# Web-Accessible Liquid Distillation Column Temperature Monitoring and Control using ilab Shared Architecture

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Abstract: *The liquid distillation column is a research facility used in chemical and processing engineering at University of Dar es salaam. Originally it has been manually operated require the presence of operators all-time. It is used to control and take measurements data under hazardous operating condition. In this work the research equipment has been automated and its control and monitoring can now operate online, hence shared by many researchers. In this paper, the major findings were data acquisition device (DAQ) NI USB 6211 for acquiring temperatures and generate signals for control purposes, and thermocouples type K sensors were used since they can operate at very wide temperature range of -270 to 1370. The main parameter which has been monitored is temperature at various parts of the distillation column including temperature of the top/bottom and reboiler temperature. The approach used was computer controlled using Data acquisition device and labVIEW graphical programming language as standalone control system to extent it control and monitoring temperature online. The Interactive ilab shared architecture has been used to make the system accessible remotely. Labserver was created then interfaced with distillation column using NI USB 6211 as a data acquisition device. The DAQ was configured for temperature acquisition and signal generation for monitoring temperature and flux flow control respectively. For the remotely operation, the Labserver was connected to the LAN/internet and the distillation column was accessed through web services.*

**Keywords:** Liquid distillation column, Data acquisition, Thermocouple type K, LabVIEW, Interactive ilab shared architecture.

## 1. Introduction

Research Labs have been very crucial in scientific or engineering discipline. Research labs can be in academic, industrial, government or private institution. They provide researcher with opportunity to search for knowledge or to perform systematic investigation to establish facts. Also students in engineering and science courses understand better the theory they get from class when they are exposed to laboratory works. Experiments in labs provide students with a good link between theory and reality (Baraka, 2010).

At University of Dar es Salaam, there is a pilot plant for bio-ethanol production developed using locally available resources which was used by both students and researchers for teaching and learning purpose (Ngowi, 2011). Prior to this work the plant was operated manually whereby the researcher or student must record temperature from each selected points along the column manually as it became tedious work to the user. This operating mode required the operator to be physically at the lab which endangers his/her safety.

Owing to some limitations of the plant, ilab was used to implement web-accessible liquid distillation column control and monitoring temperature. iLabs provide a mechanism whereby a user can interact with the plant and can change some parameters and monitoring it in real time. It provides an efficient way of sharing facilities and experiences among universities. The experiment using expensive equipment from one university can be shared by another university. In addition, compatibility of ISA with data acquisition NI USB

6211 and thermocouple type K for the better data acquisition. Below is the figure shows simple block diagram of the implemented system.
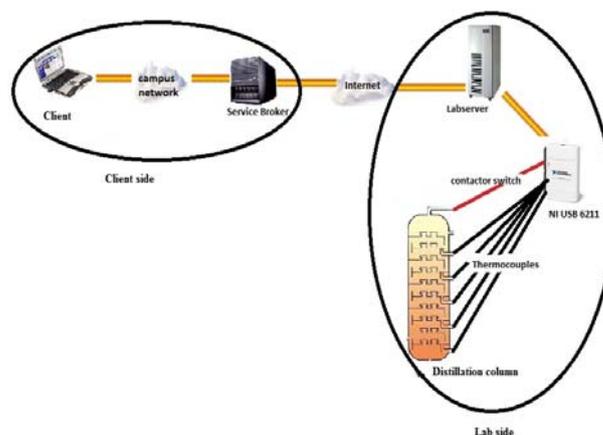


**Figure 1:** Simple block diagram of the system

The auto-control of the plant has been built from data acquisition device known as NI USB 6211 which was very crucial since it played a big role to accomplish objectives of this research. The DAQ has ability to generate signal for triggering a pump with the help of a relay switch as a triggered device for open/close action of valves for reflux flow control. The DAQ also has ability to acquire analogue signal from external via sensors which are connected to it, the temperature sensors inserted in the distillation column responsible for sensing temperatures from the different parts of the column through the NI DAQ to the lab server by using DAQ's analogue inputs channels so that output voltage of

the temperature sensors at a particular temperature can be measured. The system has been divided into temperature control and monitoring, and reflux control so when combined you get web-accessible liquid distillation column. The figure below presents the liquid distillation column located at Chemical and processing lab.
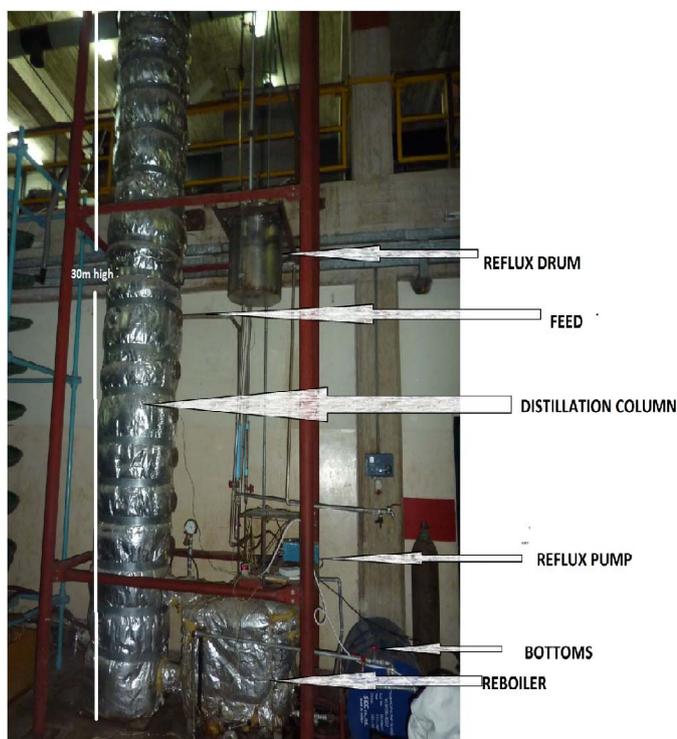


**Figure 2:** Distillation column at CPE lab, UDSM

The temperature sensors used were thermocouples type K due the fact that first is the general purpose thermocouple; it is low cost, high sensitivity, high temperature range and, owing to its popularity and it is available in a wide variety of probes. Thereby the values of both temperature and corresponding voltages can be recorded and stored for future reference and the characteristics curve can also be plotted as experiment being performed. Remote labs basically need internet tool kit and data socket from labView software for remotely operation to be possible. Client technology used in development of the remote lab, which needed a standard web browser with relevant plug-in as client. Thus simplify the client side so that students can concentrate on experiment rather than on learning client interface.

The work demonstrates that iLab can be applicable in any field of engineering, as we can see this research focused specifically in the field of Chemical and processing engineering where by the distillation column which is very important system for their daily activities successful made available online. It can provide both on-campus and off-campus students and researchers with flexibility to do the experiments at their own schedule and convenience time.

There some important parts used in this work such as thermocouple type K, Relay and also DAQ NI USB 6211.Eachone has got some advantages of why has been selected for this work.

**A. Data Acquisition device**

The typical DAQ system which includes sensors, the NI USB 6211, programming software, cables and PC that must installed labVIEW. Thus, the choice of this device was also influenced by the speed of acquiring data through USB. Also the figure below shows the input analogue circuit for NI USB 6211 which is used to input analogue signals from sensors.
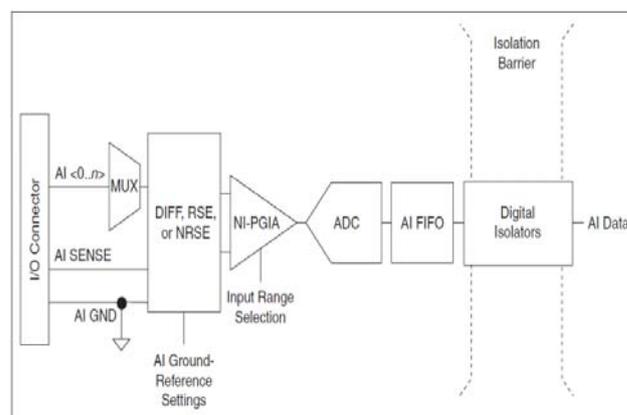


**Figure 3:** NI USB 6211 Analogue input circuitry (NI, 2009)

**B. Sensory system**

Thermocouples are the most popular temperature sensors. The choice of this type of sensor for this research work was influenced by the following; they are cheap, interchangeable, have standard connectors, Sensitivity is approx 41uV/°C and can measure a wide range of temperatures -270 to 1370. The main limitation is accuracy, system errors of less than 1°C can be difficult to achieve.

**C. Relay**

Locally designed relay was used, the DAQ is configured in such a way that after thermocouple sense a temperature at the range of a reference temperature, it generates DC voltage at the range of -10V to +10V which used to trigger relay switch then switch on the reflux pump for pumping back reflux for cooling. Since input required for the relay to operate is 10V DC so the voltage generated by NI USB 6211 was required amplification (DC voltage amplifier) first before connected to the relay. The relay circuit was designed separate and tested. Below figure is the relay circuit designed for switching ON/OFF the reflux pump.
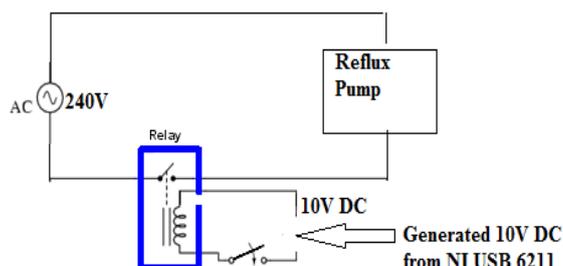


**Figure 4:** Relay circuit for reflux operation control

## 2. iLab Shared Architecture

The interactive lab client takes full control of the lab equipment for a relatively long period of time; the user must have previously scheduled time to use the experiment. The client will launch the lab client as the interface to the interactive iLab. Since the user has full control of the lab equipment it is easy for him/her to submit experiment parameters and commands as well as observing the results behavior experiments. The user can adjust parameters or submit new commands in real time. All interaction between the user and the lab are saved to form a definitive record of the experiment session.
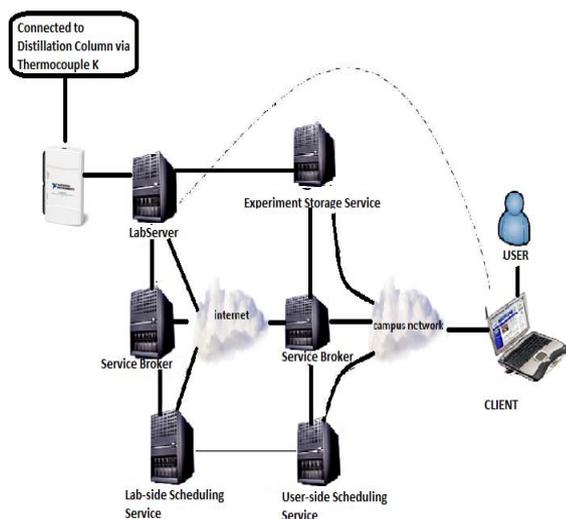


**Figure 5:** Topology of an interactive ilab shared architecture.

The left side of the system presents the lab side system which made by three blocks Labserver, Service broker and Lab Scheduling Service, and the other side constitutes the Client Side. The Service Broker sets up a connection between the client user and the lab server, and the two can communicate directly. The Lab Side Scheduling service enables the Administrator to allocate time blocks to the experiment and the User Side Scheduling Service grants an authorized client user a session within the set time block. During experiment execution, the Service Broker no longer has an upper hand in the experiment data and thus data handling is done by the Experiment Storage Service, a stand-alone service for data storage.

## 3. Actual Implementation of the System

The actual implementation of the system combines both mechanisms for temperature monitoring and control, and mechanism for reflux operation control. The below fig 7 gives the clear picture on interaction between Labserver and distillation column, on the middle part there is Labserver which installed with labVIEW to make communication interface between Labserver and DAQ NI USB 6211. The DAQ can operate in both ways that means can acquire analogue signal which is acquiring temperature from the distillation column and generating voltage for reflux control respectively. From the diagram there are two DAQ assistants VI one for acquiring signal and another for generating signal, reference temperature is a desirable temperature for

the final product whereby the system should respond for the liquid to be extracted, also there is file known as write to measurement file which is used as a path to store the recorded temperature data. Below is the block diagram for actual implementation of the system.
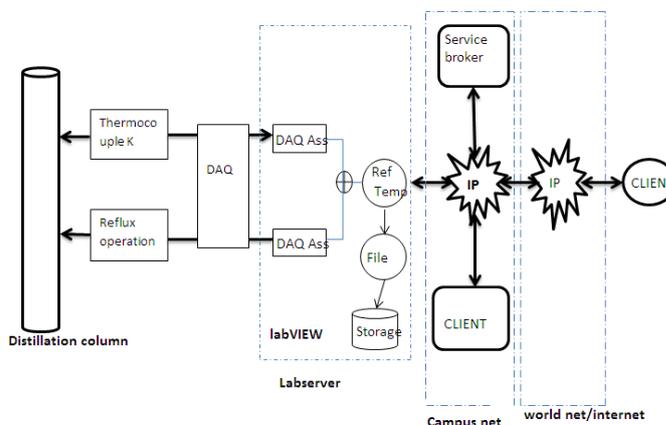


**Figure 6:** Actual implementation of the system.

The DAQ NI USB 6211 itself receive voltage from thermocouples which is analogue signal then convert them to digital for displaying numbers and then store as data. Then when the required temperature reached the DAQ NI USB 6211 gives out the DC voltage for triggering relay so that can switch reflux pump ON/OFF for reflux operation to take place. The whole process has been explained and shown clearly in the labVIEW programming codes which were used to create the main VI of the system.

### A. LabVIEW codes

The LabVIEW program was installed in the labserver so as to access drivers that were used to control the Data acquisition device. The development was done using LabVIEW 2009 which is similar to any graphical programming language except that it uses drag and drop graphical components which are connected using virtual wires to form a program. Also has built in primitive data types that are also represented graphically and provides a rich library of Virtual Instruments (VIs) that can be used to form more complex programs. These VIs are similar to function or procedure calls in convectional programming languages.

The VI was developed purposely to control the NI DAQ that was used in the temperature and reflux control for the distillation column. This VI made up of six DAQ assistants, five write to measurement files and data sockets. Five DAQ assistants were used to acquire temperatures from the five points along the distillation column labeled T1 up to T5, the NI USB 6211's five ports were configured and connected with thermocouples then inserted in the distillation column. The remaining DAQ assistant was used to generate signal that were used to trigger relay switch so as to open and close the valve for the flow of reflux. The fig 7 below are showing the DAQ assistant and write to measurement file VIs respectively with all the important features including inputs and outputs.
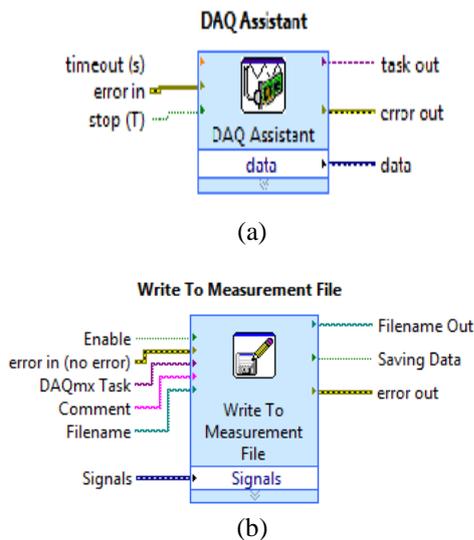
(a)



(b)

**Figure 7:** (a) Measurements file VI's with input and output parts (b)DAQ assistant's VI with input and output parts.

Another important feature in a created VI was data socket, in labVIEW data socket simplify data exchange between different applications on one computer or between computers in a network. Normally data socket in live data transfer use IP/TCP protocol which was suitable for this research which is web based. In addition, Data Socket features inter-application connectivity, rich data types, and security to make sharing data easy. The complete programing codes for web based temperature monitoring and control of the distillation column was named as **VI_for_Temper.vi**. Data Socket Open sub VI which opens a data connection in the URL via http:/196.44.162.41/VI_Temper.dat as shown in a fig 8 below which has been cropped from the programming codes.
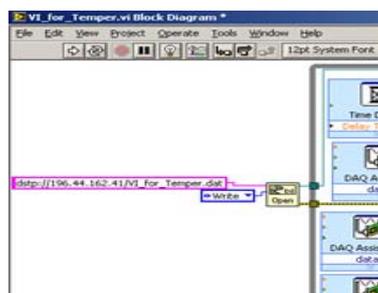


**Figure 8:** Data socket open subVI cropped from the programming codes.

**B. User interface**

The user interfaced with the system through a web page. It has a provision for user registration, authentication and authorization. It has links to documentation that guides the user through the pertinent experiments.

## 4. Execution of the Experiment

The process of doing an experiment starts when a user logs onto the ServiceBroker to access the available experiments. This process is known as the User Authentication. For the distillation column control experiment, the user has to log in

via URL http:/196.44.162.41/iLabservicebroker figure below shows the user login page of the ServiceBroker.
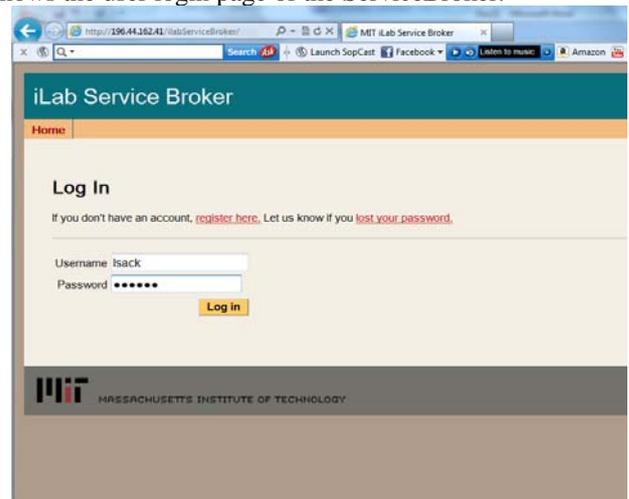


**Figure 9:** The user Login page of the service Broker

## 5. Experiment Results

The remote laboratory that was implemented had to run one experiment from Chemical and processing engineering(CPE) lab, this was done with help from one researcher from CPE who was conducting batch distillation experiment for his research and with the help of developed system he was able to collect data and plot graph for data analysis remotely. A running instance of the experiment during execution is shown in a figure 10 below.
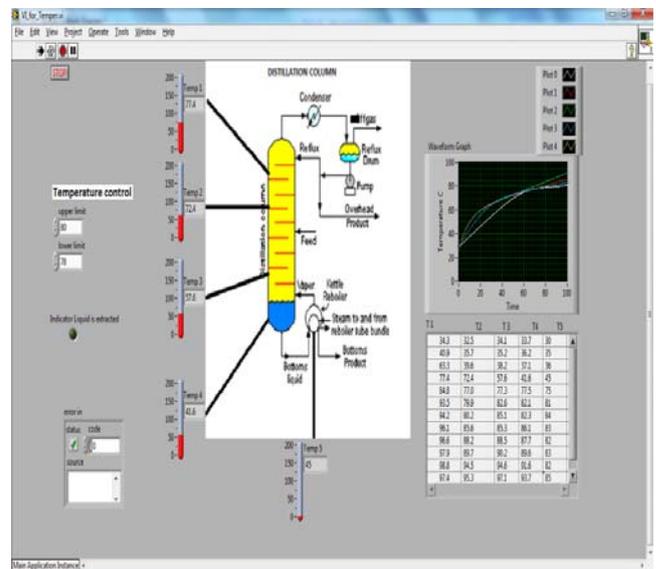


**Figure 10:** Distillation column control experiment.

As seen in a figure above, there five points along a column with yellow color were monitored. On the right side of the figure there is waveform graph and table of results both for displaying result which obtained during execution.

## 6. Conclusion

This paper demonstrates the great potential of iLab to be used in different fields of engineering. Also it shows remote labs can be applicable in other fields apart from electronics.

The web-accessible liquid column distillation was successfully completed as the research objectives were achieved. The system presents the first research in history of iLab to deal with chemical and processing engineering which is another step forward for the ilab project in Africa. The project was undertaken with the strong belief that it would give students and researchers from CPE an opportunity to smoothness and reduces their workload towards achieving their research and experimental activities. The system was successful implemented and one research was done successful by one researcher which proved the workability of the deployed system.

## 7. Acknowledgment

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