Guidelines for Electrical Hazards

Version 2

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Please contact apga@apga.org.au for further information.

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Introduction

Electrical hazards may be concealed during pipeline construction operation and maintenance, especially in metallic pipelines. It should be noted that many of these hazards can also occur in the operation and maintenance of other types of pipelines that contain conductive liquids.

Pipeline construction, operation and maintenance activities may expose workers and the public to hazards which have the potential for injury and death by contact with electrical energy. These risks may be high and need to be managed effectively during all phases of pipeline life cycle. The AS 2885 safety management study (SMS) for the specific pipeline should be the primary resource to identify the known sources and mitigation for most of these hazards.

Hazards and potential risk may increase each year especially when pipelines and power lines are installed together in energy transmission corridors. It is important to ensure the AS 2885 SMS is current.

Scope

This guideline applies to pipeline and station maintenance and construction activities conducted by pipeline workers. It is not intended to cover work performed by electrically qualified persons on electrical apparatus.

1 Electrical hazards

There are a number of electrical sources which have the ability to cause hazards to pipelines and workers. These hazards use a number of different mechanisms, to transfer electrical energy to the pipeline or workers. Understanding these mechanisms helps to identify the potentially hidden hazards. AS 4853 Electrical Hazards on Metallic Pipelines and AS 2832.1 Cathodic Protection of Metals Part 1: Pipes and Cables, list the following hazard mechanisms:

Direct coupling occurs when actual contact is made with a power line or a live source of electrical energy, or when an object is sufficiently close for an electrical arc to become established. (This mechanism is generally likely to present only during construction.).

Low frequency induction (LFI) arises due to the electrical coupling between long structures, such as between pipelines and powerlines where they run parallel for some distance.

Earth potential rise (EPR) occurs when current discharges from a power line cable or earth. EPR can also occur on transmission tower footings when there is a fault on that tower. Lightning can also be a source of EPR. A lightning strike on or near a pipeline / earth grid may cause EPR.

Capacitive coupling occurs due to the placing, temporarily or permanently, of pipe / lines adjacent to high voltage power lines; and by the accidental contact of pipelines with other electrical systems such as electricity distribution or traction systems.

This principal means where an electrical hazard may arise on an existing pipeline it is likely to be through low frequency induction (LFI) and earth potential rise (EPR).

Concerns with conductive coupling generally, only need to be addressed when machinery is operating which could contact a power line or a live source of electrical energy, and capacitive coupling is usually earthed through coating defects or other connections to the pipeline. Nevertheless these latter two factors still require consideration when preparing designs and procedures for construction, operation and maintenance of pipelines especially on pipelines which

are usually coated with high quality anticorrosion coatings that have highly effective electrically insulating properties where high quality coatings or very dry soil are may be uncounted.

The following list identifies electrical hazards to which pipeline workers may be exposed:

- overhead power transmission lines
- underground power services
- static electrical energy generation
- portable power generation equipment and electrical powered tools
- lightning strike on stations or pipelines.

Each of these sources of electrical energy has the potential to cause injury or death.

2 The hazards and mitigation to reduce risk

2.1 Overhead power lines

2.1.1 Direct contact

This can be caused by breach of mandatory minimum clearances from equipment such as sidebooms, cranes, excavators or any mobile plant that could come into contact with, or close proximity to overhead or underground power lines and cables. In such cases, electrical energy can be conducted through the equipment and the person operating it. Very often, if the mobile plant is metal tracked, the operator will survive this contact so long as the operator stays on the machine. If it is essential to leave the machine the operator must jump clear from the machine to avoid touching potential voltages on the machine, then hop away (with feet together) to avoid step potentials on the ground near the machine. Depending on the voltage being carried by the system, tyres of wheeled equipment coming into contact can be blown out and/or catch on fire and persons some distance away from the incident can be injured by the light and heat energy released by the electrical discharge (known as the arc flash).

The power system may register the contact as a line fault and trip the supply. The system may also attempt and reset the trip, within seconds. A second trip may occur and the system at fault may remain isolated. Phase to earth fault may not operate the protection system and this does not cover a circuit protected by fuses HV or LV.

2.1.1.1 Mitigation

IDENTIFY the location, voltage and height of overhead power lines that run across or adjacent to the pipeline easement. Ascertain any relevant authority permitting requirements and minimum clearances.

PRE-PLAN work activities adjacent to or underneath power lines, including placement of appropriate signage and safe clearance catenary wires, use of safety observers and fitment of earth chains to rubber tired plant when operating under HV power lines.

LIAISE with the power authority and where practicable have the power lines isolated during operations with high plant/equipment. But STILL TREAT ALL POWER LINES AS LIVE and work accordingly.

INFORM the work crews on a daily basis of the location, height and voltage of power lines they will be working adjacent to or under.
REVIEW the crew's safe work method statement (SWMS) with them and ensure that risk mitigation methods are identified and understood by all crew members.

CONFIRM the emergency procedure in case of power line contact with the power authority and all crew members on a regular basis.

2.1.2 Induced voltage

This is the effect of proximity to overhead power lines. Under normal operating conditions a three-phase power line may be expected to be operating as a balanced system such that the surrounding electromagnetic field is small. However, some induction will result due to the slightly different distances of each phase conductor from a nearby pipeline, or due to current imbalance between phases.

Long distances of exposure, typically of the order of several kilometres, may result in voltage levels sufficient to reduce the effectiveness of cathodic protection (CP) system, or possibly result in voltages sufficient to present a risk to personnel under power line fault conditions substantial voltages may be induced on adjacent parallel structures such as pipelines. Phase to earth fault currents may approach tens of thousands of amperes, flowing from the substation(s) via the faulted power conductor and returning via earth.

This presents a highly unbalanced condition to any nearby pipeline, and electromagnetic induction may result in induced voltages of many thousands of volts unless mitigation is installed. This effect relies on the following criteria:

- system voltage,
- distance from the power line,
- length of pipe / string adjacent to the power line.

Severe LFI conditions may also occur on single phase power transmission systems using an earth return. DC traction systems using the rails as a return conductor, and single wire earth return (SWER) power distribution systems that are used extensively in some rural areas.

2.1.2.1 Mitigation

Earthing of pipe strings and pipelines by approved means must be efficient to ensure electrical potential in the string is rapidly discharged. When conducting 'tie in' operations both strings need to be earthed together, to eliminate touch potential across the two strings by the following methods:

- Ensuring a good connection of earth cable to the pipe string (a bolted clamp is preferable to a crocodile clip).
- Ensuring the earth stake is driven well into the ground where practicable and in extremely dry conditions, keep the ground around the stake damp to improve its conductivity and lessen resistance.
- Maintain the earthing while moving pipe strings eg. when lowering in.
- Installation of earth safety mats or earth grids.
- Considering measures that prevent direct access to strings or pipeline facilities that have potential to reach hazardous touch / step voltages.

Human bodies are very good conductors of electricity. Earthing systems need to protect the human body from electric shock. These guidelines are found in AS/NZS 3000 and AS/NZS 3007 which give the distances from power lines that welded pipe strings can be located, to ensure that the maximum allowable potential rise in the pipe string is not exceeded. These Standards also give tables containing the earth stake or bed resistance and the distance between installations that is required to reduce the resistance and give more effective earthing.

Compliance with AS/NZS 4853 requires that precautions be taken to limit touch voltages to 'Category A' limits during construction or maintenance activities. Measures include restricting the length of welded or jointed pipeline prior to application of earthing. During operation or maintenance activities there are specific requirements in AS2832.1 Appendix G for Touch potential areas

classified as Category B in AS/NZS 4853. DR4853 provides methods to calculate the touch/ step potential and shows an example of how a single length of 1m diameter pipe insulated from ground, 10m from a 275kV power line can induce voltage, barely perceptible to touch, that can generate a spark to ignite flammable vapour in the air.

2.1.3 Power line fault

Remote or local faults on electric power lines can cause large unbalanced currents in the overhead conductors, which can induce higher than normal voltages (LFI) in adjacent pipelines by the transformer effect. Additionally, an insulator breakdown at a pylon/tower can cause the high power line fault current to flow to earth (EPR), raising the surrounding soil potential to very high voltages. A flashover on a structure can also be caused by wildlife such as bats, birds and possums. In both cases the resulting current will take the line of least resistance. Generally, a string of welded pipeline will tend to have less resistance than the ground and of course a good connection by way of the earthing systems. Fault currents can travel 50-100 km through pipelines.

Persons in contact with the pipeline may be subject to electric shock when high voltages are present, under both power line operating and power line fault conditions. Voltage levels due to lightning strikes on the power line may be sufficient to result in arcing to personnel or equipment in close proximity of the pipe yet they could be up to 100km from the location of the lightning strike and maybe even unaware of the presence of a threatening electrical storm. Lightning strike can cause a hole and subsequent 'jet fire' on operational gas transmission pipelines. A 'jet fire' is a long, single stream of ignited gas where the pipeline has not ruptured.

In Australia, power lines are well maintained and the probability of electric shock from LFI / EPR is low (1-2 faults per annum of up to 1 sec duration per 10km of exposure). However, the outcome should it occur in the vicinity of pipeline works, particularly construction where permanent mitigations are not yet installed, could be catastrophic due to the number of persons who may be in contact with the pipe at the time. Unfortunately, power line authorities cannot predict such events and would not be aware of a fault until after it actually occurred.

Persons who could possibly be at particular risk from electric shock, such as personnel requiring heart pacemakers or with known heart conditions, are advised to seek medical advice prior to engaging in work on metallic pipelines where voltages may be present, which could deliver electric shock.

The overhead earth wires on the transmission lines act as a 'collector' for lightning strikes in the corridor where pipelines share the easement. Such flash attachments do not proceed further than the nearest tower, because of the effective wire impedance and the fast rise time of the lightning surge. The net result is that during a thunderstorm the towers are caused to discharge about 15 times more often than the flash density for that area. Thus the hazard to pipeline and personnel is increased near the towers.

2.1.3.1 Mitigation

Whenever the LFI hazard is present, the risk will be high and minimisation strategies must be implemented and maintained. In this case, it is essential that ALL persons likely to come into contact with steel pipe strings are at the same potential as the pipe. This can be achieved by the use of PPE in the form of work boots / gloves with appropriate rated earth voltage ratings. As a minimum, work boots should be in good condition for maximum protection.

Other controls include equipotential screen mats and use of low resistance soil or applying a low conductivity fluid to the ground adjacent pipe strings is also feasible. In all these cases, there must be connection to a running earth. When considering the strategies outlined above, thought must also be given to environmental management. Importation of soils, especially if they contain seeds of noxious weeds or other material that could pollute the local environment, as can fluids containing chemicals that lower resistivity.

Other strategies:

- Provide information to the work party to ensure compliance with the requirement of equipotential systems.
- Maintenance of the systems by licensed electricians familiar with the hazards.
- Signage at the approaches to pipe strings, warnings or hazards.

Lightning presents a significant risk to all pipeline workers. Strategies need to be implemented to detect potential lightening events either by the use of weather services, electronic devices and training of workers to make simple observations. Preparation to shut down field activities should commence when an electrical storm is within 50km. As a minimum, once thunder is heard, workers in the field should seek protection of a building or an all metal vehicle cabin.

If no cover is available workers should stay a low as possible. Paradoxically the most shielded location in a thunderstorm is under a power transmission line, mid span. It is critical that insulated joint protectors (IJPs) are checked every six months for correct operation. All field persons must be made aware of electrical hazards and the purpose and operation of IJPs.

2.1.4 Underground power services

Damaging live underground power cable during pipeline construction can occur. The type of work activities that have damaged underground HV cables include, pipeline excavation, under-boring and directional drilling operations. Damage to cable insulation can result in electrical energy being conducted through equipment that comes into contact with the live power source. Implications are that the equipment can transfer the energy to the persons operating the equipment. This can cause injury or death.

2.1.4.1 Mitigation

IDENTIFY the location, depth and voltage of underground power cables that run across or adjacent to the pipeline easement.

PRE-PLAN work activities, including hand digging to expose cables and added protection for exposed cable during lowering of pipe strings.

LIAISE with the power authority and where practicable have the power cables isolated during exposure activities. STILL TREAT ALL POWER CABLES AS LIVE and work accordingly.

INFORM the work crews as required of the location, depth and voltage of power cables they will be working adjacent to or under.

REVIEW the Crew's JSAs with them and ensure that risk reduction methods are identified and understood by all crew members.

CONFIRM the emergency procedure in case of power cable dig-up with the Power Authority and all crew members on a regular basis.

COMPLY with approved work procedures.

2.1.5 Static electrical energy generation

Most noticeable in pipe coated with Trilaminate, static potential build up can reach up to 30,000 volts and is unpleasant for persons in contact with line. Also, there have been instances of ignition of rags soaked in cleaning fluids during preparation of weld margins for wrapping.

The following are the most common cause of electro-static generation:

- Sand and dust being blown over the pipe. The higher the velocity, the greater the charge.

- Grit blasting of the weld margin prior to wrapping.
- Railway lines with SWER having a mutual coupling effect.
- Solar activity and changes in the Earth's magnetic field (more often in pipelines running north to south and is called planetary or telluric effect).

2.1.5.1 Mitigation

- Efficient earthing of welded pipe strings using the same methodology as induced voltage.
- Maintain a distance of at least 3 welds between grit blasting and pre-wrapping.

2.1.6 Portable power generation equipment for power tools

Defective extension leads and powered hand tools are the most common cause of electrical shock to construction workers. Pipeline construction is a repetitive production process involving work crews moving along a ROW. In these circumstances, extension leads and tools are prone to physical damage.

Welding crews are most at risk from defective electrical equipment. This equipment uses quite high voltage (15,000V to 30,000V) but usually at a low amperage. These voltages can be hazardous to all persons.

2.1.6.1 Mitigation

- Inspection and tagging of all extension leads and power tools in accordance with AS/NZS 3000.
- Use of an earth leakage circuit breaker (ELCB) between the AC power generation source and electrical equipment.
- Development of a culture of continual visual monitoring of electrical equipment by work crews and the removal from service of defective or suspect equipment.
- Set up of welding rigs to minimise the risk of physical damage to extension leads and electrical power tools and the possibility of immersion in water (e.g. pools of water on the ROW).
- Ongoing information and training sessions for work crews through inductions and toolbox meetings
- Use of equipment in accordance with manufacturer's instructions.
- Compliance with recommended maintenance routines for portable generating equipment (including welding generator sets).

3 References

AS/NZS 3000; Wiring Rules
AS/NZS 3007; Earthing Systems
AS 2885; Pipelines—Gas and Liquid Petroleum Pt 1, Design and Construction
AS 2885; Pipelines—Gas and Liquid Petroleum Pt 1, Operations and Maintenance
AS 2832; Guide to the Cathodic Protection of Metals PT 1, Pipes, Cables and Ducts
AS/NZS 1768; Lightning Protection
AS 1674; Safety in Welding and Allied Processes Pt 2,
AS 4853; Electrical Hazards on metallic pipelines (including DR4853 10/6/2010)
Electrical NACE Recommended Practice RP0177-95