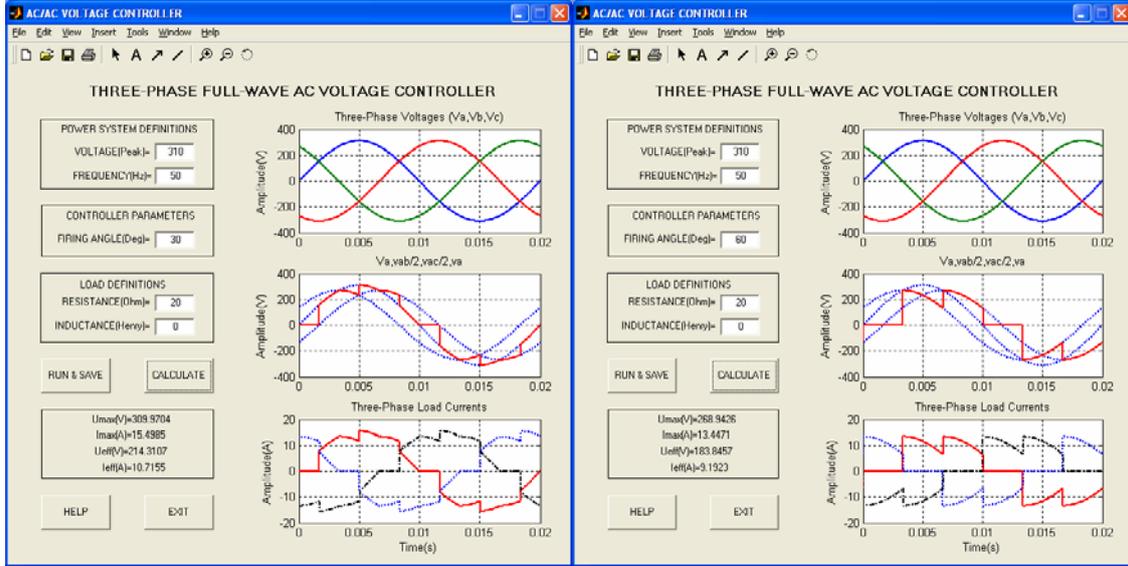


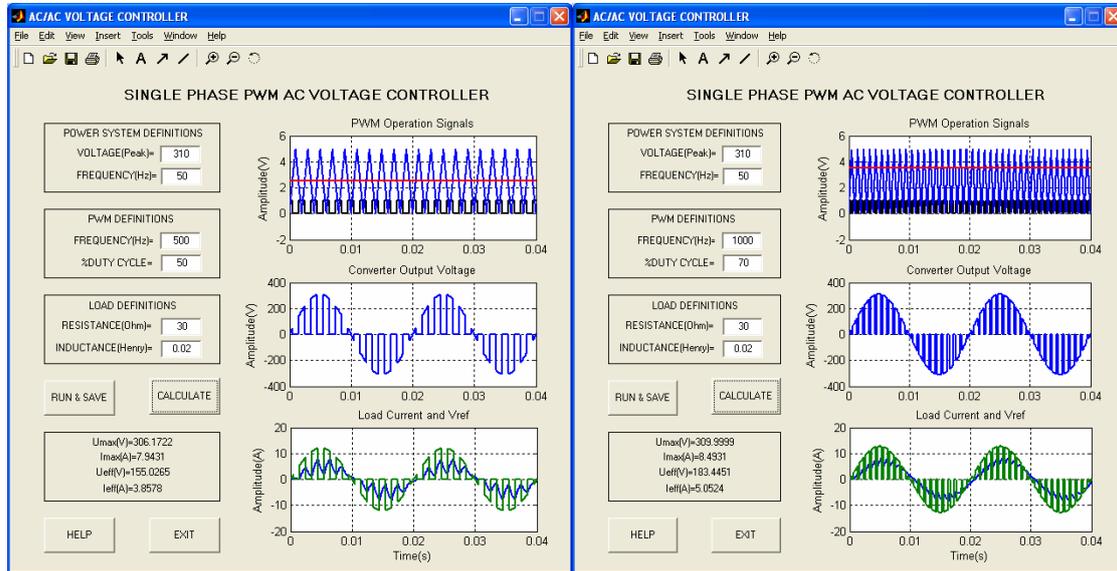
Figure 1. The main window of the GUI  
 (Şekil 1. GUI ana penceresi)

Owing to the limited space, only three demonstrative examples are given in this paper; those are three-phase full-wave ac voltage controller, single-phase pwm ac voltage controller and matrix converter. The individual window of three-phase full-wave ac voltage controller is given in Figure 2. In this figure, time profiles of three-phase line voltages and currents are displayed for defined specifications (power system, firing angle, load) in one-period time; and then, the calculations are made. To get detailed information on the voltage controller the HELP button can be used.



(a) (b)  
 Figure 2. The individual window of three-phase full-wave ac voltage controller for different firing angles, a) 30°, b) 60°  
 (Şekil 2. Farklı tetikleme açıları için üç-fazlı tam-dalgac ac gerilim kontrolcü özel penceresi, a) 30°, b) 60°)

In the same way, the individual window of single-phase pwm ac voltage controller is given in Figure 3. In this figure, time profiles of pwm operation signals, converter output voltage and load current with  $V_{ref}$  are displayed for defined specifications; and then, the calculations are made.



(a) (b)  
 Figure 3. The individual window of single-phase pwm ac voltage controller for different pwm operations, a)  $f=500\text{Hz}$  -  $\text{DCycle}=\%50$ , b)  $f=1000\text{Hz}$  -  $\text{DCycle}=\%70$   
 (Şekil 3. Farklı pwm işlemleri için tek-fazlı pwm ac gerilim kontrolcü özel penceresi, a)  $f=500\text{Hz}$  -  $\text{DCycle}=\%50$ , b)  $f=1000\text{Hz}$  -  $\text{DCycle}=\%70$ )

The window related to the matrix converter is given in Figure 4. Matrix converters are a kind of unique ac/ac conversion circuits. 9

bi-directional conductive and bi-directional blocking switches are used to connect the source and the load directly. Energy is directly converted from 3-phase, constant frequency, constant voltage inputs to 3-phase, variable frequency, variable voltage outputs. In this respect, matrix converters are most versatile and complex ac/ac voltage controller. In Figure 4, time profiles of 3-phase line voltages, pwm operation signals, converter output voltage for 1-phase and load currents are given for defined specifications respectively.

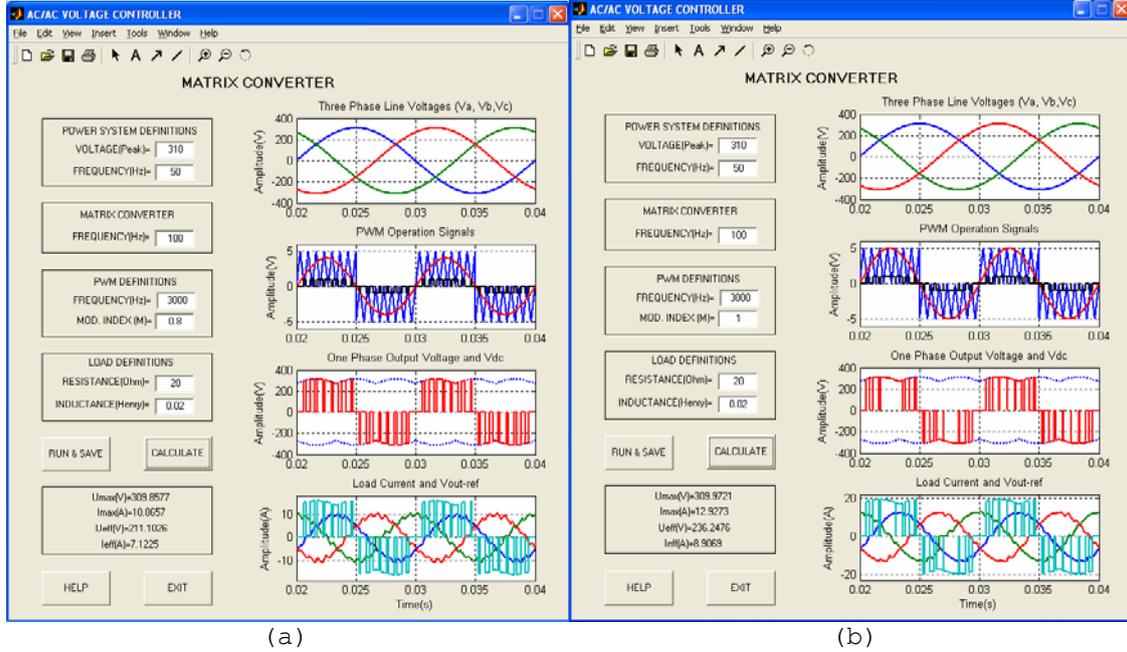


Figure 4. The individual window of matrix converter for different modulation indexes, a)  $M=0.8$ , b)  $M=1$   
(Şekil 4. Farklı modülasyon indeksleri için matrix konverter özel penceresi, a)  $M=0.8$ , b)  $M=1$ )

## 5. CONCLUSIONS (SONUÇLAR)

This paper presents an educational GUI for simulation of various topologies of power electronic ac/ac 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/ac voltage controller type, input the related controller parameters, view graphs of special parameters in time domain and get the numerical results such as maximum and effective values of line-load voltages and currents. 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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