Trends in European paper machine drive technology

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Most of the new paper machine installations and rebuilds in Europe are using sectional-drive systems. Digital/numerical control technology is now the accepted standard, with sectional ac making up almost 50% of all new installations.

Is European paper machine drive technology further advanced than North American technology? This article examines the present practices of European drive design and technology, as well as trends over the past few years.

Sectional-drive systems

A sectional-drive system is defined as multiple driven sections under the control of a common master reference. A paper machine with separate individual drives controlling the various machine sections represents a sectional-drive application. (A single drive controlling a line shaft, or helper drive, is an example of a nonsectional application.)

The trend is to provide a complete regulator/power unit for each motor rather than paralleling motors on common power units. With machines running faster and faster, this allows the best possible control of the individual sections. **Figure 1** shows a typical example of a sectional-drive system on the wet end of a paper machine.[1]

A comparison of European sales of line-shaft drives and sectional drives since 1969 shows that line-shaft drive installations are almost nonexistent. Only five line-shaft drives have been sold since 1969, compared with 192 sectional machines with a combined total of 2695 sections. These figures are based on the reference list of a major European drive supplier and are assumed to be representative of the general industry trend.

Digital/numerical control

The digital/numerical regulator uses a microprocessor to compare the speed reference, which is in the form of a 16-bit digital word, with the feedback derived from a pulse tachometer. The feedback from the pulse tachometer is converted to a 16-bit digital word for the purpose of comparison. The microprocessor uses a mathematical algorithm to perform the function of the speed amplifier in an analog system or the function of the up/down counter in the pulse–pulse system. The output error is fed to the digital current loop, where digital pulse-firing circuitry controls the firing angle of the silicon-controlled rectifier (SCR).[2]

Speed regulation and drift performance with a digital/numerical control system is comparable with that of a pulse–pulse system. In addition, a digital/numerical system offers greatly enhanced diagnostic capability, increased flexibility in making changes and adjustments to the regulator, and serial communication with other devices. The serial data link allows data to flow in both directions. The drive sections send information about their speed, load, and faults to a digital reference control, which then transfers the data to the distributed-control system. Recipe information from the distributed-control system can be sent down to the digital reference control and then on to the drive sections.

The digital system has been in use in Europe since the late 1970s, and the vast majority of new installations are using this technology. The North American market has been slower to adopt digital technology, but it is rapidly gaining in popularity. The first installation in the United States was in 1983 at a Weyerhaeuser plant in Valliant, Oklahoma. All major North American drive manufacturers currently offer numerical-type regulators.

Table I shows the number of analog and digital drives sold annually since 1979 by a leading European drive supplier for paper machine application in Europe.

Operator interface

Intelligent drop-in stations

The traditional operator/machine interface devices, such as discrete push-buttons, pilot lights, selector switches, rheostats, and meters, have been almost exclusively replaced in the European marketplace by intelligent drop-in operator stations. The intelligent drop-in consists of a number of sealed membrane-type push-buttons and alpha-

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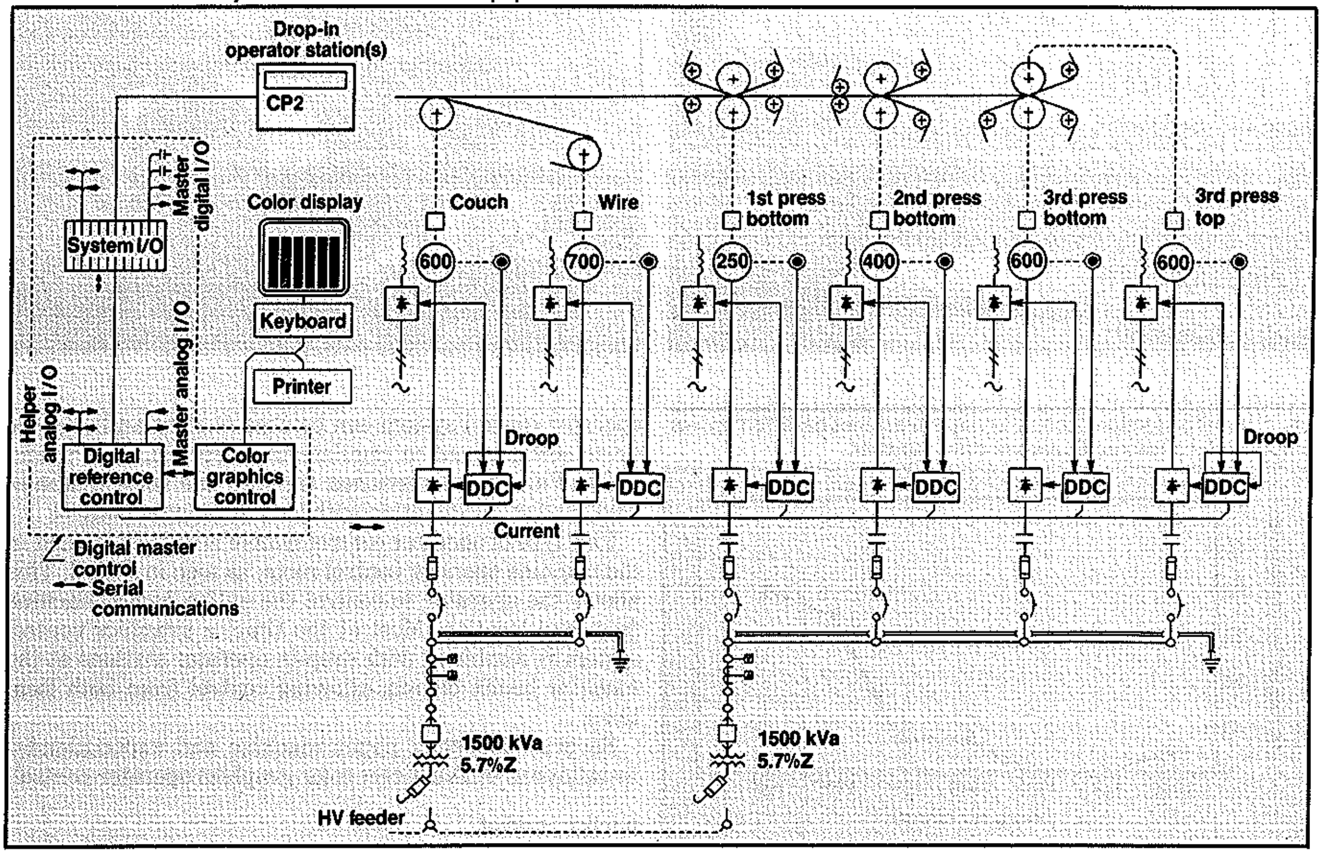
[1]Clark, C. F., Tappi J. 69(8): 76(1986).
[2]Derrick, P. E., Trends in Modern Electric Sectional Drives, presented at the Southeastern TAPPI Local Section meeting, Columbia, S.C., Sept. 18, 1986.

1. Sectional dc drive system for the wet end of a paper machine

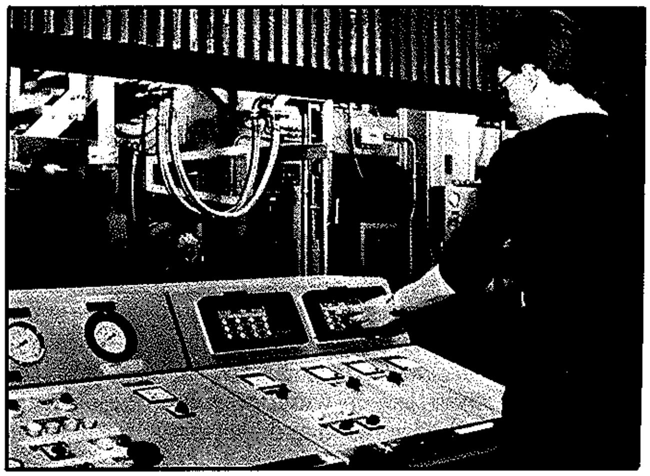


I. Annual sales of analog and digital drives for application in European paper machines*

Year	Analog drives	Digital drives
1979	147	16
1980	78	56
1981	103	21
1982	80	58
1983	58	53
1984	126	212
1985	25	189
1986	26	448

*Data supplied by a leading European drive supplier.

2. Bench board with intelligent drop-in operator station



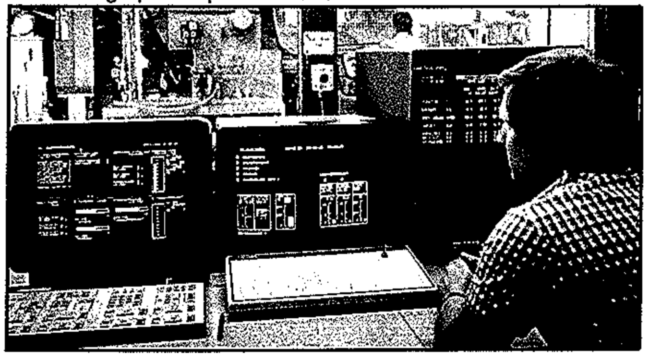
numeric displays. These are contained in a common enclosure, as shown in **Fig.** 2. The drop-in communicates with the digital master control via serial duplex communication, and the functionality of the buttons can be configured or programmed based on the application. The displays are used to indicate speeds, draws, loads, tensions, and fault data.

The major advantages of drop-in stations are in the area of maintenance and reduced downtime. Since all control functions are integrated into one enclosure, troubleshooting is greatly simplified. In the event of a failure, the drop-in operator station can be changed in a matter of minutes without shutting down the machine. Another benefit is a reduction in installation expense. Since the drop-in station communicates with the digital reference control via serial communication, nearly all external cabling is eliminated. The same type of drop-in can be used for all bench boards, with only the label overlay requiring customization. This reduces the number of different items that need to be stocked for spare parts. In addition, drop-in operator stations allow data to be displayed in alphanumeric format. More data can be displayed in a smaller area, saving on bench-board size and cost.

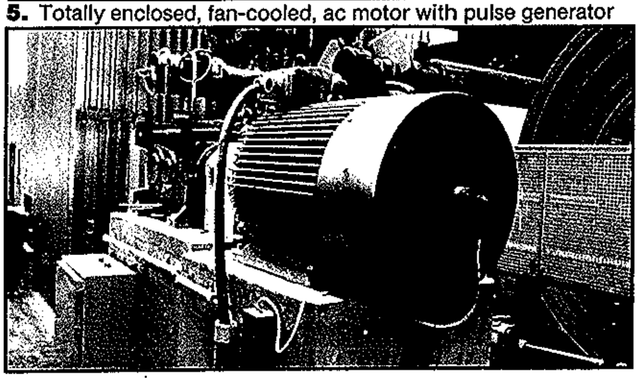
Color graphics supervisory system

Color graphics supervisory systems are the next step up

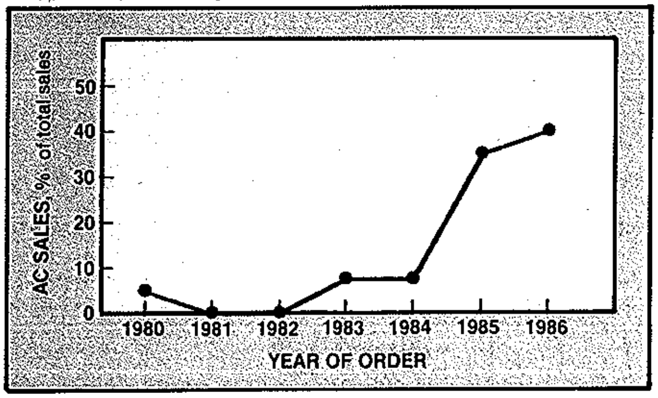
3. Color graphics operator station



5. Totally enclosed, fan-cooled, ac motor with pulse generator



4. Sales of ac sectional drives for paper machines based on figures supplied by a leading European drive supplier.



from the drop-in station. These supervisory systems consist of one or more color graphic cathode-ray tubes (CRT) located along the machine in bench boards or in the machine operator control room. The color graphic CRTs communicate with a color graphic controller that is often installed in the same cabinet as the digital reference control. The color graphics controller operates in a shared-memory mode with the digital reference control, allowing extremely fast access to drive and process information.

The color graphics CRT can generally display several different types of informational screens. A single screen might show speeds, loads, tensions, and draws for an entire machine. Another screen might display interlocking status and fault status. Yet another screen might keep track of such operator-initiated events as draw changes, stop commands, and slack take-up while providing the date and time the event was logged in and identifying the operator station that initiated the command. This provides the operating and maintenance personnel with a running record of all operator-initiated changes on the machine, which is useful in diagnosing problems. The ability to track speeds, tensions, and loads over long time periods and then display the trends on a CRT offers a powerful aid in determining process-related problems. The examples provided here are just a small sample of the types of screens available in a modern color graphics system.

The color graphics display system is commonly used in Europe on sectional paper machines, coaters, supercalenders, and winders.

Color graphics operator control

Color graphics operator control systems are basically the same as the supervisory systems. The difference is that the operator control system can be used to start and stop the drive sections and to regulate their speeds, draws, and loads. This is accomplished through the color graphics keyboard in combination with the CRT curser control.

This type of operator control system is usually located in the machine operator control room, as seen in **Fig. 3.** This allows the operator to control the entire paper machine from one location. Most of the time, a graphics control system is combined with drop-in operator stations at the machine bench boards, allowing control from both locations.

Several European paper machine and supercalender installations utilize direct color graphics operator control.

Recipe control

Recipe control is usually implemented via a color graphics system. With recipe control, the section speeds, draws, and tensions for an entire paper machine can be set up with one recipe number (such as a grade number). The color CRT functions as a window into the recipe. The operator can prepare the initial recipe, view it, edit it, store it to memory, and load it from memory.

The recipe-control function provides a snapshot of all settings. This snapshot can be stored for future use when running the same grade at a later date. Recipe files can also be sent to, and received from, a distributed-control system. This allows the distributed-control system to recipe drive settings in addition to the other machine parameters normally controlled.

Recipe control greatly reduces machine set-up time when changing grades, thus increasing production and profits.

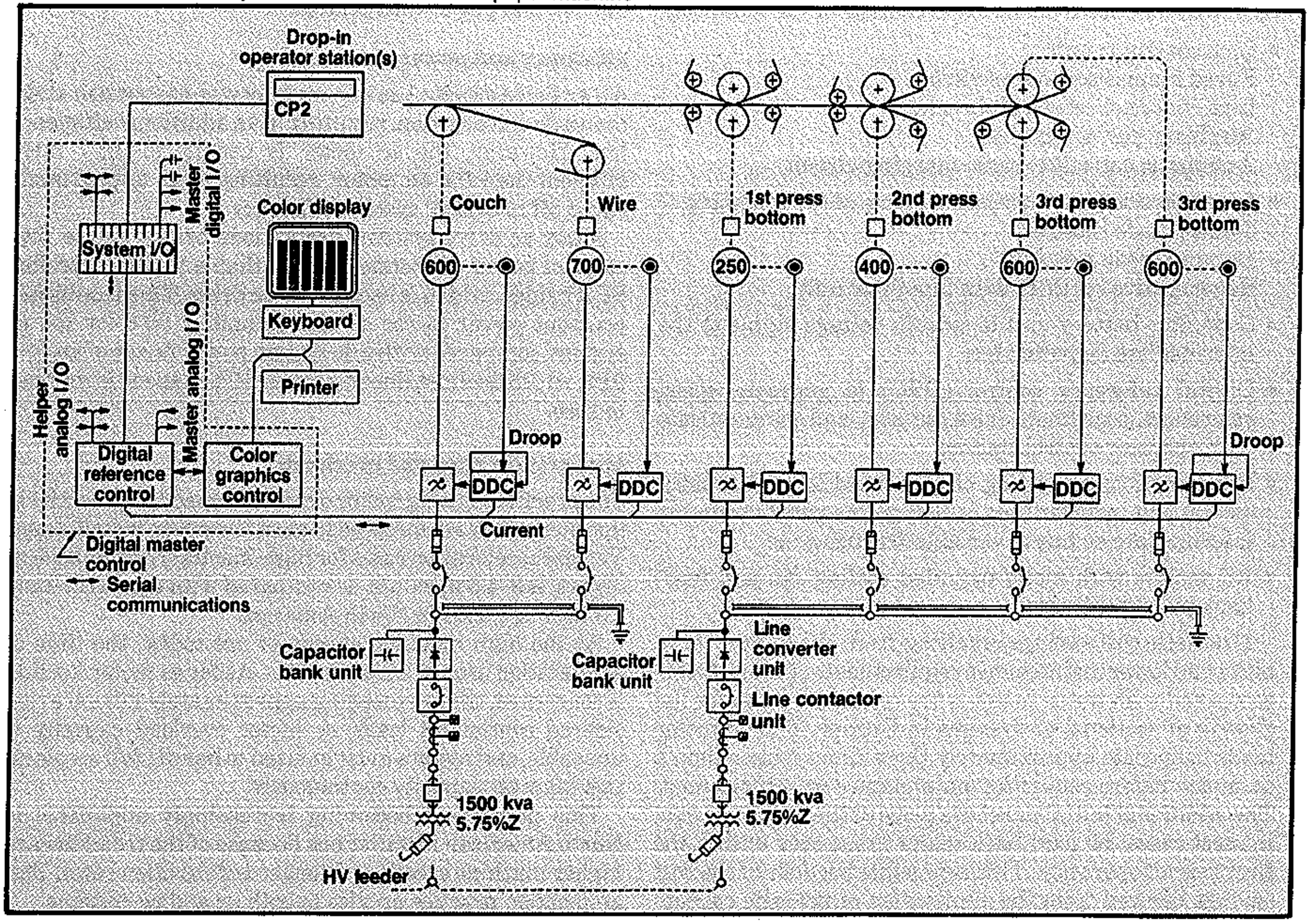
Distribution of ac power

Individual isolation transformers

The traditional method of distributing ac power to a sectional-drive system in North America has been with individual isolation transformers for each drive section. The isolation transformers provide protection for the drives in the event of a ground fault and prevent notching of the ac line. (Notching is caused by adjacent drive systems operating on the same ac feeder.)

Although there is nothing inherently wrong with the practice of using individual isolation transformers, it is a costly method. Several small transformers cost more than a single large one, and each transformer must be sized to handle the total recommended drive capacity (RDC) of its respective section. In addition, if the transformers are mounted in the drive control room, then more space is required and heat losses are greatly increased.

6. Sectional ac drive system for the wet end of a paper machine



Group transformers

A more economical method of feeding the drives has been in use in Europe since the mid-1960s and has been used almost exclusively since the mid-1970s. The method is known as the group-transformer method. Instead of having perhaps 30 separate individual isolation transformers on a paper machine, sections are grouped together and fed from common transformers. This might reduce the number of transformers on a paper machine from 30 to perhaps five or six larger ones of up to 2500 kVA. This reduces the initial cost of purchase. Small transformers typically sell for approximately \$20/kVA, while larger transformers can be purchased for approximately \$10/kVA. The transformer's overall kilovolt-amperage can also be reduced, since not all sections on a common transformer can be expected to be running at rated RDC at the same time. This provides a further savings in purchase price.

On group-transformer systems, an ac through-bus is provided in the drive enclosures to distribute the ac power. This simplifies installation and is less expensive than installing individual cables to provide ac power to each transformer and drive section.

In most European winder installations, the regenerative backstand, drums, and all other sections are grouped on one common transformer. In many installations with group transformers, the transformers are supplied as 5-kV_{ac} or 6-kV_{ac} power-center-type transformers, with 380-V_{ac} secondaries feeding directly to the drives. In an individual-transformer installation, either low-kilovolt-amperage transformers would need to have high-voltage primaries, an expensive alternative, or the power-center transformer would need to be provided in addition to the isolation transformers.

Modern digital drives utilizing digital-gating techniques operate reliably with group-transformer systems. However, it is a common practice to provide ground fault detection circuits in the transformer secondary to alert the maintenance personnel of the occurrence of a ground fault so that it can be cleared at the earliest available time.

Contactors

The dc loop contactor has long been replaced on European drives by the ac contactor. The ac contactor can be smaller and, hence, more economical. The ac sine wave crossing zero volts at a rate of 50 Hz allows the ac contactor to break full-load motor current faster than a dc contactor. In fact, most sectional ac drive systems do not use contactors in the individual drive sections at all! Instead, one main contactor is provided in the ac power bus feeding a group of drives.

Vector-control ac sectional systems

Since 1980, ac sectional drives have been used on European paper machines. The percentage of ac sectional drives vs. dc sectional drives has steadily increased since 1982. In 1986, ac drives comprised 46% of the sectional drives sold by a leading European drive supplier. **Figure 4** shows the increasing trend toward the use of ac sectional drives in Europe.

The digital/numerical vector-controlled ac drives available today approach the performance of digital/numerical dc drives. The sectional ac drive consists of the following:

- Line contactor unit:
  Fused main-disconnect switch
  Line contactor or circuit breaker
  Auxiliary power supplies
  Automatic capacitor-bank-charging circuit
- Line converter unit consisting of one of the following:
  6-pulse diode rectifier
  12-pulse diode rectifier
  Regenerative rectifier with line-filter unit
- Capacitor-battery unit to smooth voltage ripple to the intermediate dc power bus
- Digital reference control (DRC) to generate speed-references, coordinate drive sections, and communicate with operator control stations
- Drive sections consisting of a dc fused load-disconnect switch and inverter unit to change the power from the intermediate dc bus to variable-frequency ac
- AC motors with motor-mounted cooling fan and feed-back pulse generator.

Dramatic cost savings resulting from the higher reliability and lower maintenance requirements of the ac motor compared with the dc motor is the primary reason for the growth of sectional ac systems in Europe. The ac motor tends to operate approximately three times longer than a dc motor before requiring maintenance or replacement. The additional initial purchase price of the ac system can, in most cases, be paid back many times over within the first year of operation. This is possible because of the cost savings derived from the elimination of periodic carbon-brush replacement and commutator maintenance on the dc motor, longer motor life, elimination of the motor's common-duct forced-ventilation system, and the additional revenues accrued from more production hours with the ac system.

Application considerations

Motor ventilation. The ac motors used in sectional-drive applications can be supplied with separate ventilation (similar to dc motors). They can also be totally enclosed and fan cooled, totally enclosed air over construction, or they can come with separately driven fans mounted on the nondrive end of the motor. The separate fan motor allows the motor to operate over a wider range of speed, whereas a fan driven by the motor shaft would reduce air flow as the motor slowed down. The expensive motor ventilation system associated with splash-proof, separately ventilated dc motors can be eliminated. In the case of some smaller motors, such as those applied to paper rolls, fans are not used. These motors would be sized at approximately 2 × RDC, which would allow the motors to operate over a wide range of speeds, and applied as totally enclosed non-ventilated (TENV) motors.

Pulse generators. In order to accomplish vector control, the ac motor must be provided with a quadrature pulse tachometer mounted to the motor end shaft. This pulse-generator signal is sent to the drive system, where it is used as a motor-speed/angular-position feedback to the vector-control regulator. **Figure 5** illustrates a totally enclosed, fan-cooled, ac motor with pulse generator mounted.

Figure 6 is an example of an ac sectional one-line drawing showing sectional drives, digital reference control, drop-in operator stations, color graphics operator control, and power distribution.

Efficiency and power factor

An ac drive system has one more power-conversion stage than a dc drive system, resulting in an additional efficiency loss. However, the ac motor is usually slightly more efficient than the dc motor, resulting in an approximate stand-off in overall system efficiency.

Many ac drive systems use a diode bridge as the first stage of power conversion rather than a phase-controlled SCR bridge, which is used in the dc drive. This results in a constant power factor of approximately 99% for the ac system, compared with a dc system power factor of around 91%, which declines linearly toward 0% as speed is reduced to zero.

Acceleration rates and overloads

The practice of using motor overload capacity for acceleration purposes is not followed in most European installations. Typical acceleration rates for high-inertia sections, such as dryers, is 3-4.5 m/min/s, as compared with approximately 7.5 m/min/s used in North America.

At the high machine speeds in use today, the time of acceleration usually exceeds 200 s. As far as motor loading is concerned, times exceeding approximately 120 s are considered continuous loads, so motor overload capacity is unusable, and motors must be sized to handle full acceleration kilowatt capacity continuously.

This practice is becoming increasingly applicable in North American installations because of the trend toward higher machine speeds and longer acceleration rates. This application practice applies to both dc and ac systems.

Summary

It appears that the application of drive technology on European paper machines has advanced at a faster rate than in North America. Many of the practices that are considered commonplace in Europe are now beginning to find acceptance elsewhere. These practices include the use of drop-in stations, color graphics, group transformers, and sectional ac drives. The reliability and productivity of our installations in North America can be improved by watching future developments, examining the current European practices, and then applying those techniques that are deemed appropriate.

Received for review June 1, 1987.

Accepted August 26, 1987.

Published in *1987 Engineering Conference Proceedings*, a TAPPI PRESS publication.