Risk Control Hierarchy Clarifies Electrical Safety

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Abstract:
A clear and realistic set of objectives goes a long way in driving continuous improvements in electrical safety. Resources can be allocated and priorities can be defined once objectives are set. The Risk Control Hierarchy (RCH) in the ANSI-Z10 standard provides electrical safety professionals with an excellent roadmap for setting the right safety objectives that result in the reduction of electrical risks. For example, when a Department of Energy electrical safety program is analyzed under the light of the RCH, many potential electrical safety improvements begin to jump off the page. The RCH not only helps improve a plant electrical safety program, but it also inspires manufacturers to improve their electrical equipment designs. Lastly, the RCH provides a means to measure the effectiveness of an electrical safety initiative much the same way a project manager uses financial measurements (Return on Investment or Payback Analysis) to evaluate a project.

Building a successful electrical safety culture will reduce the number of workplace fatalities and electrical accidents. Yet, accomplishing that task does not happen overnight. It takes time, effort, and persistence to ripen the attitudes, beliefs and values necessary to harvest a culture of electrical safety. Still, very little can happen until safety priorities are set and budgets are approved. This understanding begs the question: How do we identify electrical safety priorities and strategically allocate budgets to fund them? Moreover, how can we measure our success? The answer is with the Risk Control Hierarchy (RCH).[1]

Focusing on electrical safety though the lens of the RCH provides new perspectives and practical applications needed to make necessary determinations that will increase electrical safety. We will improve the status quo by finding and implementing a superior way to reduce electrical risks. Consider the implementation of air bags in vehicles. Air bags ushered in a superior way of reducing the risk of head injuries during automobile accidents. Yet, had the visionaries who brought us the air bag only focused on improving seatbelt we never would have achieved the level of safety we have today. Instead, they came up with an innovative idea that required new technology to take us beyond new and improved seatbelt. The result was a huge reduction in head injuries during automobile accidents. Ironically, the effectiveness of the air bag depends upon the proper use of a seatbelt! It is important to remember that less risk equals more safety.

Safety professionals have proven the effectiveness of the RCH as an instrument for identifying, understanding, measuring and reducing the risks within a facility through the ANZI-10. The same concept will prove equally effective when applied to electrical safety. For example, once the riskiest electrical areas of a plant are identified, the RCH will help set the right priorities, find the best solutions and measure the overall effectiveness. Let's see how we can incorporate traditional electrical safety with RCH principles to further reduce electrical risks.

Electrical safety focuses on the prevention of

1. ANSI-Z10 Appendix G

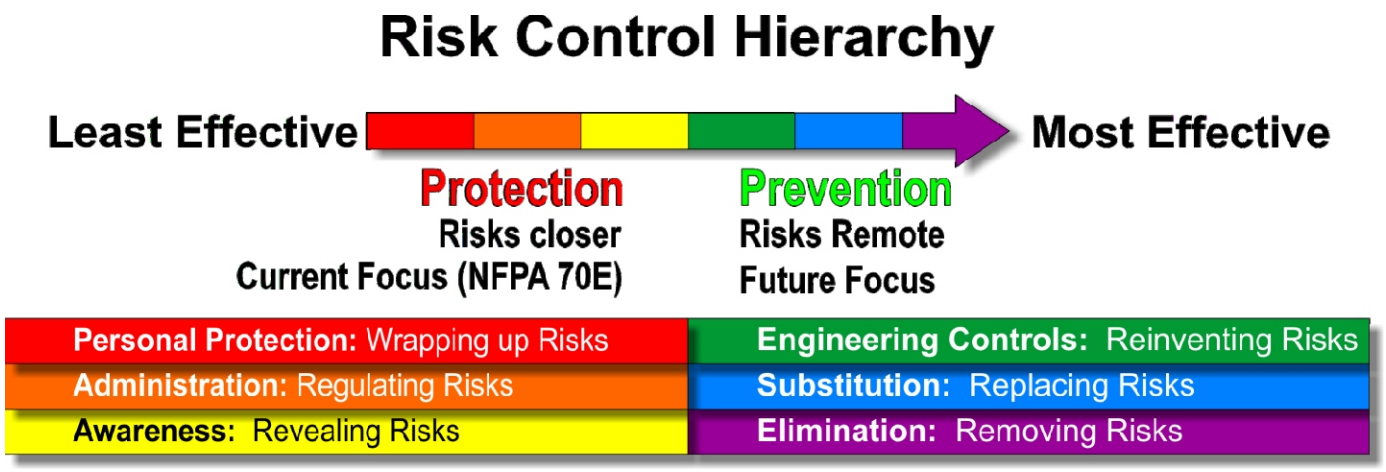

Fig. 1) Graphical representation of the Risk Control Hierarchy.

shocks and burns. Electrical explosions - or arc flash - will likely cause burns, while simple contact with live voltage results in a shock. The severe physical and financial effects of the incidents can be diminished because of the tools we use. For example, "'an arc flash with injury cost $8 million to $10 million. One case cost the insurance company $29 million,'… 'The workers' comp rate went through the roof: from $250,000 to $5 million for five years.'"[2] The severity of an accidental shock is unpredictable due to certain variables such as current path, voltage levels, and grounding practices. Let's see how the RCH principles can be applied to reduce both arc flash and shock risks.

Electrical Safety is Mysterious to Most

Keeping in mind that less risk equals more safety, setting the right order of priorities pays the biggest safety dividend because the riskiest areas get the most attention first. Understanding how to set priorities for electrical safety poses a challenge for the non-electrical safety manager. For all he knows, electricity is a mysterious bunch of invisible electrons moving instantaneously through copper wires that may zap you at anytime! The shrouded mystery of electricity compels many safety managers to depend upon plant electrical maintenance or engineering departments to manage their electrical safety program. The RCH helps to bridge the gap between these departments. So how do we use the RCH to measure and reduce electrical risks? In most cases, any risk area in a facility has already employed a risk reduction measure that falls somewhere into the RCH. When applied to electrical safety, this hierarchy provides the most effective to the least effective way to reduce electrical hazards:

1.) Elimination **-Removing any exposure to voltage**

2.) Substitution **-Replacing higher risks with lower risks**

3.) Engineering Controls **-Reinventing ways to control electrical energy**

4.) Awareness **-Revealing all sources of electrical energy**

5.) Administrative Controls **-Regulations that teach personnel how to be safe around electrical energy (NFPA 70e)**

6.) Personal Protection **Reducing risks of working on live voltage**

Each step of the RCH has equal importance to overall safety with risk reduction varying between the steps. For example, the top three steps are designed to control the risk before it gets in close proximity to the employee, while it is assumed with the bottom three steps that the employee is

[2]Plant Services: http://www.plantservices.com/articles/2007/189.html

already exposed to the electrical energy and needs to be kept safe while he is close to the hazard. The NFPA 70e - along with its PPE requirements - have been highly effective at increasing electrical safety; however they are the least effective means of improving electrical safety. This is an important distinction that should not be glossed over. In other words, **once you have done everything possible to reduce the risk to its lowest level, then you must focus on protecting the worker from the residual risk.** Protecting workers from residual risks is a big emphasis of the NFPA 70e. The most comprehensive long term electrical safety solutions will be found at the top steps of the RCH.

Electrical Safety: No Voltage, No Accident

Voltage is the common denominator in electrical safety. If voltage is present, then electrical incidents can happen. Electrical incidents only happen if voltage is present. Therefore, creating a barrier that keeps maintenance workers away from voltage, or an arc flash explosion, is a sure way to increase electrical safety.

A Real Life Application

Let's apply the RCH to the Department of Energy (DOE). In 2005, the DOE had an average of 14.1 electrical occurrences of shocks, burns, and the like per month. Electrical safety - those procedures and practices meant to prevent injury and damage - also had the highest percentage of near misses of any other recordable safety events in the DOE.[3] If we keep in mind that reducing risk increases safety, this means that electrical safety, as it was being applied, wasn't successful in its intent. The DOE cited the following primary causes for these incidents:

- Lack of hazard identification
- Lack of training
- LO/TO violations (shortcuts or lack of energy verification)[4]
- Failure to stop work to perform safe energy checks
- 33+ Electrical Shocks in 2005 (Increasing yearly)
- Poor planning

Will we increase electrical safety at the DOE with more training, better LO/TO rules or better hazard identification? - Absolutely!

Fig. 2) Convenience Interfaces on **Control Panels** ELIMINATE exposure to voltage when **programming.**

Can we be exponentially better by using the RCH to uncover even newer and better ways to reduce risk? - Absolutely! The RCH opens our eyes to see newer and better ways to reduce risks so we don't settle for minor improvements that may have little effect on risk reduction. In other words, an air bag is better than a improved seatbelt for reducing head injuries. Most of the above causes take root in the administrative level of the RCH. Now our questions become: How can we eliminate the hazards? Can we find ways to substitute or engineer a reduced the hazard? Lastly, how do we make personnel more aware of the hazard? So let's ask some hard questions and increase electrical safety by moving up the RCH. In almost every above-referenced case in the DOE example, the RCH reveals more insight that resulted in practical improvements in electrical safety as illustrated in Chart 1. Chart 2 illustrates the same concept with some common issues in electrical safety:

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[3]Department of Energy 2005 Electrical Safety Meeting, Las Vegas, NV, National Electrical Safety Incidents and Trends, November 2005

[4]Lock-Out/Tag-Out to isolate electrical energy

Chart 1 Color coded chart showing risk reductions when RCH is applied to DOE issues.

Personal Protection: Wrapping up Risks	**Engineering Controls:** Reinventing Risks
Administration: Regulating Risks	**Substitution:** Replacing Risks
Awareness: Revealing Risks	**Elimination:** Removing Risks

CAUSES OF INCIDENTS	PRESENT RCH PRINCIPLE		INCREASED RISK REDUCTION RCH PRINCIPLE	
Lack of hazard identification.	**ADMINISTRATIVE**	Properly administrating NFPA 70e requires all electrical enclosures to have warning labels with incident energy level (calories).	**AWARENESS /ELIMINATION**	Marking all energy sources on the panel exterior provides personnel with simple yet safe hazard identification.
LO/TO violations including shortcuts or lack of energy verification	**ADMINISTRATIVE**	Can the LO/TO procedure be rewritten to reduce exposure to voltage?	**SUBSTITUTION /ELIMINATION**	Thru-door voltage pre-checking 'eliminates' all exposure to voltage for mechanical LO/TO* and provide significant risk reduction for Electrical LO/TO.
		Reducing electrical energy to Cat 0/1 will greatly reduce the potential arc flash energy	**SUSTITUTION**	Lowering the arc flash energy effectively 'substitutes' for a lower risk for a higher risk.
Failure to stop work to perform safe energy checks.	**ADMINISTRATIVE**	Is a zero energy state confirmed between work break and shift changes in the LO/TO procedure?	**AWARENESS**	Can a hard wired voltage indicator be used to alert maintenance to the presences of electrical energy at any time?
Electrical Shocks (33+ in 2005, increasing yearly)	**PERSONAL PROTECTION**	Are personnel unnecessarily working on live panels? Are they using proper PPE when working on live panels?	**ADMINISTRATIVE**	Use of Live Work permits (as per NFPA 70e) to insure that personnel fully understand the system prior to voltage exposure.
		Do electricians know the locations of all electrical energy sources (including UPS and back-up generators)? Are they clearly marked on the inside or outside of the panel?	**AWARENESS**	Identifying the primary 3-phase source as well as the separate 120VAC sources clearly on the electrical enclosure.

Note (1) See Appendix A Item 1.)
Note (2) See Appendix A Item 2.)

Chart 2 Color coded chart showing risk reduction when RCH is applied other electrical issues. (See Fig. 1)

CAUSES OF INCIDENTS	PRESENT RCH PRINCIPLE		INCREASED RISK REDUCTION RCH PRINCIPLE	
Mechanical LO/TO procedures	**PERSONAL PROTECTION**	Requiring electricians to verify zero voltage with a voltmeter exposes them to potential shock and arc flash hazard*	**ELIMINATION**	Using a thru-panel voltage indicator eliminates hazardous voltage exposure altogether
Exposure to voltage during troubleshooting and maintenance on electrical systems with 50V or more requiring PPE*	**PERSONAL PROTECTION**	Control panels with programmable devices	**ELIMINATION**	Provide through door programming ports with 120VAC receptacles to program without opening the control panel door. (Fig. 2)
		Can maintenance on live panels be reduced with door mounted devices?	**ELIMINATION**	Evaulate if panel mount devices can become thru-door devices (Ethernet Switches, CB, etc.)
		Three-phase control panels with power and 24VDC control	**ENGINEERING**	Engineer a physical separation between the power and the control eliminates exposure to voltage.
		Can we reduce some volatge exposure with thru-door checking?	**AWARENESS**	All power feeds and strategic I/O points made available without voltage exposure
		Three-phase control panels with power and 120VAC control	**SUBSTITUTION**	Substitute 24VDC for 120 VAC eliminates exposure to voltage.
		Motor Control Centers (MCC's)	**ELIMINATION /ENGINEERING**	Smart MCC's are designed to facilitate most troubleshooting through a network connection without expose to hazardous voltages. (Fig. 3)
Arc flash incidents on switchgear	**PERSONAL PROTECTION**	Arc flash incidents that occur during normal operation of switchgear.	**SUBSTITUTION**	In the event of an arc flash, arc resistant switchgear are engineered to contain an arc flash within the switchgear, thereby effectively substituting a lower risk for a higher risk.
		Utilizing a remote switchgear racking mechanism.	**ENGINEERING**	Because this is the 3rd leading cause of arc flash, a remote racking mechanism is an example of an engineered solution that keeps personnel safe during an arc flash. (Fig. 5)

Note (1) See Appendix A Item 1.)
Note (2) See Appendix A Item 2.)

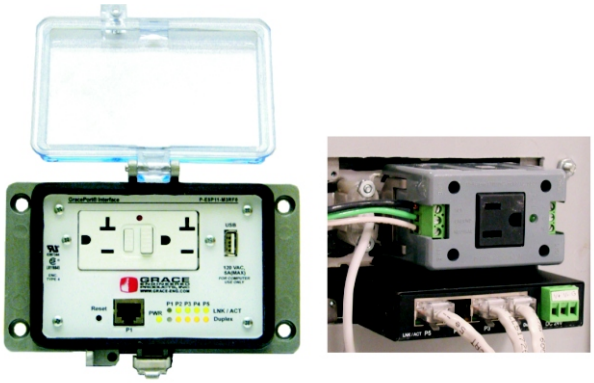

Fig 3) Redesigned Panel mount devices ELIMINATES voltage exposure. Ethernet Switch provides thru-door diagnostic LED's. GFCI allows for thru door Test/Reset function.

Fig. 4) Convenience Interfaces on Smart Motor Control Centers ELIMINATE exposure to voltage when troubleshooting.

Conclusion

Today's competitive business environment demands we invest our safety resources into areas that will truly reduce risks and

Fig. 5) Remote switchgear racking mechanism is an ENGINEERED to reduce risk.

increase safety. Financial measurements - like cash flow, ROI, and ROA - are the tools used to prioritize and quantify other budgets within an enterprise. The RCH principles discussed here can be applied to electrical safety to identify the goals and measure the effectiveness of electrical safety expenditures and the overall success of electrical safety. Fierce competition for capital dictates that projects with the best return on investment become top priorities. Therefore, if electrical safety projects are budgeted and evaluated in the same way based upon the RCH, then we would be able to prioritize specific objectives and see higher safety and productivity dividends. Furthermore, as we apply the RCH to more and more electrical safety risks, it will open our eyes to see more practical ways to reduce those risks. Most importantly, the RCH will help us find new 'air bags' for electrical safety!

About the Author

Phil is the President and Owner of Grace Engineered Products, Inc., in Davenport, Iowa. He is an innovator and holds two US Patents on a power receptacle design, and continues to consider new and more efficient ways of making electrical safety safer.

Phil did his undergraduate work at California State University, San Luis Obispo and graduated in 1984 with his BSIE.

APPENDIX A

1.) Identifying voltage sources (ChekVolt® and R-3W

A 40+ year industrial electrician once said, “I like anything that keeps me from getting bit (shocked)”. Getting a dog or snake bite is always a surprise! Since voltage is invisible, most electrical accidents happen because the electrician is unaware of a voltage source. Therefore using every possible means of marking every voltage source within an electrical enclosure will go a long way to limit these surprises. Let's go a step further and make sure all voltage sources could be seen and tested from the outside of the electrical enclosure. This tells electricians the locations and the voltage states of all the electrical energy within an electrical panel.

Voltage Portals A safe place to check voltage

Many maintenance workers check for voltage with Non-Contact Voltage Detectors (NCVD). These battery powered devices resemble a pen and beep and flash when in close proximity to a voltage source. A NCVD provides a means of quickly checking for voltage without making direct contact on a bare electrical conductor. A voltage portal mounts to the outside of the enclosure and connects to a voltage source within the enclosure. Installing these bright yellow voltage portals for every voltage source feeding an electrical panel gives

maintenance workers a quick way to see all the voltage sources from the outside of the panel. Furthermore, he can pre-verify the state of each voltage source with his NCVD before he needs to access the inside of the panel. Knowing voltage states without exposure to that voltage certainly reduces risks.

A NCVD relies on a small amount of electrical energy to trigger the alert. Sometimes the position of the conductors bleeds enough electrical energy away from the NCVD so that it cannot properly indicate the voltage state. This is less of a concern with a voltage portal because it positions the electrical conductor in order to deliver the maximum amount of electrical energy so that the NCVD operates reliably.

2.) What is a Voltage Indicator? (Figure 8 & Figure 9)

The shocking truth is that voltages only become hazardous if you are able touch the live conductors (over 50Volts). A voltage indicator resides on the outside of an electrical panel and provides maintenance people the ability to see the voltages without opening the panel. Simply put, a voltage indicator is like a permanently connected voltmeter that personnel can see all the time. Seeing voltage through closed doors is a very safe idea.

Surprisingly most low voltage (under 600V) fatalities occur at 120V. Therefore in order for a voltage indicator to be truly effective in electrical safety, it must be able to indicate voltage between 50V and 600V. Furthermore, since most electrical systems have three-phases, a voltage indicator must be able to alert workers to voltage on any of the three phases. Therefore, a typical 3-phase voltage indicator operates in a range of 40-750AC or 30-1000VDC with an earth ground connection (4-wires total). Voltage between any 2 wires will cause current to flow between phases thereby making the LED's flash. Unless voltage is present there can be no shock hazard or a potential arc flash incident (electrical explosion due to a short circuit). Voltage is extremely lethal, so once an electrician disconnects power to the electrical system, they use a voltmeter to insure that

electrical energy has been fully isolated before they begin work on the system. Sometimes just checking voltage causes a short circuit which could lead to

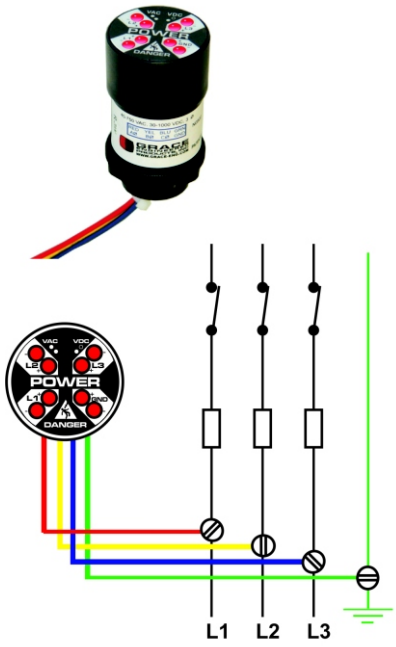

Fig. 8) Voltage indicator wired to the incoming main. Rated 40-750VAC/ 30-1000VDC. Simplifies Mechanical LOTO.

an arc flash explosion.

A voltage indicator puts a redundant layer of protection between an electrician and live voltage. The ability to 'pre-check' voltage before opening an electrical enclosure means that workers significantly reduce their exposure to voltage and offer these safety benefits:

- Reduction in arc flash incidents due voltage checking.
- Saves time due to simplified LOTO.
- Checking voltage with a meter is a major cause of arc flash incidents.
- Permanently 3-phase 24/7voltmeter with a 20+year life.
- Self-powered from the line voltage and doesn't require batteries.

By the time you physically contact raw electrical energy, most often it is too late. A thru-door voltage indicator offers a much needed level of safety over and above the traditional voltmeter and proper safety procedures.

3.) Mechanical Lock-out Tag-out

Mechanical maintenance procedures require isolation of all energy sources (including electricity) before work begins on the piece of equipment. A typically procedure requires an electrician to access the live voltage section of the equipment to verify zero voltage. Since a vast majority of electrical energy is converted into mechanical motion, the presence of voltage does not automatically guarantee mechanical motion because motors need a very specific power input for rotation to occur. For example, a three phase motor rotates only when it receives enough current and the correct voltages on all three phases. All voltages do not create mechanical motion. Furthermore, control systems are designed to determine not only when a motor starts and stops, but if it is safe to do so.

Raw electrical energy has the ability to instantaneously cause shock injuries and damage to equipment in the event of an arc flash explosion. When electricity is confined within a mechanical

system, it is inherently safer due to the system design. While 100% electrical isolation is beneficial for mechanical LOTO, is not required to make a system mechanically safe. Therefore, a voltage indicator used in conjunction with proper procedures offers a reliable means to verify zero energy state for mechanical maintenance. No longer is an electrician put at risk to physically verify a zero electrical energy state prior to maintenance. A voltage indicator is a very simple device because it only indicates voltage, and therefore any worker is able to verify zero energy prior to performing mechanical maintenance.