PROTOCOL ARTICLE REPRINT
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Rigging control system safety

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Automated rigging systems provide increased safety and reliability

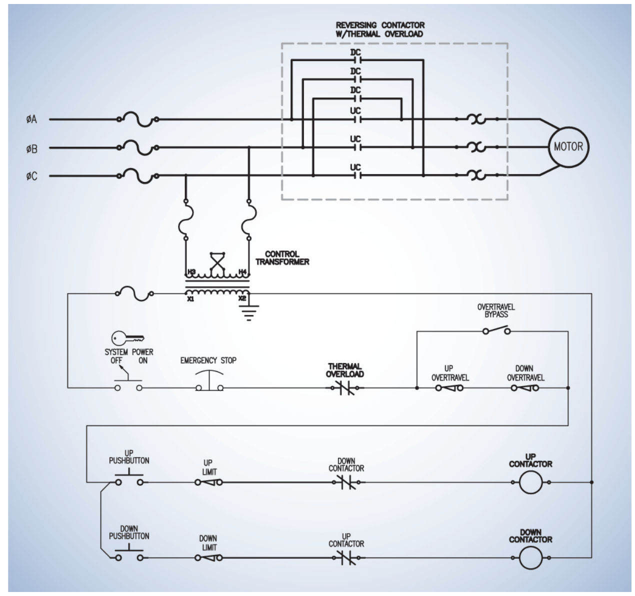

Figure 1

IN THE PAST FEW YEARS there has been a tremendous shift from manually operated counterweight systems to automated rigging. New motorized rigging systems and controls are affordable for schools, community and regional theatres, bringing automation to users who do not have prior experience with this level of equipment.

Being able to program scenery movements is attractive, and can improve backstage safety. But, we have lost the feel that comes from operating the hand line of a counterweight set. This has to be replaced with new safety measures and control system reliability.

Standards

There is no US standard that specifically covers safety in theatrical rigging control systems at the moment. ESTA's E1.6-1, Powered Winch Hoist Systems, is well along in its development, but is not complete. The ASME B30-16, Overhead Hoists (Underhung), covers industrial hoists, but says little about controls. NFPA 79, Electrical Standards for Industrial Machinery, contains a great deal of relevant material and closely follows EN60204, Safety of Machinery – Electrical Equipment of Machines.

Based on many years of rigging control systems design, and working with these standards, there are some key points that must be taken into consideration.

The basics

Most hoists use a three-phase motor. If the motor is connected to the three phases in A – B – C order, it will rotate in one direction. If the phases are reversed to C – B – A, it will rotate in the opposite direction. A basic starter (shown in **Figure 1**) has two three-pole contactors that can feed the motor in either A – B – C order ("up" in this example) or C – B – A ("down"). Auxiliary contacts are connected to the control circuit so that you cannot operate both the up and down contactors at the same time. (If you could operate them both at the same time the phases A and C would be connected to each other creating a spectacular short circuit!). Typically there is also a mechanical interlock between the two contactors that assures both cannot be closed at the same time. This is usually stated in specs as "contactors shall be electrically and mechanically interlocked."

Normal travel limit switches are shown, connected so that the up control circuit is disconnected if the up limit travel has been struck. This lets you move down once you have hit the upper limit, but prevents you from driving beyond the upper limit. The down limit is connected in a similar manner.

In the simplest system, the emergency stop button cuts power to the up and down push buttons, disconnecting the control circuit. If either the up or down button were to jam or short circuit, the E-stop would stop motion.

Reality

All this looks great, and works adequately, but, we have to interject a little reality to this picture. Failures can happen. How the control circuit works in an abnormal mode is every bit as important as how it works under ideal conditions.

First, what happens if a normal travel limit switch fails? As shown above, this should be wired as a normally closed circuit so that any loose connections or cut wires will open the circuit and stop travel, but, if the conductors become shorted, or the switch fails mechanically, motion will continue.

It is also possible for contactors to jam or weld closed so the hoist will continue to run regardless of operator commands. Control wiring could short, allowing the hoist to run regardless of the pushbuttons or E-stop. Or, a limit switch could fail as described above. Any of these simple, single failures will create a situation that endangers life and property. The simple starter shown above has no way of coping with any of these situations. The E-stop that cuts control power is of some help, but is not effective in the case of a short in the control circuit or a welded contactor. Unfortunately, this type of control system is still being manufactured and installed.

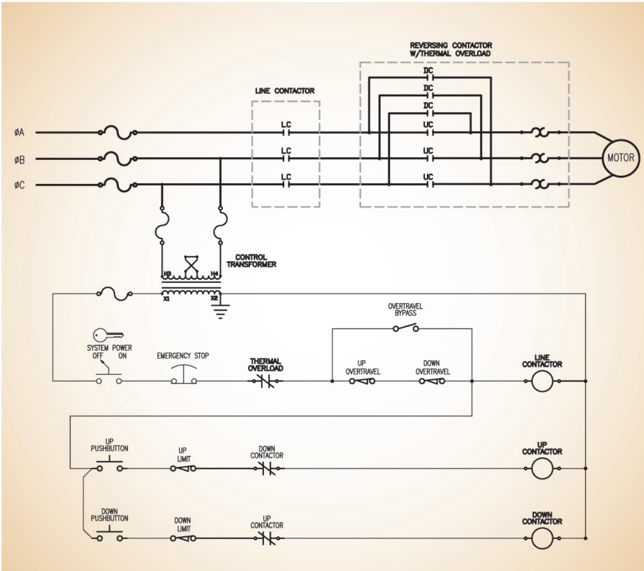

Figure 2

Redundancy to the rescue

The first corrective step is to use non-welding, positive break contactors. This solves the welding problem, but not a failure in the control wiring. The second step is the use of overtravel limits, which are triggered if the hoist moves beyond the normal travel limit switches. These are wired into the E-stop circuit, so that travel in either direction is cut, letting the user know there is a real problem that must be fixed.

The next step is to use a positive break line contactor ahead of the reversing contactor (see **Figure 2**). This is controlled by both the overtravel limit switches and the E-stop. Now we have a redundant system with two completely separate circuits that operate independently of each other, adding essential security. This second level of security provides effective stopping in the event of a single mode failure.

This meets the NFPA 79-2007 requirement that, “Final removal of power to the machine actuators shall be ensured and shall be by means of electromechanical components.” Systems that use control electronics to tell a drive to stop running depend on all the electronics operating correctly. If you are in an emergency stop situation it may be that the electronics are not operating correctly. You need the assurance of a separate E-stop circuit that physically removes power by opening hard contacts.

Variable speed hoists

Variable speed hoists offer much more versatility, and the opportunity for more dramatic scenic movement than fixed speed hoists. The starter is replaced by a variable speed drive (typically a vector drive) rated for hoisting duty. Variable frequency drives can be used, but vector drives provide superior control. Types and applications of variable speed drives could easily fill another article!

Higher speeds also present more control challenges. If you hit the E-stop on a fully loaded hoist moving at 240 fpm, an immediate hard stop will create stresses on the scenery (and the building structure) that can cause mechanical failures. This can be helped by the use of a Category 1 E-stop, (as defined in the NFPA 79, *Electrical Standards for Industrial Machinery*). This is a very fast ramped stop, followed by a hard stop (cutting power to the hoist as described for fixed speed hoists). If the variable speed drive is working, the ramped stop reduces the risks of a hard stop. If the drive is not functioning, motion will stop with a hard stop. This is an important safety feature, and should be included on all high speed hoists.

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Deadman operation

Control systems being used in productions with live talent need to use hold-to-run switches for all motion control. You really need to have a live operator actively monitoring all movement, in conformance with NFPA 79, *Electrical Standards for Industrial Machinery.*

There are still some push and run systems being manufactured, which allow motion without an operator being present at a control station. Some of these rely on load sensing to prevent damage or injury. These need to be reviewed carefully, as most load sensing systems require the batten to strike something (or someone) before the load sensing reacts. This approach has a higher risk of accident or injury than a hold-to-run system.

Components

The backstage environment is electrically noisy, with dimmers and motor controllers creating electro-magnetic interference (EMI) and radio frequency interference (RFI). Control systems need to be rated for industrial usage to ensure safety and reliability. Home or consumer grade electronics have no business backstage as they do not provide the noise immunity or reliability required for hoisting overhead.

Programmable Logic Controllers (PLCs) are widely used in European rigging consoles, and in some US manufacturers consoles (including all J.R. Clancy consoles) due to their reliability in real world applications. PLCs are widely used in passenger elevator controls, traffic control, and industrial production lines, where safety and reliability are essential. When you are looking at control systems that will be operating overhead of people, you need to consider the technology and associated risks. ■

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