

# Dangers and hazards of entry into live substations and enclosures

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**This paper looks at the dangers and hazards of entering and working in live substations and enclosures. It looks at some specific examples and incidents and the reasons why persons entering these areas must be trained and deemed competent to work in a substation unsupervised. It looks at the pre-entry requirements, as well as identifying potential or actual dangers and hazards and legal requirements.**

There are many dangers and hazards which have to be taken into account when entering live substations and enclosures and many accidents can be avoided if the correct action is taken.

## Definitions

*Substation:* Any building, room or fenced enclosure containing electrical apparatus used for control, distribution and supply of electrical power.

*Enclosure:* An indoor or outdoor site where electrical apparatus is enclosed and the access locked to prevent unauthorised entry.

*Live enclosure:* Any room, chamber, yard or enclosed area, in which it is possible for a person, from ground floor level, to make inadvertent contact with, or infringe on safety clearance to live conductors or apparatus or any room, chamber, or enclosed area fitted with an automatic fire suppression system.

*Safety clearance:* The minimum distance that any part of a person's body or work tool may come close to any bare, unearthed low voltage (LV) conductor or unscreened, unearthed medium or high voltage (MV/HV) conductor.

*Section clearance:* In the case of any bare live LV conductor and an unscreened live MV/HV conductor, the minimum clearance of the conductor, from any point on or about the permanent equipment, where a man may be required to stand, measured from the position of his feet.

*Live chamber:* Any chamber, enclosure or any situation in which inadvertent contact with conductors or live parts of electrical apparatus, working at high voltage, is possible from ground floor level.

*Prohibited area:* An enclosed area, in which live conductors or live parts of electrical apparatus, working at high voltage are accessible, but situated in such a position that inadvertent contact is not possible from ground floor level.

*Restricted area:* An enclosed area, that is neither a live chamber nor a prohibited

area as defined and that is enclosed for the purpose of power system security and the safety of personnel. In both live chambers and prohibited areas, live high voltage conductors are present, but in a live chamber, these live conductors can be touched from ground floor level, whilst in a prohibited area they cannot be touched from ground floor level.

*Barrier:* Any device that is designed to restrict approach to live electrical apparatus, excavations or other dangerous conditions.

*Breaker/circuit breaker:* A mechanical switching device, capable of making, carrying and breaking of currents under normal circuit conditions and also making, carrying for a specified time and breaking currents under specified abnormal conditions, such as fault conditions.

*Earthed:* Connected to the general mass of earth in such a manner as to ensure an immediate safe discharge of electrical energy.

*Isolate:* To physically disconnect from all possible sources of electrical potential. This can be achieved by opening of links, removing of fuses, racking out switchgear, locking off and placing a danger tag.

## Substation pre-entry

Before entering a substation there are certain pre-requisites that should be carried out:

- Check and disable any fire suppression system. This is imperative, as a person's life can be endangered, if the fire suppression system is triggered. There are several systems, but the most common are CO<sub>2</sub> and argonite gas.
- Check there is at least one fire extinguisher present, its condition and when it was last tested.
- Check substation signage and that you have correct personal protective equipment (PPE).
- Before allowing staff to enter the substation, check for any hazardous conditions, give safety talk, explaining dangers, hazards and emergency assembly point.

## Entry

After entry, certain things must be done/checked before any work is carried out:

- Sign substation log book and look for any abnormal conditions that could compromise your safety during your task.
- Call control (if there is a control centre) and inform them that you are at the substation and the reason that you are there.
- Conduct a risk assessment (Take 5) and assess any dangerous condition, discuss with staff and obtain their signatures.
- Use your senses, look for hazards, listen and smell for any arcing.
- Mitigate any hazard identified, e.g. barricade any live parts.
- Ensure that no unauthorised person can gain access to the area while work is being carried out.
- Check condition of all the circuit breakers against the drawings.
- Check for any alarms and discrepancies.
- Check first aid kit available.
- Check all equipment and operating tools are available before starting task.
- Check battery tripping unit (BTU) and perform load test.

## Risk assessment (Take 5)

A written risk assessment must be conducted before any task is carried out. This is generally referred to as a Take 5, which means that you should take five minutes to stand back and assess the risks before starting the work. This should not be an over complicated or over designed document, as a general risk assessment (code of practice) should already exist and different hazards occur at different work sites, even though the task remains the same.

When any risk is noted, control measures must be put in place – remember the hierarchy of control:

- Elimination
- Replace (method or process)
- Redesign (engineering)
- Separation (isolation or guard)
- Administration (training process)
- PPE

Mechanical	Materials	Electrical	Health	Environment	Other
Slipping	CO <sub>2</sub> gas	Shock	Gas	Air pollution	No supervision
Tripping	Argonite	Burns	Dust	Water pollution	Not trained
Moving machinery	Fire	Explosion	Noise	Ground pollution	Remote control operation
Unsupported loads	Solvents	Switching	Lighting	Spillage	Not complying with rules
Tools	Asbestos	Lock out	Ergonomic	Waste disposal	Complacency
Flying objects	Acid	Isolating wrong circuit	Fumes		Safety clearance
Hot work	Hot metal	Electrocution	Heat		Sharp edges

Severity/consequence						
Weighting	1	2	3	4	5	6
Effect	No impact	Minor	Moderate	Major	Severe	Catastrophic
Explanation	No injury	First aid case	Serious medical treatment	Lost time injury	Fatality; permanent disability	Multiple fatalities

**Risk rating = severity x probability**

Probability/likelihood						
Weighting	1	2	3	4	5	6
Frequency	Rare	Unlikely	Possible	Likely	Almost certain	Certain
Explanation	Expected never to happen	Can happen once/year	Can happen once/month	Can happen once/week	Can happen daily	Many times a day

Risk rating							
<b>Probability</b>	6	6	12	18	24	30	36
	5	5	10	15	20	25	30
	4	4	8	12	16	20	24
	3	3	6	9	12	15	18
	2	2	4	6	8	10	12
	1	1	2	3	4	5	6
	<b>Severity level</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>
<b>Severity</b>							

Task	Hazard	Risk	Control	Severity	Probability	Risk rating
<b>Signatures of risk assessment team</b>						
Name	Company	Signature	Name	Company	Signature	Date

Table 1: Hazard prompt list.

You will note that PPE is the last resort and not the first line of defence, as many people think.

### Examples of dangers and hazards

- Working in a capacitor bank enclosure – close proximity to unscreened, unearthed conductors. A control point earth must be placed at the circuit breaker and a working earth between the harmonic filters and the capacitor bank. The fence surrounding the capacitor bank, as well as any metal structure within the high voltage yard, must be effectively earthed
- (permanently) to prevent them from becoming alive via induction from the overhead lines.
- Working in an area protected by a fire suppression system – CO<sub>2</sub> gas could be released, and the worker's life would be at risk. Isolate the fire suppression system before working in the area.
- Circuit breaker racked out of the panel and the shutter unlocked, this would allow access to live connections. Lock off all live (potentially live) shutters, busbar and cable.

### Example of a Take 5 risk assessment

- Determine the task specific hazards (the hazard prompt of Table 1 can be used as a reference).
- Assess the hazards identified, using the risk rating tables (raw risk). If the risk rating is above 9, then additional controls must be implemented. After additional controls are implemented, a final risk rating (residual risk) must be calculated. If the final risk rating is not below 10, the hazard must be signed off by the responsible person.
- All members of the workforce must be aware of any risks involved and must sign the risk assessment to acknowledge the risk controls to be implemented.

### Legal requirements

#### Notices

Without derogating from any specific duty imposed on users of machinery by the act, the user shall cause notices to be exhibited within and at all designated entrances to the premises, as the case may be, on which generating plant and transforming, switching or linking apparatus are situated. The notices must:

- Prohibit unauthorised persons from entering such premises.
- Prohibit unauthorised persons from handling or interfering with electrical machinery.
- Contain directions of procedure in case of fire.
- Contain directions on how to resuscitate persons suffering from the effects of electric shock.

Provided that this regulation shall not apply to miniature substations (MSS) and distribution boxes, on condition and their access doors can be locked or bolted and that only authorised persons are permitted to open them and work thereon.

### Switch and transformer premises

The user shall cause enclosed premises housing switchgear and transformers:

- To be of ample size to provide clear working space for operating and maintenance staff.
- To be sufficiently ventilated to maintain the equipment at a safe working temperature.
- To be, as far as is practicable, constructed to be proof against rodents, leakage, seepage and flooding.
- Where necessary, to be provided with lighting that will enable all equipment, thoroughfares and working areas to be clearly distinguished and all instruments, labels and notices to be easily read.
- To have doors or gates which can be readily opened from the inside, opening outwards.
- To be provided with fire extinguishing appliances, which are suitable for use

on electrical machinery and which are in good working order: provided that, in the case of unattended premises, suitable fire extinguishing appliances need only be made available at such premises when work is in progress thereon or therein.

- To be of such construction that persons cannot reach in and touch bare conductors or exposed live parts of the electrical machinery.

No person, other than a person authorised by the user, shall enter, or be required or permitted by the user to enter premises housing switchgear or transformers unless all live conductors are insulated against inadvertent contact or are screened off, provided that the person so authorised may be accompanied by any other person acting under his control.

### General

All live substations and enclosures should be kept closed and locked to prevent unauthorised entry. Without limiting the responsibility of all employees to comply with applicable laws at all times, it must be ensured that the responsible person shall ensure that all persons working in a substation or enclosure are adequately trained to perform work in a substation.

### Categories of persons allowed to enter live substations and enclosures

*Competent person:* A person who complies with Section A1 (vii) of the OHS Act and is in possession of a competency certificate for the classes of work he is deemed to be competent to work without constant supervision.

*Authorised person:* An authorised person shall mean a person recommended, in writing, by the electrical engineer or his nominee, and appointed by the designated person to carry out switching, isolating, testing and earthing procedures on MV/HV mains and/or apparatus in liaison with and under the instructions of a control officer as applicable and to issue work permits in respect of such mains and apparatus.

*Specifically trained person:* Shall mean a person who has been sufficiently trained to undertake certain tasks on or near live electrical apparatus without being under the constant supervision of a competent person.

*Non-competent/pre-competent person:* Under the direct and personal supervision of competent person.

### Duties when entering a live substation or enclosure

- Accept responsibility for all persons assisting him and for non-competent persons personally supervised by him.
- At all times exercise proper control over these persons and issue explicit and proper instructions and obtain

confirmation that the instructions are understood.

- Ensure that only necessary persons enter a live substation, yard or enclosure.
- Ensure that all persons under his control are warned of the danger of inadvertent contact with live conductors and apparatus.
- Be responsible after entering that no unauthorised person can get access.
- Be responsible for the barricading and/or demarcating of any doors or gates left open during the work.
- Erect temporary barriers to prevent persons coming into inadvertent contact with or encroaching safety clearance to live mains/apparatus.
- On leaving the substation or enclosure, be responsible for ensuring that the door or gate is locked and that the key is removed.
- Where adjacent equipment is live, delimit the section which is set aside for work to be carried out by the use of barriers arranged so that safety/section clearances are maintained.
- Delimit the area at ground floor level and the structure or apparatus on which the work is to be carried out.
- When it is impracticable to provide adequate barriers and screens, arrangements shall be made for a competent person to watch continuously the men at work to ensure that they incur no risk.
- Use of portable ladders and long objects where there are exposed live conductors: Portable ladders and other long objects shall not be used without the permission of an appointed person who shall define the conditions of use to the person-in-charge of the work. The movement and erection of such ladders shall then be carried out only under the direct supervision of the person in charge of the work and when moved at ground level they shall be carried only in a horizontal position and as near the ground as practicable.

### OHS Act (1993) Section 8: General duties of employers

Every employer shall provide and maintain, as far as is reasonably practicable, a working environment that is safe and without risk to the health of his employees.

Without derogating from the generality of an employer's duties under subsection (1), the matters to which those duties refer include in particular:

- The provision and maintenance of systems of work, plant and machinery that, as far as is reasonably practicable, are safe and without risks to health.
- Taking such steps as may be reasonably practicable to eliminate or mitigate any hazard or potential hazard to the safety or health of employees, before resorting to personal protective equipment.

- Making arrangements for ensuring, as far as is reasonably practicable, the safety and absence of risks to health in connection with the production, processing, use, handling, storage or transport of articles or substances.
- Establishing, as far as is reasonably practicable, what hazards to the health or safety of persons are attached to any work which is performed, any article or substance which is produced, processed, used, handled, stored or transported and any plant or machinery which is used in his business, and he shall, as far as is reasonably practicable, further establish what precautionary measures should be taken with respect to such work, article, substance, plant or machinery in order to protect the health and safety of persons, and he shall provide the necessary means to apply such precautionary measures.
- Providing such information, instructions, training and supervision as may be necessary to ensure, as far as is reasonably practicable, the health and safety at work of his employees.
- As far as is reasonably practicable, not permitting any employee to do any work or to produce, process, use, handle, store or transport any article or substance or to operate any plant or machinery, unless the precautionary measures contemplated in paragraphs (b) and (d), or any other precautionary measures which may be prescribed, have been taken.
- Taking all necessary measures to ensure that the requirements of this Act are complied with by every person in his employment or on premises under his control where plant or machinery is used.
- Enforcing such measures as may be necessary in the interest of health and safety.
- Ensuring that work is performed and that plant or machinery is used under the general supervision of a person trained to understand the hazards associated with it and who have the authority to ensure that precautionary measures taken by the employer are implemented.
- Causing all employees to be informed regarding the scope of their authority as contemplated in section 37 (1) (b).

### Section 14: General duties of employees

Every employee shall at work:

- Take reasonable care for the health and safety of himself and of other persons who may be affected by his acts or omissions.
- As regards any duty or requirement imposed by his employer or any other person by this Act, co-operate with such an employer or person to enable that duty or requirement to be complied with.
- Carry out any lawful order given to him, and obey the health and safety rules and procedures laid down by his employer or by anyone authorised thereto by his employer, in the interest of health or safety.

- If any situation which is unsafe or unhealthy comes to his attention, as soon as practicable, report such situation to his employer or to the health and safety representative for his workplace or section thereof, as the case may be, who shall report it to the employer; and if he is involved in any incident which may affect his health or which has caused an injury to himself, report such incident to his employer or to anyone authorised thereto by the employer, or to his health and safety representative, as soon as practicable, but not later than the end of the particular shift during which the incident occurred, unless the circumstances were such that the reporting of the incident was not possible, in which case he shall report the incident as soon as practicable thereafter.

### NRS 040-3:1995

#### 4.7.9 No switching while work is in progress in a live chamber or enclosure:

Should any switching, other than emergency switching, at any station, on apparatus in a live chamber or live enclosure in which inspection or maintenance work is in progress, all persons shall be withdrawn from the chamber or enclosure until such switching has been completed.

#### 4.8.2 Emergency switching:

Any person is authorised to carry out emergency switching. When emergency switching has been carried out the control officer should be informed as soon as possible.

Please note that emergency switching refers to the opening only of switchgear for the two following conditions: in order to prevent injury to a person or damage to equipment.

### Incidents

#### Incident 1

Two competent electricians were working in a live 11 kV substation containing oil circuit breakers (OCBs) when a fault occurred. Both the circuit breaker feeding the fault and the incoming circuit breaker failed to trip. The upstream protection was slow in operating and the circuit breaker feeding the fault exploded, killing both of the electricians in the substation. In the ensuing accident investigation it was found that the DC supply at the substation had failed.

It is, therefore, recommended that when working in a substation the batteries and charger are checked and a load test carried out if facilities exist.

#### Incident 2

A fault developed in an outdoor voltage transformer (VT) in a live yard. The VT exploded, causing a fire and extensive damage to equipment. Shrapnel was hurled over 20 m away, embedding itself in a

wall. The investigation revealed that the VT developed an internal fault and exploded. Fortunately, there was no one present in the yard at the time of the incident, however, it can be seen that anyone in the yard at the time of the explosion would have been in great danger.

#### Incident 3

This incident also involved an OCB which exploded; fortunately there was no one in the substation at the time. The force of the explosion was such that it blew out a section of the substation brick wall, hurling bricks some distance away. The investigation revealed an internal fault inside the circuit breaker.

#### Incident 4

A fault occurred on a circuit breaker panel in a 33 kV substation. The force of the explosion blew the breaker out of the panel over 10 m away. Anyone working in the substation at the time would have been injured, had they been near the breaker at the time.

#### Incident 5

Two protection technicians had to conduct current transformer tests on an 88 kV transformer situated at a power station. Permission was obtained from control to do the tests. The gates to the 88 kV yard were open (the lock was damaged and unable to be locked). The technicians made their way to the correct transformer and checked that the links feeding the transformer were open (however, there was a double busbar and the other set of links were closed and the transformer was alive). Assuming the transformer was dead they decided to discharge the conductors before climbing on top of the transformer using a portable earthing lead. As soon as the lead came close to the line there was a flash over and an explosion. The two technicians both received arc flash burns to the face and hands and injury to their legs jumping down from the transformer. An investigation revealed the following:

- Control incorrectly gave permission for work to be carried out.
- The gate to the 88 kV yard was open and could not be locked.
- Both of the technicians were not trained on high voltage and could not identify the hazards and follow the correct procedures and were, therefore, not competent to enter the yard by themselves.
- No testing or earthing had been carried out.
- No work permit had been issued.
- No risk assessment had been conducted.

#### Incident 6

A new switchboard was being installed at

a substation and a temporary 11 kV supply was taken from a spare circuit breaker, on the existing feeder board, to the incoming panel of the new switchboard. Once the permanent supply was installed and ready for connection, it was decided to leave the temporary cable in as a back-up supply. In order to do this, the spare breaker on the existing feeder board was isolated and locked out and the cable on the new switchboard was disconnected and left open at the back of the panel.

A contractor, completing his punch list, was numbering cables. He opened the substation door and left his non-competent worker inside to complete the list. The worker walked around the back of the switchgear, where he trod on the exposed cable, causing ionisation to earth, which caused a phase-to-phase fault. The flash caused by this fault generated third degree burns to 80% of his body and he died in hospital four days later. The investigation revealed that the circuit breaker on the existing feeder board feeding this cable had tripped on earth and phase-to-phase fault. Who racked the circuit breaker in and closed it is not known. Why the ends of the temporary cable had not been removed from the switchgear on the existing feeder board and started out and earthed on either side is not known.

Looking at all six of the above incidents it is clear that a risk assessment needs to be conducted when entering these areas, to identify the hazards, put in place remedial measures and inform workers of dangers and hazards present.

### Conclusion

From the above, one can see that it is not only a legal requirement for all staff entering a substation to be trained (or under the direct and personal supervision of a competent person), it is necessary to prevent injury or even death, therefore, training is essential.

So often, at the workplace, we hear production before safety, not safety before production.

No operation or urgency of service can ever justify endangering the life of anyone. Before doing any job, ask yourself this question: Would I let my 16 year old son or daughter do this job? If not why, should I be doing it? Or expect anyone else to do it?

### References

- [1] Occupational Health and Safety Act (1993) (OHSAct)
- [2] NRS 040
- [3] Operating Regulations for High Voltage Systems (ORHVS)
- [4] Abaqulusi Municipality Safety Rules

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