

Virtual Laboratory Development for Teaching Power Electronics

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Abstract: - Distance learning has been promoting across the whole education sector as more people educates themselves after work or as part of the professional development. Web-based teaching is therefore emerged rapidly because of the need and the recent development in the Internet and information technology. The hardware experiment can therefore be redesigned such that they also can be accessed in the Web. The proposed virtual laboratory is not a web-based simulation. It is a real power electronics experiment conducted in the laboratory but remotely control and monitoring by web-based tools. The facility is useful for today's requirement of teaching in the Internet. The paper demonstrates how a power electronics experiment is programmed in a remotely controlled laboratory setup. From there students can conduct the experiment without any limitation of time and space. Feedback from the students is also very positive and it can also give an alternative solution for conducting hardware laboratory when distance learning is used.

I. INTRODUCTION

As the ease of access of the information through the Internet increases, distance learning of many courses can now be made through Web. There are many good web sites programmed from various educational institutions are now available for their students to download lecture note, study web-based material and attend web-lecture lectures [1-2]. Some of them even have web-based video lectures or seminars. However, there still exist problems of this way of teaching especially for engineering courses because the laboratory class has difficulty to be conducted through the Internet. Student cannot get hold of the skill through the practical operation of some hardware. In the pass, many of them are only computer simulation rather than real experiment. This is understandable because the web-based hardware implementation is difficult. The problem is exaggerated for power electronics laboratory because the high frequency and high power operation is difficult to be connected and controlled by the remote access. Even a undergraduate experiment has a lot of parameters to vary or record. Today, with the rapid development of Internet tool and electronics, this situation can be overcome. Also the advancement in the EMI remedy, computing and package techniques can also minimize the effect of the high frequency difficulty.

It is crucial to let students have some real practice. In fact, virtual laboratory is not new. It has been implemented in other subject areas [4-6]. However, in the power electronics field, there has not yet been reported. There is only some discussion of the feasibility for the use of the

virtual laboratory in various stream of power engineering [7]. This paper is to present a Virtual Power Electronics Laboratory (VPEL) that is a technology developed by the Department of Electrical Engineering at the Hong Kong Polytechnic University to integrate the laboratory class with the Internet. Control. It is a remotely controlled experiment that allows students to login to the university Web-site and conduct an experiment. The experiment is actually conducted in the laboratory and only remotely control through the Internet. The data and experimental results can be sent back to the students on-line. The experimental rig can also be monitored through a Web-camera system. Therefore the laboratory course will no longer be required to be conducted physically in the laboratory. Students can try the practical experiment anywhere, anytime and with any duration without many constraints.

The feature of the system is that the laboratory experiment is also incorporated with power electronics lecture notes so that the students can enjoy the lecture and laboratory class together. The system is a truly multimedia-enabled and interactive technology platform for study. It also provides self-directed and self-paced mode of learning complemented with fully instructed guidance and manual. The experiment is much better than only computer simulation such as PSpice or Saber [3] that only provides animation or circuit simulation rather than a real one. The real experiment gives the students a sense of practical testing and they can also see the effect of the second/higher order effect such as the transistor switching loss, parasitic oscillation and the real switching transition which is difficult to be simulated perfectly. They can also experience with the appearance of the instrument and the electronic components.

VPEL is developed using the platform provided by the Laboratory Virtual Instrument Engineering Workbench of National Instruments Ltd [8-9] that is traded as the LabView. Our VPEL uses a few web programming methods including JavaScript, HTML and Flash to complete the interfacing.

The power electronics course for undergraduate teaching consists of topics including switched-mode power converters, quasi-resonant converters, power factor correction, etc. The Virtual laboratory developed is to aim for these three topics. One set of each experiment has been set up and running in the laboratory. In the past, students has to come in person to the Laboratory to do the experiment. By using the LabView tool and associated CGI, a remotely control experiment of each topic is then

developed. Fig. 1 below shows a photograph of the physical experimental set up in the laboratory [10].

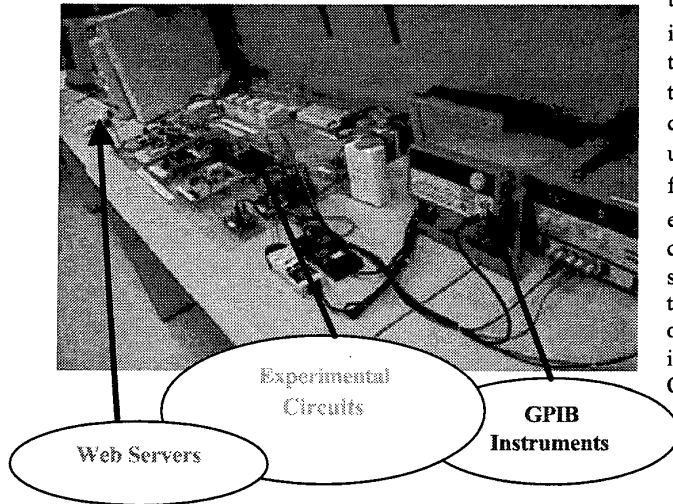


Fig. 1: Laboratory set up of the Virtual Lab

II. THE POWER ELECTRONIC EXPERIMENT

The development of the virtual laboratory is based on the LabView. All the instruments are communicated using GPIB and DAQ cards which are used to connect among the LabView and the power electronic instruments including Oscilloscope, signal generator and power supply. We also have to develop software for the communication between the system and client using the Internet transmission.

Two sets of power electronics experiments have been developed. They are: DC/DC converters [2] and the Quasi-resonant zero-current-switching converters [13]. The first experiment is not only to study at the Buck and Boost converters operations, but also to examine the effect of the spray inductance and capacitance and also the effect of the snubber. The effect of the ripple current and voltage with the duty ratio and the input voltage are also part of the study. The second experiment is to study the basic principle of operation of the zero-current switching quasi-resonant converter. This also includes the study of the condition of the zero-current switching for the Buck converter and the effect of the load to the zero-current switching as well. Therefore the instruments are needed to provide computer-controlled voltage. Also the frequency and duty ratio of the signal generator to the transistor are also needed to be controlled. The schematic diagram of the virtual laboratory system is shown in Fig 2.

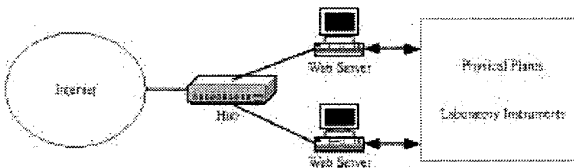


Fig 2. Schematic diagram of the Virtual Laboratory system

The schematic diagram of the DC/DC converter experiment is shown in Fig 3. The converter is a Buck switched mode type. It consists of a freewheeling diode D_F , filter inductor L_F and filter capacitor C_F . The transistor Q_1 is for the main switching. The load is connected in parallel with the C_F . In fact the load can be selected through a remotely control relay so that a number of loading condition can be used. The parasitic inductance L_s and RCD snubber formed by D_2 , R_2 and C_2 are also included in the experiment. Switched S_1 and S_2 are used to connect these components through a Web-based remote control to let students examine the effect of the parasitic components and the snubber. The examination of the basic characteristics of the Buck converter is also prepared by remote control the input voltage, transistor duty ratio and loading through the GPIB connected with the LabView.

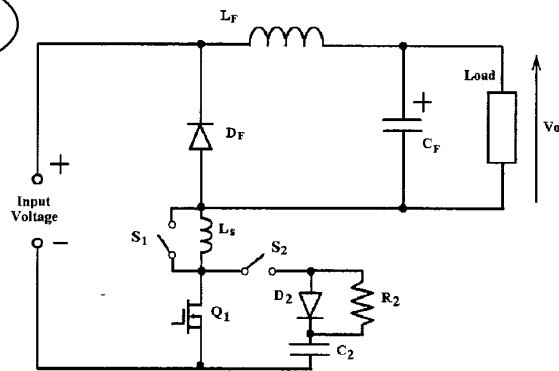


Fig 3. The DC/DC converter experiment

Fig 4 shows the experiment entitled "Quasi-resonant zero-current-switching converter" which is also a Buck type [13]. The circuit consists of the transistor for the main switching, a set of resonant components which is the resonant inductor L_r and capacitor C_r . D_F is a freewheeling diode and C_F and L_F form the filter. The load R_L can also be adjusted through the web-based remote control. A switch S_F is used to connect a diode D_2 for the study of the half-wave and full-wave modes of the converter. The basic operation of the converter is also remotely controlled with respect to its input voltage, switching frequency and duty ratio of the transistor Q_1 and the load through a GPIB (General Purpose Interface Bus) to the LabVIEW.

GPIB and DAQ (Data Acquisition) cards of LabVIEW will be used to control the experiment rig, method of the measurement and signal generation instruments (Oscilloscope, Signal Generator and Power Supply), while some interfacing software based on LabVIEW will be developed for data exchange among these instruments, other cards and the web servers of the Virtual Lab. The system to be developed has included those for data communication between the servers in the Virtual Lab and the client. Two web-servers, one for controlling the GPIB and one for the DAQ are used.

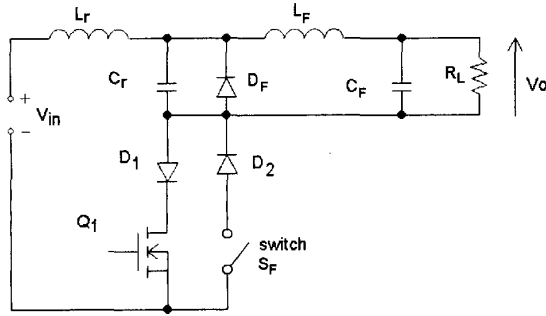


Fig 4 The Quasi-resonant zero-current-switching converter experiment

The display of the measured waveforms using the Oscilloscope can be displayed through the GPIB to the LabView. Alternatively it can be displayed through a WebCam aiming at the screen of the Oscilloscope as a real-time capture.

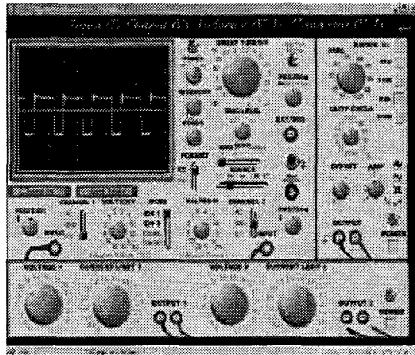


Fig 5. The display of the control button Web-based virtual laboratory.

III. THE ARCHITECTURE OF THE VIRTUAL LAB SYSTEM

A. Hardware

The remote experiment is located in one of the laboratory where needs nobody to attend. The Web is the gateway for the system to exchange the necessary information between the client machine and the server. The Web browser is a platform providing an environment to run the necessary program including the Java applets, Java Script and Flash used in the development of the laboratory. Once a login is successful, a WebCam is connected for broadcasting the environment of the hardware rig to the Internet. A typical display of the WebCam is shown in Fig 6 where we can see the whole setup of the power electronics experiment. It also gives the student a feel of the actual setup. Also the light will also be switched on to increase the visibility. It is also to give a signal for any one in the remote lab that the machine is being used and no disconnection or movement are allowed.

Fig 7 shows the structure of the whole system where the connections among each of the components are shown properly. The function of each component is described in the following paragraph.

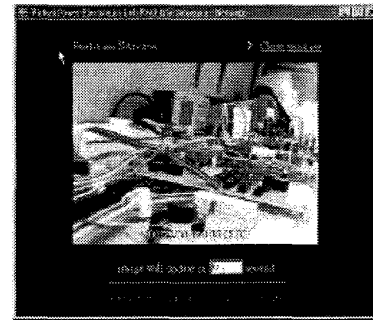


Fig 6 The Webcam boardcasts the remote laboratory setup

The Data Acquisition (DAQ) Cards, the Ethernet card and the desktop PC are served to select which experiment is to be conducted. The Ethernet is wired to the LAN through the Hong Kong Polytechnic University Network [11]. The DAQ cards control the signals from the WWW server through a TCP/IP channel. A second desktop computer is also installed with a GPIB controller card and an Ethernet card that is served to connecting the three GPIB instruments.

B. Software Structure

The structure of the software interface is shown in Fig 7. First, the web program along with the hardware is written using Flash and HTML where animation was used to raise the users' interest.

The LabView Internet Developer Tool-kit was used for the Internet control. Also Common Gateway Interface (CGI) and Transmission Control Protocol (TCP) are used for the communications between the client and the Web server. The CGI is written for the program involved with the HTML on the Web pages whereas the HTML is a popular form of access for sending data across the Internet.

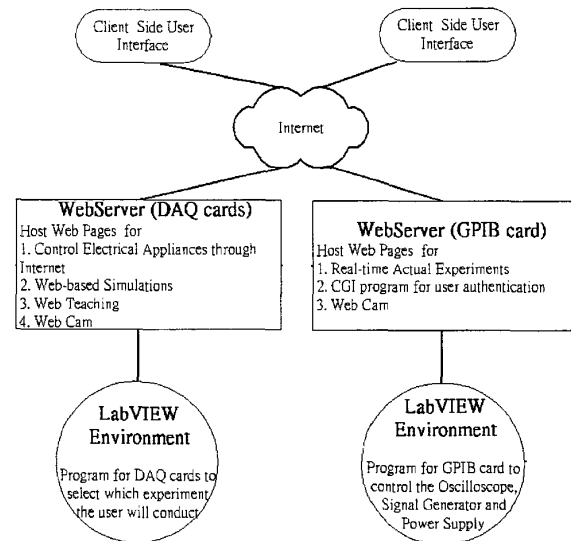


Fig 7. The block diagram of the software structure

The TCP is supported by the LabView that is implemented by Virtual Instrument (VI). The VI is LabView standard that is used to communicate the LabView via the Internet. The method is list as follows:

- o The TCP Listen.vi waits for an incoming request from TCP. A connection ID will be returned when the TCP connection is created.
- o The TCP Read.vi receives a specified maximum number of bytes to read from the specified TCP connection.
- o The TCP Write.vi writes the string data to the specified TCP connection.
- o The TCP Close Connection.vi is used to release the TCP connection.

The interfacing between the LabView and Web server is summarized in Fig 8.

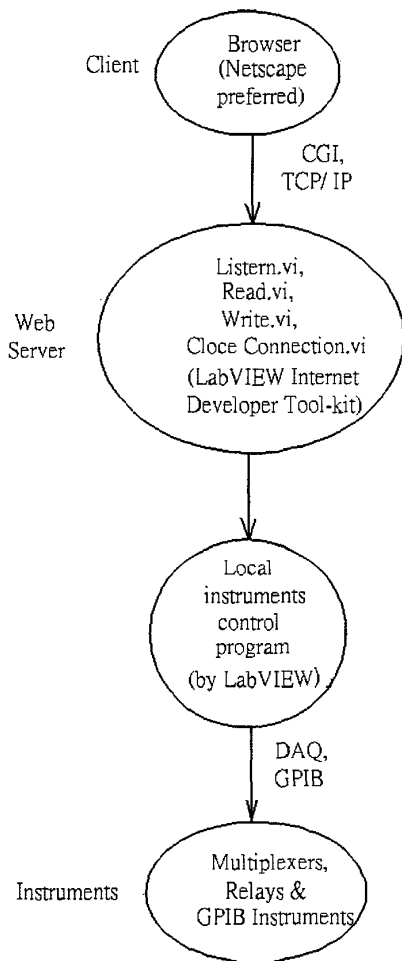


Fig 8 The block diagram of The development tool kit

C. The User Interface

After the users' logon and authentication, two sets of experiments are allowed for the selection as shown in the display in Fig 8.



Fig 8. Main page for selection of which experiment

Also the associated control panel for the instruments will be displayed as shown in Fig 5. An online Labsheet is also provided, or alternatively it can be downloaded and printed out. The user can now conduct the experiment by following the procedure of the labsheet. This includes the adjustment of the pulse-width and frequency of the signal generator output, load selection and circuit switches through some relayed controls. The time-base, vertical gain of the oscilloscope can also be controlled by simply a click through the mouse selection. The results of the waveforms are delivered on-line to the display windows of Web. Fig 8 shows the online labsheet of one of the experiment.

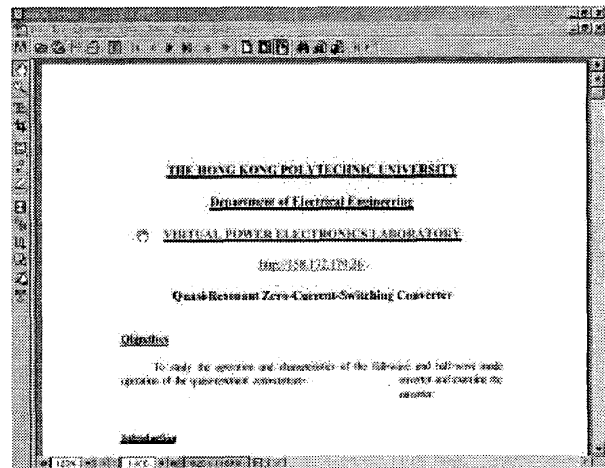


Fig 9 The Online Lab-sheet of the Quasi-resonant Zero-current-Switching converter

V. DISCUSSION

Our proposed web-based virtual laboratory has been developed and used for final year undergraduate teaching. Students can only perform the experiment 24 hours a day and 7 days a week. There is no limitation for the location

and time. Students can login in their home PC and conduct an experiment. This is especially useful for part-time students who may have difficulty to attend the laboratory class because they have a full-time job. It is also very useful for distance learning such that hardware experiment rather than only computer simulation or animation.

Another advantage is that the website also provides with the power electronics lecture materials. A power electronic lecture web page is shown in Fig 10. Students can click on any one of the lectures before trying the experiment. They can also download the lecture notes. Students can study a topic and then try the experiment. The experiment has a full instruction and procedures and it make sure that students will not get lost.

As the procedure and the setting of the lab is clearly planned. The instruments and the converters are also protected with the maximum current and voltage limit of the hardware. Therefore there is a lower risk of damaging the hardware. There is also no risk of getting an electric shock. The mentoring of the laboratory assistant is also not necessary.

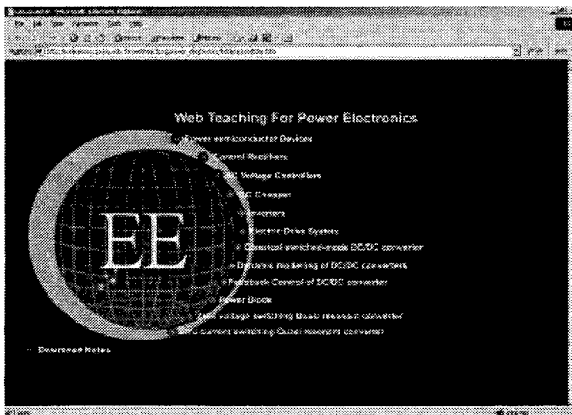


Fig 10. The power electronic lecture web page

The students' feedback on the proposed power electronics virtual laboratory is also very positive. Students like the web-based experiments because it can save their time and traveling. It also gives them a very systemic approach with plenty of materials when they perform the laboratory session. The classical laboratory session is rather limited in space and time. Whereas the proposed virtual laboratory also make them easier to record the experimental results in form of waveforms or data as they take record measurement in the client side computer. It therefore saves the trouble to print the waveforms, store in a floppy disk or export to a computer. Also, student must form in a group to perform laboratory session in the pass and that means their involvement in a laboratory is less and in many occasions, they cannot finish before the end of the laboratory session. However, the web-based power electronic virtual laboratory does not have such constraint. The opening hour is not limited as there is no need to have a technical staff

attending the laboratory. Also it is more economic as the power consumption is less as compared between a whole laboratory and a web-based virtual electronic set. Any form of the security is also easily to be maintained.

VI. CONCLUSION

A power electronic virtual laboratory is developed and described. The system is based on the LabView Internet Developer Tool-kit which gives the real-time data transfer and interactive web-based interfacing. Two popular power electronics experiments have been developed and have been currently run in the undergraduate course. Both of them can be remotely conducted through the Internet access. The main advantage of the virtual laboratory is the power electronics experiments can be carried out from any point in the world. Students have found the virtual laboratory useful and also have an actual feeling of the hardware experiment. The website is also implemented with the web-based teaching materials so that students can enjoy a web-based lecture while also try an experiment. The system is a useful tool for distance learning where physical laboratory is not feasible. Finally, the whole package can be reached via the URL: <http://elearning.polyu.edu.hk>

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REFERENCES

- [1] The Open University of Hong Kong: <http://www.ouhk.edu.hk>
- [2] The Open University, UK: <http://www.open.ac.uk>
- [3] Saber, <http://www.avanticorp.com>
- [4] Shor, M. and Bhandari, A., "Access to an Instructional Control Laboratory Experiment Through the WWW", Proc. of the 1998 American Control Conference, Philadelphia, pp. 1319-1325, 1998.
- [5] Sergio Cesare Brofferio, "A University Distance Lesson System: Experiments, Services, and Future Developments", IEEE Transactions on Education, Vol. 41, No. 1, February 1998.
- [6] Ferrero, V. Piuri, "A Simulation Tool for Virtual Laboratory Experiments in A WWW Environment", IEEE Instrumentation and Measurement Technology Conference, Vol. 1, pp. 102-107, May 18-21, 1998.
- [7] G.G.Karady, G.T.Heydt, K.J.Olejniczak, H.A.Mammoth, S.Iwamoto, M.L.Crow, "Role of laboratory education in power engineering: is the virtual laboratory feasible?", IEEE Power Engineering Society Summer Meeting pp. 1471-1477, vol. 3, July 2000.
- [8] LabVIEW User Manual, National Instruments, July 2000.
- [9] LabVIEW online help, National Instruments, 2000.
- [10] Web-based Virtual Laboratory in the Hong Kong Polytechnic University. Available: <http://158.132.179.26>
- [11] Home page of PolyU. Available: <http://www.polyu.edu.hk>
- [12] N.Mohan and M.Tore, "Power Electronics: converters, applications, and design", 2nd edition, New York, Wiley, ISBN: 0471584088
- [13] Liu, K.H, Orguganti, R., and Lee, F.C., "Resonant switches - topologies and characteristics", IEEE PESC 1985, pp. 106-116.

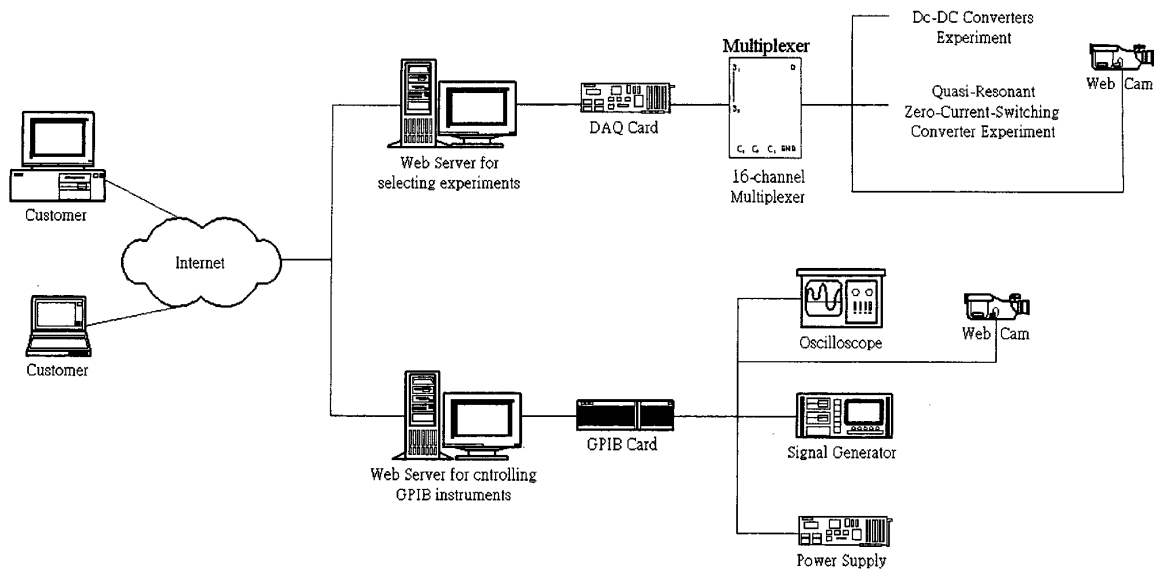


Fig 7 The Configuration of the whole system