Application of Remote Technology on Electrical Power System Laboratories

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Abstract
A prototype of a remote laboratory to conduct electrical power experiments over the internet is developed to allow students to access the setup and perform measurement and analysis of typical electrical power experiments. The main goal of the paper is to provide a mean of resource sharing of expensive power equipment to students from other universities in Jordan and beyond in addition to students in Tafila Technical University, where the traditional electrical power systems laboratory is located. The design approach is based on modifying the existing traditional systems to facilitate remote access via the web. One typical experiment addressing synchronization procedure of two generators was performed with a power system simulator. The data acquisition system and remote access of the power laboratory were designed based on the LabVIEW programming language. Initial on students' evaluation of the proposed online laboratory indicates that encouraging results may be obtained with remote experimentation when improved pedagogical aspects are integrated properly in the measurement procedures.

Introduction
Web-based education has revolutionized engineering education in many respects. They are also changing the traditional teaching style in higher education. When digital computers as well as various software and hardware are used in laboratories and classrooms, they can provide much more effective and efficient ways in teaching and make many mathematical related engineering problems easy to understand.
Modern technology enables remote access of laboratory equipment via the internet. This can be particularly useful in the case of electrical power engineering education to enable student to access such expensive laboratory instruments and equipment and to conduct experiments remotely. A consortium of universities may be formed to share laboratory resources by distributing online experiments over a given semester amongst the respective modules thereby allowing greater numbers of students to perform experiments with minimum cost.

Electrical Power Laboratory
Electrical power engineering is one the vital majors in higher educational system in Jordan. Power engineers are responsible for the establishment, operation and maintenance of the national power grid in addition to the interconnection with the neighboring countries. The laboratory of power systems is one of the most crucial laboratories in this major. In some institutions, this laboratory is computer-based without any physical components while in others; it is based on small-scale separate physical components. The most modern electrical power system laboratory is an

interconnected simulator composed of low-power generating units, different types of transformers, busbars, overhead transmission lines, cables and different types of static and dynamic loads in addition to the protection systems of the individual components and the overall system. The diversity of this laboratory depends mainly on the allocated budget. Thus, modern comprehensive power system laboratory may only be found available in few universities in the Middle East.

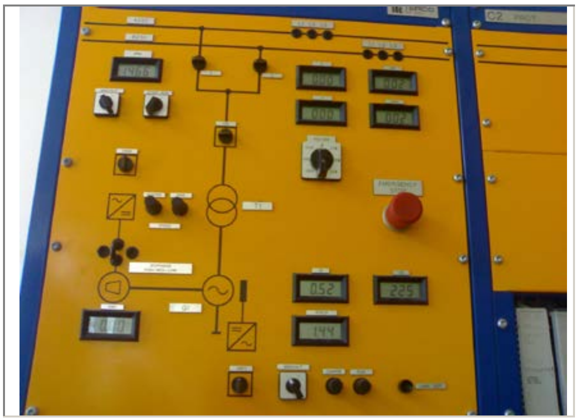
The electrical power system laboratory is fourth-year senior EE laboratory course at Tafila Technical University as well as other similar programmes in a number of universities in Jordan. The laboratory draws on and correlates with the knowledge obtained by students from their sophomore EE courses such as electric circuits and power systems. Traditionally, all of the laboratory experiments in this course were based on traditional equipments, devices, methods and techniques for measurements, data recording and result analysis. This usually makes experiments time-consuming and inefficient, and therefore, greatly limits the effectiveness in the students' understanding of fundamental concepts and theories from the hands-on experimentation.

A pilot project is currently underway at the Department of Electrical Engineering, Tafila Technical University, to implement remote experiments using its comprehensive TERCO power system laboratory. This laboratory is composed of different interconnected cubicles such as the power plant module with high voltage busbars and outgoing lines, transmission lines and distribution module, receiving substation module with high voltage side and load module. A number of experiments, under normal as well as fault conditions, are usually conducted manually and may be modified to accommodate remote setups. These experiments include settings of field control parameters, turbine control rectifier parameters, start and stop ramps and checking AC and DC supplies, alarm indications, acknowledge and canceling procedures, status indications of isolators and breakers. Differential relays can also be tested by resistive faults or trim faults caused inside the protective zones. In addition, load distribution can be varied using auxiliary transformers to keep the currents within certain limits and generator performance under steady state and dynamic conditions can be studied for different types of loads. Finally, the dynamic characteristics of a controller can be examined and the characteristics of over-current and under-impedance starting elements can be obtained.

One of the experiments that can be performed with TERCO power system simulator is synchronizing two generators Fig. (1a), each generating unit is provided by speed and voltage controllers to adjust the generator terminal voltage and frequency as shown in Fig. (1b). This experiment is usually performed by three students to achieve the conditions of synchronization (equality of the voltage magnitudes and frequencies, same phase sequence and angles): the first student adjusts the first generating unit controllers; the second adjusts the other generating unit controllers; while the third student watches the measuring devices and selects the suitable moment for connecting the two generators to a common busbars.

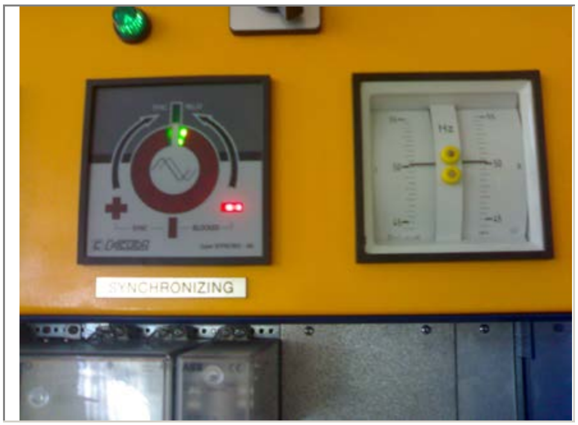
The power system simulator is provided with dual voltmeter and frequencymeter that measure and compare the voltages and frequencies at both sides of the circuit-breaker through which the connection will be performed. Rotating three-light-bulbs are provided to check the phase sequence. These bulbs are connected between the phases of the two generators. If the phase sequence is the same, the bulbs will bright and dark in a rotating manner, but if the phase sequence is wrong; they will get bright and dark together. A synchroscope is provided to the check the voltage phase difference as shown in Fig. (1c), the light in the synchroscope rotates clockwise or counterclockwise depending on which generator has a higher frequency. When the light reaches the top green area, then this means that the two generators are in phase Fig. (1d).

(a) Two Generating Unit Panels.



(b) Voltage and Frequency Controllers of a Generating Unit.

(c) Measuring Devices for Synchronizing Two Generating Units.



(d) Measuring Devices for Synchronized Two Generating Units.

Fig. (1): Generating Units Panels and Measuring Devices for Synchronizing Two Generating Units.

Remote Power Laboratory

The application of interest here is to connect two generators in parallel. The main part of the paper focuses on the understanding benefits, procedures, conditions of synchronization and power flow for proper generators connections. The procedure of the application is generating two sinewaves by determining the speed of rotation of the prime mover (rpm) and voltage parameter values for the two generators. For each parameter there are two controllers: coarse and fine, to determine accurate values. The value of rpm parameter must be 1500 since the generator is of four poles and the frequency is 50 Hz, and it is divided by 30 to determine the frequency of the sinewave signal. On the other hand, the value of voltage must be around 230 V and it is multiplied by 1.414 to determine the amplitude of sinewave signal. The rpm and the voltage values of the first generator are compared with those of the second one, and if there are equal and in phase the light is on, and then the user can switch on the circuit as shown in Fig. (3).

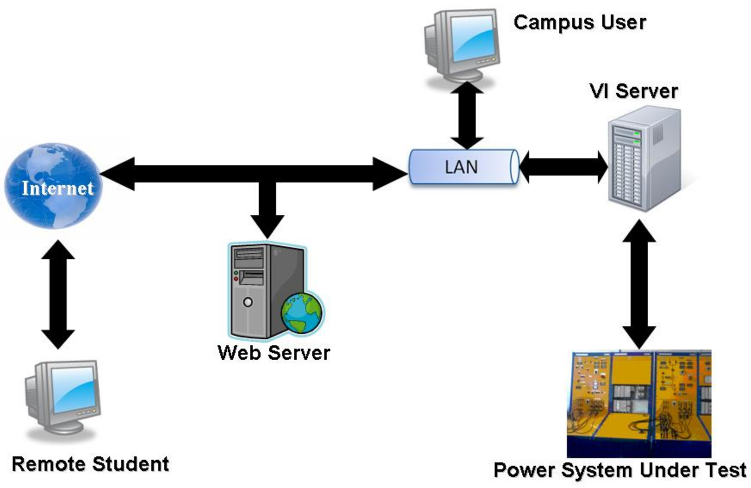


Fig. (2): Remote Power Laboratory Architecture.

In the front panel, the student can set the value of rpm parameter of the first generator using the coarse and the fine knobs, and then can watch the value on the indicator beside the knobs. The student can then set the voltage using other coarse and fine knobs, and watch the value on the other indicator, and set these the values for the second generator unit. The student's goal is to achieve the equality by controlling the previous knobs; at the same time he must watch the scope to find the point when the two sinewaves are in phase.

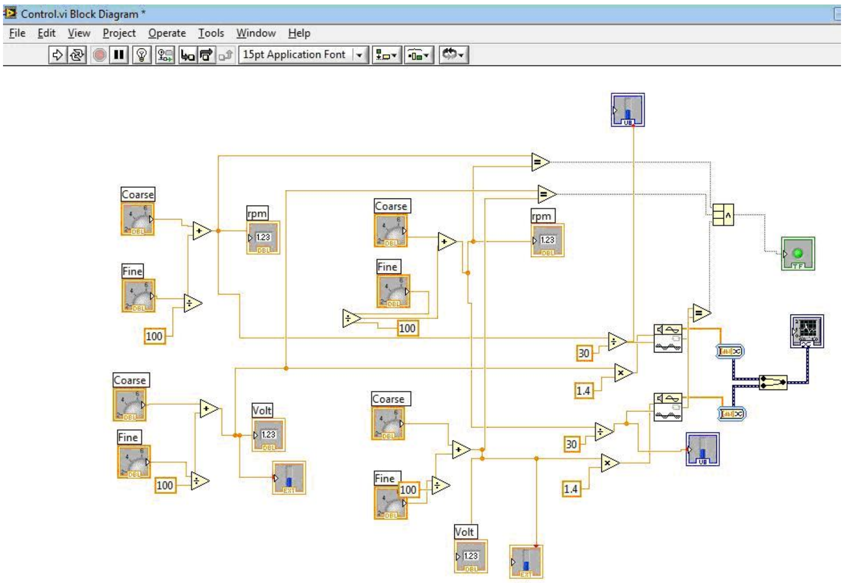


Fig. (3): LabVIEW Programme Block Diagram.

When the conditions of synchronization are met, the green LED is on. In the study case the conditions are met when both the speed of the prime mover and voltage values for the two generators are equal with values corresponding to 1500 rpm and 230 V respectively. The last condition for synchronizing that is the two phases for the signals are equal too, as shown in Fig. (4).

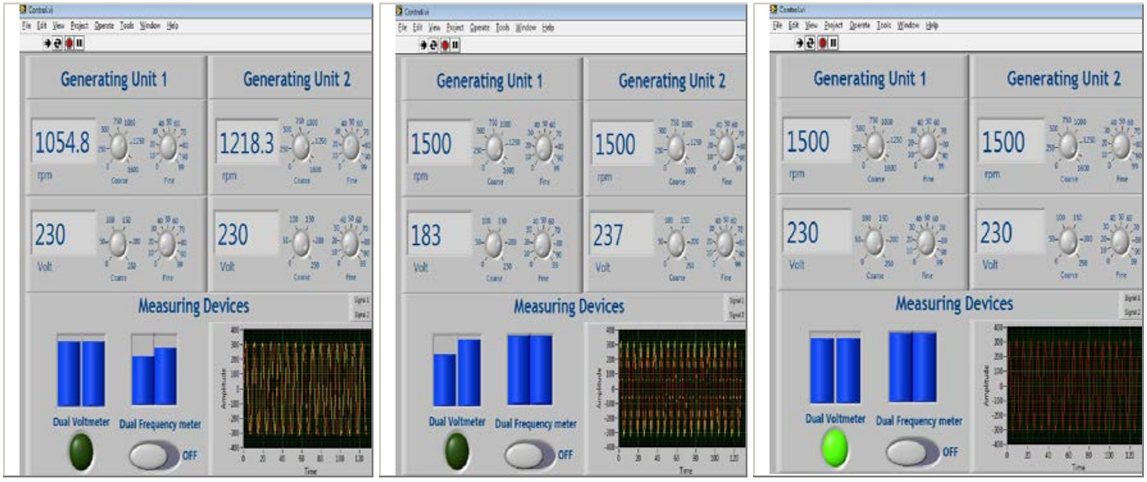


Fig. (4) Controlling and Measuring Devices on LabVIEW.

Conclusions

A prototype electrical remote laboratory was developed to enable students to access experiments via the internet. Student clients were able to access the remote laboratory using the internet.

References

[x] Denis Gillet, Anh Vu Nguyen Ngoc and Yassin Rekik, "Collaborative Web-Based Experimentation in Flexible Engineering Education", IEEE Transaction on Education, Vol. 48, No. 4, November 2005, pp 696-704.

[x] Eliane Guimarães, Antonio Maffeis, James Pereira, Bruno Russo, Eleri Cardozo, Marcel Bergerman, and Mauricio F. Magalhães, "REAL: A Virtual Laboratory for Mobile Robot Experiments", IEEE Transaction on Education, Vol. 46, No. 1, February 2003, pp 37-42.

[x] Zoe Doulgeri and Tilemachos Matiakis, "A Web Telerobotic System to Teach Industrial Robot Path Planning and Control, IEEE Transaction on Education, Vol. 49, No. 2, May 2006, pp 263-270.

[x] Costas S. Tzafestas, Nektaria Palaiologou and Manthos Alifragis, "Virtual and Remote Robotic Laboratory: Comparative Experimental Evaluation", IEEE Transaction on Education, Vol. 49, No. 3, August 2006, pp 360-369.

[x] Francisco J. Ferrero Martín, Juan Carlos Campo Rodríguez, Juan Carlos Álvarez Antón, Juan Carlos Viera Pérez, Cecilio Blanco Viejo and Manuela González Vega," An Electronic Instrumentation Design Project for Computer Engineering Students", IEEE Transaction on Education, Vol. 48, No. 3, August 2005, pp 472-481.

[x] Shyamala C. Sivakumar, William Robertson, Maen Artimy and Nauman Aslam, "A Web-Based Remote Interactive Laboratory for Internetworking Education", IEEE Transaction on Education, Vol. 48, No. 4, November 2005, pp 586-598.

[x] Michael Auer, A. Y. Al-Zoubi, Danilo Garbi Zutin and Hatem Bakhiet, "Design of Application-Specific Integrated Circuits for Implementation in a Network of Remote Labs", 2008 ASEE Annual Conference and Exposition, 22-25 June 2008, Pittsburgh, Pennsylvania, USA.

[x] Oriol Gomis Bellmunt, Daniel Montesinos Miracle, Samuel Galceran Arellano, Andreas Sumper, and Antoni Sudrià Andreu, "A Distance PLC Programming Course Employing a Remote Laboratory Based on a Flexible Manufacturing Cell", IEEE Transaction on Education, Vol. 49, No. 2, May 2006, pp 278-284.

[x] B. Weedy and B. Cory, Electric Power Systems, John Wiley and Sons, UK, 1999.

[x] Fitzgerald A., Kingsley, Jr. and Umans, D. (1992) Electric Machinery, McGraw-Hill.