Canada Foundation for Innovation (CFI)
Emerson DeltaV / MiMiC
Industrial Process Control Simulator
Technical Report

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INTRODUCTION

This document is a brief technical overview of the DeltaV / MiMiC industrial process control simulator purchased in June of 2004 using Canada Foundation for Innovation (CFI) and Ontario Innovation Trust (OIT) funding. It is intended for student or faculty researchers who need to become familiarized with the simulator’s hardware and software capabilities. It is also intended to document the implementation and usage of the network connection between Lambton College and the Universities of Toronto and Waterloo.

Due to network configuration information, this Technical Report should be considered CONFIDENTIAL.

It is not intended to be a DeltaV / MiMiC simulation development guide or a software manual. This technical report may become out of date as system use progresses, therefore references to external documentation are made wherever possible.
DELTAV & MIMIC OVERVIEW

This section is intended to orient the casual reader to terminology used to describe the DeltaV and MiMiC components. For an introduction to DeltaV, the website http://www.easydeltav.com provides a useful resource.

DeltaV Controllers

The DeltaV Digital Control System (DCS) can be thought of as a next-generation PLC (Programmable Logic Controller). Like a PLC, DeltaV controllers use a rack-mounting system to communicate with and control plant equipment via analog, discrete or digital Input/Output (I/O) cards. As for PLCs, once programmed a DeltaV controller will carry out its control activities autonomously, permitting fast control response and stand-alone control capability. However while PLCs are typically used in self-contained industrial equipment applications, DeltaV controllers are designed to be incorporated into an industrial plant-wide Ethernet network, allowing many DeltaV controllers and operator control terminals to be centrally monitored and managed.

![DeltaV I/O Interface Carrier with two Controllers (a redundant pair) and eight I/O Cards](image)

In the CFI Simulator, the DeltaV Controller is located at Lambton College and has two I/O cards installed. The first is a Foundation Fieldbus digital control interface wired to a collection of digital Fieldbus devices mounted on the north wall of the room. The second card is a Virtual I/O Module (VIM), which can simulate any type and number of I/O cards. The number of I/O that the VIM can simulate is limited by MiMiC’s capabilities (discussed below) and by the Device Signal Tag (DST) licenses purchased for the DeltaV installation.

DeltaV Workstations

Instead of using dedicated Human Machine Interface (HMI) control displays like most PLCs, DeltaV controllers are networked with and managed by standard PCs running Microsoft Windows NT and loaded with DeltaV software. There are several licensing classes of DeltaV stations: ProfessionalPLUS, Professional, Operator, Maintenance, Base and Application. A DeltaV installation will have one ProfessionalPLUS station and can have numerous other stations. The CFI Simulator has four Professional (Pro) stations. The ProfessionalPLUS (ProPLUS) station also acts as a DeltaV server. The ProPLUS and two Pro stations are located at Lambton College. The remaining two Pro stations are located at the University of Toronto (UofT) and the University of Waterloo (UW).

The ProPLUS workstation is the central configuration machine for the entire DeltaV network. It maintains the “DeltaV Database”, which contains information about Controllers, I/Os, devices,
feedback control loops, automation, users, access control privileges and more. Essentially the DeltaV Database in the ProPLUS station contains all configuration information about the DeltaV System excluding the operator graphics and any MiMiC simulations. The ProPLUS station is used for developing, maintaining, and configuring the DeltaV control system via “Configuration Studio” software applications such as “DeltaV Explorer” and “Control Studio”. The ProPLUS workstation also manages software licenses which determine what features are available and the number of I/Os (also called DSTs) that are permitted in the system.

The “DeltaV Operate” application (in “Run” mode) is used by operators to view and control the process through pre-programmed graphical user interfaces. The User privileges (set in the DeltaV User Manager) determine which areas of the plant the operators can view, which they can modify (control, configure and/or tune) and which alarms they receive. The “DeltaV Operate” application in “Configure” mode is used to create and edit the graphical user interfaces. Graphical toolbars and templates (Dynamos) can be used to create text and graphics for the user interfaces. Advanced (ecological) graphics can be programmed using Visual Basic scripts, or acquired ready-made from consultants such as ProSum Solutions. DeltaV Operate is available on the ProPLUS and Pro workstations.

MiMiC

Mynah Technologies’ MiMiC software is intended to simulate the equipment and dynamics of a process plant at the base I/O level. The VIM installed with the DeltaV Controller can impersonate up to 4096 discrete and analog I/O points (although 1500 is considered to be a good working maximum). When using a VIM to simulate a process plant, the DeltaV Controller will behave exactly as if it is communicating with real hardware.

Unlike the DeltaV Controller, the VIM is not semi-autonomous and must be in communication with the MiMiC Server software to function. A fourth PC on the Lambton network serves as a dedicated MiMiC workstation and is directly connected to the VIM via Ethernet. This workstation runs two software applications: MiMiC Server and Client. The MiMiC Server software communicates with the VIM and carries out the simulation of the virtual process plant, while the Client software communicates with the MiMiC Server and is used to load configuration files and to program MiMiC simulations.

There are four configuration files used by MiMiC, which together are called a MiMiC dataset. The first, the I/O or .DIO file, contains a hard coded list of the I/O cards that the DeltaV Controller expects to find and which the VIM is to be simulating. The tieback .TBK and tag .PTS files are used to define the behavior of each I/O, which can be in terms of simple delay, first and second order lags, or by more complex formulas. These additional formulas are defined in the user calculations .CLC file to provide higher-level calculations of plant physics, such as determining fluid flow and energy balances. All four files must be loaded into the MiMiC Server for the VIM to function. A complete MiMiC dataset defines the MiMiC simulated plant.

Overview

Together the DeltaV database, operator graphics, and MiMiC dataset make up the configuration info needed to define a simulation. A more thorough introduction to the DeltaV System is available in the “DeltaV Books Online” help files. This can be accessed from any of the DeltaV machines from the Start Menu -> DeltaV -> Help. The Emerson Educational Services DeltaV Implementation I and II courses also provide an introduction to DeltaV. More detailed information on MiMiC can be found in the MiMiC manual, available in print and PDF form.
NETWORK

The CFI Simulator networking is divided into two general areas: the DeltaV Control Network and the Plant LAN. A DeltaV “Control Network” is used to connect plant nodes (DeltaV controllers and workstations) using Ethernet connections. Each DeltaV workstation also has an additional Ethernet connection intended for the industrial plant’s Local Area Network, or “Plant LAN”. Since the control network is used exclusively for DeltaV communications, the Plant LAN provides a means of remote access to the machines. To reduce the logistical problems arising from the geographical separation between Lambton, UofT and UW, a Virtual Private Network (VPN) has been implemented to allow the Plant LAN to be accessed securely by UofT and UofW researchers.

Control Network

The DeltaV Control Network and the MiMiC network are illustrated in Figure 2.

The DeltaV Controller is represented at the left side of the illustration. The dedicated Ethernet link from the VIM to the MiMiC Workstation is shown at top. Connecting the Controller and the three Lambton DeltaV workstations are dual redundant Ethernet (TCP/IP) connections, the primary shown at top, the secondary in dashed lines. This is a standard DeltaV feature to reduce the likelihood of a communication interruption.

All DeltaV internal communication takes place over this network. As such, it is normally heavily secured in industrial installations and should not be connected to any other networks.

Note that the MiMiC Workstation is not connected to the Control Network. Thus it is not possible to run the ‘DeltaV Operate’ graphics in the same manner as on the operator workstations. Note also that the operator workstations at UofT and UofW are not connected to the Control Network.

Plant LAN

An illustration of the entire simulator network is shown in Figure 3.

Note that the Control Network from Figure 2 forms the left side of this diagram. The Plant LAN, shown in the middle, is connected to the third network card of each DeltaV Workstation and the MiMiC workstation. This network may be less secure than the Control Network, since no critical plant control communication takes place over this link. However, since the DeltaV Workstations are vulnerable to malicious software, this network is not connected to the internet and is firewalled from the Lambton intranet. Internet web surfing is not allowed from the DeltaV workstations. This may seem inconvenient, but it is much less inconvenient than reformatting and reinstalling DeltaV due to a malicious web page.

Figure 2 - CFI Simulator Control Network
Figure 3 - CFI Simulator Network Diagram
VPN

To allow remote DeltaV development and simulation management from the University of Toronto and University of Waterloo, a Virtual Private Network (VPN) has been configured to allow secure access to the DeltaV Plant LAN from the three institutions. A Juniper NetScreen 5GT VPN server is installed at Lambton. It is a member of the Plant LAN and is also accessible from the internet.

Connecting to the VPN

The VPN has several layers of security. The main three are access control, software requirements, and pre-shared keys.

Access Control

Before any communication can be made with the NetScreen 5GT device, the IP address of the client must be added by Lambton network administrators to a list of known trusted addresses. Since the IPSec VPN protocol used by the NetScreen server does not support Network Address Translation (NAT) firewalls, the VPN client computer must be connected directly to the internet.

In the Mechanical and Industrial Engineering (MIE) department at UofT, standard network policy is to have departmental computers ‘hidden’ from the internet behind NAT firewalls. An exception had to be arranged for the Simulator VPN client. Since direct exposure to the internet presents a security risk, the UofT remote client computer has two possible configurations: protected behind the MIE firewalls or exposed to the internet with its own unique IP address (See Figure 3). The configuration must be changed to the ‘external’ setting to allow VPN connection and should be returned to the ‘safe’ configuration after use, as described in the instructions available to the CFI user account at UofT.

Client Software

Six licenses of the Netscreen-Remote software are available for remote clients. This software must be installed on any computer that is to connect to the Simulator VPN. The software installation procedure is described in more detail in another document.

Pre-Shared Keys

The final requirement for a VPN client is the correct pre-shared key passphrase, similar to a conventional password. This is entered as part of the configuration of the Client Software and provides the final authentication to allow a VPN connection.

VPN Functionality

Once the VPN Client software has connected to the NetScreen VPN Server, the Client machine will effectively be a member of the Plant LAN and will be able to communicate freely with any of the DeltaV or MiMiC workstations. The research functionality that can be implemented with this arrangement depends on the capabilities of DeltaV, MiMiC, and any additional software configured on the simulator workstations.

The most immediately useful feature for simulation development and general work with DeltaV is the Windows Remote Desktop connection. With the VPN connection established, users at UofT or UofW can remotely login to any of the DeltaV or MiMiC workstations exactly as if at the actual computer console. Due to Microsoft licensing limitations, only one user at a time may
be logged into the Pro workstations, so any local user at the workstation in Lambton will be asked to logout if a remote user wishes to login over Remote Desktop. The ProfessionalPLUS DeltaV workstation is a Windows 2003 server and is thus licensed to have several local and remote users logged in simultaneously.

It is also possible to use DeltaV’s “Remote Access Server” feature to enable operator displays and controls to be accessed from the Plant LAN, and therefore from remote client machines over the VPN. This feature may require additional licensing and configuration.

The next section discusses simulator and research functionality.

**SIMULATIONS**

The DeltaV system was not designed with academic research in mind, but has a variety of support for operator training simulator development, process inspection and operator supervision that can be adapted for useful research purposes. First we will discuss the options for simulation generation in DeltaV / MiMiC and the tradeoffs between them. Next, some of the simulator functionality that is adaptable for research purposes will be discussed.

**DeltaV and MiMiC**

There are three main methods for implementing an industrial simulation using the hardware and software available in the CFI Simulator. The choice of which to use will depend mainly on availability from industrial partners and somewhat on software licensing issues.
The external hardware required for each simulation type is shown in Figure 4. Each simulation method also has different software requirements and limitations, described below.

**Option 1) – Hardware Simulation with MiMiC**

This is the configuration for which the simulator was originally purchased. The DeltaV control system is configured to use actual I/O cards, and behaves as if it is controlling a real wired system. The VIM and MiMiC are used to simulate the control hardware and to generate the response of the simulated system. This method can be described as simulation down to the “copper terminals” of the control cards.

The benefit of this type of simulation is that the DeltaV configuration database, including I/O definitions, control loops, and operator graphics can be transferred between the simulated system and a real-world equivalent without modification. This makes this type of simulation ideal for Factory Acceptance Testing of new control system and interface designs, such as those offered by ProSum Solutions, Inc. and others. The dividing line between the control system and the controlled process is clear: everything in DeltaV is part of the control system, everything in MiMiC is part of the process.

The disadvantage of this approach is that DeltaV must be sufficiently licensed to use the Virtual I/O cards. For complex MiMiC simulations this can exceed 1000 I/Os (or Device Signal Tags, DSTs in DeltaV licensing terms). The system size limit of the CFI Simulator as purchased is 50 DSTs. This can be extended through purchase of additional DST licenses.
Option 2) – DeltaV manipulated simulation with MiMiC over OPC

In this configuration, the simulated process is still programmed in MiMiC, and the control system in DeltaV. However, the Controller and the VIM are not used. The DeltaV control parameters are configured to use internal values for process plant input and outputs, and the MiMiC Server manipulates those internal values directly over the Plant LAN. The industry-standard control automation computer protocol OLE for Process Control (OPC) is used.

This results in a system which is not as immediately portable as Option 1, since the DeltaV control system will have to be modified to use real I/O cards for real world deployment. MiMiC simulations will also behave slightly differently when implemented over OPC. However, the benefit of this configuration is that no DeltaV I/O DSTs are used and therefore the simulation size is not dependent on DeltaV licensing.

Option 3) – Internal simulation entirely within DeltaV

In this configuration, the control system and simulated process are both implemented within DeltaV. The Controller, VIM, and MiMiC are not used, making for a easily distributed self-contained DeltaV simulation.

Any complicated calculations of medium or high fidelity plant physics that are too cumbersome to implement in DeltaV control modules can be handled with external software such as MatLAB, HYSYS, or other computational software that can communicate with DeltaV over OPC. However, this additional complexity and cost can be offset by the elimination of the MiMiC requirement. Adaptation of the DeltaV integrated control/process configuration to a real-world system is much more complicated, so these types of simulations are usually developed without a specific intent of application to a particular real-world process plant. Simulations of this type are more popular in educational and training than the other types, since they require less capital investment, are more portable, and do not consume DST licenses.

Research aids

Regardless of which simulation type is acquired, DeltaV provides several tools to aid research. As the operator workstations are Windows-based, additional functionality from third party software can potentially be added.

Simulation Storage

Since three academic groups intend to use the simulator, a means of keeping development separate and secure is required. While it is technically possible to operate two simulations simultaneously, it increases the likelihood of mistakenly overwriting different revisions of code and of “stepping on each others’ toes”. Since the DeltaV Database and the MiMiC Dataset together comprise the simulation, routinely exporting both to disk after each work session can prevent data loss and allow sequential access to several research groups. Operator graphics are also a key component of a simulation, however there is no harm in having extra graphics from other researchers’ simulations stored on the workstations.

Simulation Control

Control of DeltaV or MiMiC simulation parameters, such as activating failure scenarios or resetting to initial conditions can be coded in DeltaV control modules and accessed via dedicated control screens available only from the ProPLUS main DeltaV workstation. Automation such as
Sequential Flow Charts (SFC) can be used to precisely control timing of events to allow repeatable experiments. These features can allow simulation control by UofT or UofW users over the VPN, or by an experiment coordinator on-site at Lambton College.

Similar functionality is offered through the MiMiC Training Simulator, an add-on software item. This utility is somewhat out of date and not fully functional with recent versions of DeltaV. Much of its capability can be replicated in DeltaV without requiring additional software licensing.

**DeltaV Operate ‘Trace Messages’**

The DeltaV Operate graphical process interface is very customizable. The views and device faceplates (detail displays) are coded in a derivative of Visual Basic and many can be combined in the process graphics. A useful research capability is a time-stamped log of what graphics are active on the operators’ workstations. This functionality is provided by the ‘Trace Messages’ feature in DeltaV Operate. Clicking on the hammer-shaped icon in the upper right corner of DeltaV Operate will display the trace messages box, which can remain open and will indicate main view navigations as well as opening of device control faceplates, timed to within one second. This log information could then be used to calculate dependent measures such as the frequency of switching between graphics and the elapsed time for each graphic.

![Figure 5 - 'Trace Messages' DeltaV Window](image)

There is currently no option to save this data to a log file, however this should be easily implemented by an experienced Visual Basic programmer.

**DeltaV Event Chronicle / Process History View**

In process plants as well as in research simulators, it is often useful to know when operators have made changes to process parameters, such as adjusting valves, changing automation modes, or turning equipment on or off. Also, a record of process alarms and trends can be useful in evaluating performance measures.
This functionality is provided by the DeltaV Event Chronicle, accessible through the Process History module (after the Continuous Historian is enabled). Setpoint changes and alarms are displayed by default, and custom events can be defined using the “LOGEVENT” expression variable in the DeltaV Control Studio programming environment.

*DeltaV Inspect*

DeltaV includes statistical analysis functionality in the form of DeltaV Inspect. The suggested use of this feature is to analyze process variability to identify portions of the plant that are experiencing poor control, either due to process disturbances or equipment malfunctions.

This feature could be used to evaluate performance measures during experimental trials. Similar to the Event Chronicle, custom reporting can be enabled by inserting “INSPECT” Function Blocks into control loops and monitors.

*Screenlogging and other functionality*

No screen capture or mouse logging software has been tested yet, however we are optimistic that any Windows-based user monitoring software will function properly with DeltaV Operate in a Windows Desktop environment. Use with DeltaV Operate in the single-application FlexLock DeltaV Desktop mode may be more problematic.

**CONCLUSIONS**

The CFI Simulator is a complex and versatile system that presents many research possibilities. Of course, with added configurability comes added complexity, which makes training researchers, staff, and operators a significant barrier to productivity. Hopefully this document has clarified some of the capabilities and limitations of the simulator setup and will serve as a starting point for further reading.

DeltaV’s “Books Online” is an extensive resource for information and troubleshooting, as are the software manuals of other components. Training courseware has been collected at the University of Toronto and can be adapted for self-instruction.

Specifics of usernames, passwords, step-by-step instructions, and configuration files are contained in separate documents, as they are subject to change and should be distributed only as required.