ELECTRICAL EARTHING – RISK MANAGEMENT STRATEGIES FOR THE WATER INDUSTRY

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INTRODUCTION

In 2005 following the electrocution of an employee, Sydney Water with the assistance of Energy Australia and Integral Energy (the Electricity Network Operators or ENOs in Sydney Water's area of operations) and the NSW Electrical Regulators, Department of Water and Energy (formerly DEUS) and the Office of Fair Trading began a review of the impact of the use of non-conductive pipe materials on residential electrical earthing systems.

The majority of the electrical distribution systems in Australia require a connection between the supply neutral and the customer's earth system at each property, known as the Multiple Earth Neutral (MEN). This provides a safety back up to protect the electrical installation should a customers earthing system become defective. In NSW, MEN bonding became the preferential system in the 1960's based on the metallic water reticulation system.

Prior to July 1976 most properties depended on their metallic water service pipes as part of the property's electrical main earthing system. Properties built after 1976 are required to conform to Australian Standards AS/NZS 3000 (Electrical Wiring Rules) and generally have a 1.2 m vertically buried earth rod that serves as the primary earth electrode.

Regardless of age, if the water service is metallic, it and other metallic structures (such as metal frames) must be 'equipotentially' bonded to the property main earth to prevent a potentially dangerous voltage rise in the event of an electrical or appliance fault. In practice the water service at most properties formed a more effective earth than a complying earth electrode due to the conductive path to the street water main.

In the MEN system the electrical main neutral is connected, via the MEN link, to the main earthing system at the property's electrical switchboard. Under normal conditions electricity used at the property is returned to the network via the main neutral conductor. If a main neutral fault develops either on the network or customers supply, then the return electrical current will be directed to earth and hence to the water service pipe. Typical arrangement is shown in Figure 1 below.

As the majority of water supply systems are largely metallic, such faults can often remain "hidden", as the electrical impedance of the water pipes/fittings can be very low, and indeed, often only marginally greater than that of the electrical neutral supply conductor. If there is a pre-existing main neutral fault at a residence there will likely be an increased risk of electrical shock or electrocution for the Water Utility worker or the resident. For many years now the water industry has utilised non metallic pipes and fittings as part of its water main repair and renewal processes. The increased use of non metallic materials has now extended to the installation of plastic services within the building.

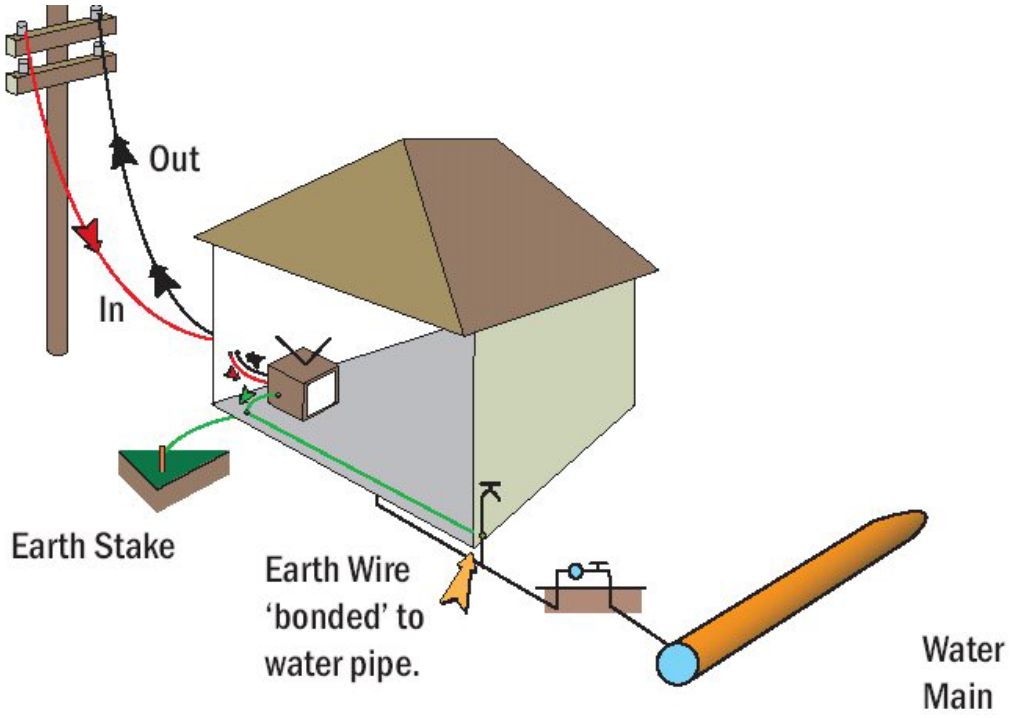

Figure 1: ***Link between the electricity system and the water supply system***

Sydney Water, with the support of the ENO's, has developed and adopted processes to detect potential main neutral faults to support its water main renewal activities. The aim is to assure occupant and worker safety by alerting the relevant ENO to undertake further investigation and repair of any main neutral fault identified.

1.0 Investigation Methodology

A trial was conducted on 216 single residential houses constructed prior to 1970 where water main renewal in non-conducting pipe material was being implemented. The trial sought to assess the impact of water main renewal on the main earthing system at individual residential properties.

The Trial included electrical test and inspections to:

- Determine the effectiveness of the property main neutral by carrying out a neutral fault loop impedance test with the MEN link disconnected.
- Determine the effectiveness of the property earthing system by carrying out an earth fault loop impedance with the MEN link disconnected, pre and post water main renewal, and subsequently, with the underground bridging conductor (or temporary earth rod) disconnected and then reconnected.
- Measure the division of return current (amps) in the main neutral, the main earth and the water service pipe.
- Determine if the property has an earth electrode installed.
- Measure the voltage and current at the property water meter.

After the initial results were obtained the trial was extended to examine the earth fault loop impedance characteristics of residences where the residential water services were installed in plastic pipe and where electrical earthing is provided by an earthing rod alone (an increasing trend nationally because plastic is less costly than copper pipe).

Full details of the trial, its findings and recommendations are included in the Joint Integral Energy, Energy Australia and Sydney Water Trial Report – 'Impact on Residential Earthing'.

2.0 OBSERVATIONS

The overall impact of replacing a metallic water main with a non-metallic main is to increase the property earth fault loop impedance. In general, the lower the impedance, the better the electrical pathway (directly analogous with hydraulics). On average, for all properties where testing was carried out in accordance with the agreed methodology (62 of 216), the effective increase was a factor of 3, from 2.5 ohms before water main renewal to 7.5 ohms, after renewal. However on certain properties, the increase was over 10 fold.

The Network "hidden" main neutral failure rate was 1.9% (1 in 52 properties) for the pre 1970 built tested properties. In comparison, during its water main renewal program over October 2005 to end June 2006, for a work program impacting about 7000 residences, a main neutral fault rate of 0.7% has been detected. Defective earthing systems were found on 5.6% (1 in 18) of the trial properties. Earth electrodes were installed on 23% (1 in 4) of the pre 1970 built properties. The nature of these defect were not investigated. However, it was observed that some properties did not have equipotential bonding to the metallic water service pipes.

On those properties with a sound main neutral, the average main earth current measured at the switchboard pre water main renewal represented 18% of the active load current. A significant variation was observed and return water service current at a number of properties was as high as 50% (with a range of zero to 50%) of the active load current. In essence, even under normal conditions with no electrical fault, current in the water service can be substantial and hence the need for robust safety procedures for Utility staff, contractors and plumbers.

3.0 DISCUSSION OF TRIAL RESULTS

The finding from the above investigation that the prevalence of network and customer "hidden" main neutral faults is higher than originally thought is of concern. It was previously accepted that the incidence of main neutral hidden faults would be in the order of 1 in 1,000 to 1 in 10,000 properties, however, Trial results and subsequent testing has quantified the incident rate as being in the range of 1:100 and 1:200 properties.

The investigations have also shown that, in residences having no neutral fault, where a conductive metallic water main and water service exists, it is normal for an average of about 20% of the load current to be returned via the property's water service and the metallic water mains. Of course, if a neutral fault exists at a residence or its neighbouring properties, then the majority of the load current will be transmitted via the water system. Unless safe work methods are used in anticipation of the presence of electricity, there will be a risk of electric shock, particularly during plumbing work undertaken by the occupant's plumber or the Utility's workers and contractors. AS/NZS 3500 provides clear safety guidelines for plumbers undertaking such work, however unlicensed or 'lay' plumbers are generally unaware of the dangers and the safe work methods that must be used and remain at risk of electrocution. In most cases of "hidden" defective main neutrals, the return current will flow via the water service at the affected residence, through the metallic water main and up the water service at a neighbouring property attached to the same section of water main, and into the neighbouring property's

main neutral conductor.
A residence can thus carry both its return current and that of its neighbour if the neighbour has a "hidden" defective neutral. This means electrical hazards to plumbers and Utility workers can arise from faults at neighbouring properties. Turning the power off at a property does not necessarily eliminate the hazard potential.

4.0 BENCHMARKING IMPACTS OF WATER MAIN RENEWAL IN NON CONDUCTIVE PIPE

With the advent of new materials and technologies, there has been an increased use of non-metallic (or plastic) water services at properties both in the water service from the Utility's water main to the property and within the building itself. Investigations to examine the earthing characteristics at these properties were included as part of the Joint Inter Agency Trial Report.

Three different areas having plastic water services were tested by Energy Australia. These areas were at Newington in Sydney's inner west, the Central Coast and in the Newcastle area. Details are included in the Inter Agency Report referred to earlier.

When the earthing characteristics of properties impacted by water main renewal were compared with those from the above areas, the following results were observed:

- On average, earth fault loop impedance at properties served by plastic water services was significantly higher (by factors of two for one area and three for another) than that at properties (tested in the trial) impacted by water main renewal in non-metallic pipe.

- At Newington, properties having plastic water services generally displayed an average fault loop earth impedance of about 5 ohms higher than that for properties impacted by water main renewal. This represents a 50% increase in average fault loop earth impedance of properties impacted by water main renewal, but the two groups of test results were only on the margin of being statistically different.

The above benchmarking exercise clearly illustrates that the impact on a property's earthing system after WMR is generally less significant than the earthing characteristics of properties served by a non-conductive water service with earth rod (alone) installed in accordance with AS/NZS 3000:2000.

5.0 RECOMMENDATIONS FROM THE TRIAL

The findings from the trial were reviewed and agreed by the Inter Agency representatives and the key recommendations included:-

- A Neutral Integrity test (NIT) based on current split or FLI and a main earth inspection be carried out at each residential property prior to water main renewal.
- The compulsory use of an approved electrical bridge, in conjunction with continuous voltage monitoring is adopted as part of the safe work method for Water Utility workers and contractors, when carrying out WMR transfer of services (and general water main / service repair work).
- The practise of installing an earth rod at the water meter (for pipe bursting jobs) and a bridging cable from the water service to the abandoned water main (for open trench jobs) to be discontinued.
- The appropriate bodies review the relevant codes and standards to confirm their adequacy and ensure that requirements are keeping pace with the introduction of

modern technologies, materials and work practices.

Sydney Water has adopted the above recommendations relating to work procedures and encourages the various regulators and agencies to seriously consider the implications of changing circumstances on the relevant standards (AS/NZS 3000 Wiring Rules and AS/NZS 3500 Plumbing and Drainage Standard), as well as customer and electrical network safety inspection programs.

6.0 RECENT FIELD EXPERIENCES

With the increased awareness and understanding of electricity in the water supply system there has been an increased level of reporting of incidents. These incidents are reviewed and any necessary actions implemented to improve the work procedures utilised by field staff. There has been an increased incidence of back feed of electricity from adjoining properties to the property at which the field crews are working. This raises a question with the option of turning off the power supply at the property at which the work is being undertaken. SWC processes utilise a range of other options in preference to turning off the power supply for its water service repair activities.

SWC has also recorded a number of incidents involving electricity in the Utilities water main whilst crews have been repairing water main breaks. Improved electrical safety procedures have been developed and are currently being implemented.

7.0 SAFETY PROCESSES

Sydney Water has undertaken a number of investigations and assessments to safeguard workers, contractors (plumbers) and customers from electrical hazards arising when work is carried out on the water supply system.

The electrical supply networks and associated earthing in NSW remains the responsibility of The Electricity Industry Regulator (DWE) and the ENO's. The property owner has an obligation to ensure the safety of their electrical mains and the earthing system on their property. The Office of Fair Trading (NSW) has recently issued a brochure to all ENO customers highlighting property owner's responsibility for Electrical Safety.

Safe work methods for workers and contractors have been reviewed and modified to include multiple safety assurance barriers. Sydney Water has adopted a mandatory requirement for two levels of control for electrical safety for work undertaken on a water service. For worker safety these primarily comprise the use of more robust (kick-off proof) bridging conductors for connection across the pipe section that is to be worked on (eg. cut, modified or even for water meter removal), enforcement of the use of approved personal protective equipment (eg. electrical insulating gloves), and the mandatory following of a set sequence of activities.

Sydney Water has now rationalised its current practices and have developed a consistent protocol in relation to Electrical Safety procedures for water main renewal and main tap replacement activities. A single standard protocol for all residential and commercial properties has been developed for water main renewal activities. Similarly a single protocol for water service repairs and main tap replacement has also been developed.

The new protocols for water main renewal activities include:

1. An electrical integrity test (Current Split Neutral Integrity Test - CS NIT) will be undertaken at all properties affected by the WMR program prior to the renewal of

metallic water mains with plastic.

2. A check for hazardous voltage on the water service will be undertaken before during and after connection to the new water main as part of Sydney Water's safe work processes. If a threshold (trigger) voltage. (>5 volts) is detected the relevant ENO will be contacted to investigate in accordance with agreed protocols.
3. Sydney Water will ensure the safety of its workers and contractors by applying appropriate up-to-date safe work methods and procedures.

For main tap replacement activities where an insulated main tap is replaced with a non-insulated main tap, a check for hazardous voltage on the water service will be undertaken before, during and after repair works. If a threshold (trigger) voltage is detected the relevant ENO will be contacted to investigate in accordance with agreed protocols. If no elevated voltage is detected Sydney Water will issue a calling card to the customer advising of work undertaken and appropriate safety information.

Sydney Water will continue to monitor and review its safety processes, as these are critical to the safety of its workers, contractors and customers.

8.0 CONCLUSIONS

Earth fault loop impedance at properties is increased when non-conducting pipes replace metal water mains as part of water main renewal. The degree of increase varies but typically earth fault loop impedance will increase by factors of two to three. Benchmarking earth fault loop impedance of properties with metallic water services that are affected by this renewal activity, with properties served by plastic water services, shows that the impact on a property's earthing system is generally less significant than the earthing characteristics of properties served by a non-conductive water service with earth rod (alone) installed in accordance with AS/NZS 3000:2000.

A neutral integrity test, based on current split or fault loop impedance, should be carried out at each property prior to water main renewal to assure the Utility that its renewal activity will not have potential adverse safety impacts on dwelling occupants or workers. A sound main neutral supply is essential for providing safety assurance to the building occupant and for preventing appliance damage.

The safety processes adopted by Sydney Water and its contractors that include pre WMR main neutral integrity testing result in early detection of both network and property associated main neutral faults. Where a main neutral fault is detected the appropriate ENO is alerted to carry out verification testing and to implement any necessary repairs. Where the fault is on the consumers supply system, the property owner is responsible for rectifying that fault.

The Network "hidden" neutral failure rate was 1.9% (1 in 52 properties) for the pre 1970 built properties tested during the trial. This defective neutral failure rate is higher than that found as a result of subsequent electrical tests carried out when Sydney Water connected property water services to renewed water mains. Approximately 7000 properties were tested in the period from October 2005 to June 2006 as part of the water main renewal program, and the detected neutral failure rate for these properties is 0.7%. These figures are far higher than originally anticipated.

Another incidental but important finding is high incidence of defective earthing systems. The appropriate authorities will be encouraged to alert residents to the critical importance

of maintaining their earthing systems.