Session 2313

A Real Time Approach to Process Control Education
– A Paradigm Shift

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Abstract

The traditional approach to process control education has been to employ the classical methods of process control that were originally developed as a substitute for the real time simulation of process systems. It is our contention that with the availability of fast and easy to use simulation software, classical methods have limited relevance for process control education. In this paper we will outline our real time approach to process control instruction. The methodology is then illustrated by application to the feedback control of liquid level in a separator. Finally, the results of student subject evaluations from two years of implementation at the University of Calgary are presented.

I. Introduction

The classical approach to process control education of chemical engineers[1-3] has been to employ the frequency response methods of process control that were originally developed as pen and paper methods for the modeling of process systems. It has been evident for some time that the way process control is taught to chemical engineers needs to be updated[4-6].

There is an academic requirement that the fundamentals of process control need to be taught in a more practical and concrete way than afforded by the traditional classical approaches. The increasingly overloaded degree syllabus provides the academic impetus to reorganize subjects and reduce superfluous detail.

There is also an industrial imperative to teach material that is of use to the practicing engineer. This imperative is reinforced by the comments such as the following that arise from practicing Chemical Engineers.
“I never made use of Bode plots or root-locus when I was designing a control loop”
“There are no transfer functions out there in the real plant”
“The material I had been taught was of no use in commissioning a control loop”

Control education clearly needs to do better.

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II. Classical Approach

Classical Control methods were developed between the 1940's and the 1960's in the mechanical and electromechanical engineering disciplines. Given the limitation of computer hardware and software at that time, it was impractical to solve large numbers of higher-order differential equations. Furthermore, since mechanical and electromechanical systems are typically linear and possess little dead time, they lend themselves to analytical and graphical techniques. Hence the development and popularization of analytical and graphical such techniques as:

- Transform methods (Laplace and Fourier Transforms)
- Graphical frequency domain methods (Bode, Nichols and Nyquist)
- Root locus analysis.

Given the fit to their purpose, classical control techniques still prevail and remain relevant in these engineering disciplines today.

Although these methods make up almost half the content of standard control texts[1-3], these methods all share a number of deleterious characteristics. They are all heavy on applied mathematics to get them to work, requiring linearization in order to apply linear analysis. The methods have a transfer function basis, focus on individual units and are generally good only for single loops and PID control. Limited multivariable and no plant wide controls are possible.

Beyond the engineering deficiencies of classical techniques, there are implications from a teaching and learning perspective. The abstraction of classical methods makes a difficult subject more difficult, and the methods lack physical meaning, obscuring the central problem of how to modify the system in order to achieve control[6]. These methods are also not suited to "what if" studies such as determining loop performance with parameter variation.

The ready availability of hardware and software now has called into question the relevance of these classical methods. A number of previous workers have also identified this need for change. Levine[4] incorporated simulation software into the syllabus and deleted previous graphical procedures, but retained the classical methods. More recently Bissell[5], and particularly Stillman[6], proposed the more radical solution of complete replacement of classical methods with computer simulation. Jeffrey *et al*[7] developed a successful simulation education module, but it was only a single laboratory in process control course. In this paper we outline and evaluate the actual implementation of such a real time approach to process control[9].

III. Real Time Approach

Unlike mechanical and electromechanical systems, chemical processes are characterized by high degrees of non-linearity, process interactions, and substantial dead time. Additionally, due to these non-idealities, chemical process control demands to be addressed with a multivariable and plant-wide view. As such, applying classical techniques to chemical process control is a bit like using a wrench to do a hammer's work. In an ideal world, the chemical engineer would have a "virtual plant" on which to experiment. This plant would capture all of the important non-idealities the real world imposes, and would allow the engineer to readily test even the most outlandish of control structures with impunity.

Early attempts to realize this “ideal world” date back to the seventies and eighties[8] when dynamic simulators first became available for the solution of the non-linear differential equations describing process dynamics, such as DYNSYS, DYFLO or SPEEDUP. However, the hardware was slow at this time, and the software was impractical for students to learn and implement in a reasonable time frame. There was effectively no user interface in that there was poor graphics and the programs were run batch-wise.

However, in today’s “simulation-rich” environment, the right combination of hardware and software is available to implement a “hands-on” approach to process control education[8]. The hardware and software, such as HYSYS™, is now fast and easy to use. Simple, complex and/or user defined process modules are available and it is now easy to do “what-if” studies, multi-loop and plant wide control simulations. The software user interface is now graphical and interactive and the software can be painlessly run on a PC. In short, the “virtual plant” has arrived.

IV. Case Study

The real time methodology will now be illustrated and compared with the classical approach by application to the feedback control of liquid level in a separator, Figure 1.

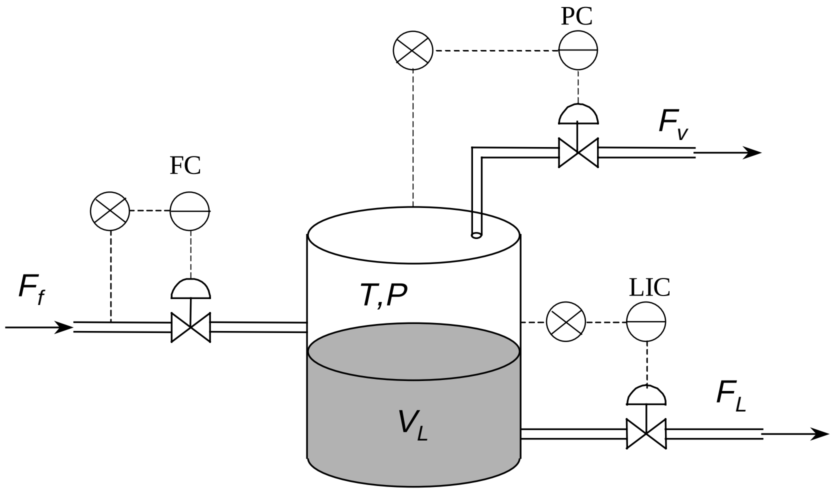


Figure 1. A schematic of vapor-liquid separator with standard feedback controls.

The plant of Figure 1 is usually represented by a system of transfer functions as shown in the block diagram for the liquid level loop of the separator, Figure 2.

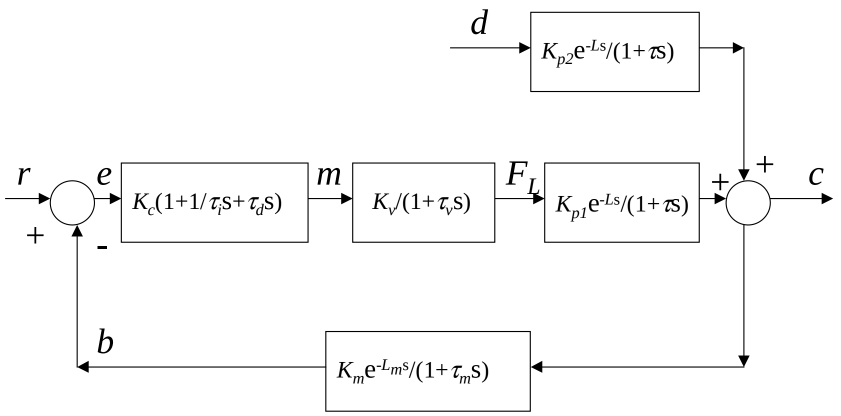


Figure 2. Classical transfer function block diagram of the liquid level loop of the separator.

It can be see immediately that, from a learning perspective, the transfer function block diagram of Figure 2 does not bear an obvious relationship to the real plant in Figure 1, i.e. the representation lacks physical meaning. Many assumptions and empirical determinations are necessarily in order to relate the two. As pointed out previously[6], the abstract nature of these sorts of classical methods makes the subject unnecessarily difficult, obscuring the key issue of real process control, i.e. how to modify the system of Figure 1 in order to achieve control.

In pursuit of the real time approach, we need to find a better, more intuitive representation of the real plant. A better start is the word block diagram of the separator liquid level loop, Figure 3.

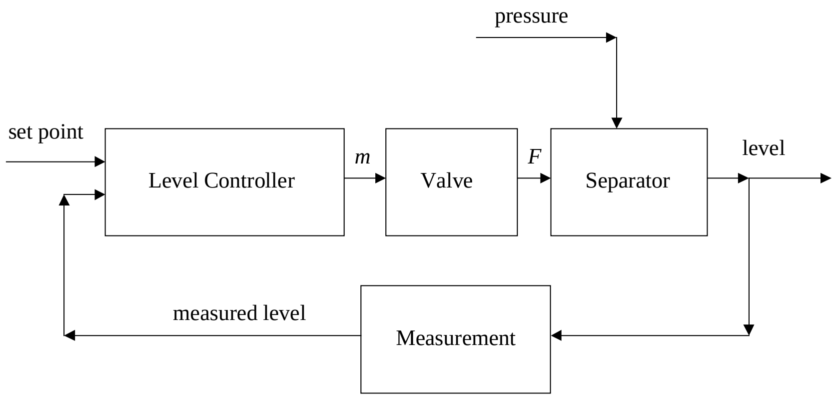


Figure 3. Word block diagram of the liquid level loop of the separator plant.

Although no underlying mathematics has been introduced, the word block diagram Figure 3 illustrates the real process control situation of Figure 1 in a more physically meaningful way. The underlying mathematical representation of the process is the non-linear differential equations that can be written for each block and are easily simulated by current process simulators such as HYSYS.Process™[10].

In the simulation approach, the student can easily now construct a real time simulation given the input flow, tank volume, temperature and pressure. Figure 4 is the plant process flow diagram simulated in HYSYS.Process™, which shows a one for one match with the real plant.

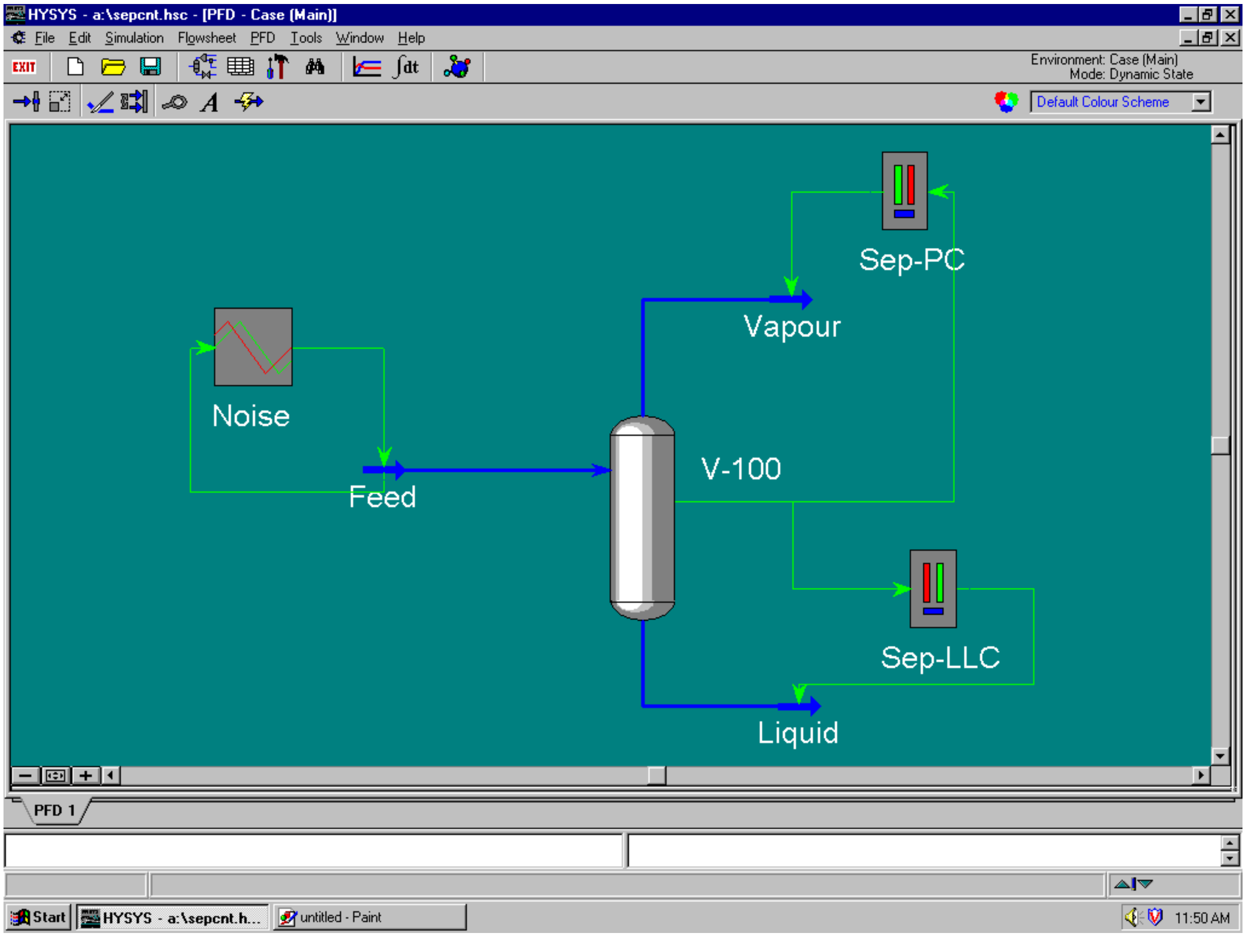
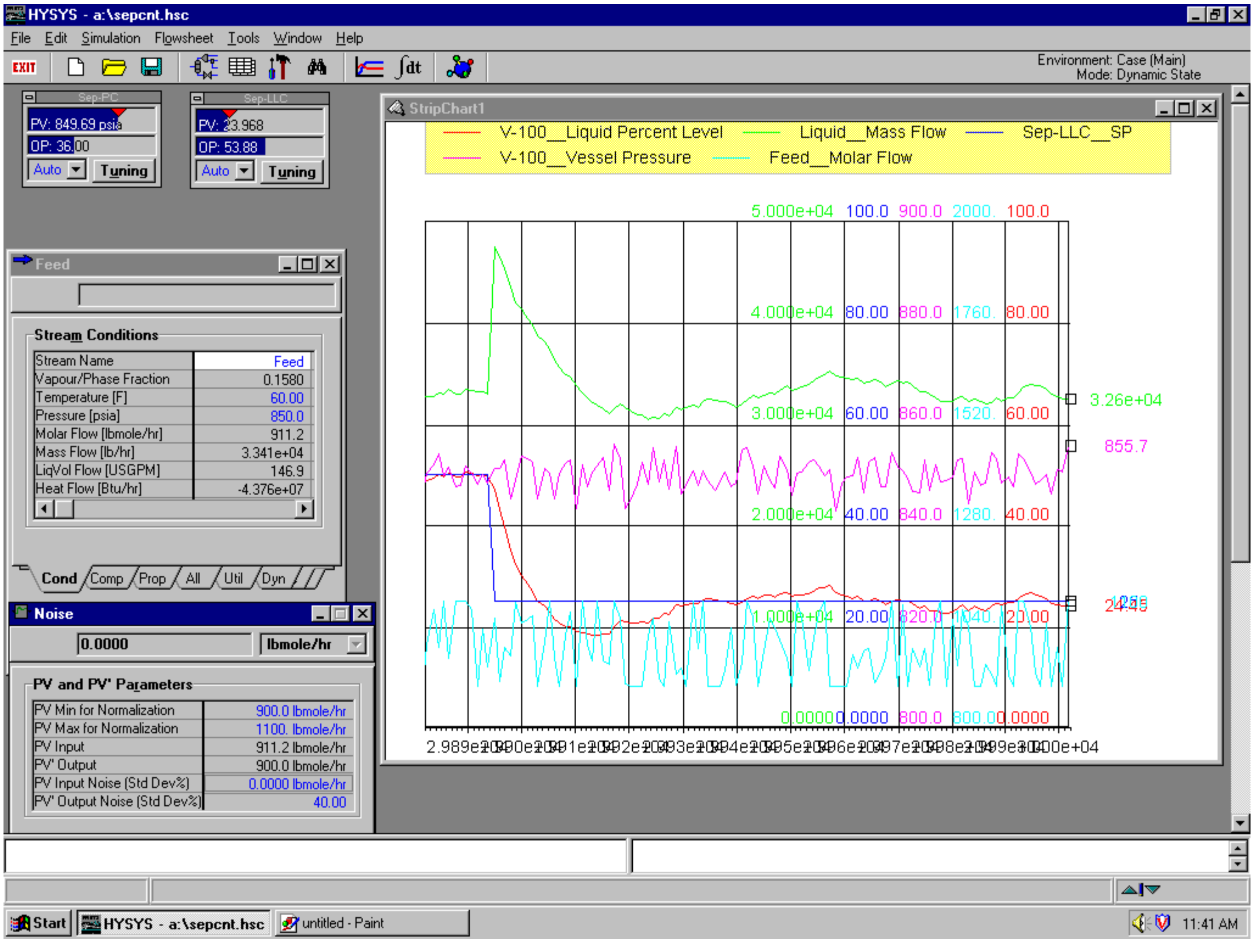


Figure 4. Plant process flow diagram simulated in HYSYS.Process™.

The student can then easily indulge in "what–if" studies to find an optimal control structure and set of control parameters for the controllers – the fundamental aim of process control. Figure 5 shows a screen shot of the simulated response of the separator to a step change in the set point of the liquid level controller, along with the controller face plates.



Sep-PC: PV: 849.69 psia; OP: 36.00

Sep-LLC: PV: 23.968; OP: 53.88

Stream Conditions

Stream Name	Feed
Vapour/Phase Fraction	0.1580
Temperature [F]	60.00
Pressure [psia]	850.0
Molar Flow [lbmole/hr]	911.2
Mass Flow [lb/hr]	3.341e+04
LiqVol Flow [USGPM]	146.9
Heat Flow [Btu/hr]	-4.376e+07

Noise: 0.0000 lbmole/hr

PV and PV' Parameters

PV Min for Normalization	900.0 lbmole/hr
PV Max for Normalization	1100. lbmole/hr
PV Input	911.2 lbmole/hr
PV' Output	900.0 lbmole/hr
PV Input Noise (Std Dev%)	0.0000 lbmole/hr
PV' Output Noise (Std Dev%)	40.00

Figure 5. Real time simulator response to a set point change in the level controller.

V. Student Evaluation

This real time approach to process education was first developed in 1996 as a text and an associated set of workshops[9]. This version was used at the University of Calgary during the 1997 academic year as a pilot course for nine students as their senior year controls course. Their comments were used and motivated a revised second version of the notes and workshops. This updated version was used as a basis for the Process Controls course for the class of 1998 at the University of Calgary, a total of forty-five students. This updated version is now being used for the class of 1999 at the University of Calgary, a total of sixty students.

As a means of generating feedback, the students were asked to complete a questionnaire. Overall, the overwhelming majority of students preferred the “hands-on real time approach” to learning process control. More than 80% of the students said the approach was clear, concise, useful and applicable.

VI. Conclusions

The need for change to conventional process control education was identified.

A real time simulation approach to process control education was presented with the aid of a case study, and compared with the traditional classical approach.

Student feedback on two years of implementation at the University of Calgary evaluated the new approach as both useful and applicable.

Symbols and Abbreviations

b	measured variable
c	controlled variable, process variable
LIC	level indicating controller
e	natural logarithm
e	controller input error signal, r-b
F	flow
K	controller gain
L	dead time
m	manipulated variable, control effort
P	pressure
PC	personal computer or pressure controller
r	set point
s	Laplace transform variable
T	temperature
τ	time constant
V	volume

Subscripts

c	controller
d	derivative or disturbance
f	flow
i	integral
L	liquid
m	measurement
v	valve
V	vapor

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