System Isolation Equipment vs. traditional manual supply disconnect isolating switches

White paper

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The Problem: Traditional Manual Disconnect Devices not durable for frequent access needs

Typical existing equipment used to isolate motive power from industrial machines and processes are not designed to handle the frequency of access required for modern machinery. Historically, a manual disconnect device has been used to remove the hazards related to motive energy sources.

Manual operated isolation disconnect switches are typically designed for 8,000 operations. “Frequent Use” AC23a rating is available at lower amperages at 20,000 Operations. Read the fine print in the manuals, one operation is one throw of the switch.

A LOTO procedure cycle requires 2 operations, throw the switch OFF and then back ON. Over 20 year mission life modern Safety Systems are designed for, that means only 1.3 operations per day on average before the manufacturer states the switch will fail. Regardless if it fails safe or unsafe replacing the switch is an inherently dangerous job often needed once every 2-3 years for frequent use applications. Larger disconnects over 600 amps are rated only 2000 operations or less.

Newly realized arc flash hazards to the disconnect operator are also a concern. The Operator is required to stand in front of the switch to operate it. Qualified Electricians are trained not to stand in front of the switch when actuating but machine operators are not. The problem is compounded in that most disconnects have the handle on the right and most operators are right handed, so uninformed operators tend to stand right in front of the switch to operate.

It is necessary when performing a lockout procedure to verify a zero energy state before performing a task. Pressing the start button after turning a disconnect switch off does not confirm power is guaranteed to stay off when a person applies a lock to a disconnect switch. Other devices may be temporarily preventing motion. For tasks requiring unexpected startup prevention a window can be installed in the disconnect housing to verify the disconnect blades are disconnected. This manual verification process has proven to be ineffective as studies have shown disconnects can fail unsafe and the operator becomes complacent in that they observe one blade out and do not notice the others. Below is an example of a failed switch.

For tasks that require servicing the hazardous energy
directly it is required to verify zero energy by suiting up in proper PPE, measuring voltage present to verify
the meter works and then turn off the switch and verify zero voltage. This puts the person in direct hazard
of a short circuit arc flash which can be caused by the act of using the test meter if not properly performed.
If a person leaves one probe on a test point and draws the second probe from the source to move to the
third point, an arc can be created and drawn across the phases.

Due to frequent access needed on modern machinery processes local disconnects are required to promote
proper usage by operators. If they have to walk a significant distance to the lockout they will tend to cheat
the proper procedures. Operators are not allowed to enter control rooms where only qualified electricians
are allowed.

The need for local disconnects is complicated by the fact that usually multiple lockout points are needed.
This requires more wire and conduit to be installed which can cost a significant amount of money,
sometimes more than the disconnect switches themselves. But when series connected what if a coworker
locked out an upstream device at the same time? The disconnect you just seemed to verify could have
failed and when the upstream disconnect is re-energized the circuit you are working on will be re-
energized.

Disconnect switches mounted local to the machine require a 36 to 42 inch free space in front of the switch.
Most machines do not have room to mount multiple larger disconnects. This means the switch may be
located in an inconvenient place for the operator which promotes misuse.

After a power failure, the disconnect remains ON so the potential of re-applying energy causing an
unexpected start-up or Shock hazard exists.

Energy from all hazardous sources must have a disconnect device. This includes but is not limited to
Electrical, Pneumatic and Hydraulic sources. This issue is compounded if multiple access points are needed.
Large machines for paper industry, semiconductor industry and automotive industry require complex LOTO
procedures prone to human failure to isolate a device.

Putting a disconnect local to the access point in a wash down food grade environment requires the
operator to be in proximity of high voltage while performing wash down tasks. Operators typically are wet
and standing in water when interacting with the equipment.

There are known incidents where an operator accessed the machine using safeguard control systems and
when another operator or maintenance person decided to use a Isolation Device the act of isolating the
energy caused motion and the person in the machine was injured. Some companies would prefer
surpassing the standards requirements by using an Isolation Device for ALL access tasks. However this is not
feasible due to manual isolation devices low cycle ratings.

The Solution: ANSI/UL 6420 Equipment used for System Isolation rated as a unit
The Pilz SLS Safety Lockout System is the 1st Safety Isolation Control System to be certified as an Isolation System to the new ANSI/UL6420 standard for “Equipment used for system isolation and rated as a unit”. Pilz was involved in the invention of this type of system back in 1996 working with Proctor and Gamble and Moeller contactors. OSHA originally accepted the system as a lockout device but then removed the interpretation from their website citing a complicated system with no standard to build to. Pilz has been working on standards committees to gain acceptance and approval ever since. In 2012 the UL6420 standard was released and in 2016 the Pilz SLS was certified.

The SLS system uses redundant contactors mounted remote from the machine by the power equipment supplying the machine, usually an MCC or other power distribution system. Power contactors have typical mechanical life ratings of 1,000,000 to 10,000,000 cycles.

Contactors can be controlled remotely by using Remote Lockout Stations (RLS). Multiple switches can be placed anywhere on the machine. They operate on 24VDC low current and are small, so they do not require a 36-42 inch space in front of the panel.

Contactors remain OFF once the main power is lost until the system is reset and re-started. Contactors can be designed to provide equal or better isolation protection than what is provided by a disconnect switch.

The SLS system prevents external voltage causing an unsafe condition with the use of a Safety PLC for control which uses test pulses to monitor not only shorting to external power but also internal short circuits in the dual channel architecture. The system is designed to category 4/ PLe according to ISO13849.

The system uses tamper seals to limit intentional intervention access to Pilz trained and certified SLS service technicians. Customers can be certified to make their own repairs.

The SLS system can control other sources of hazardous energy such as Pneumatic and Hydraulic, providing a single lockout point for all energy sources.

Zero Energy state is verified using redundant safety devices monitored by a Safety PLC. Contactor position feedback is employed to verify both contactors switch properly. If one contactor fails to isolate, the other provides the necessary isolation function and neither can turn back ON until the problem is fixed. The dual contactor system is short circuit tested at a high power test lab for the rated short circuit fault current to ensure both contactors do not weld on the same phase.

In addition, the SLS system uses the Pilz PU3Z Category 4/PLe voltage monitor which monitors via dual sense wires phase to phase, and phase to neutral/ground. Other systems on the market use a 3rd grounding contactor which is a single point of failure. On these systems it is a requirement per the manufacturer’s manual, to manually check ground once a month to maintain a Category 4/PLe rating. This requires scheduling downtime to use a Mega Ohm meter to check the ground is still bonded properly. The Pilz PU3Z Voltage Monitor performs the check automatically every cycle.

For Fluid Power Isolation Category 4/PLe safety dump valves are employed and use dual diverse pressure switches to verify zero pressure. These systems are designed to meet stringent requirements for EN693
Hydraulic and EN692 Pneumatic punch presses.

A light is used to verify when all energy is controlled by the system has been rendered safe; no light, no entry. The light uses test pulses to ensure stray voltage is not illuminating the light. Contactors are shut OFF until the fault is cleared and the system restarted. If the light fails while someone is inside the machine the system remains isolated and safe. In addition, the system can interface with any machine Safety Related Control System to monitor dual “System Isolated” contacts and prevent access to the hazard using locking guard access systems. A redundant Emergency Stop/Coast stop interface is also included. An optional Zero Speed interface allows preventing isolating the machine energy until the Safety Related Control System indicates a zero speed state.

Remote operation removes the operator from Arc Flash hazards when operating the switch.

The cost of installing 6 conductor 16ga tray rated cable to multiple Remote Isolation Switches is much less than copper power wires and conduit.

In the 90’s Battelle Integrated Risk Management Company of Columbus Ohio conducted a study for a major international manufacturing company P&G which compared traditional disconnecting means with other alternative Isolation methods including the predecessor to the Pilz SLS system which used the Pilz PU3Z safe voltage monitor. The study found that of all the technologies analyzed the manual disconnects where least safe and the PU3Z system using dual contactors was the safest, especially when multiple lockout points require complicated procedures prone to mistake when implementing the procedure. It was this study that was the basis for development of the ANSI/UL6420 standard.
Typical System Layout:

- Line IN
- Line OUT
- 24 VDC Pilz I/O Power
- Zero Energy Light
- RLS Switch
- 3 x 460V AC
- 24 VDC Safety Processor Power
- PSSu Node XX (PNOZmulti for OEM)
- Pneumatic Safety Valve & Dual Pressure Switches
- SafetyBUS p (w/ PSSu)
- System ON
- System OFF
- Air IN
- Air OUT
- Exhaust
- No Energy

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Dual Contactor system is NOT an isolation device unless proven through 3rd party

Lab testing as a unit:

Normal contactor testing per IEC60947-4-1 for Short Circuit Current Rating (SSCR) type 2 coordination with the fault current protection device (fuse, circuit breaker) allows the contactor to tack weld closed if it can be broke free easily. Samples of each Pilz SLS design and any options offered have been subjected for lab testing as a unit.

Common Cause Failure- In a dual contactor arrangement both contactors will weld on same phase when subjected to a fault current. This is OK for inhibiting motion in a typical guard door interlock because the motor will single phase and will not cause motion. But this is not OK for energy isolation. To meet ISO13849 dual channel requirements for the Safety Function- Safe Energy Isolation, the system would have to be tested for this common cause failure to qualify for safe energy isolation using a contactor. ANSI/ UL6420 requires the dual contactor “System” as a unit be tested for the same SCCR test as IEC60947-4-1, but contactors cannot weld.

After SCCR testing and again after make/break testing components are tested and UL witnessed for 600v Dielectric tested across each contact and 1000v all contacts to ground plus min 8kV Impulse voltage tests are performed to ensure isolation and simulate lightening strike.

Other common cause failures must be addressed and tested for such as EMC radiation and immunity to outside EMC sources. Below is a table regarding EMC lab tests performed on each design.

<table>
<thead>
<tr>
<th>EMC Type</th>
<th>Environment B Industrial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immunity</td>
<td>ANSI/UL6420 9.4.2.4 / IEC 61000-4-2</td>
</tr>
<tr>
<td>Electrostatic Discharge</td>
<td>ANSI/UL6420 9.4.2.5 / IEC 61000-4-3</td>
</tr>
<tr>
<td>Electromagnetic Field</td>
<td>ANSI/UL6420 9.4.2.6 / IEC 61000-4-4</td>
</tr>
<tr>
<td>Fast Transient Burst</td>
<td>ANSI/UL6420 9.4.2.7 / IEC 61000-4-5</td>
</tr>
<tr>
<td>Surges</td>
<td></td>
</tr>
<tr>
<td>Emission</td>
<td>ANSI/UL6420 9.4.3.2 / CISPR 11</td>
</tr>
<tr>
<td>Conducted Radio-Frequency</td>
<td>ANSI/UL6420 9.4.3.3 / CISPR 11</td>
</tr>
<tr>
<td>Radiated Radio-Frequency</td>
<td></td>
</tr>
</tbody>
</table>

Normal contactor endurance testing per IEC60947-4-1 requires 6X rated current. For ANSI/UL6420 compliance contactors are tested for AC23a rating like a manual disconnect which requires 10X rated current and almost twice the cycle count. This usually means over-sizing the contactors to accomplish.

ANSI/UL6420 requires the Contactor “System” must be lab tested and rated AC23a as a unit, the same rating as a manual disconnect.

Applications include Automotive Assembly lines, Semiconductor Industry, Paper and Paper converting industry, Wash down Food Grade industry, Steel Industry, Printing Industry and Packaging Industry.
What do the Standards say for usage of System Isolation Equipment:

In the 1998 OSHA had originally accepted the concept of System Isolation Equipment, utilizing Pilz Voltage Monitor technology developed specifically for the application, as a Isolation Device but rescinded the opinion citing complexity of the system design and installation and that there was no product standard for such equipment.

The National Electrical Code (NFPA 70: 2005) included a definition of such systems and allows their usage if listed to a standard.

### 430.2 Definitions

- **System Isolation Equipment:** A redundantly monitored, remotely operated contactor isolating system, packaged to provide the disconnection/isolation function, capable of verifiable operation from multiple remote locations, each having the capability of being padlocked in the OFF (open) position.

- **NEC 430.109 (A)(7) System Isolation Equipment.**

  System Isolation equipment shall be listed for disconnection purposes. SLS shall be installed on the load side of the current protection and it’s disconnecting means. The disconnecting means shall be one of the types permitted by 430.109 (A)(1) through (A)(3). (Note: 430.109(A)(1) Motor Circuit Switch (2) Molded case circuit breaker (3) Molded case switch)

NFPA 79 Electrical standard for industrial machinery 2002 edition Chapter 5 Incoming Supply Circuit Conductor terminations and Devices for Disconnecting and removing power was updated to allow such systems. From NFPA79 2012:

### 5.4 Means of removal of power for prevention of unexpected startup

- **Removal of power can be accomplished by the use of one of the following:**
  1. The supply disconnecting Means
  2. Additional devices conforming to 5.3.2, 5.5.4
  3. Other Means *(e.g. a contactor switched off by a control circuit)* that meet the requirements of 5.4.3 and 5.4.4. (Pilz Note- For prevention of unexpected startup allows unlisted remote systems not listed for isolation function)

### 5.5 Devices for disconnecting (isolating) electrical equipment

- **The following devices shall be permitted to fulfill the isolating function of 5.5.3:**
  1. Devices described in 5.3.2

  (Pilz Note - Approved Mechanical Disconnect or Circuit Breaker)
(2) A manual motor starter marked suitable for motor disconnect and compliance with UL508 where located on the supply side of the last short circuit protection device (In the branch) (Pilz Note- Similar to a Circuit Breaker)

(3) System Isolation Equipment that incorporates control lockout stations and is listed for disconnection purposes where located on the load side of the main supply circuit disconnecting means and over-current protection.

ANSI/ASSE Z244.1 2016 was updated System Isolation Equipment to align with the NFPA79, NEC and ANSI/UL6420 wording. Additional guidance for justification and usage is provided.

3.12 Energy Isolating Device. A means of preventing the transmission or release of energy.

NOTE 4: System isolation equipment that incorporates control lockout stations and is listed for disconnection purposes where located on the load side of the main supply circuit disconnecting means and over-current protection can be energy isolating devices. See NFPA 79.

8.4.4 Other Means of Hazardous Energy Isolation.

Remotely activated electro-mechanical lockout systems are an acceptable alternative to be used in selected applications such as long machines and inaccessible or inconvenient locations of primary isolation devices. The user shall install and operate such systems (e.g., remote low voltage lockout system, pneumatics systems) in accordance with the manufacturer’s directions.

See Annex B for further details. See NFPA 79 for additional information.

5.4.1 Location.

Energy isolating devices shall be accessible and, where practicable, be conveniently located to facilitate the application of isolating devices during necessary tasks.

Energy isolating device should be located outside hazardous areas and at a convenient height from an adjacent walking area (i.e. not overhead or under machinery).

If unable to position or install isolating device(s) at a convenient location, measures shall be taken to provide proper access to the devices.

NOTE: As an example, a remote lockout or a system isolation equipment rated as a unit and listed for the purpose of isolating energy may be implemented as one such measure. See Annex B.
Annex B:

**Justification to use a remote lockout system instead of a manual disconnect for service disconnect isolation purposes includes:**

- When frequency of the task exceeds the capability of a manual disconnect.
- When environment is not acceptable to place a manual disconnect.
- Large complicated machinery involving many lockout devices making the lockout procedure too cumbersome.
- Reduce to a single lock point directly at the access point.
- To prevent machine operators from standing in front of large disconnect switches in case of short circuit fault.
- Large disconnects can be physically hard to operate for some operators.
- Required spaces not available (service access, electrical hazards, adequate ventilation, etc.).

*NOTE: Types of electrical lockout systems available include, but are not limited to remote low voltage system, and listed system isolation equipment.*

Annex R reveals a need for System Isolation Equipment in Steel industry

In the steel making industry, several tasks need to be completed on stacker transfer tables that move individual steel bars (including rounds, flats, and angles). These tasks involve personnel entering into the transfer table to perform tasks such as tagging bundles, quality inspection, un-jamming or straightening steel, etc.

Applications are usually high amperage where disconnects are only rated at 1000 ON/OFF cycles. Usually it is not feasible to locate local disconnects at access points. Sometimes disconnect is in control room where operators do not have access.

Annex R Case Study: Nucor Steel OSHA variance requested

Lockout was required under a strict interpretation of OSHA’s 29 CFR 1910.147 (citations had been issued). The frequency of these tasks resulted in the knife switches failing on a regular basis, exposing employees to arc flash and other hazards.

The industry has developed an alternative method that employs a combination of engineered safeguards, warning devices, procedures and safe work practices to provide effective alternative protection to lockout or tagout. As shown in Figure R-3, a light curtain disables the table drives when personnel cross onto the transfer table. The area is marked with an awareness barrier (red line). Safe work practices are followed to limit access to only those employees who have been...
appropriately trained of the hazards in this work area and the proper procedures to be followed to avoid them. Additionally, documented safe work procedure prohibit the restart of the transfer table if an employee is on the working side of the light curtain. The restart control is in direct line of sight of the work area.

(Pilz Note: The systems installed for the variance implement Remote Lockout Systems NOT listed for isolation)

Annex S:

Annex S is quite lengthy and describes a need for control systems in semiconductor industry instead of traditional LOTO due to system complexity. System Isolation Equipment Listed for disconnect purposes provides equal protection to a manual LOTO device.

Semiconductor Industry has it’s own “S” standard which needs to be updated to align with NFPA 79, IEC 60204, Z244.1 2016 and NFPA 70 for use of SLS Listed for purpose of Isolation

ANSI/UL6420 Equipment used for System Isolation and rated as a unit

1.1 Scope

1.1.1 General

1.1.1.1 This standard applies to isolating equipment incorporating electromechanical contactors remotely controlled and monitored to provide remote isolation status indication with a defined integrity level. This equipment is intended for use as an additional isolating means on the load side of the required supply-disconnecting device and over current protection. This standard applies to isolating equipment that is to be used in circuits of which the rated voltage does not exceed 1000 Vac or 1500 Vdc.

1.1.1.2 The system isolation equipment is expected to be used both as a means for removal of power for prevention of unexpected start-up of a stopped machine and as an isolator to provide protection from electric shock by ensuring the removal of electrical energy.

1.1.1.3 This equipment is intended for installation in accordance with the National Electrical Code, NFPA 70 and the Electrical Standard for Industrial Machinery, NFPA 79:2012.

Note – Reference to System Isolation Equipment is found in Article 430.109(A)(7) of the National Electrical Code NFPA 70; in Clause 5.5.4(3), Devices for Disconnecting (Isolating) Electrical Equipment, of the Electrical Standard for Industrial Machinery, NFPA 79:2012; and in Clause 5.3.2(d) of the Standard for Safety of Machinery – Electrical Equipment of Machines – Part 1: General Requirements, IEC 60204-1.

1.1.2.1 Typical application

1.1.2.1.1 The system isolation equipment is principally intended for industrial machine applications where, isolation of power is so frequently required that the mechanical life of a typical disconnecting means is
unacceptably short or where there are multiple entry points on the machine where disconnection is required, or both.

Note – Multiple entry points are a function of access needs and the layout of the machine.

Excerpt from Annex A

Intended Applications
(informative)
A1 General

A1.1 As with the opening of any other isolation device, safe work on associated machinery is predicated on knowing that correct operation of the device has occurred, and thus upon opening a typical disconnecting device, before work can be performed on the associated machinery, Standard for Electrical Safety in the Workplace, NFPA 70E, and the OSHA regulations requires verification to confirm that isolation has occurred. The system isolation equipment uses electromagnetic contactor(s) to provide isolation and, internal design features to provide verification that the isolation has been completed.

International Standards allowing SLS:

ISO14118 allows the use of SLS when disconnects cannot handle the access rate. System does not have to be listed, In fact the standard allows just inhibiting the startup function by locking the stop control off. Applicable sections are listed below.

4.2 Other means to prevent unexpected [unintended] start-up

If the use of isolation and energy dissipation is not appropriate (e.g. for frequent short interventions), the designer shall provide, according to the risk assessment in accordance with ISO 14121, other measures (see clause 6) to prevent unexpected start-up.

(Pilz Note- Clause 6 allows using control systems based on risk assessment not listed for the purpose of isolation for preventing unexpected startup by preventing start commands.)

EN60204-1 section 5.3.2(d)

d) any other switching device in accordance with an IEC product standard for that device and which meets the isolation requirements and the appropriate utilization category and/or specified endurance requirements defined in the product standard;

(Pilz Note- The ANSI/UL6420 standard is the only product certification standard worldwide addressing all the issues of using a contactor system as an isolation device. The standard was written in IEC format and includes IEC standard requirements in hopes that IEC would adopt the standard.)
From ANSI/UL6420 section 1.1.1.3:

Note – Reference to System Isolation Equipment is found in Article 430.109(A)(7) of the National Electrical Code NFPA 70; in Clause 5.5.4(3), Devices for Disconnecting (Isolating) Electrical Equipment, of the Electrical Standard for Industrial Machinery, NFPA 79:2012; and in Clause 5.3.2(d) of the Standard for Safety of Machinery – Electrical Equipment of Machines – Part 1: General Requirements, IEC 60204-1.

CSA Z460 2013 Control of Hazardous Energy- Lockout and Other Methods

Annex I Remote Low Voltage Lockable Systems

(Pilz Note- This annex is similar to the Z244.1 2003 Annex B and allows the use of SLS or other remote lockout systems such as remote solenoid operated Molded Case Circuit Breakers)

CSA Z462-2012 Workplace Electrical Safety

R.3.3 Disconnects and fuses

Disconnect switches are commonly used in substations to isolate electrical equipment or systems. These switches can be manually operated or motor operated and can be load-break or non-load-break design.

IEC EN 61140 2016 Protection Against Electrical Shock- Common Aspects for Installation and Equipment

3.41 isolation

function intended to disconnect and maintain for reasons of safety adequate clearance from every source of electric energy

8.4.1 Devices for Isolation and 8.4.2 Devices for isolation for low voltage

(Pilz Note- These clauses give requirements for isolation devices and does not require mechanical link to locking mechanism. All the requirements are fulfilled because the ANSI/UL6420 standard references information in these clauses.)

EN 50110-1 2014 Operation of Electrical Equipment ,allows use of remote isolation devices

3.4.6 isolate

disconnect completely a device or circuit from other devices and circuits by creating a
physical separation able to withstand the anticipated voltage differences between the
device or circuit and other circuits


(Pilz Note- does not require lock applied to isolation device)

6.2 Dead Work

6.2.3 Secure against re-connection

All switching devices that have been used to disconnect the electrical installation for the
work activity shall be secured against re-connection, preferably by locking the operating
mechanism. In the absence of locking facilities, equivalent prohibitive actions, in
accordance with established practice, shall be taken in order to secure against re-
connection. If an auxiliary power source is required for operation of the switching device,
this power source shall be made inoperative. Notices, e.g. warning sign(s), shall be
attached to forbid interference. Where remote control devices are used to secure against
re-connection local operation of the devices shall be prevented. All signaling and
interlocking systems used for this purpose shall be reliable.

EN 692 2012 Machine Tools Safety- Mechanical Presses

Section 6 in regards to Pneu Isolation Safety Control System Requirements

EN 693 2015 Machine Tools Safety- Hydraulic Presses

Section 6 in regards to Hydraulic Isolation Safety Control System Requirements

Other Application:

Food Industry- Meat grinding or Cheese Extruder

• Meat grinding for example requires stopping the grinder every hour to take bacteria samples from
the knife blades.
• Even though it is a frequent task OSHA has ruled it requires LOTO because the grinder is stopped and meat cleared out before sampling and the task requires putting a body part in the area where hazardous work is performed. Therefore it is not a task that is “Integral to Production”. Highlights OSHA stringent view on requiring Isolation.

• Disconnects will only last a few months at this rate of operation. Changing disconnects is an inherently dangerous task.

• The area is wash down thereby exposing operators to high voltage and maintenance is exposed to harm more frequently due to frequent equipment failure.

Paper Production and Packaging industries-

• Paper and Paper converting machines require frequent access, are complicated due to many devices in a zone to lock out and have many zones of control. Many tasks are involved that are complicated to separate Normal Production Tasks with tasks that are not production but “Routine, Repetitive and Integral to production” from Maintenance Tasks. It is safest to provide System Isolation Equipment listed for purpose of Isolation for all tasks.

• Frequent Access is required and disconnects cannot handle the cycle rate.

• Multiple isolation devices and zoned isolation make the traditional lockout process difficult to perform.