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Use of simulation and power electronics hardware trainer for teaching an introductory undergraduate power electronics course

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Abstract

An introductory power electronics undergraduate level course at Purdue University Fort Wayne has been upgraded, incorporating theoretical and simulation analyses for comparison to actual measured values obtained from a Lucas Nuelle Power Electronics and Drives 300 W training system. Lecture and laboratory content have been revised to more fully integrate lectures with laboratory assignments. Close agreement between theoretical and simulation values and the measured values obtained in laboratory provide a strong argument that for educational institutions where the cost of such equipment is prohibitive, the combination of theory and simulation yield a very effective alternative. In this work, the specifics of this course are explained in detail.

1 Introduction

Power electronics involves the study of converting electrical power from one form to another, for example, AC to DC or DC to AC. Applications of power electronics are wide-ranging, encompassing high power DC transmission as well as the powering of everyday appliances. The introduction within the last 40 years of efficient power supplies based on power electronics principles has revolutionized the power industry. Nevertheless, these benefits have not come without cost. The introduction of additional switching frequencies associated with these supplies has introduced new problems to the grid. Subsequently, power electronics has been used to find solutions to these problems. Thus, power electronics continues to be a rapidly evolving technology, and electrical engineering students must be properly educated in this arena. An introductory power electronics undergraduate level course at Purdue University Fort Wayne has been upgraded, incorporating theoretical and simulation analyses for comparison to actual measured values obtained from a Lucas Nuelle Power Electronics and Drives 300 W training system. Lecture and laboratory content have been revised to provide a cohesive approach with intentionality to link lectures to lab. In this work, the specifics of this course are explained in detail.

2 Background

Many recognize the need for incorporating both simulation and laboratory experiments in power electronics undergraduate education. Mi et al. [1] articulated the need for hands-on learning experience in power electronics courses, to be accomplished via computer simulation and/or laboratory experiences. They developed a short, two- or three-day continuing education course in power electronics, geared specifically for practicing electrical and nonelectrical engineers in the automotive field who had not received formal training in power electronics. Their course included a session on simulation and laboratory demonstration.

Kayisli et al. [2] developed a software simulation tool to be used for active power factor correction in DC – DC converter circuits, enabling students to compare theory learned in lecture to simulation. Yamin et al. [3] integrated PSpice simulations to enhance laboratory hands-on experiments. Students perform PSpice simulations of the circuit prior to building it in laboratory. Subsequently, in laboratory, they perform hardware experiments on the circuit and compare performance of the actual hardware to that of simulation. The authors report that the experience gained in simulation made the students more knowledgeable about the expected behavior of the circuit prior to arriving in the laboratory.

Bonislawski and Holub [4] designed their own test stand configuration to be used for power electronics laboratory experiments. The system consists of a PC computer equipped with LabView or equivalent software for hosting a Graphical User Interface (GUI) for interfacing with the user, the Texas Instruments (TI) 2000 Piccolo LaunchPad DSP with TMS320F28027 cores for performing analog-to-digital (ADC) and digital-to-analog (DAC) conversion and for generating pulse-width modulated (PWM) signals, a control and measurement hardware module for monitoring voltage and current, a variety of converter configurations to be analyzed, and a digital oscilloscope for capturing waveforms as well as measurements of voltage, current, power, and energy. Their design is flexible, enabling study of a wide variety of power electronics topologies, including rectifiers, AC/AC converters, inverters, modulation schemes, and buck, boost, flyback, and push-pull converters. They report that the unit is beneficial in reinforcing theory taught in lecture.

Elmas and Sonmez [5] developed a simulation tool to be used in teaching power electronics in lieu of laboratory hardware testing. They cited high cost, potential for electrical accidents, potential malfunctioning of equipment due to misuse, and the frequent lack of availability of hardware testing equipment as reasons for choosing simulation over hardware laboratory investigation. Yalcin and Vatansever [6] developed a web-based power electronics virtual laboratory (VPwrLab) for use in power electronics education in lieu of a laboratory consisting of experiments on hardware. They cite insufficient/nonexistent laboratories in some universities, high installation, maintenance, and operating costs, and potential safety issues due to high currents and voltages as reasons for choosing simulation over a hardware laboratory option. VPwrLab was designed using MATLAB and Visual Studio. Features include the ability to simulate many power electronics circuits online or offline, descriptions and animations of relevant circuits, capability of preparing and sending laboratory reports, and online availability of support from instructors.

Przybyla et al. [7] designed and built their own platform for the teaching of a remote power electronics laboratory. It consists of a reconfigurable power converter board, microcontroller-based control board, Raspberry PI 4, model B, oscilloscope, control and viewing applications, remote control application, and the PCs of connected students. Students connect to the system from their computers via a remote-control application such as Zoom. The instructor is logged in to the same Zoom session and can guide a group of students, giving screen control to one student at a time. The Raspberry PI enables connection to the Internet. It hosts the GUI application to interface with the user. It communicates with the dsPIC33CK256MP206-based control board, which sends control signals to the power converter board. The power converter board can be reconfigured to study a variety of power electronics converter topologies: buck, boost, series resonant inverter, three-phase voltage inverter, single and three-phase AC voltage controller, and three-phase thyristor rectifier. The system enables students to vary parameters on a given converter and view resulting waveforms and measured values of variables such as voltage and current.

Bauer et al. [8] explored the benefits and limitations of using animation and simulation to enrich the teaching of power electronics and electrical drive systems. They reported that simulation enabled the study of behavior of a device for varying parameters and operating conditions, enabling investigation that would not be possible with simply a textbook, lecture, or even during an actual laboratory exercise. They identified commonly used commercially available simulation software packages for electronic circuits: SPICE, MicroCAP, Saber, and Electronics Workbench. They also identified specialized simulation packages for power electronics and electrical drives: CASPOC, Krean, ATOSEC, PSIM, and Simplorer. Their study was based on CASPOC due to prior familiarity with this platform. They described the powerful capabilities of CASPOC to perform simulations and animations of power converter circuits enabling visualization, for example, of how a motor starts to rotate. They further describe how CASPOC can be integrated with other software packages to provide even more powerful analysis. Interfacing CASPOC with MATLAB/Simulink Control Toolbox enables creating system models of electric machines and drives. Coupling CASPOC with ANSYS provides capability for solving electromagnetic, thermal and mechanical resonance effects. While recognizing the multiple benefits of simulation and animation, they conclude that these are not a substitute for an actual laboratory exercise.

In their power electronics laboratory, Kawakami et al. [9] require students, in a collaborative learning environment, to design a boost converter from scratch, and fabricate and test it. Lamar et al. [10] introduced project-based learning (PBL) methodology in a Power Supply Systems course that covers switch-mode power supplies and power supply systems. Two projects were introduced in the laboratory session: the design and construction of a boost converter and the static study of a DC – DC converter topology. Chu et al. [11] introduced project-based laboratory learning in their Power Electronics and Drives course. To avoid potential safety hazards due to high mains voltage as well as mechanical hazards associated with motors, they introduced a project which uses a programmable intelligent computer (PIC) microcontroller and H-bridge to design a control system for DC machines to simulate a practical application such as, a washing machine, an electric lift, or a tram or robot. The power source and the control signals were all below 20 V. The project was accomplished in groups of 4 – 6 students, over the course of six weeks and commenced after completion of four more traditional laboratory sessions involving DC generator and motor, three-phase rectifier, DC boost converter, and 4-quadrant DC machine control.

3 Methods

The introductory Power Electronics course, ECE 460, at Purdue University Fort Wayne, is a 4-credit hour course. It has been taught once a year since Spring Semester 2008. The course prerequisites are ECE 202, Linear Circuit Analysis II, and ECE 255, Introduction to Electronic Analysis and Design. The class meets for lecture 2.5 hours a week for 16 weeks, in addition to a weekly 3 hour laboratory session. It is a required course for students pursuing a Bachelor of

Science degree in Electrical Engineering (BSEE). It has recently been upgraded, incorporating theoretical and simulation analyses for comparison to actual measured values obtained from a Lucas Nuelle Power Electronics and Drives 300 W training system. Lecture and laboratory content have been revised to provide a cohesive approach with intentionality to link lectures to lab. Topics covered in the course are listed in Table 1. Hart's *Power Electronics* textbook [12] is the required course textbook.

The course lectures cover the theory of each of the topics listed in Table 1. For each of the power conversion topologies listed in Table 1, lectures include expected input and output voltage and current waveforms and their resulting Fourier spectrums, as applicable, calculations of root-mean-square (rms) and average values for source and load current and voltage, power factor, average power absorbed by the load, distortion factor (DF), and Total Harmonic Distortion (THD). The Hart textbook contains many example problems, which are used as in-class practice problems, worked on the board, by students, under the supervision of the instructor.

Prior to the weekly laboratory session, students are required to complete a pre-lab encompassing these theoretical calculations introduced in lecture. In addition to theoretical calculations, the pre-lab assignments also include simulation of the various circuits in Multisim as well as occasional plotting of voltage and/or current waveforms in MATLAB [13]. Multisim Electronics Workbench [14] is industry-standard SPICE simulation and circuit design software for analog, digital, and power electronics. The pre-lab must be submitted at the start of each lab session, and is worth 10% of the grade for the associated lab.

In the laboratory, the students are introduced to the state-of-the-art Lucas Nuelle Power Electronics and Drives 300 W training system, featuring the CO3636 Line commutated and self-commutated converter circuits and associated three-phase isolating 300 VA transformer, 300 W load set, and the Interactive Lab Assistant course software [15]. For each lab module, the software provides step-by-step instructions for wiring and powering the circuit, configuring the virtual instruments, and capturing a multitude of real-time measurements, such as average and rms input and output voltage, power factor, input and output active, reactive, and apparent power, and input distortion power. In addition, the software enables display of a variety of waveforms of interest, in the form of timing charts, including, but not limited to, the input and output voltage and current, instantaneous input and output power, and input current and voltage waveforms at the fundamental frequency. Furthermore, input and output power vectors may be displayed in a three-dimensional representation. Display of the input and output current and voltage spectrums is also an option. For circuits involving phase control, such as the controlled half-wave and full-wave rectifiers, a control characteristic may be plotted, for a variety of waveforms of interest, such as the average output voltage or power as a function of the control angle. All of these waveforms generated using the virtual instruments can be saved and imported into Excel or MATLAB for further analysis and evaluation.

Students are introduced to the Lucas Nuelle Power Electronics and Drives 300 W training system in the first laboratory session, Lab Zero. They are provided with a procedure which walks them through the various features of the hardware. Special attention is given to the safety instructions.

Upon completion of Lab Zero, the students are given a safety quiz, and 100% is required before continuing.

Table 1. Topics for ECE 460, Power Electronics

Topic
Introduction to Power Electronics
Computer Simulation using Multisim & MATLAB
Power Electronics versus Linear Electronics
Power Computations Relating to Nonsinusoidal Voltages and Current
Single-Phase AC Voltage Controller
Single-Phase Half-Wave Rectifiers
Single-Phase Controlled Half-Wave Rectifiers
Single-Phase Full-Wave Rectifiers
Single-Phase Controlled Full-Wave Rectifiers
Three-Phase Rectifiers
Controlled Three-Phase Rectifiers
DC – DC Converters: • Buck • Boost • Buck-Boost • Flyback • Forward • Push-Pull • Full-Bridge • Half-Bridge • Resonant
DC – AC Converters (Inverters) • Square-wave • Sinusoidal Pulse-Width Modulation • Three-Phase inverter operating with sine modulation
Drive Circuits, Snubber Circuits, and Heat Sinks

3.1 Example Laboratory Exercise

One of the laboratory assignments involves investigation of the controlled half-wave rectifier circuit with resistive load. For the prelab, the students are provided with the circuit of Figure 1, which is taken from the Lucas-Nuelle module *Controlled mid-point circuits (M1C)*.

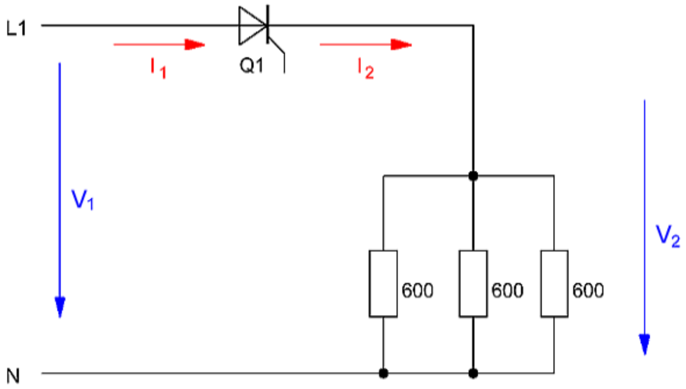


Figure 1. Controlled half-wave rectifier with resistive load

Given that the input to the circuit of Figure 1 is a sinusoid of 93 V rms at a frequency of 60 Hertz (Hz), and the delay angle, α, is 60°, the students must determine theoretical values for the following:

a. The average load current and average output voltage
b. The RMS load current and RMS output voltage
c. The average power absorbed by the load
d. The power factor of the circuit.

In addition, the students must simulate the circuit in Multisim using the circuit shown in Figure 2. This circuit is a modified version of one found in the example circuits provided in Multisim. In Figure 2, S1 is a silicon controlled rectifier (SCR), within the Power library of Multisim (family: SWITCHES), and U1 is a phase angle controller, also classified in Multisim as a Power group component (family: POWER_CONTROLLERS). The voltage on V1 specifies the control angle, α, in degrees. The default parameters of S1 are used: Trigger gate voltage: 2.5 V, Holding current: 10 mA, Forward voltage drop: 0 V, On resistance: 10 mΩ, and Off resistance: 10 MΩ. The default parameters of U1 are used: line frequency: 60 Hz, Pulse width: 20°, and Pulse amplitude: 5 V. The students perform an Interactive Simulation in Multisim to yield simulated measurements corresponding to the theoretical values calculated above. The result of the Interactive Simulation (using the default analysis options) is shown in Figure 3.

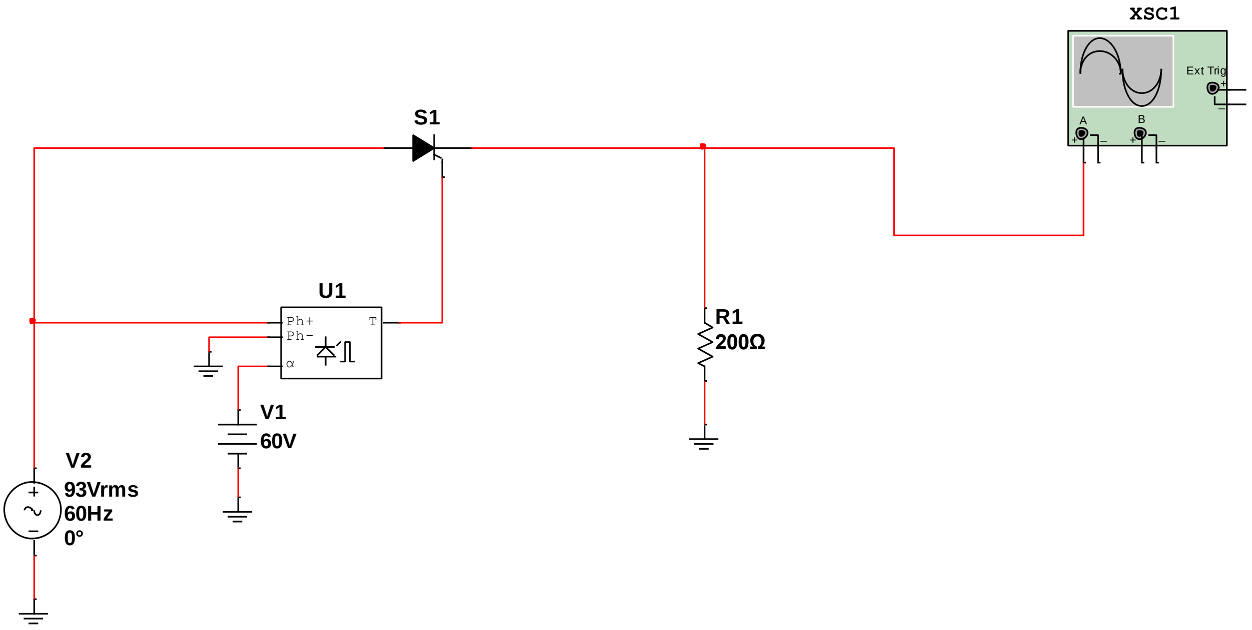


Figure 2. Multisim circuit for a controlled half-wave rectified circuit

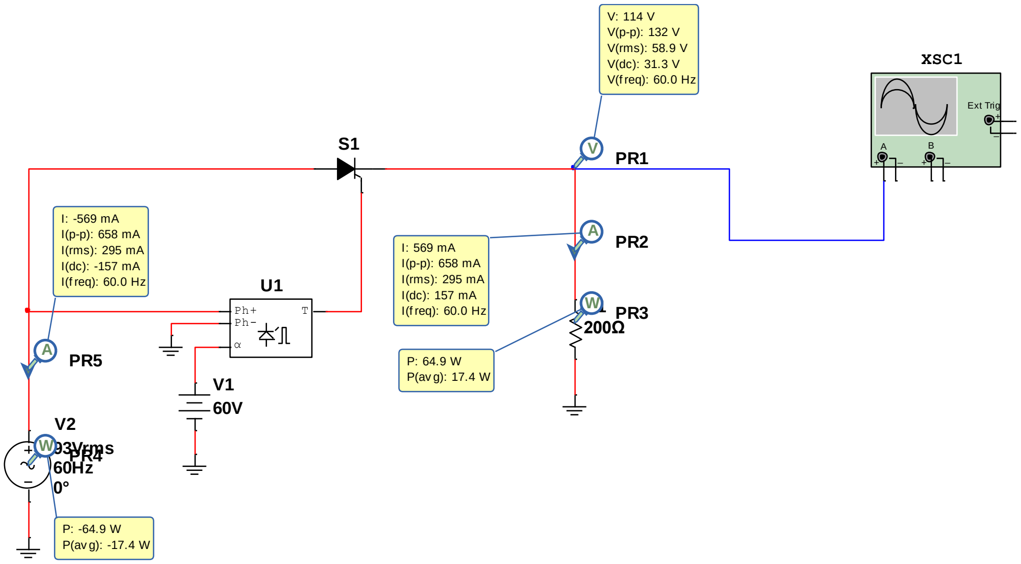


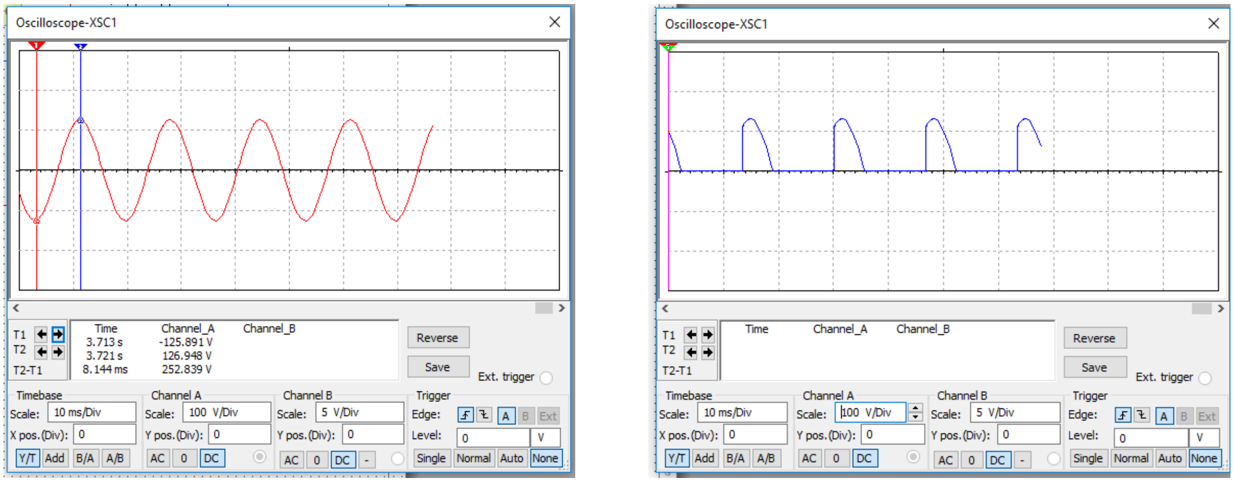
Figure 3. Results of the Multisim Interactive Simulation of the circuit of Figure 2.

Using values obtained from the Interactive Simulation, students calculate the simulated power factor, *pf*, per Equation 1.

$$pf = \frac{P}{V_{s,rms} I_{s,rms}} = \frac{17.4}{(93)(0.295)} = 0.63 = 63\% \qquad (1)$$

In Equation 1, P is the power delivered to the load, in Watts (W), displayed on probe PR3 of Figure 3, $V_{s,rms}$ is the rms value of the source voltage, and $I_{s,rms}$ is the rms value of the source current, displayed on probe PR5 of Figure 3.

The students must also display the input and output voltage waveforms resulting from the Multisim Interactive Simulation, which are shown in Figure 4.



	Time	Channel_A	Channel_B
T1	3.713 s	-125.891 V	
T2	3.721 s	126.948 V	
T2-T1	8.144 ms	252.839 V	

Timebase Scale: 10 ms/Div X pos.(Div): 0
Channel A Scale: 100 V/Div Y pos.(Div): 0
Channel B Scale: 5 V/Div Y pos.(Div): 0
Trigger Level: 0 V

	Time	Channel_A	Channel_B
T1			
T2			
T2-T1			

Timebase Scale: 10 ms/Div X pos.(Div): 0
Channel A Scale: 100 V/Div Y pos.(Div): 0
Channel B Scale: 5 V/Div Y pos.(Div): 0
Trigger Level: 0 V

(a) (b)

Figure 4. (a) Input voltage (b) output voltage (across R1) resulting from the Multisim Interactive Simulation of the circuit of Figure 2

In addition to the Interactive Simulation, the students are required to perform a Transient Analysis in Multisim to display the current through the load resistor, R1. The result is shown in Figure 5.

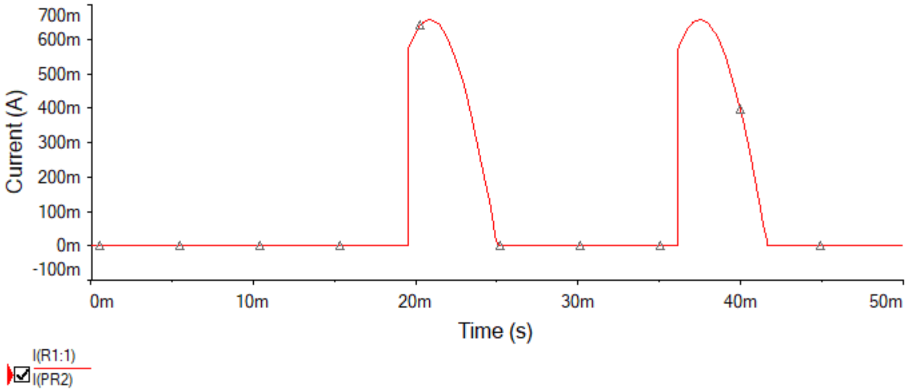
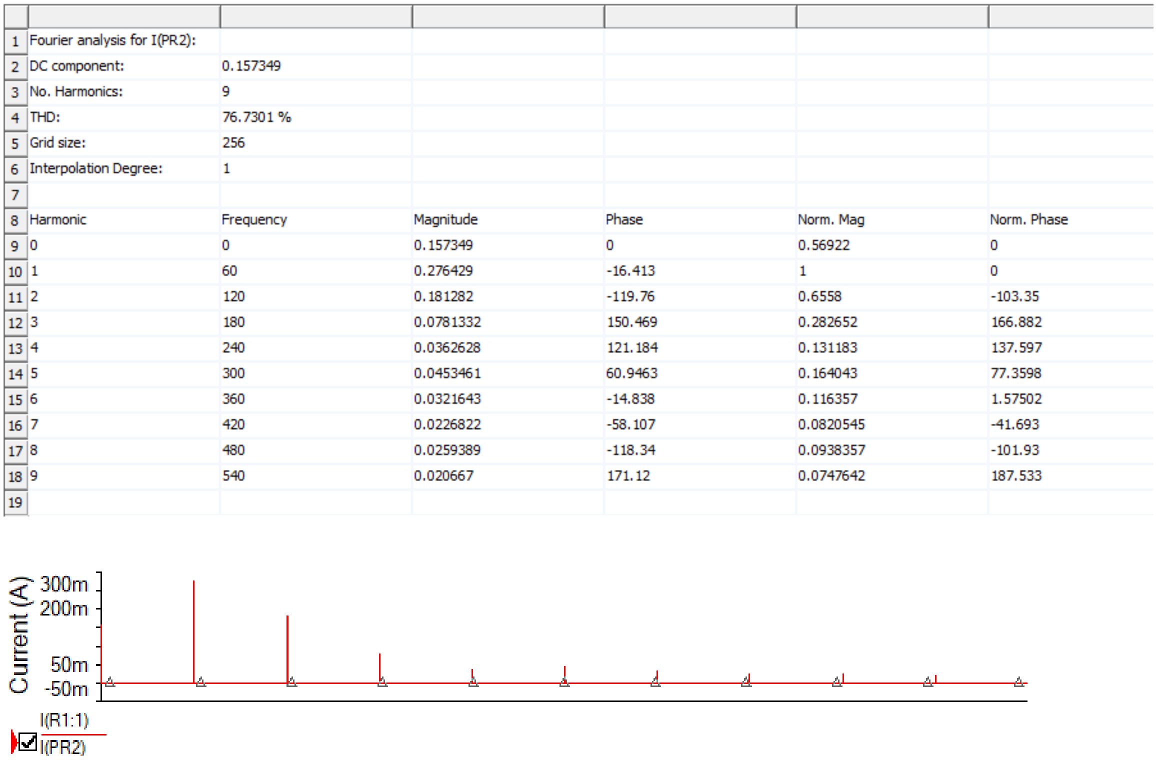


Figure 5. Display of the load current of the circuit of Figure 2, obtained using a Multisim Transient analysis, using default parameters

Finally, the students use Multisim to perform a Fourier analysis on the load current (the current through PR2 in Figure 3), which is the same as the source current, in the circuit of Figure 2. For the Fourier analysis parameters, a frequency resolution of 60 Hz is specified, and the default parameters of 9 for number of harmonics, 0.001 s for stop time, and 6000 Hz for sampling frequency are used. The result of the Multisim Fourier analysis is shown in Figure 6.



1	Fourier analysis for I(PR2):					
2	DC component:	0.157349				
3	No. Harmonics:	9				
4	THD:	76.7301 %				
5	Grid size:	256				
6	Interpolation Degree:	1				
7						
8	Harmonic	Frequency	Magnitude	Phase	Norm. Mag	Norm. Phase
9	0	0	0.157349	0	0.56922	0
10	1	60	0.276429	-16.413	1	0
11	2	120	0.181282	-119.76	0.6558	-103.35
12	3	180	0.0781332	150.469	0.282652	166.882
13	4	240	0.0362628	121.184	0.131183	137.597
14	5	300	0.0453461	60.9463	0.164043	77.3598
15	6	360	0.0321643	-14.838	0.116357	1.57502
16	7	420	0.0226822	-58.107	0.0820545	-41.693
17	8	480	0.0259389	-118.34	0.0938357	-101.93
18	9	540	0.020667	171.12	0.0747642	187.533
19						

Figure 6. Multisim Fourier analysis of the source (and load) current of the circuit of Figure 2.

Using the results of the Fourier analysis, students calculate Distortion Factor (DF) and Total Harmonic Distortion (THD) for the load (and source) current, per Equations 2 and 3:

$$DF = \frac{I_{1,rms}}{I_{rms}} = \frac{\frac{0.276429}{\sqrt{2}}}{0.295} = 0.6626 \qquad (2)$$

$$THD = \sqrt{\frac{I_{rms}^2 - I_{1,rms}^2}{I_{1,rms}^2}} = \sqrt{\frac{0.295^2 - \left(\frac{0.276429}{\sqrt{2}}\right)^2}{\left(\frac{0.276429}{\sqrt{2}}\right)^2}} = 1.1304 \qquad (3)$$

In Equations 2 and 3, $I_{1,rms}$ is the rms value of the first harmonic, and I_{rms} is the rms value of the load current, displayed on probe PR2 of Figure 3.

After completing the pre-lab assignment, and upon arrival to the laboratory, the students proceed to the *Controlled mid-point circuits (M1C)* experiment in the Line-commutated converters section of the Lucas Nuelle Power Electronics and Drives 300 W training system. This provides step-by-step instructions for wiring the circuit of Figure 1, starting with a listing of the equipment used in the experiment, which is depicted in Figure 7.

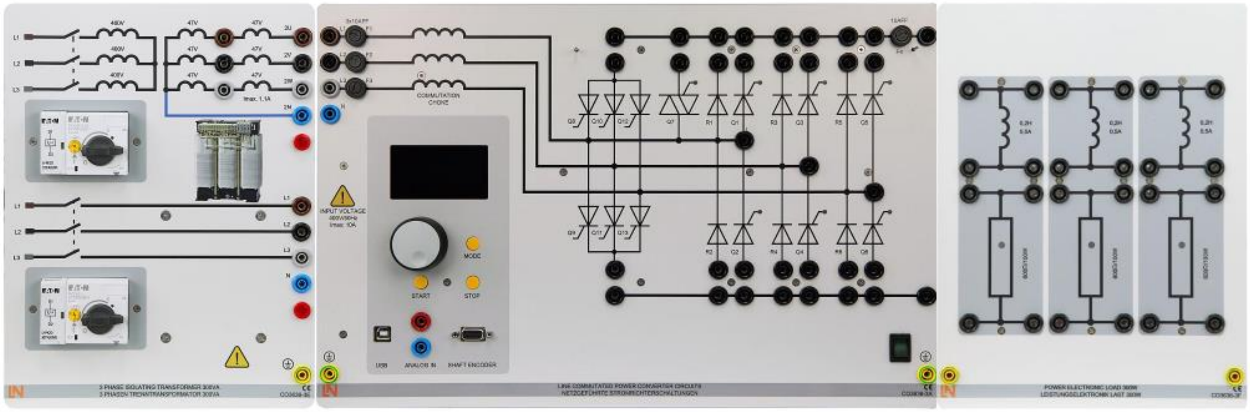


Figure 7. Equipment used for the *Controlled mid-point circuits (M1C)* experiment (i.e., half-wave controlled rectifier) in the Lucas Nuelle Power Electronics and Drives 300 W training system

The equipment of Figure 7, from left to right, includes the CO3636-3E7 Three-phase isolating 300 VA transformer, the CO3636-3A8 Line-commutated power converters, and the CO3636-3F Power Electronics 300 W Load Set. The technical specifications for these components are included in Table 2.

Table 2. Technical Specifications of the Equipment depicted in Figure 7.

Component	Name	Technical specifications
CO3636-3E7	Three-phase isolating 300 VA transformer	• Input voltage 3x 208 V, 50/60 Hz • Output voltage: 3x 94 V with center tap, 47 V • Output voltage 3x 208 V • Power range: 300 VA
CO3636-3A8	Line-commutated power converters	• Control unit with 6 power diodes, 12 thyristors, and a triac • DSP controlled gate firing and measuring unit • Integrated measurement of current and voltage • Integrated controller function for setting up variable-speed drives
CO3636-3F	Power Electronics 300 W Load Set	• 3 individual resistors, 600 Ω, 100 W • 3 x 0.2 H, 0, 5 A

The assembly instructions for the circuit include specification of the overlay mask for the particular power electronics topology of interest. For the *Controlled mid-point circuits (M1C)* experiment, the overlay mask is as shown in Figure 8.

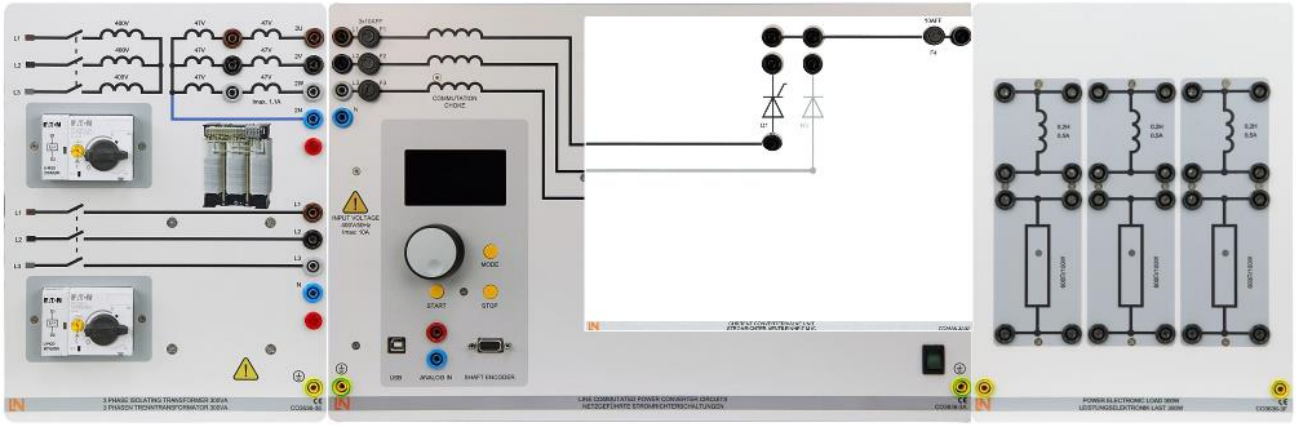


Figure 8. Equipment used for the *Controlled mid-point circuits (M1C)* experiment in the Lucas Nuelle Power Electronics and Drives 300 W training system with overlay mask

The assembly instructions include step-by-step instructions for connecting the line-commutated power converter unit to the PC and completing the wiring of the input circuit and the load. The complete wiring is depicted in Figure 9.

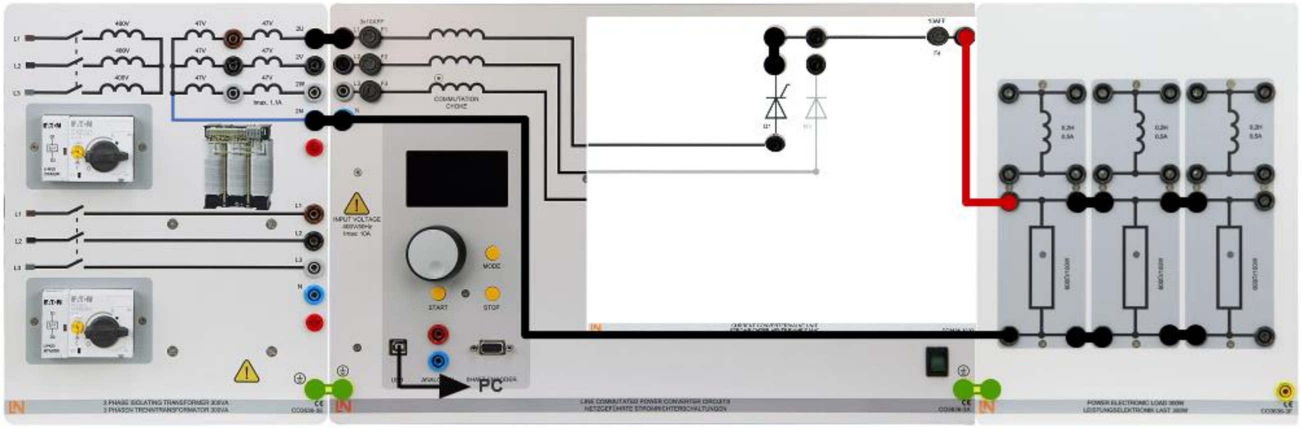
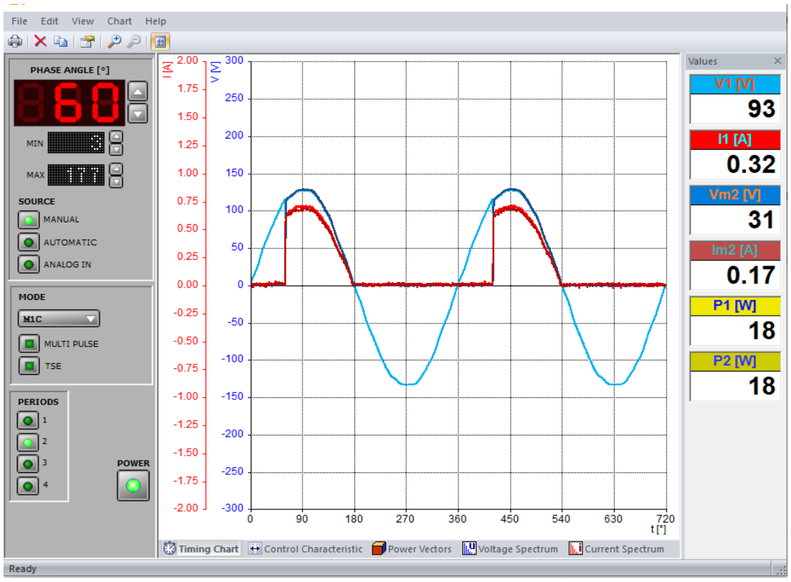


Figure 9. Complete wiring for the *Controlled mid-point circuits (M1C)* experiment in the Lucas Nuelle Power Electronics and Drives 300 W training system

The students are not permitted to power on their circuits until the wiring has been reviewed by the instructor. Upon obtaining instructor review and approval, the circuit is powered on. The circuit assembly instructions then direct students to open the Converter Control virtual instrument and configure it per provided settings. Upon proper configuration, the input and output voltage and current waveforms will be displayed. An example of such a display is shown in Figure 10.



PHASE ANGLE [°] 60

MIN

MAX

MODE M1C

V1 [V] 93

I1 [A] 0.32

Vm2 [V] 31

Im2 [A] 0.17

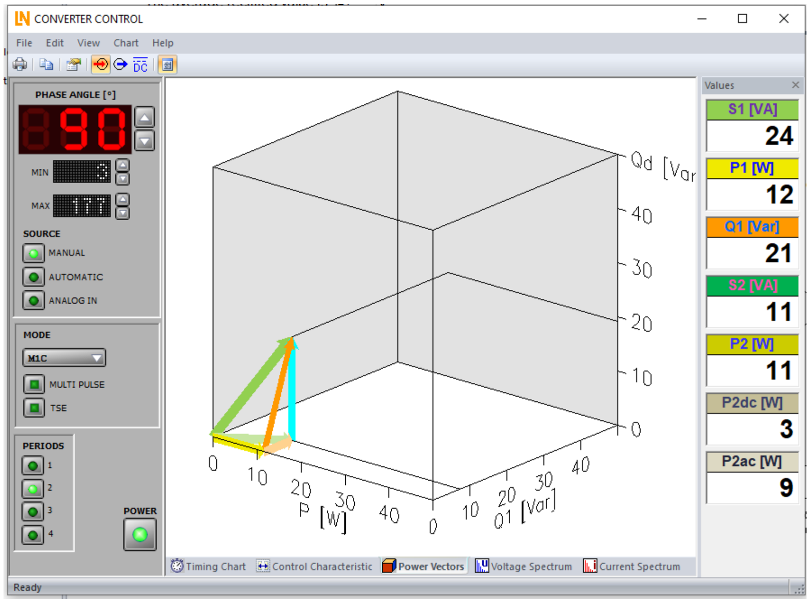
P1 [W] 18

P2 [W] 18

Figure 10. Voltage and current characteristics for *Controlled mid-point circuits (M1C)* experiment (i.e., half-wave controlled rectifier), phase-control angle 60°, resistive load

In Figure 10, the Timing Chart option is shown on the Converter Control virtual instrument. By default, both input and output voltage and current waveforms are displayed, but this can be changed at the preference of the user. In Figure 10, the light blue waveform is the input voltage; the dark blue waveform is output voltage. Input and output currents, in different shades of red, are superimposed in Figure 10. Again, per the preference of the user, just a single or multiple waveforms can be displayed. Various measurements are shown on the right-side panel in Figure 10. 93 V is the rms value of the input voltage, 0.32 A is the rms value of the input current, 31 V is the average output voltage, 0.17 A is the average load current. The measurements of 18 W displayed in yellow on the right-side panel of Figure 10 signify input (P1) and output (P2) active power, in Watts. Additional measurements may be added, at the discretion of the user.

In addition to the Timing Chart, input and output power vectors, control characteristic, as well as voltage and current spectrums may also be displayed on the Converter Control virtual instrument. An example of power vectors is shown in Figure 11. Figure 11 displays the input apparent, active, reactive, and distortion power vectors for a single-phase controlled half-wave rectifier with resistive load and a phase control angle of 90°. All figures generated in the Converter Control virtual instrument are available for download as text files or images and can be imported into MATLAB or Excel for further analysis.



PHASE ANGLE [°] 90

MODE M1C

S1 [VA]	24
P1 [W]	12
Q1 [Var]	21
S2 [VA]	11
P2 [W]	11
P2dc [W]	3
P2ac [W]	9

Figure 11. Input power vectors for *Controlled mid-point circuits (M1C)* experiment, phase-control angle 90°, resistive load

4 Results

Theoretical and simulation values computed in pre-lab assignments are in close agreement, typically within 5%, of the actual measured values obtained in laboratory from the Lucas Nuelle Power Electronics and Drives 300 W training system. Occasionally the errors between theoretical/simulated values compared to actual measured values is up to 10%. A typical result is shown in Table 4, which displays theoretical, simulated, and actual measured values for the uncontrolled six-pulse bridge circuit (uncontrolled three phase rectifier) with resistive load.

Table 4. Comparison of Theoretical, Simulated and Actual Values for Uncontrolled Three Phase Rectifier Circuit with Resistive Load

	Theoretical	Simulated	Actual	Accuracy Theoretical $\frac{\text{Actual} - \text{Theoretical}}{\text{Actual}} \times 100\%$	Accuracy Simulated $\frac{\text{Actual} - \text{Simulated}}{\text{Actual}} \times 100\%$
Average load current (A)	1.05 A	1.05 A	1.07 A	1.87%	1.87%
RMS load current (A)	1.05 A	1.05 A	1.07 A	1.87%	1.87%
Average output voltage (V)	210.7 V	209 V	203 V	-3.79%	-2.96%
RMS output voltage (V)	210.88 V	209 V	203 V	-3.88%	-2.96%
RMS source current (A)	0.857 A	0.865 A	0.86 A	0.35%	-0.58%
Average power absorbed by the load (W)	220.5 W	219 W	229 W	3.71%	4.37%
Power factor	95%	94%	96%	1.04%	2.08%

5 Discussion

At Purdue University Fort Wayne, an introductory course for undergraduate teaching of power electronics, ECE 460, has been revised to provide a more cohesive delivery of lectures and laboratory. The course lectures cover the theory of a wide variety of power electronics topologies. In-class practice problems performed as a group during lecture demonstrate application of theoretical equations. Pre-lab assignments encompass the theoretical calculations introduced in lecture and introduce simulation to corroborate them. Measurements taken in laboratory using the state-of-the-art Lucas Nuelle Power Electronics and Drives 300 W training system further reinforce concepts.

The course redesign was originally conceived when the author took over the laboratory portion of the course in Spring 2021, after having taught the lecture portion once annually since Spring 2018. The intent was to more fully utilize the Lucas Nuelle training system and demonstrate how it relates to theory covered in lecture. At the time, the student end-of-semester course assessments indicated that the lab did not relate to material covered in lecture. In addition, it was desired to develop some additional labs to introduce content on DC – DC converters, which are not included in the Lucas Nuelle training system. For this, the Texas Instruments (TI) Power Electronics Board mounted on the National Instruments (NI) ELVIS III platform was adopted for three of the fourteen labs. However, the students' end-of-semester ABET assessments expressed extreme frustration with this platform, and it was ultimately abandoned. Since the course redesign, the course evaluations and ABET assessments have been outstanding, and have not highlighted any concerns or shortcomings.

6 Conclusions

An introductory course for undergraduate teaching of power electronics, ECE 460, has been revised to more fully integrate lectures with laboratory assignments. The Lucas Nuelle Power Electronics and Drives 300 W training system has proven to be an invaluable asset in the teaching of this course. This state-of-the-art equipment is able to capture a multitude of real-time measurements, such as average and rms input and output voltage, power factor, input and output active, reactive, and apparent power, and input distortion power. In addition, the software enables display of a variety of waveforms of interest, in the form of timing charts, including, but not limited to, the input and output voltage and current, instantaneous input and output power, and input current and voltage waveforms at the fundamental frequency. Furthermore, input and output power vectors may be displayed in a three-dimensional representation. Display of the input and output current and voltage spectrums is also an option. Use of this equipment enhances the classroom experience, reinforcing theory learned in lecture.

A minor limitation of this system is the lack of content on DC – DC converters. Some practical and useful labs to cover linear regulators and buck converters were developed with input from industry representatives to fill this void. Due to space limitations, those are not discussed here.

For most of the laboratory experiments involving the Lucas Nuelle Power Electronics and Drives 300 W training system, there was close agreement, typically within 5%, between theoretical and simulation values and the measured values obtained in laboratory. These results provide a strong argument that for educational institutions where the cost of such equipment is prohibitive, the combination of theory and simulation yield a very effective alternative.

The use of Multisim has also proven invaluable in the teaching of this course. It reinforces theory taught in the classroom and is accurate in predicting and visualizing behavior of experiments subsequently conducted on the Lucas Nuelle Power Electronics and Drives 300 W training system. The platform is robust, and the circuits are easy to configure using default parameters. It contains a repository of helpful example circuit designs. Potential future upgrading of Multisim’s performance in higher resolution Fourier analysis will further enhance its utility.

Finally, guest lectures from industry professionals have made a significant contribution in augmenting classroom delivery with real-life power electronics applications. Due to space constraints, these are not discussed here.

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