Confirming Electrical Isolations

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4	**Jun 05**	**Cost Update**	**CJD**
3	**Jun 04**	**Expanded Attempt Start, pilot lamp**	**CJD**
2	**Mar 04**	**Included pilot lamp neutral & breach problems**	**CJD**
1	**Oct 03**	**Included pilot lamp problems**	**CJD**
0	**Sep 03**	**Initial**	**CJD**
Rev	**Date**	**Revision Description**	**By**

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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.

The structure of the report is as follows:

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

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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:

> Division 2 – Basic requirements for electrical work
> Section 11 – Requirements for electrical work
> (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:

> 207 - Electrical work on electrical installations—safety measures
> 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.

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"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

3.1 Current Practice

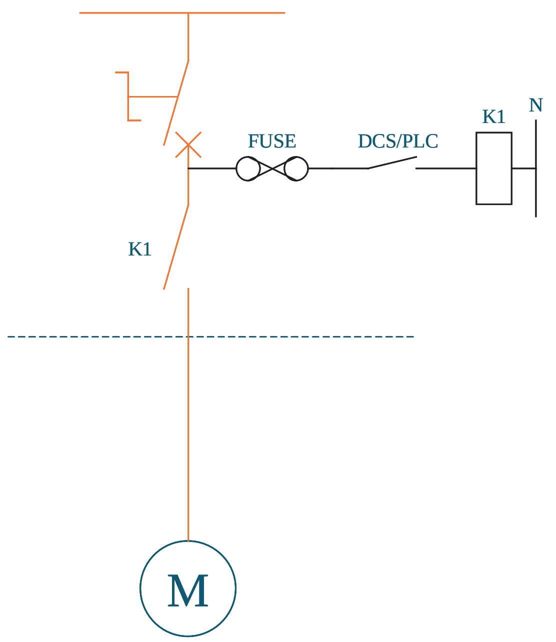
Three methods are commonly used by Industry to address the requirement for confirming isolations. They are:

1. "Test Dead at Load"
2. "Attempt Start" & "Test Dead at Load"
3. Isolation Switch – line & load side pilot lamps

3.1.1 "Test Dead at Load" Isolation Procedure

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) runs the motor on an as needs basis.

The "Testing Dead" Isolation Procedure simply involves turning the Isolating Switch off and locking the switch, followed by testing all active conductors for the absence of power. In step form the procedure is as follows:

1. Isolate the switch (in the substation)
2. Lockout the switch (in the substation)
3. Test each <u>line</u> side phase of the isolating switch for system voltage (in the substation)
4. Test each <u>load</u> side phase of the isolating switch for the absence of system voltage (in the substation)
5. Test each phase of the motor supply for the absence of system voltage (at the motor)
6. Test the voltmeter for operation on a known voltage source

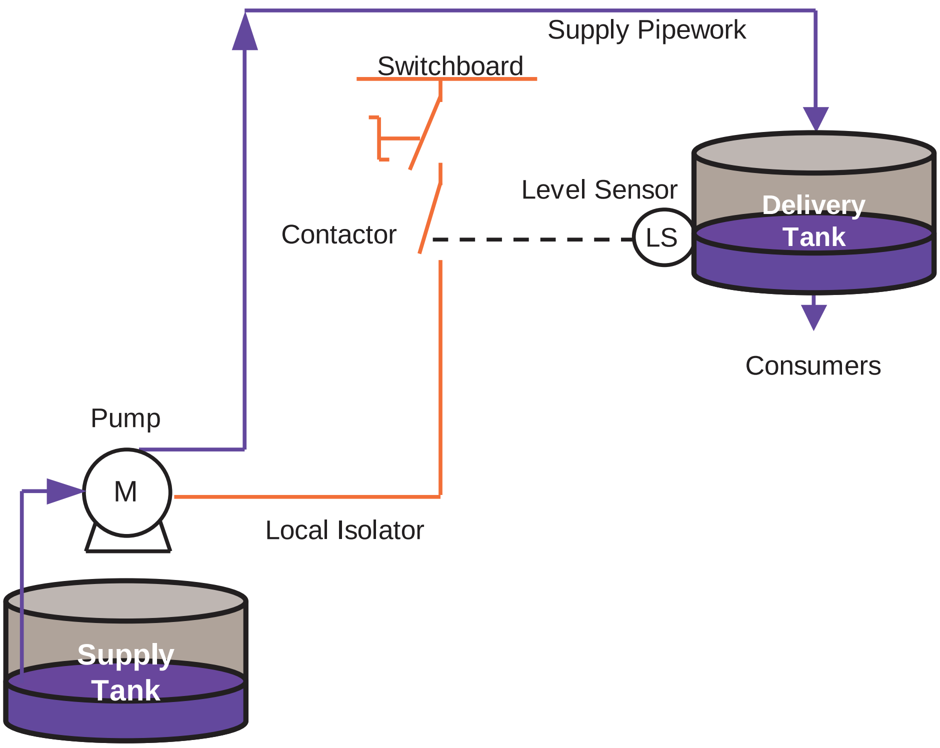
Steps 3 and 4 are vital to the success of this procedure. They test whether the switch is isolating the supply. It could be argued that Step 5 is redundant if steps 3 and 4 are performed. However, as an additional safety check most electricians faced with an open terminal box on a motor will check for voltage prior to coming into direct contact with conductors.

Although the above procedure should be followed rigorously, steps 3 and 4 are usually not performed. If the “Test Dead” is performed only at the motor terminals, a zero voltage result is inconclusive and misleading.

When the remote controller is not demanding the motor to be run, the contactor (K1) is off. Should the “Test Dead” be performed at the motor terminals at this time it would indicate that the machine is safe to access. However, the isolation switch may also be faulty at this time. If the maintenance person accesses the machine, after determining that there is no voltage at the motor terminals, the controller may later determine a need for the motor to be running. When the controller operates the contactor power flows through the faulty isolation switch, through the contactor and presents at the motor. An electric shock, physical injury or death is a likely outcome for the maintenance person.

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 “Testing Dead” Isolation Procedure.

Figure 2



After testing for power at the motor terminals and determining that no power exists it is still not safe to commence work.

If the level in the consumer tank is high, then the level switch will not be actuated and the contactor will be off. So a "Test Dead" at the motor terminals will reveal that the contactor is interrupting the power. However, if the Local 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 contactor, through the faulty Isolator and appear at the motor that is in the process of being maintained.

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 Dead at Load" Isolation Procedure:

a. The actual isolation point, the switch that is locked, has not been confirmed as being sound.
b. It does not detect 1,2,3 phase isolator or handle faults. Mechanical and electrical maintenance personnel are at risk if the contactor is activated whilst working
c. The procedure relies on a certainty that the line side of the switch is alive.
d. The procedure can only be performed by an electrician
e. Power is initially required to perform the isolation procedure correctly which makes coordination difficult on planned maintenance down days
f. Electromagnetic induction can provide confusing results
g. Requires a person to follow a procedure - human error

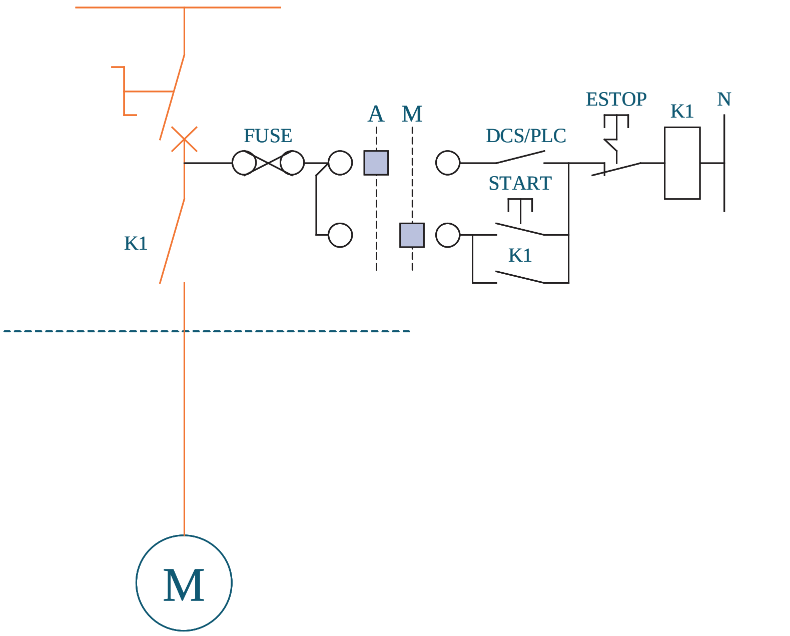
The "Test Dead" Isolation Procedure identified as Steps 1 to 6 above should always be performed if reliance is placed on this method for personnel safety. However, it suffers from being a more detailed procedure than the "Test Dead at Load" Isolation Procedure and is likely to require additional commuting to and from the substation and motor.

Despite the above paragraphs discussing how the "Test Dead at Load" Isolation Procedure can provide misleading results in certain circumstances it is always worthwhile to test whether a conductor is dead before directly contacting. In fact in Australia it is required by law.

3.1.2 "Attempt Start" & "Test Dead at Load" Isolation Procedure

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

The "Attempt Start" 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.

In step form the procedure is as follows:

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

Mechanical work can commence

The "Attempt Start" Isolation Procedure provides a conclusive check of the isolation before mechanical maintenance is performed. It determines that the isolation switch is interrupting at least one of the phases. On this basis prevention of motor rotation is assured.

In could be argued that steps 8,9,10 are redundant as the isolation switch has already been proven sound for the purposes of mechanical maintenance. However, these steps may go some way to increase maintainer confidence in the isolation.

If electrical work is also carried out on the motor a "Test Dead at Load" Isolation Procedure is also usually performed following the "Attempt Start" Isolation Procedure. The pitfalls of the "Test Dead at Load" Isolation Procedure was presented earlier in Section 3.1.1

Even after performing an "Attempt Start" and "Test Dead at Load" Isolation Procedure the isolation is unsound for the purposes of electrical maintenance. That is, a 1,2 phase isolator fault combined with the accidental pushing in of the contactor armature, which is not locked, would present a dangerous situation at the motor. An electric shock or death is a likely outcome for the electrical maintenance person.

The location of push buttons and additional isolators either on the Motor Control Centre (MCC) or on a Local Control Station (LCS) does influence the outcome of this analysis. An 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, it does not change the fact that mechanical isolations can be proven soundly whilst electrical isolations suffer from the pitfalls of the "Test Dead at Load" Isolation Procedure that was presented earlier in Section 3.1.1.

In addition, the following shortcomings exist with the "Attempt Start" Isolation Procedure:

a. Push button control facilities to perform the procedure are not always available.
b. Power is required to perform the isolation procedure correctly which makes coordination difficult on planned maintenance down days or alternatively it may be inconvenient to stop plant via opening the isolator.
c. Manually performed procedure introduces the prospect of human error. Particularly a multiple step manual procedure such as the "Attempt Start" and "Test Dead" Isolation Procedure (16 steps).
d. The "Attempt Start" Isolation Procedure maybe inconvenient to use. That is several other items may be required to start before starting the equipment of interest.
e. 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 8 above would incorrectly reveal that the isolation was sound. (I. Gayton – Hatch Engineers). 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 correct isolating procedures.

3.1.3 Isolation Switch – line & load side pilot lamps

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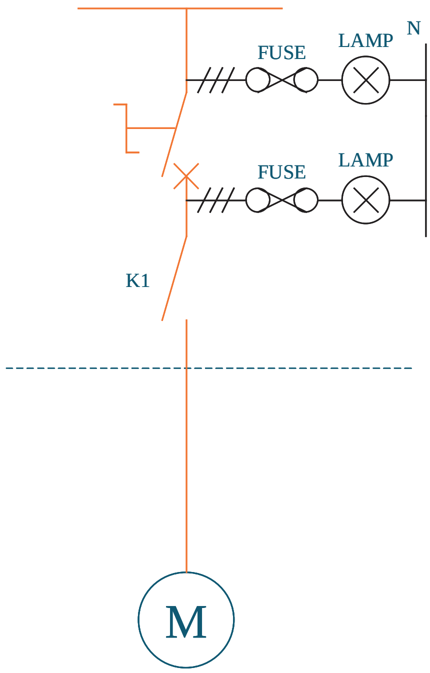
This approach utilises fixed pilot lamps installed on the line and load side of a switch that can be read by a non-electrician. See Figure 4 below:

Figure 4



The thinking being that prior to initiating the isolation all lamps are illuminated and after performing the isolation the load side lamps are extinguished while the line side lamps remain illuminated. This result is taken as being a confirmed isolation.

The Pilot Lamps provide a conclusive check of the isolation before both mechanical maintenance and electrical maintenance is performed, so long as lamp test circuitry is provided and utilised. It determines that the isolation switch is interrupting all three phases.

The disadvantages of this approach are as follows:

a. Using a strict testing approach, which is what is required when confirming an isolation, the approach to achieving a certain test result involves testing the lamps, testing the switch, testing the lamps = confirmed result. Clearly, when using pilot lamps, the last "testing the lamps" step cannot be conducted without reversing the isolation. Reversing the isolation 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 regularly fail due to vibration. Operating a switch handle causes significant transient vibration.
c. If the lamp is extinguished when the switch is turned off this does not mean that there is 0V on the load side of the switch? That is, if the lamp is extinguished there could still be sufficient leakage for a shock current! Although for this analysis this prospective danger has been dismissed.
d. If the line side of the isolation point is dead, lamp indication as a means of confirming an isolation cannot be performed.
e. 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 very dangerous and is similar to the issues associated with "Testing Dead at Load" as a proof of isolation.
f. A neutral conductor is required as the lamps must be connected phase to neutral. In the case of a phase to phase lamp connection a single shorted switch contact will not illuminate any lamp! Therefore lamps have to be star connected at the neutral conductor. Neutrals are generally not available in field isolators.
g. Designing circuitry to provide lamp test function introduces the problem of knowing whether the lamp test circuitry is functioning correctly.

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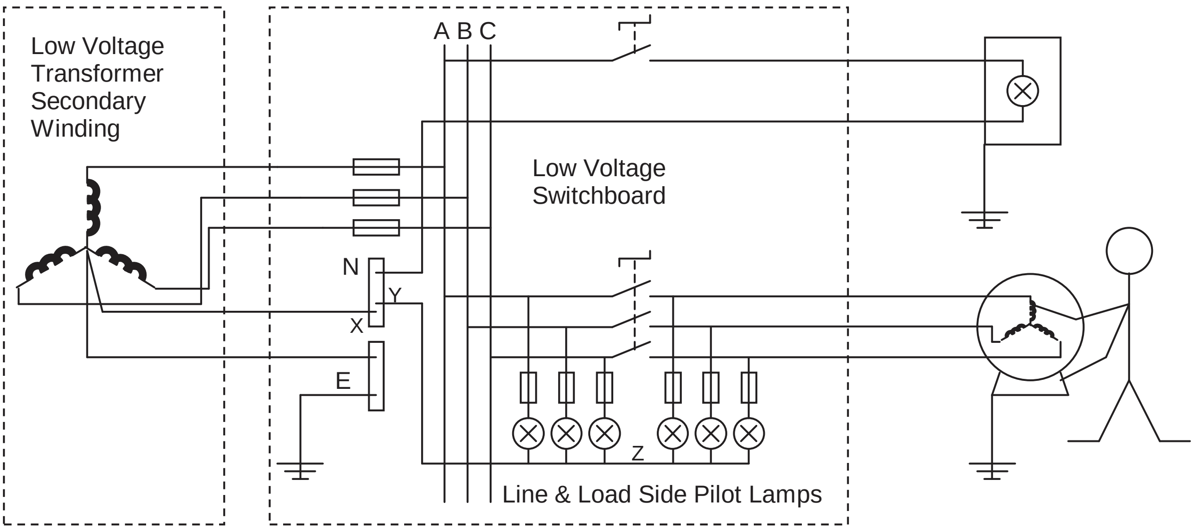
h. Requires significant penetrations in switchboards which reduce the short circuit containment capabilities of the panel
i. Ongoing lamp maintenance
j. Requires a person to follow a procedure - human error
k. LED lamp visibility is poor in daylight conditions
l. Fault level withstand of lamps and wiring is generally insufficient for most industrial applications. Requires fault limiting fuses as well
m. Providing six lamps, fault limiting fuses, lamp test pushbutton and circuitry per isolator is expensive

Figure 5



n. 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 line and 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. Very dangerous!
o. A high impedance joint at point Y in Figure 5 may exist at the same time that the motor isolator's A phase contacts weld. In this case current would flow through the faulted A phase isolator contacts, through the load side A phase lamp to the load side lamp star point. Current would then flow into the B and C phase, line side lamps. An isolator problem would then be correctly identified. If the line side lamps were omitted the A phase load side lamp would not illuminate in the case of welded A phase contacts on the motor isolator. The point worth making is that both line and load side lamps are required. In addition, prior knowledge of the existence of a high impedance joint at point Y is unlikely.
p. A high impedance joint at point Y in Figure 5 may exist at the same time that A phase line side pilot lamp blows while maintenance work is being performed on the motor that has been isolated. In this case the load side lamp star point would elevate to phase voltage (240VAC in Australia). Current would then flow into the A phase load side lamp, down the motor cable and enter the maintenance person. Provided the maintenance person was connected in some way to earth he/she would receive an electric shock. The point worth making is that connecting the load side pilot lamps to the neutral conductor provides a breach around an otherwise safe isolation. In addition, prior knowledge of the existence of a high impedance joint at point Y is highly unlikely.
q. A high impedance joint at point X in Figure 5 may exist at the same time that maintenance work is being performed on the motor that has been isolated. In this case any single phase load, neutral current (see top of Figure 5) would seek a path to the transformer star point through both the line and the load side pilot lamps. In a similar scenario to point "o" above the maintenance person would receive an electric shock. The point worth making is that connecting the load side pilot lamps to the neutral conductor provides a breach around an

otherwise safe isolation. In addition, prior knowledge of the existence of a high impedance joint at point X is unlikely. Further, the high impedance joint at point X may develop whilst maintenance is in progress.

r. Notes n,o,p,q high light 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 requires significantly more conductor runs and is difficult to police at installation time and when apparently harmless wiring modifications are made in the future.

3.2 Future Practice

Shortcomings of current methods for confirming isolations has lead industry experts to specify the minimum requirements of a procedure used to prove an isolation is sound. The six basic requirements are as follows:

a. Identify the correct Switch – Cannot be taken lightly in large substations
b. Test what you lock! - This is the point of personal protection hence the lock
c. Test accurately - Conclusive result whatever the isolation equipment configuration
d. Test simply - Everyone (skilled and unskilled) needs to understand and repeat
e. Test uniformly - Same test all over your site. Multiple methods should not be tolerated.
f. No safety compromise – The confirmation method should in no way compromise the integrity of the isolation

Table 1 below summarises the previously discussed methods for proving isolation are sound as well as introduces four new methods:

Table 1

Confirming Isolation Method	Right Switch	What you Lock	Accurate	Simple	Uniform	Safety 1st
Test Dead at Load				✓		✓
Attempt a Start & Test Dead at Load			✓			✓
Pilot Lamps		✓	✓	✓		
Plug & Socket / Withdrawable Switches		✓	✓	✓	✓	✓
Manual Isolator Testing		✓	✓		✓	✓
VBI		✓	✓	✓	✓	✓
SwitChek	✓	✓	✓	✓	✓	✓

A brief discussion of the four new methods follows:

3.2.1 Plug & Socket / Withdrawable Switches

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.

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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.

The disadvantages of this approach are as follows:

a. A protection mechanism is required to prevent inadvertent and premature reconnection and hence subsequent defeat of the isolation.
b. Plugs and Sockets are not always available or easy to use for large loads

3.2.2 Manual Isolator Testing

Manual Isolator Testing involves the manual application of a high voltage across each contact of an open switch. At the same time the voltage is applied, monitoring of switch leakage is performed. This approach is commonly referred to as "Meggering". Figure 6 below depicts a sign on a Ball Mill local isolator cabinet.

Figure 6

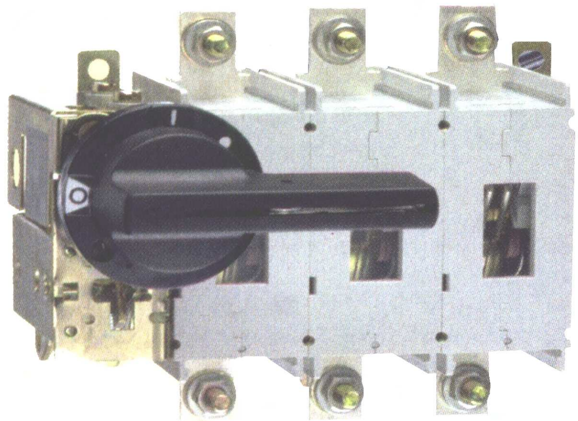

Figure 7

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 infrastructure.

3.2.3 Visible Break Isolators

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 window in isolating switch cabinet.

VBIs are available from most switch manufacturers. Figure 7 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 mechanical bits 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 which are primary interest!

3.2.4 Automatic Isolator Testing – SwitChek

SwitChek allows the automatic application of a high voltage across each contact of an open isolating switch. At the same time the voltage is applied, monitoring of switch leakage is performed. Figure 8 below depicts SwitChek.

Figure 8

The two primary objectives of SwitChek are as follows:

- Confirm, with absolute certainty, that equipment is disconnected from electricity.
- Block electrical current passing through its test circuitry before, during and after testing

This functionality is achieved through the use of self-checking software, hardware and a design emphasis on fault tolerant components and methods.

SwitChek can be implemented in 3 modes as follows:

- Fixed – One SwitChek dedicated to one switch. Intended for large switches and circuit breakers or for frequently isolated equipment.
- Portable –Tests all of the switches in a plant with one SwitChek.
- Switchboard – Space limited implementation to allow testing of all of the switches in one Switchboard or Motor Control Centre (MCC).

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. Hourglass white LED flashes (confirms function)
3. Result displayed after 10 seconds – Tick = Pass, Cross = Fail

The result of the test is apparent in low/high noise and low/high light environments. SwitChek is convenient as specially trained, licensed, electrical personnel are not required to conduct a test.

The full SwitChek test is completed in 10 seconds.

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4 Comparison of Options

4.1 Technical Comparison

Table 2 below illustrates a comparison matrix of the options available to confirm an isolation.

Table 2

	Manual Isolator Test	VBI/ Withdraw -able Switch	SwitChek
Tests Live Switch - (500V stress)			✓
Accurate Result - (500V stress, cable shorts)	✓		✓
Clear Result - (dirty & dark environments)			✓
Convenient - (no electrician)		✓	✓
Inexpensive - (see cost comparison)	✓		✓
Simple - (immune to test method errors)		✓	✓
Fast		✓	✓
Safe		✓	✓
Easy to Retrofit	✓		✓
Provides “Self Test” capability			✓
Blocks electric current whilst testing		✓	✓
Automatic Test Start			✓
Automatic Audit Trail			✓
Remote Test Start			✓
Remote Test Indication			✓
Suitable for Hazardous Areas		✓	✓

4.2 Cost 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 locations for confirming isolations. In addition, whether the site is new or existing also affects the outcome of the analysis.

4.2.1 Cost Comparison – Field Isolators, Existing Plant (Existing Standard Isolators)

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A cost comparison of the options to confirm isolations on field local isolators follows. This comparison is relevant to an existing plant that incorporates standard isolation switches as local field isolation switches. Management has the option to manually test switches, retrofit Visible Break Isolators (VBIs), retrofit Fixed SwitCheks or retrofit Portable SwitChek. The comparison focuses on differential costs and incorporates typical Australian labour rates for relevant skills in Australian Dollars ex-GST.

Example – Manual Isolator Test

Item	125A	250A	630A	1250A
Operations Co-ordination (2 people for 0.25h@$60p/h)	30	30	30	30
Test – Callout (2 people for 1h@$60p/h)	120	120	120	120
Test – Execution (2 people for 0.25h@$60p/h)	30	30	30	30
Total per unit	$180	$180	$180	$180

Example – 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)	50	70	90	120
Fitout – Labour (1 person for 3h@$60p/h)	180	180	180	180
Engineering – Drafting (1 person for 1h@$60p/h)	60	60	60	60
Management (1 person for 2h@$80p/h)	160	160	160	160
Total per unit	$800	$1,255	$2,390	$4,820

Example – Retrofit Fixed SwitCheks

Item	125A	250A	630A	1250A
Isolator	0	0	0	0
Fitout – Materials (SwitChek, 2 x SwitChek Interfaces)	1,285	1,285	1,285	1,285
Fitout – Labour (1 person for 2h@$60p/h)	120	120	120	120
Engineering – Drafting (1 person for 1h@$60p/h)	60	60	60	60
Management (1 person for 2h@$80p/h)	160	160	160	160
Total per unit	$1,625	$1,625	$1,625	$1,625

Example – Retrofit Portable SwitChek

Item	125A	250A	630A	1250A
Isolator	0	0	0	0
Fitout – Materials (10% x SwitChek, 2 x SwitChek Interfaces)	490	490	490	490
Fitout – Labour (1 person for 2h@$60p/h)	120	120	120	120
Engineering – Drafting (1 person for 1h@$60p/h)	60	60	60	60
Management (1 person for 2h@$80p/h)	160	160	160	160
Total per unit	$830	$830	$830	$830

The 10% costing of SwitChek assumes that the plant incorporates ten 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 ten isolation switches.

Figure 10 below illustrates the first year costs associated with confirming isolations that are performed monthly for a varying quantity of isolating switches.

Figure 10

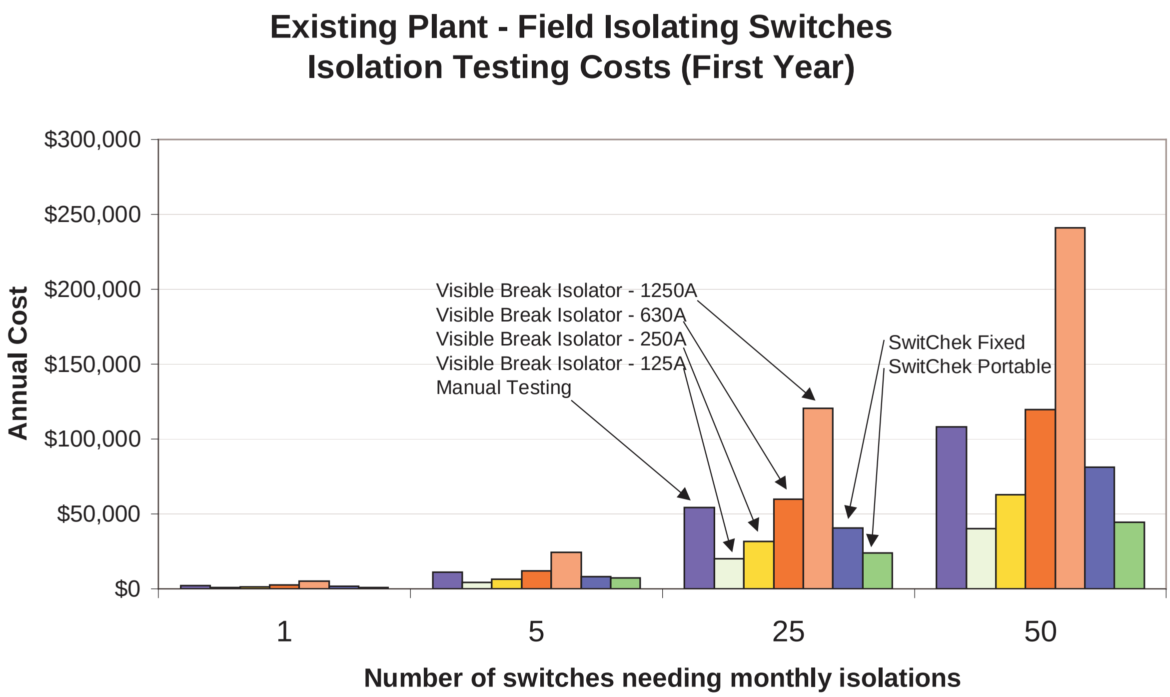

Figure 10 illustrates the following points regarding implementing confirmation of field isolations in an existing plant:

1. For small numbers of switches needing monthly isolations, manual testing is best
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 better solution than Fixed SwitChek and Visible Break Isolators.

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

1. The comparisons are cost based only. Technical advantages and disadvantages have not been considered.
2. Cost comparisons are for the first year only. In subsequent years manual testing costs continue to climb while Visible Break Isolators and Fixed SwitChek costs reduce to zero.

4.2.2 Cost Comparison – Field Isolators, New Plant

A cost comparison of the options to confirm isolations on field local isolators follows. This comparison is relevant to a new plant where the choice of isolation switches as local field isolation switches is yet to be made. Management has the option to manually test switches, install Visible Break Isolators (VBIs), install Fixed SwitCheks or install Portable SwitChek. The comparison focuses on differential costs and incorporates typical Australian labour rates for relevant skills in Australian Dollars ex-GST.

Example – Manual Isolator Test – Initial Install

Item	125A	250A	630A	1250A
Isolator - Standard	295	420	960	2,710
Fitout – Materials	0	0	0	0
Fitout – Labour (1 person for 2h@$60p/h)	120	120	120	120
Engineering – Drafting (1 person for 1h@$60p/h)	60	60	60	60
Management (1 person for 2h@$80p/h)	160	160	160	160
Total per unit	$635	$760	$1,300	$3,050

Example – Manual Isolator Test – Confirmation Test

Item	125A	250A	630A	1250A
Operations Co-ordination (2 people for 0.25h@$60p/h)	30	30	30	30
Test – Callout (2 people for 1h@$60p/h)	120	120	120	120
Test – Execution (2 people for 0.25h@$60p/h)	30	30	30	30
Total per unit	$180	$180	$180	$180

Example – 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)	50	70	90	120
Fitout – Labour (1 person for 3h@$60p/h)	180	180	180	180
Engineering – Drafting (1 person for 1h@$60p/h)	60	60	60	60
Management (1 person for 2h@$80p/h)	160	160	160	160
Total per unit	$800	$1,255	$2,390	$4,820

Example – Install Fixed SwitCheks

Item	125A	250A	630A	1250A
Isolator	295	420	960	2,710
Fitout – Materials (SwitChek, 2 x SwitChek Interfaces)	1,285	1,285	1,285	1,285
Fitout – Labour (1 person for 3h@$60p/h)	180	180	180	180
Engineering – Drafting (1 person for 1h@$60p/h)	60	60	60	60
Management (1 person for 2h@$80p/h)	160	160	160	160
Total per unit	$1,980	$2,105	$2,645	$4,395

Example – Install Portable SwitChek

Item	125A	250A	630A	1250A
Isolator	295	420	960	2,710
Fitout – Materials (10% x SwitChek, 2 x SwitChek Interfaces)	490	490	490	490
Fitout – Labour (1 person for 2h@$60p/h)	120	120	120	120
Engineering – Drafting (1 person for 1h@$60p/h)	60	60	60	60
Management (1 person for 2h@$80p/h)	160	160	160	160
Total per unit	$1,125	$1,250	$1,790	$3,540

The 10% costing of SwitChek assumes that the plant incorporates ten 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 ten 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

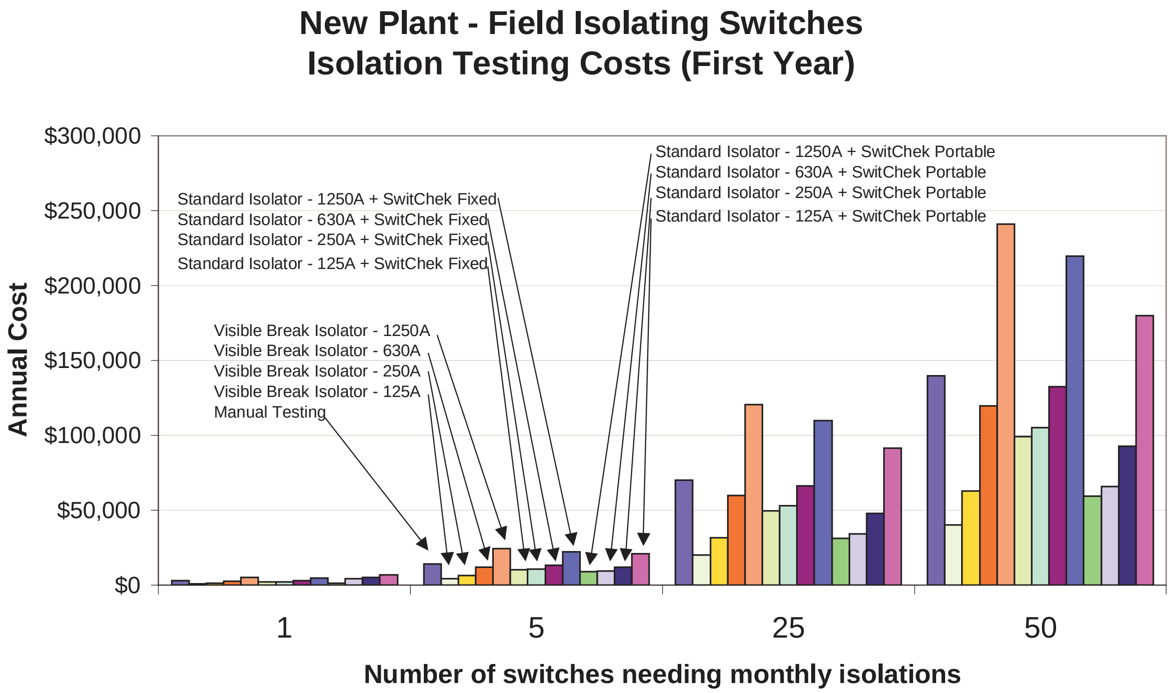

Figure 11 illustrates the following points regarding implementing confirmation of field isolations in a new plant:

1. In most circumstances manual testing is the least attractive method of confirming isolations
2. Visible Break Isolators are likely to be a better 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. The comparisons are cost based only. Technical advantages and disadvantages have not been considered.
2. Cost comparisons are for the first year only. In subsequent years manual testing costs continue to climb while Visible Break Isolators and Fixed SwitChek costs reduce to zero.

4.2.3 Cost Comparison – Switchboard Isolators, New and Existing Plant

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

A cost comparison between isolation confirmation methods for switchboard isolators would reveal similar conclusions to that reached for field isolators. However, the practicalities of using Visible Break Isolators in switchboards and motor control centres is difficult to justify as:

1. Achieving switchboard fault containment ratings where a portion of the cubicle door has been removed and a glass window has been inserted, is difficult.
2. 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.

For these reasons SwitChek methods for confirming electrical isolations in switchboards is the preferred approach and a cost based analysis is not practical.

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5 Conclusions

This report investigated the process of confirming an electrical isolation. That is, confirmation that the electrical isolation switch stops electricity.

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:

- Identify the correct Switch – Cannot be taken lightly in large substations
- Test what you lock! - This is the point of personal protection hence the lock
- Test accurately - Conclusive result whatever the isolation equipment configuration
- Test simply - Everyone (skilled and unskilled) needs to understand and repeat
- Test uniformly - Same test all over your site. Multiple methods should not be tolerated.
- No safety compromise – The confirmation method should in no way compromise the integrity of the isolation

Current methods associated with confirming an electrical isolation such as:

- "Testing Dead at Load"
- "Attempt a Start" & "Testing Dead at Load"
- Isolation Switch – line & load side pilot lamps

have been investigated and subsequently dismissed as either being too complex or not 100% reliable in all circumstances, or a combination of both.

Four approaches are regarded as being reliable options to prove that an isolation is sound:

- Plug & Socket/Withdrawable Switches
- Manual Isolator Testing
- Visible Break Isolators
- Automatic Isolator Testing – SwitChek

A cost and technical analysis for new and existing installations and for both field and switchboard isolators revealed that a SwitChek based solution is likely to be best solution for confirmation of electrical isolations.

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

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