Pertanika J. Soc. Sci. & Hum. 24 (S): 111 – 122 (2016)

SOCIAL SCIENCES & HUMANITIES

Journal homepage: http://www.pertanika.upm.edu.my/

Implementation of Evidence-Based Learning in the Course, Power Electronics

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ABSTRACT

The evidence-based learning approach was introduced and implemented in a course on power electronics in this study. In order to implement the evidence-based learning approach, the power electronic course run by the Department of Electrical, Electronics and System, Faculty of Engineering and Built Environment, UKM was divided into three complementary phases. The first phase begins with learning the theories of power electronics topics such as rectifier circuit etc. in the classroom; the second phase is learning to design, model and simulate the rectifier circuit using a dedicated software tool; and the last phase is learning to develop the rectifier circuit hardware and to investigate the circuit's characteristics in the laboratory. As a result, students understood the lesson on rectifier circuit better than if they had only been introduced to theory alone or a combination of both theory and computer simulation lessons as they have undertaken all specified phases step by step. Moreover, the proposed learning concept also increased the students' confidence in handling the rectifier circuit experiment. Hence, evidence-based learning should be considered a preferred and alternative learning approach for the power electronics course.

Keywords: Evidence, experiment, rectifier circuit, simulation, theory

INTRODUCTION

Evidence-based education is an approach in education where the approach is based on significant and reliable evidence derived from experiments; the idea that education should be or become an evidence-based practice has recently come to prominence

ARTICLE INFO

Article history:
Received: 09 October 2015
Accepted: 31 March 2016

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ISSN: 0128-7702

in several countries (Biesta, 2007; George, 2009). Evidence-based education operates at two levels. The first level utilises existing evidence from worldwide research and literature on education and its associated subjects. The second level is to establish concrete and appropriate evidence, when existing evidence is lacking, questionable, uncertain or weak in nature (Davies, 1999). Cranney and McDonald (2012) define evidence-based learning as a class of approaches that have been empirically demonstrated to produce learning outcomes. Bruniges (2011) reports that evidence-based teaching and learning has been implemented in Australian schools. Thus, evidence-based learning offers a lot of advantages and benefits, other than close correlation with engineering education that needs to be investigated.

Learning is a compulsory task undertaken by students to meet the requirements of their enrolment in a formal educational institution. In the context of higher educational institution, students are learners; lecturers are professionals who facilitate students' learning in the form of teaching, supervising, guiding and advising students. Usually, teaching and learning in higher educational institutions are based on delivering knowledge by theory or practical example from a lecturer to students literally or by the aid of teaching assisted tools (Carlson & Sullivan, 1999). However, do students really understand? In the context of electrical engineering it is very hard for students in the first place to imagine current flow in a circuit, for example. They need to strive hard and seriously study in order to understand to what has been delivered in the classroom (Lynch & Russel, 2005). For the lecturer, it is common to evaluate students' understanding through a written examination. If students perform well in the examination, they get excellent results, meaning that they understand the subject matter in depth. However, this is not the case in the context of the course, Power Electronics.

In general, the application of power electronics is to process and control the flow of electric energy in a form that is optimally suited for user loads (Mi, Shen, & Ceccarelli, 2005). Torrey (2004) stated that Power Electronics as a course can be considered application-orientated and a multi-discipline course in which students' understanding and confidence in mastering the subject matter are less than expected if teaching is based merely on theory. Based on these arguments, new methods of teaching and learning need to be introduced and implemented in this course. Evidence-based learning for arbitrary new findings in power electronics applications has long being practised. Almost all publications related to power electronics research must provide real results, which can be obtained via hardware-based experimental work verification or validation method. In this case, real result means a voltage or current waveform response or measurement value for a specific power converter circuit. Without real evidence, a real situation cannot be validated because theory and computer simulation are impractical and cannot be validated (Yusof, Za'im, & Shareef, 2015). In order to employ the proposed approach, the traditional learning approach needs to be restructured. In this study, three phases of a different learning approach were introduced. The three phases related to and complemented one another. The first phase was building the learning foundation, which was introducing theory; the second phase was learning based on computer-assisted tools, such as modelling and simulation; and the third phase was real application-orientated learning i.e. experimental work. The different approach using three learning phases seeks to cater for students' level of understanding. Not every student understands clearly topics taught in the classroom, thus computer simulation was believed to be able to help them. If a few students still found it difficult to catch up with the lessons being taught, it was expected that experimental work would greatly them grasp the learning points. Nevertheless, evidence-based learning is not a new learning approach, as it has been implemented in teaching and learning in medicine and nursing (Johnson et al., 2011).

In the Department of Electrical, Electronics and System Engineering (JKEES), Faculty of Engineering and Built Environment, UKM, Power Electronics is a compulsory course for fourth-year students who enrol in the electrical and electronics engineering programme. The faculty handbook for students prepared by FKAB (2013) states that Power Electronics has four course outcomes (CO). The evidence-based learning fulfils three out of the four course outcomes, which are: ability to understand Power Electronics and its applications (CO1); ability to design, analyse and operate power converter circuits (CO2); and ability to model, simulate and analyse power converter circuits using computer tool (CO3). The fourth course outcome is ability to understand the operation of a motor (CO4). Evidence-based learning is therefore is an effective method to strengthen and improve knowledge delivery of this course.

Evidence-based learning was expected to achieve the objective related to experimental work in the laboratory for this course. Experiments provide a concrete basis for abstract and formal concepts in electrical engineering education (Groccia & Buskist, 2011). Furthermore, laboratory experiments provide hands-on experience and practical training opportunity in power electronics application (Jimenez-Martinez, Soto, de Jodar, Villarejo, & Roca-Dorda, 2005). Nevertheless, the guided experiment conducted by the instructor is a simplified practical approach for many students. However, for the fourth-year student, this approach of doing an experiment needs to be changed. It is proposed that experiments be conducted by students without first watching a demonstration by the instructor. The objective of having such unguided experiments is to encourage the students to be independent and to work seriously and with great effort without relying on a manual or the instructor in carrying out the experiment. While an instruction manual for such experiments is not required, the objectives of the experiments must be clearly stated. The instruction manual for the unguided approach will contain only the learning objectives, equipment used and brief instructions. However, assistance from the instructor is still required, but must be kept to the minimum in order to ensure that students achieve the lesson outcomes. This will nurture students' self-confidence and sense of independence in carrying out laboratory work. This study focusses on the topic of the single-phase rectifier circuit operation. A summary of the differences between the traditional method i.e. theory-based learning approach and evidence-based learning is listed in Table 1.

METHODOLOGY

Teaching and learning for the chosen topic, the single-phase rectifier circuit, was implemented in three phases; firstly, the concept or theory was delivered, followed by application of computer-based modelling and simulation, and finally, laboratory work was carried out. In total, 25 students enrolled in the Power Electronics course for the 2014-2015 academic session participated in this study. Details of the phases are discussed in the subsequent sections.

Table 1
Traditional Method Versus Evidence-Based Method

Traditional method	Evidence-based method
1. Teaching and learning in classroom • Theory • Revision • Tutorial • Examination	1. Teaching and learning in classroom • Theory • Revision • Tutorial • Examination 2. Computer software tool • Modelling • Simulation 3. Hardware experiment • Set-up and testing • Validation

Phase 1 – Theoretical Lesson

In this phase, the students were introduced to the theory and foundation of the rectifier circuit. The circuit operation, schematic circuit design, related mathematical equation, tutorial and analysis of the rectifier circuit were among the subtopics taught. After the theory class, a quiz was given to measure students' performance and comprehension. The single-phase bridge rectifier as illustrated in Figure 1 was chosen for this study.

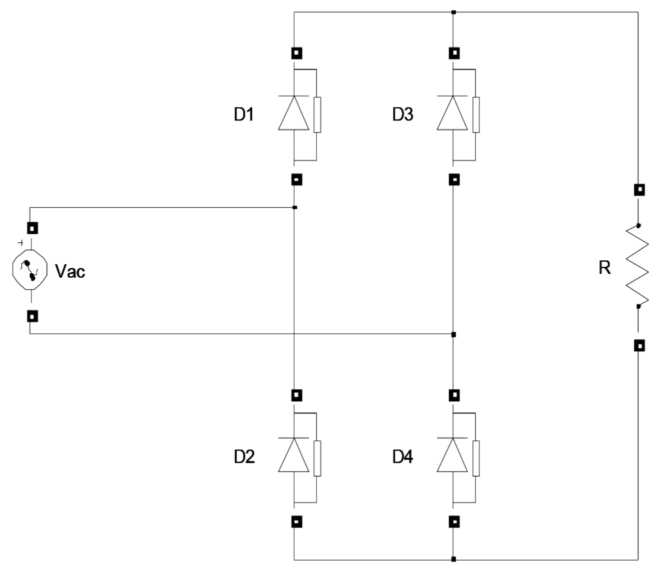

Figure 1. Single phase diode bridge rectifier circuit model.

Theoretically, alternative current (AC) supply voltage v_{ac} can be formulated as follows:

$$v_{ac} = V_m \sin \omega t \text{ V} \quad [1]$$

where V_m is the amplitude of v_{ac} with sinusoidal waveform at fundamental frequency f = 50Hz. According to voltage waveform, the input-output relationship of the rectifier circuit in mathematical representation is derived. Since the input is AC voltage, to transform it into DC voltage an integral method is applied in equation [1] for a half-cycle time duration, $T/2$. Hence, if rotating frequency $\omega = 2\pi f$ [rad/s] and phase angle, $\omega T/2 = \pi$ radian, then the average DC output voltage, V_o with resistive load can be calculated as follows:

$$V_o = \frac{1}{\pi}\int_0^{\pi} V_m \sin \omega t \; d(\omega t) = \frac{V_m}{\pi}\left[-\cos \omega t\right]_0^{\pi} = \frac{2V_m}{\pi} \text{V} \quad [2]$$

Phase 2 – Computer Simulation Lesson

After being introduced to the theory, the students were exposed to computer-assisted modelling and simulation application using the MATLAB Simulink software tool (Yusof & Rahim, 2010). The MATLAB Simulink software tool was introduced to students in their first year of study in the department. Thus, the learning process was not time consuming because the students remembered how to use the software tool. By modelling the rectifier circuit in Figure 1, the particular waveforms could be obtained by means of simulation as depicted in Figure 2. The advantage of this method was that the theory and concept of the rectifier circuit learnt in the classroom could be realised virtually. This allowed students to better comprehend the topic than if they had been asked to just imagine and listen to a lecture. Furthermore, analysis of the rectifier circuit could be done and the characteristics of the circuit could be identified. Nevertheless, in doing so, some assumptions had to be taken into account, such as that the components were ideal, there were no environmental effects etc. Computer simulation can provide substantial knowledge regarding a rectifier circuit. However, real-life conditions were absent because of problems related to environmental and unpredicted factors such as humidity, temperature, power disturbances and reduction of component effectiveness due to the ageing process, among others. These problems are usually not considered in computer modelling and simulation (Tattje & Vos, 1995).

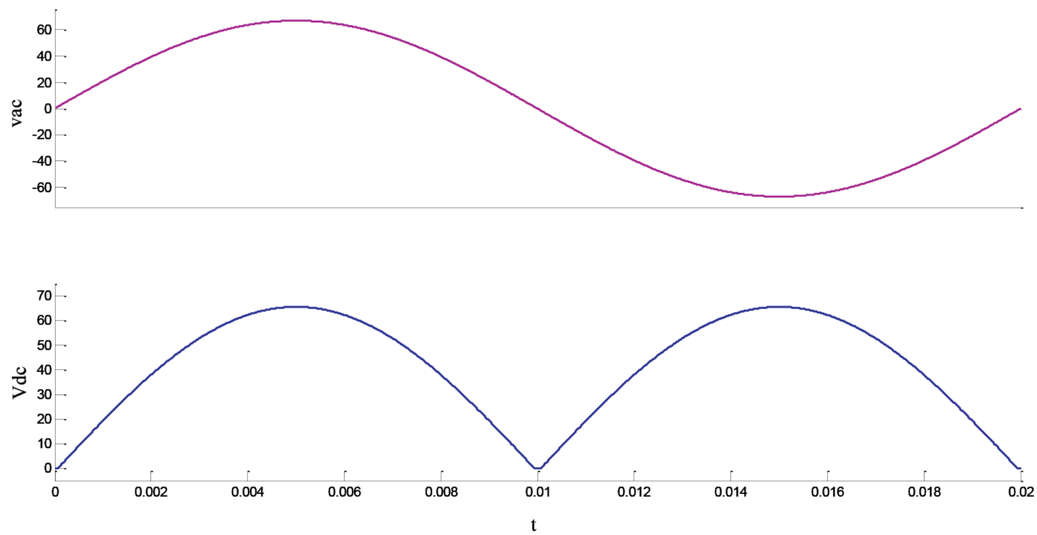

Figure 2. Simulation results of v_{ac} (upper trace) and V_{dc} (lower trace).

Phase 3 – Experimental Work

The rectifier circuit experiment was conducted to prove and validate the aforementioned two phases. Without real data or in this case, the waveform of average DC output voltage for a single-phase diode rectifier circuit, validation of the theory that was delivered and the computer simulation results could not be made. To run the experiment, the required equipment and components were: 1 unit of AC supply voltage; 4 units of power diode; 1 unit of resistor bank (100 Ω); 1 unit of oscilloscope and 2 units of differential probes. The computer simulation assignment was performed by a group of two. The group that completed and passed their computer simulation assignment was allowed to undertake the diode rectifier circuit experiment while groups that did not complete the experiment within the time allocated or whose results were flawed had to repeat the task. All the students managed to complete their computer simulation assignment on time. Each group was required to construct a single-phase diode rectifier in bridge configuration, similar to the schematic model design shown in Figure 1. The instruction manual was simple and objective. The flow chart of the single-phase diode rectifier circuit experiment is depicted in Figure 3. Since the students already understood what they had to do, the instructor was required to check the circuit connection before the students started their experiment. Two differential probes were used to measure the input AC voltage and the average DC output voltage of the rectifier circuit. As expected, the oscilloscope displayed the waveforms of both measured voltages shown in Figure 4 and Figure 5, respectively. These results were real evidence, and were expected to be identical to the computer simulation results. Hence, the experiment results verified the theory that had been taught about the rectifier circuit.

RESULTS AND DISCUSSION

As depicted in Figure 2, the simulated waveform was a sinusoidal AC source voltage v_{ac} with peak value 67 V, which can be translated into an effective value of 47.4 V_{rms} $\left(=67/\sqrt{2}\right)$. Figure 2 also shows the average DC output voltage V_{dc} measured at 42.6 V. Here, the minimum value was 0, while the maximum value was V_m, which equals to 67 V. According to equation [2], the average value was a constant DC voltage. Moreover, the DC pulse frequency was 100 Hz because two pulses appeared within a full cycle of 50 Hz. Hence, the DC pulse frequency was obtained from a calculation of 50 Hz times two pulses per full cycle. To verify the calculated average DC voltage of 46.2 V in equation [2], the result as given in Figure 4 was used as reference. Based on the plots in Figure 4 and Figure 5, as expected, both waveforms of v_{ac} and V_{dc}, were similar to the simulated waveforms indicated in Figure 2. Table 2 indicates the values of v_{ac} and V_{dc} for each phase of the learning approach. For measured v_{ac} and V_{dc}, the respective values were 47.7 V_{rms} and 43 V. Comparing the three values resulted in discrepancies, but they were neglected as the error values were very small and could be tolerated. This implies that the values obtained from the respective theoretical calculation, simulation result and measured experiment were considered identical. In consequence, the results obtained from the experimental investigation indicated a very close agreement with the theoretical results and the computer-based simulation results. In this case, it was already understood that the evidence could be obtained through experimental work. Without real evidence such as the measured v_{ac} and V_{dc} of the rectifier circuit, the theoretical aspect could not be validated, which could create uncertainty or cast doubt on the students' understanding of the rectifier circuit. In other words, validation via experimental work can strengthen and further enhance students' confidence and comprehension.

Table 2
Comparison Between Respective Theoretical, Simulation and Experiment Values

	Theoretical [V]	Simulation [V]	Experiment [V]
$V_{ac,\, rms}$	47.4	47.4	47.7
V_{dc}	42.7	42.7	43

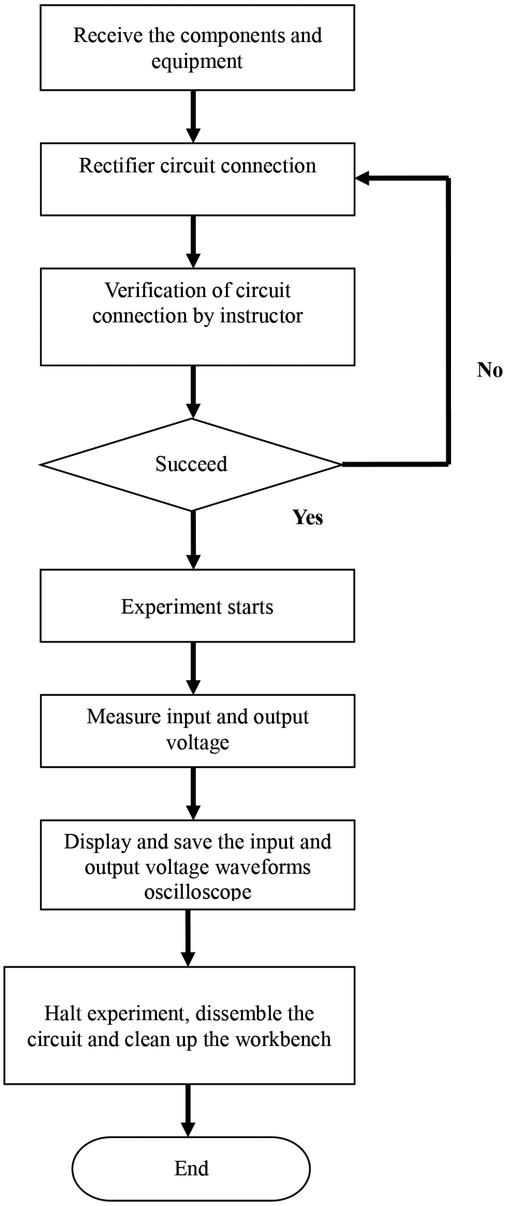

Figure 3. Flow chart of single-phase diode rectifier circuit experiment.

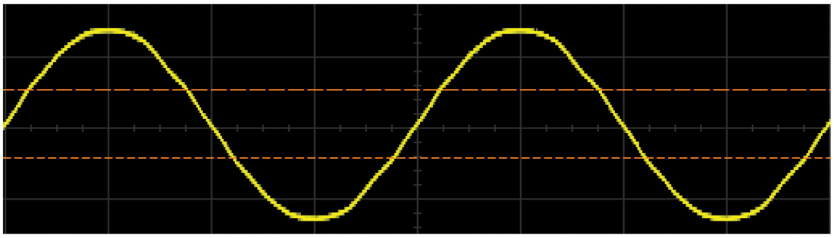

Figure 4. Measured AC source voltage, v_{ac} (scale: 50 V/div).

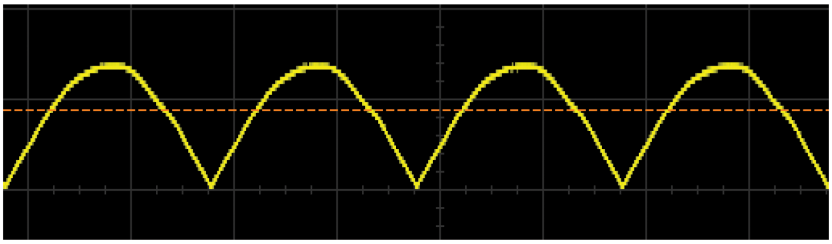

Figure 5. Measured average DC output voltage, V_o (scale: 50 V/div).

CONCLUSION

This paper discussed the implementation of evidence-based learning of a topic in the Power Electronics course in the Department of Electrical, Electronics & System, UKM. Each implemented learning phase was well received and students performed well in them according to the proposal. After the students completed the final phase of learning, they were satisfied with the level of knowledge and understanding they had acquired. Nevertheless, evidence-based learning cannot be successful only by doing experimental work alone; theory and computer-based simulation together contribute to bringing about this achievement. In terms of students' effort in learning, only the first phase indicated less effort than the lecturer's as the students only listened to the lecturer. On the other hand, the second and the third phases required huge effort from the students in order for them to accomplish the proposed learning objectives. With respect to real application, external disturbances could affect the performance of the rectifier circuit. Normally such effect is not taken into account for theoretical and computer-simulation-based learning. Furthermore, the proposed evidence-based learning approach did not contradict the previous approaches in many aspects; instead, it enhanced the students' understanding and improved their hands-on skills. On top of that, the students' confidence was observed to have increased as very few unnecessary questions were asked by them and the laboratory experiment was completed before the allocated time. As required by Power Electronics common practice, when any new circuit topology design is proposed, validation of the design is required to be done by experts in order to assess if it operates properly according to basic principles. The evidence-based learning implemented in the Power Electronics course at the Department of Electrical, Electronics & System, UKM was in line with common practice in the study of Power Electronics. This evidence-based learning should be introduced in the Power Electronics course in other universities as well.

ACKNOWLEDGEMENT

The authors would like to thank UKM for financial support under PTS-2012-104 and PTS-2014-033 grants respectively.

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