Confirming Electrical Isolations

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3	**Jun 04**	**Expanded Attempt Start, pilot lamp**	**CJD**
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Table of Contents

1 Introduction

The need to perform installation or maintenance work on electrically powered equipment necessitates that the equipment must be isolated (de-energised) so that it is safe to access. Equipment commonly used for isolating plant and machinery from electrical power includes circuit breakers, isolators, switches, links and fuses.

Simply switching off and locking an isolating switch is not sufficient. Isolations need to be proven sound.

Confirming that the isolation is sound involves answering “yes” to the following two questions:

1. Has the correct switch handle been turned off?
2. Is the switch electrically off?

Accessing incorrectly isolated equipment could result in electric shock or injury to personnel or damage to equipment.

In recent times operators, maintainers and installers of equipment have considered the risks associated with the mal-operation of isolating devices. Most manufacturers of Isolating Switches incorporate in their range a version of switches that allow an operator to view the state of the switch contacts. The aim being to enhance the confidence that when the switch is turned off – it is in fact, electrically off!

This report provides details relating to the practice of Confirming Isolations on low voltage equipment i.e. < 1,000V in automated or remotely controlled, industrial, manufacturing and mining installations. It will discuss the different aspects of electrical isolations for electrical maintenance and electrical isolations for non-electrical maintenance.

The structure of the report is as follows:

- The **Need** to confirm isolations
- The **Options** available to confirm isolations
- A **Comparison** of the options

Chris Devine is a Director of Redbusbar Pty Ltd. Redbusbar markets and distributes a range of electrical isolation technology products.

2 The need to confirm isolations

The recent interest surrounding the practice of confirming isolations can be attributed to three drivers as follows:

- Worker Accidents
- Industry Regulations and Codes of Practice
- Isolation Switch Failures

2.1 Worker Accidents

A fatality occurred in the mid 1990s in a Queensland, Engineering Workshop.

The fatality involved a Mechanical Fitter working on an overhead Gantry Crane. Prior to accessing the equipment he isolated and locked the isolating switch in accordance with the company's Isolation Procedure. Whilst maintaining the crane he contacted the crane power supply rail and was subsequently electrocuted.

An investigation into the death was conducted. The investigator found one pole of the isolating switch remained closed. The switch's lockout keys were found in the dead man's pocket.

A NIOSH Investigation (National Institute for Occupational Safety and Health - USA) into workplace fatalities during the period 1982–1997, revealed 152 fatalities - 3 related factors contributed to these:

- Failure to completely de-energize, isolate, block, and/or dissipate the energy source (82% of the incidents, or 124 of 152)
- Failure to lockout and tagout energy control devices and isolation points after de-energization (11% of the incidents, or 17 of 152)
- **Failure to verify that the energy source was de-energized before beginning work (7% of the incidents, or 11 of 152)**

2.2 Industry Regulations

An extract from the Queensland Electricity Safety Regulation 2002, Part 2, regarding confirmation of isolations follows:

> <u>Division 2 – Basic requirements for electrical work</u>
> <u>Section 11 – Requirements for electrical work</u>
> (2) Without limiting what the employer or self-employed person must do to ensure compliance with subsection (1), the employer or self employed person must ensure that –
> 1. each exposed part is treated as if it is energised until it is isolated ***and proved not to be energised***; and
> 2. each high voltage exposed part is earthed.

Similarly, an extract from the New South Wales Occupational Health and Safety Regulation 2001, regarding confirmation of isolations follows:

> <u>207 - Electrical work on electrical installations—safety measures</u>
> 1. An employer must ensure that any electrical work on an electrical installation at a place of work is carried out using a safe system of work.
> 2. An employer must ensure that such work is not carried out while the installation's circuits and apparatus are energised.
> 3. The safe system of work ***must include checks to ensure the installation's circuits and apparatus are not energised before work commences and remain that way until the work is completed*****.**

Similarly, AS4024.1 Safeguarding of Machinery, Part 1 - General Principles, regards facilities that allow confirmation of an isolation point as an integral part of a machine.

> "machine isolation shall be designed so that verifying and, if necessary, **testing of the effectiveness of the isolation** ... can be performed easily and reliably"

2.3 Switch Failures

Whilst most accidents occur when workers do not isolate properly, even after following the correct procedures accidents still happen. Switch failure mechanisms that have been reported include:

- Welded switch contacts
- Worn handles that fail to rotate the switch mechanism when the handle is rotated
- Misaligned handles that fail to engage with the “handle to switch” connecting shaft
- Switch bypass faults – cable-to-cable faults

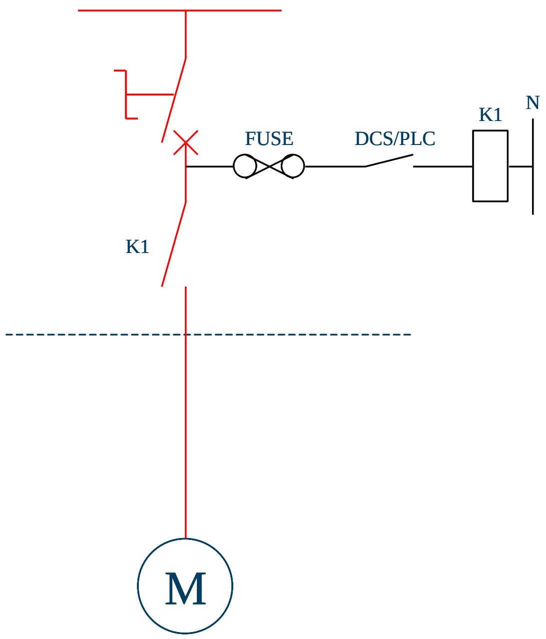
3 The options to confirm isolations

A detailed discussion presenting the various methods that are used today to confirm electrical isolations follows.

3.1 "Test for Dead" direct contact verification of isolation

A single line diagram and simple control circuit for a typical, remotely controlled motor is depicted below as Figure 1.

Figure 1



A remote controller (human or computer) activates the motor on an as needs basis.

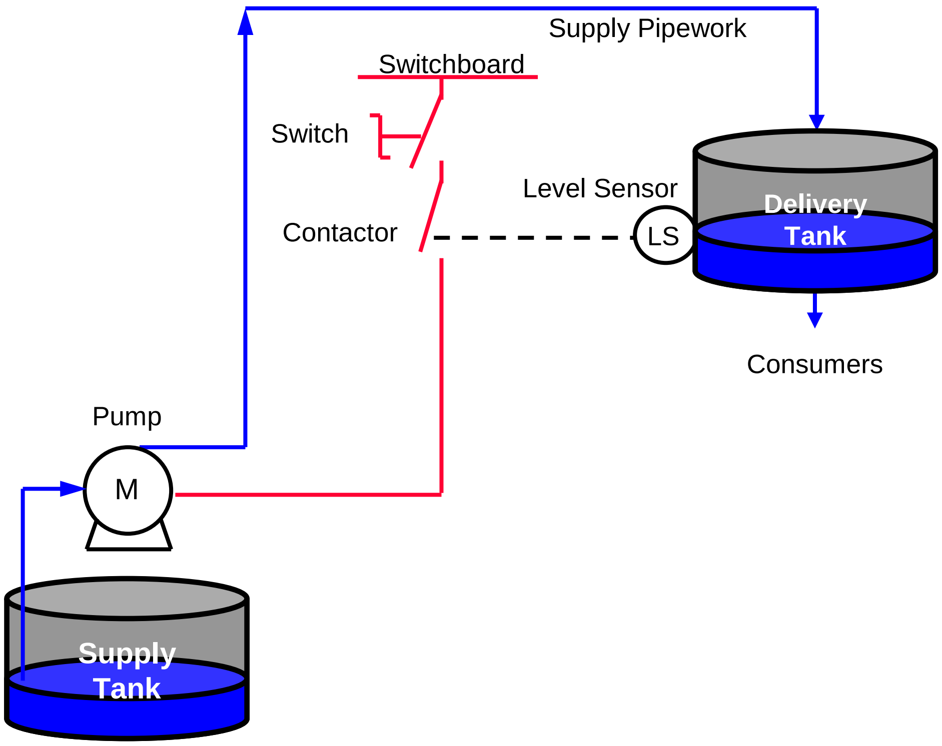
The "Test for Dead" confirmation of isolation procedure is as follows:

1. Open the isolation switch
2. Lock the isolation switch
3. Confirm that each phase on the line side of the isolating switch is alive using a portable voltmeter / indicator or the switchboard voltmeter
4. Test each phase conductor on the load side of the isolating switch with a voltmeter/indicator to confirm the absence of voltage
5. Test the voltmeter / indicator for correct operation on a known voltage source

Steps 3 and 4 are vital to the success of this procedure. They test whether the switch is isolating the supply. The procedure is intended for the confirmation of isolations prior to both mechanical work and electrical work being performed. The person performing the test only requires a voltage indicating device as such equipment costs are very low. Where electrical work is to be performed on the motor it is often a legal requirement that a "Test for Dead" test be performed at the motor as well.

Although the above procedure should be followed rigorously, steps 3 and 5 are usually not performed. What is even more alarming is that if the "Test for Dead" test is performed only at the motor terminals, measuring a lack of voltage is potentially misleading. To illustrate the situation, Figure 2 below depicts a simple pumping system where the supply tank delivers to the delivery tank under the automatic control of a level switch and actuated pump. In the circumstance when the pump has failed and requires replacement, consider the application of the "Test for Dead" Isolation Procedure.

Figure 2



After testing for power at the motor terminals and determining that no power exists, some people think that it is safe to commence work on the motor. In the case where the level in the consumer tank is high, the level switch will not be actuated and the contactor will be off as illustrated. However, if the isolator is turned off, but is faulty, as soon as the level in the consumer tank drops and the level switch operates and actuates the contactor, then a dangerous situation results. That is, power will pass through the faulty isolator, through the closed contactor and appear at the motor that is in the process of being maintained. An electric shock, physical injury or death is a likely outcome for the maintenance person. So a "Test for Dead" at the motor terminals will reveal that the motor is deenergised at the time of testing but not that it is effectively isolated.

Whilst this example illustrates the danger associated with an automatic system, manual control from a remote location such as a control room or push button station will also present the same potential danger. In addition, the following shortcomings exist with the "Test for Dead" confirmation of isolation procedure:

a. The procedure can only be performed by an electrician
b. Power is initially required to perform the confirmation of isolation procedure which makes coordination difficult during plant wide shutdowns
c. Electromagnetic induction can provide confusing results
d. Requires a person to follow a procedure - human error

Despite the above paragraphs discussing how the "Test for Dead" confirmation of isolation procedure can provide misleading results in certain circumstances, it is always worthwhile to test whether a conductor is dead before touching. In fact, in Australia, it is required by law.

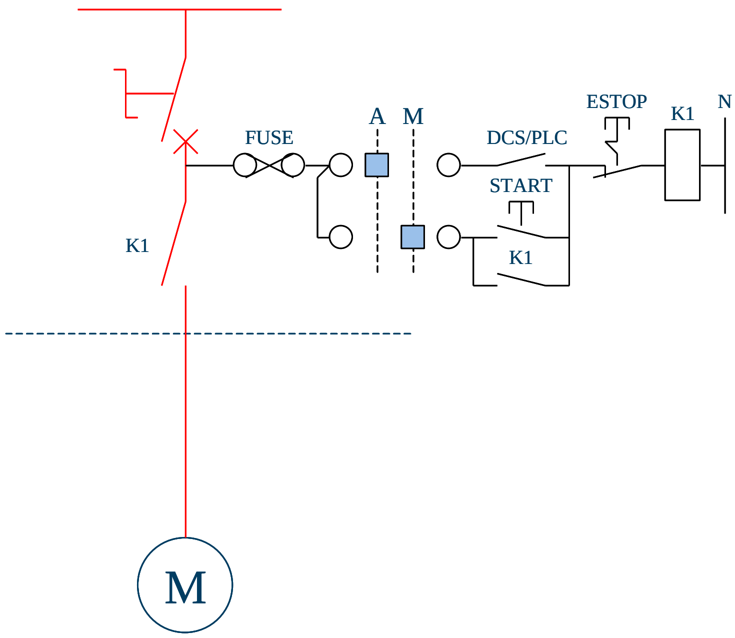
3.2 "Test for Dead" non-contact verification of isolation

Portable, non-contact voltage testers provide a method for detecting the presence or absence of voltage. As such they are often used when performing the "Test for Dead" confirmation of isolation procedure. They are inexpensive, convenient and safe to use however unless special attention is given by the operator to ensure a ground connection, they can and have reported inaccurate results. As such, non-contact voltage testers are banned from some sites. They can only be used on AC (alternating current) systems whose voltage is referenced to earth (TN system), which tends include most conventional supply systems. The devices are used extensively in both medium and high voltage applications where separate testing devices are used to ensure the integrity of the test device. In addition, earthing of the supply conductors prior to commencing work is regarded as the primary method of worker protection.

3.3 "Attempt a Start" verification of isolation

A single line diagram and simple control circuit for a typical, local and remote control motor is depicted below as Figure 3.

Figure 3



Local or remote (manual) controls are afforded by the start and estop (emergency stop) pushbuttons. A remote (automatic) controller (human or computer) activates the motor on an as needs basis.

The "Attempt Start" confirmation of isolation procedure aims to determine that operation of the isolation switch prevents the motor from running. This is useful in enabling non-electricians to determine whether it is safe to perform mechanical maintenance on a motor e.g. greasing bearings. The procedure is as follows:

1. Confirm that the motor is in manual mode
2. Confirm that the latching emergency stop push button is not latched
3. Press the start push button
4. Confirm that the motor starts
5. Open the isolation switch
6. Confirm that the motor stops
7. Lock the isolation switch
8. Press the start push button
9. Confirm that the motor does not start

The "Attempt Start" confirmation of isolation procedure provides a check of the isolation before mechanical maintenance is performed. It determines that the isolation switch is interrupting at least one of the phase conductors. On this basis prevention of motor rotation is assured. The procedure is cost effective in many instances as existing local control stations are all that is required to perform the isolation confirmation. In addition, it is a relatively safe procedure to perform. However, the location of push buttons, additional isolators and control circuit arrangements alters the procedure steps. A Local Control Station (LCS) tends to increase the likelihood that the correct isolator and controls will be identified as it is adjacent to the motor rather than part of a large MCC.

However, the following shortcomings exist with the "Attempt to Start" confirmation of isolation procedure:

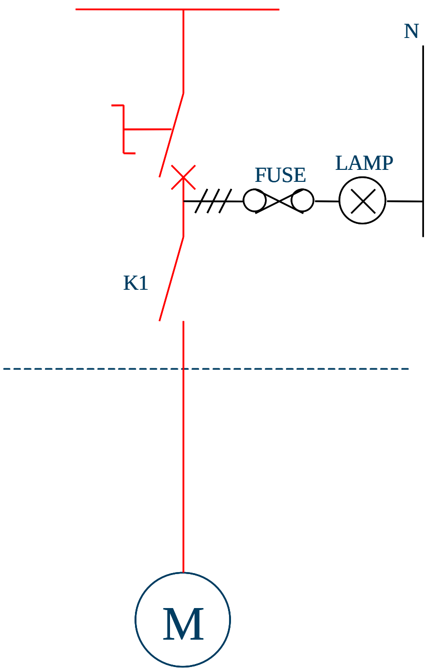
a. The procedure is intended for the confirmation of isolations prior to mechanical work, but not electrical work, being performed.

b. Push button control facilities to perform the procedure are not always available.
c. Power is required to perform the confirmation of isolation procedure which makes coordination difficult during plant wide shutdowns
d. It may be inconvenient to stop equipment via opening the isolator or unwise due to the interrupting capability of the isolation switch.
e. Manually performed procedures introduce the prospect of human error. Particularly a multiple step manual procedure such as the "Attempt Start" confirmation of isolation procedure (9 steps).
f. The "Attempt Start" confirmation of isolation procedure maybe inconvenient to use. That is, several other items may be required to start before starting the equipment of interest.
g. Some companies have already abandoned the use of the "Attempt Start" method. They believe that if a motor shaft is locked, due to a blockage on a screw feeder for example, then the absence of rotation in step 9 above would incorrectly reveal that the isolation was sound. This view identifies why steps 1 to 5 are important in the above procedure. It also reinforces the fact that personnel either look for short cuts in, or simply forget the correct isolating procedure steps.

3.4 Load side, direct contact, indicating lamps verification of isolation

This approach utilises fixed pilot / indication lamps, one per active phase, connected to the load side of a switch. See Figure 4 below:

Figure 4



Prior to initiating the isolation, the load side lamps are illuminated and after performing the isolation the lamps are extinguished. This result is taken as being a confirmed isolation. The procedure is as follows:

1. Confirm that all three lamps are illuminated
2. Open the isolation switch
3. Confirm that all three lamps are extinguished
4. Lock the isolation switch

The use of load side pilot lamps provides a check of the isolation before mechanical maintenance is performed. It determines that the isolation switch is interrupting each phase conductor. On this basis prevention of motor rotation is assured. The procedure is relatively easy to perform. In addition, it is a relatively safe procedure to perform.

The disadvantages of this approach are as follows:

a. The approach to achieving a conclusive test result should involve testing the lamps, testing the switch, testing the lamps. Clearly, when using pilot lamps, the last "testing the lamps" step cannot be conducted without reversing the isolation or incorporating lamp test circuitry. Reversing the isolation to test the lamps defeats the purpose of the isolation in the first place. Hence, it is necessary to provide and utilise a lamp test function.

b. A blown lamp could yield an incorrect confirmation of isolation result. Lamps sometimes fail due to vibration. Operating a switch handle causes significant transient vibration. In some cases dual lamps / LEDs per phase are used to address the problem of single lamp failure events. However, another failure mode, open circuit connecting wiring is not addressed by dual lamps / LEDs per phase.

c. If the line side of the isolation point is deenergised, lamp indication as a means of confirming an isolation cannot be performed.

d. In the case of field isolation points it is not possible to be sure that the switch is providing the isolation rather than an upstream contactor? This is misleading and is similar to the issues associated with "Testing for Dead" as a proof of isolation.

e. A neutral conductor is required as the lamps must be connected phase to neutral. If a phase to phase lamp connection were employed a single shorted switch contact will not illuminate any lamp! Therefore lamps must be star connected with their star point connected to the neutral conductor. Neutrals are generally not available in field motor isolators.

f. The method requires significant penetrations in switchboards which reduces the short circuit containment capabilities of the switchgear enclosure

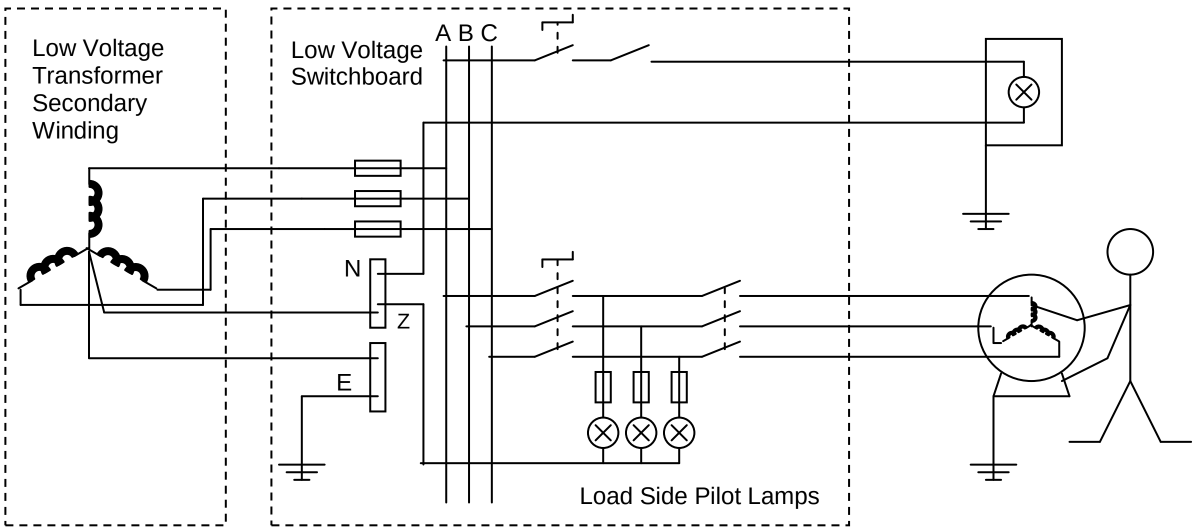
g. The facilities require ongoing lamp maintenance or the use of LED lamps

h. LED lamp visibility is poor in daylight conditions

i. The fault level withstand of lamps and wiring is generally insufficient for most industrial applications. Therefore, fault current limiting fuses are required as well

j. Providing three lamps, fault current limiting fuses, lamp test pushbutton and cabling per isolator is expensive and consumes significant panel space.

Figure 5



k. A high impedance joint at point Z in Figure 5 may exist at the same time that the motor isolator's "A" phase contacts weld. When the isolator is turned on all load side lamps would illuminate. When the isolator is turned off all load side lamps would extinguish. This would lead the maintainer to believe that the isolation is sound when in fact "A" phase contacts have welded. In addition, prior knowledge of the existence of a high impedance joint at point Z is unlikely. Whilst not an issue for mechanical maintenance, the method cannot be relied upon by itself to provide proof of isolation for electrical works.

l. Star connecting the load side pilot lamps to the neutral conductor provides a breach around an otherwise safe isolation. Any neutral potential rise is conveyed through the pilot lamps and onto the phase conductors on the load side of the isolation switch. This voltage then appears at the terminals of the motor which are being maintained. Testing for Dead may reveal this voltage prior to the commencement of work but transient conditions that create high neutral currents will not be detected. Events such as activation of single phase loads or out of balance three phase loads eg variable speed drives and power system faults create neutral potential rises.

m. Notes k and l highlight how the safety and accuracy of pilot light use is susceptible to problems in the star point neutral conductor. The theoretical solution to this problem is to connect all lamps in star directly at the neutral busbar. However, this solution needs to be identified at installation time and when apparently harmless wiring modifications are made in the future.

3.5 Load side, non-contact, indicating lamps – DeadEasy verification of isolation

This approach utilises fixed pilot / indication LEDs, connected to the load side of a switch as well as self-testing facilities. See Figure 6 and 7 below:

Figure 6

Figure 7

The fixed pilot / indication lamp holder, depicted in Figure 6, incorporates a green and red LED as well as a non-contact pushbutton to initiate the instrument self-test. Figure 7 depicts the DeadEasy instrument that is mounted inside the switchgear enclosure and that incorporates the sensing, logic processing and self test generator circuitry.

The DeadEasy confirmation of isolation procedure aims to determine that the switch has interrupted all three phases. This is useful in enabling non-electricians to determine whether it is safe to perform mechanical maintenance on a motor e.g. greasing bearings. The procedure is as follows:

1. With the isolator “On”, the red LED only should be illuminated
2. Turn the isolator “Off”, the green LED only should be illuminated
3. With the isolator “Off”, activate the self test by touching the lamp and the red LED only, is illuminated for 3 seconds

The procedure is easy and safe to perform. The self testing not only tests the indicating LEDs but also the voltage sensing cables. As the instrument is fixed inside a switchboard enclosure a sound earth connection is likely. The disadvantage of this device is that it is only suitable for used on AC (alternating current) systems whose voltage is referenced to earth (TN system), which tends include most conventional supply systems. In addition, as it is a voltage detection device it is practical to use in installations where the line side of the switch is alive eg motor control centres as opposed to local control stations.

3.6 Plug & Socket / Withdrawable Switches verification of isolation

Plug and sockets are available in industrial formats from many suppliers. Withdrawable switches are removable drawers in a switchboard that allow the isolator and switchgear associated with a cell to be completely removed.

Plug and sockets or fully withdrawable switches offer positive and visual indication that the circuit has been interrupted and that the isolation is sound. In short they offer a conclusive result. The method is simple to use and easy to understand. Their main disadvantages are that a protection mechanism is required to prevent inadvertent and premature reconnection and hence subsequent defeat of the isolation. In addition, plugs and sockets are not always available or easy to use for high current (>500A) loads and are usually exposed to damage in industrial environments.

3.7 Visible Break Isolators verification of isolation

Visible Break Isolators (VBIs) indicate the state of the switch either by a flag mounted on the body of the switch or by direct observation of the contact position. The flag or contacts are viewed through a window in isolating switch cabinet.

VBIs are available from most switch manufacturers. Figure 9 above depicts a commonly available VBI.

VBI's are simple to understand and operate. Their main disadvantages are that they are often difficult to read in dirty or dark environments. Secondly, knowing what to look at, to confirm the isolation is often confusing. Manufacturers, have tried to make this less confusing by placing indicators on the body of the switch which tends to defeat their purpose in the first place. It is the contacts that are of primary interest!

3.8 Manual Insulation Resistance Testing verification of isolation

Manual Isolator Testing involves the manual application of test voltage across each contact of an open switch. At the same time the voltage is applied, monitoring of switch current leakage is performed. This approach is commonly referred to as "Meggering". Figure 8 below depicts a sign on a Ball Mill local isolator cabinet.

Figure 8

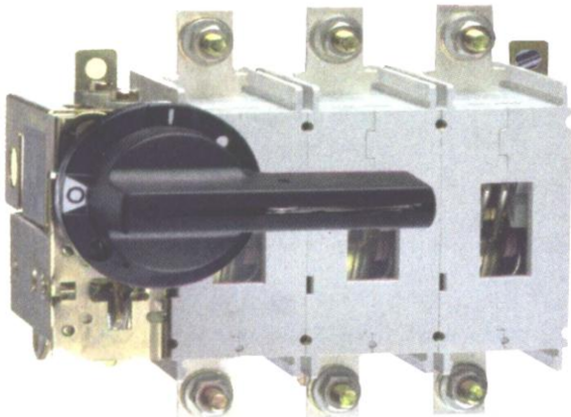


Figure 9

Meggering can only legally be performed by a licensed electrician in Australia. It exposes the electrician to potentially live terminals and generally requires a competent safety observer as well. The advantage of Meggering is that it does not require installation of any confirmation of isolation infrastructure.

3.9 Automatic Insulation Resistance Testing – SwitChek verification of isolation

SwitChek allows the automatic application of a high voltage across each contact of an open isolating switch. At the same time that the voltage is applied, monitoring of switch leakage is performed. Figure 10 below depicts SwitChek.

Figure 10

SwitChek can be implemented in 2 modes as follows:

- Fixed – One SwitChek dedicated to one switch. Intended for large switches and circuit breakers or for frequently isolated equipment.
- Portable – Using a fault current limiting interface and a socket installed in each switch enclosure, multiple switches can be tested using one SwitChek instrument.

The SwitChek control panel is depicted in Figure 8. Conducting a test with a fixed SwitChek incorporating the Remote Test Request feature involves:

1. Isolate the equipment (Turn the switch off)
2. SwitChek senses the switch has been turned off and the hourglass white LED flashes (confirms testing in progress)
3. The isolation confirmation result is displayed after 10 seconds – Tick (flashing green LED) = Pass, Cross (flashing red LED) = Fail

The result of the test is apparent in low/high noise and low/high light environments. SwitChek is convenient to use as specially trained, licensed, electrical personnel are not required to conduct a test. As it is a resistance measurement device it can be used on switches whether or not the line side of the switch is alive or dead. SwitChek can be used on earthed, isolated and DC systems.

4 Comparison of the Options to Confirm Isolations

Electrical isolations for electrical maintenance are likely to always involve the "Test for Dead" direct contact, verification of isolation procedure. Most regulators have mandated this requirement in the USA, Canada, UK and Australia. However, most electrical isolations are conducted for non-electrical maintenance works. For this reason, the comparisons below will be made with isolations for non-electrical maintenance works in mind. An analysis of isolation incidents suggests that the requirements of a procedure used to prove that an electrical isolation is sound are as follows:

1. Identify the correct switch – Cannot be taken lightly in large substations
2. Test safely – The person performing the test should not be placed in an unsafe situation
3. Test accurately - Conclusive result whatever the isolation equipment configuration
4. Test simply - Everyone (skilled and unskilled) needs to understand and repeat
5. Test uniformly - Same test all over the site. Multiple methods should be resisted
6. System Integrity – The confirmation method should not compromise the integrity of the isolation
7. Practical to Implement - The confirmation method should be easy to implement, require minimal downtime. In essence, it needs to be cost effective to purchase, install and operate.

Requirement one is heavily slanted toward the inherent benefit of local (to the equipment) isolation facilities. Attributes two to six represent minimum technical requirements of any isolation arrangement. Attribute seven can be compared on an objective basis by considering implementation costs. An analysis with these considerations in mind follows.

4.1 Technical Comparison

Table 1 below represents the author's assessment of the previously discussed methods for proving that an isolation is sound against technical requirements two to six listed above. Satisfying the requirement to identify the correct switch, in the authors view, requires local isolation facilities, which is not always possible. A failure of any one attribute should cast doubt as to the suitability of the method for proof of isolations for non-electrical maintenance works.

Isolation Verification Method (Non-electrical maintenance works)	Technical Attributes					
	Safe to Test	Accurate	Simple	Uniform	System Integrity	**Score**
"Test for Dead" direct contact[1]	Fail	Pass	Fail	Pass	Pass	**3**[1]
"Test for Dead" non-contact	Pass	Fail	Fail	Pass	Pass	**3**
"Attempt a Start"	Pass	Fail	Fail	Fail	Pass	**2**
Load side, direct contact, indicating lamps	Pass	Fail	Pass	Pass	Fail	**3**
Load side, non-contact, indicating lamps – DeadEasy	Pass	Pass	Pass	Pass	Pass	**5**
Plug & Socket	Fail	Pass	Pass	Fail	Fail	**2**
Withdrawable Switches	Pass	Pass	Pass	Fail	Pass	**4**
Manual Insulation Resistance Testing	Fail	Pass	Fail	Pass	Pass	**3**
Visible Break Isolators	Pass	Fail	Pass	Pass	Pass	**4**
Automatic Insulation Resistance Testing - SwitChek	Pass	Pass	Pass	Pass	Pass	**5**

Note 1 - Even though "Test for Dead" direct contact is indicated as an average solution, the method is mandated by most electricity regulators and must be performed where electrical maintenance is involved.

Table 1

Table 1 suggests that, in the author's opinion, only the following methods for proof of isolations for non-electrical maintenance works should be considered on technical grounds:

- DeadEasy - Load side, non-contact, indicating lamps
- SwitChek - Automatic Insulation Resistance Testing

4.2 Commercial Comparison

Electrical Isolations are generally performed either at Field Isolators (Local Control Stations) or Motor Control Centres (MCCs). Professionals, faced with their options for confirming isolations, need to understand the cost of the various options for the two circumstances for confirming isolations. In addition, whether the site is new or existing and the current rating of the isolation switch also affects the outcome of the analysis.

4.2.1 Field Isolators in an Existing Plant

A cost comparison of the options to confirm isolations on field, local isolators in an existing plant follows.

This comparison is relevant to an existing plant that incorporates standard isolation switches as local field isolation switches. Table 2 represents practical isolation confirmation choices in this arrangement.

Method	Applicable?
Manual Insulation Resistance Testing	**Yes**
Visible Break Isolators	**Yes**
Automatic Insulation Resistance Testing - SwitChek	**Yes** – Both Fixed and Portable Versions
"Attempt a Start"	**Yes**
"Test for Dead" direct contact "Test for Dead" non-contact Load side, direct contact, indicating lamps Load side, non-contact, indicating lamps – DeadEasy	No – These are voltage testing methods and as such are technically deficient as in most circumstances the line side of the switch is deenergised at the time of isolation
Plug & Socket	No – This method is not sufficiently practical in most industrial environments
Withdrawable Switches	No – Only MCC installations

Table 2

The commercial costs of implementation are also dependent on the current rating of the isolator. The following comparison focuses on the differential cost of the above options and incorporates typical Australian labour rates for relevant skills in Australian Dollars ex-GST.

Manual Insulation Resistance Testing

Item	125A	250A	630A	1250A
Operations Co-ordination (2 people for 0.25h@$90p/h)	45	45	45	45
Test – Callout (2 people for 1h@$90p/h)	180	180	180	180
Test – Execution (2 people for 0.5h@$90p/h)	90	90	90	90
Total per unit	$315	$315	$315	$315

Retrofit Visible Break Isolator

Item	125A	250A	630A	1250A
Isolator – Visible Break 3 Pole	350	785	1,900	4,300
Fitout – Materials (window, blanks for exist panel holes)	120	120	150	200
Fitout – Labour (1 person for 3h@$90p/h)	270	270	270	270
Engineering – Drafting (1 person for 1h@$100p/h)	100	100	100	100
Management (1 person for 1h@$140p/h)	140	140	140	140
Total per unit	$980	$1,415	$2,560	$5,010

Retrofit Fixed SwitCheks

Item	125A	250A	630A	1250A
Isolator	0	0	0	0
Fitout – Materials (SwitChek, 2 x SwitChek Interfaces)	1,545	1,545	1,545	1,545
Fitout – Labour (1 person for 2h@$90p/h)	180	180	180	180
Engineering – Drafting (1 person for 1h@$100p/h)	100	100	100	100
Management (1 person for 1h@$140p/h)	140	140	140	140

Total per unit	$1,965	$1,965	$1,965	$1,965

Retrofit Portable SwitChek

Item	125A	250A	630A	1250A
Isolator	0	0	0	0
Fitout – Materials (5% x SwitChek, 2 x SwitChek Interfaces)	835	835	835	835
Fitout – Labour (1 person for 1h@$90p/h)	90	90	90	90
Engineering – Drafting (1 person for 1h@$100p/h)	100	100	100	100
Management (1 person for 1h@$140p/h)	140	140	140	140
Total per unit	$1,165	$1,165	$1,165	$1,165

The 5% costing of Portable SwitChek assumes that the plant incorporates twenty isolation switches, each fitted with a SwitChek Interface and Interface Connector. On this basis the cost of the SwitChek instrument can be distributed across the twenty isolation switches.

Figure 11 below illustrates the first year costs associated with confirming isolations that are performed monthly for a varying quantity of isolating switches.

Figure 11

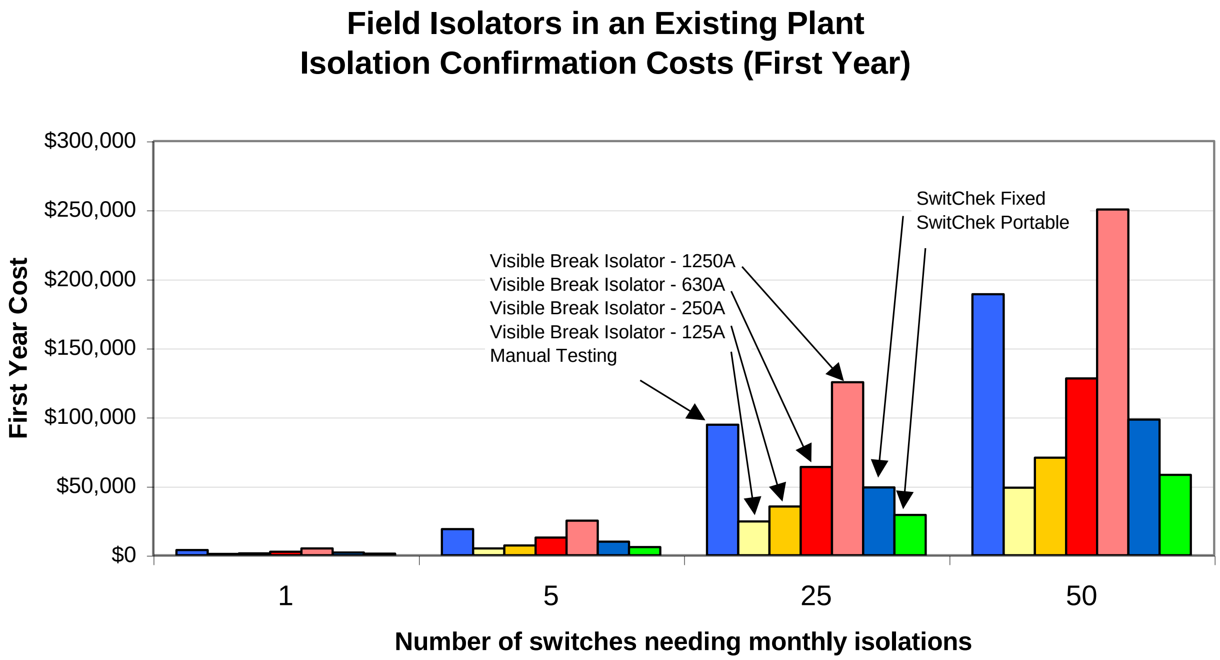


Figure 11 illustrates the following points regarding implementing confirmation of field isolations in an existing plant:

1. Manual Insulation Resistance Testing is an expensive option in most circumstances
2. Visible Break Isolators and Fixed SwitChek are comparable solutions. The preferred solution depends on the mix of small to large isolators.
3. Portable SwitChek is a lower cost solution than Fixed SwitChek and Visible Break Isolators.

The following points should be kept in mind regarding the above statements:

1. If the installation already incorporates “Attempt a Start” local control station facilities, this solution is the least expensive solution to deploy.
2. Cost comparisons are for the first year only. For subsequent years, manual testing costs continue to climb while Visible Break Isolators and Fixed SwitChek costs reduce to zero.
3. The comparisons are cost based only. Technical advantages and disadvantages also need to be considered.

4.2.2 Field Isolators in a New Plant

A cost comparison of the options to confirm isolations on field, local isolators in a new plant follows.

This comparison is relevant to a new plant where the choice of the type of isolation switch as the field isolation switch is yet to be made. Table 2 above represents the practical isolation confirmation choices in this arrangement.

The commercial costs of implementation are also dependent on the current rating of the isolator. The comparison focuses on the differential cost of the above options and incorporates typical Australian labour rates for relevant skills in Australian Dollars ex-GST.

Manual Insulation Resistance Testing – Initial Installation

Item	125A	250A	630A	1250A
Isolator - Standard	295	420	960	2,710
Fitout – Materials	0	0	0	0
Fitout – Labour (1 person for 2h@$90p/h)	180	180	180	180
Engineering – Drafting (1 person for 1h@$100p/h)	100	100	100	100
Management (1 person for 1h@$140p/h)	140	140	140	140
Total per unit	$535	$660	$1,200	$2,950

Manual Insulation Resistance Testing – Conducting a Test

Item	125A	250A	630A	1250A
Operations Co-ordination (2 people for 0.25h@$90p/h)	45	45	45	45
Test – Callout (2 people for 1h@$90p/h)	180	180	180	180
Test – Execution (2 people for 0.5h@$90p/h)	90	90	90	90
Total per unit	$315	$315	$315	$315

Install Visible Break Isolator

Item	125A	250A	630A	1250A
Isolator – Visible Break 3 Pole	350	785	1,900	4,300
Fitout – Materials (window, blanks for exist panel holes)	120	120	150	200
Fitout – Labour (1 person for 3h@$90p/h)	270	270	270	270
Engineering – Drafting (1 person for 1h@$100p/h)	100	100	100	100
Management (1 person for 1h@$140p/h)	140	140	140	140
Total per unit	$980	$1,415	$2,560	$5,010

Install Fixed SwitCheks

Item	125A	250A	630A	1250A
Isolator	295	420	960	2,710
Fitout – Materials (SwitChek, 2 x SwitChek Interfaces)	1,545	1,545	1,545	1,545
Fitout – Labour (1 person for 2h@$90p/h)	180	180	180	180
Engineering – Drafting (1 person for 1h@$100p/h)	100	100	100	100
Management (1 person for 1h@$140p/h)	140	140	140	140
Total per unit	$2,260	$2,385	$2,925	$4,675

Install Portable SwitChek

Item	125A	250A	630A	1250A
Isolator	295	420	960	2,710
Fitout – Materials (5% x SwitChek, 2 x SwitChek Interfaces)	835	835	835	835

Fitout – Labour (1 person for 1h@$90p/h)	90	90	90	90
Engineering – Drafting (1 person for 1h@$100p/h)	100	100	100	100
Management (1 person for 1h@$140p/h)	140	140	140	140
Total per unit	$1,460	$1,585	$2,125	$3,875

The 5% costing of Portable SwitChek assumes that the plant incorporates twenty isolation switches, each fitted with a SwitChek Interface and Interface Connector. On this basis the cost of the SwitChek instrument can be distributed across the twenty isolation switches.

Figure 12 below illustrates the first year costs associated with confirming isolations that are performed monthly for a varying quantity of isolating switches.

Figure 12

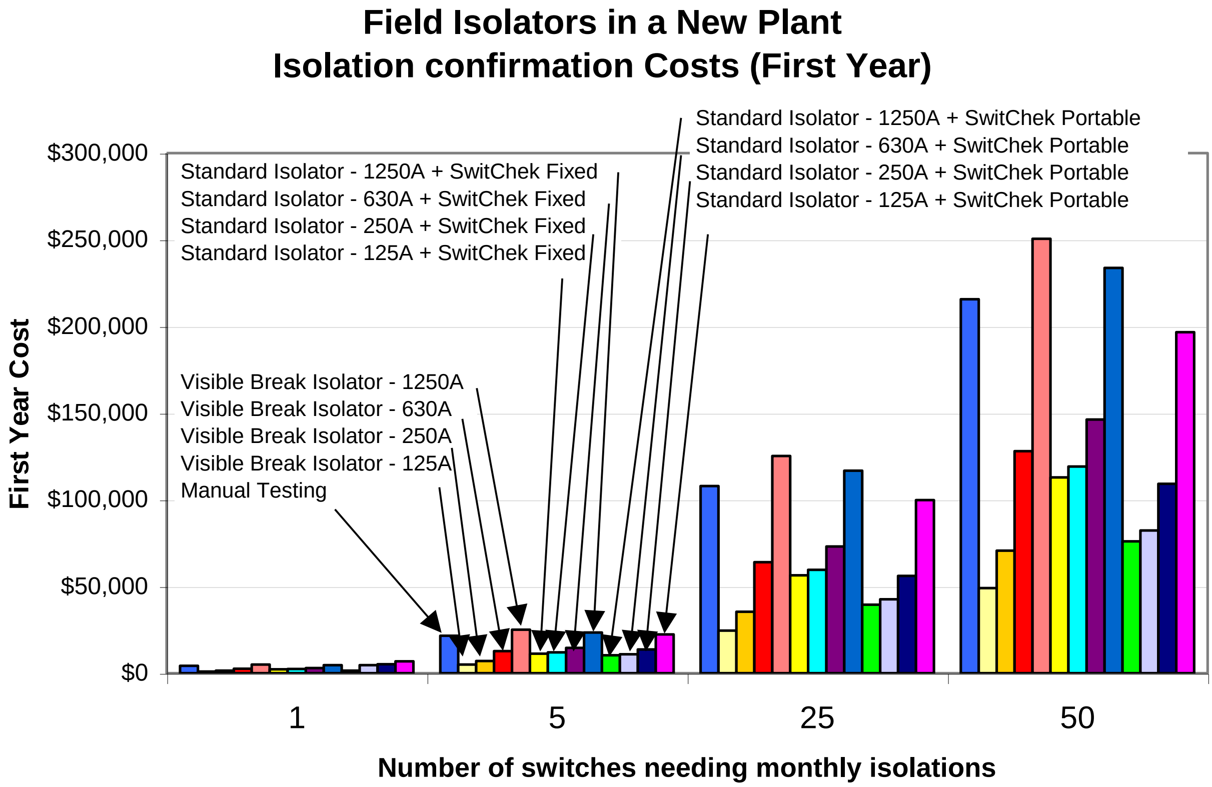


Figure 12 illustrates the following points regarding implementing confirmation of field isolations in a new plant:

1. Manual Insulation Resistance Testing is an expensive option in most circumstances
2. Visible Break Isolators are likely to be a lower cost solution than Fixed SwitChek in most situations except where isolation switches are mostly large in size.
3. Visible Break Isolators and Portable SwitChek are comparable solutions. The preferred solution depends on the mix of small to large isolators.

The following points should be kept in mind regarding the above statements:

1. If the installation already incorporates "Attempt a Start" local control station facilities this solution is the least expensive solution to deploy.
2. Cost comparisons are for the first year only. In subsequent years manual testing costs continue to climb while Visible Break Isolators and SwitChek costs reduce to zero.
3. The comparisons are cost based only. Technical advantages and disadvantages also need to be considered.

4.2.3 Switchboard Isolators in an Existing Plant

There is an increasing trend in Australia to forgo the installation of local, field isolator stations and rely only on isolations being performed at the supply switchboard or motor control centre.

A cost comparison of the options to confirm isolations on remote, switchboard or motor control centre isolators in an existing plant follows.

This comparison is relevant to an existing plant that incorporates standard isolation switches as switchboard or motor control centre switches. Table 3 represents practical isolation confirmation choices in this arrangement.

Method	Applicable?
Manual Insulation Resistance Testing	**Yes**
Automatic Insulation Resistance Testing - SwitChek	**Yes** – Both Fixed and Portable Versions however the fixed unit requires moderate internal switchboard space that is probably not available
"Attempt a Start"	**Yes**
"Test for Dead" direct contact "Test for Dead" non-contact	**Yes**
Load side, direct contact, indicating lamps	**Yes**
Load side, non-contact, indicating lamps – DeadEasy	**Yes**
Withdrawable Switches	No – Whilst this approach is technically possible it is not a reasonable retrofit option as switchboard replacement is necessary
Visible Break Isolators	No – Achieving switchboard fault containment ratings where a portion of the cubicle door has been removed and a glass window has been inserted, is difficult. In addition, Visible Break Isolators do not offer circuit protection. This necessitates the use of fuses or a circuit breaker. The use of fuses adds to increased maintenance spares holdings and adds to the risk of motors single phasing. The addition of a circuit breaker adds significantly to switchgear costs and switchboard size
Plug & Socket	No – This method is not sufficiently practical in most industrial environments

Table 3

The commercial costs of implementation of the above options are independent of the current rating of the isolator. The comparison focuses on the differential cost of the above options and incorporates typical Australian labour rates for relevant skills in Australian Dollars ex-GST.

Manual Insulation Resistance & "Test for Dead" Direct Contact and Non-Contact Testing

Item	Cost
Operations Co-ordination (2 people for 0.25h@$90p/h)	45
Test – Callout (2 people for 1h@$90p/h)	180
Test – Execution (2 people for 0.5h@$90p/h)	90
Total per unit	$315

Retrofit Portable SwitChek

Item	Cost
Fitout – Materials (5% x SwitChek, 2 x SwitChek Interfaces)	835

Fitout – Labour (1 person for 1h@$90p/h)	90
Engineering – Drafting (1 person for 1h@$100p/h)	100
Management (1 person for 1h@$140p/h)	140
Total per unit	$1,165

Retrofit Load side, direct contact, indicating lamps

Item	Cost
Fitout – Materials (Three lamps, fault current limiting fuses, labels and cabling)	275
Fitout – Labour (1 person for 3h@$90p/h)	270
Engineering – Drafting (1 person for 1h@$100p/h)	100
Management (1 person for 1h@$140p/h)	140
Total per unit	$785

Retrofit Load side, non-contact, indicating lamps - DeadEasy

Item	Cost
Fitout – Materials (DeadEasy, labels and cabling)	495
Fitout – Labour (1 person for 1h@$90p/h)	90
Engineering – Drafting (1 person for 0.75h@$100p/h)	75
Management (1 person for 0.75h@$140p/h)	105
Total per unit	$765

The 5% costing of Portable SwitChek assumes that the plant incorporates twenty isolation switches, each fitted with a SwitChek Interface and Interface Connector. On this basis the cost of the SwitChek instrument can be distributed across the twenty isolation switches.

Figure 13 below illustrates the first year costs associated with confirming isolations that are performed monthly for a varying quantity of isolating switches.

Figure 13

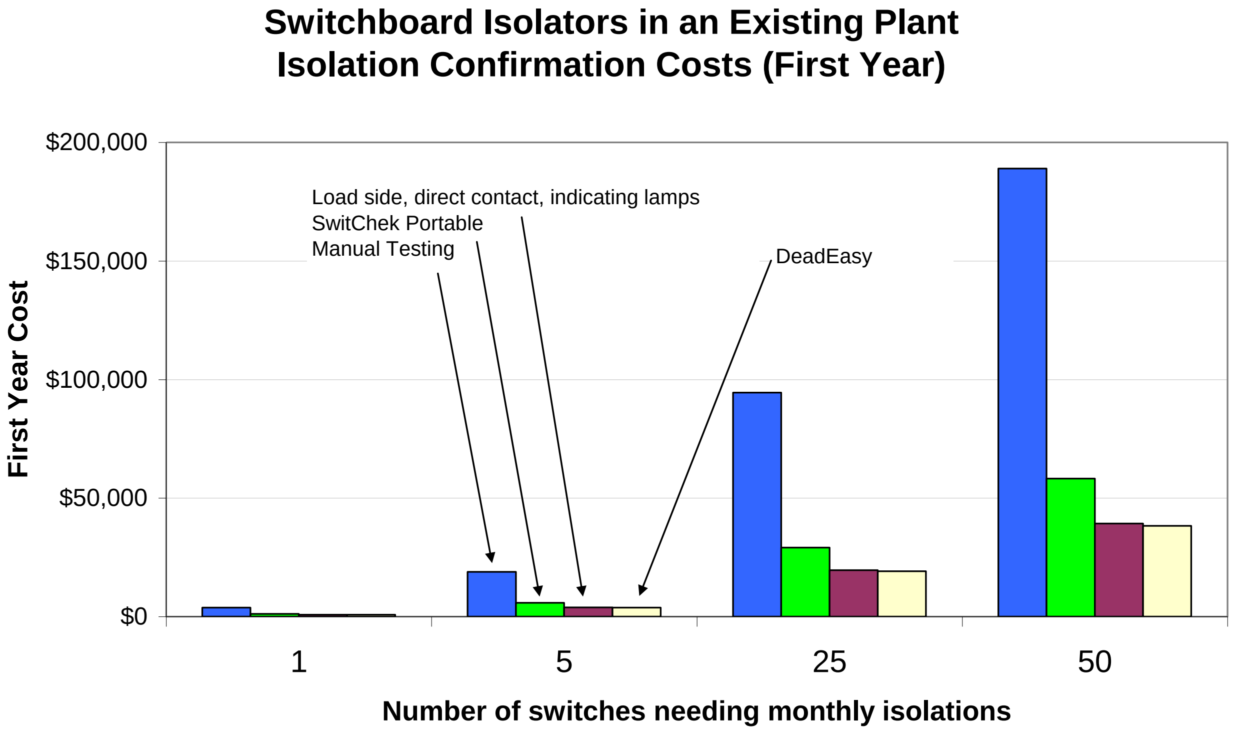


Figure 13 illustrates the following points regarding implementing confirmation of switchboard isolations in an existing plant:

1. Manual Insulation Resistance Testing is the most expensive option
2. SwitChek Portable represents a reasonable solution
3. Load side, direct contact, indicating lamps and DeadEasy are low cost comparable solutions.

The following points should be kept in mind regarding the above statements:

1. If the installation already incorporates "Attempt a Start" local control station facilities this solution is the least expensive solution to deploy.
2. Cost comparisons are for the first year only. In subsequent years manual testing costs continue to climb while SwitChek, Load side Lamps and DeadEasy costs reduce to zero.
3. The comparisons are cost based only. Technical advantages and disadvantages also need to be considered.

4.2.4 Switchboard Isolators in a New Plant

A cost comparison of the options to confirm isolations on remote, switchboard or motor control centre (MCC) isolators in a new plant follows.

This comparison is relevant to a new plant where the choice of the type of isolation switch as the switchboard or motor control centre isolation switch is yet to be made. Table 3 above represents the practical isolation confirmation choices in this arrangement. In addition, where the decision on the type of switchboard is yet to be made Withdrawable Switches can also be added to Table 3. Recent data suggests that Withdrawable Switches housed in MCCs can add 25% to 50% to the cost of the MCC.

Neglecting Withdrawable Switches, Figure 13 still holds as a reasonable comparison between possible options. On this basis the conclusions drawn for Switchboard Isolators in Existing Plants can be applied to Switchboard Isolators in New Plants.

5 Conclusions

This report investigated the process of confirming an electrical isolation. That is, confirmation that the electrical isolation switch stops electricity. It principally focuses on the subject of verification of isolation on low voltage equipment i.e. < 1,000V prior to commencing non-electrical (mechanical) works.

The reasons for confirming an electrical isolation include:

- Isolation switches fail and their typical failure modes subject people to the risk of injury and death.
- Injuries and deaths due to faulty isolation switches have been recorded locally and internationally
- Legislation in all states of Australia and at a national level specify the need for confirming electrical isolations
- Injuries and deaths of workers result in the prosecution of Supervisors and Managers

An approach to confirm electrical isolations on a site wide basis should conform to the following basic requirements:

1. Identify the correct switch – Cannot be taken lightly in large substations
2. Test safely – The person performing the test should not be placed in an unsafe situation
3. Test accurately - Conclusive result whatever the isolation equipment configuration
4. Test simply - Everyone (skilled and unskilled) needs to understand and repeat
5. Test uniformly - Same test all over the site. Multiple methods should be resisted
6. System Integrity – The confirmation method should not compromise the integrity of the isolation
7. Practical to Implement - The confirmation method should be easy to implement, require minimal downtime. In essence, it needs to be cost effective to purchase, install and operate.

Requirement 1 can only be achieved through the use of local (to the equipment) isolation facilities. Requirements 2 to 5 represent basic and largely non-negotiable technical requirements. Requirement 7 is a measure of the cost of implementation.

The following methods for confirming isolations were investigated:

- “Test For Dead” Direct Contact
- “Test For Dead” Non-Contact
- “Attempt A Start”
- Load Side, Direct Contact, Indicating Lamps
- Load Side, Non-Contact, Indicating Lamps – Deadeasy
- Plug & Socket / Withdrawable Switches
- Visible Break Isolators
- Manual Insulation Resistance Testing
- Automatic Insulation Resistance Testing – Switchek

In the case of local (to the equipment) isolation facilities, the methods most attractive for confirming isolations were:

- Visible Break Isolators - for new plants only as retrofit attracts high cost
- Switchek – the portable Switchek represents a lower cost option than a fixed Switchek

In the case of remote (switchboard and motor control centre) isolation facilities, the methods most attractive for confirming isolations were:

- Withdrawable Switches - high cost for both new and retrofit applications
- DeadEasy

Can you afford not to test switches and risk people’s lives?