Refinery automation in the fieldbus era

Toni Bennett, Mike Newell and Jody Verret, Calcasieu Refining Company, USA, describe the operation of a refinery with the latest generation of process automation from Emerson Process Management.

It was a daunting leap into the unknown for the Calcasieu's atmospheric crude topping refinery near Lake Charles in Louisiana, USA, (Figure 1) when the company decided to step into the 21st century with respect to process automation two years ago. The plant had almost become a museum of the pneumatic controls era, a period that began between the wars and was coming to an end as the refinery was being built in 1977. The control room faintly resembled the cockpit of a Lancaster bomber on a larger scale and wall panels were crowded with pneumatic indicators, controllers, strip chart recorders and thermocouple indicators and recorders. At the gas fired heaters and reboilers, burner management systems were electromechanical. The tank farm had locally indicating float gauges, hand valves, locally switched pumps and local pneumatic controllers. The main token of progress was a small supervisory control and data acquisition (SCADA) system that had been installed in 1998, consisting of remote terminal units (RTUs) at two pipeline stations linked by radio to a computer in the control room.

The old controls worked well enough, but the time for a plant wide update had long past, with glittering promise of giant boosts in control quality, operating economy, throughput and human resource productivity. It was a fearsome challenge, because the change would not merely be an incremental shift from one generation of process control technology to the next. Instead, as it turned out,the plant fairly leapfrogged over two generations at once. The first was electronic analogue instrumentation, by which pairs of signal wires had begun replacing pneumatic tubing in the 1960s. The second, originating in the 1980s, was the architecture displayed in common by distributed control systems (DCSs) and networks of programmable logic controllers (PLCs), all based on analogue field instruments. Since approximately 1998, that concept has been giving way to architecture based instead on networks of intelligent field instruments (microprocessor based transmitters and digital valve controllers or DVCs) that communicate as one computer to another.

The new era of intelligent field instruments is commonly identified with the principal communication style employed, known as fieldbus. The dominant fieldbus standard for process automation is FOUNDATION fieldbus 'H1', by which an ordinary twisted pair line called a segment can handle signals and power for as many as 16 intelligent instruments. That Calcasieu was able to make the drastic transition to the latest automation architecture with scarcely a break in stride is testimony to the enormous means unleashed by devolving computer intelligence to the field with open, industry standard methods.

Figure 1. Calcasieu crude topping refinery near Lake Charles, Louisiana, USA.

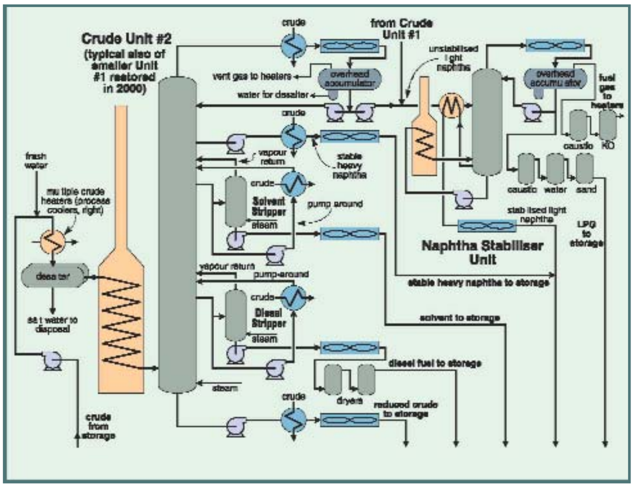

Figure 2. Simplified process flow diagram of Calcasieu refinery after Crude Unit 1 was restored in 2000, bringing the plants capacity up to 22 000 bpd.

Restoring a crude unit triggers automation experiment

An opportunity to modernise the refinery's controls came in the middle of 1999 with a decision to increase the plant's capacity from 15 000 – 22 000 bpd (Figure 2).The original crude distillation Unit 1, which had been decommissioned in 1980 when the similar but larger unit shown in Figure 2 was added, would be restored to service. Most of the old unit's equipment except the idle tower, strippers and accu-

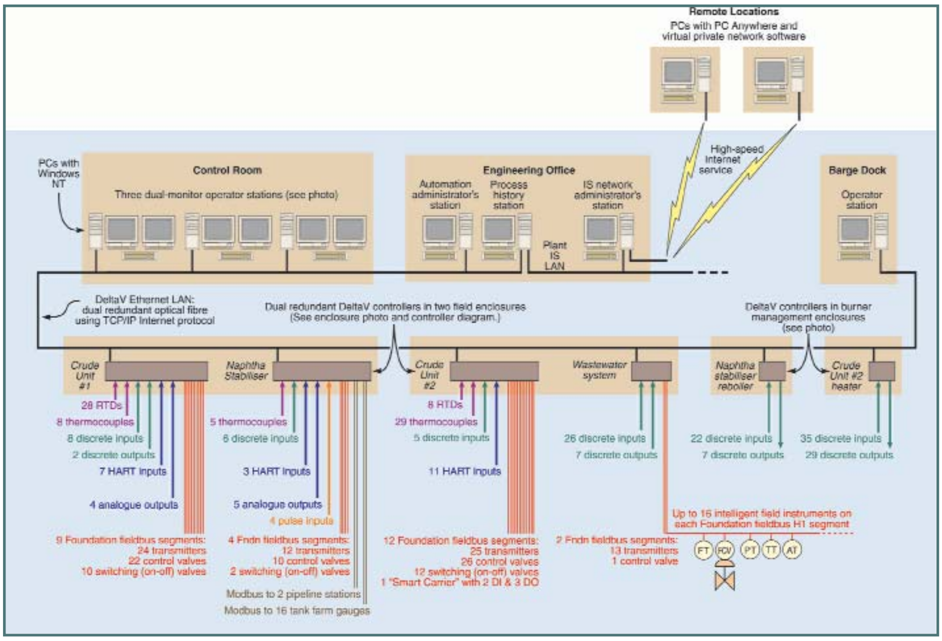

Figure 3. Simplified diagram of the PlantWeb network as of July 2002.

mulator, had been incorporated into Unit 2 through the years in order to increase its capacity. Thus, restoring Unit 1 would be almost like building a new crude distillation unit. At the same time, the capacity of Unit 2 would be enhanced by reworking tower trays and installing a larger heater with PLC-based burner management to replace one being returned to Unit 1.

At first, the intent was to upgrade of the refinery's controls on a cautious, stepwise basis. The restoration of Unit 1 would be a trial of the latest and best digital automation system with minimal risk and, if the results were satisfactory, the system would later be scaled up to encompass the entire plant. It would eventually embrace Unit 2 and the naphtha stabiliser unit (Figure 2), the tank farm and barge docks (Figure 1), the pipeline stations and tank truck stations, and auxiliary equipment including a wastewater treatment facility, a package boiler, several heat recovery steam generators and a feedwater treatment unit, plus any number of plant expansions for years to come.

After a thorough review of alternatives from several vendors, including conventional DCS and PLC products, a choice was made in April 2000: PlantWeb® digital plant architecture from Emerson Process Management (known as Fisher-Rosemount at that time) implemented by its DeltaV™ digital automation system with all the latest trimmings. Features that were especially important in this decision were maximum use of intelligent field instruments on FOUNDATION fieldbus and Emerson's 'AMS' asset management software for remote configuration, calibration, diagnostics and preventive maintenance of intelligent instruments.

Figure 4. Authour Verret inspects a field enclosure containing the DeltaV controllers for the naphtha stabiliser (top rack) and Crude Unit 1(second rack).

The trial turns into an overhaul

Restoration of Unit 1 with PlantWeb architecture began in June 2000, under an urgent directive to finish by the end of that year. Calcasieu personnel had already developed the necessary drawings and instrument specifications. One of the athors, Mike Newell, attended a few days of schooling at Emerson and with four operators attended a one day review of the system. Very soon, plans for PlantWeb began to seem overly cautious and by September, Calcasieu's management had seen enough to desire the extension of PlantWeb throughout the refinery as quickly as possible. This was like ending an exceptionally favourable clinical trial very early for the benefit of other patients needing the treatment in question. Thus, PlantWeb immediately began to be applied to the other main processing areas: Unit 2 and the naphtha stabiliser.

The Emerson Process Management representative for the area, John H. Carter Company, provided the initial systems configuration, integration, field enclosures and operator console. Most of the instrument wiring was installed by Calcasieu personnel and supplemented by local trade labour. All instrumented areas are classified as Division 2 (normally safe from explosive atmosphere) rather than Division 1 (normally hazardous). This circumstance allowed use of the favourable protection method called 'non incendive circuits', so that electrical conduits and purged enclosures were not required for most signal lines. Operator displays were mostly configured at the refinery. Operators received inhouse training. In December 2000, after a shutdown of only two weeks, the plant started up again under the new controls with no problems. The installation time was less than six weeks for a controls revamp that would have taken at least six months with a conventional DCS. The approximate total cost to that point was only US$ 1 million.

Since then, with scarcely any outside help, Calcasieu has further extended PlantWeb to most of the remaining plant areas and added controls within the original network. For instance, early in 2001, the existing pipeline RTUs and new intelligent gauges at the tank farm were integrated into the network. Later, when the flare, the naphtha stabiliser reboiler and the wastewater treatment unit were replaced, the new units were equipped mostly with intelligent instru-

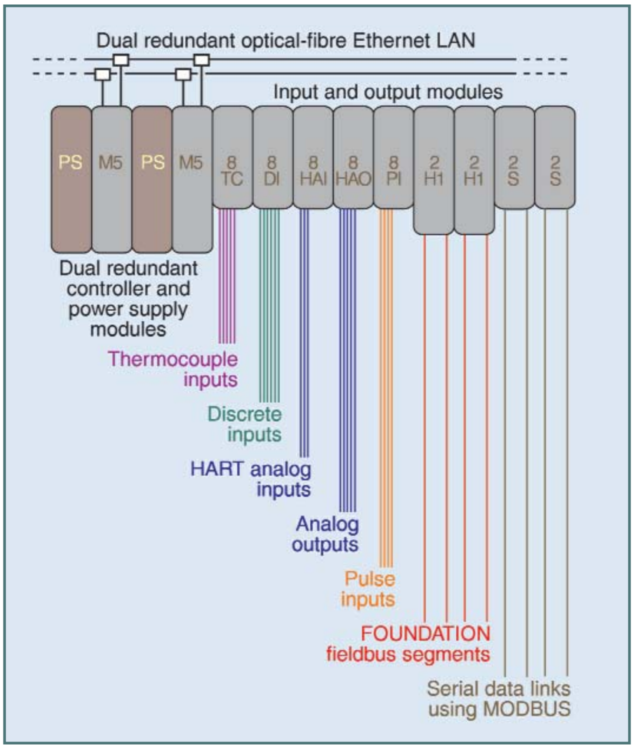

Figure 5. Simplified diagram of the DeltaV controller for the naphtha stabiliser, illustrating modular construction and dual redundancy. If one controller, power supply or LAN fails, the other takes over without interrupting the service.

ments and incorporated into PlantWeb. Enhancements have been made in tower trays, strippers, overhead condensers, heaters and reboiler. These measures, coupled with control improvements enabled by PlantWeb, have further raised the plant's capacity to 30 000 bpd.

Applying digital field based automation

At first, DeltaV installation was considered merely to be an exceptionally advanced DCS that uses mostly intelligent instruments on FOUNDATION fieldbus. It seemed to be DCS in the fieldbus era. Only gradually has Calcasieu's people come to realise that what they have is different enough from a conventional DCS of the 1980s and 1990s to be recognised as a creature of an entirely different genus. Calling it a DCS that makes the most of intelligent field networks is like calling a human an ape with superior intelligence. The generic description currently applied to this new concept by Emerson Process Management is 'digital plant architecture that leverages field based intelligence'. PlantWeb is the name of their specific version. That this is indeed a new generation of process automation will become apparent from reviewing the structure and operation of Calcasieu's installation.

Figure 6. Fisher controls intelligent DVCs (digital valve controllers) on two switching valves (foreground) and one throttling control valve (further back). They communicate and receive power through a FOUNDATION fieldbus segment, via flexible yellow cables with weather tight, quick disconnect fittings and the branch block on the column.

The architecture of the PlantWeb network, as of July 2002, is summarised in Figure 3. Field instruments, enumerated at the bottom of the diagram, are incorporated into the network through DeltaV servers known as controllers. These devices are modular assemblies mounted in enclosures in partly sheltered field locations near the equipment they serve, rather than being concentrated in a central equipment room as is typical for conventional DCS controllers (Figures 4 and 5). Nearly all of the transmitters and valve controllers are intelligent ones. There are 27 FOUNDATION fieldbus segments serving 157 intelligent transmitters and digital valve controllers (DVCs), as shown in Figure 6. However, 21 intelligent transmitters instead use the HART method of superimposing digital pulses on a conventional 4-20 mA analogue signal. Furthermore, there are 16 intelligent float gages in the tank farm that communicate by Modbus master slave protocol on two serial data buses served by master units in a DeltaV I/O module.

Conventional (non intelligent) field devices are incorporated into the predominantly intelligent network in several ways (Figures 3 and 5). There are four conventional flowmeters with pulse type outputs in the naphtha stabiliser and a conventional analogue level transmitter in the wastewater system, all connected to appropriate input modules at DeltaV controllers. Similarly, there are nine non intelligent variable frequency fan speed controllers. These receive conventional analogue signals without making use of the HART communication capability that is available in the corresponding output modules. The DeltaV controllers also have I/O modules for conventional thermocouple and RTD (resistance temperature detector) signals, as well as discrete (on-off) inputs and outputs. For the pipeline, the existing Modbus links to two radios communicating with distant RTUs were simply transferred from the SCADA host computer to a serial I/O module like the one serving the tank farm. Finally, notice that among the FOUNDATION fieldbus devices shown for Unit 2 in Figure 3, there is one from Emerson called an H1 Smart Carrier. It provides remote mounting for DeltaV I/O modules serving conventional (non-itelligent) devices. Smart Carriers extend the multidrop benefits of FOUNDATION fieldbus to conventional field devices, eliminating the need to pull separate signal lines from the instruments all the way to a controller.

Referring again to Figure 3, the chief nodes of the automation network are linked by a standard Ethernet LAN (local area network) using standard TCP/IP Internet protocol, rather than a proprietary data highway after the fashion of a DCS. At Calcasieu, the DeltaV LAN uses optical fibres and dual redundancy (Figure 5). All of the other principal nodes are industrial grade IBM compatible PCs (personal computers) running ordinary Microsoft Windows NT, rather than proprietary DCS consoles (Figure 7).

As shown in Figure 3, communication between the automation LAN and the plant IS (information systems) LAN is afforded by two Ethernet ports on the process history station. The IS LAN, in turn, is accessible to remote computers in a secure fashion via a high speed Internet port and commercially available VPN (virtual private network) software. Commercially available 'PC Anywhere' software, in turn, connects the remote user's keyboard, mouse and monitor to one of the computers on the automation network. In this fashion, the authors easily access the automation network at home and consultants do so at Emerson Process Management or John H. Carter Company, all in the familiar Windows environment.

Refinery operation in the new era

According to Cervantes, the proof of the pudding is in the eating and, according to Calcasieu, the proof of PlantWeb is in the operating. The main basis of comparison in this instance is, of course, the old pneumatic controls: changing from that to PlantWeb was rather like stepping from a 1948 Morris Minor into a 2000 Jaguar V-12. If the company had gone instead from a conventional DCS to PlantWeb, the difference would not have seemed so drastic, but nevertheless substantial.

The first thrill of acceleration came when FOUNDATION fieldbus cables (Figure 6) began to be strung and connected to intelligent instruments. As soon as someone plugged a live cable into a transmitter or DVC, the device powered up and commenced an autonomous conversation with the associated DeltaV controller. In most cases, specific application data, including the tag name, such as PT-402, had already been stored in the instrument at the Emerson factory. Immediately, an icon representing that device appeared on an engineering display at one of the computer stations (Figure 8). There, a person verified the instrument's location by radio conversation with the field and followed screen prompts to order self check and self calibration. Finally, by merely dragging and dropping a connection icon in a display such as Figure 9, the device was linked to a control function that had already been developed for that control loop by graphic methods. Unlike a conventional DCS, such functions can be performed in transmitters or DVCs instead of a controller if desired. Signals pertaining to that instrument immediately began registering on operator displays that had likewise been developed by potent graphic methods. Thus, the hours that a conventional DCS would require for running a separate signal line, loop check, calibration and commissioning were reduced to as many minutes with FOUNDATION fieldbus and PlantWeb.

Operators who had known no controls other than pneumatic, but who knew Windows on their home computers, eagerly learned to drive their exciting new automation vehicle almost as soon as they got their hands on it. They and others soon realised that in day to day refinery operation, PlantWeb is distinguished by regular use of some very handy and powerful tools. Subtle failures in controllers, communication links, transmitters and DVCs are detected very early by self-check routines, then immediately diagnosed and corrected (Figure 10) rather than degrading control quality for days or even years. The behaviour of control loops is regularly evaluated by a DeltaV feature called 'Inspect' (Figure 11). Excessive variability can often be eliminated by automatic loop tuning (Figure 12), which is another standard feature. Control strategies can be improved and adapted very easily.

Proceeds of PlantWeb

By means such as these, control quality in terms of accuracy, reliability, stability and variability have been improved by an order of magnitude throughout the refinery. Loops that

Figure 7. The operator stations in the control room consist of dual monitor PCs running Windows NT. Parts of the superceded pneumatic control panels are seen

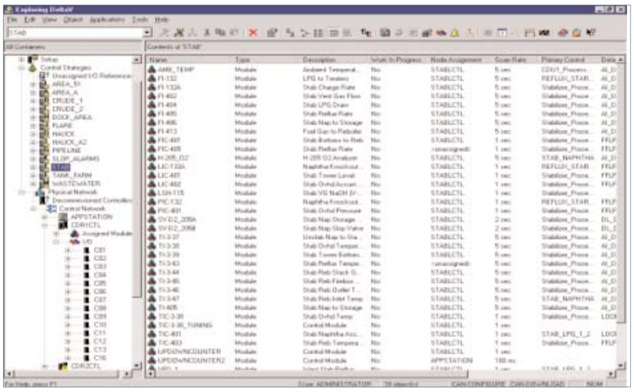

Figure 8. When an intelligent instrument is first connected, it automatically appears as an icon on a Windows style DeltaV display such as this.

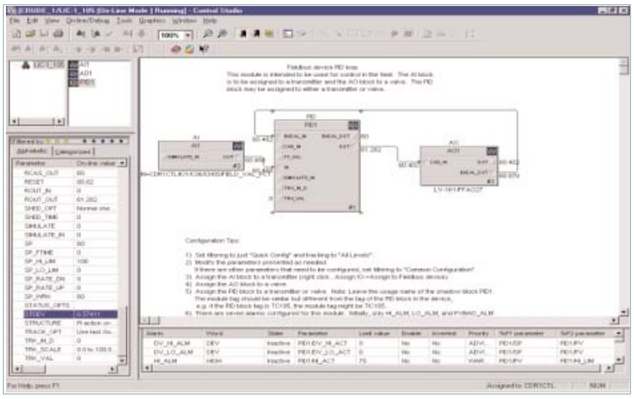

Figure 9. In the friendly Windows environment, control connections and functions are configured by dragging and dropping with graphic tools as shown here.

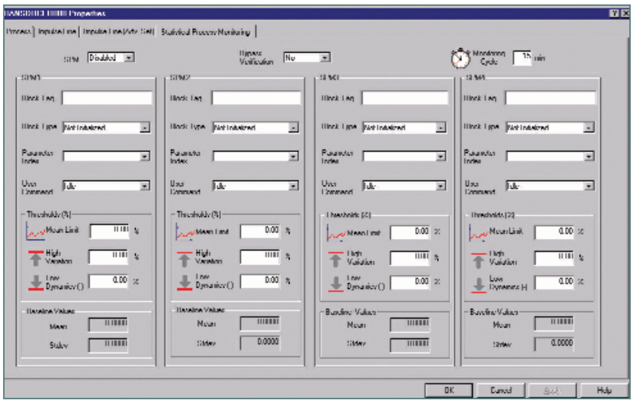

Figure 10. A stage in advanced diagnostics of a transmitter with AMS.

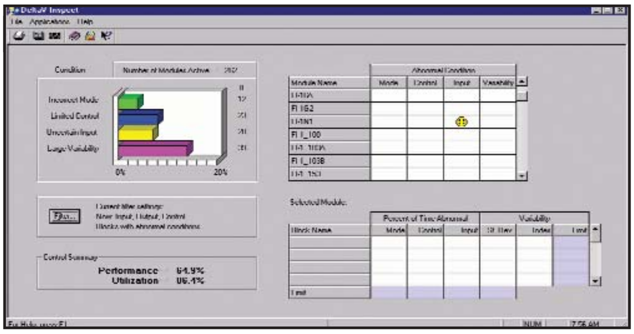

Figure 11. Variability and other performance qualities of a control function can be automatically evaluated by the DeltaV 'Inspect' tool.

would otherwise be operating in manual mode stay in full automatic. As a result, processes approach ideal operating conditions much more closely than would be possible with less advanced control technology, yielding considerable benefits in terms of operating cost, capacity and product quality. For instance, tight control has allowed towers to operate with new high capacity, high efficiency internals at elevated throughputs of liquid and vapour that would otherwise result in frequent flooding upsets. Similarly, an advanced control scheme for the naphtha stabiliser has substantially decreased loss of valuable naphtha with the LPG byproduct.

Another important characteristic of the new era at Calcasieu is that no additional operating or maintenance personnel have been required, even though an entire crude unit has been restored ,to service and the refinery's capacity has been doubled.

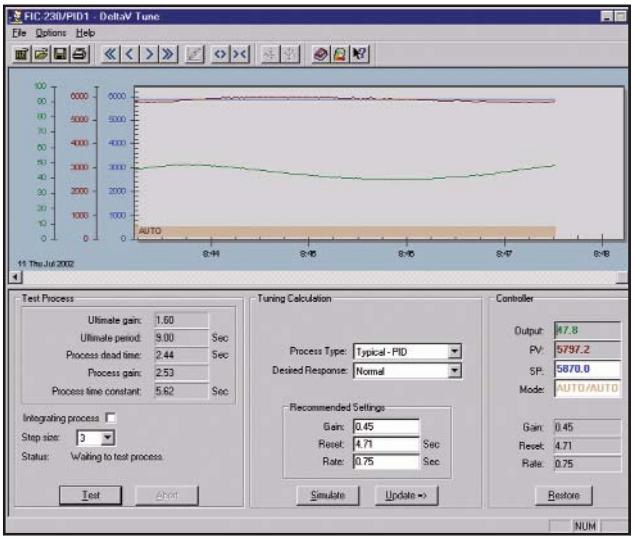

Figure 12. Automatic tuning of control loops is built into DeltaV.

All in all, it has been calculated that the original US$ 1 million PlantWeb investment in 2000 has yielded savings equivalent to a return on the order of 80% during 2001.

Now, after nearly two years of experience with PlantWeb, the company has especially come to appreciate the ease with which Calcasieu's lean work force has been able to expand the network constantly with very little outside help. There seems to be no end to the scalability and applicability of DeltaV and Calcasieu, who scarcely knew an algorithm from an alligator two years ago, can handle it by themselves.