Integrating paper machine control components to achieve a single-window control system

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Mills that have invested in automation equipment can integrate these components to achieve true "single-window" distributed control.

All manufacturers worry about efficiency, product quality, customer satisfaction, market share, and profitability. In the case of the paper industry, these considerations translate into specific concerns regarding the performance of the paper machine, the off-machine coater, and the supercalender. Papermakers have sought relief by automating their production processes and measuring product quality with a variety of sensors.

The big paper companies are looking for better process control and are converting their packaged sensor and mill instrumentation systems over to distributed control systems (DCS). The incentives for this trend toward "single-window" control include increased product quality and lower manufacturing costs. The flexibility of the DCS also facilitates rapid response to shifting market conditions, allowing mills to change grades economically and reliably when the opportunity arises.

The downside, of course, is that conversion to a DCS is likely to be expensive, and such costs can be difficult to justify in the short term. In addition, the costs are not confined to the initial capital outlay. Limitations in the existing packaged systems present a clear risk in lost production while the mill converts its operations to accommodate the DCS.

Over the past 15 years, the major paper companies have invested between $1 million and $2 million per machine on sensors and packaged process control systems. During the next ten years, these companies will be converting to distributed control at a cost of $2 million to $3 million per machine. This article examines alternative architectures for achieving a single window in environments where a mill has already invested substantially in automation equipment. The advantages and disadvantages of the various approaches are reviewed.

Hardware and software components

There are several single-window alternatives. The feasibility of a given option depends on the hardware and the designated level of performance. The first step in evaluating these options is to review the hardware components involved in a paper machine control system.

Measurement

Gauge suppliers provide a significant amount of front-end investment in developing the specialized equipment used to measure such key parameters as weight, moisture, caliper, ash, opacity, color, coat weight, and gloss. These costs are passed on to the user, who also assumes the added expense of maintenance. Because development costs are so high, there are only a few suppliers, and in most cases, the control, display, and reporting functions are in the same system as the scanning-measurement function.

Signal processing

The function of processing signals from sensors/scanners is invariably included as part of a packaged system. Every analog signal from each primary sensor is read, together with any accuracy-enhancing signals (*1*). These signals are checked, converted, and averaged into elements of scan-data boxes, based on readings from each head-position signal. Other functions include scanner control, sensor standardization, and calibration support.

Profile processing

Each data-box profile array is processed at the end of each scan to form a deviation profile around the average value for that array. If required, arrays of calculated variables (e.g., dry weight or density) are formed. The average of each array is available for MD (machine-direction) control. Each deviation profile is generally filtered to attenuate MD variations from the diagonal profiles (*2, 3*).

Management information systems

Management information systems (MIS) for paper machines have become fairly sophisticated. Short- and long-term statistics are computed for parameters in both the MD and the cross-machine direction (CD). This is done by reel, grade, shift, and often by roll and set within the reel. In computing such statistics, the system must be sophisticated enough to handle initial and ending

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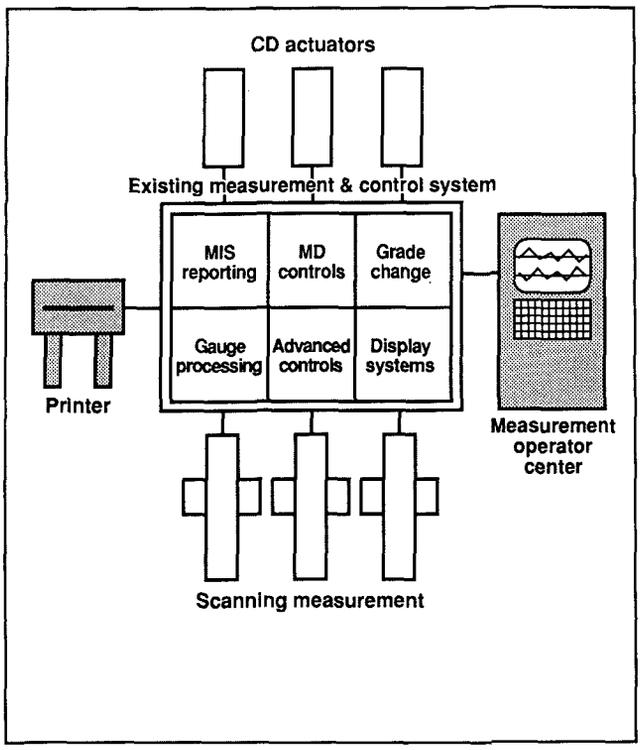
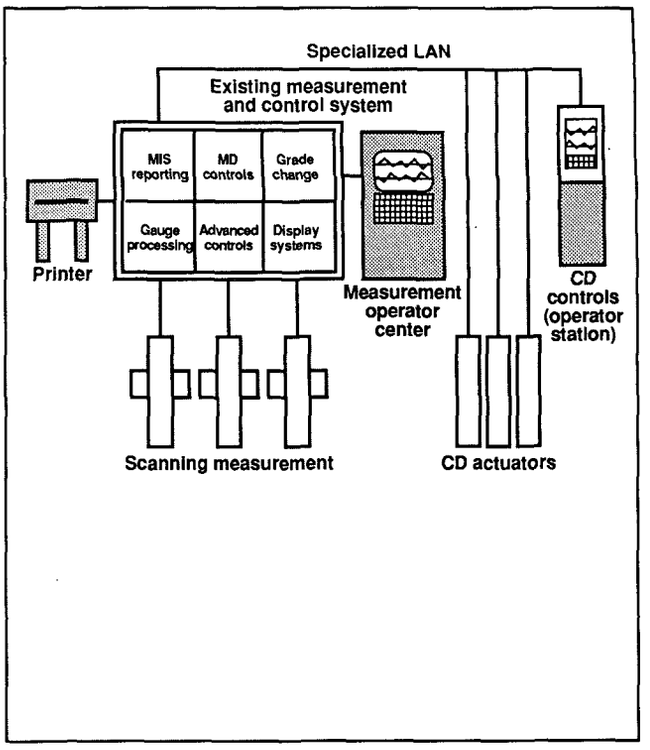
1. Standard packaged system for single-window control of paper machine



2. Early integration using a specialized LAN for distributed CD control



conditions, bad data points, and varying array sizes resulting from varying sheet widths within a grade. If the profile array is used for CD control, the processor must be able to interpolate the array to the width of the CD control actuator zones and then display these interpolated values.

Advanced controls

Advanced control functions require a great deal of computing power. Such functions include coordinated grade change, production/speed optimization, speed/draw control, and headbox control. A noteworthy addition has been CD actuator control, which has become an essential aspect of the papermaking process. In fact, many system replacements are initiated by the desire to add these functions.

MD controls

Suppliers of computer-based measurement systems have always provided algorithms (model reference adaptive, dead-time compensated, decoupled weight/moisture, etc.) that were not available in conventional control systems. Control of other functions (refiner, stock blending, headbox) is commonly implemented as part of the measurement supplier's system despite the fact that control of these functions is more suited to a DCS. These functions are basic proportional integral derivative (PID) loops initiated by data from the measurement system and easily integrated into the packaged control system for the paper machine.

Display systems

The video display capabilities of the specialized paper machine control systems have been improved in an effort to enhance the operator interface. These displays present a large array of data points in both tabular form as well as profiles.

CD actuators

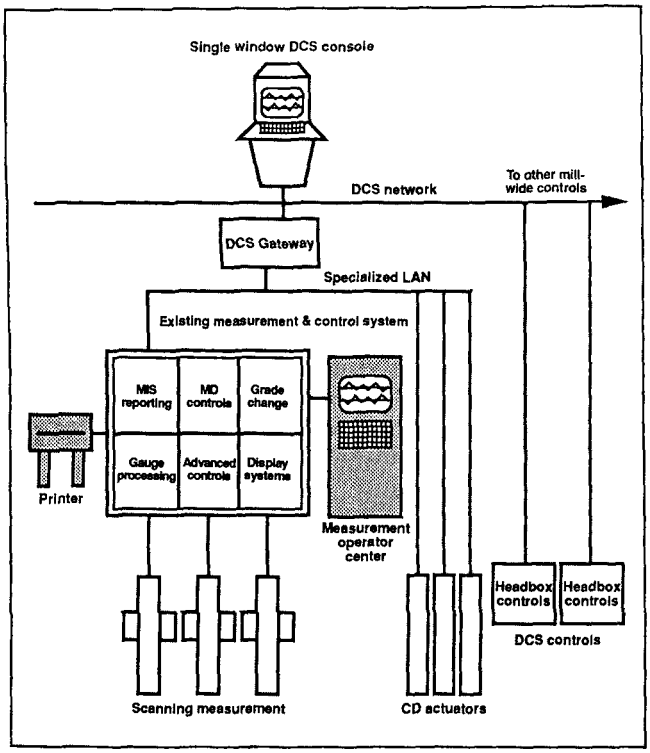
Over the course of the past eight years, CD actuators—specialized hardware for basis weight, moisture, caliper, gloss—have proved to have equal or even greater return than the original MD controls (4). These actuators have introduced a great deal of new technology to the industry and pose the greatest problem for a DCS in the area of control.

Integrated configuration options

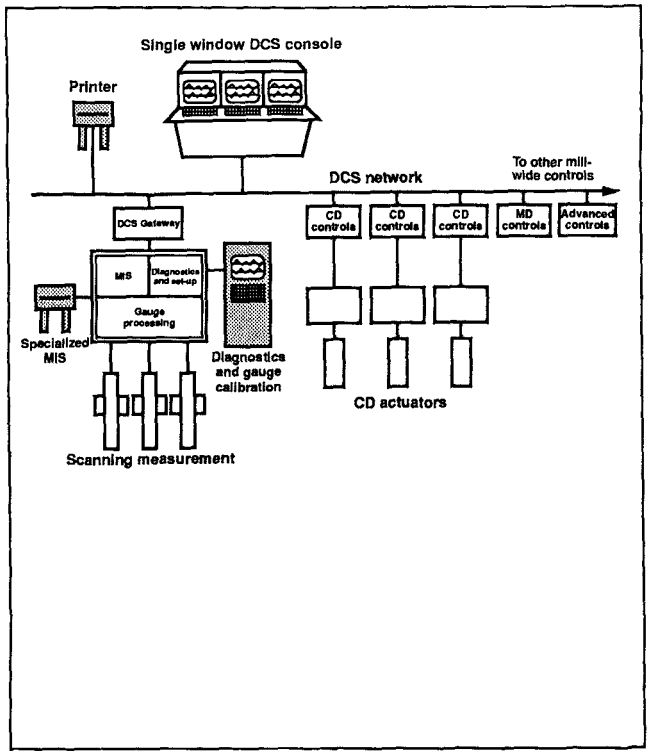
The initial single-window approach to paper machine control involved the use of a basic packaged system, illustrated in **Fig. 1**. This system contained all of the components of control, measurement, and associated functions. CD actuators were provided by the system vendor or by a specialty actuator company.

The advent of enhanced "smart" (stand-alone) CD actuators and specialized control algorithms led papermakers to pursue interconnected hardware and software capable of using data from the paper machine's measurement system. Specialized "link" software was developed and tied directly to a distributed local area network (LAN), as seen in **Fig. 2**. The LAN distributed profile data to the controls housed in the smart actuators. While this approach expanded the feasibility of connecting hardware and software from different suppliers, it did not enhance the single-window concept. In fact, in many cases, it introduced a new window. Nevertheless, this approach

3. Expansion of existing measurement and control system via a DCS window to the process



4. Transfer of control to DCS network, with data prepared by stand-alone sensors. DCS resolves data on its network and distributes control.



provided flexible control options without compromising system integrity. The increased flexibility in options also stimulated competition among the suppliers.

As the paper industry struggled toward the goal of a single window, it became apparent that the ability to connect components from various suppliers over specialized LANs enhanced the distributed architecture of DCSs. However, DCSs have been designed for application across several industries.

The major DCS suppliers provide the same I/O (input/output) hardware as well as general-purpose software for use in a variety of continuous-process applications, including chemical, petrochemical, paper, metals, mining, and utilities. Most of these applications deal with single-point control systems, which were previously handled by PID-type control systems. While the repertoire of control algorithms has been vastly increased, single-point systems are characterized by individual-point data identified by tags or labels in the system. In contrast, the rather specialized requirements of scanning-measurement control systems involve arrays of variables. The number of variables in these arrays continues to increase with the requirement for better CD resolution. For example, there are 80 points per measurement on a 20-ft-trim machine with 3-in. measurement zones. With four measurements per scanner on a four-scanner fine paper machine, this translates to 1280 points. If these are addressed point by point in a DCS, their manipulation may become inefficient to the point that the job cannot be completed at reasonable cost.

Several such systems were successfully integrated following development of a "simple" DCS gateway, which allowed the specialized LAN to communicate with the DCS network (*5*). The DCS gateway system is illustrated in **Fig. 3**. Functions such as data processing and specialized controls continued to reside within the different components from various suppliers. However, the gateway allowed these activities to be monitored by the DCS, thus providing a rudimentary operator interface. In short, the papermaker had access to a single-window interface without having to worry about the system's ability to handle large arrays and process large quantities of data.

The next stage of evolution, illustrated in **Fig. 4**, transfers all control functions to the DCS. With this system, the basic measurements reside within the packaged system or through intelligent stand-alone sensors. Diagnosis and configuration of measurements take place through the interface provided by either the packaged system's operator station or the intelligent sensor. Again, a gateway is needed to transfer the measurement data to the DCS network. Initially, this occurs through an RS-232 interface. However, DCS suppliers are developing enhanced gateway devices designed specifically to receive measurement data at speeds up to 19.2 kbaud. Once the data are on the DCS network, the paper machine can be controlled using the DCS hardware (*6*). Using the setup shown in Fig. 4, the specialized CD control hardware and I/O are used to optimize the performance of the actuators. The downside to this approach is the serial gateway and the amount of traffic on the DCS network after each scan.

The most recent stage of evolution is depicted in **Fig. 5**, which shows all functions occurring within the DCS. Signals from conventional or smart sensors are sent directly to the DCS, which does all the processing, calibration, etc. All information is then available on the DCS network and utilized by all controls. The specialized

I/O and hardware for the CD controls is replaced with standard DCS I/O and hardware. Only the simple actuator remains from the CD supplier.

While this approach has been implemented successfully, it has some shortcomings. Presently, not all CD actuators can be operated per their original design due to the limitations in DCS I/O capabilities. This limits the flexibility to pursue all options and may yield less-than-optimal performance.

Signal processing and array handling is cumbersome and ties up a great deal of computer power. This is very expensive and can delay the response time of the DCS. Limited resolution of data boxes on some video displays can also be troublesome. Given these constraints, this approach is better applied to smaller machines.

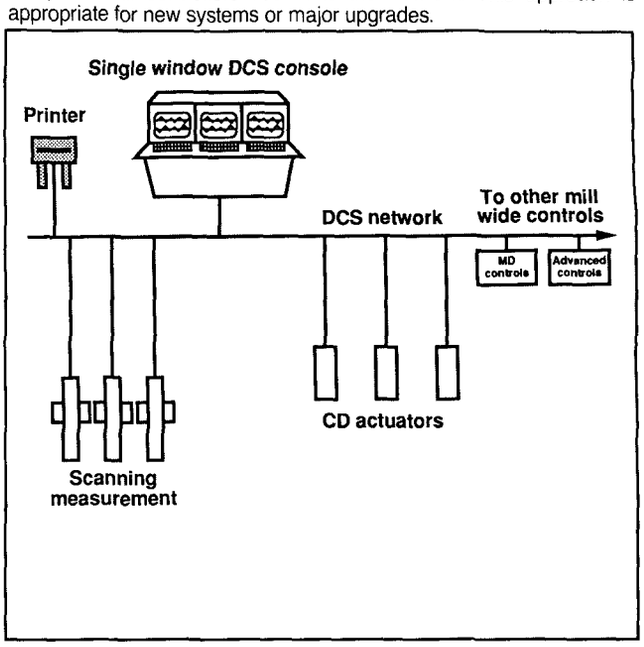
Conclusion

There are several options for integrating the various paper machine control components into a single-window control system. The systems illustrated in Figs. 3-5 have a single-window interface and are transparent to the operation where the processing is occurring. Each option has advantages and should be evaluated on the basis of cost, performance, and long-term planning.

The system depicted in Fig. 3 provides the window through the use of a gateway tapped into a local area network. The system in Fig. 4 receives data from stand-alone sensors with built-in processing and uses this information to control the process. Both of these systems are stepping stones on the path to the distributed control system (DCS) shown in Fig. 5. However, given the current limitations in DCS input/output (I/O) capabilities and hardware, this system is best applied to smaller paper machines. DCS suppliers are working to enhance their equipment so that it can emulate the functions that now occur in specialized measurement and CD control I/O and hardware.

The important point is to recognize that the single-window option has become a reality. Existing and newly purchased equipment can be integrated to achieve a true single window without wasting limited capital funds. With effective planning, the available technology can help papermakers achieve their quality and production goals.□

5. All functions occur within the DCS. Signals from sensors are sent directly to DCS, where they are processed, calibrated, and then used to operate all controllers tied in to the network. This approach is appropriate for new systems or major upgrades.



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