A case history of a short shutdown drive upgrade

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ABSTRACT

Various approaches can minimize the amount of paper machine downtime needed for upgrading its drive system. The method uses existing dc motors, cabling, drive control enclosures, and power feed sources. The authors discuss the new drive equipment, control technologies, tachometer technologies, and innovative installation techniques. All these items are important in reducing the installation downtime for the paper machine.

Application:

Reusing certain equipment, aggressive scheduling, and commitment by all parties can reduce machine downtime.

WHEN THE DRIVE SYSTEM that has been operating on a paper machine or winder becomes old and difficult to maintain, the user must find an alternative to solve the immediate problems and minimize the capital outlay. Rebuilds are the typical selections because of their low initial cost. Whether the drive is for a new or rebuilt system, the total equipment package must provide the user with a better source for parts, enhanced diagnostics, and increased reliability. A "new" drive system does not always mean that everything is new. Budgetary constraints may prevent a complete replacement. It may mean replacing the old drive power structure and controller while maintaining as much of the motor and power circuit wiring as possible.

A major constraint involved with upgrades of many paper machine drives is the amount of machine downtime necessary for the replacement and tie-in of new equipment. The downtime demand is a heavy factor in determining the selection of the supplier of the equipment, the type of technology (ac or dc), and the definition of the scope of the replacement.

The costs associated with replacing a paper machine drive system can be very high despite the technology chosen for a new or upgraded drive system. Downtime of the paper machine required for the installation of "new" drives may even exceed the out-of-pocket costs for equipment and installation.

The term "drive system" refers to the equipment used to power the individual rotating sections of the paper machine and to control their absolute and relative speeds or torques whether using ac or dc technologies.

A drive system typically includes the following basic components:

- Incoming line power source
- Transformer
- Isolation, overcurrent, and overload protective devices
- Power converter
- Precise speed and current regulators
- Power and control wiring to the motors, input and output (I/O) devices, and operators' control stations
- Motors
- Gear reducers, couplings, and shafts
- Tachometers, resolvers, or other speed feedback devices
- Equipment enclosures.

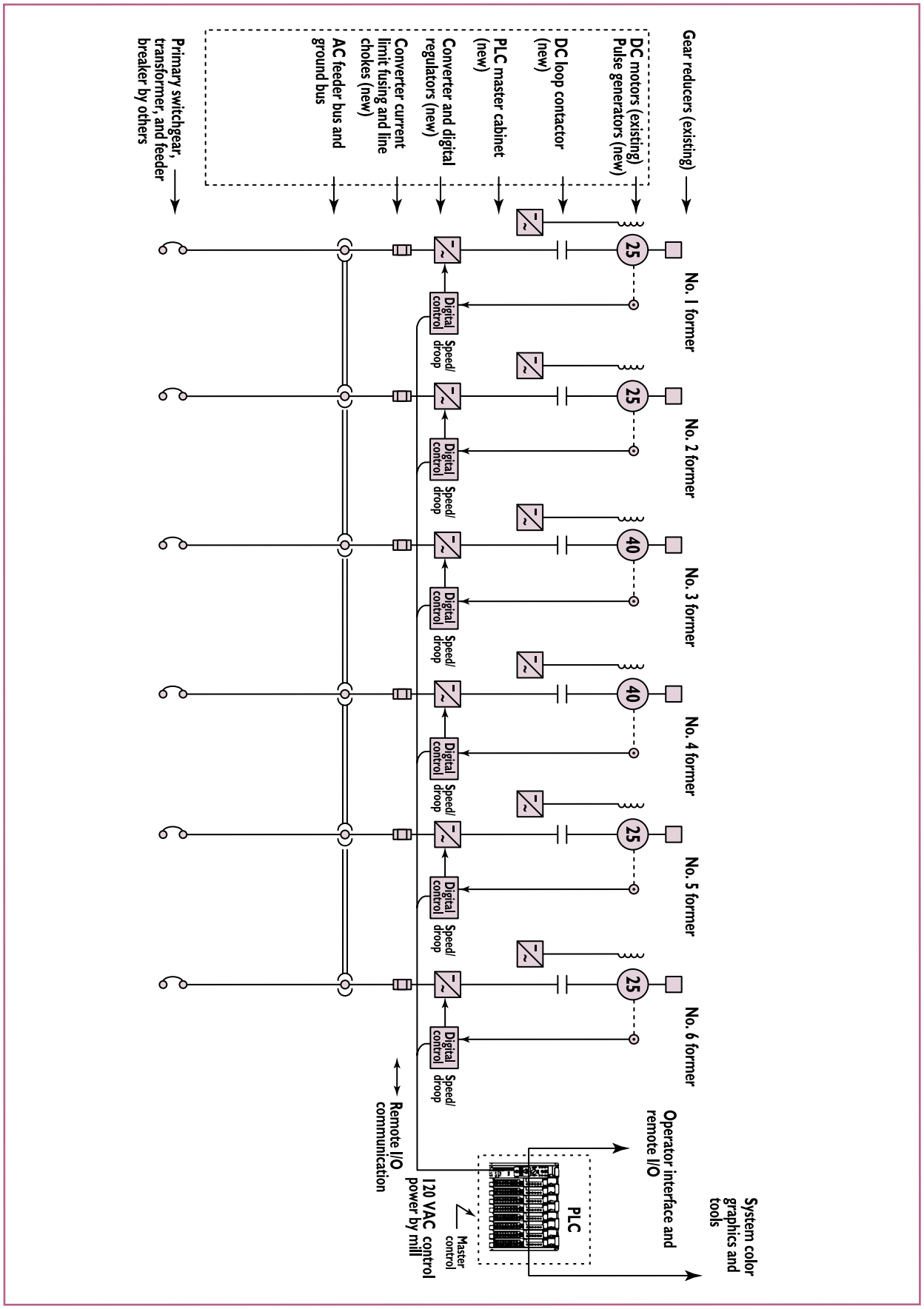
Decisions regarding each item can have profound effects on the purchase cost, the installation cost, and the downtime for the drive system installation.

This paper presents a case study of the Jefferson Smurfit mill in Middletown, OH. They chose to minimize paper machine downtime for the installation of replacement drives through appropriate scheduling during normal machine maintenance downtimes. This can only work properly when the new equipment is flexible enough to integrate into the older control system. At some time, a group of sections can be cut over to the new master control. **Figure 1** shows the drive systems described in this paper.

CONCEPT

The major determinants of paper machine downtime for upgrade of a drive system are the amounts of time for removing the existing equipment and replacing with new enclosures, power and control wiring, motors and gear reducers, and operators' controls.

A shutdown replacement program will typically require 10–20 days of lost paper machine production taken in one complete outage. If one can separate the replacement activities into smaller components, it is possible to use the regularly scheduled paper machine maintenance outages for the drive replacements. Such a program can save considerable paper machine downtime. The program described for this mill reuses the existing dc motors and cabling, existing drive control enclosures, and existing power feeds. It incorporates new drive and operator control and diagnostic technologies, tachometer technology, and innovative installation techniques to minimize the installation downtime for the paper machine drive replacement.



1. One-line diagram for #1 paper machine formers

EXISTING POWER DISTRIBUTION SYSTEM

The incoming power source for the drive system comes from a 12.5 kV/480 V supply transformer. This is an uncommon case for power distribution to the individual sections of the drive system.

Each section is fed from a dedicated isolation transformer that is in turn fed from a disconnect switch on a bus duct. The wet end drives' and the dry end drives' bus ducts are connected by power cable. Here the primary of each three phase transformer is 480 V three-wire delta, although the secondaries vary in voltage rating and connection.

Since the power feeders connect directly into the cabinet disconnect switch and the transformer is loop fed from the enclosure, it was simple to disconnect the transformer from the circuit. To avoid "cross talk" and limit the di/dt, reactors were supplied upstream of each power module as part of the drive package.

One concern regarding use of dc drives is the effect of notching and harmonics on the ac power system feeding the dc drives. Isolation and power distribution transformers alleviate this problem, if properly applied. Information regarding this will be available following a power system study and power system measurements taken after installation.

POWER CONVERTERS

When specifying the power modules for the drive upgrade project, this user determined it was necessary to look beyond the immediate need to replace an old drive system and to examine what might satisfy future needs of increasing machine production. Historically, either mechanically modifying the machine or increasing the maximum operating machine speed has accomplished this.

Mechanical paper machine modifications to the machine were not allowed within the scope of this project or budgeted for future projects. The user therefore opted for pushing the machine to its mechanical limits and plans for a future machine speed increase when more funds become available. Having sized the drive modules to meet future needs, the user successfully satisfied his present needs and took a step toward meeting long-term objectives. Proposing a budget that handles relocation costs for a few existing motors, a small amount of new motors, and gears will be easy compared to the cost of a completely new system.

Keeping all this in mind, the project team worked toward sizing for the new drive power requirements. First, a consultant reviewed the machine configuration and performed drive calculations. The data obtained from these calculations compared to machine normal running load data provided conclusions regarding the validity of the existing drive and motor sizes. All existing drive power ratings were adequate or slightly oversized (as **Table I** shows).

The future speed increase would raise the total machine speed by 400 ft/min. All operating criteria and conditions for the future gear-in speed remained constant. Consequently, the present horsepower values were increased by the ratio of the future speed to the present speed. This value then became the benchmark for the new drive power module sizing.

There were attempts to minimize the number of module sizes to accommodate the user's project funding. Ultimately, four module sizes were selected: 30 hp, 60 hp, 100 hp, and 150 hp.

NEW DRIVES CONTROL TECHNOLOGIES

The new drive modules supplied for this project provide all the standard features required for high-speed paper machine and winder control and operation. Their high-speed microprocessors benefit the user in packaging, performance, and diagnostics.

The new drives easily adapt to interface with the older analog master control and reference system because of the flexibility of its onboard I/O and onboard programming capability. With a minimal amount of digital I/O interface, the user can control the new drives from the existing relay logic until the time when all drives within a section can be transferred to the new programmable logic controller (PLC)–based master controller. With the controller in place, the new operator interface can be phased in with larger groups of the new drives.

The operator interface will be significantly different from the existing operator control. Presently, the operator works through several hard-wired push buttons, potentiometers, and analog meters. The new control uses a color touch screen station that eliminates all the hard-wired control previously used except the hard-wired personal safety interlocks. Some hard-wired maintenance I/O will remain. These devices will mount on the machine frame for clothing-related functions.

The color touch screen unit gives the operator a significant amount of information and flexibility that was not available previously. This device is on a high-speed local area network (LAN) communicating with the master controller. All data is transmitted without any noticeable delay experienced by the operator.

Remote I/O modules are being strategically mounted at various points along the machine to facilitate minimal new wire pulls for the interface between the machine logic and the drive control. There is often more than adequate space for mounting these modules in the existing machine control cabinets.

Eight existing drives were upgraded to digital control from the older, analog technology equipment

	Existing drive & motor RPM	HP	Motor HP ratioed up to new gear in speed	Proposed motor HP at new gear in speed	Proposed motor HP for this project	Proposed motor HP for future speed up	Proposed drive HP for this project	Proposed drive HP for future speed up
No. 1 former	1750	25	40	40	25	40	40	40
No. 2 former	1750	25	40	40	25	40	40	40
No. 3 former	1750	40	60	60	40	60	60	60
No. 4 former	1750	40	60	60	40	60	60	60
No. 5 former	1750	25	40	40	25	40	40	40
No. 6 former	1750	25	40	40	25	40	40	40
VR press drum roll	1750	125	200	125	125	125	125	125
1st transfer roll	1750	60	100	75	60	75	75	75
2nd transfer roll	1750	50	75	75	50	75	75	75
1st press bottom roll	1750	75	125	75	75	75	75	75
1st press top roll	1750	25	40	60	20	60	60	60
2nd press bottom roll	1750	100	150	125	100	125	125	125
2nd press top roll	1750	20	30	75	20	75	75	75
3rd press bottom roll	1750	100	150	125	100	125	125	125
3rd press top roll	1750	25	40	75	20	75	75	75
1st dryer	1750	60	100	60	60	60	60	60
2nd dryer	1750	60	100	60	60	60	60	60
3rd dryer	1750	60	100	60	60	60	60	60
4th dryer	1750	60	100	60	60	60	60	60
5th dryer	1750	60	100	60	60	60	60	60
6th dryer	1750	60	100	60	60	60	60	60
7th dryer	1750	60	100	60	60	60	60	60
1st calender	1750	150	250	100	150	100	100	100
2nd calender	1750	100	150	100	100	100	100	100
Reel	1750	75	125	100	60	100	100	100
Dryer roll	1750	15	25	25	15	25	25	25
Dryer exit roll	1750	3	10	10	3	10	10	10
Pull roll	1750	7.5	15	15	7.5	15	15	15
Turning roll	1750	7.5	15	15	7.5	15	15	15
No. 1 coater backing	1750	30	50	50	30	50	50	50
No. 1 coater applicator	1750	10	15	15	10	15	15	15
No. 2 coater backing	1750	10	15	15	10	15	15	15
No. 2 coater applicator	1750	10	15	15	10	15	15	15
Infeed roll	1750	10	15	15	10	15	15	15
Smoothing roll	1750	10	15	15	10	15	15	15
Coater rope drive	1750	20	30	30	20	30	30	30

I. Drives list

used approximately six years ago. These drives have a special interface module that allows them to communicate with the new PLC master via high-speed, remote I/O communications.

The new drive system provides additional operator and maintenance information through an advanced color graphics package installed on a central data gathering computer. The various drive diagnostic packages also use this computer.

PRECISE SPEED AND CURRENT REGULATORS

Almost all drives supplied today include a state-of-the-art microprocessor based drive speed and current regulator. Under normal operating constraints of system voltage levels, frequency, temperatures, etc., the drive will provide 0.001% regulation of top speed over a 100:1 speed range.

All regulators are digital whether one looks at the speed and current regulators in the drive package or the tension regulators that exist in the PLC. This helps to eliminate any long-term drift problems the user previously experienced in the older analog control or variations due to heat.

EXISTING DC MOTORS

Most existing motors at this installation are 1978 vintage General Electric dc motors. They are 500 V dc, splash proof, separately ventilated motors with each speed-regulated motor equipped with a dual output tachometer. New technology tachometers could easily be mounted on these motors with almost no modification and with relative ease. The motors are new enough to have a long life span ahead of them. They have performed reliably for the user.

Investigations of the running loads of the dc motors with the application of the TAPPI drives' calculations led to the conclusion that the existing motors are large enough for the continued operation of the paper machine as presently configured. Future modifications and speed increase of the paper machine will require larger motors in many positions, some of which will only be determined at the time of the machine rebuild.

To increase the size of the drive motors and gear boxes now would be premature and would expose the user to future duplication of costs, if motors of different power and speed ratings are necessary for a future machine rebuild.

There are advantages and disadvantages to reusing the existing dc motors. Following are the advantages:

- Avoids time-consuming removal and reinstallation of motors and possibly gear boxes
- Avoids time-consuming modifications to motor pedestals
- Avoids the costs of new motors
- Provides a reliable motor for startup of the new drives' systems
- Avoids the need for finding space for new and possibly larger motors on the crowded drive side of the wet end of the paper machine
- Avoids the need for modifications to the dc motors' ventilation system and duct work
- Allows the reuse of armature and field wiring between the enclosures and the motors.

Disadvantages would include the following:

- May lack sufficient horsepower to support a machine speed increase program
- Postpones the replacement activities rather than dealing with them immediately
- Requires the continued maintenance and costs of the dc motors' ventilation system and duct work
- Requires the continued maintenance and repair costs of the dc motors
- Eliminates the use of ac drives.

EXISTING MOTOR WIRING

The existing dc motors are presently fed by multiconductor, interlocked armored cable (IAC) routed through cable tray along the drive side of the paper machine. The armature, field, and control circuits are in separate cables.

The routing of the cables within the electrical rooms allows shortening them as they are disconnected from the existing enclosures and reconnected to new drives in the existing enclosures. Location of the new drives is in vacant enclosures that are closer to the points where the cable trays leave the electrical rooms.

The advantages of reusing the existing dc motor wiring are as follows:

- Avoids costly removal and reinstallation of motor wiring
- Avoids the need to make space within the ceilings of the existing electrical rooms for additional cable tray and conduit
- Provides reliable motor wiring for startup of the new drives systems
- Supports the decisions to reuse existing dc motors and existing enclosures.

There are the following disadvantages:

- Lacks capability to supply future larger motors consistent with the larger power supplies being installed now
- Eliminates the use of ac drives.

GEAR REDUCERS, COUPLINGS, AND SHAFTS

Since none of the motors have been replaced at this point, the mechani-

cal portion of the drive train—in-shafts, gears, couplings, etc.—will not be modified. Ultimately, when the remainder of the machine rebuild takes place and the size of the motor is changed to handle future demands, this part of the machine will require extensive investigation and modifications.

NEW TACHOMETER TECHNOLOGY

The tachometer selected for the drive rebuild project has many advantages for the user from an operational and maintenance standpoint. It is a bearingless, couplingless, modular design that mounts easily on the existing older dc machines. These are now supplied for all existing motors.

The tachometer has two main parts: the rotor and the stator. The rotor is a magnetized hub that mounts on the stub shaft of the motor. The stator assembly simply conforms to the motor mounting face. The tachometer has an internal mechanism for setting the correct gap between the rotor and stator sensor.

This tachometer continuously monitors its duty cycle and adjusts to compensate for component drift, temperature changes, and mechanical wear. It provides a fault-check output to notify the drive controller when the adaptive electronics has reached an adjustment limit.

DRIVE CONTROL ENCLOSURE

The project team began with a decision to reuse the enclosures that house the existing regulators, power converters, armature circuits, and overcurrent protective devices. The decision was easy because of the compactness of the new drive module technology. Changes in drive packaging techniques allowed repackaging the components into smaller and complete units. Each module contains the incoming line short circuit fusing, line reactors, power conversion unit, regulators, and output dc contactor. The space required by the modern drive power and control unit is always far less than that of the analog technology it is replacing.

The basic plan was to strip the existing components from each sectional drive enclosure and replace them with a packaged drive premounted on a sub-panel that easily mounts to the channels within the existing enclosure.

Here the dimensions of the lower horsepower drives are small enough to allow mounting two units on a single common sub-panel inside an existing drive enclosure. This frees one enclosure for premounting a drive before the removal of the existing sectional drive components. With one or more enclosures available for premounting of the new drives, the replacement program can proceed with the new drives entering service on successive machine maintenance days. This typically occurs approximately every four weeks.

An important consideration in reusing the existing enclosures is the ability to satisfy the cooling needs of the new drives. Here the room has good air conditioning, and each enclosure has adequate forced air ventilation to meet the needs of the new drive units.

Naturally, starting the program required preparation, since there were no empty enclosures in the wet end drives' room. To free an enclosure, the existing No. 1 former drive was relocated across the aisle. This was possible due to the No. 1 former being out of service for the mechanical repairs.

In the dry end drives room, there were empty enclosures available for mounting new drives before removing existing drives. These became available by a previous project that replaced the dryer sections and first calender section drives with separately mounted dc drives. This has allowed the consolidation of the paper machine drives into one end of the room leaving space for future coater drives and paper machine process computer expansions.

The following listing shows the advantages of reusing existing enclosures:

- Avoids time-consuming demolition and removal of large units
- Avoids costs of new enclosures
- Provides space for staging new drive units before removing existing drives from service
- Provides space for PLC and drives' master controllers
- Allows reuse of power feeders to the enclosure
- Allows reuse of motor wiring
- Allows reuse of field device control wiring
- Allows reuse of tachometer wiring.

There are some disadvantages associated with reuse of existing enclosures:

- Space may not exist within the room to make the initial relocation of an existing drive unit
- Space may not exist within the enclosure to take a replacement drive unit
- Space may not exist to take two replacement drive units
- Sufficient ventilation may not exist for the replacement drive units.

INNOVATIVE INSTALLATION TECHNIQUES

This project shows that innovation is the child of necessity. The need was to maximize the drives' upgrade while staying within a constraining budget and minimizing machine downtime. By incorporating new regulator, control, power conversion, and tachometer technologies, the user has updated the portions of the drives' systems that provided the most operational improvements. By reusing power sources, power feeders, drives' enclosures, motor armature and field wiring, and motors and

Drive location	Proposed motor HP	Day	Date	Type of shutdown	Comments
No. 1 former	40	Wednesday	11/8/95	8 hour field day	Local control
No. 2 former	40	Tuesday	12/5/95	8 hour field day	PLC master
No. 3 former	60	Wednesday	11/8/95	8 hour field day	Local control
No. 4 former	60	Wednesday	11/8/95	8 hour field day	Local control
No. 5 former	40	Tuesday	12/5/95	8 hour field day	PLC master
No. 6 former	40	Monday	10/30/95	8 hour field day	Local control
VR press drum roll	200	Tuesday	12/26/95	Christmas outage	PLC master
1st transfer roll	100	Tuesday	12/26/95	Christmas outage	PLC master
2nd transfer roll	75	Tuesday	12/26/95	Christmas outage	PLC master
1st press bottom roll	125	Tuesday	12/26/95	Christmas outage	PLC master
1st press top roll	40	Tuesday	12/26/95	Christmas outage	PLC master
PLC master		Tuesday	11/8/95	8 hour field day	PLC master
2nd press bottom roll	150	Thursday	2/1/96	8 hour field day	PLC master
2nd press top roll	30	Thursday	2/1/96	8 hour field day	PLC master
3rd press bottom roll	150	Thursday	2/1/96	8 hour field day	PLC master
3rd press top roll	40	Thursday	2/1/96	8 hour field day	PLC master
1st dryer	100	Tues.-Thurs.	4/23-25/96	3 day spring outage	PLC master
2nd dryer	100	Tues.-Thurs.	4/23-25/96	3 day spring outage	PLC master
3rd dryer	100	Tues.-Thurs.	4/23-25/96	3 day spring outage	PLC master
4th dryer	100	Tues.-Thurs.	4/23-25/96	3 day spring outage	PLC master
5th dryer	100	Tues.-Thurs.	4/23-25/96	3 day spring outage	PLC master
6th dryer	100	Tues.-Thurs.	4/23-25/96	3 day spring outage	PLC master
7th dryer	100	Tues.-Thurs.	4/23-25/96	3 day spring outage	PLC master
1st calender	250	Thursday	2/29/96	8 hour field day	PLC master
2nd calender	150	Thursday	2/29/96	8 hour field day	PLC master
Reel	125	Thursday	2/29/96	8 hour field day	PLC master
Dryer roll	25	Thursday	2/29/96	8 hour field day	PLC master
Dryer exit roll	10	Thursday	2/29/96	8 hour field day	PLC master
Pull roll	15	Thursday	2/29/96	8 hour field day	PLC master
Turning roll	15	Thursday	2/29/96	8 hour field day	PLC master
No. 1 coater backing roll	50	Tues.-Thurs.	4/23-25/96	3 day spring outage	PLC master
No. 1 coater applicator	15	Tues.-Thurs.	4/23-25/96	3 day spring outage	PLC master
No. 2 coater backing roll	15	Tues.-Thurs.	4/23-25/96	3 day spring outage	PLC master
No. 2 coater applicator	15	Tues.-Thurs.	4/23-25/96	3 day spring outage	PLC master
Infeed roll	15	Tues.-Thurs.	4/23-25/96	3 day spring outage	PLC master
Smoothing roll	15	Tues.-Thurs.	4/23-25/96	3 day spring outage	PLC master
Coater rope drive	30	Tues.-Thurs.	4/23-25/96	3 day spring outage	PLC master

II. Replacement schedule

gear boxes, the amount of installation costs and machine downtime remained within acceptable bounds.

MINIMIZING THE INSTALLATION DOWNTIME

The primary items contributing to minimizing the machine downtime were as follows:

- Reuse of power sources and power wiring to the drives' enclosures
- Reuse of existing drives' enclosures
- Reuse of existing motor armature, field, and control wiring
- Reuse of existing motors and gear boxes
- Aggressive scheduling by all parties
- Commitment of mill management
- Commitment and active involvement of mill electrical crew and supervision.

In the truest sense, machine downtime has been used rather than minimized. The result has been that the paper machine experienced less scheduled downtime for this method of drives installation than with a conventional drive's replacement project.

This has been accomplished by using scheduled maintenance downtime for drives' installation. It includes the regularly scheduled 8-hour-long maintenance day typically held every three weeks, annual plant outages, and other opportunities that present themselves. **Table II** shows the schedule.

It has been necessary to adopt an

KEYWORDS
Down time, drives, electric drives, machinery, modernization, paper machines, paper making equipment, planning, rebuilding.

aggressive attitude toward scheduling activities and in preparing for the installation opportunities. Each drive must be installed in its selected enclosure, prepared for operation, wired into either local or master control, and thoroughly checked before the cut over day. Accomplishing this has required the unwavering commitment of mill management. It has required following prearranged schedules instead of reacting to unforeseen production outages when preparation is incomplete. In addition, it requires that the project team have preparations completed ahead of published schedules to take proper advantage of unforeseen opportunities.

Active involvement of the mill electrical crew and supervision has accomplished this. They have undertaken the responsibility of planning and executing the section-by-section installation, checkout, and startup of the new drives' system. This has required relocating active equipment, stripping out unused enclosures, preparing the enclosures, installing the individual drives' systems, wiring them, and cutting them over. Their participation has been the key element in making this program a success.

ADDITIONAL CONCLUSIONS AND ADVICE

The importance of cooperation among the supplier, user, and consulting engineer cannot be over emphasized! Each must be committed to the course of action for the program to succeed.

A consequence of this approach is the staggered installation schedule with periods of preparation punctuated by intense, short periods for cut over and startup of small groups of drives. Each partner in the program must devote time periodically to the activities while not running up excessive costs during the preparation periods. Another consequence is the need to control costs and remain in the limited budget available. This is especially true for the engineering staff.

Finally, this approach places burdens on the plant's electrical maintenance and engineering staffs. They must provide capable talent for at least some installation and wiring. They are integrally involved in checkout, startup, and training of the operators. The group has to plan the outages and respond to unplanned opportunities and unforeseen difficulties. They must become users and operators of the new drives' systems long before the installation is complete and fully commissioned. This requires a talented and dedicated group of people. The Jefferson Smurfit maintenance and engineering staffs did this. **TJ**

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Received for review March 7, 1996.
Accepted Aug. 13, 1996.
Presented at the TAPPI 1996 Process Control, Electrical & Information Conference.