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Intelligent Drives Put Safe Motion on Board

Faster Safety, More Productivity

As motion-based machines have an increased number of axes running at higher speeds and faster accelerations, the requirement to make machines safer is being driven both by competitive pressures and regulations. The days of interlock switches on guarding as the primary safety mechanism are long gone. Operators often need access with open guards during setup or for clearing jams or other malfunctions. As a result, safety considerations require that motion be *controlled* at safe limits when guards are open to prevent injury to personnel and secondarily, damage to equipment. Essentially, safe motion is the most important type of safety because it directly affects the movement of the machine.

Consider, for example, what happens if a stacking sequence is out of order or if the product is misaligned when a palletizing robot is moving several hundred pounds back and forth to the pallet. Fixing the malfunction requires an operator to be inside the protective guarding with the machine on. However, it must be running slowly and at limited torque with other axes held motionless as the operator jogs one or two axes at slow speed. Similarly, setup and workpiece inspections or clearing machine jams may require that axes be held at a safe standstill while other axes are safely jogged at low speeds by an operator inside the work envelope.

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Drive-Integrated Safety Speeds Reaction Times, Reduces Costs Over PLCs

Given the speed of equipment, safety devices must react quickly to a fault, either bringing equipment to a stop or to safe operating speeds. High axis acceleration on the order of 1 m/s^2 means that full speed will be realized in a fraction of a second. Therefore, emergency devices must react in milliseconds.

One approach to safety is to use discrete external circuits and controls to limit motion. This approach has several drawbacks. It increases the complexity of design through the addition of an extra safety layer. It often results in a “non-standard” solution to meet requirements of the user. Finally, it’s an add-on solution that is not necessarily optimized for best performance.

Modern, intelligent safety solutions are often associated with safety PLCs that replace conventional hard-wired safety relays. But safety PLCs still present a delay in reaction times, due to the PLC scan rates and the path from sensor to PLC and back. Alternatively, putting the safety responsibility in the drive and allowing autonomous monitoring overcomes this drawback.

Autonomous monitoring allows very fast reaction times, without the delays between drive and controller. Faster reaction times correspond directly to reduced axis movement. With contact-based verification, by the time an operator in a protected zone has managed to respond to an error a linear axis with roller ball spindles can move about four to eight inches, and linear motors as much as 31 inches. In contrast, the integrated Safe Motion™ technology in the Bosch Rexroth digital IndraDrive, for example, detects the error within just 2 ms and limits the axis moves to just 2 mm (Figure 1). Such fast reaction times - up to 400 times faster than a controller-based solution - dramatically demonstrate the advantages of putting safety control closer to the action.

The Rexroth IndraDrive with safety on board integrates the safety function directly into the intelligent drive. The PLC or CNC is not needed, and the drive's footprint remains the same. Safety functions take up no extra space. Unlike conventional approaches to safety, drive-based safety technology requires no contactors on the main power or motor power lines, needs no additional external speed-monitoring devices, and operates independent of any supervisory control system. In addition, drives with safety on board save costs by eliminating hardware and wiring for additional I/O.

Distributed Intelligence Is the Key

The advances in microelectronics make it practical to move the processing power outward: into sensors, motors, drives, and other components. The mantra of electronic intelligence is "smaller, faster, cheaper"—meaning you can now pack considerable processing power and memory into a small space very economically.

In simple cases, this intelligence is rudimentary. A sensor, for example, can consolidate information about temperature trends and even send an alarm if thresholds are exceeded. In other cases, the intelligence can be sophisticated. An intelligent drive can do all the complex camming, monitoring, and other processor-intensive functions. The processing power is sufficient enough to provide all control and housekeeping functions of the driven axis and to synchronize with other drives. The central PLC becomes a supervisor, watching over all the axes, initiating recipes/job parameters, and communicating upwards in the factory network.

Simply put, the difference between centralized and distributed intelligence is that:

- With centralized intelligence, finite processing power is divided among all axes. The processing power available for each axis diminishes as axes are added.
- With distributed intelligence, processing power is added each time an axis is added. The processing power available for each axis remains constant (since it resides in the axis itself).

The same intelligence applies to machine safety, where putting the intelligence in the drive allows it to handle the safety functionality. Hardware-based intelligence is becoming a commodity. Much of the real progress is in software/firmware to direct and inform the intelligence—intelligent monitoring of conditions and effective routine to achieve safe operation.

Flexible Safety

In the case of the Bosch Rexroth intelligent IndraDrive, the following safety functions can be selected directly at the drive:

- Safe standstill
- Safe operational stop
- Safe drive interlock
- Safely reduced velocity (speed)
- Safely reduced maximum velocity
- Safely limited increment
- Safely limited absolute position
- Safe direction of movement
- Safely monitored stopping process
- Safe control of protective doors
- Forced dynamic sampling
- Safe brake management

While many solutions offer "safe stop," key to safe operation is a *controlled* stop. Rather than simply removing power to stop motion, Safe Motion technology in the drive controls the motion so that stopping is both expeditious and orderly.

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Depending on the cause, the drive can decelerate an axis at the best possible speed, or at the fastest speed. Drives can be de-energized to remove all torque, or they can be held in position under energy to allow jogging at safely-reduced speeds.

All safety-related information is transmitted and processed by two independent channels. The basic control unit of the drive is the primary channel. The secondary channel is an optional safety module. The two channels constantly compare data to ensure that the correct safety parameters are in place. Any deviation in the comparison results in an error. The drive goes into the safety mode. Axes are brought to a safe standstill. This cross-checking of two channels makes is easy to detect the following problems:

- Safety function activated on only one system
- Wrong safety function activated
- Different monitoring parameters used
- Safety function does not work
- Accidental hardware errors
- Accidental software errors

Dual-Channel Monitoring

A machine can be set for safe operation via the dual channels (Figure 2) directly at the drive by changing the position of the operating mode switch from normal to special operating mode. As soon as all the selected drives have switched independently to safe status, a drive that has been defined as the master enables holding the protective door open so that the operator can enter the protected area without danger for testing or inspection. Thus, the machine builder saves himself the implementation of power protection in the network or motor feed areas. For the use of robots (such as the palletizer mentioned earlier) with this drive, it is no longer necessary to move to a particular safe position before the processing area can be accessed. The operator can switch to the special operating mode from any position. The drives remain in position-monitoring mode.

Once at a safe standstill, axes can be jogged at safely-reduced speeds to allow maintenance, troubleshooting, repair, or setup. If axes carrying heavy weights are located in the access area, dropping is an additional danger. After a request for access, the drive tests the corresponding stopping brake function before enabling the protective door to be held open. While someone is underneath the axes, the safe operation stop and the tested brake both operate in parallel so that redundant stopping systems prevent uncontrolled falling of the axes.

With access request signals, which are connected redundantly to the drives, multiple safe velocities or movement increments can be made. Monitoring of the limits using redundant software and hardware modules occurs inside the drive, so no additional rotary velocity measuring system is needed. The operator does not have to use external measuring systems and monitoring equipment, which are only appropriate for certain highly dynamic movements because of their switching delays. The safely reduced maximum velocity can be permanently activated as a protection for a machine.

Printing rollers, for example, must be limited in their maximum rotary velocity, since the centrifugal force can cause danger. The use of Safe Motion eliminates the need for special mechanical devices like torque-limiting couplings, as well as additional velocity measurement devices. For applications that have protection for only one rotational direction, such as a glue-feed roller, the safely-reduced velocity can also be combined with the safe rotation direction. In order to restrict areas within the open protected area (for example, in robot applications), a safe absolute position range can be pre-set for each axis. Likewise, the safely-limited absolute end position can be permanently active as a machine protection and can therefore take over the function of hardware end switches or position cams for detecting the area.

Productivity Benefits

The push for productivity demands that machine downtime and setup time be minimized. One advantage of drive-integrated safety is that it allows the machine to be returned to normal production in the shortest possible time. Because power does not have to be removed from the drive, the drive can return to work without waiting for capacitors to recharge or for the operator having to recover from an emergency stop condition. And since there is no loss of position, machines do not have to "home" before restarting production.

Flexible Implementation

Because not all machines have the same requirements for safe motion, drive-integrated systems offer flexible, password-protected programming of all safety parameters. For example, printing equipment may allow safely-reduced speeds of 5 meters per minute, while general automation equipment may limit the speed to 2 meters per minute. While there have been general guidelines developed for different types of machinery, equipment OEMs will generally perform a hazard analysis to determine specific safety values. With the Bosch Rexroth Safe Motion technology for example, the machine safety can also be pre-certified so the OEM doesn't have to worry about the certification process.

EN 954-1 and Certified Safety Functions

Before a machine builder/OEM is allowed to put a machine into circulation in Europe, the manufacturer must make a risk analysis in accordance with the European Machine Guideline to determine the possible risks arising during use of the machine. Regarding uncontrolled machine movements, the risk analysis must cover the possible degree of severity of the injury, the duration and frequency of stay within the hazardous area, and the assessment of a possibility for the operator to escape. The result of this analysis can be used to define the safety category for the safety-related components in accordance with EN 954-1.

Bosch Rexroth, for example, designed its drives with safety on board in accordance with EN61508 and EN954-1 SIL3 standards. EN 954-1 is a European safety standard for providing safe operation at open guarding. The standard contains several classifications for the ability of machine components to withstand faults. Demand is growing in Europe for equipment that meets EN 954-1 safety guidelines. Today, for international OEMs dealing on a global basis, EN 954-1-compatible equipment is a competitive advantage. Soon, lack of compatibility will be a disadvantage.

EN 954-1 defines several categories or levels of safety. Category B is the basic requirement on which all other categories are built. Basic requirements involve component selection of safety-related control systems so that the system will withstand basic machine operating conditions, such as operating stresses, vibration, or process materials such as fluids or other agents. Category B does not require that the safety system be operational after a fault.

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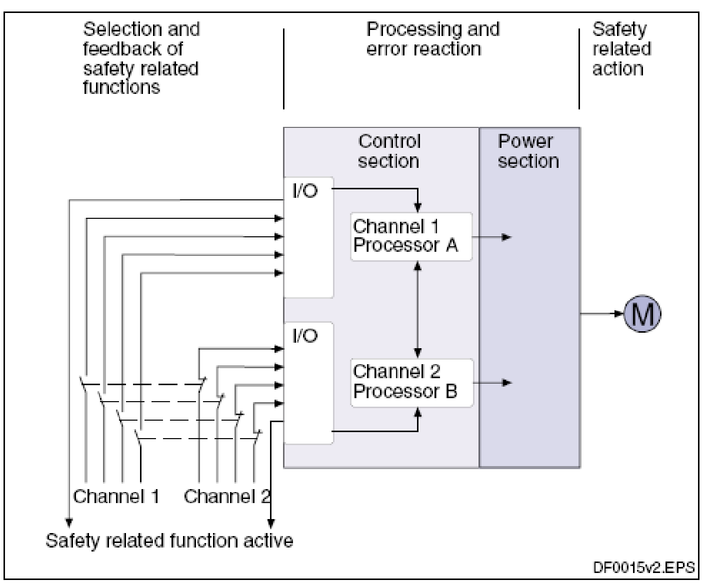
The safety functions integrated in the Rexroth IndraDrive meet safety category 3. Category 3 means single-fault safety - a single fault does not lead to the loss of the safety function and this fault must be detected by cyclical tests.

Photo References and Captions:

IndraDrive with Safe Motion.jpg
SafetyAdvertorial.jpg
The IndraDrive digital drive system with Safe Motion technology puts the safety function in the drive for faster response times, autonomous operation, and a range of safety functions.



Two-channel safety processing cross-compares parameters to catch errors and activate safe standstills.

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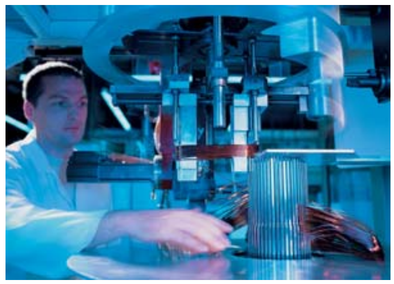

ABL2072_01T.jpg;
ASO2215_01T.jpg
With a drive-based safe motion solution, setup and work piece inspection can be done with axes held at a safe standstill while other axes are safely jogged at low speeds by an operator inside the work envelope.

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