Integration of drive and distributed control systems at the Willamette Marlboro greenfield paper mill

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ABSTRACT: Many microprocessor-based distributed control systems users have struggled to achieve the benefits of a "single window" control system that efficiently and effectively combines and presents all process data and control information in a timely manner, including data from the variable-speed drives and drive systems. The major obstacle when assembling this system is the task of combining the different types of individual control systems so that they appear to the design engineer, operating personnel, and maintenance technicians as a homogeneous unit. An optimum solution to reduce or eliminate problems would be to use a single-architecture controller for the mill control system from the drives to process control. The concept was to provide not only a "single window" control system, but a true "single control" system. With few exceptions, the control system at the Willamette Marlboro mill achieved complete millwide control using the single-architecture concept.

KEYWORDS: Control systems, design, distributed control, drives, information systems, integration, machine components, machinery, process control.

A survey of various mill personnel indicates that they view total integration of the multiple control subsystems as highly desirable and consider the attainment of this goal significant for all mills. The group also indicates that, for this to be realistically considered as viable, the total integration package should not present any additional cost or complexity for the end user. The highest value of total integration can be found by following these requirements as they relate to the overall system:

- Provide the operators with the ability to control any process within or outside their area and access millwide information from a single interface platform.
- Provide direct scanner and sensor capability from the same controller and operator interface used for process control.
- Use a unified system software package for all processes, including system and standalone drives.
- Ensure hardware compatibility from one process to the next, to limit requirements for spare parts.
- Use uniform hardware and software documentation.
- Consider future upgrade capability and compatibility.

The survey clearly indicated that many mill operators were ready for a unified control system for their plants and processes. Many users were growing tired of multiarchitecture control systems with customized communication links and related difficulties during startup, service, and software upgrades. As many of the process control companies continue to grow and expand into various other facets of control in the industry, some have already

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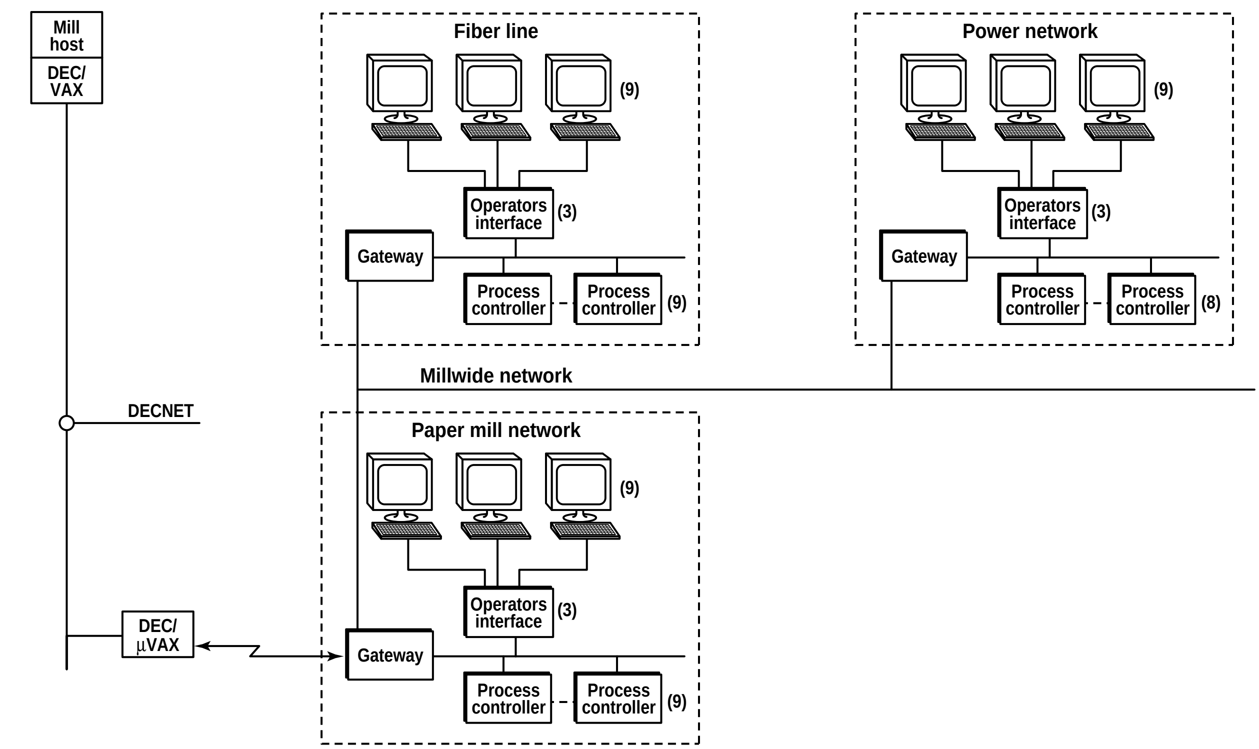
1. Plant network structure



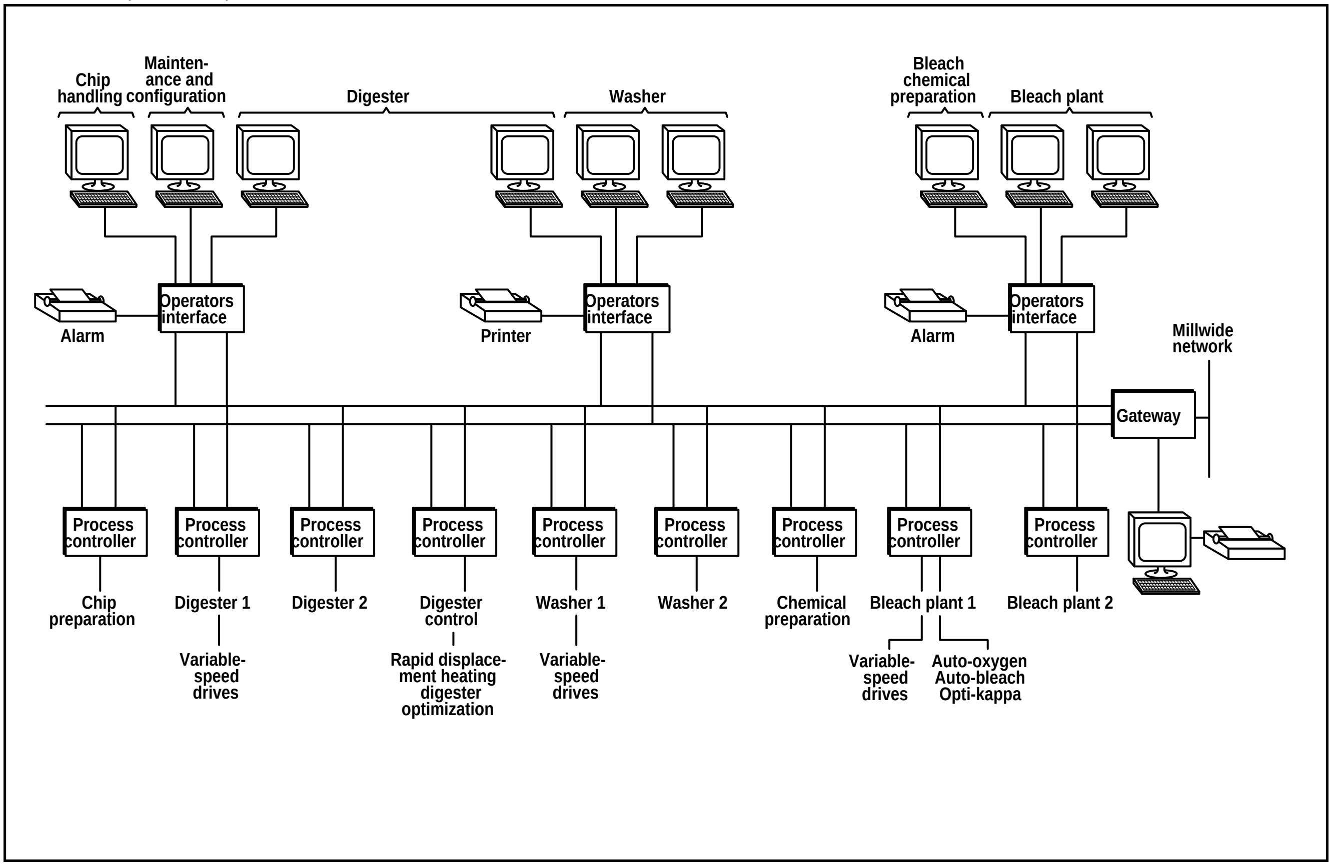
taken steps toward integrating gauges and scanners into a single platform on the distributed control system (DCS). One major capability that has been found to be lacking in most of these modern control systems is clean, high-speed access to the various standalone and system drives required in the paper mill.

Many process control systems effectively control various standalone ac and dc drives used on applications relating to fans, pumps, etc. by utilizing hardwired analog and digital input/output (I/O) for control and status information. This typically involves digital I/O for start, stop, and fault indication, as well as analog I/O for speed references and speed and load indication. Although this method of drive control has been used quite often and is simple to understand in most cases, the shortcomings are fairly extensive when more comprehensive information must be transferred between the drive and controller. Additional information relating to diagnostics and feedback signals normally use a significant amount of I/O and still fall short of providing a comprehensive amount of information. A high-speed communication link between the DCS and the drive would handle almost any requirement imposed on the system and provide the desired flexibility for any future modification deemed necessary.

Generally speaking, most drive vendors have established serial communication links to the various DCS suppliers utilizing a variety of protocols and have found that these links offer a satisfactory gateway for information flow between the two systems. These “gateways” are normally limited in speed to 19.2 K-baud and can sometimes provide a bottleneck, depending on the type and amount of information required by the user. It is normally up to the customer to unpack the data from the drives and decide how the information should be presented to the operator. The ideal system should incorporate both a high-speed communication link, greater than 1 Mbit/s, between the DCS and the drive vendor, preconfigured program and database modules, and a series of specially designed DCS graphics that present the drive data in an effective manner for both the operator and maintenance personnel.

In 1989, Willamette Industries decided to break ground with a new design approach involving complete control using system integration that was unique for the U.S. market at that time. Its greenfield pulp and paper mill in Marlboro County, SC, is managed almost entirely through a single-architecture control system. This DCS utilizes 26 individual controllers and nine operator interface platforms, handling over 16,000 I/O, all working together through an Ethernet communication network.

2. Fiber line (network 1)



The control system handles everything from the normal paper mill process control functions, the paper machine gauges, and, finally, the system and standalone ac and dc drives. The only parts of the mill not under direct control from the integrated DCS are related to a few small programmable logic controllers (PLCs) supplied by the mechanical original equipment manufacturer for paper machine and winder logic.

Although the concept of constructing an entire mill with a pulp machine, paper machine, and winder utilizing a single, unconventional control system seems a bit adventurous, Willamette had already established a good track record with previous projects at two of its other mills that utilized the same control platform. These individual projects gave Willamette confidence that the overall performance would not be compromised by the use of a single control platform for various applications. The drive systems that had been installed at other mill sites were very well accepted by operating and maintenance personnel; thus, the concept of utilizing a single platform was not as revolutionary as originally expected.

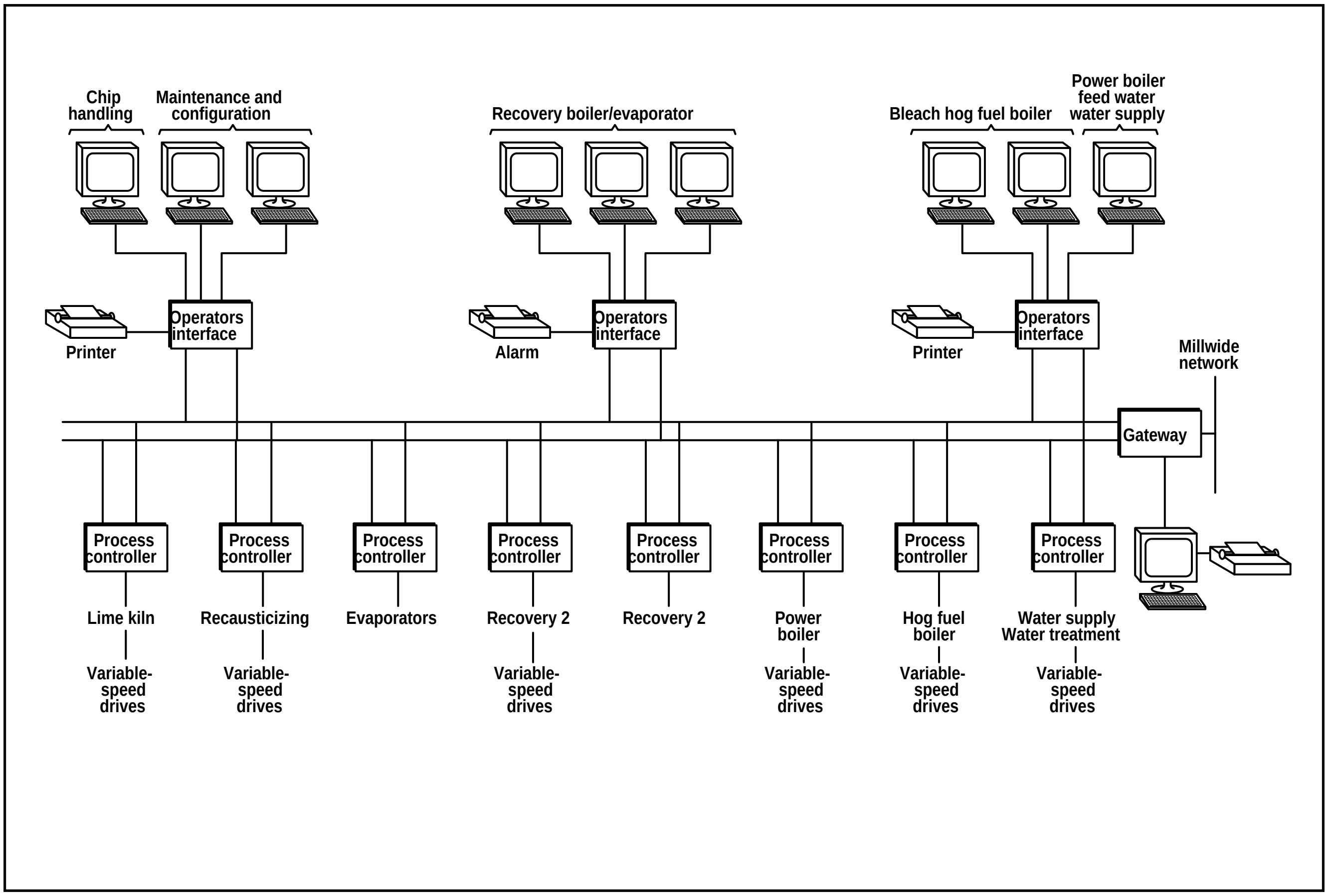
Both the ac and dc standalone and system-type drives are capable of being controlled through the single window into the entire system or through a variety of local operator control stations. The drives communicate via a 2 Mbit/s network that transfers information back to their associated controller. This high-speed local area network is the same hardware design as the remote I/O network used by the controller for field mounted I/O. Data transfers from the drives and remote I/O units to the application program in the controller must pass through the process controller database. Each controller database is open for information flow to and from any operator interface platform located in the single-window operator interface.

The use of a single-architecture control system for all mill functions has been implemented successfully in Europe. However, it had not been widely accepted, or even attempted, in the United States prior to Willamette's undertaking at the Marlboro mill.

The single-platform control system manages the following functions:

- Conventional mill DCS control for the pulp mill, paper mill, recovery, and utilities areas
- Sectional drive systems for the paper machine, winder, and pulp machine
- Various standalone ac and dc drives, ranging in size from 5 hp to 1500 hp
- Sodium chlorate generator rectifier equipment

3. Recovery area and power boiler (network 2)



- Paper machine and pulp mill measurement and gauging systems
- Millwide database and information system
- Various Level 2, or supervisory, optimization controls.

This paper will outline a number of areas that are normally crucial when making a decision on the type of control that will be implemented at a greenfield paper mill. The items specifically covered include:

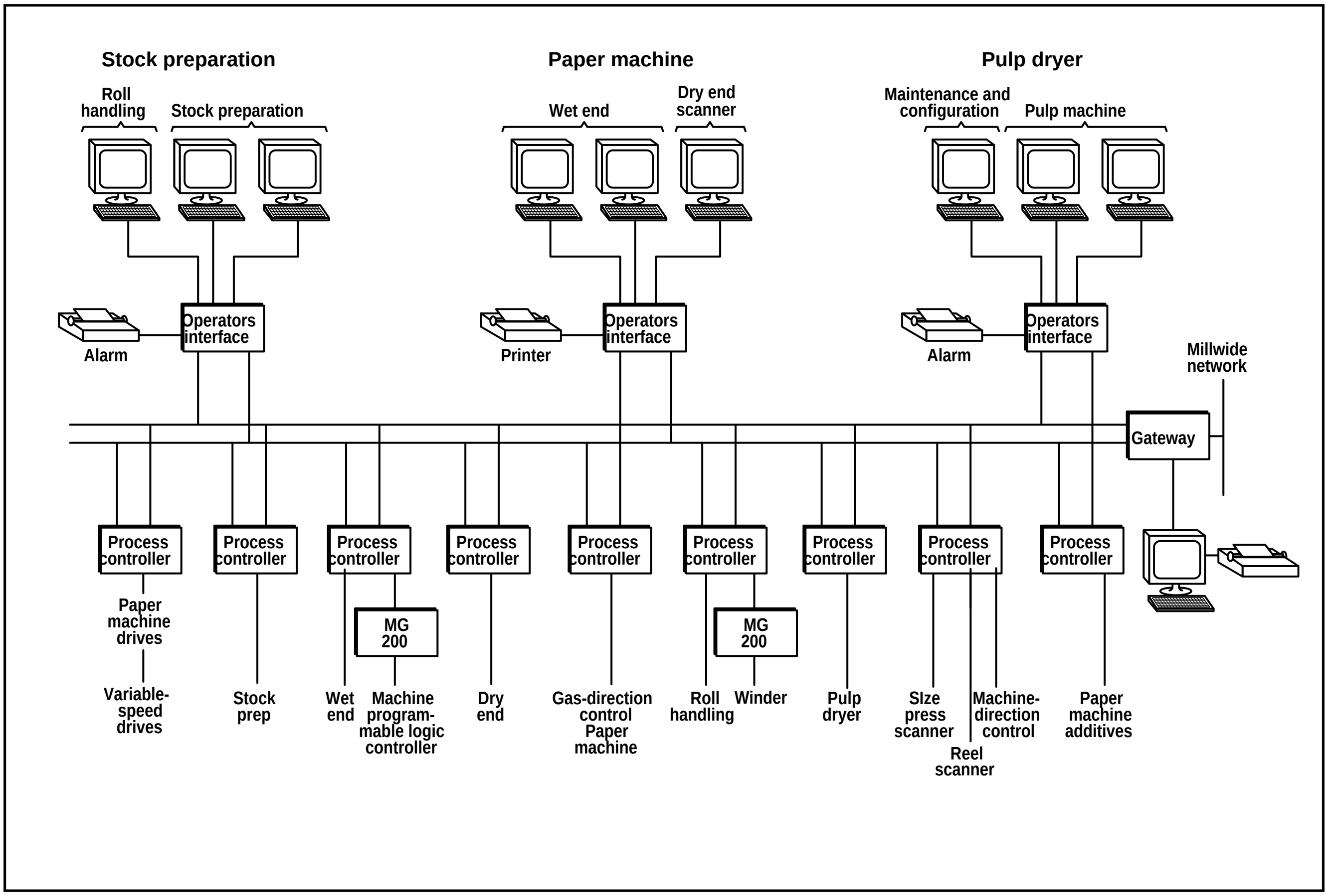
- System configuration
- Project engineering considerations (circuit types, efficiency of design)
- Operator interface (simple configuration methods, standards)
- Drive and other system diagnostics
- Startup and continued maintainability (spares and reliability)
- After startup customer comments.

System configuration

To achieve these results, the Willamette Marlboro mill was configured with three control networks (**Fig. 1**) that are linked together via a plant network. All networks utilize an Institute of Electrical and Electronic Engineers (IEEE) 802.3 Ethernet network standard. One network is used for the fiber line, the second handles the recovery and utilities network, and the last network handles the paper mill and pulp machine functions. The data from one control network can be accessed from any other control network via the millwide plant network. A device that acts as a traffic director, protecting the control network and filtering (priority discrimination), also connects the control network to the plant network. The same device is used to connect a dedicated μVax to the plant network to manage data flow to the plant management information system software.

Each control network is comprised of a number of processors and operator stations that share data through a high performance, medium distance Ethernet bus data link that uses an IEEE 802.3 CSMA/CD medium-access control protocol with data transmission at 10 Mbits/s. The fiber line network (**Fig. 2**) links a number of processors that control chip preparation, digesting, pulp washing and screening, chemical preparation, and pulp bleaching. The power and utilities network (**Fig. 3**) handles the recovery area and power boiler portion of the mill. The processors on this network control the

4. Paper mill (network 3)



lime kiln, causticizing, evaporator, recovery boiler, power boiler, feed water, hog fuel boiler, water supply, and water treatment. The paper mill network processors (**Fig. 4**) control the paper machine drives, stock preparation, paper machine wet end and dry end process, cross-machine control acutators, winder roll handling, winder drives, pulp dryer, size press and reel scanners, and, finally, the machine direction/cross direction controls.

Each of the individual networks is provided with three high-performance operator interface platforms. A single interface platform is equipped with up to three viewing screens for advance operator communication to the distributed control system. The work stations are capable of providing the process and drive data through process graphics displays, object displays, trend curves, and various reports. All operator stations have access to the distributed control system database via the communication networks defined earlier. All interaction with process variables or objects takes place via the network.

All system and standalone drives are provided with a high-speed modem connection (2 Mbits/s) to their respective process controller through a field bus network. The field bus handles all processor remote I/O units and drive modules. The data that is transferred between these devices is available through the individual process controller database for display at any operator station.

Every signal that enters the system, whether it be a discrete digital signal, a proportional integral derivative (PID) loop controller, or communication and control of a drive, must pass its data through the controller database files. This database file is available for interrogation and manipulation from any controller, operator station, or gateway link to and from the mill host computer. Each database element is also equipped with a unique presentation display (known as the object display) that gives the status of its variables and a short-term trend window.

The paper machine drive system consists of 29 sections of dc drives ranging in size from 15 hp to 1000 hp. The winder includes six sections of dc drives ranging in size from 40 hp to 800 hp. The pulp machine adds eight sections of dc drives ranging in size from 5 hp to 100 hp. There are also 83 standalone drives, six being dc and the remainder variable-frequency ac drives.

Project engineering considerations

The main goal of a project engineering team is to first determine what systems are required to satisfy the defined project design and scope of operation. Next, the engineers must configure each system to provide its desired function. Then they must coordinate how these systems will work together, presenting the appearance of a truly homogeneous system. Finally, they must provide methods and information for proper function, installation, and connection of all systems. The most difficult tasks are those encountered when trying to attain a sufficient level of understanding of the individual systems and the interface requirements and complexities for information flow between systems.

The training necessary to fully understand multiple systems takes a great deal of time and increases costs because more engineering preparation time is required. One can rely on various vendors to provide detailed information and design help; however, they cannot do the complete design. This still places the burden on the design engineer to coordinate the systems and assure that the equipment supplied meets the project requirements.

Utilizing a single-architecture control system reduced the time required to train engineers and provided a conducive situation for the project team to more completely understand the features available within the system. An understanding of the process control hardware and software automatically provided an understanding of the sectional variable-speed drive master control, standalone drive control, motor control, and coordinated system logic (i.e., roll handling system, etc.).

The single-architecture system reduced engineering time by providing a common I/O system that allowed a cohesive hardwired interface, preconfigured database elements, preconfigured complex logic element blocks, and dynamic display elements. The software system provided the ability to program closed-loop control and motor logic in the same program module. It also provided the capability of establishing different processing times (from 50 to 2000 milliseconds) and priorities for each program module. This created an additional benefit of making process group starts much simpler to implement. Continuity of application software allowed for the development of "type circuits" for commonly used and repeated functions. These type circuits were configured on an off-line programming unit and used to significantly reduce programming and system configuration time. Type circuits were developed for process control, ac and dc drives, constant-speed motor starters, and group starts.

Transfer of data between control processors, including those for sectional drive control, could now be accomplished using the proprietary system communication interfaces. This would replace the various gateways normally required for multiple system configurations and the difficulties associated with them, including:

- Protocol compatibility
- Processing of received data so it can be placed in the correct database locations
- Format selection (16 or 32 bit) and type of link (simplex, duplex, or half duplex).

These items usually complicate check-out, field modifications, and future expansions.

The single-architecture control system reduced the engineering effort relating to coordination due to the elimination of various gateways between the subsystems. The project team devoted more time to determining all of the application standards that were required and developed "type circuits" and proper operator interaction requirements and standards for the mill. All of the type circuits were carefully customized to provide the exact control functionality and operator interaction as determined by Willamette's engineering department and mill organization.

Operator interface

All operator control was implemented through the color graphics viewing screen and the operator interface platform mentioned previously. The status of the process, including the ac and dc drives, was presented using a combination of the following displays:

- **Process displays.** Application-specific graphics entirely defined by the user. Static presentations are configured to follow the process flow diagram while the status and values of objects (i.e., controllers, sequences, measured variables, motors, etc.) are presented dynamically. This is the display that is predominantly used by the operator.
- **Object displays.** Present all information that is available for the single database object along with a four-minute trend window. These displays require no configuration and are automatically generated for all objects defined in the control system (AI, AO, DI, DO, sequence, PID controller, motor control, on/off valves).
- **Alarm and event presentation.** For the drives, process, and DCS system.
- **Trend presentations.** Display of short- and long-term historical data.
- **Group displays.** Present a survey of different parts of the process. Objects are oriented in group faceplates corresponding to specific sections of the process. The layout is standardized. These displays are used infrequently and predominately where there might

be an advantage for interrelated processes.

- **Control System Hardware Status.**

Given the ability to access any element from any operator station on any control network, it became the task of the project engineering team control engineers, vendor system experts, and mill operating personnel to determine what information and control should be included in the display and graphics and in what format.

To provide greater flexibility, all area displays were installed in each operator interface platform on a control network. This allows access to any process area within the control network from any viewing screen. Authority for control accessibility and alarm indication can be activated or deactivated for individual viewing screens if that is required. Process graphic displays can be accessed for monitoring from one control network to another through the plant network. The global tag name database structure provides plantwide access to information. This is particularly convenient for this system because such a large percentage of the process information resides in the DCS system.

The operator can select any object for control by pointing to a dynamic point with the cursor on any process graphic, overview, or group display. It is also possible to select the object by entering its unique tag name or by selecting the alarm line (most recent alarm) via a dedicated key. Tag name standards were developed for the system that use loop or equipment numbers in configuration with generally accepted standards for item designation. Once the object is selected, a dynamic key display is available on the viewing screen to provide an operation menu.

Alarms and events are presented in chronologically ordered lists. The event list is circular, so the new event overwrites the oldest ones. Alarms are removed from the alarm list when they are acknowledged by the operator. A copious amount of alarms is available in the system. However, to prevent the operator from being overwhelmed by alarms, only those alarms considered to be appropriate and necessary are specified by the design engineer during the design phase. Repeat failure mode is usually selected for the alarms to eliminate multiple alarms from persistent faults. Alarms are normally indicated with a red display, but to provide a means for the operator to decipher between different alarms, critical alarms were configured to display with a yellow color. This was designed to increase operator awareness of the need to act immediately.

Trend data logging is carried out locally in the individual controllers. Variables are sampled and stored in logs. Analog as well as binary variables can be logged. The values to be stored in the trend logs are specified by the design engineer. Once the logs are programmed, the trend displays can be configured by the operator. They can choose whether the values shall be momentary, mean, maximum, minimum, or a number of samples within the log interval.

Reports can be configured for various processes and are generated from the process data. They can be presented as user defined displays on the viewing screen or as hard copy printouts. All necessary calculations of report data are done in the personal computer programs in the system controllers. The report function was most often used for continuous monitoring and electronic log sheets.

All process graphics followed a defined set of standards based on ergonomically sound principles for display building. These included standards for color, static display elements, text, dynamic points, size, placement, process flow, display density (many graphics exceeded 40–50 dynamic points), and special display elements (many were added). Because of the simplicity and ease of configuration, one person configured 90% of the process graphics. This provided for excellent continuity between screens and a greater degree of efficiency.

Drive and other system diagnostics

The diagnostic platform and presentation of data are common for all drive and system information available plantwide and to all controllers. When an alarm is detected by the system (this detection of an alarm is based on the limits of the variable imposed by the user—motor overcurrent, drive fault, etc.), the signal is time tagged and immediately displayed on both the alarm list and the top line of the process display presently used by the operator. Selection of this variable allows the operator or maintenance personnel to enter a dialog with the system where the signal status is indicated via an object display. From this display, the operator is shown a four-minute trend window of the signal status, along with all information relating to its reference, feedback, and logical status. Indications relating to whether the function is blocked (forced) are also displayed.

The integrated control system architecture enabled the implementation of powerful system diagnostics across conventional control boundaries. For example, detailed drive object displays are implemented for each drive in the system and can be viewed by the operator for drive diagnostic data on his or her DCS interface platform. The electrolyzer rectifiers also have similar diagnostic screens that display equipment problems on the DCS as if the drives and rectifiers were an integral part of the DCS system. Examples of the process control, DCS hardware, and drive hardware diagnostics most used by the mill include:

Process Control Diagnostics. Configured to indicate abnormal process conditions, these consist of a combination of system preconfigured and user defined diagnostics.

- Limit alarms
- Motor status
- Controller status
- Interlock status
- Safety system status (fire alarms, emergency generators, transformers, etc.)
- On/Off valve position status
- Sequence status
- Scanner and CD actuator status and calibration information.

DCS Hardware Diagnostics. System preconfigured.

- Processor status
- Local analog and digital I/O status
- Remote analog and digital I/O status
- Control network communication status
- Field bus network status
- Object status query function.

Drive Hardware Diagnostics. System preconfigured.

- Control status (remote/local/auto)
- Setpoints and actual values
- Drive electronic card status
- Communication status
- Power electronic status
- Ground fault status
- Overload status
- Drive fault status
- Remote drive reset.

The integrity and diagnostic capabilities of the totally integrated system show the limitations in diagnostic information where the standard practices of using a PLC with customized gateways to the DCS are used. These gateways have already proven to be bottlenecks in the transmission of diagnostic information. Production time has been lost when one gateway did not transmit enough detailed diagnostic information from the PLC to the DCS regarding the origin of the alarm for loss of vacuum to the machine. This clearly points to the various problems associated with a conventional approach, which would typically include a substantial number of gateways.

Startup and continuing maintenance

Some of the benefits related to a single-platform architecture include the following factors that can offer significant cost savings, both initially and ongoing:

- **Programming tools.** The same programming tools are used throughout the mill.
- **Training.** Common training is used for all control systems (the only variable related to process knowledge).
- **Troubleshooting.** Even though the process varies, the troubleshooting techniques are similar or the same.
- **Spares.** Using the same hardware platform throughout the mill eliminates confusion related to spare parts and reduces spare parts inventory.

Programming tools

The main programming tool required to work on the system software is a package that can be installed on any standard IBM-compatible AT Personal Computer (PC). The package includes a computer expansion board and software kit, which permits an IBM-compatible PC to be used as the programming tool. It can perform the following functions:

- Program entry and editing (on-line and off-line)
- Graphical control block language
- Parameter setting
- Reading data and system status
- Simulation of digital/analog input and output data
- Signal faults and system messages
- Database entry and modification
- Self documentation of the system program
- Program backup and download
- Live block display for troubleshooting
- Modem capability.

Controller programming can be done by connecting to the individual controller or across the control network.

Troubleshooting

Troubleshooting the system is relatively simple because all I/O systems are present and can be viewed from the programming tools and technician stations available from a single point. This allows technicians and engineers to see the raw signals produced by the sensing devices and the conditioned value after program manipulation. Output signals and program execution can all be observed through the single window. Also, and very importantly, anywhere a technician goes in the system they will see the same hardware, software program language, and database. This is an excellent troubleshooting expeditor. The integrated system approach includes the recording of system problems through separate printers that record alarms and events. The programming interface supports the additional feature of an error message function that provides special information about tasks and problems related to hardware and software. All of these features assist in determining where the problem actually exists.

Training

An integrated DCS and drives training system was installed at the onsite facility. This was used for operator and maintenance training and simulation. Several simulation programs were implemented and greatly enhanced the operator training.

Maintenance or engineering training for the system controller or the color graphics operator stations is common, whether the individual is working on a particular portion of the process or a drive. The procedure and the tools that are used to access the program for modifications are the same whether the individual is changing the logic for a drive section or the lime kiln. The training normally involves a one-week school on the system hardware and general commands, a one-week school that gets into detailed programming and, finally, a one-week school on the color graphics operator station programming.

Once this training is completed, an individual should be able to work on any of the controllers in the system. The only missing variable relates to application experience.

Spares

A single source of supply for the platform simplifies maintenance by reducing the number of resources required to maintain inventory spares. Highly reliable, fault tolerant electronics minimize component failure. In fact, most component failures occur during construction due to improper handling, installation, or general unfamiliarity with the product. The component failure rate, once the system was in operation, has proven to be relatively low. With normal DCS environmental protection (filtration and clean positive-pressure rooms), the owners can expect a long component life and minimal service.

After startup user comments

For the personnel at the Marlboro mill, the single-platform architecture provides:

- Lower field material and labor cost because of installation flexibility
- Global database for information exchange and processing
- Flexible display presentations enhance technician and operator training and daily operations.
- Single-source supplier that simplifies maintenance and spare parts inventories.
- Increased training commitment for engineers to learn how to program the system while reducing the troubleshooting time required for hardware
- More information to operator helps him or her make better decisions.
- Improved quality control
- Common programming language and designer tools
- True process control integration.

Summary

There was significant risk in deciding to go against traditional wisdom and accepted industry practice by installing a single-architecture control system that included not only process control and logic but also variable-speed drives and machine gauging systems. Because the system had been applied across the board and throughout the mill, any deficiencies in the system would have been glaringly apparent, creating serious consequences. On the other hand, if the system satisfied all of the requirements and expectations of performance and provided the features and benefits outlined throughout this paper, the results far outweighed that risk.

The system has been an unequivocal success and has provided the benefits and flexibility originally envisioned. In many ways, it has surpassed original expectations for a system that could provide complete process control in one system combined with a very efficient operator interface platform. TJ

Received for review Dec. 7, 1993.

Accepted July 25, 1994.

Presented at the TAPPI 1993 Engineering Conference.