Test harness development to analyse the performance of an algorithmic based High Voltage Fault Detection, Isolation and Restoration application

A dissertation submitted by

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Abstract

Energex is a South-East Queensland electricity distribution company supplying power to domestic and commercial consumers. Energex is considering implementation of automated software applications such as fault detection, isolation and restoration (FDIR) on its 11kV distribution network. FDIR could minimise supply interruption times, and ideally reduce the burden on human controllers, particularly accidental re-energising of faulted sections on the network. While the FDIR application could enhance Energex high voltage network operations, thorough testing and validation is required before implementation.

At the time of writing no Australian electricity distribution utility has implemented an in-service, algorithmic-based FDIR application. This project has enhanced knowledge through: development of an FDIR application and associated test device specific to a network; the processes for testing an algorithmic FDIR on a network; and the benefits and challenges of implementing an FDIR application.

The key outcomes of this work include the development of the test network, associated fault scripts, and the identification of current network limitations restricting the implementation of an FDIR application. The project is now ready for testing stage one of the application and is supported by technical documentation.

This project has enabled the development of the logic for governing this application and a suitable test network. Creation of the test scripts has permitted validation of the application and ensured its accurate testing after each upgrade of PowerOn Fusion, the distribution management system used by Energex. The test scripts are also the building blocks for testing further versions of the FDIR application.

The project has concluded there is further scope in the next version of the FDIR application to respond to additional network faults, considered more complex in nature, such as 11kV feeder circuit breaker fail conditions, mesh networks and the replacement of Substation SACS driven ACO schemes.

University of Southern Queensland

Faculty of Health, Engineering and Sciences

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Limitations of Use

Certification

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

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Chapter 1

INTRODUCTION

1.1 Chapter Overview

This Chapter provides the background information to the project, outlines why this project is required and details the main aims and primary objectives of the project.

1.2 Project Background

There has been unprecedented growth in demand for reliable electricity supply in recent decades, particularly in Queensland. Energex, an electricity distribution company supplies power to domestic and commercial consumers in South East Queensland, is committed to meeting such demand by considering the potential for system automation in its high voltage network. It is believed that this will allow the network to be operated more safely, efficiently and reliably.

The Energex network consists of a sub transmission network and a distribution network. The sub transmission network includes voltage levels of 132kV and 110kV which provides the link between the Transmission Service Provider (Powerlink QLD) and Energex owned Bulk and Zone substations. The sub transmission network also included an extensive 33kV network. The 11kV and 240/415V levels comprise the distribution network and typically connect directly to the domestic and commercial customers. Figure 1 below outlines the Queensland electricity network and the role Energex plays in distributing this electricity.

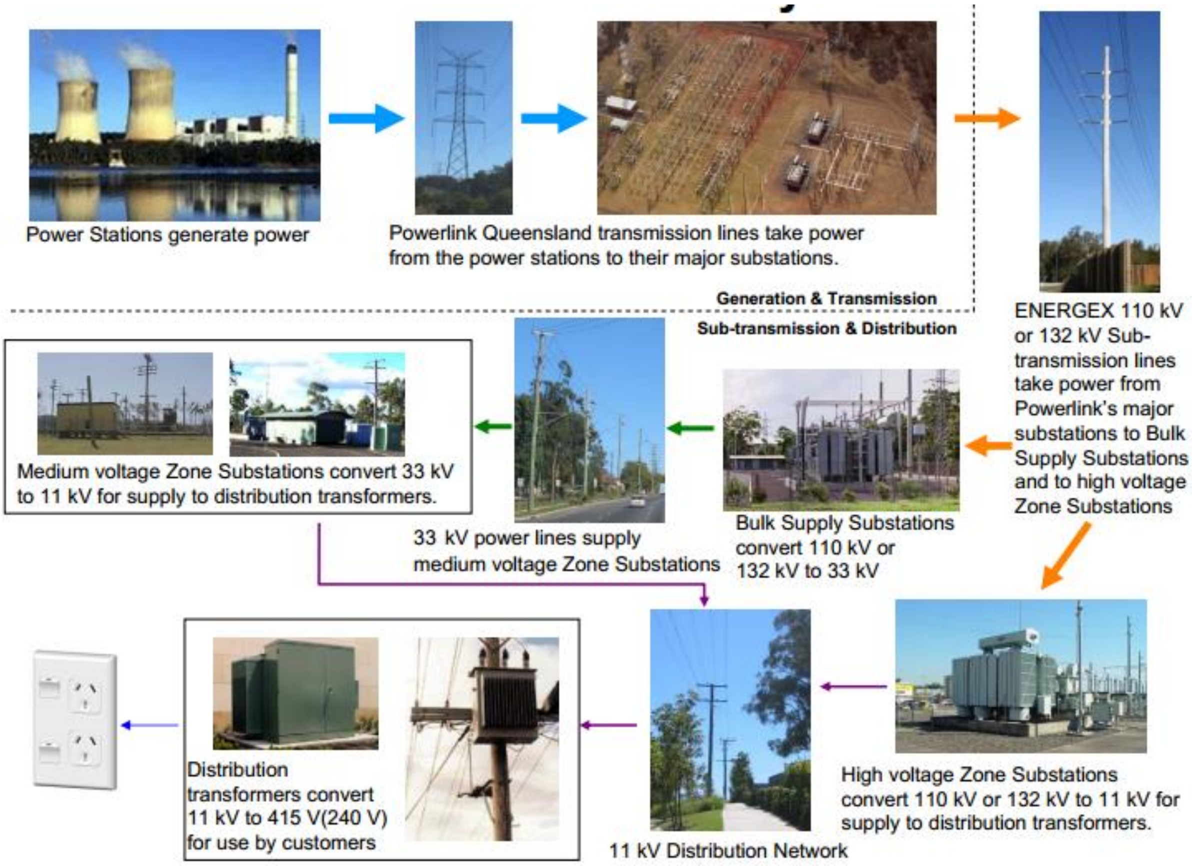

Figure 1: Key roles of Energex within the Queensland electricity network

For Energex, the voltage level that would typically affect the largest amount of customers due to a system fault is the 11kV network. While the sub transmission network may potentially disrupt supply to more customers than a fault on the 11kV network, there is much greater security of supply at the sub transmission levels which usually requires more than one fault event to initiate an outage at the customer distribution level.

A large section of high voltage overhead conductors or underground cable is often referred to as a feeder. The Energex Operating Practices Manual (OPM) classifies a feeder as an overhead line or underground cable, of full load current carrying capacity, used in the transmission of electric power; it serves to interconnect generating stations, substations and feeding points, usually without intermediate connections. An 11kV feeder can be many kilometres in length. When a loss of supply condition occurs on an 11kV high voltage feeder due to automatic disconnection, the term - '11kV lockout' is assigned to the incident. The majority of 11kV lockouts would usually only have one 'small' faulted section (in comparison to the entire feeder length), resulting in a number of customers losing power for a period of time even though their supply may be totally unaffected by the fault.

Energex employs high voltage switching coordinators to co-ordinate all activities on the high voltage network. When faults occur, high voltage switching coordinators are required to analyse multiple data streams, identify the fault location, possible cause and isolation and restoration options within critical time constraints. This occurs in an environment that must ensure safety of the public and field crews, maintain the integrity of infrastructure and assets, and minimise interruption to supply. An interrogation of Energex network data revealed that 1078 11kV feeder lockouts occurred between 1 January and 31 December 2016. In the 2015 calendar year, 1012 11kV feeder lockouts occurred, and in the 2014 calendar year, 700 11kV feeder lockouts. Of the total 2790 11kV feeder lockouts between 2014 and 2016, an extremely low percentage of unaffected or healthy sections of the feeder were restored within the ideal minimal timeframes.

To reduce the burden on human controllers, minimise supply interruption times and, ideally, the chance of accidently re-energising faulted sections of the network, there is now a focus upon implementing automated software applications such as fault detection, isolation and restoration (FDIR). The concept of an FDIR application is being considered as an enhancement to Energex high voltage network operations, but requires thorough testing and validation before implementation.

1.3 Project Aims

Energex is considering the implementation of an FDIR application into its 11kV radial distribution network. The successful introduction of this application is a key part of the 'smart grid' concept. This project aims to develop a test harness that will simulate the most onerous real time conditions to verify the FDIR application, and permit sound engineering justification for the introduction of the application. In this context, the test harness is a software system that 'supports automated testing and can assist in test environment setup, test execution, result logging and analysis (where) the test implementation maybe a single class or procedure, a subsystem or an entire application' (Rocha and Martins 2008).

The project will further consider possible failure modes and assess their consequences, and develop the necessary documentation to facilitate engineering approval of the application.

1.4 Project Objectives

While the project's main aim is the development of a test harness to verify the correct operation of the FDIR application, an equally important element is the extraction and analysis of relevant data and the associated development of application documentation. Accurate and well written documentation will aid in adoption of the technology into a real time control environment. The following six objectives were identified to ensure successful completion of the project (these objectives also form part of Appendix A - Project Specification):

1. Identify common and unusual 11kV network outage scenarios.

2. Extract relevant data from the last one hundred 11kV feeder lockouts and identify common and unusual scenarios from this data.

3. Create a test network in the GE PowerOn Fusion Production environment.

4. Develop a test harness to simulate the identified scenarios and carry out application testing/validation of the FDIR application.

5. Provide a review of FDIR Stage 1 Advisory mode system responses.

6. Develop the associated FDIR application documentation.

Chapter 2

LITERATURE REVIEW

2.1 Chapter Overview

A literature search was undertaken to develop a core framework for the project, and clarify the key definitions, background and techniques for analysis of a Fault Detect, Isolation and Restoration (FDIR) application. The literature review assisted in an understanding of the FDIR application and its potential in a high voltage distribution network.

Additional information sources identified the types of control algorithms currently utilised by various power utilities and key scheme abort logic requirements. These information sources also highlighted the advantages of implementing an algorithmic FDIR application compared to traditional controlling methods and protocols and non-algorithmic based FDIR applications. The literature review also revealed a gap in knowledge, with the need for a specific ‘test’ harness device to prove and validate the GE PowerOn Fusion FDIR application.

The literature review focused on a number of key areas, being the identification of relevant information on:

- The Swiss Cheese Model and the relationship to the Energex high voltage network;
- Fault Detection, Isolation and Restoration, an explanation of the technology, and how it operates and the benefits of implementing an algorithmic based FDIR scheme as opposed to a pre-configured switching scheme;
- FDIR abort conditions, outlining a large number of variables that need to be considered/satisfied prior to initiating a reclose attempt;
- The existing pre-defined automated change over schemes currently utilised by Energex;
- The available types of communication schemes currently utilised by power utilities to remotely control distribution plant and receive data feedback;
- Data collection techniques, to provide guidance on the collation of one hundred real world, 11kV network faults;

- Software automation testing, to assist in the development of guidelines for creating the 'test harness';

- Failure Modes and Effects Analysis from a software point of view; and

- The management of engineering documentation.

2.2 System variables, consequences and the Swiss Cheese Model

Introducing change into a complex system can be fraught with risk. This project focuses on introducing technology into a power distribution network, where network operational risks are currently identified and managed by human controllers, and not by automated response software programs. Understanding the potential effect of more than one variable in a power distribution network is therefore crucial to reducing risk. EuroControl (2006) noted it is widely accepted that incidents in complex systems occur as a result of a linking effect of multiple factors, where each factor by itself can be considered a minor concern, however, when aligned in a series, with other factors, the result can be a major incident. Examining these complex systems reveals they all contain multi-causal variables, but only rarely do they create the possibility of an incident. This description of events leading to an incident is known as the 'Swiss Cheese Model' (Reason 1997).

While the concepts of a 'Swiss Cheese Model' are often applied to air navigation systems and patient safety, the explanations for consequential failures may also be applied to power distribution networks. In relation to air navigation, The European Organisation for the Safety of Air Navigation (2006, p 2) observes that:

> 'The Swiss Cheese Model is an explanatory device for communicating the interactions and concatenations that occur when a complex well-defended system suffers a catastrophic breakdown. In particular, it conveys the fact that no one failure, human or technical, is sufficient to cause an accident. Rather, it involves the unlikely and often unforeseeable conjunction of several contributing factors arising from different levels of the system. It also indicates what defines an organizational accident, namely the concurrent failure of several defences, facilitated, and in some way prepared, by suboptimal features of the organisation design.'

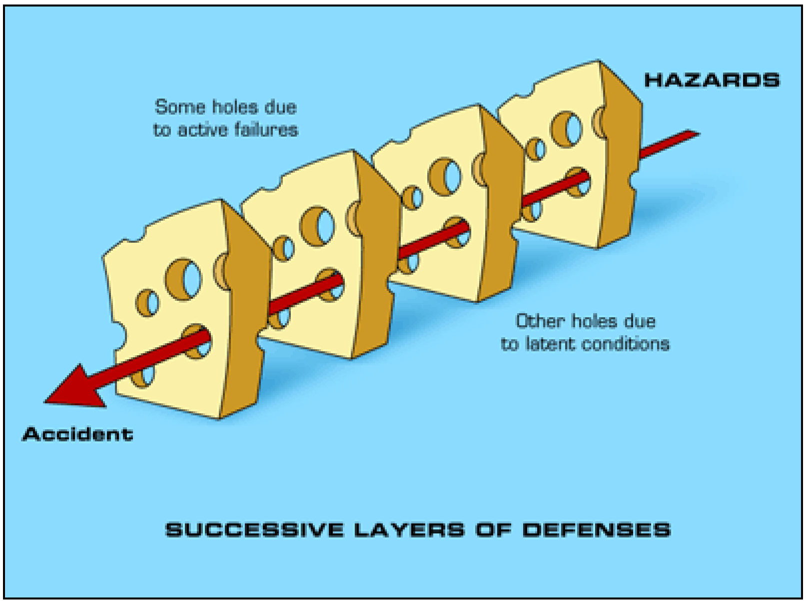

Figure 2: The Swiss Cheese Model – Successive Layers of Defences *(Source: Duke University School of Medicine 2016)*

The Energex 11kV distribution network is a complex and highly dynamic environment with many possible variables existing under both system 'healthy' and system fault conditions. As such, the adopted FDIR application must be flexible enough to respond to these variables, and limiting susceptibility to consequential events that may become a major incident (i.e. 'Swiss Cheese'). The chosen testing methodology must be able to successfully reproduce these system variables to ensure the FDIR application outputs can be analysed and confidence can be gained prior to enabling firstly, in an Advisory mode and finally, in the real time Production environment.

2.3 Artificial Intelligence (AI)

The commissioning of a Fault Detect, Isolate and Restore application within the Energex high voltage network is the introduction of Artificial Intelligence (AI) as the application is designed to replicate the decisions and associated actions taken by a human Switching Coordinator. Artificial Intelligence was first described in 1956 by John McCarthy, as the automation of activities associated with human thinking, particularly decision making, problem solving and learning.

For artificial intelligence to succeed, both intelligence and an artefact are required. Since the inception of artificial intelligence, the computer has been unanimously acclaimed as the artefact most likely to demonstrate or replicate human intelligence activities. Each generation of computer hardware has brought an increase in speed and capacity, and a subsequent decrease in price (Russell and Norvig, 1995). The generational improvements in computer hardware, from smart phones to satellite navigation systems, self-reversing car applications and medical procedures, are indicative of complex practical problems being resolved through artificial intelligence based technologies (Russell and Norvig, 1995). The benefits of AI include the ‘removal of dangerous, repetitive and dehumanising jobs,’ and the capacity to conduct ‘super-charged decision-making and problem-solving’ (O’Neill, 2017).

In contrast to the benefits of AI, the following concerns in implementing AI-based technologies have been noted:

- Mass unemployment due to artificial intelligence and robotics;
- Reduced privacy and democracy through greater mass surveillance by governments and companies;
- Biased algorithms manipulating important life issues, including insurance claims, job applications, loan applications and even judicial sentencing; and
- Regulation and control of artificial intelligence, particularly where large technology companies (e.g. Facebook, Google, Microsoft and Apple) seek to increase AI integration (O’Neill, 2017).

The implementation of an FDIR application into the high voltage network will bring Energex a number of system operational improvements; however it does also raise a number of concerns. The perceived benefits of the application include a reduction of supply interruption times for un-faulted sections of a locked out 11kV feeder and in theory, removes the chance of re-energising a downed 11kV conductor whilst attempting to restore supply. The concerns include the security surrounding the FDIR algorithms and the effect the application may have on current and future employment opportunities.

2.4 Fault Detection, Isolation and Restoration (FDIR) technology

Ghorbani Choudhry & Feliachi (2012) observed that a long-term objective for power distribution networks is to improve the quality of the electricity and continuity of supply in a cost effective way. Uninterrupted power is the primary element in the quality of power distribution. Responses by network Switching Coordinators to high voltage network interruptions involve the processing, in short timeframes, of multiple types, and typically large, volumes of data to expedite fault isolation and repair with minimal service disruption. To enhance these response rates, energy companies are focusing upon automated systems that identify and isolate faults, reducing the burden for human controllers. When a high voltage fault occurs on the network, multiple types of information must be analysed in a short timeframe. This rapid assessment occurs in a context of determining the protection scheme that has operated, the device that has opened, an accurate presumption of the fault location, ensuring the safety of people (both members of the public and workers on the network), safeguarding plant (assets) and restoration of supply to the un-faulted section/s of the network.

Restoring supply to un-faulted sections of the network is a highly critical action, requiring significant human information analysis, with time sensitive decisions on identifying which sections can be safely re-energised via remote controlled switches. Even if remote switches are available, this analytical process still takes time and in some cases, several minutes before supply is restored to un-faulted sections of the network. To facilitate rapid restoration times some electricity distribution companies have adopted the FDIR technology. FDIR applications involve using advanced distribution automation technologies (both hardware and software components) to accelerate the process of restoring power to unaffected customers in the event of a network fault (Australian Commonwealth Department of Industry, 10 August 2016).

Energex is currently developing an 11kV algorithmic FDIR automation scheme that seeks to reproduce the actions that a high voltage Switching Coordinator would take when responding to a lockout situation. The main objective of this application is to restore supplies quickly and reliably, and in less time than a human Switching Coordinator would take to analyse the information, identify the fault location and respond accordingly. As a result of improving restoration times, a noticeable improvement in customer service would be realised.

The 11kV distribution network is typically operated in a radial configuration. A radial configuration is considered to be a circuit breaker or an automatic circuit recloser, connected to an 11kV source busbar, supplying the circuit (feeder) extending to normally open points. The normally open points provide interconnection capability with other 11kV feeders. This allows supply to be maintained during planned maintenance and upgrade works as well as providing options to restore supply during lockouts. Figure 3 below shows an example 11kV radial feeder.

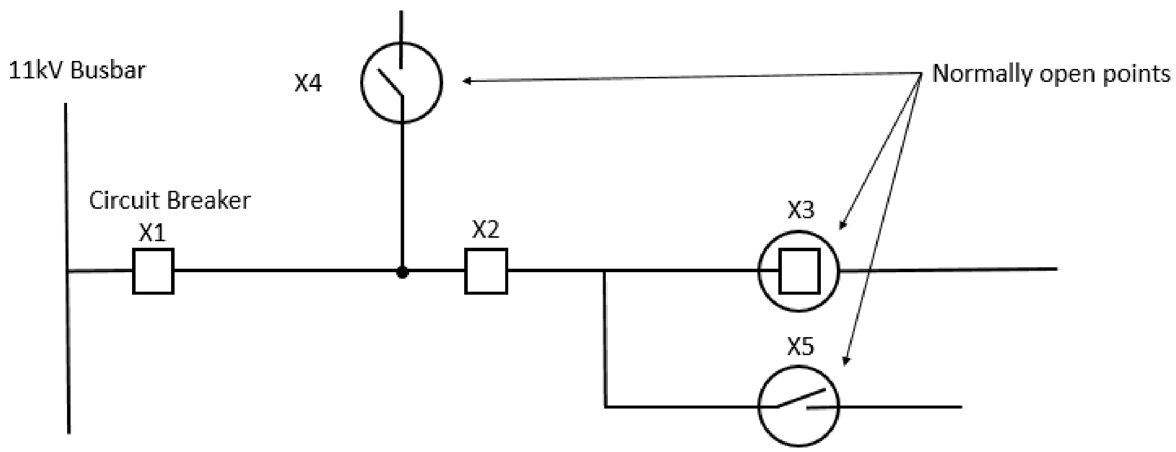

Figure 3: 11kV radial feeder

Typically a circuit will interconnect with a number of other 11kV feeders (via open point switches). However the number of interconnections varies depending on the feeder; an urban feeder would typically have more transfer options available than a rural feeder. The FDIR application Energex is adopting will initially only be applied to radially fed 11kV distribution networks.

When a permanent network fault is detected, the FDIR application will open the nearest line switches either side of the fault location, isolating the faulted feeder section from both directions. This creates two healthy (un-faulted) sections and one faulted section within the feeder. The upstream healthy section is then restored by closing the circuit breaker or automatic circuit recloser supplying the distribution feeder. To facilitate restoration of supply to the downstream un-faulted sections, a restoration strategy is derived by maximizing the area of service restoration with the minimum number of switching operations, based on the status of a number of real time dependant variables. Lin et al (2009) note that these variables include queries, for example, confirmation no work was underway on the faulted feeder and loads on the adjacent transfer feeder and associated high voltage plant will not be breached.

2.5 Fault Detection, Isolation and Restoration (FDIR) scheme abort logic

When a lockout occurs on the power system, regardless of the voltage, there are a number of key check items that a Switching Coordinator will consider prior to contemplating a manual reclose. The FDIR algorithmic application is designed to replicate this logic and will have to satisfy a number of conditions before attempting to restore supply. If any of these conditions are not satisfied then the scheme must abort.

In a paper presented at a CIRED Seminar, Cox (2008) outlined a number of check conditions to be satisfied before attempting to restore supply. These check conditions include:

- Confirm the type of protection scheme that operates. If Sensitive Earth Fault (SEF) protection operates, abort FDIR application;

- Confirm the faulted 11kV feeder was configured in a radial configuration at the time the fault occurred. This is so the direction of fault current flow can be determined and thus, healthy and unhealthy 11kV feeder sections can be ascertained;

- Confirm no work is currently underway on the faulted 11kV feeder. The application checks for work documents (Live Line Work Authority, Access Permit, etc.) and instructed switching items;

- Confirm the faulted 11kV feeder has remote paralleling/transfer points available;

- Confirm no work is currently underway on the alternative 11kV transfer feeders.

- Confirm the alternative 11kV transfer feeder is in a radial configuration. If the alternate transfer feeder was in a parallel configuration it would be assumed to be a temporary arrangement due to switching being underway. A parallel configuration would also cause inaccurate plant rating determinations. If the transfer feeder is in a parallel configuration then the application needs to choose another suitable transfer feeder;

- Confirm relevant plant ratings associated with the alternate transfer feeder will not be breached;

- Confirm no devices on faulted 11kV feeder or alternate 11kV transfer feeder have received a commanded close item within a defined period of time prior to the lockout occurring;

- Check for system operating notes prior to the application attempting to close a remote controlled switch;

- Confirm fault indication protection settings enabled in remote controlled devices on the faulted 11kV feeder; and

- Confirm 45 second time delay has expired before attempting any outputs to allow for communications polling of relevant devices.

A number of these conditions will be applicable to the Energex FDIR application. There are, however, some differences between the Energex application and the scheme presented by Cox (2008) and a number of additional key checks unique to the Energex system will be performed. The Energex model includes the following differences and additional checks:

- A ‘master’ isolation switch. This provides a facility to isolate the application if required to do so (ie, prior to a major weather event taking place);

- The FDIR application is triggered from a change of state of a protective device (ie, closed → tripped);

- The requirement to perform a number of server checks. This is required to confirm the priority server has not been lost at any stage of a device lockout and thus prevent multiple instances of the FDIR application from initiating from different servers and sending multiple commands;
- The type of protection to operate on an 11kV Energex radial feeder will have no influence on the FDIR algorithm logic meaning that Overcurrent Earth fault (OCEF), Overcurrent (OC), Earth fault (EF) or Sensitive Earth Fault (SEF) protection will not abort the scheme. By the

time the application is implemented within the Production Environment it is envisaged that all 11kV Load Transfer Switches will be considered as trust worthy devices for fault indication purposes. There is currently a program underway to improve the integrity of these switches via firmware upgrades, secondary injection testing, etc. Another issue that will be addressed is the physical positioning of the low voltage tie points (normally open LV switches between two distribution transformers). These switches will be aligned with the HV switch (ie, both LV and HV switches on the same pole). Currently there is the chance when restoring the HV up to an open switch that a section of LV overhead conductors to be energised could extend past the open HV switch and into the faulted area (supplied via a distribution transformer from the restored side of the open HV switch). Presently, therefore, there is the possibility of re-energising fallen 11kV conductors at LV potential. This exact scenario has occurred in the past, but was considered as a possible fault scenario by the Switching Coordinator prior to re-energising the 11kV network;

- An initial time delay will be set greater than the auto sequence timing to allow the device auto sequence scheme to time out. Confirmation of a device lockout is confirmed by the status of the devices auto reclose alarm. Confirm the feeder is definitely locked out (avoid application initiating before an automated reclose is attempted);

- When a lockout occurs, the application will immediately poll all remote devices on the faulted feeder. A time delay for feedback will be set. Device communication will provide confirmation of the communication scheme of all relevant, remote devices on the faulted feeder ensuring accurate alarm/fault information has been received;

- No more than one protective device on a faulted feeder has locked out. There are occasions where multiple protective devices almost simultaneously lock out on a feeder due to secondary fault conditions. An example of this is when conductor clashing occurs due to fault current and physical overhead constructions (insufficient clearance between conductors) resulting in overhead conductors burning to the ground. At this point in time, the scheme will abort when multiple protective devices lock out; and

- The application will check disabled or disable the auto reclose function on relevant upstream protective devices prior to attempting to restore supply.

2.6 Benefits of an algorithmic based FDIR application

The algorithmic FDIR application Energex is implementing utilises real-time tracing and analysis of the electrical 11kV network diagram, which is stored within the GE PowerOn Distribution Management System (DMS). This approach offers a number of advantages over local automation and pre-configured switching schemes. Cox (2008) has described numerous benefits of an algorithmic based FDIR application which include:

1. All relevant information about the entire 11kV network is held within the DMS. This information includes a single line 11kV schematic diagram, SCADA/device alarms, etc. and can be considered when deciding what switching actions are appropriate.

2. The data maintenance overhead is minimal as the only network configuration to be known by the FDIR application is that a certain type of device should be a trigger.

3. Abnormal network configurations and conditions are automatically taken into account via network tracing (permits on issue, instructed items, load transfers, etc.).

4. Switching Coordinators do not have to switch the schemes in and out.

5. Any scheme changes only need to be made in the one database.

The Energex 11kV distribution network is constantly changing due to feeder extension works, upgrade works or the decommissioning of sections of feeder or pieces of plant. As such the greatest advantage of an algorithmic based application over a pre-defined or logic based application for Energex is the minimal data maintenance that is required. In theory, once the application has been thoroughly tested both via simulation and in the advisory mode, no changes should be required until the application is expanded to cater for different network faults (11kV Feeder Circuit Breaker Failure conditions, mesh network faults, replacement of SCADA driven zone substation auto changeover schemes, etc.).

2.7 Existing ENERGEX 11kV Auto Change Over (ACO) schemes

Energex currently has a number of 11kV sites utilising automated change over schemes. These sites include Zone Substations and critical customer installations such as Hospitals and various other utilities. Consulting Energex Engineering design documentation revealed the auto change over schemes currently utilised within Energex Zone Substations are Supervisory Control and Data Acquisition (SCADA) driven schemes installed where there is a split 11kV busbar configuration. The protection line diagram shown in Figure 4 below shows such an arrangement. The ACO scheme is employed to restore supply to an entire 11kV busbar when a loss of supply condition occurs on the alternate 11kV busbar. The ACO schemes utilised in sites such as Hospitals are typically Programmable Logic Controller (PLC) driven and are used to restore a smaller section of the 11kV network when compared to the Zone Substation schemes.

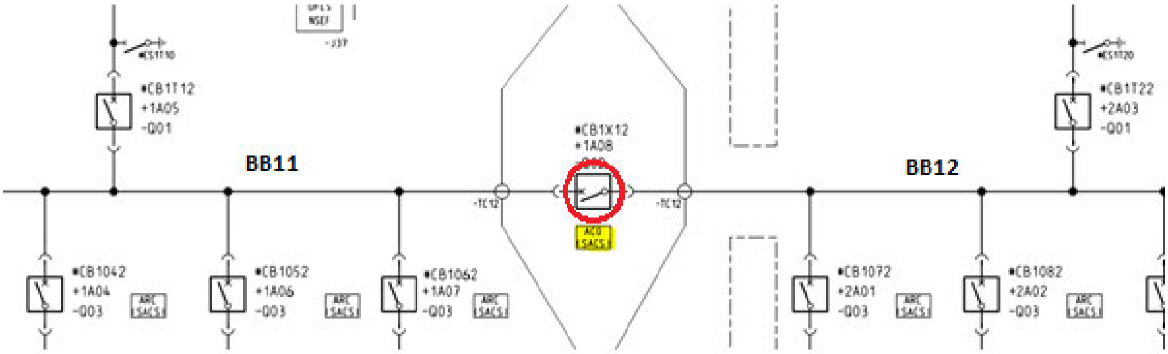

Figure 4: Protection Line Diagram showing normally open 11kV bus section circuit breaker (Energex, 2017)

Just like the FDIR application, these schemes have a number of conditions to be satisfied prior to attempting to restore supply. In contrast to the FDIR application, these existing ACO schemes operate on pre-defined logic which is suitable for these sites as the network in which they are located (primary switches, busbars, etc.) do not typically change. The only time these sites would change is through major project works and the relevant amendments to the ACO schemes would be captured as part of this project work. A section of an Energex protection logic diagram displaying the typical Zone substation 11kV ACO logic is shown below in Figure 5.

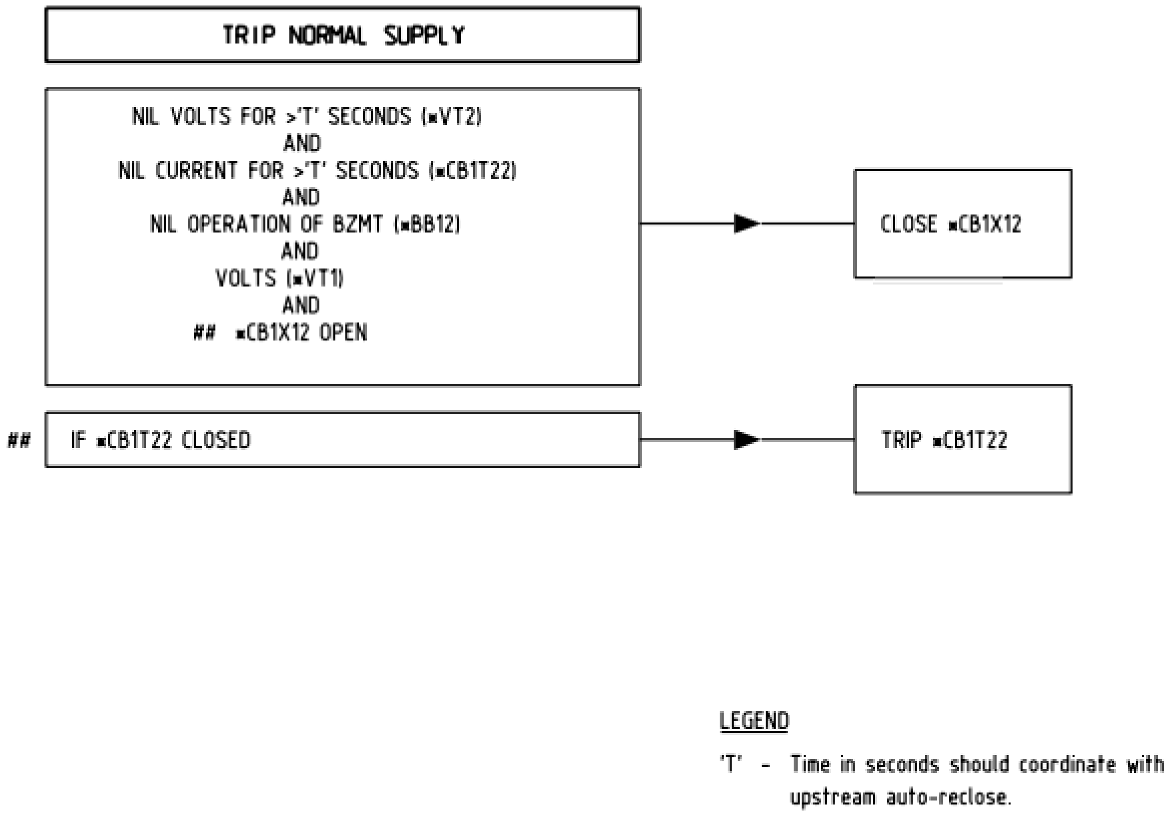

Figure 5: Protection Logic Diagram showing 11kV SCADA driven ACO logic (Energex, 2017)

Although these existing, pre-defined schemes are not applicable to this project and the initial introduction phase of the FDIR application, analysing the logic requires consideration on the types of system faults that can occur and the design of the scheme abort logic to ensure the ACO does not initiate a reclose onto a permanent fault. At a later stage, it is intended to extend the FDIR application to respond to 11kV Feeder Circuit Breaker Fail conditions that result in the loss of one or more Zone substation transformers. When this occurs, the existing ACO logic may need to be revisited.

2.8 Distribution network communication systems

In order for the FDIR application to be successful, a reliable and efficient means of communicating with the distribution plant is required. To be able to determine the location of the permanent fault relative to the 11kV remote controlled devices, the speed at which the fault data is received is critical. There are currently a number of communications methods available for implementing the required remote control and alarm reporting facilities. In the General Electric Network Protection and Automation Guide (2011) these methods include:

- Hard wired communications;

- Switched Telephone Networks;
- Power Line Carrier Communication (PLCC);
- Mobile radio (packet switched data);
- Conventional or low-powered radio including Microwave link; and
- Fibre Optics

Although reliable, the hard wired communication method is not generally a viable option, as the infrastructure is not available and the costs of installing the required infrastructure would be too much (General Electric 2011).

For distribution networks in metropolitan/urban areas, using an existing telephone network infrastructure would be a viable option, however rural distribution networks may be unable to utilise telephone networks as the infrastructure may not be available. There may be additional issues including line quality and the amount of data that can be transmitted. While microwave transmission is also an option, repeater stations may be required as the technology operates on a line of sight protocol (General Electric 2011).

Mobile radio is an attractive option as many telecommunication companies offer packet-switched data techniques to business users and this method is well suited in both urban and rural areas. However, in urban areas, there are potential issues with the shielding of required antennas by other buildings and transport vehicles. By contrast, rural areas may be affected by a lack of infrastructure and inadequate signal strength (General Electric 2011).

A common practice within distribution power companies and the method chosen by ENERGEX is to use low powered radio.

Energex utilises a low powered radio manufactured by Utilinet. Each device radio is connected in a mesh which forms part of the Distribution System SCADA (DSS) scheme. This configuration permits remote controlling and receiving of SCADA data from remote distribution plant (Energex 2015).

According to the Energex Learning Guide (2005) the Utilinet mesh network is a proprietary communications technology which uses spread spectrum radios operating in the unlicensed 900 MHz band and provides a framework for the DSS communications network. This network allows data to be passed from a DSS Gateway through the mesh to a remote site without the requirements of a direct connection, providing the ability to control and collect SCADA information from remote distribution switches and regulators.

The Utilinet mesh network comprises the following key components:

- Intelligent Electronic Device (IED) is the microprocessor-based controller at the device itself (i.e. Schneider ADVC2, Nulec CAPM2 or even SICM) which provides an interface between the mechanical component and communications protocol.

- UtiliNet Radio is a spread spectrum radio which is located at the device itself and works in conjunction with the aerial.

- Radio Repeater Site is a combination radio receiver / transmitter that receives a weak or low-level signal and retransmits it at a higher level or higher power, which is beneficial where line of sight is not available from one device to another.

- Head End is a UtiliNet radio which has a direct connection (fibre, copper, Ethernet or Microwave) to the Gateway and transfers data from a cluster of UtiliNet radios through to the Gateway.

- Gateway is a computer that processes information from the head-end radios and transfer to one of the 3 Master Data Concentrators (Southern, Central & Northern). The Gateways also house the databases that identify the switches on the network (MN1, SW1, NC1 etc.). There are three Gateways located on the ENERGEX network.

- Master Data Concentrator (MDC) is another computer which collates data from the local Gateway and converts RDCCOM communications into the DNP3 protocol and forwards the information via the Energex OTE network to the PowerOn Fusion Front End Processor and HMI.

The Energex Learning Guide (2005) describes one advantage of the meshed design as the ability to communicate with devices which would otherwise not be contactable by a traditional line of sight type of technology. With each radio installation the density of the mesh increases on the distribution network which then aids overall performance. This network topology provides a number of other benefits including faster device response times, fault location diagnosis information, the ability to remotely restore sections of unaffected network post fault and shift load. All of these benefits make the implementation of an FDIR application far easier.

2.9 Data collection techniques

Data assists in the assessment of past performance, and prediction of future performance. Allan and Billinton (1995) note that data facilitates the evaluation of the past performance of plant and systems in three ways: by identifying vulnerabilities that require strengthening; the development of bench marks for future events; and comparison of earlier predictions with subsequent incidents. One of the key components to this project on the implementation of an FDIR application involves extracting data from a significant number of previous system faults to assist in identifying what can be classed as both normal and abnormal fault scenarios.

The data collection process in the project was to facilitate knowledge of past experience and then to consider future performance with an FDIR application as the intervention. In this context, Allan and Billinton (1995) identify two main bases for collecting data, being the component approach and the unit approach. The unit approach is an accepted ideal for assessing chronological changes in the reliability of existing networks, but is less applicable to the predictive assessment, of the future performance of network systems. The component approach is applied to individual items of an operating plant and is collective data (also classed as stochastic data) associated with system outages, failures and restoration techniques.

In order to evaluate relevant statistical indices from the stochastic data, it is essential to know certain exposure parameters which can be viewed as deterministic data (Allan and Billinton 1995). The required data should include:

- The number of operating components of each designated type - this is necessary to pool relevant and related data together and indicate the number of components exposed to failure;

- Length of lines and cables - this includes lengths of double circuits and lines on common right of-ways. This enables the exposure parameter to be determined;

- Exposure time - this is the continuous elapsed time during which an event can take place. For example, the up-time if failure is being considered, the down-time if repair is being considered; and

- Discrete exposure - this represents the number of occasions when a failure can occur. It is relevant only to those components which receive commands to operate.

Such data would assist in identifying the project’s required statistics, to be used in the methodology for monitoring and modelling system components, and for assessing and predicting system behaviour. These statistics therefore form the interface between the collected data and the quantitative methodology that will be employed for assessing decisions (Allan & Billinton 1995).

2.10 Software automation testing

One of the project’s aims is to pilot an FDIR application, being the writing of a software program that will recognise system faults and implement a sequence of interventions. Writing software is a difficult and expensive task as the large volume of software, unclear software requirements and frequent software updates make software vulnerable without rigorous testing (Ali and Saha 2012).. Ali and Saha have stated that manual testing is not feasible in such an environment and may lead to unwanted changes in code and specification. A combination of both manual and automatic testing is utilised in this project, with the automatic testing element being the pre-written scripts and the manual component involving the validation of the applications response. However, the manual testing used in this project does not have any effect on the testing scripts.

Wang (2004) defines software testing as the process for revealing software defects and evaluating software quality by executing the software. Testing techniques are not only limited to the process of executing a program or application but is a process to identify software bugs (errors or other defects). The FDIR application test scripts have been created, firstly, to prove the correct operation of the application before testing individual elements of the application abort logic. By understanding the logic prior to developing the fault scenarios and testing the application, ensures any defects in the application code will be easily identified.

Zhang and Shen (2011) observe that, unlike general types of software, an embedded-type software application acquires its unique features from the specialty of its operating environment and required tasks. The ‘correctness’ of many embedded systems are decided not only by the function and behavioural feature of the particular system, but also by its unique time performance. One of the main aims of the FDIR application is to reduce restoration times to healthy sections of network. To achieve this, the application needs to perform all checks quickly, efficiently and have no negative impacts on computer system performance. The application testing stage will identify any negative processing issues.

Embedded software therefore acquires features that differ from common software, leading to the particularity of embedded software testing. The cross-linking relationship of an embedded system is complex, with strong reaction and instantaneity, resulting in large input scale and other restraints, such as sequential relationship. This then leads to a greater complexity in input, which simultaneously requires an increase in both the number and quality of test cases, in order to run a sufficient test. As embedded software contains large amount of hardware information, many tests conducted on the software alone are not sufficient; effective system testing only occurs where the embedded system is integrated into the hardware environment (Zhang & Shen 2011).

According to Qian and Zheng (2009) a good model for embedded software testing process should demonstrate the following characteristics:

- Software testing is introduced during each 'requirement' phase, to ensure that each requirement is well understood, and clearly and accurately described, so that software defects in the requirement are identified as soon as possible. The FDIR application logic has been developed utilising a flow chart where each function block of the flow chart represents a key process. The sub routine code has then been developed independently before being combined to create the overall application. The testing methodology is to create fault scenarios that will prove all facets of the application logic and also allow for fast identification of defects in code;

- The system architecture must be reviewed in the process, through establishment of a system software performance engineering model to evaluate whether the system architecture of embedded software meets performance requirements (timeliness). Experience indicates that performance problems are often caused by basic architecture or design factors, and not by inefficient coding. As previously stated, the FDIR application testing will identify any processing issues;

- The different stages in development have an appropriate testing technology, where a reasonable compromise is made between host-based testing and target-based testing. The simulator used for testing the FDIR application is located within the Master Data Concentrator which is essentially the interface between the remote terminal units and the Distribution Management System (DMS). The commissioned field devices that the test scripts are manipulating have previously had their alarm mapping proven from the actual physical field device all the way through to the PowerOn Fusion DMS. Thus, the simulator provides the ideal testing technology for this application;

- Embedded software testing tools are introduced in the model, and embedded software test automation is realized to improve the efficiency of software testing. The test scripts developed in this project automatically simulate the desired fault scenarios however evaluating the applications response to these fault scenarios is currently a manual process. In the future it is planned to automate the application response evaluation process by developing a form of a closed loop testing system; and

- After defects are identified and resolved, the affected domain should be analysed, with test cases being reasonably designed to carry out regression testing and avoid the appearance of new defects. After a defect has been identified and rectified during this project, testing is to be conducted to prove the defect has been rectified and that no other new errors have occurred whilst the initial defect was fixed.

2.11 Failure Modes and Effects Analysis (FMEA)

Over the last decade, considerable research has been undertaken to improve the reliability of software. Software error, reliability, and complexity models have been formulated and applied experimentally to a variety of projects [steps 1-3 in Qian & Zheng 2009, noted above]. Most of the current work in software reliability is directed toward producing quantitative models that can be used to measure, manage, and predict the level of software perfection, primarily during the test phase. Yet, the software engineering community has agreed that the greatest leverage on error reduction and thereby cost avoidance can be exerted during the requirements and design stages of the software development cycle [step 4 in Qian and Zheng 2009, noted above]. In this context, significant amounts of time have been spent during this project designing the FDIR application logic to ensure there is guidance for writing the application code.

Failure Modes and Effects Analysis (FMEA) is a system-based approach, aimed at identification and elimination or compensation of failure modes for reliability improvement. It has been used successfully for many years to identify, rank, and compensate for known failure modes of critical functions in space and missile systems where the consequences of failure are often catastrophic (e.g., inadvertent detonation of a nuclear missile near a populated area) (Pillay and Wang 2003; Reifer 1979).

The five major objectives for performing FMEA are:

1. To identify single point failure modes and define their effects.

2. To identify those areas of a design where redundancy should be implemented.

3. To identify compensating features for those single point failure modes where elimination is impractical.

4. To identify redundancy which is not, or cannot be, tested.

5. To assist in ranking the most serious failure modes and for establishing a critical items list.

When a problem has been identified, the first solution may be too risky, so that a less optimal fix is initially proposed, with a more complete solution provided in a later software release. Failures need to be prioritized according to how serious their consequences are, how frequently they occur and how easily they can be detected. A Design Failure Modes and Effects Analysis (DFMEA) performs this, and also documents current knowledge and actions about the risks of failures for use in continuous improvement. DFMEA provides a systematic method of identifying a large number of potential failures using thought experiments. DFMEAs provide risk mitigation, in both product and process development phases. Each potential failure is considered for its effect on the product or process or customer and, based on the risk level, actions are determined to reduce, mitigate, or eliminate the risk prior to software implementation and deployment. The DFMEA initiates a series of actions, with the aim of preventing or reducing the potential of failures or severity of failures, with the 'highest priority' areas being first. Each failure scenario removed during the product design phase provides large dividends and cost-benefits for the company when a more robust and reliable product is deployed (Gaval and Iyer 2014).

In context of this project, the system failure can be interpreted as either:

- Failure of the FDIR application to respond as anticipated; and / or
- The created fault scripts fail to satisfactorily validate a part of the FDIR application.

The following steps have been taken to reduce the chances of these failures occurring:

- Developing the application logic in consultation with another Engineer;

- Identifying possible fault scenarios based on network topology, real world experiences and historical fault data;
- Generating the test scripts based on these identified scenarios and comparing these fault scenarios against the developed application logic to ensure all parts of the logic have been proven; and
- Clearly documenting the applied testing methodology so that someone performing an independent review of the testing process can easily understand and critically analyse the steps taken.

2.12 Engineering Document Management

When introducing new technology, it is imperative that the subject matter is well documented and the information is written in a clear and concise manner. One of the key objectives of this project is to provide the necessary technical documentation for key stakeholders within ENERGEX to facilitate acceptance and approval.

Pecas Lopes et al, (2006) recommend that implementing changes in the operational policy of a network should aim to reduce the magnitude of new problems, particularly where operational changes occur in ‘areas of coordination of protection systems, and coordination of operation regarding ancillary services.’ Organisations need to provide for investment in ‘communication infrastructures and development of new tools for the environments needed to support the required changes’ (Pecas Lopes et al 2006). Harris et al (1997) refer to the importance of a ‘structured approach’ where ‘company-specific strategies, plans, models and requirements’ are key factors in engineering document management; this is particularly important where new technologies are being introduced into critical environments, such as power distribution networks.

In this context, the project aims to produce detailed documents that capture all stages in the research and testing phase, facilitating management decision-making and also to assist human controllers in understanding the approach taken, data collection and analysis, and implementation.

2.13 Contributions to research

The literature review has identified issues relevant to introducing new technologies into a critical infrastructure system, the risk management process, and the benefits and challenges of implementing an FDIR system within the Energex network.

It is proposed that this project will enhance knowledge through the development of an FDIR specific to a network, the processes for testing FDIR on a network, and identify both the benefits and challenges in implementation. This project will therefore address a significant gap in knowledge.

Chapter 3

METHODOLOGY

3.1 Chapter Overview

As stated previously, the anticipated benefits for Energex in implementing an algorithmic based FDIR application include:

- Reducing restoration times to healthy sections of network. If the intervention and data analysis required by a human controller is reduced by the introduction of an FDIR application, then more timely and effective responses to network faults will occur, contributing to an enhanced, reliable electricity supply; and
- Minimising the chance of inadvertently energising fallen conductors during initial restoration attempts, thus improving public safety.

The background literature search has identified a number of points to consider when collecting data, designing the logic conditions, developing the test network and test harness and simulating system faults. This chapter will outline and justify the methodology chosen to achieve the project aims and will explore the following sections:

- Data collection and categorisation;
- FDIR logic;
- Development of the test network;
- Fault simulation software; and
- Fault scenario scripting.

3.2 Data Collection and Categorisation

The project's aim is the development of a software based FDIR application test harness that will demonstrate that the application is fit for purpose and can operate satisfactorily under the most onerous of real time conditions as well as considering possible failure modes and assessing their consequences.

In order to build the test harness and validate the application, test case scenarios were developed first, with clearly defined and documented performance outcomes. As anticipated, the basic fault scenarios were not too difficult to replicate. The challenges were considered to be the identification of unusual scenarios where a number of variables assert simultaneously within the one incident. In an attempt to determine such scenarios, fault scenarios have been identified and developed based off the 11kV network topology, previous real world experiences and historical fault data. These scenarios have then been categorised to distinguish between normal and abnormal events.

The purpose of analysing and categorising this historical fault data are to develop abnormal test scenarios, ensuring the application has correct and sufficient abort logic. If there is any doubt the application has to utilise the failsafe logic and abort.

The main problem faced when attempting to provide the scenarios to validate the application is "have all possible situations been considered?" To ensure that all possible lockout scenarios have been identified and in addition to analysing historical lockout data, a number of experienced ENERGEX employees were consulted. These employees work in various roles including High Voltage Switching Coordinators, Shift Managers and Network Operations Engineers.

Energex's DMS (GE PowerOn) includes a tool known as the Outage Management System (OMS). Within OMS, historical data on all system outages that have occurred within the last three months can be extracted. These system outages include, but are not limited to, categories such as Area Troubles, Emergency High and Low Voltage Interruptions, Car Hit Pole, Zone Substation Losses and Lockouts (11kV, 33kV and 132kV). Each incident includes various data such as outage times, plant affected and a completed fault report from either the Switching Coordinator or field staff responsible for completing the work.

The FDIR application is designed to generate an output in response to a lockout on the 11kV network, which forms the basis for data collection in this project. Recent 11kV lockouts have been extracted from OMS by using filtering tools and then categorised accordingly; data selection was undertaken between 18 February 2017 and 27 March 2017. A data sample comprising one hundred 11kV lockouts were identified. This dataset comprises information entered by Switching Coordinators; it is expected practice for Switching Coordinators to enter as much relevant information as possible into the fault report, including any abnormalities, secondary faults or even protection mal-operations. Although there are often lockouts where abnormal scenarios occur, a sample size of one hundred lockouts is considered to include a sufficiently large dataset for this exercise; however, there is still potential for these recent lockouts to not include abnormal scenarios.

Once the data was collected it was categorised based on the following criteria:

- What was the type of protection scheme that operated?
- Was the system in a ‘normal’ state when the fault initiated?
- Were there any protection mal-operations?
- Were there any unusual scenarios associated with the fault?
- Was the faulted component overhead or underground?
- Were there any 11kV conductors down?

Some examples of abnormal fault conditions that were identified in these queries included the following:

- 11kV protective devices failing to open under fault conditions resulting in the upstream protective device clearing the fault;
- 11kV Automatic Circuit Reclosers (ACR’s) tripping but failing to generate an associated protection operated alarm;
- Initial 11kV feeder fault creating a secondary feeder fault;
- 11kV Substation circuit breaker Earth Switch failed to be opened as per the reversal of the switching schedule. When attempting to re-energise the area remotely, the 11kV circuit breaker was closed in on earth potential, locking the circuit breaker out and damaging equipment;
- 11kV Capacitor circuit breaker vacuum bottles failing (circuit breaker fail condition), resulting in the 11kV feeder circuit breaker clearing the fault;
- Field Switching Crew were conducting the reversal on a planned switching schedule and had been instructed by a Switching Coordinator to open an air break switch. The switching schedule had disabled SEF protection prior to reversing the load shift. The switching crew performed the open item and informed the Switching Coordinator the item was complete. As per the schedule the Switching Coordinator then reversed the paralleling condition including reinstating SEF protection. Shortly after reinstating SEF protection, both 11KV feeders locked out on SEF protection. One arcing horn had been left in on the normally open three phase switch;

- Similar fault occurred to the previous fault except in this incident the circulating current was large enough to operate the feeder earth fault protection;
- Possum contacted 11kV overhead conductors on a normally open switch causing large fireball and locking out both 11kV feeders;
- A switching crew were carrying out planned switching and were instructed in an item to disable SEF protection on a non-telemetered ACR. The switching crew misread the item and tripped the switch instead;
- 11kV feeder circuit breaker tripped on OCEF protection but failed to attempt an auto reclose due to a trip circuit faulty alarm asserting;
- A large section of 11kV feeder had previously been transferred onto an alternate feeder. A genuine 11kV fault then occurred in the transferred section of feeder resulting in a large outage;
- A non-telemetered ACR tripped for a genuine fault downstream of its location, however the resultant fault current flowing resulted in wrapped 11kV conductors upstream of this switch causing the upstream protective device to trip as well;
- As per a planned 11kV switching schedule, a switching crew were instructed to close a normally open 11kV air break switch. As the switching operators assistant closed the switch, 'c' phase 11kV conductor dead end (termination device) failed causing the conductor to fall into the low voltage overhead conductors below. The fallen 11kV conductor did not go open circuit. Because the normally open switch was now in the closed position there were two feeders supplying fault current. The correct protective devices (11kV Substation ACRs) on both feeders detected the fault condition and tripped before reclosing onto the fault. One of the feeder ACRs successfully tripped again, locking the feeder out. However, when the other ACR reclosed, the 11kV closing coil dragged the substation battery volts down to an unsatisfactory level which resulted in a number of protection relays powering down. Because the fault was still being fed from one 11kV feeder and its associated microprocessor protection relay was powered down, this relay did not detect the presence of a fault condition. The substation electromechanical neutral earth fault (NEF) protection relay detected the fault condition and proceeded to 'time out.' Eventually the substation batteries recovered, and the protection relays became healthy again. Because the electromechanical NEF protection relay had detected the fault was present and its disk had been timing out it operated before the faulted feeder's protection relay, resulting in complete loss of the substation.

3.3 FDIR Logic

Prior to undertaking any form of testing, the expected results need to be known. Thus, a master logic diagram has been developed outlining the key check and abort conditions for the FDIR application. The standard master logic was designed for application to every 11kV radial feeder within the Energex network and, provided all the master abort conditions are correct, permits the FDIR application to make the correct decision under both normal and abnormal lockout conditions.

The key steps in the FDIR application logic are listed below:

- Application initiation - A change in status of a protective device from closed to open is the trigger for the application to commence.
- Master application isolation switch, this provides a way to isolate the application if required. For example, the application may require isolation prior to the occurrence of a large weather event, when it may be beneficial to isolate the application.
- Conduct Server checks, which involve confirming the client is on the priority server and no alternative processes are running. This eliminates the possibility for multiple instances of the FDIR application running on different servers due to a changeover in servers during any stage of the application initiating;
- Initiation checks are then conducted to rule out the device tripping following a commanded action, that a valid protection operated alarm indication has asserted and been received, that there are no Crew On Line tags on issue on the feeder (this indicates Live Line work or tree trimming work could be underway on the feeder) the feeder is in a radial configuration and there are no instructed items on apparatus relevant to the device / feeder;
- Confirm that a protective device has locked out on the faulted feeder. The programming of a pre-defined time delay allows the auto sequence to expire. Lockout status is then confirmed through the device auto reclose alarms status;
- If the auto-reclose checks are satisfied (device has locked out) then the application will continue on to conduct a check of the device status. This is effectively a second check to confirm the device has locked out;
- If the lockout checks indicate a device has locked out, the next sub process is to conduct network checks. The network checks are to confirm one side of the available remote transfer points is de-energised and the upstream network is in a stable state. Stable state checks confirm no operations have occurred within the last minute on the upstream device and the available remote transfer points and confirmation that pant ratings will not be jeopardised;
- The application will then generate a model specific to the faulted network, comprising all remote controlled devices;

- The next sub process will check that all received alarm indications are consistent. For example, if a downstream device generates an SEF fault indication alarm but the upstream circuit breaker trips on OCEF protection, then the application will abort;
- From the generated model, all remote devices are then checked to confirm all alarms are commissioned and uninhibited, and remote supervisory control is enabled. If a device's remote supervisory control is in the local position (switch state cannot be changed from a remote command) or the alarms associated with the device are non-commissioned and/or inhibited, this device will be excluded from the FDIR application model, effectively treating the switch the same as a manually operated switch (i.e. an air break switch or ring main unit isolator);
- The next sub process identifies the faulted 11kV section of network. This is achieved by analysing the generated fault indication alarms;
- Confirm successful polling of all remote devices on faulted 11kV feeder immediately after confirmation a protective device has locked out;
- Confirm no more than one protective device on faulted feeder locked out;
- Confirm the alternative 11kV transfer feeder is in a radial configuration. If the alternate transfer feeder was in a parallel configuration it would be assumed to be a temporary arrangement due to switching being underway. A parallel configuration would also cause inaccurate plant rating determinations. If the transfer feeder is in a parallel configuration then the application needs to choose another suitable transfer feeder;
- Confirm no work is currently underway on the alternative 11kV transfer feeders; and
- The application is to be implemented into the Production environment in two distinct stages. The first stage will be an Advisory mode (generates the items to be taken but does not automatically execute these actual items) and the second stage will be a completely functioning version which will provide real time execution of items. At this point in the decision tree, the application will check to see which mode the application is set at. If the application is in the Advisory mode, the application will then create a Fault Job (switching schedule that has a list of items to be carried out in a specific sequence). The Fault Job will list the steps to be carried out to isolate the faulted section and disable auto reclose on the relevant upstream devices before restoring supply to the un-faulted sections. Once the Fault Job has been populated, a Switching Coordinator will check all items are correct. If the items are correct then the Switching Coordinator will be able to execute the items;

3.4 Test Network Development

The GE PowerOn Fusion Distribution Management System application provides two environments for users to work in. These are the Development and Production environments. The Production environment is real time, enabling users to remotely control field devices allowing for management of the network. In contrast, the Development environment is essentially a replica of the Production environment but does not permit remote controlling of any actual field device. It does however provide the means to conduct certain forms of testing and prepare diagram modifications prior to alterations physically occurring in the high voltage network. These diagrams can then be transferred into the real time Production environment once the work has physically been completed in the field.

The Energex 11kV distribution network is made up of a number of switches with and without protection functions. These switches include circuit breakers, automatic circuit reclosers, sectionalisers and load transfer switches, with each switch having multiple available application types due to different switchgear manufacturers and the ability to be applied in multiple configurations. Before creating the test network a search was performed to determine all of the 11kV downline remote controlled devices and their varying configurations currently installed within the Energex 11kV distribution network. An 11kV downline device is classified as either an automatic circuit recloser, sectionaliser or a load transfer switch. Figure 6 below shows the available switch hardware device configurations.

Plant Manufacturer	Device Type	Plant Model	Switch Function	Hardware Channel Default (SCADAbase)
NOJA	RC01	OSM15	RECLOSER	NOJA - DSS, Recloser, OSM15
NOJA	RC10	OSM15	RECLOSER	Noja - DSS, Recloser, RC10
NOJA	RC10	OSM38	RECLOSER	Noja - DSS, Recloser, RC10
NULEC	CAPM2	N12	RECLOSER	Nulec - DSS, Recloser, DNP, CAPM2
NULEC	CAPM2	N12	RECLOSER as LTS	Nulec - DSS, Recloser as LTS, DNP, CAPM2
NULEC	CAPM2	N36	RECLOSER	Nulec - DSS, Recloser, DNP, CAPM2
NULEC	CAPM2	RL27	SECTIONALISER	Nulec - DSS, Sectionaliser, DNP, CAPM2
NULEC	CAPM4	N12	RECLOSER	Nulec - DSA, Recloser, DNP, CAPM4
NULEC	CAPM5	N12	RECLOSER	Nulec - DSS, Recloser, DNP, CAPM5
NULEC	CAPM5	N12	RECLOSER as LTS	Nulec - DSS, Recloser as LTS, DNP, CAPM5
NULEC	CAPM5	N36	RECLOSER	Nulec - DSS, Recloser, DNP, CAPM5
NULEC	CAPM5	RL27	SECTIONALISER	Nulec - DSS, Sectionaliser, DNP, CAPM5
NULEC	CAPM5	W27	RECLOSER SWER	Nulec - DSS, W27 Recloser, DNP, CAPM5, 1 Phase
SCHNEIDER	ADVC2	N38	RECLOSER	Schneider/Nu-Lec in DSS>>>DSS Nu-Lec Recloser 33kV DNP ADVC2
SCHNEIDER	ADVC2	N38	RECLOSER as LTS	Schneider/Nu-Lec in DSS>>>DSS Schneider Recloser, LTS Operation, DNP ADVC2
SCHNEIDER	ADVC2	RL27	SECTIONALISER	Schneider/Nu-Lec in DSS>>>DSS Schneider Sectionaliser 11kV DNP ADVC2
TAVRIDA	MPM	OSM 15	RECLOSER	Tavrida - DSS, Recloser, DNP, MPM

Figure 6 – Available 11kV remote device configurations (Energex, 2017)

From this search, multiple queries were conducted within the PowerOn Production Environment to locate each of these devices. A number of switches were then identified and recorded to ensure a reasonable cross section of devices would be available to be included within the test network. Figure 7 below shows a scaled down version of the device categorisation. It is noted that although the database querying did identify the Nulec CAPM2 N36 Reclosers and Nulec CAPM5 N36 Reclosers as 11kV devices, there are currently none of these configurations in service on the 11kV distribution network.

Plant Manufacturer	Device Type	Plant Model	Switch Function	Device ID	RTU
Nulec	CAPM2	N12	RECLOSER	X96110	SC0
Nulec	CAPM2	N12	RECLOSER as LTS	X762443	SC0
Nulec	CAPM2	N36	RECLOSER	All 33kV Reclosers	
Nulec	CAPM2	RL27	SECTIONALISER	X8656-A	NC5
Nulec	CAPM2	RL27	SECTIONALISER	X384666 (N/O)	SW4
Nulec	CAPM4	N12	RECLOSER (No prot)	X448450	NC4A
Nulec	CAPM5	N12	RECLOSER	X26063-B	SC3
Nulec	CAPM5	N12	RECLOSER as LTS	X1083396	SC5
Nulec	CAPM5	N36	RECLOSER	All 33kV switches	
Nulec	CAPM5	RL27	SECTIONALISER	X17749-B	SW5
Nulec	CAPM5	W27	RECLOSER SWER	X21940-A	SW0
Schneider	ADVC2	N38	RECLOSER	SSEMD RE1032	EMD
Schneider	ADVC2	N38	RECLOSER as LTS	X18814-B	SW8
Schneider	ADVC2	RL27	SECTIONALISER	X101192-A	MN1A
Tavrida	MPM	OSM 15	RECLOSER	X18524-B	MN2

Figure 7 – Actual 11kV remote devices matching available configurations (Energex, 2017)

The commissioned 11kV distribution network also includes manual switches such as Ring Main Units (RMU's) and Air Break Switches (ABS's). An RMU isolator is used on the underground network whereas an ABS is used in overhead applications.

The testing of the FDIR application within the Production Environment involves the creation of a test remote terminal unit (RTU). An RTU is an electronic device controlled by a micro-controller, providing a link between a control system and real world physical devices. Its purpose is to 'Interface with distributed control systems (DCS) and supervisory control and data acquisition (SCADA) systems by sending telemetry data to these systems. An RTU can also monitor a field's analogue and digital parameters through sensors and data received from connected devices and systems; it then sends this data to the central monitoring station' (Techopedia 2017). An RTU within the Energex distribution network provides remote control of devices (switches, regulators, etc.) and the ability to receive the associated status indication and alarms from these devices (primary switch status changes, fault indication, protection operations, etc.). The FDIR application will make decisions based on the alarms and status changes received from field devices via the relevant RTU.

On a yearly basis, Energex carries out a major software upgrade on the PowerOn application. Unlike the PowerOn Development Environment, the Production Environment is immune to network changes resulting from the upgrade (i.e. Master copy of the network). The original test network methodology for this project was to design and commission the test network within the real time Production Environment, with the testing taking place within this environment. This would provide two main benefits for installing the test network and conducting acceptance testing within the Production environment as opposed to the Development Environment. These benefits are noted as:

- The test network does not have to be recreated each time an upgrade takes place as no changes will occur; and

- The commissioned test harness scripts will have previously been proven to operate on a known and established network. Each time an upgrade is carried out, the scripts will be run again to identify any test case failures occurring as a result of the upgrade. If the network has not changed, one less variable is removed that could possibly give a misleading result.

The test RTU was to be developed by the Energex Network Automation Department, which would then allow the required 11kV devices (cross section of remote 11kV devices) to be linked to this RTU, which would then permit creation of the test network. In order to link the devices to the test network, the devices need to firstly be created within the Energex Network Facilities Management (NFM) application. However, Energex is currently undergoing a large upgrade of its Geographical Information System (GIS) software application which involves major upgrade works to the NFM database.

To overcome these issues, another approach was taken to facilitate the completion of this project. Instead of developing a test RTU and creating and linking the devices via the NFM database, the test network was created within the Development Environment utilising existing 11kV devices from throughout the network. These devices are ‘commissioned, in service’ real time devices and already have their own RTU allocations.

Within PowerOn, each 11kV device has an attributes library. The attributes library includes a number of sub-categories all specific to the selected device. These categories include properties, tags and links. Of most significance to the FDIR application is the linking category as it provides an interface between the device alarms and the FDIR application logic. As there are a number of different manufacturers and alarm mapping configurations available, the linking category provides a means to convert any number of alarm points to a common and standardised set of seven FDIR logic inputs for downstream devices. These seven logic inputs form part of the check and abort conditions for the FDIR logic. For substation source devices (circuit breakers or automatic circuit reclosers), the device alarm to FDIR application linking is achieved via a slightly different way. An in depth detail of how the component linking is achieved for both downstream devices and substation protective devices is documented in Appendix C. By including all of the different available device configurations identified in Figure 6 within the test network, all alarm linking combinations have been accounted for.

To verify the application, a realistic test network was built with circuits that provide the necessary components to test the developed scenarios. These components include manual switches, remote switches and sections of underground and overhead networks. The test network that has been developed to validate the FDIR application is comprised of three 11kV feeders all originating from a ‘source’ 11kV bus bar. The completed test network is shown below in Figure 8.

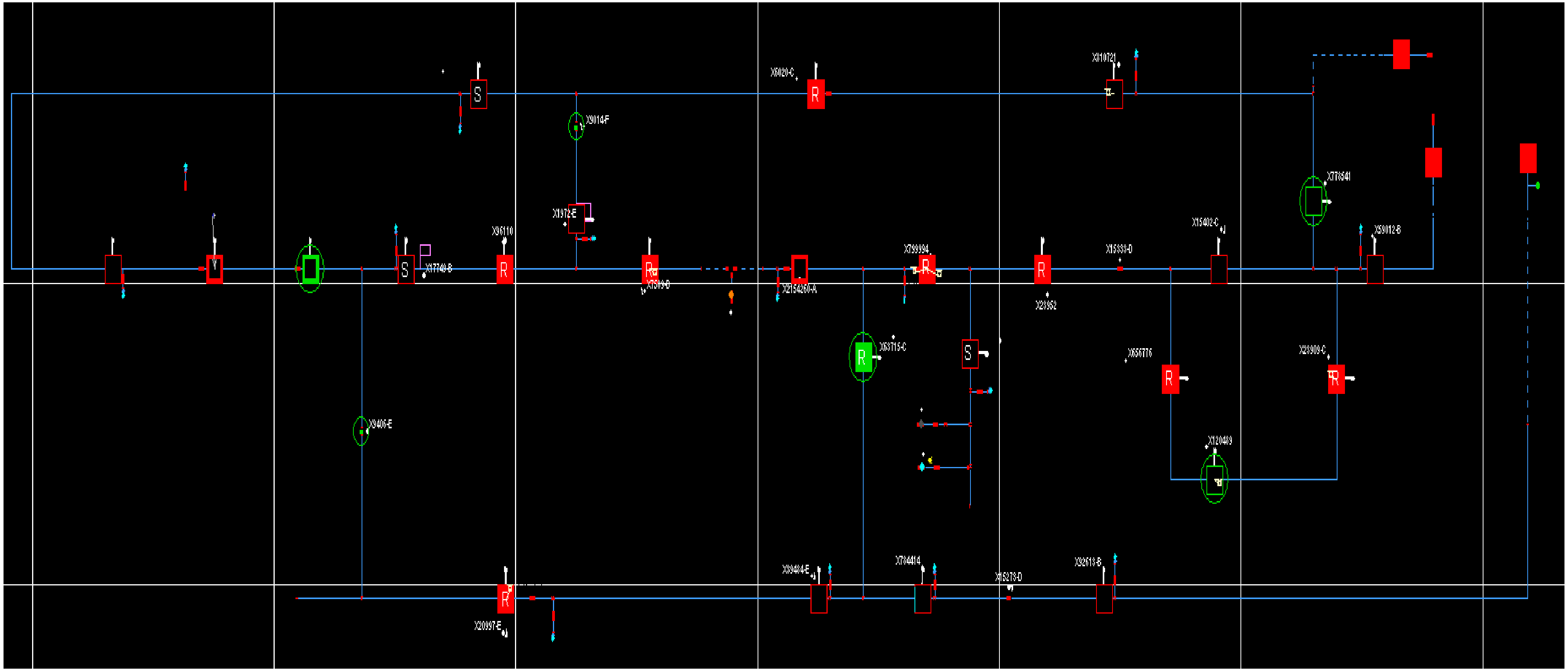

Figure 8 – 11kV test network (Energex, 2017)

3.5 Fault Simulation Software

The Energex Distribution Management System (DMS) / SCADA interface is shown below in Figure 9. The GE PowerOn Fusion is a Windows-based application with the PowerOn Client machine having the ability to switch between four different, dedicated servers. The FDIR application is a part of the GE PowerOn application and sits within each of these four servers. From these four servers is a connection to the PowerOn Front End Processors (FEPs). The FEP communicates with the Linux-based Master Data Concentrator (MDC) and provides the interface between the PowerOn environment and the Energex SCADA network. The MDC is linked with the RTUs which then provide the communication path to and from the field devices.

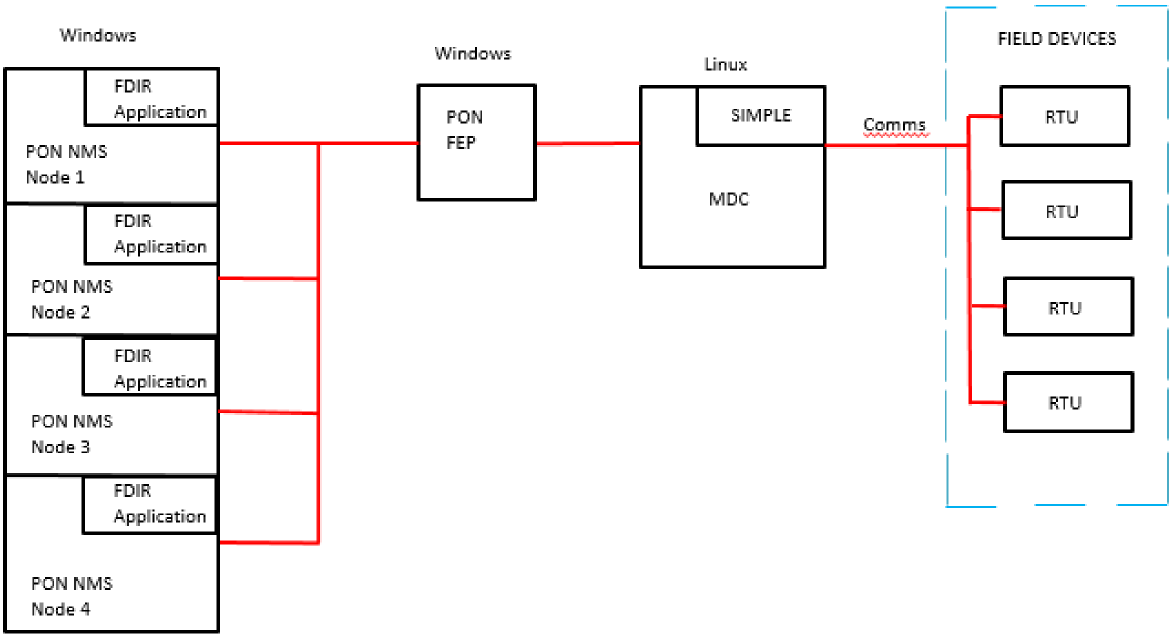

Figure 9 – Energex DMS / SCADA architecture (Energex, 2017)

Replicating each fault scenario involves changing specific alarm points and switch statuses to simulate the required chain of events. A program called kiTTy was used to access the Master Data Concentrator (MDC) simulator. This simulator is an Energex 'in house' built application which is essentially an RTU simulator allowing users to set the inputs, either analogue or digital, as if it were the actual input/output board on the RTU receiving information from a field device. In relation to the DMS / SCADA architecture, the SIMPLE simulator sits within the MDC as shown in Figure 9 above.

Once the kiTTy session was running, a WinSCP session was then opened. The WinSCP application is an open source free client for Windows. Its main function is to allow for file transfers between a local and a remote computer as well as offering scripting and basic file manager functionality (WinSCP, 31

July 2017). In this case, the WinSCP client permits the transfer of files between the Linux-based Master Data Concentrator (MDC) and the Windows-based PowerOn Fusion Front End Processor (FEP).

In order to manipulate all the required analogue and digital field device points, and replicate the required fault scenarios, command lines via jiggle scripts were created. Jiggle can be used in either an interactive mode or a command file mode. The interactive mode is where the jiggle command is invoked with a single command line and all further commands are entered via the keyboard whereas the command file mode is where the jiggle command is invoked with a command file parameter such as “test.jig.” The command file mode was utilised in this project allowing pre-written scripts to be executed.

3.6 Fault Scenario Scripting

For each fault scenario, a dedicated jiggle script was created. The following lines of code form part of a pre-written script and provide an example of how a trip and close of automatic circuit recloser X20997-E is executed.

```
set sub sc1A % Define X20997-E RTU
alias 'NSL105750609.Scan Value' 2 % Trip X20997-E
wait 2000 % 2s time delay between trip and close commands
alias 'NSL105750609.Scan Value' 1 % Close X20997-E
```

To run this script automatically the file would firstly be saved with any file name and a .jig file extension. In this case the file has been saved as ‘example.jig.’ Within the Linux-based KiTTy emulator, the following command is entered into KiTTY to run the script:

```
jiggle –f example.jig
```

Figure 10 below shows the script output within the KiTTy emulator. Further information of the fault scenario scripting is available in Appendix D.

```
[root@dev02sim1 jd083]# jiggle -f example.jig
JIGGLE : GJW20150625a PCSACSV3/5/LNX
###: set sub sc1a
sc1a: alias 'NSL105750609.Scan Value' 2
Component Alias : NSL105750609.Scan Value
DPN             : 55 : x20997
Mask            : 0x0300
Value           : 2
sc1a: wait 2000
sc1a: alias 'NSL105750609.Scan Value' 1
Component Alias : NSL105750609.Scan Value
DPN             : 55 : x20997
Mask            : 0x0300
Value           : 1
sc1a: exit
[root@dev02sim1 jd083]#
```

Figure 10– Running example.jig script – changing digital point (Energex, 2017)

Chapter 4

FAULT SCENARIOS

4.1 Chapter Overview

The adopted testing methodology was to firstly simulate faults on the test network with no abnormal conditions as per the master logic diagram (all logic conditions satisfied and no abort conditions asserted). The subsequent test scripts were then designed based on identified fault scenarios and aligned with the application logic to ensure all abort conditions were proven. The purpose of proving all abort conditions is to ensure the application defaults to the safest possible state. The safest possible state being no outputs initiated from the application.

As per the Energex Operating Practices Manual (OPM), the following definitions are applicable to the applied methodology of this project.

- Circuit Breaker - An enclosed mechanical switch at a substation, which satisfactorily makes and breaks a circuit under rated load and trips automatically under fault conditions;

- Automatic Circuit Recloser (ACR) - A non-air-insulated pole mounted switch installed outside of a substation that trips automatically to clear faults, and then recloses after a predetermined time interval;

- Sectionaliser - A pole mounted switch used to open automatically in the (second or more) dead time of the feeder;

- Lockout - The state which exists when a switch is automatically tripped, but where it can only be subsequently closed by a manual operation;

- Feeder operation – Term used to describe a successful auto reclose;

- Auto-Reclose - The automatic reclosure (without manual intervention) of a switch that has tripped;

- Dead time - The time between the tripping and automatic reclosing of the circuit breaker or recloser during which no current flows; and

- Reclaim time - The time that must elapse after a successful auto-reclose of a circuit breaker or recloser, in order that another auto-reclosing sequence can be initiated.

This chapter outlines and briefly describes each of the developed fault scenarios.

4.2 Fault Scenarios

4.2.1 Scenario 1

The aim of this first test was to verify that the FDIR application would operate as intended for what is considered a simple network fault. This scenario is simulating an 11kV underground cable fault between SSCRB 11kV CB1252 and the first cable termination as shown below in Figure 11. This fault results in 11kV CB1252 Overcurrent protection operating. However, due to the secondary systems circuitry design and alarm mapping configuration in this substation, Overcurrent Earth fault (OCEF) protection operated alarm indication is received. All other system conditions and parameters relevant to the FDIR application are healthy for this test. In this situation the FDIR application should initiate once SSCRB CB1252 trips. The application will then carry out all necessary checks (including confirmation CB1252 has locked out) before opening X15402-C and attempting to restore supply to the remainder of CRB25A feeder via closing of X778541, X15886-B or X26003-C.

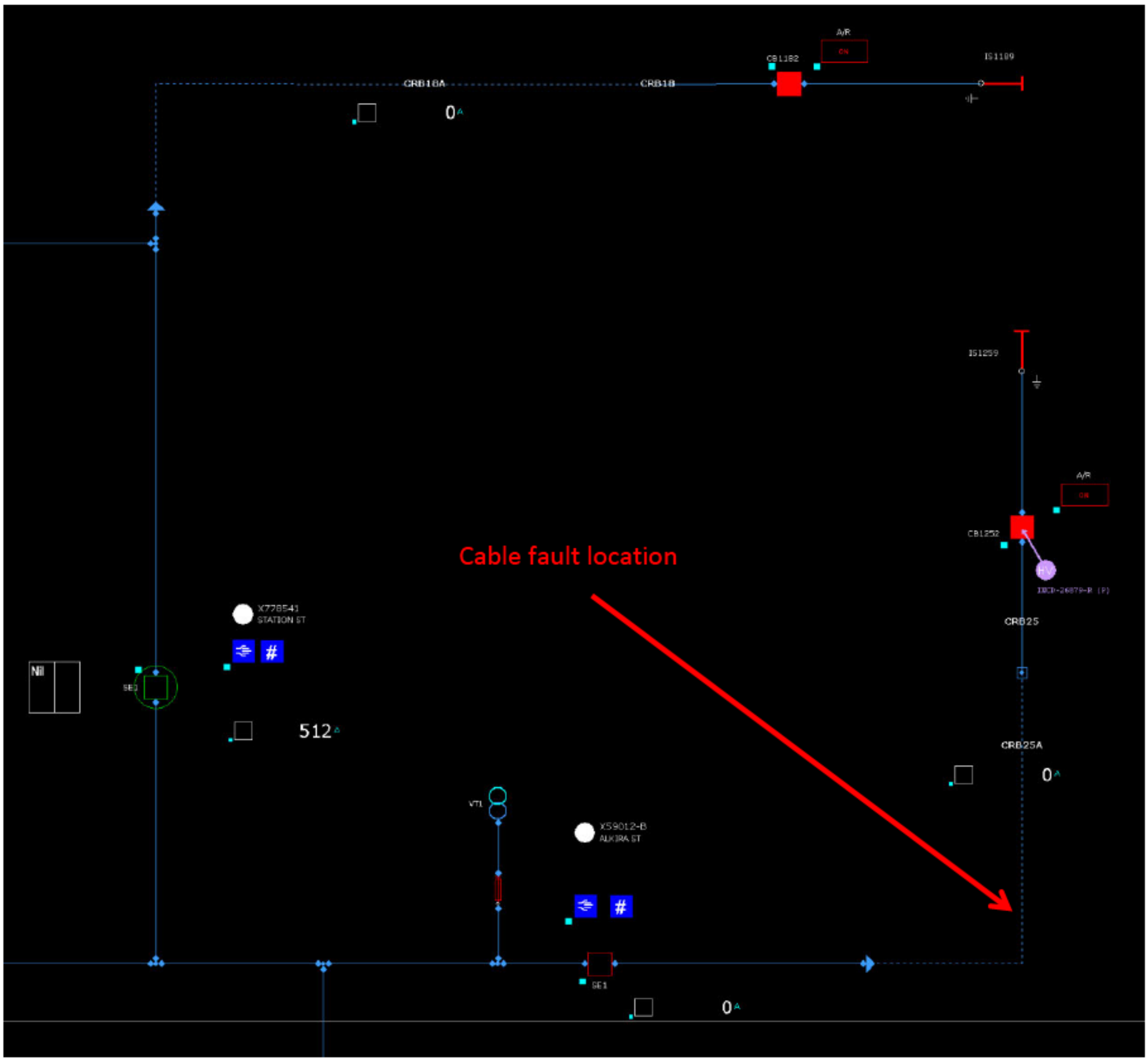

Figure 11 – Scenario 1 fault location (Energex, 2017)

The script that was created to replicate this fault scenario is shown below.

```
Echo % Command prints anything that follows and appends a newline character
set sub crb % Define Currumbin RTU
alias 'SPN365075.Eng Value' 4000 % Simulating a high current analogue prior to tripping (781A)
wait 1000 % Fault duration – waiting for IDMT OC element to time out
alias ' SPN365068.Scan Value' 1 % SSCRB OC EF protection operated alarm
alias ' NSL104059695.Scan Value' 0 % Transitioning of SSCRB 11kV CB1252 pallet switches
```

```
alias ' NSL104059695.Scan Value' 2 % SSCRB 11kV CB1252 trips
alias 'SPN365075.Eng Value' 0 % Current = 0A
alias ' SPN365068.Scan Value' 0 % SSCRB OC EF protection operated
alarm resets
wait 20000 % 20s dead time before SSCRB 11kV CB1252 auto-recloses
alias ' NSL104059695.Scan Value' 0 % Transitioning of SSCRB 11kV
CB1252 pallet switches
alias ' NSL104059695.Scan Value' 1 % SSCRB 11kV CB1252 recloses onto
permanent fault
alias 'SPN365075.Eng Value' 4000 % Simulating a high current
analogue prior to tripping
wait 1000 % Waiting for IDMT OC element to time out
alias ' SPN365068.Scan Value' 1 % SSCRB OC EF protection operated
alarm
alias ' NSL104059695.Scan Value' 0 % Transitioning of SSCRB 11kV
CB1252 pallet switches
alias ' NSL104059695.Scan Value' 2 % SSCRB 11kV CB1252 trips and
locks out
alias 'SPN365075.Eng Value' 0 % Current = 0A
alias ' SPN365068.Scan Value' 0 % SSCRB OC EF protection operated
alarm resets
```

4.2.2 Scenario 2

This fault simulates a high impedance earth fault condition between SSCRB 11kV CB1252 and the first load transfer switch (LTS) X59012-B on the feeder. An example of this situation occurring on the 11kV distribution network is when an overhead conductor falls onto a tree. In this fault scenario, all conditions are the same as scenario one, with the only exception being that SSCRB 11kV CB1252 Sensitive Earth Fault (SEF) protection operates, as opposed to OCEF protection. When SEF protection on a protective device operates, the device immediately locks out. The logic behind this philosophy is that, when SEF protection operates, there is typically an 11kV conductor down to ground or within the vicinity of ground. As per scenario one, all other system conditions and parameters relevant to the FDIR application are healthy for this test. It is expected that in this situation the FDIR application should initiate when SSCRB CB1252 trips. The application will then carry out all necessary checks (including confirmation CB1252 has locked out) before opening X15402-C and attempting to restore supply to the remainder of CRB25A feeder via closing of X778541, X15886-B or X26003-C.

4.2.3 Scenario 3

This scenario simulates a tree branch falling across all three 11kV overhead conductors between X15402-C, X656776 and X23952. SSCRB 11kV CB1252 registers a 'high analogue' (limits temporarily exceeded) before OCEF protection operates tripping the circuit breaker. 11kV CB1252 then has one reclose attempt before locking the feeder out. OC fault indication is received from X15402-C and X59012-B. All other system conditions and parameters relevant to the FDIR application are healthy during this test. Figure 12 below shows the fault location.

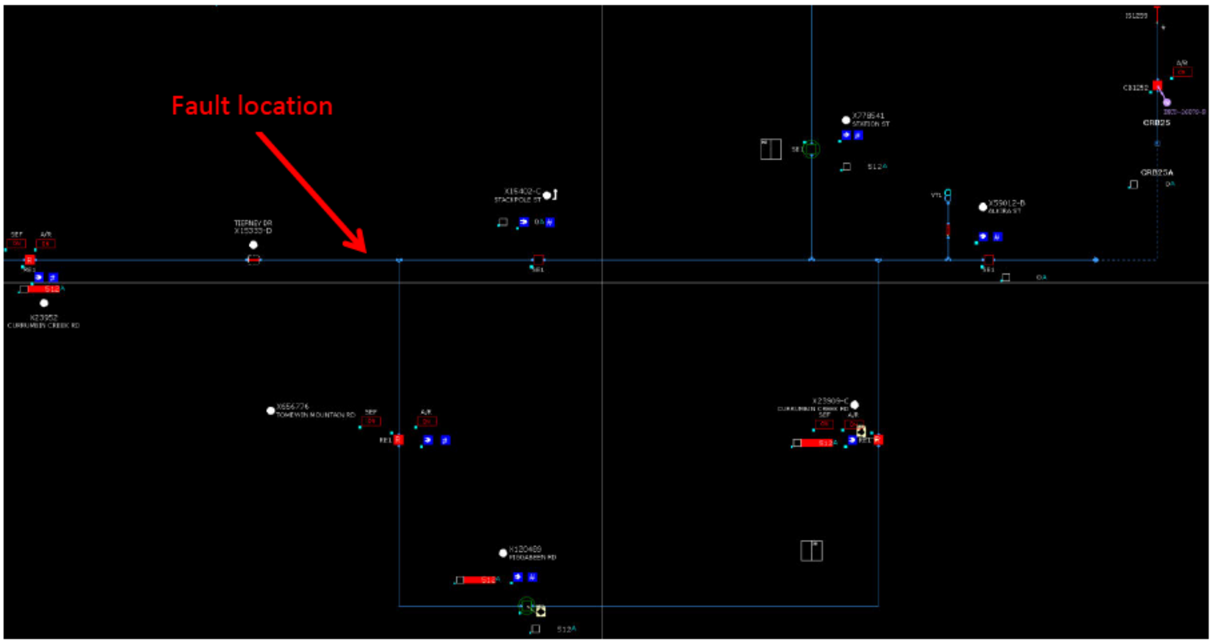

Figure 12 – Scenario 3 fault location (Energex, 2017)

The anticipated response to this fault scenario is that, once all necessary checks have been satisfied, the application will open X15402-C, X656776 and X23952. The application will then disable auto reclose on SSCRB 11kV CB1252 before attempting to restore the front end of the feeder by closing this circuit breaker. The application will then attempt to restore supply to the back end of CRB25A feeder via closing of either X15886-B or X26003-C once auto reclosing has been disabled on the next upstream protective device associated with the chosen transfer point. X120489 would then be closed, restoring supply to all customers in the un-faulted sections of the feeder.

The jiggle commands that form the script for this fault scenario are shown below.

```
echo
set sub sc1 % Define X15402-C RTU
alias 'SPN794200.Scan Value' 1 % Assert X15402-C OC Fault Indication
alarm
set sub sc1a % Define X59012-B RTU
alias 'SPN769747.Scan Value' 1 % Assert X59012-B A phase OC Fault
Indication alarm
alias 'SPN769748.Scan Value' 1 % Assert X59012-B B phase OC Fault
Indication alarm
alias 'SPN769749.Scan Value' 1 % Assert X59012-B C phase OC Fault
Indication alarm
set sub crb % Define SSCRB RTU
```

```
alias 'SPN365075.Eng Value' 4000 % Generate high current analogue
(781A) on CRB25A feeder analogue
wait 1000 % Fault duration - waiting for IDMT OC element to time out
alias 'SPN365068.Scan Value' 1 % CRB25A OCEF protection operated
indication
alias 'NSL104059695.Scan Value' 2 % SSCRB CB1252 trip
alias 'SPN365075.Eng Value' 0 % CRB25A feeder analogue falls to 0A
alias 'SPN365068.Scan Value' 0 % CRB25A OCEF protection operated
indication de-asserts
wait 20000 % 20s auto reclose dead time
alias 'NSL104059695.Scan Value' 1 % SSCRB CB1252 closes (auto
reclose attempt)
alias 'SPN365075.Eng Value' 4000 % Generate high current analogue
(781A) on CRB25A feeder analogue
wait 1000 % Fault duration
alias 'SPN365068.Scan Value' 1 % CRB25A OCEF protection operated
indication
alias 'NSL104059695.Scan Value' 2 % SSCRB CB1252 trips and locks out
alias 'SPN365075.Eng Value' 0 % CRB25A feeder analogue falls to 0A
alias 'SPN365068.Scan Value' 0 % CRB25A OCEF protection operated
indication de-asserts
```

4.2.4 Scenario 4

This scenario is similar to the previous scenario, except instead of overcurrent protection operating, an earth fault condition occurs between X15402-C, X656776 and X23952. SSCRB 11kV CB1252 OCEF protection operates, tripping the circuit breaker. 11kV CB1252 then has one reclose attempt before locking the feeder out. EF fault indication is received from X15402-C and X59012-B. All other system conditions and parameters relevant to the FDIR application are healthy during this test. Just like scenario three, the output of the FDIR application will attempt to restore supply to the back end of CRB25A feeder via closing of either X15886-B or X26003-C once auto reclosing has been disabled on the next upstream protective device associated with the chosen transfer point. X120489 would then be closed, restoring supply to all customers in the un-faulted sections of the feeder.

4.2.5 Scenario 5

This scenario simulates a high impedance earth fault between X15402-C, X656776 and X23952. SSCRB 11kV CB1252 SEF protection operates with no auto reclose attempt. SEF fault indication is received from X15402-C and X59012-B. All other system conditions and parameters relevant to the FDIR application are healthy during this test. Once again it is anticipated the output of the FDIR application will attempt to restore supply to the back end of CRB25A feeder via closing of either X15886-B or X26003-C once auto reclosing has been disabled on the next upstream protective device associated with the chosen transfer point. X120489 would then be closed, restoring supply to all customers in the un-faulted sections of the feeder.

4.2.6 Scenario 6

This scenario simulates a tree branch falling onto the 11kV overhead conductors between X15402-C, X656776 and X23952. SSCRB 11kV CB1252 registers a 'high analogue' (limits temporarily exceeded) before OCEF protection operates tripping the circuit breaker. A trip circuit faulty alarm on11kV CB1252 asserts after CB1252 trips, aborting the auto reclose attempt. OC fault indication is received from X15402-C and X59012-B. Due to SSCRB 11kV CB1252 generating a trip circuit faulty alarm, it is expected the FDIR application will be aborted. In future versions of the FDIR application, it is envisaged that it could cater for these types of scenarios. where a piece of plant fails the device check logic but all plant associated with the other side of the faulted section of feeder is 'healthy' and could restore supply to a portion of un-faulted network.

4.2.7 Scenario 7

This scenario simulates a tree branch falling onto the 11kV overhead conductors between X15402-C, X656776 and X23952. SSCRB 11kV CB1252 registers a 'high analogue' (limits temporarily exceeded) before OCEF protection operates tripping the circuit breaker. 11kV CB1252 then has one reclose attempt before locking the feeder out. A CRB25A protection relay faulty alarm asserts after CB1252 has locked out. OC fault indication is received from X15402-C and X59012-B. It is anticipated the application will be aborted as the device check logic will not be satisfied.

4.2.8 Scenario 8

This scenario simulates a tree branch falling onto the 11kV overhead conductors between X15402-C, X656776 and X23952. Fifteen seconds prior to the fault occurring, an X15402-C Equipment at Risk alarm asserts. SSCRB 11kV CB1252 registers a 'high analogue' (limits temporarily exceeded) before OCEF protection operates tripping the circuit breaker. 11kV CB1252 then has one reclose attempt before locking the feeder out. OC fault indication received from X15402-C and X59012-B. The device check logic is not satisfied, therefore it is expected the application will be aborted.

4.2.9 Scenario 9

This scenario simulates a tree branch falling onto the 11kV overhead conductors between X15402-C, X656776 and X23952. SSCRB 11kV CB1252 registers a 'high analogue' (limits temporarily exceeded) before OCEF protection operates, tripping the circuit breaker. During SSCRB 11KV CB1252 dead time, X15402-C generates an Equipment at Risk alarm. 11kV CB1252 then auto recloses onto the permanent fault, locking the feeder out. OC fault indication is received from X15402-C and X59012-B. Once again, the device check logic is not satisfied and therefore it is expected the application will be aborted.

4.2.10 Scenario 10

This scenario simulates an 11kV OC condition between X15402-C, X656776 and X23952. SSCRB 11kV CB1252 registers a 'high analogue' (limits temporarily exceeded) before OCEF protection operates tripping the circuit breaker. 11kV CB1252 then has one reclose attempt before locking the feeder out. X15402-C registers a high analogue but no OC fault indication. X59012-B generates a B phase OC fault indication alarm. It is expected the application will abort for this type of scenario due to the high analogue on X15402-C combined with no overcurrent fault indication. The script written to replicate this scenario is shown below.

```
echo
set sub sc1 % Define X15402-C RTU
alias 'SPN794213.Eng Value' 4000 % X15402-C high current analogue
set sub sc1a % Define X15402-C RTU
alias 'SPN769748.Scan Value' 1 % Assert X59012-B B phase OC Fault
Indication alarm
set sub crb % Define Currumbin RTU
alias 'SPN365075.Eng Value' 4000 % Generate high current analogue
(781A) on CRB25A feeder analogue
wait 1000 % Fault duration - waiting for IDMT OC element to time out
alias 'SPN365068.Scan Value' 1 % CRB25A OCEF protection operated
indication
alias 'NSL104059695.Scan Value' 0 % Transitioning of SSCRB 11kV
CB1252 pallet switches
alias 'NSL104059695.Scan Value' 2 % SSCRB CB1252 trip
```

```
set sub sc1 % Define X15402-C RTU
alias 'SPN794213.Eng Value' 0 % X15402-C analogue falls to 0A


set sub crb % Define Currumbin RTU
alias 'SPN365075.Eng Value' 0 % CRB25A feeder analogue falls to 0A

alias 'SPN365068.Scan Value' 0 % CRB25A OCEF protection operated
indication de-asserts

wait 20000 % 20s auto reclose dead time

alias 'NSL104059695.Scan Value' 0 % Transitioning of SSCRB 11kV
CB1252 pallet switches
alias 'NSL104059695.Scan Value' 1 % SSCRB CB1252 auto recloses
alias 'SPN365075.Eng Value' 4000 % Generate high analogue (781A) on
CRB25A feeder analogue
set sub sc1 % Define X15402-C RTU
alias 'SPN794213.Eng Value' 4000 % X15402-C high current analogue
set sub crb % Define Currumbin RTU
wait 1000 % Fault duration - waiting for IDMT OC element to time out
alias 'SPN365068.Scan Value' 1 % CRB25A OCEF protection operated
indication
alias 'NSL104059695.Scan Value' 0 % Transitioning of SSCRB 11kV
CB1252 pallet switches
alias 'NSL104059695.Scan Value' 2 % SSCRB CB1252 trips and locks out
alias 'SPN365075.Eng Value' 0 % CRB25A feeder analogue falls to 0A

alias 'SPN365068.Scan Value' 0 % CRB25A OCEF protection operated
indication de-asserts


set sub sc1 % Define X15402-C RTU
alias 'SPN794213.Eng Value' 0 % X15402-C analogue falls to 0A
```

4.2.11 Scenario 11

This scenario simulates an 11kV OC condition between X15402-C, X656776 and X23952. SSCRB 11kV CB1252 registers a 'high analogue' (limits temporarily exceeded) before OCEF protection operates tripping the circuit breaker. 11kV CB1252 then has one reclose attempt before locking the feeder out. X15402-C initially registers a high analogue, does not detect an OC fault indication and generates a data fail alarm (communications fail) which asserts after the initial feeder operation. X59012-B generates a B phase OC fault indication alarm. This test is simulating the loss of X15402-C communications after initially indicating fault current is present. Based on the loss of communications, it is expected that the application will abort.

4.2.12 Scenario 12

This scenario simulates an 11kV OC condition between X15402-C, X656776 and X23952. Prior to the feeder fault, X15402-C data fail alarm asserts. SSCRB 11kV CB1252 registers a 'high analogue' (limits temporarily exceeded) before OCEF protection operates tripping the circuit breaker. 11kV CB1252 then has one reclose attempt before locking the feeder out. X59012-B generates a B phase OC fault indication alarm. Fifteen seconds prior to the fault occurring, X15402-C experiences a loss of communications. Based on the loss of communications, the expected result from this test is the application will abort.

4.2.13 Scenario 13

This scenario simulates an 11kV circulating current condition occurring whilst two 11kV feeders are in parallel due to a planned switching action. Shortly after closing the normally open remote switch X778541 tying 11kV feeder's CRB18A and CRB25A together, SSCRB 11kV CB1252 trips on OC protection. Both X59012-B and X778541 have registered OC fault indication. It is expected the application will be aborted due to the opening of SSCRB 11kV CB1252 occurring shortly after a commanded close action has been executed.

4.2.14 Scenario 14

This scenario simulates a genuine fault condition occurring on one 11kV feeder whilst two 11kV feeders are tied together. Shortly after closing X778541 as part of a load transfer (tying 11kV feeder's CRB18A and CRB25A together), a genuine overcurrent fault condition occurs between X59012-B, X23909-C, X778541 and X15402-C which is on CRB25A locking both feeders out. It is expected the outcome of this test is that the application aborts due to the 11kV feeder not being in a radial configuration.

4.2.15 Scenario 15

The following three fault scenarios are based on a present problem regarding some Schneider ADVC2 remote controlled devices. A firmware issue has been identified in ADVC2 controlled load transfer switches, where fault indication alarms are issued, bypassing the device time delay settings. The effect is that false fault indications may be triggered when certain faults occur upstream of the device. This predominantly affects the SEF fault indication due to its low pickup setting. Although it is envisaged a firmware upgrade will rectify these scenarios prior to the commissioning of the FDIR application in the Production environment, the simulation of these three scenarios is still considered valid. In this particular scenario, SSCRB 11kV CB1182 trips on SEF protection, whilst X810721 registers SEF fault indication. In this scenario, current practice is to assume the fault could either be in the first section of the feeder between CB1182 and X810721 or the next section of feeder between X810721 and X6020-C. In response to this fault condition, it is expected the application will open X6020-C and refrain from closing CB1182. Restoration of supply to the back end of the feeder will be achieved by closing X26003-C after auto reclose has been disabled on X96110. Figure 13 below is an extract from the current Energex Equipment Operating Restriction pertaining to ADVC2 devices with firmware issues and shows the fault scenario that is being replicated.

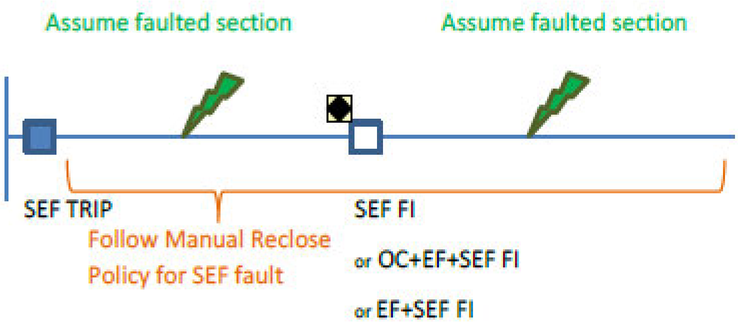

Figure 13 – Scenario 15 fault scenario replication and required course of action (Energex, 2017)

4.2.16 Scenario 16

This fault scenario still pertains to the ADVC2 with fault indication firmware issues. In this scenario, SSCRB 11kV CB1182 trips on OCEF protection, whilst X810721 registers SEF fault indication. In response to this fault condition, it is expected the application will assume the fault is in the front section of the feeder and open X810721 before closing X26003-C. Prior to closing X26003-C, the application will also need to disable auto reclose on X96110. Figure 14 below is an extract from the current Energex Equipment Operating Restriction pertaining to ADVC2 devices with firmware issues and shows the fault scenario that is being replicated.

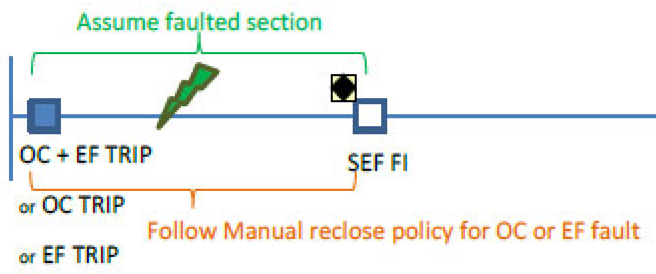

Figure 14 – Scenario 16 fault scenario replication and required course of action (Energex, 2017)

4.2.17 Scenario 17

This fault scenario still pertains to the ADVC2 with fault indication firmware issues. In this scenario, SSCRB 11kV CB1182 trips on OCEF protection, whilst X810721 registers OC, EF and SEF fault indication. It is expected the application will assume the fault is in the section of the feeder between X810721 and X6020-C and, in response to this situation, open X810721 and X6020-C before closing CB1182 and X26003-C. Prior to closing SSCRB 11kV CB1182 and X26003-C, the application will also need to disable auto reclose on the relevant protective devices. Figure 15 below is an extract from the current Energex Equipment Operating Restriction pertaining to ADVC2 devices with firmware issues and shows the fault scenario that is being replicated.

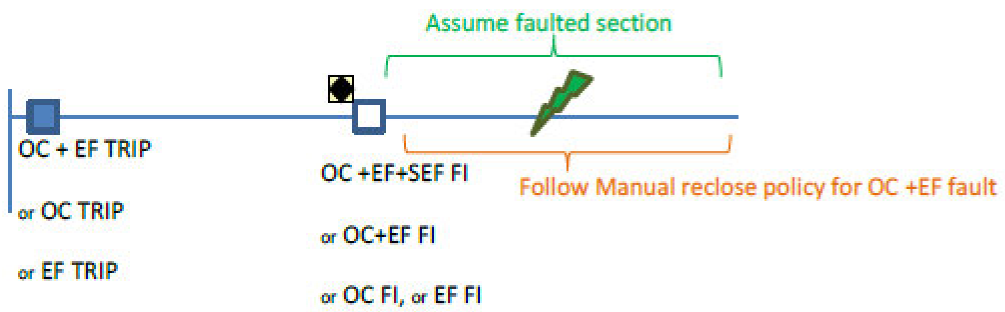

Figure 15 – Scenario 17 fault scenario replication and required course of action (Energex, 2017)

4.2.18 Scenario 18

A tree falls across the 11kV conductors between X6020-C, X9014-F and X101192-A. X6020-C trips on over current protection. Conductor clashing is then experienced upstream of X6020-C, resulting in conductors burning to the ground and CB1182 tripping on OCEF protection (400ms after X6020-C tripped). X6020-C then recloses ten seconds after tripping (CB1182 is still within its dead time). Another 9.6s then elapses before CB1182 recloses onto the downed conductors locking the feeder out. X810721 OC fault indication asserted.

4.2.19 Scenario 19

A permanent fault occurs between X6020-C, X9014-F and X101192-A. X6020-C trips on over current protection. Conductor clashing is then experienced upstream of X6020-C, however, no damage occurs to these conductors. X6020-C then recloses ten seconds after tripping (CB1182 is still within its dead time). A further 9.6s elapses before CB1182 recloses, re-energising the fault. X6020-C detects the fault is still present and trips. No conductor clashing is experienced upstream of X6020-C on this occasion. Another 10s elapses, X6020-C recloses before tripping once again, this time locking out. It is expected the application will open X101192-A, disable auto reclose on X96110 and then restore supply to the bottom end of the feeder by closing X26003-C.

4.2.20 Scenario 20

This scenario is simulating the catastrophic failure of normally open point X778541. OCEF protection operates on both CRB18A and CRB25A, resulting in both CBs tripping. Both CBs then almost simultaneously reclose onto the fault before tripping once again and locking both feeders out. As a result of this fault condition, the scheme is expected to abort due to multiple devices being locked out.

4.2.21 Scenario 21

This scenario is simulating the catastrophic failure of normally open point X26003-C. ACR's X6020-C and X96110 trip on overcurrent protection before reclosing and tripping again. After the second trip, both Sectionalisers X101192-A and X17749-B open in the ACR dead time (after confirmation of a loss of supply [no volts]). ACRs X6020-C and X96110 then reclose, restoring supply up to the open Sectionalisers. Overcurrent fault indication is received from multiple devices along the backbone of both feeders including X8656-A which is downstream of X101192-A. The application is expected to remotely open X8656-A and restore supply up to this load transfer switch by closing X101192-A after auto reclosing has been disabled on X6020-C. Figure 16 below shows the network configuration when X17749-B and X101192-A have locked out. X87342-B has a system note placed, stating that this device has no fault indication settings installed due to an old DSS design.

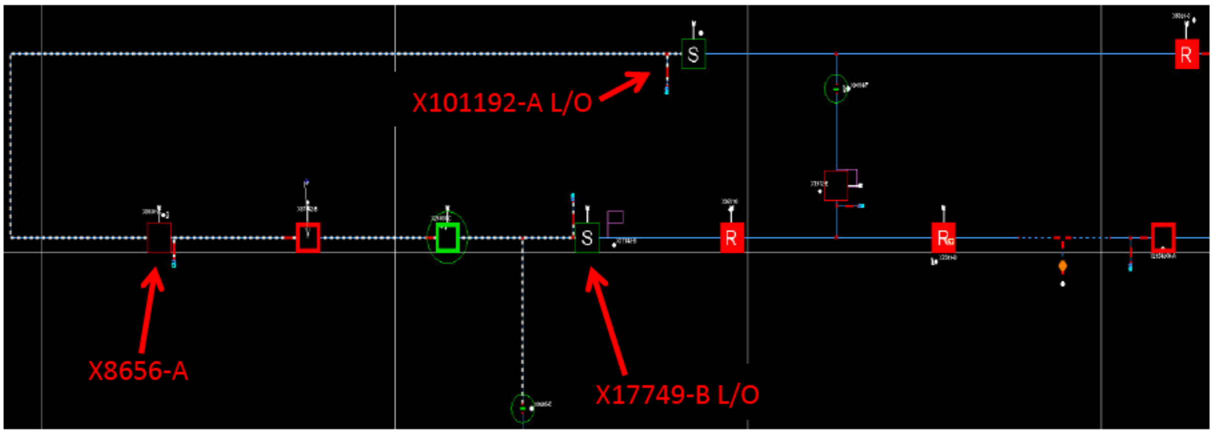

Figure 16 – Scenario replicating the failure of normally open point X26003-C (Energex, 2017)

4.2.22 Scenario 22

This scenario is simulating the catastrophic failure of normally open point X15886-B. This results in both ACR X23952 and SSYTA 11kV CB1022 locking out. ACR X799994 is a protective device but has no alarm points commissioned. Once again, multiple devices have locked out and it is anticipated that the application will be aborted.

4.2.23 Scenario 23

This scenario simulates an event where a protective device trips, but no protection operated alarm indication asserts. 11kV ACR X23952 trips with no protection operation alarm indication registering and no auto reclose attempt taking place. It is expected the application will not output in response to this scenario due to the absence of a positive protection operated alarm.

4.2.24 Scenario 24

Occasionally, on the 11kV distribution network, a certain type of fault condition occurs initially before evolving into another type of fault condition. This scenario replicates an initial overcurrent fault condition that, over time, transforms into an earth fault condition. An example of this is when a tree branch falls across the 11kV overhead conductors, then one or more conductors burn to the ground. This fault occurs between ACR X23952, Sectionaliser X120080 and ACR X799994. X23952 initially trips on overcurrent protection before reclosing onto the fault and subsequently tripping on earth fault protection. X23952 has one more reclose attempt before locking out on earth fault protection. The script simulation this fault scenario is shown below.

```
echo
set sub sc1
alias 'SPN794472.Scan Value' 1
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 2
set sub sc1a
alias 'SPN769755.Eng Value' 40
alias 'SPN769756.Eng Value' 40
alias 'SPN769757.Eng Value' 40
alias 'SPN641545.Eng Value' 0
alias 'SPN703502.Eng Value' 0
set sub crb
alias 'SPN365075.Eng Value' 224
set sub sc0
alias 'SPN896113.Eng Value' 0
set sub sw5
alias 'SPN895371.Eng Value' 0
set sub sc1
alias 'SPN794213.Eng Value' 20
alias 'SPN748361.Eng Value' 0
wait 10000
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 1
wait 2400
alias 'SPN794474.Scan Value' 1
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 2
wait 10000
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 1
wait 2400
alias 'SPN794474.Scan Value' 1
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 2
wait 10000
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 1
```

```
wait 2400
alias 'SPN794474.Scan Value' 1
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 2
```

4.2.25 Scenario 25

This is a similar situation to Scenario 24, except in this case, an initial overcurrent fault condition downstream of X23952 transforms into a sensitive earth fault condition after the first auto reclose attempt. The code written to produce this fault condition and the active alarm browser are shown below.

```
echo
set sub sc1
alias 'SPN794472.Scan Value' 1
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 2
set sub sc1a
alias 'SPN769755.Eng Value' 40
alias 'SPN769756.Eng Value' 40
alias 'SPN769757.Eng Value' 40
alias 'SPN641545.Eng Value' 0
alias 'SPN703502.Eng Value' 0
set sub crb
alias 'SPN365075.Eng Value' 224
set sub sc0
alias 'SPN896113.Eng Value' 0
set sub sw5
alias 'SPN895371.Eng Value' 0
set sub sc1
alias 'SPN794213.Eng Value' 20
alias 'SPN748361.Eng Value' 0
wait 10000
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 1
wait 5000
```

```
alias 'SPN794473.Scan Value' 1
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 2
```

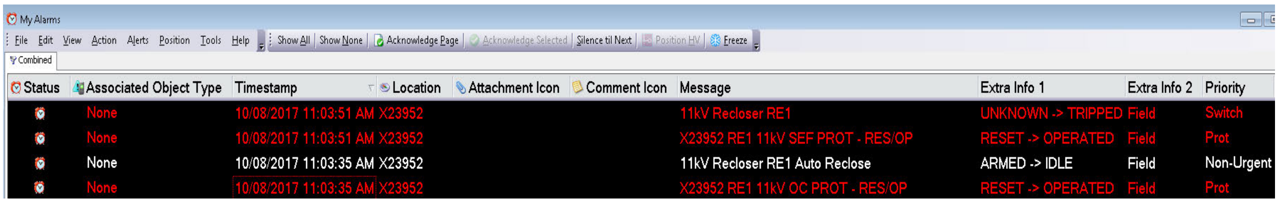

Figure 17 – Alarm browser showing X23952 OC and SEF protection operated alarms (Energex, 2017)

4.2.26 Scenario 26

The fault being replicated in this scenario is an overcurrent fault condition occurring between X15402-C, X656776 and X23952, with X23952 remote supervisory control switch being left in the ‘local’ position prior to the fault occurring (no remote control available). Because X23952 is in the local position, no remote trip and close commands can affect the status of the switch. This test is designed to confirm that the FDIR application logic will undertake a status check on a switch after an open command is sent.

4.2.27 Scenario 27

Prior to the fault occurring, all three 11kV feeders are in a ‘healthy’ state with the only exception being CRB18A load current is encroaching 90% of its normal cyclic limit. A fault then occurs on CRB25A between SSCRB CB1252 and X59012-B. This test is designed to test the FDIR application plant rating logic checks on the possible transfer feeders and, in this case, when the faulted section has been isolated, restores supply to the rest of CRB25A via remote switch X15886-B (YTA2B) and not X778541 (CRB25A).

4.2.28 Scenario 28

Prior to the fault initiating, all three 11kV feeders are in a ‘healthy’ state with the only exception being X96110, which is approaching 90% of its normal cyclic limit. A fault then occurs on CRB18A between X810721 and X6020-C. This test is similar to scenario 27, except in this scenario, the device that would have its plant ratings exceeded is a downstream feeder device.

4.2.29 Scenario 29

GE PowerOn Fusion allows authorised users to 'mask' alarms by placing inhibits. There are currently five classifications of inhibits available within the PowerOn Fusion application, which include:

- Switching Inhibits;
- Work Request Inhibits;
- General Inhibits;
- Long Term Inhibits; and
- Control Inhibits

A switching inhibit is applied to alarms generated by the execution of a Switching Sheet and subsequent isolation. A Work Request Inhibit is placed when a piece of equipment alarms and requires a work request to be raised for repairs on the equipment. Application of a General Inhibit occurs if an alarm is not related to switching; a fault or network configuration is asserted. An example of the alarm type that fits this category is where pole-mounted equipment loses communications during the night because it may rely on some form of solar power. Long Term Inhibits are typically applied when an alarm is asserting due to the network configuration. An example of applying a long term inhibit to a piece of plant is Audio Frequency Load Control (AFLC) signal alarms on a hot standby transformer. A Control Inhibit is applied to prevent the remote operation of a device.

In this scenario a fault occurs between X15402-C, X656776 and X23952. Prior to the fault occurring, a single switching alarm inhibit has been placed on X15402-C overcurrent fault indication alarm. It is expected that the FDIR application will ignore this device from the model, effectively treating the device the same as a manual air break switch.

4.2.30 Scenario 30

In this scenario a fault occurs between X15402-C, X656776 and X23952. Prior to the fault occurring, a single switching alarm inhibit has been placed on X15402-C Equipment at Risk alarm. It is expected that the FDIR application will ignore this device from the model, effectively treating the device the same as a manual air break switch.

4.2.31 Scenario 31

In this scenario a fault occurs between X15402-C, X656776 and X23952. Prior to the fault occurring, all alarms associated with X23952 (including status) have been inhibited via a group switching inhibit. It is expected that the FDIR application will ignore this device from the model, effectively treating the device the same as a manual air break switch.

4.2.32 Scenario 32

An overcurrent fault condition occurs between X23952, X120080 and X799994. This test is assuming ACR X23952 is set three shots to lockout with a dead time of 10s and a reclaim time of 15s. The fault initiates and X23952 has two shots before the fault clears and the reclaim time expires. The fault then returns; this time X23952 has three shots and locks out. This test is to prove that the application confirms a feeder device has locked out prior to initiating any outputs. A locked out device is proven by confirming the status of the auto reclose alarm.

4.2.33 Scenario 33

This test is similar to the previous scenario, with the exception that, instead of the Automatic Circuit Recloser being the protective device, a circuit breaker is the protective device. The circuit breaker has different dead-time and reclaim-time settings compared to the ACR. A fault occurs between SSCRB 11kV CB1252 and X59012-B. Assuming CB1252 has a dead time of 20s and a reclaim of 10s, CB1252 goes through an operation and the reclaim time expires. The fault then returns and is now permanent in nature, resulting in CB1252 locking out. The FDIR application should only initiate upon receiving confirmation that the feeder has locked out.

4.2.34 Scenario 34

An analysis of historical fault data revealed that, on multiple occasions, downstream protective devices failed to open under fault conditions as per their intended design. This test simulates the failure of a Sectionaliser to open for a downstream fault. Sectionaliser X101192-A generates positive fault indication, but fails to open in the dead time of X6020-C. ACR X6020-C opens after its third shot is unsuccessful.

4.2.35 Scenario 35

This test simulates the failure of an Automatic Circuit Recloser to open for a downstream fault. ACR X23952 generates a positive overcurrent protection operated alarm indication, but fails to open. SSCRB 11kV CB1252 OCEF protection backs up, clearing the fault and locking the feeder out. Figure 18 below shows the generated alarms that are produced from this fault, and Figure 19 shows a section of the locked out CRB25A feeder with X23952 still in the closed position.

Status	Associated Object Type	Timestamp	Location	Attachment Icon	Comment Icon	Message	Extra Info 1	Extra Info 2	Priority
	None	10/08/2017 11:55:02 AM	SSCRB			CRB25A 11kV OC EF PROT - RES/OP	DAP Chatter	Count Exceeded	Non-Urgent
	None	10/08/2017 11:55:02 AM	SSCRB			11kV Circuit Breaker CB1252	DAP Chatter	Count Exceeded	Non-Urgent
	None	10/08/2017 11:54:25 AM	SSCRB			11kV Circuit Breaker CB1252	UNKNOWN -> TRIPPED	Field	Switch
	None	10/08/2017 11:54:25 AM	SSCRB			CRB25A 11kV OC EF PROT - RES/OP	OPERATED -> RESET	Field	Prot
	None	10/08/2017 11:54:04 AM	SSCRB			11kV Circuit Breaker CB1252 Auto Reclose	ARMED -> IDLE	Field	Non-Urgent
	None	10/08/2017 11:54:03 AM	X23952			X23952 RE1 11kV OC PROT - RES/OP	RESET -> OPERATED	Field	Prot
	None	10/08/2017 11:54:02 AM	X15402-C			X15402-C SE1 11kV OC FAULT INDICATION - NOR/AB	NORMAL -> ABNORMAL	Field	Prot
	None	10/08/2017 11:54:02 AM	X59012-B			X59012-B SE1 11kV OC FAULT INDICATION B PH - NOR/AB	NORMAL -> ABNORMAL	Field	Prot
	None	10/08/2017 11:54:02 AM	X59012-B			X59012-B SE1 11kV OC FAULT INDICATION C PH - NOR/AB	NORMAL -> ABNORMAL	Field	Prot
	None	10/08/2017 11:54:02 AM	X59012-B			X59012-B SE1 11kV OC FAULT INDICATION A PH - NOR/AB	NORMAL -> ABNORMAL	Field	Prot

Figure 18 – Alarm browser showing generated alarms after CRB25A has locked out (Energex, 2017)

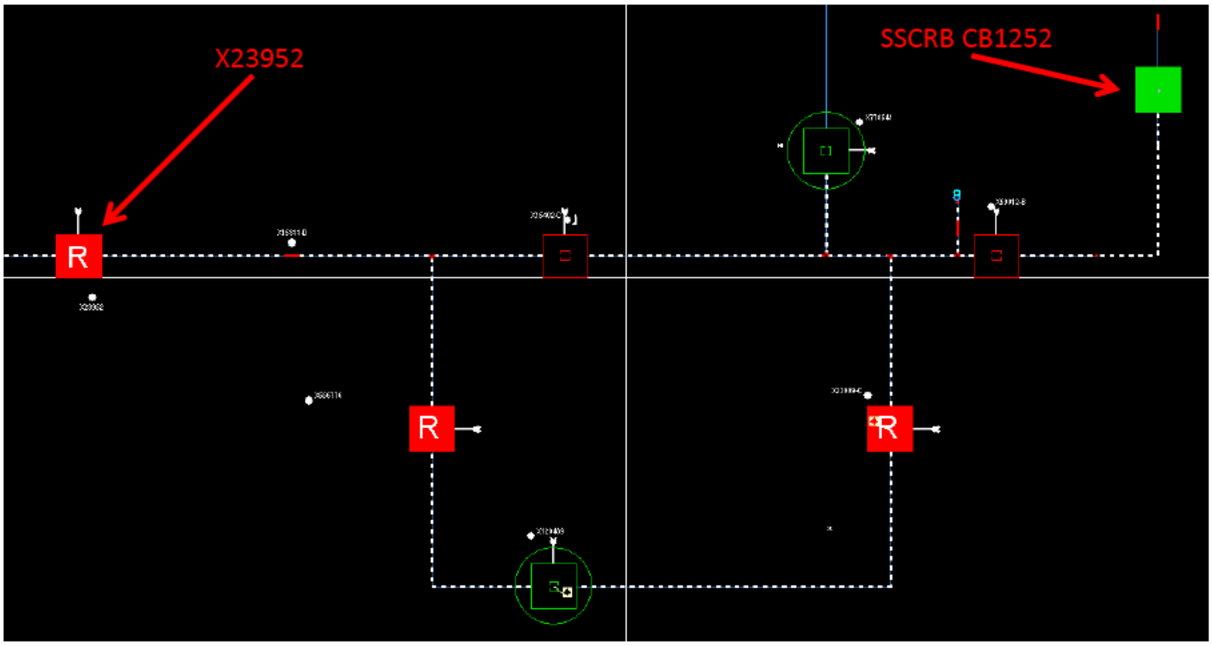

Figure 19 – X23952 remaining in the closed position (Energex, 2017)

4.2.36 Scenario 36

In this test, load is transferred off CRB25A feeder as part of a planned switching schedule. There are no permits on issue (A/P's, T/P's, W/A's, etc.) and no instructed items present. An example of this scenario is where a field crew has completed its work, surrendered and cancelled all permits, and restored all switching, bar the reverse load transfer. The script includes adjustment of the relevant network loads to mimic the load transfer. A permanent fault then occurs on the ‘normal,’ front end section of the feeder between X59012-B, X23909-C, X15402-C and X778541. This test is designed to confirm the FDIR application will initiate when an 11kV feeder is in an abnormal radial configuration with no permits on issue and no instructed items present.

4.2.37 Scenario 37

In this test, the bottom end of of CRB18A is de-energised as part of a switching schedule. There are no permits on issue (A/P’s, T/P’s, W/A’s, etc.) and no instructed items present. A permanent fault then occurs on CRB25A between X23952, X120080 and X799994. There are no energised remote transfer points available on CRB18A to restore supply to the bottom end of CRB25A feeder. This test aims to verify the application will check for healthy supply on one side of the chosen transfer point prior to attempting a remote close. It is expected the application will not attempt to restore supply to the bottom end of the feeder as X799994 alarm points are not currently commissioned.

4.2.38 Scenario 38

In this scenario, X778541 is remotely closed as part of a load transfer on a planned switching schedule. Closing X778541 ties CRB18A and CRB25A together. A permanent fault then occurs on YTA2B between SSYTA 11kV CB1022 and X92613-B, locking the feeder out. There is an available remote transfer point between CRB25A and YTA2B, being X15886-B. However, because CRB18A and CRB25A are currently tied together, the scheme needs to restrain from closing X15886-B as load flow and plant ratings cannot be accurately determined; in addition, there is the added risk of locking out an additional two 11kV feeders if the fault were happened to be re-energised. The expected result is the application will abort. Figure 20 below shows the network configuration post lockout of 11kV feeder YTA2B.

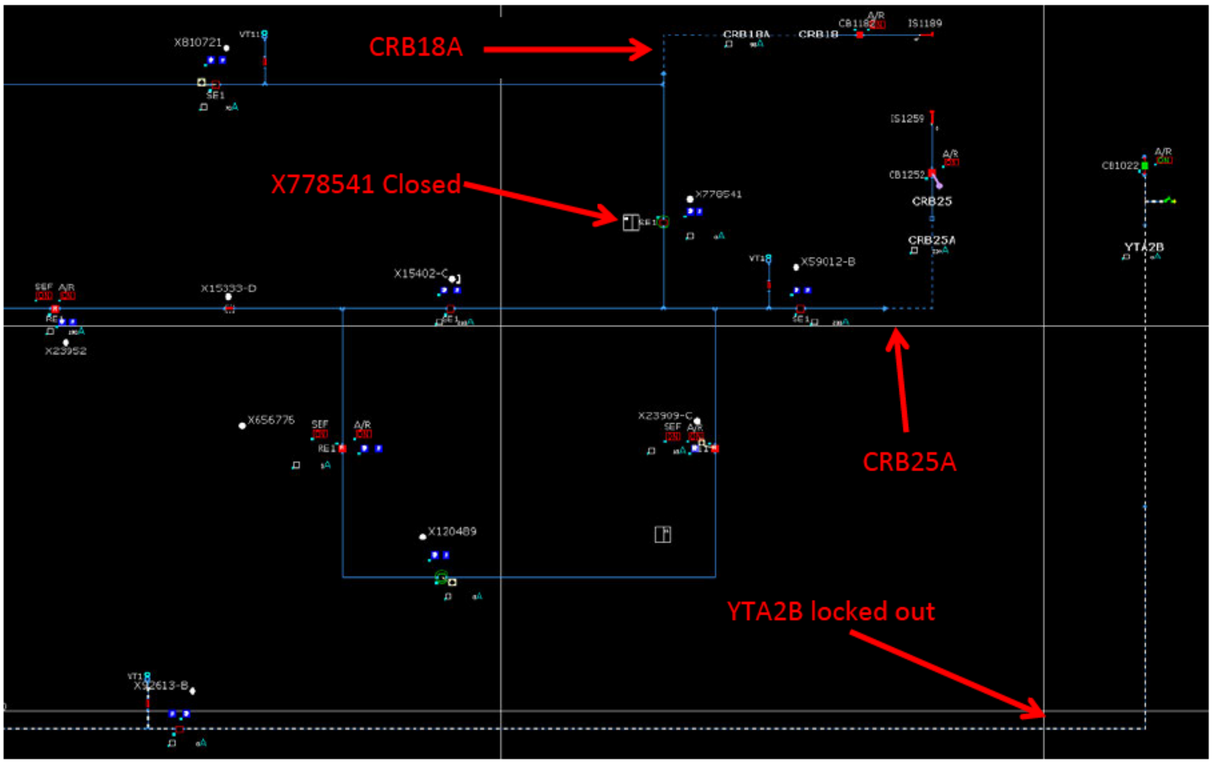

Figure 20 – CRB18A and CRB25 in parallel configuration via X778541 and YTA2B locked out (Energex, 2017)

4.2.39 Scenario 39

In this scenario a fault occurs between X15402-C, X656776 and X23952. SSCRB 11kV CB1252 OCEF protection operates, tripping the circuit breaker. 11kV CB1252 then has one reclose attempt before locking the feeder out. OC fault indication is received from X15402-C and X59012-B. Prior to the lockout occurring, an Equipment at Risk alarm has asserted on the normally open point X26003-C. In response to this situation, the application should choose YTA2B as the donor feeder via X15886-B.

4.2.40 Scenario 40

In this scenario a fault occurs between X15402-C, X656776 and X23952. SSCRB 11kV CB1252 OCEF protection operates, tripping the circuit breaker. 11kV CB1252 then has one reclose attempt before locking the feeder out. OC fault indication is received from X15402-C and X59012-B. Prior to the lockout occurring, Equipment at Risk alarm has asserted on both normally open points X26003-C and X15886-B.

4.2.41 Scenario 41

In this scenario a fault occurs between X15402-C, X656776 and X23952. SSCRB 11kV CB1252 OCEF protection operates, tripping the circuit breaker. 11kV CB1252 then has one reclose attempt before locking the feeder out. OC fault indication is received from X15402-C and X59012-B. During CB1252 dead time, Equipment at Risk alarm asserts on the normally open point X26003-C.

4.2.42 Scenario 42

In this scenario a fault occurs between X15402-C, X656776 and X23952. SSCRB 11kV CB1252 OCEF protection operates, tripping the circuit breaker. CB1252 fails to attempt an auto reclose.

4.2.43 Scenario 43

In this scenario a fault occurs between X15402-C, X656776 and X23952. Prior to the fault occurring, X15402-C 24V battery volts drop below the low volt threshold of 23.5V. When the fault occurs, positive overcurrent fault indication is received from X15402-C. Upon confirmation the feeder has locked out, it is expected the FDIR application will still attempt to open X15402-C despite the low volt alarm.

4.2.44 Scenario 44

In this scenario a fault occurs between X15402-C, X656776 and X23952. SSCRB 11kV CB1252 OCEF protection operates tripping the circuit breaker. 11kV CB1252 then has one reclose attempt before locking the feeder out. Following the second tripping of SSCRB 11kV CB1252, the OCEF protection relay has latched up the trip output. Overcurrent fault indication is received from X15402-C and X59012-B. In this scenario, a remote close command will not be successfully issued to SSCRB 11kV CB1252. For a latched substation CB/ACR radial feeder protection operated alarm, it is anticipated the FDIR application will abort.

4.2.45 Scenario 45

In this scenario a permanent fault occurs between X15402-C, X656776 and X23952. SSCRB 11kV CB1252 OCEF protection detects the fault condition and locks the feeder out. The FDIR application determines the feeder has locked out, opens the nearest boundary switches, and disables auto reclose on SSCRB 11kV CB1252 before attempting to restore supply to the front end of the feeder. SSCRB

11kV CB1252 closes onto a secondary fault in the front end. It is anticipated that, if the application closes onto a fault when attempting to restore supply, the application will be aborted.

4.2.46 Scenario 46

Planned switching is being conducted to isolate the section of 11kV network on CRB25A between X15333-D and X23952. A remote load transfer is conducted shifting a large portion of CRB25A onto CRB18A (X26003-C closed and X23952 opened) prior to instructing an item to the switching operator to Open, Place DNOB on X15333-D. Shortly after being instructed this item, 11kV feeder CRB25A locks out. The expected FDIR application response to this situation is an abort.

4.2.47 Scenario 47

Lockout occurs on a feeder with instructed items on an alternate transfer feeder.

4.2.48 Scenario 48

In this scenario a permanent fault occurs between X15402-C, X656776 and X23952. SSCRB 11kV CB1252 OCEF protection detects the fault condition and locks the feeder out. The FDIR application determines the feeder has locked out, opens the nearest boundary switches, and disables auto reclose on SSCRB 11kV CB1252 before restoring supply to the front end of the feeder. Prior to the fault, a group switching inhibit has been applied to remote, normally open, point X26003-C. The FDIR application should restrain from closing X26003-C and instead choose the alternate transfer point X15886-B when attempting to restore supply to the back end of the feeder.

4.2.49 Scenario 49

In this scenario a permanent fault occurs between X15402-C, X656776 and X23952. SSCRB 11kV CB1252 OCEF protection detects the fault condition and locks the feeder out. The FDIR application determines the feeder has locked out, opens the nearest boundary switches, and disables auto reclose on SSCRB 11kV CB1252 before restoring supply to the front end of the feeder. Prior to the fault, a control inhibit has been applied to remote, normally open, point X26003-C. The FDIR application should respond accordingly and choose the alternate transfer point X15886-B when attempting to restore supply to the back end of the feeder.

4.2.50 Scenario 50

In this scenario a fault occurs on CRB25A feeder. SSCRB 11kV CB1252 OCEF protection operated alarm is generated, however, CB1252 fails to open. SSCRB 11kV CB1T22 and CB1T32 both trip on backup OCEF protection, clearing the fault on CRB25A and de-energising both busbars BB12 and BB13. In this version of FDIR, the application is expected to be aborted for this type of scenario. As a result, both CRB18A and CRB25A are de-energised whilst YTA2B remains energised. This scenario corresponds to legacy substations with no 11kV check tripping schemes in service. In this version of FDIR, the application is designed to abort for this type of scenario. Future versions will cater for this type of fault.

4.2.51 Scenario 51

This scenario is simulating an earth fault condition occurring on CRB25A. SSCRB 11kV CB1252 OCEF protection indication is received but CB1252 fails to open. Another 240ms elapses before SSCRB earth fault check trip protection operates, opening CB1252. The 11kV transformer SEL protection relays have been detecting the fault condition is present from fault inception. Once CB1X22 is open, TR2 11kV SEL relay no longer detects any fault current is present; however, TR3 11kV SEL relay is still detecting fault current is present and approximately 240ms after CB1X22 has opened, TR3 SEL relay trips CB1T32 on earth fault protection. As a result, busbar BB13 is now de-energised, whilst BB12 is still energised and carrying load. CRB18A remains energised as it is connected to BB12. This scenario corresponds to the current standard substation designs with 11kV check tripping schemes in service. In this version of FDIR, the application is expected to be aborted for this type of scenario. Future versions will cater for this type of fault.

4.2.52 Scenario 52

In this test, the bottom end of of CRB18A is de-energised as part of a switching schedule. There are no permits on issue (A/P’s, T/P’s, W/A’s, etc.) and no instructed items present. A permanent fault then occurs on CRB25A between X15402-C, X656776 and X23952. SSCRB 11kV CB1252 OCEF protection detects the fault condition exists and locks the feeder out. Overcurrent fault indication is received from X15402-C and X59012-B. There are no energised remote transfer points available on CRB18A to restore supply to the bottom end of CRB25A feeder. This test is aiming to verify the application does check for healthy supply on one side of the chosen transfer point prior to attempting a remote close. It is expected the application will attempt to restore supply to the bottom end of CRB25A feeder via X15886-B (YTA2B feeder).

4.2.53 Scenario 53

In this test, the section of network between SSCRB 11kV CB1252 and X59012-B is isolated for planned works. The switching crew complete their works but fail to remove a set of earths. As per the switching schedule, the Switching Coordinator closes 11kV CB1252 in an attempt to re-energise the section of network. After closing, the circuit breaker almost instantaneously trips on OCEF protection. The switching schedule had disabled auto-reclose on 11kV CB1252 prior to the remote close item being carried out. It is expected the FDIR application will abort due to the trip of the circuit breaker occurring directly after a close command has been executed.

4.2.54 Scenario 54

This test is simulating a phase to phase overcurrent fault condition occurring downstream of the non-telemetered ACR X2154260-A. Due to the fault current flowing, conductor clashing occurs upstream of X2154260-A resulting in wrapped 11KV conductors (A and B phase conductors wrapped together). ACR X23952-A detects that this fault condition exists before having multiple reclose attempts and locking out. Because X2154260-A is a non-telemetered device and X799994 is effectively a non-commissioned protective device, the FDIR application should disregard these devices from the model and assume there is a fault on the backbone of the feeder, somewhere between X23952-A and X7509-D.

Chapter 5

CONCLUSION AND FUTURE WORK

5.1 Chapter Overview

This chapter evaluates the project's achievements in terms of meeting the objectives and outlines the scope of future works. The chapter also discusses current network limitations that need to be addressed prior to the implementation of the FDIR application into the real time environment. These limitations include, the need to conduct firmware upgrades and apply adequate fault indication settings on 11kV downstream devices prior to commissioning of the FDIR application as well as implementation of low voltage network reconfigurations in certain locations within the distribution network.

5.2 Achievement of Objectives

Identify common and unusual 11kV network outage scenarios

- All 11kV lockouts that occurred in 2014, 2015, 2016 and so far through 2017 were identified and briefly analysed to ascertain any possible unusual fault scenarios; and
- A number of experienced Energex Switching Coordinators provided information on unusual 11kV lockouts that have taken place on the network.

Extract relevant data from the last one hundred 11kV feeder lockouts and identify common and unusual scenarios from this data

- Information pertaining to one hundred recent 11kV lockouts were successfully analysed and categorised into common and unusual fault scenarios.

Create a test network within the GE PowerOn Fusion Production environment

- The test network was successfully created within the Development environment. The test network comprises of three 11kV radial feeders and utilises existing, commissioned 11kV devices from throughout the network. All work associated with this project was conducted in the development world. At a later point in time this test network will be copied over to the real time production environment with application testing taking place within this environment.

Develop a test harness to simulate the identified scenarios and conduct application testing/validation of the FDIR application

- Fifty four jiggle scripts were created to simulate the identified fault scenarios. These scenarios are designed to prove all elements of the application logic; and
- This intention of this project was not to develop the FDIR application algorithm. At this point in time the FDIR application algorithm has not yet been developed and as such the application has not been validated. The development of the FDIR application algorithm was beyond my control. However, the test harness is available to complete application acceptance testing when required.

Provide the associated FDIR application documentation

- Relevant formation from this Dissertation that is specific to the test harness will be extracted and utilised as an information source for the FDIR application test harness.

5.3 Future Work

This section provides an outline of future work that will occur using these project findings as a basis.

Conduct application testing/validation of the FDIR application

- Testing of the FDIR application is yet to commence as the application is currently being developed. However, all test scripts have been developed and are available to test the application once built. As this project will be ongoing, it is envisaged that application testing will take place in the very near future.

Provide a review of FDIR Stage 1 Advisory mode system responses

- Once the application satisfies acceptance testing and has been functioning in the real time Advisory mode for a determined time frame, a review of the application's responses to real world faults will be conducted.

Improving the integrity of 11kV downstream device fault indication

- The FDIR application relies heavily on correct fault indication from 11kV remote load transfer switches. There is currently a mistrust of positive fault indication and in recent times it has been identified and confirmed that there is in fact a firmware issue with certain devices that causes them to ignore time delay settings. This can result in a false indication for any capacitive current that flows past a switch for an upstream fault or in situations where the fault is in close proximity to the device, raising the remaining line to line voltages. This can and has caused human switching coordinators to assume that the fault is in the wrong section of the 11kV feeder resulting in a manual reclose onto a section that may have conductors on the ground. There is currently a project underway to upgrade the version of firmware in the affected devices; and

- Another issue with installed 11kV load transfer switches is the process in which fault indication settings are issued, applied and maintained. Historically, the Pole Mounted Plant Commissioning Coordinator has provided the relevant field crews with the upstream protective device settings or default settings to be installed in these devices. Official relay settings from an Engineering Department have never been issued for these devices. There is also no complete repository of the settings and very few devices have been entered into the relay setting database. Currently, there is also no device settings installed on normally open points and there is no trigger for a review of fault indication settings when the network is reconfigured or regraded. This means not all normally closed switches have settings. This causes mistrust in the non-indication of devices and limits the capability of restoring sections of feeders without patrolling the line. A formal process for the handling of these device settings is currently being developed.

Physical Positioning of low voltage tie points

- Just like the high voltage network, the low voltage network incorporates normally open points (overhead and underground switches) that provide flexibility in terms of low voltage network reconfiguration and maintaining continuity of supply under certain network conditions. These normally open low voltage switches are typically energised on either side by two different distribution transformers and are commonly referred to as tie points. A simplified diagram showing an example low voltage network with tie points is shown below in Figure 21.

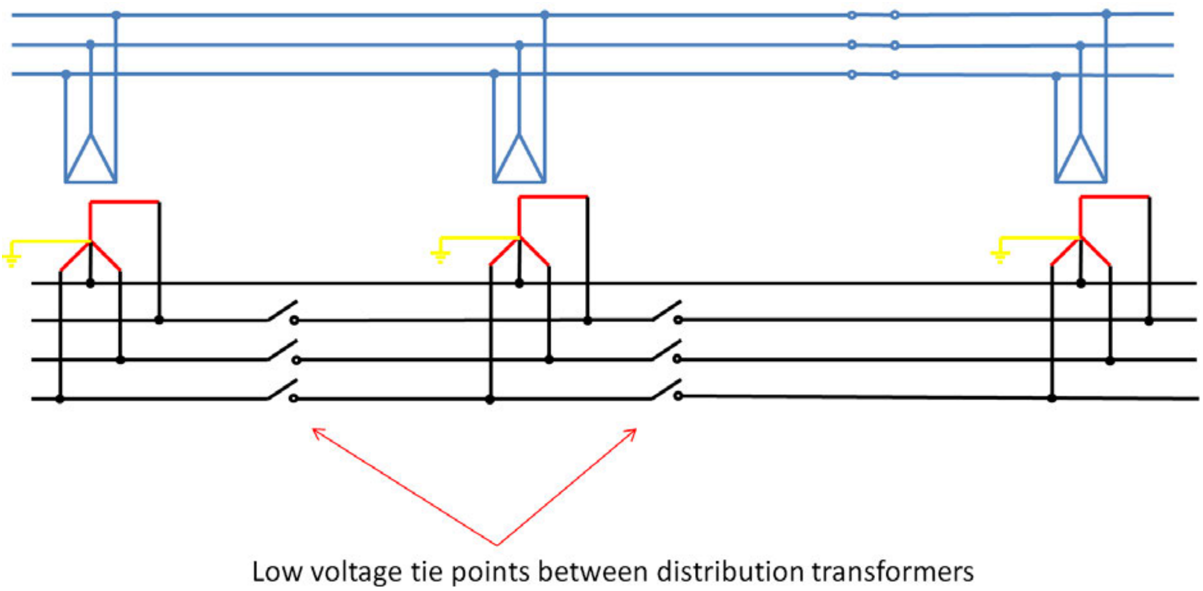

Figure 21 – LV network showing normally open tie points between transformers (Energex, 2017)

Currently not all low voltage tie points are physically aligned with the high voltage switches (both LV and HV switches located on the same pole). This means there is a chance when restoring the 11kV overhead conductors up to an open switch that a section of LV overhead conductors to be energised could extend past the open HV switch and into the faulted area (supplied via a distribution transformer from the restored side of the open HV switch). Therefore there currently is the possibility of reenergising fallen 11kV conductors at low voltage potential. This scenario presents a dangerous situation to members of the public, power system workers and animals / livestock and has occurred in the past. Figure 22 below shows a visual representation of this scenario occurring. There is currently work being done to identify all overhead low voltage tie points that do not align with the 11kV switches so that a project can be raised to shift these low voltage open points.

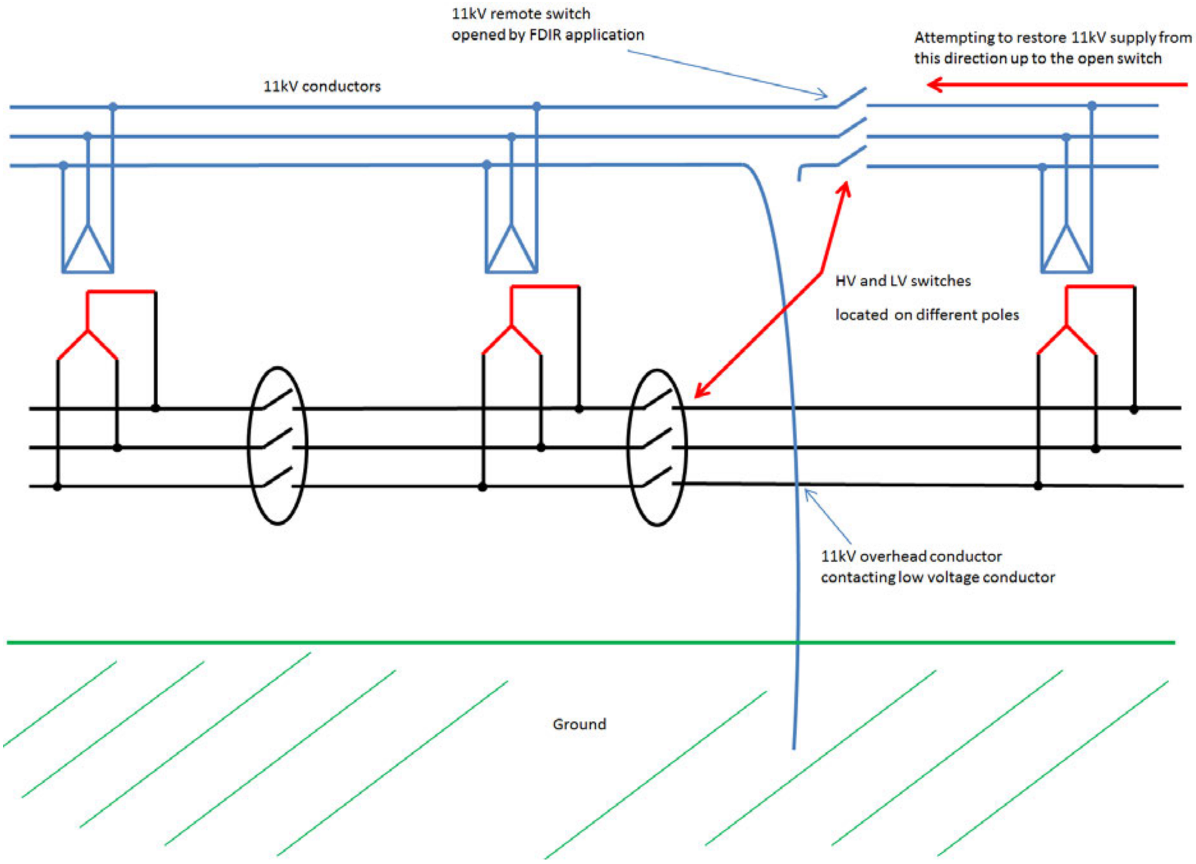

Figure 22 – Energising fallen 11kV conductor at low voltage potential (Energex, 2017)

Developing subsequent versions of the FDIR application to cater for network faults that are considered more complex in nature

- Future versions of the FDIR application will be designed to handle situations where 11kV feeder circuit breakers have failed to open (CBF condition), 11kV Bus Zone schemes have operated and even replacing the Zone Substation SACS driven auto changeover schemes.

LIST OF REFERENCES

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Appendix A

ENG4111/4112 Research Project

Project Specification

For: Jack Delaforce

Title: Test harness development to analyse the performance of an algorithmic based High Voltage Fault Detection, Isolation and Restoration application

Major: Power engineering

Supervisors: Dr Andrew Hewitt

Mitchell Bradley, Energex Pty Ltd

Emma Rogers, Energex Pty Ltd

Sponsorship: Energex Pty Ltd

Enrolment: ENG4111 – EXT S1, 2017

ENG4112 – EXT S2, 2017

Project Aim: To develop an FDIR application test harness that will permit sound engineering justification for the most onerous of real time conditions. The project will further consider possible failure modes and assess their consequences as well as also developing the necessary documentation to facilitate engineering approval/signing off of the application.

Programme: Version 1, 19th February 2017

1. Identify common and unusual 11kV network outage scenarios.
2. Extract relevant data from the last one hundred 11kV feeder lockouts and identify common and unusual scenarios from this data.
3. Create a test network in GE PowerOn Fusion Production environment.
4. Develop a test harness to simulate the identified scenarios and carry out application testing/validation of the FDIR application.
5. Provide a review of FDIR Stage 1 Advisory mode system responses.
6. Provide the associated FDIR application documentation.

Appendix B

Categorisation of one hundred recent 11kV Lockouts

L/O ID	Incd ID	Date	Feeder	Prot	Fault Location	Cause	OH or UG	>1 protective device L/O	System status at time of lockout	Prot mal-operation	Equip failure at time of lockout	Classify as normal or abnormal lockout
1	INCD-213494-g	18/02/2017	TBV2	OCEF	SP754864	Tree branch across 11kV OH conductors.	OH	No	Normal	No	No	No
2	INCD-213529-g	18/02/2017	MLS11	OCEF	SP60983	Possum shorted out across 11kV insulator (concrete pole with steel x-arm)	UG	No	Normal	No	No	No
3	INCD-213548-g	19/02/2017	BWH13	OCEF	P162216	CB1132 locked out for fault downstream of X753107. Tree branch across 11kV OH conductors.	OH	No	Normal	Yes	Yes	Yes
4	INCD-213552-g	19/02/2017	CBW6	OCEF	X841166	CB1062 locked out after operation of X841166. Backbone of feeder patrolled up to X841166, with no cause found. Assumed to	UG	Yes	Normal	No	No	Yes

						be conductor clashing						
5	INCD-214811-g	25/02/2017	SPD9	OCEF	SPD9	Gazebo from unit complex blew onto 11kV OH conductors	OH	No	Normal	No	No	No
6	INCD-214739-g	24/02/2017	NBR5A	OCEF	P52772-A	Tree branch across 11kV OH conductors	UG	No	Normal	No	No	No
7	INCD-214490-g	23/02/2017	YTA35	OCEF	P161011-A	UG cable fault between SC2048491/IS27 and SG657818/IS18	OH	No	Normal	No	No	No
8	INCD-214454-g	23/02/2017	BWH12A	OC	P161011-A	Broken x-arm	UG	No	Normal	No	No	No
9	INCD-214089-g	21/02/2017	SFD10	OCEF	Between P837676 and P45714-D	No cause initially. Feeder restored. Approximately 10 minutes later feeder locked out again due to a cable fault	UG	No	Normal	No	No	No
10	INCD-213922	21/02/2017	BLB6	OCEF	Between CB1062	UG cable fault	UG	No	Normal	No	No	No

	-g				and P348574							
11	INCD-213705-g	20/02/2017	PRG2A	OCEF	P69391	Tree branch across 11kV OH conductors. Sectionaliser X17774 failed to clear fault	OH	No	Normal	Yes	Yes	Yes
12	INCD-213701-g	20/02/2017	YTA39A	OCEF	P105705-A	Bamboo brought down 11kV OH conductor	OH	No	Normal	No	No	No
13	INCD-213674-g	19/02/2017	MLY1	OCEF	P160822	Tree branch across 11kV OH conductors.	OH	No	Normal	No	No	No
14	INCD-213651-g	19/02/2017	MLB12	OCEF	P93696	Tree branch across all three 11kV OH conductors.	OH	No	Normal	No	No	No
15	INCD-213585-g	19/02/2017	NIP5A	EF	P998-G	Tree branch contacted 11kV OH conductors.	OH	No	Normal	No	No	No
16	INCD-214874-g	26/02/2017	BBS8	OCEF	Between CB1082 and P17420-F	UG cable fault	UG	No	Normal	No	No	No

17	INCD-214935-g	27/02/2017	BTA3	OCEF	P802200	Tree branch across 11kV OH conductors	OH	No	Normal	No	No	No
18	INCD-214964-g	27/02/2017	SMF3A	SEF	P434271	Two 11kV conductors down	OH	No	Normal	No	No	No
19	INCD-214975-g	27/02/2017	BBS15	OCEF	UG cable between SC4882 and SC798860	UG cable fault	UG	No	Normal	No	No	No
20	INCD-215111-g	27/02/2017	CBW11	OCEF	P54378	Tree branch across 11kV OH conductors	OH	No	Normal	No	No	No
21	INCD-215184-g	28/02/2017	AHL14	OCEF	SP4612	Possum across 11kV conductors	OH	No	Normal	No	No	No
22	INCD-215405-g	01/03/2017	NVL9	OCEF	P44337-B	NGK LBS failed when possum created short circuit	OH	No	Normal	No	No	No
23	INCD-215424-g	01/03/2017	AHL5	OCEF	Nil	Feeder patrolled. No cause found	OH	No	Normal	No	No	No

24	INCD-215427-g	01/03/2017	RCN12	OCEF	P414162	Possum found at base of pole. Short trident cross arm	OH	No	Normal	No	No	No
25	INCD-215429-g	01/03/2017	CHL4	OCEF	X1815-L	Possum found on switch with blown arrestors and insulators	OH	No	Normal	No	No	No
26	INCD-215430-g	01/03/2017	CHL11	OCEF	X1815-L	Possum found on switch with blown arrestors and 12insulators	OH	No	Normal	No	No	No
27	INCD-215431-g	01/03/2017	SRD3	OCEF	P23333-C	Possum found at base of pole	OH	No	Normal	No	No	No
28	INCD-215597-g	01/03/2017	CMV12	OCEF	SC1484376 (#217 Benhiam St, Calamvale)	Excavator damaged 11kV CMV12A and LV circuit from SC1484376 (CMV14)	UG	No	Normal	No	No	No
29	INCD-215617-g	01/03/2017	YTA22	OCEF	X251229	Tree branch across 11kV conductors between X251229	OH	No	Normal	No	No	No

						and P251228						
30	INCD-215674-g	02/03/2017	TWT6	OCEF	P302036	Two 11kV conductors brought down during storm, possible lightning strike	OH	No	Normal	No	No	No
31	INCD-215679-g	02/03/2017	SFD4	OCEF	Nil	Feeder patrolled. No cause found	OH	No	Normal	No	No	No
32	INCD-215680-g	02/03/2017	AHD9	OCEF	X152479	LBS hit by lightning – significant damage	OH	No	Normal	No	No	No
33	INCD-215813-g	02/03/2017	IPL2A	OCEF	P16192	Tree branch across 11kV OH conductors	OH	No	Normal	No	No	No
34	INCD-215869-g	02/03/2017	BLB9	OCEF	P9547	Failed 11kV dead end	OH	No	Normal	No	No	No
35	INCD-215881-g	02/03/2017	ACR6	OCEF	P78982-B	Dead bat found at the base of pole. CB1062 did not attempt to auto-reclose	OH	No	Normal	No	Yes	Yes

36	INCD-216037-g	03/03/2017	DBS4	OCEF	Nil	Feeder patrolled. No cause found	OH	No	Normal	No	No	No
37	INCD-216119-g	03/03/2017	LBH3	OCEF	P93836-A	Flying fox found at base of pole. CB1032 OCEF relay had latched trip output	OH	No	Normal	No	Yes	Yes
38	INCD-216129-g	04/03/2017	HPE3	OCEF	SP27989-B	Possum shorted across concrete pole causing 11kV B phase conductor to contact the ground	OH	No	Normal	No	No	No
39	INCD-216136-g	04/03/2017	SMF3A	EF	X2076935	Feeder patrolled with no cause found. PMR had faulty firmware issue	OH	No	Normal	Yes	Yes	Yes
40	INCD-216284-g	05/03/2017	NRG16A	Nil	X15533	PMR opened with no protection indication. Feeder patrolled with no cause found	OH	No	Normal	Yes	Yes	Yes
41	INCD-	06/03/2017	NMK9	OCEF	X4452	Possum shorted	OH	No	Normal	No	No	No

	216518-g		A			out across ABS						
42	INCD-216918-g	08/03/2017	GYN3A	OC	SSGYN CB1032	During planned switching, GYN3A and GYN15A were paralleled together when CB1032 tripped on OC. RSR set to 180A, tripped at 195A	OH	No	Abnormal	No	No	Yes
43	INCD-217129-g	10/03/2017	MLS26	OCEF	Between SC484404/IS12 & X129R	UG cable fault	UG	No	Normal	No	No	No
44	INCD-217360-g	11/03/2017	NMC15	SEF	P72459-C	Tree branch burnt through 11kV B phase conductor	OH	No	Normal	No	No	No
45	INCD-217383-g	11/03/2017	BTY5	OCEF	P75125-A	Car hit pole. Failed to initiate an auto reclose attempt	OH	No	Normal	No	Yes	Yes
46	INCD-217458-g	12/03/2017	GYS6A	OCEF	SP53-D	Tree branch brought down one 11kV conductor	OH	No	Normal	No	No	No
47	INCD-217483	13/03/2017	OXL8	OCEF	Nil	Feeder patrolled.	OH	No	Normal	No	No	No

	-g					No cause found						
48	INCD-217513-g	13/03/2017	MCW7	OCEF	P844786	Possum caused cable termination failure	UG	No	Normal	No	No	No
49	INCD-217755-g	14/03/2017	ESK5A	OCEF	SP1438	Multiple 11kV conductors down due to storm	OH	No	Normal	No	No	No
50	INCD-217803-g	14/03/2017	WSE5A	OCEF	Nil	Storm in area. Supply restored via alternative feeder as both 33kV feeders to SSWSE were OOS due to damage	OH	No	Abnormal	No	No	Yes
51	INCD-217804-g	14/03/2017	JBB12B	OCEF	P97139	Tree branch on 11kV conductors	OH	No	Normal	No	No	No
52	INCD-218114-g	15/03/2017	BMT5	OCEF	P52396	Tree branch across 11kV OH conductors with one 11kV conductor down on ground	OH	No	Normal	No	No	No
53	INCD-218119	15/03/2017	NBR1	OCEF	X792248	Feeder patrolled.	UG	No	Normal	No	No	No

	-g		1A			No cause found						
54	INCD-218123-g	15/03/2017	PRG2A	OCEF	P185322 – P185323	Trees across 11KV conductors between P185322 and P185323	OH	No	Normal	No	No	No
55	INCD-218128-g	15/03/2017	MFD8	OCEF	SP5696-E	Broken x-arm	OH	No	Normal	No	No	No
56	INCD-218131-g	15/03/2017	WSE3A	OCEF	SP481231	Tree branch across 11kV conductors	OH	No	Normal	No	No	No
57	INCD-218157-g	15/03/2017	BWH7A	OCEF	X710732	Storm caused damage to 11kV OH conductors	OH	No	Normal	No	No	No
58	INCD-218680-g	16/03/2017	GYN12	OCEF	SP306219	Suspected lightning strike during storm. CB1122 failed to auto reclose due to processor board failure	OH	No	Normal	No	Yes	Yes
59	INCD-218704-g	16/03/2017	GBN4	OCEF	X2009	Blown 11kV Surge Diverters	OH	No	Normal	No	No	No

60	INCD-218805-g	16/03/2017	CLM9	OCEF	X21718	Lightning strike	OH	No	Normal	No	No	No
61	INCD-218807-g	16/03/2017	CLM3	EF	X19468	Lightning strike	OH	No	Normal	No	No	No
62	INCD-218816-g	16/03/2017	PWC4	OCEF	SP82458	Tree branch across 11kV OH conductors	OH	No	Normal	No	No	No
63	INCD-218858-g	17/03/2017	WMD 14	OCEF	X9873	Lightning strike	OH	No	Normal	No	No	No
64	INCD-218911-g	17/03/2017	NBR7	SEF	X3579-A	Stay wire damaged and hanging into 11kV OH conductors	OH	No	Normal	No	No	No
65	INCD-219095-g	17/03/2017	JBB1	OCEF	P102289	Large tree branch across 11kV OH conductors	OH	No	Normal	No	No	No
66	INCD-219230-g	17/03/2017	GNA12	OCEF	P280620	Bat caught in 11kV OH conductors	OH	No	Normal	No	No	No
67	INCD-219252	18/03/2017	MRE1	OCEF	P49133-F	11kV cable	UG	No	Normal	No	No	No

	-g					termination failed						
68	INCD-219324-g	18/03/2017	WMR1	SEF	Between P136 and P137	11kV conductor down on ground	OH	No	Normal	No	No	No
69	INCD-219332-g	18/03/2017	IBL2	SEF	SP2942	Lightning strike	OH	No	Normal	No	No	No
70	INCD-219402-g	18/03/2017	LGV5	OCEF	P79069-B	Tree fell across 11kV OH conductors	OH	No	Normal	No	No	No
71	INCD-219409-g	18/03/2017	CCY7	OCEF	P97955-B	Possum on 11kV cable termination	UG	No	Normal	No	No	No
72	INCD-219470-g	19/03/2017	EMP4	OCEF	P360541	11kV cable termination failed	UG	No	Normal	No	No	No
73	INCD-219532-g	19/03/2017	TWT15A	OCEF	P302997	Tree branch across 11kV OH conductors	OH	No	Normal	No	No	No
74	INCD-219569-g	20/03/2017	MGP4	OCEF	P322995	Tree branch across 11kV OH conductors	OH	No	Normal	No	No	No
75	INCD-	20/03/2017	CPB3	OCEF	P232042	Broken 11kV x-arm	OH	No	Normal	No	No	No

	219697-g											
76	INCD-21979-g	20/03/2017	CPB4	OCEF	SP2795-D	Tree fell across 11kV OH conductors	OH	No	Normal	No	No	No
77	INCD-219848-g	20/03/2017	CRB25A	OCEF	X18896-E	Dead tree fell across 11kV OH conductors	OH	No	Normal	No	No	No
78	INCD-219850-g	20/03/2017	BLN1	OCEF	Nil	Feeder patrolled. No cause found. No auto reclose attempt due to a trip circuit faulty alarm asserting after CB1012 tripped.	OH	No	Normal	No	Yes	Yes
79	INCD-219857-g	20/03/2017	BKD3	OCEF	X16211-C	Possum found at the base of X16211-C. Failed to initiate auto reclose.	OH	No	Normal	No	Yes	Yes
80	INCD-219870-g	21/03/2017	BLN16A	OCEF	Between P79797 and P79798	Tree across 11kV OH conductors	OH	No	Normal	No	No	No

81	INCD-220147-g	21/03/2017	KRN7	OCEF	SC692045/IS35, SC854559/IS25 and P1427563	11kV UG cable fault	UG	No	Normal	No	No	No
82	INCD-220150-g	22/03/2017	MFN2	OCEF	X70274-C	Birds nest on switch. Piece of wire from nest made contact with 11kV conductors causing catastrophic failure of switch	OH	No	Normal	No	No	No
83	INCD-220151-g	22/03/2017	CMA20	OCEF	P1427563	Copper fencing wire found on cable termination. Appears to have been dropped by a bird	OH	No	Normal	No	No	No
84	INCD-220153-g	22/03/2017	NBR3	OCEF	P53815-A and X6483-B	Both cable terminations failed	UG	No	Normal	No	No	No
85	INCD-220246-g	22/03/2017	RPN7	OCEF	X5753	Truck brought down 11kV OH conductors	OH	No	Normal	No	No	No

86	INCD-220292-g	22/03/2017	YDA5A	OCEF	P86160	Tree branch across 11kV OH conductors	OH	No	Normal	No	No	No
87	INCD-220352-g	22/03/2017	MDR2A	OCEF	Between CB1022 and P657051	11kV UG cable fault	UG	No	Normal	No	No	No
88	INCD-220387-g	22/03/2017	WRG15	OCEF	SP1312-F	Car hit pole causing broken 11KV x-arm. LV ties had previously been left in on SP1312-F creating multiple fires	OH	No	Normal	No	No	Yes
89	INCD-220445-g	22/03/2017	AHL14	OCEF	P913676-A	11kV cable termination and porcelain surge diverters failed	UG	No	Normal	No	No	No
90	INCD-220457-g	22/03/2017	CPK9	SEF	Nil	Feeder patrolled. No cause found	N/A	No	Normal	No	No	No
91	INCD-220491-g	23/03/2017	IPS1	OCEF	SSIPS	Switching error by field crew. IS1025 was put into the Earth position	UG	No	Normal	No	No	Yes

						instead of closing						
92	INCD-220650-g	23/03/2017	EMP21	OCEF	Between X359803 and P360064	A phase 11kV conductor down caused by failed Helical splice	OH	No	Normal	No	No	No
93	INCD-220794-g	24/03/2017	YTA2	OCEF	P107187	Tree brought down 11kV OH conductors	OH	No	Normal	No	No	No
94	INCD-220795-g	24/03/2017	THL2	OCEF	P7439-B	LV OH conductor snapped during pole works contacting 11kV OH conductors	OH	No	Normal	No	No	Yes
95	INCD-220904-g	24/03/2017	NRA1	OCEF	P1453182	Tree branch fell on 11kV OH conductors. Front end of feeder also tripped and failed to auto reclose (possible conductor clashing)	OH	No	Normal	No	Yes	Yes
96	INCD-220907-g	24/03/2017	MGP12A	OCEF	P232357	Tree across 11kV OH conductors	OH	No	Normal	No	No	No

97	INCD-220922-g	25/03/2017	AHL5	OCEF	P400926	Car hit pole causing 11kV OH conductors to flick up into the OH 33kV conductors. 11kV UG cable termination failed at P400937-A	OH	No	Normal	No	No	No
98	INCD-220996-g	25/03/2017	CMV14	OCEF	P32864	Tree branch across 11kV OH conductors		No	Normal	No	No	No
99	INCD-221021-g	25/03/2017	NVL3	SEF	P44261-B	Helical splice burnt off at P44261-B. Fault current then burnt down mains at P44272. HV into LV at SP6777 and SP2353		No	Normal	No	No	No
100	INCD-221122-g	27/03/2017	AGT31	OCEF	P34449	Tree branch across 11kV OH conductors		No	Normal	No	No	No

Appendix C

FDIR application equipment linking

Section 3.4, pages 38 and 39, provided a brief overview of how linking between 11kV remote device alarms and the FDIR application. This appendix extends on from the information contained in Section 3.4 and provides further detail into how the application to equipment linking is achieved.

As stated in Section 3.4, the links tab is divided into three sections and contains the directional links that exist between the device and other devices/applications. The significance of the linking category is that it provides an interface type role between the primary plant alarms and the FDIR application logic.

Figure 9 below shows an 11kV ACR (Site ID = X23952) and its associated links tab within the Attributes library. It can be seen that there are a number of alarm names (X23952 Data Fail, Equipment at Risk, etc.). Different manufacturers, models and applications can result in a differing amount of alarm names. For example, the device shown in Figure 9 is a NULEC CAPM5 and all device alarms associated with X23952 are contained within these eight alarm naming categories. Although there are eight alarm categories, there are a number of conditions that can initiate one of these output alarms. For example the category name ‘X23952 Equipment at Risk’ may be initiated from one or more of any of the following alarm points:

- 12V DC supply fail;
- High or low DC supply outside of pre-defined thresholds;
- Capacitor charge failure;
- The device controller is in Low Power mode;
- The insulation medium is low or invalid (SF6 gas pressure);
- Invalid switchgear data;
- Less than 20% remaining primary contact life on one or more phases;
- The mechanism has failed to operate following a trip or close request;
- The switchgear is not connected to the controller;
- The firmware in the controller is not compatible with the connected switchgear;
- The controller is in a non-calibrated state; or
- The auxiliary power supply voltage is exceeding a predefined threshold.

In Figure 23 below, the lower pane can be seen which shows the linking between the alarm names and the link types. In this example, any condition that initiates an X23952 Equipment at Risk alarm has been used to abort the FDIR application. Alternatively, an X23952 Overcurrent protection operation is used as part of the application's check and confirmation logic.

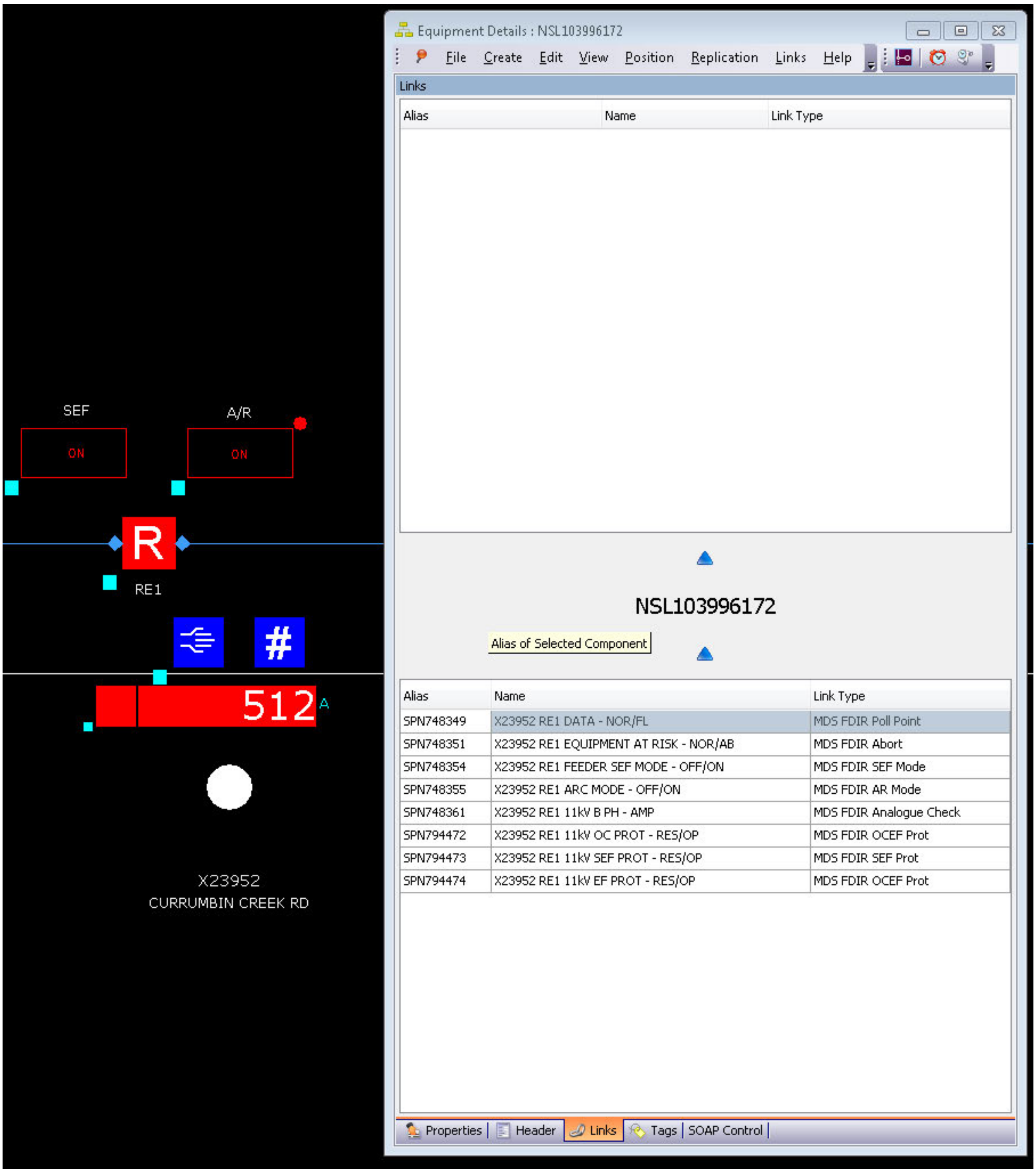


Figure 23 – X23952 alarms and linking to FDIR application (Energex, 2017)

However, regardless of the device manufacturer, model, type of application and number of alarm naming categories, there will always only be a maximum of seven link types required for downstream devices. In Figure 9 above it can be seen that the eight alarm naming categories have been mapped to seven FDIR link types whereas in Figure 24 below, X20997-E has eleven alarm naming categories but only the seven FDIR link types.

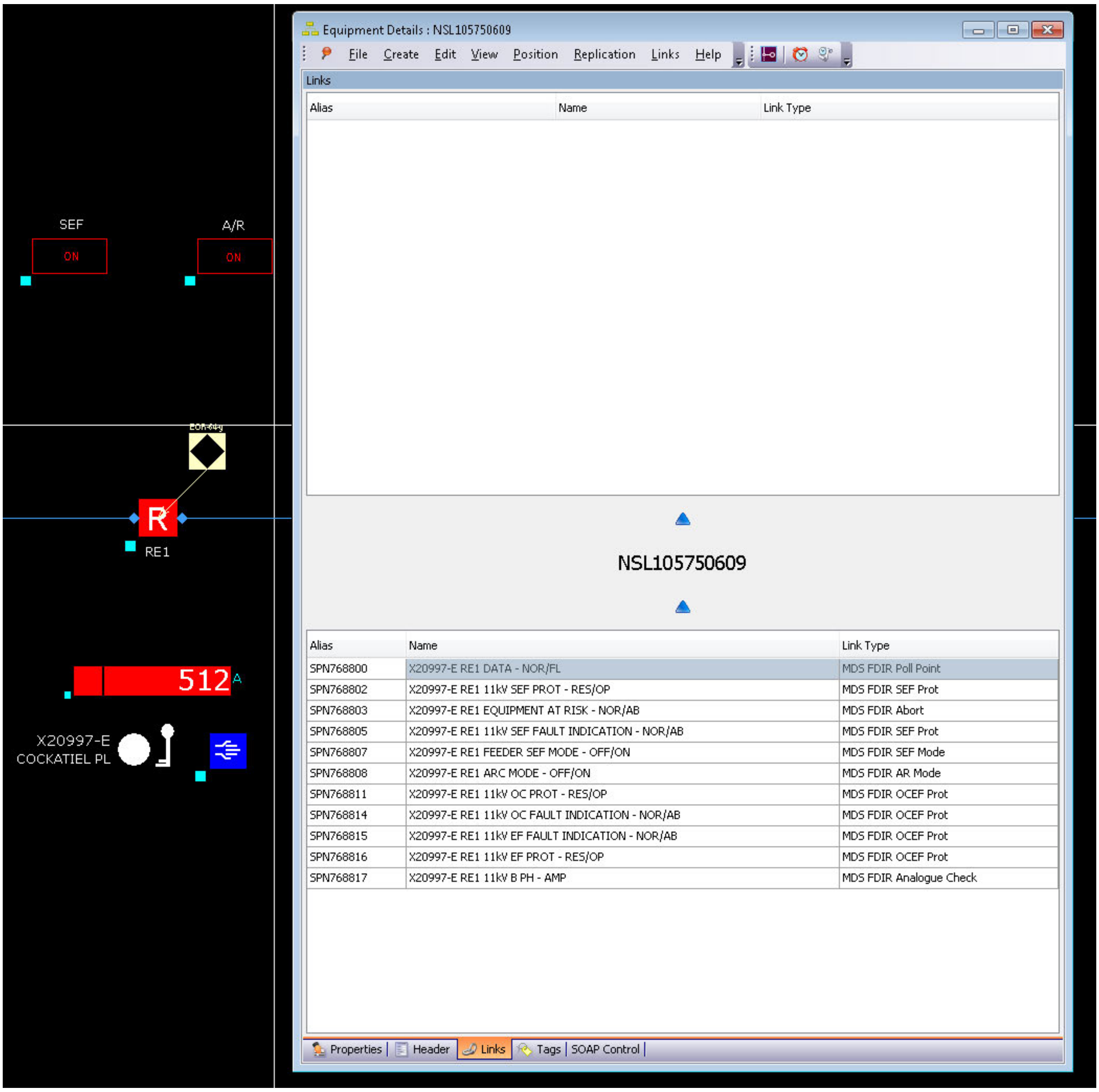


Figure 24 – X20997-E alarms and linking to FDIR application (Energex, 2017)

Within PowerOn, all devices are stored in a database under a parent-child hierarchical type structure. For example, an 11kV feeder circuit breaker would be stored in the database under EGX/Sites/Sites_SS/SSCRB/CB1252. Figure 25 below shows SSCRB 11kV CB1252 and its associated alarm points as well as the directory structure relevant to this device.

ROOT ▸ EGX ▸ Sites ▸ Sites_SS ▸ SSCRB ▸ CB1252 ▸

Point Name	Alias	Version
CB1252 ARC MODE - OFF/ON	SPN333457	2
CB1252 ARC SHOT 1 TIME - SEC	SPN333461	2
CB1252 ARC SHOT 2 TIME - SEC	SPN333460	2
CB1252 ARC SHOT 3 TIME - SEC	SPN333459	2
CB1252 ARC SHOT COUNT - UNITS	SPN333456	2
CB1252 GROUP ASSIGN - UNITS	SPN873073	2
CB1252 TRIP CIRCUIT - FAULTY	SPN365073	2
CB1252 UF LOAD SHED - INIT	SPN873072	2
EGX_D1	ALIAS-2197553-N	2
EGX_D2	ALIAS-2197552-N	2

Figure 25 – SSCRB 11kV CB1252 parent – child hierarchical relationship (Energex, 2017)

However, as can be seen from Figure 11, not all alarm points relevant to this device/feeder are stored under CB1252. For example, there are no protection operated alarms (either OCEF or SEF) or protection relay faulty alarms under CB1252, even though they are directly related to the circuit breaker and are a critical piece of information utilised in the FDIR application logic. The remaining alarms that correlate to the circuit breaker are stored under the 11kV feeder labels that are associated with the circuit breaker in question. For example, 11kV feeder CRB25A is one feeder that is connected to SSCRB 11kV CB1252. Figure 26 below shows SSCRB 11kV CB1252 and the associated feeder labels.

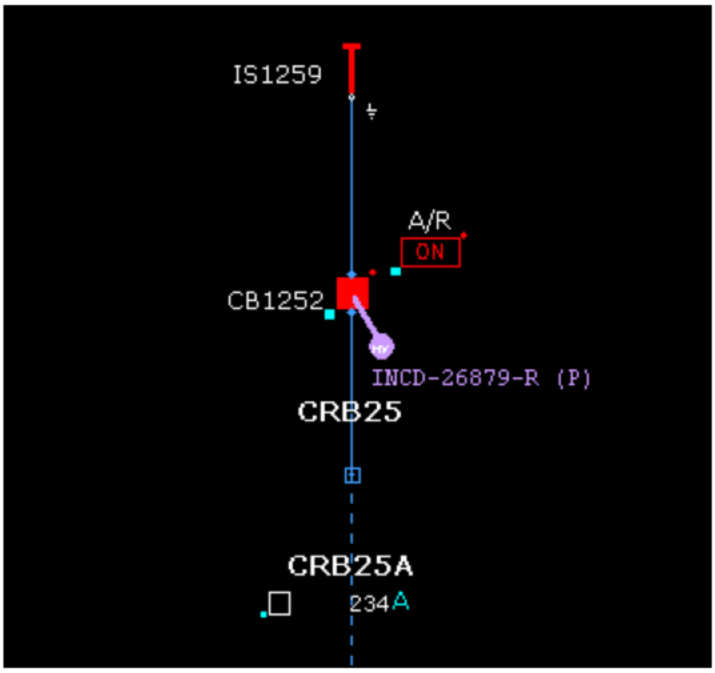


Figure 26 – SSCRB 11kV CB1252, connected feeder CRB25A and associated labelling (Energex, 2017)

Within the database, 11kV feeder CRB25A is located under EGX/Sites/Sites_SS/SSCRB/CRB25A. Figure 27 below shows the alarm points associated with CRB25A and the directory structure. Of note, is the association of the protection operated alarms with the feeder label

ROOT ▸ EGX ▸ Sites ▸ Sites_SS ▸ SSCRB ▸ CRB25A ▸

Point Name	Alias	Version
CRB25A 11kV B PH - AMP	SPN365075	1
CRB25A 11kV OC EF PROT - RES/OP	SPN365068	1
CRB25A 11kV SEF PROT - RES/OP	SPN365069	1

Figure 27 – 11kV feeder CRB25A alarm points and directory association (Energex, 2017)

It should be noted there is no hierarchical linking relationship between the connected 11kV feeder and the source 11kV circuit breaker, but instead a connectivity linking relationship. However, in order for the FDIR application to be able to work correctly it needs to have access to all relevant circuit breaker alarms. To overcome this problem, component association logic is used which utilises traces to link components that are linked by connectivity and not by hierarchy. This then allows an Overcurrent Earth fault Protection operated alarm (which resides under a feeder component) to be associated with a circuit breaker by using a tracing link between the circuit breaker and the feeder.

Figure 28 below shows the links tab associated with CRB25A. It can be seen that there are no longer any alarm points located in the lower pane but, instead, there is a file in the upper pane which contains the configuration for both the hierarchy relationships between components and components that have been linked by traces (MDS_FDIR_MAINT_TRACES).

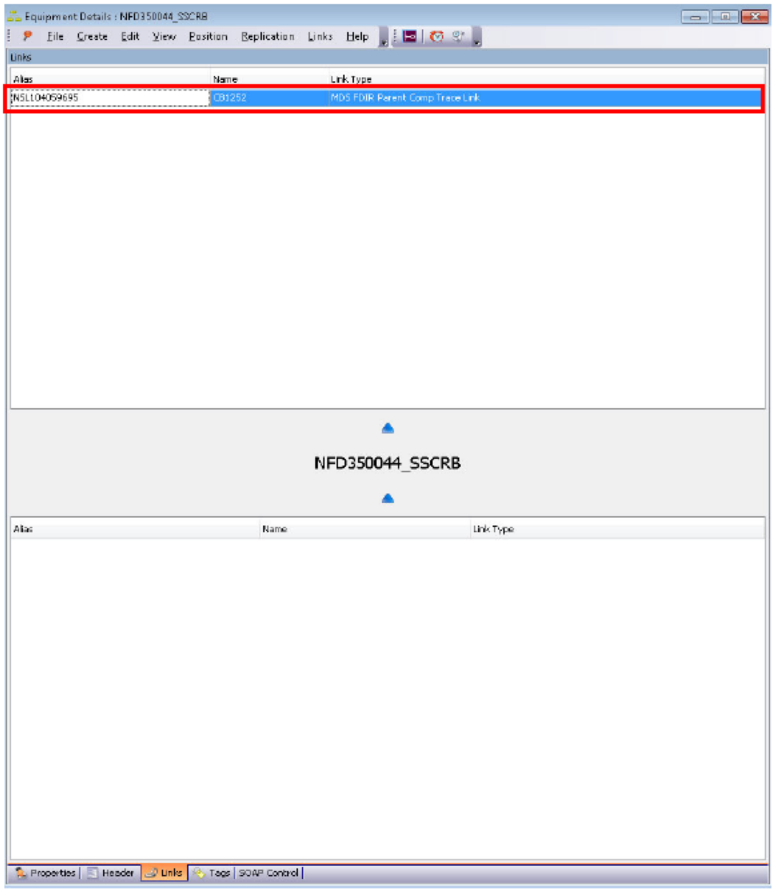


Figure 28 – 11kV feeder CRB25A FDIR alarm linking (Energex, 2017)

Figure 29 below shows the links tab associated with SSCRB 11kV CB1252. It can be seen that, within the lower pane, all alarm points have now been linked to the FDIR application either via direct alarm mapping or through the MDS_FDIR_MAINT_TRACES file configuration.

Figure 29 – SSCRB 11kV CB1252 FDIR alarm linking (Energex, 2017)

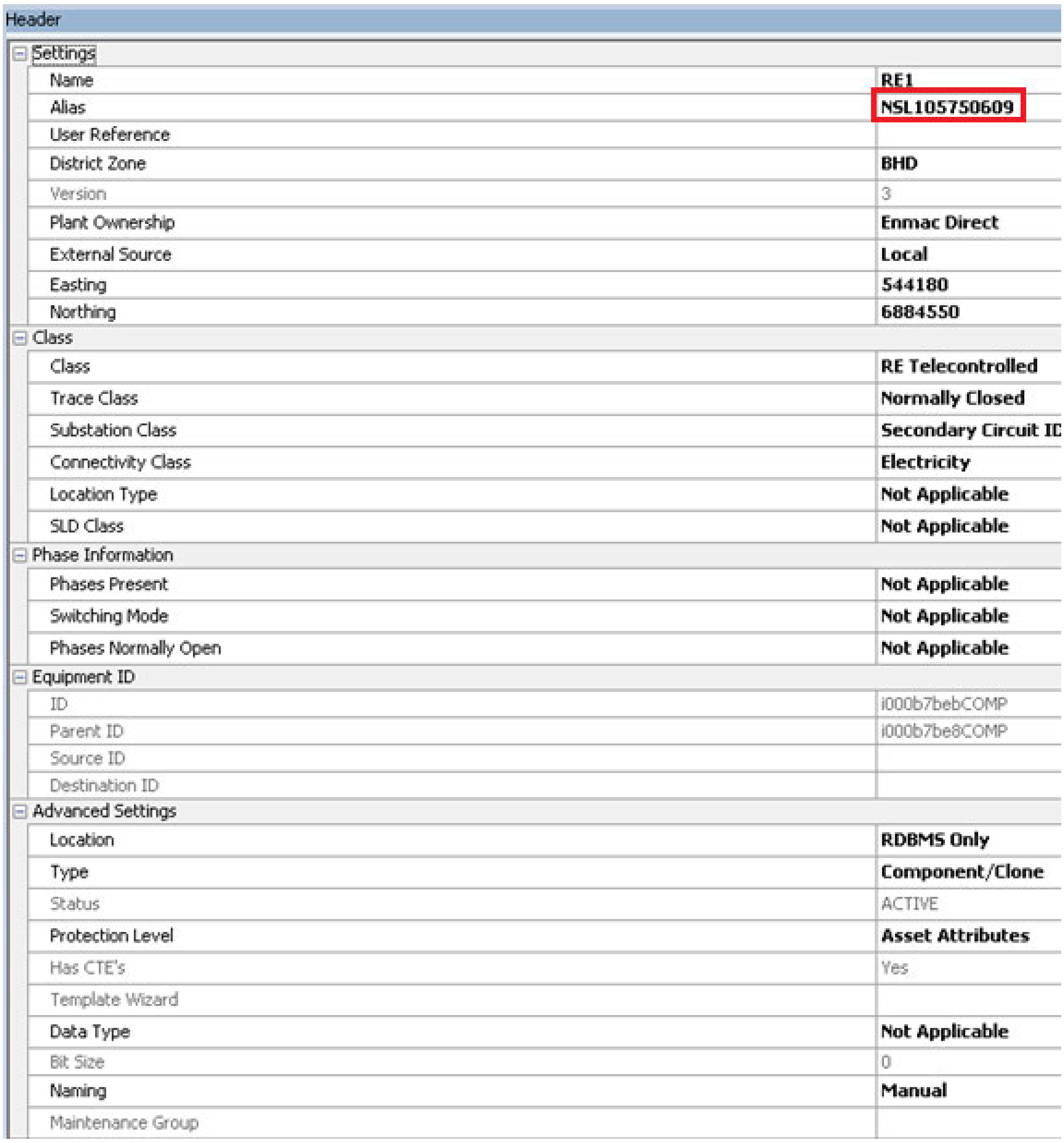
Appendix D

Fault Scenario Scripting

As per Section 3.6, pages 42 and 43, an overview of how the individual jiggle scripts were developed for each fault scenario was provided in addition to how the scripts were initiated. Following on from Section 3.6, this appendix provides further detail into how the fault scenario scripting was achieved.

Within the PowerOn application each network device has its own specific alias identifier. This identifier can be located within the device's Attributes / Header categories tab. For example, in Figure 30 below, 11kV ACR X20997-E has an alias identifier of NSL105750609. The manipulation of digital points using jiggle commands is performed using a 'Scan Value' classification, so in this case if an open status of this device is to be achieved then the line of code would be as follows:

```
alias 'NSL105750609.Scan Value' 2
```



Header	
Settings	
Name	RE1
Alias	NSL105750609
User Reference	
District Zone	BHD
Version	3
Plant Ownership	Enmac Direct
External Source	Local
Easting	544180
Northing	6884550
Class	
Class	RE Telecontrolled
Trace Class	Normally Closed
Substation Class	Secondary Circuit ID
Connectivity Class	Electricity
Location Type	Not Applicable
SLD Class	Not Applicable
Phase Information	
Phases Present	Not Applicable
Switching Mode	Not Applicable
Phases Normally Open	Not Applicable
Equipment ID	
ID	i000b7bebCOMP
Parent ID	i000b7be8COMP
Source ID	
Destination ID	
Advanced Settings	
Location	RDBMS Only
Type	Component/Clone
Status	ACTIVE
Protection Level	Asset Attributes
Has CTE's	Yes
Template Wizard	
Data Type	Not Applicable
Bit Size	0
Naming	Manual
Maintenance Group	

Figure 30 – Device header tab and specific Alias identifier (Energex, 2017)

Once a fault scenario script was built the file would firstly be saved with a suitable file name and a .jig file extension. The next step was to locate the required working directory within the Linux-based KiTTy emulator as shown in figure 31 below.

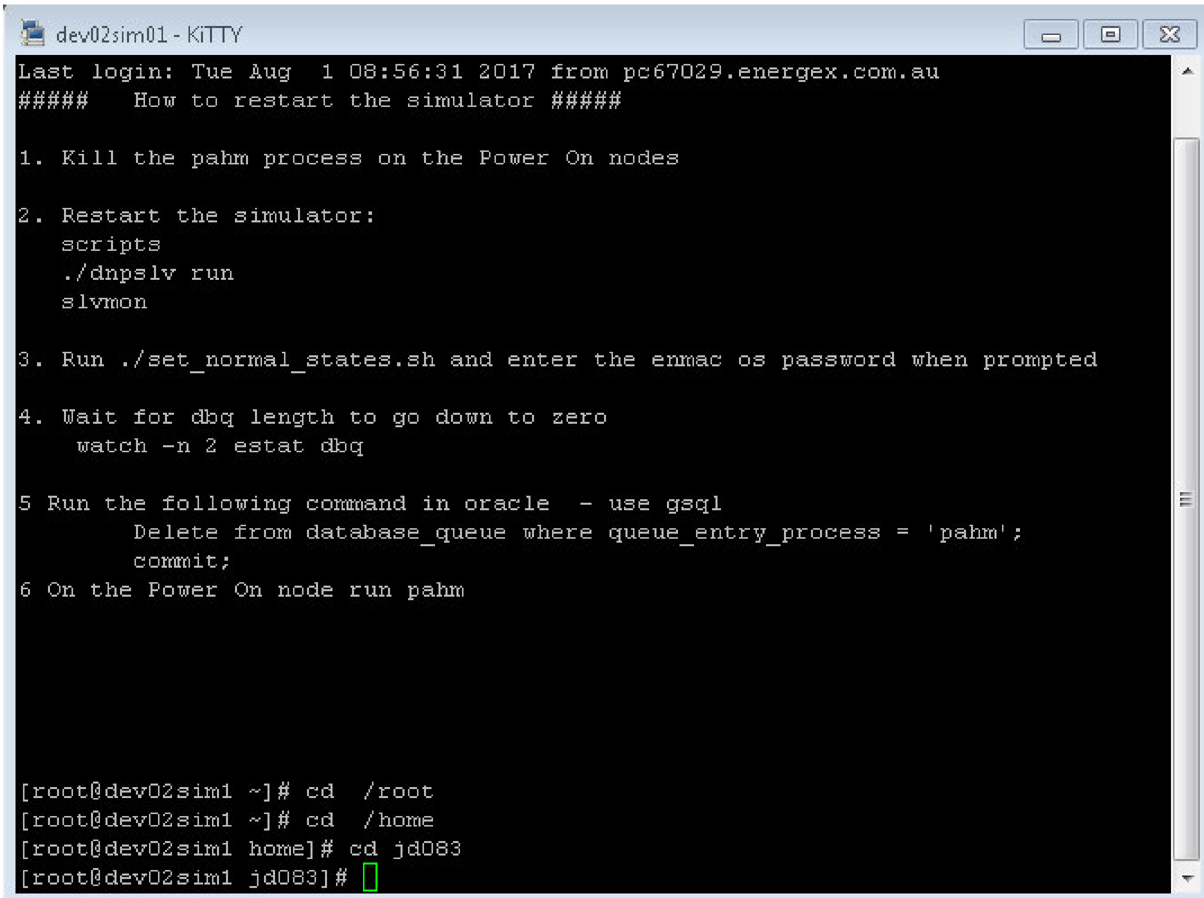


Figure 31 – Locating working directory in KiTTy (Energex, 2017)

To run the script, a jiggle –f command along with the file identifier is entered into KiTTY. To illustrate this, using a script titled 'example.jig' the following command would be entered into KiTTY:

```
jiggle -f example.jig
```

The script would then automatically run with the output from within the KiTTy emulator shown below in Figure 32.

```
[root@dev02sim1 jd083]# jiggle -f example.jig
JIGGLE : GJW20150625a PCSACSV3/5/LNX
###: set sub sc1a
sc1a: alias 'NSL105750609.Scan Value' 2
Component Alias : NSL105750609.Scan Value
DPN             : 55 : x20997
Mask            : 0x0300
Value           : 2
sc1a: wait 2000
sc1a: alias 'NSL105750609.Scan Value' 1
Component Alias : NSL105750609.Scan Value
DPN             : 55 : x20997
Mask            : 0x0300
Value           : 1
sc1a: exit
[root@dev02sim1 jd083]#
```

Figure 32 – Running example.jig script – changing digital point (Energex, 2017)

Manipulation of an analogue point within PowerOn using jiggle commands is performed using an ‘Eng Value’ classification. The following lines of code toggle X20997-E, 11kV ‘B’ phase analogue from 0A - 300A - 0A. It is noted that the alias identifier in this example is different to the previous example as this unique identifier is associated with the analogue component.

```
set sub sc1a % Define X20997-E RTU
alias 'SPN768817.Eng Value' 300 % Set current analogue to 300A
wait 2000 % Hold analogue reading at 300A for 2s
alias 'SPN768817.Eng Value' 0 % Set current analogue to 0A
```

Figure 33 below shows the script output within the KiTTy emulator and figure 34 shows the analogue value changing from 300A to 0A on the 11kV network diagram.

```
[root@dev02sim1 jd083]# jiggle -f example1.jig
JIGGLE : GJW20150625a PCSACSV3/5/LNX
###: set sub sc1a
sc1a: alias 'SPN768817.Eng Value' 300
Component Alias : SPN768817.Eng Value
DPN             : 1522 : i20997
Value           : 300
sc1a: wait 2000
sc1a: alias 'SPN768817.Eng Value' 0
Component Alias : SPN768817.Eng Value
DPN             : 1522 : i20997
Value           : 0
sc1a:
sc1a:
sc1a: exit
[root@dev02sim1 jd083]#
```

Figure 33 – Running example.jig script – changing analogue point (Energex, 2017)

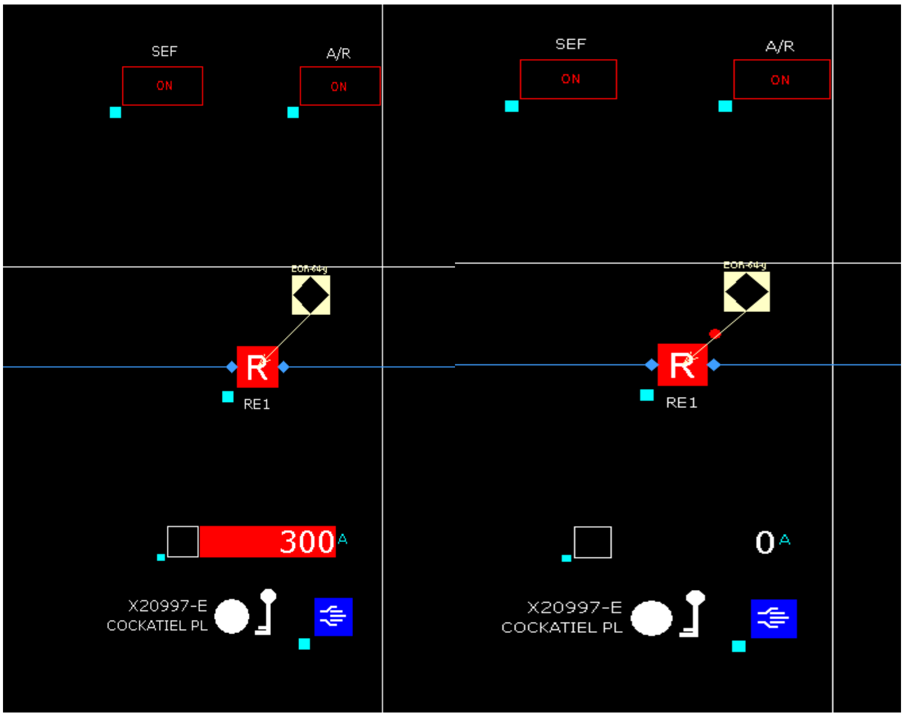


Figure 34 – X20997-E analogue changing due to script (Energex, 2017)

Appendix E

11kV Fault Scenario Jiggle Scripts

Scenario 1

```
echo
set sub crb
alias 'SPN365075.Eng Value' 4000
wait 1000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
wait 10
set sub sc1a
alias 'SPN769755.Eng Value' 0
alias 'SPN769756.Eng Value' 0
alias 'SPN769757.Eng Value' 0
alias 'SPN666031.Eng Value' 0
alias 'SPN641544.Eng Value' 0
alias 'SPN641545.Eng Value' 0
alias 'SPN641546.Eng Value' 0
alias 'SPN703502.Eng Value' 0
alias 'SPN768936.Eng Value' 0
set sub sc1
alias 'SPN794213.Eng Value' 0
alias 'SPN748382.Eng Value' 0
alias 'SPN748361.Eng Value' 0
set sub sc0
alias 'SPN896113.Eng Value' 0
set sub sw5
alias 'SPN895371.Eng Value' 0
set sub crb
wait 20000
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 1
alias 'SPN365075.Eng Value' 4000
wait 1000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
```

Scenario 2

```
echo
set sub crb
alias 'SPN365069.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365069.Scan Value' 0
wait 10
set sub sc1a
alias 'SPN769755.Eng Value' 0
alias 'SPN769756.Eng Value' 0
alias 'SPN769757.Eng Value' 0
alias 'SPN666031.Eng Value' 0
alias 'SPN641544.Eng Value' 0
alias 'SPN641545.Eng Value' 0
alias 'SPN641546.Eng Value' 0
alias 'SPN703502.Eng Value' 0
alias 'SPN768936.Eng Value' 0
set sub sc1
alias 'SPN794213.Eng Value' 0
alias 'SPN748382.Eng Value' 0
alias 'SPN748361.Eng Value' 0
set sub sc0
alias 'SPN896113.Eng Value' 0
set sub sw5
alias 'SPN895371.Eng Value' 0
```

Scenario 3

```
echo
set sub sc1
alias 'SPN794200.Scan Value' 1
set sub sc1a
alias 'SPN769747.Scan Value' 1
alias 'SPN769748.Scan Value' 1
alias 'SPN769749.Scan Value' 1
set sub crb
alias 'SPN365075.Eng Value' 4000
wait 1000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
wait 10
```

```
set sub sc1a
alias 'SPN769755.Eng Value' 0
alias 'SPN769756.Eng Value' 0
alias 'SPN769757.Eng Value' 0
alias 'SPN666031.Eng Value' 0
alias 'SPN641544.Eng Value' 0
alias 'SPN641545.Eng Value' 0
alias 'SPN641546.Eng Value' 0
alias 'SPN703502.Eng Value' 0
alias 'SPN768936.Eng Value' 0
set sub sc1
alias 'SPN794213.Eng Value' 0
alias 'SPN748382.Eng Value' 0
alias 'SPN748361.Eng Value' 0
set sub sc0
alias 'SPN896113.Eng Value' 0
set sub sw5
alias 'SPN895371.Eng Value' 0
set sub crb
wait 20000
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 1
alias 'SPN365075.Eng Value' 4000
wait 1000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
```

Scenario 4

```
echo
set sub sc1
alias 'SPN794211.Scan Value' 1
set sub sc1a
alias 'SPN769750.Scan Value' 1
set sub crb
wait 1000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365068.Scan Value' 0
wait 10
alias 'SPN365075.Eng Value' 0
set sub sc1a
```

```
alias 'SPN769755.Eng Value' 0
alias 'SPN769756.Eng Value' 0
alias 'SPN769757.Eng Value' 0
alias 'SPN666031.Eng Value' 0
alias 'SPN641544.Eng Value' 0
alias 'SPN641545.Eng Value' 0
alias 'SPN641546.Eng Value' 0
alias 'SPN703502.Eng Value' 0
alias 'SPN768936.Eng Value' 0
set sub sc1
alias 'SPN794213.Eng Value' 0
alias 'SPN748382.Eng Value' 0
alias 'SPN748361.Eng Value' 0
set sub sc0
alias 'SPN896113.Eng Value' 0
set sub sw5
alias 'SPN895371.Eng Value' 0
set sub crb
wait 20000
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 1
wait 1000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365068.Scan Value' 0
```

Scenario 5

```
echo
set sub sc1
alias 'SPN794203.Scan Value' 1
set sub sc1a
alias 'SPN769751.Scan Value' 1
set sub crb
alias 'SPN365069.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365069.Scan Value' 0
wait 10
alias 'SPN365075.Eng Value' 0
set sub sc1a
alias 'SPN769755.Eng Value' 0
alias 'SPN769756.Eng Value' 0
alias 'SPN769757.Eng Value' 0
```

```
alias 'SPN666031.Eng Value' 0
alias 'SPN641544.Eng Value' 0
alias 'SPN641545.Eng Value' 0
alias 'SPN641546.Eng Value' 0
alias 'SPN703502.Eng Value' 0
alias 'SPN768936.Eng Value' 0
set sub sc1
alias 'SPN794213.Eng Value' 0
alias 'SPN748382.Eng Value' 0
alias 'SPN748361.Eng Value' 0
set sub sc0
alias 'SPN896113.Eng Value' 0
set sub sw5
alias 'SPN895371.Eng Value' 0
```

<u>Scenario 6</u>

```
echo
set sub sc1
alias 'SPN794200.Scan Value' 1
set sub sc1a
alias 'SPN769747.Scan Value' 1
set sub crb
alias 'SPN365075.Eng Value' 4000
wait 1000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
wait 10
alias 'SPN365075.Eng Value' 0
set sub sc1a
alias 'SPN769755.Eng Value' 0
alias 'SPN769756.Eng Value' 0
alias 'SPN769757.Eng Value' 0
alias 'SPN666031.Eng Value' 0
alias 'SPN641544.Eng Value' 0
alias 'SPN641545.Eng Value' 0
alias 'SPN641546.Eng Value' 0
alias 'SPN703502.Eng Value' 0
alias 'SPN768936.Eng Value' 0
set sub sc1
alias 'SPN794213.Eng Value' 0
alias 'SPN748382.Eng Value' 0
```

```
alias 'SPN748361.Eng Value' 0
set sub sc0
alias 'SPN896113.Eng Value' 0
set sub sw5
alias 'SPN895371.Eng Value' 0
wait 5000
set sub crb
alias 'SPN365073.Scan Value' 1
wait 20000
```

Scenario 7

```
echo
set sub sc1
alias 'SPN794200.Scan Value' 1
set sub sc1a
alias 'SPN769747.Scan Value' 1
set sub crb
alias 'SPN365075.Eng Value' 4000
wait 1000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
wait 10
set sub sc1a
alias 'SPN769755.Eng Value' 0
alias 'SPN769756.Eng Value' 0
alias 'SPN769757.Eng Value' 0
alias 'SPN666031.Eng Value' 0
alias 'SPN641544.Eng Value' 0
alias 'SPN641545.Eng Value' 0
alias 'SPN641546.Eng Value' 0
alias 'SPN703502.Eng Value' 0
alias 'SPN768936.Eng Value' 0
set sub sc1
alias 'SPN794213.Eng Value' 0
alias 'SPN748382.Eng Value' 0
alias 'SPN748361.Eng Value' 0
set sub sc0
alias 'SPN896113.Eng Value' 0
set sub sw5
alias 'SPN895371.Eng Value' 0
set sub crb
wait 20000
```

```
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 1
alias 'SPN365075.Eng Value' 4000
wait 1000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
alias 'SPN365072.Scan Value' 1
```

Scenario 8

```
echo
set sub sc1
alias 'SPN794201.Scan Value' 1
wait 15000
alias 'SPN794200.Scan Value' 1
set sub sc1a
alias 'SPN769747.Scan Value' 1
set sub crb
alias 'SPN365075.Eng Value' 4000
wait 1000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
wait 10
set sub sc1a
alias 'SPN769755.Eng Value' 0
alias 'SPN769756.Eng Value' 0
alias 'SPN769757.Eng Value' 0
alias 'SPN666031.Eng Value' 0
alias 'SPN641544.Eng Value' 0
alias 'SPN641545.Eng Value' 0
alias 'SPN641546.Eng Value' 0
alias 'SPN703502.Eng Value' 0
alias 'SPN768936.Eng Value' 0
set sub sc1
alias 'SPN794213.Eng Value' 0
alias 'SPN748382.Eng Value' 0
alias 'SPN748361.Eng Value' 0
set sub sc0
alias 'SPN896113.Eng Value' 0
```

```
set sub sw5
alias 'SPN895371.Eng Value' 0
set sub crb
wait 20000
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 1
alias 'SPN365075.Eng Value' 4000
wait 1000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
```

Scenario 9

```
echo
set sub sc1
alias 'SPN794200.Scan Value' 1
set sub sc1a
alias 'SPN769747.Scan Value' 1
set sub crb
alias 'SPN365075.Eng Value' 4000
wait 1000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
wait 10
set sub sc1a
alias 'SPN769755.Eng Value' 0
alias 'SPN769756.Eng Value' 0
alias 'SPN769757.Eng Value' 0
alias 'SPN666031.Eng Value' 0
alias 'SPN641544.Eng Value' 0
alias 'SPN641545.Eng Value' 0
alias 'SPN641546.Eng Value' 0
alias 'SPN703502.Eng Value' 0
alias 'SPN768936.Eng Value' 0
set sub sc1
alias 'SPN794213.Eng Value' 0
alias 'SPN748382.Eng Value' 0
alias 'SPN748361.Eng Value' 0
set sub sc0
```

```
alias 'SPN896113.Eng Value' 0
set sub sw5
alias 'SPN895371.Eng Value' 0
wait 2000
set sub sc1
alias 'SPN794201.Scan Value' 1
set sub crb
wait 18000
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 1
alias 'SPN365075.Eng Value' 4000
wait 1000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
```

Scenario 10

```
echo
set sub sc1
alias 'SPN794213.Eng Value' 4000
set sub sc1a
alias 'SPN769748.Scan Value' 1
set sub crb
alias 'SPN365075.Eng Value' 4000
wait 1000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
set sub sc1
alias 'SPN794213.Eng Value' 0
alias 'SPN748382.Eng Value' 0
alias 'SPN748361.Eng Value' 0
set sub crb
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
wait 10
set sub sc1a
alias 'SPN769755.Eng Value' 0
alias 'SPN769756.Eng Value' 0
alias 'SPN769757.Eng Value' 0
alias 'SPN666031.Eng Value' 0
alias 'SPN641544.Eng Value' 0
```

```
alias 'SPN641545.Eng Value' 0
alias 'SPN641546.Eng Value' 0
alias 'SPN703502.Eng Value' 0
alias 'SPN768936.Eng Value' 0
set sub sc0
alias 'SPN896113.Eng Value' 0
set sub sw5
alias 'SPN895371.Eng Value' 0
set sub crb
wait 20000
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 1
alias 'SPN365075.Eng Value' 4000
set sub sc1
alias 'SPN794213.Eng Value' 4000
set sub crb
wait 1000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
set sub sc1
alias 'SPN794213.Eng Value' 0
```

Scenario 11

```
echo
set sub sc1
alias 'SPN794213.Eng Value' 780
set sub sc1a
alias 'SPN769756.Eng Value' 780
set sub crb
alias 'SPN365075.Eng Value' 4000
wait 1000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
set sub sc1
alias 'SPN794213.Eng Value' 0
alias 'SPN748382.Eng Value' 0
alias 'SPN748361.Eng Value' 0
set sub crb
alias 'SPN365075.Eng Value' 0
```

```
alias 'SPN365068.Scan Value' 0
wait 10
set sub sc1a
alias 'SPN769756.Eng Value' 0
alias 'SPN666031.Eng Value' 0
alias 'SPN641544.Eng Value' 0
alias 'SPN641545.Eng Value' 0
alias 'SPN641546.Eng Value' 0
alias 'SPN703502.Eng Value' 0
alias 'SPN768936.Eng Value' 0
set sub sc0
alias 'SPN896113.Eng Value' 0
set sub sw5
alias 'SPN895371.Eng Value' 0
set sub crb
wait 20000
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 1
alias 'SPN365075.Eng Value' 4000
set sub sc1
alias 'SPN794198.Scan Value' 1
alias 'SPN794213.Eng Value' 780
set sub sc1a
alias 'SPN769756.Eng Value' 780
set sub crb
wait 1000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
set sub sc1
alias 'SPN794213.Eng Value' 0
set sub sc1a
alias 'SPN769756.Eng Value' 0
```

Scenario 12

```
echo
set sub sc1
alias 'SPN794198.Scan Value' 1
wait 15000
set sub sc1a
alias 'SPN769756.Eng Value' 780
set sub crb
alias 'SPN365075.Eng Value' 4000
wait 1000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
set sub sc1
alias 'SPN794213.Eng Value' 0
alias 'SPN748382.Eng Value' 0
alias 'SPN748361.Eng Value' 0
set sub crb
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
wait 10
set sub sc1a
alias 'SPN769756.Eng Value' 0
alias 'SPN666031.Eng Value' 0
alias 'SPN641544.Eng Value' 0
alias 'SPN641545.Eng Value' 0
alias 'SPN641546.Eng Value' 0
alias 'SPN703502.Eng Value' 0
alias 'SPN768936.Eng Value' 0
set sub sc0
alias 'SPN896113.Eng Value' 0
set sub sw5
alias 'SPN895371.Eng Value' 0
set sub crb
wait 20000
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 1
alias 'SPN365075.Eng Value' 4000
set sub sc1a
alias 'SPN769756.Eng Value' 780
set sub crb
wait 1000
alias 'SPN365068.Scan Value' 1
```

```
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
set sub sc1a
alias 'SPN769756.Eng Value' 0
```

Scenario 13

```
echo
set sub sc1
alias 'NSL104728486.Scan Value' 0
alias 'NSL104728486.Scan Value' 1
wait 50
alias 'SPN793980.Eng Value' 234
alias 'SPN793967.Scan Value' 1
set sub sc1a
alias 'SPN769747.Scan Value' 1
alias 'SPN769748.Scan Value' 1
alias 'SPN769749.Scan Value' 1
set sub crb
alias 'SPN365075.Eng Value' 3070
wait 2500
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
wait 50
alias 'SPN365012.Eng Value' 1700
alias 'SPN365068.Scan Value' 0
set sub sc1
alias 'SPN793980.Eng Value' 234
set sub sc1a
alias 'SPN769755.Eng Value' 4
alias 'SPN769756.Eng Value' 4
alias 'SPN769757.Eng Value' 4
set sub crb
wait 20000
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 1
alias 'SPN365012.Eng Value' 500
alias 'SPN365075.Eng Value' 3070
set sub sc1
wait 50
alias 'SPN793980.Eng Value' 600
```

```
set sub crb
wait 2500
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365012.Eng Value' 1700
alias 'SPN365068.Scan Value' 0
set sub sc1
alias 'SPN793980.Eng Value' 234
set sub sc1a
alias 'SPN769755.Eng Value' 4
alias 'SPN769756.Eng Value' 4
alias 'SPN769757.Eng Value' 4
```

Scenario 14

```
echo
set sub sc1
alias 'NSL104728486.Scan Value' 0
alias 'NSL104728486.Scan Value' 1
wait 50
alias 'SPN793980.Eng Value' 52
wait 8000
alias 'SPN793967.Scan Value' 1
set sub sc1a
alias 'SPN769748.Scan Value' 1
set sub crb
alias 'SPN365075.Eng Value' 4000
alias 'SPN365012.Eng Value' 4000
wait 1200
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
wait 2
alias 'SPN365005.Scan Value' 1
alias 'NSL104059689.Scan Value' 0
alias 'NSL104059689.Scan Value' 2
alias 'SPN365012.Eng Value' 0
alias 'SPN365005.Scan Value' 0
wait 10
set sub sc1a
```

```
alias 'SPN769755.Eng Value' 0
alias 'SPN769756.Eng Value' 0
alias 'SPN769757.Eng Value' 0
alias 'SPN666031.Eng Value' 0
alias 'SPN641544.Eng Value' 0
alias 'SPN641545.Eng Value' 0
alias 'SPN641546.Eng Value' 0
alias 'SPN703502.Eng Value' 0
alias 'SPN769101.Eng Value' 0
alias 'SPN768936.Eng Value' 0
set sub sc1
alias 'SPN794213.Eng Value' 0
alias 'SPN748382.Eng Value' 0
alias 'SPN748361.Eng Value' 0
alias 'SPN793980.Eng Value' 0
set sub sc0
alias 'SPN896113.Eng Value' 0
set sub sw5
alias 'SPN895371.Eng Value' 0
set sub nc4a
alias 'SPN898439.Eng Value' 0
set sub mn1a
alias 'SPN688406.Eng Value' 0
set sub nc5
alias 'SPN861299.Eng Value' 0
set sub sc5
alias 'SPN828065.Eng Value' 0
set sub crb
wait 19998
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 1
alias 'SPN365075.Eng Value' 4000
wait 2
alias 'NSL104059689.Scan Value' 0
alias 'NSL104059689.Scan Value' 1
alias 'SPN365012.Eng Value' 4000
wait 1200
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
wait 2
alias 'SPN365005.Scan Value' 1
alias 'NSL104059689.Scan Value' 0
```

```
alias 'NSL104059689.Scan Value' 2
alias 'SPN365012.Eng Value' 0
alias 'SPN365005.Scan Value'
```

Scenario 15

```
echo
set sub sc1a
alias 'SPN769096.Scan Value' 1
set sub crb
alias 'SPN365006.Scan Value' 1
alias 'NSL104059689.Scan Value' 0
alias 'NSL104059689.Scan Value' 2
alias 'SPN365012.Eng Value' 0
alias 'SPN365006.Scan Value' 0
set sub sc1a
alias 'SPN769101.Eng Value' 0
set sub nc4a
alias 'SPN898439.Eng Value' 0
set sub mn1a
alias 'SPN688406.Eng Value' 0
set sub nc5
alias 'SPN861299.Eng Value' 0
set sub sc5
alias 'SPN828065.Eng Value' 0
```

Scenario 16

```
echo
set sub sc1a
alias 'SPN769096.Scan Value' 1
set sub crb
wait 1200
alias 'SPN365005.Scan Value' 1
alias 'NSL104059689.Scan Value' 0
alias 'NSL104059689.Scan Value' 2
alias 'SPN365012.Eng Value' 0
alias 'SPN365005.Scan Value' 0
set sub sc1a
alias 'SPN769101.Eng Value' 0
set sub nc4a
alias 'SPN898439.Eng Value' 0
```

```
set sub mn1a
alias 'SPN688406.Eng Value' 0
set sub nc5
alias 'SPN861299.Eng Value' 0
set sub sc5
alias 'SPN828065.Eng Value' 0
set sub crb
wait 20000
alias 'NSL104059689.Scan Value' 0
alias 'NSL104059689.Scan Value' 1
wait 1200
alias 'SPN365005.Scan Value' 1
alias 'NSL104059689.Scan Value' 0
alias 'NSL104059689.Scan Value' 2
alias 'SPN365005.Scan Value'
```

Scenario 17

```
echo
set sub sc1a
alias 'SPN769093.Scan Value' 1
alias 'SPN769095.Scan Value' 1
alias 'SPN769096.Scan Value' 1
set sub crb
wait 1200
alias 'SPN365005.Scan Value' 1
alias 'NSL104059689.Scan Value' 0
alias 'NSL104059689.Scan Value' 2
alias 'SPN365005.Scan Value' 0
wait 50
alias 'SPN365012.Eng Value' 0
set sub sc1a
alias 'SPN769100.Eng Value' 0
alias 'SPN769101.Eng Value' 0
alias 'SPN769102.Eng Value' 0
set sub nc4a
alias 'SPN898439.Eng Value' 0
set sub mn1a
alias 'SPN688405.Eng Value' 0
alias 'SPN688406.Eng Value' 0
alias 'SPN688407.Eng Value' 0
set sub nc5
alias 'SPN861299.Eng Value' 0
set sub sc5
```

```
alias 'SPN828065.Eng Value' 0
set sub crb
wait 20000
alias 'NSL104059689.Scan Value' 0
alias 'NSL104059689.Scan Value' 1
wait 1200
alias 'SPN365005.Scan Value' 1
alias 'NSL104059689.Scan Value' 0
alias 'NSL104059689.Scan Value' 2
alias 'SPN365005.Scan Value' 0
```

Scenario 18

```
echo
set sub sc1a
alias 'SPN769092.Scan Value' 1
set sub nc4a
wait 1200
alias 'SPN898434.Scan Value' 1
alias 'NSL100056783.Scan Value' 0
alias 'NSL100056783.Scan Value' 2
set sub crb
wait 400
alias 'SPN365005.Scan Value' 1
alias 'NSL104059689.Scan Value' 0
alias 'NSL104059689.Scan Value' 2
alias 'SPN365005.Scan Value' 0
wait 50
alias 'SPN365012.Eng Value' 0
set sub sc1a
alias 'SPN769100.Eng Value' 0
alias 'SPN769101.Eng Value' 0
alias 'SPN769102.Eng Value' 0
set sub nc4a
alias 'SPN898439.Eng Value' 0
set sub mn1a
alias 'SPN688405.Eng Value' 0
alias 'SPN688406.Eng Value' 0
alias 'SPN688407.Eng Value' 0
set sub nc5
alias 'SPN861299.Eng Value' 0
set sub sc5
alias 'SPN828065.Eng Value' 0
set sub crb
```

```
wait 9600
set sub nc4a
alias 'NSL100056783.Scan Value' 0
alias 'NSL100056783.Scan Value' 1
wait 10400
set sub crb
alias 'NSL104059689.Scan Value' 0
alias 'NSL104059689.Scan Value' 1
wait 1200
alias 'SPN365005.Scan Value' 1
alias 'NSL104059689.Scan Value' 0
alias 'NSL104059689.Scan Value' 2
alias 'SPN365005.Scan Value' 0
```

Scenario 19

```
echo
set sub sc1a
alias 'SPN769092.Scan Value' 1
set sub nc4a
wait 1200
alias 'SPN898434.Scan Value' 1
alias 'NSL100056783.Scan Value' 0
alias 'NSL100056783.Scan Value' 2
set sub crb
wait 400
alias 'SPN365005.Scan Value' 1
alias 'NSL104059689.Scan Value' 0
alias 'NSL104059689.Scan Value' 2
alias 'SPN365005.Scan Value' 0
wait 50
alias 'SPN365012.Eng Value' 0
set sub sc1a
alias 'SPN769100.Eng Value' 0
alias 'SPN769101.Eng Value' 0
alias 'SPN769102.Eng Value' 0
set sub nc4a
alias 'SPN898439.Eng Value' 0
set sub mn1a
alias 'SPN688405.Eng Value' 0
alias 'SPN688406.Eng Value' 0
alias 'SPN688407.Eng Value' 0
set sub nc5
alias 'SPN861299.Eng Value' 0
```

```
set sub sc5
alias 'SPN828065.Eng Value' 0
wait 9600
set sub nc4a
alias 'NSL100056783.Scan Value' 0
alias 'NSL100056783.Scan Value' 1
wait 10400
set sub crb
alias 'NSL104059689.Scan Value' 0
alias 'NSL104059689.Scan Value' 1
alias 'SPN365012.Eng Value' 295
set sub sc1a
alias 'SPN769101.Eng Value' 30
wait 1200
set sub nc4a
alias 'NSL100056783.Scan Value' 0
alias 'NSL100056783.Scan Value' 2
wait 10000
alias 'NSL100056783.Scan Value' 0
alias 'NSL100056783.Scan Value' 1
wait 1200
alias 'NSL100056783.Scan Value' 0
alias 'NSL100056783.Scan Value' 2
wait 10000
alias 'NSL100056783.Scan Value' 0
alias 'NSL100056783.Scan Value' 1
wait 1200
alias 'NSL100056783.Scan Value' 0
alias 'NSL100056783.Scan Value' 2
```

Scenario 20

```
echo
set sub sc1a
alias 'SPN769747.Scan Value' 1
alias 'SPN769748.Scan Value' 1
alias 'SPN769749.Scan Value' 1
set sub crb
alias 'SPN365075.Eng Value' 4000
alias 'SPN365012.Eng Value' 4000
wait 1000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
```

```
alias 'SPN365068.Scan Value' 0
wait 10
alias 'SPN365005.Scan Value' 1
alias 'NSL104059689.Scan Value' 0
alias 'NSL104059689.Scan Value' 2
alias 'SPN365012.Eng Value' 0
alias 'SPN365005.Scan Value' 0
wait 50
alias 'SPN365012.Eng Value' 0
set sub sc1a
alias 'SPN769100.Eng Value' 0
alias 'SPN769101.Eng Value' 0
alias 'SPN769102.Eng Value' 0
alias 'SPN769755.Eng Value' 0
alias 'SPN769756.Eng Value' 0
alias 'SPN769757.Eng Value' 0
alias 'SPN666031.Eng Value' 0
alias 'SPN641544.Eng Value' 0
alias 'SPN641545.Eng Value' 0
alias 'SPN641546.Eng Value' 0
alias 'SPN703502.Eng Value' 0
alias 'SPN768936.Eng Value' 0
set sub nc4a
alias 'SPN898439.Eng Value' 0
set sub mn1a
alias 'SPN688405.Eng Value' 0
alias 'SPN688406.Eng Value' 0
alias 'SPN688407.Eng Value' 0
set sub nc5
alias 'SPN861299.Eng Value' 0
set sub sc5
alias 'SPN828065.Eng Value' 0
set sub sc1
alias 'SPN794213.Eng Value' 0
alias 'SPN748382.Eng Value' 0
alias 'SPN748361.Eng Value' 0
set sub sc0
alias 'SPN896113.Eng Value' 0
set sub sw5
alias 'SPN895371.Eng Value' 0
set sub crb
wait 19900
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 1
alias 'SPN365075.Eng Value' 4000
```

```
wait 10
alias 'NSL104059689.Scan Value' 0
alias 'NSL104059689.Scan Value' 1
alias 'SPN365012.Eng Value' 4000
wait 990
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
alias 'SPN365005.Scan Value' 1
alias 'NSL104059689.Scan Value' 0
alias 'NSL104059689.Scan Value' 2
alias 'SPN365012.Eng Value' 0
alias 'SPN365005.Scan Value' 0
```

Scenario 21

```
echo
set sub sw5
alias 'SPN895368.Scan Value' 1
alias 'SPN895347.Scan Value' 1
set sub sc1
alias 'SPN794200.Scan Value' 1
set sub sc1a
alias 'SPN769747.Scan Value' 1
alias 'SPN769748.Scan Value' 1
alias 'SPN769749.Scan Value' 1
alias 'SPN769092.Scan Value' 1
alias 'SPN769093.Scan Value' 1
alias 'SPN769094.Scan Value' 1
set sub nc5
alias 'SPN861286.Scan Value' 1
set sub mn1a
alias 'SPN784317.Scan Value' 1
alias 'SPN784318.Scan Value' 1
alias 'SPN784319.Scan Value' 1
wait 1000
set sub sc0
alias 'SPN896109.Scan Value' 1
alias 'NSL100168539.Scan Value' 0
alias 'NSL100168539.Scan Value' 2
wait 100
set sub nc4a
alias 'SPN898434.Scan Value' 1
```

```
alias 'NSL100056783.Scan Value' 0
alias 'NSL100056783.Scan Value' 2
wait 50
alias 'SPN898439.Eng Value' 0
set sub mn1a
alias 'SPN688406.Eng Value' 0
set sub nc5
alias 'SPN861299.Eng Value' 0
set sub sc5
alias 'SPN828065.Eng Value' 0
set sub sc0
alias 'SPN896113.Eng Value' 0
set sub sw5
alias 'SPN895371.Eng Value' 0
set sub sc1a
alias 'SPN769101.Eng Value' 40
alias 'SPN703502.Eng Value' 85
alias 'SPN769756.Eng Value' 215
set sub sc1
alias 'SPN748361.Eng Value' 175
alias 'SPN794213.Eng Value' 195
set sub crb
alias 'SPN365012.Eng Value' 295
alias 'SPN365075.Eng Value' 1120
wait 9850
set sub sc0
alias 'NSL100168539.Scan Value' 0
alias 'NSL100168539.Scan Value' 1
wait 10
set sub nc4a
alias 'NSL100056783.Scan Value' 0
alias 'NSL100056783.Scan Value' 1
wait 1000
set sub sc0
alias 'NSL100168539.Scan Value' 0
alias 'NSL100168539.Scan Value' 2
wait 100
set sub nc4a
alias 'NSL100056783.Scan Value' 0
alias 'NSL100056783.Scan Value' 2
set sub sw5
alias 'NSL104221648.Scan Value' 0
alias 'NSL104221648.Scan Value' 2
set sub mn1a
alias 'NSL105659406.Scan Value' 0
```

```
alias 'NSL105659406.Scan Value' 2
wait 9990
set sub sc0
alias 'NSL100168539.Scan Value' 0
alias 'NSL100168539.Scan Value' 1
wait 10
set sub nc4a
alias 'NSL100056783.Scan Value' 0
alias 'NSL100056783.Scan Value' 1
wait 50
alias 'SPN898439.Eng Value' 10
set sub sc0
alias 'SPN896113.Eng Value' 65
```

Scenario 22

```
echo
set sub sc1a
alias 'SPN768959.Scan Value' 1
alias 'SPN768960.Scan Value' 1
alias 'SPN768961.Scan Value' 1
alias 'SPN769747.Scan Value' 1
alias 'SPN769748.Scan Value' 1
alias 'SPN769749.Scan Value' 1
set sub sc1
alias 'SPN794200.Scan Value' 1
wait 1000
alias 'SPN794472.Scan Value' 1
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 2
wait 50
set sub yta
alias 'SPN812032.Scan Value' 1
alias 'NSL5940623.Scan Value' 0
alias 'NSL5940623.Scan Value' 2
alias 'SPN812032.Scan Value' 0
wait 10
set sub sc1a
alias 'SPN769755.Eng Value' 40
alias 'SPN769756.Eng Value' 40
alias 'SPN769757.Eng Value' 40
alias 'SPN768967.Eng Value' 0
alias 'SPN768968.Eng Value' 0
alias 'SPN768969.Eng Value' 0
alias 'SPN768817.Eng Value' 0
```

```
alias 'SPN641545.Eng Value' 0
alias 'SPN703502.Eng Value' 0
alias 'SPN768936.Eng Value' 0
set sub sc1
alias 'SPN794213.Eng Value' 20
alias 'SPN793959.Eng Value' 0
alias 'SPN748361.Eng Value' 0
set sub sc0
alias 'SPN896113.Eng Value' 0
set sub sw5
alias 'SPN895371.Eng Value' 0
set sub crb
alias 'SPN365075.Eng Value' 224
set sub yta
alias 'SPN812042.Eng Value' 0
wait 9950
set sub sc1
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 1
wait 1000
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 2
wait 9950
set sub yta
alias 'NSL5940623.Scan Value' 0
alias 'NSL5940623.Scan Value' 1
wait 50
set sub sc1
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 1
wait 950
set sub yta
alias 'SPN812032.Scan Value' 1
alias 'NSL5940623.Scan Value' 0
alias 'NSL5940623.Scan Value' 2
alias 'SPN812032.Scan Value' 0
wait 50
set sub sc1
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 2
wait 10000
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 1
wait 1000
alias 'NSL103996172.Scan Value' 0
```

```
alias 'NSL103996172.Scan Value' 2
```

Scenario 23

```
echo
set sub sc1
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 2
set sub sc1a
alias 'SPN769755.Eng Value' 40
alias 'SPN769756.Eng Value' 40
alias 'SPN769757.Eng Value' 40
alias 'SPN641545.Eng Value' 0
alias 'SPN703502.Eng Value' 0
alias 'SPN768936.Eng Value' 0
set sub crb
alias 'SPN365075.Eng Value' 224
set sub sc1
alias 'SPN794213.Eng Value' 20
alias 'SPN748361.Eng Value' 0
set sub sc0
alias 'SPN896113.Eng Value' 0
set sub sw5
alias 'SPN895371.Eng Value' 0
```

Scenario 24

```
echo
set sub sc1
alias 'SPN794472.Scan Value' 1
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 2
set sub sc1a
alias 'SPN769755.Eng Value' 40
alias 'SPN769756.Eng Value' 40
alias 'SPN769757.Eng Value' 40
alias 'SPN641545.Eng Value' 0
alias 'SPN703502.Eng Value' 0
alias 'SPN768936.Eng Value' 0
set sub crb
alias 'SPN365075.Eng Value' 224
set sub sc0
alias 'SPN896113.Eng Value' 0
```

```
set sub sw5
alias 'SPN895371.Eng Value' 0
set sub sc1
alias 'SPN794213.Eng Value' 20
alias 'SPN748361.Eng Value' 0
wait 10000
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 1
wait 2400
alias 'SPN794474.Scan Value' 1
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 2
wait 10000
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 1
wait 2400
alias 'SPN794474.Scan Value' 1
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 2
wait 10000
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 1
wait 2400
alias 'SPN794474.Scan Value' 1
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 2
```

Scenario 25

```
echo
set sub sc1
alias 'SPN794472.Scan Value' 1
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 2
set sub sc1a
alias 'SPN769755.Eng Value' 40
alias 'SPN769756.Eng Value' 40
alias 'SPN769757.Eng Value' 40
alias 'SPN641545.Eng Value' 0
alias 'SPN703502.Eng Value' 0
alias 'SPN768936.Eng Value' 0
set sub crb
alias 'SPN365075.Eng Value' 224
set sub sc0
```

```
alias 'SPN896113.Eng Value' 0
set sub sw5
alias 'SPN895371.Eng Value' 0
set sub sc1
alias 'SPN794213.Eng Value' 20
alias 'SPN748361.Eng Value' 0
wait 10000
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 1
wait 5000
alias 'SPN794473.Scan Value' 1
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 2
```

Scenario 26

```
echo
set sub sc1
alias 'SPN748358.Scan Value' 1
wait 10000
alias 'SPN794200.Scan Value' 1
set sub sc1a
alias 'SPN769747.Scan Value' 1
alias 'SPN769748.Scan Value' 1
alias 'SPN769749.Scan Value' 1
set sub crb
alias 'SPN365075.Eng Value' 4000
wait 1000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
wait 20000
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 1
alias 'SPN365075.Eng Value' 4000
wait 1000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
```

Scenario 27

```
echo
set sub crb
alias 'SPN365012.Eng Value' 2082
set sub sc1a
alias 'SPN769101.Eng Value' 240
set sub nc4a
alias 'SPN898439.Eng Value' 100
wait 15000
set sub crb
alias 'SPN365075.Eng Value' 4000
wait 1000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
wait 10
set sub sc1a
alias 'SPN769755.Eng Value' 0
alias 'SPN769756.Eng Value' 0
alias 'SPN769757.Eng Value' 0
alias 'SPN666031.Eng Value' 0
alias 'SPN641544.Eng Value' 0
alias 'SPN641545.Eng Value' 0
alias 'SPN641546.Eng Value' 0
alias 'SPN703502.Eng Value' 0
alias 'SPN768936.Eng Value'0
set sub sc1
alias 'SPN794213.Eng Value' 0
alias 'SPN748382.Eng Value' 0
alias 'SPN748361.Eng Value' 0
set sub sc0
alias 'SPN896113.Eng Value' 0
set sub sw5
alias 'SPN895371.Eng Value' 0
set sub crb
wait 20000
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 1
alias 'SPN365075.Eng Value' 4000
wait 1000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
```

```
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
```

Scenario 28

```
echo
set sub sc0
alias 'SPN896113.Eng Value' 204
wait 15000
set sub sc1a
alias 'SPN769096.Scan Value' 1
set sub crb
alias 'SPN365006.Scan Value' 1
alias 'NSL104059689.Scan Value' 0
alias 'NSL104059689.Scan Value' 2
alias 'SPN365006.Scan Value' 0
wait 50
alias 'SPN365012.Eng Value' 0
set sub sc1a
alias 'SPN769100.Eng Value' 0
alias 'SPN769101.Eng Value' 0
alias 'SPN769102.Eng Value' 0
set sub nc4a
alias 'SPN898439.Eng Value' 0
set sub mn1a
alias 'SPN688405.Eng Value' 0
alias 'SPN688406.Eng Value' 0
alias 'SPN688407.Eng Value' 0
set sub nc5
alias 'SPN861299.Eng Value' 0
set sub sc5
alias 'SPN828065.Eng Value' 0
```

Scenario 29

```
echo
set sub sc1
alias 'SPN794200.Scan Value' 1
set sub sc1a
alias 'SPN769747.Scan Value' 1
alias 'SPN769748.Scan Value' 1
alias 'SPN769749.Scan Value' 1
wait 1000
set sub crb
alias 'SPN365068.Scan Value' 1
```

```
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
wait 10
set sub sc1a
alias 'SPN769755.Eng Value' 0
alias 'SPN769756.Eng Value' 0
alias 'SPN769757.Eng Value' 0
alias 'SPN666031.Eng Value' 0
alias 'SPN641544.Eng Value' 0
alias 'SPN641545.Eng Value' 0
alias 'SPN641546.Eng Value' 0
alias 'SPN703502.Eng Value' 0
alias 'SPN768936.Eng Value' 0
set sub sc1
alias 'SPN794213.Eng Value' 0
alias 'SPN748382.Eng Value' 0
alias 'SPN748361.Eng Value' 0
set sub sc0
alias 'SPN896113.Eng Value' 0
set sub sw5
alias 'SPN895371.Eng Value' 0
set sub crb
wait 20000
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 1
alias 'SPN365075.Eng Value' 4000
wait 1000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
```

Scenario 30

```
echo
set sub sc1
alias 'SPN794201.Scan Value' 1
wait 15000
alias 'SPN794200.Scan Value' 1
set sub sc1a
alias 'SPN769747.Scan Value' 1
alias 'SPN769748.Scan Value' 1
```

```
alias 'SPN769749.Scan Value' 1
wait 1000
set sub crb
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
wait 10
set sub sc1a
alias 'SPN769755.Eng Value' 0
alias 'SPN769756.Eng Value' 0
alias 'SPN769757.Eng Value' 0
alias 'SPN666031.Eng Value' 0
alias 'SPN641544.Eng Value' 0
alias 'SPN641545.Eng Value' 0
alias 'SPN641546.Eng Value' 0
alias 'SPN703502.Eng Value' 0
alias 'SPN768936.Eng Value' 0
set sub sc1
alias 'SPN794213.Eng Value' 0
alias 'SPN748382.Eng Value' 0
alias 'SPN748361.Eng Value' 0
set sub sc0
alias 'SPN896113.Eng Value' 0
set sub sw5
alias 'SPN895371.Eng Value' 0
set sub crb
wait 20000
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 1
alias 'SPN365075.Eng Value' 4000
wait 1000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
wait 5000
set sub sc1
alias 'SPN794201.Scan Value' 0
```

Scenario 31

```
echo
set sub sc1
alias 'SPN794200.Scan Value' 1
set sub sc1a
alias 'SPN769747.Scan Value' 1
alias 'SPN769748.Scan Value' 1
alias 'SPN769749.Scan Value' 1
wait 1000
set sub crb
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
wait 10
set sub sc1a
alias 'SPN769755.Eng Value' 0
alias 'SPN769756.Eng Value' 0
alias 'SPN769757.Eng Value' 0
alias 'SPN666031.Eng Value' 0
alias 'SPN641544.Eng Value' 0
alias 'SPN641545.Eng Value' 0
alias 'SPN641546.Eng Value' 0
alias 'SPN703502.Eng Value' 0
alias 'SPN768936.Eng Value' 0
set sub sc1
alias 'SPN794213.Eng Value' 0
alias 'SPN748382.Eng Value' 0
alias 'SPN748361.Eng Value' 0
set sub sc0
alias 'SPN896113.Eng Value' 0
set sub sw5
alias 'SPN895371.Eng Value' 0
set sub crb
wait 20000
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 1
alias 'SPN365075.Eng Value' 4000
wait 1000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
```

Scenario 32

```
echo
set sub sc1a
alias 'SPN769747.Scan Value' 1
alias 'SPN769748.Scan Value' 1
alias 'SPN769749.Scan Value' 1
set sub sc1
alias 'SPN794200.Scan Value' 1
alias 'SPN794472.Scan Value' 1
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 2
set sub sc1a
alias 'SPN769755.Eng Value' 40
alias 'SPN769756.Eng Value' 40
alias 'SPN769757.Eng Value' 40
alias 'SPN641545.Eng Value' 0
alias 'SPN703502.Eng Value' 0
alias 'SPN768936.Eng Value' 0
set sub crb
alias 'SPN365075.Eng Value' 224
set sub sc1
alias 'SPN794213.Eng Value' 20
alias 'SPN748361.Eng Value' 0
set sub sc0
alias 'SPN896113.Eng Value' 0
set sub sw5
alias 'SPN895371.Eng Value' 0
set sub sc1
wait 10000
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 1
wait 1000
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 2
wait 10000
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 1
wait 17000
alias 'SPN794472.Scan Value' 0
alias 'SPN794200.Scan Value' 0
set sub sc1a
alias 'SPN769747.Scan Value' 0
alias 'SPN769748.Scan Value' 0
alias 'SPN769749.Scan Value' 0
wait 1000
```

```
set sub sc1a
alias 'SPN769747.Scan Value' 1
alias 'SPN769748.Scan Value' 1
alias 'SPN769749.Scan Value' 1
set sub sc1
alias 'SPN794200.Scan Value' 1
alias 'SPN794472.Scan Value' 1
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 2
wait 10000
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 1
wait 1000
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 2
wait 10000
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 1
wait 1000
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 2
wait 10000
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 1
wait 1000
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 2
```

Scenario 33

```
echo
set sub crb
alias 'SPN365075.Eng Value' 4000
wait 1000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0

wait 10
set sub sc1a
alias 'SPN769755.Eng Value' 0
alias 'SPN769756.Eng Value' 0
```

```
alias 'SPN769757.Eng Value' 0
alias 'SPN666031.Eng Value' 0
alias 'SPN641544.Eng Value' 0
alias 'SPN641545.Eng Value' 0
alias 'SPN641546.Eng Value' 0
alias 'SPN703502.Eng Value' 0
alias 'SPN768936.Eng Value' 0
set sub sc1
alias 'SPN794213.Eng Value' 0
alias 'SPN748382.Eng Value' 0
alias 'SPN748361.Eng Value' 0
set sub sc0
alias 'SPN896113.Eng Value' 0
set sub sw5
alias 'SPN895371.Eng Value' 0
set sub crb
wait 20000
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 1
wait 100
alias 'SPN365075.Eng Value' 1200
set sub sc1
alias 'SPN794213.Eng Value' 210
alias 'SPN748382.Eng Value' 5
alias 'SPN748361.Eng Value' 190
set sub sc0
alias 'SPN896113.Eng Value' 80
set sub sc1a
alias 'SPN769755.Eng Value' 230
alias 'SPN769756.Eng Value' 230
alias 'SPN769757.Eng Value' 230
alias 'SPN666031.Eng Value' 10
alias 'SPN703502.Eng Value' 100
alias 'SPN641544.Eng Value' 6
alias 'SPN641545.Eng Value' 6
alias 'SPN641546.Eng Value' 6
set sub sw5
alias 'SPN895371.Eng Value' 15
set sub crb
wait 11000
alias 'SPN365075.Eng Value' 4000
wait 1000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
```

```
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
wait 10
set sub sc1a
alias 'SPN769755.Eng Value' 0
alias 'SPN769756.Eng Value' 0
alias 'SPN769757.Eng Value' 0
alias 'SPN666031.Eng Value' 0
alias 'SPN641544.Eng Value' 0
alias 'SPN641545.Eng Value' 0
alias 'SPN641546.Eng Value' 0
alias 'SPN703502.Eng Value' 0
set sub sc1
alias 'SPN794213.Eng Value' 0
alias 'SPN748382.Eng Value' 0
alias 'SPN748361.Eng Value' 0
set sub sc0
alias 'SPN896113.Eng Value' 0
set sub sw5
alias 'SPN895371.Eng Value' 0
set sub crb
wait 20000
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 1
alias 'SPN365075.Eng Value' 4000
wait 1000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
```

Scenario 34

```
echo
set sub nc5
alias 'SPN861286.Scan Value' 1
set sub mn1a
alias 'SPN784317.Scan Value' 1
alias 'SPN784318.Scan Value' 1
alias 'SPN784319.Scan Value' 1
wait 1000
set sub nc4a
alias 'SPN898434.Scan Value' 1
```

```
alias 'NSL100056783.Scan Value' 0
alias 'NSL100056783.Scan Value' 2
alias 'SPN898439.Eng Value' 0
set sub mn1a
alias 'SPN688406.Eng Value' 0
set sub nc5
alias 'SPN861299.Eng Value' 0
set sub sc5
alias 'SPN828065.Eng Value' 0
set sub sc1a
alias 'SPN769101.Eng Value' 30
set sub crb
alias 'SPN365012.Eng Value' 295
set sub nc4a
wait 10000
alias 'NSL100056783.Scan Value' 0
alias 'NSL100056783.Scan Value' 1
wait 1000
alias 'NSL100056783.Scan Value' 0
alias 'NSL100056783.Scan Value' 2
wait 10000
alias 'NSL100056783.Scan Value' 0
alias 'NSL100056783.Scan Value' 1
wait 1000
alias 'NSL100056783.Scan Value' 0
alias 'NSL100056783.Scan Value' 2
wait 10000
alias 'NSL100056783.Scan Value' 0
alias 'NSL100056783.Scan Value' 1
wait 1000
alias 'NSL100056783.Scan Value' 0
alias 'NSL100056783.Scan Value' 2
```

Scenario 35

```
echo
set sub sc1a
alias 'SPN769747.Scan Value' 1
alias 'SPN769748.Scan Value' 1
alias 'SPN769749.Scan Value' 1
set sub sc1
alias 'SPN794200.Scan Value' 1
wait 1000
alias 'SPN794472.Scan Value' 1
wait 400
```

```
set sub crb
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
wait 10
set sub sc1a
alias 'SPN769755.Eng Value' 0
alias 'SPN769756.Eng Value' 0
alias 'SPN769757.Eng Value' 0
alias 'SPN666031.Eng Value' 0
alias 'SPN641544.Eng Value' 0
alias 'SPN641545.Eng Value' 0
alias 'SPN641546.Eng Value' 0
alias 'SPN703502.Eng Value' 0
alias 'SPN768936.Eng Value' 0
set sub sc1
alias 'SPN794213.Eng Value' 0
alias 'SPN748382.Eng Value' 0
alias 'SPN748361.Eng Value' 0
set sub sc0
alias 'SPN896113.Eng Value' 0
set sub sw5
alias 'SPN895371.Eng Value' 0
set sub crb
wait 20000
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 1
wait 1000
alias 'SPN794472.Scan Value' 1
wait 400
set sub crb
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365068.Scan Value' 0
```

Scenario 36

```
echo
set sub sc5b
alias 'NSL105862948.Scan Value' 0
alias 'NSL105862948.Scan Value' 1
wait 5000
```

```
set sub sc0
alias 'NSL100168539.Scan Value' 0
alias 'NSL100168539.Scan Value' 2
wait 50
alias 'SPN896113.Eng Value' 0
set sub sw5
alias 'SPN895371.Eng Value' 80
set sub sc5b
alias 'SPN825493.Eng Value' 95
set sub sc1a
alias 'SPN769100.Eng Value' 265
alias 'SPN769101.Eng Value' 265
alias 'SPN769102.Eng Value' 265
set sub nc4a
alias 'SPN898439.Eng Value' 195
set sub mn1a
alias 'SPN688406.Eng Value' 155
set sub nc5
alias 'SPN861299.Eng Value' 125
set sub sc5
alias 'SPN828065.Eng Value' 105
set sub crb
alias 'SPN365012.Eng Value' 1862
wait 4000
set sub sc1a
alias 'NSL105791413.Scan Value' 0
alias 'NSL105791413.Scan Value' 2
wait 50
alias 'SPN703502.Eng Value' 0
alias 'SPN769755.Eng Value' 130
alias 'SPN769756.Eng Value' 130
alias 'SPN769757.Eng Value' 130
set sub sc1
alias 'SPN748361.Eng Value' 90
alias 'SPN794213.Eng Value' 110
set sub crb
alias 'SPN365075.Eng Value' 687
wait 10000
set sub sc1
alias 'SPN794200.Scan Value' 1
set sub sc1a
alias 'SPN769747.Scan Value' 1
alias 'SPN769748.Scan Value' 1
alias 'SPN769749.Scan Value' 1
set sub crb
```

```
alias 'SPN365075.Eng Value' 4000
wait 1000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
wait 10
set sub sc1a
alias 'SPN769755.Eng Value' 0
alias 'SPN769756.Eng Value' 0
alias 'SPN769757.Eng Value' 0
alias 'SPN666031.Eng Value' 0
alias 'SPN641544.Eng Value' 0
alias 'SPN641545.Eng Value' 0
alias 'SPN641546.Eng Value' 0
alias 'SPN768936.Eng Value' 0
set sub sc1
alias 'SPN794213.Eng Value' 0
alias 'SPN748382.Eng Value' 0
alias 'SPN748361.Eng Value' 0
set sub crb
wait 20000
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 1
alias 'SPN365075.Eng Value' 4000
wait 1000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
```

Scenario 37

```
echo
set sub mn1a
alias 'NSL105659406.Scan Value' 0
alias 'NSL105659406.Scan Value' 2
wait 50
alias 'SPN688406.Eng Value' 0
set sub sc1a
alias 'SPN769100.Eng Value' 40
alias 'SPN769101.Eng Value' 40
alias 'SPN769102.Eng Value' 40
set sub nc4a
```

```
alias 'SPN898439.Eng Value' 10
set sub nc5
alias 'SPN861299.Eng Value' 0
set sub sc5
alias 'SPN828065.Eng Value' 0
set sub crb
alias 'SPN365012.Eng Value' 295
wait 10000
set sub sc1a
alias 'SPN769747.Scan Value' 1
alias 'SPN769748.Scan Value' 1
alias 'SPN769749.Scan Value' 1
set sub sc1
alias 'SPN794200.Scan Value' 1
alias 'SPN794472.Scan Value' 1
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 2
set sub sc1a
alias 'SPN769755.Eng Value' 40
alias 'SPN769756.Eng Value' 40
alias 'SPN769757.Eng Value' 40
alias 'SPN641545.Eng Value' 0
alias 'SPN703502.Eng Value' 0
alias 'SPN768936.Eng Value' 0
set sub crb
alias 'SPN365075.Eng Value' 224
set sub sc1
alias 'SPN794213.Eng Value' 20
alias 'SPN748361.Eng Value' 0
set sub sc0
alias 'SPN896113.Eng Value' 0
set sub sw5
alias 'SPN895371.Eng Value' 0
set sub sc1
wait 10000
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 1
wait 1000
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 2
wait 10000
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 1
wait 1000
alias 'NSL103996172.Scan Value' 0
```

```
alias 'NSL103996172.Scan Value' 2
wait 10000
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 1
wait 1000
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 2
```

Scenario 38

```
echo
set sub sc1
alias 'NSL104728486.Scan Value' 0
alias 'NSL104728486.Scan Value' 1
wait 50
alias 'SPN793980.Eng Value' 52
wait 11000
set sub yta
alias 'SPN812032.Scan Value' 1
alias 'NSL5940623.Scan Value' 0
alias 'NSL5940623.Scan Value' 2
alias 'SPN812032.Scan Value' 0
alias 'SPN812042.Eng Value' 0
set sub sc1a
alias 'SPN768967.Eng Value' 0
alias 'SPN768968.Eng Value' 0
alias 'SPN768969.Eng Value' 0
alias 'SPN768817.Eng Value' 0
set sub sc1
alias 'SPN793959.Eng Value' 0
wait 20000
set sub yta
alias 'NSL5940623.Scan Value' 0
alias 'NSL5940623.Scan Value' 1
wait 1000
set sub yta
alias 'SPN812032.Scan Value' 1
alias 'NSL5940623.Scan Value' 0
alias 'NSL5940623.Scan Value' 2
alias 'SPN812032.Scan Value' 0
```

Scenario 39

```
echo
set sub sc5b
alias 'SPN825479.Scan Value' 1
wait 45000
set sub sc1
alias 'SPN794200.Scan Value' 1
set sub sc1a
alias 'SPN769747.Scan Value' 1
alias 'SPN769748.Scan Value' 1
alias 'SPN769749.Scan Value' 1
set sub crb
alias 'SPN365075.Eng Value' 4000
wait 1000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
wait 10
set sub sc1a
alias 'SPN769755.Eng Value' 0
alias 'SPN769756.Eng Value' 0
alias 'SPN769757.Eng Value' 0
alias 'SPN666031.Eng Value' 0
alias 'SPN641544.Eng Value' 0
alias 'SPN641545.Eng Value' 0
alias 'SPN641546.Eng Value' 0
alias 'SPN703502.Eng Value' 0
alias 'SPN768936.Eng Value' 0
set sub sc1
alias 'SPN794213.Eng Value' 0
alias 'SPN748382.Eng Value' 0
alias 'SPN748361.Eng Value' 0
set sub sc0
alias 'SPN896113.Eng Value' 0
set sub sw5
alias 'SPN895371.Eng Value' 0
set sub crb
wait 20000
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 1
alias 'SPN365075.Eng Value' 4000
wait 1000
alias 'SPN365068.Scan Value' 1
```

```
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
```

Scenario 40

```
echo
set sub sc5b
alias 'SPN825479.Scan Value' 1
set sub sc1a
alias 'SPN672223.Scan Value' 1
wait 45000
set sub sc1
alias 'SPN794200.Scan Value' 1
set sub sc1a
alias 'SPN769747.Scan Value' 1
alias 'SPN769748.Scan Value' 1
alias 'SPN769749.Scan Value' 1
set sub crb
alias 'SPN365075.Eng Value' 4000
wait 1000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
wait 10
set sub sc1a
alias 'SPN769755.Eng Value' 0
alias 'SPN769756.Eng Value' 0
alias 'SPN769757.Eng Value' 0
alias 'SPN666031.Eng Value' 0
alias 'SPN641544.Eng Value' 0
alias 'SPN641545.Eng Value' 0
alias 'SPN641546.Eng Value' 0
alias 'SPN703502.Eng Value' 0
alias 'SPN768936.Eng Value' 0
set sub sc1
alias 'SPN794213.Eng Value' 0
alias 'SPN748382.Eng Value' 0
alias 'SPN748361.Eng Value' 0
set sub sc0
alias 'SPN896113.Eng Value' 0
set sub sw5
alias 'SPN895371.Eng Value' 0
```

```
set sub crb
wait 20000
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 1
alias 'SPN365075.Eng Value' 4000
wait 1000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
```

Scenario 41

```
echo
set sub sc1
alias 'SPN794200.Scan Value' 1
set sub sc1a
alias 'SPN769747.Scan Value' 1
alias 'SPN769748.Scan Value' 1
alias 'SPN769749.Scan Value' 1
set sub crb
alias 'SPN365075.Eng Value' 4000
wait 1000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
wait 10
set sub sc1a
alias 'SPN769755.Eng Value' 0
alias 'SPN769756.Eng Value' 0
alias 'SPN769757.Eng Value' 0
alias 'SPN666031.Eng Value' 0
alias 'SPN641544.Eng Value' 0
alias 'SPN641545.Eng Value' 0
alias 'SPN641546.Eng Value' 0
alias 'SPN703502.Eng Value' 0
alias 'SPN768936.Eng Value' 0
set sub sc1
alias 'SPN794213.Eng Value' 0
alias 'SPN748382.Eng Value' 0
alias 'SPN748361.Eng Value' 0
set sub sc0
```

```
alias 'SPN896113.Eng Value' 0
set sub sw5
alias 'SPN895371.Eng Value' 0
wait 5000
set sub sc5b
alias 'SPN825479.Scan Value' 1
set sub crb
wait 15000
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 1
alias 'SPN365075.Eng Value' 4000
wait 1000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
```

Scenario 42

```
echo
set sub sc1
alias 'SPN794200.Scan Value' 1
set sub sc1a
alias 'SPN769747.Scan Value' 1
alias 'SPN769748.Scan Value' 1
alias 'SPN769749.Scan Value' 1
set sub crb
alias 'SPN365075.Eng Value' 4000
wait 1000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
wait 10
set sub sc1a
alias 'SPN769755.Eng Value' 0
alias 'SPN769756.Eng Value' 0
alias 'SPN769757.Eng Value' 0
alias 'SPN666031.Eng Value' 0
alias 'SPN641544.Eng Value' 0
alias 'SPN641545.Eng Value' 0
alias 'SPN641546.Eng Value' 0
alias 'SPN703502.Eng Value' 0
```

```
alias 'SPN768936.Eng Value' 0
set sub sc1
alias 'SPN794213.Eng Value' 0
alias 'SPN748382.Eng Value' 0
alias 'SPN748361.Eng Value' 0
set sub sc0
alias 'SPN896113.Eng Value' 0
set sub sw5
alias 'SPN895371.Eng Value' 0
```

<u>Scenario 43</u>

```
echo
set sub sc1
alias 'SPN794218.Eng Value' 2000
wait 15000
alias 'SPN794200.Scan Value' 1
set sub sc1a
alias 'SPN769747.Scan Value' 1
alias 'SPN769748.Scan Value' 1
alias 'SPN769749.Scan Value' 1
wait 1000
set sub crb
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
wait 10
set sub sc1a
alias 'SPN769755.Eng Value' 0
alias 'SPN769756.Eng Value' 0
alias 'SPN769757.Eng Value' 0
alias 'SPN666031.Eng Value' 0
alias 'SPN641544.Eng Value' 0
alias 'SPN641545.Eng Value' 0
alias 'SPN641546.Eng Value' 0
alias 'SPN703502.Eng Value' 0
alias 'SPN768936.Eng Value' 0
set sub sc1
alias 'SPN794213.Eng Value' 0
alias 'SPN748382.Eng Value' 0
alias 'SPN748361.Eng Value' 0
set sub sc0
alias 'SPN896113.Eng Value' 0
```

```
set sub sw5
alias 'SPN895371.Eng Value' 0
set sub crb
wait 20000
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 1
alias 'SPN365075.Eng Value' 4000
wait 1000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
```

Scenario 44

```
echo
set sub sc1
alias 'SPN794200.Scan Value' 1
set sub sc1a
alias 'SPN769747.Scan Value' 1
alias 'SPN769748.Scan Value' 1
alias 'SPN769749.Scan Value' 1
wait 1000
set sub crb
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
wait 10
set sub sc1a
alias 'SPN769755.Eng Value' 0
alias 'SPN769756.Eng Value' 0
alias 'SPN769757.Eng Value' 0
alias 'SPN666031.Eng Value' 0
alias 'SPN641544.Eng Value' 0
alias 'SPN641545.Eng Value' 0
alias 'SPN641546.Eng Value' 0
alias 'SPN703502.Eng Value' 0
alias 'SPN768936.Eng Value' 0
set sub sc1
alias 'SPN794213.Eng Value' 0
alias 'SPN748382.Eng Value' 0
alias 'SPN748361.Eng Value' 0
```

```
set sub sc0
alias 'SPN896113.Eng Value' 0
set sub sw5
alias 'SPN895371.Eng Value' 0
set sub crb
wait 20000
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 1
alias 'SPN365075.Eng Value' 4000
wait 1000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
```

Scenario 45

```
echo
set sub sc1
alias 'SPN794200.Scan Value' 1
set sub sc1a
alias 'SPN769747.Scan Value' 1
alias 'SPN769748.Scan Value' 1
alias 'SPN769749.Scan Value' 1
wait 1000
set sub crb
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
wait 10
set sub sc1a
alias 'SPN769755.Eng Value' 0
alias 'SPN769756.Eng Value' 0
alias 'SPN769757.Eng Value' 0
alias 'SPN666031.Eng Value' 0
alias 'SPN641544.Eng Value' 0
alias 'SPN641545.Eng Value' 0
alias 'SPN641546.Eng Value' 0
alias 'SPN703502.Eng Value' 0
alias 'SPN768936.Eng Value' 0
set sub sc1
alias 'SPN794213.Eng Value' 0
alias 'SPN748382.Eng Value' 0
```

```
alias 'SPN748361.Eng Value' 0
set sub sc0
alias 'SPN896113.Eng Value' 0
set sub sw5
alias 'SPN895371.Eng Value' 0
set sub crb
wait 20000
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 1
alias 'SPN365075.Eng Value' 4000
wait 1000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365068.Scan Value' 0
alias 'SPN365075.Eng Value' 0
wait 10000
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 1
alias 'SPN365075.Eng Value' 4000
wait 1000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365068.Scan Value' 0
alias 'SPN365075.Eng Value' 0
```

Scenario 46

```
echo
set sub sc5b
alias 'NSL105862948.Scan Value' 0
alias 'NSL105862948.Scan Value' 1
wait 4000
set sub sc1
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 2
wait 100
alias 'SPN748361.Eng Value' 0
set sub sc5b
alias 'SPN825493.Eng Value' 120
set sub sc5
alias 'SPN828065.Eng Value' 130
set sub nc5
alias 'SPN861299.Eng Value' 140
```

```
set sub mn1a
alias 'SPN688406.Eng Value' 150
set sub nc4a
alias 'SPN898439.Eng Value' 170
set sub sc1a
alias 'SPN769101.Eng Value' 200
set sub crb
alias 'SPN365012.Eng Value' 1200
alias 'SPN365075.Eng Value' 450

set sub sw5
alias 'SPN895371.Eng Value' 105
set sub sc0
alias 'SPN896113.Eng Value' 40
set sub sc1a
alias 'SPN703502.Eng Value' 20

set sub sc1
alias 'SPN794213.Eng Value' 50
set sub sc1a
alias 'SPN769755.Eng Value' 70
alias 'SPN769756.Eng Value' 70
alias 'SPN769757.Eng Value' 70

wait 30000
alias 'SPN794200.Scan Value' 1
set sub sc1a
alias 'SPN769747.Scan Value' 1
alias 'SPN769748.Scan Value' 1
alias 'SPN769749.Scan Value' 1
wait 1000
set sub crb
alias 'SPN365075.Eng Value' 4000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
wait 10
set sub sc1a
alias 'SPN769755.Eng Value' 0
alias 'SPN769756.Eng Value' 0
alias 'SPN769757.Eng Value' 0
alias 'SPN666031.Eng Value' 0
alias 'SPN641544.Eng Value' 0
```

```
alias 'SPN641545.Eng Value' 0
alias 'SPN641546.Eng Value' 0
alias 'SPN703502.Eng Value' 0
alias 'SPN768936.Eng Value' 0
set sub sc1
alias 'SPN794213.Eng Value' 0
alias 'SPN748382.Eng Value' 0
alias 'SPN748361.Eng Value' 0
set sub sc0
alias 'SPN896113.Eng Value' 0
set sub sw5
alias 'SPN895371.Eng Value' 0
set sub crb
wait 20000
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 1
alias 'SPN365075.Eng Value' 4000
wait 1000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
```

Scenario 47

To be simulated using other techniques.

Scenario 48

```
echo
set sub sc1
alias 'SPN794200.Scan Value' 1
set sub sc1a
alias 'SPN769747.Scan Value' 1
alias 'SPN769748.Scan Value' 1
alias 'SPN769749.Scan Value' 1
wait 1000
set sub crb
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
wait 10
set sub sc1a
```

```
alias 'SPN769755.Eng Value' 0
alias 'SPN769756.Eng Value' 0
alias 'SPN769757.Eng Value' 0
alias 'SPN666031.Eng Value' 0
alias 'SPN641544.Eng Value' 0
alias 'SPN641545.Eng Value' 0
alias 'SPN641546.Eng Value' 0
alias 'SPN703502.Eng Value' 0
alias 'SPN768936.Eng Value' 0
set sub sc1
alias 'SPN794213.Eng Value' 0
alias 'SPN748382.Eng Value' 0
alias 'SPN748361.Eng Value' 0
set sub sc0
alias 'SPN896113.Eng Value' 0
set sub sw5
alias 'SPN895371.Eng Value' 0
set sub crb
wait 20000
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 1
alias 'SPN365075.Eng Value' 4000
wait 1000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365068.Scan Value' 0
alias 'SPN365075.Eng Value' 0
```

Scenario 49

```
echo
set sub sc1
alias 'SPN794200.Scan Value' 1
set sub sc1a
alias 'SPN769747.Scan Value' 1
alias 'SPN769748.Scan Value' 1
alias 'SPN769749.Scan Value' 1
wait 1000
set sub crb
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
```

```
wait 10
set sub sc1a
alias 'SPN769755.Eng Value' 0
alias 'SPN769756.Eng Value' 0
alias 'SPN769757.Eng Value' 0
alias 'SPN666031.Eng Value' 0
alias 'SPN641544.Eng Value' 0
alias 'SPN641545.Eng Value' 0
alias 'SPN641546.Eng Value' 0
alias 'SPN703502.Eng Value' 0
alias 'SPN768936.Eng Value' 0
set sub sc1
alias 'SPN794213.Eng Value' 0
alias 'SPN748382.Eng Value' 0
alias 'SPN748361.Eng Value' 0
set sub sc0
alias 'SPN896113.Eng Value' 0
set sub sw5
alias 'SPN895371.Eng Value' 0
set sub crb
wait 20000
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 1
alias 'SPN365075.Eng Value' 4000
wait 1000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365068.Scan Value' 0
alias 'SPN365075.Eng Value' 0
```

Scenario 50

```
echo
set sub crb
alias 'SPN365075.Eng Value' 4000
wait 1000
alias 'SPN365068.Scan Value' 1
wait 400
alias 'SPN365409.Scan Value' 1
alias 'SPN365423.Scan Value' 1
alias 'NSL104059697.Scan Value' 0
alias 'NSL104059697.Scan Value' 2
alias 'NSL104059698.Scan Value' 0
alias 'NSL104059698.Scan Value' 2
```

```
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
alias 'SPN365428.Eng Value' 0
alias 'SPN365414.Eng Value' 0
alias 'SPN365012.Eng Value' 0
alias 'SPN365409.Scan Value' 0
alias 'SPN365423.Scan Value' 0
wait 10
set sub sc1a
alias 'SPN769755.Eng Value' 0
alias 'SPN769756.Eng Value' 0
alias 'SPN769757.Eng Value' 0
alias 'SPN666031.Eng Value' 0
alias 'SPN641544.Eng Value' 0
alias 'SPN641545.Eng Value' 0
alias 'SPN641546.Eng Value' 0
alias 'SPN703502.Eng Value' 0
alias 'SPN768936.Eng Value' 0
set sub sc1
alias 'SPN794213.Eng Value' 0
alias 'SPN748382.Eng Value' 0
alias 'SPN748361.Eng Value' 0
set sub sc0
alias 'SPN896113.Eng Value' 0
set sub sw5
alias 'SPN895371.Eng Value' 0
alias 'SPN365012.Eng Value' 0
set sub sc1a
alias 'SPN769100.Eng Value' 0
alias 'SPN769101.Eng Value' 0
alias 'SPN769102.Eng Value' 0
set sub nc4a
alias 'SPN898439.Eng Value' 0
set sub mn1a
alias 'SPN688405.Eng Value' 0
alias 'SPN688406.Eng Value' 0
alias 'SPN688407.Eng Value' 0
set sub nc5
alias 'SPN861299.Eng Value' 0
set sub sc5
alias 'SPN828065.Eng Value' 0
```

Scenario 51

```
echo
set sub crb
alias 'NSL104059696.Scan Value' 0
alias 'NSL104059696.Scan Value' 2
wait 10000
alias 'SPN365068.Scan Value' 1
wait 400
alias 'SPN365024.Scan Value' 1
alias 'NSL104059691.Scan Value' 0
alias 'NSL104059691.Scan Value' 2
wait 10
alias 'SPN365024.Scan Value' 0
wait 230
alias 'SPN365423.Scan Value' 1
alias 'NSL104059698.Scan Value' 0
alias 'NSL104059698.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
alias 'SPN365428.Eng Value' 0
alias 'SPN365012.Eng Value' 0
alias 'SPN365409.Scan Value' 0
alias 'SPN365423.Scan Value' 0
wait 10
set sub sc1a
alias 'SPN769755.Eng Value' 0
alias 'SPN769756.Eng Value' 0
alias 'SPN769757.Eng Value' 0
alias 'SPN666031.Eng Value' 0
alias 'SPN641544.Eng Value' 0
alias 'SPN641545.Eng Value' 0
alias 'SPN641546.Eng Value' 0
alias 'SPN703502.Eng Value' 0
alias 'SPN768936.Eng Value' 0
set sub sc1
alias 'SPN794213.Eng Value' 0
alias 'SPN748382.Eng Value' 0
alias 'SPN748361.Eng Value' 0
set sub sc0
alias 'SPN896113.Eng Value' 0
set sub sw5
alias 'SPN895371.Eng Value' 0
alias 'SPN365012.Eng Value' 0
set sub sc1a
alias 'SPN769100.Eng Value' 0
```

```
alias 'SPN769101.Eng Value' 0
alias 'SPN769102.Eng Value' 0
set sub nc4a
alias 'SPN898439.Eng Value' 0
set sub mn1a
alias 'SPN688405.Eng Value' 0
alias 'SPN688406.Eng Value' 0
alias 'SPN688407.Eng Value' 0
set sub nc5
alias 'SPN861299.Eng Value' 0
set sub sc5
alias 'SPN828065.Eng Value' 0
```

Scenario 52

```
echo
set sub mn1a
alias 'NSL105659406.Scan Value' 0
alias 'NSL105659406.Scan Value' 2
wait 50
alias 'SPN688406.Eng Value' 0
set sub sc1a
alias 'SPN769100.Eng Value' 40
alias 'SPN769101.Eng Value' 40
alias 'SPN769102.Eng Value' 40
set sub nc4a
alias 'SPN898439.Eng Value' 10
set sub nc5
alias 'SPN861299.Eng Value' 0
set sub sc5
alias 'SPN828065.Eng Value' 0
set sub crb
alias 'SPN365012.Eng Value' 295
wait 10000
echo
set sub sc1
alias 'SPN794200.Scan Value' 1
set sub sc1a
alias 'SPN769747.Scan Value' 1
alias 'SPN769748.Scan Value' 1
alias 'SPN769749.Scan Value' 1
set sub crb
alias 'SPN365075.Eng Value' 4000
wait 1000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
```

```
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
wait 10
set sub sc1a
alias 'SPN769755.Eng Value' 0
alias 'SPN769756.Eng Value' 0
alias 'SPN769757.Eng Value' 0
alias 'SPN666031.Eng Value' 0
alias 'SPN641544.Eng Value' 0
alias 'SPN641545.Eng Value' 0
alias 'SPN641546.Eng Value' 0
alias 'SPN703502.Eng Value' 0
alias 'SPN768936.Eng Value' 0
set sub sc1
alias 'SPN794213.Eng Value' 0
alias 'SPN748382.Eng Value' 0
alias 'SPN748361.Eng Value' 0
set sub sc0
alias 'SPN896113.Eng Value' 0
set sub sw5
alias 'SPN895371.Eng Value' 0
set sub crb
wait 20000
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 1
alias 'SPN365075.Eng Value' 4000
wait 1000
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
```

Scenario 53

```
echo
set sub sc1
alias 'NSL104728486.Scan Value' 0
alias 'NSL104728486.Scan Value' 1
wait 50
alias 'SPN793980.Eng Value' 20
wait 4000
set sub sc1a
alias 'NSL105736182.Scan Value' 0
alias 'NSL105736182.Scan Value' 2
```

```
alias 'SPN769756.Eng Value' 0
alias 'SPN793980.Eng Value' 234
set sub sc1
alias 'SPN793980.Eng Value' 332
set sub crb
alias 'SPN365075.Eng Value' 0
alias 'SPN365012.Eng Value' 1700
wait 4000
set sub crb
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
wait 10000
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 1
alias 'SPN365075.Eng Value' 4000
wait 400
alias 'SPN365068.Scan Value' 1
alias 'NSL104059695.Scan Value' 0
alias 'NSL104059695.Scan Value' 2
alias 'SPN365075.Eng Value' 0
alias 'SPN365068.Scan Value' 0
```

Scenario 54

```
echo
set sub sc1
alias 'SPN794472.Scan Value' 1
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 2
set sub sc1a
alias 'SPN769755.Eng Value' 40
alias 'SPN769756.Eng Value' 40
alias 'SPN769757.Eng Value' 40
alias 'SPN641545.Eng Value' 0
alias 'SPN703502.Eng Value' 0
alias 'SPN768936.Eng Value' 0
set sub crb
alias 'SPN365075.Eng Value' 224
set sub sc0
alias 'SPN896113.Eng Value' 0
set sub sw5
alias 'SPN895371.Eng Value' 0
set sub sc1
alias 'SPN794213.Eng Value' 20
alias 'SPN748361.Eng Value' 0
wait 10000
```

```
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 1
wait 1000
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 2
wait 10000
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 1
wait 1000
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 2
wait 10000
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 1
wait 1000
alias 'NSL103996172.Scan Value' 0
alias 'NSL103996172.Scan Value' 2
```