

DIGITAL FIELDBUS IMPLEMENTATION FOR MINERAL PROCESSING

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Abstract

A technological change is emerging in the process control and monitoring environment. The enormous economic benefits of the application of digital communication for instrumentation equipment are influencing decisions to abandon the conventional point-to-point technology, making the shift to digital technology imminent.

To date the large-scale use of digital technology has been limited to the petro-chemical sector; however, Alcan Inc has taken steps to keep abreast of this technological change as demonstrated by the introduction of FOUNDATION™ fieldbus and Profibus DP as part of the AUD2bn expansion of Alcan Gove's alumina refinery.

This paper discusses the implementation of digital communication technology for process control equipment from concept to commissioning. The primary focus of the paper is a technology plan developed by Alcan Engineering Pty Limited (ALCENG). The topics covered include migration to new technology and associated risk management, engineering design process and commissioning, as well as the benefits gained and "tips and traps" for a successful project implementation.

Introduction

Fieldbus is a robust, digital, two-way, multi-drop communication link between sophisticated industrial measurement and control devices. It allows multiple industrial devices to connect to a single pair of wires resulting in significant reductions of cabling, intrinsic safety barriers, I/O cabinets, marshalling panels and field junction boxes. The combination of these physical entity reductions, the time-savings produced from using fieldbus function blocks, and the additional process and device "health" information results in lower costs of engineering, installation, commissioning, documentation and ownership of instrumentation and control systems (I&C).

ALCENG was commissioned by Alcan Gove (formerly NABALCO) to develop a technology upgrade plan as part of its continuous improvement process. Following preliminary investigations, ALCENG realized that the current legacy distributed control system (DCS) installed at Alcan Gove needed to be upgraded or replaced, thus creating an opportune time to consider a plant-wide technology upgrade. The plan also identified that continuing to use traditional 4-20mA I&C devices and wiring practices would place Alcan Gove at a technical disadvantage in the not too distant future.

The investigation emphasized that staying in the "comfort zone" simply wasn't an option and that there was an eminent need to

invest resources in learning more about fieldbus technologies. Alcan needed to understand the organizations backing the various fieldbus technology platforms, and the offerings and plans of the control system manufacturers supporting the various fieldbus communication protocols.

Technology Migration

In 1999, when ALCENG began formally assessing the current and future I&C requirements for the Alcan Gove facility, fieldbus technology was still quite new, multiple fieldbus technologies were being developed and promoted, and Standards development groups were struggling to sort out the best, long-term solution(s) for technology implementation.

At about the same time, I&C manufacturers were merging, acquiring, divesting, retooling, refocusing, obsolescing and generally leaving users scratching their heads trying to figure out which organizations and manufacturers, and more importantly, which control systems would survive in the long-term.

Before ALCENG engineers began their investigative analysis, they identified the risks associated with migrating to fieldbus technology and developed strategies to mitigate each risk. The mitigation strategies targeted the following key areas:

- Alcan Inc's fundamental criteria of placing Environment, Health and Safety (EHS) "first" and not compromising EHS at any cost.
- Continued utilization of and integration with business management systems at Alcan Gove.
- Evaluating and ensuring that fieldbus devices will provide the same level of interoperability as traditional point-to-point 4-20mA technology.
- Retaining fieldbus technology expertise to assist in developing operationally secure segment designs.
- Ensuring that I&C equipment selected will be capable of supporting multiple fieldbus technologies, their connectivity and integration with current I&C systems.

ALCENG management also expected the investigation to confirm fieldbus proponents' claims about cost savings – specifically cost savings applicable to Alcan Gove in the following areas:

- **EHS** – Reduced frequency and severity of EHS incidents as a direct result of improved diagnostics, more information and increased operator awareness.
- **Engineering** – Reduction in the number of drawings, cable schedules, cabinets, footprint and configuration efforts.
- **Material and labor** – Increased use of multi-variable devices resulting in fewer process penetrations, devices,

junction boxes, marshalling cabinets, terminations, control system I/O cards and engineering activities.

- **Installation and commissioning** – Reduced times to install and commission I&C systems.
- **Incremental expansion** – Increased flexibility and simplification when adding I&C devices at a later date as necessary to improve and/or optimize the process.
- **Maintenance** – Reduced maintenance and related documentation resulting from embedded fieldbus device diagnostics, alarms and alerts.

The investigative analysis focused on evaluation of different bus systems and interoperability issues. Visits were arranged to existing fieldbus installations in Australia and Singapore to learn about the experiences of early fieldbus adopters. At the end of the investigation, ALCENG engineers were convinced that while the fieldbus technology was still evolving, it was:

- Technically superior to traditional point-to-point solutions;
- Likely to garner continued enhancements for years to come; and
- Providing early adopters the opportunities to gain a competitive advantage.

The ALCENG investigations eventually revealed that the fieldbus technologies best suited to Alcan Gove operations were FOUNDATION fieldbus for process-related measurements and control, Profibus DP for intelligent discrete devices, such as “smart” motor control centers (MCC) and variable frequency drives (VFD), and AS-Interface (AS-I, www.as-interface.com) for simple discrete indications and functions.

While these technologies provide robust solutions, have an extensive installed base and an impressive list of manufacturers offering compatible products (even in 1999), it was comforting to learn that no individual company, nation or regulatory body “owns” Fieldbus Foundation (www.fieldbus.org) or Profibus Nutzerorganisation e.V. (www.profibus.com).

Each is a not-for-profit organization supported by end-users and instrumentation equipment manufacturers. While each organization exists to advance its respective fieldbus technology, they work in a cooperative manner. For example, both technologies use files created using Device Description Language (DDL) to communicate among the respective fieldbus networks.

In 2003 the two organizations formed a cooperative project to enhance DDL (thus creating EDDL) to facilitate the increasing sophistication of such devices as control valves, radar level gauges and variable frequency drives (VFD). The project has now been completed and device manufacturers recently began releasing sophisticated devices that plug-and-play on their respective fieldbus.

A noteworthy aspect of DDL, and now EDDL, is that the files created using DDL permit instrument number one to work right alongside instrument number 15 million¹ – never once requiring an upgrade, revision or patch of any kind.

¹ As of May 2004, an estimated 15 million devices were installed using files created using DDL. Source: May 2004 issue of InTech Protocol

Technology Implementation

Satisfied that migrating to fieldbus technology would better position Alcan Gove competitively, ALCENG developed a plan to introduce and familiarize Alcan Gove operations with fieldbus technologies.

Not wanting to commit the entire facility all at once, the plan identified the following tasks:

- Secure executive management support;
- Ensure adequate ownership and resources were thoroughly prepared to embrace the technology. This included arranging for appropriate hardware and software training;
- Retain the services of a fieldbus expert/consultant;
- Evaluate candidate control systems suitable to replace Alcan Gove’s installed legacy control systems as well as to provide an interface for the digital bus devices for the expanded plant; and
- Develop a multiple-phase fieldbus technology implementation plan that mitigated risk by the time Alcan Gove was ready to begin its 3rd stage expansion project, tentatively scheduled for 2004.

Phase 1 was to be a small pilot project consisting of ~20 monitoring devices, carefully selected for fieldbus implementation and not critical to plant operation upon loss of device or fieldbus segment.

Assuming phase 1 results were successful, phase 2 was to be part of a planned project in the gas conversion area. This would serve as a medium-size project (~2,000 field devices).

ALCENG engineers recognized that it would be easy to begin installing the phase one project immediately, thus introducing fieldbus technology to the plant very quickly. However, the goal of the pilot project wasn’t just to get fieldbus technology installed as quickly as possible; it was to develop a complete fieldbus framework of practices and procedures for designing, engineering, installing, commissioning, operating and maintaining fieldbus technology.

One of ALCENG’s original investigation goals was to learn just how well manufacturers of Alcan Gove’s current I&C systems would be able to support connectivity to multiple fieldbus technologies. In this regard, it had become apparent that the current system was in “legacy system” status, meaning that while parts were available, the system manufacturer was not intending to invest in new enhancements.

It is nearly impossible to investigate the various fieldbus technologies without being exposed to a variety of different manufacturers’ control systems. Thus the investigation of one leads to a very good understanding of the others and provides valuable insight into how well manufacturers have embraced and embedded various fieldbus technologies into their control systems architecture.

supplement, p.6, “Demystifying a protocol – Fieldbus device descriptions provide interoperability, by Stephen Mitschke.”

Once the decision to use FOUNDATION fieldbus, Profibus DP and AS-I, had been made, the list of control systems that might be used to replace the installed legacy control systems had already been narrowed.

ALCENG engineers noted that it was interesting how European and North American manufacturers of I&C equipment had established a niche product presence in Australia, not always offering the same complement of products and/or services available to other parts of the world.

Following an extensive technical evaluation, ALCENG chose to replace the installed legacy control system with Emerson Process Management's DeltaV™ digital automation system (www.easydeltav.com). Key factors influencing this decision included:

- Major fieldbus installation experience;
- System and device support in Australia;
- Diversity of approved fieldbus equipment;
- Breadth and depth of installed devices, systems and support available in Australia;
- Availability and completeness of fieldbus related standards and guidelines that Alcan Gove could utilize;
- Commercial considerations.

With the fieldbus technologies and control system manufacture selection process completed, ALCENG's next step was to hire a fieldbus expert/consultant. Eventually an Emerson consultant was chosen, one who was familiar with the three fieldbus technologies of choice as well as the inter-workings of the DeltaV system.

Phase one

Using traditional CHAZOP (Control Hazards and Operability) study techniques, ALCENG engineers identified 20 monitoring points that could be retrofitted to fieldbus technology without serious ramifications to plant operations in the event of a device or segment failure.

Because interoperability had been identified as a key technology migration risk, ALCENG carefully selected devices from multiple instrument manufacturers in order to gain a first-hand experience of the interoperability issues.

An added benefit of selecting devices from multiple instrument manufacturers was the opportunity to:

- Gain experience with installation, set-up, configuration and troubleshooting of multiple devices from multiple manufacturers.
- Review and use device specific documentation from a variety of manufacturers.

Phase two

We all have experienced that even the very best of plans are subject to change: the multiple-phase fieldbus implementation plan was no exception.

The gas conversion project earmarked as the platform for the phase two of the fieldbus implementation was placed on hold. However, the 3rd stage expansion project that had been identified

as the final phase of fieldbus implementation had received approval to proceed.

This had ALCENG engineers facing a major question: "Had the phase one fieldbus project, combined with the plant visits and interaction with I&C manufacturers provided ALCENG engineers and Alcan Gove management with sufficient confidence in the technology to commit to using it on the large scale project?"

Phase three

The phase one had produced positive results in the areas of:

- Development of standards for documentation, wiring methods, equipment, etc.;
- Development and use of CHAZOP to ensure the robustness of the installed fieldbus;
- Effective training for engineering and maintenance personnel;
- Efficient, quick and easy commissioning of devices and segments; and
- Verification that significant cost savings could be realized on future projects.

When everything was considered, ALCENG engineers and management were convinced that the phase one project had established sufficient confidence in the fieldbus technology. It had also reinforced the fact that it was an appropriate path for Alcan Gove to continue pursuing. The decision was made: "Utilize fieldbus technology on the green-field plant of the AUD2bn 3rd stage expansion project (G3), while retaining the conventional 4-20mA system for the brown-field retrofit." Also the choice of bus technology was further narrowed to utilize FOUNDATION fieldbus and Profibus DP.

The I&C scope for the G3 expansion project consisted of ~5,000 field devices, VFD and motors, which equated to ~15,000 traditional I/O points.

While ALCENG had been using a conventional CHAZOP process for quite some time, the introduction of fieldbus technology introduced some important new considerations. Working in conjunction with Emerson fieldbus consultants, ALCENG engineers modified the CHAZOP process to accommodate fieldbus technologies and the DeltaV digital automation system.

In a traditional HAZOP study, piping and instrumentation diagrams (P&ID) are the main documents being studied. In the CHAZOP for Alcan Gove's 3rd stage expansion project, fieldbus segment design along with the control system functionality and operator interface became the focus of the studies.

While viewing a segment design, CHAZOP participants were presented with a "flash card" developed to address a specific aspect of the segment design. For instance,

- "What would be the consequences if the segment failed at a particular connection point?" or
- "Does this segment have sufficient critical measurement design segregation?"

Segregation design policies often insist that critical, congruent measurements not share a common point of failure. For example,

the temperature and pressure measurements inside a vessel may be congruent, meaning the pressure increases as the temperature rises and vice-versa. Good engineering practices would insist that these two measurements do not share a common point of failure, such as sharing the same segment or be connected to the same I/O interface (H-1) card. The CHAZOP flash card review helped identify where these congruent conditions exist and helped ensure such measurements are appropriately segregated.

Through the use of the flashcard CHAZOP approach, ALCENG engineers were able to thoroughly review such things as:

- Implementation of correct segregation of segments, devices, I/O cards, cables, etc.;
- Interface for “smart” MCC equipment, as well as motor stop/start and protection designs; and
- Documentation completeness of design, installation, testing and maintenance.

One of the unique approaches adopted for the G3 expansion project was the concept of modular construction, also referred to as Pre-assembled Modules (PAM).

PAMs are fully fitted out off-site to form a complete plant module including electrical and instrumentation equipment. Upon shipment from the assembly area, each PAM is fully pre-commissioned and ready for installation at site. (See Figure 1)



Figure 1 Fully fitted-out PAM

More than 300 PAM assemblies, ranging in size from 200 to 1,200 tonnes are being built and delivered to the Gove site. This is producing such benefits as:

- Improved safety by reducing the number construction personnel and activities required on-site;
- Improved project schedule through the simultaneous use of multiple unit assembly locations;
- Improved efficiency and quality by implementing a “controlled factory” construction environment;
- Reduced costs by assembling where people and equipment are already located;
- Reduced social impact by avoiding the mobilization of a large construction work force to the Gove site;
- Reduced environmental impact by minimizing on-site personnel and activities; and

- Reduced on-site material lay-down and staging requirements.

Though it was not initially part of the fieldbus investigation or identified as a cost saving factor, the use of fieldbus technology proved to be an excellent fit with the PAM concept. It delivered benefits that were beyond initial expectations and that had not been included during the investigation and approval process.

PAMs could be fully assembled including field instruments, control valves, conduit, wiring, junction boxes, terminations, etc. The completeness of the assembly facilitates an exhaustive factory acceptance test (FAT), and makes on-site connection of the PAM to the DeltaV system much easier.

To minimize on-site work and achieve a trouble-free plant commissioning, ALCENG developed:

- A device testing procedure that commences when a device is originally removed from its box and extends until the device is shipped to the site as part of the assembled PAM;
- A collection of field test reports designed to aid stage one and stage two commissioning activities;
- Detailed segment health check procedures that facilitate a more efficient commissioning of the PAM on-site as well as establishing a future “segment health” reference signature;
- Documentation for sign-off just prior to the shipment of a PAM; and
- Sign-off and ownership transfer process for each PAM.

A portable DeltaV system was used to facilitate the testing of I&C equipment contained within each PAM prior to its shipment to the Gove site.

Because DeltaV was designed by Emerson to be fieldbus aware, its use made PAM testing highly efficient. For example, when field devices are connected to a fieldbus segment and powered up, each device completes its on-board diagnostics, establishes communication with the segment, and automatically reports its presence and identity to the DeltaV system.

Once all devices have initialized, a comparison between the devices that actually reported and the segment’s design documentation is made. Any discrepancies are easily spotted and corrective action is taken. Once all devices are verified to be electrically present, the next phase of testing can begin.

ALCENG also utilized sophisticated 3D models for the design of each PAM. The software used to produce the 3D models supports establishing rules that ensure even the smallest detail of engineering consistency is maintained throughout the project, including such items as cable segregation. This is helping to ensure fieldbus segment design requirements are being consistently applied.

This attention to detail resulted in the elimination of the risk of electrical noise on fieldbus segments during detail design, and allowing ALCENG to engineer reliability into the installed solution.

ALCENG is one of the first companies to implement the automated generation of segment connection drawings and other engineering deliverables in a true fieldbus project environment.

It has been ALCENG's aggressive use of technology, automated engineering processes, attention to detail and extensive planning exercises that are providing better management of preliminary and detailed design changes while, at the same time, eliminating the risk of fieldbus segment performance issues.

Business Case

The days of installing technology for the sake of technology have long since disappeared. In today's highly competitive business environment, every capital investment requires analysis and a justification that the expenditure will produce an acceptable cost benefit.

Acceptable cost advantages are achieved through quantified improvements in product throughput and quality, as well as reduced variability, installation, maintenance and operating costs, when upgrades to process instrumentation equipments is being considered.

The initial economic value analysis for migrating/upgrading the Alcan Gove's alumina refinery to fieldbus technology included both hard (quantified tangibles) and soft (intangible) entities.

Hard entities include actual costs associated with engineering, purchasing, installation and commissioning; while soft entities include estimated costs associated with improved operations resulting from additional process and device diagnostics, and reduced efforts to gather, assemble and maintain accurate, up-to-date calibration and maintenance records.

Additionally, ALCENG was interested in establishing cost reductions for both the green-field (new) and the overall project, which included both the green-field and brown-field retrofit.

The estimates produced indicate that by using digital fieldbus technology, ALCENG could expect to produce hard cost savings greater than 60% for the green-field part of the project, which was implemented using the fieldbus technology; however, the overall cost savings for the project would be around 40% when both green-field and brown-field aspects of the work are considered.

Despite the slightly higher cost of fieldbus products (less than 20%), overall savings were determined to come from a significant number of engineering, construction, implementation, maintenance and operational areas. From among these areas, ALCENG engineers determined the greatest hard savings would be achieved in the areas of engineering drawings, material and labor, and commissioning.

The material and labor savings alone, which amounted to >40% from an overall project perspective, were largely delivered due to the reduction in the following:

- Cabling requirement;
- Cable terminations;
- I/O cards and system cabinets;
- DCS interface hardware; and
- Field junction box assemblies.

However, there are other areas expected to produce savings. When considered, these would result in even higher saving projections, but were not included in developing the overall savings calculations. These include:

- Reduction in other engineering deliverables, e.g. cable schedule, system configurations, etc.
- Cable tray reductions;
- Reduced real estate;
- On-site versus off-site cost of delivery.

Although the G3 project is still in the construction phase, soft benefits already worthy of mention include:

- The first fully tested control system cabinet was designed, assembled and delivered to site six months after project approval, a feat ALCENG engineers are convinced could not have been achieved using traditional 4-20mA technology.
- The first fully fitted-out PAM, including 98% of instrumentation work, was completed and shipped to site eight months after receipt of project approval (See Figure 2). The fieldbus installation enabled the reduction of on-site work to just twelve trunk cables wired back to the DCS and eight 24V power supply cables to feed the local distribution boards.



Figure 2 PAM being delivered to Gove

The value proposition of soft entities, such as improved operations resulting from additional process and device diagnostics, can be difficult to quantify. However, according to a report by independent industry experts at ARC Advisory Group (www.arcweb.com), operations and maintenance are the very areas where fieldbus technology provides its greatest benefits. In other words, the introduction of fieldbus technology becomes the enabler to achieving a heightened level of production effectiveness.

Fieldbus technology expands the quantity of process and device data that is available. At the same time it simplifies the gathering of that data for plant asset management systems designed to watch over devices, tracking their "health," and even detecting problems before they adversely affect operations and/or product quality – a capability that is known as predictive or proactive maintenance.

The effective use of plant asset management systems results in increased process availability, thus preventing unnecessary process costs that often are incurred as a result of unexpected process excursions and/or shutdowns.

Fieldbus technology also enables easier, quicker and more accurate instrument calibrations to be performed. In fact, digital technology and advanced diagnostics have allowed some instrument manufacturers to extend the recommended period between instrument calibrations to as much as six years, thus freeing maintenance personnel for other activities.

Fieldbus technology, when combined with plant asset management systems, also enables developing and maintaining more accurate records of device calibrations and maintenance activities. Where traditional calibration and maintenance record-keeping relies on handwritten entries, calibration and maintenance activities using fieldbus technology and plant asset management systems are automatically recorded and saved.

Developing a sound business case for migrating/upgrading to fieldbus technology requires identifying benefits beyond reduced wiring and installation costs. It requires identifying and quantifying costs associated with:

- Preventable process excursions and shutdowns
- Control valve turnaround maintenance
- Instrument calibration and maintenance
- Calibration and maintenance documentation.

Tips and Traps

Sharing of lessons learned doesn't occur nearly as often as everyone would like, thus opportunities such as those provided by The Minerals, Metals and Materials Society are extremely valuable.

ALCENG believes that the factors that played a significant role in the success of its migration to a digital fieldbus include:

- **Planning** – The amount and level of detailed planning that went into every aspect of this migration journey is absolutely vital and is producing significant dividends from concept through commissioning.
- **Standards and documentation** – The simultaneous development of fieldbus specific standards and associated documentation templates is helping to ensure new documentation has a similar look and feel to the existing I&C documentation – something maintenance personnel appreciate.
- **Tools and processes** – Taking the time to develop structured robust engineering tools, processes and rules for such activities as segment design and segregation, automated drawing development and management, CHAZOP and commissioning is producing an installed solution that is consistent, easier to engineer, test and maintain, and will be less costly to own and operate.

In 1999 ALCENG was concerned about interoperability issues resulting from installing different manufacturers' products on the same fieldbus segment. However, it has now become more apparent that Fieldbus Foundation and Profibus Nutzerorganisation e.V.'s cooperative use of DDL and EDDL, combined with the robust independent testing provided by the two

fieldbus organizations, provides users the freedom to choose the best field devices for each application with little, if any, concern for interoperability issues.

ALCENG engineers also believe avoiding the following "traps" is playing a significant role in the overall success of its on-going fieldbus migration initiative.

- **Technology upgrade considerations** – For any large operating facility, there is a very close integration between field instrument equipment, MCC, plant control systems, emergency shutdown, burner management, telemetry, and other resource planning systems. The migration to newer technology in any of these entities must not occur in isolation. The technology upgrade path must ensure that a sound and supportable integration solution has been applied; one that is the best overall choice while protecting the investment into current systems.
- **Retain expert help** – It is very easy to falsely believe that we have the know-how to implement a robust fieldbus installation through books, journals and attending an occasional two-day course or a seminar. Also everyone has a good understanding of "office" type networks. However, office networks and fieldbus networks are not the same. Ensuring each and every fieldbus segment is designed and implemented correctly as well as operationally robust requires heeding the advice of experts.
- **Crawl before you walk** – Fieldbus has been around for nearly two decades, thus there is a tendency to jump in with both feet. Unfortunately, no two operating facilities or installations are exactly alike. New adopters can save themselves a lot of anguish by starting with a small installation and progressing from there. What they learn about fieldbus specific to their company, plant and application will prove invaluable in the long run.

Conclusion

Since ALCENG initially began investigating the feasibility of migrating to fieldbus technologies, the installed base, capabilities and number of manufacturers supporting FOUNDATION fieldbus and Profibus DP have continued to increase, especially in Asia and Australia.

When all these aspects are viewed as a whole, it confirms ALCENG's wisdom of deciding to move out of the "comfort zone" and begin the migration to fieldbus technologies at the Alcan Gove refinery – one that will help Alcan Inc. obtain and maintain a competitive advantage well into the future.