PQ Case Study

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ELECTRIC POWER RESEARCH INSTITUTE

Addressing Power Quality Issues at a **Foam Manufacturer**

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ABSTRACT

A foam manufacturer desired to improve the response of its processes to power quality events experienced at the plant. The utility supplying power to the plant asked EPRI to investigate and recommend solutions. EPRI engineers recommended control-level solutions as well as parameter changes for adjustable-speed drives (ASDs).

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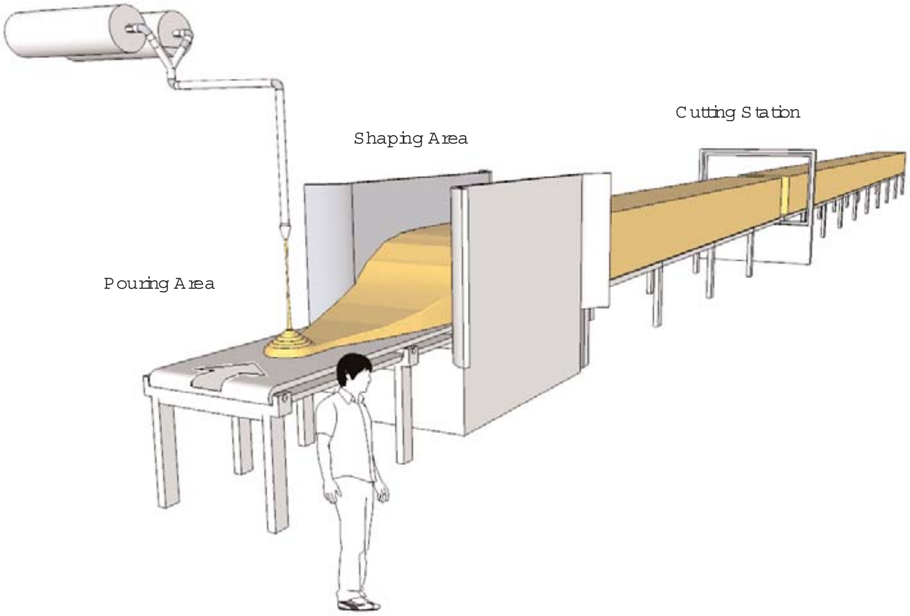
Addressing Power Quality Issues at a Foam Manufacturer

INTRODUCTION

What happens when a foam run suddenly stops due to a power quality event? Basically, around 1300 cubic feet of hardening foam pile up in a big, costly mess. Not only is the product lost, but the foam pile—occupying much of the production area and covering parts of the foam-pouring machine—monopolizes time and resources required to clean it up before any more product can be manufactured. As illustrated in **Figure 1**, the process involves tanks of fluids that mix to produce the foam, a nozzle that directs the expanding foam onto a moving plastic sheet riding slowly on rollers, and a shaping section for the slowly-moving, expanding and hardening foam. The expanded foam becomes a "bun" 150 feet long, 3 feet wide, and of varying feet in height. Should the process shut down, the rollers stop and the expanding foam runs out of the piping at the front of the foam-pouring machine. The worst time for such a process shutdown is at the beginning of foam pouring because, once mixed, the expanding foam cannot be stopped.

Figure 1. The Foam-Pouring Process



The other major process at the facility involves a large cutting and shaping machine, shown in **Figure 2**, that trims the foam bun to its final dimensions. The bun feeds into the structure where the ends are joined with adhesive to form a large loop. As this loop spins around the shaper in the direction indicated in Figure 2, cutting blades shave off the sides to achieve a consistent dimension. Finally, the loop is cut, removed from the shaper, and sent to a storage area prior to shipping, as shown in **Figure 3**. While not as disastrous as with the foam-pouring operation, sudden shutdowns due to voltage sags have resulted in re-trimming and some lost product.

Figure 2. The Shaping Process

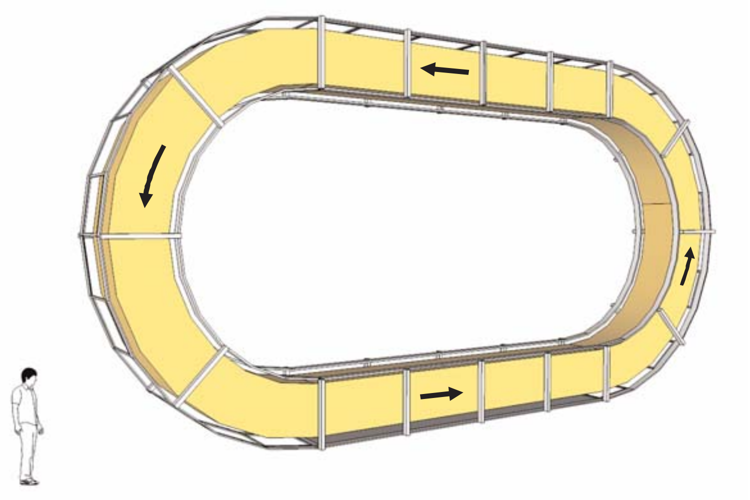


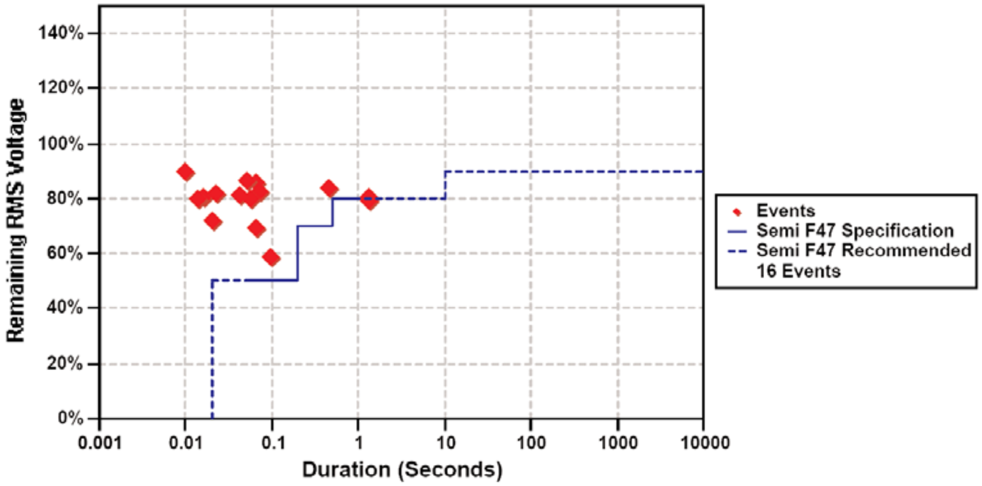
Figure 3. Finished Foam

BACKGROUND

The foam manufacturer wanted to improve the pouring process so that at least the horrendous clean-up headache would go away. What caused the problem in the first place? Usually voltage sags. The manufacturer thought it might be power outages—same thing, right? Not quite.

Fortunately, a power quality meter had been installed at a different facility nearby. The data (shown in **Figure 4**) reveal that, of 16 power quality events, all were voltage sags, only one being outside the SEMI-F47 performance curve—and not by much. Therefore, if the processes in the plant had been SEMI-F47 compliant, only one power quality event would have been expected to have had any effect at all. Many processes at the plant, foam-pouring in particular, were not SEMI-F47 compliant.

Figure 4. Power Quality Data



What causes voltage sags? Any number of events may result in a voltage sag. A very large motor starting up will cause the voltage at points nearby to drop. Lightning strikes can cause voltage sags some distance from the line that was hit. Line operations due to lightning and fault-clearing operations result in momentary voltage sags. Capacitor switching events cause voltage sags. The SEMI-F47 standard came about in response to the increasing sensitivity of modern industrial equipment. Of the data shown in Figure 4, all but one sag occur above the SEMI-F47 curve. Therefore, any processes compliant with the standard would be unaffected by these sags.

PROTECTING CONTROL CIRCUIT SENSITIVE LOADS

The affected processes included the previously described foam-pouring and -shaping operations. Also affected were the cut-off process at the end of foam pouring, where the hardening foam bun was cut in 150-foot lengths, as well as a conveyer that moved the newly cut segments out of the way. The shaper had two areas of suspected sensitivity: the shaper itself and its main control panels. **Table 1** shows the affected areas and suspected reasons for susceptibility.

Table 1. Areas Affected by Voltage Sags

Area	Equipment	Reason for Susceptibility	Cycles	% Vnom	Control-Power Transformer kVA
Foam Pouring	Main Control Cabinet	AC Ice Cubes	1	65%–70%	7 kVA
Foam Pouring	Auxiliary Cabinet	AC Ice Cubes	1	65%–70%	3 kVA
Cut-Off	Cabinet 1	General Controls	1	60%	.13 kVA
Cut-Off	Cabinet 2	AC Ice Cubes	1	65%–70%	2 Units 0.2 kVA and 0.15 kVA
Conveyor	Conveyor 2	AC Ice Cubes (but not critical)	1	65%–70%	Remotely Powered
Finishing	Shaper	AC Ice Cubes	1	65%–70%	Powered from Main Cabinet
Finishing	Main Control Panels	Siemens S7-400 PLC	1	50%	3 Units 1.0 kVA, 0.51 kVA, 1.0 kVA

What makes a process susceptible to variations in power quality? In responding to power quality problems, manufacturing processes reveal a typical gang of suspects. This case proved no exception. The source of the sensitivity may typically be found in the control circuitry. **Figure 5** shows a typical motor-control circuit. The problem often turns out to be the control relay, CR. Should CR be a 24-Vac or 120-Vac "ice cube" relay, as shown in **Figure 6**, it will simply open when the voltage drops to between 60% and 70% of nominal for as little as 1 cycle—even for a fraction of a cycle. When CR opens, the emergency stop circuit appears to open, as if the emergency stop button were pushed. Should any other relay in a control circuit be of the 24-V or 120-Vac ice cube variety, a similar opening will likely happen for such a voltage sag, and the process controlled by the relay will stop.

Figure 5. Typical Motor Control Circuit

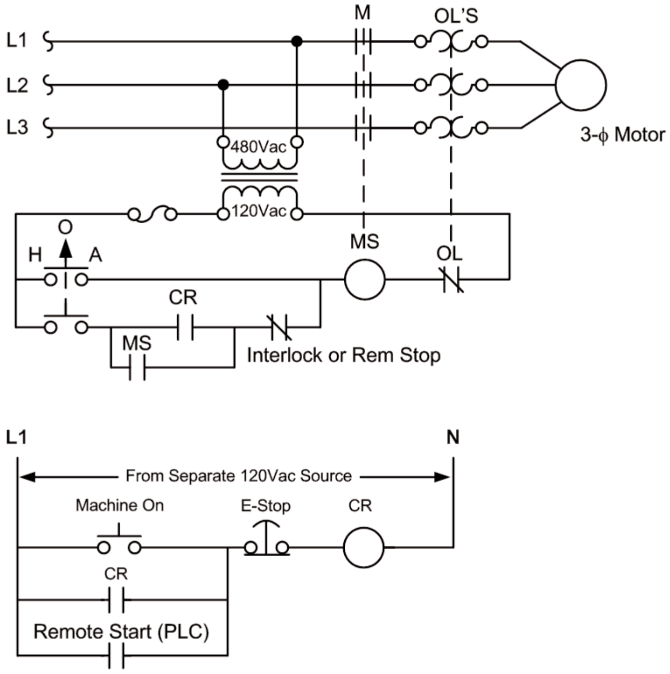
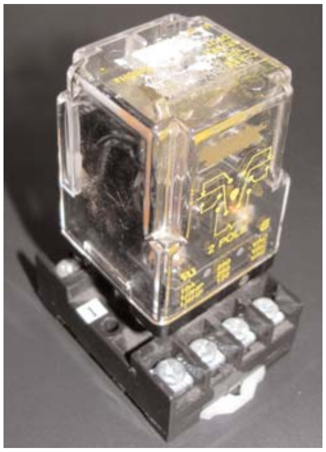
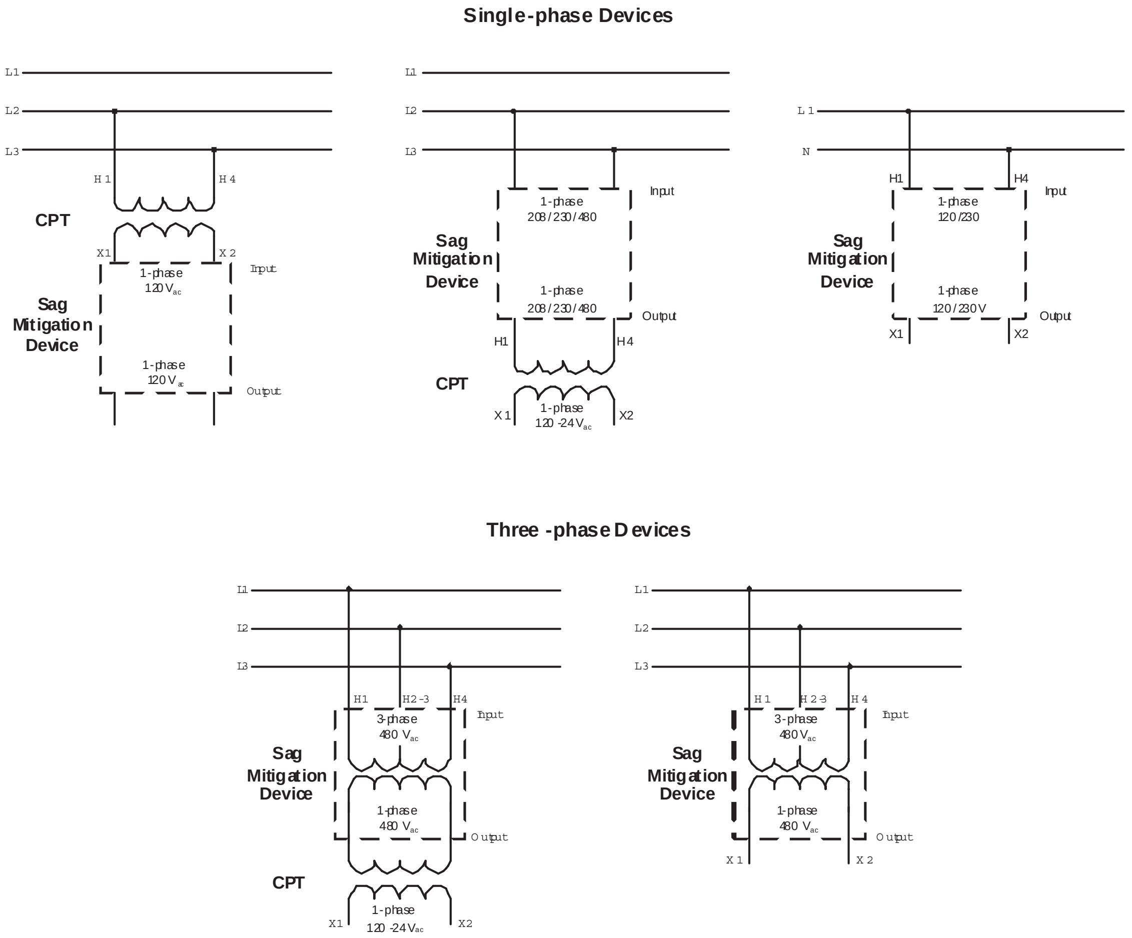


Figure 6. Typical Voltage Sag–Susceptible AC Ice Cube Relay



Two common mitigation methods involve either protecting the CR relay or the control-power transformer (CPT) powering the relay. Some CPTs allow tap changing to boost the available voltage at the secondary, which may make a mitigation device unnecessary. Coil hold-in devices may be connected to a 120-Vac relay to supply it with enough power to keep the coil energized through most commonly experienced voltage sags. However, such devices are not available for 24-Vac relays. In this case, or if the 120-Vac relay may not be protected using a coil hold-in device, the CPT may be protected or even replaced using a number of devices such as the constant-voltage transformer (CVT), a voltage-dip compensator (VDC), or a dynamic sag corrector (DySC). The power ratings of sag-mitigation devices should match that of the CPT except for the CVT—its rating should be at least double that of the CPT. Typical configurations are shown in **Figure 7**.

Figure 7. Typical Sag Mitigation Configurations



Another source of vulnerability for industrial processes, in this case, the shaper machine, is the ASD. Adjustable-speed drives show vulnerability to power quality problems, but many have the advantage of being programmable to achieve a level of robustness. Modifying several parameters in the drive will enable it to ignore some common power quality effects.

Figure 8 shows a panel layout featuring the PowerFlex 70 and ice cube relays, while **Figure 9** illustrates a typical ASD schematic.

Figure 8. Sensitive Components

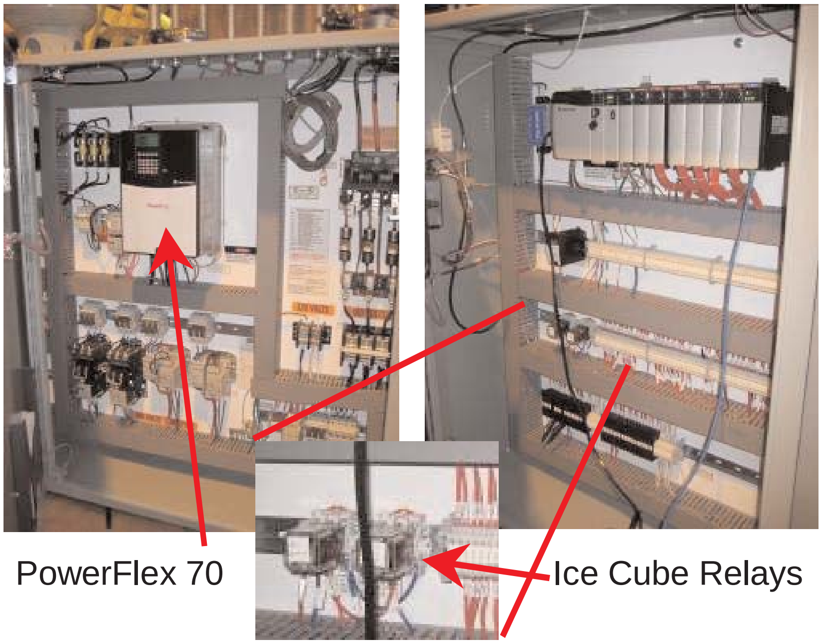


Figure 9. The ASD

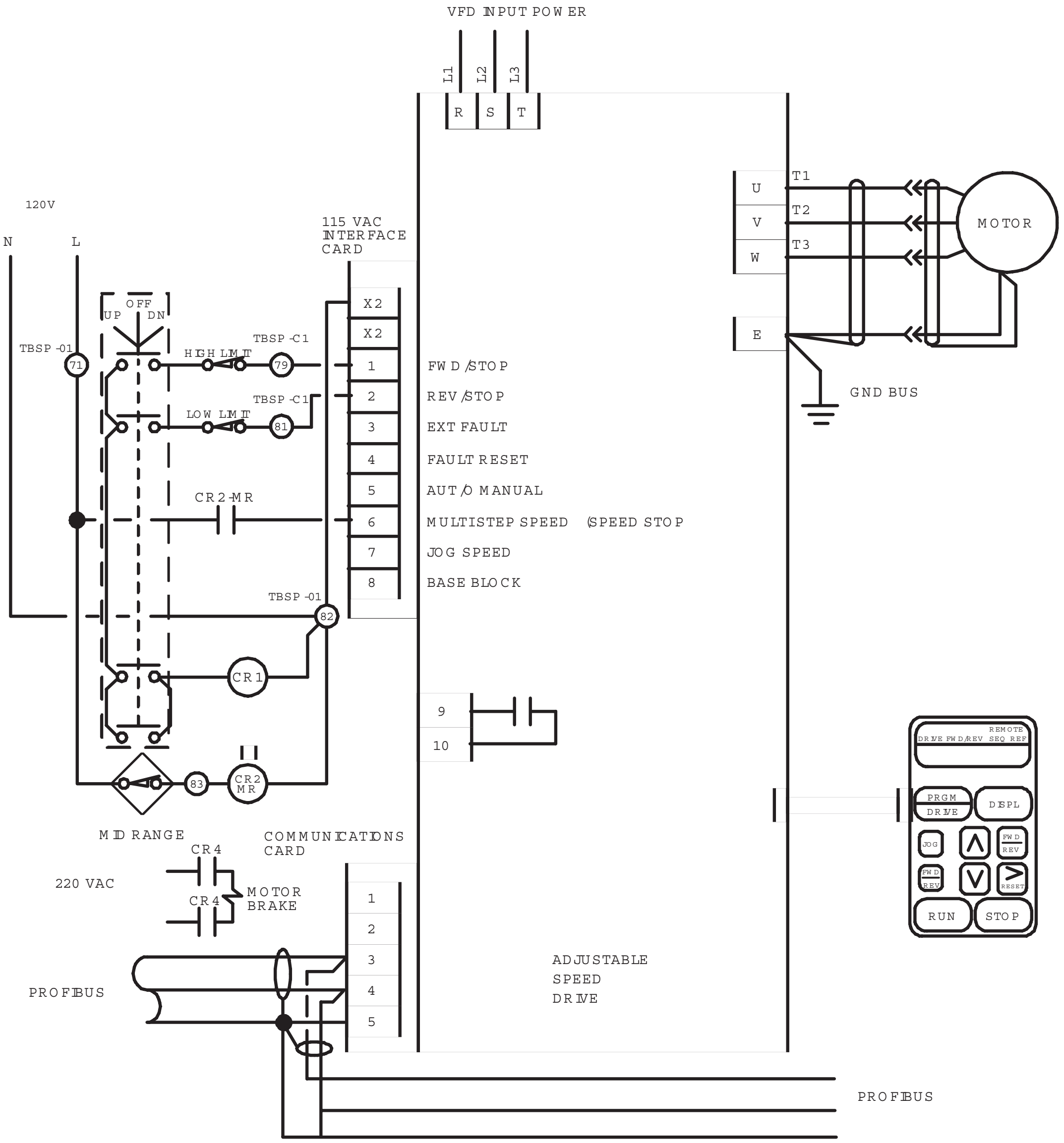


Figure 10 with an inserted table shows the parameter changes that will allow the ASD to ride through common voltage sags. Figure 10 shows the PowerFlex 70 Drive and a relevant page in the manual for some of the parameter changes possible.

Figure 10. PowerFlex 70

Undervoltage trips at 300 Vdc.

Function **169** enables the ability to restart. This command, when enabled, will reconnect to a spinning motor. Suggest enabling.

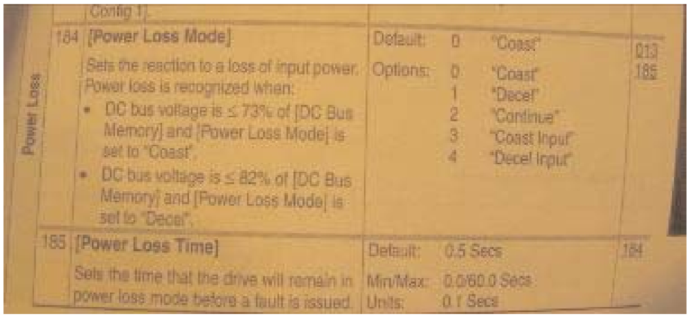
Function **174** gives the amount of tries that the drive will attempt (0-9) . Suggest setting =1 or greater

Suggest setting pump Voltage Sag Settings to:

Restart Mode

SET **P184** = "DECEL" OR "Continue"

Drive is Compliant to SEMI F47



Power Loss		Config 1].		
	184	**[Power Loss Mode]** Sets the reaction to a loss of input power. Power loss is recognized when: • DC bus voltage is ≤ 73% of [DC Bus Memory] and [Power Loss Mode] is set to "Coast". • DC bus voltage is ≤ 82% of [DC Bus Memory] and [Power Loss Mode] is set to "Decel".	Default: 0 "Coast" Options: 0 "Coast" 1 "Decel" 2 "Continue" 3 "Coast Input" 4 "Decel Input"	013 185
	185	**[Power Loss Time]** Sets the time that the drive will remain in power loss mode before a fault is issued.	Default: 0.5 Secs Min/Max: 0.0/60.0 Secs Units: 0.1 Secs	184

Due to a lack of pertinent drawings, the specific source of power for all areas listed in Table 1 could not be determined. One assumption was that all areas received power from the 150-kVA transformer in the main control cabinet located in the foam-pouring area. Should that be the case, then all areas could be protected with a mitigation device of similar size connected to the transformer. While a significantly more expensive solution in terms of equipment cost, it would involve less wiring, labor, and downtime for individual production areas. A far less expensive solution would involve the application of smaller mitigation devices in the areas listed in Table 1. While the equipment costs would be less expensive, this solution would require more wiring, labor, and individual process downtime.

OTHER RECOMMENDATIONS

The foam overflow problem, however less likely with respect to the suggested control-power protections and ASD parameter changes, would prove so costly in time, clean-up, and lost product that further measures to remedy the problem may be worth consideration—especially in the event of an actual power outage rather than a voltage sag. Specifically, a better route for the overflow should be considered. EPRI engineers suggested an alternate path consisting of a manually-operated valve installed just before the nozzle that directs the foam onto the moving plastic sheet. Piping connected to the valve would route the foam to another less inconvenient location—perhaps into a container or platform that would allow a speedier disposal of the waste foam.

While this proposal would seem very reasonable given the circumstances, it remains to be determined whether or not it would be feasible. Presuming a better location existing nearby, and presuming the by-pass valve and piping connections to be possible and in place, the expanding foam may simply clog the by-pass pipes and back up and run out onto the foam-pouring machine anyway. Should this scheme prove possible, a cost analysis should be performed to determine the economic practicality of such an undertaking. One would expect that the cost of diverting the foam in this way would be much less than the cost of clean-up and associated downtime.

The voltage sag mitigation suggestions, however, may render the foam by-pass suggestion unnecessary, because the shaping and conveyor system that functions despite power quality variations will continue to shape and move the foam away from the foam-pouring area.

CONCLUSIONS

The good news is that changing the parameters for the ASDs will allow them to ride through the common voltage sags and will incur no equipment costs. The manual for each drive should be consulted, the required parameter identified, and the correct value entered.

The more costly news is that two approaches will provide adequate voltage sag mitigation—protecting the control-power transformers for the foam-pouring, foam-cutting, foam-shaping processes or protecting the foam-pouring three-phase transformer.

The cost of voltage sag mitigation—hardening the control-power transformers at the five CPT locations—will be approximately $14,600 USD. Protecting only the three-phase transformer powering the foam-pouring machine, thus protecting any other loads on that transformer, will cost approximately $41,000 USD. The worst case—should only the foam-pouring processes be protected in this way—would mean providing control power protection for the cut-off, conveyor, and shaper CPTs, for a total of around $50,000 USD. These costs do not include required wiring, conduit, panels, or labor.