Hazards of Working Electrical Equipment Hot

Accident reports continue to confirm that people responsible for the installation or maintenance of electrical equipment often do not turn the power source off before working on that equipment. Working electrical equipment hot (energized) is a major safety concern to the electrical industry, and we have to question why. The purpose of this article is to alert electrical contractors, electricians, facility owners and managers, and other interested parties to some of the hazards of working on hot equipment and to emphasize the importance of turning the power off before working on electrical circuits.

I. WHY SHOULD THE POWER BE TURNED OFF?

- **DANGER OF SHORT CIRCUIT ARCING FAULTS**. A short circuit occurs when conductors of opposite polarity are accidentally bridged by a conductive object or bridged to grounded metal. Metal screwdrivers, wrenches, fish tapes, test instruments, etc. have all been found to have made inadvertent contact while persons were working on live equipment. An arcing fault may be established that is limited only by the total impedance of the circuit. The arcing will continue until circuit breaker, fuse, or equipment ground fault protection device on the line side of the fault opens the circuit. Even if the short circuit protective device opens the circuit without any intentional delay, portions of the conductors and other metallic materials in the path of the arc may explode violently, showering the area with hot molten metal that can cause severe burns or death. The flash associated with the arc can also cause permanent eye damage. Finally, a short circuit may expel shrapnel toward the workman, penetrating clothing or the body.

- **DANGER OF NORMAL OR ABNORMAL SWITCHING OPERATIONS**. Many of the components of an electrical system (switches, circuit breakers, contactors, etc.) are required to be mounted in an enclosure intended to prevent accidental contact with the live electrical parts. The enclosures are also intended to contain byproducts from normal or abnormal switching operations. When a switch, circuit breaker, or contactor opens a circuit

that is carrying rated current or perhaps an overcurrent, an arc is established across the contacts of the device. Hot gasses and tiny metal particles may be expelled, under pressure, from the device. This is a perfectly normal consequence, and the closed enclosure contains the hot gasses and particles, protecting personnel from possible severe injury. If the cover of the enclosure is opened or removed while the equipment is still energized and a switching operation occurs, severe burns to the body can result from the hot gasses and ejected metal particles, and permanent eye damage can occur as a result of the associated flash. Enclosures for electrical equipment are designed to safely contain normal or abnormal conditions. They cannot do their job if they are opened when equipment is energized.

- **DANGER OF SHOCK OR ELECTROCUTION**. The human body will conduct electrical current! A circuit path can be through both arms, through an arm or leg to ground, or through any body surface to ground. There is a certain current level at which an individual cannot voluntarily release from the circuit. This is the "no let go current" from which burns and death by electrocution can result. Studies have shown that the perception of electrical shock begins when the current through the affected parts of the body is about 0.002 amperes. When the current increases to about 0.015 to 0.020 amperes, it becomes impossible to let go of the circuit. At higher values of current, e.g. above about 0.100 amperes, ventricular fibrillation and/or heart stoppage will cause certain death. The value of current will depend on the body's electrical resistance and the voltage applied. From Ohms law ($I = V/R$) it can be seen that an increase in current through the body occurs when either the applied voltage increases or the body's resistance decreases. Electrical circuits of 120V can be just a lethal as 240V, 480V, 600V, or higher voltage circuits because the current through the body is dependent on the body's resistance. Electrical shock can also cause involuntary muscular reactions which may result in other injuries.

II. WHY ISN'T THE POWER TURNED OFF?

- **LACK OF PROPER TRAINING.** Many people are just not aware of the inherent dangers as noted above. Victims and witnesses of electrical accidents are often amazed at

the violent and explosive nature of electrical energy, the fireballs, bright flashes, acrid smoke, and hot molten metal. Often safety training of electricians is done on an informal basis and may be done by instructors who have already developed bad habits. Sometimes unqualified and unlicensed people work on electrical circuits, and safety training is given lip service, or there is no training at all. It is essential that safety training be emphasized to preclude any such complacency. There are courses in electrical safety provided by state and community colleges, by the IBEW and other labor groups, and by various contractors' associations. Industry management can promote increased safety by requiring more of their employees to attend such formal safety courses.

- **THE ELECTRICAL SERVICE "CAN'T" BE INTERRUPTED.** Countless electrical accidents have been the result of this philosophy. Invariably, the accidents cause major shut downs, outages, and equipment replacement. Thus, what could not be shut down is shut down! With detailed planning, almost any piece of electrical equipment can be taken out of service. While this planning may take additional time and involve additional costs, the risks of not doing it may be an accident that can result in massive equipment damage, personal injury, or death. The time and cost of an accident will far exceed the time and cost of a properly planned outage.

- **THE JOB MUST BE DONE QUICKLY.** When the pressures of time dominate any work activity, mistakes and accidents invariably happen. Caution and good judgment give way to haste. Again, a resulting accident will inevitably take more time to resolve.

- **"I'VE NEVER HAD A PROBLEM BEFORE."** There is a common misconception that if a known safety practice is violated several times without resulting in an accident, then a future accident won't happen either. Many electricians who receive safety training learn on 120V/240V circuits. Much of their work deals with 120V to ground. While it is possible to be shocked, burned and/or electrocuted on 120V/240V systems, these individuals may lose their fear by continually working equipment hot until it becomes second nature. A few shocks, sparks, and burned wires may not deter them. It may be faster to make connections

without having to turn off the power. Transferring this 120V experience to 480V and above can be a fatal error.

- **THE EQUIPMENT NEEDS TO BE ENERGIZED TO PERFORM TESTS.** It is recognized that there are some situations where electrical measurements need to be taken while the equipment is energized. In these situations, there are certain legal requirements that must be met before any work is performed. The National Electrical Code (NFPA 70) is adopted as law by most states and many other government entities. This Code mandates that only qualified persons performing electrical work be permitted access to live parts[1]. A qualified person is "one familiar with the construction and operation of the equipment and the hazards involved." The possession of an electrical license may not be sufficient to qualify a person to work on all equipment. Education and training may be necessary for the specific equipment involved. The Occupational Safety and Health Act (OSHA) is a Federal law requiring that employers provide a safe place to work. In the OSHA Regulations[2], reference is made to the NFPA 70E standard on ELECTRICAL SAFETY REQUIREMENTS FOR EMPLOYEE WORKPLACES[3]. Both OSHA and NFPA 70E require personal protective equipment that is adequate for the particular job at hand.

III. OTHER HAZARDS

There are a number of other hazards related to working equipment hot that are not obvious. In particular, determining that a circuit is OFF can be difficult in some instances. Even with the best of intentions to avoid working hot, it is necessary and important to check for circuit voltage with an appropriate voltmeter before working on equipment presumed to have been deenergized. This situation results when the equipment involves items such as tie breakers, double-throw disconnect switches, automatic transfer switches and emergency generators. In such cases, turning the equipment to OFF may result in power being supplied by another circuit route or from another source. Working on these circuits requires extra knowledge and caution.

The use of lock outs and lock off tags and equipment is essential (and mandated by OSHA Regulation 29 CFR 1910.333(b) (2) et al.) when working remotely from a disconnect device. The electrician must assure that the power is OFF and stays OFF.

Another less obvious hazard can exist when restarting equipment after a fault. Resetting or replacing an overcurrent protective device without correcting the cause can result in circuit breaker tripping, fuse opening, and possible equipment and personnel damage from arc byproducts. This problem can occur at initial start up, restart after rework, and restart after incidents such as short circuits or water damage. It is important that the validity of the circuit phase isolation be verified by both dielectric strength testing (hi-pot) and insulation resistance testing (megger). Also, prior to restart, all loads should be shed, i.e., the load switches turned off so that the restart does not close into a large number of motor loads. This sort of activity takes knowledge, education, and training and should only be attempted by qualified persons.

IV. IN SUMMARY

No electrical accident can happen when the power is not present. While that statement seems to make obvious sense, this article has attempted to make another statement clearer. Electrical accidents can and do happen when working on equipment that is energized. A simple accident can result in severe explosion causing major equipment damage, severe personnel injury, and death. Employers need to require the wearing of proper protective clothing and on-going safety training programs so that their employees are adequately protected and informed of the hazards involved.

[1] See NFPA 70 (National Electrical Code) Section 110-17 and 110-31

[2] See NFPA 70E, Part II

[3] See 29 CFR 1910