EPRI

Printing Press Shutdowns Caused By Sensitivity of DC Drive to Voltage Sags

The Situation

The survival of a newspaper depends upon the timely dissemination of news. If the day's edition reaches readers after rival media sources have delivered their products, then the newspaper content is no longer news. Once the day's edition leaves the editorial offices and enters the press room, newspaper production resembles many other industrial processes—a mechanically and electrically complex system prints, folds, and stacks thousands of newspapers each day. This complex printing process shares another feature with industrial processes: a vulnerability to momentary low voltages (or voltage sags).

A newspaper facility in Baltimore, Maryland was experiencing voltage sags that disrupted the printing presses and cost the newspaper thousands of dollars in lost material, overtime labor, and late deliveries. During a voltage sag, the DC drives that control paper-spool motors would trip and restart, causing paper to tear. In addition, fuses or electronic components in the DC drives would sometimes fail during voltage sags. To evaluate the problem, the supplying utility, Baltimore Gas & Electric (BG&E), installed a power quality monitor at the newspaper facility to determine the severity and frequency of voltage sags.

Meanwhile, to mitigate the effect of voltage sags on the printing process, the newspaper modified the drive-motor circuit by installing a sag-sensing monitor and contactor to initiate a controlled shutdown of the spooling process during a voltage sag. If the process shut down in a controlled fashion, the paper would not tear, and the presses could be restarted within a minute. However, this modification promised to provide *only* orderly shutdown of the printing process; it was not designed to extend the ride-through capability of the equipment.

The newspaper staff and BG&E wanted to test the effect of this modification before fitting it to the remaining DC drives. Rather than waiting weeks or even months for a voltage sag to occur, BG&E asked EPRI's Power Electronics Applications Center (PEAC) to inject voltage sags into the DC drives with a portable sag generator to test the effectiveness of the modification.

Investigative Approach

An investigative team of technical staff from BG&E, the newspaper facility, the printing press supplier, the DC drive manufacturer, and PEAC examined the printing process at the newspaper facility. The newspaper has four printing presses, each fed from 12 large spools of paper. Each spool of paper is powered by a reel tension pastor (RTP) that employs belts to turn the spool of paper. Figure 1 shows an RTP system, which is powered by a 12-horsepower DC motor connected to the utility supply via a 480-volt DC drive.

During normal operation, the RTP system operates at a speed slightly slower than the speed of the press it feeds. This

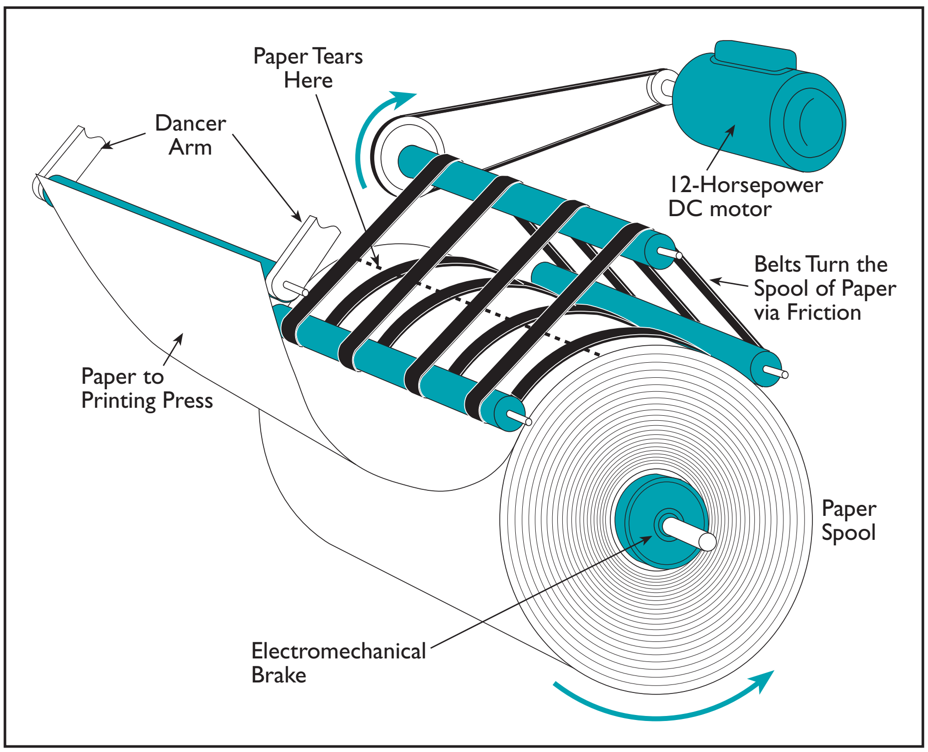

Figure 1. One of twelve RTP systems that feed a single printing press

speed differential provides the proper tension on the paper for feeding the press. The paper is routed past a dancer arm that moves away from the paper if the tension becomes too great.

When a voltage sag or low-voltage condition occurred, the DC drive would trip off-line, causing the motor and the RTP belts to slow momentarily. The motor would approach zero revolutions per minute (RPM) before resuming normal speed after voltage recovery. The sudden slowing in belt speed created friction between the belts and the coasting, high-inertia paper spool, resulting in the paper tearing on the spool.

The sag-sensing monitor and contactor were installed in the RTP electrical cabinet. When the monitor sensed a voltage sag, the contacts between the DC drive and the motor would open, allowing the belts to coast with the paper spool until voltage recovery, and preventing paper tears. Figure 2 shows the configuration of a sag-sensing monitor and contactor.

To test whether the sag-sensing monitor and contactor worked as intended, the investigative team employed the Process Ride-Through Evaluation System, or Porto-Sag, to inject voltage sags into the RTP electrical cabinet. By monitoring the response of the critical process components, PEAC was able to characterize the most susceptible components of the printing process to voltage sags. The investigative team chose to evaluate the success of the modification based upon two criteria: 1) The paper does not tear on the spool and 2) the fuse or electronic components in the DC drive do not fail.

During the investigation, the team discovered that the electromechanical brake, which was fitted to each paper spool, was not configured to activate

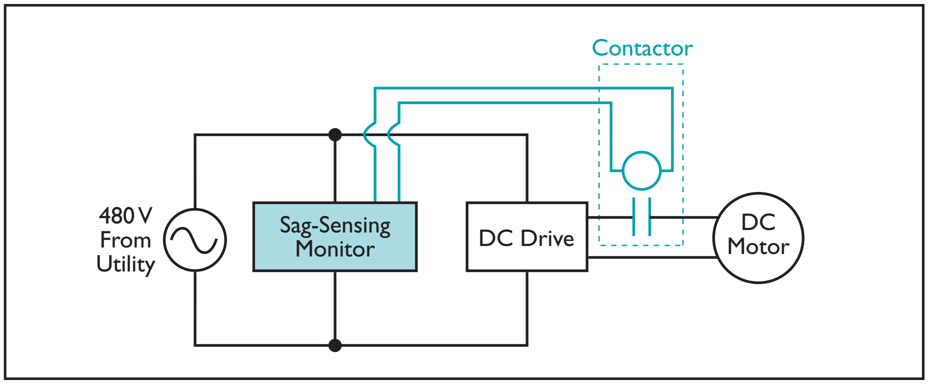

Figure 2. Sag-sensing monitor and contactor installed in the RTP cabinet

during a voltage sag. An electromechanical brake is a common solution to slow a process when a drive trips. The team reasoned that such a brake would slow the spool, further reducing the friction caused when the belts slowed and the paper spool coasted. After the brake was enabled on the spool, testing began.

On-Site Testing

Three-phase, two-phase, and single-phase voltage sags were applied line-to-neutral, beginning at 90 percent of nominal voltage and decreasing in ten-percent steps until a low of 50 percent of nominal voltage was reached. For each magnitude, sag duration was varied from four to 30 cycles. The team then recorded the duration and magnitude points at which the DC drive tripped, as well as the RTP response to the voltage sag.

The RTP system was able to shutdown without tearing the paper during voltage sags of 90, 80, and 60 percent of nominal voltage. However, when a 70-percent voltage sag was injected, the paper again tore on the spool. Further investigation revealed that the DC drive was *more sensitive* to a 70-percent voltage sag than the three-phase sag-sensing monitor. Orderly shutdown could occur only if the sag-sensing monitor detected the sag before the DC drive did.

After injecting several voltage sags and consequently cleaning out old paper and re-threading new, the team opted to continue testing without re-threading paper. The RTP belt mechanism was raised off the spool of paper, and during sag testing the belts were closely observed for speed change. Any sudden decrease in belt speed would indicate a possible paper tear.

In this test configuration, a complete set of voltage sags was injected into the RTP electrical cabinet. Although single- and two-phase voltage sags did not significantly affect the RTP system, three-phase sags did. Table 1 shows the results of three-phase voltage sags on the RTP system. “Controlled Stop” indicates that the sag-sensing monitor reacted to the sag before the DC drive, and the belt mechanism coasted to a gradual stop with no paper tears. “Sudden Pull” represents a sudden change in observed belt speed, indicating that the DC drive was more sensitive than the sag-sensing monitor, which could result in a paper tear.

Although the combination of the sag-sensing monitor, contactor, and electromechanical brake considerably improved the ability of the RTP to come to a controlled stop during a voltage sag, an area of vulnerability still existed during voltage sags of 70 percent of nominal for short durations. The data previously collected with BG&E's power quality monitor showed that a significant percentage of voltage sags occurring at the newspaper were around 70 percent of nominal for short durations. If the RTP was left in this configuration, the newspaper facility would still have to contend with paper tearing. Therefore, BG&E sponsored additional testing at the PEAC laboratory.

Table 1. Effects of three-phase voltage sags with sag-sensing monitor, contactor, and electromechanical brake enabled

Sag Duration (Cycles)	Percent of Nominal Voltage			
	90%	80%	70%	60%
4	No Effect	No Effect	Sudden Pull	Controlled Stop
5	No Effect	No Effect	Sudden Pull	Controlled Stop
6	No Effect	Conrolled Stop	Sudden Pull	Controlled Stop
10	No Effect	Controlled Stop	Controlled Stop	Controlled Stop
15	No Effect	Controlled Stop	Controlled Stop	Controlled Stop
20	Controlled Stop	Controlled Stop	Controlled Stop	Controlled Stop
30	Controlled Stop	Controlled Stop	Controlled Stop	Controlled Stop

Back to the Laboratory

The manufacturer of the DC drive was asked to help set up the drive and motor in the laboratory. Using PEAC's Controllable Dynamic Dynamometer Test Setup (CDS), the team was able to model the newspaper's RTP process and further characterize the ride-through characteristics of a DC drive without disrupting the newspaper's tight printing schedule. The CDS enables PEAC to precisely duplicate virtually any motor load to determine the tolerance of the motor system to electrical disturbances, including voltage sags.

In the RTP system, the belts and large spool of paper represent a high-inertia, low-friction load. The 12-horsepower motor that powers the RTP system is overpowered in order to start the spool spinning from a stopped position. Otherwise, steady-state operation requires only about 17 percent of the total horsepower output to maintain a constant speed. Because the newspaper was interested in preventing paper tears that occurred during normal operation, the team decided to test the DC drive using a constant-torque load to simulate the steady-state operation.

Again, three-phase, two-phase, and single-phase voltage sags were injected into the drive at the same magnitudes and durations that were used at the newspaper site. The speed of the motor was monitored with a frequency-to-voltage converter. Single-phase and two-phase voltage sags of short duration (four to ten cycles) had little or no effect on the motor speed. Longer-duration single- and two-phase sags (up to 30 cycles) did cause a change in motor speed. However, the RTP's dancer arm, shown in Figure 1, could compensate for slight speed changes. Three-phase sags, on the other hand, significantly affected the simulated RTP system, as shown in Table 2.

A representative of the drive manufacturer suggested that the ramp feature incorporated into the DC drive may be causing the problem. When a voltage sag was sensed, the ramp feature was designed to re-accelerate the spool from a stopped condition. It would therefore force the motor to quickly stop before ramping the motor up to its normal speed. The forced slowdown, as shown in Figure 3, increased the friction between the RTP belts and the

Table 2. Effects of three-phase voltage sags on motor speed

Sag Duration (Cycles)	Percent of Nominal Voltage	
	80%	70%
4	No Effect	Sudden Decrease
5	Sudden Decrease	Sudden Decrease
6	Sudden Decrease	Sudden Decrease
10	Sudden Decrease	Sudden Decrease
15	Sudden Decrease	N/A

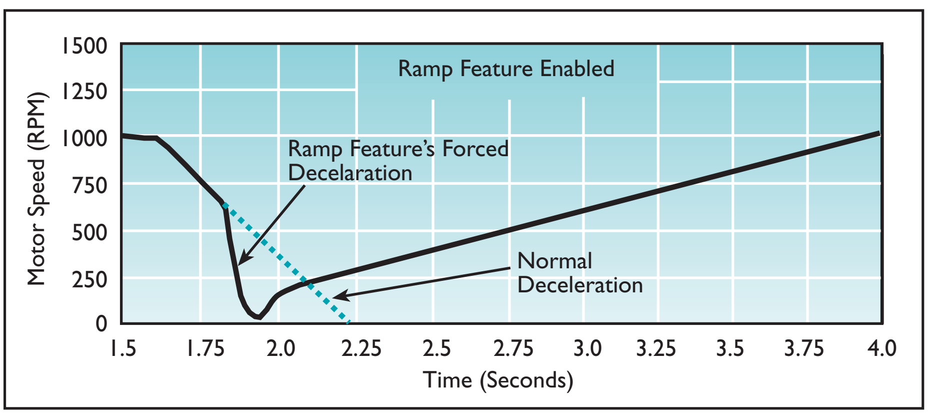

Figure 3. Change in motor speed with the ramp feature enabled during a sag to 70 percent of nominal

paper spool. The drive representative suspected that as the motor speed was forced to zero RPM, the belts were dragging against the coasting paper spool, tearing the paper on the spool.

After disabling the ramp feature of the DC drive, voltage-sag testing was repeated. The results, shown in Table 3, are dramatic. A "Tolerable Speed Change" was defined as a drop from 1000 RPM—the normal operating speed of the newspaper press—to 600 RPM, which, according to the newspaper staff, would not cause the paper to tear on the spool. Figure 4 shows the speed change of the motor with the ramp feature disabled.

Table 3. Effects of three-phase voltage sags on motor speed after disabling the ramp feature

Sag Duration (Cycles)	Percent of Nominal Voltage		
	90%	80%	70%
4	No Effect	Tolerable Speed Change	Tolerable Speed Change
5	No Effect	Tolerable Speed Change	Tolerable Speed Change
6	No Effect	Tolerable Speed Change	Tolerable Speed Change
10	No Effect	Tolerable Speed Change	Tolerable Speed Change
15	No Effect	Tolerable Speed Change	Tolerable Speed Change
20	No Effect	Tolerable Speed Change	Tolerable Speed Change
30	No Effect	Tolerable Speed Change	Tolerable Speed Change

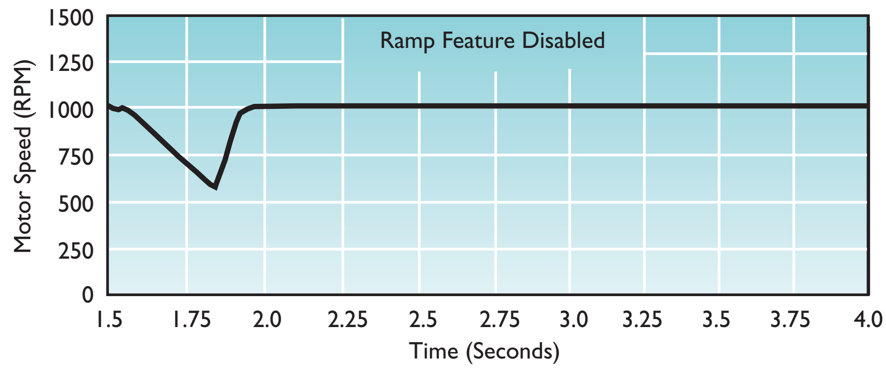

Figure 4. Change in motor speed with the ramp feature disabled during a sag to 70 percent of nominal

Conclusion

The newspaper's goal was to reduce the frequency of paper tears caused by voltage sags. The sag-sensing monitor, contactor, and electromechanical brake were intended to shut down the RTP system in an orderly fashion without tearing paper. However, this modification was only partially successful, leaving the printing press still vulnerable to voltage sags at 70 percent of nominal. After successfully creating a model of the RTP system in the PEAC laboratory, the team was able to determine that the ramp feature of the DC drive was contributing to the paper-tear problem.

The team recommended that the newspaper install sag-sensing monitors and contactors, engage the electromechanical brake, and disable the ramp feature of the DC drives on several of the RTP systems in the press room. Because no power-conditioning equipment was necessary, the cost to the newspaper would be relatively low.

Using both field-investigation techniques and laboratory testing, the investigative team was able to troubleshoot the problem and recommend a solution without disrupting the time-sensitive mission of the newspaper. The results of the investigation will also enable the newspaper facility to specify voltage-sag performance for any equipment purchased in the future. This Case Study demonstrates how electric utilities can work with manufacturers to reduce costly process interruptions.

Key Terms: Printing Press, DC Drives, Paper Tears, Voltage Sags

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