A WEB-BASED REAL-TIME POWER ELECTRONICS REMOTE WIRING AND MEASUREMENT LABORATORY (*RwmLAB*): HALF-WAVE RECTIFIER

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ABSTRACT

This paper presents a new architecture, called "Remote Wiring and Measurement Laboratory (*RwmLAB*)", that acts as a local multi-circuit board on a common distributed panel on the Internet. Matrix switching, data acquisition, data processing and analysis, and graphical unit interface enabled-device characterize the *RwmLAB*. *RwmLAB* is intended to address real-time data acquisition over the Internet instead of using simulated data, to provide new ways of using the Internet and a new approach of revitalizing power electronics, which has seen decline student enrollment. It is so flexible that it can be used for power and industrial electronics experiments. The paper will analyze a half-wave rectifier (AC – DC converter) circuit connected over the Internet using the *RwmLAB*. The results will show that the *RwmLAB* allowed students to obtain real data by wiring a real circuit in the laboratory using a real "virtual breadboard" on the Web. The *RwmLAB* provides hands-on real-world Web-based experience that will excite the student. This Web-based instrument allows for flexibility and the spontaneous delivery of laboratory material, and ensures a global access to worldwide audience.

I. INTRODUCTION

In the last few decades' computers have been used in the training of engineering students [1]. The last few years have seen the Web as an integral part of distance learning in many engineering courses. In the field of engineering, the Web has been used for analysis, design, and simulation of both electrical and electronics circuits. Some of the simulation packages have been integrated into curriculum and have contributed greatly to the training of engineering students.

Some Web applications such as "computer based training" (CBT) and "computer assisted learning" have been developed to take over part of the teaching-learning process [1]. Such Web-based approaches still depend on simulation software packages. The real challenge is to provide innovative new ways of using the Web for the training of engineering students. There has been call for new remedies for revitalizing engineering in order to make engineering more attractive to students. For example, at the University of Minnesota NSF has funded projects [2 - 3] aimed at developing new approaches of teaching power electronics.

A new Web-based hands-on real-time remote wiring and measurement laboratory has been developed [4]. Students are physically able to wire up electrical and electronics circuits at the host laboratory site using the Internet access and by means of a conventional "virtual breadboard" on the Web. The data acquisition interface allows students to make real-time data measurements and the data collected are made available on Web. The *RwmLAB* interface is greatly simplified by using a graphical interface to allow the students to experience the frustrations and hands-on experiences of a real-world laboratory environment. In this paper the desirability and effectiveness of *RwmLAB* as a teaching laboratory for power electronics will be discussed.

II. POWER ELCTRONICS CIRCUIT: HALF- RECTIFIER

A. *RwmLAB* Building-Block:

The *RwmLAB* consists of a matrix switching board, *Xecom's* [5] AWC86A as the main controller with a Web-based server, and a Complex Programmable Logic Device (CPLD). At the front-end of the AWC86A is a Web server and at the back-end is an AMD 40-MHz AM186ES-based micro controller with SRAM and Flash memory. The AWC86A Web server incorporates a multi-tasking operating system and TCP/IP stacks with 10Base-T Ethernet access. The controller portion allows the setting and resetting of up to sixteen dedicated TTL signals.

A switching matrix board is wired using a standard electronic relay latch components and laid on a printed circuit board. A pictorial representation of the various components of the switching matrix board is shown in Fig. 1. Figure 2 is an example showing the features of a portion of the matrix board. The CPLD is used to control the switching pattern of the relays. The setting and resetting of the matrix board relays are accomplished by the sixteen dedicated TTL signals of the AWC86A Web-controller through the CPLD.

An Internet enabled embedded system software is created that appears like a standard "virtual breadboard" similar to those typically used in undergraduate electrical and electronics laboratories. A pictorial representation of the various components available for the laboratory is also presented on the side of the screen. In some components, color-coded bands are displayed to indicate the appropriate values of the component. For example, resistors look like the actual color-coded resistors. For other components, a tool tip is used to display the appropriate value or display a data-sheet.

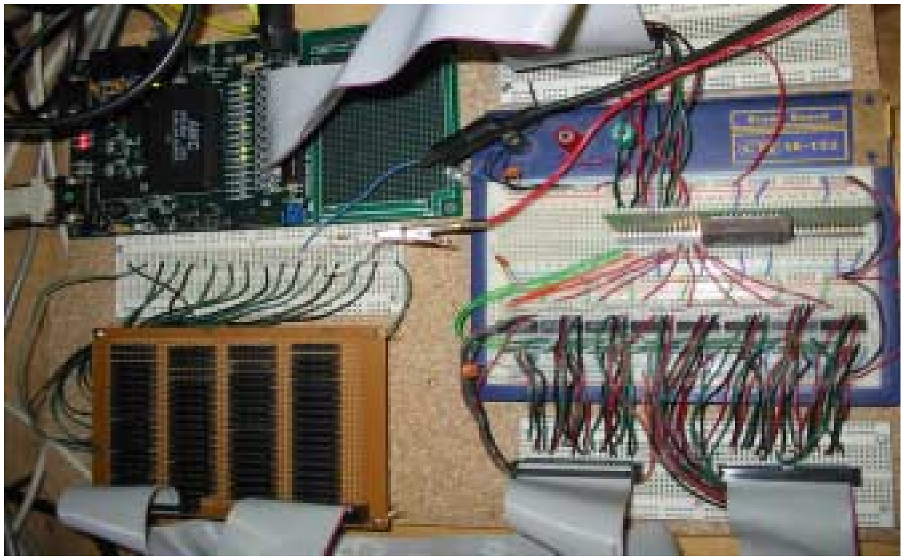

Fig. 1 Pictorial Representation of the Various Components on Breadboard

B. Half-Wave Rectifier Circuit Setup And Matrix Board:

The Fig. 2(a) shows a half-wave circuit diagram taken from ECE 420 – Power Electronics I, an elective undergraduate course. Figure 2(b) shows the pictorial representation of the multi-circuit switching matrix board. This simplified matrix diagram can be used to wire remotely Fig. 2(a) by using solid-state relays with low resistance. The embedded web-controller provides the signals to switch the solid states relays ON and OFF, and to collect data from the nodes. When relays A1-A2, B1-B2, C1-C2, E1–E2, F1-F2, and G1-G2 of Fig. 2(b) are switched ON, the circuit of Fig. 2(a) is completed.

Figure 3 shows a typical Web-based "virtual breadboard". The user is able to drag any components around the virtual breadboard as desired to accomplish the necessary wiring. When the user completes the circuit and presses a "Submit" button, the software at the host analyzes the circuit to determine which hardware leads are connected together. The lead connections represent nodes. The software first sends a reset signal to clear all the physical relays. The software running on the Web site sends a clear signal, and then sequentially sends the digital code associated with each lead/node combination through the dedicated TTL signals using a CGI (Common Gate Interface) protocol. These signals are decoded by the CPLD and routed to appropriate relay latches. The latches in turn drive electronic LED-based relays. When a relay is set, it physically connects a leg of the component to a node. Any other components connected to that node are then also physically in the circuit.

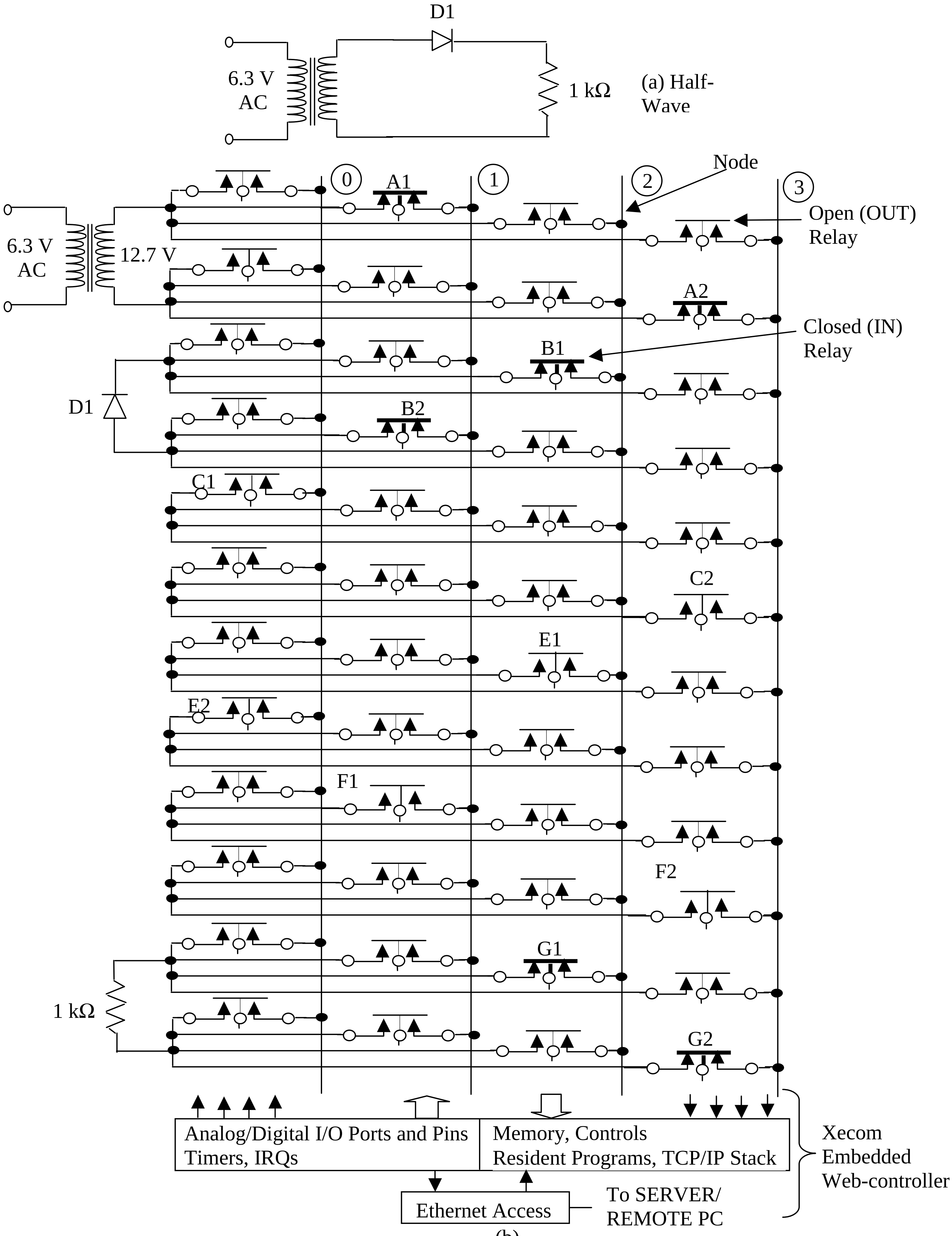

Fig. 2 Features of the *RwmLAB*

The circuit may be wired (correctly or incorrectly) on any portion of the virtual breadboard on the Web but the AWC86A software turns on the appropriate relays to connect the circuit wired on the virtual breadboard.

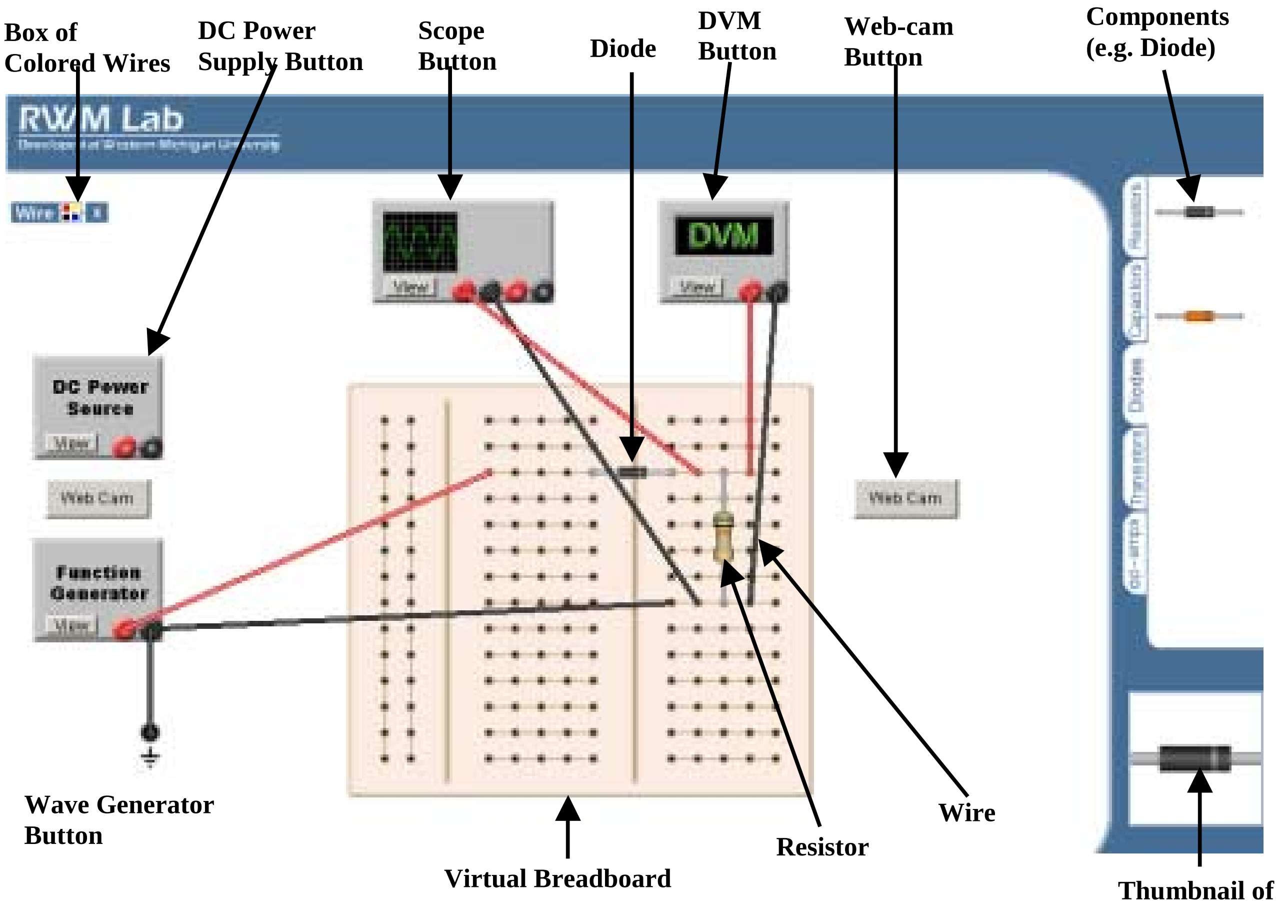

Fig. 3 Web Capture of Wired Half-wave Rectifier

All the software is done in HTML, JavaScript, Java, and in C language for the CGI interface. The HTML, JavaScript and the Java reside in the Web server of the AWC86A and the C language resides in the controller portion of the AWC86A. The AWC86A fully integrates the Web sever and the micro controller.

III. RESULTS: INTERACTIVITY

The Web-based software, written in HTML, JavaScript, and Java, integrates the virtual breadboard, components, scope, digital voltmeter, power supplies, and waveform generator. Figure 3 shows a Web capture of the circuit of Fig. 2. The power supply is represented by "*DC*" button image and the waveform generator is by the "*AC*" button image. The circuit of Fig. 3 is wired on the virtual breadboard just like any student will do in a normal laboratory.

The resistor is also color-coded. The power supply and the waveform generator are also connected in a similar fashion. If an instrument is double clicked, it will open as a separate window on the Web. This will allow the student to physically change the settings in real-time in the laboratory: all the equipment settings can be changed because they all use GPIB interface protocol. The student will also see simultaneous changes on the Web window. In addition to this, A Web-Cam can also be activated in the laboratory to open another Web window showing live the equipment and its reading changes. At the present time the Web-based laboratory can be used for experiments with the following components: resistors, diodes, opams, and transistors. The following equipment can also be used: digital multimeter, oscilloscope, power supplies, and a waveform generator (sine, triangular, and rectangular waveforms with adjustable duty ratio).

A. Real-time Physical Control of Real Instruments

All the instruments used in *RwmLAB* have GPIB interface and each instrument is fitted with a Web-cam. The GPIB interface allows each instrument to be controlled from the Web and also shows the real-time reading of the instrument. There are four instruments – digital multimeter, digital oscilloscope, digital power supplies, and digital waveform generator. Each instrument has its own IP address and with a Web update cycle of eight seconds for all four instruments (including the Web-cams) in the sequence – multimeter: 0 – 1st second, oscilloscope: 2nd – 3rd second, power supplies: 4th – 5th, and waveform generator: 6th – 7th second. In this way there is no interference of the updates of all four instruments if they are requested at the same time. An instrument reading and its Web-cam are synchronously updated within two seconds. When an instrument is requested, a window pops up showing the GPIB controls for the instrument and the reading of the instrument (see Fig. 4). The reading of the instrument can be changed by the controls on the Web. A Web-Cam, when activated, will simultaneously show live the changes in the reading (or waveform) of the instrument. An instrument or a Web-cam must be requested by clicking on it in the Web window. The *RwmLAB* cannot be configured by the students from the Web because of safety issues at the host laboratory. When an instrument or a Web-cam button on the Web is clicked, a cgi-packet is sent to the host laboratory to reset all instruments, and to receive and assemble the Web wired circuit.

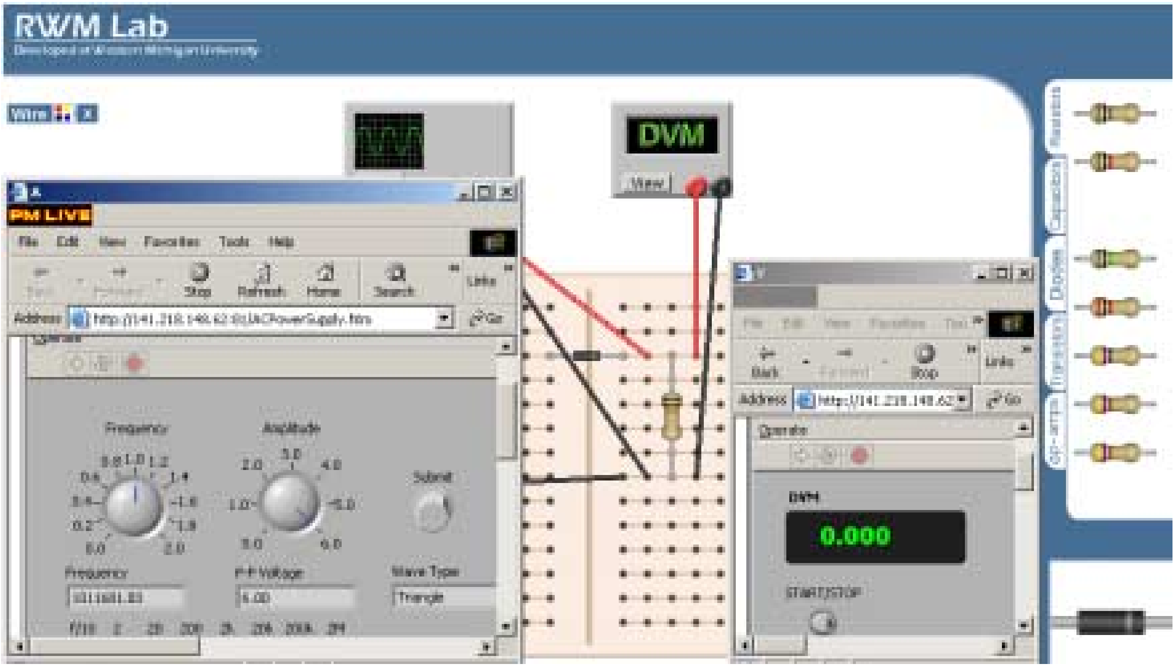

Fig. 4GPIB Controls and Display, and Live Web-cam Capture of Waveform Generator and DVM

The output waveforms obtained from the data of the Web-based laboratory are shown in Fig. 5: the output voltage and voltage across one of the diode. These waveforms are exactly the same waveforms obtained from a “normal” laboratory session. This Web-based hands-on real-time laboratory provides interactivity through a Web browser window. It also provides fun as well as frustrations in a real world laboratory environment. This approach forces the students to think before interacting with the system because an electrical or an electronics circuit must be wired correctly in order to obtain any useful results. This increases the chances of the learner going from “*surface learning to deep learning*” [1]. This in turn ensures long-term retention and absorption of the laboratory material. It is also fun.

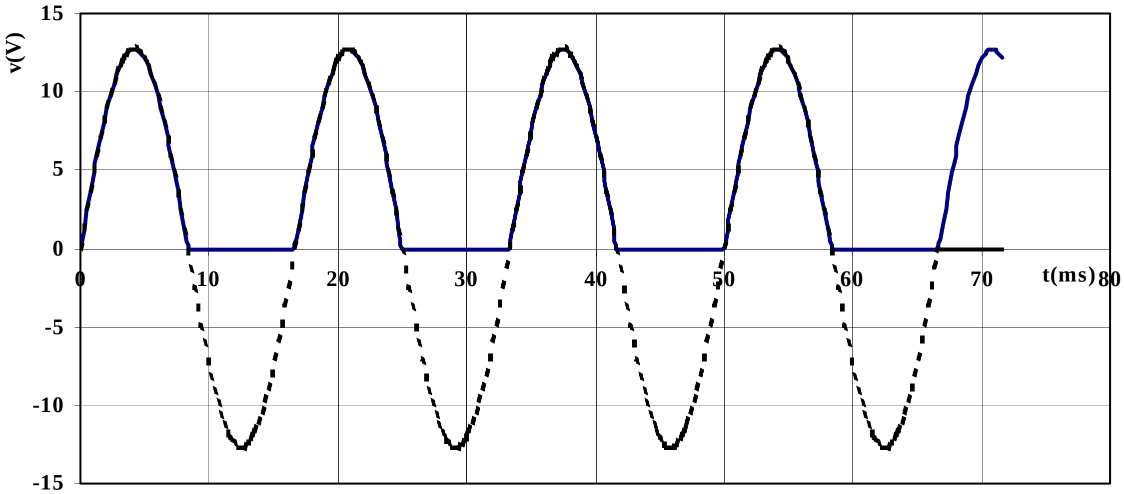

Fig. 5 Output and Diode Voltages

IV. CONCLUSION

The present work adapts existing, proven, and workable technologies to implement an electrical and electronics, and power electronics laboratory that will be attractive to students. An added advantage is that the web now becomes a medium for active teaching and learning. The laboratory can also be accessed from anywhere in the world. This ensures a global access to a worldwide audience in higher institutions without electrical and electronics laboratories format such as in developing countries who lack resources to develop laboratories such as a power electronics laboratory. The experience gained in developing this Web-based module has also confirmed that real stream of data can be obtained over that Internet without having to use simulated data. It is fun to see students having frustrated fun using this Web-based laboratory.

ACKNOWLEDGMENT

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REFERENCES

[1] P. Andre and V. Rajagopalan, "Web-Based Learning for Power Electronics: A Case Study", *Proceedings of National Science Foundation Workshop on Multimedia Delivery of Power Electronics Education*, Holiday Inn Select – Orlando International Airport, Orlando, Florida November 11 – 13, 2000.

[2] Proceedings of NSF-sponsored Faculty Workshop on Teaching of Courses in Power Electronics and Electric Drives, Tempe, Arizona, January 4–5, 2003, http://www.ece.umn.edu/groups/workshop2003/

[3] T. Undeland and N. Mohan, "Meeting the Challenge: Revitalizing Courses in Power Electronics and Electric drives", http://www.ets.kth.se/eme/norpie/program_detail.pdf

[4] Asumadu, J. A. and Tanner, R., "Remote Wiring and Measurement Lab," *Proceedings of the 2001 American Society of Engineering Education Annual Conference & Exposition*, Albuquerque, New Mexico, June 24-27, 2001, Session 1526.