LABVIEW APPLICATION: ENERGY LABORATORY UPGRADE

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Abstract

This paper describes an effort to upgrade the quality and timeliness of the VMI's Mechanical Engineering Department Energy Laboratory. Two of the current laboratory experiments were selected for modernization. These experiments were a steam power plant experiment and a cooling tower experiment. Both of these experiments were old, but the machinery was in good condition. The upgrades include modern instrumentation and data analysis capability, which made these old experiments valuable teaching resources for many more years. The hardware and software necessary for both of these experiment upgrades is discussed and budget estimates are provided.

Both of the equipment upgrades described in this paper were accomplished using Labview. Labview is a graphical programming language specifically designed to interface data acquisition system (DAS) hardware to a user-friendly (graphical) computer environment. With Labview, many different types of DAS hardware can be controlled from the computer keyboard. The interface for each of the current experiments, as well as future equipment upgrades, was designed in a similar fashion, thereby reducing the learning curve for each new hardware component. This means that instead of having to run multiple programs from different vendors, each with a different user interface, a common user interface can be developed for each instrument. Labview can be used not only for data acquisition or instrument control applications, but also for general-purpose applications, such as database development, data analysis programs, and network communications. These features allow room for expansion of scope as new experiments using Labview are developed.

Introduction

All junior mechanical engineering students at the Virginia Military Institute are required to complete the course *Mechanical Engineering Energy Laboratory*. The course is a one semester, one credit hour course that meets for two hours each week. Two semesters of thermodynamics, are pre-requisites and one semester each of heat transfer and fluid mechanics are co-requisites. The laboratory course includes applied engineering investigations into the areas of energy, thermodynamics, fluid mechanics, and heat transfer. The laboratory simulates real life engineering team experiences in the use of laboratory testing and measuring equipment. Technical report writing and laboratory safety measures and practices are stressed. During the one semester course each four-person team conducts ten experiments. These experiments include the following:

1. Small Power Plant
2. Heat Transfer – Conduction
3. Solid Fuel Combustion
4. Supersonic Nozzle
5. Small Engine Theory and Measurements
6. Internal Combustion Engine Performance
7. Water Cooling Tower
8. Parallel/Series Pump Operation
9. Vapor Compression Refrigeration
10. Cross Flow Convective Heat Transfer

This paper describes an effort to upgrade the quality and timeliness of the VMI's Mechanical Engineering Department Energy Laboratory. Two of the current laboratory experiments were selected for modernization and upgrade. These experiments were the Steam Power Plant and the Cooling Tower. Both of these experiments were old, but the machinery is in good condition. The upgrades include modern instrumentation and data analysis capability, which will make these old experiments valuable teaching resources for many more years.

Both of the equipment upgrades described in this paper were accomplished using Labview. Labview is a graphical programming language specifically designed to interface data acquisition system (DAS) hardware to a user-friendly (graphical) computer environment. With Labview, many different types of DAS hardware can be controlled from the computer keyboard. The interface for each of the current experiments, as well as future equipment upgrades, was designed in a similar fashion, thereby reducing the learning curve for each new hardware component. This means that instead of having to run multiple programs from different vendors, each with a different user interface, a common user interface can be developed for each instrument. Labview can be used not only for data acquisition or instrument control applications, but also for general-purpose applications, such as database development, data analysis programs, and network communications. These features allow room for expansion of scope as new experiments using Labview are developed.

Steam Plant Experiment

The first experiment to be upgraded was the Small Power Plant. This steam plant is a small-scale steam turbine plant built by the Westinghouse Electric Corporation[1] in 1961. It includes all of the components of a full-scale electric generating plant including steam superheater, steam turbine, electrical generator, condenser, hotwell, and condenser cooling water system. Saturated steam for operation of the plant is obtained from the Institute's steam heating plant. The experiment was originally instrumented using Bourdon tube pressure gages, mercury-in-glass thermometers and analog flow meters (rotameters). The current upgrade includes replacement of the existing instrumentation with pressure and temperature transducers that provide electrical signal outputs. These electrical data signals were digitized using analog to digital converters and the digitized data is then computer processed to display steam plant operating state parameters. Figure 1 is the computer generated instrument panel that was developed for this experiment.

This display was produced using a system diagram drawn in Microsoft PowerPoint and superimposed on the Labview display.

To provide the necessary data to allow the students to calculate the steam turbine performance the steam plant was instrumented to measure turbine inlet steam pressure and temperature, condenser pressure, condensate temperature, condenser cooling water inlet and outlet temperatures, and the electrical generator voltage and current supplied to the electrical load. Figure 1 shows the location of the new instrumentation. In addition, the condensate and condenser cooling water flow rates were measured. At present the measurement of these flow rates have not been included in the upgrade. Flow meters that provide electrical output signals have been purchased and they will be installed in the future to complete the instrumentation upgrade.

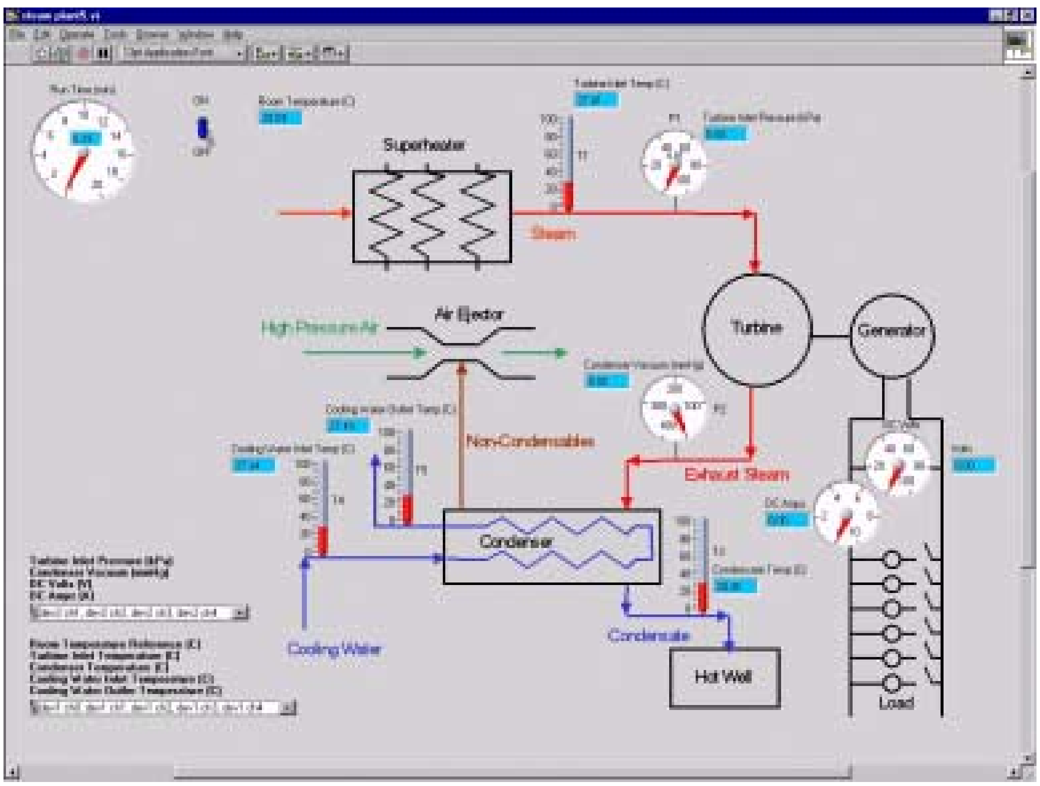

Figure 1. Steam Plant Instrument Panel Developed Using Labview

The mercury-in-glass thermometers used in the Steam Plant were replaced with Type T thermocouples. The Bourdon tube pressure gages were replaced with Kobold constant current transducers. These pressure transducers provide a 4 to 20-ma output. This current was passed through a 250-ohm shunt resistor, across which voltage was measured. This arrangement provides a 1 to 5 volt signal for the DAS board. The DAS hardware chosen for this project includes two National Instruments PCI-MIO-16XE-50 Multifunction analog-to-digital input/output cards. These cards provide 20 kHz sampling rate with 16-bit resolution and 16 analog channels. All instrument connections were made to a shielded connector block, which was connected to the DAS board via a shielded cable. The connector block contained a built-in thermocouple temperature compensation cold junction.

Figure 2. Steam Plant with New Instrumentation in Place

Cooling Tower Experiment

The second experiment selected for modernization was the Water Cooling Tower manufactured by the Armfield Technical Education Company Limited[2], Ringwood Hampshire England, in 1989. The cooling tower is shown in Figure 3, it is a small-scale water cooling tower that includes all of the components of a full-scale cooling tower including baffles, fan, sump and a water circulating pump.

Figure 3. Experimental Cooling Tower

While the equipment was in good condition and would provide many years of service the instrumentation was dated. The unit was originally designed using an inclined liquid manometer to measure pressure differential across the tower to determine air flow and wet and dry bulb temperatures were measured using mercury-in-glass thermometers. The new instrumentation was developed to utilize electronic temperature and pressure transducers and the modern computer data acquisition system interface described above. The electrical data signals were digitized using analog to digital converters and the digitized data were computer processed to display operating state parameters. Figure 4 is the computer generated instrument panel that was developed for this experiment.

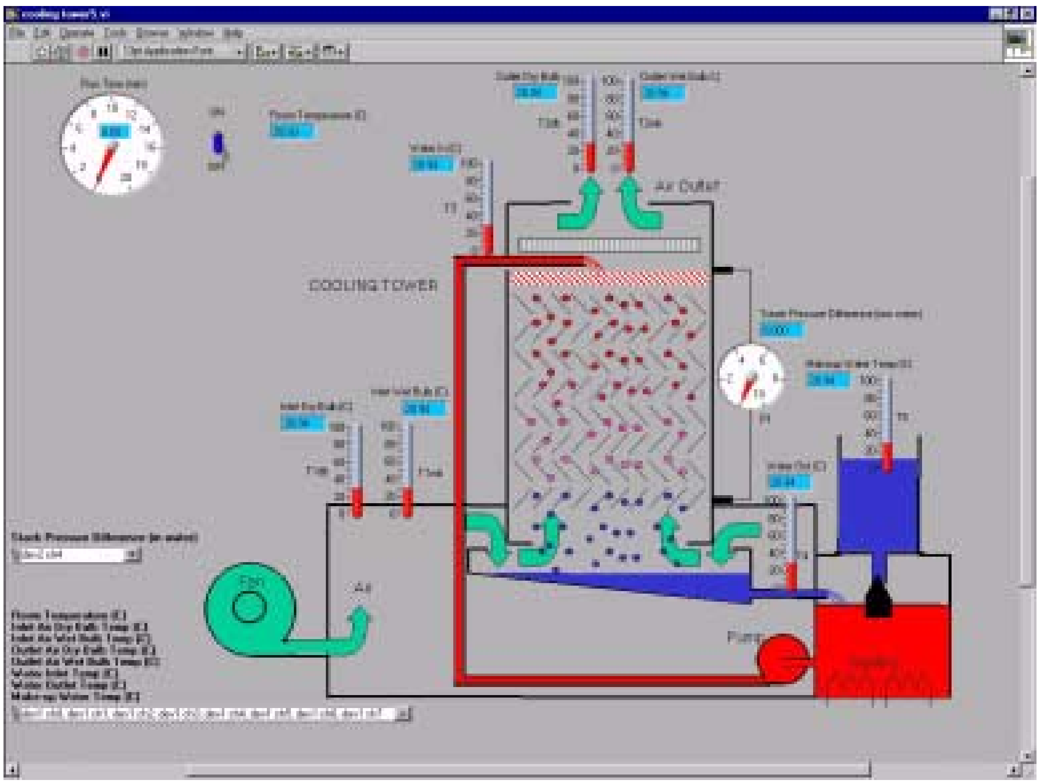

Figure 4. Cooling Tower Instrument Panel Developed Using Labview

To provide the necessary data to allow the students to calculate the water cooling tower performance the cooling tower was instrumented to measure tower inlet and outlet dry bulb and wet bulb air temperatures, water inlet and outlet temperatures, and air pressure drop through the tower. Figure 2 shows the location of the new instrumentation. In addition, the water flow rate was measured. At present the measurement of this flow rate has not been included in the upgrade. A Flow meter that will provide an electrical output signal has been purchased and will be installed in the future to complete the instrumentation upgrade.

Type T thermocouples, PCI-MIO-16XE-50 DAS boards, and a shielded connector block were also used in the Cooling Tower experiment. However, a different type of pressure transducer was used. For this experiment, an Omega PX 142 constant voltage transducer was chosen. This pressure transducer provided a 0 to 5 volt signal. By using both constant current and constant voltage transducers, applications of both instrument types could be demonstrated. This allows for a discussion with the students concerning why one type would be better for certain applications. When the transducer is close to the readout device, the less expensive constant voltage transducer will provide sufficient accuracy. When longer distances are involved, the constant current transducers must be used.

Summary:

The dedicated equipment cost for upgrading the steam power plant experiment was approximately $1600. This includes the cost of two pressure transducers, two flow meters, four type T thermocouples, two shielded connector blocks, and cables. For the cooling tower experiment the dedicated equipment cost for upgrading was approximately $1200. Included in this figure were five thermocouples, a flow meter, a pressure transducer, two shielded connector blocks, and cables. Equipment common to both experiments (located on the portable cart) includes two data acquisition cards, Labview development software, and the computer. Total cost of this equipment was approximately $4600. This common equipment will also be available for use with any additional experiments as they are upgraded.

The Labview interface provides the students with the experience of using a state-of-the-art data acquisition system. For less that $7400 these two older laboratory experiments were successfully upgraded to provide a new modern computer interface for data collection. To purchase a new version of either of these experiments for the laboratory would easily cost in excess of $10,000. After the initial setup of the computer, DAS cards, and software, the cost per experiment is very reasonable and should be investigated as a cost effective solution to breath new life into older mechanical laboratory experiments.

Bibliography

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2. Instruction Manual Water Cooling Tower UOP6, Armfield Technical Education Company Limited, Ringwood Hampshire England, 1989.

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